National Conference
On
Sustainable Development of Groundwater Resources in Industrial Regions

SDGRIR 2012

Editors

Prasoon Kumar Singh
Anshumali
Brijesh K. Mishra
Alok Sinha
A. K. Pal
Dipanwita Bhakat

DEPARTMENT OF ENVIRONMENTAL SCIENCE & ENGINEERING
CENTRE OF MINING ENVIRONMENT
INDIAN SCHOOL OF MINES
DHANBAD - 826004 (INDIA)

National Conference

On

Sustainable Development of Groundwater Resources in Industrial Regions

(SDGRIR 2012)

Proceedings

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Organised By

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND ENGINEERING
Indian School of Mines
Dhanbad 826004, India
March 22 -23, 2012

Department of Environmental Science and Engineering,
Indian School of Mines
Dhanbad, Jharkhand, India

National Conference on
Sustainable Development of Groundwater Resources in Industrial Regions
Department of Environmental Science and Engineering
Indian School of Mines, Dhanbad-826004, Jharkhand, India
Ph.: +91-326-2296624
Fax: +91-326-2296624, 2296563

March 22-23, 2012

Email: pks0506@yahoo.co.in
Website: http://www.ismdhanbad.ac.in/noticeboard/seminars.htm

PREFACE

The Department of Environmental Science and Engineering, Indian School of Mines is organizing two days national conference on **"Sustainable Development of Groundwater Resources in Industrial Regions (SDGRIR 2012)"** during 22 and 23 March, 2012 with a primary focus on issues related to our country's growing needs of freshwater requirement and also to foster a strong cooperation among industry, academic institutions and research institutes. We hope your participation will make this event fruitful and glorious for all the participants.

We observed an excellent response to our call for participation in the conference across India. As many as 51 papers have been accepted for Oral Presentation out of the 70 received papers. Acceptance decision of the papers has been taken on the basis of the recommendation of the eminent reviewers and subsequent recommendations of the technical program committee. We would like to thank to all the reviewers from reputed organizations for their valuable review reports without which it could not be published in this form. The papers have been arranged in technical sessions, some of which would run parallel, spread over two days. Papers have been categorized in five different areas- Mining and their Impact on Groundwater, Groundwater Quality, Groundwater Pollution and Remedial Practices, Groundwater Management and Modeling. The valuable keynotes and the invited talks are ornamenting this collection. We are happy to record the constant help received from the Chief Patron, Patron, members of the Advisory Committee and other members of the Organizing Committee. We would also like to appreciate enormous efforts of the Research Scholars of the department, M. Tech. (Environmental Science & Engineering) and B. Tech. (Environmental Engineering) students for their constant support.

Some errors still may be remained unnoticed and uncorrected. We, therefore, request all the participants to bear with error and lacuna, if any.

We earnestly believe that the paper presented in this conference will benefit all the academicians, industry people and the researchers in the areas of Water Resource Management.

Dhanbad
March 22, 2012

EDITORS
Prasoon Kumar Singh
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Dipanwita Bhakat

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QUALITY OF GROUNDWATER IN VADDESWARAM, GUNTUR DISTRICT, ANDHRA PRADESH

M.Sujatha[1] , Dr.T.Satyanarayana[2] and Dr.Bhramaji Rao[3].
[1]Assistant Professor, Ecology and Environment Division , KLUniversity.
[2]Professor Department of Civil Engineering, SRK Engineering college, Enikepadu.
[3]Professor Department of Environmental Sciences, Acharya Nagarjuna University.
Email of corresponding author: sujatha7klu@gmail.com

ABSTRACT:

The quality of groundwater's of different locations of Vaddeswaram in Guntur district Andhra Pradesh was assessed by examining various physico-chemical parameters such as pH, alkalinity, electrical conductivity, total dissolved solids, hardness, chlorides, calcium, magnesium and potassium. Comparative study with reference to WHO and Indian Standards revealed that the ground waters are suitable for intended use for the villagers.

Key words: groundwater, physico-chemical parameters, Indian Standards.

INTRODUCTION:

Water is essential for the survival of any form of life. The demand for the water has increased over the years, and has led to general water scarcity. Pollution of air, water and land has an effect on the quality of groundwater's. The solid, liquid and gaseous wastes, if not disposed off properly, result in pollution of the environment. This affects groundwater too due to hydraulic conductivity in the hydrological cycle, reverted by the problem of water pollution.

Water pollution is a phenomenon that is characterized by the deterioration of its quality as a result of various human activities. In India only 12% of people get good drinking water(Kudesia, 1980). Inadequate management of water resources as directly or indirectly resulted in the degradation of hydrological environment (Karanth, 1989).Pollution of groundwater resources has become a major problem today. Thus the present study was undertaken at Veddeswaram in Guntur District Andhra Pradesh.

STUDY AREA:

The study area is situated at the bank of river Krishna nearly 10 km away from Vijayawada towards south west, with flood plain and top soils as black cotton. The area is covered with lawn thick vegetation ,plants gardens and agricultural crops.

The main groundwater recharging areas in the study area are Buckingham canal and the Krishna river. The Krishna river is passing on N-E side, where as the Buckingham canal passes on S-W side of the study area.

Vaddeswaram is underlined by palaeo-channels, which are extensively developed. The paleao or buried channels are the main ground water potential zones for the high ground water occurrence in the area of investigation. The ground water levels in both, open dug wells and bore wells, are varying from 2 to 4 meters below the ground level.

The important geological formations in and around the area of investigations consists of Khondolite suit of rocks with alternate bands of quartz and feldspars with same basic minerals. Hydrogeologically, these rocks are known as crystalline metamorphosed rocks. Generally they have lack of primary porosity of hydraulic conductivity however the secondary porosity generates due to weathering and deformation of the rocks to store and transmit the water. The ground water flow in the study area is towards east.

MATERIALS AND METHODS:

The ground water samples are collected in 2-litre clean polyethylene bottles from dug wells and bore wells at various earmarked locations. All the chemicals utilized were of analytical grade. Standard methods were followed for analysis of water(APHA 1995).

The pH was measured by the digital solids by gravimetric method. Digital conductivity meter was used to measure electrical conductivity(EC).Sodium was measured by flame photometer. The remaining parameters were analyzed by titrimetric methods.

RESULTS AND DISCUSSIONS:

The results of the study area were given in table1.

pH:

pH of water indicates the form in which carbon dioxide is present. change of pH from7 to 6 indicates that there is a ten-fold increase in the hydrogen ion concentration. The pH value of natural water changes due to the biological activity and industrial contamination. In a similar fashion, a change of pH from 7 to 8 indicates a ten-fold increase in hydroxyl ions. During the study, pH value of groundwater varied from 7.5 to 8.5, which is reported as within the permissible limits of drinking water (WHO1991).

Alkalinity:

Alkalinity is a measure of the ability to neutralize acids. Excess alkalinity gives bitter tastes to water and reacts with cations forming precipitates, which can damage pipes and other appurtenances like valves etc. However, some alkalinity ranged from 105mg/L to 250mg/L during the study. Excess chlorides causes cardio-vascular problems, salty taste to water, steel corrosion and reduced strength of concrete. The chloride values ranged from 59.98 mg/L to 127.49 mg/L in the study, which are below the standards.

Electrical conductivity:

Conductivity is a measure of current carrying capacity. Electric conductivity is also a norm to measure solids; 560 µmhos/cm to 880 µmhos/cm was reported during the investigation.

Total Dissolve Solids:

Total dissolved solids up to 500-1500 mg/L can be used for drinking as well as other domestic purposes.TDS also affect the strength and solidity of concentrate and palatability of the food cooked.TDS concentration in the present study ranged from 335.4 mg/L to 55 6.8 mg/L.

Hardness:

Hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solutions. Hardness is caused mainly by the multivalent metallic cations like calcium ,magnesium, iron and strontium. Waters with hardness greater than 300 mg/L may lead to the heart and kidney problems. Hardness varied from 105 mg/L to 280 mg/L during the investigation.

Calcium:

Calcium is a major constituent of most igneous , metamorphic ,and sedimentary rocks. The principal sources of calcium in ground water are some groups like placioclase, uroxene, limestone, dolomite and gypsum. The calcium values are reported between30.06 mg/L and 66.13mg/L. The principal sources of magnesium are basalts, talc, termolite schists and dolamites. Magnesium ranged between 18.03 mg/L and 76.15 mg/L during the study.

Sodium:

Sodium content of the ground water would raise due to weathering of plagioclases feldspar. Sodium content in the ground water ranges from 1 mg/L in humid areas and 10,00000 mg/L in brines.58.8 mg/L of minimum sodium concentration and 84.7 mg/L of maximum concentrations were found in the study.

All the values are in mg/L except EC(µmho/cm)

SI=Near Computer Block ;S2=Besides FED; S3=S-W corner of indoor stadium; S4=Opposite to FED and garden; S5=N-W corner of ladies hostel; S6=Behind Satyam college; S7=Between two workshops; S8=Behind thermal lab; S9=Behind canteen; S10=N-E corner of indoor stadium; S11=S-W corner of Mechanical Block.

Table:1

s.no	SI	pH	Alkalinity	Acidity	TH	Cl	Ca	Mg	TDS	EC	Na
1	s1	8.5	235	5	225	102.49	50.1	40.08	355.4	560	69
2	s2	8.5	250	10	220	87.49	66.13	22.04	563.2	880	84.7
3	s3	7.5	235	5	230	114.99	52.1	40.08	550.4	860	76.7
4	s4	8.5	105	10	185	87.49	38.07	36.07	364.8	570	69.1
5	s5	8.5	155	10	125	67.49	32.06	18.03	512	800	70.5
6	s6	8.5	150	5	105	59.98	30.06	22.04	390.4	610	58.8
7	s7	8.5	245	10	280	82.49	36.07	76.15	441.6	690	58.8
8	s8	8.5	235	10	240	127.49	60.1	46.09	486.4	760	75.2
9	s9	8.5	220	5	195	74.99	46.09	32.06	556.8	870	77.1
10	s10	8.5	190	5	165	79.99	34.06	20.04	435.2	680	59.3
11	s11	7.5	250	10	250	109.99	50.1	50.1	371.2	580	60

CONCLUSION:

In the present study area, ground water is the only source, exploited by the people through number of shallow tube wells and dug-wells. Investigation revealed that almost all the parameters are within the limits of standards. Hence ,water can be used safely for drinking and domestic use after proper disinfection.

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ANALYTICAL SOLUTION OF CONTAMINANT TRANSPORT IN TWO-DIMENSIONAL HOMOGENEOUS SEMI-INFINITE AQUIFER

Mritunjay Kumar Singh* and Priyanka Kumari
*Department of Applied Mathematics, Indian School of Mines, Dhanbad-826004, India
Email: drmks29@rediffmail.com, sinki_burnwal@yahoo.com

ABSTRACT:

The contaminant distribution patterns in a groundwater reservoir for example, an aquifer of finite or semi-infinite in nature play a vital role in the field of groundwater resources and management. In this regard, mathematical tools are able to describe the contamination patterns in geological formations such as aquifer. A two-dimensional homogeneous semi-infinite aquifer is considered to observe the longitudinal as well as lateral component of contaminant concentration. Initially the aquifer is not solute free i.e. some initial background concentration exists in the aquifer and the input source concentration is taken time-dependent. The Laplace transform technique is applied to derive the analytical solution of the homogeneous semi-infinite aquifer. The solutions are derived under two conditions: 1) the flow velocity in the aquifer is of sinusoidal nature and 2) the flow velocity is an exponentially decreasing nature. The graphical representation is made through MATLAB 7.5.

Keywords: Solute Transport; Groundwater Contamination; Aquifer; Laplace Transform Technique

1. INTRODUCTION

In the last few decades, due to increasing demand of water in the industry, irrigation, domestic use and daily life of human being, we need to understand the functioning of groundwater reservoirs in response to natural and man-made changes in conditions in the system (Karanth, 1987). The utilization of fertilizers, pesticides, disposal of solid wastes, and untreated waste water on land has also deteriorated groundwater quality (USEPA, 1989; Anderson & Woessner, 1992; Charbeneau, 2000; Kebew, 2001; Rausch et al., 2005; Thangarajan, 2006). A well-known water contamination problem results from mining due to pumping of mine water and its discharge into an existing drainage system. For example, the Jharia coal field is one of the best examples for producing coal in Jharkhand and it is directly or indirectly affecting the surface water and subsurface water contamination.

The remediation of groundwater contamination usually requires a quantitative knowledge about the distribution and fate of the concerned contaminants. This kind of knowledge may be obtained by means of mathematical modeling which solves the advection/dispersion equation either analytically or numerically. The advection/dispersion equation is widely used in describing pollutant distribution behavior in aquifers, rivers, lakes, streams and oil reservoirs. In this context, many analytical models were developed for simulating transport problems under different initial and boundary conditions (Ebach and White 1958; Ogata and Banks 1961; Al- Niami and Rushton 1977; Marino 1978; Sharma and Reddy 2004; Rausch et. al. 2005; Kumar et. al. 2006, Singh et. al. 2008, 2009a, 2009b). An analytical and experimental investigation of the longitudinal and lateral dispersion coefficient, for a wide range of Reynolds number in two-dimensional isotropic porous media was also studied (Harleman and Rumer, 1963). The study of both longitudinal and lateral dispersion in a steady flow field in semi-infinite non-adsorbing porous media subjected to a constant input concentration were discussed (Bruce and Street, 1967). The analytical solutions for chemical transport in two-dimensional aquifers in which a constant velocity field, linear adsorption, and first-order decay were considered (Latinopoulos et al, 1988). A generalized two-dimensional analytical solute transport model in bounded media for flux type finite multiple sources was discussed (Batu, 1993). A two dimensional solute transport problem in a homogeneous finite aquifer was studied in which the input source concentration was taken at the far end away from the origin and the analytical solution was obtained by Hankel Transform Technique (Singh et al, 2010).

The present work deals with the contaminant concentration distribution along two-dimensional transient groundwater flow in homogenous, semi-infinite and shallow aquifers. The objective of this study therefore is to derive an analytical solution, using the Laplace transform technique, for two-dimensional space-time distribution of contaminant concentration in a shallow aquifer in which the flow velocity distribution is transient, and the aquifer is subjected to time dependent point-source contamination in the form of sigmoid function. Initially the aquifer is not solute free which means that some initial background concentration exists. The direct relationship between dispersion coefficient and velocity concept is used which helps to convert the time dependent coefficients of advection-dispersion equation into constant coefficients.

2. MATHEMATICAL FORMULATION OF THE PROBLEM

Let $c[ML^{-3}]$ be the contaminants concentration in the aquifer at any time $t[T]$. The groundwater velocity components are $u[LT^{-1}]$ and $v[LT^{-1}]$ while dispersions coefficients are $D_x[L^2T^{-1}]$ and $D_y[L^2T^{-1}]$ along the x and y, axes respectively. The two-dimensional solute transport equation in a homogenous isotropic porous medium can be written as

$$\frac{\partial c}{\partial t} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} - u(t)\frac{\partial c}{\partial x} - v(t)\frac{\partial c}{\partial y} \tag{1}$$

$$u = u_0 f(t) \text{ and } v = v_0 f(t) \tag{2}$$

where $u_0[LT^{-1}]$ and $v_0[LT^{-1}]$are the initial values of u and v, respectively; and $f(t)$ is the sinusoidally varying function or an exponentially decreasing function of time. Let

$$D_x = au_0 f(t) \quad \text{and} \quad D_y = av_0 f(t) \tag{3}$$

where a is the dispersivity $[L]$ that can depend upon the pore geometry. Using equation (2), equation (3) can be written as

$$D_x = D_{x_0} f(t) \quad \text{and} \quad D_y = D_{y_0} f(t) \tag{4}$$

where $D_{x_0} = au_0$ and $D_{y_0} = av_0$ are initial values of D_x and D_y, respectively. Let $c_i[ML^{-3}]$be the uniform initial concentration at the origin. The input point source concentration is taken as time-dependent in the form of sigmoid function while at the other end it is supposed to be zero. Thus, the initial and boundary conditions can be written as:

$$c(x,y,t) = c_i; \quad x > 0,\ y > 0,\ t = 0 \tag{5}$$

$$c(x,y,t) = \frac{c_0}{\left[1 + exp(-qt)\right]}; x = 0, y = 0, t > 0 \tag{6}$$

and, $c(x,y,t) = 0; \quad x \to \infty, y \to \infty, t > 0$ (7)

where $q[T^{-1}]$is the contaminant decay rate coefficient and for $q = 0$, input concentration become uniform nature. The physical system of the problem is graphically shown in Fig.1.

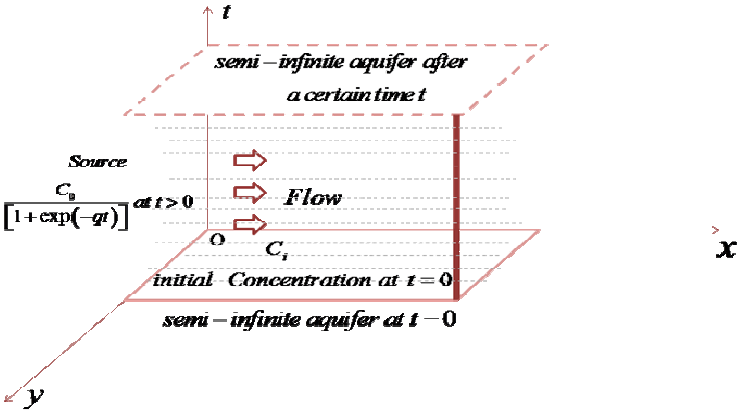

Fig. 1. Physical system of the problem

3. ANALYTICAL SOLUTION

Introducing a new time variable T by the following transformation (Crank, 1975):

$$T = \int_0^t f\left(t\right) dt \tag{8}$$

Using equations (2), (4) and (7), Equation (1) can be written as

$$\frac{\partial c}{\partial T} = D_{x_0} \frac{\partial^2 c}{\partial x^2} + D_{y_0} \frac{\partial^2 c}{\partial y^2} - u_0 \frac{\partial c}{\partial x} - v_0 \frac{\partial c}{\partial y} \tag{9}$$

Let us define a new space variable as follows

$$\xi = x + y\sqrt{\frac{D_{y_0}}{D_{x_0}}} \quad or \quad x + y\sqrt{\frac{v_0}{u_0}} \tag{10}$$

With the aid of equation (10), equation (9) can be written as

$$\frac{\partial c}{\partial T} = D\frac{\partial^2 c}{\partial \xi^2} - U\frac{\partial c}{\partial \xi} \tag{11}$$

where, $D = D_{x_0}\left[1+\left(\frac{D_{y_0}^2}{D_{x_0}^2}\right)\right]$ and $U = \left(u_0 + v_0\sqrt{\frac{v_0}{u_0}}\right)$

Also, equations (5)-(7) can be written as

$$c\left(\xi,T\right) = c_i; \quad \xi > 0\ ,\ T = 0 \tag{12}$$

$$c\left(\xi,T\right) = \frac{c_0}{\left[2-qT\right]}; \quad \xi = 0\ ,\ T > 0 \tag{13}$$

$$c\left(\xi,T\right) = 0; \quad \xi \to \infty\ ,\ T > 0 \tag{14}$$

In order to reduce the advection terms from equation (11), we use the following transformation

$$c\left(\xi,T\right) = K\left(\xi,T\right)exp\left[\frac{U}{2D}\xi - \frac{U^2}{4D}T\right] \tag{15}$$

And hence the equations (11)-(14) can be transformed as

$$\frac{1}{D}\frac{\partial K}{\partial T} = \frac{\partial^2 K}{\partial \xi^2} \tag{16}$$

$$K\left(\xi,T\right) = c_i\, exp\left(-\frac{U}{2D}\xi\right); \xi > 0, T = 0 \tag{17}$$

$$K\left(\xi,T\right) = \frac{c_0}{2}\left[1+\frac{qT}{2}\right]exp\left(\frac{U^2}{4D}T\right); \xi = 0, T > 0 \tag{18}$$

$$K\left(\xi,T\right) = 0; \quad \xi \to \infty, \quad T > 0 \tag{19}$$

Applying the Laplace transform to equations (16)-(19), we get

$$\bar{K}\left(\xi,p\right) = c_1\, exp\left(\sqrt{\frac{p}{D}}\right)\xi + c_2\, exp\left(-\sqrt{\frac{p}{D}}\right)\xi + \left[\frac{c_i}{\left(p - \frac{U^2}{4D}\right)}\right]exp\left(-\frac{U}{2D}\xi\right) \tag{20}$$

where, c_1 and c_2 are constants.

Using equations (13) and (14) in the equation (20), constants c_1 and c_2 can be obtained as

$$c_1 = 0 \text{ and } c_2 = \frac{c_0}{2}\left[\frac{1}{\left(p-\frac{U^2}{4D}\right)}+\frac{q}{2}\frac{1}{\left(p-\frac{U^2}{4D}\right)^2}\right]-\frac{c_i}{\left(p-\frac{U^2}{4D}\right)} \tag{21}$$

Thus, the equation (20) can now be written as

$$\bar{K}(\xi,p)=\frac{c_0}{2}\left[\frac{1}{\left(p-\frac{U^2}{4D}\right)}+\frac{q}{2}\frac{1}{\left(p-\frac{U^2}{4D}\right)^2}\right]-\frac{c_i}{\left(p-\frac{U^2}{4D}\right)}exp\left(-\sqrt{\frac{p}{D}}\right)\xi$$
$$+\frac{c_i}{\left(p-\frac{U^2}{4D}\right)}exp\left(-\frac{U}{2D}\xi\right) \tag{22}$$

Now, taking the inverse Laplace transform of equation (22) and substituting the value of $K(\xi,T)$ in equation (15), the required solution can be written as

$$c(\xi,T)=\left[\left(\frac{c_0}{2}-c_i\right)F_1(\xi,T)+\frac{qc_0}{4}F_2(\xi,T)\right]+c_i \tag{23}$$

where,

$$F_1(\xi,T)=\frac{1}{2}erfc\left[\left(\frac{\xi}{2\sqrt{DT}}\right)-\left(\frac{UT}{2\sqrt{DT}}\right)\right]+\frac{1}{2}exp\left(\frac{U}{D}\xi\right)erfc\left[\left(\frac{\xi}{2\sqrt{DT}}\right)+\left(\frac{UT}{2\sqrt{DT}}\right)\right] \tag{24}$$

$$F_2(\xi,T)=\frac{1}{2U}(UT-\xi)erfc\left[\left(\frac{\xi}{2\sqrt{DT}}\right)-\left(\frac{UT}{2\sqrt{DT}}\right)\right]$$
$$+\frac{1}{2U}(UT+\xi)exp\left(\frac{U}{D}\xi\right)erfc\left[\left(\frac{\xi}{2\sqrt{DT}}\right)+\left(\frac{UT}{2\sqrt{DT}}\right)\right] \tag{25}$$

4. NUMERICAL RESULTS AND DISCUSSION

To discuss the numerical results of the problem, the two time-dependent forms of velocity expressions are taken into consideration such as

1. Sinusoidal form of velocity expression, $u = u_0[1\text{-}\sin(mt)]$, m =0.0165(/day)
2. Exponentially decreasing form of velocity expression, $u = u_0\exp(\text{-}mt)$, $mt < 1$, m =0.0002(/day)

Here, $m\left[T^{-1}\right]$ is the flow resistance coefficient. The corresponding new time variable T can be written as

$$T = \frac{1}{m}\left[mt\ \text{-}\left(1\text{-}\cos mt\right)\right] \tag{26}$$

$$T = \frac{1}{m}\left[1\text{-}\exp\left(\text{-}mt\right)\right] \tag{27}$$

The values of $mt = 3k + 2$ is chosen where k is the whole umber. Here, we have consider the value of k as $11 \le k \le 13$. In particular, for the sinusoidal velocity expression the values of are 35, 38, 41, and hence groundwater velocity components have maximum and minimum records in December and June for the 6th and 7th years. These values of mt yield $t = 2122$, 2304 and 2486 days at a regular interval of approximately 182days. If the value $t = 2122$ days represent some date in the month of 6th year December when groundwater velocity is maximum, then $t = 2304$days represent some date in 7th year June when groundwater velocity is minimum. Again, the next value of t represent some date in the month of 7th year December in the next year and so on. Thus, the velocity expression represents the sinusoidal behavior of groundwater velocity often observed in a tropical region of India.

The two-dimensional analytical solution given in equation (23) for sinusoidally varying velocity expression is computed for the values $u_0 = 0.05 km/day,\ v_0 = 0.005 km/day,\ D_{x0} = 0.1 km^2/day,\ D_{y0} = 0.01 km^2/day$, $m = 0.0165(/day),\ q = 0.0001(/day),\ c_i = 0.1,\ c_0 = 1,\ x = 100km,\ y = 100km$ and is shown graphically in fig. 2. However, for the same set of values subject to an exponentially decreasing velocity expression with $m = 0.0002$(/day), the analytical solution given in equation (23) is also computed and shown graphically in fig.3.

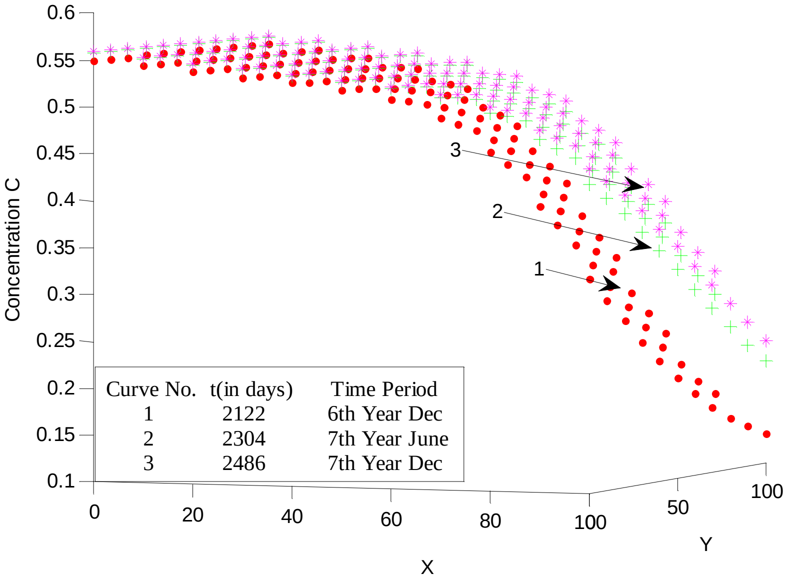

Fig. 2

Time-dependent contaminant source concentration pattern along sinusoidal varying groundwater flow

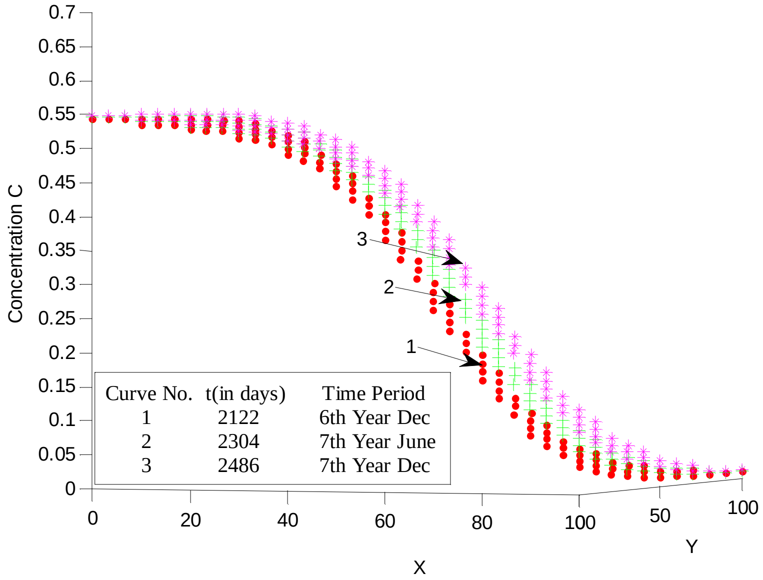

Fig. 3

Time-dependent contaminant source concentration pattern along exponentially decreasing groundwater flow

5. CONCLUSION

On the basis of observation of this study following conclusions are made:

1. In two-dimensional semi-infinite aquifer the contaminant concentration decreases with space and time for both sinusoidal and exponential decreasing form of velocity expressions.
2. The contaminant concentration decreasing more rapidly in exponentially decreasing form of velocity expression as compared to the sinusoidal one.
3. In case of sinusoidal form of velocity expression, at initial stage the decreasing rate of contaminant concentration is not much visible but after a certain period of time it decreases drastically.
4. The pattern of contaminant concentration in both type of velocity expressions are almost identical to each other i.e. the different type of velocity expression cannot change the pattern of contaminants distribution pattern in the system.

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IMPACT OF OPEN CAST MINING ON THE HILLY NATURAL SPRINGS OF JODA-BADBIL AREA OF ORISSA

P. K. Naik, Gulab Prasad, Scientist,
Rajiv Gandhi National Ground Water Training & Research Institute, Mowr, Govt. of India, Raipur.

ABSTRACT

Springs are the gift of nature which plays a vital role in catering to the water needs of the people and the habitat in the high altitude hilly areas where the prospect of ground water is very poor. Springs are not the mere discharge of water along the hill slopes. The origin of the springs is controlled by the regional tectonics of the area. The bedding planes, lineaments/ faults, shear zones acts as recharge inlets through which rain water also gets recharged in the upper reaches. The total hills acts as recharge area. The water is discharged through well defined fault/bedding planes along the hill slope as perennial springs and in summer there is only little decrease in discharge. During drilling for iron ore in Thakurani mines, of Keonjhar district, Orissa on the hill top 5 lps discharge was encountered. The major fractures like faults, shear zones developed during the Iron Ore Orogeny which has given rise to the present high hilly topography has important control on the occurrence of springs. A number of perennial springs such as Thakurani, Khandadhar, Gudguda, Gonasika and Bolani are present in the hilly tract of Joda-Badbil-Koira area of Keonjhar-Sundargarh District, Orissa. The area is densely forested with rich deposits of Fe and Mn, which are mined using the opencast method of mining.

Keywords: ground water, Thakurani mines, rice deposits.

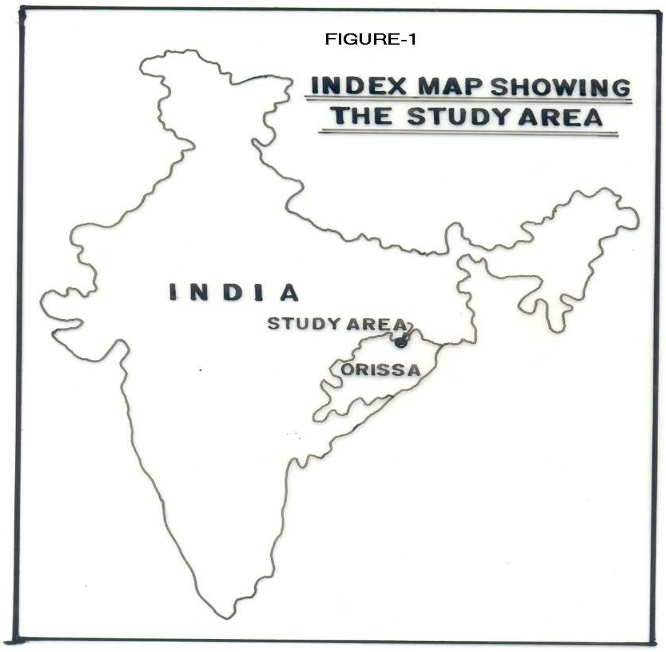
INTRODUCTION

Springs originate from the various combinations of geologic, physiographic, hydrologic, hydraulic, pedologic and climatic and biological control. A spring is a localised natural discharge of ground water issuing on the land surface through well defined outlets. In any geological horizon the water table follows the topographic contours. As in hilly areas the topography is undulating when the water table intersects the slope water oozes out and a spring is formed. Generally the elevated hilly areas acts as recharge areas and most of the springs located along the hill slopes acts as discharge areas. In rainy season the discharge of the stream is high and the discharge gradually decreases towards the summer. Consolidated rocks are traversed by a number of joints through which seepage of water takes place and form fracture spring.

In Orissa most of the springs are located in the central axial high land. In the Similipal plateau, Keonjhar plateau & Bonai hill ranges of the northern Orissa a number of springs are located. The Banded Iron Formation consisting of quartzite forms stiff cliff and gives rise to the picturesque Khandadhar waterfalls at a height of 244m. In Gudguda of Sambalpur district the granite gneiss are highly jointed and has formed step like features.

MINING IN JODA-BADBIL AREA OF KEONJHAR DISTRICT

Keonjhar district of Orissa with a total geographical area of 8303 sq km is having 3097 sq km of forest cover. Different economic mineral deposits present in the district are chromite, iron, and manganese, pyrophyllite & quartzite. In the year 2000 there were 83 working mines with total area coverage of 27003 hectares and output of 8908(000’MT). In Keonjhar district the reserve of Iron is 2555 million tonnes and in the Bonai- Keonjhar belt there is 23.4 million tonnes of manganese reserve. The Banded Iron Formation of North Orissa and Bihar is present in Northern part of Keonjhar district which form high hill ranges and dense forests. The study area is shown in **Figure-1**.



Different salient points are given below:

1. All the mineral deposits are present in forested hilly tract which are exploited as open cast mines. In the western part of Keonjhar at Suakati altitude attains a height of 1062m and west of Joda 808m above MSL. Development of any open cast mines involves clearance of vast forest area for making approach road and placement of machinery. There is impact of mining on the existing hill slopes and it totally changes the existing topography. There are a number of open cast mines such as Joda, Bansapani, Bamebari, Roida, Bhadrasahi, Thakurani, Bolani ,Nalda etc.

2. It disturbs the wildlife and forest biodiversity of the area. There is indiscriminate cutting of trees. As the hill slopes are mined, there is huge amount of excavation of overburden and if they are not properly dumped ultimately during rainy season washed away by rain water and reaches the stream. Impact of mining on environment is given in figure 2 & 3.

FOREST COVER IN THE AREA

Study reveals that a total of 353 leases of the five minerals namely, bauxite, chromite, copper, iron and mangenese are spread over an area of 90,695 ha in the States of Orissa, Bihar and M.P. The extent of forest cover in the lease area is 53,217 ha, out of which 71% is dense forest and 29% is open forest. M.P Orissa and Bihar account for 45%, 36% and 19% of the total cover respectively. Forest cover in mining area by states is given below in **table**:

Table. Forest cover in mining areas by state

State	Lease area(ha)	Forest cover(ha)
Bihar	21,589	10,151
Orissa	37,664	19,263
M.P	31,442	23,803
Total	90,695	53,217

HYDROGEOLOGY OF THE AREA

The Keonjhar district shows conspicuous physiographic variations and is mainly represented by high hills, isolated hillocks, domal granitic outcrops, vast undulating plains and alluvial tract which is a replica of tectonic deformational history of the area, stratigraphy and mineralogical characteristics of the rock formations. Highly resistant rocks lik quartzites, B.H.J. and B.H.Q bearing Iron Ore Group of rocks, Proterozoic volcanics and Kolhan sedimentaries costitute the high hill ranges rising to a maximum height of 1062m above MSL in Suakati-Banspal sector. This range continues along the western boundary of the district to the Joda, Barbil sector.

In the topographic highs the depth to water level in pre- moonsoon is more than 10m. But in the valley fill and topographic lows water level varies from 3-6m. The northwestern part of the district is covered with high hill ranges. In the topographic high the prospect of ground water is very poor as they act as recharge areas. The depth to water level is more than 10m and in summer season most of the tube wells go dry.

ROLE OF SPRINGS/STREAMS IN THE HILLY AREAS

In the hilly areas dug wells go dry and bore wells are also not feasible. A number of perennial springs/streams exist in the area which acts as the lifeline of the people. Most of the springs are perennial in nature and the vast hilly areas acts as the recharge areas. Different perennial streams existing in the area are Khandadhar, Murga Mahadeb etc. People in Bolani area are doing paddy cultivation from perennial stream in the summer. The mining activities threaten the existence of these perennial springs. Photograph of Gudguda spring is given in **figure-4**.

The discharge of a spring is controlled by rainfall, land use, vegetation, grazing incidence and geomorphology of the recharge zone in a mountain watershed. Also, geohydrological studies suggest that the lineaments produced by joints, fractures, and faults play a significant role on the hydrogeological regime of a catchment. Springs located in these areas have high discharge (more than 20 l/s) like a small stream, controlled by the geology such as faults, lineaments, shear zones and bedding planes. Rainfall is recharged in these fractures and discharged in the form of springs and seepages along the major fault planes formed by major tectonic movements, joints and permeable layers forming a spring.

The water from the springs is potable, except for the leaves and soil particles that are present. Electrical conductivity varies from 11 to 60 µs/cm. This water is also the lifeline of the local tribal people living in the hilly forested areas. As the hills act as recharge areas, there is acute shortage of water after December. People travel for several kilometers to collect drinking water. In the Thakurani and Bolani mining colony, spring water is supplied directly from the hilly spring as the groundwater potential in these areas is poor. People use water from the Bolani spring for rabi cultivation, as the spring is perennial nature.

IMPACT OF MINING ON HYDROLOGICAL REGIME

Interaction with local people reveals that since last two decades there is decrease in discharge of the springs and some of the minor springs are at the verge of extinction. It is due to the mining activity in the hilly areas where there is ecological imbalance. Due to destruction of forest there is increase in soil erosion, decrease in recharge of rainfall and increase in run off. In the hilly area most of the people are dependent on stream water as in summer season most of the dug wells and tube wells go dry. In those areas the depth to water level in dug wells is more than 18m. The different rivers flowing in the area are Karo, Baitarani, Kundra, Mahadeba Nala, etc. Karo River which originates in the extreme north western part of the district flows in NE direction and passes through Bolani and west of Barbil and enters the Jharkhand state through Gua mines. In this area the Karo River forms the lifeline of the people. But this river is mostly affected by the mining activity. As the mine overburden are indiscriminately dumped during rainy season they are washed by rainfall and ultimately reaches the river. The open cast mines are affecting the hydrological regimes also. The rain water after passing through the mine dumps and by products from industry reaches the stream which is the lifeline of the people of this area. They carry the suspended particles and other harmful elements which pollutes the stream water.

As mineral deposits are mined using the opencast method of mining, there is huge excavation and the overburden is dumped, resulting in deforestation and slope instability along the hill slopes. The overburden dumps carried by rainwater choke the drainage channels. As a result, there is decrease in recharge of rainwater, which is manifested in the decrease in discharge of these springs.

CHEMISTRY OF THE SPRING WATER

The electrical conductivity of the spring water varies from 11 to 60 µs/cm and pH varies from 6.29 to 8.5. As the springs are in recharge areas the interaction with soil/rock zone is less so the EC value is less. All the chemical parameters like Ca, Mg, Na, K,Cl, F are within permissible limit and suitable for both drinking and irrigation purposes. The spring water is HCO_3 type.

ENVIRONMENTAL POLICY AND CONSERVATION

Indian mineral policy was amended in the year 1993, to include minimization of adverse effects on forest, environment and ecology with due regards to safety and health of all concerned people and rehabilitation of mine closures and displaced persons. As per these rules, all he metalliferous mines in India are statutorily required to prepare and submit the environmental management plan to Indian Bureau of Mines (IBM). These mining plans are being examined, approved and implemented by IBM.

Objectives of Mine Reclamation and Rehabilitation

While formulating the rehabilitation objectives for the site, it is important to consider the existing or the pre-mining land use of the site and how the operation will affect this activity. Some operations such as mining in agricultural areas have clearly defined this objective of returning the land to viable agricultural purposes. In forested areas the aim may be to re-establish a self-supporting forest community. The main objectives are given below:

The different criterias are given below:

I. Physical stability:

All anthropogenic structures, which include mine workings, waste dumps; buildings etc. remaining after mine abandonement should be physically stable. They should present no hazard to public health and safety as a result of failure or physical deterioration and they should continue to perform the functions for which they were designed.

II. Chemical stability

The resources within the mine site should be chemically stable. This means that the consequence of chemical changes or conditions leading to leaching of metals, salts or organic compounds should not endanger public health and safety nor result in the deterioration of environmental resources.

III. Biological stability

The biological stability of the mine site itself is closely related to rehabiliation and final land use. Establishment of a vegetation cover over the disturbed site is usually one of the main objectives of the rehabiliation programme, as vegetation cover is the best long-term method of stabilizing the site. For reclaiming the land by vegetation cover local community must be involved as they are the ultimate beneficiaries and also they are conversant with the local parameters which will help to rebuild the forest. Near waterbodies and other favourable places wherever possible horticulture plantation can be done and handed over to local people who will improve their economic standard.

Species selection for plantation

Multi-Species, bio-diversified plantation in mining areas includes mainly the following varieties:

Botanical Name	Common Name
1. Albizzia lebbek	Siris
2. Prosopis Juliflora	Juliflora
3. Malia azadirachta	Bakain
4. Terminalia Arjuna	Arjun
5. Melina arborea	Gamhar
6. Luceana lucocephalia	Subabul
7. Psidium guajava	Guava
8. Acacia auriculiformis	Acacia
9. Azadirachta indica	Neem
10. Torminalia tomenstosa	Asan
11. Zizypus jujuba	Ber
12. Shorea robusta	Sal
13. Tectona grandis	Teak
14. Dalberga sisso	Sisham

Figure 2. Impact of open cast mines on hill slopes, Joda area, Keonjhar district.

Figure 3. Clearance of forest for setting sponge iron factory near Barbil.

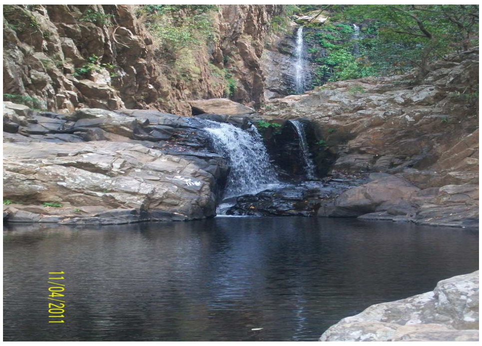


Figure 4. Photograph of Gudguda spring which shows steps like structure.

CONCLUSIONS

Because of mining activity the recharge area is disturbedand as a result there is ecological imbalance. Due to destruction of forest there is increase in soil erosion, decrease in recharge of rainfall and increase in run off. There is general decrease in discharge of the spring. Minor springs are at the verge of extinction. It is the responsibility of the different mining agencies to conserve the hilly springs. The discharge potential of the springs could be enhanced through construction of rainwater-harvesting structures for artificial recharge at suitable locations on hilltops. Soil erosion has to be checked. Integrated Watershed Management Programme at the hill top can restore the recharge area. Afforestation programme has to be taken up in a scientific manner, which will enhance recharge of rainwater. Otherwise all these springs will become dry in future, causing a lot of damage to the biodiversity. The mined land can be reclaimed by floriculture, horticulture. This will lead to land reclamation as awell as help the local tribal in earning their livelihood. It is time that the Government takes some initiative to conserve these springs.

ACKNOWLEDGEMENTS

The authors are grateful to Chairman, Central Ground Water Board for rendering permission to publish this paper. The authors are also thankful to the Director, RGNGWT&RI, CGWB, for his encouragement in the work. The opinions offered by the authors do not necessarily reflect those of CGWB.

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ADSORPTION OF COPPER (II) FROM AQUEOUS SOLUTION BY NANO ADSORBENT ZIRCONIUM OXIDE SPHERES

Anuj Kumar Shrivastava
Department of chemistry
VMIT, Tupudana, Hatia, Ranchi-834003
E-mail-anuj123nifft@yahoo.co.in

ABSTRACT:

Copper is an important engineering material and metal of choice for technologists, engineers due to use in various engineering purposes. Intake of copper is drinking water above the permissible limit causes several health hazards, acute and chronic disorders in human beings. In the present study, the nanoabsorbent zirconium oxide sphere has been used for remediation of copper (II) from aqueous solution/water/waste water. The parameters like contact time, pH and temperature are studied on absorption of copper. A fair amount of copper (II) i.e. 98% is absorbed by zirconium oxide spheres at the above conditions.

KEYWORDS: Adsorption, Copper (II), Nanoadsorbent, Zirconium Oxide Spheres(ZOS)

INTRODUCTION:

Copper is an important engineering material and metal of choice for technologists, engineers due to use in various engineering purposes (Shrivastava, 2009). Intake of copper in water above the permissible limit (ISI,1983) causes health hazards , acute and chronic disorders in human beings such as hemochromatosis , gastrointestinal catarrh ,cramps in the calves and skin dermatitis brasschills usually accompanied by high fever (Comp,1964;Mukherjee,1986).

Various sources of copper in the aquatic environment include metal plating and cleaning baths, pulp and paper mills , fertilizers , petroleum refineries , basic steel work foundries, non-metal ferrous works , motor vehicles ,air crafts plating and finishing (Forstner and Wittmann,1981;Dalang and Buffle,1984).Among this electroplating industries is one of the major contributor of copper to the aquatic environment (Jenkins,1976).

In Switzerland, copper is released into water from roofs, gutters and pipes (Steiner and Boller, 2006). The average wash off rate of 1.8 g. Cu $m^{-2}y^{-1}$ leads to relatively high emissions $m^{-2}y^{-1}$ especially in the case of fully copper covered roofs (Boller and Steiner, 2002).

Due to toxic effects on human-beings , it is mandatory to control copper from industrial effluents and polluted waters following various techniques such as precipitation , ion exchange , cementation , reverse osmosis , solvent extraction and adsorption (Prasad and Rupainwar,1989;Yadava and Singh,1987;Pandey and singh,1985). Ion exchange and solvent extraction methods are comparatively costly. Adsorption process is cheap and effective for Cu (II) removal. Various adsorbents such as activated carbon (Huang,1978) , Fly ash (Pandey, 1985), Peat- moss (Gosset and Theverst,1986), powdered leaves (Susheela and Nandi,1985), serpentine mineral (Sundereshan and Pathak,1978) , barley straw (Larsan and Schierup,1981), red wood bark (Randal and Hautala,1975), bark sample (Kumar and Dara,1980), chitosan (Masri and friedman,1974), water hyacinth (Rai and Rupainwar,1993), bituminous coal dust (Singh and Rawat,1993) , novel polycarboxylated starch based sorbent (Chauhan and Ahn,2010), etc. have been used for removal of Copper (II) and some other heavy metals from water/wastewaters.

Now a days, nanoadsorbents have been used for remediation of heavy metals from water /wastewater.(Wikipedia,2009) In the present study, nanoadsorbent Zirconium oxide spheres has been used for removal / remediation of Copper (II) from aqueous solution / water/ wastewater , as an engineering intervention .

MATERIAL AND METHODS:

The Nanoadsorbent material Zirconium spheres were available commercially. This chemical was treated chemically for environmental studies. The structure of zirconium spheres is shown in Figure 1 and Figure 2.

Chemicals

The stock solution of copper was prepared from analytical grade copper sulphate. All the other chemicals used in this experiment were also AR grade. Double distilled water was used throughout in these experiments.

Batch adsorption experiments

The batch adsorption experiments were performed at room temperature in a rotatory shaker. 100 ml solution of Copper (II) having 100 mg/l concentration was agitated with 1g. of adsorbent in a rotatory machine at different environmental conditions like pH, contact time, temperature etc. At the end of pre-determined time intervals the samples were removed from shaking machine and carried to centrifugation for 2 minutes. After centrifugation, the supernatant solution was analyzed for concentration of Copper (II) by Atomic Absorption Spectrophotometer (AAS).

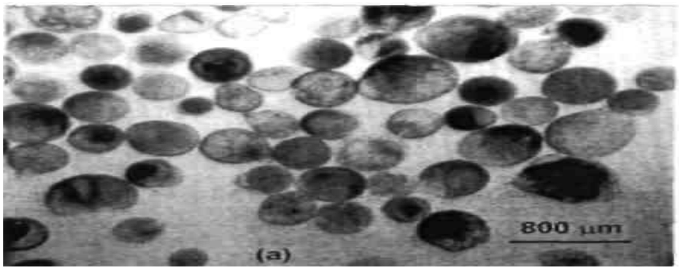

Figure.1 $Zr0_2$ spheres observed using a focused X-ray microscope

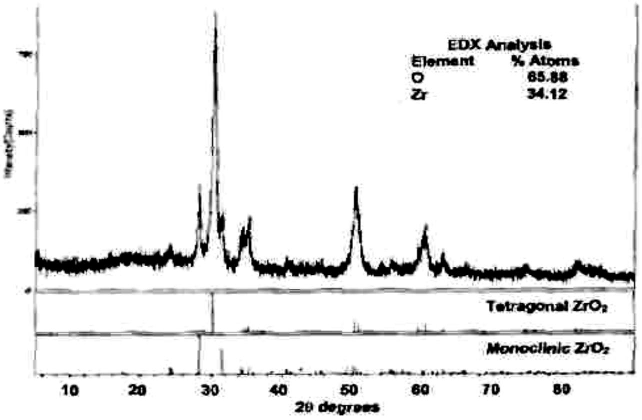

Figure.2: X-ray diffraction (XRD) and energy dispersive X-ray (EDX) analysis of the $Zr0_2$ spheres.

RESULTS:

The results of experimental studies are given in different Tables e.g. Table-1, Table-2 and Table-3 respectively.

Table -1: Effect of contact time

S.No.	Contact time in minutes	Cu(II) in filtrate (mg/l)	Cu(II) adsorbed (mg/l)	% removal of Cu(II)
1	5	94	06	6
2	10	88	12	12
3	15	80	20	20
4	30	65	35	35
5	60	50	50	50
6	90	34	66	66
7 7	120	14	86	86
8	180	13	87	87

Initial concentration of Cu (II) = 100mg/l or 100ug/ml

Table -2 : Effect of pH

S. No.	pH	Cu(II) in filtrate (mg/l)	Cu(II) adsorbed (mg/l)	% removal of Cu(II)
1	2	49	51	51
2	4	39	61	61
3	6	29	71	71
4	6.5	19	81	81
5	7.5	09	91	91
6	8.0	10	90	90

Initial concentration of Cu(II) = 100 mg/l
Contact time = 2 Hours

Table -3: Effect of Temperature

S. No.	Temp ^{0}C	Concentration of Cu(II) in filtrate (mg/l)	Cu(II) adsorbed mg/l	% removal of Cu(II)
1	30	09	91	91
2	40	03	97	97
3	50	05	95	98

Initial concentration of Cu(II) =100mg/l
Contact time =2 Hours
pH= 7.5

DISCUSSION:

Characteristics of adsorbent

Nanoadsorbent Zirconium oxide spheres are highly porous (particle porosity =0.92). The estimated value for the pore diffusion coefficient was $Dp = 6.4 \times 10^{-6} cm^2 S^{-1}$. The high porosity of the media provides for improved pore diffusion and faster overall mass transfer. The EDX analysis of the nanoadsorbent Zirconium oxide spheres shows the presence of elements Zr = 34.12 % and O = 65.88 %.

Because of unique characteristics such as larger surface area and functionality, the nanomaterial Zirconium oxide spheres may be proved an excellent alternative to the conventional adsorbent (material hydroxide). This material was used in the removal of pollutants from water. Fixed bed adsorption based on this nanoadsorbent may be very effective in remediation of heavy metals especially for Cu.

Effect of contact time

The concentration of copper(II) solution used for experiment was 100 mg/ml, which was agitated with 1 gram of nanoadsorbent Zirconium oxide spheres in rotatory shaker for different period of contact time. The results are given in Table-2. It is observed that % removal of Cu (II) reaches to 86 %, when contact time is 2 hours, which is clear from figure 3. Further increase in contact time of 180 minutes causes slight increase in % removal of Cu (II) i.e. 87% . That is why contact time of 2 hours is selected for further studies.

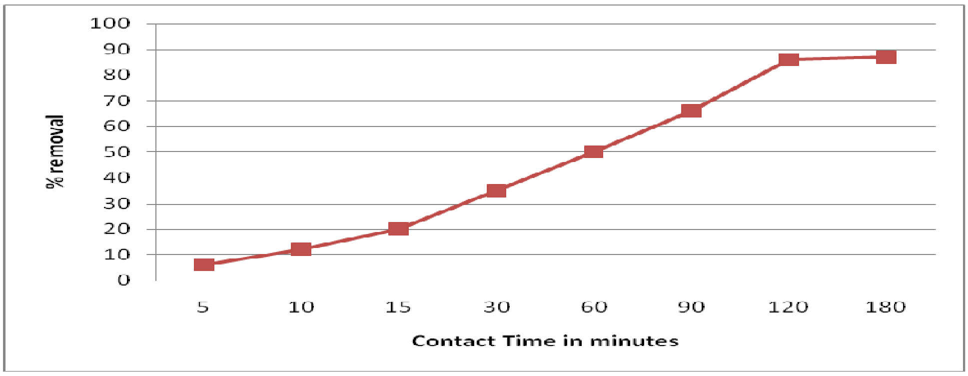

Figure 3: Effect of contact time on removal of Copper(II) by ZS

Effect of pH on adsorption of Cu(II)

pH plays an important role during the removal of Cu(II) from wastewater. At varying pH, adsorption studies on removal of Cu(II) using nanoadsorbent Zirconium spheres was made. 1 gram of nanoadsorbent Zirconium spheres (ZS) was gently agitated with 100 ml of 100mg/l of Cu (II) solution for 2 hours . The pH of the solution varied between 2 to 8. It is obvious from Table-2 and figure-4, that as pH increased from 2 to 8 , there has been increase in the % removal of Cu(II) from 51 to 91 %. The maximum removal of Cu(II) i.e. 91% takes place at pH 7.5. Further increase in pH causes reduction in % removal of Cu(II) from aqueous solution/ wastewater. Hence, for all further experiment the pH of the solution was maintained at 7.5.

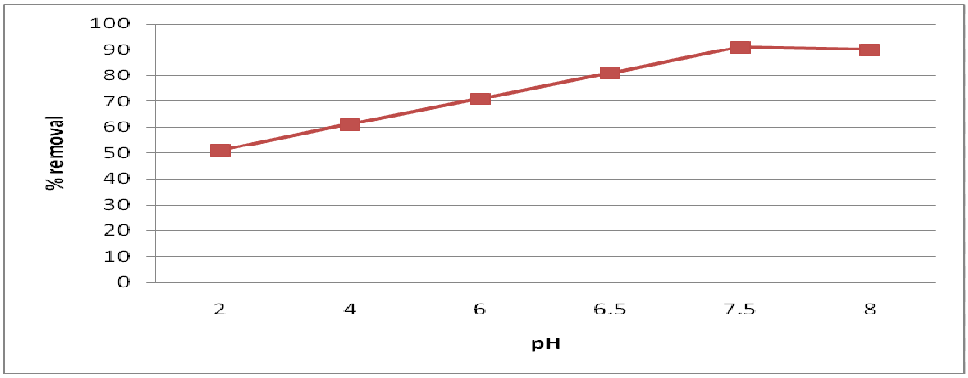

Figure 4: Effect of pH on removal of Copper(II) by ZS

Effect of Temperature

The temperature affects the removal of Cu(II) from aqueous solution using nanostructured Zirconium spheres (ZS). The adsorption experiments were carried out at three temperature ranges e.g. 30°C, 40°C and 50°C having fixed pH =7.5, contact time = 2 hours (120 minutes) in adsorption experiment. The increase of temperature from 30°C to 50°C favours the increase in adsorption. Maximum adsorption of Cu(II) about 97% occurs at 40°C, so optimum temperature selected for the adsorption studies was 40°C.

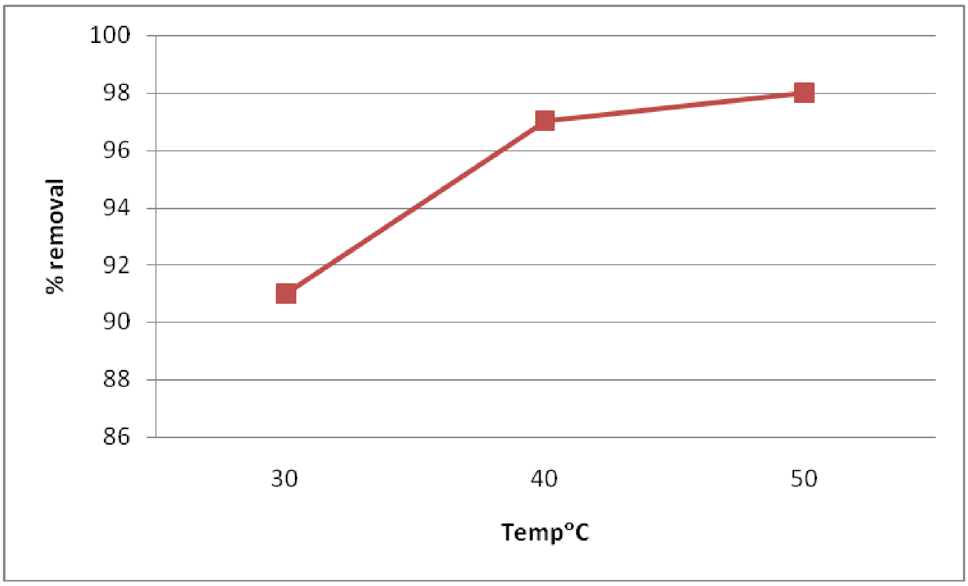

Figure 5: Effect temperature on removal of Copper(II) by ZS

CONCLUSION:

It is concluded from the above experimental studies that a good amount of Cu(II) i.e. 97% is removed by adsorption on nanoadsorbent zirconium oxide spheres (2S) at pH=7.5, contact time of 2 hours and temperature 40°C. It is successful and promising technology, which may be useful in column studies for adsorptive removal of Cu(II) rich waste water.

ACKNOWLEDGEMENT

The author is thankful to the director NIFFT, Hatia for providing necessary facilities. The author is also thankful to director and principal VMIT, Tupudana for support.

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ARSENIC REMOVAL FROM GROUND WATER BY LOW COST METHOD WASTE RUST FILTER MEDIA

Shailesh Kumar Jha, Yashvi Agrawal
Environment Engineering Department,
Hindustan College of Science & Technology, UPTU

ABSTRACT

Arsenic contamination of groundwater is a naturally occurring high concentration of arsenic in deeper levels of ground water, which became a high-profile problem in recent years due to the use of deep tube-well for water supply, causing serious arsenic poisoning to large numbers of people. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water. Arsenic is a carcinogenic which causes many kinds of cancers including Skin, Lung, and bladder cancer as well as cardiovascular disease.

Like many places of India, Arsenic in ground water is a serious problem at Bharatpur region of Rajasthan; the sample which was tested for arsenic was collected from ground water source from hand pump which was being used for so many daily needs like agricultural use, for animals and for drinking also. There the ground water was being processed by R.O but still the Arsenic removal was unsatisfactory. In this research work we did lots of experiments upon Bharatpur groundwater sample as well as on an artificial standard arsenic sample also and we found drastic results from it.

This study was done to check potential of removing Arsenic from ground water by available waste of common Iron rust, which is chemically Fe_2O_3 . It was found that the arsenic removal capacity of this rust is more than 90 % and which is superior to using hydrous ferric oxide (FeOOH) gel, for removing Arsenic, TDS and color too. In this work various experiments were done to prove the better Arsenic removal capacity of rust, which were compared with the results of FeOOH for various water parameters. Lastly it was found that using Iron rust is more efficient in removing arsenic from ground water.

KEYWORDS: Iron (III) oxides, Silica, Adsorbent, Arsenic removal, Iron rust, Eco-Friendly Arsenic removal Filter

INTRODUCTION

The problem of Arsenic pollution of ground water has been creating serious threat to a number of districts in West Bengal and some selected pockets of other parts of India like Bharatpur City (Rajasthan), Aligarh (UP), Darbahnga (Bihar) {3}. While WHO permissible limit of Arsenic in ground water is known to be 0.01 mg/L (10 parts per billion (ppb)) {16}, it has been reported that in the above part of India with a population of about 30 million, the Arsenic content is much more higher than the WHO limit. It may be noted here that Bureau of Indian Standards (BIS) has also revised the limit of Arsenic in drinking water from 0.05 to 0.01 mg/L (5 to 1 ppb) since 2003.

TABLE I: Affected Areas by Arsenic Toxicity

DISTRICT AND CITY	CONCENTRATION IN mg/L
South 24 Parganas, West Bengal	0.06-3.20
North 24 Parganas, West Bengal	0.06-1.28
Malda, West Bengal	0.05-1.434
Nadia, West Bengal	0.05-1.00
Murshidabad, West Bengal	0.05-0.90
Bharatpur City, Rajasthan	**0.4-0.5**
Darbahnga, Bihar	0.05-0.1

(Source: A Study on Arsenic Contamination in Indian Urban, Sub-Urban & Rural Area – WHO Report)

These results provide substantial evidence of prolonged Arsenic ingestion by the people through food chain as well as drinking water sources. Hair, nails, scales, urine and liver tissue analyses of people living in affected areas show elevated levels of Arsenic(**refer:** *Kamal, ASM and Preeda, P (2002) Arsenic Pollution in Hizla, Bangladesh: Causes, Effects and Remedies,* *Journal ScienceAsia, 2002, Vol. 28. No.2 and International Agency for Research on Cancer, 1980*). The source of Arsenic is geological. The contamination is mostly reported from aquifers at a depth of 20-80 meters below ground. Various social problems are known to result from the Arsenic skin lesion in these districts. What is worrying is that malnutrition, poor economic/socio conditions, illiteracy, food habits and constant ingestion of Arsenic contaminated water for prolonged periods have aggravated Arsenic toxicity. In all these districts, it has been found that major water demands are met from ground water. High withdrawal of water causes leaching of Arsenic from the aquifer to source. If proper remedial measures are not taken, it is possible that large percentage of 30 million people of these districts may become exposed to Arsenic toxicity in near future.

BACKGROUND

I. What is Arsenic?

Arsenic is a heavy metal that is placed in the group of Inert Metal group. The presence of it in a small quantity in water or food may affect the Human health drastically and some time may lead to Death {4}. The speciation of arsenic governs its availability, accumulation, and toxicity to organisms as well as its mobility in the environment. Arsenic (V) is the form that is more readily precipitated with or adsorbed onto metal oxides {9}. An ingested dose of 70-180 mg of arsenic trioxide ($As2O3$) is lethal to humans. Somewhat lower doses produce sub-acute effects in the respiratory, gastrointestinal, cardiovascular, and nervous systems. Chronic exposure to arsenic in drinking water has been linked to serious dermatological conditions; including black-foot disease, epidemiological studies have linked arsenic in drinking water with cancer of the skin, bladder, lung, liver, and kidney and other ailments. Both As (III) and As (V) are strongly adsorbed in the human body. As (III) tends to accumulate in the tissues, whereas As (V) and organic arsenic are rapidly and almost completely eliminated via the kidneys [3]. The MCL for arsenic in drinking water for many years was 0.05mg/L [8], but recent research has suggested that the cancer risk at

0.05mg/L is unacceptably high. A review of the available arsenic- and health-related data prompted the USEPA to lower the level to 0.01mg/L, the same as the World Health Organization’s standard.

II. Arsenic in ground water in Bharatpur city:

Bharatpur is located at a distance of 55 kms from Agra, 22 kms from Fatehpur Sikri, 32 kms from Deeg, 39kms from Mathura,

176 kms from Alwar and184 kms from Jaipur. The water sample collected from Bharatpur city was collected from a tube well shown below which was being used by the local peoples for drinking washing and many other routine purposes, even this water being given to their pet animals also. After the numbers of tests performed, it was found that the samples have high arsenic concentration as per WHO Standards.

MATERIAL AND METHODS

Column filtration method: The column filtration method was used in this practical work. This method requires quite less financial investment and facilitates the researcher to change the filling material easily for cleaning and any required corrections/amendments. Three kinds of columns were used independently for comparing with each other to see the efficiency of particular column. Different - different arsenic positive samples (0.10 to 2.00 mg/l) were passed through these columns at the same input flow rate (200ml/hrs). The filtered water was then tested for Arsenic, TDS and color etc (TDS was examined by using TDS meter). Lastly the results were compared with each other. Column first was containing Sand, Gravels, Sieve, Cotton cloth, Glass Beads and our main arsenic removal FeOOH gel, second column was containing all above of first column except the gel, the waste Iron rust was used instead of that. The third column was same as second column but there was an extra layer of charcoal present beneath iron rust layer. Back wash was given to all the three columns time to time.

I. FeOOH Gel prepared for column Treatment

The gel of FeOOH can be prepared by using:

Sodium Hydroxide – NaOH - 500 ml
Ferric Chloride — FeCl3 - 500 ml
Sodium Silicate – Na2SiO3 - 500 ml

When all mixed in required proportion pouring slowly and stirring for some about 1-2 Hour by using automatic stirrer a gel like substance is obtained which has a definite and some iron like property.

II. Treatment Using RUST

Rust is a general term for a series of iron oxides, usually red oxides, formed by the reaction of iron and oxygen in the presence of water or air moisture. Several forms of rust are distinguishable visually and by spectroscopy, and form under different circumstances. Rust consists of hydrated iron (III) oxides $Fe_2O_3 \cdot nH_2O$ and iron (III) oxide-hydroxide (FeO (OH), Fe $(OH)_3$). Rusting is the common term for corrosion of iron and its alloys, such as steel. Other metals undergo equivalent corrosion, but the resulting oxides are not commonly called rust. Given sufficient time, oxygen, and water, any iron mass eventually converts entirely to rust and disintegrates. We have taken the sample of RUST from common Household and easily available substances. A common type of Rust from a thrown Cooler as we have obtained is shown in the following figure.

Fig1. Showing used Cooler as a source of raw rust. (Source: Picture taken from camera: Self)

A Set-Up of Column using RUST is shown below. This set-up also contains Sand, gravels, glass beads, filter papers, sieve and cotton cloth.

Fig2. Showing a Full Setup of Rust Column (Source: Picture taken from camera: Self)

III. Treatment using Rust + charcoal

Third and one of the important method for the removal of Arsenic from the ground water. Charcoal has the property to decrease the unwanted impurities like colour and some biological impurities from the water.

ARSENIC TEST

Arsenic concentration in water was tested by a highly sensitive arsenic test kit by Merck KgaA, Germany. Measuring range (color scale graduation): 0, 0.005, 0.01, 0.025, 0.05, 0.1, 0.25, 0.5 mg/l. The kit work on the principle that, When zinc and a solid acid are added to compounds of arsenic (III) and arsenic (V), arsenic hydride is liberated, which in turn reacts with mercury (II) bromide contained in the reaction zone of the test strip to form yellow-brown mixed arsenic mercury halogenides. The concentration of arsenic (III) and arsenic (V) is measured **semi-quantitatively** by visual comparison of the reaction zone of the test strip with the fields of a color scale.

RESULTS

Table II: Comparison between treatments obtained by three columns (Bharatpur sample)

S.No.	Parameters	FeOOH Gel		Rust		Rust - Charco	
		Initial	Final	Initial	Final	Initial	Final
01	Arsenic concentratio (mg/lit)	0.5	0.1	0.5	0.05	0.5	0.05
02	Arsenic Removal in	---	80 %	---	90 %	---	90 %
03	Total solids (mg/lit	2,100	2,900	2100	2,200	2100	1,900
04	Color	Clear	Reddish orang	Clear	yellowis	Clear	Clear

(Source: Both Table II & III – Self Experimental Data in Laboratory)

Table III: Comparison between treatments obtained by three columns (Std. Sodium Arsenite Solution 2 mg/lit).

S.No.	Parameters	FeOOH Gel		Rust		Rust - Charcoal	
		Initial	Final	Initial	Final	Initial	Final
01	Arsenic concentration (mg/lit)	2.0	0.4	2.0	0.2	2.0	0.2
02	Arsenic Removal in %	---	80 %	----	90 %	-----	90 %
03	Total solids (mg/lit)	2.5	125	2.5	76	2.5	12.0
04	Color	Clear	Reddish orange	Clear	yellowish	Clear	Clear

CONCLUSION & RECOMMENDATION

This study proves that the waste iron rust has the capacity to adsorb Arsenic from Ground water even in greater strength in compare to FeOOH Gel. The Arsenic removal capacity of Gel was found to be 80 % while the Arsenic removal capacity of rust was 90 %. The backwash was required more frequently in the rust column otherwise the arsenic removal capacity was lowering down. The TDS and color were increased more in FeOOH Gel while less in rust column. In the test with third column (i.e., rust with charcoal) we found very good results, its efficiency was 90 % Arsenic removal with no extra cost and color and TDS also remained constant. Through this study it is clear that rust technology is more effective and low cost and needs less effort, even maintains the solid waste problem of the area upto a level.

- It is strongly recommended that Arsenic contaminated water should not be used for drinking but for cooking, washing, bathing and irrigation/agricultural purposes, a proper scientific study has to be carried out. Also, the issue of permissible limits of Arsenic in vegetables / fruits / crops, etc. has also to be looked into.
- Treatment options for Arsenic removal have to be foolproof with zero environmental impact and inbuilt arrangement for sanitary disposal of Arsenic bearing sludge.
- Best long term/medium term/techno-economically viable options need to be prescribed on absolute terms on the parameters such as capital cost, recurring cost, capability of decentralized management and utilization of technologies/options in the field and best technological options on least cost basis.

- Many technologies meant for removing Arsenic also removed iron from the water. Therefore, stringent monitoring mechanism is required. It was also observed that presence of Iron along with Arsenic in drinking water improved the Arsenic removal in adsorption process.
- Any Arsenic Removal package must comprise both the technology for sludge disposal as well as a package for technical education for the users and also should ensure a continuous supply of chemicals/media etc.
- Treatment of Arsenic – affected water appears to be feasible only in areas where piped water supply cannot reach. Arsenic removal using different technologies will work only if the methodology is backed by ways and means to educate all affected villagers in the working of the plant.
- Rain Water Harvesting should be in place as a local solution wherever it is feasible.
- The State has increasingly gone in for surface water and its efforts in this direction are commendable. It may be safe to completely stop using affected water.
- It may be necessary to treat water from ponds / pools to remove contamination and supply it as piped water wherever feasible.
- Standard methods need to be explained regarding safe disposal of sludge that comes out of arsenic treatment plant at the community as well as district level. Central Pollution Control Board standards need to be clearly indicated in this regard.
- It may also be noted that although the contract is given to Agency for installation, operation and maintenance and safe disposal of sludge but, in reality, once the arsenic contaminated sludge is taken away by the Agency from the treatment site, one does not know whether the sludge is disposed off in a safe manner.
- Sludge Disposal Methods have to be foolproof, user-friendly and environment friendly.
- It was strongly felt that whichever technology is being adopted there should be very strong monitoring mechanism to control the filtered water quality.

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MAJOR ION CHEMISTRY OF MELT WATER DRAINING FROM CHHOTA SHIGRI GLACIER, WESTERN HIMALAYA, INDIA

Virendra Bahadur Singh*, AL. Ramanathan, Jose George Pottakkal, Parmanand Sharma,
Anurag Linda and Naveen Kumar
School of Environmental Sciences, Jawaharlal Nehru University, New Delhi-110067, India.
Email: virendrasinghjnu@gmail.com

ABSTRACT

Major ion chemistry of meltwater daring from Chhota Shigri Glacier has been carried out to understand weathering and geochemical processes controlling hydrochemistry of glacier. The presence of anions and cations varied as $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^- > PO_4^{3-}$and $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ in the meltwater of Chhota Shigri Glacier respectively. The relative high contribution of (Ca+Mg) to the total cations (TZ^+), high (Ca+Mg)/(Na+K) ratio and low (Na+K)/TZ^+ ratio indicate the dominance of carbonate weathering as a major source for the dissolved ions in the glacier meltwater.

Keywords: Major ion chemistry, weathering, Chhota Shigri Glacier, Western Himalaya

INTRODUCTION

Little work has been done on the hydrochemistry of Himalayan glaciers. The Hydro-geochemical characteristics of meltwater discharge from the glacier can be distinguished in terms of chemical activity from other aqueous systems. Analysis of meltwater draining from the glacier snout shows them to be enriched in numerous chemical species (Drewry, 1986). The presence of such constituents serves as an indicator of effective hydro-geochemical reactions within the glacier environment, particularly at the base of the ice masses.

Various studies on alpine glaciers by Rainwater and Guy (1961), Beherens *et al* (1971), Lorrain and Souchez (1972), Collins (1978, 1979 a,b), Tranter and Raiswell (1991) and in Himalayan region Singh *et al* (1998) and Ahmad and Hasnain (2001) have suggested two principal flow components, viz. water passing through subglacial channels in contact with the rock substrate and water running off rapidly through englacial channels without undergoing significant chemical change. These studies indicate the high rate of chemical weathering in glaciated regions resulting from long residence times of meltwater in contact with bed rock. The purpose of the present work is to understand hydro-chemical characteristics including weathering and geochemical processes controlling major ion chemistry of Chhota Shigri Glacier meltwater.

Study area

The Chhota Shigri Glacier is one of the well-developed and easily accessible glacier of the Chandra-Bhaga River basin. Geographically this glacier is located between 32°11' - 32°17' N and 77°29'-77°33' E and known as valley type glacier. Table 1 gives a list of geographical and topographical characteristics of Chhota Shigri Glacier. The total area of Chhota Shigri basin from the location of hydrological station on the proglacial stream at 3900 m a.m.s.l is 34.7 km^2 (47 % glacierized). The total glacierized area including tributaries is 16.3 km^2 while the Chhota Shigri glacier covers 15.7 Km^2 (Wagnon et al., 2007).

The Chhota Shigri Glacier drains into the Chandra River. The Chhota Shigri Glacier stream flows in a NW direction and meets the Chandra River at right angles at about 2.5 Km downstream of the snout. The Chandra River flows in E to W direction at the confluence. A gauging site was established for the meltwater sampling. The gauging station was located at 32°17'24.58" N and 77°31'55.21" E on the Chhota Shigri Glacier stream at about 3900 m a.s.l., 2.0 km downstream from the snout of the Chhota Shigri Glacier (Figure 1).

Table: 1 Geographical and topographical characteristics of Chhota Shigri Glacier

General features	
Country, state	India, Himachal Pradesh
Mountain range	Western Himalaya, Pir Panjal rang
District	Lahaul and Spiti
Drainage system	Chandra River-Indus River (Chenab branch)
Climate	Monsoon-arid transition zone
Glacier characteristics	
Latitude	32.19-32.28^{O} N
Longitude	77.49-77.55^{O} E
Maximum elevation	6263 m a.s.l
Snout position	~ 4050 m a.s.l
Basin area	34.7 Km^2 (47 % glacierized) at 3900 m a.s.l on proglacial stream
Total glacierized area	16.3 Km^2
Chhota Shigri Glacier area	15.7 Km^2
Glacier length	9.0 Km
Mean orientation	North

Source: (Wagnon et al., 2007)

Geology of area

Chhota Shigri glacier lies within the Central Crystallines of the Pir Panjal range of the Himachal Himalaya. Here meso- to ketazonal metamorphites, migmatites and gneisses are found (Kumar and Dhobal, 1997). Granite rocks of different composition and younger age found in a few places indicate rejuvenation. The main lithologic unit of the Chhota Shigri Glacier catchment is Rohtang gneiss (Kumar et al., 1987), while 3 km upstream of Chhota Dara, in the upper Chandra valley, older Palaeozoic granitic rocks are exposed. The Haimanta formation overlies these within a tectonic break, where black slates, phyllites and fine-grained biotite schists are exposed (Kumar and Dhobal, 1997). The rocks between Chhota Shigri and Bara Shigri glaciers are granite, granite gneiss, augen gneiss, parphyritic granite, schistose gneiss, milky-white muscovite-quartzite and muscovite-biotite schist. Late stage pegmatitic veins are quite common in which light grey-green feldspar crystals are found (Kumar et al., 1987).

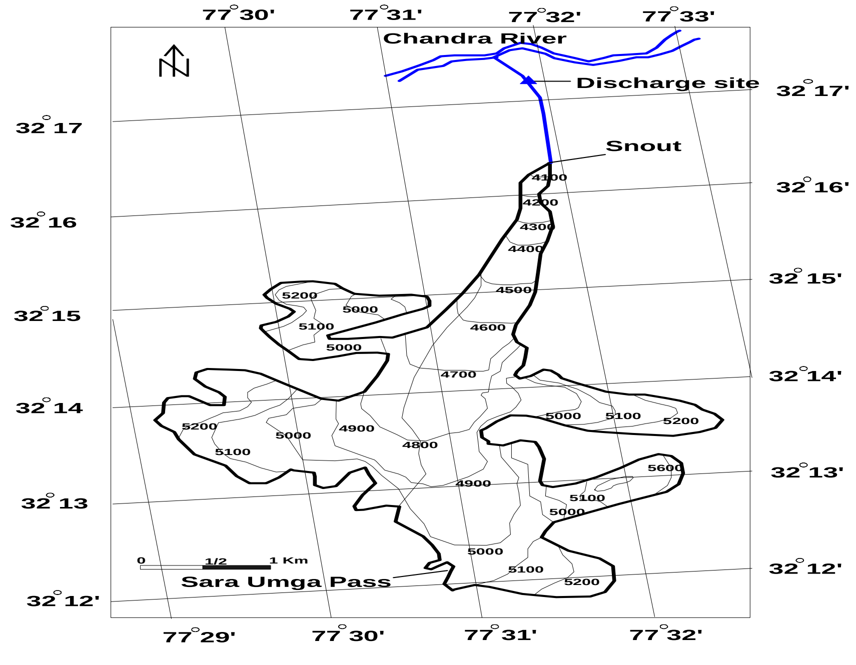

Fig.1: Map showing location of the study area

MATERIALS AND METHODS

Meltwater draining from Chhota Shigri glacier was collected in prewashed polyethylene bottles of 250 ml capacity. pH and electrical conductivity (EC) were measured in the field by using portable pH and EC meter. Bicarbonate was analyzed by acid titration method (APHA 2005). The samples were filtered through 0.45 µm Millipore membrane filters. Dissolved silica analysis was carried out by molybdosilicate method (APHA 2005). Chloride concentration was determined by mercury (II) thiocyanate method (Florence and Farrar 1971). The turbidimetric method and brucine-sulphanilic acid method (APHA 2005) were used to measure the concentrations of sulphate and nitrate respectively. Major cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were analysed by atomic absorption spectrophotometer (Electronic Corporation of India Limit, AAS4141). Ca^{2+} and Mg^{2+} were determined in the absorbance mode and Na^{+} and K^{+} in the emission mode.

RESULTS AND DISCUSSION

Meltwater draining from Chhota Shigri Glacier is slightly acidic in nature. HCO_3^- was the dominant anion accounting 68.5% of the total anions. In anionic abundance HCO_3^- was followed by SO_4^{2-}, Cl^-, NO_3^- and PO_4^{3-} accounting 28.2%, 2.3% and 1.0 % of total anions respectively. In cationic abundance Ca^{2+} was dominant cation accounting 42.9% of the total cations followed by Mg^{2+} (28.8%), Na^{+} (15.2%) and K^{+} (13.1%).

Chemical characteristics of glacier meltwater are mainly controlled by chemical weathering of freshly weathered rock materials at the base of the glacier and atmospheric input (dry and wet deposit) (Ahmad and Hasnain, 1999). The Scatter plot of (Ca+Mg) vs TZ^+ (Figure 2) shows that all points fall above 1:1 line with an average equivalent ratio of 0.7. The relatively high contribution of (Ca+Mg) to the total cations (TZ^+) and high (Ca+Mg)/(Na+K) ratio (2.70) indicate that carbonate weathering is a major source of dissolved ions in the Chhota Shigri Glacier meltwater. The (Na+K) vs TZ^+ scatter plot (Figure 3) shows that low equivalent ratio i.e 0.3 indicating a relatively low contribution of dissolved ions from silicate weathering.

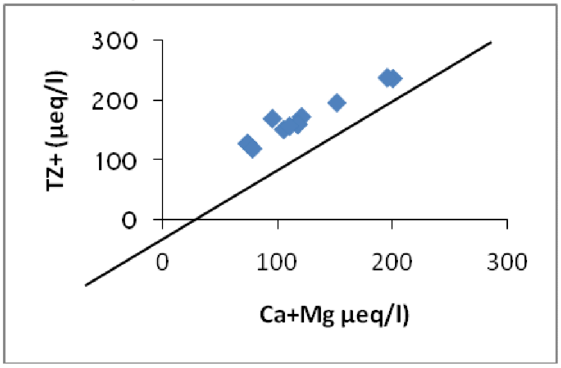

Fig. 2: Scattered plot between Ca+Mg vs TZ^+

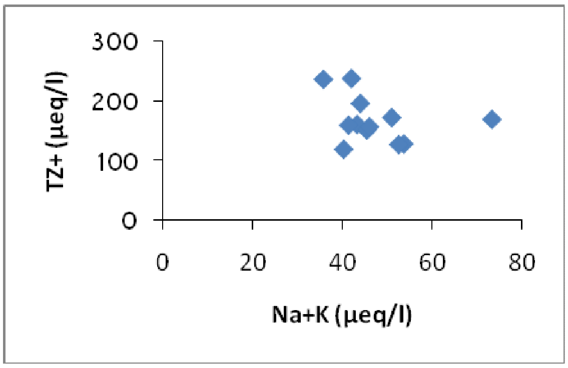

Fig. 3: Scatter plot between Na+K vs TZ^+

(Ca+Mg) vs (HCO_3+SO_4) scatter plot (Figure 4) shows that good correlation throughout the range of data and all points fall above 1:1 line requiring a portion of the (HCO_3+SO_4) to be balanced by cations (Na+K) from weathering of silicate rocks (Pandey et al., 1999). Trace amount of NO_3^- and PO_4^{3-} were also reported from the study area, indicating possible influence of anthropogenic activities in the sampling area. The scattered plot of (Na+K) vs Cl^- (Figure 5) shows that (Na+K) content is much higher than Cl^- and average Na+K/Cl ratio for the study area is significantly higher than expected marine aerosols. The average equivalent ratio of Na/Cl was 8.8, whereas K/Cl ratio was 7.6.These ratios are significantly higher than those of sea water (i.e.- Na/Cl= 1.0 and K/Cl= 0.2 respectively). These ratios indicate relatively minor contribution from atmospheric precipitation to the observed dissolved ions budget of the meltwater of Chhota Shigri Glacier as reported by other researchers (Pandey et al., 1999).

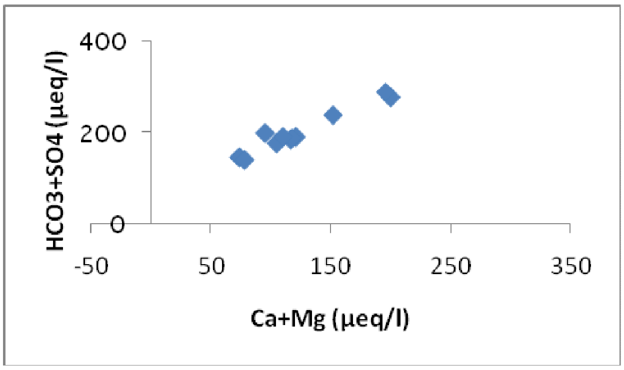

Fig. 4: Scatter plot between Ca+Mg vs HCO_3+SO_4

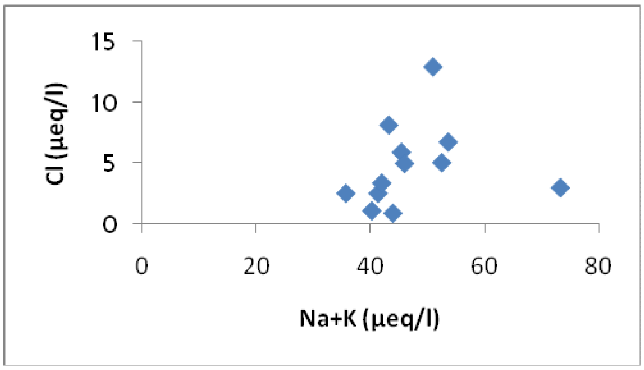

Fig. 5: Scatter plot between Na+K vs Cl

From Piper Tri-linear diagram (1944), it is clear that alkaline earth metals (Ca+Mg) are significantly higher than alkalis (Na+K) and weak acids (HCO_3), which dominated over strong acids (SO_4+Cl) (Figure 6) and majority of samples fell in the category of Ca-HCO_3 type water. This further confirms that carbonate weathering is the major source for the dissolved ions in the meltwater of Chhota Shigri Glacier.

A correlation matrix of measured parameter is given in Table 2. EC was better correlated with HCO_3^- (r^2=0.68), SO_4^{2-} (r^2=0.88), H_4SiO_4 (r^2=0.96), Ca^{2+} (r^2=0.95), Mg^{2+} (r^2=0.99) and TDS (r^2=0.98). These associations suggest the dependency of EC on $HCO3^-$, H_4SiO_4, SO_4^{2-}, $Ca^{2+,}$ Mg^{2+} and TDS of the meltwater of Chhota Shigri Glacier. Strong correlation was observed between Ca^{2+} and Mg^{2+} (r^2=0.96) and Na^+ and K^+ (r^2=0.83) indicating the same source, which may be carbonate and silicate weathering respectively. Good correlation was also observed between Ca^{2+} and SO_4^{2-} (r^2=0.92) and Mg^{2+} and SO_4^{2-} (r^2=0.92), probably resulting from dissolution of sulphate minerals.

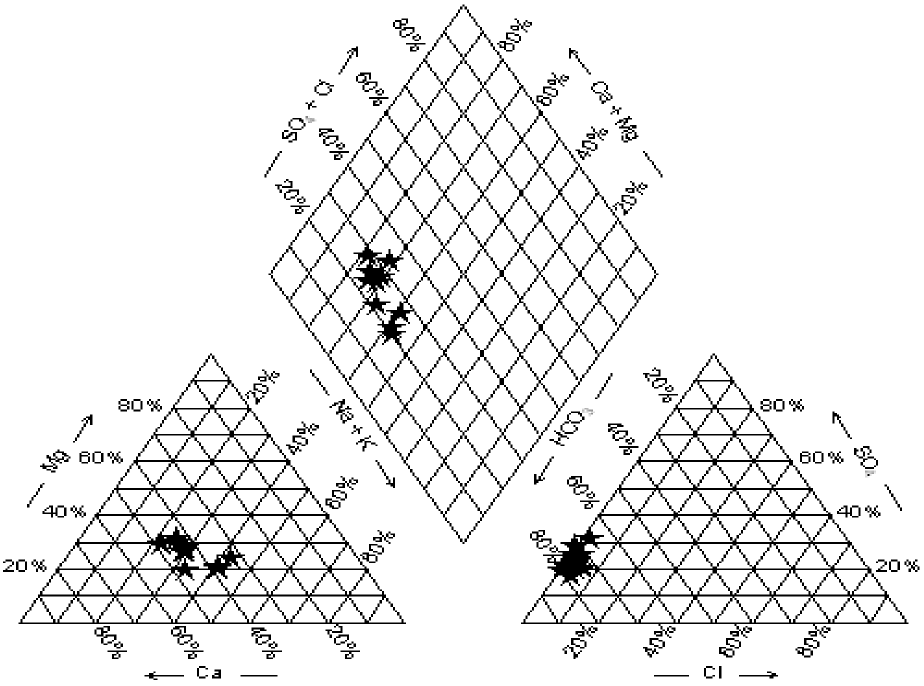

Fig.6: Piper plot for concentration of ions

Table: 2 Correlation matrix of measured parameters in Chhoota Shigri Glacier melt water

	EC	pH	HCO_3	SO_4	Cl	PO_4	NO_3	H_4SiO_4	Ca	Mg	Na	K	TDS
EC	1.00												
pH	0.13	1.00											
HCO_3	0.68	-0.14	1.00										
SO_4	0.88	0.43	0.34	1.00									
Cl	-0.13	-0.79	-0.04	-0.32	1.00								
PO_4	-0.41	-0.11	-0.06	-0.48	0.11	1.00							
NO_3	0.01	-0.29	0.13	-0.23	0.50	0.46	1.00						
H_4SiO_4	0.96	0.01	0.71	0.78	-0.11	-0.29	0.06	1.00					
Ca	0.95	0.21	0.58	0.92	-0.24	-0.56	-0.13	0.87	1.00				
Mg	0.99	0.17	0.64	0.92	-0.17	-0.43	-0.10	0.94	0.96	1.00			
Na	-0.49	-0.13	0.04	-0.55	0.15	0.79	0.18	-0.43	-0.62	-0.50	1.00		
K	-0.23	-0.09	0.23	-0.35	0.21	0.74	0.27	-0.18	-0.41	-0.26	0.83	1.00	
TDS	0.98	0.15	0.78	0.85	-0.17	-0.30	-0.02	0.94	0.92	0.97	-0.33	-0.08	1.00

CONCLUSION

Meltwater draining form Chhota Shigri Glacier, order of cationic abudance is $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$, while anionic abundance order is $HCO_3^{-} > SO_4^{2-} > Cl^{-} > NO_3^{-} > PO_4^{3-}$. The high ratios of (Ca+Mg/Na+K), (Ca+Mg)/TZ^{+} and low value of (Na+K)/ TZ^{+} suggest that carbonate weathering as a major source of dissolved ion in the meltwater of Chhhota Shigri Glacier. The equivalent ratios of Na/Cl and K/Cl are significantly higher than those of marine aerosols indicating minimal contribution from atmospheric precipitation to the dissolved ion budgets of the Chhota Shigri Glacier meltwater. Piper plots indicate the dominance of alkaline earth metals (Ca+Mg) over the alkali metals (Na+K) and week acid (HCO_3) over strong acid (SO_4+Cl) in the meltwater. This further confirms that carbonate weathering is the major source of dissolved ions in the meltwater of Chhota Shigri Glacier.

ACKNOWLEDGMENTS

The authors are thankful to Department of Science and Technology (DST), Govt. of India for funding the research project on Chhota Shigri Glacier.

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WASTE MANAGEMENT IN DISTILLERIES THROUGH AGRICULTURE

Gurmeet Singh, H.C.Joshi and Navindu Gupta
Environmental Sciences Division,
Indian Agricultural Research Institute, New Delhi-12

ABSTRACT

Waste management in distilleries has been a challenging task due to enormous amount of wastewater, which can defile the natural ecosystem if discharged directly into water bodies. Various options have been explored to utilize the molasses distillery effluent in formulations viz, direct one time pre-sown irrigation, continuous irrigation with effluent diluted with normal water, application of effluent through press mud compost, application of effluent dried by mixing with fly ash and effluent composted with rice straw. These formulations have been tried on different agricultural crops and the results suggest profitable application of distillery effluent in agriculture. The addition of effluent increased fertility of the soil. However, effluent application at higher doses caused accumulation of salts, particularly the potassium, in the soil profile. The compost prepared of rice straw and methanated effluent. The application of graded levels of fly ash and distillery effluent mixtures to soil proportionately increased the pH and electrical conductivity. The major nutrients like nitrogen, phosphorus and potassium registered significant increase after application. Agricycling of wastewater thus may offer many significant low cost alternatives for pollution control in distilleries.

Key words: Distillery effluent, Ferti-irrigation, press mud, compost, agri-cycling, fly ash.

INTRODUCTION

Distilleries are one of the most important agro based industries in India and generate enormous amount of wastewater, which can defile the natural ecosystem if discharged directly into water bodies. The demand for alcohol in India has grown up from 285 distilleries producing 1.41×10^9 L of alcohol per year in 1998-99 to 319 distilleries producing 3.25×10^9 L of alcohol (Uppal 2004). This demand is continuously increasing because of mixing 5% ethanol with petrol and further raising this amount to 10% (The gazette of India, 2002) as well as due to other usages of ethanol such as industrial solvent and beverages. Consequently, there has been significant increase in the waste water generation from this sector (4×10^{10} L of wastewater annually). Alcohol production from molasses started in late 1930 as a result of increase in sugar factories (29 factories) in 1931 producing 1.2 lakh tonnes sugar and 50,000 tonnes of molasses to 135 units by 1935-36 producing 9.34 lakh tonnes sugar and 3.36 lakh tonnes of molasses. This drastic increase led the Government to encourage alcohol production using molasses. By year 2006-07, the production of molasses amounted to 11.36 million litres and molasses based alcohol production as 2.3×10^9 L (Ethanol India, 2010).

The effluents from molasses based distilleries contain large volume of dark brown colored molasses spent wash (MSW) characterized by very high organic pollutant load. Approximately, 15 L of spent is generated for the production of one litre of alcohol (Beltran *et al*., 2001). MSW is one of the most difficult waste products to dispose because of low pH, high temperature, dark brown colour, high ash content and high percentage of dissolved organic and inorganic matter (Beltran *et al*., 1999). The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) typically range between 35,000–50,000 and 100,000–150,000 mg L^{-1}, respectively (Nandy *et al*., 2002). These highly coloured MSW not only can block out sunlight from rivers and streams in which they are discharged; but also can reduce oxygenation of the water by photosynthesis. The high nutrient load can lead to eutrophication of the water bodies (FitzGibbon *et al*., 1998). The estimated LC_{50} for distillery spent wash was observed as 0.5% using a bio-toxicity study on fresh water fish *Cyprinus carpio var. Communis* (Mahimaraja and Bolan, 2004; Ramakritinan *et al*., 2005). Spent wash also leads to significant levels of soil pollution and acidification in the cases of inappropriate land discharge. It is reported to inhibit seed germination, reduce soil alkalinity, cause soil manganese deficiency and damage agricultural crops. However, effect of distillery effluent on seed germination is governed by its concentration and is crop-specific (Kannabiran and Pragasam, 1993; Agrawal and Pandey, 1994).

Safe discharge of the waste water from distillery has received attention worldwide. It has been considered among 37 most hazardous industries in India. Central Pollution Control Board; the apex pollution control authority in India; has put strict norms for the zero discharge of spentwash from distillery industry by December (CPCB, 2003). As per the legislation imposed by CPCB/SPCBs, 100% utilization of spentwash has to achieved as well as the controlled and restricted discharge of treated effluent from lined lagoons during rainy season will be allowed in such a way that the perceptible colouring of river water bodies does not occur.

Several physical, chemical and biological treatment approaches have been developed/ employed for the treatment of distillery wastewater such as anaerobic digestion and RO technologies (Pant and Adholeya, 2007). Spent wash is therefore, recycled to produce methane that helps to meet the energy requirements of the distillery boiler and the post methanation effluent (PME) has considerably lower organic load and near neutral pH (Joshi, 1999; Kumar and Joshi, 2001; Kaushik *et al*., 2005). Secondary treatment of the methanated effluent generally does not succeed in controlling the BOD of the effluent. The new options of evaporation and drying of effluent and application of RO technologies have neither proved to be cost effective nor provided complete solution towards zero discharge wherever these are introduced.

USE OF DISTILLERY EFFLUENT IN AGRICULTURE

Distillery effluents are valuable sources of plant nutrients especially N, P, K and organic substrates as well as its also rich in micronutrients, essential for plant growth such as Fe, Cu, Zn and B etc(Pathak *et al*. 1999, Chhonkar *et al*., 2000). Despite that fact that the concept is to shift a hazardous pollutant from one ecosystem (water) to another (soil); therefore, an economically and environmentally viable solution for the problem faced by generation of such large volumes of effluent from distilleries has become imperative. It is extremely important to examine the effects of PME applications on various physico-chemical properties of soil as well as on crop growth and yield.

The application of PME in agriculture has been tested by various researchers in different agroclimatic regions. Efforts have been made across the world to see the effect of industrial effluents on agricultural crops (Behera and Mishra, 1982; Singh *et al.,* 1985; Choudhray *et al.,* 1987; Gautam *et al.,* 1992; Agarwal *et al.,* 1995; Kumar and Rai, 2001; Saliha, 2003; Pandey *et al.,* 2007; Tripathi *et al*., 2010). Distillery effluent in combination with bioamendments such as farm yard manure, rice husk and Brassica residues was used to improve the properties of sodic soil (Kaushik *et al*., 2005). Enhanced production of oyster mushrooms (Pleurotus sp.) using distillery effluent as a substrate amendment have been reported (Pant *et al*., 2006). However, soil conditions, crop type and concentration of the effluent are the factors governing the sensitivity of the plants. Ramana *et al*. (2002a,b,c) showed that the germination percent in five crops decreased with increase in concentration of the effluent and it was inhibited in all the five crops studied with concentration exceeding 50% (Pathak *et al*., 1999). A pragmatic approach is imperative for providing agricycling options for control of water pollution caused by distilleries which may include direct use for ferti-irrigation and production of bio-compost with pressmud and other filler materials. Some case studies have been discussed which show promise in use of distillery effluent as direct application and as biocompost prepared from different filler materials.

SOLIDIFICATION OF DISTILLERY EFFLUENT

Despite the fact, that the distillery industries have started utilizing PME in their field due to its good manurial potential, the application of the techniques has failed to reach farmers located at field far away from distilleries. Transportation of huge quantity of liquid effluent to the fields far from distilleries as well as the requirement of large area for channelising the effluent irrigation stands major hindrance in utilizing the beneficial effects of the direct application of diluted PME. In order to further explore the encouraging results, the possibilities of transforming the liquid effluent into solid form of compost were explored for easy transportation to distant places.

DISTILLERY EFFLUENT COMPOSTS WITH PRESSMUD

Distilleries situated along with sugar factories have successfully used pressmud (a byproduct of sugar industry) as filler material for making PME compost. This compost was applied on rice, mentha and maize cultivation and encouraging results were observed.

Distillery Effluent Composts with Rice Straw and Barley Mash

Quite often distilleries are not located in vicinity of sugar mills as well as the availability of pressmud is not adequate for complete utilization of distillery effluent. Hence, rice straw and barley mash were tested for the preparation of compost for the easy reach to the farmers located at distant places. Rice is grown throughout northern India and disposal of rice straw in efficient way is also a huge challenge for the farmers. Short gap period(25- 35 days) between the crop rotation (harvest of rice and sowing of wheat) is inadequate for the decomposition of rice straw in the field. Hence burning is opted by farmers as a quick and easy approach for disposal and to clear the field for wheat plantation. These wasteful practices not only cause environmental pollution but also the loss of energy and nutrients. Similar compost can be made from the barley mash, a waste product in breweries making beer.

DISTILLERY EFFLUENT ABSORBED ON FLY ASH

The safe disposal of flyash generated from thermal power plants is a major concern Mixture of PME and flyash mixture on soil health and crop productivity of flowers was assessed though the field experiment, conducted with Marigold (and Gladiolus as the test crop. The number of buds and corns were more in T_4 and showing values (12-15) and (43) respectively, than that of the control (Anandh Kumar, 2003).

CONCLUSION

Irrigation with diluted post methanation distillery effluent increased the yield of rice and wheat grown in sequence. The organic carbon, N, P and K content of soils were also increased post harvest. No drastic variations in soil pH after harvest of wheat and rice were observed as a result of diluted PME application. However, increase in the electrical conductivity of soil indicated the possibility of salinity development in the long term with higher levels of effluent application. The distillery effluents because of their high manurial potential could supply nutrients either through direct irrigation or application of solidified material as rice straw- PME compost, pressmud-PME compost to the crops for reducing the fertilizer requirement. The utilization of post methanation distillery effluents in agriculture will not only minimize the pollution hazard in recipient waters, but also prove to be eco-friendly viable technology for supplementing the nutrient requirements of agricultural crops.

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GROUNDWATER QUALITY ASSESSMENT IN PART OF NOIDA METROPOLITAN CITY, UTTAR PRADESH

ABHAY KUMAR SINGH
CSIR - Central Institute of Mining and Fuel Research
Barwa Road, Dhanbad - 826 001, India
Email: singhak.cimfr@gmail.com

ABSTRACT

An attempt has been made to study the hydro-geochemistry of the groundwater resources in part of the NOIDA metropolitan city and assessing the hydro-geochemical processes controlling the water composition and its suitability for drinking and irrigation uses. The results show that Na and Ca are the major cations and HCO_3 and Cl are the major anions in this water. The hydro-geochemical study of the area reveals that many parameters are exceeding the desirable limits and quality of the potable water has deteriorated to a large extent at many sites. High concentrations of TDS, Na, Cl, SO_4, Fe, Mn, Pb and Ni indicate anthropogenic impact on groundwater quality and demand regional water quality investigation and integrated water management strategy. SAR and %Na, values show that water is of good to permissible quality and can be used for irrigation. However, higher salinity and boron concentration restrict its suitability for irrigation uses at many sites.

Key words: NOIDA, BGIR, Groundwater quality, TDS, SAR, RSC, Hydro-geochemistry

INTRODUCTION

Public ignorance of environment and related considerations, lack of provisional basic social services, indiscriminate disposal of increasing anthropogenic wastes, unplanned application of agrochemicals, and discharges of improperly treated sewage/industrial effluents; result in excess accumulation of pollutants on the land surface and contamination of water resources. Subsurface leaching of contaminants from landfills as well as seepage from canals, rivers and drains cause severe degradation of the groundwater quality in urban areas. Groundwater in India is at risk of contamination due to rapid and unplanned urbanization, industrialization and indiscriminate disposal of domestic, industrial, agricultural and mining wastes (Subramanian 2000; Kumaresan and Riyazddin 2006; Mohan et al. 2000; Kumar et al. 2006; Ramesh et al. 1995; Singh et al. 2005; Singh et al. 2007). In recent years, scarcity of clean and potable drinking water has emerged as the most serious developmental issue in the Indian metropolitan cities including National Capital Region (NCR). The area of the NCR extends over 30,242 km^2 and covers parts of states of Haryana, Uttar Pradesh, Rajasthan and union territory of Delhi. The present study area is a part of NCR and located in NOIDA, at the outer fringe of Delhi. This paper deals with the hydrogeochemistry of groundwater, identification of potential contaminants and assessment of the suitability of water for domestic and agricultural uses.

STUDY AREA

NOIDA (New Okhala Industrial Development Authority) is a part of the National Capital Region (NCR) of Delhi in the river basin of Yamuna. It is located in the Gautam Budh Nagar district of Uttar Pradesh, 14 km south-east of Delhi, the national capital of India (**Fig. 1**). NOIDA emerges as a well planned, integrated and modern industrial city which is well connected to Delhi and other parts of North India. It is bounded in the north by NH-24 bye-pass, in the east by the River Hindon, in the west by the river Yamuna, and in the south by the confluence of the rivers Yamuna and Hindon. The sewerage collection of the city is mainly through existing open drains. The developed sectors of the city have an extensive sewer system and the city generates about 70 MLD of wastewater. Out of this, only about 9 MLD is being treated in an oxidation pond, the rest being discharged untreated to an agricultural canal running through the city and ultimately reaching the river Yamuna. The present investigation is confined in and around the proposed Botanical Garden of Indian Republic (BGIR). The investigation area lies between $28^{0}32'$N and $28^{0}36'$N latitudes and $77^{0}18'$ and $77^{0}22'$E longitudes with a mean altitude of 190 m above mean sea level. Large water reservoir of Okhala barrage along the Yamuna River exists on the western side. NOIDA situated north of Tropic of Cancer experiences a fairly hot summer and cold winter. The months of May and June are very hot and dry, while December and January are very cold. The average annual rainfall is approximately 797 mm, most of which (80%) falls during the monsoon months of July and August. It is an alluvial plain, which gently slopes towards south. There are depressions in the ground at a few places, which function as water channels form storm water drainage.

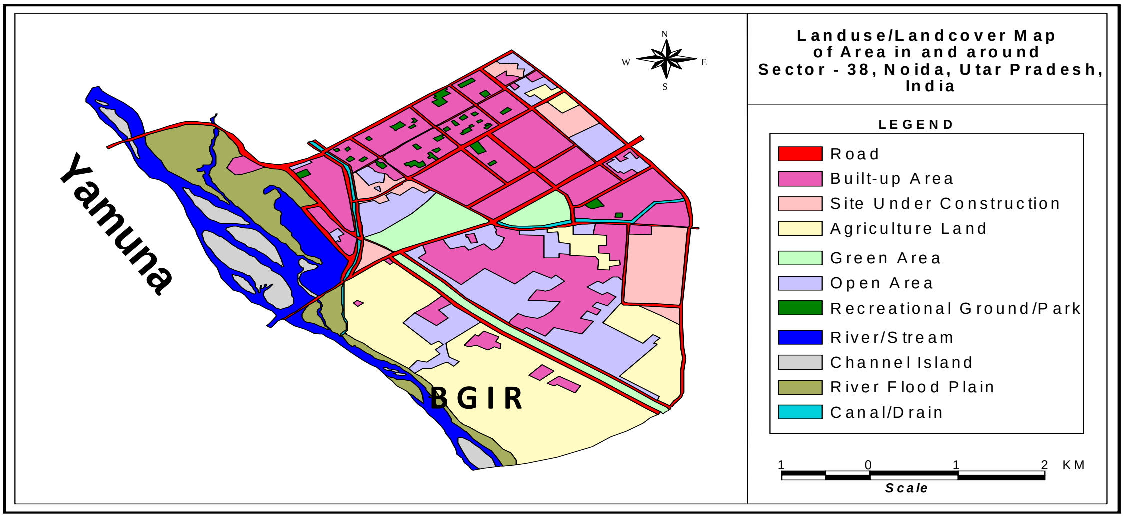

Fig. 1: Location of the BGIR and Study Area

NOIDA is occupied by newer alluvium consisting of clay and sand mixed with gravel of medium size. Newer alluvium is underlain by older alluvium consisting of predominantly clay and kankar mixed with fine to medium sand. Groundwater occurs in unconfined to semi-confined condition in medium to fine sands of newer alluvium, and fine to medium sands mixed with kankar of older alluvium. Depth to phreatic zone is usually around seven meters below ground level. The water table is relatively shallow in the southern and southwestern parts of the BGIR and deep in the northern and northeastern parts. The river Yamuna and associated Okhala reservoir play an important role in groundwater recharge of the area, besides rainfall.

Materials and Methods

In order to adjudge the quality of groundwater, 14 water samples in the post-monsoon (October) and 33 in the pre-monsoon (April-May) seasons, were collected from different tube wells, Ranney wells (large diameter well) and hand pumps during the year 2006-07 (**Fig. 2**).

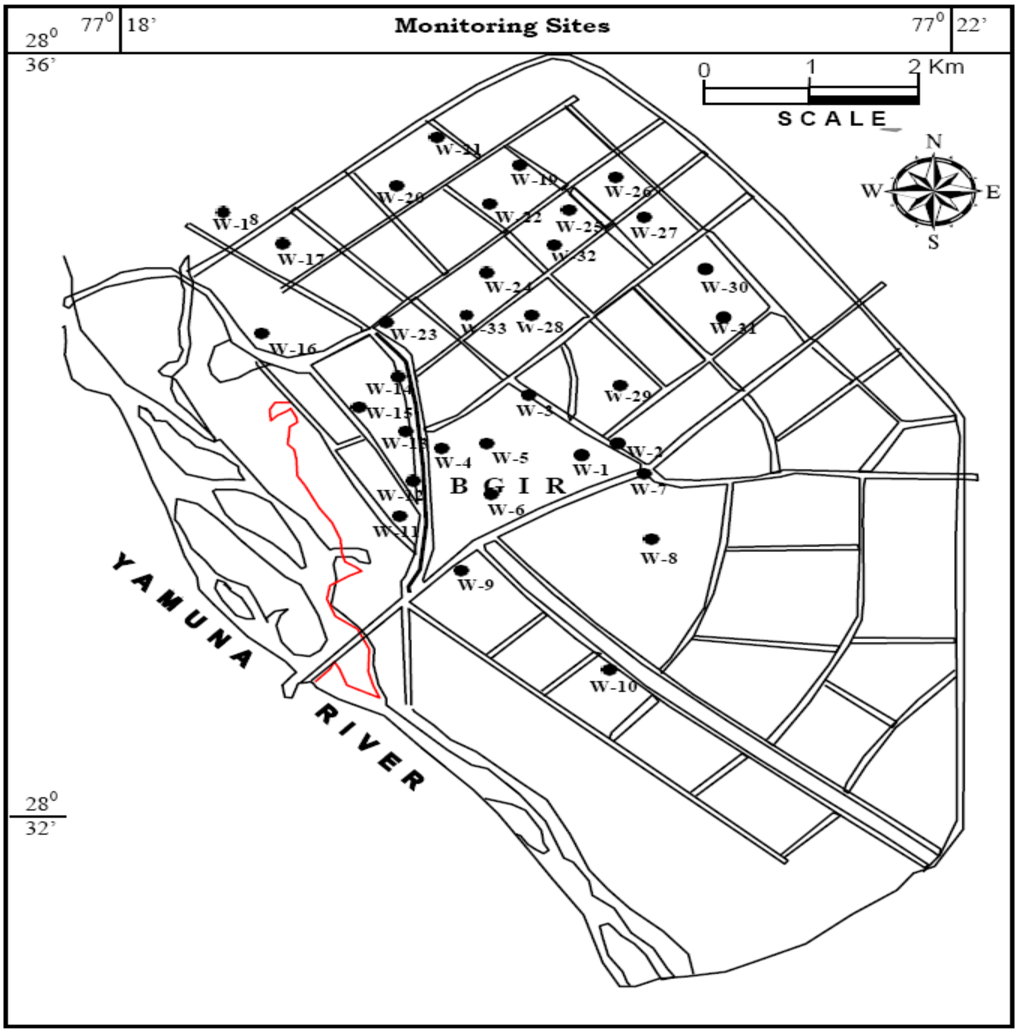

Fig. 2: Location of the water sampling sites

The water samples were collected in one-liter narrow-mouthed pre-washed polyethylene bottles. For heavy metal analysis, 100 ml of samples were acidified with HNO_3 and preserved separately. Acid titration method was used to determine the concentration of bicarbonate (APHA 1992). Major anions (F, Cl, SO_4) and major cations (Ca, Mg, Na, K) were measured by ion chromatograph. Concentrations of heavy metals in water samples were determined by ICP-MS (Perkin Elmer). The accuracy of the analysis was checked by analyzing NIST 1643b water reference standard. The precision obtained in most cases was better than 5% RSD with comparable accuracy.

RESULTS AND DISCUSSION

The analytical results of the water samples are summarized in Table 1. The water temperature in groundwater samples measured during the field collection varied in the range of 23-29^{0}C during pre-monsoon and 18-22^{0}C in the post-monsoon. The mean water temperature based on both season samples is 24^{0}C for the entire area. The pH of the analysed samples is of the order of 7.10-7.61 (average 7.40) during the post-monsoon and 7.13-7.88 (average 7.59) in the pre-monsoon months, indicating alkaline nature of the water.

The electrical conductivity (EC) values varied from 662 µS cm^{-1} to 3250 µS cm^{-1} for post-monsoon and 589 to 3930 µS cm^{-1} for pre-monsoon seasons. The EC contours for pre-monsoon season show that the electrical conductivity values of groundwater are relatively lower along the river side in the southern and northwestern parts, and high values in the eastern and northeastern parts (**Fig. 3**). The spatial variation in the EC values may reflect the wide variation in the activities and processes prevailing in the region and dilution effects due to recharging of groundwater from the Yamuna River and the Okhala Barrage reservoir.

Table 1: Range in values of chemical parameters in waters of study area and WHO (1993) and Indian Standards (IS:10500) for drinking water

Parameter	Concentration Range		WHO (1993)	BIS (1991) IS:10500	
	Pre-Monsoon	*POST-MONSOON*		Maximum Desirable	Highest Permissible
Major ions (mg l^{-1}, except EC in µS cm^{-1} and pH)					
pH	7.13 – 7.88	7.10 – 7.61	7.0-9.5	6.5-8.5	No relaxation
EC	589 – 3930	662 – 3250	-	-	-
TDS	507 – 2949	504 – 2678	1200	500	2000
Ca	55 – 269	72 – 530	-	75	200
Mg	18 – 137	19 – 131	-	30	100
Na	40 – 496	48 – 414	200	-	-
K	5.2 – 35	5.6 – 11.0	-	-	-
HCO_3	195 – 628	243 – 522	-	200	600
SO_4	11 – 837	16 – 748	250	200	400
Cl	24 – 970	21 – 713	250	250	1000
F	0.15 – 2.30	0.40 – 1.50	1.5	1.0	1.5
TH	243 - 1169	265 -1865	500	300	600
Heavy/Trace Metals (µg l^{-1})					
B	999 – 1515		300	1000	5000
Al	167 – 2920		200	30	200
Cr	7.3 - 19.7		50	50	No relaxation
Mn	10 – 1342		500	100	300
Fe	329 – 944		300	300	1000
Ni	BDL - 85.7		20	-	-
Co	04 – 2.2		-	-	-
Cu	42 – 204		2000	50	1500
Zn	91 – 2683		4000	5000	15000
As	3 – 119		10	50	No relaxation
Se	1.8 - 7.2		10	10	No relaxation
Cd	BDL - 24.2		3.0	10	No relaxation
Pb	39 – 531		10	50	No relaxation

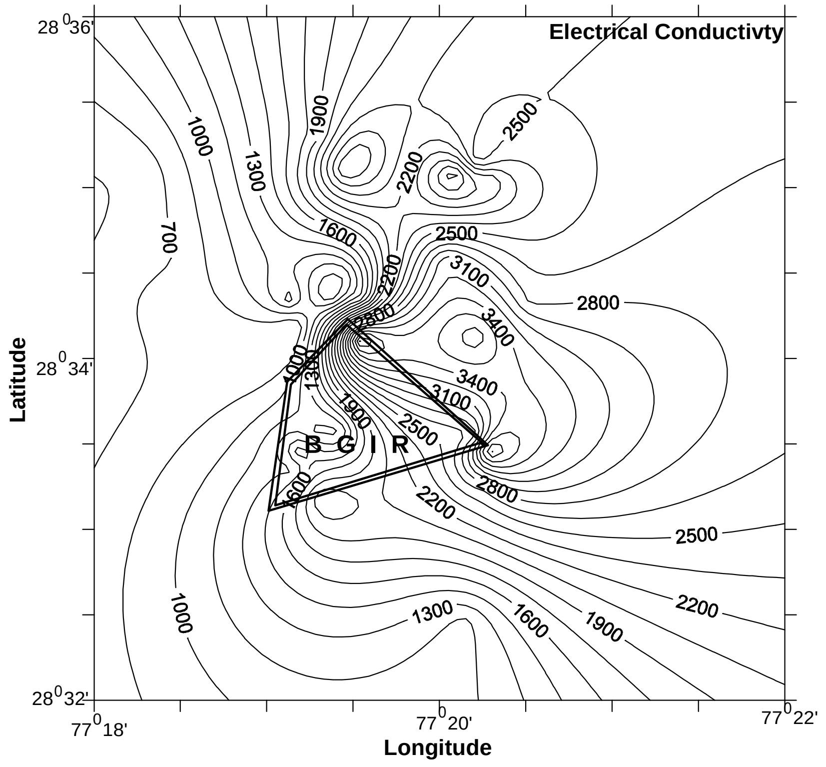

Fig. 3. Concentration contour for electrical conductivity (EC)

The total dissolved solid (TDS) concentration varies between 504 and 2678 mg l^{-1} (average 1380 mg l^{-1}) during the post-monsoon and 507 and 2949 mg l^{-1} (average 1408 mg l^{-1}) in the pre-monsoon seasons. A high value of TDS has been observed at site W-3, W-7, W-19, W-29 and W-32 during pre-monsoon and at W-1, W-29 and W-33 in post-monsoon seasons. Observed high values of TDS at these sites may be attributed to infiltration from the sewage canals, unprotected drainages and industrial wastes. The anion chemistry of the analysed samples shows that $HCO_{3,}$ Cl and SO_4 are the dominant ions both in pre and post monsoon seasons. The concentration of bicarbonate varies in the range of 243 mg l^{-1} to 522 mg l^{-1} in the post-monsoon, and 195 to 628 mg l^{-1} during pre-monsoon periods. HCO_3 contributes on an average 41% to the total anions in equivalent unit. Bicarbonates are derived mainly from the neutralization of $CO_{2,}$ originated either by adsorption from the atmosphere or from the decomposition of organic matter in the recharge area. The chloride concentration in the analysed samples varies from 21 to 713 mg l^{-1} in post-monsoon, and 24 to 970 mg l^{-1} in pre-monsoon seasons. On an average chloride is contributing 37% of the total anionic balance. The spatial distribution of Cl concentration shows relatively higher values at sites W-1, W-2, W-3, W-7, W-29, W-30, W-31 and W-32. The large lateral variation and observed high concentration of chloride in some subsurface waters indicate local recharge and may be attributed to the contamination by untreated industrial and domestic waste effluents from nearby areas. The concentration of sulphate varies from 16 to 748 mg l^{-1} (average 276 mg l^{-1}) in post-monsoon and between 11 to 837 mg l^{-1} (average 261 mg l^{-1}) in pre-monsoon seasons. Sulphate is contributing on an average 22% (2-45%) to the total anions. The contour pattern of SO_4 resembles that of Cl and shows higher concentration at sites W-3, W-7, W-19, W-29, W-31, W-32. The concentration of fluoride varies in the range of 0.17–2.30 in pre-monsoon and 0.40-1.50 during post-monsoon seasons. Relatively higher concentration of fluoride is noticed at sites W-17, W-19, W-20 and W-22. Such a higher concentration may be attributed to the percolation of phosphatic fertilizers from the irrigational runoff from the nearby lands. Discharge of domestic waters and the wastes from the surrounding industries can also increase the fluoride values. The cationic chemistry is dominated by sodium and calcium. The concentration of sodium in the post-monsoon samples was reported in the range of 48 mg l^{-1} to 414 mg l^{-1} with an average value of 192 mg l^{-1}. The concentration of the same ion in the pre-monsoon varies from a minimum value of 40 mg l^{-1} to a maximum of 496 mg l^{-1}. On an average, sodium accounts for 40% (21-71%) of the total cations (TZ^+). The sodium concentration shows relatively low concentration along the river stretches and near the reservoirs in the south and western parts, and higher concentration towards the north and northeastern sides. In cationic abundance, sodium is followed by calcium (35%), magnesium (23%) and potassium (1.3%) in the order of Na>Ca>Mg>K.

HEAVY METAL CONCENTRATION

Concentration of 13 heavy metals analysed in the 30 groundwater samples collected during pre-monsoon season. The results show that concentrations of Zn, Cu, Cr, Cd, As, Se, and Co are found below the desirable limits for drinking water with a few exceptions. However, concentrations of Fe, Mn, Pb, Al, Ni, and B at many sites are found above the desirable limit of drinking water specified by WHO (1993) and Indian standard (BIS 1991). In the water samples studied, the amount of iron (Fe) ranges from 329 µg l^{-1} to 944 µg l^{-1}. The concentration of Fe exceeds the desirable limit of 300 µg l^{-1} at all sites, however it is below the maximum permissible limit of 1000 µg l^{-1}. The results of this study reveal that the concentration of Mn exceeded the permissible limit of 300 µg l^{-1} at ten sampling sites. Lead (Pb) in drinking water is derived primarily from corrosion of materials containing lead and copper in the distribution systems, and from lead and copper plumbing materials. The amount of lead was detected in the range of 39 to 531 µg l^{-1} and the concentration of Pb is exceeding the Indian permissible limits of 50 µg l^{-1} in 90% of the samples. The amount of highly toxic metals, cadmium (Cd) and arsenic (As) are found well within the prescribed limits except at sites W11 and W22; and W2, W16 and W28 respectively. Concentration of boron varies from

999 µg l^{-1} to 1515 µg l^{-1}, exceeding desirable limit of drinking water (1000 µg l^{-1}) in 99% of the samples. The natural sources of boron are saline water and evaporite deposits with non-natural sources being fertilizer, pesticides and washing powder.

GEOCHEMICAL EVOLUTION AND HYDROCHEMICAL FACIES

The evolution of groundwater and chemical relationship between dissolved ions may also be evaluated by plotting the data on Piper (1944) trilinear diagram. The trilinear diagram reveals that the majority of the water samples fall in the areas of 1, 2, 3, 4, 5, 7 and 9 indicating chemical character of the water (**Fig. 4**). Water falling in the region 1 is significantly dominated by the alkaline earths (Ca and Mg) over the alkalis (Na and K). About 15% of the samples fall in the region 2 indicating dominance of alkalies over alkaline earth. Most of the water samples having high EC and TDS values, fall in the field 4 of the central diamond shaped field indicating that strong acids (SO_4+Cl) exceed the weak acids (HCO_3). Weak acids are dominant in about 32% of the samples and fall in the field 3 of the trilinear plot. Majority of the samples (30%) having carbonate hardness as indicated by secondary alkalinity (Field 5) and about 13% samples have non-carbonate alkali (primary salinity) and fall in the field 7. However, numbers of the samples (42%) indicate an intermediate (mixed) chemical character, in the middle portion of the diamond shaped field (Field 9). The facies mapping approach applied to the present study shows that Ca-Na-HCO_3-Cl-SO_4 and Ca-Na-Cl-SO_4-HCO_3 are the dominant hydrochemical facies (Back 1961).

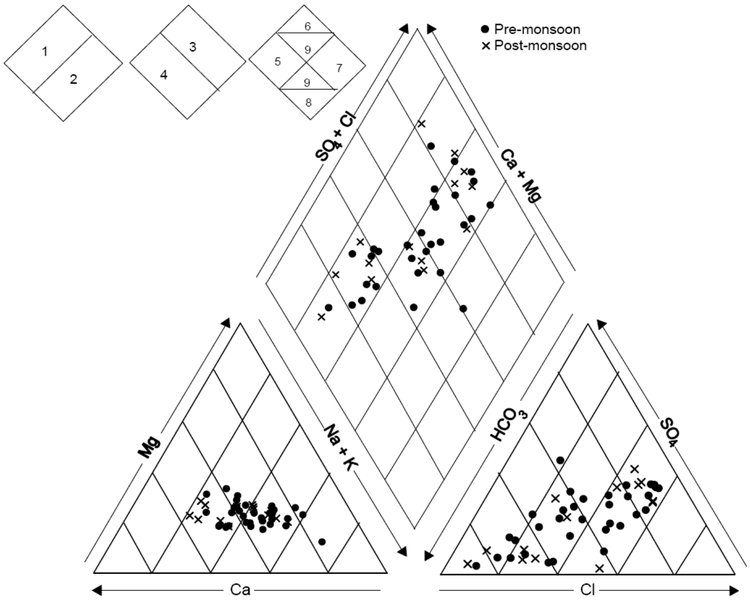

Fig. 4: Piper's trilinear diagram showing the relationship between dissolved ions

WATER QUALITY ASSESSMENTS

The data obtained by chemical analyses were evaluated in terms of its suitability for drinking and irrigation uses.

(A) Drinking and General Domestic Uses

Most of the water samples of the study area are not suitable for direct uses for drinking and domestic purposes. Carroll (1962) proposed four classes of water based on TDS concentration as fresh (0-1000 mg l^{-1}), brackish (1000-10000 mg l^{-1}), saline (10000-100000 mg l^{-1}) and brine water (100000 mg l^{-1}). TDS values of the analysed water samples fall in the category of fresh and brackish water. Water with TDS less than 500 mg l^{-1} is considered good for drinking purposes and water with more than 1000 mg l^{-1} is considered unsafe for use. In the present study area, 66% of samples exceeded the permissible limit of 1000 mg l^{-1} (WHO 1993). Hardness of the water is the property attributed to the presence of alkaline earths. Hardness defined as the concentration of multivalent metallic cations in solution. On the basis of hardness, water can be classified in to soft (>75 mg l^{-1}), moderately hard (75-150 mg l^{-1}), hard (150-300 mg l^{-1}) and very hard (>300 mg l^{-1}) categories. The total hardness (TH) of the analysed water samples vary from 257 to 1865 mg l^{-1} (avg. 692 mg l^{-1}) in the post-monsoon and 243 to 1169 mg l^{-1} (avg. 609 mg l^{-1}) in the pre-monsoon periods, indicating hard to very hard types of water. The data indicate that 46% of the analysed samples have TH values higher than 600 mg l^{-1}, which is the maximum permissible limit (BIS 1991). Hardness has no known adverse effect on health, but it can prevent formation of lather with soap and increases the boiling point of the water. The high TH may cause encrustation on water supply distribution systems, water heater, boilers and cooking utensils. There is some suggestive evidence that long term consumption of extremely hard water might lead to an increased incidence of urolithiasis and cardiovascular disorders (Durvey et al. 1991). The very hard water requires softening for household or commercial use. The main advantages in limiting hardness levels (by softening water) are economical e.g. less soap requirements in domestic and industrial cleaning, and less scale formation in pipes and boilers. Water treatment by reverse osmosis often requires water softening pretreatment to prevent scale formation on RO membranes. Concentrations of SO_4 and F also exceed the desirable limits of 200 mg l^{-1} and 1.0 mg l^{-1} respectively in some 55% and 31% of the water samples, restricting its direct use for drinking purposes. High sulphate concentration may also have a laxative effect with excess of Mg in water. Waters with about 200-400 mg l^{-1} of sulphate have bitter taste and those with 1000 mg l^{-1} or more of SO_4 may cause intestinal disorder and respiratory problems (Maiti 1982; Subba 1993). Sulphate may also cause corrosion of metals in the distribution system, particularly in water having low alkalinity. Sulphate also causes odor and corrosion of sewer in anaerobic conditions, because it gets converted to hydrogen sulphide.

In general, violation of WHO drinking water standards in respect of TDS, SO_4, F, Na, Cl and TH have been evident in over 25-40% of the samples. The heavy metal analysis shows that in a few groundwater samples concentrations of some heavy metals (Fe, Mn, Pb, B and Al) were present well above the desirable levels for the drinking water (BIS 1991). Concentrations of Cr, As, Se and Cd are found well within the threshold values with some exception.

(B) Suitability for Irrigation Uses

Electrical conductivity (EC) and sodium concentration are very important parameters in classifying irrigation water. The sodium percentage (Na%) in the study area is in the ranges of 21.2–55.9% (avg. 37.1%) in post-monsoon and 22.7–71.5% (avg. 43.1%) in pre-monsoon water samples. High Na% causes deflocculation and impairment of the permeability of soils (Karanth 1987). As per the Bureau of Indian Standards (BIS 1991), maximum sodium of 60% is recommended for irrigation water. Plot of analytical data on Wilcox (1955) diagram relating electrical conductivity to sodium percent shows that Na% are within the recommended values, and in general water is of good to permissible quality, which may be used for irrigation purposes. However, about 42% of the water samples have high EC values making it doubtful to unsuitable for irrigation use (**Fig. 5**).

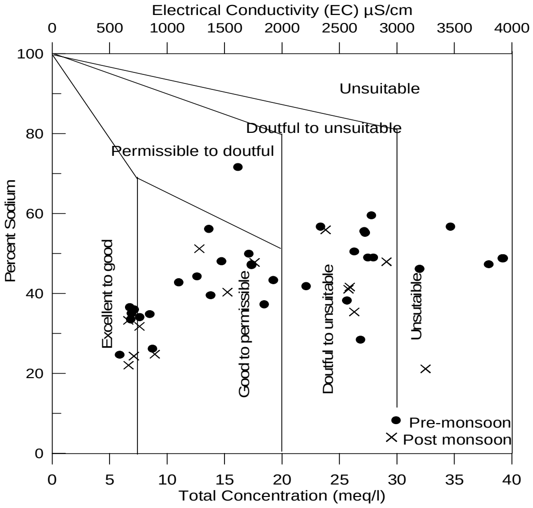

Fig. 5. Plot of sodium percent Vs electrical conductivity (after Wilcox 1955)

The total concentration of soluble salts in irrigation water can be expressed as low (EC = <250 µS cm^{-1}), medium (250-750 µS cm^{-1}), high (750-2250 µS cm^{-1}) and very high (>2250 µS cm^{-1}) and classified as C-1, C-2, C-3 and C-4 salinity zone respectively (Richards 1954). While a high salt concentration (high EC) in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). Irrigation waters are classified into four categories on the basis of sodium adsorption ratio (SAR) as: S-1 (<10), S-2 (10-18), S-3 (18-26) and S-4 (>26). The calculated value of SAR in the study area ranges from 1.05-6.32 in post-monsoon and 1.0-8.6 in the pre-monsoon water. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that most of the water samples fall in the category C3S1 and C4S2, indicating high to very high salinity and low to medium alkali water (**Fig. 6**). This water can be used only for plants with good salt tolerance.

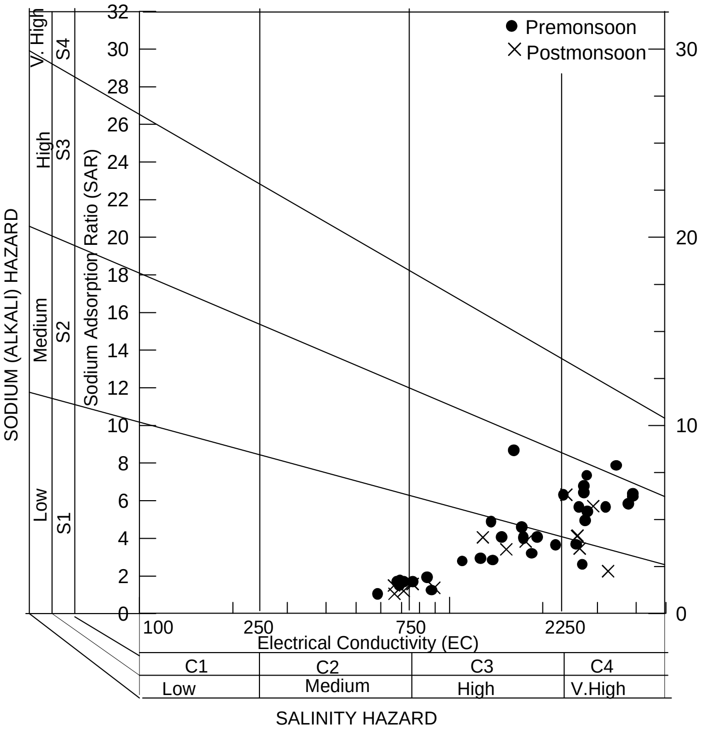

Fig. 6: US salinity diagram for classification of irrigation waters (USSL 1954)

CONCLUSIONS:

Groundwater in the investigated area is alkaline and fresh to brackish in nature. On critical examination of the data, it can be seen that certain major ions and heavy metal concentrations in groundwater exceed the desirable limits for drinking water at many places. Concentrations of TDS, Cl, Na, SO_4, TH, Fe, Mn, Pb, Ni, Al, and B at many sites are beyond the safe limits of drinking water indicating contamination by untreated industrial and domestic waste effluents. The different hydrogeochemical processes like dissolution, mixing, ion exchange processes along with the weathering of silicate and carbonate minerals control the chemistry of the groundwater. The calculated values of SAR and sodium percentage indicate the quality of water for irrigation uses as good to permissible category. However, a high salinity value restricts its suitability for agricultural purposes, and plants with good salt tolerance should be selected for such area. A detailed hydro-geochemical investigation and integrated water management is suggested for sustainable development of the water resources of the area for better plant growth as well as maintaining human health.

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GROUNDWATER QUALITY ASSESSMENT OF PANANDHRO LIGNITE MINING REGION, GUJARAT, INDIA

Prasoon Kumar Singh[1], Dipanwita Bhakat [2], Gurdeep Singh[3]
[1]Associate Professor, [2]SRF, [3]Professor
Department of ESE, Indian School of Mines, Dhanbad, Jharkhand, India
Email: singh.prasoon910@gmail.com, pks0506@yahoo.co.in

ABSTRACT

The study was conducted to evaluate the groundwater quality of the selected locations in Panandhro Lignite mining region. Groundwater samples were collected from different wells at various locations in Panandhro lignite mining region, Gujarat during Pre monsoon and Post monsoon season for examining the various physico-chemical parameters. The results were compared by the existing drinking water standards WHO which shows that the water is nearly suitable for drinking purposes except at few locations it was slightly alkaline in nature with high Total Dissolved Solids and Total Hardness. The correlation study among the different parameters reveals that maximum numbers of the parameters are showing good correlation in the region.

Key Words: Groundwater, Physico- chemical parameters, Water quality, Drinking water standards, Correlation.

INTRODUCTION

In Panandhro lignite mines the lignite seams and the sand aquifer are separated by a intervening shale-clay formation except in the central part, where they are in direct contact. When the mining operation started in 1978 this sand aquifer was observed to exert upward artesian pressure. With continuous withdrawal of groundwater first by GMDC and subsequently by GEB, the water level has gone down. So groundwater conditions in the area are strongly influenced by hydrogeology as well as human interventions.

As the area does not receive any significant rainfall, and as the area contains formations which are not good aquifers, occurrences of ground water is rare. However, it is reported that mild artesian condition exist in the area due to aquifer sand occurring between lignite beds and basement (Trap).Nevertheless, the quantity and quality of artesian water appear to be very poor. Both the surface and sub-surface water availability in the area is very poor.

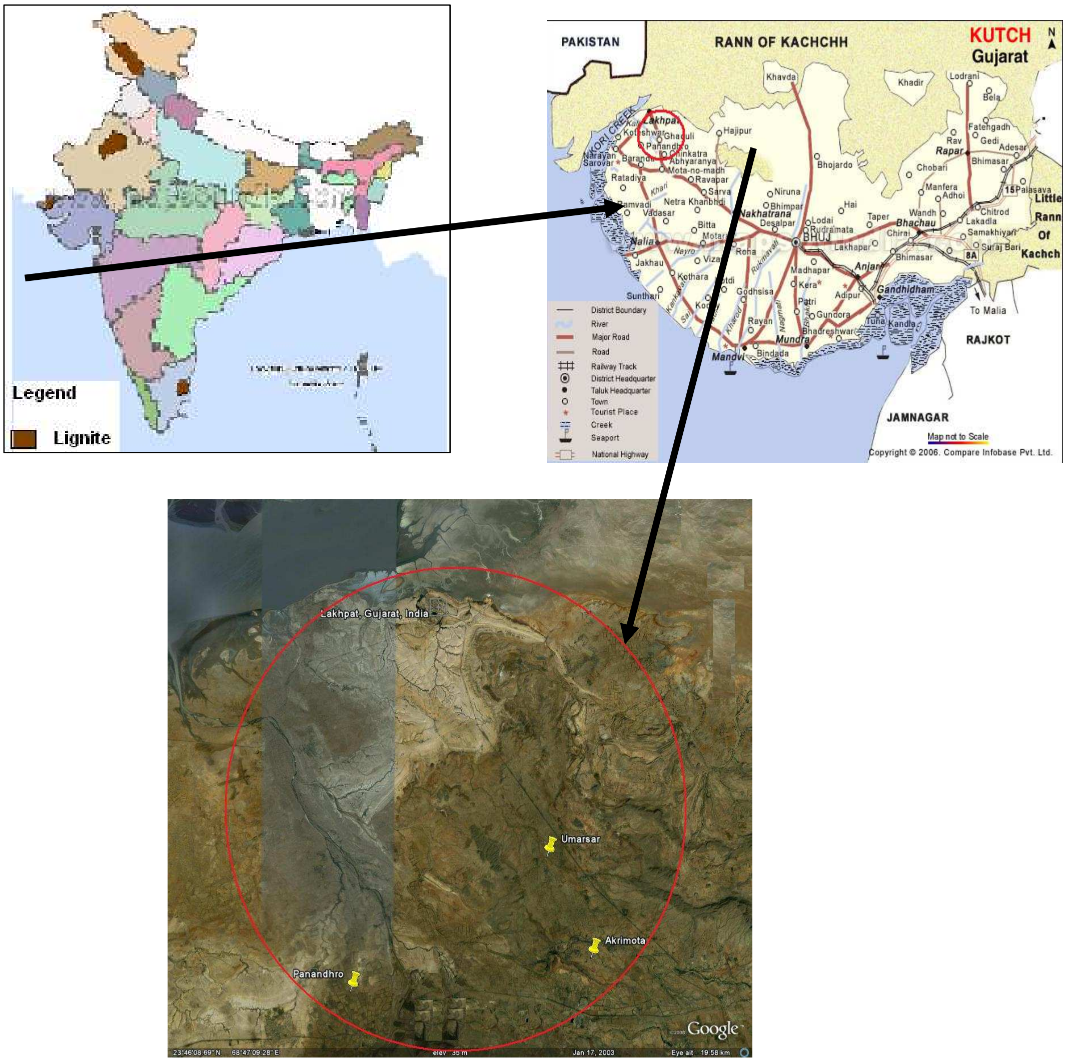
STUDY AREA

Panandhro Lignite field located in Lakhpat taluka of Kutch district is surrounded by villages like Panandhro, Fulra and Khanot. It has an extent of 8.50 sq.km. and it lies between latitudes 23° 35’ 33”N and 23° 45’56”N and longitudes 68°45’ 00”E & 68°48’55”E which is covered by Survey of India Toposheet No.41 F/14. Panandhro Lignite field lies nearly 80 miles away on North –West direction of Bhuj, the district Headquarters and the Western Railway meter-gauge terminus in Kutch district (**Fig.1**).

LOCAL GEOLOGY

Mesozoic sandstones of Bhuj series are exposed in the area of North of Mata-no-Madh and in the area east of Arkimota village. The geological map of Panandhro lignite field has been show in **Fig.2**. These consist of white to yellowish course sandstones and sandy shales and at places ferruginous, current bedding is a general feature in these sandstones. Besides local variations, generally the dip of the beds is towards west. The maximum thicknesses of various formations encountered are as follows:

a.	Alluvial Soil	15.85metres
b.	Hard & Compact Sandstone	08.63metres
c.	Nummulitic Limestone	19.28metres
d.	Laki Shale / Clay	97.83 metres



Source: Google Earth

Fig.1: Location map of the Study Area

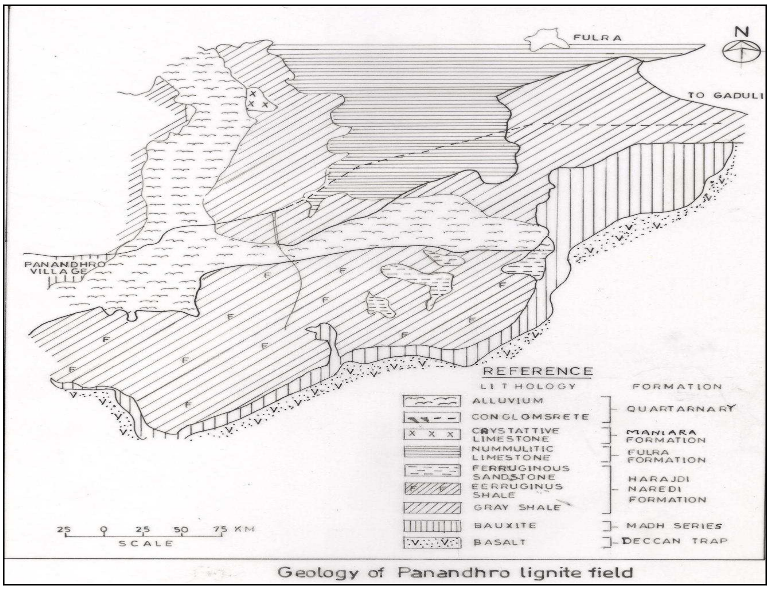


Fig. 2: Map showing Geology of Panandhro lignite field

Table 1: Location details of the Groundwater Sampling Stations in Study Area

Sl.No.	Sample Code	Location	Detail about the well
1	GW1	Kaner village , in field	Well in the field
2	GW2	Lakhpat village	Mr. P.P.Giri
3	GW3	Old Umarsar village	Well on the road side
4	GW4	Panandhro village -1	Mr. Sewakji
5	GW5	Panandhro village -2	Mr. Dharam Singh ji
6	GW6	Panandhro village -3	Mr. Surjit Singh ji
7	GW7	Panandhro village (near DS Enterprise)	Mr. Nirmal Singh ji
8	GW8	Panandhro village -4	Mr.B.K.Patel
9	GW9	Panandhro village (near Entrance Gate)	Mr. Mansingh ji
10	GW10	Panandhro village -5	Mr. Mansingh ji

RESULT AND DISCUSSION

The wells of ten villages as shown in **Table 1** have been selected for the testing of groundwater quality. The well water samples of the villages were collected and analysed as per WHO standards. Results of the water quality during Pre-monsoon and Post-monsoon have been shown in the **Table 2** and **Table 3** respectively. The results show that, in the Post-monsoon, maximum pH (8.16) was found in Mr. Mansingh ji's well (GW10) which is just behind the Subhaspar village and minimum pH(6.17)found in the Sewakji's well (GW4) in Panandhro village -1 which is nearer to the standard (WHO). Salinity was high in the Mr. Sewakji's well (GW4) in Panandhro village -1 and low in the well near Old Umarsar village (GW3) at the road side. Total Dissolved Solid, Total Hardness, Ca-Hardness, and Iron were high in the well (GW4) of Mr. Sewakji in Panandhro village-1, due to high salinity and maximum dissolve of the ions.

In Pre monsoon, maximum pH was found in Mr. Nirmal Singh ji's well (GW7) in Panandhro village (DS Enterprise). Salinity and TDS were high in the Sewakji's well (GW4) in Panandhro village -1.

The correlation between physicochemical parameters in Pre-monsoon and Post- monsoon has been shown in **Table 4** and **Table 5** respectively. In pre monsoon pH has positive correlation with Mg- Hardness, Alkalinity and Fluoride. Conductivity and Salinity are correlated very strongly with each other and they have also good correlation with TDS, Total Hardness, Ca-Hardness, Mg-Hardness and Acidity. Both TDS and Total Hardness are positively correlated to the Ca-Hardness, Mg-Hardness and Acidity. Ca-Hardness and Acidity positively correlated whenever Mg- Hardness and Fluoride have positive correlation with Alkalinity.

In post monsoon all the parameters are positively correlated with each other except fluoride has negatively correlate with Conductivity, Salinity, TDS, Mg hardness, Alkalinity and Acidity.

Table 2: Groundwater Quality of Study Area (Pre-monsoon)

Sl. No.	**Parameters**	**Sample locations with code**										**Permissible Limits (CPCB)**
		GW1	**GW2**	**GW3**	**GW4**	**GW5**	**GW6**	**GW7**	**GW8**	**GW9**	**GW10**	
1	pH	7.33	7.20	7.34	6.17	7.35	7.63	7.73	7.61	7.44	8.16	6.5-8.5
2	Electrical cond. (ms)	5.42	3.01	1.66	9.34	5.52	5.33	6.15	5.29	7.05	4.43	-
3	Salinity (mg/l)	3020	1620	840	5430	3110	2980	3440	2900	4000	2410	-
4	TDS (mg/l)	3990	2220	1200	9800	4100	3920	5800	3840	5160	3230	1000
5	Total hardness(mg/l)	1200	756	787.5	2350	1627.5	1110	1620	1000	1050	640	500
6	Ca-Hardness(mg/l)	682.5	577.5	764	1942.5	1100	1050	315	682.5	472.5	472.5	-
7	Mg - Hardness(mg/l)	517.5	178.5	23.5	407.5	527.5	60	1305	317.5	577.5	167.5	-
8	Alkalinity(mg/l)	324	340	132	160	236	208	210	328	204	152	-
9	Acidity(mg/l)	30	10	10	20	10	30	10	10	10	20	-
10	Fluoride (mg/l)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.26	BDL	BDL	1.5

Table 3: Groundwater Quality of Study Area (Post monsoon)

Sl. No.	**Parameters**	**Sample locations with code**										**Permissible Limits (CPCB)**
		GW1	**GW2**	**GW3**	**GW4**	**GW5**	**GW6**	**GW7**	**GW8**	**GW9**	**GW10**	
1	pH	7.44	7.55	7.51	7.71	7.61	7.13	8.06	7.97	7.76	7.62	6.5-8.5
2	Electrical cond. (ms)	8.56	1.57	0.49	9.47	7.03	3.96	7.51	6.58	5.57	3.11	-
3	Salinity (mg/l)	4670	720	229	5150	3800	2110	4070	3570	2960	1580	-
4	TDS (mg/l)	5710	986	330	6260	4940	208	4740	4570	3890	2170	1000
5	Total hardness(mg/l)	1830	290	115	2740	1500	700	2040	700	770	470	500
6	Ca-Hardness(mg/l)	630	73.5	94.5	2068	1375.5	577.5	1176	420	388.5	178.5	-
7	Mg - Hardness(mg/l)	1200	216.5	20.5	672	124.5	122.5	864	280	381.5	291.5	-
8	Alkalinity(mg/l)	360	340	148	268	320	200	360	360	344	320	-
9	Acidity(mg/l)	76	40	24	48	52	40	36	60	52	36	-
10	Fluoride (mg/l)	0.0003	0.04	0.05	0.07	0.02	0.05	0.04	0.05	0.0009	0.03	1.5

Table 4: Pearson Correlation Matrix of Study Area in Pre –monsoon

	pH	**Cond.**	**Salinity**	**TDS**	**Total Hardness**	**Ca Hardness**	**Mg Hardness**	**Alkalinity**	**Acidity**	**Fluoride**
pH	1.000	-.480	-.502	-.616	-.702	-.812	.045	.033	-.032	.147
conductivity		1.000	1.000	.955	.801	.522	.459	-.112	.211	-.005
Salinity			1.000	.960	.811	.540	.450	-.123	.210	-.021
TDS				1.000	.887	.623	.453	-.216	.164	-.073
Total Hardness					1.000	.721	.486	-.181	.082	-.145
Ca Hardness						1.000	-.255	-.258	.293	-.092
Mg Hardness							1.000	.073	-.255	-.086
Alkalinity								1.000	-.001	.453
Acidity									1.000	-.250
Fluoride										1.000

Table 5: Pearson Correlation Matrix of Study Area in Post -monsoon

	pH	**Cond.**	**Salinity**	**TDS**	**Total Hardness**	**Ca Hardness**	**Mg Hardness**	**Alkalinity**	**Acidity**	**Fluoride**
pH	1.000	.372	.369	.549	.291	.238	.256	.580	.051	.053
conductivity		1.000	1.000	.938	.902	.788	.709	.494	.687	-.118
Salinity			1.000	.937	.902	.789	.709	.483	.686	-.114
TDS				1.000	.832	.707	.689	.607	.683	-.208
Total Hardness					1.000	.914	.718	.281	.402	.082
Ca Hardness						1.000	.375	.075	.201	.286
Mg Hardness							1.000	.514	.575	-.303
Alkalinity								1.000	.601	-.499
Acidity									1.000	-.508
Fluoride										1.000

CONCLUSION

Groundwater has emerged as an important source to meet the water requirements of various sectors including the major consumers of water like industries, irrigation and domestic. The sustainable development of groundwater requires precise qualitative assessment of the region. Aridity and inherent salinity of the region are the major challenges for restoration and redevelopment of the sites. Freshwater availability, therefore, is a critical factor.

In general groundwater quality of Panandhro Lignite mining region is not harmful to human beings. Except at few locations where some parameters such as TDS, Total Hardness crossed the prescribed limits of drinking water (WHO) because of intense industrial and mining activities, weathering and erosion of bed rocks etc. In Panandhro lignite mining region the GEB Power Plant draws saline water from the saturated aquifer are using to meet all its needs after desalinisation through Reverse Osmosis (RO). If possible, some desalinization plant should be establish in or around the study area (especially near Godhatand Dam or Sanandhro Dam) so that the maximum amount of salinity in the water can be removed and to make the water potable.

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HYDROGEOLOGY AND GROUND WATER QUALITY OF KODERMA DISTRICT OF JHARKHAND STATE

T.B.N.Singh, S.N.Sinha, G.K.Roy
Senior Hydrogeologist, CGWB, Suo, 30/C, Park Road- 1b, Asok nagar, Ranchi -834002,
Email: tbnsingh07@rediffmail.com

ABSTRACT

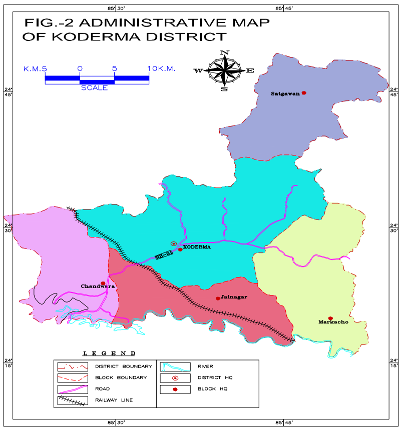
Ground water resources occur in dynamic state and hence it is subjected to periodic changes. The issues related to ground water have assumed great significance in view of the scientific, technological changes in water sector. District ground water management studies are undertaken to assess the status of ground water regime periodically. It forms an important activity of central ground water board. These studies are carried out to obtain an updated picture of ground water occurrence, availability, its utilization and also the present status of ground water quality. The data generated gives the status of ground water regime and it can be utilized for formulations of future ground water development programmes and management strategy. Koderma district spreads over an area of 1500 Sq.Km. Koderma is known as Mica Capital of India. The Koderma district was carved out from Hazaribagh in April 1994.Ground water is an important natural asset of the country. Ground water is the lifeline of Jharkhand state. Koderma district lies in the northern part of the Jharkhand state and is bounded by the longitude 85^0’26’01” and 85^0’54’16” E and latitudes 24^0’15’46” and 24^0’40’18” N**.** Area is included in degree sheet 72H and survey of India toposheets (1:50,000 scale) no. 72H/6,7,10,11,13,14,15,16.The district has a total area of 1500 sq. km. consisting of five blocks, (Chandwara, Koderma, Jainagar, Markacho and Satgawan) 80 panchayats and 706 villages. It has a population of 5, 40, 901 persons as per 2001 census.Pre-monsoon depth to water level vary between 3-10 mbgl. Post-monsoon depth to water level in Koderma block varies between 2-3 mbgl except in Gajhandi area and Southern portion of Markacho block where depth to water level is between 3-4 mbgl. High concentration of fluoride was found both in upper weathered aquifer and lower fractured aquifer. Fluoride concentration was found beyond permissible limit in 23 percent hand pump samples and 12 percent dug well samples. It shows that deeper aquifers are more contaminated as compared to shallow aquifer. Correlation between % calcium and fluoride was found to be inverse i.e. an increase in fluoride ion concentration results in decrease in calcium ion concentration and vice versa. The maximum concentrations of fluoride were found to be 5.53 mg/l at Gajhandi village and 5.37 mg/l at koderma sadar hospital hand pump and concentration of calcium was found to be 80 mg/l and 56 mg/l at both locations**)**. Majority of the groundwater samples with high fluoride are characterized by high pH and this indicates that alkaline environment is more favoured for F concentration (Hem 1975). These results are in conformity with the correlation analysis. Bicarbonates show direct relationship with fluoride i.e. increase in fluoride concentration results in increase of bicarbonates concentration. At Dhubba, fluoride value is 5.07mg/l and corresponding bicarbonates value is 578 mg/l**.** Groundwater samples in general were found to be medium saline in nature. Suitability of water for drinking purpose can be known by plotting the chemical constituents in piper’s diagram. Pipers diagram for Ground water types).It indicates Ca-Mg-HCO_3 type of water of koderma district i.e. water is of recharge areas. To determine the suitability of ground water for Irrigation purpose, U.S.S.L. diagram is used. 47% of samples are found in C2S1 class, 34% of samples fall in C3S1 class, 10.4% of samples fall in C1S1 class, 4.6% of samples are in C4S1 class and only 2.3% of samples are in C3S2 class

Keywords: Weathered aquifer, Fractured Aquifer, Fluoride, Piper diagram, USSL diagram

INTRODUCTION

Koderma district spreads over an area of 1500 Sq.Km. It is the gateway district of Jharkhand. Koderma is known as Mica Capital of India. The Koderma district was carved out from Hazaribagh in April 1994.Ground water is an important natural asset of the country. Ground water is the lifeline of Jharkhand state. Koderma district lies in the northern part of the

Jharkhand state and is bounded by the longitude 85^0’26’01” and 85^0’54’16” E and latitudes 24^0’15’46” and 24^0’40’18” N**.** Area is included in degree sheet 72H and survey of India toposheets (1:50,000 scale) no. 72H/6,7,10,11,13,14,15,16.The district has a total area of 1500 sq. km. consisting of five blocks, (Chandwara, Koderma, Jainagar, Markacho and Satgawan) 80 panchayats and 706 villages. It has a population of 5, 40, 901 persons as per 2001 census. **(Fig-1 & 2)**



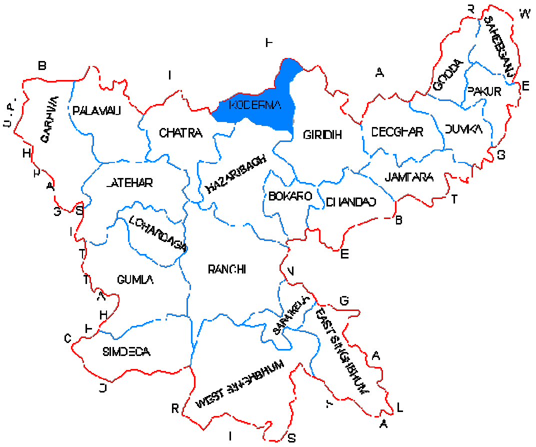


FIG-1 Location Map of Koderma district in Jharkhand

PHYSIOGRAPHY

Koderma district is the part of Chotanagpur plateau. The area exhibits undulating topography comprising hills, hillocks, mounds and plains. Valley fills with low to moderate frequency of lineaments, pediplains with moderate frequency of lineaments and pediplains are major geomorphological units of the district. Concentrations of lineaments are more in Chandwara, Koderma and Jainagar blocks and less in Satgawan and Markacho blocks of the district. Northern part of the district is occupied by Koderma Reserve forest. The highest peak is Debour Ghati (677 meter) that is the state boundary of Jharkhand and Bihar.Jainagar, Markacho blocks are covered by pediplain. Koderma block consists monthly of directed plateau (Hills / Valley). Upper part of Chandwara block consists of dissected plateau and lowest part by pediplain. Satgawan block is covered by pediplain in upper parts, ridges and valley in middle parts and erosional valley in lower parts. **(Fig-3)**

SOILS

Soils of Koderma district can be divided on two types based on rock types. Soils developed on mica schist are light textured silty in nature yellowish to reddish yellow in colour, neutral in reaction and moderately well drained. These soils are poor in N and P and moderately to rich to very rich in K. Soils developed on granitic gneisses are related to physiography. The soils of upland are gravely to sandy thin, acidic and very poor fertile. Medium land soils are yellow coloured slightly to moderately acidic, somewhat poorly drained and moderately fertile. However many location remains wet for long.The whole Koderma district is divided into the following four types of soils depending upon lithology and physiography of the area**. (Fig-4)**

1. Reddish yellow, yellow, grayish and yellow deep catenary soil.
2. Hill and forest soil of steep slopes and high-dissected retions.
3. Red yellow and light grey catenary soil
4. Pale yellow, Yellow and pinkish catenary soil on high micaceous schist

DRAINAGE- Barakar, Sakri River and their tributaries drain the district of Koderma. The flow of Barakar is from west to east and in the southern part of the district. The river Ponchkhara, Keso, Akto, Guro and Gukhana nadi flow from west to east and are the tributaries of Barakar river.Sakri River is the main river of northern part of the district that flows from Southeast to northwest part of the district. Ghagra and Chhotanari nadi are the tributaries of Sakri river.**(Fig-5) .**

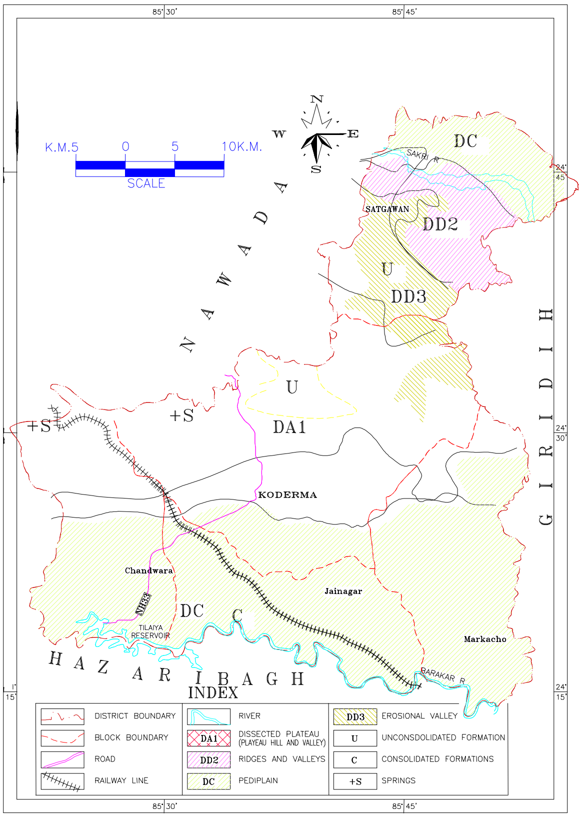
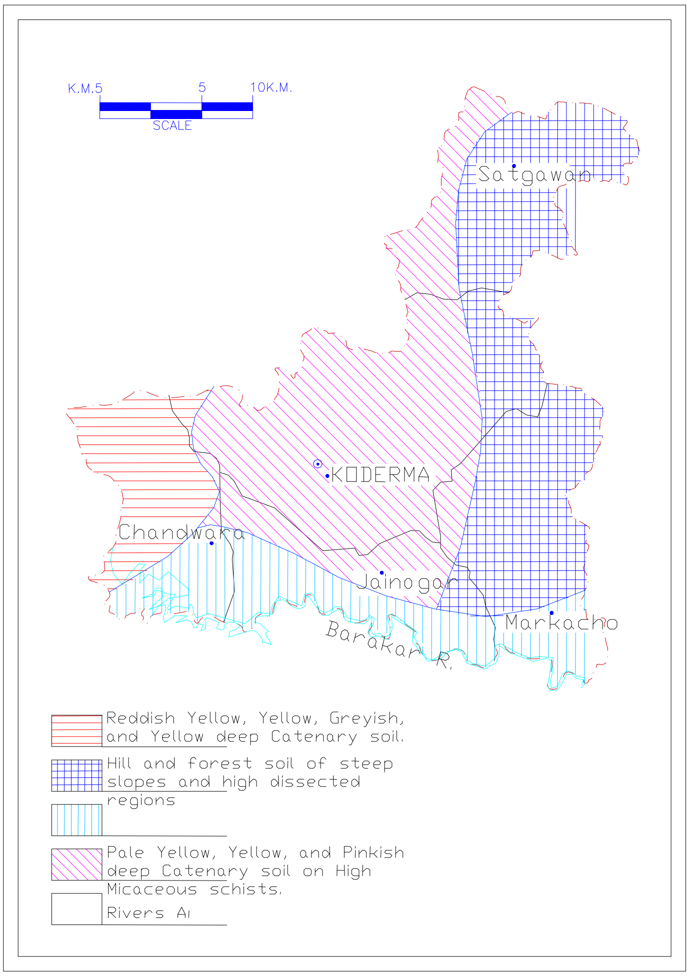
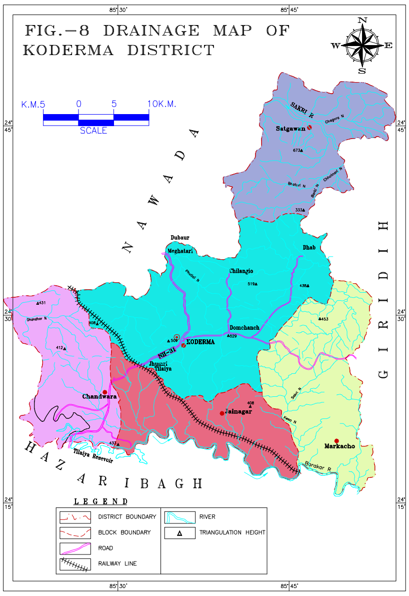


Fig.3: Geomorphological Map





Surface water Resources---Twin township of Koderma and Jhumri Tiliya has water supply schemes of 1 lakh gallon per day capacity. Per day 4-5 lakh gallons of surface water of Tilaiya dam is being supplied for drinking water purpose. There are two major Reservoir schemes in Koderma district-

1. **Tilaiya multipurpose river valley project** is situated in Koderma district. It is based on Barakar River.Drainage area of the Tilaiya dam catchment is 984.2 sq. km. The height of Dam is 30.18 metres and has been constructed near Sainik School Tilaiya in the Jainagar block .The dead storage capacity is 75.25 million cu.m and storage to top of gates is 394.74 million cu.m.Allocation of storage capacities are 141.86 mcm for irrigation and power and 177.63 for flood control.
2. **Panchkhero Reservoir scheme**-The scheme is situated in the village Arkosa, Markacho Block,Koderma district. Details of the scheme is enclosed below (**CWC, Ranchi** [1])

S. No.	Components	Salient features
1.	Hydrology	
a.	Catchment area	64.75 sq. Km.
b.	Average annual monsoonal Rainfall	1066 mm
c.	75% dependable run-off	807.7 mm
d.	75% dependable yield	15.38 mcum(543 mcft)
e.	Maximum design flood	633.45 cumecs (22361 cusec)
2.	Irrigation	
a.	Gross command area	7100 ha.(17543 acres)
b.	C.C.A.	3238 ha.
c.	Annual Irrigation Khariff (Paddy) Rabi (Wheat,potato,vegetables)	 1618.8 Ha. 2226 ha.

GEOLOGY

The entire district is underlain by the rocks of wide variety of geological formation ranging in age from Archean to Recent. Phyllite, Mica Schist, Granite gneiss and intrusive granite are the main geological formation of the district. Sporidic occurrence of Dolerite, Quartz pegmatite veins and Quartzites are also found. Few portion of Gondwana sediments are found in the block of Markacho and Jainagar. Thin deposits of alluvium are found along the course of rivers. The Geological succession of Koderma district is given below.

GEOLOGICAL SUCCESSION

The district is underlain by wide range of geological formations ranging in age from Archeans to Recent. Phyllite, Mica Schists, Granite gneiss and intrusive granites are the main geological formations of the district. Sporadic occurrence of Dolerite, Quartz, quartz pegmatite veins and quartzite are also found. Thin venner of alluvium are found near the course of rivers.

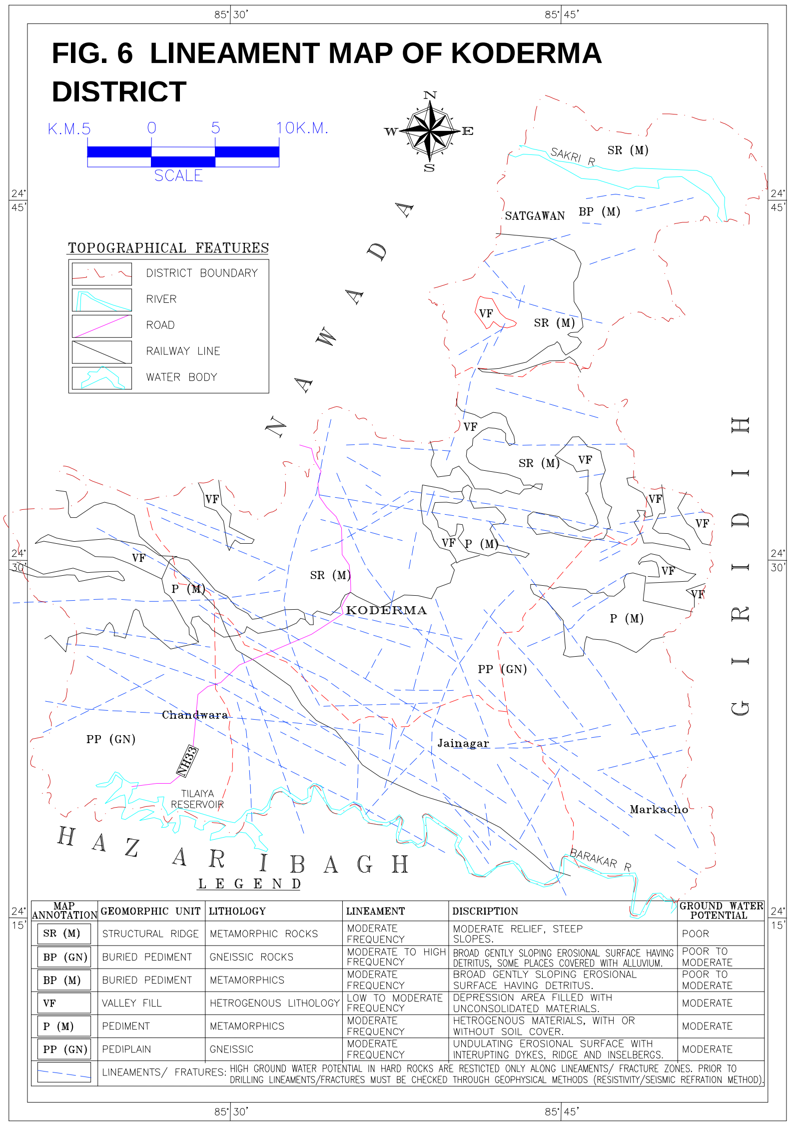
Table 1- Geological succession of Koderma mica belt (Mahadevan 2002 [2])

Age	Rocktype
Recent	Alluvium
Permo-carboniferous	Gondwana sediments
-------------------------------Unconformity-------------------	
Proterozoic	Dolerite dyke
	Rapakavi granite and pegmatites
	Biotite augen gneiss
	Medium grained massive granites and pegmatites
	Massive quartzite with slaty and phyllitic intercalations
	Sillimanite muscovite schist,calc silicate rocks,hornblende schist
	Quartz mica schist
	Garnetiferous biotite schist
	Migmatite and composite gneisses
---------------------------Unconformity-------------------------------	
Archean	Chotanagpur granite gneisses

LINEAMENT STATUS—

Position and orientation of lineament plays an important role in locating ground water. Concentrations of lineaments are more in Chandwara, Jainagar and southern portion of Koderma blocks. Two types of orientations are more prominent—Major one has orientation NNW-SSE and minor one has orientation NW-SE. (**JSAC,Ranchi** [3])

FIG. 6 LINEAMENT MAP OF KODERMA DISTRICT



MAP ANNOTATION	GEOMORPHIC UNIT	LITHOLOGY	LINEAMENT	DISCRIPTION	GROUND WATER POTENTIAL
SR (M)	STRUCTURAL RIDGE	METAMORPHIC ROCKS	MODERATE FREQUENCY	MODERATE RELIEF, STEEP SLOPES.	POOR
BP (GN)	BURIED PEDIMENT	GNEISSIC ROCKS	MODERATE TO HIGH FREQUENCY	BROAD GENTLY SLOPING EROSIONAL SURFACE HAVING DETRITUS, SOME PLACES COVERED WITH ALLUVIUM.	POOR TO MODERATE
BP (M)	BURIED PEDIMENT	METAMORPHICS	MODERATE FREQUENCY	BROAD GENTLY SLOPING EROSIONAL SURFACE HAVING DETRITUS.	POOR TO MODERATE
VF	VALLEY FILL	HETROGENOUS LITHOLOGY	LOW TO MODERATE FREQUENCY	DEPRESSION AREA FILLED WITH UNCONSOLIDATED MATERIALS.	MODERATE
P (M)	PEDIMENT	METAMORPHICS	MODERATE FREQUENCY	HETROGENOUS MATERIALS, WITH OR WITHOUT SOIL COVER.	MODERATE
PP (GN)	PEDIPLAIN	GNEISSIC	MODERATE FREQUENCY	UNDULATING EROSIONAL SURFACE WITH INTERUPTING DYKES, RIDGE AND INSELBERGS.	MODERATE
‒ ‒ ‒	LINEAMENTS/ FRATURES: HIGH GROUND WATER POTENTIAL IN HARD ROCKS ARE RESTICTED ONLY ALONG LINEAMENTS/ FRACTURE ZONES. PRIOR TO DRILLING LINEAMENTS/FRACTURES MUST BE CHECKED THROUGH GEOPHYSICAL METHODS (RESISTIVITY/SEISMIC REFRATION METHOD).				

HYDROGEOLOGY

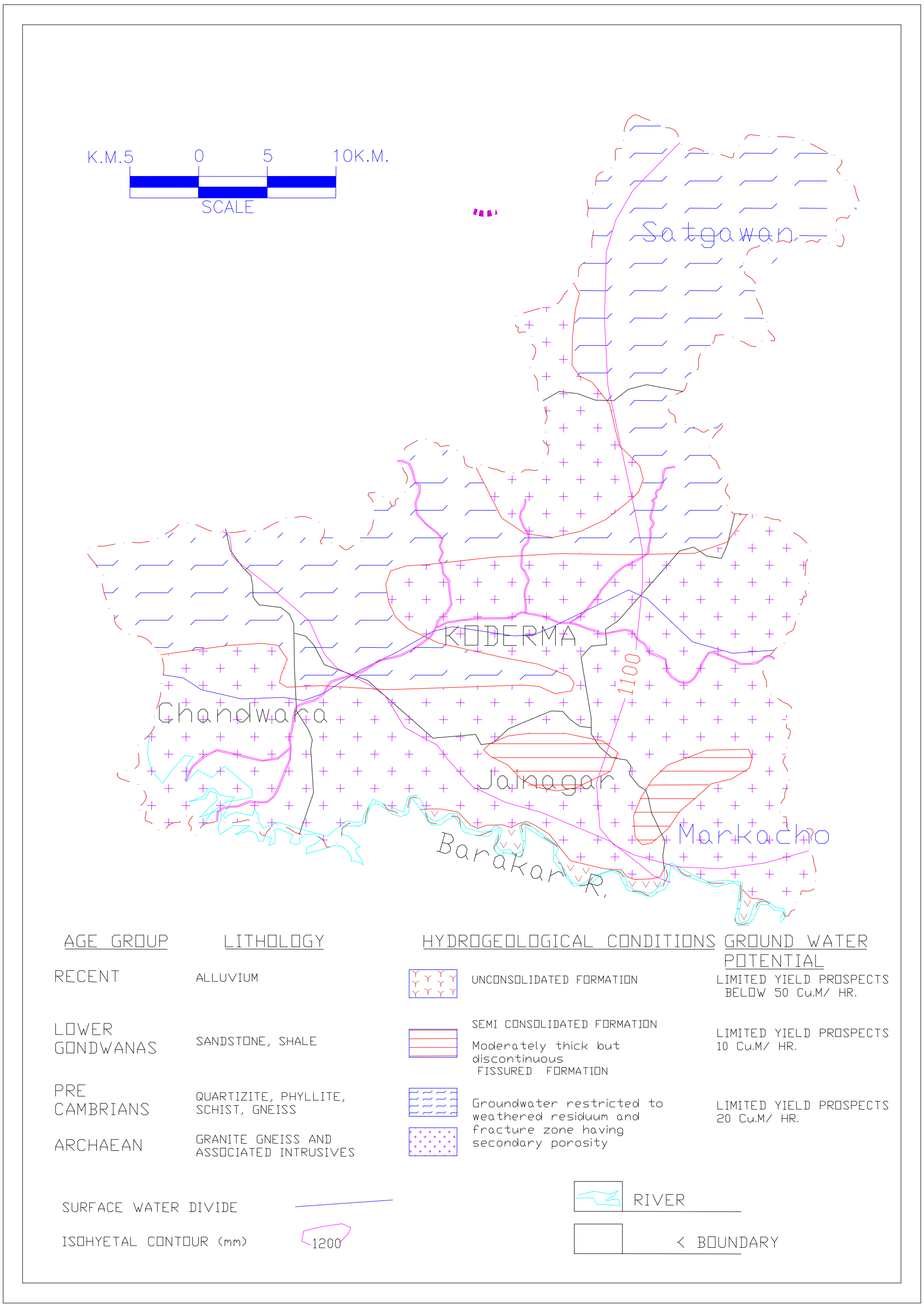
CHARACTERISTIC OF WATER BEARING FORMATION

The rock type in the area are mainly granite gneiss, schist, pegmatite and Quartzite which have undergone intensive weathering both due to structural disturbances and physical condition. Fractures and weathered mantle form the main repository for the movement of ground water. Owing to the process of weathering the following subsurface section can normally be found in the district of Koderma. Thickness as well as depth goes on varying from one place to another

“D”	Soil covers	Sandy clay and clayey sand often with Concretion.
“C”	Decomposed Zone (Weathered/pediment)	Altered massive clays commonly plastic
“B”	Disintegrated Zone	Disintegrated crystal aggregate and rock (Saprolite) fragments.
“A”	Fresh Fracture Zone	Fractured rock.

The above profile has been encountered in many places in the district. Near Domchanch thickness of section “B” is very meager, however, section’C’ in this area is found to be of considerable thickness. There is variation in porosity and permeability of the weathered mantle in different zones. Zone’C’ has comparatively more porosity as compared to other three zones. Thick weathered mantle maybe considered as potential and productive aquifer. Hence, pediment & buried pediment may be proved as Ground Water worthy area.

In places where there is thin weathered mantle ground water occurs in the fracture system. The thin weathered mantles absorb rainfall infiltration and transmit it to deeper fracture system. **(Fig. 7 Hydrogeological map)**



GROUND WATER CONDITION

A) Archean and Pre- Cambrian rocks

Ground water mostly occurs under water table condition in weathered residuum and semi-confirmed condition in deeper fractures. Maximum thickness of weathered mantle is attained in Granitic rocks in favorable topographic and drainage condition. These formations has got yield prospect of approximately 2-20 cu.m/hr.

b) Lower Gondwana rocks

Gondwana rocks represent semi-consolidated formations, which are moderately thick but discontinuous. In the area where lower Gondwana sediments are exposed or underlain in relatively shallower depth, ground water occurs under water table condition. in relatively deeper Gondwana aquifer occurs under semi confined to confined condition. They have yield prospect approximately 3-10 Cu m/hr.

c) Quaternary

Thin deposits of quaternary sediments occur along the river and nala courses. Thickness of these sediments vary from 2 to 10 m. Ground Water occur under unconfined conditions.

DEPTH TO WATER LEVEL

The depth from ground at which the ground water rests is called Depth to Water level. It is deepest during pre monsoon and attains its maximum peak. It is shallowest during August and again stabilizes during the month of November and this level represents post -monsoon level.

PRE-MONSOON DEPTH TO WATER LEVEL

The depth to water level varies between 3-10 mbgl. Depth to water level in Koderma block is largely between 3-5 mbgl around Koderma, Jhumri Tilaiya, Chilongi and Gajhandi area. In Domchanch, Dhab area it is between 5-10 mbgl. In Chandwara block depth to water level becomes deeper from north to south. In northern portion the depth to water level varies between 3-5 mbgl where as in southern portion it varies between 7-10 mbgl. The depth to water level lies between 7-10 mbgl in Markacho block. The Satgawan block has depth to water level varying between 5-7 mbgl. The shallowest depth to water level is reported from southern portion of Jainagar block and it varies between 3-5 mbgl.

POST- MONSOON DEPTH TO WATER LEVEL

In general Post-monsoon depth to water level in Koderma block varies between 2-3 mbgl except in Gajhandi area and Southern portion of Markacho block where depth to water level is between 3-4 mbgl. In Satgawan block and Chandwara block post-monsoon depth to water level varies between 2-3 mbgl. In Markacho block depth to water level varies between 2-3 mbgl except in southern part where it is between 3-4 mbgl. Jainagar block has depth to water level between 1-2 mbgl in eastern part and 2-3 mbgl in western part of the block. **(Fig-8-Water table contour map)**

GROUND WATER EXPLORATION

Central Ground Water Board has drilled altogether five nos. of wells in Koderma district. These wells are drilled at Chotki Dhamraj, Gumo village, J.J. College Campus, Koderma, Chutiyaro village and Koderma block campus. These wells were drilled in Granite gneiss, phyllite, mica schist and intrusive granite. The depth of casing varies from 10.68 m at Tilaiya block compound to 24.49 m at Chutiyaro. Drilling depth varies from 130.20m at Chotki dhamrai to 172.52 m at J.J. College campus, Koderma. Fractures encountered at 50-51m, 65-67m, 83-85m, 98-100m at Chotki Dhamrai and 27-29 m, 75-77m at Gumo.

The static water level varies from 2.7m at J.J. College, Koderma to 7.38m at Gumo. The discharge varies from 1.5m^3 /hr at Tilaya to 13.2m^3 /hr at J.J. College, Koderma. The transmissiivity is reported as 8.5m^2 /day, 21.12m^2 /day at J.J. College, Koderma respectively. The details of exploration carried by CGWB is given at (**Table-2)**

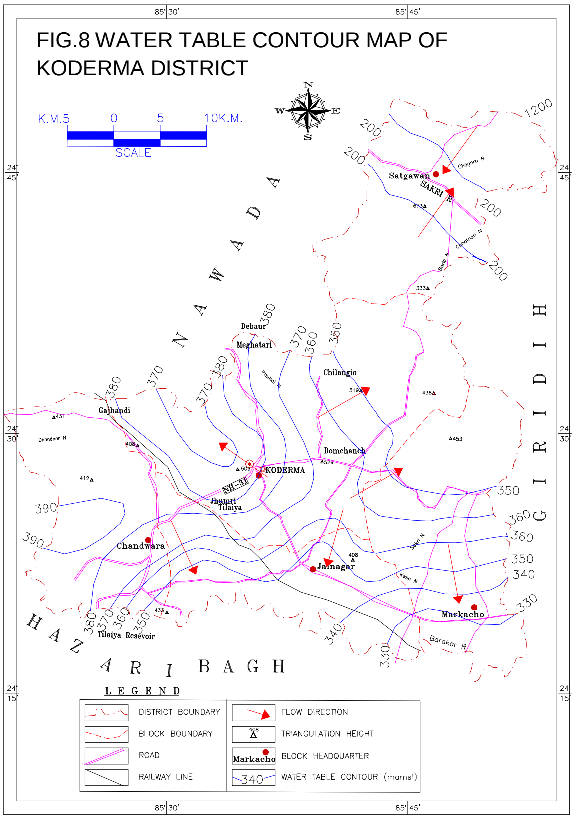


FIG.8 WATER TABLE CONTOUR MAP OF KODERMA DISTRICT

Table- 2 Exploratory wells drilled in Koderma district (Exploration Repot, Jharkhand [4])

Sl. No.	Location	Block	Depth drilled (mbgl)	Length of Casing pipe (m)	Static water level (mbgl)	Discharge (m^3/hr.)	Formation
1	J.J.College,Koderma	Koderma	172.52	14.00	2.7	13.2	Granite-gneiss
2	Tilaiya block campus	Koderma	149.59	10.68	6.10	1.5	Granite-gneiss
3	Chotki Dhamrai	Chandwara	130.20	21.62	5.34	12.02	Granite-gneiss
4	Gumo	Koderma	150.00	24.44	5.63	7.5	Granite-gneiss
5	Chutiyaro	Koderma	150.00	24.49	-----	-------	Mica-Schist

GROUND WATER QUALITY PROBLEMS

INTRODUCTION

The quality of ground water is as important as quantity. The quality of water plays a prominent role in promoting both the standards of agriculture production and human health .To evaluate the quality of ground water/surface water, water samples have been collected from 86 representative dug wells, streams as well as hand pumps during the May 2007. One-litre HDP plastic bottles were used for collecting representative ground water samples. Both dug wells and hand pumps samples were collected. Depth of dug well varies from 4.50 m to 18.10 m while depth of hand pump varies from 27.30 m to 60 m. Altogether 86 numbers of groundwater samples were collected from the entire area. 41 no. of ground water samples were collected from dug wells, 37no. of ground water samples were taken from hand pumps and 8 no. of samples were collected from surface water sources. Samples were chemically analyzed by the standard methods as per the APHA (1985). Fluoride was chemically detected by ECR method at 540 nm.

These samples were analyzed in the chemical laboratory of C.G.W.B., M.E.R., Patna.The samples have been considered to assess the chemical quality of ground water and its suitability for drinking, domestic as well as irrigational purposes. Since the samples are collected from the dug wells, surface water and hand pumps, they represent Shallow (phreatic zone) as well as deeper zone.

ANALYTICAL RESULTS

All the constituents are within permissible limit except fluoride. Ground water of the district is generally potable except few localities in Koderma block and Satgawan block**.** Electrical conductivity varies between 138 to 2340 micro siemens/cm at 25^0c.pH value of the district varies between 6.70 to 9.13. It indicates that ground water is alkaline in nature. Bi-carbonate varies between 115.9 mg/l to 341.6 mg/l but in some localities like kutta and Dhab the value is 506 and 542mg/l.chloride concentration varies between 39 mg/l to 266 mg/l in general but in few areas like Jhumri tilaya railway station and Markacho its values are 383.4 and 809.9 mg/l. Concentration of sulphate varies between 10.6 to 165.6mg/l.In koderma block and parts of satgawan block the value of fluoride varies between 0.43 to 5.53mg/l and 0.30 to 2.23 mg/l while in other parts of the district it is between 0.11to 1.25 mg/l. Concentration of Calcium varies between 20 to 48.6mg/l. Na varies between 10 to 287mg/l and K varies between 1.0 to 34.0 mg/l. Total hardness as $CaC0_3$ varies between 110 to 630 mg/l.

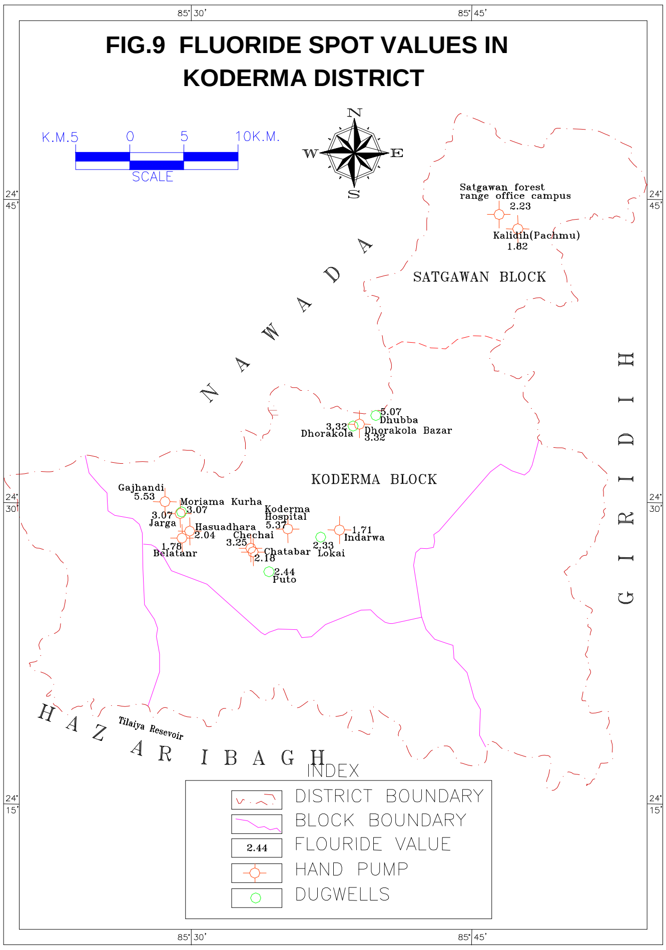
Table 3- Concentration of Chemical constituents (F, Ca, HCo3) at different locations in Koderma block (Singh T.B.N.)[6]

Sl no.	Location	Type of well	F	Ca	HCO3
1	Lokai	D/W	2.33	40	211
2	Indarwa	H/P	1.71	92.2	341.6
3	Dhorakola (kari pahari)	D/W	3.32	32.0	176.9
4	Dhorakola bajar	H/P	3.32	84.1	213.5
5	Dhubba	D/W	5.07	56.1	573.4
6	Puto	D/W	2.44	52.1	366.0
7	hasuadhara	H/P	2.04	28.0	79.3
8	Jarga	H/P	3.07	32.0	122.0
9	Moriama Kunha	D/W	3.07	68.1	176.9
10	Gajhandi	H/P	5.53	80.1	298.9
11	Belatanr	H/P	1.78	72.1	152.5
12	Chechai	H/P	3.25	88.0	146.4
13	Chatabar	H/P	2.18	76.0	170.8
14	Koderma sadar Hospital	H/P	5.37	56.0	384.3

DISCUSSIONS

High concentration of fluoride was found both in upper weathered aquifer and lower fractured aquifer. Fluoride concentration was found beyond permissible limit in 23 percent hand pump samples and 12 percent dug well samples. It shows that deeper aquifers are more contaminated as compared to shallow aquifer **(Fig.9- Fluoride Spot Value map of Koderma District)**. Correlation between % calcium and fluoride was found to be inverse i.e. an increase in fluoride ion concentration results in decrease in calcium ion concentration and vice versa. **(Fig-10 Calcium Vs Fluoride correlation).** The maximum concentrations of fluoride were found to be 5.53 mg/l at Gajhandi village and 5.37 mg/l at koderma sadar hospital hand pump and concentration of calcium was found to be 80 mg/l and 56 mg/l at both locations**)**. Majority of the groundwater samples with high fluoride are characterized by high pH and this indicates that alkaline environment is more favoured for F concentration (**Hem 1975** [5]). These results are in conformity with the correlation analysis. Bicarbonates show direct relationship with fluoride i.e.increase in fluoride concentration results in increase of bicarbonates concentration. At Dhubba, fluoride value is 5.07mg/l and corresponding bicarbonates value is 578 mg/l**. (Fig.-11-Bicarbonate Vs Fluoride correlation)**

Groundwater samples in general were found to be medium saline in nature. Suitability of water for drinking purpose can be known by plotting the chemical constituents in pipers diagram **(Fig-12 Pipers diagram for Ground water types).**It indicates Ca-Mg-HCO3 type of water of koderma district i.e. water is of recharge areas. To determine the suitability of ground water for Irrigation purpose, U.S.S.L. diagram is used. 47% of samples are found in C2S1 class, 34% of samples fall in C3s1 class, 10.4% of samples fall in C1S1 class, 4.6% of samples are in C4S1 class and only 2.3% of samples are in C3S2 class **(Fig-13 U.S.S.L. Diagram for Irrigational water quality)**. Ground water quality is suitable for irrigation purposes.



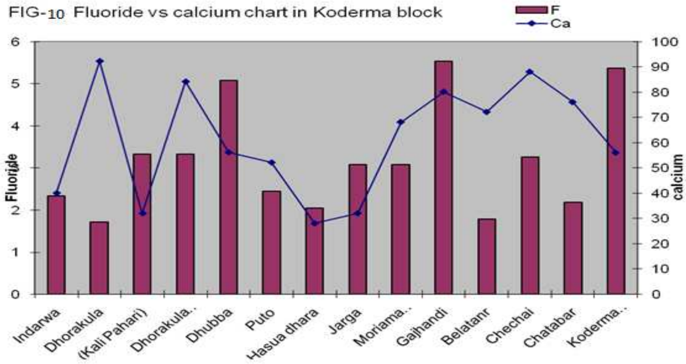


Fig 10-Fluoride Vs Calcium chart in Koderma district

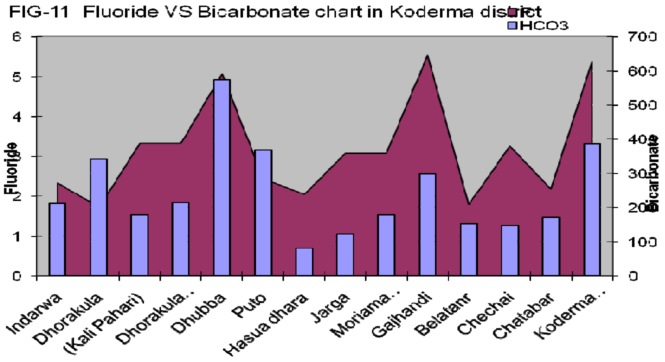


Fig-11-Fluoride Vs Carbonate chart in Koderma district

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FIG.12 PIPER DIAGRAM FOR GROUND WATER TYPES IN KODERMA DISTRICT

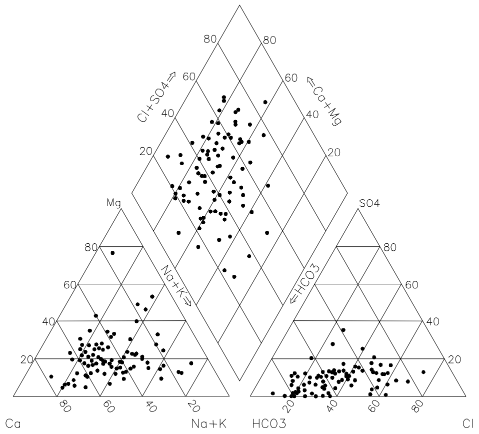
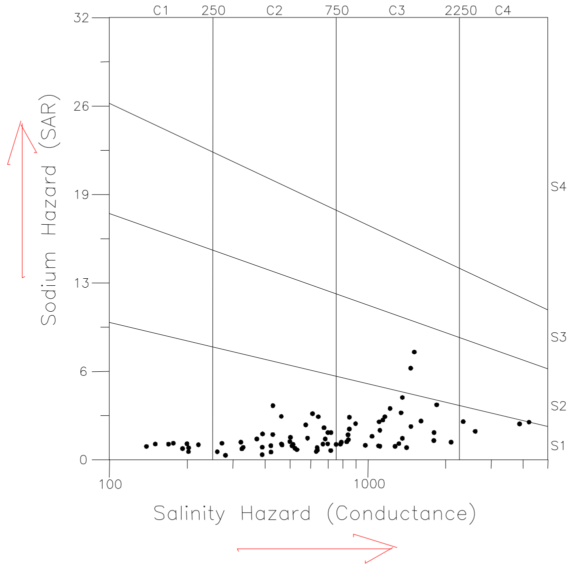


FIG. 13 U.S.S.L. DIAGRAM FOR IRRIGATIONAL WATER QUALITY IN KODERMA DISTRICT



CONCLUSIONS

Ground water occurs under unconfined condition within the weathered residuum (Maximum thickness 15 to 20 meters) and underlying fracture zones. There is possibility that at deeper level Ground water may occur under semi confined to confined condition at places. In the granite gneiss depth to water table varies from 3.00 to 10.00 m bgl during pre monsoon and 1.5 to 4.00 m bgl during post monsoon. Pumping test of the borewells indicate coefficient of Transmissivity varying from 8.5 m^2/day to 21.12 m^2/day.

The productive fracture zones (two to three in nos.) are found to occur within the depth zone of 27 m to 100 m bgl and are capable of yielding 1.5 m^3/hr to 13 m^3/hr of water with the static water level ranging approximately from 2.7 m to 7.3 m bgl. The depth ranges of bore wells vary between 130 to 170 m bgl.

The ground water quality in the district in general is good both for drinking and irrigation purpose. The electrical conductivity ranges from 96 to 4210 micro seimen/cm at 25^0c. Nowhere any parameter has exceeded the maximum permissible limits for domestic use except Koderma and Satgawan where F has exceeded the permissible limit. High concentration of fluoride in ground water of the study area is mainly due to rock water interaction. Possible source rock may be granite/Pegmatite and leaching of fluoride rich minerals in the ground water contributes to this abnormal concentration. Concentration of

Fluoride is above permissible limit in Mica belts of Koderma like Domchanch, Dhubba, Gajhandi areas. Flouride contamination has been observed in the Parts of Koderma and Satgawan blocks. Pegmatite veins containing micas are the main source of fluoride. Hand pumps and dug wells affected by fluorosis should be red marked and chemical analysis must be done yearly to know about the changes in fluoride concentration. Local people awareness programme should be organized. Mica schist areas are devoid of ground water.

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WATERSHED MANAGEMENT: FOCUS ON MINING IMPACTS

Ajit Kumar, Mayukh Sarkar
Department of Mechanical Engineering & Mining Machinery Engineering,
Indian School of Mines, Dhanbad, Email: ajit.ism185@gmail.com

ABSTRACT

Today, mining sector has major contribution in economic development than any other sector. Mining has became the power-house of every unit. But, at the same time, given the vast scale of modern mining operations, it is also the sector with the highest environmental impacts. There is a need to ascetically review the effectiveness of existing policies, and to develop new approaches to watershed management to ensure that vital economic activities can be carried out in a protractable way. Ground water is becoming a major concern with respect to surface as well as underground mining of coal. Two major concerns are ground-water quality and ground-water quantity. Despite the new emphasis placed on ground water by regulatory authorities, the effects of coal mining on ground water are still poorly understood. It is my intention through this paper to elaborate on general aspects of watershed management and mining impacts. This paper also provides a brief overview of the impacts of mining on physical hydrogeology. In the account which follows, the following topics are examined:

- The fundamental types of mine which exists (underground, surface), the geometry of voids which they produce, and their impacts on watershed.
- Origin and nature of Mine wastes
- The implications of the above for physical hydrogeology of mined ground.

Key words: Mining, surface mining, underground mining, impacts, hydrogeology

1. INTRODUCTION

Watershed management has been the common activity among the developmentalists in India. Soil, water, air, light and heat are the essential environmental components that support life on earth. Among them soil and water form the substrata for the generation and degeneration process among the living beings. Obviously soil and water management is key to every natural and human resource management activities. Everything comes from the soil through the water into the micro-organisms, plants, animals and human beings. And everything goes back into the soil mostly through the water. Therefore soil and water conservation should be the primary concern of all human beings irrespective of the profession, occupation, interest, economic and social status.

Watershed is a geographical area in which both the water cycle and organic matter cycle are taking place and it is through these processes that all the biomass including human beings are produced in the nature. In watershed management man takes control of the organic matter cycle and water-cycle in such a way that the whole biomass production becomes more suitable to him. Watershed has been defined as a geographical area which has a common drainage point. In this definition there is no mention of the people for whom the watershed is managed. Therefore for the proper human and natural resource management the watershed should be defined as a socio-political unit of people and their geographical area which they manage and on which they depend on for their existence and development.

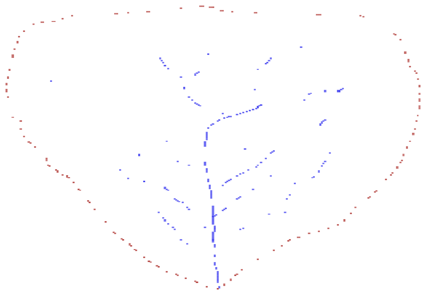

Fig.1. Hydrographic Basin

2. TYPES OF MINE

Fundamentally, there are two types of mine distinguished by the mining industry:

i. Underground Mine: Underground mining involves extraction from beneath the surface, from depths as great as 10,000 ft (3 km), by any of several methods i.e. any mine in which the miner and/or his machinery work beneath a cover of soil or rock (irrespective of absolute depth below ground surface).

ii. Surface Mine: Opencast mining/ Surface mining is done either from pits or gouged-out slopes or by surface mining, which involves extraction from a series of successive parallel trenches. Any mine in which the miner and/or his machinery work in an excavated void which is open to the skies.

3. EFFECT OF MINING ON GROUND WATER QUALITY

Ground water occurs in a variety of ways, depending upon depth below land surface, rock type, and topography. Three important aspects of ground water related to the "hydrologic balance" are the storage capacity of rocks for ground water, the rate of movement of ground water and chemical quality. Rock units that have relatively high storage capacities and that allow relatively rapid movement of ground water are termed aquifers. A simple practical definition of an aquifer is a rock unit of other underground layer or zone that yields a sufficient quantity of water to a well or spring being used as a water supply source. This is generally at least one gallon per minute for domestic supplies for single families. Rock types that are usually considered aquifers, where they occur in thick enough units, are sandstone, limestone, and coal. Thick coal seams sometimes are the best yielding aquifers in certain localities, because of the coal cleats or fractures. Shales, mudstones, and clays are usually not aquifer units. Ground water can be classified by depth. Shallow ground water usually supplies springs and dug wells, whereas deeper ground water supplies mostly drilled wells. Shallow ground water is intersected beneath the water table, and deeper ground water (in drilled wells) commonly is artesian water under significant pressure. Deeper ground water is usually at least 30 feet deep, and has typically been in the ground longer and is flowing slower than shallow ground water. Ground water typically moves at rates ranging from a few feet per year to a few feet per day, which is much slower than stream flow.

Ground-water pollution can occur both directly and indirectly as a result of mining. Direct degradation can occur to ground water situated downhill or down gradient from a surface mine, by flow of contaminated drainage from the mine. This mine drainage can come from pits, ponds, or from rainfall infiltration and ground-water flow during mining and after reclamation. Ground-water pollution would result from the same toxic overburden and coal materials that cause surface water contamination. Indirect degradation of ground water could result from blasting, which causes a temporary shaking of the rock and results in new rock fractures near working areas of the mine. Ground water contaminated by mine drainage often is different in chemistry from polluted surface water before chemical treatment. Polluted ground water typically has undergone a higher degree of natural neutralization than has polluted surface water, because of its greater contact with carbonate minerals and slower rates of movement. Several factors affect the severity of mine drainage contamination of ground water. The acid-producing potentials of coal and overburden rock are a prime factor. The type and degree of surface-mine reclamation also probably affect the severity of subsequent ground-water pollution, since it affects the degree of stream-water pollution. Although less pollution should occur with better reclamation, we have not yet evaluated this factor in our research.

3.1 Effect of Surface Mining

Where surface mines are excavated into aquifer materials, they clearly remove part of the aquifer, which in itself may represent a loss of resource (e.g. increased evaporation from the post-mining pit-lake) or at least an increase in vulnerability for the surrounding aquifer resources (i.e. removal of the barrier to pollutants represented by the unsaturated zone). Besides these obvious impacts, most other effects of surface mines on natural hydrogeology are rather subtle. A “halo” of increased permeability (≤100 times greater than background values) can develop around open-pit walls, due to extensional fracturing induced by blasting and the reduction of lateral stresses. Indeed, permeability close to the void may be so high as to favour turbulent flow near the void, resulting in a near-pit water table which is much steeper than would be expected if groundwater flow remained strictly Darcian. On the other hand, although many pit lakes are in hydraulic continuity with the surrounding ground water, in some cases the blinding of the pit floor with fine-grained sediments can effectively “perch” water in the open-pit, with little or no interaction with the surrounding ground water system. Pit lakes are complex environments from a limnological and geochemical perspective. Limnologically, the key difference between pit lakes and natural lakes can be quantified by a parameter known as the relative depth (DR) (Castro & Moore, 2000)

$DR = 100 (zm/d)$

where zm is the maximum depth of the lake and d is some standardised diameter (e.g. for circular lakes, d = 2 v(A/p), where A is the surface area). Typical DR values for natural lakes are usually < 2 %, and few have values of more than 5 %.

By contrast mine Pit-Lake typically have DR values in the range 10 to 40 %. Such high values of DR have important hydrological consequences. Most notably a high DR means that evaporative losses as percentage of stored water (and therefore evaporative concentration) from the pit lake will be limited compared to a natural lake with a similar surface area. High DR also has profound effects on density stratification: with high DR values, pit lakes promote the development of three-layer systems in which the third, deepest layer is never involved in seasonal overturn (“meromictic” conditions).

3.2 Effect of Underground Mining

The hydrogeology of abandoned deep mines is essentially “non-standard” when compared with natural aquifers. The flow in flooded deep mines is usually highly channelised (i.e. most flow is associated with old mine voids) and very often turbulent (hence Darcy’s Law is inapplicable). Collapse of voids and erosion by turbulent flow can lead to permeability and storativity changes over a scale of days or even hours. Records of water level rises in shafts accessing abandoned, flooding underground workings are known as “rebound curves”. These typically show staged variations in rebound gradient which are particularly clear on semi-log (“Jacob”) plots. The variations in gradient record vertical variations in storage properties as the water level successively passes through worked and unworked zones (corresponding hydraulically to alternating unconfined and confined storativity conditions).

4. WATERSHED MANAGEMENT

4.1 Causes of watershed deterioration

These activities are:

- Faulty agriculture, forestry and pasture (Grass land) management leading to degradation of land.
- **Unscientific mining and quarrying.**
- Faulty road alignment and construction.
- Industrialization
- Forest Fires
- Apathy (less interest) of the people.

4.2 Results of watershed deterioration

- Less production from agriculture, forests, grass lands etc.
- Erosion increases and decreases biomass production
- Rapid siltation of reservoirs, lakes and river beds.
- Less storage of water and lowering of water table.
- Poverty as a result of less food production.

5. APPROACHES IN WATERSHED MANAGEMENT

Based on the various basic concepts so far described we can have a number of approaches in watershed. Thus we can have a short term or a long term approach, an exploitative or extractive approach, economic and consumeristic approach, regenerative and restorative approach, conservation approach, flora or fauna centered approach, sustainability approach, carrying capacity, developmental approach, economic & commercial approach, environmental & ecological approach, flora & fauna centered approach, human centered approach, socio-cultural approach, political approach & administrative approach, human centered comprehensive approach, human centered market approach, human centered value addition and marketing approach, conservation-production-processing and marketing approach etc.

At present watershed management seems to consist of only a certain number of soil and water conservation practices, introduce few cropping systems and animal husbandry practices. In a few instance few social issues are talked about. People seem to be happy with whatever little improvement; they see and the share of little more income they receive while the lion's share of the total income goes out of their hand. There is a semblance of improvement while actually there is no improvement. At present people have no control over the market and the prices of their products. Until and unless people have control over the marketing of their own labour and their products in the watershed management will have no lasting developmental impact on the people of the watershed. People in the watershed will remain as dignified bonded labourers. Ultimately watershed should be considered as the socio-economic and political unit of people and their land resources from which they derive all the needs for their existence and development.

Watershed management is a human activity by which man takes control of all the natural resources in such a way that while developing their full potential they are preserved, enriched and sustained. Along with the natural resource development all the necessary infrastructural facilities should be developed and made available within the easy reach of every one. The human resources are managed and adjusted in such a way that there is justice in the things distributed for their existence and development.

The idea is to have a comprehensive integrated approach in which both the environment and the human beings are made sustainable.

6. GROUND WATER RESOURCE ASSESSMENT

In the management of a ground water system in which decisions must be made with respect to water quality and water quantity, a tool is needed to provide the decision maker with information about the future response of the system. Depending on the nature of the management problem, decision variables, objective functions, and constraints, the response may take the form of future spatial distributions of contaminant concentrations, water levels, etc. This tool is the model. Its predictive capacity makes it the most useful tool for planning, design, implementation and management of the groundwater resources.

6.1 Shortfalls in watershed resource assessment

Currently, there is gross inadequacy of hydrogeological data and research into the understanding of groundwater resources, renewability, apportionment and management. Data gathering and dissemination are fundamental to the development and management of the resources. However, concerns have emerged over the lack of basic data gathering and collation on groundwater resources. There is a culture of secrecy about data-sharing which much impedes water development - from the Government to the private sector. There are also certain issues and challenges in ground water resource management. These include:

1. Quantification of the groundwater resources.

2. Modeling of groundwater management scenarios have suffered in the past and are presently handicapped by the lack or wrongly collation of data.
3. Other challenges include definition of measured parameters and unifying mode of data collection and central collation, especially where exists differences in aquifer characteristics and level of usability of aquifers.
4. Hydrogeologists have to play a critical role in assisting the development and maintaining the survival of national groundwater databases.

6.2 Designing and maintenance of groundwater databases

There are several factors which monitor design and maintenance of ground water databases. These are:

1. The design of a groundwater monitoring programme should be based on clear and well thought out aims & objectives and should ensure that the planned monitoring activities are practicable.
2. Sustained monitoring of hydrogeological parameters and groundwater quality should be ensured rather than short-term project-oriented data collection.
3. A strategy for initiating monitoring in priority areas may be a better starting point. This may necessitate the review of existing monitoring programs & use of information tools that could facilitate the definition of priority areas.

6.3 Technical base necessary for managing and monitoring water shed

1. Characterization of geo-hydrodynamic parameters, quality, level and flow of the groundwater.
2. Identification of the recharge and discharge and of the sub-domains of the Aquifer System.
3. Development of mathematical models of geo-hydrodynamic behavior and of risks (vulnerability and potential pollutant on local and regional scale).
4. Structuring of a network and an information system integrating a groundwater data base (quantity and quality parameters, constructive aspects of wells, use and protection).

7. STRATEGIES FOR EFFECTIVE DATA MONITORING

1. On the national scale water-related issues are generally governed through the respective countries water authorities.
2. Knowledge concerning the spatial distribution of groundwater and groundwater quality data across the countries (on a national scale) is still very sparse.
3. Strategic issues as they play an important role in defining network resource requirements:
    - determination of the number of monitoring stations that will be appropriate for the monitoring network;
    - existing boreholes should initially be used but specifically constructed and dedicated boreholes will ultimately be required;
    - a measurement or sampling protocol document will be required to define frequency and prescribe mode of measurements;
    - the selection of monitoring tools, e.g. divers, water level meters and field-based or laboratory-based equipments, in cases where groundwater quality is incorporated into the monitoring programme.
    - Establishing a rather representative monitoring network may not be easy task, existing structures should be used as much as possible.
    - The network should start at a simple, unsophisticated level and then work towards the ideal.
    - Initiating a country-country level (national) network is fundamental to the attainment of a functional groundwater monitoring programme.

8. AGENTS INVOLVED IN WATERSHED MANAGEMENT PROGRAMME

A number of people as individuals or groups are involved in the implementation of the watershed management programme. People are involved as managers and beneficiaries, women, landless labourers, rich, poor, old, young, people's representatives, government officials, administrators, revenue, development, educationalists, 'NGOs/ vas, watershed experts, scientists, technicians, other experts on soil, forestry, crops, animals, horticulture etc., socio-cultural scientists, developmentalists, bankers and financiers, marketing people etc.

Obviously each agent will have his own perception of the watershed management and his approach will be different. Therefore for a successful watershed management there should be common targets on which everyone concerned agreed formally in writing.

Technical staff seems to play a key role in the watershed management planning and implementation. They are the ones who have a clear idea of the technical and constructional details of the soil and water conservation structures. The technical success of the programme entirely depends on them. Therefore they should take guarantee for the structures they plan and construct.

CONCLUSION

1. Mining affects natural hydrogeology quite profoundly, in ways which are often not readily amenable to analysis using conventional methods of groundwater hydrology.
2. Bodies of mine waste have distinctive hydrological characteristics which complicate their analysis and their geotechnical behaviour.
3. Withdrawn water can be used after proper treatment in domestic and industrial sector.
4. More characterization is necessary for water contamination and other potential watershed issues.
5. The watershed management measures will be evaluated in order to determine their efficacy and will be adjusted in order to make the most of past experiences.
6. Corrective measures can be taken after ground-water pollution is detected.
7. There are too many differences, conflicts, ideologies, strategies and constraints to be solved among the agents of the present watershed management.

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BIOREMEDIATION TECHNOLOGIES FOR HEAVY METAL CONTAMINATED GROUNDWATER IN OPEN CAST COAL MINING AREA

Vipin Kumar* and Shrabani Sen**
* Assistant Professor and ** JRF
Department of Environmental Science and Engineering
Indian School of Mines, Dhanbad, India
e-mail: vipinmicro1@gmail.com

ABSTRACT:

The contamination of groundwater by heavy metal, originating either from coal mine sources or any other sources is a matter of concern to the public health. Remediation of contaminated groundwater is of highest priority since billions of people all over the world use it for drinking purpose. In this paper, various approaches for groundwater treatment *viz* chemical, biological /biochemical and physico-chemical treatment processes have been reviewed. Selection of a suitable technology for contamination remediation at a particular site is one of the most challenging jobs due to extremely complex soil chemistry and aquifer characteristics and no thumb-rule can be suggested regarding this issue. In the past decade, iron based technologies, microbial remediation, biological sulphate reduction and various adsorbents played versatile and efficient remediation roles. In-situ chemical injection in the aquifer is a very promising technique but the soil chemistry and aquifer may get disrupted in the process of cleaning. Some chemicals are non biodegradable, even produce toxic intermediates and are carcinogenic. Hence, caution should be taken while introducing chemicals in aquifers. Keeping the above environmental concern in mind, the technologies encompassing bioremediation are recommended to be adopted in appropriate cases.

Key words – Bioremediation, Heavy metals, Coal mine waste, Leachate, Ground water

INTRODUCTION:

In mining of coal by open cast method, the overburden (and inter-burden) rocks are emplaced in overburden dumps (external and/or internal) many a times without proper soil covering. Suitable leachate and gas management systems for these dumps are also generally non existent. The open dumping of the overburden rocks results into leachate contamination of surface water as well as of groundwater resources. Currently, environmental and human health impacts of mine waste disposal are increasing day by day, hence it required more effort to management of mine waste. The leachate contamination can cause ecological toxic effect in the surrounding area. A variety of toxicants in the leachate such as organic matter, heavy metals and nitrogen influences the toxicity level. Determination of the contribution of heavy metals to the leachate toxicity level is necessary in understanding the environmental toxic impact of heavy metal leaching. Also, it is important to investigate the toxic pollutant in the leachate needed for treatment to reduce the toxicity.

Heavy metals are extremely toxic for living beings and they are highly persistent pollutants. Once they get into the soil sub-surface or in groundwater, it becomes extremely difficult to handle them due to the complex speciation chemistry coming into play. However, many techniques have been devised over the past few decades to remediate heavy metal contaminated groundwater. In the environment, the heavy metals are generally more persistent than organic contaminants such as pesticides or petroleum byproducts. They can become mobile in soils depending on soil pH and their speciation. So a fraction of the total mass can leach to aquifer or can become bio-available to living organisms (Santona et al., 2006).

Heavy metal is a general collective term, which applies to the group of metals and metalloids with atomic density greater than 4000 kgm^{-3}, or 5 times more than water (Garbarino et al., 1995) and they are natural components of the earth's crust. Although some of them act as essential micro nutrients for living beings, at higher concentrations they can lead to severe poisoning (Lenntech, 2004). The most toxic forms of these metals in their ionic species are the most stable oxidation states e.g. Cd^{2+}, Pb^{2+}, Hg^{2+}, Ag^{+} and As^{3+} in which, they react with the body's bio-molecules to form extremely stable bio-toxic compounds that are difficult to dissociate (Duruibe et al., 2007).

Heavy metals in ground water: Heavy metals occur in the earth's crust and may get solubilize in ground water through natural processes or by change in soil pH. Moreover, groundwater can get contaminated with heavy metals from landfill leachate, sewage, leachate from mine tailings and mine wastes, deep well disposal of liquid wastes, seepage from industrial waste lagoons or from industrial spills and leaks (Evanko and Dzombak, 1997).

EXISTING TECHNOLOGIES FOR TREATMENT OF HEAVY METAL CONTAMINATED GROUNDWATER

Several technologies exist for the remediation of heavy metals contaminated groundwater and soil and they have some definite outcomes such as:

(i) Complete or substantial destruction/degradation of the pollutants
(ii) Extraction of pollutants for further treatment or disposal
(iii) Stabilization of pollutants in forms that are less mobile or toxic
(iv) Separation of non-contaminated materials and their recycling from polluted materials that require further treatment and
(v) Containment of the polluted material to restrict exposure of the wider environment (Nathanail and Bardos, 2004; Scullion, 2006).

MECHANISM OF BIOREMEDIATION

Natural biological activity does not have the ability to remove heavy metals from deeper layers of soil or from aquifers. However, the biological processes such as phyto-remediation, phyto extraction and hyper accumulation can be used for long term remediation purposes in conjugation with some other more intense remediation process. Genetically engineered organisms can be used for more active role in this process. Enhanced bio-restoration is a highly researched area. Immobilization of radio nuclides such as U, Tc and Ra by micro-organisms of *Geobacter* species is very novel method which is adopted world wide.

Use of micro-organisms and ferrous oxides has been proved to be a very effective and sustainable technology in practice for removal of in-situ arsenic. It is a long term process and has long lasting effect on aquifer. No waste is generated and practically no chemical is required to create an oxygenation zone in the aquifer in this process. It maintains a very fine balance between coprecipitaion of As(V) with Fe(III) and adsorption of the former into the later.

Biosorption is a highly practical solution for heavy metal remediation and is a much researched field of study. It is a cost effective method, has possibility of metal recovery and also generates minimum sludge. However, its field application for heavy metal removal is still limited. Metal uptake by various organisms is principally a slower natural process that can be used in field for long term remediation measures.

Bioremediation Technology for Heavy Metal treatments

Biological treatment methods exploit natural biological processes that allow certain plants and micro-organisms to help in the remediation of metals in soil and groundwater. Plant based remediation methods for slurries of dredged material and metal contaminated soils had been proposed since the mid-1970s (Cunningham and Berti, 1993). A number of researchers (Barona et al., 2001; Boopathy, 2000) were skeptical about significant metal extraction capability of plants. According to a recently published paper focusing on the use of plants and micro-organisms in the site restoration process, ex-situ bioleaching, bio-stimulation such as addition of carbon sources and mineral nutrients, ex-situ or in-situ biosorption, coprecipitation with biogenic solids or sulphides and introduction of proper biosorbents or microorganisms to produce active biosorbents inside the aquifer or soil were found to be suitable techniques for this purpose (Kavamura and Esposito, 2010).

Salati et al. (2010) reported a highly efficient technique of augmenting phytoremediation process by using organic fraction of municipal solid wastes (OFMSW) to enhance heavy metal uptake from contaminated soil by maize shoots. High presence of dissolved organic matter, 41.6 times greater than soil control, exhibiting ligand properties due to presence of large amount of carboxylic acids made the process very much efficient (Salati et al., 2010).

The biological processes for heavy metal remediation of groundwater or sub-surface soil occur through a variety of mechanisms including adsorption, oxidation and reduction reactions and methylation (Means and Hinchee, 1994). According to Boopathy (2000), some of the examples of in-situ and ex-situ heavy metal bioremediation are - land farming, composting, use of bioreactors, bioventing by oxygen, using bio-filters, bio-augmentation by microbial cultures and bio-stimulation by providing nutrients. Some of the other processes include bio-accumulation, bioleaching and phyto-remediation. Potentially useful phyto-remediation technologies for remediation of metals-contaminated sites include phyto-extraction, phyto-stabilization and rhizo-filtration (Evanko and Dzombak, 1997; USDOE, 1996).

A hyper accumulator is defined as a plant with the ability to yield 0.1% Cr, Co, Cu, Ni or 1% Zn, Mn in the above-ground shoots on a dry weight basis (Evanko and Dzombak, 1997). Since metal hyper-accumulators generally produce small quantities of biomass, they are not suitable agronomically for phyto-remediation.

Biological sulphate reduction (BSR)

BSR is the process of reduction of sulphate to sulphide, catalyzed by the activity of sulphate-reducing bacteria (SRB) using sulphate as electron acceptor (Gibson, 1990). BSR has been proved to be an effective means in reducing heavy metal concentrations in contaminated water (Suthersan, 1997). Moreover, metal sulphides due to their low solubility precipitate with metal ions already present in the solution. BSR was investigated for treatment of AMD on-site in reactive barriers (Benner et al., 1999; Blowes et al., 1998; Waybrant et al., 1998) as well as off-site in anaerobic bioreactors (Greben et al., 2000; Hammack and Edenborn, 1992). AMD is characterized by low Eh, low pH and high concentrations of sulphate, Fe and heavy metals. The use of BSR was aimed at pH increase and sulphate and metal removal. A wide range of electron donors such as ethanol, lactate, hydrogen and economically favorable waste products, pure substrates or inoculated with monocultures or media (manure, sludge, soil) containing SRB had been reported to be quite effective in the BSR process (Annachhatre and Suktrakoolvait, 2001; Dvorak and Hedin, 1992; Lens et al., 2000; Prasad et al., 1999; van Houten et al., 1994; Waybrant et al., 1998).

Biological arsenic reduction (BAR)

High concentration of arsenic in sub-surface aquifer may arise due to the presence of bacteria, using As bearing minerals as a energy source, reducing insoluble As(V) to soluble As(III). Das et al. (1994) reported As in groundwater of West Bengal in massive scale while Camacho et al., (2011) did a detailed study on the occurrence of As in groundwater of Mexico and south western USA. The micro-organisms *Gallionella ferruginea* and *Leptothrix ochracea* were found to support biotic oxidation of iron by Katsoyiannis and Zouboulis (2004), who performed some experiments in laboratory where iron oxides and these micro-organisms were deposited in the filter medium, offering a favorable environment for arsenic adsorption. These micro-organisms probably oxidized As(III) to As(V), which got adsorbed in Fe(III) resulting in overall arsenic removal of up to 95% even at high initial As concentrations of 200 mg L^{-1}. Leupin and Hug (2005) passed aerated artificial ground water with high arsenic and iron concentration through a mixture of 1.5 g iron fillings and 3-4 g quartz sand in a vertical glass column. Fe(II) was oxidized to hydrous ferric oxides (HFO) by dissolved oxygen while As(III) was partially oxidized and As(V) adsorbed on the HFO. Four filtrations reduced total As below 50 mg L^{-1} from 500 mg L^{-1} without any added oxidant.

Reduction of multi-contaminants by mixing biotic components with ZVI:

Mixing biotic components with ZVI:

Some studies indicated that micro-organisms when coupled with Fe^0 increase the contaminant removal efficiency (Parkin et al., 2000). Coupling of bio-augmentation with the ZVI technology was found to have a symbiotic effect (Oh and Alvarez, 2002; Till et al., 1998). Till et al. (1998) proved that Fe^0 can stoichiometrically reduce nitrate to ammonium and that hydrogen produced (during anaerobic Fe^0 corrosion by water) can sustain microbial denitrification to reduce nitrate to more innocuous products (i.e., N_2O and N_2). Experiments with mixtures of contaminants have also shown that bio-augmentation of PRBs with bacteria offers promise when more than one contaminant is present. Batch experiments with mixtures of carbon-tetrachloride, Cr and nitrate showed that bioaugmentation reduced competition among these pollutants for active sites on the Fe^0 surface (Parkin et al., 2000).

Bioremoval of hexavalent chromium (Cr(VI))

Hexavalent chromium (Cr(VI)) and trivalent chromium (Cr(III)) are the most prevalent species of chromium in the natural environment. Cr(III) is relatively insoluble in water and exhibits little or no toxicity. In mammals Cr(III) promotes effective glucose, protein, and lipid metabolism. The hexavalent form (Cr(VI)) is, however, highly soluble and mobile in water and displays toxic, mutagenic, and carcinogenic to living systems, including microorganisms, at low concentrations. Cr(VI) is an irritant at relatively high concentrations. It has also been linked to morphological changes and growth reduction in plants. Major sources of Cr(VI) pollution include - leather tanning, chromium electroplating, wood preservation, alloy preparation and nuclear wastes (due to its use as a corrosion inhibitor in nuclear power plants). Although some living organisms require Cr as an essential element, its toxic, mutagenic, and carcinogenic nature render it hazardous. Health problems associated with Cr pollution of terrestrial surfaces and aquatic systems is of increasing world-wide concern (Okeke, 2008).

CONCLUSION:

Groundwater treatment technologies have come a long way since the days of their inception. Much research has been done on numerous technologies ranging from simple ex-situ physical separation techniques to complex in-situ microbiological and adsorption techniques. In modern days, sustainability is the keyword to any process. Instant remedy may provide a temporary solution to a problem but it may not be a permanent one. Therefore, natural processes and biogeochemistry of the soil should be given due consideration before planning remediation processes. Mine waste leachate containing heavy metals tend to destroy the soil profile and should be performed to recover metals from heavily polluted sites. In-situ chemical injection in the aquifer is a very promising technique but the soil chemistry and aquifer may get disrupted in the process of cleaning. Some chemicals are non biodegradable, produce toxic intermediates and are carcinogenic. Hence, caution should be taken while introducing chemicals in aquifers.

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STUDY OF THE YAMUNA RIVER WATER QUALITY IN ALLAHABAD CITY

Ibadaiahun myrthong1, Brijesh Kumar Mishra[2], Richa Sharma [1] N N Harry[3]
[1] Dept. of Environmental Science, School of Forestry & Environment, SHIATS, Allahabad, U.P.
[2] Dept. of Environmental Science & Engineering, Indian School of Mines, Dhanbad, Jharkhand, India
[3] Assistant Professor, Department of Civil Engg., SHIATS- DU, Allahabad- 211007, U.P.

ABSTRACT

The main objective of this study was to assess the current status of physical & chemical characteristics of Yamuna River at Allahabad city during Magh-Mela 2010. The results of the statistical analysis revealed that there is significant difference in months due to variations in temperature or weather conditions or even rainfall but there is no significant difference in sites. The results also shows that the water is suitable for irrigation purpose as the values are found to be within the permissible limit. Data shows that the river Yamuna comes under C category of the water quality criteria since almost all the values are within the permissible limit except for DO whose values are found to be slightly less than the permissible limit which makes it unsuitable for aquatic ecosystem.

INTRODUCTION

Rivers are important since they provide water for economic development and human consumption; they provide recreational facilities - fishing, boating etc.; they support a large variety of wildlife and they are part of our natural scenic heritage. Industrial development, improvements in living standards and changes in agricultural practices, have resulted in an increased demand for good quality water. However, such developments have produced increased amounts of sewage, industrial wastewater, agricultural discharges and agricultural run-off. A comprehensive river water quality monitoring programme is necessary in order to safeguard public health and to protect our valuable fresh water resources for present and future generations.

The river Yamuna, the largest tributary of the river Ganga originates from the Yamunotri glacier in the Missouri range peaks 38˚59', 78˚27'E of the lower Himalayas at an elevation of 6320 meter above mean sea level in the state of Uttaranchal of northern India. The total length of Yamuna is 1376 km. covering a catchment area of 3, 66,220 km^2. The river Yamuna covers as many as seven states and it flows almost entirely through Delhi, where it is exploited the most.

Nearly 57 million people depend on the river Yamuna. In the past the river used to be the main source of life for drinking water, communication and irrigation. Yamuna outnumbers any other river in the number of industries on its banks because it passes through many major industrial cities.

The water of the river Yamuna is also used for irrigation purpose so degradation in the water quality will have some impact on agricultural purposes. The river water in the upper segment is relatively unpolluted. However, domestic and industrial water from urban and rural areas are discharged into the river polluting the downstream.

Yamuna is among one of the sacred river facing degradation in its water quality as a result of modernization. Allahabad is known for collision of three sacred rivers so it becomes important to always keep an eye on the quality of the river water. Moreover Allahabad is still not getting any recognization under YAP even when its IIIrd phase was being framed. The task of the YAP was to clean up the river Yamuna, but so far, they have not yet succeed. It has been reported that the Yamuna river water is so polluted that it can hardly sustain marine life.

OBJECTIVES

1. To analyze the physical and chemical parameters of the river Yamuna
2. To understand the quality of the river through surface water quality criteria
3. To study the impact of the river Yamuna water quality on some selected chemical characteristics of the concrete structures

MATERIALS AND METHODS

The water samples were collected from seven different sites of the river Yamuna at Allahabad during January to May 2010

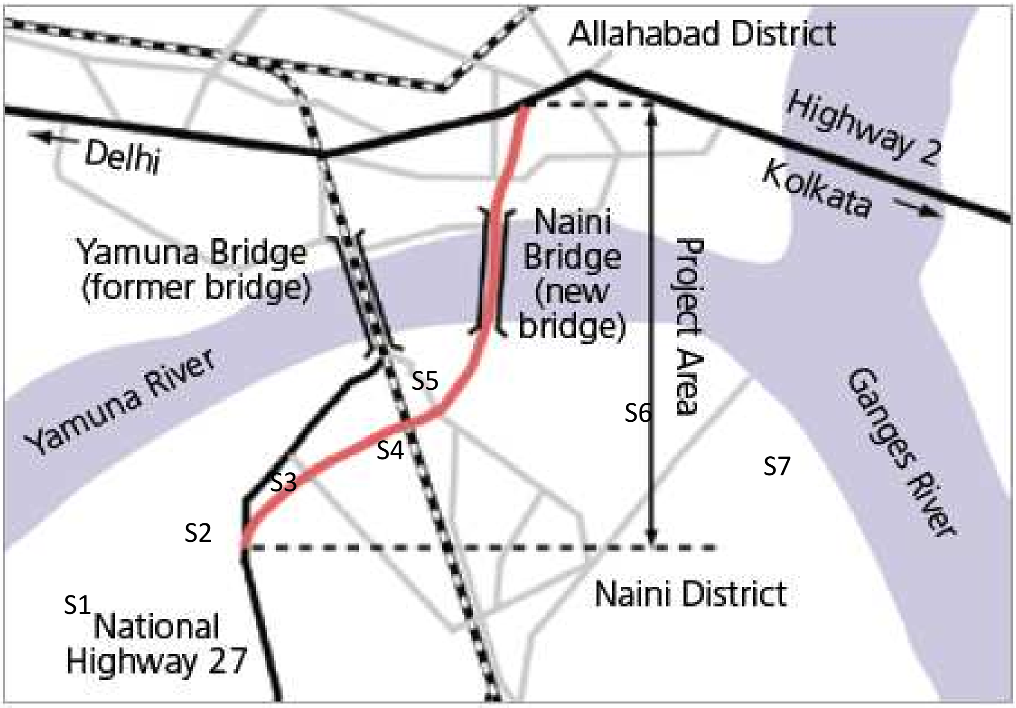

Fig 3.1- Map of the different sites of the river Yamuna from which the samples were collected

SAMPLE COLLECTION

The samples were collected once in a month from the sderent sites for a period of five months starting from January to May 2010. Three samples were collected from each site. The different parameters analyzed were pH, EC, DO, BOD, Chloride, Sulphate, Total alkalinity, Acidity, Total hardness, Calcium, Magnesium and Sodium.

RESULTS AND DISCUSSION

The results are based on the data collected during the experimental investigation of the study and are presented through subjective analysis and tables. Discussions are made for elaborating the interpretation of the results. The chemical characteristics of the water sample from the different sites of the river Yamuna in Allahabad city has been collected and analyzed from the month of January 2010 to May 2010. The different parameters include pH, EC, DO, BOD_5, Acidity, Alkalinity, Hardness, Sulphate, Sodium, Calcium, and Magnesium.

The pH of all the water samples taken from the river Yamuna was found to be above 7 which show that the water is alkaline in nature. It is necessary to check the pH because it affects the solubility and availability of nutrients to the different organisms present in water. EC is also influence by pH, whereby an increase in pH increases the EC of water and decrease in pH decreases the EC of water. Increase in EC also indicates the presence of polluting matter. DO test is one of the most important indicators of pollution in rivers. It can also indicate whether there is excessive plant growth present. Normally water is 100% saturated with oxygen but if the oxygen is used up, either by polluting material or by plants that live in the water, the oxygen levels can decrease so it is necessary to carry out these test to maintain the quality of the water. Any organic waste matter entering a river/lake acts as a food source for the micro-organisms living in the water. These micro-organisms use the dissolved oxygen present in the water to break down the food. The amount of oxygen used up by the micro-organisms is measured using the Biochemical Oxygen Demand (BOD) test and provides a measure of whether the water is clean or polluted. Unpolluted river waters are likely to have a BOD value <3mg/1 O2 and values significantly above 4-5 mg/1O2 indicate possible pollution. The BOD value in rivers can also be affected by high flows or floods.BOD is also affected by temperature, higher the temperature, higher will be the BOD and lower the temperature lower is the BOD. The data which has been recorded shows that the BOD for January is higher than that of February although January is much colder than February. This is because of the Magh Mela festival in which thousands of pilgrims from all over the world comes to perform their religious rituals and sacrifices. The Chloride content and the acidity of the water are highly affected by the amount of sewage and industrial effluent which are discharge into the water. It is necessary to check the quantity of chloride as the human population and the number of industries is increasing day by day. Increase in chloride content causes contamination of rivers and groundwater which can make it unsuitable for human to drink. High levels of chloride kill plants and wildlife. Hardness and Alkalinity in water are mainly due to the presence of calcium and magnesium salts and bicarbonate formed in reactions in the soil and rock through which the water percolates. Water with low alkalinity or hardness may be susceptible to pH reduction by 'acid rain'. Increase concentration of CO_2 in water causes increased in alkalinity which also raises the pH level which in turn kills fish and other aquatic organisms. The increase concentration of Sulphate was mainly due to acid rain. It is important to check the concentration of sulphate regularly as its increase adds to the increase of electrical conductivity of water.

After analyzing the samples the results for pH and EC was found to be more or less similar to that of the water sample but for Chloride, Acidity and Alkalinity the results were recorded to be three or four times higher than that of the water sample. This shows that there is accumulation in the deposition of the concrete structure. Although at present the values were found to be within the permissible limit when compared with the prescribed standards of water quality criteria however this accumulation suggest that there is a possibility that the strength and durability of the concrete structure will be harm which will further cause damage to life and economics. As it has already been stated that increased in chloride and acidity concentration on water will have a negative impact on the concrete structure.

The results of the statistical analysis revealed that there is significant difference in months due to variations in temperature or weather conditions or even rainfall but there is no significant difference in sites

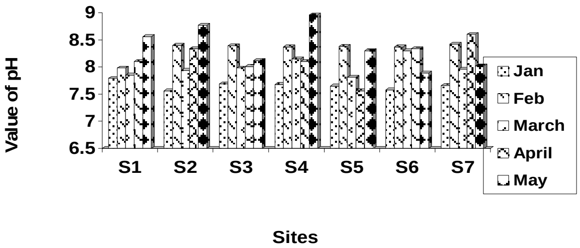

Fig 1: Graphical representation of pH of the river Yamuna at the different sites

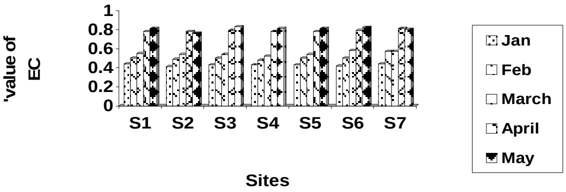

Fig 2: Graphical representation of EC of the river Yamuna at the different sites

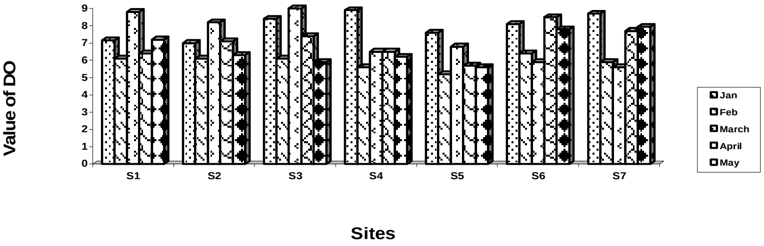

Fig 3: Graphical representation of Dissolved Oxygen of the river Yamuna at the different sites

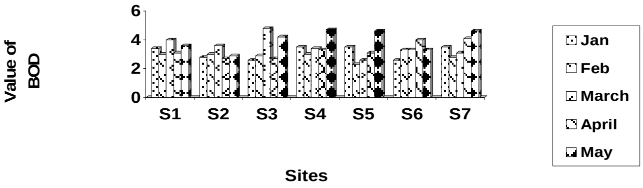

Fig 4: Graphical representation of Biochemical Oxygen Demand of the river Yamuna at the different sites

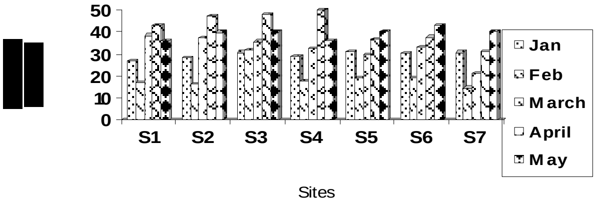

Fig 5: Graphical representation of chloride of the river Yamuna at the different sites

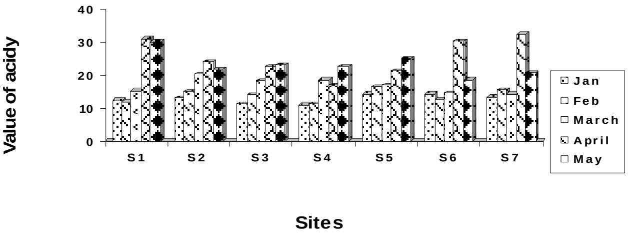

Fig 6: Graphical representation of Acidity of the river Yamuna at the different sites

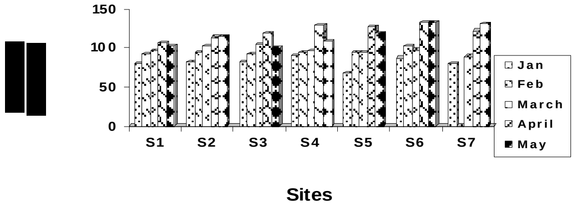

Fig 7: Graphical representation of Alkalinity of the river Yamuna at the different sites

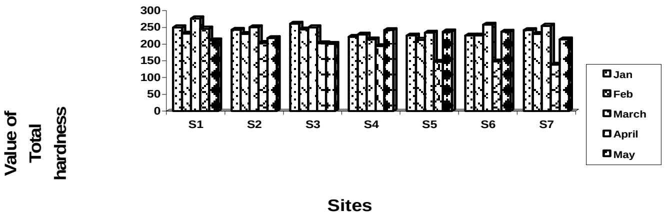

Fig 8: Graphical representation of Total Hardness of the river Yamuna at the different sites

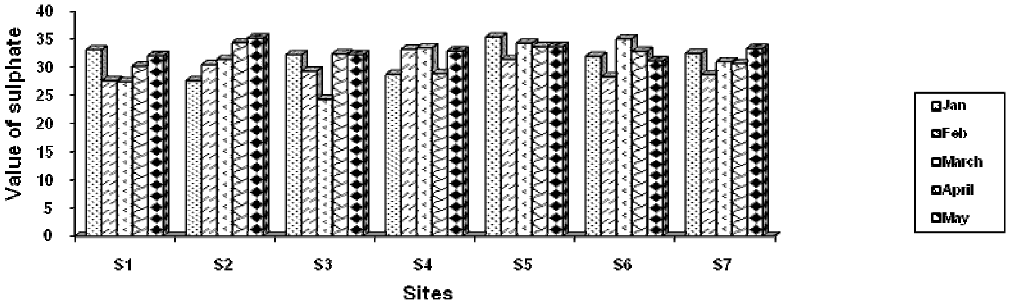

Fig 9: Graphical representation of Sulphate of the river Yamuna at the different sites

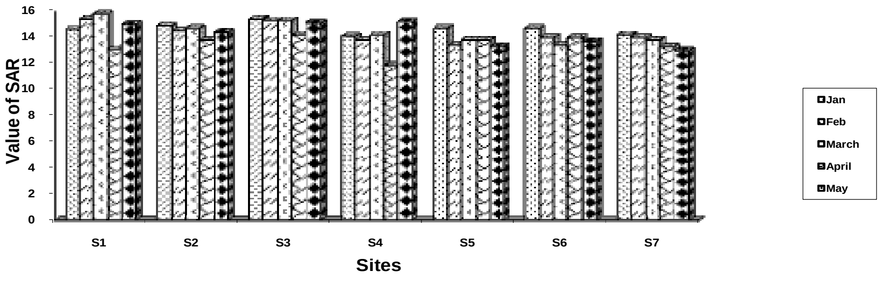

Fig 10: Graphical representation of SAR of the river Yamuna at the different sites

SUMMARY AND CONCLUSION

In this research the results obtained helps us to conclude that the River Yamuna at Allahabad comes under C category of the water quality criteria since almost all the values are within the permissible limit except for DO whose values are found to be slightly higher than the permissible limit which makes it unsuitable for bathing activities.

According to the Hindu Mythology the Yamuna is a holy river in Allahabad city. Therefore proper monitoring is necessary for proper maintenance of its natural quality and beauty as the river becomes more polluted day by day with the increase in population, increase in pollution from various industries, urbanization, industrial effluent, domestic sewage and municipal waste thrown into the river.

The results also shows that the water is suitable for irrigation purpose as the values are found to be within the permissible limit.

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GROUNDWATER QUALITY ASSESSMENT IN DIFFERENT MINING AREA OF JHARIA COALFIELD, JHARKHAND, INDIA

*Prasoon Kumar Singh[1], Dipanwita Bhakat[2] & Mukesh Kumar Mahato[3]
Associate Professor[1], SRF[2] & JRF[3]
Department of Environmental Science and Engineering, Indian School of Mines, Dhanbad
*Prasoon Kumar Singh, Email: prasoon0506@ yahoo.co.in

ABSTRACT

The water bodies are continuously subjected to a dynamic state of change with respect to lithological characteristics and geo-climatic condition. This dynamic balance in the aquatic system is upset by human activities, resulting in pollution. Damaging the quality of groundwater due to dumping of overburden (OB), mining activities, spoils or spreading of OB through rolling and washing may cause the chemical pollution. The Jharia Coal mining area (JCF) is one of the India's oldest well known Coal mining area producing prime coking coal and is actively associated with mining activities. In the present study, detail investigation of water chemistry of dug well & tube well water of Jharia Coal mining area has been carried out to know the major ion chemistry and to assess the suitability of water for drinking purposes.

Representative twenty water samples from ground water (tubewell and dug wells) were collected from different sampling sites including mining, rural and town areas of Lodna, Bastacolla, Sijua, Western Jharia, Block-II, Barora, Digwadih, Dhansar, Alkusa and Tasra mining area of Jharia Coal mining area. Water samples were analyzed for pH, EC, TDS; dissolve silica, anions (Cl, HCO_3, and SO_4) and cations (Na, K, Ca, Mg). The pH of the analysed water samples varies from 6.9 to 8.3, indicating alkaline in nature. Total dissolve solid (TDS) varied from 219 to 1485.5 mg/L and electrical conductivity (EC) varied from 357 to 1600 µs cm-^{1} in ground water samples of the study area. The depth of the open dug well varied from 1.4 to 7 meter during the post- monsoon. The quality assessment shows that in general, the water is suitable for domestic purposes with some exceptions. However, EC, TDS, $NO_{3,}$ Mg, Ca and SO_4 values are exceeding the desirable limits at some site, making it unsafe for drinking.

Key words: Dug Well, Tube Well, Ground water quality, Jharia Coal Mining Area.

1.0 INTRODUCTION:

Water resources are sources of water that are useful or potentially useful to humans. Uses of water include agricultural, industrial, household, recreational and environmental activities; virtually all of these human uses require fresh water. Ground water is fresh water located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. About 75% of the world's surface area is covered with water. Out of which 97% of the earth's water is in the ocean, not fit for human use due to its high salt content. Remaining 2% is locked in polar ice caps and only 1% is available as fresh water in rivers. Groundwater in India is at risk from contamination due to rapid and unplanned urbanization, industrialization and indiscriminate disposal of domestic, industrial, agricultural and mining wastes. Inferior quality of groundwater may cause water-born diseases and crop damages. About 80% of water born diseases in the world and over one-third of the total deaths in the developing countries is caused by consumption of polluted water (Earth Summit 1992). Public ignorance to environmental considerations, lack of provisional basic social services, indiscriminate disposal of increasing anthropogenic wastes on land, into river and unlined drains, unplanned application of agrochemicals and discharges of improperly treated sewage/industrial and mining effluents, resulting in excess accumulation of pollutants on the land surface and contamination of available water resources. Subsurface leaching of contaminants from landfills as well as seepage from canals/rivers and drains cause severe degradation of the groundwater quality in urban and industrial areas. Adsorption/dispersion processes in the soil zone, degrees of evaporation/recharge and lateral inter-mixing of groundwater determine the level of contaminations in groundwater. Hydro geochemical study is useful tool to identify the chemical processes that are responsible for ground water chemistry.

The groundwater quality determination in recent times has gained importance owing to the reason of being affected by various contaminants. In order to obtain an adequate assessment of the groundwater quality of an area, distribution of various chemical constituents and the types of groundwater present are the prerequisites. In Jharia Coal mining area, it has been stated by Ghosh and Ghosh (1991) that over the years, water resource conditions had been affected due to unplanned mining history prior to 1970 and urban sprawl resulting in severe damage to the quality and water table. This has necessitated the need to develop an adequate groundwater resource management plan of the area with specific reference to identification of the processes responsible and their evaluation. The hydro geochemical conditions that is responsible for causing significant variations in groundwater quality.

The area suffers from chronic water shortage. In the shallow zone groundwater occurs in an unconfined condition and is generally abstracted by dug well. The depth to water table generally varies between 6 m to 8 m below the ground surface in the pre-monsoon period and 4 m to 6 m in the post-monsoon period. Near the Coal mining area the depth to water level is usually deep and declines considerably during the pre-monsoon period. The dug well even dry up totally. The depth of the open dug well varied from 1.4 to 7 meter during the post- monsoon.

2.0 MATERIAL AND METHODS

2.1 **Description of the Study area**

Jharia Coal mining areas is one of the most important Coal mining areas in India. It is roughly elliptical or sickles – shaped, located in Dhanbad district of Jharkhand lies between latitude $23^{o}39^{/}$ N and $23^{o}48^{/}$ N and longitudes $86^{o}11^{/}$ E and $86^{o}27^{/}$ E. It stretches from Chandanpura on the west to Sindri on the east. The grand chord Railway line passes along north of this Coal mining area. It is bounded in the North by Eastern Railway and in the south by Damodar River. The main component of the natural drainage in JCF is the Damodar river, a fourth order stream that flows approximately west to east and captures all the surface drainage from the JCF, the drainage pattern of the drainage system in the area is dendritic. There are eight major streams, a few perennials and the rest intermittent, which drains the JCF from north to south to join the Damodar River. They are Tisra, Chatkari, Katri, Khudia, Jamuniya, Kumari and Bansjora etc. The climate in the Jharia Coal mining area is very pleasant during cold weather months starting from November to February. The occasional rain during the hot weather from March to June makes the climate, a little more comfortable for a time during mains. But from June to October the conditions are not on the whole very unpleasant during October to November. The days are warm and the nights are cool. There is relatively higher average rainfall along the northern margin of the field than in the Damodar valley. The general climate may broadly be described as the of the tropical monsoon belt. The temperature range in Jharia Coal mining area varies between 5°Cand 48ºC. In the month of May and June, weather becomes very sultry due to high temperature and increasing humidity. The relative humidity is highest during the month of July to September. The annual rainfall in Jharia and adjacent region varies from 1197 mm to 1382 mm.

This is the most exploited Coal mining area because of available metallurgical grade coal reserves. Mining in this Coal mining area was initially in the hands of private entrepreneurs, who had limited resources and lack of desire for scientific mining. The mining method comprised of both opencast as well as underground. The opencast mining areas were not backfilled, so large void is present in the form of abandoned mining. Extraction of thick seam by caving in past at shallow depth has damaged the ground surface in the form of subsidence and formation of pot holes or cracks reaching upto surface, enhancing the chances of Spontaneous heating of coal seams and mine fire. This Coal mining area is engulfed with about 70 mine fires, spread over an area of 17.32 sq. km., blocking 636 million tonnes of coking coal and 1238 million tonnes of non-coking coal. Around 34.97 sq. km. area of the JCF is under subsidence. It is mentioned in JCF reconstruction program that 70% of the underground production of coal would come by caving and balance 30% by stowing and thus about 101 sq. km. underground mining area would be affected by subsidence. The other factor, which damages the land in JCF, is opencast mining and overburden dumps.

2.2. Sample collection and preservation

For the assessment of Ground water quality of Jharia Coal mining area area, the systematic sampling was carried out as per IS: 3025. Representative 20 (Dug well and tube well) Ground water samples were collected from different mines of Lodna, Bastacolla, Sijua, Western Jharia, Block-II, Barora, Digwadih, Dhansar, Alkusa and Tasra mining area of Jharia Coal mining area. The ground water samples were collected from both open well as well as tube well in one litre narrow-mouth pre-washed polyethylene bottles. Prior to each field work polyethylene bottles were washed in the laboratory with dilute hydrochloric acid and then rinsed twice with double distilled water. At the sampling sites, before collecting the samples bottles were also washed with the mine water. About one litre water samples were collected from each site. Suspended sediments were separated from the water samples in the laboratory by using 0.45µm Millipore membrane filters.

2.3. Analytical methods

Analysis of mine water samples was done as per Standard Methods (APHA, 1985) for water quality parameters. pH and electrical conductivity was measured by using E.C and pH meter while turbidity of the samples was analyzed by using turbidity meter. Sulphate was measured by UV-Visible Spectrophotometric method (SHIMADZU, UV-2550). Chloride and bicarbonate were estimated using titrimetric method. Major cations were determined by Flame Atomic Absorption Spectrophotometer (GBC Avanta).

3.0 RESULTS AND DISCUSSION

3.1 Ground water quality of the Study area

The results of the physico-chemical analysis and descriptions of the sampling sites of Ground water (Dug well, tube well) collected from Jharia Coal mining area areas is given in Table: 1 and Table: 2. respectively. The pH of the ground water samples were found to be ranging from 6.9 to 8.3. The water samples are slightly acidic to alkaline in nature. According to W.H.O low pH is likely to give rise to off taste and to promote corrosion. Limit is 6.5 to 8.5(W.H.O).Electrical conductivity is a measurement of water’s capacity for conveying electric current and is directly related to the concentration of ionized substance in the water. It is the measure of the mineralization and indicative of the salinity of ground water .the electric conductivity with 400 micro-mhos/cm at 25^{o}C is consider suitable for human consumption. The overall conductivity ranges from 399 µS/cm to 1600 µS/cm ground water of study area. The highest value (1600 µS/cm) was recorded in tube well water of Alkusha colliery, while the lowest value (145 µS/cm) was recorded at - Ghanuadih 12 No. The total dissolved solid consists of inorganic substances. The principal constituents of total dissolved solids are calcium, magnesium sodium, bicarbonates, chlorides and sulphates. The palatability of water with a TDS level less than 600 mg/L is generally considered to be good whereas at TDS level greater than 1200 mg/L in drinking water becomes increasingly unpalatable (WHO, 1984).the TDS were varied from 296.7 mg/L to 1485.5 mg/L. The maximum TDS was found to be 1485.5 mg/L in tube well water of Alkusha colliery of Jharia coal mining area which was beyond the desirable limit (500mg/L). Most of ground water samples exceed the Indian drinking water limits.

Fluoride is naturally present in water, it becomes toxic to animal and human being when present at more than 1 mg/L.at level above 1.5 mg/L. molting of teeth and bones has been reported very occasionally, and above 3,0mg/L Skelton flourishes may be observed. The Fluoride content in the study area varies from 0.2 to 2.1mg/L in the ground water.

Chloride is present in all potable water supplies. High concentration of Chloride in water gives an undesirable taste to water. Young children may suffer if they consume water high in chloride as their delicate kidney tissues may be damaged by the higher osmotic pressure brought about by the presence of high concentration of salts. It is therefore, important that the chloride content of water supplies should be kept as low as possible. The chloride content in the study area varies from 11.1 to 220.6 mg/L in the ground water. Chloride content was found maximum in the Barora mining area (near Satabdi colliery tube well water) permissible limits of 250 mg/L as laid by IS: 10,500. (**Fig.1**)

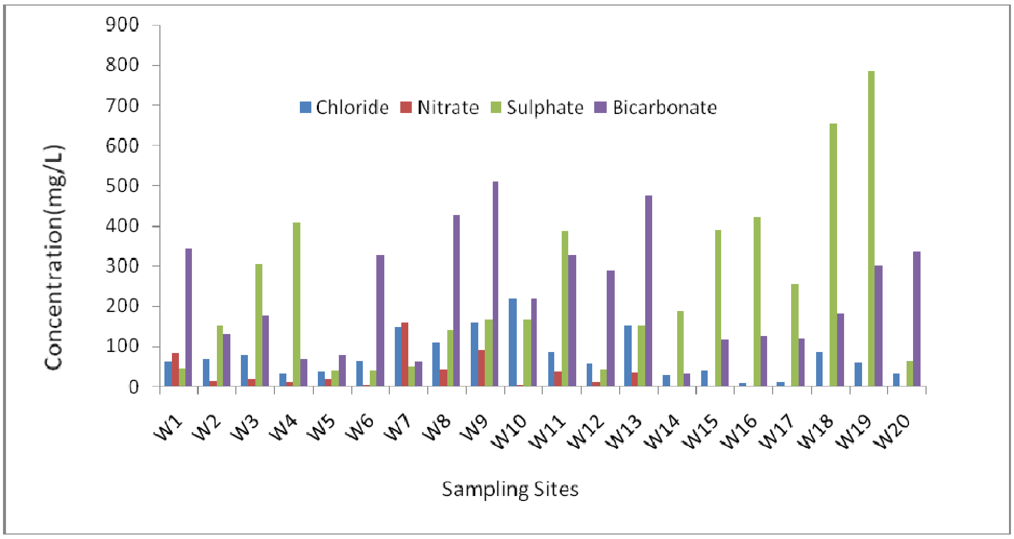

Fig.1 Variation of major anions

Table: 1. Physico chemical parameters of Ground water of Jharia Coal mining areas

Code	pH	EC	TDS	HCO3	F^-	Cl^-	NO_3^-	SO4--	Na	K	Mg	Ca
W1	6.9	923	627	345.2	2.1	62.5	81.0	46.0	25.5	5.4	7.7	51.7
W2	7.1	847	477.5	131.2	0.4	70.4	14.4	154.8	29.4	7.9	10.7	58.3
W3	7.1	614	544.4	177.1	0.6	77.9	18.2	306.3	43.9	10.2	21.8	88.6
W4	6.9	399	279.1	70.1	1.0	33.6	9.6	407.6	21.6	5.3	36.4	93.9
W5	7.2	1314	296.7	77.7	0.2	40.1	18.7	41.3	53.8	14.1	13.5	37.2
W6	7.8	876	594.3	326.1	0.4	64.6	2.7	42.9	57.2	6.6	24.6	69.1
W7	6.9	522	683.1	62.4	0.3	148.9	158.1	50.9	106.6	24.9	24.9	106.1
W8	7.9	1323	727.5	425.4	0.6	110.2	42.7	142.5	96.4	14.7	62.0	128.9

W9	7.5	1221	1193.6	510.7	0.8	159.3	89.4	168.1	100.3	4.5	45.7	114.9
W10	7.2	899	782.1	220.3	0.7	220.6	2.4	167.4	60.5	2.7	40.5	67.0
W11	7.0	1111	1082.1	327.3	1.5	85.3	37.2	388.5	46.6	21.2	73.9	94.1
W12	7.8	753	559	290.0	0.7	56.7	11.1	45.3	42.5	79.4	32.5	0.9
W13	8.0	1466	1145	475.0	0.5	155.3	34.2	154.4	105.7	184.2	34.1	1.8
W14	7.5	499	364.6	33.3	0.2	28.9	0.1	188.5	24.6	66.8	17.6	4.6
W15	7.8	886	745.5	116.7	0.2	40.7	0.2	391.1	43.5	121.0	31.6	2.5
W16	8.1	846	756.6	129.2	0.4	11.1	0.2	423.2	34.2	115.8	38.1	4.4
W17	8.1	697	526.3	120.8	0.4	12.5	0.1	256.9	21.2	81.2	28.9	3.4
W18	8.2	1495	1273.8	183.3	0.5	86.1	0.1	655.3	105.7	185.2	53.0	4.6
W19	8.3	1600	1485.5	300.0	0.5	59.4	0.3	785.9	56.7	197.0	79.1	6.6
W20	8.3	655	591	337.5	0.8	33.0	1.2	64.2	25.9	107.6	19.7	1.2

All the parameters are in mg/L unless and until specified. Except pH, conductivity

Table:2. Descriptions of the sampling sites of Ground water

Code	Site Descriptions	Water Type	Code	Site Descriptions	Water Type
W1	South Tisra	T/W	W11	Near Barora	D/W
W2	Ghanuadih 4 No.	D/W	W12	Near CFRI Campus	T/W
W3	Chandmari Chanak(Bastacola Colliery)	D/W	W13	Digwadih	T/W
W4	Ghanuadih -12 No.	D/W	W14	Dhansar Colliery	D/W
W5	Telha Pandedih,Tetulmari	D/W	W15	Bastacolla	D/W
W6	Loyabad More near Electric tower	T/W	W16	Dhobani Colliery	T/W
W7	Pandedih , Tetulmari, Near pond	T/W	W17	Ghanuadih 4 no	D/W
W8	Near Shiva temple ,Moonidih Colliery	D/W	W18	Bera Colliery	D/W
W9	Block II Area Near Shiv Mandir	T/W	W19	Alkusha Colliery	T/W
W10	Barora Near Satabdi Opencast project	T/W	W20	Kandra Colliery	T/W

Note: *T/W:- Tube well , D/W:- Dug well*

Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural water. Nitrate poisoning in infant animals including human, can cause serious problems and even death. Nitrate poisoning has been referred to as the ‘blue baby’ syndrome, although the correct term is ‘Methenoglobinemia’. The Nitrate content in the Mine water samples varied from 0.1 to 158.1mg/L. The Highest desirable level of Nitrate in drinking water is 45 ppm as per IS:10500. The high value of Nitrate is due to the use of Explosives of ammonium Nitrate base and use of Fertilizer in agriculture. High concentration of sulphate in association with Sodium or magnesium in the drinking water might give rise to gastrointestinal irritation. According to the IS:10500 the desirable limit is 200 mg/L. The sulphate in the water samples ranged from 41.3 to 785.9 mg/L.Half of the samples falls well within the permissible. According the WHO limit is 400 mg/L. low concentration is physiologically harmless. The overall concentration of sulphate in th study area is within the safe limit. The bicarbonate concentration of the study area was 33.3- 510.7 mg/L. The maximum bicarbonate concentration was found in block II area (near Shiv mandir) tube well water. The ground water containing 600 mg/L of bicarbonate is considered fairly safe and good domestic purpose.

The sodium concentration in the water samples was found between 21.2 to 106.6 mg/L. The desirable limit for sodium is given as 200 mg/L according to WHO (1984) guidelines. Potassium is less common cation in the ground water. The range of the potassium in the water samples was 2.7 to 197 mg/L. After calcium, magnesium is the most important alkaline earth metal present in the ground water Calcium is one of the principle cation in ground water .the calcium is most abundant element in human body, which required 0.7 to 2.0 gm/ day., It also helps in the formation of bones and teeth. The Highest desirable level of calcium in drinking water is 75 ppm and maximum permissible level is 200 ppm (W.H.O. 1984). The calcium content in under groundwater varied from 1Calcium is one of the principal cation in ground water. The highest desirable limit for calcium is 75 mg/L and maximum permissible level is to 200 mg/L. The range of calcium ions was 0.9 to 128.9 mg/L in ground L.The maximum Calcium was found to be 128.9mg/L in tube well water of Moonidih colliery of Jharia coal mining area which was beyond the desirable limit, Though calcium is an important mineral constituent of the human body and an adequate intake is essential for normal growth and health. Excessive concentration tends to cause some adverse effects. It has a tendency to control the toxicity effect of potassium and sodium. After calcium, magnesium is the most important alkaline earth metal present in ground water .it is the one of the most important contributor to the hardness of water. The lower concentration of magnesium is not harmful but higher concentration is laxative. According to W.H.O (1984) and the maximum acceptable limit of magnesium in drinking water is 30 mg/L. The magnesium ranged from 7.7 mg/L to 79.1 mg/L in the water samples of the study area.(**Fig.2**)

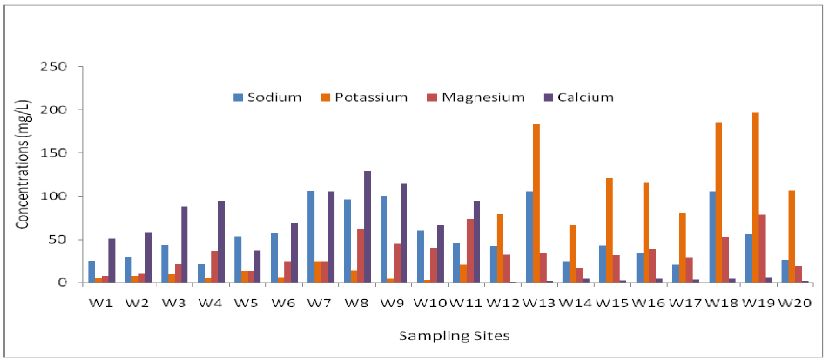

Fig.2 Variation of major caions

ACKNOWLEDGEMENT

Thanks are due to Head of the Department of Environmental Science and Engineering, Indian school of Mines, Dhanbad for providing the laboratory facilities necessary for the study.

4.0 CONCLUSIONS

The ground water evaluated in terms of major ion chemistry, spatial variation in concentration of dissolved ions, sources of different elements and the possibility and suitability of the ground water of the area for domestic uses. For drinking water assessment, the ground water quality data was compared with the prescribed limits of WHO and Indian Standard for drinking water (IS-10500). Representative twenty water samples from ground water (tubewell and dug wells) were collected from different sampling sites including mining, rural and town areas of Lodna, Bastacolla, Sijua, Western Jharia, Block-II, Barora, Digwadih, Dhansar, Alkusa and Tasra mining area of Jharia Coal mining area. Water samples were analyzed for pH, EC, TDS; dissolve silica, anions (Cl, HCO_3, and SO_4) and cations (Na, K, Ca, Mg). The pH of the analysed water samples varies from 6.9 to 8.3, indicating alkaline in nature. Total dissolve solid (TDS) varied from 219 to 1485.5 mg/L and electrical conductivity (EC) varied from 357 to 1600 µs cm-^{1} in ground water samples of the study area. The depth of the open dug well varied from 1.4 to 7 meter during the post- monsoon. The quality assessment shows that in general, the water is suitable for domestic purposes with some exceptions. However, EC, TDS, NO_3, Mg, Ca and SO_4 values are exceeding the desirable limits at some site, making it unsafe for drinking.

5.0 REFERENCES:

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ENVIRONMENTAL IMPACT STUDIES OF COAL MINING ON DIFFERENT WATER RESOURCES

Avantika Chandra * and M. K. Jain **
* JRF and ** Associate Professor
Department of Environmental Science & Engineering
Indian School of Mines, Dhanbad – 826 044, Jharkhand, India.
e-mail: avantika4jan@gmail.com

ABSTRACT

Water contamination from heavy metals released from mining activities is a worldwide environmental problem. This study aimed to evaluate the rehabilitation and mining potential of waste from dumpsite in Jharia coal field area. The influence of heavy metal contamination were explored by conducting sequential extraction analysis and toxic characteristic leaching potential test (TCLP) on waste samples collected from dumpsite. The quality of leachate, ground water and surface water resources in the surrounding area of dumpsite were evaluated. pH level, turbidity of the water was appropriate as per norm. BOD and COD were slightly higher observed in surface water. High levels of suspended and dissolved solids were found both in surface and ground water. Hardness value of ground water is more than that of surface water. Oil and grease was found to be much below the general standards for discharge of environmental pollutants.

Key Words: Coal Mine, Environmental Impact, Leachate, ground water, surface water.

INTRODUCTION

Coal mining is one of the core industries that contribute to the economic development of a country but deteriorate the environment. Being the primary source of energy coal has become essential to meet the energy demand of a country. It is excavated by both opencast and underground mining methods and affects the environment, especially water resources, by discharging huge amounts of mine water. The mine water may be acidic or neutral depending upon the pyrite content in the coal as inorganic impurities. It degrades the water quality of the region in terms of lowering the pH of the surrounding water resources and increasing the level of total suspended solids, total dissolved solids and some heavy metals. In non acidic mines, water quality shows high hardness, TSS and bacterial contaminants (Peplow and Edmonds, 2005).

Mining waste is the high-volume material that originates from the processes of excavation, dressing and further physical and chemical processing of wide range of metalliferous and non-metalliferous minerals by opencast and deep shaft methods. It comprises overburden, run-of-mine rock as well as discard, slurry and tailings from the preparation/beneficiation or extraction plants assessment of heavy metals contamination in soils using data on the total content of the individual heavy metals (Dybowska et al, 2006).

Leachate is a combination of infiltrated precipitation and any liquids squeezed from the waste as it naturally compacts. Leachate is a potentially major source of pollution. Leachate is a widely used term in the Environmental sciences where it has the specific meaning of a liquid that has dissolved or entrained environmentally harmful substances which may then enter the environment. Water entering a surface or underground mine is referred to as mine water. Sources of this water are groundwater seepage, surface water inflow, or direct precipitation. In the absence of a natural or manmade drainage, active mine operations below the water table must pump out mine water to access the ore body. Depending on the hydrogeology of the mine this can be accomplished as simply pumping the water from the mine to grouting the rock in the mine to prevent inflow to using a series of extraction wells around the mine (Ngoc et al., 2009).

Water from abandoned mines may contain significant concentrations of heavy metals and total dissolved solids and may have elevated temperatures and altered pH, depending on the nature of the ore body and local geochemical conditions. These waters may become acidic over time when exposed to oxygen and, if present, pyrites or other sulfide minerals. The acidic water may also solubilize metals contained in the mine and mined materials, creating high concentrations of metals in solution. These acidic metal-laden waters may contaminate down-gradient ground-water and surface water resources. Neutral and alkaline mine waters may also contain metals in excess of water quality standards and be of significant concern to human health and the environment (Groudev et al., 2008).

The most significant impact of a mining project is its effects on water quality and availability of water resources within the project area. Key questions are whether surface and ground water supplies will remain fit for human consumption, and whether the quality of surface waters in the project area will remain adequate to support native aquatic life and terrestrial wildlife (Chernaik, 2010).

METHODOLOGY

Sample Collection

Ground water and surface water

Ground water samples were collected from different locations, near the mine waste site and away from the mine waste site. The Surface water samples in dumpsite were randomly collected in ponds and canals nearby the mine waste site and away from the mine waste site, for the comparative study of the water quality.

Analysis of Physicochemical and Biological Characteristics:

Various physico- chemical and biological parameters were evaluated to assess the water sample such as Color, pH, Turbidity, Electrical conductivity, TSS, TDS, Total Hardness, Calcium Hardness, Magnesium Hardness, Heavy metals, COD, Microbial analysis (APHA, AWWA, WPCF, 1998).

RESULTS AND DISCUSSION

The result obtained from the analysis of the water was that the pH level of the water was appropriate as per norms, varies between 6.25 to 8.10. BOD and COD range from 12-49 and 45-143 respectively. Hence BOD value was found to be above the general standards for discharge of environmental pollutants, but COD value was within the limit. High levels of suspended and dissolved solids were found both in surface and ground water range from 83-456 and 267-794 respectively. These high level of solids results into increase level of turbidity particularly in the case of surface water. Turbidity was found to be within the limit in ground water but beyond the limit in surface water. Turbidity in surface water is basically caused by suspended and colloidal matter such as clay, silts, finely divided organic and inorganic matter, plankton and other microscopic organisms.

Hardness was found to be beyond the limit except for one surface water (SW_3) sampling point. The level of hardness is related to the amount of dissolved mineral particularly calcium and magnesium in the water. These minerals may occur in ground water passing through limestone rocks, or other rocks with a calcium mineral content. As a result hardness value of ground water is more than that of surface water, which was also found in our study area. Hard water does not pose a health risk but it can cause "scale" (mineral build up in pipes and plumbing fixtures) and reduce the effectiveness of soap for bathing and laundry. Hardness at a moderate level of 50 to 120 mg/l may be beneficial because water could become acidic at low hardness levels, which may cause plumbing corrosion or leaching of lead from soldered plumbing joints. Oil and grease was found to be much below the general standards for discharge of environmental pollutants. Little amount of oil and grease at different location is due to the spillage of oil and other toxic reagents from mining machineries and vehicles used mining operation (Table - 1).

Table-1: Physico-chemical parameters of water samples.

Parameters	**SW1**	**SW2**	**SW3**	**SW4**	**GW1**	**GW2**	**GW3**	**GW4**
pH	6.50	7.34	7.39	8.10	6.25	7.34	6.60	6.95
Temperature(^{O}C)	23	27	25	27	18	21	19	22
Conductivity(ms)	0.792	0.911	0.839	0.676	0.729	0.656	0.689	0.736
Turbidity (mg/L)	10.81	37.54	23.06	10.65	2.11	8.03	2.73	2.18
TDS (mg/L)	653	703	512	794	467	247	401	371
TSS (mg/L)	345	456	279	301	112	98	117	83
TS (mg/L)	998	1159	791	1095	580	345	518	454
Dissolved Oxygen (mg/L)	6.9	3.7	4.0	6.6	8.5	7.6	8.0	7.3
BOD (mg/L)	28	36	49	43	12	23	18	19
COD (mg/L)	73	143	117	109	45	67	67	71
Total Hardness (mg/L)	382	398	267	371	428	389	377	402
Ca Hardness (mg/L)	137	89	119	149	191	165	138	175
Mg Hardness (mg/L)	245	313	148	222	237	224	239	227
Oil & Grease (mg/L)	0.05	0.10	0.05	1.14	--	--	--	--

Water contamination from heavy metals released from mining activities is a worldwide environmental problem. Heavy metals and other contaminants might release from mining sites, especially from waste dumps or tailing ponds (Alligui and Boutaleb, 2010; Liang-qi *et al*., 2010). So, the monitoring wells should be established around the nearby areas in order to monitor the groundwater pollutions. However, such monitoring is quite expensive and time consuming. Various mathematical simulation models have been developed for the assessment of groundwater vulnerability to groundwater contamination, water resources management and design of monitoring well systems. Contamination of the underlying aquifer beneath a mining area is usually of great concern even when a prevention plan has been implemented. To assess the potential risk of heavy metal contamination, a study will be carried out with special reference to leachate contaminates (Chotpantarat and Chakkaphan, 2011).

CONCLUSION

Mine waste management is one of the major environmental problems worldwide. Improper management of mine waste causes hazards to inhabitants. Various studies reveal that about 90% of mine waste is disposed of unscientifically in open dumps. The open dumping results to leachate contamination of surface water and groundwater resources, creating problems to public health and the environment. Mine waste can raise toxic environmental effects, slow leaching of these heavy metals during the degradation process leads to leachates with high contamination. Since leachates are one of the potential sources of soil, surface and ground water pollution.

The analysis of the water is of great concern because of its high potential toxicity to the various biological forms. The leachate contamination can cause ecological toxic effect in the surrounding area. A variety of toxicants in the leachate such as organic matter, heavy metals and nitrogen influences the toxicity level. Determination of the contribution of heavy metals to the leachate toxicity level is necessary in understanding the environmental toxic impact of heavy metal leaching from the dumpsite. Also, it is important to investigate the toxic pollutant in the leachate needed for treatment to reduce the toxicity.

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IMPACT OF OPENCAST MINING ON SURFACE WATER QUALITY IN JHARIA COALFIELD: A CASE STUDY

Sweta Sinha*, M. Ahmad**
*Junior Research Scholar, ISM, Dhanbad.
** Sr. Scientist, Central Institute of Mining & Fuel Research, Barwa Road, Dhanbad 826 015.

ABSTRACT

India has largest reserve of coal in the world, and it will continue to be a key factor for India’s energy requirement for decades to come. Hence, coal is the primary source of energy in our country. To extract coal, there are broadly two methods i.e. Underground mining and Opencast mining. Due to high risk of human life and safety in Underground mining, now a day’s Opencast mining method is mostly preferred.

The impact of Opencast mining on surface water quality is directly from the land disturbance of the surrounding area. The water quality of Jharia coalfield becoming polluted mainly by addition of toxic substances like heavy metals, coal dust sediments and discharge of effluents including acid mine water. These pollutants cause a serious threat to environment quality and reduce the potential of water for immediate and subsequent beneficial use.

Under this background, the study was performed to know the existing surface water quality of Jamadoba colliery at Jharia coalfield area, which is a captive mine of Tata Steel Plant. The study was conducted in year 2008 . Sampling was done at three sampling stations in the experimental site. All the samples were analyzed in the laboratory and compared with the standards as prescribed by IS: 10500 through APHA methods.

The present paper aims to highlight the physico-chemical characters of the surface water quality in and around the Jamadoba colliery, to access the drinking and surface water quality degradation in and around the mining area.

Key words: *Opencast mining, Surface water quality, Heavy metals, Acid mine water, Effluents, Water pollution.*

INTRODUCTION:

Coal mining is a major industry in India, which is contributing inadvertently towards the pollution of environment mainly water environment. However at the same time, it also assures the energy supply that is indispensable for the development of our country. During the process of coal mining huge volume of water with various chemicals is being discharged on the surface as a waste, thus polluting the significant impact on the quality as well as quantity of water. As a result of opencast mining, the recharge area in the core zone is increased and chances of contamination of surface & ground water increases with time due to expansion of mine dimension. During opencast Coal mining, large volume of coal associated rocks is being dumped in de-coaled area. Not only this, wind blown dust from these dumps also degrades the quality of water. There is continuous seepage of water through aquifers and along bedding plans. Due to seepage from faces, lowering of ground water table in buffer zone is reported. Which causes drying up and depletion of water yield in wells & tube wells. (Anderson, 1984 Bear, 1972). Water contamination is generally irreversible so, it becomes necessary to regular monitor the level of pollution in water source and examines their toxic effects on health. The present study aims to monitor the physico-chemical characters of the surface water quality in Jamadoba colliery.

STUDY AREA:

Kalimela Block is located in leasehold area of Jamadoba Colliery of TATA STEEL at a distance of about 14 Km from Dhanbad. The area falls in the Survey of India toposheet No. 72 I/6 and is bounded by latitude 24^0 31’ 30”N to $24^0$32’ 30”N and longitude 87^0 25’ E to 87^0 30’E.

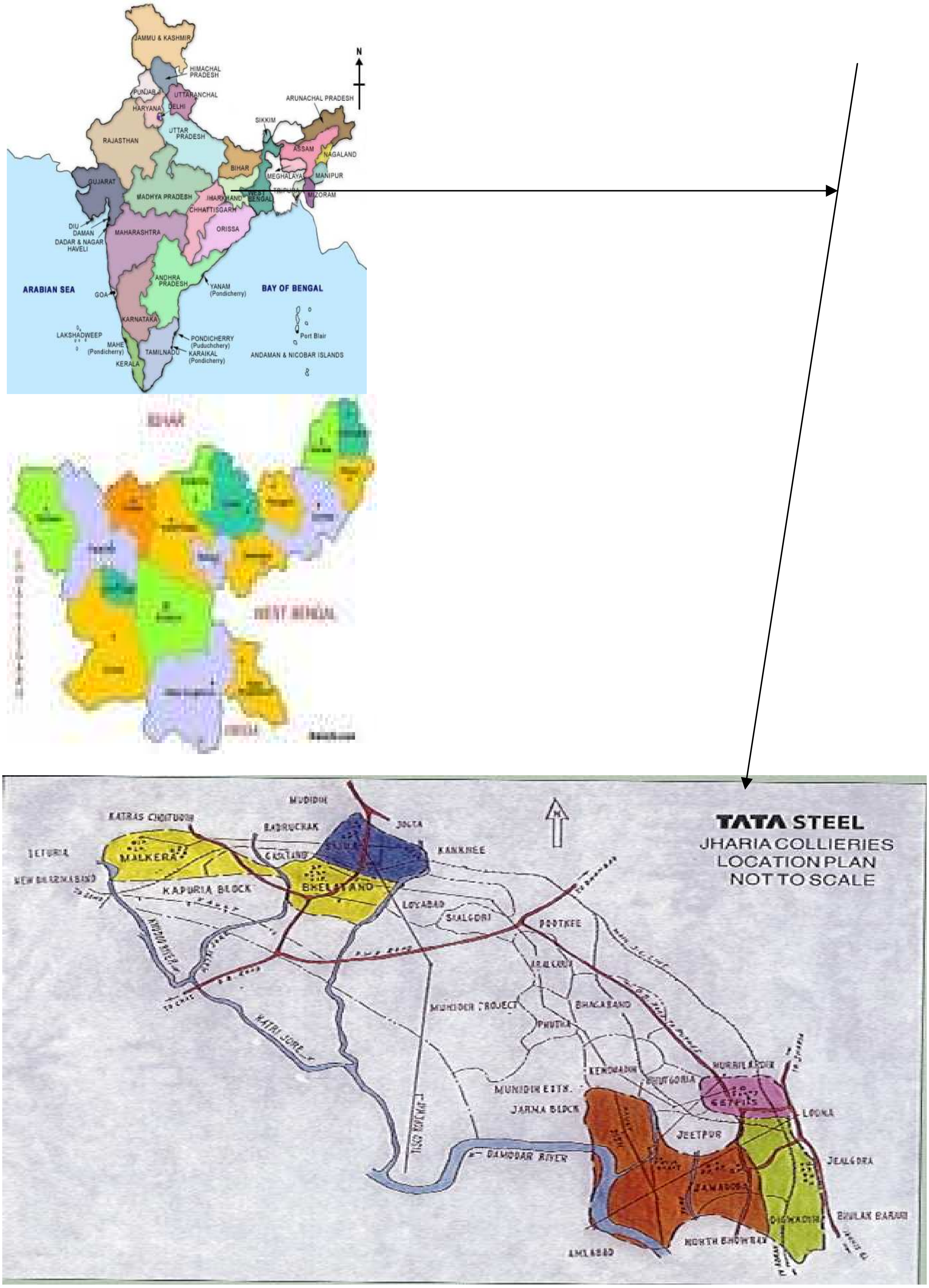


Fig.1. Location map of the study area

Geology

The Jharia coalfield in the Dhanbad district of Jharkhand, is the most important and the most productive coalfield of the India and is situated in the heart of the Damodar valley, mainly along the north of the river. The chief center is Jharia in the eastern part of the field, after which the coalfield is named.

The field is roughly elliptical of sickle shaped, its longer axis running North-west – South-east, covering an area of over 450 sq. km. and extending for a maximum of about 38 km. East-West, and 19 km. North-south.

The surface topography is generally flat or gently undulating. However, to the east and to the west, the gradients are steep in the vicinity of Dungri jore & Damodar river. Damodar river flowing north to south along the western boundary of the proposed dump area while Dungri jore is flowing from north to south along the boundary of project area.

The oldest rocks are exposed along the northern margin and younger formations outcrop as we proceed towards south. The field is surrounded on all sides by Archaean rocks and along its southern margin runs a great boundary fault having a throw of over 1525 m and partly running along the Damodar river.

Climate

The study area experiences a typical dry tropical climate with hot summer (40° C) and cold winters (10° C). The annual rainfall, which is mostly confined to monsoon months, is around 860 mm.

Hydrology and major soil type in the area

Kalimela is a small triangular area with gently undulating surface, located in the SW part of Jamadoba Colliery bounded between Dungri Jore to the East and Eastern bank of Damodar River to the West. Dungri Jore also forms the lease boundary between Jamadoba colliery of Tata Steel North Bhowrah Colliery of BCCL. Dungri Jore is a perennial nallah, which joins Damodar river in the southern tip of this block at forms measure drainage channel of the area. The low-lying area of the undulating topography is covered with alluvial soil containing sands. gravel, silt etc. which gets recharged in monsoon and partly from streams.

METHODOLOGY

The water analysis was carried out for three sampling stations from core and buffer zone. Mining lease area was considered as core zone and ten kilometers from the center of the mining lease area was considered as the buffer zone area. Water samples collected in the water bottles at the interval of 15 days for three months, during summer, monsoon and winter season respectively. The samples were brought to the laboratory and analyzed.

Three water sampling stations in Kalimela area have been idenfied for three seasons i.e, Summer, monsoon and winter. The parameters monitored were pH, TSS, TDS, BO, BOD, COD, Sulphates and Iron as per the IS :10500 standard methods.

Table 1: Water Quality monitoring Stations for the Study Area

Sl. No.	**Location Code**	**Location Name**
Surface Water		
1.	**W1**	Damodar River Jamadoba U/S
2.	**W2**	Damodar River Jamadoba D/S
3.	**W3**	Dungri Jore

RESULT AND DISCUSSION

Surface water quality of the study area

Table 2: Surface Water Quality of the Area (Summer 2008)

Sl. No.	Parameters	Station Code		
		W1	W2	W3
	pH	7.2	6.8	7.1
	Colour	Colourless	Colourless	Colourless
	Total Dissolved Solids	173	175	174
	Total Suspended Solids	149	198	200
	Dissolved Oxygen	6.0	6.9	7.0
	BOD (5 days at $20^{o}C$)	1.3	3.1	1.2
	COD	22.0	41.4	25.0
	Sulphate (as SO_4^{--})	12.8	12.7	11.8
	Iron (as Fe)	0.06	0.04	0.05

Note: All parameters are expressed in mg/l except pH and Colour.
As per classification of inland surface water (CPCB Standard)

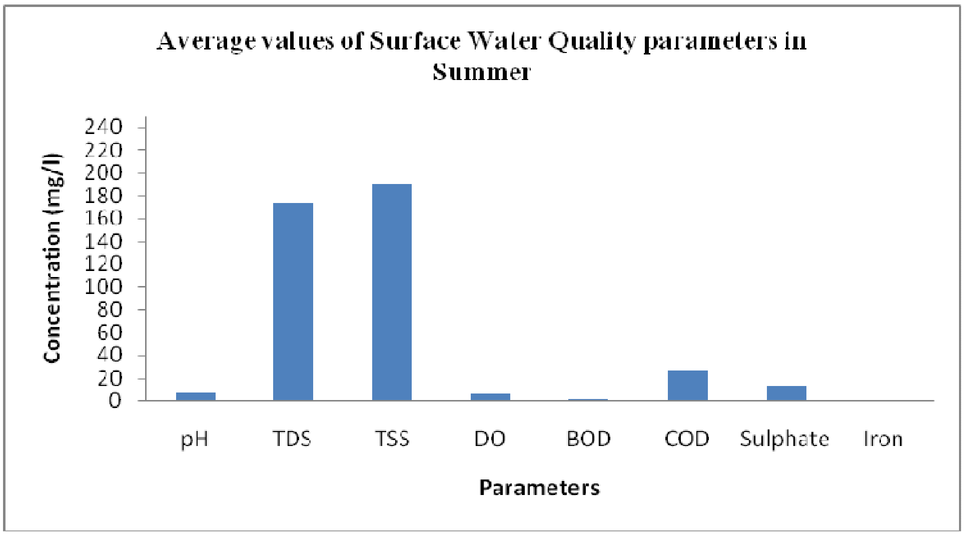


Table 3 : Surface Water Quality of the Area (Monsoon 2008)

Sl. No.	Parameters	Station Code		
		W1	W2	W3
	pH	6.9	6.1	6.7
	Colour	Colourless	Colourless	Colourless
	Total Dissolved Solids	172	169	149
	Total Suspended Solids	188	215	312
	Dissolved Oxygen	6.8	6.9	7.4
	BOD (5 days at $20^{o}C$)	3.6	3.0	2.9
	COD	20.9	45.3	22.5
	Sulphate (as SO_4^{--})	11.9	11.0	12.6
	Iron (as Fe)	0.03	0.06	0.04

Note : All parameters are expressed in mg/l except pH and Colour.
As per classification of inland surface water (CPCB Standard)

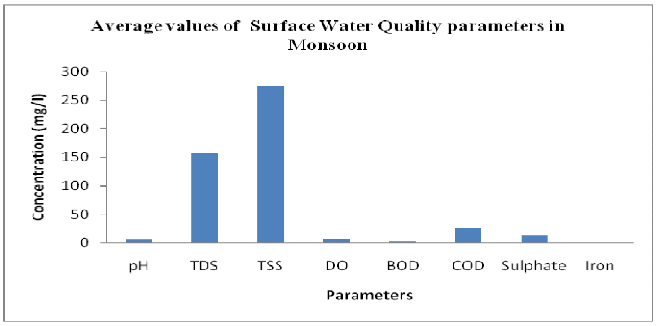
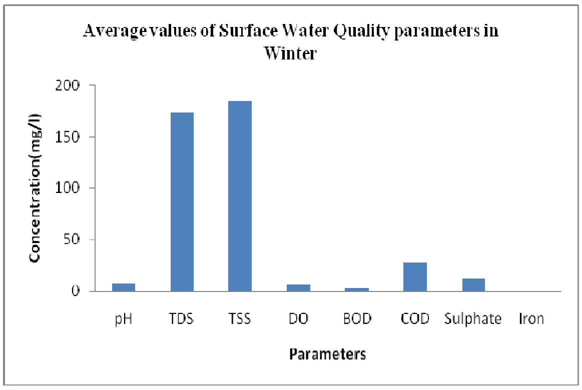


Table 4 : Surface Water Quality of the Area (Winter 2008)

Sl. No.	Parameters	Station Code		
		W1	W2	W3
	pH	6.8	7.1	7.1
	Colour	Colourless	Colourless	Colourless
	Total Dissolved Solids	172	175	174
	Total Suspended Solids	170	149	198
	Dissolved Oxygen	6.6	6.8	6.2
	BOD (5 days at 20°C)	3.2	2.1	2.2
	COD	22.1	39.2	26.2
	Sulphate (as SO_4^{--})	12.36	11.8	12.12
	Iron (as Fe)	0.03	0.04	0.05

Note: All parameters are expressed in mg/l except pH and Colour. As per classification of inland surface water (CPCB Standard) BDL: Below Detection Limit.



The effect of physico-chemical properties in surface water during **summer season** is summarized in table 2.The pH of investigated site varies from 6.8 to 7.2. The TDS value of surface water is maximum in Damodar river downstream area 175 mg/l followed by Dungri jore 174 mg/l and lowest in Damodar river upstream part. TSS ranged between 200 mg/l to 149 mg/l with total average of 170.66 mg/l. Dissolved oxygen concentration of surface water is maximum at Dungri jore followed by damodar river downstream and lowest in Damodar river upstream. BOD of the surface waterin study site ranges from 3.1 mg/l to 1.2 mg/l. COD of the area was an average of 29.53 mg/l. Sulphates concentration ranges12.8 to 11.8 mg/l and Iron was observed 0.04 to 0.06 mg/l.

In **monsoon season**, pH value varies from 6.9 to 6.1. The TDS value of surface water is maximum in Damodar river Upstream area 172 mg/l followed by its downstream169 mg/l and lowest in Dungri jore 149 mg/l. TSS ranged between 312 mg/l to 188 mg/l with total average of 238.3 mg/l. Dissolved oxygen concentration of surface water is maximum at Dungri jore 7.4 mg/l followed by Damodar river downstream and lowest in Damodar river upstream area 6.8 mg/l. BOD of the surface water in study site ranges from 3.6 mg/l to 2.9 mg/l. COD of the area was an average of 29.5 mg/l. Sulphates concentration ranges 12.6 mg/l to 11.0 mg/l and Iron was observed 0.06 to 0.03 mg/l.

In **winter season,** the pH concentration varies from 6.8 to 7.1. The TDS value of surface water is maximum in Damodar river downstream area 175 mg/l followed by Dungri jore 174 mg/l and lowest in Damodar river upstream part. TSS ranged between 198 mg/l to 149 mg/l with total average of 170.66 mg/l. Dissolved oxygen concentration of surface water is maximum at Damodar river downstream followed by damodar river upstream and lowest in Dungri jore. BOD of the surface water in study site ranges from 3.2 mg/l to 2.1 mg/l. COD of the area was an average of 29.1 mg/l. Sulphates concentration ranges 12.36 to 11.8 mg/l and Iron was observed 0.05 to 0.03 mg/l.

CONCLUSIONS AND RECOMMENDATION

The monitoring of the health of water environment of the study area requires a long term commitment, a dense network of monitoring sites and well functioning laboratory facilities. Human needs degrades the natural system by their very much interference. The present study represents an in-depth investigation of the current status of surface water environment of Jharia coalfield region. The findings of this study have resulted in environmental degradation of water environment.

The Coal industry and its surroundings are growing fast due to rapid urbanization and industrialization in last four decades. However if proper environmental management is not followed, then the situation may degrade further.

The surface water in the Jharia coalfield area was found to various mining related activities as well as industrial activities. Some water quality parameters are approaching towards the permissible limits because of leaching, percolating and other such phenomenon. There are various measures which can be made to control the water pollution, however the following measures are important depending on the metrological and topographical consideration of the area under study.

Industrial and mine water should be treated before it is released to the water bodies. Proper water management planning should be implemented before using the surface water.

From the above studies and field observation, it can be commented that by adopting proper technology, the resource can be identified and tapped to meet the growing water demands in buffer zone areas as well as for mining purpose. Near to the mining areas water system is prone to disturbance and in such areas the water can be tapped from deeper zones by means of deep tube wells for drinking and proper rain water harvesting methods as well as utilizing the pumped & treated mine water for any domestic or irrigation purpose. With good amount of rainfall and large amount of cracks and fissured etc, large amount of precipitation is contributing to the recharge of groundwater resources.

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IMPACT OF INDUSTRIES ON GROUNDWATER HARDNESS: A REVIEW

Sanjay Kumar Yadav*, Manisha Rani* and Anshumali**
* M.Tech Student, ** Assistant Professor
Department of Environmental Science & Engineering
Indian School of Mines, Dhanbad - 826 004, Jharkhand,
E-mail:ismsanjay@gmail.com,

ABSTRACT:

Groundwater is generally presumed to be good for human consumption and is used as a potential source of drinking water. There is a growing realization of the importance of protecting groundwater for its beneficial uses such as drinking, irrigation and industrial supply. Agricultural development, urbanization and industrialization are the major causes for all changes in the quality of water. Hardness is an important water quality parameter especially when water is used for drinking purpose. Hardness of water is attributed to the presence of alkaline earth cations like calcium, magnesium, strontium and barium. In a developing country such as India, there is immense demand for advancement in various facets of living and economic development, this has led to increase in industries resulting in an increased quantity of discharge and a wide range of pollutants reaching underground water bodies.

***Key words**: Water, Quality, Industrial Cities, Hardness.*

OBJECTIVE:

The objective of this review is to analyze the status of underground water hardness due to different industries in various cities of India.

INTRODUCTION:

Water is nature’s most wonderful, abundant and useful compound and it is the basis of all lives-ecological resources for the flora and fauna of our earth and a fundamental necessity for all lives. Without a properly functioning water supply, it is difficult to imagine productive human activity, be it agriculture or forestry, livestock, farming, trade or industry (Tatawat and Singh 2007). Factors such as low capital cost, required for the development of groundwater resources, convenient availability “close” to where water is needed and its natural quality are influencing many developed and developing nations, in changing to sub-surface source of water, for both domestic and industrial purposes. Though it is important to know the quantity of groundwater available, it is also necessary to determine its quality status as it is an indicator of its suitability for various purposes. Variation of groundwater quality in any area is a function of physicochemical quality parameters which are greatly influenced by geological formations and anthropogenic activities of the area. Major anthropogenic sources of pollution in groundwater include leachate from municipal refuse dumpsite, industrial discharge, domestic waste, salt water intrusion, application of agricultural chemicals (Abdulrafiu et al., 2011) whereas natural sources includes geological formations. In general, groundwater contains mineral ions which get dissolved from soil particles, sediments, and rocks as the water travels along mineral surfaces in the pores or fractures of the unsaturated zone and the aquifer which are also referred as dissolved solids (Davis et al., 2003). Many studies have been carried out in this regard by considering the impact of various possible pollution sources on the quality of groundwater.

Groundwater hardness based on the presence of different chemical constituent can be classified into two major categories **i.** Water with temporary hardness **ii.** Water with permanent hardness (Ryzner, 1994). It is found that water belonging to temporary hardness occupies a major part and there is a gradual change of hardness from temporary to permanent, depending on the time of residence of groundwater in the subsurface. Hardness in groundwater can be attributed to the presence of alkaline earth metals (Calcium, Magnesium, Strontium and Barium) and Anion (Bicarbonate, Carbonate, Sulphate, Nitrate, Chloride and Fluoride) which is shown in table 1.

Table1. Primary and secondary constituents in natural ground water which cause the hardness. (Source: waterquality.ucanr.org)

Types of ions	Primary Constituents (1.0 – 1,000 mg/l)	Secondary constituents (0.01 – 10 mg/l)
Cation	Sodium	Potassium
	Calcium	Iron
	Magnesium	Strontium
Anion	Bicarbonate	Carbonate
	Sulphate	Nitrate
	Chloride	Fluoride

REVIEW OF LITERATURE:

Various workers in our country have carried out extensive studies on Water Quality. Jayashree et al. (2011) have studied water quality of different rivers. Shriniwas et al. (2007) and Jha et al. (2008) studied water quality in Hyderabad and Bihar, respectively. Patnaik et al. (2010) reported water pollution in industrial area. Studies of industrial wastewater and ground water and pollution problem in groundwater have also been studied in laboratory recently. Tatawat and Singh (2007) have made scientific investigations is to determine the hydrochemistry of the ground water and to classify the water in order to evaluate the water suitability for drinking, domestic and irrigation uses and its suitability for municipal, agricultural and industrial use. Total Hardness Standards for drinking water quality as per different organization found as BIS: 1999 (600 mg/l), ICMR: 1975 (600mg/l), WHO: 2003 (500mg/l).

Data for this review paper was obtained from several previous work done and literatures available on this issue for various industrial and urban areas in India. The results obtained were evaluated in accordance with the norms prescribed under ‘Indian Standard Drinking Water Specification IS 10500 (1991)’ of Bureau of Indian Standards (1991). Information on water quality and supply within Indian cities was obtained at the Ministry of Agriculture and water resources. This review paper shows water quality status (Groundwater Hardness) of the major industrial Indian cities. The industries that induce the pollutants into the groundwater resources from their activities do not strictly regulate their pollutants to safe limits. Most of the industries discharge their effluents without proper treatment into nearby open pits or pass them through unlined channels, which move towards the low lying depressions on land, resulting in the contamination of groundwater (Purandara and Varadarajan 2003). The industrial effluents if not treated and properly controlled, can pollute and cause serious damage to the groundwater resources (Olayinka 2004). A case study of Peenya industrial area Bangalore where good number of industries of different types have been established, which has been loading the environment with ever increasing levels of pollutants. The Department of Mines and Geology carried out investigations to evaluate the groundwater quality in Bangalore Metropolis and based on the analysis, (Shivashankar and Bhaskar 1998). Recently, the Central Groundwater Board carried out studies on industrial pollution in Bangalore city covering major industrial belts of an area of 80 km2 and reported that the groundwater was slightly alkaline in nature and dominated by calcium and magnesium as cations and Chloride and Nitrate as anions (Shankar et al. 2008).

ENVIRONMENTAL HEALTH CONCERNS:

Hard water is mainly an aesthetic concern because of the unpleasant taste that a high concentration of calcium and other ions give to water. It also reduces the ability of soap to produce lather, and causes scale formation in pipes and on plumbing fixtures. Soft water can cause pipe corrosion and may increase the solubility of heavy metals such as copper, zinc, lead and cadmium in water. In some agricultural areas where lime and fertilizers are applied to the land, excessive hardness may indicate the presence of other chemicals such as nitrate. (www.hc-sc.gc.ca)

Table 2: Selected the study area like industrial, agricultural and urban from different part of India showing total hardness.

SN	Types of Location	Range of TH $CaCO_3$ ppm	Sources from research paper
1	Jaipur city	40-845	Tatawat and Singh (2007)
2	Bichhwal Industrial Area Bikaner	269-360	Kaur and Singh (2011)
3	Greater Visakhapatnam	256-1100	Swarna and Rao (2010)
4	Okhla Industrial Area, New Delhi	215-520	Siddiquiand Sharma (2009)
5	Tumkur Taluk, Karnataka	70-1660	Ramakrishnaiah and Sadashivaiah et.al. (2008)
6	Peenya industrial area, Bangalore	100-2800	Shank and Balasubramanya (2008)

Table 3: The Guidelines for Canadian Drinking Water Quality Hardness divide hardness into the following categories

SN.	Hardness Category	Equivalent Concentration of $CaCO_3$
1	Soft	< 60 mg/L
2	Medium hard	60 mg/L to < 120 mg/L
3	Hard	120 to < 180 mg/L
4	Very hard	180 mg/L or greater

CONCLUSION:

Pollutants originated from different types industries (steel, aluminium, brick, tile industries etc.) and waste disposal activity from urban areas were associated significantly with high positive loading of Hardness causing alkaline earth metals (Calcium, Magnesium, Strontium and Barium) and Anion (Bicarbonate, Carbonate, Sulphate, Nitrate, Chloride and Fluoride). Hardness is also depending upon the types of industries and concentration of hardness causing pollutant has been discharged from them, which has been given in the table 2.

The high degree of hardness in the study area can definitely be attributed to the disposal of untreated or improperly treated sewage and industrial wastes, so it is absolutely essential to initiate measures to check the pollutant concentration in industrial effluents through strict enforcement of legislation in order to prevent groundwater contamination. Besides this monitoring stations network should be established for regular assessment of groundwater quality.

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PHYSICOCHEMICAL CHARACTERIZATION OF CATCHMENT AREA WATER IN ALLAHABAD CITY

Arpan Herbert [1], Brijesh Kr. Mishra [2], Yeetendra Kumar [1*], Neelam Khare[3]
[1] Assistant Professor, Department of Civil Engg., SHIATS- DU, Allahabad- 211007, U.P.
[2] Assistant Professor, Environmental Science & Engg., ISM Dhanbad - 826004, Jharkhand
[3] Assistant Professor, School of Forestry & Environment, SHIATS- DU, Allahabad- 211007, U.P.
*yeetendrakumar@gmail.com

ABSTRACT:

Physicochemical characteristics of inland water bodies were tested by collecting samples from three stations in Allahabad city on three different intervals. Said characteristics were compared with norms defined by Central Pollution Control Board (CPCB) and Bureau of Indian Standards (BIS). It was found some of the characteristics were in accordance with defined norms whereas some of them were above norms. It was found that Dhoomanganj catchment area of River Ganges prevailed in higher values of Total Hardness, Biochemical Oxygen Demand and Chemical Oxygen Demand. An effort was also made to make the study more efficient by statistical analysis. Total Dissolved Solid and Chemical Oxygen Demand showed high correlation coefficient with other parameters.

Keywords: physicochemical characteristics, water quality parameter, correlation coefficient

1. INTRODUCTION:

The inland fresh water ecosystem both lentic and lotic contributes a greater fraction towards the available water resources on the planet, which is now being increasingly subjected to greater stress from various activities (National Academy of science 1969, and Duncan and Rzoska 1978). The physicochemical and biological characteristics of the water depend upon: the location of water bodies; types of sewage and domestic water disposal; localized human population; recreation and construction of road and building etc. these activities add large utilities of organic and inorganic allochthonous nutrients in the water. The enrichment of nutrients occurs due to disposal of the domestic and industrial disposal from the surrounding area.

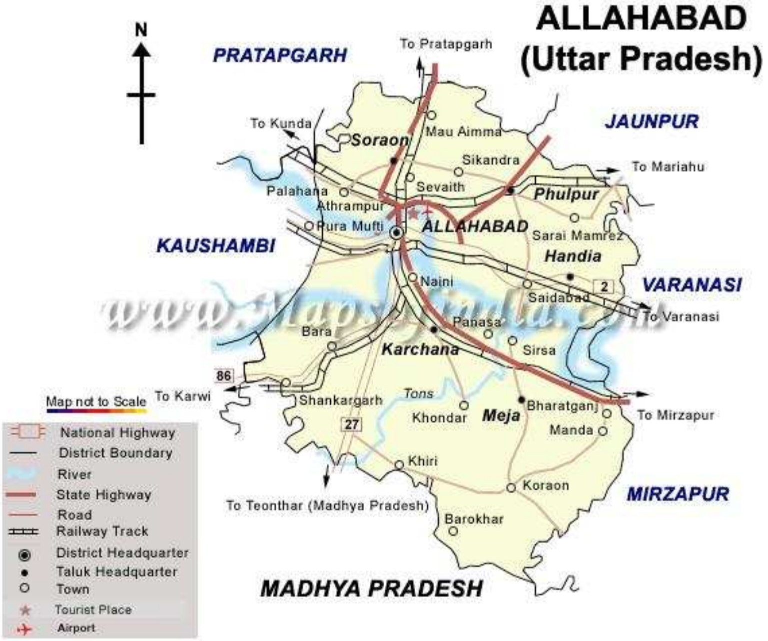
There has been numerous investigation of the impact of domestic sewage on changes in the physicochemical and biological characteristics of fresh water in Europe and America (Hasler 1947, Endmondson 1969, King 1970, Schindler 1971, Linkens 1972 and Schindler and Fee 1974). In India also there have been limnological investigations (Srinivasan 1964 and 1970, Zafar 1966, Kaul 1970,) demonstrating the role of water quality on population however, mostly confined to the fresh water available at lower altitudes (Plain area).

2. MATERIALS AND METHODOLOGY:

The Allahabad district is located between 25°27′N 81°51′E, it is also known as Sangam City and Prayag, and is by some accounts the second-oldest city in India. It is located in the north Indian state of Uttar Pradesh, lying some 205 kilometers (127 mi) south of the state capital, Lucknow (Figure 1). Its density is 1,087 /km^2 (2,815 /sq mi). The population of Allahabad is 5,959,798 (2011) form which it has been ranked the world's 130th fastest growing city (growth rate: 2.09 per cent (2011)).

The study was conducted on three major water bodies Dhoomanganj catchment area of river Ganges, Meerapur catchment area of river Yamuna and NSIC pond, Naini of district Allahabad.

The water samples were collected from these water bodies in clean plastic container. The sampling was done at 15 days interval during winter season. Immediately after collection the water samples were brought to the laboratory and kept at 40 ^{0}C till used for analysis (APHA 1998).



3. SAMPLING AND ANALYSIS:

In situ measurements was carried out on; temperature, electrical conductivity and total dissolve solid using a portable-hand held HM digital COM-100, EC/TDS/temperature meter colour and odour were determined through physical observation. The samples were taken to the laboratory for the determination of physical, chemical parameters. These include total suspended solid, pH, chloride, biological oxygen demand, chemical oxygen demand, dissolve oxygen. All samples were analyzed as described in the standard methods for the examination of wastewater (APHA 1998). Results were compared with Central Pollution Control Board and BIS standards.

4. RESULTS AND DISCUSSION:

All the collected water samples were collected form Dhoomanganj catchment area of river Ganges, Meerapur catchment area of river Yamuna and NSIC pond, Naini of district Allahabad. The physical, chemical parameters are tabulated along with standard value in Table 1, 2 and 3.

Table 1: The physical and chemical parameters of water bodies collected form Dhoomanganj catchment area of river Ganges [1], Meerapur catchment area of river Yamuna [2] and NSIC pond, Naini [3] of district Allahabad.

Station	Day	pH	T*	BOD	COD	DO	EC	Free CO_2	TA*	Hardness	Chloride	Sodium	Potassium	TS*	TSS*	TDS*
1	D1	8.6	18	456.3	753.3	4.8	380	33.9	258.7	328.3	258.1	8.9	6.4	721	173.3	584
	D2	8.3	13	436.8	601	5.7	330	16.8	284.3	325.7	189.3	8.2	3.4	800.3	155.3	654.7
	D3	8.2	16.9	452.4	533	7	301	14.8	303.3	320.7	117.4	8.15	3	848	149.7	701
2	D1	8.5	21.3	356.3	605	6	1100	14.3	181.31	120	153.5	1.2	1.7	315	180	160.3
	D2	8.3	18.4	347	472	7.1	946	8.5	210.3	106	110.2	0.8	1.1	401	174.6	235.7
	D3	8.2	19.6	350	440	8	903	7.4	261.7	100	99.8	0.7	0.85	420	170.3	261
3	D1	7.9	22	200	335	6.9	701.3	19.23	158.7	160.3	168.7	5.8	1.8	611.7	180	310.3
	D2	7.8	19	198.7	315	7.2	530	19	180	150	104.9	5.5	2	503.7	174.6	340
	D3	7.5	21.3	186	290	8.8	507	16.2	231.7	140	90.8	5	1.7	531.3	170.3	389.7

*T- Temperature, TA- Total Alkalinity, TS- Total Solis, TSS- Total Suspended Solid, TDS- Total Dissolved Solid pH was within permissible limit as specified by Central Pollution Control Board however slightly higher when compared to water quality standards prescribed by BIS. Total hardness is almost 1.5 times high in Dhoomanganj catchment area with the set standards of BIS. BOD and COD were extremely high whereas suspended solids were slightly high from Central Pollution Control Board limits. Dissolved oxygen in Dhoomanganj catchment area was high however remained within limit in other stations.

Table 2: Descriptive statistics of wastewater analysis

S.No.	Parameters	Mean	Standard Deviation	Variance	Coefficient of Variation %
1.	pH	8.14	0.35	0.12	4.30
2.	Temperature	18.83	2.77	7.68	14.72
3.	BOD	331.50	111.00	12321.98	33.49
4.	COD	482.70	155.61	24214.53	32.24
5.	Dissolved Oxygen	6.83	1.20	1.45	17.62
6.	EC	633.14	292.86	85768.71	46.26
7.	Free CO_2	16.68	7.67	58.86	46.00
8.	Total Alkanity	230.00	50.62	2561.92	22.01
9.	Hardness	194.56	99.67	9934.40	51.23
10.	Chloride	143.63	54.70	2991.59	38.08
11.	Sodium	4.92	3.29	10.85	66.94
12.	Potassium	2.43	1.69	2.87	69.68
13.	TS	572.44	186.01	34598.45	32.49
14.	TSS	169.79	10.50	110.15	6.18
15.	TDS	404.08	195.16	38087.90	48.30

Correlation is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of the other. The correlation is said to be positive when increase in one parameter causes the increase in the other parameter and it is negative when increase in one parameter causes the decrease in the other parameter. The correlation coefficient (r) has a value between +1 and -1. The correlation between the parameters is characterized as strong, when it is in the range of +0.8 to 1.0 and -0.8 to -1.0, moderate when it is having value in the range of +0.5 to 0.8 and -0.5 to -0.8, weak when it is in the range of +0.0 to 0.5 and-0.0 to -0.513.

The correlation coefficients (r) among various water quality parameters were calculated and the values of the correlation coefficients (r) are given in Table 4. The strong correlation are between BOD – pH (0.847), COD – pH (0.921), COD – BOD (0.898), Sodium – EC (0.939), Sodium – Hardness (0.895), Potassium – Free CO_2 (0.889), TS – EC (0.913), TS – Hardness (0.925), TS – Sodium (0.923), TSS – TA (0.871), TDS – EC (0.925), TDS – Hardness (0.950), TDS – Sodium (0.890), TDS – TS (0.965).

Table 3: Correlation coefficient (r) for different parameters in the water bodies collected form Dhoomanganj catchment area of river Ganges, Meerapur catchment area of river Yamuna and NSIC pond, Naini of district Allahabad

Parameters	pH	T*	BOD	COD	DO	EC	Free CO_2	TA	Hardness	Chloride	Sodium	Potassium	TS	TSS	TDS
pH	1.000														
	-0.381	1.000													
BOD	0.848	-0.683	1.000												
COD	0.922	-0.496	0.898	1.000											
DO	-0.799	0.443	-0.647	-0.855	1.000										
EC	0.181	0.575	-0.227	-0.130	0.188	1.000									
Free CO_2	0.187	-0.080	0.147	0.429	-0.629	-0.554	1.000								
T A*	0.286	-	0.734	0.466	-	-	0.015	1.000							

		0.712			0.113	0.576									
Hardness	0.364	-0.719	0.668	0.620	-0.623	-0.832	0.604	0.673	1.000						
Chloride	0.619	-0.300	0.502	0.756	-0.900	-0.308	0.799	0.121	0.644	1.000					
Sodium	-0.018	-0.496	0.271	0.282	-0.434	-0.939	0.733	0.424	0.895	0.557	1.000				
Potassium	0.465	-0.436	0.562	0.719	-0.755	-0.650	0.889	0.416	0.839	0.850	0.781	1.000			
T S*	0.062	-0.643	0.448	0.309	-0.350	-0.914	0.478	0.644	0.925	0.441	0.924	0.659	1.000		
T SS*	-0.063	0.766	-0.562	-0.231	0.027	0.680	0.101	-0.871	-0.692	0.050	-0.530	-0.247	-0.755	1.000	
T D S*	0.130	-0.732	0.556	0.406	-0.355	-0.926	0.457	0.773	0.950	0.406	0.891	0.700	0.966	-0.831	1.000

*T- Temperature, TA- Total Alkalinity, TS- Total Solis, TSS- Total Suspended Solid, TDS- Total Dissolved Solid

5. CONCLUSION:

Data of water quality for physical and chemical properties from the analysis of 03 water bodies were statistically interpreted. . A large number of factors and Local conditions influence the correlations between different pairs directly or indirectly. An appreciable significant positive correlation have been recorded between BOD – pH, COD – pH, COD – BOD, Sodium – EC, Sodium – Hardness, Potassium – Free CO_2, TS – EC, TS – Hardness, TS – Sodium, TSS – TA, TDS – EC, TDS – Hardness, TDS – Sodium & TDS – TS**.** The deterioration in water quality is found due to the regular direct discharge of sewage water from local house hold. Due to presence of such huge amount of pollutants in to surface water, water bodies there their self purifying nature, resulting high level of pollution.

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GROUNDWATER QUALITY ASSESSMENT AND ITS SUITABILITY FOR DOMESTIC AND AGRICULTURE USES OF DURGAPUR INDUSTRIAL CITY, WEST BENGAL, INDIA

*Mukesh Kr. Mahato, Ashwani Tiwari, G.C. Mondal, Abhay Kr. Singh and B.K. Tewary
Geo-environment Division (EMG) CIMFR, Barwa Road, Dhanbad - 826 015
*Research Scholar, Department of Environmental Science & Engineering, Indian School of Mines, Dhanbad.
E-mail: catchmukesh8317@gmail.com

ABSTRACT

Durgapur is an industrial city in the state of West Bengal, India. In order to assess the suitability of water for drinking, domestic and irrigation uses, the chemical characteristic of ground water of Durgapur Industrial area have been analyzed and evaluated. For this purpose, 9 water samples from tube wells and dug wells were collected and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS),Turbidity, major cations (Ca^+, Mg^{2+}, Na^+ and K^+) major anions (HCO_3^- F^- , Cl^-, NO_3^-, SO_4^{2-}). To understand the water quality and utilization aspect of ground water, calculated parameters like Residual Sodium Carbonate (RSC), Permeability Index (PI), Percent Sodium, Sodium Adsorption Ratio (SAR) and Donnen diagram, Wilcox diagram and Salinity diagram were plotted based on the analytical results. The pH of the analysed water samples varies from 5.27-7.75 and the average pH was found to be 6.84, indicating acidic to alkaline nature. Total dissolved solid varies from 185 mg/L to 1043 mg/L in groundwater samples of study area. The quality assessment shows that in general the water is suitable for domestic purpose with some exceptions. However, high values of EC, TDS, TH and SO_4 at some sites make it unsafe for drinking and irrigation uses. The assessment of water for irrigation shows that the water is good to permissible quality. However high values of salinity, SAR, RSC, and MH at certain sites restrict its suitability uses.

Keywords: Ground water quality, SSP, SAR, RSC, Agriculture.

1.0 INTRODUCTION

Groundwater is the lifeline for many rural, agricultural and industrial regions and their associated cultures and populations around the globe and a cornerstone of global food production. Groundwater constitutes nearly half the world's drinking water and much of the world's irrigation water supply. Population growth, overexploitation, salinization, nonpoint source of pollution from agricultural activities (including animal farming, ranching, forestry activities, mining and growing industries), impacts to surface water, and groundwater quality and quantity conflicts at the urban-rural interface have reached global dimensions and threaten the health and livelihood of this planet.. Further, it is possible to understand the change in quality due to rock-water interaction (weathering) or any type of anthropogenic influence (Todd 1980, Kelly 1940). The rate of depletion of ground water level and deterioration of ground water quality is of immediate concern in major cities and towns of country (Khurshid et al. 1997, Das et al. 1998, Sohani et al. 2001, Jain 2002, Meenkumari and Hosmani 2003, Dhindsa et al. 2004, Jain et al. 2004, Ramashubramanian et al. 2004).

The definition of water quality is much depending on the desired use of water. Therefore different uses require different criteria of water quality as well as standard method for reporting and comparing result of water analysis (Babiker 2007). Ground water often consist of major chemical elements Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, Cl^-, F^- NO_3^- and SO_4^{2-}. The ground water of Durgapur industrial area is very much affected by natural and anthropogenic sources. Dissolution of rock minerals in the ground water is another source of minerals. The major sources of fluoride in ground water are fluoride bearing rocks such as fluorspar, cryolite, fluorapatite and hydroxylapatite (Agarwal et al. 1997). The fluoride content in ground water is a function of many factors such as availability and solubility of fluoride minerals, velocity of flowing water, temperature, pH, concentration of calcium and bicarbonate ions in water, *etc.* (Chandra et al. 1981; Largent 1961).The anthropogenic sources of ground water pollution include various sources like the agricultural wastes and domestic sewage disposals. The chemical parameters of ground water play a significant role in classifying and assessing water quality. Sodium adsorption ratio (SAR) and Residual sodium carbonate (RSC) can be used as a criterion used in the classification of water for a particular purpose considering the individual concentration may not find its suitability for other purposes and better result can be obtained only by considering the combination chemistry of all the ions rather than individual or paired ionic characters (Handa 1965, Hem 1985). The objective of the present study was to assess the ground water composition and its suitability for different uses (i.e. drinking and irrigation purposes) in the study area.

2.0 STUDY AREA

Durgapur is located in the district of Burdawan, in the state West Bengal, India, about 160 km from Kolkata. Durgapur is a well-planned industrial city with a population of about 250,000. Durgapur is situated on the bank of river Damodar, just before it enters the alluvial plains of Bengal. The topography is undulating. The coal-bearing area of the Raniganj coalfields lies just beyond Durgapur, although some parts intrude in to the area. Its surrounding area is very fertile and is a big producer of rice in the country. The average temperature during summer season is 32 °C while at the cold season is 20 °C. The maximum temperature during summer rises up to 45 °C while minimum temperature during winter comes down to 6°C. Average rainfall is 1500 millimeters with the bulk of rainfall occurring around the July-September period. The location map of the study area along with the sampling locations is given in **Fig. 1.**

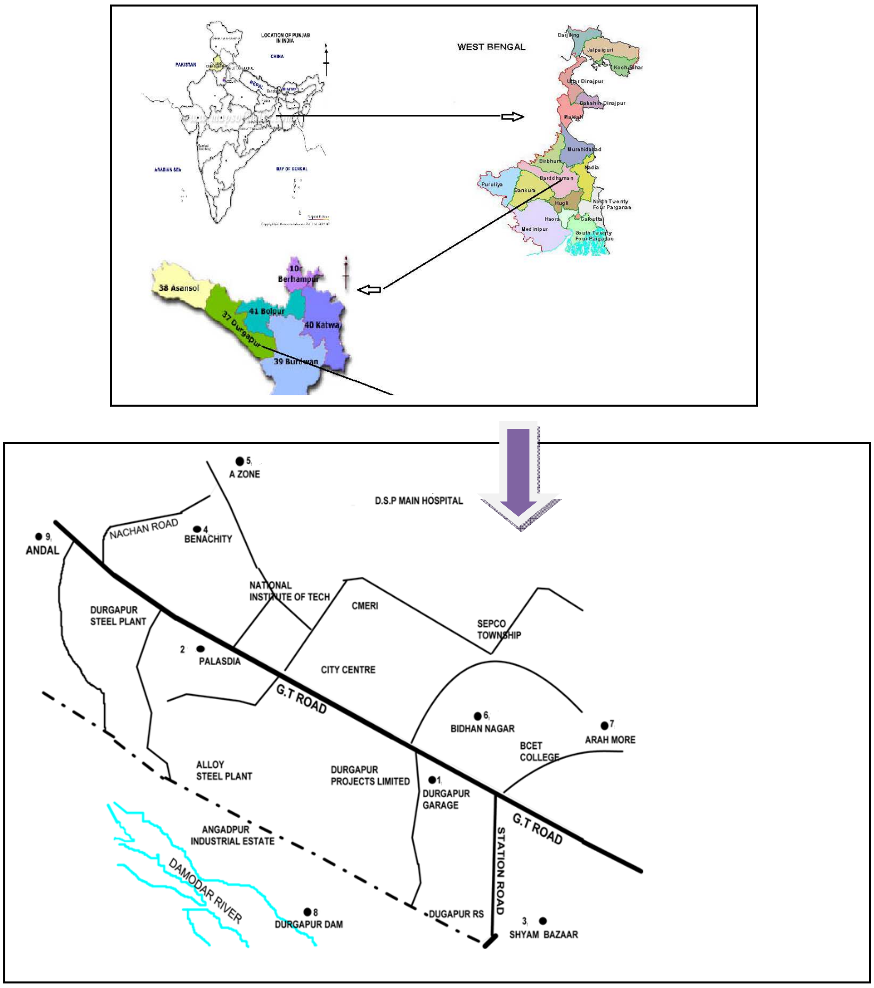

Fig.1: Sampling location map of the study area

3.0 MATERIALS AND METHODS

Sampling and Analytical Procedure

For the assessment of water quality of Durgapur industrial area, a systematic sampling was carried out during June-July 2010. Representative 9 ground water samples from deep (tube well) and shallow (dug well) aquifer were collected including rural and town areas (**Table 1**). The analysis of ground water samples were carried out in the laboratory as per Standard Methods (APHA, 1985). pH and electrical conductivity ware measured in the field using a portable conductivity and pH meter. In the laboratory, the water samples were filtered through 0.45 µm Millipore membrane filters to separate suspended sediments. Acid titration and molybdosilicate methods were used to determine the concentration of bicarbonate and dissolved silica, respectively. Major anions (F^-, Cl^-, NO_3^- and $SO_4^{2-)}$ were estimated by Ion Chromatograph DIONEX (DX 120) using anion (AS12A/AG12) columns coupled to an self-regenerating suppressor (ASRS) in recycle mode. Concentration of major cations (Ca^+, Mg^{2+}, Na^+ and K^+) were determined by Flame Atomic Absorption Spectrophotometer (VARIAN-AA280 FS).

4.0 RESULTS AND DISCUSSIONS

The results include the hydro-chemical analysis of the samples collected from study area are as follows:

4.1 pH, EC and TDS

The pH of the analyzed samples varies from 5.27 to 7.75 and the average pH was found to be 6.89 indicating acidic to alkaline nature of the ground water samples in study area. The electrical conductivity (EC) value in the analyzed samples varies from 272 µs cm-^{1} to1394 µs cm-^{1} and the average EC value for the areas was found to be 721 µs cm-^{1}. The total dissolved solids concentration of the ground water of the study area range from 185 to 1043 mg/L and the average TDS of the area is 513 mg/L in the collected water samples. The large variation in the EC, TDS and ionic concentration in the ground water of the area may be attributed to variation in geo-chemical processes and anthropogenic activities.

4.2 Bicarbonate (HCO_3)

Bicarbonate is the most abundant anion in the ground water of the Durgapur, constituting about 52.7% of the total anions in equivalent unit .The concentration of bicarbonate varies from a minimum of 10.5 mg/L to maximum value of 399.4 mg/L and average concentration of bicarbonate is found to be 162.7 mg/L in the collected water samples.

Bicarbonate is mainly derived from rock weathering (80%) and pollution contributing only 20% of the global bicarbonate. It derived from the soil zone CO_2 and dissolution of carbonates and reaction of silicates with carbonic acid. The soil zone in the subsurface environment contains elevated CO_2 pressure (produced as result of decay of organic matter and root respiration), which in turn combines with rainwater to form bicarbonate by the following reactions:

$$CO_2 + H_2O = H_2CO_3$$
$$H_2CO_3 = H^+ + HCO_3^-$$

Bicarbonate may also be derived from the dissolution of carbonates and/or silicate minerals by the carbonic acid from the reactions:

$CaCO_3 + H_2CO_3 = Ca^{2+} + 2HCO_3^-$
Limestone
$CaMg(CO_3)_3 + 2H_2CO_3 = Ca^{2+} + Mg^{2+} + 4HCO_3^-$
Dolomite
$2NaAlSi_3O_8 + 2H_2CO_3 + 9H_2O = Al_2Si_2O_5(OH)_4 + 2Na^+ + 4H_4SiO_4 + 2HO_3^-$
Albite Kaolinite

4.3 Chloride (Cl) and Sulphate (SO_4)

The presence of chloride in natural water can be attributed to dissolution of salt deposit, discharge of effluent from chemical industry, oil well operation and sea water intrusion of coastal areas. Abnormal concentration of chloride may result from anthropogenic sources including agricultural runoff, domestic and industrial wastes and leaching of saline residues in the soil. The chloride concentration in the analyzed samples varies between 6 mg/L to 215.9 mg/L.

On a global basis, one third of the SO_4 in aquatic systems is derived from the rock weathering and about 60% from fossil fuel burning and minor amounts from volcanism (5%) and cycling salts (2%). The sulphate concentration varies between 29.4 mg/L to 96.7 mg/L, with the average value of 52.8mg/L

4.4 Fluoride (F) and Nitrate (NO_3)

Fluoride occurs as fluorspar (fluorite), rock phosphate, triphite, phosphorite minerals etc in nature. Among the factors, which control the concentration of fluoride includes climate of the area and the presence of accessory minerals in the rock mineral assemblage through which the groundwater is circulating. Concentration of fluoride ranges from 0.20 mg/L to 0.91 mg/L and average concentration value is 0.51 mg/L in the analysed samples.

The chief sources of the nitrate are atmosphere sources, legumes, plant, debris, animal, excrement. Nitrogen is recycled continually by plant and animal and is found in the cells of all living things. Concentration of nitrate ranges from 17.7 mg/L to 127.7 mg/L and average concentration value is 57.9 mg/L. In general nitrate concentration is low and found within the prescribed limits with some exceptions.

4.5 Dissolved Silica (H_4SiO_4)

Dissolved silica in the ground water of Durgapur belt varies from 11.4 mg/L to 61.5 mg/L (Average 31.9 mg/L). At some Locations of the ground water of Durgapur belt the concentration of dissolved silica content is relatively high and some cases it exceeds concentration of chloride and sulphate. A high concentration of dissolved silica in these waters reflects the contribution from weathering of silicate rocks, with clay minerals as by product by the following reactions:

$2\ KAlSi_3O_8 + 2\ H^+ + 9\ H_2O = Al_2SiO_5\ (OH)_4 + 2K^+ + 4\ H_4SiO_4$

K-feldspar Kaolinite

$2\ NaAlSi_3O_8 + 2\ H^+ + 9\ H_2O = Al_2SiO_5\ (OH)_4 + 2Na^+ + 4\ H_4SiO_4$

Na-Feldspar Kaolinite

$K_2Mg_3Fe_3Al_2SiO_6O_{22}(OH)_4 + 14CO_2 + 7H_2O = Al_2SiO_2O_5(OH)_4 + 2K^+ + 3Mg^{2+}$

Biotite $+14\ HCO_3^- + 4\ SiO_2$

$CaMgFeAl_2Si_3O_{12} + 6CO_2 + 5H_2O = Al_2SiO_5 + Ca + Mg + Fe + 6HCO_3 + SiO_2$

Augite

Table: 1: Physico-chemical characteristics of ground water of Durgapur industrial City

Sl.No	***Sampling site***	***pH***	***E.C***	***T.D.S***	***Turb***	***HCO_3***	***TA***	***Cl***	***F***	***NO_3***	***SO_4***	***Na***	***K***	***Mg***	***Ca***	***Si***	***TH***
1	Durgapur Garage	6.34	659	411	24.1	122.1	132	78.0	0.51	13.2	47.7	64.7	11.8	18.9	28.9	26.3	150
2	Palasdia	5.27	502	321	1.3	10.5	48	90.0	0.91	32.6	42.0	48.3	7.8	11.0	17.4	61.5	89
3	Shyam Bazar	6.94	513	444	1.1	122.1	160	44.0	0.41	12.1	96.7	44.3	49.0	16.6	18.6	40.9	115
4	Benachity	7.12	1042	730	0.5	325.0	340	70.0	0.50	15.0	42.4	62.5	5.7	28.1	146.4	34.6	481
5	A. Zone	7.75	335	242	6.4	101.8	100	16.0	0.79	10.2	41.0	20.1	5.9	14.7	20.7	11.4	112
6	Bidhan Nagar	6.66	1028	567	0.7	122.1	128	124.0	0.37	9.9	54.3	127.7	33.1	31.4	41.4	23.4	233
7	Arah More	6.84	663	540	0.8	118.7	128	80.0	0.20	118.5	43.7	43.7	19.7	22.5	56.4	37.4	234
8	Near Durgapur Dam	7.63	1394	1043	1.6	399.4	364	215.9	0.71	75.5	57.3	80.1	1.5	61.3	117.0	35.1	545
9	Andal	7.52	272	185	1.3	84.9	100	6.0	0.24	2.3	29.4	17.7	3.9	8.9	12.5	19.7	68
Minimum		5.27	272	185	0.5	10.5	48	6.0	0.20	2.3	29.4	17.7	1.5	8.9	12.5	11.4	68
Maximum		7.75	1394	1043	77.2	399.4	364	215.9	0.91	118.5	96.7	127.7	49.0	61.3	146.0	61.5	545
Average		6.84	721	513	16.1	162.7	170	81.3	0.51	39.8	52.8	57.9	19.8	25.0	53.9	31.9	232

Unit: Concentration in mg l$^{-1,}$ except pH, EC (μS cm^{-1}), Turbidity (NTU)

4.6 Calcium (Ca) and Magnesium (Mg)

Weathering and dissolution of calcium carbonate (limestone and dolomite) and calc-silicate minerals (amphiboles, pyroxenes, olivine, biotite etc) are the most common source of calcium and magnesium in water. Presence of calcium and magnesium makes the water hard. Calcium cation (Ca^+) and calcium salts are among the most commonly encountered substances in water, arising mostly from dissolution of minerals. Calcium often is the most abundant cation in river and ground water. The Concentration of calcium in the ground water samples of the Durgapur belt varied from minimum value of 12.5 mg/L to maximum of 146.0 mg/L. The average concentration of calcium was measured 53.9 mg/L.

Magnesium is abundant in earth crust and is a common constituent of natural water. In the analyzed ground water samples, Mg concentration ion varies from 8.9 mg/L to 61.3 mg/L (average 25.0 mg/L. The presence of calcium and magnesium make the water hard.

4.7 Sodium (Na) and Potassium (K)

Sodium bearing minerals like albite and other members of plagioclase feldspars, nepheline, soda lite, glaucophane, etc. are not as widespread or abundant as the calcium and magnesium bearing minerals. In the analyzed ground water samples of Durgapur belt the concentration of sodium ranges between 17.7 mg/L to 127.7 mg/L with the average values of 57.9 mg/L.

The common sources of potassium are the silicate mineral orthoclase, microcline, nepheline, Lucite and biotite in igneous and metamorphic rocks, and evaporate containing highly soluble sylvite and niter in some sedimentary rocks. Although potassium is nearly as abundant as sodium in igneous rocks and metamorphic rocks, its concentration in ground water is one-tenth or even one-hundredth that of sodium. Potassium concentration varies between 1.5 to 49.0 mg/L (average 19.8 mg/L) in the analyzed water samples.

4.8 Alkalinity

The determination of alkalinity is of important in water softening, chemical treatment of waste water, treatment of natural water, corrosion control and in removal of ammonia by air stripping.The minimum alkalinity obtained in water sample is 48 mg/L and maximum of 364 mg/L and the average value is 170 mg/L.

5.0 WATER QUALITY ASSESSMENT

5.1 Suitability for drinking and general domestic uses:

To assess the suitability for drinking and public health purposes, the hydro chemical parameters of the ground water of the study area are compared with the prescribed specifications of WHO (1997) and Indian standard for drinking water i.e. IS-10500 (BIS 1991). **Table 2** shows that in general, ground water of the study area are suitable for drinking and domestic uses with few exceptions, as most of the parameters are within the permissible limits.

The total hardness (TH) of the analyzed water samples of Durgapur belt varies between 68 mg/L to 545 mg/L and (Avg. 232 mg/L) respectively indicating hard to very hard types of water (**Table 3**). Hardness of the water is property attributable to the presence of alkaline earths i.e. Ca and Mg. The data indicate that 2 ground water samples have TH values higher than 300 mg/L, which is the potable limit (BIS 1991).Hardness has no known adverse effect on health but it can prevent water from the formation of lather with the soap and increases the boiling point of the water. The high TH may cause the encrustation on water supply distribution systems.

Concentration of sulphate and nitrate at some sites in ground water are also exceeding the Indian permissible limits (400 mg/L and 45 mg/L) restricting its direct uses for drinking purposes. High concentration of nitrate levels can cause "*methaemoglobinaemia*" in infants and high sulphate may contribute to the corrosion of metals in the distribution system, particularly in waters having low alkalinity. High sulphate concentration may cause a laxative effect on human system with excess of Mg in water. Waters with about 200-400 mg/L Sulphate have a bitter taste and those with 1000 mg/L or more of SO_4 may cause intestinal disorder.

Table 2: Range of chemical parameters in study area and WHO and Indian Standard (IS: 10500) for drinking waters

Parameters	**Water Samples**	**WHO (1997)**		**IS:10500 (BIS 1991)**	
	Range	**Highest Permissible**	**Max. Desirable**	**Highest Permissible**	**Max. Desirable**
pH	5.27-7.75	6.5-9.2	7.0-8.5	8.5-9.2	6.5-8.5
EC	272-1394	1,500	750	-	-
HCO_3	10.5-399.4	600	200	600	200
Cl	6.0-215.9	600	250	1,000	250
F	0.2-0.91	1.5	0.6-0.9	1.5	0.6-1.2
NO_3	2.3-118.5	50	-	100	45
SO_4	29.4-96.7	600	200	400	200
Na	17.7-127.7	200	50	-	-
Ca	12.5-146	200	75	200	75
Mg	8.9-61.3	150	30	100	30
K	1.5-49.0	200	100	-	-
TDS	185-1043	1,500	500	2,000	500
TH	68-545	500	100	600	300

Unit: All parameters are in mg/L, except EC- ($\mu s\ cm^{-1}$) and pH

Table 3: Hardness Classification of water

Hardness(mg/L)	**Water Class**	**No. of samples**
0-75	Soft	1
75-150	Moderately hard	1
150-300	Hard	4
>300	Very hard	3

5.2 Suitability for irrigation:

The parameters like total hardness (TH), sodium percentage (Na%) residual sodium carbonate (RSC), total dissolved solids (TDS), sodium adsorption ratio (SAR), permeability index (PI) and magnesium hazard (MH), which affects the quality for irrigation purposes were also computed and results are furnished in (**Table 3 & 4**). The important hydro chemical properties of ground water to determine its suitability for irrigation are:

5.2.1 Alkali and Salinity Hazard

The total concentration of soluble salts in irrigation water can thus be expressed for the purpose of classification of irrigation water as low (EC = <250 μS cm^{-1}), medium (250-750 μS cm^{-1}), high (750-2250 μS cm^{-1}) and very high (2250-5000 μS cm^{-1}) salinity classes. While a high salt concentration (high EC) in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). It can be estimated by the formula:

$SAR = Na/[(Ca+Mg)/2]^{0.5}$

Irrigation waters classified into four categories on the basis of sodium adsorption ratio (SAR):

Table 3: Classification of water Irrigation water

SAR	*Water Category*
0 – 10	Excellent (S-1)
10 – 18	Good (S-2)
18 – 26	Fair (S-3)
>26	Poor (S-4)

Table: 4 Parameters to assess the ground water quality of Durgapur for irrigation uses

Sample ID	SAR	%Na	RSC	MH	PI
1	2.30	51.0	0.50	51.8	73
2	1.87	47.6	0.43	35.9	74
3	1.80	58.1	0.85	59.5	79
4	1.24	23.0	0.51	24.0	41
5	0.82	31.4	0.54	53.9	70
6	3.64	57.9	1.56	55.6	74
7	1.24	34.0	-0.40	39.7	50
8	1.49	24.5	1.07	46.3	42
9	0.94	39.1	0.71	54.1	92
Min	**0.82**	**23.0**	**-0.40**	**24.0**	**40.77**
Max	**3.64**	**58.1**	**1.56**	**59.5**	**91.78**
Avg	**1.71**	**40.7**	**0.64**	**46.7**	**65.98**

Units: Concentration in SAR and RSC (meq l^{-1}), %Na and MH (%); MH=Magnesium hazard, SAR= Sodium adsorption ratio, RSC=Residual sodium carbonate

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. The calculated value of SAR in the study area ranges from 0.82 to 3.64 in ground water. The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that six water samples fall in the category C2S1 and three water samples fall in C2S1, indicating medium to high salinity and low alkali water, which can be used for irrigation in most soil and crops with little danger of development of exchangeable sodium and salinity (**Fig. 2**). High saline water cannot be used on soils with restricted drainage and requires special management for salinity control. Plants with good salt tolerance should be selected for such areas. Three analyzed samples of fall in the very high saline category. Very high saline water

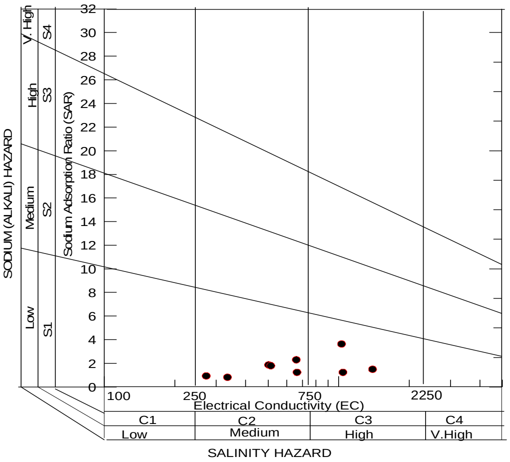

Fig. 4.1: US Salinity diagram for classification of irrigation water

is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and salt tolerance crops/plants should be selected.

5.2.2 Electrical conductivity (EC) and Soluble sodium percentage (Na %)

Electrical conductivity (EC) and sodium concentration are very important in classifying irrigation water. Water used for irrigation always contains measurable quantities of dissolved substances as salts. They include relatively small but important amount of dissolved solids originating from the weathering of the rocks and soils and from the dissolving of lime, gypsum and other salt sources as water flows over or percolate through them. The salts, besides affecting the growth of the plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth. The sodium percentage (Na %) in the water samples of sub-surface water is calculated by the equation:

$$\text{Na\%} = \text{Na+K/(Ca+Mg+Na+K)X100}$$

The soluble %Na of the analyzed ground water sample of Durgapur belt varies from 23% to 58.1% with an average value of 40.7%. A high soluble sodium percent causes deflocculation and impairment of the tilt and permeability of soil. As per the Indian Standard, maximum sodium of 60% is recommended for irrigation water. Plot of analytical data on diagram relating electrical conductivity and sodium percent shows that six water samples of Durgapur belt have excellent to permissible quality, which may be used for irrigation purposes. However, rest water samples have high %Na and EC making it doubtful to unsuitable category (**Fig. 3**).

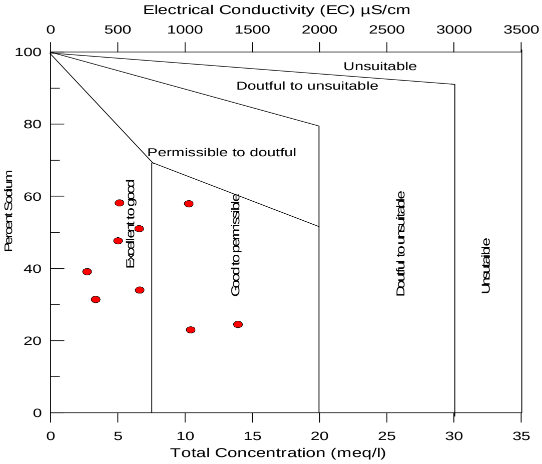

Fig. 3: Plot of %Na Vs EC

5.2.3 Residual Sodium Carbonate (RSC)

The quantity of bicarbonate and carbonate in excess of alkaline earths (Ca + Mg) also influence the suitability of water for irrigation purposes. When the sum of carbonates and bicarbonates is in excess of calcium and magnesium, there may be possibility of complete precipitation of Ca and Mg. To quantify the effects of carbonate and bicarbonate, residual sodium carbonate (RSC) has been computed by the equation:

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \text{ in meq/l}$$

A high value of RSC in water leads to an increase in the adsorption of sodium on soil. Irrigation water having RSC values greater than 5 meq/l are considered harmful to the growth of plants, while water with RSC values above 2.5 meq/l are not considered suitable for irrigation purpose. In most of the analyzed water samples of of the study area, RSC values are below 2.5 meq/l and are suitable for irrigation purposes.

5.2.4 Permeability Index (PI)

Permeability Index (PI) is another parameter for assessing the suitability of water for irrigation uses. Doneen (1964) classified irrigation waters based on the Permeability Index (PI). PI is defined by:

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100$$

where concentration in meq/l

Calculated parameter Permeability Index About 66.6 % of the water samples fall in Class–I and 22.2% in Class-II in the Doneen’s chart (Domenico and Schwartz 1990), implying that the water is of good quality for irrigation purposes with 75% or more of maximum permeability. Only 11.1% groundwater samples belong to Class-III i.e. unsuitable category, **(Fig. 4.)**.

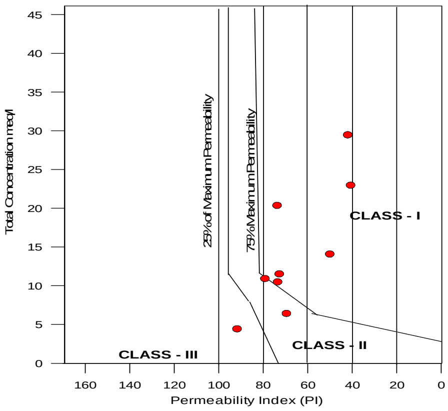

Fig. 4: Permeability Index Vs Total Concentration

5.2.5 Magnesium Hardness (MH)

Magnesium hazard (MH) is another parameter for assessing the suitability of water for irrigation uses. The magnesium hazard (MH) value can be calculated by the following formula:

$$MH = Mg / (Ca + Mg) \times 100.$$

MH >50 is considered harmful and unsuitable for irrigation use. Out of analyzed 9 sample water samples, 5 samples have a MH value (>50) and falls in unsuitable zone.

6.0 CONCLUSION

The large variation in the EC, TDS and ionic concentration in the ground water of the Durgapur belt may be attributed to variation in geo-chemical process and anthropogenic activities. Higher concentrations of dissolved ions were observed in the water samples collected from industrial and urban areas. The quality assessment shows that in general, the water is suitable for domestic purposes with some exceptions. However, high values of EC, TDS, TH, NO_3 and SO_4 at some site make it unsafe for drinking and irrigation uses. The assessment of water for irrigation uses show that the water is good to permissible quality. However, high values of salinity, sodium percentage, residual sodium carbonate (RSC) and Magnesium Hazard (MH) at certain sites restrict its suitability for agriculture uses.

ACKNOWLEDGEMENT

The authors are thankful to Director, CIMFR for his permission to publish this paper. Help rendered by Mr. K.K Singh in analysis is thankfully acknowledged.

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CHLORINATION BY-PRODUCTS FORMATION AND THEIR REMOVALS FROM DRINKING WATER

Minashree Kumari, Dr. S. K. Gupta & B.K.Mishra
Department of Environmental Science and Engineering
Indian School of Mines, Dhanbad

ABSTRACT

Water is one of the basic needs and vital concern for human beings. Water treatment for the purpose of drinking has attained much importance due to its requirement in our daily life. New treatment techniques are evolving providing more clean and safe drinking water. Disinfection has been the most important part of drinking water treatment as it kills the harmful pathogenic organisms but the disinfectant, mainly chlorine, has been reported to form harmful disinfection by-products i.e. Trihalomethanes (THMs), halo acetic acids (HAAs) etc. Amongst various DBPs, THMs have been found to have more severe adverse health effects. The health effects include reproductive/developmental effects in addition to various types of cancers as reported in various epidemiological and animal studies. The treatment technologies include coagulation with polymer, alum, lime or iron sulphates, adsorption on activated carbons, aeration, oxidation, ion exchange and membrane processes. The advanced control techniques such as adsorption, ion exchange and membrane filtration are more efficient in removing the compounds but they are very expensive to be applied for treatment at large scale water treatment plant. Adsorption and coagulation are the most commonly used techniques to reduce THMs and have been widely accepted with various modifications for the efficient removal of DBPs. This paper presents a comprehensive review of various treatment & control techniques being studied for control of THMs in drinking water supplies.

Keywords: Disinfection by-products (DBPs), Coagulation, Trihalomethanes, Adsorption.

1. INTRODUCTION

Water is one of the basic needs and vital concern for human beings. It is the most precious gift to humanity. It flows down, connects people, shapes generation, and infuses the “culture” it carries into their lives, thus serving as an engine of growth and development. Though water is regarded as a “human right” rather than a “human need”, the access to “closer and cleaner drinking water” is still a distant dream for about one-sixth of humanity on this planet (UNDP 2006, WHO 2004).

The global drinking water scenario presents a dismal picture with most of the developing countries fighting with the scarcity and contamination of drinking water. It is reported that nearly half of the population of developing countries suffer from health problems associated with lack of potable drinking waters (WHO, 1994). The UN General Assembly has proclaimed the 10 year period of 2005-15 as the UN International Decade for Action - "water for life” (UNEP Report, 2004).

Disinfection of drinking water prior to its distribution into water supply systems is necessary and has been used since the early 1900s. Disinfection is generally accomplished by chemical oxidation and it is used as a final step in water treatment plants following clarification/filtration of water. Characteristics of an ideal disinfectant include an effective removal of pathogens, long-term stability in water, an easy handling and measurement by the analytical methods, no undesirable by-products formation, and low cost. However, none of the used disinfectants meets all these requirements. Choosing an appropriate reagent is a compromise which depends on the quality of the source water including type of micro-organisms, the size of the supplied population, complexity and reliability of technology, and disinfection efficiency.

Formation of the disinfection by-products (DBPs) has been known since mid-1970s (Bellar *et al.* 1974, Rook 1976, Symons *et al.* 1975). The first and most widely studied group of DBPs was trihalomethanes (THMs) (Rook, 1974), followed by halo acetic acids (HAAs). Most of DBPs are detrimental to human health and must be regularly monitored in drinking water networks. Some of them are potential carcinogens, and a short-term exposure can lead to dizziness, headaches, as well as to problems associated with the central nervous system and reproductive disorders. Association between the ingestion of chlorinated drinking water in excess with risk of bladder and rectal cancer followed by mortality have been reported (IARC, 1991). An apparent association between bladder cancer, reproductive disorders and trihalomethanes has also been established (Bielmer *et al.* 2001). Their limit concentrations are usually given by government regulations.

In the 30 years since the THMs were identified as DBPs in drinking water, significant research efforts have been directed toward increasing our understanding of DBP formation, occurrence and health effects. Though considerable information on the control and other aspects related to DBPs developed to date is available, it is randomly scattered in literature, and therefore, the authors feel that a concise review of this significant area is highly appropriate and timely to catalyze further advancements.

2. CHEMISTRY OF CBPs FORMATION

The extensive literature pertaining to DBP levels in disinfected source waters and control of DBPs by various treatment processes attests to the wide variety of factors influencing DBP formation and the complex interrelationships between these factors. Variables including the concentration and characteristics of precursor material, pH, chlorine concentration, bromide level, presence of chlorine-demanding substances such as ammonia, temperature and contact time all play a role in DBP formation reactions.

Chlorination disinfection by-products (CDBPs) are chemical compounds that form when water containing natural organic matter (the decay products of living things such as leaves, human and animal wastes, etc.) is chlorinated. Chlorination of water can lead to the formation of a number of chlorination by-products of which trihalomethanes (THMs) are of major concern today. Among the many chlorination by-products, THMs are most often present in greatest concentration in the drinking water and as are used as indicators of total disinfection by-product formation (Kitis *et al.* 2001). The formation of these products mainly takes place during reactions in which organic substances, such as humic acid and fulvic acid, play an important role. These materials end up in water during the decomposition of plant matter (Nikolaou *et al.* 2004). Krasner *et al.* (1996) and Lin *et al.* (2000) have shown that fulvic acid has a THMs formation potential analogous to that of the humic acid. Formation of THMs occurs both during and after the disinfection process in the water treatment plant and subsequently in the distribution system.

Chlorine and its compounds are the most commonly used disinfectants for the treatment of water due to their higher oxidizing potential. Chlorine reacts with the natural organic materials found in water such as algae and decaying plants (Iriarte et al. *2003) forming a variety of halogenated DBPs, such as THMs, HAAs, HANs, chloral hydrate and chloropicrin as follows:*

$$\text{NOM} + \text{Chlorine Compound} \rightarrow \text{CBPs}$$

The reaction between chlorine and humic substances, a major component of NOM, is responsible for the production of organ chlorine compounds during drinking-water treatment. Rook (1977) proposed resorcinol structures to be the major precursor structure in humic material for chloroform formation and set the base for the study of the mechanism of formation of DBPs. Humic and fulvic acids show a high reactivity towards chlorine. Hydrophilic acids such as citric acid and amino acids will react with chlorine to produce chloroform and other products and may contribute towards total organochlorine production (Ma *et al.* 1992). Several researchers have shown that monochloramine readily transfers its chlorine at a comparatively rapid rate to organic amines to form organ halogen amines (Bercz *et al.* 1986 and Johnson *et al.* 1986). HANs and non-halogenated acetonitriles are produced when chloramines are reacted with humic materials and amino acids (Trehy *et al* 1981). Ozone has been shown to oxidize bromide to hypobromite and bromate, and hypochlorite to chlorate (Golfinopoulos *et al.* 2001, Siddiqui *et al.* 1995, Siddiqui 1996). Bromate generally forms through a combination of molecular ozone attack and reaction of bromide with free radical species.

Both THMs and HAAs concentration have been found to increase with increasing pH, temperature, Total Organic Carbon (TOC), contact time and disinfectant dose. All these factors have been found to influence the concentration of DBPs significantly. Hence, a control of all these factors will help a lot in controlling the formation of CBPs.

3. CONTROL TECHNIQUES OF DBPs

The U.S. EPA realized that Public Water Systems (PWSs) could have difficulties when attempting to meet both DBP limits and disinfection regulations. The regulations developed for disinfection and DBP control are of equal importance and both regulations must be met simultaneously. There are three basic methods for controlling DBPs in a water system (i) to reduce the DBP formation by lowering the organic precursor concentration at the point of disinfection (ii) reduce DBP formation by decreasing the disinfectant dose, altering the type of disinfectant or optimizing the disinfection environment and finally (iii) remove the DBPs after they have formed (Clark *et al.* 1994, Singer *et al.* 1999).

3.1 Altering Disinfection Conditions

THMs formed in the drinking water can also be controlled by varying disinfection conditions like pH, temperature, bromide ion concentration etc. All these factors play an important role in the formation of disinfection by products

3.1.1 pH

The adjustment of pH in the water treatment plant also plays a significant role in altering the concentration of DBPs. When the pH was decreased to 7.0, the TTHMs concentration decreased by 50%. These results indicated that maintaining a low pH during disinfection could reduce THM problems, and the pH can be raised once free chlorine residual is no longer present. Stevens *et al*. (1976) performed three experiments using Ohio River water at the Cincinnati treatment plant for different pH values which exhibited higher THMs formation at higher pH. Depending on the source of organics and chlorination conditions, 30% to 50% increase in THMs formation was noted when the pH was increased from 7 to 11 (Oliver and Lawrence, 1979).

3.1.2 Temperature

Temperature also affects the formation of THMs in drinking water. Stevens *et al.* (1976) performed experiments at three different temperatures (3, 25 and 40°C), constant pH of 7 and chlorine dose 10 mg/L using Ohio River water from the Cincinnati water treatment plant. The formation of THMs was found to be 1.5 –2 times higher at each stage of temperature change. The increase in THMs formation per 10^{o}C increase in temperature has been estimated to range between 25-50% (Engerholm and Amy, 1983). El-Shahat *et al.* (2001) and Hellur-Grossman *et al.* (2001) reported higher THMs formation during the summer months than during the winter months, where at higher summer temperatures, reaction rates increased yielding a higher rate of THMs formation. Similar results were also found out on studies carried out at Sangar Water Treatment Plant (SWTP) and Rasht Water Distribution System (RWDS) Iran Hassani, A. H. et al. (2010).

3.1.3 Bromide ion concentration

The presence of bromide ions in chlorinated water results in an increase in the formation of brominated THMs (Barrett *et al*., 2000).When the ratio of chlorine dosage to bromide ions increases, the formation of brominated THMs is favored (Nokes *et al.* 1999). During chlorination, bromide ions are oxidized to hypobromous acid (HOBr), which reacts more readily with organic precursors than chlorine, forming brominated THMs (Stevens *et al.*, 1976; Singer and Chang, 1989).The combined action of chlorine and hypobromous acid leads to the formation of mixed chloro-/bromo-THMs and other mixed halogenated by-products (Singer and Chang, 1989). To date, the presence of bromide ions has not been found correlated with other water quality parameters (Nokes *et al.*, 1999). This may be attributed to the fact that most surface waters, other than those of coastal regions, do not have significant bromide ions (Black *et al.*, 1996). Total THMs (TTHMs) formation increased from 112 to 190μg/L with the increase concentrations of bromide ions from 0.67 to 6.72 mg/L, but the chlorine-substituted THMs were replaced by bromine-substituted THMs (Zhang *et al.*2010).

3.2 Coagulation

Chemical coagulants are effective in removing a broad range of impurities from water including, colloidal particles and dissolved organic substances. Improved or modified coagulation can decrease the amount of humic and fulvic matters in natural waters. In developing countries, alum is the main coagulant used in the drinking water treatment plants.

Another coagulant is polyaluminium chloride (PACl) that has chemistry similar to that of alum, except that PACls contain highly charged polymeric aluminium species as well as the monomers as alum. A higher DOC removal was observed when chlorine is added after treatment with polyaluminium chloride (PACl). Enhanced coagulation by combination of alum and polymer technique could be used to improve THMs precursor removal (Bolto *et al.* 1999, Hubel *et al.* 1987). 60% removal of TOC was achieved using coagulation-sedimentation-filtration with alum (Symons 1975). Improving coagulation and altering the point of chlorine addition after removal of significant portion of the TOC can produce effluent water with lower trihalomethane levels. Modified coagulation was also found to be successful at reducing the concentrations of trichloroacetic acid, dichloroacetic acid and dibromochloroacetic acid as well as TTHMs (Reckhow *et al.* 1990). Similar observations were made by Bose *et al.* 2007. USEPA has identified enhanced coagulation (EC) as one of the best available technologies for reducing DBP precursors in conventional water treatment plants under Stage-I of the disinfectants/disinfection by-products rule (D/DBPR) (USEPA 1998).

Pre coagulation, with polyaluminium chloride (PACl) or aluminium sulphate (alum) have been found to significantly improve the ability of a microfiltration membrane to remove organic material and THM precursors contained in raw water (Berube *et al.* 2002).

Ferric chloride not only functions as a reactant to remove water impurities but it also functions as both a coagulant and a flocculent (CA water Technologies). DOC and UV 254 removal of 42% and 63% were achieved using ferric chloride. As the ferric chloride dosage increased further, the reduction in DOC and UV 254 also increased gradually (Boorman *et al.* 1999, USEPA 2003). Coagulation coupled with intermediate ozonation was more effective on removing SUVA and decreasing DBPs formation than that of coagulation alone (Bose *et al.* 2007, Cabassud *et al.* 1990).

The use of disinfectants other than chlorine is another way to control the concentration of halogenated by-products. Two major disinfection alternatives (ozone and chloramines) with regard to DBP formation potentials had been examined by various researchers. Studies have revealed 9-11% reduction in the concentration of THMs and HAAs when chloramine or ozone was used compared to that of chlorine and also when chloramines or ozone was used as a secondary disinfectant (Clark *et al* 1994, Morris *et al.* 1978, Norman *et al.* 1980, Nissinen *et al.* 2002, Siddiqui *et al.* 1995). It was observed that when chloramine was used for disinfection, pH plays a significant role in DBPs formation.

Although various methods of coagulation alone or in combination with other techniques are used for the treatment, coagulation coupled with alum showed the best results for THMs removal. Polyaluminium chloride (PACl) has chemistry similar to that of alum, but contains highly charged polymeric aluminium species. Disinfectants other than chlorine are another way to control the concentration of halogenated by-products. Modified coagulation has added advantages of being less cost intensive and more reliable process as compared to other treatment techniques.

3.3 Adsorption

Adsorbents like carbon based and polymer based compounds are used to remove the natural organic matter (NOM) present in water. One of the best available technologies recommended by the USEPA for the control of DBPs is the adsorption of precursor such as NOM by granular activated carbon (GAC) (USEPA 1998). In general, precursors are more absorbable than DBPs therefore adsorption by activated carbon is generally applied before chlorination (Singer *et al.* 2002, 2003). A pilot plant study carried out at Athens water treatment plant showed that the efficiency of GAC for the removal of TTHMs is 3.5 times, 3 times for HAAs and 4.5 times for DOC as compared to GAC post filter adsorber (Babi *et al.* 2005). The removal of THMs and the most part of a small part of HAAs and DOC may be attributed to biological activity in the filter bed. The adsorption kinetics of THMs on activated carbon fibre (ACF) and granulated activated carbon (GAC) showed that with the increase in adsorption time the removal percentage of the four species of THMs also increases, while when the adsorption time was longer than 0.5 h, the removal percentage of three bromine substituted THMs ($CHBrCl_2$, $CHBr_2Cl$ and $CHBr_3$) was almost up to 100%, and that of $CHCl_3$ was more than 90% (Ma *et al.* 1992). Chloroform was significantly removed by the treatment of biological activated carbon (BAC) in comparison with the ozone treatment (Young Gyu Park 2002).

The GAC adsorbs some of NOM (humic and fulvic acids), thereby reducing the amount of TTHMs formed upon chlorination. The result for GAC indicated a trend somewhat similar to that for ACF, but the removal percentage was significantly lower than that of ACF.

3.4 Oxidation

Many studies have been done in the past tp explore the possibility of removing trihalomethanes by oxidation, using either ozone or chlorine dioxide as the oxidant. Combined treatment by ozone and UV was much more effective, lowering the concentration of trihalomethanes to one half of their initial values. Ozone is known as a powerful oxidant which can reduce the disinfection by products effectively, OH radicals in comparison to ozone have a higher oxidation potential and can react more rapidly with most organic compounds (Glaze *et al.* 1998). During last two decades, advanced oxidation processes (AOPs) have been applied to enhance the bio degrability of refractory organic pollutants and xenobiotics found in the ground water (Scott *et al.* 1995). A common objective of the AOPs is to produce large amount of radicals (especially OH) to oxidize the organic matter. The combination of ozone and hydrogen peroxide is used essentially for the oxidation of contaminants, which is difficult and consumes large amount of oxidant (Legube *et al.* 1999, Mokrini *et al.* 1997).

3.4.1. Permanganate pre oxidation

Permanganate has long been used to remove iron and manganese from ground water, to control taste and odour, in particular of algal origin. It has also been used as a disinfectant and an algicide. Recent studies indicated significant improvements through the application of potassium permanganate. It was shown that permanganate with pre oxidation obviously enhanced the coagulation of several kinds of surface waters, with substantial reduction in the settled turbidity (Ma *et al*. 1991, 1996). The quality of filtered water was also improved by permanganate preoxidation through a jar test and direct filtration process (Ma *et al.* 1991, Norton *et al*. 1997). It was demonstrated that permanganate preoxidation reduced the THMFP for surface waters and also reduced the formation of chlorophenols in the chlorine-disinfection process (Ma *et al.* 1994, Siddiqui 1996) as well as showed substantial reduction in mutagenic activities in filtered and disinfected waters (Larson *et al*. 1979). The use of potassium permanganate as a pre-treatment process preceding alum coagulation could reduce the level of chloroform in the treated water when the raw water contains high proportions of monomeric precursors (Ma *et al.* 1998).

3.5 Aeration

The volatile nature of the THMs aids in their removal from water by aeration. Rook (1976) studied the removal of chloroform in a 4 m high cascading countercurrent aerator. The results of this study showed that there was a 50% removal of chloroform at an air–to–water ratio of 3.2 to 1 (Rizzo *et al.* 2005).Three modes of aeration techniques, viz. diffused, quiescent and cascade had been studied to analyze the efficiency of the aeration techniques in the removal of individual THMs in water **(**Tan *et al.* 2005, Teksoy *et al.* 2008, Ma *et al.* 2001).The removal of chloroform, DCBM, DBCM and bromoform was found to be 94.2, 95, 93.7 and 77.3 % respectively in tray type cascade aerator with a contact period of 12.5 min. The removal efficiency of free fall cascade aerator for chloroform, DCBM, DBCM and bromoform at 5 l/min flow rate has been found as comparatively lower 62.70, 55.80, 67.65 and 71.30 % respectively. Quiescent aeration was carried out in tanks exposed to the atmosphere for 5 days. There was a steep increase in removal (80%) up to 42 hours of exposure but thereafter the increase is slow and gradual.

Among different types of aeration techniques tray type cascade aerator showed the better removal of THMs but all the above methods suffers from the disadvantage of being time dependent.

3.6 Advanced techniques

More interesting proposition to remove THMs and their precursors from water involves the application of membrane techniques. Depending on the barrier structures and the transmembrane gradients used, different membrane processes like reverse osmosis, nano filtration/ultra filtration and electro dialysis are also used.

3.6.1 Ultra Filtration

Ultra Filtration membranes with cut-off exceeding MW 1000-5,000 are not particularly efficient for removal of THM-precursors (Johnson *et al.* 1986). Hydrophilic membranes were found to give much better results than hydrophobic membranes supported by results of trial operation in pilot plants in France (Cabassud *et al.* 1990). Ultrafiltration membrane UPM-67 removed 98.1 to 99.2% of humic acid from aqueous solutions with the addition of a weakly basic, cationic water soluble polymer. To achieve NOM removals in excess of 75%, membrane filtration generally requires the use of nano filters with membranes having molecular weight of cutoffs of 200-500D (Taylor *et al.* 1987). Nano filtration techniques using different types of membranes like NF200 and DS5 had been evaluated to determine their THMs removal efficiency (Singer *et al.* 1980). NF200 membrane removed more THMs than DS5 membrane suggesting the NF membranes as one of the best available technologies for removing THM compounds.

3.6.2 Ion-exchange membrane

Anion exchange processes have received increased attention in recent years as an efficient alternative technique for removing DOM (Bolto *et al.* 2002, Bruggen *et al.* 2003, Glazeet *et al.* 1993) that are not readily removed by conventional techniques. Advantages of employing anion exchange in water treatment is its low cost as compared to activated carbon (Golfinopoulos *et al.* 2001), the ability to regenerate resins after the treatment without using a thermal process, saving energy, prolonged resin life and effective in reducing TTHMs formation by removing relatively large organic fractions, which accounted for the majority of THM production (Li *et al.* 1997, USEPA 2003). Ion exchange resins preferentially removed smaller highly charged hydrophilic molecules, which also exhibited significant THM formation potentials (Bolto *et al.* 2002). The treatment with a combination of enhanced coagulation and a magnetic ion exchange resin was very effective in removing THMs and HAAs precursors, and it was better than coagulation alone (Singer *et al.* 1999).

The formation of chlorinated DBPs in drinking water like trihalomethanes (THMs) has emphasized the need for exploring new treatment technologies and alternate disinfectants for controlling the DBP formation in water. Because organic/inorganic substances act as precursors for DBPs, their removal prior to disinfection has proven to be an effective method for reducing chlorinated DBP formation potential. Conventional treatment methods like coagulation, flocculation, sedimentation and filtration are used for the removal of CBPs. Alum is most widely used as a coagulant but it has been found out that there are other coagulants that do a more efficient and good job for precursor removal. PACls has been identified as the most economical and efficient coagulant for the removal of organic precursors. But the main disadvantage with PACl is that it is more expensive than other coagulants. Another effective method to control chlorinated DBPs in drinking water is the use of alternative disinfectants - ozone, chloramines, chlorine dioxide and more recently ultraviolet (UV) light - alone or in combination with chlorine. The use of various disinfectant alternatives to chlorination must be considered, however, they may form non-chlorinated DBPs. Among the methods studied, GAC adsorption seems to be the most applicable for reducing the levels of DBPs but it is relatively expensive process. Membrane filtration may be promising as a truly non-chemical disinfection method however the need to maintain a residual disinfectant in the distribution system means a chemical disinfectant would still have to be added after this process because such devices can become sources of bacterial contamination in water. Despite the potential advantages of membrane filters, relatively little work have been done to investigate the ability of ion exchange treatment of DOM to reduce subsequent DBP formation. Finally, a better control of operational factors (e.g. control of pH or disinfection contact time) may contribute to a reduction in the formation of DBPs.

4. GUIDELINE VALUES OF DBPs FORMATION

Identification of disinfection by products and concern over the possible adverse health impacts of these compounds has promoted considerable research interest world-wide in order to minimize risks of cancers other diseases. USEPA, WHO and the EU have already set-up regulations for THMs in drinking water. In 1979, the USEPA initiated a regulatory standard of 100µg/L for TTHMs under the safe drinking water Act. The European Union (EU) drinking water standard has also introduced total THMs levels of 100µg/L. To assure consumers that drinking water is safe and can be consumed without any risk, The WHO published drinking water guidelines for a few DBPs including THMs, haloacetic acids (HAAs), haloacetonitriles (HANs), chlorite, chloral hydrate, formaldehyde and cyanogen chloride (Waniek *et al.* 2002). According to WHO guideline the values for THMs are,60μg/L for BDCM, 100μg/L for bromoform, 300μg/L for chloroform, and 100μg/L for DBCM. In addition to individual THM guidelines, the WHO has also suggested that the sum of the ratios of the THM levels to the guideline values should not exceed 1 (Sadiq *et al.* 2004). In Germany the guideline value for total THMs is 10µg/L. In Canada the regulatory situation is comparable to Australia and accordingly standards are laid down. The U.S. EPA revised this rule when it issued the Stage 1 Disinfectants/Disinfection By-Products Rule (D/DBP) in 1998 reducing the MCL for TTHMs to 80 ppb. A concentration level of 60µg/L has also been introduced for the sum of all five HAAs and 10µg/L for bromate. Bromate and chlorite are also regulated by USEPA (2001a).

5. CONCLUSION

This paper has reviewed on the one hand the formation of the Disinfection By-products and on the other hand their control in drinking water supplies. Moreover this paper has mainly focused on the removal technologies which are in use and are reported to reduce the concentration of the compounds.

Based on the review done it can be concluded that not only chlorine but other disinfectants like ozone, chloramines and chlorine dioxide have also been reported to form DBPs. As chlorine is the most widely used disinfectant, the risk is more with chlorination. Hence, an optimized and careful maintenance of these factors can reduce the level of DBPs formed. Coagulation and adsorption are the two most widely used control techniques for DBPs as they are cheaper and easy to apply methods. Enhanced and optimized coagulation have also been reported to significantly reduce the concentrations of DBPs from water. Aeration and oxidation methods have also been tested for their THMs removal efficiency and have been found to give an acceptable result. Advanced techniques like reverse osmosis, membrane technologies like nano filtration, microfiltration and ultra filtration and ion exchange methods are nowadays used for the removal of DBP precursors and DBPs from water. These methods have been found to be highly efficient and showed high percentage removal of DBPs. But due to their high costs their use is a constraint for developing and less developed countries. Therefore Pre-ozonation – enhanced coagulation – activated carbon filtration treatment train appears to be the most effective method for reducing THM precursors in drinking water treatment. India has not developed any regulatory standards for this disease causing compounds due to the lack of sufficient occurrence data from all over the country. No control measures are taken in the water treatment plants to remove these compounds. Hence it is highly appropriate to develop a database for the occurrence of DBPs in drinking water and simultaneously, their control measures.

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TREATMENT OF TEXTILE WASTEWATER CONTAINING AZO DYES BY PHYSICAL AND CHEMICAL PROCESSES

Raja Kumar[a]* and Alok Sinha[b]
[a] Research Scholar, Centre of Mining Environment, ESE Department, ISM, Dhanbad
[b]Assistant Professor, Centre of Mining Environment, ESE Department, ISM, Dhanbad
*E-mail: raja.kumar1010@gmail.com

ABSTRACT

Textile wastewaters containing azo dyes are highly recalcitrant in nature and are difficult to treat by conventional processes. Certain azo dyes and their aromatic amine metabolites produced through biotransformation of dye compounds have been found to be carcinogenic. The release of colored wastewaters represents a serious environmental problem and a public health concern. Color removal, especially from textile wastewaters, has been a big challenge over the last few decades; until now there is no single and economically attractive treatment that can effectively decolorize textile mill effluent. Tightening government legislation has prompted the textile industry to find appropriate and environmentally friendly treatment technologies to achieve increasingly high effluent standard. This review paper highlights and provides an overview of major physical and chemical methods for treatment of wastewater containing azo dyes. The advantages and disadvantages of the various methods are discussed and their efficiencies are compared to highlight their current limitations and future research needs.

1.0 INTRODUCTION

The textile industry has been condemned as being one of the world's worst offenders in terms of pollution. As many as 2,000 different chemicals are used in the textile industry, from dyes to transfer agents. Over 100,000 commercially available dyes exist and over $7x10^5$ tons of synthetic dyes are produced annually worldwide. There are many structural varieties, such as, acidic, basic, disperse, azo, anthroquinone based and metal complex dyes. In 1991, the world production of dyes was estimated 668,000 tons (Ollgaard *et al.*, 1998) of which azo dyes contributed 70% (ETAD, 1997). This group of dyes is characterized by reactive groups that form covalent bonds with OH–, NH–, or SH– groups in fibres (cotton, wool, silk, nylon). Due to their chemical structure, dyes are resistant to fading on exposure to light, water and many chemicals (Poots and McKay, 1976a; McKay, 1979). Many dyes are difficult to decolourise due to their complex structure and synthetic origin.

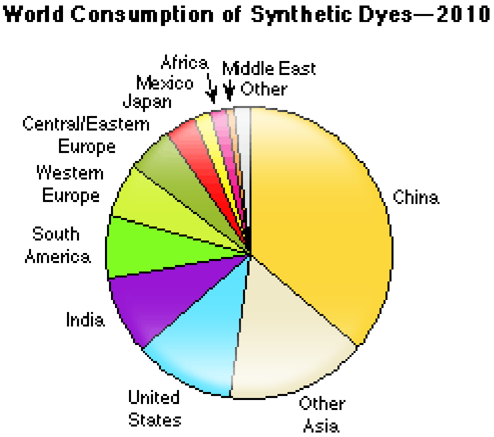

Figure 1: World Consumption of Synthetic Dyes (Source SRI, 2010)

All aromatic compounds absorb electromagnetic energy but only those that absorb light with wavelengths in the visible range (~350-850 nm) are colored. Dyes contain chromophores (delocalized electron systems with conjugated double bonds) responsible for color and auxochromes (electron-withdrawing or electron-donating substituent that intensify the color of the chromophore by altering the overall energy of the electron system) (Christie, 2001). Common chromophores are -C=C-, -C=N-, -C=O, -N=N-, $-NO2$ and quinoid rings, and usual auxochromes are $-NH_3$, -COOH, $-SO_3H$ and –OH (Van der Zee, 2002). The auxochromes can belong to the classes of reactive, acid, direct, basic, mordant, disperse, pigment, vat, anionic and ingrain, sulphur, solvent and disperse dye (Welham, 2000).

During production, the cloth has to pass through various processes and chemical operations like sizing, desizing, scouring, bleaching, mercerizing and dyeing processes (EPA, 1997; Dos Santos, 2001; Dos Santos et al., 2006a). In these processes, a number of dyes chemicals and auxiliary chemicals are used to impart desired quality in the fabrics. According to an estimate about 10-15% of dyes are lost into the wastewater during the dyeing process (Zollinger, 1987). Approximately 75% of the dyes discharged by Western European Textile-processing industries belong to the classes of reactive (~36%), acid (~25%) and direct (~15%) dyes, all of which are dye classes with mostly azo dyes. With the increased use of a wide variety of dyes, pollution by dye's wastewater is becoming increasingly alarming. Decolouration of textile dye effluent does not occur when treated aerobically by municipal sewerage systems (Willmott et al., 1998).

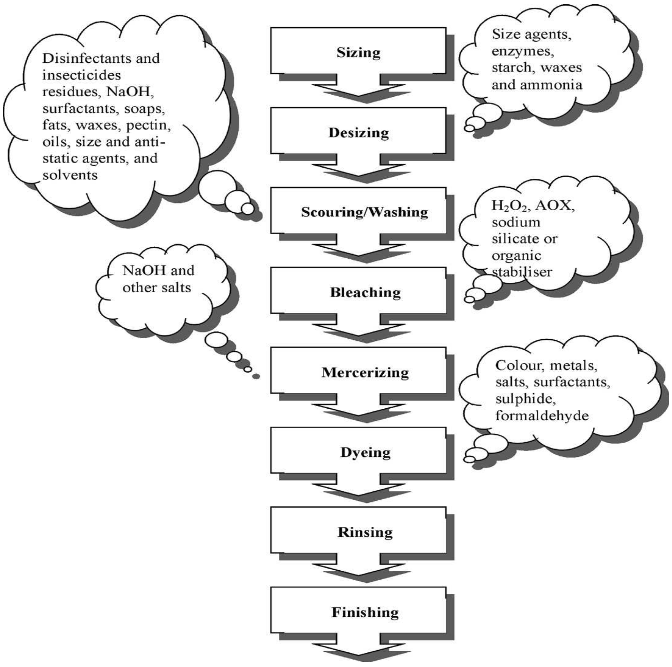

Figure 2: Schematic of operations involved in textile cotton industry and the main pollutants from each step [adapted from Dos Santos et al. (2006a)]. AOX: Adsorbable Organic Halogens.

1.1 Characteristics of effluent from Textile industries

Textile mills produce mixed wastewater in large quantities, up to 600 m^3 per kg fabric, that are characterized by high organic load, up to 1000 mg COD/l, and the presence of dyes. The common characteristics of textile wastewater are high chemical oxygen demand (COD), high biological oxygen demand (BOD), high temperature, high pH, solid materials, phenol, sulphur and the colors caused by different dyes. In textile dyeing process alone, 40-65 liters of wastewater is generated per kg of the product (Manu and Chaudhari, 2002), thus, becoming the major pollution source in textile industry. The main characteristic parameter of the wastewater, that appears at the end of the dyeing process, is color and the source of that decomposed and colloidal formed color are the dyeing substances used in those processes (Olmez et al., 2006). The color of the effluent is harmful for life. Moreover, disposal of wastewater on an open ground can contaminate drinking water sources imparting color as well as bad taste. Typical effluent characteristics of textile waste water are given in Table 1**.**

Table 1: Typical raw effluent characteristics of textile waste water (Ali, 2006)

PARAMETER	*RANGE*
pH	*6-10*
Temperature	*35-45^{0}C*
Total Dissolved Solids	*8000-12000 mg/l*
BOD	*300-500 mg/l*
COD	*100-1500 mg/l*
Total Suspended Solids	*200-400 mg/l*
Chloride	*3000 -6000mg/l*
Free Chlorine	*< 10 mg/l*
Sodium	*70 %*
Trace elements ligands (Fe ,Cu, Zn, As, B, F,V, Mn ,CN, Hg, PO_4, Ni)	*<10 mg/l*
Oil & Grease	*10-30 mg/l*
TKN	*10-30 mg/l*
NO_3- N	*< 5mg/l*
Free Ammonia	*< 10 mg/l*
SO_4	*600-1000 mg/l*
Silica	*< 15 mg/l*

1.2 Health Impacts of Dyeing Industry wastes

Many dyes are visible in water at concentrations as low as 1mg/ l. Textile- processing wastewaters, typically with dye content in the range 10-200 mg/l (O'Neill *et al.,* 1999) are therefore usually highly colored and discharge in open waters presents an aesthetic problem. As dyes are designed to be chemically and photolytically stable, they are highly persistent in natural environments. The majority of dyes pose a potential health hazard to all forms of life (Prakash and Solank, 1993). These dyes may cause allergic responses, skin dermatoses, eczema (Su and Horton, 1998), and may affect the liver (Jaskot and Costa, 1994), the lungs, the vasco-circulatory system, the immune system and the reproductive system (Nikulina et al, 1995) of experimental animals as well as humans. Textile dyes have found to be toxic, genotoxic and mutagenic in various test systems (Friedman et al, 1980).

Reduction of azo dyes, i.e. cleavage of the dye's azo linkage(s), leads to formation of aromatic amines and several aromatic amines are known mutagens and carcinogens. In mammals, metabolic activation (reduction) of azo dyes occurs due to bacterial activity in the anaerobic parts of the lower gastrointestinal tract, liver and kidney (Van der Zee, 2002) and the released aromatic amines are absorbed by the intestine and are excreted in the urine. The acute toxic hazard of aromatic amines is carcinogenesis, especially bladder cancer. In 1975 and in 1982, the International Agency for Research on Cancer (IARC) summarized the literature on suspected azo dyes, mainly amino-substituted azo dyes, fat-soluble azo dyes and benzidine azo dyes, but also sulphonated azo dyes (IARC, 1975). Mostly, genotoxicity is associated with all aromatic amines with benzidine moieties, as well as with some aromatic amines with toluene, aniline, and naphthalene moieties. The toxicity of aromatic amines depends on the nature and location of other substituent. As an example the substitution with nitro, methyl or methoxy groups or halogen atoms may increase the toxicity; whereas substitution with carboxyl or sulphonate groups generally lower the toxicity (Chung and Cerniglia, 1992).

The Ministry of Environment and Forests, Government of India has prohibited the handling of benzidine based dyes vide the notification published in the Gazette in January, 1990. As per this notification, handling of all the 42 benzidine based dyes is prohibited from 1993 onwards. These are related to ban amines. The Ministry of Environment and Forests has further prohibited the handling of 70 more azo dyes which came under the banned category as per the notification published in the Gazette on 26th March, 1997. Thus, the Ministry of

Environment and Forests has prohibited the handling of 42+70=112 dyes which are capable of releasing any of the harmful amines.

Table 2: Aromatic amines and potential dye metabolites that may be considered human carcinogens (Brown and DeVito, 1993)

Aromatic amine group	*Human Carcinogen evidence*
1-Napthylamine	*Slight/Mixed*
2-Napthylamine	*Good*
2,5-diaminotoluene	*Slight*
3,3-Dichlorobenzidine	*Slight/Mixed*
3,3-Dimethoxybenzidine	*Slight/Mixed*
3,3-Dimethylbenzidine	*Slight*
4-Biphenylamine	*Good*
4,4-Nitrobiphenyl	*Slight/Mixed*
4,4-Methylenebis (2-Chloroaniline)	*Slight*
Auramine	*Slight*
Benzidine	*Good*
Magenta	*Slight*
N-Phenyl 1-2-napthylamine	*Some*
N,N-Bis (2-chloroethyl)-napthylamine	*Good*

This review illustrates the study of most widely used physical and chemical methods of dye removal from azo dye containing textile wastewater. It highlights the efficacy and limitations of these physical and chemical technologies.

2.0 PHYSICAL METHODS

2.1 Adsorption

Adsorption of synthetic dyes on inexpensive and efficient solid supports was considered as a simple and economical method for their removal from water and wastewater. The good sorption characteristics of sulfonated coals for the removal of synthetic dyes have also been demonstrated (Mittal and Venkobachar, 1993). Activated carbon is the most common adsorbent (Walker and Weatherley, 1997) and is very effective for adsorbing cationic, mordant, and acid dyes and to a slightly lesser extent, dispersed, direct, vat, pigment and reactive dyes (Raghavacharya, 1997; Rao et al, 1994). It has been further found that powdered active carbon efficiently removes the azo dyes Orange P and Red Px from wastewater (Danis et al., 1999). A similar study proved that granular activated carbon can bind acid dyes (Walker and Weatherley, 1997). The good adsorption capacity of silica was exploited in the removal of the textile dye Acid Red 4(Saleem et al., 1993). Wood chips show a good adsorption capacity for acid dyes although due to their hardness, it is not as good as other available sorbents (Nigam et al., 2000) and longer contact times are required (Poots and McKay, 1976). A number of low-cost adsorbent materials like peat, bentonite clay and fly ash, have been investigated on color removal (Ramakrishna and Viraraghavan, 1997; Anjaneyulu et al., 2005). However, the efficiency of these materials varied with the dye class.

2.2 Coagulation/Flocculation

Important factors influencing the mechanism of coagulation–flocculation included the coagulant dose and the initial pH. Decolorization of dye-containing effluent using mineral coagulant produced electro-coagulation was studied by Zidane et al (2008).They labeled the inorganic coagulants used as C1 (produced from electrolysis of NaOH, 7.5×10^{-3}M), C2 (from electrolysis of NaCl, 10^{-2} M) and C3 (from electrolysis of NaOH, 7.5×10^{-3} M + NaCl, 10^{-3} M). Results showed that the best performance of CI Reactive Red 141 removal was obtained with C2. The comparison between chemical treatment using C2 coagulant and direct electro-coagulation revealed that in the first 10 min, the removal efficiency was higher using C2 as compared to direct electrocoagulation. However, after 60 min of treatment, direct coagulation showed 100% removal of CI Reactive Red 14. Papic et al (2003) studied the combined effect of Al(III) coagulation and activated carbon. Coagulation as a main treatment process followed by adsorption achieved almost the total elimination of both dyes from wastewater with significant reduction (90%) of chemical oxygen demand (COD), total organic carbon (TOC) and adsorbable organic halide (OX). Recently electrokinetic coagulation has been found to be economically feasible method of dye removal. It involves the addition of ferrous sulphate and ferric chloride, allowing excellent removal of direct dyes from wastewaters. Unfortunately, poor results with acid dyes, with the high cost of the ferrous sulphate and ferric chloride, means that it is not a widely used method (Robinson et al, 2001). Production of large amounts of sludge occurs and this results in high disposal costs (Gahr et al., 1994).

2.3 Membrane Filtration

Filtration methods such as ultrafiltration, nanofiltration and reverse osmosis have been used for water reuse and chemical recovery. Han et al(2010) used copoly(phthalazinone biphenyl ether sulfone) (PPBES) ultrafiltration (UF) membrane with low molecular weight cut-off which is suitable to be used in dye wastewater treatment at high temperature It showed 100% rejection for Congo Red. Wastewater generated by a textile factory during dyeing of cotton with reactive dyes was treated using membrane filtration (Altenbaher & Turk, 2009). Three membranes were used in this study, one membrane for nanofiltration (NF) and two membranes for reverse osmosis (RO). The value of pH, COD, conductivity and coloration in terms of SAC were determined before and after filtration. Results revealed that the treated wastewater can be reused in the dyeing process. The main drawbacks of membrane technology are the high investment costs, the potential membrane fouling, and the production of a concentrated dye bath which needs to be treated (Robinson et al., 2001).

3.0 CHEMICAL PROCESSES

3.1 Oxidation

This is the most commonly used method of decolourisation by chemical means mainly due to its simplicity of application. The main oxidizing agent is usually hydrogen peroxide (H_2O_2). This agent needs to be activated by some means, for example, ultra violet light. Many methods of chemical decolourisation vary depending on the way in which the H_2O_2 is activated (Slokar and Le Marechal, 1997). Chemical oxidation removes the dye from the dye-containing effluent by oxidation resulting in aromatic ring cleavage of the dye molecules (Raghavacharya, 1997).

3.1.1 Fentons reagent (H_2O_2/Fe^{2+} salts)

Fenton’s reagent is a suitable chemical for treating wastewater which are resistant to biological treatment (Slokar and Le Marechal, 1997). Chemical separation uses the action of sorption or bonding to remove dissolved dyes from wastewater and has been shown to be effective in decolourising both soluble and insoluble dyes (Pak and Chang, 1999). This method is relatively cheap and also presents high COD removal and decolourisation efficiencies (Van der Zee, 2002). The main process drawbacks are the high sludge generation due to the flocculation of reagents and dye molecules (Robinson et al., 2001) as well as the need for decreasing the bulk pH to acidic conditions. Fenton's oxidation (FO) was used to degrade Remazol Black 5, Remazol Red, Remazol Blue, Remazol Yellow and was found highly effective in their decolourisation (>99%)(Meric et al, 2005). More than 95% of colour was removed with Fenton’s oxidation process for RB5, RB13, and AO7 azo dyes (Badawy and Ali, 2006).

3.1.2 Ozonation

The use of ozone was first pioneered in the early 1970s, and it is a very good oxidising agent due to its high instability (oxidation potential, 2.07) compared to chlorine, another oxidising agent (1.36), and H_2O_2 (1.78). Oxidation by ozone is capable of degrading chlorinated hydrocarbons, phenols, pesticides and aromatic hydrocarbons (Lin and Lin, 1993; Xu and Lebrun, 1999). The dosage applied to the dye-containing effluent is dependent on the total colour and residual COD to be removed with no residue or sludge formation (Ince and Gonenc, 1997) and no toxic metabolites (Gahr et al., 1994). Ozonation leaves the effluent with no colour and low COD suitable for discharge into environmental waterways (Xu and Lebrun, 1999). This method shows a preference for double-bonded dye molecules.One major advantage is that ozone can be applied in its gaseous state and therefore does not increase the volume of wastewater and sludge. The biodegradability index (BOD_5/COD) of textile waste water tends to increase due to ozone. However, this increase depends on the type and concentration of dye (Al-kdasi, 2004) Bio-treated textile wastewater on 40-60 min ozonation yielded 99% of decolourization efficiency (Ahmet et al, 2003).

A disadvantage of ozonation is its short half-life, typically being 20 min. This time can be further shortened if dyes are present, with stability being affected by the presence of salts, pH, and temperature. In alkaline conditions, ozone decomposition is accelerated, and so careful monitoring of the effuent pH is required (Slokar and Le Marechal, 1997). One of the major drawbacks with ozonation is cost; continuous ozonation is required due to its short half-line (Xu and Lebrun, 1999).

3.1.3 UV/H_2O_2

In this process, HO radicals are formed when water-containing H_2O_2 is exposed to UV light, normally in the range of 200–280 nm (Metcalf and Eddy, 2003).The H_2O_2 photolysis follows the reaction:

$$H_2O_2 + UV \longrightarrow HO^{\bullet} + HO^{\bullet}$$

Degradation is caused by the production of high concentrations of hydroxyl radicals. The rate of dye removal is influenced by the intensity of the UV radiation, pH, dye structure and the dye bath composition (Slokar and Le Marechal, 1997). There are advantages of photochemical treatment of dye-containing effluent; no sludge is produced, foul odors are greatly reduced and a high COD removal in a short retention time is achieved (Safarzadeh et al., 1997). UV light activates the destruction of H_2O_2 into two hydroxyl radicals. This causes the chemical oxidation of dyes.

Galindo and Kalt (1998) have demonstrated that UV-H_2O_2 process is able to destroy totally the chromophoric structure of dyes with the varying reaction rates for different monoazo dyes. pH plays a significant role in the discoloration of dyes by H_2O_2/UV process. The process has been found to be more effective in an acid medium in context to discoloration. Amin et al (2008) demonstrated that increasing the pH from the 7.29 to 11.11 led to a decrease in the removal efficiency from 100% to 86.96%.

3.1.4 TiO_2/UV

The mechanism lies in the production of OH free radical by induction of electron transformation using UV illuminati-on. Although its mechanism is similar to that of H_2O_2/UV, O_3/UV, etc, TiO_2 is preferred over other due to its stability under various conditions, its high potential to produce radicals and its easy availability and low price (Vogelpohl and Kim, 2004). A study on effect of TiO_2/UV on acid blue 9 has shown the degradation efficiency to be 97%.The azo dye Acid Orange 7 was successfully decomposed on titanium oxide particles in visible light in the presence of oxygen (Vinodgopal et al., 1996). Monoazo dyes were more easily decomposed than trisazo dyes; disazo dyes were not included in the experiment (Reutergardh and Iangpashuk, 1997). Tanaka et al (1999) studied photocatalytic degradation of seven azo dyes in TiO_2 suspension. They achieved 75% TOC removal. Silva et al (2005) studied the degradation of three commercially available textile azo dyes, Solophenyl Green BLE 155% (SG), Erionyl Red B (ER) and Chromotrope 2R (C2R), has been studied by using photochemical and photocatalytic processes under UV irradiation. They achieved high degradation efficiency at low initial dye concentration.

3.2 Reduction

Chemical reduction of azo dyes is not very famous because it leads to the generation of harmful aromatic amines which are more harmful than the parent dye molecule and needs further treatment. However, chemical reduction process like Zero valent iron has been used in combination of other methods as a pretreatment alternative.

3.2.1 Zero valent iron

The reduction of azo dyes by Fe^0 is of interest, not only for its potential application in the decolorization of waste-waters from dye use and manufacturing, but also because it provides a convenient model system for invesigating (i) the abiotic reduction of azo linkages and (ii) the kinetics of fast reactions with granular iron metal. Fe^0 has recently been studied to decolorize textile wastewater (Weber, 1996; Cao et al, 1999; Deng et al, 2000; Nam and Tratnyek, 2000). The destruction of the azo bond (N=N) in the chromophore of azo dyes leads to decolorization of the dye solutions as shown in figure 3. The iron particle is oxidized while the dye molecule is reduced. The dye molecule receives electrons from the iron and combines with H^+ from an acid to form the transitional product. This product gains electrons and combines with H^+ again, forming the terminal products (Cao et al, 1999). Additionally, in the presence of Fe^0, aromatic azo compounds are susceptible to reduction to produce aromatic amines which are easily degraded by microorganisms (Nam and Tratnyek, 2000). Several experiments also confirm that under reactive conditions, azo dyes are decomposed through N-N cleavage with the formation of aromatic amines such as aniline (Pielesz et al, 2002; Zhang et al, 2005). As aromatic amines are toxic, a combination treatment of zero-valent technique with other wastewater treatment technologies may be required.

Batch kinetic studies using different dyes show that the decolourization rate follows first order equation (Nam and Tratnyek, 2000). It was found that only small amount of dyes was adsorbed on the iron.Lin et al (2008) investigated the removal of AB24 dye in aqueous solution by nano/micro-size zero-valent iron. Results indicated that the degradation efficiency increases with increasing ZVI concentration and temperature but decreases with particle size of ZVI.

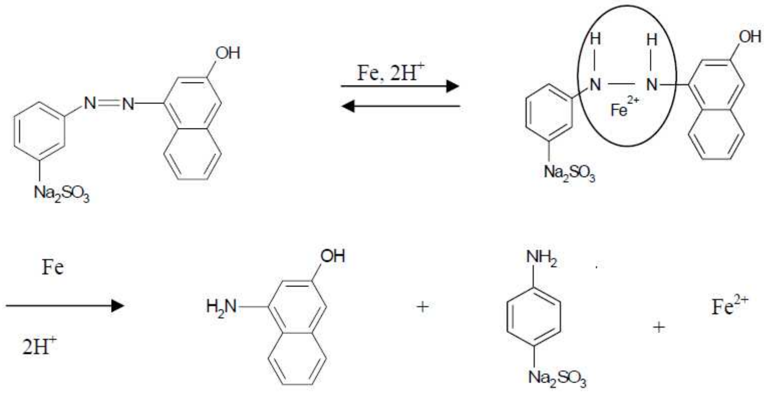

Figure 3: Degradation mechanism of Acid Orange II in Fe^0-H_2O system (Cao et al, 1999)

4.0 CONCLUSIONS

All the decolourisation methods described in this review have both advantages and drawbacks, and their selection will depend on the wastewater characteristics like class and concentration of dye, pH, salinity and toxic compounds. Physical and chemical methods of dye removal are effective only if the effluent volume is small. This limits the use of physical methods, such as membrane filtration and coagulation, to small-scale in situ removal. Compared to the physical treatment technologies advanced oxidation processes like Fenton's reagents and ozone are found more efficient for the complete mineralization of azo dyes. But cost is a major limiting factor for these methods. Therefore, the treatment of textile wastewater to meet the prescribed effluent standards should be composed of a sequence of treatments, and each scenario should be analyzed individually. Selection of a particular method will depend on their treatment cost, operational simplicity of the technology, treatment efficacy with actual contaminated water and nature of treatment by-products formed.

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ANAEROBIC AMMONIUM OXIDATION (ANAMMOX) PROCESS FOR NITROGEN REMOVAL – A REVIEW

Swati Tomar[1], Dr. S. K. Gupta[2] & B.K.Mishra[3]
1.Student (M.tech, Environmental Science and Engineering, 2. Associate Professor & 3. Assistant Professor
Department of Environmental Science and Engineering,
Indian School of Mines,Dhanbad – 826004 Jharkhand, INDIA

ABSTRACT

Nitrogen is being considered as one of the essential parameter in waste water treatment systems, as it has significant adverse impacts on the environment. Anaerobic ammonium oxidation (Anammox) is a biological process in which ammonium is directly converted to dinitrogen gas with nitrite as the electron acceptor under anoxic conditions (Jetten et al., 1999). The Anammox reaction was first discovered in a denitrifying pilot plant reactor in Delft, the Netherlands (Mulder et al., 1995), and today Anammox reactions have been reported from several other treatment plants (Egli et al., 2001; Fux et al., 2002; van Dongen et al.,2001). The Anammox process is a new and promising alternative to the conventional nitrogen removal processes. The application of Anammox to nitrogen removal would lead to a significant reduction of costs for aeration and exogenous electron donor as compared to the conventional nitrification–denitrification

process (Van Dongen et al., 2001).There are three genera of Anammox bacteria found so far in different environmental habitats such as marine sediments, water columns, arctic sea ice, subtropical mangrove sediments and fresh water. No organic carbon is needed in such nitrogen removal systems, since ammonia is used as electron donor for nitrite reduction. This paper reviews a various nitrogen removal technologies; microbial aspects (occurrence, physiology, microbiology and biochemistry) of *ANAMMOX*, followed by comparison of different electron acceptors used in *ANAMMOX* process and finally highlights the implication of the *ANAMMOX* process for nitrogen management.

Keywords: Wastewater, nitrogen, nitrification, and ANAMMOX

1. INTRODUCTION

Water demand is increasing rapidly with increased industrialization and growing population. Conventional wastewater treatment plants have not been designed for nitrogen removal, and many plants do not meet the current discharge limits (Jetten et al., 2002). Rapid growth in industrialization and development during the last few decades has led to the discharge of a number of pollutants into various environmental resources specially water bodies. This has led to drastic deterioration of water quality world over. Hence, water pollution control is presently on high priority among pollution control agencies because water is a basic human need . Nitrogen in wastewater treatment effluent can cause a serious problem to receiving watercourses, such as Eutrophication.

Conventionally, treatment of nitrogen can be achieved by nitrification followed by a denitrification process.

Recent findings indicated that nitrogen removal can also be accomplished through ‘‘anaerobic ammonium oxidation’’(Anammox) under anaerobic conditions. The uncovered process can save up to 90% of operation cost as compared to typical nitrogen treatment processes (Jetten et al., 2001).Wastewater originated from many other sources such as tannery, food processing, fertilizer manufacturing, slaughter house, landfill leachate and coke oven contain greater amount of nitrogen load, which should be treated before discharge into the surface water body (Table 1). Wastewater containing huge amount of nitrogen compounds is not allowed to be released to the surface water as it has ecological impacts and can affect human health (Kelter et al. 1997).

Chemical, Physicochemical and biological methods are broadly used for treatment of wastewater loaded with highly concentrated NH4+-N. In considering the criterion like cost-benefit analysis, requirement of energy and chemical doses, familiarity with operational procedures, and environmental sustainability, a particular treatment for a specific pollutant is usually selected

According to Mulder (2003) three concentration ranges could be differentiated:

- *NH4+-N concentration less than 100 mg NH4+-N/l* - In this range biological N-removal is the preferred process based on cost-effectiveness. Domestic wastewater is within this range.
- *NH4+-N concentrations in the range 100-5000 mg NH4+-N/l* - A typical example is sludge liquor for which after extensive investigations biological treatment was preferred (Janus *et al*., 1997). Although ammonia stripping and producing MgNH4PO4 were identified as interesting alternatives for resource recovery these options were not cost-effective (Priestley *et al*., 1995; Janus *et al*., 1997).
- *NH4+-N concentrations greater than 5000 mg NH4+-N/l* - In this range physicochemical method
  are technically and economically feasible. A successful example is the steam stripping of a wastewater with an ammonium concentration of 1.5% followed by ammonia recovery which has been in operation on industrial scale since 1985 (Harmsen *et al*., 1986).

Table 1. Wastewater containing high concentrations of nitrogen content

Sources of Nitrogen	TN (mg/L)	Reference
Landfill leachate	500 - 2500	Chung et al (2003)
Starch Production	800 - 1100	Abeling and Seyfried (1993)
Wastewater from pectin industry	1600	Deng Peterson et al (2003)
Wastewater from slaughter house, after treatment in aerobic lagoon	170 - 200	Keller et al (1997)
Wastewater from tannery	128 - 185	Marat et al (2003)
Coke Oven Effluent	50	Mulder (2003)
Discarded water	260 - 958	Gil and Choi (2004)

Means of treatment in which the application of physical forces predominate are known as unit operations. Means of treatment in which removal of contaminants is achieved by the addition of chemicals or by biological activity are known as unit processes. The unit operations and chemical unit processes occur in various combinations in different treatment systems, but the fundamental principles of their operation do not change .The principles developed can be applied to design the waste water treatment for nitrogen removal . Available technologies using these principles include adsorption, chemical precipitation, membrane filtration, reverse osmosis, ion exchange, air stripping, breakpoint chlorination (Aguilar et al. 2002) investigated physico-chemical removal of NH_4-N using activated silica, powdered activated carbon and precipitated calcium carbonate. They found very low ammonia removal of around 3–17%. Ion exchange usually employs organic resins, which are very selective but expensive. However, there are cheaper alternative natural and waste materials that can be used to replace high cost materials. Various researchers have studied the effectiveness of a variety of low cost materials for ammonia removal such as clay and zeolite (Sarioglu, 2005; Demir et al., 2002; Celik et al., 2001; Rozic et al., 2000); limestone (Aziz et al., 2004a); natural and waste materials such as waste paper, refuse cement and concrete (Ahsan et al., 2001) and sepiolite and activated sepiolite (Ozturk and Bektas, 2004; Balci and Dincel, 2002).

2. BIOLOGICAL NITROGEN REMOVAL

The two most important nitrogen converting processes in traditional nitrogen removal in wastewater treatment plants are nitrification and denitrification. The biological process is cheaper and is the most widely practiced approach for nitrogen control in wastewater treatment.

Nitrification: conversion of ammonia into nitrite (NO_2-), and then into nitrate (NO_3-), which is the form that plants take up mostly. It is carried out by nitrifying bacteria under aerobic conditions.

Denitrification: conversion of nitrate (NO_3-) back to gaseous nitrogen (N_2) and, to a lesser extent, nitrous oxide gas, which is a strong greenhouse gas. It is carried out anaerobically by denitrifying bacteria. Through denitrification nitrogen is removed from ecosystems and it is a way to contrast the increased nitrogen fixation.

In Table 2, three process options of the new system are presented and compared to a conventional nitrogen removal system based on autotrophic nitrification and heterotrophic denitrification system

Table 2. Qualitative comparison of several components of the ANAMMOX technology with conventional Nitrogen removal systems

System	Sharon	Anammox	Cananon	Conventional nitrification dinitrification
Number of reactor	1	1	1	2
Feed	Wastewater	Ammonium Nitrite mixture	Wastewater	Wastewater
Discharge	NH_4+, NO_2-	N_2, NO_3-	N_2, NO_3-	N_2, NO_3-; NO_2-
Conditions	Oxic	Anoxic	Oxygen limited	Oxic; anoxic
Oxygen requirement	Low	None	Low	High
pH control	None	None	None	Yes
Biomass retention	None	Yes	Yes	None
Sludge production	None	None	None	Yes
Reactor capacity (kg N/m3day)	1	6-12	1-3	0.05-4
Bacteria	Aerobic NH_4+ Oxidizers	Planctomycetes	Aerobic NH_4+ oxidizers + Planctomycetes	Nitrifiers + Various heterotrophs
COD requirement	None	None	None	Yes

3. AEROBIC AND ANAEROBIC AMMONIUM OXIDATION

Ammonium oxidation has been observed in many bacterial species. The possible pathway of Anammox process is the biological oxidation of ammonium with hydroxylamine as an electron acceptor by hydrazine hydrolase, the hydrazine forming enzyme (Jetten et al., 1999; Van Niftrik et al., 2004). Hydrazine oxidizing enzyme, which has some similarity to hydroxylamine oxidoreductase, is the responsible enzyme for hydrazine oxidation to dinitrogen gas (Jetten et al., 1999; Schmidt et al., 2003; Van Niftrik et al., 2004). The oxidation of hydrazine is supposed to generate four electrons that combine with five protons of nitrite reducing enzyme for initial reduction of nitrite to hydroxylamine (Kuenen and Jetten, 2001; Schmidt et al., 2003; Van Niftrik et al., 2004). Anaerobic ammonium oxidation (anammox) has received special attention since its discovery, because it is an efficient biological alternative to conventional nitrogen removal from wastewaters. Anammox needs ammonium and nitrite in a ratio of roughly one to one.

$$NH_4^+ + NO_2^- \Longrightarrow N_2 + 2H_2O$$

Anammox bacteria are classified in a group of planctomycete bacteria. The planctomycetes, two of which have been named provisionally; Candidatus Brocadia Anammoxidans, and Candidatus Kuenenia Stuttgartiensis, are an interesting group of bacteria with many rare or unique properties. They have a doubling time of 10–30 d and are physiologically distinct from the other known Planctomycetes:- they are anaerobic chemolithoautotrophs.

The **AN**aerobic **AMM**onium **OX**idation (***ANAMMOX***) process, which was discovered 10 year ago (Mulder, 1992) but already predicted to exist 30 years ago (Broda, 1977), could offer an alternative for the treatment of this return stream. Later, Van de Graff *et al.* (1997) and Bock *et* al. (1995) observed that nitrite was the preferred electron acceptor for the process. In the *ANAMMOX* process ammonium is oxidized under anoxic, i.e. oxygen depleted, conditions with nitrite as electron acceptor. Ammonium and nitrite are consumed on an almost equimolar basis. The *ANAMMOX* process should always be combined with a partial nitritation process, such as the SHARON process (van Dongen *et al.*,2001a&b), where half of the ammonium is oxidized to nitrite. Both autotrophic processes will increase the sustainability of wastewater treatment as the need for carbon addition (and concomitant increased sludge production) is omitted and oxygen consumption and the emission of nitrous oxide during oxidation of ammonia are largely reduced (Jetten *et al.*, 1997). As such,the combined process (partial nitritation and *ANAMMOX*) was termed autotrophic nitrogen removal process (Jetten *et al*., 2002)

3.1 Occurrence

The existence of *ANAMMOX* bacteria capable of producing nitrogen gas from ammonium and nitrate/nitrite was demonstrated for the first time in denitrifying fluidized bed reactor treating sewage sludge digester effluent and ammonia laden wastewater (Mulder et al., 1995; and Van de Graff et al., 1995),.The coccoid anammox bacteria have usually a diameter of less than 1 m and a generation time of 10 - 30 days. They belong to the order of Planctomycetes and are therefore anaerobic chemolithoautotrophs (van Niftrik et al., 2004). So far all trials to get pure cultures of anammox bacteria failed because it is very hard to isolate them. Thus there are just enrichment cultures available (Dalsgaard et al., 2005) and all we know about anammox bacteria is derived from those cultures.

3.2 Biodiversity

Three genera of anammox bacteria have been discovered so far: Brocadia, Kuenenia and Scalindua (Schmid et al., 2003). In these genera the following species have been identified from various authors:

-Brocadia anammoxidans (Strous et al., 2002)

-Brocadia fulgida (Kartal et al., 2004)

-Kuenenia stuttgartiensis (Schmid et al., 2000; Egli et al., 2001)

-Scalindua wagneri (Kuypers et al., 2003; Schmid et al., 2003)

-Scalindua brodae (Kuypers et al., 2003; Schmid et al., 2003)

-Scalindua sorokinii (Kuypers et al., 2003; Schmid et al., 2003)

3.3 Microbiology of Anammox

Ten years ago, an anaerobic ammonium oxidation ('anammox') process was discovered in a denitrifying pilot plant reactor. From this system, a highly enriched microbial community was obtained, dominated by a single deep-branching planctomycete, *Candidatus* Brocadia anammoxidans. Phylogenetic inventories of different wastewater treatment plants with anammox activity have suggested that at least two genera in Planctomycetales can catalyse the anammox process. Electron microscopy of the ultrastructure of *B. anammoxidans* has shown that several membrane-bounded compartments are present inside the cytoplasm. Hydroxylamine oxidoreductase, a key anammox enzyme, is found exclusively inside one of these compartments, tentatively named the 'anammoxosome'.The physiology of anaerobic ammonium oxidizing aggregates cultivated in a sequencing batch reactor was investigated by Strous *et al.* (1999). One of the main characteristics of anammox bacteria is the anammoxosome. It is a membrane-bound compartment in the cell bounded by a single membrane (figure 3) containing ladderane lipids. The anammox process is believed to take place inside of it (van Niftrik et al., 2004). The ladderane lipids (called ladderanes) are unique to anammox bacteria and have an unusual structure made of rigid lipids .

Growth

Anammox bacteria grow slowly. Measured doubling times in laboratory are under optimum conditions 11 days and in average 2-3 weeks (Strous et al., 2002). The biomass-yield is 0.07

C-mol fixed per mol ammonia oxidized which consists with the anammox catabolism's Gibbs free energy change (Strous et al., 1998; Strous et al., 2004). The temperature-optimum has been determined for different habitats. In waste water treatment the optimum was at 37 °C (Kuenen et al., 2001).The ph requirement is 7.5-8 . Oxygen can inhibit the growth.

3.5 Biochemistry of *Anammox*

Two possible pathways were hypothesized by van de Graaf *et al.*(1997) for the *ANAMMOX* process:

- Oxidation of ammonium ion to hydroxylamine, that reacts with nitrite which is further reduced to nitrogen. Hydroxylamine-formation from ammonium ion via the ammonium monooxygenase,however, seems unlikely because of the strong oxygen inhibition (van de Graaf et al., 1996;Jetten et al., 1999).
- Partial reduction of nitrite with the formation of hydroxylamine (NH_2OH_4), that reacts further with ammonium to form hydrazine (N_2H_2). Hydrazine is further converted into nitrogen. This oxidation would give the necessary reducing equivalents for the initial reduction of nitrite

3.6 Electron acceptors used for anammox process

Two possible pathways were hypothesized by van de Graaf *et al.* (1997) for the *ANAMMOX* process:

- Oxidation of ammonium ion to hydroxylamine, that reacts with nitrite which is further reduced to nitrogen. Hydroxylamine-formation from ammonium ion via the ammonium monooxygenase, however, seems unlikely because of the strong oxygen inhibition (van de Graaf *et al.*, 1996; Jetten *et al.*, 1999).
- Partial reduction of nitrite with the formation of hydroxylamine (NH_2OH), that reacts further with ammonium to form hydrazine (N_2H_4). Hydrazine is further converted into nitrogen. This oxidation would give the necessary reducing equivalents for the initial reduction of nitrite.

So to generate Anammox condition nitrite is required, If it is already present internally in the water to be treated we don't need to add, we just need to maintain its ratio with ammonium i.e. 1:1.In case it is not present then we need to add it externally. Once we get Anammox condition in our system then we can replace nitrite with the addition of other electron acceptors like sulphate etc.The removal efficiency will get reduce, as study has been carried out and removal efficiency achieved is 40-50% (Yang Zhiquan , 2009) .During the anammox process, the highest removal efficiency of ammonium and nitrite was up to 97 and 98%, respectively. The extra electron acceptor, such as sulfate , nitrate was thought to react with ammonium by bacteria.The removal efficiency of ammonium was achieved 40% and 30%, respectively.Here, the ammonium and sulfate in form of NH_4Cl and $NaSO_4$ was added into the synthetic water. The simultaneous removal of ammonium and sulfate was detected in the bioreactor after 60days operation. The molar ratio of ammonium to sulfate consumption was close to 2:1.

4. LIMITATIONS

One of the biggest challenges is to accelerate the slow rate of nitrogen removal from these systems (the rate is less than half that of aerobic nitrification) (Strous *et al.*, 1999; and Jetten *et al.*, 1998), as start-up period only takes plenty of time due to mainly slow growth rates of Anammox bacteria (Egli et al., 2001; van Dongen et al., 2001) (the doubling time was reported to be approximately11 days) (Strous et al., 1998). Additionally, since Anammox bacteria are strictly anaerobes and autotrophs, they are very difficult to be cultured. To promptly establish anammox reactors, appropriate seeding sludge or starter cultures must be selected and used, and sufficient amounts of anammox bacteria must be efficiently retained in the reactors.

5. FUTURE SCOPE

Providing world with suitable and most feasible technologies for removal of nitrogen, Research is necessary to know the feasibility of applying *ANAMMOX* process technology with different industrial wastewater and leachates using appropriate reactor types and configuration. The performance of*ANAMMOX* process in treating actual wastewater/leachate would not only depend on *ANAMMOX* bacteria but also on the co-existence of other important oxygen scavenging and ammonia generating/ammonia to nitrite oxidizing bacteria. Research is needed to be carried out to work out optimal conditions and to find feasibility of using different electron acceptors for such an ecosystem to sustain in a reactor and develop methodologies to monitor the responsible microbial community in the system.

6. DISCUSSION

Analysing various treatment methods of nitrogen removal from waste water and comparing with Anammox , removal of ammonia from waste water via Anammox is very cost effective and efficient method to be adopted by industries for waste water treatment.

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COMPACTION OF FLY ASH OF JHARIA COAL FIELDS, INDIA

***Neha Shreya ,** Aviral Singh Rana ,**Vipin Singh Rawat and *Dr. Biswajit Paul
***Junior Research Fellow,.** M. Tech Student,.*Associate Professor,
Department of Environmental Science & Engeeniring
,Indian School of Mines, Dhanbad.

ABSTRACT

Fly ash is produced in million tons all over the world and regarded as solid waste material. A basic concept of utilizing it in an economical and environmental friendly manner is its utilization as a construction material. The utilization of fly ash as a constituent material in the formation of a natural landfill barrier to protect municipal leachate needs proper compaction of the construction material in order to achieve maximum impermeability. A comprehensive series of compaction tests were conducted on fly ash of Jharia coal fields to evaluate the effect of test parameter on the effectiveness of compaction. The effect of each parameter was evaluated and analyzed using data interpretation.

Key words: Fly ash, compaction, data interpretation.

1. INTRODUCTION

The major contribution to India’s power production programme comes from coal based thermal power stations, hydroelectric power generation and non - conventional sources (wind ,tidal and nuclear etc.) According to Central Electricity Authority of India on March 31, 1998 total 82 coals fired power plants and 305 hydro power plants existing in India. Total installed capacity, of coal energy at thermal power plant in India is 53216 MW/Day (67% of total power output) – India most abundant fuel resource. A thermal power plant uses around 1,000 tons of coal and churns out 13.34 tons (coal: fly ash = 75:1) of fly ash. Fly ash in itself is a waste product and contains a huge problem for disposal. (Singh et al, 2007). Studies have shown that fly ash dumping would continue to cause groundwater contamination, surface water contamination during flooding events, and air pollution relative to dust emission via wind erosion, if preventive measures are not implemented. Studies also have shown that even where some leaching of trace elements from fly ash has occurred, its effects didn’t pose public health risk.

In many engineering practices soil is used as a construction material. Since the properties of fly ash are very similar to those of soil so an approach was developed to use fly ash as a construction material. The properties of coal fly ash are strongly dependent on the geological origin and the combustion process of the coal. It is important to characterize regional fly ash in detail to ascertain its potential uses as raw material in the production of high value products. The Fly ash can be effectively used as construction/building material due to its cementitious character. Fly ash is pozzolanic in nature. Pozzolana is a siliceous and aluminous material which reacts with calcium hydroxide in the presence of water to form compounds possessing cementitious properties at room temperature. In addition to underwater use, the pozzolana's high alkalinity makes it especially resistant to common forms of corrosion from sulphates. It can replace up to 50% by mass of Portland cement, which can add to the final strength of the concrete and increase chemical resistance and durability (Regional Research Laboratory (CSIR), 2003). Fly ash is also used as a component in the production of flowable fill (also called controlled low strength material, or CLSM), which is used as self-leveling, self-compacting backfill material in lieu of compacted earth or granular fill. Flowable fill includes mixtures of Portland cement and filler material and can contain mineral admixtures, such as fly ash. Filler material usually consists of fine aggregate (in most cases, sand), but some flowable fill mixes may contain approximately equal portions of coarse and fine aggregates. More recently, fly ash has been used as a component in geopolymer mixtures. Another new application is using fly ash in roller compacted concrete dams. .In the construction engineering such as highway, embankments and earth dams, for example loose fills as are required to increase the soil density and improve their strength characteristics. Compaction is the most common and important method of soil improvement. The densification of soil by the application of mechanical energy is known as compaction (Ranjan G., Rao A.S.R., 2010). Compaction generally leads to an increase in shear strength and helps improve the stability and the bearing capacity of the soil. It also reduces the compressibility and permeability of the soil. The degree of compaction is measured in terms of dry unit weight, i.e., the amount of soil solids that can be packed in a unit volume of the soil.

2 MATERIAL AND METHODS

2.1 Study area

The Jharia Coalfields (JCF): It is one of the most important coalfields in India, located in Dhanbad district, between latitude 230 39' to 230 48' N and longitude 860 11' to 860 27' E the chief mining area is the eastern part of the field. This is the chief house of metallurgical coal of India. This is the most exploited coalfield because of available metallurgical grade coal reserves. This coalfield is also affected by about 70 mine fires, spread over an area of 17.32 sq. km., blocking 636 million tons of coking coal and 1238 million tons of non-coking coal. There are about 15 large opencast mines which can be used as landfill sites for different waste materials like municipal solid wastes, industrial waste as well as fly-ash from thermal power plants. Development of a landfill barrier will reduce the problem of ground water contamination. In the present study, Tata Iron & Steel Company Limited (TISCO) power plant (10 MW capacity), Jamadoba, Jharia Coalfields (JCF) and Chandrapura thermal power station (CTPS)and Bokaro Thermal Power Station (BTPS) were selected as they are very near to ISM Dhanbad. The Tata Iron & Steel Company Limited consists of six collieries in the Jharia division, located in the Dhanbad district of Jharkhand, which is about 180 km away from Jamshedpur city, and 12 km away from Dhanbad district of Jharkhand. Chandrapura thermal power station is located in the Bokaro district of Jharkhand state. It is 50 km from the Dhanbad and 1 km from the Chandrapura railway station and situated at Dhanbad –Bokaro roadways and BTPS is 80 km from Dhanbad district. Fly ash samples were collected from the respective sites and brought in sealed plastic bags to Geotechnical engineering laboratory of ISM Dhanbad.

2.2 Aim and Objective

The objective of the current study was to determine the compaction characteristics of the fly ash and to attain maximum dry density so that the compacted mixture would allow very low hydraulic conductivity and the fly ash of Jharia coal fields can be considered as a constituent material for the construction of a natural land fill barrier.

2.3 Laboratory analyses

An extensive laboratory testing program was carried out to determine the compaction characteristics of fly ash. The compaction characteristics (B.I.S., 1987) of fly ash were studied in the laboratory using Standard Proctor test. The equipment used in the test consists of cylindrical mould (with detachable base plate) having an internal diameter of 100 mm and 127.5 mm effective height, whose internal volume is 1000 ml. The rammer has a mass of 2.6 kg with a drop of 310 mm.

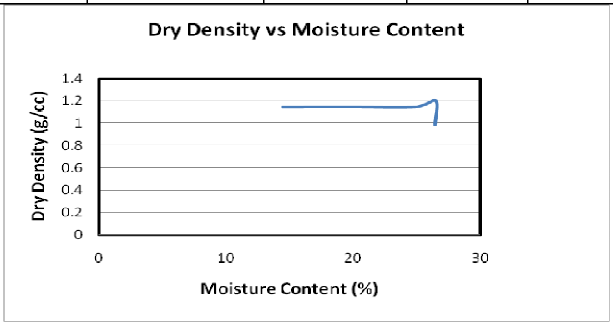
In compaction test, tests had been carried out at each specific ash using various range of water content. A premeasured amount of fly ash 2000 gm, measured as percent of dry soil by weight, was mixed thoroughly to produce a homogeneous fly ash mixture. Water was added slowly during mixing as 5 % each time before compaction of fly ash sample. The relationship between dry density of solid particles and moisture content waste samples was determined. The degree of compaction of a given fly ash is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the moisture content and dry density to obtain the maximum dry density and optimum water content.

Dry density = (M / V) / (1+ ω) where M = total mass of sample, V = volume of sample and ω=water-content.

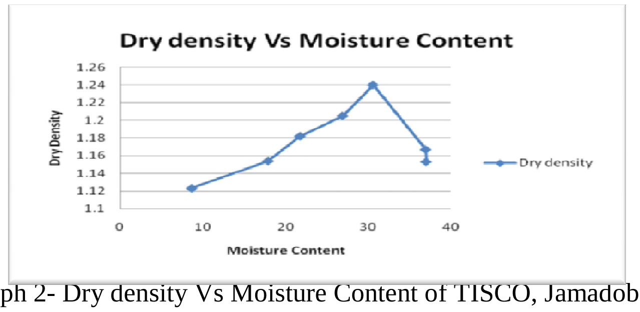
3. RESULT AND DISCUSSIONS

Table 1. Values of Maximum Dry Density and Moisture Content of Fly ash Samples.

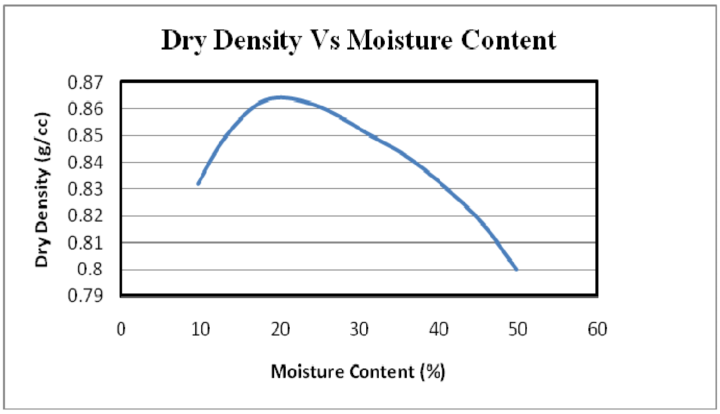
Sample	Moisture content (%)	Dry Density (g/cc)	Sample	Moisture content (%)	Dry Density (g/cc)	Sample	Moisture content (%)	Dry Density (g/cc)
Fly ash of CTPS	14.41	1.1430	**Fly ash of TISCO Jamadoba**	8.63	1.1231	**Fly ash of BTPS**	09.69	0.8320
	19.45	1.1450		17.88	1.1545		13.29	0.8500
	24.84	1.1433		21.77	1.826		18.14	0.8630
	26.48	1.12000		26.92	1.2055		24.14	0.8619
	26.42	0.9850		30.60	1.2404		30.98	0.8510
				37.01	1.1679		37.04	0.8400
				37.06	1.1533		44.70	0.8200
							49.77	0.8000



Graph 1- Dry density Vs Moisture Content of CTPS



Graph 2- Dry density Vs Moisture Content of TISCO, Jamadoba.



Graph 3- Dry density Vs Moisture Content of BTPS.

Ash mixtures of different samples were prepared and tested by the standard proctor compaction procedure. The compacted dry unit weight versus the moisture content curves of the ash mixtures are displayed in the Graph 1, 2, and 3. The values of maximum dry unit weight and corresponding optimum water content are tabulated in Table 1. The results were plotted in the form of dry density versus moisture content curves. The maximum dry density for fly ash of CTPS TISCO Jamadoba and BTPS are 1.2 g/cc, 1.24 g/cc and 0.865 g/cc is at the optimum moisture content of 28%, 30% and 22.5% respectively. The result shows that the max dry unit weight decreases and the optimum water content increases in each case. The decrease in max dry unit weight as water content increases are associated with the notion that fly ash is light weight compared to soil only .The increase in optimum moisture content was due to water absorption by fly ash and increase in amount of held water within the flocculent fly ash structure and also follows from the need to release the capillary tension from the greater exposed surface of the fine fly ash particles. Maximum dry density was achieved to reduce permeability and prevent cracking in land fill barrier and to have a stronger material to prevent build-up of high pore water pressure. Thus an increased max dry density would produce a fly ash material which is stronger, less compressible and less permeable and can be used as a constituent material in the construction of a landfill barrier.

4. CONCLUSIONS

Soil densification include compaction and consolidation, it is a process that brings about an increase in soil density or unit weight, accompanied by a decrease in air volume. There is usually no change in water content. The purpose of compaction is to improve strength and stiffness of fly ash and to decrease voids ratio and so permeability. Optimum moisture content is also achieved by doing compaction. Here in this case OMC of three samples that is CTPS, TISCO and BTPA are 28%, 30% and 22.5 % respectively. Compaction results in a decrease of thickness of sedimentary units associated with progressive expulsion of pore fluid and reduction of pore space processes which ultimately result in porosity loss. (Perrier and Quiblier, 1974; Sclater and Christie, 1980, Taylor et al 2008). Compared with the max dry unit weight of compacted soil and max dry unit weight the values of ash mixtures tends to be lower than those of soils, which range typically from 17 kN/m3 to 20 kN/m3 (U.S. Navy., NAVFAC DM-7, 1986). In addition, the specific gravity of Fly ash also contributes to the reduced dry density of the sample (Bund R., 2010). It is recommended to carry out a detailed research to evaluate the potential effect of fly ash of Jharia coal fields as land fill barrier constituent material with very low permeability by adding some additive materials like bentonite which would decrease the permeability to the maximum extent so as to protect underground water from the municipal and other harmful leachate.

ACKNOWLEDGEMENT

We are thankful to the Department and staff members of the Department of Environmental Science & Engineering, ISM Dhanbad for providing their help and laboratory facilities to complete this research work.

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GROUNDWATER MANAGEMENT IN MINING AREAS

Navneet Sharma[a] Komal Agrawal[b], Alok Sinha[c] and Brijesh K. Mishra[d]
[a,b]B.Tech. Student, [c,d]Assistant Professor, Department of Environmental Science and Engineering, ISM, Dhanbad
E-mail: aloksinha11@yahoo.com

ABSTRACT

Groundwater resources in Mining areas are vulnerable to exploitation both quantitatively and qualitatively. Excessive pumping of groundwater during mining activities causes depletion of precious resource. Breaching of groundwater table and exposure of minerals deteriorates the groundwater quality. This paper discusses various impacts of mining activities on physical hydrology and quality of water. The groundwater may be polluted due to generation of Acid Mine Drainage, heavy metal contamination, radioactive contamination and pathogenic contamination. Paper highlights various management options to be carried out during the mining activities.

1.0 INTRODUCTION

The crucial role groundwater plays as a decentralized source of drinking water for millions rural and urban families cannot be overstated. According to some estimates, it accounts for nearly 80 per cent of the rural domestic water needs, and 50 per cent of the urban water needs in India. Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. Also, the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata. Due to mining operations the groundwater resources have been threatened and chances of contamination increases. Mining operations such as drilling and blasting the ground water is breached and huge pumping of water results into loss of groundwater aquifers. On the other hand exposure of minerals to atmosphere may lead to problems such as acid mine drainage (AMD) and groundwater pollution by heavy metal contamination. Sustainability of groundwater can only be achieved if both qualitative and quantitative aspects are being considered. Quantitative problems are faced mainly due lack of planning, data collection and improper management of water resources. On the other hand qualitative aspects can be improved by studying the geology of the area, climatic patterns, pollution sources, regular monitoring and appropriate remediation methods depending on the groundwater characteristics. Qualitative and quantitative aspects can be simultaneously taken care by proper treatment and management of groundwater.

The objective of this review paper is to identify different sources of water contamination during mining activities, their impacts and management techniques to mitigate these problems.

2.0 IMPACT OF MINING ON PHYSICAL HYDROLOGY

Mining operations alter the physical hydrology directly by removal of aquifers if any, increasing the permeability of ground and nearby areas and fracturing leading to increase of porosity and storativity. Road construction, logging, and clearing of areas for buildings, mills, and process facilities can reduce infiltration and increase the amount of surface runoff to streams and other surface water bodies. Constructions of stream diversions and ditches that control and divert runoff from upland watersheds prevents the contamination of water from mine wastes but they often alter natural drainage patterns in a watershed, which, in turn, can impact vegetation resources, wetlands, and wildlife habitat. Pumping ground water lowers the water table in the immediate area of a well, creating a “cone of depression” which extends radically outward from the well. A dewatered mine acts as a large diameter well; consequently the water table in an aquifer can be drawn down for a relatively large radial distance. Drawdown can affect the direction of ground water flow by shifting gradients and lines of flow toward the mine or well field (Younger, 2003).

3.0 IMPACTS OF MINING ON GROUNDWATER QUALITY

3.1 Acid Mine Drainage

Acid mine drainage (AMD) is one of the most perpetual pollution problem which occurs world-wide in the mining areas. It refers to the distinctive type of wastewater that originates from the weathering and leaching of sulphide minerals present in coal and metalliferrous ore bodies. Digging introduces rapid circulation of oxygen and water into the deep geoshpere, in zones where there are high concentration of oxidizable minerals (sulphides). The sulphide minerals which were previously present in the reduced environment now get a chance to oxidise and thus lead to formation of sulphates and increase in acidity of mine water. Similarly the waste dumps created during mining show similar kinds of reactions and thus leading to AMD.

Following reactions represent the oxidation of FeS_2 and production of acid (H+):

$2FeS_2(S) + 7O_2 + 2H_2 = 2Fe^{2+} + 4\ SO^{2}_{4} + 4H^{+}$

$Fe^{2+} + \frac{1}{4}\ O_2 + O_2 + H^{+} = Fe^{3+} + \frac{1}{2}\ H_2O$

$Fe^{3+} + 3H_2O = Fe(OH)_3(S) + 3H^{+}$

$FeS_2(S) + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2\ SO\ ^{2}_{4} + 16H^{+}$

From the above reactions it is quite clear that pyrite oxidation in presence of Ferric(III) ions is highly acidity producing and thus even more dangerous. In general, the pyrite oxidation depends on: the surface area of pyrite, the form of pyretic sulfur, oxygen concentration, solution pH, catalytic agents, flushing frequencies, and the presence of thiobacillus bacteria.

Groundwater produced generally is a vital resource to humans and can be utilised in many ways but due to AMD which leads to increase in acidity of the mine water further leading to pollution of that water due to heavy metal contamination. As acidity of water increases its ability to leach trace elements substantially increases thus polluting the mine water and making it unfit for any further utilization. On the other hand it becomes a liability to the environment as its mixing with the surface waters may lead to destruction of aquatic ecosystems due to change in ph and trace elements further devastating its effects.

AMD is generally caused by open-cut and underground mining of base metal sulphide deposits, precious metal deposits or uranium deposits with sulphide minerals, sulphide rich heavy mineral sands, coal deposits. In India mine waters of north eastern coal fields and mines with high pyrite contents are affected by this problem (Banerjee and Singh, 1993).

3.2 Heavy metal contamination

The presence of heavy metals in groundwater is generally influenced by the geological formations. Mineralized bedrock will act as a source of metals to the local environment through physical and chemical weathering processes. The presence of metals in solution in groundwater will not only reflect the magnitude of metal inputs but will be controlled by the solubility of metals in solution, which is in turn influenced by chemical parameters including pH and Eh. Metal mining is one of a large number of human activities that can result in groundwater contamination, especially with heavy metals such as Cadmium, Copper, Lead, Zinc, Arsenic, etc. Arsenic is produced by phosphate mining and is a by product of copper, gold and Lead refining. Trace elements are present in earth surface in quite low quantities and generally do not dissolve in water. Only under highly acidic and oxidising conditions significant quantities of these metals are found. The exposure of these metals to the atmosphere and water may dissolve these contaminants. These elements can be lethal for drinking purposes even if present in very small quantities many of them being potent carcinogens.Tailings may contain trace quantities of metals found in the host ore and substantial amounts of added compounds used in the extraction process. These toxic substances may get into the surface water bodies and groundwater as well during runoff and infiltration processes thus leading to contamination of water resources. If these tailings are used in back filling of mines or are abandoned as it is along river banks then they may cause contamination of the hydrological basins.

Heavy metal contamination may occur due to the exposure of rock containing various metals like arsenic, copper, zinc, lead, cadmium, cobalt, zinc comes into contact with water. The metals are leached out especially when the pH of water is low and in occurrence of AMD in mines (Reza et al., 2009). Oxidation of exposed minerals can lead to acidic leachate which can dissolve a number of trace metals like PbS releases lead, (Zn, Fe, Cd) S releases Zn, Fe and Cd which can reach groundwater as well as surface water. Extraction of Chromite from Sukinda Valley, Orrisa, resulted in high Cr (VI), Fe and Cu contents in groundwater during post monsoon seasons (Dhakate and Singh, 2008). Dhanbad town reported high Mn and Fe Contents (HPI<100). Near Kolaghat Thermal Power Station (KTPS), high Concentration of trace elements like Al, Li, As, Zn, Ag, Sb, Si, Mo, Ba, Rb, Se and Pb, due to leaching from ash pile, were reported (Mandal and Sengupta, 2005). Dubna Manganese Mines, Orrisa also reported high Levels of Mn in urinary level (>10mg/l), whole blood level (>19mg/l) and serum level (>1.3mg/l) of the workers though less than 0.4 mg/L Mn was reported in groundwater (Das and Goswami, 2008). Copper Mining may also lead to Arsenic contamination. Run-off from OB Dumps and tailing ponds can be a source of contaminant leachate.

3.3 Radioactive Contamination

These days with the nuclear energy in emergence there have been considerable mining of radioactive elements throughout this world especially uranium. The ores of these elements contain low quantities of uranium (generally<0.1%) and thus produce a lot of overburden waste which is still potentially injurious to us. Mine tailings form these contain numerous radioactive elements and continue to contaminate the environment long after the mine has been closed. It is estimated that mine tailing retain 85% of their original radioactive energy. In a process known as in situ leaching which is rarely used the uranium is released from rock into the groundwater using a solvent and then pumped to the surface which may totally contaminate the groundwater. In general the process of extraction of groundwater involves the uses of multiple toxic chemicals including industrial solvents and strong acids and bases which are released in the tailings pond. Other than this mining of other minerals and coal may generate some radioactive wastes. Saline waters from underground coal mines in Poland often contain natural radioactive isotopes, mainly ^{226}Ra from the uranium decay series and ^{228}Ra from the thorium series. As a result of precipitation of radium from radium-bearing waters, highly radioactive deposits are formed (Csövári at al., 2003).

3.4 Pollution due to UCG (Underground Coal Gasification)

UCG is a newly emerged technology which is used to generate energy from coal without actually excavating the coal seam. A variety of hazardous water-born contaminants have been identified during different UCG operations conducted so far, and in some locations long term groundwater contaminations were observed. Characteristic organic UCG-related pollutions are mostly the phenols, benzene with its derivatives, polycyclic aromatic hydrocarbons, and heterocycles. In the inorganic array, ammonia, cyanides, sulphates, and heavy metals are usually identified. Although the fact that the coal rank affects the contaminants formation and release processes during the UCG is known, the information is still scarce.

3.5 Mineral Processing Chemicals Pollution

This kind of pollution occurs when mineral processing chemical agents (such as ammonia, phenol, cyanide, sulphuric acid used by mining companies to separate the target mineral from the ore) spill, leak, or leach from the mine site into nearby water bodies. These chemicals can be highly toxic to flora and fauna of the area (www.safewater.org).

3.6 Effluent from Workshops and Vehicle Wash Plants

Mining needs extensive transportation system and excavation, thus a number of excavators and HEMM are employed in mining areas. These vehicles require regular maintenance and washing. Thus the effluents from the workshop thus contain suspended particles, oil and grease. Since this effluent is in small quantities, the problem can be solved by collecting and treating the effluent in the workshop area only (Banerjee & Singh, 1993).

3.7 Pathogenic Contamination from Municipal Waste Water

Sewage generated from the communities living near the mining areas may result in pathogenic contamination of drinking water resources. This may lead to various water borne diseases like cholera, typhoid, dysentery, jaundice etc. in mining areas. Significant Faecal coliform organisms were reported in Subarnarekha River near the copper and uranium mines (Banerjee & Singh, 1993).

4.0 WATER RESOURCE MANAGEMENT AT MINING AREAS

For more efficient environmental management of water, it is recommended to include aspects like reduced consumption, the efficient use of water resources and the sustainable management of aquifers and ecosystems that supply them. Following steps may be taken to manage the water resources in mining areas:

- In order to manage resources at the site, it is key to have water consumption measurement systems in each step of the mining production process. It is advisable for all mining operations to have a complete water balance that allows them to assess the current situation, provide corrective actions for reducing consumption, assess the impact of these actions and consider these practices in future plans.
- Augmentation of mined out water, its treatment and use as drinking water source for the communities living mining areas. Simple treatment methods like settling, filtration, coagulation and flocculation followed by disinfection may prove to beneficial.
- Abandoned mines may be source of major water pollution. Thus backfilling of mine voids by OB materials and additional sand and soil must be done to prevent pollution of water resources.
- Treatment and neutralization of Acid Mine Drainage (AMD) must be done to prevent the heavy metal contamination in water resources.
- Afforestation and vegetation, by utilizing the native species, must be carried out to reduce the erosion and sedimentation in mining areas.
- Top soil must be conserved and preserved before the commencement of mining and must be utilized during the backfilling of mine voids. Top soil cover, having high nutrient value, will promote the vegetation in the area and will help in eco-restoration of mined out areas.
- The effluents from the workshops and domestic use must be properly treated and then discharged into the surface water bodies
- Mine water must be treated properly using conventional treatment methods or by using constructed wet lands and made potable for supply to the public.
- The in-situ method of treatment like construction of Permeable Reactive Barriers may be installed for remediation of contaminated site.

5.0 CONCLUSIONS

Mining activities impose serious threat to the groundwater both qualitatively and quantitatively. This may lead to water stress and scarcity of drinking water in the mining areas. Proper management and treatment may lead to the utilization of this water resource feasibly and amicably.

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EVALUATION OF GROUNDWATER QUALITY INDEX OF THE JHARIA COALFIELD REGION, JHARKHAND, INDIA

Dipanwita Bhakat[1], Prasoon Kumar Singh [2], Gurdeep Singh[3]
SRF[1], Associate Professor[2], Professor3
Department of ESE, Indian School of Mines, Dhanbad, Jharkhand, India
Email: singh.prasoon910@gmail.com, pks0506@yahoo.co.in

ABSTRACT

Groundwater is the most important natural resource required for drinking to many people around the world, especially in rural areas. The resource cannot be optimally used and sustained unless the quality of groundwater is assessed. Assessment of water quality can be defined as the analysis of physical, chemical and biological characteristics of water. Water quality indices aim at giving a single value to the water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data. The present work is aimed at assessing the water quality index (WQI) for the groundwater of Jharia Coalfield region. This has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physicochemical analysis. For calculating the WQI, the following 10 parameters
have been considered: pH, Alkalinity, Turbidity, TDS, Total Hardness, Ca++, Mg++, $Cl^{- -}$, $SO^{--}_{4,}$ NO^{--}_{3}. The WQI for these samples ranges from 45 to 101in Pre monsoon and in Post monsoon ranges found from 52 to 126. The high value of WQI has been found to be mainly from the higher values of total dissolved solids, hardness, and manganese in the groundwater. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption and it also needs to be protected from the perils of contamination.

Keywords: Water quality index, Groundwater quality, National sanitation foundation

INTRODUCTION

Water is one of the most indispensable resources and is the elixir of life. Life is not possible on this planet without water. It exists in three states namely solid, liquid and gas. About 97.2% of water on earth is salty and only 2.8% is present as fresh water from which about 20% constitutes groundwater. Groundwater is highly valued because of certain properties not possessed by surface water. Water, a natural resource which has been used for different purposes, namely for drinking, domestic, irrigation and industrial, mainly depends on its intrinsic quality hence it is of prime importance to have prior information on quality and quality of water resources available in the region, while planning developmental projects. Peoples around the world have used groundwater as a source of drinking water and even today more than half the world's population depends on groundwater for survival. The value of groundwater lies not only in its wide spread occurrence and availability but also in its consistent good quality, which makes it an ideal supply of drinking water. Assessment of water quality is very important for knowing the suitability for various purposes**.** Water Quality Index (WQI) is regarded as one of the most effective way to communicate water quality. Water quality index is one of the most effective tools to communicate information on the quality of water to the concerned citizens and policy makers. It, thus, becomes an important parameter for the assessment and management of groundwater. WQI is defined as a rating reflecting the composite influence of different water quality parameters. WQI is calculated from the point of view of the suitability of groundwater for human consumption.

STUDY AREA

Jharia Coalfield is located in Dhanbad district of the state of Jharkhand that is bounded within latitude 23º39´ N and 23º48´ N and longitude 86º11´E and 86º27´ E covering an area of 450 sq. km. It falls within the Survey of India topographic map numbers 73 I/1, 73 I/2, 73 I/5 and 73 I/6. A map of the Jharia Coalfield along with the sample network stations is shown in Fig.1.Physiographical Jharia

Coalfield represents a low lying flat to gently sloping topographic surface roughly corresponding to the underlying bedding structure. The average altitude of surface varies from 140 to 300 m above MSL. The central area of coalfield shows gentle slopes (1 to 3%) while northern and north western fringe exhibits gently to moderate (3 to5%) slopes. Characteristic slopes have been observed between Chandrapura and Katrasgarh, Chandrapura and Mahuda while Dhanbad-Jharia region shows appreciable variation in ground slope from almost level (0 to 1%) to gentle slope (1 to 3%). Such characteristics slope has also been observed to the south of the Jharia town upto Chasnala. The general climate of the region is of tropical monsoon with four seasons in a year. The drainage is mostly ephemeral and receives much water in rainy season which extends from June to September and also from retreating south-west monsoon during October & November. During this season, most of streams get swell by rain water and quickly drain off to perennial Damodar River.

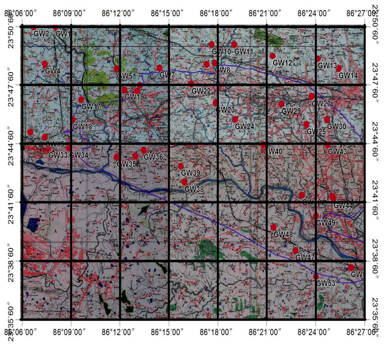

Fig 1: Location map of the study area along with sampling locations

MATERIALS AND METHODS

The water samples were collected from fifty three different dug wells during Pre and post monsoon season in and around Jharia Coalfield region. The ground water samples were collected in acid washed plastic container to avoid unpredictable changes in characteristic as per standard procedures. Ten of parameters were analyzed for WQI such pH, Alkalinity, Turbidity, TDS, Total Hardness, Ca++, Mg++, Cl^{--}, SO^{--}_{4}, NO^{--}_{3} .

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. It is calculated from the point of view of human consumption. Water quality and its suitability for drinking purpose can be examined by determining its quality index. The standards for drinking purpose have been considered for calculation of WQI. In this method the weightage for various water quality parameters is assumed to be inversely proportional to the recommended standards for the corresponding parameters.

RESULT AND DISCUSSION

The WQI was calculated using standard *Q*-value of each parameter and weighting factor by using NSF information software and compared with standard water quality rating (Table.1). The graphical representation of WQI rating in different season is given in Fig.2, Fig.3 and Fig.4.

Table 1: Status categories of WQI

WQI	Status
0-25	Very good
26-50	Good
51-75	Poor
> 75	Very poor

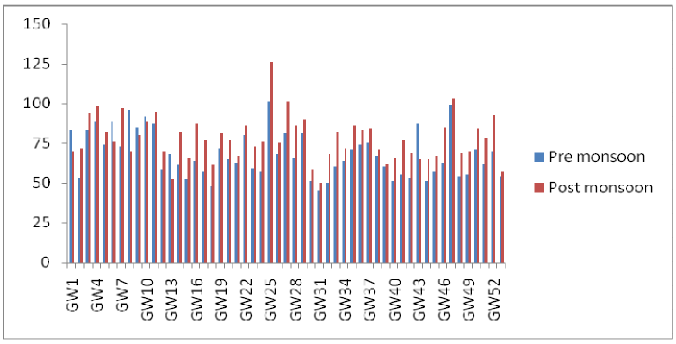

Fig 2: WQI of different locations of the Study area

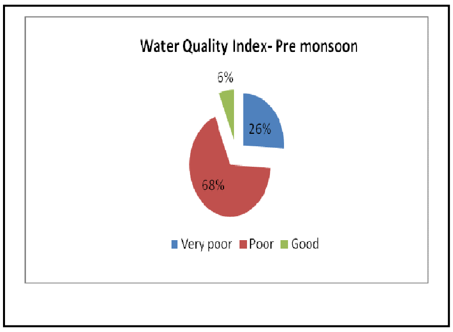

Fig 3: WQI Categories of samples (%) in Pre monsoon

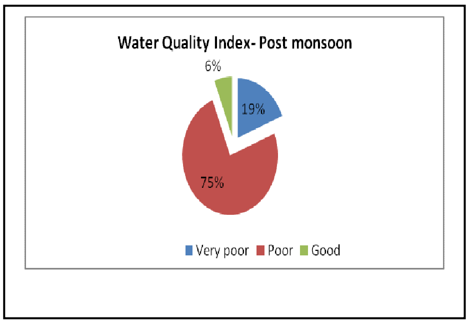

Fig 4: WQI Categories of samples (%) in Post monsoon

The observed range of WQI in pre monsoon was 45 to 101 and in post monsoon it was found 52 to 126.Only 6% water is in good condition in both pre and post monsoon season. In Pre monsoon 68% groundwater quality is poor and 26% is very poor where in Post monsoon75% groundwater quality is poor and 19% is very poor.

CONCLUSION

On the basis of the above discussion, it may be concluded that the underground drinking water at almost all the regions was disturbed as indicated by WQI. In few sites, it was moderately polluted in the study area. The groundwater quality was found to start deteriorating, after the onset of monsoon. People dependent on this water are often prone to health hazards due to poor water quality. Therefore, some effective measures are urgently required to enhance the groundwater quality by delineating an effective groundwater quality management plan for the Jharia Coalfield region.

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CONTAMINATION OF GROUNDWATER BY PESTICIDE AND ITS BIOREMEDIATION-A SHORT REVIEW

Tripti[*], Vipin Kumar [**] and Anshumali[**]
[*]JRF, [**] Assistant Professor
Department of Environmental Science & Engineering
Indian School of Mines, Dhanbad – 826 044, Jharkhand, India
e-mail: vipin_micro@rediffmail.com

ABSTRACT

The manufacturing and use of pesticides has been rising tremendously in India. The waste generated by the pesticide industry as well as by the agricultural practices has become an environmental problem due to the present insufficient and ineffective waste treatment technology involving physico-chemical and biological treatment. Bioremediation of chemical pesticides is a relatively new technology that has undergone more intense investigation as of recent decades. Pesticides are a common hazard around the world, as these chemicals are leaching into soils, groundwater and surface water and creating health concerns in many communities. The recent advances in bioremediation technology using microbial consortium has been found effective for treatment of pesticides in underground water. This process is focused on destroying or immobilizing toxic waste materials. The bioremediation of pesticides can be divided into two broad categories: in-situ and ex-situ treatment. Both methods have significant advantages and disadvantages.

Keywords: Bioremediation, pesticide, treatment, microorganisms, contamination

INTRODUCTION

A number of pesticides of different chemical nature have been used for agricultural purposes all over the world since long time. They are detected in various environmental matrices, such as soil, water and air, because of their widespread use. Pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematocides, plant growth regulators and others. The major pesticides used in the agricultural field are organochlorine and organophosphorous compounds. Organochlorine pesticides are known to resist biodegradation and takes years to get degraded. It has been cited that the degradation of DDT in soil is 75-100% in 4-30 years. This group of pesticides are believed to be possible carcinogens or mutagens as well as endocrine disruptors (Thomas et al., 1998; Peter et al., 2002). Due to its harmful effects organochlorines were banned after the 1960s in most of the technologically advanced countries which led to introduce organophosphates as an alternative compound.

Oraganophosphorous pesticides (OPPs), on other hand, are known to degrade rapidly depending on their formulation method of application, climate and the growing stage of the plant (Sankararamakrishnan et al., 2005). Organophosphorus pesticides are widely found in water resources. They are released into the environment from manufacturing, transportation and agriculture applications (Honeycutt et al., 1994). OPPs are very toxic when absorbed by human organisms because of acetyl-cholinest estrase de-activation (Toukali et al., 2005). Drinking Water Guideline (1998) of the European Union (EU) allows a maximum concentration of 0.1 g/L of each individual pesticide and 0.5g/L of the sum of pesticides in drinking water. These pesticides enter in to the water bodies by various means. The processes of transportation of pesticides through soil and into groundwater include adsorption/desorption, degradation, volatilization, runoff, and plant uptake (Helling et al., 1986). Many pesticides are not effective, and exhibit low toxicity, before they are metabolically transformed into active toxic substances (Loomis and Hayes, 1996). Pesticide concentration greater than the recommended dose pose a threat to the well-being of the environment and to human health.

Bioremediation offers the possibility to destroy or render harmless various contaminants using natural biological activity. It is an important means of detoxification of several commonly used pesticides and insecticides. Pesticides in water can be degraded by biotic and abiotic pathways. In this section, an attempt is made to review the progress made in research on the contamination of pesticides in groundwater and its degradation by mean of microorganisms.

Production and Usage of pesticide in India

India is the second largest manufacturer of pesticides in Asia after China and ranks twelfth globally (Mathur, 1999). In India the production of pesticides started in 1952 with the establishment of a BHC technical plant at Rishra near Kolkata. There has been a steady growth in the production of technical grade pesticides from 5,000 metric tonnes in 1958 to 102,240 metric tonnes in 1998 (Saiyed et al., 1999) Today, the Indian pesticides industry comprises of more than 125 basic producers of large and medium scale and more than 500 pesticide formulations. As the cropping pattern is becoming more intensive use of these chemical pesticides is also increasing.

According to a Green Peace Report, India is now producing 90,000metric tons of pesticides as the largest industry in the whole of Asia and twelfth largest in the entire world. In addition to organochlroine class of chemical pesticides, the other major category which is used in India is organophosphate pesticides. Monocrotophos, phorate, phosphamidon, methyl parathion and dimethoate are some of highly hazardous organophosphate pesticides that are continually and indiscriminately used in India. The use of herbicides and fungicides is correspondingly less heavy. The main use of pesticides in India is for cotton crops (45%), followed by paddy and wheat. Pesticides commonly used in India are presented in Table 1 (Abhilash & Singh, 2009).

Table 1. Organophosphate Pesticides commonly used in India.

Pesticide: common name	Chemical family
I a Extremely hazardous[a]	
1. Phorate	Organophosphate
I b Highly hazardous[a]	
2 Monocrotophos	Organophosphate
3 Profenofos & Cypermethrin	Combination pesticide
II Moderately hazardous[a]	
5 Dimethoate	Organophosphate
6 Quinalphos	Organophosphate
9 Chlorpyrifos	Organophosphate
11 Fenthion	Organophosphate
III Slightly hazardous[a]	
14 Malathion	Organophosphate

[a] WHO classification

Entry of Pesticides into Ground Waters

Surface runoff and erosion

Runoff is the movement of water over a sloping surface. The pesticides are either mixed in the water or bound to eroding soil. Runoff carry pesticides which are dissolved in water and pesticides sorbed to eroding soil. Runoff can also occur when water is added to a field faster than it can be absorbed into the soil. Pesticides may move with runoff as compounds dissolved in the water or attached to soil particles. (Tiryaki & Temur, 2010).

However, for most pesticides losses via runoff are considered far more important than losses via erosion, because the amount of eroded soil lost from a field is usually small compared with the runoff volume (Leonard 1990).

Leaching

Leaching is the movement of pesticides in water through the soil. The factors which influence the leaching of pesticide into groundwater include characteristics of the soil and pesticide, and their interaction with water from a rain or irrigation. Leaching can be increased when: (a) the pesticide is water soluble, (b) the soil is sandy, (c) a rain-event occurs shortly after spraying, and (d) the pesticide is not strongly adsorbed to the soil (Anonymous 2009). Leaching of water and dissolved pesticides to depth in soil occurs by matrix flow and preferential flow. Matrix flow is the slower transport process in which the simultaneous movement of pesticides with water is determined by the physical-chemical properties of the pesticides. Such movement is dependent on its water solubility, vapour pressure, K_h and K_{oc} (Cessna 2009).

Point sources

Point-source inputs of pesticides consist of runoff from hard surfaces, mostly farmyards, storage facilities or roads. The contamination of hard surfaces arises from filling and cleaning of sprayers, improper handling of tank mix left overs, leaking of faulty equipment, incorrect storage of canisters. Of course accidental spills can occur due to leaking tanks on the road to the field to be treated (Reichenberger et al. 2007).

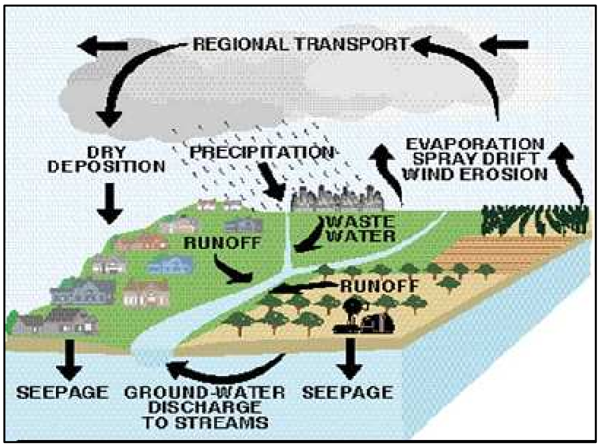

Figure 1. Pathways of pesticide into aquatic system (Kerle et al. 2007).

Principles of Bioremediation

Bioremediation is defined as the process whereby organic wastes are biologically degraded under controlled conditions to an innocuous state, or to levels below concentration limits established by regulatory authorities (Mueller et al., 1996). It uses naturally occurring bacteria and fungi or plants to degrade or detoxify substances hazardous to human health and/or the environment. The microorganisms may be indigenous to a contaminated area or they may be isolated from elsewhere and brought to the contaminated site. Bioremediation melds an understanding of microbiology, chemistry, hydrogeology, and engineering into a cohesive strategy for planned and controlled microbial degradation of specific classes of organic compounds and in certain instances, inorganic compounds. This assemblage of science and engineering requires a rigorous degree of data evaluation to determine the effect and efficiency of bioremediation.

Biodegradation of a compound is often a result of the actions of multiple organisms. When microorganisms are imported to a contaminated site to enhance degradation we have a process known as bio-augmentation. Like other technologies, bioremediation has its limitations. Some contaminants, such as chlorinated organic or high aromatic hydrocarbons, are resistant to microbial attack. They are degraded either slowly or not at all, hence it is not easy to predict the rates of clean-up for a bioremediation exercise; there are no rules to predict if a contaminant can be degraded.

Bioremediation techniques are typically more economical than traditional methods such as incineration, and some pollutants can be treated on site, thus reducing exposure risks for clean-up personnel, or potentially wider exposure as a result of transportation accidents. Since bioremediation is based on natural attenuation the public considers it more acceptable than other technologies. Most bioremediation systems are run under aerobic conditions, but running a system under anaerobic conditions may permit microbial organisms to degrade otherwise recalcitrant molecules (Colberg & Young, 1995).

A Systematic Approach to Bioremediation in Groundwater

In situ bioremediation

In situ biodegradation involves supplying oxygen and nutrients by circulating aqueous solutions through contaminated soils to stimulate naturally occurring bacteria to degrade organic contaminants (Figure 2). Generally, this technique includes conditions such as the infiltration of water-containing nutrients and oxygen or other electron acceptors for groundwater treatment.

Biosparging involves the injection of air under pressure below the water table to increase groundwater oxygen concentrations and enhance the rate of biological degradation of contaminants by naturally occurring bacteria. Biosparging increases the mixing in the saturated zone and thereby increases the contact between soil and groundwater. The ease and low cost of installing small-diameter air injection points allows considerable flexibility in the design and construction of the system.

Bioventing is the most common in situ treatment and involves supplying air and nutrients through wells to contaminated groundwater to stimulate the indigenous bacteria. Bioventing employs low air flow rates and provides only the amount of oxygen necessary for the biodegradation while minimizing volatilization and release of contaminants to the atmosphere. It works for simple hydrocarbons and can be used where the contamination is deep under the surface.

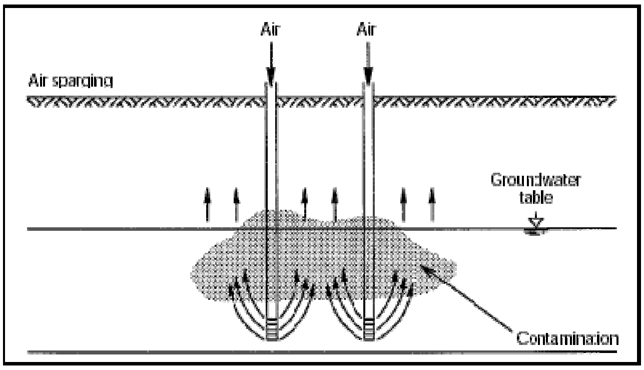

Figure 2. Remedial pumping

Ex situ bioremediation

Ex situ techniques are those that are applied to soil and groundwater at the site which has been removed from the site via excavation (soil) or pumping (water) (Figure 3). Bioaugmentation techniques involve the addition of microorganisms with the ability to degrade pollutants. Ex situ treatment generally requires shorter time periods, and there is more certainty about the uniformity of treatment because of the ability to monitor and continuously mix the groundwater. However, ex situ treatment requires pumping of groundwater, leading to increased costs and engineering for equipment, possible permitting, and material handling.

It has been well documented that upto 99.8% of pesticide contamination has been treated by ex situ remediation (U.S. EPA. 1995; Cincinnati et al. 1999; Dupont, et al 1998.). Although not all organic compounds are amenable to bioremediation, but the techniques have been successfully used to remediate groundwater contaminated caused not only by pesticides but also by petroleum hydrocarbons, solvents, wood preservatives, and other organic chemicals. The rate at which microorganisms degrade contaminants is influenced by the specific contaminants present; temperature; oxygen supply; nutrient supply; pH; the availability of the contaminant to the microorganism (clay soils can adsorb contaminants making them unavailable to the microorganisms); the concentration of the contaminants (high concentrations may be toxic to the microorganism); the presence of substances toxic to the microorganism, e.g., mercury; or inhibitors to the metabolism of the contaminant. These parameters are discussed briefly in the following paragraphs.

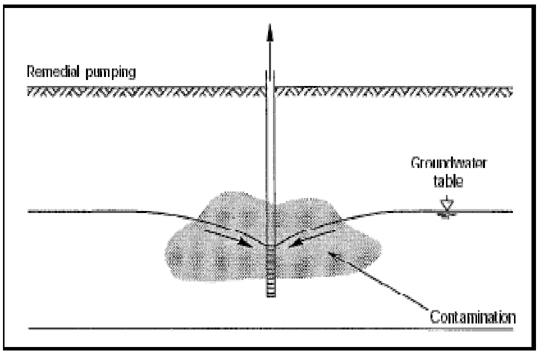

Figure 3. Remedial pumping

Degradation mechanism

For bioremediation to be effective, microorganisms must enzymatically attack the pollutants and convert them to harmless products. As bioremediation can be effective only where environmental conditions permit microbial growth and activity, its application often involves the manipulation of environmental parameters to allow microbial growth and degradation to proceed at a faster rate.

There are classes of microbial enzymes which have been identified to degrade harmful organophosphorus (OP) compounds that are present in some pesticides. Till date, the most studied and potentially important OP-degrading enzymes are organophosphorus hydrolase (OPH) and organophosphorus acid anhydrolase (OPAA), which have both been characterized from a number of organisms (Theriot & Grunden, 2011).

Organophosphorus hydrolase, was first isolated from the soil bacteria *P. diminuta* MG and *Flavobacterium* sp. (Mulbry et al. 1986; Serdar et al. 1982). It has broad substrate specificity and is able to degrade organophosphorus compounds with P–O, P–CN, and P–F bonds and is the only enzyme known to cleave the P–S bond. Whereas, Organophosphorus acid anhydrolases have been isolated from higher animals (Hoskin and Roush 1982; Little et al. 1989) as well as from the soil bacteria (Attaway et al. 1987). OPAAs have been shown to hydrolyze a variety of OP agents. OPAAs isolated from halophilic *Alteromonas* species (*Alteromonas* sp. JD6.5, *Alteromonas undina* and *Alteromonas haloplanktis*) have been the most extensively studied (Cheng et al. 1999; Cheng and DeFrank 2000; DeFrank et al. 2000; Vyas et al. 2010). Molecular weight of OPAAs is ranged between 50 and 60 kDa, an optimum pH from 7.5 to 8.5, a temperature optimum ranging from 40°C to 55°C, and they require Mn^{2+} for maximum activity (Cheng et al. 1997).

CONCLUSION

Pesticides manufacturing and its application in a large extent become a common hazard around the world. These chemicals contaminate soils, groundwater and surface water through leaching and create health concerns in living communities. The bioremediation technology is found to be an advanced treatment technique which uses microbial consortium for effective treatment of pesticides in underground water. The process of microbial remediation is focused on microbial enzymes for the degradation and detoxification of OP compounds which is important for our environmental health. Apart from these technologies, the best way to reduce pesticide contamination (and the harm it causes) in our environment is for all of us to do our part to use safer, non-chemical pest control (including weed control) methods.

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SALINIZATION AS GROUND WATER POLLUTION IN INDIA: A REVIEW

Manisha Rani[1], Sanjay Kumar Yadav[2], Anshumali[3]
Department of Environmental Science & Engineering,
Indian School of Mines, Dhanbad, Jharkhand 826004

Abstract

Groundwater is a very useful natural resource and makes up about twenty percent of the world's fresh water supply so it is assumed to be the best source for flora and fauna as well as industries. In the present era, anthropogenic activities like urbanization, industrialization, agriculture and natural activities like weathering of rocks, salt lakes, salt marshes are main source for groundwater salinity in the inland and coastal regions respectively the Punjabs, Haryana, Western Rajasthan etc. and West Bengal, Chennai, Andhra Pradesh, Gujarat, Mumbai etc. in different part of India. Salinity is broadly related to total dissolved solids (TDS) and electrical conductivity (EC). Salinity is the accumulation of dissolved ions in water such as cations: Na^+, K^+, Mg^{++}, Ca^{++} or in anions: Cl^-, NO_3^-, HCO_3^-, SO_4^{-2}. However, the concentrations of these dissolved ions reflect the level of salinity in water and after a certain level impact human health, live-stocks, plant growth and development. Therefore, quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated and industrial area to conserve water resources considering the social, economic and ecological implications of increased salinity and groundwater depletion.

Keywords: Salinity, Total dissolved solids, Electrical Conductivity

1 INTRODUCTION

The groundwater resources of the country play a major role in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities, etc. According to National Water Policy (2002), in the planning and operation of systems, water allocation priorities should be broadly as: (i) drinking water (ii) irrigation (iii) hydropower (iv) ecology (v) agro-industries and non-agricultural industries and (vi) navigation.
In some of the most populous and poverty stricken regions of the world—particularly in South Asia—groundwater has emerged at the center-stage of the food-agricultural economy. In India, for example, some 60 percent of the irrigated food grain production now depends on irrigation from groundwater wells. Between India, China, the US and Pakistan, some 325 km^3 of groundwater is used every year; the 14 countries included Indonesia, Iran, Mexico, Japan, Italy etc. use some 520 km^3 (FAO 1972, 1994); over 35 countries of the world use more than 1 km^3 of groundwater annually (Llamas et al., 1992).

Traditionally, India has been an agriculture-based economy. A major part of India's population is rural and agriculturally oriented for whom the rivers are the source of their prosperity. With rapid growing population and improving living standards, the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day (Kumar et al., 2005). The groundwater resources of the India have been estimated for freshwater based on the guidelines and recommendations of the GEC-1997 by C.P. Kumar and stated 433 billion cubic meter (BCM) or Km^3 as the total annual replenishable groundwater resources of the country. Keeping 34 BCM for natural discharge, the net annual groundwater availability for the entire country is 399 BCM. The annual groundwater draft is 231 BCM out of which 213 BCM is for irrigation use and 18 BCM is for domestic and industrial use. However, the stage of groundwater development in the country is 58%. Highly intensive development of groundwater in certain areas in the country has resulted in over exploitation of groundwater resources. Out of 5723 numbers of assessment administrative units (Blocks/Taluks/Mandals/Watershed), 839 units are "overexploited", 226 units are "critical", 550 units are "semi-critical", 4078 units are "safe" and 30 units are "saline". As per Hydro visions (2009), the impacts of salinity include increasing concentrations of many salts in groundwater used for municipal and agricultural supplies, retirement of hundreds of thousands of acres of agricultural land due to saline soils.

2 LITERATURE REVIEW

In India, on Groundwater quality parameters various studies have been carried out to determine the hydrochemistry of the ground water and to classify the water in order to evaluate the water consumption for drinking, domestic and irrigation uses and its suitability for municipal, agricultural and industrial use (Tatawat and Singh,2006). As per IDNP report 2002, in India, it has been estimated that about 6.0 m ha land is affected from various nature and orders of waterlogging and about 8.5 m ha land is affected from different degrees of soil salinity. In the report, a paradoxical situation in Haryana is also shown that nearly 52% of the state is experiencing rising water table while the remaining 48% area is experiencing decline in the water table due to salinization and
waterlogging of groundwater.

On the basis of criteria given by the National Commission of Agriculture (1976) and Ministry of Water Resources (MoWR, 1991), waterlogged/critically waterlogged areas may be defined where water table is within 2 m from the surface. Salinity always exists in ground water but in variable amounts. IDNP (2002) report states that the waterlogging and salinity (92%) and poor permeability of the soil (87%) are the major factors responsible for poor crop productivity for example the state of Karnataka is no exception as about 0.141 million ha (about 10.5 per cent of the irrigated command) area has been estimated to be waterlogged saline.

The total dissolved solids (TDS) indicates the general nature of salinity of water (Singh et.al. 2004). At a high TDS concentration, water becomes saline. Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines).Water with a TDS above 1,500 to 2,600 mg/l (Electrical Conductivity > 2.25- 4 mmho /cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance. The BIS specifies a desirable total dissolved solids limit of 500 mg/l and a maximum permissible limit of 2000 mg/l. In ground water, dissolved ions consists mainly of inorganic salts such as carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium, iron etc. and small amount of organic matter and dissolved gases. The measurement of electrical conductivity is directly related to the concentration of ionized substance in water and therefore, is also related to problems of excessive hardness, salinity or other mineral contamination. GWQS report of 2007-2008 year relates the salinity of different metropolitan cities with the electrical conductivity which has been elucidated below as Table 1:

Table 1: Salinity of different metropolitan cities along with electrical conductivity

S. No.	Location	EC Pre-Monsoon Range (µS/cm)	EC Post-Monsoon Range (µS/cm)	Salinity Nature
1	Jabalpur	258 to 1731	226 to 1498	High
2	Indore	696 to 2740	646 to 2430	High
3	Bhopal	175 to 1741	160 to 1498	High
4	Jaipur	486 to 2300	430 to 2110	High
5	Delhi	507 to 12180	448 to 2804	High
6	Nagpur	322 to 3100	280 to 2828	High
7	Nasik	681 to 2610	605 to 1853	Moderate
8	Pune	79 to 2630	74 to 2423	High
9	Bangalore	281 to 4270	279 to 3970	High
10	Hyderabad	566 to 3789	493 to 3072	High
11	Vishakhapatnam	793 to 11770	727 to 11560	Very High
12	Surat	540 to 12388	524 to 11268	Very High
13	Vadodara	552 to 4920	498 to 3615	Slightly High
14	Patna	517 to 1422	440 to 1312	Medium
15	Dhabi	382 to 1645	335 to 1700	High

Why Salinity is so important?

Eighty per cent of our drinking water needs are met by groundwater, which is depleting at an alarming rate, compounded with large scale contamination. According to the report of IDNP (2002), it is estimated that an area of nearly 8.5 million ha is affected by soil salinity and alkalinity, of which about 5.5 million ha in the irrigation canal commands and 2.5 million ha in the coastal areas. The problem of increasing salinity caused by the rise of the water table and the lack of drainage is considered as a major environmental problem that threatens the capital investment in irrigated agriculture, industrial activities and its sustainability. Salinity also affects some environment and social values

Environmental Impact: Salinity impacts environment adversely which include reduced biodiversity in stream fauna, riparian vegetation, wetlands and reduced food for wildlife populations. Salinity results in the loss of nesting sites, wetland-dryland habitat and decline in bird populations, aquatic populations (fish) along with native vegetation. Sometimes, the excess salinity causes undesirable changes in plant populations and increases the weeds, soil and wind erosion.

Social Impact: Salinity impacts on the framework and structure of our society which include many parameters such as reduction in recreational/tourism values, agricultural incomes, regional population due to productivity losses in both rural and urban communities. It exceeds the pressure for consolidation of agricultural properties and flow-on impact on employment.

3 Salinity

3.1 Definition

Salinity is the saltiness or dissolved salt contents of a water body which is an important factor in water use. Salinity can be technically defined as the total mass in grams of all the dissolved substances per Kilogram of water. Different substances dissolve in water giving it taste and odour. In fact, humans and other animals have developed senses which are, to a degree, able to evaluate the portability of water, avoiding water that is too salty or putrid.

According to Podmore (2009), Salinity is the accumulation of salts (often dominated by sodium chloride) in water to levels that impact on human and natural assets (e.g. plants, animals, aquatic ecosystems, water supplies, agriculture and infrastructure).

3.2 Types and Causes of Salinity

Acc to Munns (1993), salinity occurs through natural or human-induced processes that result in the accumulation of dissolved salts in the water to an extent that inhibits plant growth and impact human-health. It is of two types mainly- Primary (Natural) salinity and Secondary (Human induced) salinity.

3.2.1 Natural or primary salinity

Primary salinity results from the accumulation of salts over long periods of time, through natural processes, in the soil or groundwater. It is caused by two natural processes.

The first is the weathering of parent materials containing soluble salts. Weathering processes break down rocks and release soluble salts of various types, mainly chlorides of sodium, calcium and magnesium, and to a lesser extent, sulphates and carbonates. Sodium chloride is the most soluble salt.

The second is the deposition of oceanic salt carried in wind and rain. 'Cyclic salts' are ocean salts carried inland by wind and deposited by rainfall (containing 6 to 50 mg/kg of salt, mainly sodium chloride (Table 2). The composition of rainwater varies greatly depending on prevailing winds and distance from the coast. It is measured as mg/kg or ppm (parts per million). The composition of seawater is uniform around the globe, and is expressed as g/kg or ppt (parts per thousand). The electrical conductivity of rainwater is about 0.01 dS/m, and of seawater is 55 dS/m.

3.2.2 Secondary or human-induced salinity

Secondary salinization results from human activities that change the hydrologic balance of the soil between water applied (irrigation or rainfall) and water used by crops (transpiration). The most common causes are (i) land clearing and the replacement of perennial vegetation with annual crops, and (ii) irrigation schemes using salt-rich irrigation water or having insufficient drainage. Prior to human activities, in arid or semi-arid climates, the water used by natural vegetation was in balance with the rainfall, with the deep roots of native vegetation ensuring that the water tables were well below the surface.

Table 2: Concentration of salts in rain and seawater

Source: (Northern hemisphere Encyclopaedia Britannica)

Ion	rainwater (local)		seawater (global)	
	mg/kg (ppm)	(µmol/L) µM/L	g/kg	(mmol/L)
Sodium (Na^+)	2.0	86	10.8	470
Chloride (Cl^-)	3.8	107	19.4	547
Sulfate (SO_4^{2-})	0.6	6	2.7	28
Magnesium (Mg^{2+})	0.3	11	1.3	53
Calcium (Ca^{2+})	0.1	2	0.4	10
Potassium (K^+)	0.3	8	0.4	10

But today, Clearing and irrigation changed this balance, so that rainfall on the one hand, and irrigation water on the other, provided more water than the crops could use. The excess water raises water table and mobilises salts previously stored in the subsoil and brings them up to the root zone. Plants use the water and leave the salt behind until the soil water becomes too salty for further water uptake by roots. The water table continues to rise, and when it comes close to the surface, water evaporates leaving salts behind on the surface and thus forming a ‘salt scald’. The mobilised salt can also move laterally to water courses and increase their salinity.

Therefore, irrigation water adds appreciable amounts of salt, even with good quality irrigation water containing only 200-500 mg/kg of soluble salt. If drainage is not adequate, the excess water causes the water table to rise, mobilising salts which accumulate in the root zone. When the crop is unable to use all the applied water, waterlogging occurs.

Another major cause for concern is the pollution of ground water from the different industries manufacturing medicine, salt, fertiliser, pesticide, inorganic and organic chemicals on the increasing rate for example the consumption of fertilisers shot up from 7.7 million tonnes in 1984-85 to 13.9 million tonnes in 1994-95 and that of pesticides from 24,305 tonnes in 1974 to 85,030 tonnes in 1994-95.

Table 3: Ground Water Quality Problems due to Industrial Activities

Source: Central Pollution Control Board

S. No.	Area	Industrial Activities
1	Dhanbad (Jharkhand)	Fertilizers, Chemicals, Coke plants, Cement factory
2	Botharam Patncheru (AP)	Pesticide, Pharamaecuticals
3	Greater Cochin(Kerala)	Fertilizer, Pesticides, Chemicals, Chloralkali
4	Ratlam Nagda (MP)	Distillary Dye (intermediates), Pharmaceutical (intermediates)
5	Vapi Gujarat	Dyes, Pesticides, Paper & Pulp mills, organic & inorganic Chemicals
6	Drain Basin Area, Najafgarh (Delhi)	Insecticides, Caustic Soda, Vanaspati

4 Example of Salinity Impact in India

Salinity in groundwater can be of broadly categorized into two types, i.e. inland salinity and coastal salinity.

Inland salinity in groundwater is prevalent mainly in the arid and semi-arid regions of Rajasthan, Haryana, Punjab and Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu. There are several places in Rajasthan and southern Haryana where EC values of groundwater is quite high making water non-potable. In some areas of Rajasthan and Gujarat, groundwater salinity is so high that the well water is directly used for salt manufacturing by solar evaporation. Inland salinity is also caused due to practice of surface water irrigation without consideration of groundwater status. The occurrence of inland salinity may be due to over development of ground water, use of surface water and ground water in complete isolation, characteristics of aquifer or some other reasons.

The coastal tracts in India cover parts of Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Orissa & West Bengal. Besides the Inherent ground water salinity in the coastal tract Sea water intrusion is also reported. The coastal salinity problems have been observed in a number of places in coastal areas of the country. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast. In Orissa, in an 8-10 km. wide belt of Subarnrekha, Salandi, Brahamani out fall regions in the proximity of the coast, the upper aquifers contain saline horizons decreasing landwards. In Pondicherry region east of Neyveli Lignite Mines salinity ingress has also been observed.

Table 4: Districts affected by salinity in ground water in different States of India

S. No.	State	Parts of districts having Electrical Conductivity > 3000 µS/cm
1	Andhra Pradesh	Anantapur, Chittoor*,Kurnool, Kadapa (Cuddapah), Nellore, Prakasam, Guntur, Mahbubnagar, Nalgonda, Krishna, Khammam, Warangal, Medak, East Godavari, Srikakulam, Visakhapatnam
2	Delhi	North West, West, South West
3	Gujarat	Ahmadabad, Amreli, Anand, Bharuch, Bhavnagar, Banaskantha, Dohad, Porbandar, Jamnagar, Junagadh, Kachchh, Kheda, Mehsana, Navsari, Patan, Panchmahals, Rajkot, Sabarkantha, Surendranagar, Surat, Vadodara
4	Haryana	Bhiwani, Faridabad , Fatehabad, Gurgaon, Hissar, Jhajjar, Kaithal, Mahendragarh, Panipat, Rewari, Rohtak, Sirsa, Sonepat, Yamunanagar*
5	Himanchal Pradesh	Mandi*
6	Karnataka	Bijapur,Bagalkot, Belgaun, Bellary, Chitradurga, Chikmagalur, Davangiri, Dharwar,Gadag, Gulburga, Hassan*, Haveri, Mandya*, Raichur, Udupi
7	Kerala	Palakkad*
8	Maharashtra	Ahmadnagar,Aurangabad*,Akola, Amravati, Beed*, Buldana, Chandrapur, Dhule*, Jalna,Jalgaon,Nagpur*,Nasik, Parbhani, Raigarh*, Satara, Solapur*, Wardha
9	Madhya Pradesh	Bhind, Indore, Jhabua*, Sheopur*, Ujjain
10	Orissa	Jagatsinghpur*
11	Punjab	Bhathinda,Firozepur, Faridkot, Gurudaspur*, Mansa, Muktsar, Patiala*, Sangrur
12	Rajasthan	Ajmer, Alwar, Barmer, Bharatpur, Bhilwara, Bundi, Bikaner, Churu, Jalor, Chittaurgarh, Dhaulpur, Dausa, Ganganagar, Hanumangarh, Jaipur, Sirohi, Jaisalmer, Jhunjhununn, Jodhpur,Karoli, Nagaur, Neemuch, Pali, Sikar, RajaSamand, Sawai Madhopur, Tonk, Udaipur
13	Tamil Nadu	Coimbatore, Chennai, Cuddalore, Dindigul,Dharmapuri, Erode, Pudukkottai, Ramanathapuram, Salem, Karur, Namakkal, Perambalur, Thiruvannamalai, Tiruchirapalli, Thanjavur, Thoothukkudi, Tirunelveli, Theni*,Vellore, Villupuram, Virudhanagar
14	Uttar-Pradesh	Agra, Allahabad*, Aligarh, Hamirpur*, Hathras, Jyotibaphulenagar*, Mathura
15	West-Bengal	Bankura*,Haora, Medinipur,N-24 Pargana, S- 24 Parganas

Source: ICAR studies, CGWB, March 2008

* present in Minor/ local spots

According to Raychoudhury (2007), saline water impact Kidney stones due to poor hydration in humans. He determined the social cost of salinity also. In salinity affected villages,

- Medical costs = Rs. 5790 per person per year
- Wage loss costs = Rs. 2690 per person per year
- Drinking water costs = Rs. 750 per household per year

5. THE REPERCUSSIONS OF SALINITY

5.1 The Effect of Salinity on Plants

As salts accumulate in saline discharge areas they can reach levels that affect plants in a number of ways. This leads to poor plant health, a loss of productive species and dominance of salt-tolerant species (Podmore, 2009). Under normal conditions, plants readily obtain water from the soil by osmosis. As soil salinity increases this balance shifts making it more difficult for plants to extract water.

Plant growth can be directly affected by high levels of toxic ions such as sodium and chloride. Excess sodium accumulation in leaves can cause leaf burn, necrotic (dead) patches and even defoliation. Plants affected by chloride toxicity exhibit similar foliar symptoms, such as leaf bronzing and necrotic spots in some species. Defoliation can occur in some woody species.

An excess of some salts can cause an imbalance in the ideal ratio of salts in solution and reduce the ability of plants to take up nutrients. For example, relatively high levels of calcium can inhibit the uptake of iron (‘lime induced chlorosis’), and high sodium can exclude potassium.

5.2 The effect of Salinity on Humans

Biologically speaking, salt (mainly sodium) plays a major role in human health. It not only feeds nutritional mineral elements to our cells, it also dissolves, sanitizes, cleanses toxic wastes from our system and acts as a healing substance. Saline water causes hypertension, problems related to kidney, strokes, heart and blood pressure. Saline Water is inferior palatability and may induce an unfavorable physiological reaction in the transient consumer and gastro intestinal irritation.

6. CONCLUSION

The increase in salinity leads to soil degradation and adversely affects agricultural productivity and induces changes in land use. Since the overexploitation of groundwater and the resultant degradation in terms of salinity ingress is largely the result of lack of proper integrated water resource management practice, there is a real need to understand the magnitude of economic losses due to salinity ingress so that appropriate measures can be adopted for desalinization and groundwater replenishment.

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ASSESSMENT OF GROUNDWATER POLLUTION DUE TO LEACHING OF COAL COMBUSTION BYPRODUCTS

Arpita Das[1]*, Manish Kumar Jain[2], Gurdeep Singh[3]
[1]Research Scholar, [2]Associate Professor, [3] Professor
Dept. of Environmental Science & Engineering,
Indian School of Mines, Dhanbad, Jharkhand, India
E-mail:arpitadas98@gmail.com

ABSTRACT

The main objective of this study was to predict the level of groundwater pollution due to leaching of coal combustion byproducts (CCBs) of Tisco fluidized bed combustion plant, Jamadoba, Jharkhand, India. From the column leaching study of approximately three years, it has been found that CCBs are slightly acidic to alkaline in nature. Elements such as Na, K and Ca were found continuously in the leachate but their concentrations decreased substantially with time. Beside that Mg, Cu, Zn, Cd, Co, Pb, Mn, Ni and Fe were found in the leachate samples at varied concentration levels but sometimes they were found below detectable limit. Other elements such as As, Hg, B, Ba, V, Se, Cr, Sb and Mo could not be found in the leachate samples throughout the period of this leaching study. Overall this study suggested that CCBs of Tisco fluidized bed combustion plant, Jamadoba do not create any harmful impact on surrounding groundwater with respect to this long term column leaching experiment.

Key words: CCBs, Leaching, Groundwater, Pollution

INTRODUCTION

Coal is one of the essential fuels for power generation. Massive amount of coal combustion byproducts are generated during the time of coal combustion. Presently, more than 175 million tonnes of coal combustion byproduct is generated in India from several thermal power plants and it is expected about 300 million tonnes of CCBs will be generated in the year of 2016-17 (www.indiacsr.in). During the time of burning of coal, trace elements are enhanced as a result of carbon loss as CO_2 and they are accompanied with the surface of the CCBs due to evaporation and condensation (Choi et al., 2002). These CCBs are used as backfill material in open cast mines or underground mine in recent time. So there is a greater chance of groundwater contamination due to leaching of trace elements presents in CCBs. The groundwater region is more vulnerable than surface water bodies due to lower velocity under low permeability and the aggregation of leached toxic elements in the ground water (Le Seur and Drake, 1987). That's why it is very much important to determine the leaching potentiality of CCBs to predict the level of ground water pollution. Tisco fluidized bed combustion plant, Jamadoba is the study area of this present research work. It is 16 km from Dhanbad railway station and situated at Dhanbad district on Jharkhand State. It is the first power plant in India where washery rejects are used for power generation. The power plant has an installed capacity of 10 MW and covers an area of about 260 hectares excluding the ash pond area. This leaching test has been carried out to determine the impact of leaching of various trace elements from CCBs to groundwater.

MATERIALS AND METHODS

TISCO fly ash (TFA) and TISCO pond ash (TPA) samples were collected from Tisco fluidized bed combustion plant, Jamadoba. Columns for open column percolation leaching experiment were made up of PVC pipes of approximately 75 cm in length and 10 cm in diameter. The CCB samples were placed into column by proper packing and 7.5 cm space was left unpacked from the top of the column to allow the addition of distilled water. A hole is present at the centre of the bottom end of the column for the collection of leachates. About 200 ml distilled water was added to the column twice in a week and similarly leachates were collected from the conical flask attached with the bottom end of the column through a tube. The upper portion of the column and conical flask were protected by zip lock plastic cover from dust. After the collection of leachates pH, conductivity, TDS and salinity were carried out using Digital pH Meter (Model 101 E), Digital Conductivity Meter (Model 612), Digital TDS Meter (Model 651 E) and Digital Salinity Meter (Model 671) respectively. Elemental analysis of leachates was carried out using Atomic Absorption Spectrophotometer (AAS) GBC-902. Sodium, potassium and calcium were determined by Systronics Flame Photometer 128.

RESULTS AND DISCUSSION

pH of the leachates were initially found slightly acidic and then alkaline in nature. It was varied from 6.45-9.33 in case of TFA and 5.85-9.57 in case of TPA respectively. pH was almost within permissible limits of IS:2490 (1981). Conductivity of the leachate samples was initially very high and then it was decreasing with leaching time. Conductivity of the TFA and TPA samples were observed in the range of 0.172-1.708 and 0.174-1.638 mS/cm. The TDS values of the leachates were found below the permissible limits of IS: 2490, 1981. It was ranged from 86-854 ppm (TFA) and 87-819 ppm (TPA). Salinity was also follow the similar trend and it was initially higher and then decreased gradually with leaching time. It was found 62-791 ppm and 58-787 ppm in case of TFA and TPA samples respectively. From the results of open column percolation leaching experiment it was found that out of twenty one elements only Na, K, Ca, Mg, Fe, Mn, Cu, Zn, Cd, Pb, Ni and Co were found in the leachate samples of TFA and TPA. Among them only Na, K and Ca were found continuously in the leachates throughout the period of leaching study but their concentrations decreased considerably with leaching time. Na concentration varied from 4-154 and 2-121 ppm in case of TFA and TPA respectively. The concentration of K varied between 2-48 ppm in case of TFA and 1-87 ppm in case of TPA respectively. Ca was found in the range of 3-97 ppm in case of TFA sample and sometimes it was found below detectable limit in case of TPA sample. Elements such as Mg, Fe, Mn, Ni, Co Cu, Zn, Cd and Pb were found in the leachate samples at significant concentration levels but sometimes they were found below detectable limits. In some cases Pb crossing the permissible limits of IS: 2490 (Part-I), 1981. The concentration of Pb varied from below detectable limit to 0.138 ppm (TFA) and below detectable limit to 0.257 ppm (TPA) respectively. Other elements like As, Hg, B, Ba, V, Se Sb Cr, and Mo could not be detected in the leachate samples during the whole study period of this column leaching experiment. Most of the elements were found below the standard values of IS: 2490 (Part-I), 1981 (Table 1).

CONCLUSIONS

From the above research work it can be concluded that coal combustion byproducts of Tisco fluidized bed combustion plant, Jamadoba are not harmful for the surrounding groundwater with respect to this long term column leaching experiment. Trace elements which are present in these CCBs were almost found below the permissible limits of IS: 2490, 1981. So these can be easily used for various purposes such as mine land filling, reclamation of wasteland or any other applications.

ACKNOWLEDGMENT

The authors are thankful to the concerned authorities of the Tisco fluidized bed combustion plant, Jamadoba, Jharkhand for providing the sample materials and necessary information for carrying out this research work.

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Table 1. Tolerance Limits for Industrial Effluents [IS: 2490 (Part 1), 1981, Indian Standard Institute, New Delhi]

Parameters	(IS:2490, 1981)	
	Inland surface water	On land for irrigation
pH	5.5-9.0	5.5-9.0
EC (mS/cm)	-	-
TDS (ppm)	2100	2100
Na (ppm)	-	60
Ni (ppm)	3	-
Cu (ppm)	3	-
Zn (ppm)	5	-
Pb (ppm)	0.1	-
Cd (ppm)	2	-
Se (ppm)	0.05	-
As (ppm)	0.2	2
Hg (ppm)	0.01	-
B (ppm)	2	2
Cr (ppm)	2	-

TDS-Total Dissolved Solid,

DISTRIBUTION AND PROPAGATION OF ARSENIC IN INDOGANGETIC PLAIN AND REMOVAL TECHNOLOGY

Pramod Kr. Singh[1], B. K. Mishra[2], S. K. Gupta[3] and Alok Sinha[2]
[1] Scholar, Department of Environmental Science and Engineering, ISM Dhanbad
[2] Assistant Professor, Department of Environmental Science and Engineering, ISM Dhanbad
[3] Associate Professor, Department of Environmental Science and Engineering, ISM Dhanbad

ABSTRACT

After the detection of Arsenic 1983 in west-Bengal the cases have been on the rise year after year. This geo-genic hazard has spread into eleven states of India. The reason is not completely natural but also anthropogenic. Elevated arsenic content mainly found in shallow aquifers are due to increasing dependency on groundwater for irrigation purposes. This poses health risk for millions of people living in these affected areas of Ganga-Brahmaputra Plains which includes cardiovascular problem, skin diseases, and other neural disorders. India being a developing nation cannot afford the expensive and large-scale treatment to remove Arsenic from drinking water to acceptable limits, so to solve this problem, low cost effective techniques should be developed, and the technology should applicable for wide range of Arsenic concentration, easy to use, use lesser energy, readily available ,and suitable for reuse. The most common technologies utilized for Arsenic removal uses Oxidation, Co-precipitation, Adsorption, Ion exchange and membrane technology. Although these technology are effective in arsenic removal but they suffer from some shortcomings like sorbents (Iron fillings, ferric salts, granular ferric oxides) are low cost but are slow, fixed bed column using activated Alumina and Iron-coated sand do not work well with high concentration of iron; Synthetic sorbents pose significant waste disposal concern and naturally occurring solids slow and harbor bacteria. Membrane technology removes almost all kind of dissolved solid but have high capital cost and most membrane cannot withstand oxidizing agent. So it is required to develop technology which works on wide range of Arsenic concentration, easy to use, use lesser energy, readily available, and suitable for reuse.

INTRODUCTION

General

Arsenic is a chemical element with the symbol *As*, atomic number 33 and relative atomic mass 74.92. Arsenic mainly occurs in association with sulphur and metals and sometimes in as pure elemental crystal. Arsenic is ubiquitous element that ranks 20th in abundance in earth crust, 14th in the sea water and 12th in the human body (Mandal and Suzuki, 2002).

Arsenic is notoriously poisonous to multicellular life. Arsenic has been used as synonymously with toxicity and has been referred as 20th -21st century calamity (Dinesh Mohan and Charles U. Pittman Jr., 2007). Arsenic contamination of groundwater is a problem that affects millions of people across the globe. It is believed that around 57 million people are drinking groundwater with arsenic concentrations elevated above the World Health Organization`s standard of 10 parts per billion. The source of arsenic in groundwater is of natural origin and comes from the sediments around it. In India elevated amount of arsenic in groundwater is found mainly in the areas of Ganga-Brahmaputra Flood Plains. Geographically the affected areas could be located into eleven states of India but, majority of the drinking water problem is found in the states of Bihar and West Bengal. Apart from these states high arsenic content in groundwater is found in Jharkhand; Uttar Pradesh in the flood plain of Ganga River; Assam and Manipur in the flood plain of Brahmaputra and Imphal River and Rajnandgaon village in Chhattisgarh state.

Origin

Arsenic contamination is understood to be of geogenic origin released from soils under conditions conducive to dissolution of arsenic from solid phase on grains to liquid phase in water and percolation of fertilizer residues might have played a modifying role in its exaggeration (Ghose and Singh). Extensive field-work has been carried out by Geological

Survey of India and Central Ground Water Board to find the provenance source of the solid state Arsenic. The origin has been routed to the veins of Arseno-pyrites present in Himalayas.

Health Hazards

From the ancient time Arsenic was used by the kings to kill each other due to which it has been defamed as *Poison of kings or the king of Poison.* According to study carried out by the National Academy of Sciences during 1999 reveals that arsenic in drinking water causes bladder, lung & skin cancer, and may cause kidney & liver cancer. The study also found that arsenic harms the central and peripheral nervous systems, as well as heart & blood vessels, and causes serious skin problems. It also may cause birth defects and reproductive problems. Non-cancer effects can include thickening and discoloration of the skin, stomach pain, nausea, vomiting; diarrhea; numbness in hands and feet; partial paralysis; and blindness. In Higher dose arsenic is toxic to plant, it may leads to inhibition of seed germination, reduction of root growth, decrease in shoot growth, reduction of plant height, lower fruit and grain yield.(Rahman et al 2007).

Occurrence of Arsenic in Nature

In nature arsenic found in almost 200 different forms, out of which 60% is in Arsenates, 20% sulfides and sulfosalts and rest include Elemental arsenic, arsenites, arsenides and oxides. In the form of ore it is mainly associated with pyrites but absent in galena and chalcopyrites and less commonly with sphalerite. Its terrestrial abundance is almost 1.5-3 mg/kg. (Mandal and Suzuki, 2002).

In natural water arsenic is found in low concentration. In India, the average concentration of arsenic was found to be 0.20 mg/l in west Bengal, In tube well water arsenic mainly found in the form of Arsenite and arsenate current range was found to be 10 -3700µg/l with average of 200 µg/l .(Mandal et al 1996).

Arsenic: Contamination in India

In India Arsenic contamination is found in Ganga-Brahmaputra fluvial plains, which seen as the world’s largest natural ground water calamities.it was first detected in 1983 and after that it has been found that seven states has been contaminated namely, West Bengal, Bihar, Jharkhand, and Uttar Pradesh in flood plain of river Ganga, Assam and Manipur in flood Plain of Brahmaputra and Rajnandgaon in Chhattisgarh state. In Bihar, Bhojpur, Bhagalpur, Begusarai, Buxar, Patna and Saran district has been found to be more affected where as in the West Bengal Inter-fluvial region of the Bhagirathi-Hugli and Jalangi-Ichamati River is mostly affected. Apart from this Malda district, Purbasthali block of Bardhaman district and Balagarh block of Hugli district has been badly affected.

Sources of arsenic in Ground water

The source of Arsenic bearing sediment is still a matter of study and research work, it has been found that Drainage pattern plays an important role as a source in ground water, The release of arsenic by the natural process in ground water has been recognized from the Holocene sediments comprising of sand, silt and clay (Bhattacharya et al 1997).The parent material is the most important factor affecting Arsenic content. By establishing relationship between river system i.e. drainage pattern and the area from where sediment have been bought i.e. parent material, we can trace out the source of arsenic in ground water.(), In Ganga Brahmaputra delta succession of quaternary sediments of varying thickness has been found, the deltaic region of Bengal is bounded by Pre-Cambrian crystalline rocks on three sides and on the eastern side by tertiary hill ranges of Assam-Burma arc.

In last 2000 years the sediment has been deposited from northern Himalayan provinces, metamorphic terrain of the Chotanagpur plateau the meta-sedimentary rocks of Eastern Himalaya .The Tista, Torsa and other tributaries of the Brahmaputra river cut across the Darjeeling Coalfields carry pyrites, arsenopyrites etc., from the exposed coal seams occurring all along the eastern Himalayan foothills. In eastern Himalayan foothills, the existences of Arsenopyrite Veins were reported at the altitude 1200 m above mean sea level.The basaltic rocks of Rajmahal area lying in the north-western part of the delta might have also supplied sedimentary detritus. Again, all the easterly flowing river cutting across Raniganj and other coalfields might also be responsible for bringing arsenic minerals from the mine workings (Elangovan and Chalakh, 2006).In case of West Bengal the Arsenic contamination is considered to be the arsenic-rich sediments transported from the Chotonagpur Rajmahal Highlands (Acharya et al., 2000; Saha et al., 1997) and deposited in under reducing conditions.

Arsenic Mobilization

Arsenic in soil is highly mobile, once it is liberated from its compound either through geological process or through human activity; it enters the aquifer leading to ground water contamination (Acharyya and Shah, 2010). Presence of arsenic in ground water does not related to high arsenic concentration in rock but it has been found that it depends on very groundwater, and second, the mobilized arsenic should be retained in the aquifer (Smedley and Kinniburgh, 2002).Arsenic mobilization may occur due to mineral dissolution, desorption under alkaline and oxidising agent or reducing condition, reduction of oxide mineral surface area or due to weakening of bond strength between arsenic and mineral surface. Basically two hypothesis have been proposed for the mobilization of Arsenic, namely:

1. Pyrite Oxidation Hypothesis
2. Hydroxide Reduction Hypothesis

Pyrite Oxidation Hypothesis

According to this hypothesis Arseno-pyrites remains stable unless it is exposed to oxygen or nitrate, after oxidation Arseno-pyrites mobilize to ground water (Safiuddin et al 2011). During Dry season, when extraction of ground water is more for the irrigation and drinking purpose, due to withdrawal of ground water a zone of aeration (Vadoze zone) is formed in the clayel and peaty sediment containing arseno-pyrites, due to diffusion and dissolution of oxygen in upper portion of groundwater. According to this theory Arsenic removal is mainly due to anthropogenic activity. Though there is not enough hydrological and geological data for this hypothesis, the intensive irrigation development and lack of cases before development, support this hypothesis. The chemical involves oxidation of Arsenopyrite (FeAsS), to realize soluble As (III), sulphate (SO_4^{2-}), and ferrous iron (Fe^{2+}).

$$\mathbf{FeAsS + 13\ Fe^{3+} + 8\ H_2O \rightarrow 14\ Fe^{2+} + SO_4^{2-} + H_3AsO_4\ (aq.)}$$

Hydroxide reduction hypothesis

This hypothesis was first proposed by Nickson et al (1998). According to this hypothesis adsorbed arsenic is released into the ground water due to reductive dissolution of arsenic, which present in the alluvial soil as an adsorbed coating onto amorphous ferric oxy-hydroxide (FeOOH).(Acharya and Shah,2010). So this hypothesis supports the geological removal process. The extent of arsenic release depends on amount of arsenic bearing ferric oxy-hydroxide and organic matter present in sediments, this hypothesis is acceptable in contest of reducing condition in Bangladesh (Safiuddin et al 2011).The chemical reaction can be explained as:

$$\mathbf{8\ FeOOH - As_{(s)} + CH_3COOH + 14\ H_2CO_3 \rightarrow 8\ Fe^{2+} + As_{(d)} + 16\ HCO_3^{-} + 12\ H_2O}$$

Where $As_{(s)}$ $_{\text{is}}$ adsorbed As, and $As_{(d)}$ is dissolved As.

Treatment of Arsenic Contaminated Water

There are several methods available for removal of arsenic from water. The most commonly used technologies include oxidation, co-precipitation and adsorption onto coagulated flocs, lime treatment, adsorption onto sorptive media, ion exchange resin and membrane techniques. Technology used for the removal of arsenic can be broadly classified into Physico-Chemical and Biological Technique (Mondal et al, 2006):

Physico-Chemical Technology

- Adsorption and Co-precipitation
- Sorptive filtration media
- Ion Exchange
- Filtration technique

Biological Technique

- Phytoremediation
- Biological treatment with living microbes/Bio-filtration.

Oxidation as a Pretreatment Step

It has been found that As is found as As(iii) and As(v) in ground water and most of the technology used for the removal of Arsenic are capable of removing Arsenic (v) more effectively , due to its lower mobility. So it is better to convert As (iii) into As(v) by oxidation. Oxidation can be done by using various oxidizing agent like Oxygen, Ozone, free Chlorine, Hypochlorite, Permanganate, Hydrogen peroxide and fluton's reagent. Air oxidation, hypochlorite and permanganate are the most commonly used oxidizing agent. (Ahmed, 2001). It has been seen that Air oxidation is quite slow (Pierce and Moore, 1982). Chemistry involves:

H_3AsO_3 + ½ O_2---$H_2AsO_4^-$ + $2H^+$
H_3AsO_3 + HClO—$HAsO_4^-$ +$3H^+$
$3H_3AsO_3$+$2KMnO_4$----$3HAsO_4^{--}$ +$2MnO_2$+ +$2K^+$ + $4H^+$ + H_2O

Adsorption and Co-Precipitation

Oxidation process is needed as pretreatment stage before Adsorption or co precipitation process as As (v) adsorb and react more readily than As (iii) (K.B.Vu et al, 2003). In the treatment of Arsenic, coagulants like Alum $Al_2(SO4)_3.18H_2O$, Ferric chloride and Ferric sulfates used Aluminium or Ferric hydroxide micro flocs are first formed and then all kinds of micro-particles and negatively charged ions are attached to the flocs by electrostatic precipitation.As (iii) removal is not at significant level as in this state As found in non-ionized form.(Ahmed,2001). Arsenic is finally removed by sedimentation or filtration of Al-As complex or as Fe-As complex.

Chemistry involves:
$Al_2(SO4)_3.18H_2O$----$2Al^{3+}$ +$3SO4^{--}$+18 H_2O
$2Al^{3+} + 6H_2O \rightarrow 2Al(OH)_3 + 6H^+$
$H_2AsO_4^-$ +$Al(OH)_3$→ Al-As(complex) + other product
For Ferric chloride:
$FeCl_{3(s)} + H_20 \rightarrow Fe(OH)_3$
$Fe(OH)_3 + H_3AsO_4 \rightarrow FeAsO_4.2H_2O + H_2O$

Alum removal is most effective at pH range of 7.2-7.5 and Iron coagulation with a wider range of 6.0-7.5(Ahmed and Raham, 2000).

Sorptive Filtration Media

Agents which are used to remove Arsenic through formation of insoluble compounds with Arsenic by precipitation or co-precipitation are referred to as sorbents. Activated alumina, Activated carbon, Iron and Manganese coated sand , Clay, hydrated ferric oxide , activated bauxite , Titanium oxide are few of the several sorptive media that has been used for removal of Arsenic. Clay and mineral containing rocks are very much effective but are slower in terms of rate (Elizalde-Gonzalez et al, 2001, Su and Puls, 2001). It has been seen that due to presence of Mg^{2+}, $Ca^{2+ \text{ and}}$ other naturally occurring ions, which compete with Arsenic for adsorbent site, field results varies from that we get in laboratory (Kepner et al, 1998).Efficiency of sorptive media depends on the use of oxidizing agent that as aids to sorption of Arsenic (Ahmed, 2001).due to affinity of media with different metals and contaminants, media get saturated during operation and need regeneration.

Activated Alumina

Activated alumina is one of the most effective sorptive surfaces for arsenic removal. In activated alumina process, when raw water passes through the insoluble granular column of Alumina the impurities along with arsenic get adsorbed on the surface and water percolates down. The bed saturates first at the upstream and then moves downstream. For regeneration of media 4% caustic soda (NaOH) is used and then media is neutralized by rinsing with 2% solution of H_2SO_4. The media need to be replaced after 3-4 regeneration as the 5-10% alumina is lost and capacity of media is reduced to 30-40% each time.

Iron-Oxide Coated Sand

Iron oxide coated sand has shown promising result in laboratory to be used for removal of arsenic at small scale system and home treatment units (Joshi and Chaudhari, 1996). United States Environmental Protection Agency has also reported iron oxide coated sand as one of most viable technological option for arsenic removal. Though this method depends upon several factors like pH, temperature, iron concentration, no of coating, aging for the removal of As (iii) and As (v). (D. M. Ramakrishna et al, 2005)

Ferric Hydroxide

Khair et.al. (1999) have described ferric hydroxide-coated newspaper pulp low-cost absorbent. Newspaper pieces were put into a blender and pulped then mixed with fixed hydroxide, which is prepared by adding dilute ammonia drop wise to an aqueous solution of ammonium ferric alum. This fixes the ferric hydroxide onto the cellulose fiber. Khair found that ferric hydroxide-coated newspaper pulp removed the most arsenic, to about 50 ppb.

Read-F Arsenic Removal Unit

Shin Nihon Salt Co Ltd, Japan has developed Read-F as adsorbent for Arsenic removal in Bangladesh. It is Ethylene vinyl alcohol copolymer borne hydrous cerium oxide, in which hydrous cerium oxide is the adsorbent. It does not contain organic solvent or other volatile substance and is not considered as hazardous material.

Ion Exchange

A reversible chemical reaction between an insoluble solid and a solution during which ions may be interchanged; the insoluble solid is usually a resin. The process is similar to similar to activated alumina. The arsenic removal capacity depends on sulfate and nitrate concentration in raw material,it is preferable to have sulfate concentration less than 25 mg/l. this process is less depends on pH but the dissolved solid concentration should be less than 500mg/l. Preoxidation step improves the arsenic removal capacity but excess of oxidants may cause damage to resin. The spent or exhausted resin is regenerated by recirculating 5-10% NaCl. Since the spent waste water contains high concentration of arsenic, so it requires proper treatment before disposal.

$2R\text{-}Cl + HAsO_4^- \text{------} R_2HAsO_4 + 2Cl^-$

$R_2HAsO_4 + 2N^+ + 2Cl^- \text{----} 2R\text{-}Cl + HAsO_4^- + 2Na^+$

Where R stands for ion exchange resin.

Membrane Techniques

Membrane technology mainly includes Reverse osmosis, Nano filtration and Electro dialysis. These methods are most effective in arsenic removal. In these methods the the raw water is allowed to pass through a membrane under some gradient like pressure. As water is allowed to pass through special filter media, the impurities retains on the membrane. The raw water should be free from suspended solid and arsenic should be in As (v) form.

Reverse Osmosis

It is basically pressure driven membrane process, it retain almost all ions and passes water through it in accordance with its membrane character and removes almost 86% of arsenic (Susan Mercott, 1999). It removes arsenic on the basis of size exclusion, when pressure gradient is subjected against the membrane. Reverse osmosis membranes are more selective than nanofiltration membrane but require higher driving pressure and hence higher energy cost. (Khandekar et al, 2009).

Nanofiltration

Like reverse osmosis process it also work on the basis of size exclusion.it is capable of removing almost 90% of arsenic and its recovery ranges between 15-20 %(Susan Mercott, 1999). It is relatively less sensitive than Reverse osmosis and hence requires less energy cost. It is less sensitive to pH but Arsenite is more removed at pH>8. (Narsimhan et al 2005).

Electrodialysis

Electrodialysis removes arsenic by filtration, electric repulsion and adsorption.of arsenic bearing compounds.A water recovery of 85% is achievable.reported arsenic removal varies from 28% to 86 %. (L.feenstra et al 2007).

Table. Comperative Analysis of Techniques

Technology	Advantage	Disadvantage
Adsorption	Commercially available Good removal efficiency	pH needs to be monitored regularly Sludge disposal is a problem.
Co precipitation	Used at house hold and commercial level. Chemicals easily available. Low capital cost.	Sludge disposal problem Requires trained operators Medium removal of toxic trivalent arsenic
Sorptive filtration media	Relatively well known and commercially available Well defined technique	Produces solid toxic waste Regeneration/replacement required
Ion exchange	High arsenic removal efficiency Low space requirement	Resin regeneration Sulfate and nitrate interference
Membrane techniques Reverse osmosis Nanofiltration Electrodialysis	High Arsenic removal efficiency. Low space requirement.	Initial investment high. Operation and maintenance cost high. Requires pretreatment of water.

Phytoremediation of Arsenic:

Phytoremediation is considered as environmentally friendly and low cost technique, the capacity of some of the ferns like Chinese brake fern (*Pteris vittata L.*) to hyper accumulate As in there frond is main attraction. The fern grows in arsenic-contaminated soils and accumulates large amounts of arsenic in its aboveground biomass. *Pteris vittata* was tolerant of high concentrations of arsenic, up to 1,500 mg As kg-1 soil. (Rathinasabapathi et al 2006).Phytoremediation technology includes Phytoextraction, phytodegradation, rhizofiltration, phytostabilization and phytovolatalization (Rahman and Hasegawa, 2011). Among aquatic plants, water hyacinth (E. crassipes), duckweed (Lemna, Spirodela, and Wolffia), water fern (Azolla spp.), and Hydrilla (H. verticillata) have been proposed to be potential for phytoremediation due to their arsenic hyper accumulation ability and growth habit (Rahman and Hasegawa, 2011).

Biological treatment with living microbes /Bio-filtration.

In this case conversion of As (iii) to As(v) is performed by the extra cellular enzyme and the oxidised As is adsorbed or precipitated or co precipitated onto the biolayer formed on the solid support medium. There is also a probability that arsenic enters in microbial cell through Trans membrane protein and within cell methylation or oxidation-reduction of Arsenic takes place. The removal efficiency is mainly controlled by plasmid gene.(Mondal et al, 2006).

CONCLUSION

Arsenic contamination in Indogangatic plain is **due** to both natural and anthropogenic sources, naturally the sediments of parent material and its Arsenic content is the main reason whereas artificially the withdrawal of underground water for the irrigation and drinking purpose and Agricultural practices are the main concern. Arsenic mobilization occur mainly due to mineral dissolution, desorption under alkaline and oxidising agent or reducing condition, reduction of oxide mineral surface area or due to weakening of bond strength between arsenic and mineral surface.

The most common technologies utilized for Arsenic removal uses Oxidation, Co-precipitation, Adsorption, Ion exchange and membrane technology. Although these technology are effective in arsenic removal but they suffer from some shortcomings.Some are slow and some produces disposal problem like adsorption and coprecipitation, Membrane techniques are not cost effective As India being a developing nation cannot afford the expensive and large-scale treatment to remove Arsenic from drinking water to acceptable limits, so to solve this problem, low cost effective techniques should be developed, and the technology should applicable for wide range of Arsenic concentration, easy to use, use lesser energy, readily available ,and suitable for reuse.

Biological treatments are still in infant stage though some the results are quite encouraging like *Pteris vittata* can tolerant of high concentrations of arsenic, up to 1,500 mg As kg-1 soil. Some aquatic plants, like water hyacinth (*E. crassipes*), duckweed, water fern(Azolla spp.), and Hydrilla (H. verticillata) have been proposed to be potential for phytoremediation due to their arsenic hyper accumulation ability and growth habit But their application to large scale water treatment is still a matter of concern.

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ENVIRONMENTAL SCENARIO OF CHROMITE ORE MINING AT SUKINDA VALLEY BEYOND 2030

Subhashree Pattanaik
Faculty, Eastern Academy of Science and Technology
B.P.U.T., Bhubaneswar

ABSTRACT

Sukinda valley in Jajpur and Dhenkanal district of Odisha contains about 98% of the chromite reserve of the country. Extraction of chromite ore by Opencast Mining in this region commenced during 1950. Since then the landscape of the area is getting obliterated day by day. Chromite ore occur as six linear and parallel bands of varied width within weathered ultrabasics. Chromite Band-I is thickest and proved to extend beyond 300 mtr below ground level. Ground water in the valley is encountered at a shallow depth in semi-confined aquifer. Discharge of mine seepage by pumping facilitates mine operation at deeper level. Most of the promising pits in this region shall be discontinued beyond 2030 due to non-viability of open cast mining and absence of feasibility study for underground mining. Due to occurrence of nickel in the limonitic overburden and continuance of chromite ore at ultimate pit bottom, it is not permitted for reclamation by backfilling. Therefore all the opencast quarries will be reclaimed as large water reservoirs. Leaching of overburden and weathered ultrabasics in mine seepage water shall contributes hexavalent chromium (Cr^{+6}) in to the water in the reservoir. Cr^{+6} is carcinogenic beyond permissible limit (0.05mg/l). Therefore there is a threat of contamination of Cr^{+6} to the groundwater regime of the valley. Author felt that all the Stakeholders, Regulatory authorities and Environmental Scientists should come out with a time bound action plan to minimize the adverse effect of Cr^{+6} on groundwater environment in the valley and conserve and utilize the mineral in the ambit of sustainable development.

KEY WORDS: Cr^{+6}, Limonite, Ultimate Pit Limit, Water Reservoir.

INTRODUCTION

Chromium, out of the most commonly occurring elements in the Earth's crust occupies 21st position in order of abundance. The geographical distributions of chromite deposits in the World are uneven. Over 95% of economically viable chromite deposits are situated in South Africa. The other important World chromite ore producing countries are India, Kazakhstan, Brazil, Turkey and Russia. Major production of world chromite ore is from stratified deposits (Mineral Year Book-2010 by IBM). Chromite in India is considered as a strategic mineral due to its limited reserve potential. Chromite is indispensible for aerospace, Iron and Steel industry. Manufacture of superior military armaments for defense depend largely on this mineral.

DESCRIPTION OF THE STUDY AREA

In India Chromite deposit was discovered in Sukinda valley (21° 0' 00"– 21° 04' 07" N: 83° 43' 16"–85° 52' 30" E), confined to Survey of India Topo Sheet Nos.73 G/16 SE & SW and 73 G/12 SE, in 1:25000 scale spread in Jajpur district, Odisha, in 1950. The valley runs in NE-SW direction closing towards east and fanning out towards west. It is situated 50 km NE of Jajpur-Keonjhar Road Railway station. It is flanked by Tomka-Daitari Hill ranges to North and Mahagiri Hill ranges to the East. Damsal Nala flowing south-westerly drains the entire valley and is perennial in nature. The maximum 220 AMSL is at Kansa and minimum 100 AMSL is at Klarangi in the valley. Dendritic drainage pattern of 1st to 3rd order streams from eastern and western slopes of Mahagiri and Daitari Hills respectively drain to Damsal Nala, being a 6th order rivulet.

GEOLOGICAL SET UP

Ultrabasics hosts the chromite deposits that intrude as a transgressive sill in to the pre-cambrian iron ore Supergroup (Acharya S., 1983). This was subsequently co-folded to asymmetric synclinal structures plunging steeply to south-west. Both laterally and vertically, chromite occurs as persistent layers, lenses or pockets in the serpentinized and silicified dunite-peridotite. Sukinda Valley chromitites of Odisha are predominantly stratiform in nature (Chakraborty K.L.et al., 1984). Chromite deposits occur as six parallel chromite ore bands. The width of the chromite bands vary from 3.0 mtr to 50.0 mtr and separated each other by limonite and pyroxenite (Source: GSI). The ore bands the east dip westerly at 40^0 to sub-vertical. Except Band-V, all other chromite bands occur within chert limonite, proved to be continuing beyond 300 mtr below ground level (Source: OMC). This weathered limonite is nickeliferous (Pattanaik R.N., 1990). The limonite on hanging wall side show more nickel values (Pattanaik R.N., 1989). During extraction of chromite ore the limonite is excavated as overburden and stored as dump for future use.

DEVELOPMENT OF CHROMITE DEPOSITS

Opencast Mining for chromium in Sukinda valley commenced since 1950. Total 23 mining leases have been granted for chromite ore mining in Jajpur and Dhenkanal district, Odisha. Out of which open cast mining is continuing at 13 mining leases, two are operating underground and the balance 10 mining leases are not in operation due to want of statutory clearances (www.orissaminerals.gov.in). The list of mining leases predominantly with incompetent host rock is given in Table No.1, 2.

Table No.1: Details of the mining leases where underground mining is under feasibility study.

Index No. as in Fig.1	**Name of the lease**	**Name of the lessee**	**ML area in ha.**	**Mineral Reserve in million tons**	**Approved production per annum in million tons**	**Life of the opencast mine**	**Land use at conceptual stage in ha**			**Water discharge from mine (m^3/hr)**
							Mining	**Dump**	**Total**	
1	Kaliapani Chromite Mines	O.M.C Ltd	971.245	1.79	0.065	27	104.19	38.50	142.69	971.25
2	Sukinda Chromite Mines	TISCO	406.00	1.395	-	-	-	-	-	604
3	Sukinda chromite Mines	IMFA Ltd	26.62	0.528	0.011	48	9.03	7.92	16.95	180
4	Kaliapani Chromite Mines	Jindal Steel Ltd	89.00	2.91	0.01		43.09	26.74	69.83	140
5	Kaliapani Chromite Mines	Balasore Alloys Ltd	64.463	6.72	0.42	16	22.02	27.79	49.81	65.8
6	Mahagiri Chromite Mines (UG)	ICC Ltd	73.777	1.458	0.078	18	7.41	5.77	13.18	28.94
7	Not allotted									
8	South Kaliapani Chromite Mines	O.M.C. Ltd	552.457	31.843	1.40	23	265.07	80.02	345.09	552.46
9	Sukurangi chromite Mines	O.M.C. Ltd	382.709	5.283	0.13	40	73.10	76.48	149.58	1616.40
10	Saruabil Chromite Mines	Misrilal Mines Pvt. Ltd	246.858	3.793	0.07	54	63.50	120.05	183.55	82.95
11	Kamarda Chromite Mines	B.C.Mohanty & Sons Pvt.Ltd	107.241	14.401	0.088	-	29.42	41.307	70.727	205.20
12	Saruabil Chromite Mines	IMFA Ltd	116.76	5.433	0.351	15	41.50	54.00	95.50	108.78

Table No.2: Hexavalent Chromium content in surface water (Date of sampling: Dt 26.02.2012)

Sl. No.	Location			Hexavalent Chromium content	
	Description	Co-ordinates by GPS		Permissible Limit (mg/l)	Actual value (mg/l)
		Longitude	Latitude		
1	Entry point of Damsal Nala (Sukurangi ML)	85^0 48’ 23.8”	21^0 03’ 32.8”	0.10	0.085
2	Kansa on Damsal Nala	85^0 52’ 13.0”	21^0 03’ 54.2”	0.10	0.071
3	D’Quarry water on Band-I Chromite lode	85^0 46’ 44.9”	21^0 02’ 39.9”	0.10	0.404
4	F’Quarry water on Band-IV Chromite lode	85^0 47’ 59.1”	21^0 32’ 27.0”	0.10	0.149
5	AC Quarry water on Band-IV chromite lode	85^0 48’ 36.2”	21^0 02’ 41.5”	0.10	0.04
6	Down stream of F’Quarry on Damsal Nala	85^0 46’ 55.4”	21^0 03’ 12.1”	0.10	0.063
7	D’Quarry Eastern wall at bottom	85^0 47’ 14.4”	21^0 02’ 56.8”	0.10	0.41
8	D’Quarry Western wall at bottom	85^0 47’ 10.3”	21^0 02’ 53.2”	0.10	0.919
9	Down stream of D’Quarry on Damsal Nala	85^0 46’ 04.2”	21^0 02’ 57.6”	0.10	0.144
10	Pump House on Damsal Nala	85^0 45’ 04.8”	21^0 02’ 18.2”	0.10	0.093
11	Down stream TISCO near Kalarangi	85^0 43’ 30.5”	21^0 01’ 14.3”	0.10	0.125

Chromite ore Band-I to Band-V are confined to weathered limonite. Band-I is the most promising chromite lode in Sukinda valley which is folded and abruptly ended near Damsal Nala (Source: GSI). Considering the safety zone of Damsal Nala for mining operation (50 mtr on either side), bench slope in the quarry as per DGMS (27^0 up to 50 mtr depth and 24^0 thereafter), monitoring of the slope stability by CMRS and the stripping ratio, the deepest ultimate pit limit in the valley is fixed at -30 AMSL (www.envfor.nic.in). This being the thickest deposit the ultimate pit depth is highest. The continuity of Band–I in six mining leases as shown in Fig.No.1 has been proved and being worked.

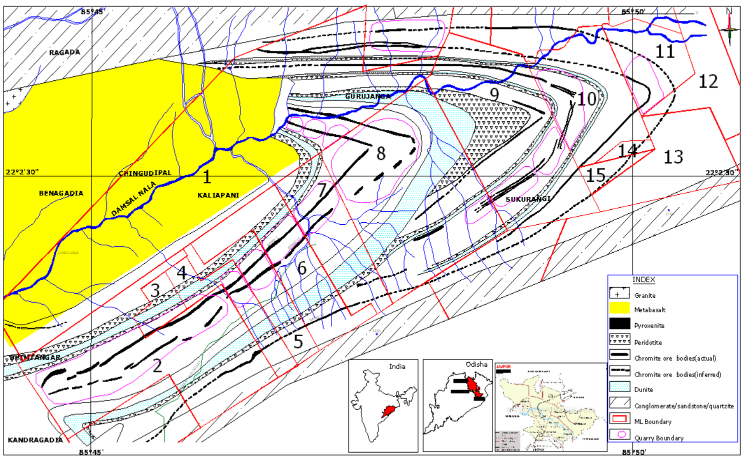

Fig.No.1: Geological map of Sukinda valley showing water reservoirs at the end of life of the mine.

Therefore in the conceptual stage at least six deep pits will be available on Band-I. As Band No.II is very close to Band-I the chromite ore of this band can also be taken out during the same excavation period which is proved to be continuing in all the above six mining leases. Band-III is proved to be continuous in three mining leases but so far not developed. Band-IV is a cluster of thin parallel bands. It is developed by open cast mining in five mining leases in the valley (Source: IBM). The discovery of Platinum Group of Elements (PGE) and nickel in limonite if found promising will augment the activity still further (Pattanaik R.N., 1990).

METHODOLOGY

98% of the chromite reserve of the country is confined to Sukinda valley only (www.ibm.nic.in). Karnataka shares 1% and other states are accountable for balance reserve (Fig No.2). In Odisha Sukinda chromite belt is most promising than Boula-Nuasahi chromite belt and shares 99% of the total resources (Mineral Year Book-2010 by IBM).

There is a sudden two fold rise of chromite ore production during 2003-04 as per the figures in Table No.3 (www. orissapcb.nic.in). This infers that the projected life of individual mines will be still shorter.

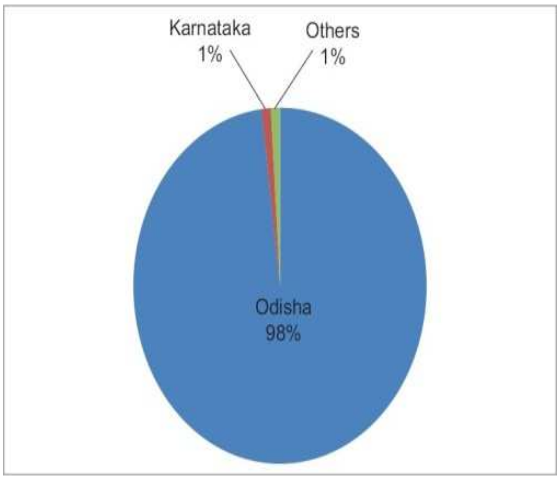

Fig.No.2: Production of chromite in 2011

Table No.3: Production of chromite ore from Odisha (www.orissaminerals.gov.in).

Year	Chromite ore in million ton
1995-1996	1.12
1996-1997	1.66
1997-1998	1.36
1998-1999	1.44
1999-2000	1.40
2000-2001	1.75
2001-2002	1.93
2002-2003	1.76
2003-2004	3.29
2004-2005	2.88
2005-2006	3.42
2006-2007	3.29
2007-2008	3.72
2008-2009	3.28
2009-2010	2.79

The list of all the mining leases along with the boundaries was plotted on the Geological map of Sukinda valley in 1:25000 scale (Source: OPCB). The exposure of the chromite ore body picked up from individual mine lease maps were plotted (Source: GSI). The existing quarry boundaries and the ultimate pit configuration were demarcated on it. The detail mine wise information is compiled to determine the life of the mine, ultimate pit limit and the dump area. It is ascertained from the Geological map and report that the mining leases listed from 1 to 12 as per the Map at Fig.No.1 is mostly confined to weathered limonite. The excavation area estimated is 850.0 ha and that of the area to be occupied by overburden dump will be 400.0 ha (Pattanaik D.K., 2012). The DGMS circular and guidelines by IBM are collected to ascertain the bench slope and reclamation procedure and restriction of backfilling the quarried voids by nickeliferous limonite overburden.

All these information lead the author to think about this conceptual paper regarding possible environmental hazard and its projected mitigation measures after mine closure.

ENVIRONMENTAL CONCERN

Higher concentration of Cr^{+6} in Sukinda was noticed in the 1990's and many studies have been done on this issue since then.

1. Chromium occurs in several oxidation states, ranging from Cr^{+2} to Cr^{+6} (Dubey C.S.et al., 2001). Approximately 35% chromite released from anthropogenic activity is hexavalent chromium out of which mining is considered as one of the major anthropogenic activities. Hexavalent chromium is highly mobile and can readily move through soil and ground water. It originates out of leaching of overburden and weathered

serpentinite causing threat of pollution to the groundwater regime of the valley (G Godkul et al.,1994, Dutta A.K., 2012). Hexavalent chromium is considered to be carcinogenic in nature beyond certain limit.

2. At the approved rate of chromite production the life of the individual mine will commence closing by 2030 (Source: IBM) or even early as there is a steady rise in the production of chromite ore (Table No.4).

Table No. 4 : Reserve of chromite ore as on 01.04.2012

INDIA (In million tons)			ODISHA (In million tons)			
Proved	Remaining resources	Reserve	Proved	Probable	Reserve	Total Resources
54.00	149.00	203.00	31.26	21.81	136.95	190.02

3. As per the mining plan and mine closure plan of individual leases approved by IBM, due to occurrence of nickel in the limonitic overburden, it is advised to stack separately for future use. This contains a lot of Cr^{+6}.

4. The chromite ore bands are proved to be continuing beyond 300 mtr below ground level (Source: OMC). Therefore it is not possible to exhaust the mineral completely by opencast mining. IBM therefore does not permit for reclamation of the worked out pits by dumping of overburden.

5. Consequent upon closure of the mines, heavy seepage of ground water will accumulate in the pits gradually and convert it in to large water reservoirs at the end of life of the mine.

6. Huge overburden dumps stacked adjacent to the quarry is susceptible for erosion by surface run off thereby carrying hexavalent chromium in to these water reservoirs as original drainage channels are to be cut for mining (www.envfor.nic.in). Due to paucity of space the dumps are still active and will continue to be so for some more years. Water samples collected from existing disused quarry show has high Cr^{+6} values (Table No.2).

7. All the 1st to 3rd order seasonal drainage channels emanating from Mahagiri Hill will discharge to these deep pits instead of Damsal Nala. Therefore the water availability in Damsal Nala will be substantially reduced.

8. Ground water is affected by mining by depletion of ground water table and by pollution of aquifers (Kar A., 1993). Recharge of Ground water is not in practice.

9. The major issue in Sukinda is the pollution of Damsal Nala (Pattanaik L.N. et al., 2008). Discharge of mine effluent in to Damsal Nala without proper treatment increases Cr^{+6} at some stretches of the Nala.

10. The surface water is highly affected by pollution as the runoff and erosion potential of soil is high.

11. The ground water movement being south-westerly the movement of the contaminated water in the reservoirs shall be in the same direction to pollute the ground water regime (Pattanaik D.K.,et al. 2011).

12. The mining lease boundaries are separated by a safety zone barrier of 7.5 mtr on either side which gradually increases at depth. Percolation of accumulated water under pressure may cause piping which may threaten failure of the barrier and flash flood downstream.

13. The standing water shall exert a static load which is adverse to any underground mining operation, if at all found feasible in future.

14. Even after closure of the mine if beneficiation of low grade chromite is continued by utilizing water from the reservoir the tailing and the concentrate shall cause a threat of addition of Cr^{+6} by leaching to the ground water.

15. Due to sub-vertical nature of ore body underground method of working is technically ideal to avoid high stripping ratio. But incompetent host rock as well as the ore body cannot withstand rock pressure for underground development. It is still under feasibility study. Large area of excavation is therefore required to win ore from deeper level.

SUGGESTED MITIGATIVE MEASURES

- Each and every anthropogenic activity that contributes hexavalent chromium to the environment should be regulated in such a manner so that the adverse impacts are containable within reasonable limits. Regular online monitoring is highly essential.
- Regulatory authorities and environmental scientists should formulate an acceptable and economically viable proposal so that at the beginning of the activities the possible adverse impacts are regulated. There needs a provision of legal frame work to address the issue. This should be preferably concurrent with the mining activity.
- Nickel ore is not produced in India R & D efforts should be made to use limonite for extraction of nickel. This will sort out the problem of accumulation of overburden dump. The existing dumps may be stabilized properly.
- Once these dumps are reclaimed there should be a provision to reutilize the said area if nickel extraction is economically viable.
- More R & D efforts may be taken up for bio-remediation of Cr^{+6}.
- Sincere effort is required for fixing of hexavalent chromium by bacteria as laboratory tests by some of the researchers are found to be encouraging (Dey Satpura, et al, 2010).
- Post mine closure monitoring of ground as well as surface water is desired.
- Suitability of use of water from the reservoirs for agricultural purpose need to be confirmed as some of the literature available are in favour of accumulation of Cr^{+6} in paddy crop (IBM-BRGM Report,2001).
- Check dams, gulley plugging, garland drains, etc. may be provided at selected locations to arrest soil erosion and reduce suspended particulate matter in the runoff.
- All the major mines in Sukinda valley will close with open cast mining due to want of adequate R & D effort on feasibility of underground mining where the host rock is weathered limonite (Mishra G.B., 2000).
- Agricultural practice may be encouraged to utilize the stretch of land available to the west of Damsal Nala. This will facilitate engagement of the local workers even after mine is closed.
- Water from these reservoirs can be utilized for beneficiation of low grade chrome ore after closure of mine but the tailing pond should be properly lined to prevent leaching.
- The regulatory authorities through legal procedure should see that the ground water is not contaminated even after closure of all the mining operation.
- All the stakeholders, regulatory authorities and Environmental Scientists should come out with a time bound action plan to counterbalance the adverse effect and to conserve and utilize the mineral in the ambit of sustainable development.
- Surface run off from the catchment area of individual mines needs to be treated before it goes out of individual mining lease area.

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ASSESSMENT OF GROUND WATER QUALITY OF DHANBAD TOWN AREA

Binu Kumari, M.R.Mondal, R.K.Tiwary & B.K.Tewary
Central Institute of Mining and Fuel Research, Dhanbad

ABSTRACT

In this study an attempt has been made to understand the ground water quality of Dhanbad town. For this purpose grab samples were collected from different hand pumps of the Dhanbad town area. Twenty four water samples were collected during the month of December 2010 as per standard method of sampling. Parameters like pH, TDS, Salinity and Conductivity has been analyzed at the site while TSS, DO, Total hardness, calcium hardness alkalinity and chloride in the laboratory. The values of total hardness, Total dissolved solid and chloride has been found exceeding from its prescribed permissible limits with the value 1700 mg/l, 966 mg/l and 908.8 mg/l respectively which is making it unsuitable for drinking purpose.

Keywords: Ground water quality, Contamination, Urbanisation

INTRODUCTION

Contamination of water bodies such as rivers, lakes, Oceans, and ground water is caused by human activities and when it exceeds the permissible limit it is called polluted water .This becomes harmful to organism and plants which live in the water bodies. Urbanization and the unregulated growth of the population have altered the surface and sub surface terrains of the many areas. Changes in local topography and drainage system directly affect both quality and quantity of the ground water. Inadequate environmental measure in the coal mining and related industries as well as the presence of active and abandoned coal mines , waste dumps, coal washeries, coking coal plants, thermal power plants , steel plants, cement plants, have resulted in significant water pollution.

Ground water quality depends on the quality of recharged water, atmospheric precipitation, inland surface water, and subsurface geochemical processes. Water pollution not only affects water quality but also threats human health, economic development, and social prosperity. Dhanbad town getting water from Jamadoba water works from water towers erected in different localities of the town. Later on PHED felt a genuine need for more water for growing population of Dhanbad and therefore envisaged ideal scheme for adequate water supply from Maithon Dam. The first phase under this scheme which has been now commissioned is supplying 1770 cubic meter /hour which is equivalent to approximately 2MGD covering only for about 30% of the population against the requirement of an expected 20 MGD for about 10 lakhs of population of Dhanbad town. The shortage of water is met through surface water, wells, ponds, hand pumps and deep hole boring. All these activities have severely strained the ground aquifers causing depletion in ground water availability. This brings about an acute water crisis especially in summer season. The total population of Dhanbad is 10 lakhs, the requirement of water for whole district is worked out to be 124 MGD i.e. 225 litres/head/day as per IS: 1172/1973 estimation. Now Bureau of Indian Standard has estimated for general water requirement per head is 135l/day. In view of these facts Govt. of India has sanctioned a scheme under Jawaharlal Nehru Urban Renewal Mission (JNNURM) to supply 40 millions litres of water per day by 2039.The scheme yet to be executed by Dhanbad Municipal Corporation. (Ref. Jawaharlal Nehru National Urban Renewal development plan for Dhanbad , Dhanbad municipal corporation 2007)

STUDY AREA

The Dhanbad district is situated in the state of Jharkhand and lies between 23º 37' 3" and 24º 4' North latitude and between 86º6´30" and $86^0$50' East longitude. Dhanbad district shares its boundries with West Bengal in the eastern and south part Dumka and Giridih district in North and Bokaro district in West. It is about 500-1000 ft above sea level. The map of Dhanbad region is shown in fig -1.

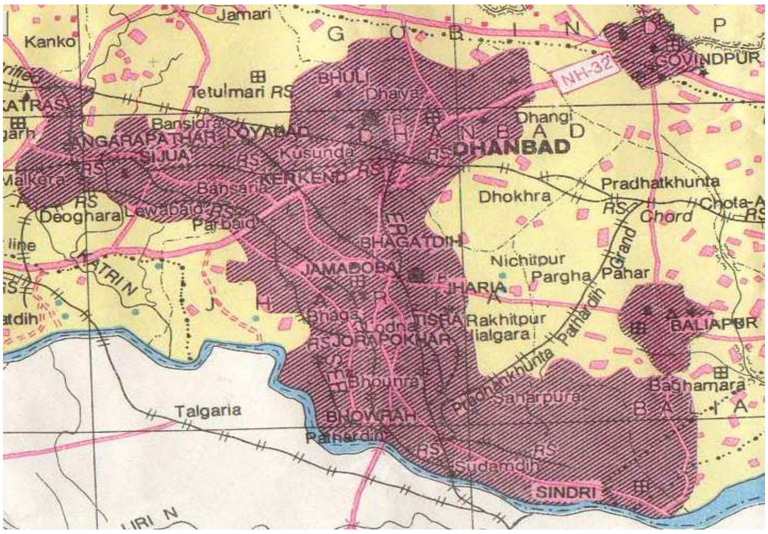

Figure 1: Location Map of Dhanbad

Dhanbad has an average elevation of its geographical length extending from North to South is 43 miles and the breadth stretching across East to West is 47 miles. Dhanbad comes under the Chota-Nagpur Plateau.

The climate is tropical in nature with hot summer. In winter, the minimum temperature remains around 8ºC with a maximum of 22ºC. The soil and geology of Dhanbad town which have been taken into consideration for the study cover an area between G.T.Road and Bank More in N-S direction and between Govindpur East and Hirak Bye pass Road in E-W direction.

Two types of soil around the district, namely, Alfiso red sandy soil and Ultiso red and yellow soil. The Alfiso red sandy soil is found in north and northwest part of the district which is a densely wooded hilly terrain. The rest part of the district has cultivated lands having ultiso red and yellow soil. Although ground water potentiality is not very much encouraging for the whole district, even then Dhanbad town and its surrounding areas have moderately thick confined or unconfined aquifers beneath the surface. In the rest part of the district, the ground water is restricted to weathered zone having poor porosity. Over and above the soil of Dhanbad town and its adjoining areas has reasonably better water holding capacity compared to other part of the district.

The rocks beneath Dhanbad and its adjoining terrains are metamorphic rocks made up of older basement rocks – Mica-Schist, Amphibolites, quartze-felspatite, sniessis and granitite. These older basement rocks have been intruded by Dolerite and later on these rocks were again intruded by acid intrusive rock layers of quartzite, etc. Though, metamorphic rocks are impermeable but some associated fissured rock layers are in aquifers which might have joined with fault planes or shear planes but their exact location and depth are not known exactly. Their depth differs from place to place. Therefore, in deep borings for water, it has been found that at a particular location, no water is found, but in the same vicinity few meters near about water is found. Such phenomena have been found at many locations during deep hole boring for water. All these findings can be attributed to folding characteristic of rocks beneath the ground.

MATERIALS AND METHODS

Sampling locations were selected in the residential area and water samples were collected from 24 different hand pumps during the month of December 2010 in pre washed plastic containers as per standard procedure. Some parameters like pH, TDS, salinity Conductivity had been analyzed at the spot using **Kit test r –35** and the remaining parameters like DO, Total hardness, calcium hardness, magnesium hardness, chloride and sulphate have been analysed in the laboratory following Standard method (Ref. Standard Method for the Examination of water and Waste water, APHA) .

RESULTS AND DISCUSSIONS:

The Physico-chemical characterization of ground water sample collected from 24 different hand pumps of Dhanbad Town Area has shown in Table 1.

Table 1:Physico- chemical characterization of ground water of Dhanbad Town Area.

Sl. No.	**Sample code**	**Name of sampling site**	**pH**	**Conducti-vity (μS/cm)**	**Salinity (mg/l)**	**TSS (mg/l)**	**TDS (mg/l)**	**DO (mg/l)**	**Total hardness (mg/l)**	**Calcium hardness (mg/l)**	**Magnesium hardness (mg/l)**	**Alkalinity (mg/l)**	**Chloride (mg/l)**	**Sulphate (mg/l)**
1	GW1	Polytechnique campus	7.2	322	155	100	229	5.1	170	84	20.89	13.6	568	0.116
2	GW2	Grewal colony	8.12	815	397	95	659	6.1	390	210	43.74	22	142	0.049
3	GW3	Railway colony Rangatard	7.19	1035	509	100	733	4.1	430	294	33.04	21	205.9	0.674
4	GW4	Bank more near Thana	8.13	737	360	524	624	4.0	350	231	28.91	14	106.5	0.082
5	GW5	Munical office Bank More	7.64	901	632	110	640	5.2	150	336	42.28	19	241.4	0.082
6	GW6	Washepur near Noorie Masjid	7.44	1273	442	180	902	6.9	340	147	46.89	186	106.5	0.069
7	GW7	Matkuria	7.33	885	437	100	628	5.1	350	231	28.91	372	85.2	0.053
8	GW8	Barmasia	7.39	1257	489	170	892	3.2	480	304.5	42.64	25	397.6	0.065
9	GW9	Gandhi nagar	7.31	1790	671	100	397	3.1	340	178.5	39.24	25	63.9	0.025
10	GW10	Gaguatard	7.42	923	1455	90	655	3.9	630	399.0	56.13	13	305.3	0.094
11	GW11	Tikkiapara	6.41	1185	278	110	841	5.0	118.0	777.0	97.92	14	653.2	0.119
12	GW12	Barmasia	7.39	1257	248	17o	892	5.5	130	84	11.17	9.6	21.3	0.102
13	GW13	Chiragora	7.47	1353	1364	180	960	4.3	330	325.5	49.69	21.4	205.9	0.098
14	GW14	Hari mandir campus	6.73	1328	1328	210	943	3.1	550	367.5	44.34	37	156.2	0.049
15	GW15	Telipara	7.18	1364	1353	190	966	5.3	560	252	26.24	36	184.6	0.053
16	GW16	Hirapur near pani tanki	7.27	248	1257	176	346	5.2	600	304.5	71.80	31.6	227.2	0.037
17	Gw17	ThanaMore Saraidhela	6.27	278	467	200	298	4.2	380	147	56.61	18.6	120.7	0.004
18	GW18	Near Steel Gate	7.38	1455	605	210	704	3.6	480	325.5	37.54	26.2	149.1	0.074
19	GW19	Near Bhoipur Mandir	6.28	671	933	210	704	3.0	650	210	106.92	41.4	276.9	0.090
20	GW20	Dhaiya Clinic, Dhaiya	7.68	983	656	250	701	5.2	1700	997.5	170.70	28.2	880.4	0.144
21	GW21	Housing colony	6.29	462	529	60	328	54	1470	1207.5	63.78	20.0	908.8	0.115
22	GW22	CIMFR Campus outside gate	7.85	644	230	10	451	4.9	650	630	4.86	7.2	390.5	0.041
23	GW23	Bekar Bandh	6.78	1280	398	20	908	3.9	360	315	3.64	21.8	85.2	0.069
24	GW24	Bishunpur near Zila School	6.48	790	323	80	561	6.4	1240	525	173.74	21	369.2	0.049
25		Drinkinng water Standard(IS:10500)	6.5-8.5	-	-	-	500	-	300	75	75	-	250	150

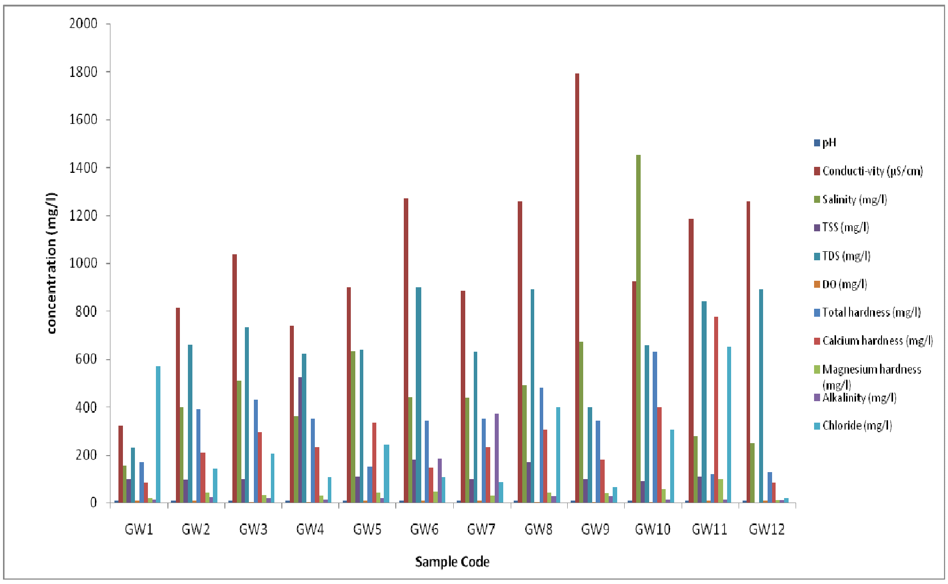

Fig. 2: Concentration (mg/l) (Except pH and conductivity) of Salinity, TSS, TD, DO, Hardness, Alkalinity , Chloride, Sulphate in ground water sample at different sampling locations.

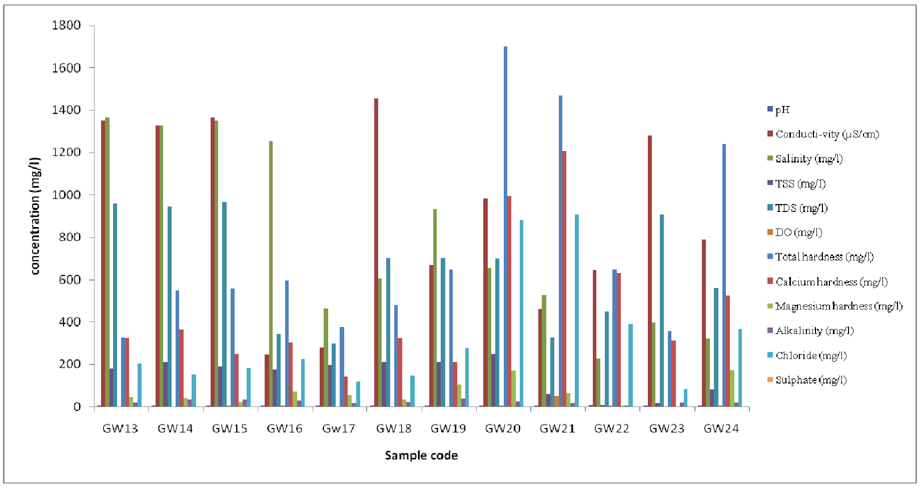

Fig. 3: Concentration (mg/l)Except pH and conductivity) of Salinity, TSS, TD, DO, Hardness, Alkalinity , Chloride, Sulphate in ground water sample at different sampling locations.

Water samples collected from Dhanbad area have been analyzed for physico-chemical parameters. The analytical result shows that pH varied from **6.27 to 8.13** which indicate that pH is within the permissible limit. Conductivity has been observed to be varied from 248µs/cm to 1790µs/cm. Salinity varies from 155-1455 mg/l with maximum value at Gaguatard. Total Suspended solid (TSS) is found to be maximum at Bank more near thana with the value ranging between 10-524mg/l whereas Total Dissolved Solids (TDS) varies from 229-966mg/l which has been observed above the permissible limit of 500mg/l at all the locations except Poly technique campus, Gandhinagar, Hirapur near Pani tanki, Thana more near Saraidhela, housing colony and CIMFR campus. Dissolved Oxygen (DO) varies from 3 to 6.9mg/l. The minimum DO is shown in Gandhi nagar area/near bhoiphor mandir. Hardness varies from 118-1700 mg/l. Among Ca and Mg hardness, Ca hardness is found to be more than the Mg hardness, with the value ranging between 84-1207.5 mg/l. Alkalinity has been found to be within the permissible limit of 200mg/l except water sample of Matkuria (372 mg/l). Chloride level has been found above permissible limit with the value ranging between 21.3-908.8 mg/ lbeing maximum at housing colony. Out of 24 water samples, 18 samples exceeds from TLV in case of TDS, 20 in case of T. Hardness, 9 in case of chloride.

In Dhanbad, due to urbanization and unregulated growth many environmental changes have taken place which indirectly affects the hydrology while the water infiltration ratio has resulted in the lowering of ground water. Soil and rock layers beneath the surface are recharged

Comparison of IS: 10500 drinking water standards with Dhanbad District ground water samples analysis results

Chemical constituents	Indian standards (IS:10500) (mg/l)	Analytical results of Dhanbad district Ground water samples (mg/l)
pH	6.5-8.5	6.27 - 8.13
Salinity	-	155-1455
TSS	-	10-524
TDS	500	229-966
DO	-	3.0-6.9
Total Hardness	300	118-1700
Calcium Hardness	75	84-1207.5
Mg Hardness	75	3.64-173.74
Alkalinity	-	7.2-372
Chloride	250	21.3-908.8
Sulphate	150	0.004-0.674

with water by two Means River and rain water. Dhanbad town and its adjoining area are not in prominent of any river hence lands open to sky are the only option left to receive rainwater for recharging ground water through percolation but builders are increasingly occupying lands which were once open to sky and other intending settlers for high rise apartments, buildings and colonies. As such an open land in and around Dhanbad is shrinking, so in rainy season reduced area of land are available to receive rain water resulting in adequate recharging of ground water. In Dhanbad and its adjoining area excessive deforestation has almost negated the convectional rain. Intermittent, untimely and insufficient monsoon rains do not recharge the ground water adequately causing depletion in ground water which ultimately lowers the water level especially in summer. Mining process surrounding the Dhanbad town is also one of the most important factors for depletion of ground water. Water is drawn during the mining process which affects the water table by disturbing the aquifers.

On the other hand population growth of Dhanbad town and its adjoining areas has increased many folds accordingly consumption of water has increased in the same proportion. Though PHED has eased the drinking water problem to a great extent through water supply system even then there is shortage of water. So the inhabitants in such a grim situation are solely dependent on ground water. The water level which is already gone down because of reasons stated above is further going down due to excessive withdrawal of ground water. Consequently many surface water wells get dried up with not a drop of water specially in summer seasons Even water is not found at greater depth of 120 meters and more in deep hole drilling at many locations . This happen only because of excessive withdrawal of water beyond its holding capacity when there is no replenishment of any kind.

CONCLUSION

As Dhanbad lies near the coal mines area and thus the quality of ground water is affected due to the mines. The parameters like total hardness, total dissolved solids and chloride have been observed above the permissible limit with the value ranging between 1700 mg/l, 966 mg/l and 908.8 mg/l respectively.Total hardness being maximum at Dhaiya clinic, Dhaiya, TDS being maximum at Telipara, and chloride being maximum at Housing colony. The high value of chloride ions (908.8 mg/l) in the ground water may result from pollution by sewage waste and leaching of saline residues in the soil and may be attributed to anthropogenic activity. Most of the people of Dhanbad town use ground water for drinking purposes from the ground water aquifers so the water should be treated and also people should use the treated water especially for drinking purpose. .

However, despite the coal mining and heavy industry, analysis of 24 different hand pumps indicates that it is generally suitable for drinking purposes, except where it exceeds the permissible for total hardness, TDS and Chloride.

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ASSESMENT OF GROUND WATER QUALITY IN DIFFERENT VALLAGES OF KARCHANA TEHSIL, ALLAHABAD, U.P.,INDIA

Satyendra Nath[1] Josmi Joe[2], S.B.Lal [1], Manisha[2] and Anita Pant[2]
[1] Deptt. of Environmental Science, SHIATS –Deemed University, Allahabad-211007, U.P,.
E-mail: satyendranath2@gmail.com
[2] Research scholar**,** Deptt. of Environmental Science, SHIATS –Deemed University,
Allahabad-211007, U.P.

ABSTRACT

Ground water samples were collected in six villages of karchana tehsil, Allahabad, U.P(India). Laboratory tests were performed for the analysis of samples for pH, Hardness, Chloride, Alkalinity, TDS etc. On comparing the results against drinking water quality standards laid by World Health Organization (WHO), it is found that some villages water sample exceed the permissible limit. This paper aims to review the groundwater quality in the villages and clarify the basics and related issues.

Keywords: Pollution, Ground water and water quality parameters

INTRODUCTION

Water, the precious gift of nature to human being, is going to be polluted day-by-day with increasing urbanization. Although three-fourth part of earth is being surrounded by water but a little portion of it can be used for drinking purpose (Shah et al, 2007). The quality of ground water also depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Application of fertilizers, pesticides, manure, industrial and municipal waste has emerged as one of the leading cause of pollution of surface and ground water. Now a days high rate of exploration, recharging, inappropriate dumping of solid /liquid wastes and anthropogenic activities creates a water pollution and lack of strict enforcement of law and loose governance are the cause of deterioration of ground water quality (Garg et al, 1999). Water is an elixir of life. It is an important component to human survival. Water should be purified for a better life style. It is the basic duty of every individual to conserve water resources (Jothivenkatachalam, et. al., 2010).

MATERIAL AND METHODS

Present study comprises of interpretation and analysis of water samples collected from six villages of Karchana Tehsil. The experimental values are compared with Standard values recommended by World Health Organization for drinking purposes.

STUDY AREA

The Groundwater (Hand pump) samples were collected from selected villages (Lawainkala, Mungari, Godheyav, Panchdevra, Nova and Kova) of Karchana tehsil for assessing the water quality for drinking purposes. The major sources of drinking water in these areas are hand pumps and tubewells.

PREPARATION OF WATER SAMPLES

The samples were collected in clean polythene bottles without any air bubbles. Prior to collection, the sample bottles are rinsed thoroughly with the sample water and tightly sealed after collection and labeled in the field. The hand pumps were continuously pumped prior to the sampling, to ensure that ground water to be sampled was representative of ground water and to avoid contamination from the surface. The samples were collected as per the Standard Methods of Water Examination, APHA (1995).

ANALYSIS OF WATER SAMPLES

Analysis was carried out for various water quality parameters such as pH(Potentiometer/Electrode), E.C (Electrolytic), Temperature (Thermometer/electrode), Total Dissolved Solids (TDS meter), Chloride (Argentometry), Total Hardness (EDTA titrimetric), Nitrate (UV Spectrophotometer), Alkalinity(Tritrimetry), Turbidity (Nephlo-Turbidity), as per Standard procedures.

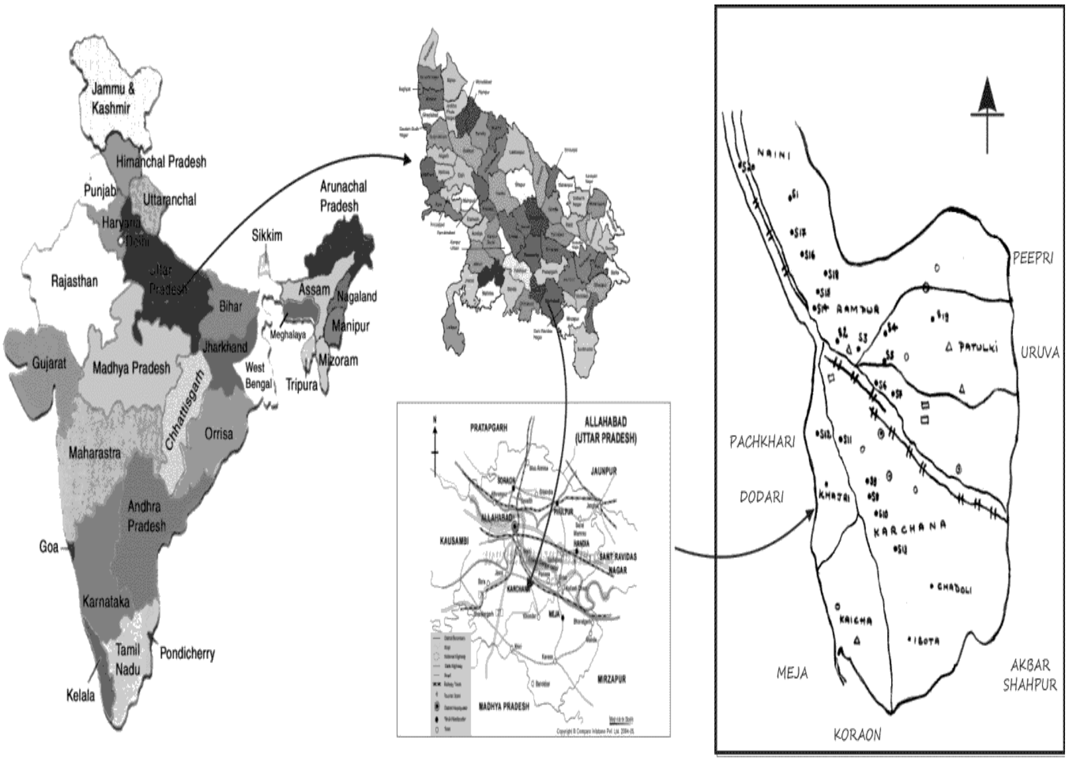

Figure 1: Location map

Figure 1. Present study comprises of interpretation and analysis of water samples collected from six different Villages of Karchana Tehsil.

RESULT AND DISCUSSION

The water quality analysis of different ground water samples has been carried out for Temperature, pH, EC, Total Hardness, Calcium Hardness, Total alkalinity, Chloride, Nitrate, Turbidity and Total Dissolved Solids. The results of the physic-chemical analysis of the groundwater samples are appended in Table 1.

pH :

pH is the parameter for measuring acidity and alkalinity of the water. The pH values of water are one of the indicator commonly used to find out the level of pollution. The WHO recommended value for pH is 6.5-8.5. pH values of all the sites lies within the limit. The highest pH was found to be 7.56 in Nova during the month of January while the lowest value 6.8 was found in Lawainkala in the month of January.

Turbidity:

Turbidity of ground water samples varied from 1-26 NTU. According to WHO specifications the desirable limit of turbidity in water is 5 NTU. Turbidity is due to the presence of excess amount of total solids. All the station except Mungri and Godheyav was found to have permissible level of turbidity. The turbidity level of Mungri was found to be 26 NTU in January while that of Godheyav was found to be 9 NTU.

Temperature:

The atmospheric temperature influence water temperature. The increase in temperature speeds up various chemical reactions; reduce the solubility of the gases. Temperature can control the degree of dissolved oxygen saturation and carbon dioxide concentration. The increased temperature increases the amount of oxygen required by organisms. The temperature of all the sites during all the three months ie January, February and March was found to be 20^0C except for Kova where the temperature was recorded to be 30^0C during the month of March.

Electrical Conductivity:

Conductivity is a measure of water's capacity to convey electric current. Conductivity of water varies directly with the temperature and is proportional to its dissolved mineral matter content. The range of Electrical Conductivity was found between 0.489 to 2.11mS/cm.

Total Dissolved Solids:

The WHO recommended value for TDS is 500 mg/l. Almost all the sites showed permissible level of TDS, except for the Mungri where the highest value of 790 mg/ l was recorded in the month of March.

Alkalinity:

The Standard desirable limit of alkalinity in potable water is 120 mg/l. The maximum Permissible level is 600 mg/L. The value of Alkalinity of groundwater exceeded standard desirable limit in all stations compared to the prescribed value but were within the maximum permissible limit, given by WHO, except for Mungri where the alkalinity was found to be 718 mg/l in the month of March. The Total Alkalinity value of groundwater samples ranged from 416-530 mg/l in Lawainkala during the month of January to March. The cause of Alkalinity is the minerals which dissolve in water from soil. The various ionic species that contribute to Alkalinity include Bicarbonate, Hydroxides; Carbonates from Alkalinity point of view quality of water samples in all regions is poor.

Nitrate:

The nitrate concentration is found to be vary in the range of 1.38 to 13.76 mg/l. Highest range of nitrate was found at Mungri where the nitrate level was found to be 13.76, 11.38 and 10.5 mg/lt in the month of January, February and March respectively. Presence of nitrate in water indicates the final stage of mineralization. The main source of nitrate pollution was found to be the heavy use of nitrate fertilizers in these regions, as these regions have plenty of cultivating land. Nitrate indicates the pollution in ground water due to sewage percolation beneath the surface. Major contributors of nitrate in groundwater are decaying matter, sewage, Burn yard waste and nitrate fertilizers. Excessive nitrate is responsible for water pollution primarily because they stimulate the growth of micro-organisms.

Chloride:

The permissible limit of chloride in drinking water is 250 mg/l. Chlorides may get into water from several sources including, rocks containing chlorides, agricultural run off, industrial effluents, discharge of domestic waste, man and animal excreta. Chloride content of the ground water samples ranges from 11 to 124 mg/l. The lowest concentration of chlorides was recorded in Godheyav ie. 11 mg/l in the month of March whereas the highest concentration ie. 124 mg/l was found in Mungri in January.

Total Hardness:

WHO has specified the total hardness to be within 500 mg/l of $CaCO_3$. Water hardness is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulfate in water. The range of Total Hardness varied from 88 mg/l in Nova in the month of January to 666 mg/l in Mungri in February.

Calcium Hardness:

The value of calcium hardness as $CaCo_3$ was found in the range of 34 -320 mg/l. The highest value was found in the groundwater of Mungri in the month of March while the lowest value was recorded in the water of Nova in March.

CONCLUSION

This study reveals that groundwater is the only source for drinking water in the study area, and the results of the physic chemical analysis of groundwater indicate considerable variation. Most of the water samples comply with WHO standards for drinking purposes except Mungri where most of the parameters exceeds the recommended value of WHO.

Table 1: Physico-chemical characteristics of ground water quality of different villages Karchana Tehsil

	PARAMETERS										
SAMPLING SITES	**SAMPLING TIME**	**pH**	**Temp**	**Turbidity**	**EC, mS/cm**	**TDS**	**Total hardness**	**Ca Hardness as $CaCO_3$**	**Nitrate**	**Chloride**	**Alkalinity**
LAWAINKALA	JAN	6.80	20.00	3.00	1.02	410.00	204.00	80.00	4.07	28.00	416.00
	FEB	7.38	20.00	1.00	0.71	340.00	294.00	150.00	3.36	24.00	500.00
	MAR	7.07	20.00	1.00	0.89	480.00	186.00	60.00	3.00	17.00	530.00
	MEAN	**7.08**	**20.00**	**1.67**	**0.87**	**410.00**	**228.00**	**96.67**	**3.48**	**23.00**	**482.00**
MUNGRI	JAN	7.07	20.00	26.00	2.11	290.00	440.00	80.00	13.76	124.00	488.00
	FEB	7.44	20.00	3.00	2.03	760.00	666.00	270.00	11.38	120.00	560.00
	MAR	7.05	20.00	4.00	1.74	790.00	400.00	320.00	10.50	121.00	718.00
	MEAN	**7.19**	**20.00**	**11.00**	**1.96**	**613.33**	**502.00**	**223.33**	**11.88**	**121.67**	**588.67**
PANCHDEVRA	JAN	6.92	20°	2.00	1.13	310.00	246.00	100.00	6.30	79.00	250.00
	FEB	7.45	20°	2.00	0.49	480.00	346.00	206.00	3.92	75.00	366.00
	MAR	6.98	20°	5.00	0.93	310.00	230.00	110.00	7.49	76.00	440.00
	MEAN	**7.12**	**20.00**	**3.00**	**0.85**	**366.67**	**274.00**	**138.67**	**5.90**	**76.67**	**352.00**
GODHEYAV	JAN	7.11	20°	9.00	0.83	230.00	170.00	60.00	5.03	30.00	324.00
	FEB	7.16	20°	1.00	0.56	210.00	220.00	110.00	2.49	30.00	240.00
	MAR	7.12	20°	2.00	0.65	310.00	130.00	76.00	5.03	11.00	400.00
	MEAN	**7.13**	**20.00**	**4.00**	**0.68**	**250.00**	**173.33**	**82.00**	**4.18**	**23.67**	**321.33**
NOVA	JAN	7.56	20°	4.00	0.71	290.00	88.00	24.00	3.84	39.00	184.00
	FEB	7.18	20°	3.00	0.78	310.00	276.00	180.00	7.17	35.00	160.00
	MAR	7.04	20°	3.00	0.65	240.00	104.00	34.00	4.39	20.00	340.00
	MEAN	**7.26**	**20.00**	**3.33**	**0.71**	**280.00**	**156.00**	**79.33**	**5.13**	**31.33**	**228.00**
KOVA	JAN	7.15	20°	4.00	1.00	400.00	280.00	120.00	6.14	48.00	330.00
	FEB	7.40	20°	1.00	0.49	430.00	304.00	80.00	1.61	44.00	224.00
	MAR	7.15	30°	1.00	0.89	410.00	240.00	132.00	5.26	63.00	460.00
	MEAN	**7.23**	**23.33**	**2.00**	**0.79**	**413.33**	**274.67**	**110.67**	**4.34**	**51.67**	**338.00**
WHO (1993)	**Permissible limit**	6.5-8.5	-	5		500	300	100	20	250	120
	Excessive limit		-	10		1000	600	-	45	1000	600

All values reported in mg/l, except turbidity, electrical conductivity (EC) and pH

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EFFECT OF GROUND WATER ON SOIL AND VEGETATION IN COLD DESERT AREAS OF HIMACHAL PRADESH

Afaq Majid Wani[1] and B.K. Mishra[2]
1:School of Forestry and Environment; Sam Higginbottom Institute of Agriculture Technology and Sciences, Allahabad
2: Dept. of Environment Science Indian School of Mines Dhanbad

INTRODUCTION

Deserts are arid regions of the earth, generally distinguished by scarcity of vegetation and a low population density. Desertification is one of the most serious problems facing the world today. Large parts of the dry areas that cover more than one third of the earth surface are being degraded with serious effects on the environment (Negi, 1996). It has been observed that most of the countries and areas which are experiencing serious desertification are economically under developed and therefore lack the resources to respond to these changes in a sustainable way (Cold Well, 1984). During the past, few decades there has been appreciable divergence from traditional system resulting in environmental degradation and decline in socio-economic values. Indigenous knowledge is being over shadowed by modern culture and looked upon as backward, irrational and mostly labour intensive, lacking scientific reasoning and documentation. Regenerative and traditional environment friendly practices were and are still being replaced by modern technology in the Himalayan belt.

The cold deserts in India cover an area of 74,809 sq. km and are spread through Leh and Kargil districts of Jammu & Kashmir and Lahaul and Spiti with some parts of Chamba and Kinnaur districts of Himachal Pradesh. Cold deserts are characterized by dry temperate and cold arid climate. Large diurnal variations in temperature and severe dry weather make conditions extremely inhospitable for the growth and development of living organisms. It represents a vast sandy tract with barren lofty mountains. Fragile ecosystem of the cold deserts is at the brink of environmental degradation due to a complex web of social, technological and environmental factors. Vegetation is restricted to the places where plenty of moisture is available, such as along the river banks, nallahs (water channels) and snow melts etc. Very few trees and shrub species are native to this region.

National Afforestation Programme (NAP) was started with a view to increase the forest cover in the country. Of the many objectives, one was rehabilitation of deserts, coastal areas, mined areas and problematic lands like saline/alkaline soils, ravines etc. The mandate of NAP was to promote people’s participation to achieve its objectives in the 10th Five Year Plan. It was emphasized that committees involving forest department officials and village people should be constituted which will work together. Thus Joint Forest Management Committee (JFMCs) and Forest Development Agencies (FDAs) were constituted in every forest division of the country, so as to execute various plantation schemes of the central/state government. The present study is thus a tool to determine the increase in forest cover in cold desert areas through FDA plantations and the impact of these plantations on the soil health. The study was carried out in the cold deserts of Jammu and Kashmir and Himachal Pradesh. Leh and Kargil districts of Ladakh region represent cold desert of J&K, while, Pooh sub division of Kinnaur district and Lahaul & Spiti district constitute the cold desert of H.P.

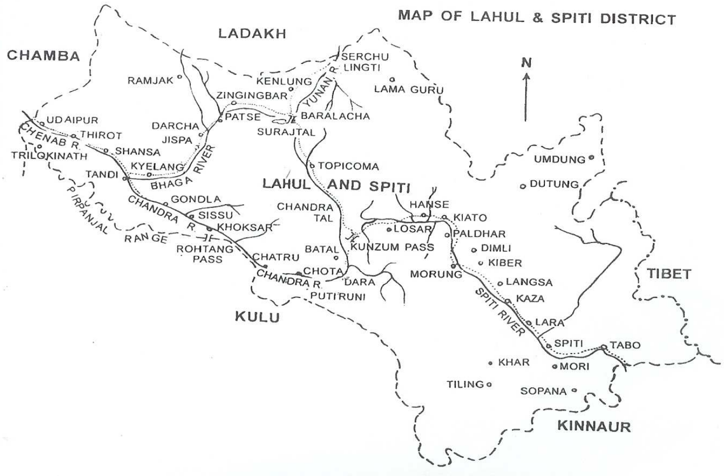
MATERIAL AND METHODS

The areas under NAP scheme were selected and the plots were demarcated. Simple random sampling techniques were used. At least five quadrats were laid at each site. The number of trees, shrubs and herbs present in these plots was used to calculate the approximate plant density on hectare basis. The dimensions of trees falling in each plot were recorded as height, diameter (dbh), and the basal area was recorded for shrubs and herbs. The sizes of the plots were 33 x 33m for trees, 10 x 10 m for shrubs and 5 x 5 m for herbs (Singhal, 1996). Data were obtained from each sampling plot/quadrat. Observations recorded were, Plantation area, Name of sampling unit, Name of the species planted, Survival percentage in the plantation, Mean tree diameter, Total no. of trees present in Quadrats, Total no. of shrubs present in Quadrats, Composite samples of soil (0-15cm depth), pH, Electrical Conductivity, Organic Carbon of the soil at each site, N, P and K content of the soil at each site. Following parameters such as Per cent frequency, Density, Mean basal area, Total basal area, Relative dominance, Relative density, Relative frequency and Importance value Index (IVI) were also computed. The soil samples were taken from each plantation site in order to classify them to assess the physico-chemical characteristics of the soil. Each planted and un-planted site was divided into different (4 -8) sections depending upon the size of the site and composite soil samples were taken from 0 -15 cm depth. The samples were collected with the help of soil auger. The soil samples were air dried in shade on filter paper sheets, ground with pestle and mortar, passed through 2 mm plastic sieve and were finally stored in cloth bags for analysis. Soil pH, Electrical Conductivity (EC) and Organic Carbon (OC): Soil pH and EC were determined in 1: 2.5 soil water suspension with the help of pH meter and conductivity bridge respectively and Organic carbon was determined by Walkley and Black (1934) rapid titration method. Total N, P, K: Total Nitrogen (N) was determined by Macro Kjeldahl method and total Phosphorus (P) was extracted by digestion in HCl and determined by Vanadomolybdate phosphoric yellow colour method. Total Potassium (K) content was determined in 6 N HCl extract as given by Agricultural Education Association provisional method (Piper, 1966, Oslen *et .al.,* 1954 and Jackson 1973). For interpretation of results, data on pH, EC, OC, N, P, and K were statistically analyzed by analysis of variance technique in RBD Design (Factorial).

RESULTS AND DISCUSSION

Kinnaur

The rain shadow area of Kinnaur lies in Kalpa-Pangi valley towards Murang and beyond Sangla and is adjoining to Spiti area. The northern side of Sangla is dominated by two great peaks, the first (6157 m) above Sangla village and the second (6610 m) about 18 kms from further on. The physical features are extremely rugged, wind-swept and frost bitten cold areas. The total area of Kinnaur is 10820.29 sq. km. However, no FDAs have been established in Kinnaur.



Map 3 : Cold desert area of Lahul & Spiti in Himachal Pradesh (Not to the scale)

Lahaul

The range of elevation of the peaks in Lahaul is between 4550 m and 5400 m. The lowest point is about 450 m where river Chenab makes its exit from the district. The Lahaul-Spiti district occupies an area of about 12210 sq. km. The vegetation of this area is quite similar to that of Ladakh region. Depending upon the geography, Lahaul & Spiti district is divided into two valleys. In Lahaul the total number of FDAs were 24 where afforestation and entry point activities (EPAs) were carried out. There were 11 plantation sites selected for this study. In six of the FDAs a few EPAs and pit digging had been done. Plantation work could not be done due to late arrival of funds in FDAs. Total area under plantation was 74 ha out of which 44.0 ha were sampled for the study (59.45%). At Lahaul the maximum plantation and survival was recorded at Shansha with 6.5ha and 71.16 per cent respectively followed by Lingar where Poplar and Salix showed good survival percentage of 60.92. Minimum survival per cent of 43.23 was recorded at Jobrang (Table-1).

Table 1: Survival percentage in the plantations at Lahaul

Observations recorded	Sites				
	Mooring	**Jobrang**	**Rapey**	**Rashil**	**Mooling**
Plantation area (ha)	4.5	3.5	3.0	4.5	3.0
Species planted	Poplar Robinia	Poplar Salix	Poplar Salix Robinia	Deodar Salix	Poplar Salix
Total survival (%)	52.00	43.23	58.06	55.41	50.66
Area Sampled (ha)	0.67	0.53	0.45	0.67	0.45

Mooring

Mooring in Lahaul division was considered for vegetation analysis because VFC had been established there. This site revealed two tree and one shrub species. The highest density (200.0 trees ha^{-1}) was recorded for Robinia, whereas, lowest density was found for Poplar (125.0 trees ha^{-1}). The highest basal area was exhibited by Robinia 1468.25 cm^2 ha^{-1} and lowest for Poplar 628.25 cm^2 ha^{-1}. Total density of Seabuckthorn recorded on this site was 260 stems ha^{-1} with basal area of 484.04 cm^2 ha^{-1} (Table 2). Total density and basal area for Robinia and Poplar was recorded as 325.0 and 2096.5 cm^2 ha^{-1}, respectively. Importance Value Index (IVI) of the trees indicated that Robinia was the dominant species with a value of 181.57 (Table-2).

Table 2 : Species composition at Mooring

Shrubs/Trees	Density/ ha	Basal area (cm^2 ha^{-1})	RD	RBA	RF	IVI
Seabuckthorn	260	484.04	100	100	100	300
a) Poplar	125	628.25	30.46	29.97	50.0	118.43
b) Robinia	200	1468.25	61.54	70.03	50.0	181.57
Total (a+b)	325	2096.5	100	100	100	300

Jobrang

In this area two tree species and a shrub were present. The total density of the sites was 352.5 trees ha^{-1} with a basal area of 6423.75 cm^2 ha^{-1}. The maximum density of 215.0 trees ha^{-1} was recorded for Salix with maximum basal area 5534 cm^2 ha^{-1}. The minimum density of 137 trees ha^{-1} was observed for Poplar with the lowest basal area of 889.75 cm^2 ha^{-1} (Table-3). The only shrub present was Wild Rose with a density of 150.0 stems ha^{-1} and basal area of 598.5 cm^2 ha^{-1}. The Importance Value Index (IVI) of trees indicated that Salix was the dominant species with IVI of 197.14 and Poplar was the co-dominant with IVI value at 102.86 (Table-3).

Table 3 : Species composition at Jobrang

Shrubs/ Trees	Density/ ha	Basal area (cm^2 ha^{-1})	RD	RBA	RF	IVI
Wild rose	150	598.5	100	100	100	300
a) Poplar	137.5	889.75	39.01	13.85	50	102.86
b) Salix	215	5534	60.99	86.15	50	197.14
Total (a+b)	352.5	6423.75	100	100	100	300

Rapey

This site contained three tree species having a total density of 450.0 trees ha^{-1} with basal area of 5683.8 cm^2 ha^{-1} (Table-4). The highest of density 275 trees ha^{-1} were recorded for Robinia with a basal area of 4416.75 cm^2 ha^{-1} whereas, lowest density 75 trees ha^{-1} was recorded for Poplar with a basal area of 7012.75 cm^2 ha^{-1}. Importance Value Index (IVI) showed that Robinia was the dominant species with IVI of 138.42, Salix being the co-dominant with 103.78 (Table-4).

Table 4: Species composition at Rapey

Trees	Density/ ha	Basal area cm^2 ha^{-1}	RD	RBA	RF	IVI
Poplar	75	702.75	16.67	7.79	33.33	57.79
Salix	100	484.30	22.22	48.23	33.33	103.78
Robinia	275	4416.75	61.11	43.98	33.33	138.42
Total	450	5683.8	100	100	100	300

Rashil

At this site, two tree species and two shrubs were present. A total of 412.5 trees ha^{-1} were present on this site with a basal area of 13246.75 cm^{2} ha^{-1}. The highest density of 237.5 trees ha^{-1} was recorded for Salix with a basal area of 13094.25 cm^{2} ha^{-1}. However, the lowest density of 175 trees ha^{-1} was recorded for Deodar with a basal area of 152.5 cm^{2} ha^{-1} (Table 5). The Importance Value Index showed that Salix was the dominant species with IVI of 206.43, Deodar being co-dominant with 93.57 IVI. The total density of shrubs recorded at this site was 410 stems ha^{-1} with the basal area of 736.54 cm^{2} ha^{-1}. The maximum density was recorded for Seabuckthorn at 224.0 stems ha^{-1} with the maximum basal area of 526.28 cm^{2} ha^{-1}.

Table 5 : Species composition at Rashil

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^{2} ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Wild rose	186	210.26	45.37	28.55	50	123.92
Seabuckthorn	224	526.28	54.63	71.45	50	176.08
Total	410	736.54	100	100	100	300
a) Deodar	175	152.5	42.42	1.15	50	93.57
b) Salix	237.5	13094.25	57.58	98.85	50	206.43
Total (a+b)	412.5	13246.75	100	100	100	300

Mooling

There were two tree species at this site. The density was 112.5 trees ha^{-1} and basal area was 13039.5 cm^{2} ha^{-1}. The highest density of 62.5 trees ha^{-1} was recorded for Poplar and the lowest density for Salix 50.0 trees ha^{-1}. The maximum basal area of 11194.0 cm^{2} ha^{-1} was recorded for Salix and the minimum basal area of 1845.5 cm^{2} ha^{-1} for Poplar (Table-6). The IVI showed that Salix was the dominant species with the value at 180.29 (Table-6).

Table 6 : Species composition at Mooring

Trees	**Density/ ha**	**Basal area (cm^{2} ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Poplar	62.5	1845.5	55.55	14.15	50	119.70
Salix	50	11194	44.44	85.85	50	180.29
Total	112.5	13039.5	100	100	100	300

Spiti

Spiti in comparison to Lahaul, is higher in elevation with more rugged and difficult terrain. The average elevation is about 4600 m. All round Spiti are lofty ranges and peaks with Chocho Lang Kilta Peak (6400 m) in the north and main Himalayan range in the east. Spiti region has very little vegetation. It is a typical mountain desert. In Spiti valley, the total number of FDAs constituted was 12 out of which 5 FDAs were selected as sampling units for the study. In rest of the VFCs due to some unexplained reasons plantation work could not be carried out and only digging of pits, fencing and other entry point activities had been conducted uptill July, 2006. The total area under plantation was 31.5 ha out of which 19.0 ha were taken for the study i.e. 61.90 per cent area was sampled. In Spiti, the highest plantation and survival per cent were recorded at Key Gonpa i.e. 5.5 ha with 82.42 per cent. However, the minimum (41.23 %) survival per cent was recorded at Sumling (Table7).

Table 7: Survival percentage in the plantations at Spiti

Observations recorded	Sites				
	Kaza	Key Gonpa	Sumling	Lossar	Tabo
Plantation area (ha)	1.5	5.5	4.0	7.0	1.0
Species planted	Robinia Salix	Poplar Salix	Poplar Salix	Poplar Salix	Poplar Salix
Total survival (%)	47.23	85.42	41.23	55.29	46.82
Area Sampled (ha)	0.23	0.80	0.60	0.70	0.15

Kaza

VFC Kaza under Spiti was considered for vegetation analysis which revealed only two tree species and three shrubs. A total of 350.0 tree ha^{-1} were recorded on this site with a basal area of 3391.88 cm^{2} ha^{-1}. The highest density of 262.5 trees ha^{-1} was recorded for Salix, and the lowest density for Poplar was 87.0 trees ha^{-1}. The highest basal area was exhibited by Salix at 3129.25 cm^2 ha^{-1} and the lowest basal area was recorded for Poplar at 262.63 cm^2 ha^{-1} (Table-8). The Importance Value Index (IVI) of trees indicated that Salix was the dominant species with the value of 217.25.The total density of the three shrubs recorded on this site was 96.0 stems ha^{-1} with a basal area of 217.00 cm^2 ha^{-1}. The maximum density was recorded for Seabuckthorn with 54 stems ha^{-1} with the maximum basal area of 151.42 cm^2 ha^{-1}. However, the minimum density was recorded for Wild Rose with 1800.0 stems ha^{-1} and the lowest basal area for *Artemisia* at 28.04 cm^2 ha^{-1}. The IVI for shrubs indicated that Seabuckthorn was dominant with value of 159.36.

Table 8 : Species composition at Kaza

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^2 ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
a) Artemisia	24	28.04	25.00	12.93	33.33	71.26
b) Rose	18	37.54	18.75	17.29	33.33	69.37
c) Sea- buckthorn	54	151.42	56.25	69.78	33.33	159.36
Total (a+b+c)	96	217.00	100	100	100	300
d) Robinia	87.5	262.63	25	7.75	50.0	82.75
e) Salix	262.5	3129.25	75.0	92.25	50.00	217.25
Total (d+e)	350.0	3391.80	100.0	100.0	100.0	300.0

Key Gonpa

The site at Key (Table-9) revealed that there were two tree and two shrub species. The density of 462.50 trees ha^{-1} was recorded here with the basal area of 39892.0 cm^2 ha^{-1}. The highest density of 275.0 trees ha^{-1} was recorded for Salix and the lowest for Poplar with 187.5 tree ha^{-1}. The maximum basal area of 39309.0 cm^2 ha^{-1} was recorded for Salix and the minimum basal area for Poplar at 582.25.0 cm^2 ha^{-1}. The IVI revealed that Salix was the dominant species with a value of 208. The total density of shrubs was 226 stems ha^{-1} with a basal area of 318.32 cm^2 ha^{-1}. The maximum density was recorded for Wild Rose with 162.0 stems ha^{-1} with the maximum basal area of 256.42 cm^2/ha. The IVI revealed that Wild Rose was the dominant species among the shrubs.

Table 9 : Species composition at Key Gonpa

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^2 ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Artemisia	64	61.90	28.31	19.44	50.00	97.75
Rose	162	256.42	71.69	80.56	50.00	202.25
Total	226	318.32	100	100	100.00	300
a) Poplar	187.5	582.25	40.54	1.46	50.00	92.00
b) Salix	275	39309	59.46	98.54	50.00	208.00
Total (a+b)	462.5	39892.00	100	100	100	300

Sumling

There were two tree species at this site with a total density of 300.0 trees ha^{-1} and a basal area of 1871.13 cm^2 ha^{-1}. The highest density (187.5 trees ha^{-1}) was recorded for Poplar and the lowest for Salix 112.5 trees ha^{-1}. Highest basal area was exhibited by Poplar with 1060.50 cm^2 ha^{-1} and the lowest by Salix with 810.6 cm^2 ha^{-1} (Table-10). The Importance Value Index (IVI) of trees indicated that Poplar was the dominant species of this site (169.17).

Table 10 : Species composition at Sumling

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^2 ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Poplar	187.5	1060.5	62.5	56.67	50.5	169.17
Salix	112.5	810.63	37.5	43.33	50.5	130.83
Total	300	1871.13	100	100	100	300

Lossar

At Lossar two tree species viz. Poplar and Salix were present. The total density of 475.0 trees ha^{-1} was recorded at Lossar with basal area of 6983.38 cm^2 ha^{-1}. The maximum density of 362.5 trees ha^{-1} was recorded for Poplar, whereas, the minimum density of 112.5 trees ha^{-1} was recorded for Salix (Table-11). The maximum basal area was recorded for Poplar at 3815.5 cm^2 ha^{-1} whereas, the minimum for Salix at 3167.88 cm^2 ha^{-1}. The IVI values indicated that Poplar was the dominant tree species with the value of 180.96 and Salix was the co-dominant (119.04).

Table 11 : Species composition at Lossar

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^2 ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Poplar	362.5	3815.50	76.32	54.64	50.0	180.96
Salix	112.5	3167.88	23.68	45.36	50.00	119.04
Total	475.0	6983.38	100	100	100	300

Tabo

This site carried two trees species and three shrubs. At this site the density was 400.0 trees ha^{-1} and the basal area was 1748.75 cm^2 ha^{-1}. The maximum density of 275.0 trees ha^{-1} was recorded for Poplar and the minimum density of 125.0 trees ha^{-1} was recorded for Salix. The highest basal area of 1041.25 cm^2 ha^{-1} was recorded for Salix and the minimum for Poplar at 707.50 cm^2 ha^{-}1. The Poplar was the dominant tree with IVI of 159.21 and Salix was the co-dominant with IVI of 140.79 (Table-12). The total density of shrubs at this site was 336 stems ha^{-1} with a basal area of 722.14 cm^2 ha^{-1}. Whereas maximum density of 148.0 stems ha^{-1} was recorded for *Ephedra*, the minimum density (76 stems ha^{-1}) was recorded for *Artemisia*. The highest basal area of 406.26 cm^2 ha^{-1} was recorded for *Rosa* (wild Rose) and the minimum basal area 95.18 cm^2 ha^{-1} for *Ephedra* (Table-12). The IVI revealed that Wild Rose was the dominant species (122.92) among the shrubs and *Ephedra* was the co-dominant with IVI 90.50.

Table 12: Species composition at Tabo

Shrubs/ Trees	**Density/ ha**	**Basal area (cm^2 ha^{-1})**	**RD**	**RBA**	**RF**	**IVI**
Artemisia	76	220.70	22.62	30.56	33.33	86.51
Rose	112	406.26	33.33	56.26	33.33	122.92
Ephedra	148	95.18	44.05	13.18	33.33	90.50
Total	336	722.14	100	100	100	300
a) Poplar	275	707.50	68.75	40.46	50.00	159.21
b) Salix	125	1041.25	31.25	59.54	50.00	140.79
Total (a+b)	400	1748.75	100	100	100	300

Soil Analysis

Lahaul

Data in Table 13 revealed that the mean pH value was recorded maximum at Mooling (8.49), Rashil (8.39) and Mooring (8.38). However, EC was recorded maximum for sites under plantation sites (0.7702) and under non - plantation areas the mean value of EC was 0.4662. The mean value of organic carbon was maximum at Rashil (1.13) which was statistically different from rest of the sites and the minimum was recorded atRashil (0.13). Mean value of organic carbon was 0.54 under plantation sites and the minimum (0.42) under non - plantation areas.

Table 13: Soil analysis for pH, EC and OC of plantation and non - plantation areas of Lahaul.

Sites	pH			EC (d ms^{-1})			OC (%)		
	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean
Mooring	7.94	8.82	8.38	0.780	0.347	0.059	0.78	0.35	0.56
Jobrang	8.11	8.05	8.08	0.500	0.210	0.165	0.50	0.21	0.36
Rapey	7.44	8.67	8.05	0.428	0.630	0.069	0.63	0.43	0.53
Rashil	7.99	8.80	8.39	1.490	0.767	0.071	0.14	0.76	0.13
Mooling	8.21	8.78	8.49	0.653	0.377	0.062	0.65	0.38	0.52
Mean	7.938	8.624	8.278	0.7702	0.4662	0.0852	0.54	0.42	0.42

CD PH	OC	EC
S = 0.32	S=0.04	S=0.005
P = 0.17	P=0.02	P =0.002
SxP= 0.47	SxP=0.06	SxP=0.006

Data appended in Table 14 showed that mean value of Nitrogen content was maximum at Mooling (286.7) which was statistically different from rest of the sites. The minimum value of mean nitrogen content was recorded at Rashil (113.9). The mean value of nitrogen content under plantation sites was 244.7 and the minimum under non-plantation areas (92.06). The mean value of phosphorus content was the maximum at Rapey (40.54) which was statistically different from rest of the sites. On the other hand, the mean phosphorus content under plantation sites was 36.81and under non – plantation it was 11.35 which were statistically different from each other. Mean value of potassium was the maximum at Rashil (231.8) which was statistically different from rest of the sites. However, the mean potassium content of plantation sites was 215.48 and under non plantation it was 61.13.

Table 14: Soil analysis for Nitrogen, Potassium and Phosphorous of plantation and non - plantation areas of Lahaul

Sites	Nitrogen (Kg/ha)			Phosphorus (Kg/ha)			Potassium (Kg/ha)		
	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean
Mooring	267.7	76.26	172.0	42.91	11.64	27.27	194.1	50.64	122.4
Jobrang	163.6	53.57	108.6	23.38	9.61	16.50	128.2	41.12	84.67
Rapey	255.8	66.16	161.0	67.88	13.20	40.54	201.0	71.49	136.2
Rashil	154.3	73.43	113.9	45.65	9.91	27.78	371.7	91.94	231.8
Mooling	382.4	190.9	286.7	4.23	12.39	23.31	182.4	50.47	116.4
Mean	244.7	92.06	168.44	36.81	11.35	27.08	215.48	61.13	138.2

CD Nitrogen Potassium Phosphrous
S =4.99 S=3.31 S=1.39
P= 2.13 P=1.41 P =0.59
SxP=7.35 SxP=4.86 SxP=2.05

Spiti

The data in Table 15 revealed that the mean value of pH was maximum at key Gonpa (8.41) which was statistically at par with Sumling (8.40) Lossar (8.24) and Tabo (8.06). For the plantation sites, the mean value of pH was 7.48, while for non – plantation sites it was 8.47.The mean value of EC was the maximum at Tabo (0.235) which was statistically different from the rest of the sites and was the minimum (0.115) for Kaza. The mean value of EC was 0.253 under the plantation sites and was (0.063) under non – plantation areas. The mean value of organic carbon was maximum at Lossar (0.867) which was statistically different from rest of the sites.

Table 15: Soil analysis for pH, EC and OC of plantation and non - plantation areas of Spiti

Sites	pH			EC (d ms^{-1})			OC (%)		
	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean
Kaza	6.99	8.35	7.67	0.139	0.091	0.115	0.863	0.413	0.638
Lossar	8.09	8.39	8.24	0.267	0.055	0.161	1.237	0.049	0.867
Sumling	8.16	8.65	8.41	0.221	0.042	0.131	0.643	0.330	0.487
Key Gnpa	8.06	8.76	8.41	0.256	0.038	0.147	0.443	0.177	0.310
Tabo	7.91	8.21	8.06	0.382	0.088	0.235	0.767	0.277	0.220
Mean	7.48	8.47		0.253	0.063		0.790	0.339	

CD PH OC EC
S =0.42 S=0.003 S=0.006
P=0.27 P=0.023 P =0.003
SxP=0.59 SxP=0.051 SxP=0.008

The mean value of nitrogen content was the maximum at Kaza (134.4) which was statistically at par with Sumling (132.8). On the other hand the minimum was recorded at Tabo 123.8. Under plantation sites, the mean nitrogen content was 186.0 and under non - plantation sites it was observed 71.16. The mean value of phosphorus content (26.13) was the maximum at Tabo site and minimum at Sumling (15.13). On the other hand the phosphorus content recorded under plantation sites was 27.36 which was statistically different from non - plantation sites where it was observed to be only 12.39. The mean value of potassium content was recorded maximum at Kaza (287.4) and minimum for Key Gonpa (130.2). The mean value of potassium content recorded highest under plantation site was 270.2 and less or minimum (62.77) under non - plantation area (Table 16).

Table 16: Soil analysis for Nitrogen, Potassium and Phosphorous of plantation and non - plantation areas of Spiti

Sites	Nitrogen (Kg/ha)			Phosphorus (Kg/ha)			Potassium (Kg/ha)		
	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean	Plantation	Non plantation	Mean
Kaza	205.1	63.67	134.4	33.00	11.68	22.34	500.8	74.06	287.4
Lossar	192.4	55.36	123.9	8.92	12.52	15.72	218.0	62.14	140.1
Sumling	197.9	67.68	132.8	20.30	9.96	15.13	215.3	52.16	133.7
Key Gonpa	186.4	69.57	128.0	28.90	11.22	20.06	202.1	58.32	130.2
Tabo	148.1	99.54	123.8	35.70	16.55	6.13	214.6	67.16	140.9
Mean	186.0	71.16		27.36	12.39		270.2	62.77	

CD Nitrogen (N) Potassium Phosphorus
S =4.07 S=5.83 S=2.40
P=2.57 P=3.69 P =1.52
SxP=.76 SxP=8.25 SxP=3.39

SUMMARY

Lahaul showed maximum density (450.00 ha $^{-1}$) was also observed for Rashil (412.5). Rashil showed the maximum basal area 13246.75 cm^{2} ha$^{-1`}$ followed by Mooring (1309.50 cm^{2} ha^{-1}). The Importance Value Index (IVI) revealed that Salix was the most dominant tree species at Rapey and Rashil. Spiti recorded the maximum survival percentage (85.42) was recorded at Key Gonpa. The maximum density (475.0 trees ha^{-1}) was recorded at Lossar followed by Key Gonpa (462.5 trees ha^{-1}) and Tabo (400.0 trees ha^{-1}). The maximum basal area (39891.25 cm^{2} ha^{-1}) was recorded for Key Gonpa followed by Lossar (6983.38 cm^{2} ha^{-1}).The Importance Value Index (IVI) revealed that Poplar was dominant at most of the sites i.e. Sumling, Lossar and Tabo, however, Salix was dominant at Kaza and Key Gonpa.

CONCLUSIONS

The most dominant species almost for all the sites was Salix followed by Poplar, however, at Lahaul Robinia, a fast growing tree was dominant. These were the only three species which showed good performance under the harsh conditions of cold desert. Lahaul and Spiti pH was alkaline under non - plantation areas but at plantation area it was slightly alkaline i.e towards neutral. EC was under the safe limits in all the sites i.e < 0.8 dsm $^{-1}$. Organic carbon content as recorded higher under plantation than under non-plantation areas in all the sites.The plantation has shown increasing trend in the species diversity as shrubs and herb growth has started at a few sites.The plantation works have generated employment for local people. The plantations raised through FDA are a better way to green these cold deserts in short period by planting Salix, Poplar and Robinia, which are fast growing species.

SUGGESTIONS

Delay in release of funds has affected the plantation programme through FDA, so funds should be released in time to carry out the works smoothly. Provision of fencing should be there to protect the plants. Irrigation facilities should be provided, if possible. There should be some other benefits provided to VFC members. VFC members in these FDAs were demanding more benefits from the department.

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EFFECT OF CLIMATE CHANGE ON GROUNDWATER AND DIFFERENT MODELLING APPROACHES FOR ITS ASSESSMENT- A REVIEW

Vinod Babu.V[1], Pravesh Kumar Yadav[2], M.K.Ghritlahre[3], Anshu Rakesh[4], B.K.Mishra[5]
[1,2,3,4] Scholars, [5] Assistant Professor , Department of Environmental Science and Engineering,
Indian School Of Mines, Dhanbad

ABSTRACT

Climate change is a crisis catalyst and an ongoing phenomena, which brings out unavoidable environmental problems, one of which is altering the hydrological cycle, which is already been affected due to the human activity, with climate change and human intervention's being at the peak the outcome with respect to man and environment is prejudicial. This effect of climate change on groundwater is analyzed by various modelling approaches. Climate change effect on groundwater since 1860 has been assessed using the models. This assessment is the key for determining the level of protection to be taken. "This paper analyzes the relationship between the climate change and groundwater, assessment of the rate of depletion of groundwater and mitigation process".

INTRODUCTION

Groundwater is a vital resource, with a large fraction of the population relying on the resource directly or indirectly for livelihoods. Groundwater accounts for about 50–80% of domestic water use and 45–50% of irrigation in India (Kumar R et al., 2005) Groundwater depletion can be stated as a reduction in the volume of groundwater in storage in the subsurface, which along with having negative impacts on water supply, also leads to land subsidence, reductions in surface water flows , spring discharges, and loss of wetlands [Bartolino and Cunningham, 2003; Konikow and Kendy, 2005]. Groundwater depletion is now of major concern as an accelerating serious global problem that threatens sustainability of water supplies [e.g., Schwartz and Ibaraki, 2011]. The World Bank estimate in 2005 warned that if the current trends continue, 60% of all aquifers in India will be in a critical condition within 20 years (Briscoe J et al., 2008) The global volume of groundwater is estimated at between 13% and 30% of the total volume of fresh water of the hydrosphere (Jones 1997; Babklin & Klige 2004) and groundwater provides 15% of the water used annually (Shiklomanov 2004b), the remainder being from surface water. United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. Global change may include natural and anthropogenic influences on terrestrial climate and the hydrologic cycle. Greenhouse gases are assumed to drive much of the contemporary climate change, and global atmospheric CO_2 concentration is the primary indicator of greenhouse gases, as well as a primary regulator of global climate (Petit et al., 1999). For millennia, India used surface storage and gravity flow to water crops. During the last 40 years, however, India has witnessed a decline in gravity-flow irrigation and the rise of a booming 'water-scavenging' irrigation economy through millions of small, private tube wells. For India, groundwater has become at once critical and threatened. Climate change will act as a force multiplier; it will enhance groundwater's criticality for drought-proofing agriculture and simultaneously multiply the threat to the resource. (Shah,T.(2009). Climate change can have profound effects on the hydrologic cycle through precipitation, evapotranspiration, and soil moisture with increasing temperatures. The hydrologic cycle will be intensified with more evaporation and more precipitation. (R. D. Singh et al., 2010)

DEPLETION OF GROUND WATER

Estimated global groundwater depletion during 1900–2008 totals 4,500 km^3, equivalent to a sea level rise of 12.6 mm (>6% of the total). Furthermore, the rate of groundwater depletion has increased markedly since about 1950, with maximum rates occurring during the most recent period (2000–2008), when it averaged -145 km3/yr (equivalent to 0.40 mm/yr of sea level rise, or 13% of the reported rate of 3.1 mm/yr during this recent period). (Konikow, L. F. 2011) Groundwater flow in shallow aquifers is part of the hydrological cycle and is affected by climate variability and change through recharge processes (Chen et al., 2002), as well as by human interventions in many locations (Petheram et al., 2001).

EFFECTS OF CLIMATE CHANGE ON GROUND WATER

The main concern raised by global warming is that climatic variations alter the water cycle; indeed, in many cases, the data show that the hydrological cycle is already being impacted (Dragoni 1998; Buffoni et al., 2002; Labat et al., 2004; Huntington 2006; IPCC 2007). As the warming process continues, it will bring about numerous environmental problems, among which the most severe will relate to water resources (Loa´iciga 1996, 2000; Milly et al., 2005; Holman 2006; IPCC 2007). Climate change, including anthropogenic-global warming and natural climate variability, can affect the quantity and quality of various components in the global hydrologic cycle in the space, time, and frequency domains (Loaiciga et al., 1996; Sharif and Singh, 1999; Milly et al., 2005; Holman, 2006; IPCC, 2007).

POTENTIAL IMPACTS OF CLIMATE CHANGE ON GROUNDWATER RESOURCES

Direct impacts

- Variation in duration, amount and intensity of precipitation and evapotranspiration will increase or decrease recharge rates (Hiscock and Tanaka 2006).
- Rising sea levels will allow saltwater to penetrate farther inland and upstream in low lying river deltas. (Wassmann et al., 2004; Stern 2006; Cruz et al., 2007).
- Variation in CO_2 concentrations may affect carbonate dissolution and the formation of karst. (Green et al., 2007).
- Indirect impacts
- Land cover changes (viz. natural vegetation and crops) may increase or decrease recharge. (Scanlon et al., 2006).
- Increase in groundwater extraction due to decrease in reliability of surface water as a result of increased floods and droughts. (Kundzewicz et al., 2007).
- Increase in flood frequencies may affect groundwater quality of alluvial aquifers.
- Variation in soil organic carbon content may affect the infiltration properties above aquifers.

RELATION OF CLIMATE CHANGE TO GROUND WATER

The components of the surface hydrologic cycle affected by climate change include atmospheric water vapour content, precipitation and evapotranspiration patterns, snow cover and melting of ice and glaciers, soil temperature and SWC, and surface runoff and stream flow (Bates et al., 2008).

The challenges of understanding climate-change effects on groundwater are unprecedented because climate change may affect hydrogeological processes and groundwater resources directly and indirectly, in ways that have not been explored sufficiently (Dettinger and Earman, 2007). The IPCC (2007a) stated that a lack of necessary data has made it impossible to determine the magnitude and direction of groundwater change due solely to climate change (Kundzewicz et al., 2007). Groundwater resources are related to climate change through the direct interaction with surface water resources, such as lakes and rivers, and indirectly through the recharge process. The direct effect of climate change on groundwater resources depends upon the change in the volume and distribution of groundwater recharge. Therefore, quantifying the impact of climate change on groundwater resources requires not only reliable forecasting of changes in the major climatic variables, but also accurate estimation of groundwater recharge. (Dragoni et al., 2008). However, increased forest cover will have impacts on groundwater recharge, through increased evapotranspiration, that may require on-site research before proceeding with specific projects. Some research has revealed that groundwater recharge is generally lower in forested areas than non-forested areas (Scanlon et al., 2006). Groundwater and reforestation. As trees are CO_2 sinks, reforestation coupled with new tree plantation has been considered key to maintaining control over CO_2 in the atmosphere (Schellnhuber et al., 2006; IPCC 2007). However, in forested areas, groundwater recharge is generally lower than in non-forested areas, and thus the water table and groundwater storage are generally lower (Scanlon et al. 2006). Recent research, based on computer simulations suggests that, despite carbon dioxide absorption, reforestation in high latitudes would help warming, because the tree would decrease albedo and increase evapotranspiration; conversely in the tropics the trees would have an overall cooling effect (Bala et al., 2007). These findings support the idea that tropical arid and semi-arid areas should, whenever possible, be reforested and afforested, as, according to some preliminary estimates, the sequestration of CO2 could be in the range of 30–50% of industrial emissions (Issar 2006, personal communication,: Dragoni et al., 2008). Evaporative demand, or ‘potential evaporation’, is projected to increase almost everywhere. This is because the water-holding capacity of the atmosphere increases with higher temperatures, but relative humidity is not projected to change markedly. Water vapour deficit in the atmosphere increases as a result, does the evaporation rate (Trenberth et al., 2003). The climate is expected not only to affect input (recharge) and output (discharge), but also to influence the quality of the groundwater. For example, water recharged during an arid period may have a higher concentration of salts and hence higher TDS, while during a wet period the converse may occur (Sukhija et al., 1998).

MODELS AS A TOOL

Hydrologists and climate scientists construct global land surface models that use meteorological fields (e.g., precipitation, temperature) as boundary conditions, to estimate and predict water storage (Bonan et al., 2002). However, many models lack groundwater or surface water components (though they do usually include snow) (Maxwell and Miller, 2005). Furthermore, anthropogenic modifications to the hydrologic cycle, such as groundwater pumping, irrigation, and reservoir impoundment, are absent from operational models at these scales (Sacks et al., 2009). The principal focus of climate change research with regard to groundwater has been on quantifying the likely direct impacts of changing precipitation and temperature patterns (Yusoff et al., 2002; Loaiciga et al., 2000; Arnell 1998). Such studies have used a range of modelling techniques such as soil water balance models (Kruger et al., 2001; Arnell 1998), empirical models (Chen et al., 2002), conceptual models (Cooper et al., 1995) and more complex distributed models (Croley and Luukkonen 2003; Kirshen 2002; Yusoff et al., 2002), but all have derived changes in groundwater recharge by assuming that parameters other than precipitation and temperature remain constant. In order to quantify potential effects of climate change on groundwater systems, future projections of climate are needed. This can be done with the help of climate models. Climate models are effective tools for studying local, regional or global climate behaviour and its variations with changing conditions on the Earth. They are of different types, ranging from simple climate models (SCMs) of the energy-balance type to Earth-system models of intermediate complexity (EMICs) to comprehensive three-dimensional (atmosphere–ocean) general circulation models or global climate models (GCMs). GCMs are the most sophisticated tools available for simulation of the current global climate and future climate scenario projections. They takes into account the behaviour and interaction of flow systems in the biosphere, hydrosphere, cryosphere, atmosphere and geosphere in the climate system. Earlier versions of GCMs developed in the 1960s and 1970s had some limitations which were then refined with considerable growth in knowledge of climate processes and in the complexity of climate research. Over the last decades, not only has the spatial resolution of GCMs increased, but the physical processes incorporated into these models has increased from simple rain and CO2 emissions to complex biogeochemical (including water vapour) feedbacks (Le Treut et al., 2007, Fig. 1.2). These newer GCMs also included oceanic component. They model freshwater fluxes, improved river and estuary mixing schemes, sea ice, etc. (Randall et al., 2007, Table 8.1). GCMs are able to simulate extreme warm temperatures, cold air outbreaks and frost days reasonably well. However, simulation of extreme precipitation is dependent on resolution, parameterization and the thresholds chosen. (Randall et al., 2007) The ability of any particular GCM to reproduce present-day mean climate and its historical characteristics with respectable realism and good overall performance in comparison with the other models are presumed to indicate that it can be used to project credible future climates (i.e., up to the 2080s). IPCC (2007).In addition, the IPCC (2007a) assessment of the recent scientific literature shows that the current models can simulate extremes of climate particularly temperature, reasonably well. These models have been more successful in simulating temperature extremes than precipitation extremes (Randall et al., 2007).

GCMs are fed with concentrations of greenhouse gases and other constituents derived from various emissions scenarios ranging from low high emission scenario to idealized low emission scenarios. The IPCC (2007b) (4) Fourth Assessment Report considered six scenarios for projected climate change in the 21st century. These included a subset of three IPCC Special Report on Emission Scenarios (SRES; Nakic´enovic´ and Swart, 2000) non-mitigation emission scenario simulations: B1, A1B and A2, representing ‘low’, ‘medium’ and ‘high’ scenarios, respectively, these scenarios and its effect on ground water depletion are derived. A GCM may have a spatial grid with cells on the order of 200 km*200 km GCMs hence cannot provide information at scales finer than their computational grid. GCMs do not accurately predict local climate. The physical basis of RCMs is same as that of GCMs but their spatial resolution is much finer, RCMs have achieved resolutions on the order of 20 km*20 km. Improvements to climate projections will likely come by developing regional and GCMs that couple groundwater and atmospheric processes (Gutowski et al., 2002; Cohen et al., 2006). Even RCM’s outputs are too coarse and hence their further downscaling is required for the correct hydrological impact studies, this can be effectively done using downscaling models. (Fowler and Kilsby 2007, Kleinn et. al., 2005)

The climate models simulate various climate-forcing variables of hydrologic interest such as : precipitation, air temperature, radiant-energy fluxes, wind speed, atmospheric pressure, atmospheric humidity, latent-heat flux, and runoff averaged over the models’ surface-grid cells. The output of RCMs such as precipitation, surface-air temperature, ground-level radiant-energy fluxes, water-vapor pressure, and wind speed become the input variables to hydrologic models, which then calculate, the dependent hydrologic variables of our interest, examples are stream flow and ground-water levels. (Locaiga H A et al., 2003)
GRACE, Gravity Recovery and Climate Experiment satellites, simulated soil-water variations from a hydrological modelling system to show that groundwater is being depleted at a mean rate of 4.0±1.0 cm yr^{-1}equivalent height of water (17.7±4.5 km^3 yr^{-1}) over the Indian states of Rajasthan, Punjab and Haryana (including Delhi). (Rodell et al., 2009)
Temporal change in earth gravity field in Northern India is recorded by GRACE satellite and its combined with hydrological models to remove the variability and it was shown that the region lost ground water at a rate of 54 ± 9 km3/yr between April 2002 (start of GRACE mission) and June 2008 which is the largest rate of groundwater loss in any comparable sized region on Earth. (Tiwari, V. M., et al., 2009)

GROUNDWATER MANAGEMENT

Water recycling is a sustainable approach towards adaptation to climate change and can be cost-effective in the long term. However, the treatment of wastewater for reuse that is now being practised in Singapore, and the installation of distribution systems, can initially be expensive compared to water supply alternatives such as the use of imported water or

S.No	Model	Reference	Description
1.	SUTRA (Saturated Unsaturated TRAnsport)	Ghosh and Bobba (2002)	Analyses effects of human activity and sea level change of fresh and salty water through Godavari basin
2.	MOHISE	Broyere et al., (2004)	Study the impacts of climate on hydrological cycle. This model considers most hydrological process in consistent manner and models ground water in spatially distributed, fine element approach.
3.	HadCM2	Johns et al., 1997 Mitchell et al., 1995	It simulated the climate change due to Greenhouse gases from early industrial era(since 1860)
4.	HadCM3	Gordon et al.,(2000) Pope et al. (2000)	IT has two emission scenarios (SRES A2 and B2). Both indicated annual fresh ground water resources loss as an increasing trend in all stressed area.
5.	CGCM1 (Canadian Global Coupled Model)	Flato et al., 2000	It linked climate model and groundwater model to evaluate impacts of climate change on groundwater
6.	SDSM (Statistical Downscaling Model)	Scibek and Allen (2006)	The output of the global models is downscaled to local conditions with the help of this model.
7.	LARS-WG	Scibek and Allen (2006)	It is a weather generator model. The output of this model is feed into recharge models.
8.	HELP (Hydrologic Evaluation of Landfill Performance)	Scibek and Allen (2006)	It simulates the direct recharge to the aquifer from infiltration of precipitation data and is linked to GIS(geographical information system)
9.	MODLOW	Scibek and Allen (2006)	It is a three-dimensional transient groundwater flow model. It is used to simulate four climate scenarios in 1-year runs (1961–1999 present, 2010–2039, 2040–2069, and 2070-2099) and compare groundwater levels to present scenario.
10.	ArcGIS Geostatistical Analyst	Fu et al., (2007)	It estimate the impacts of global climate change on regional hydrological regimes. The model is easily used and can be expanded to different watersheds. It provides a comprehensive set of tools for creating surfaces. users can rapidly compare different interpolation techniques in order to obtain the best results.
11.	WetSpass.	Woldeamlak et al .,(2007)	It takes into detailed account of soil, land use, slope, groundwater depth and hydroclimatological maps. It uses seasonal GIS input to estimate annual groundwater recharge water value.

groundwater. (WGII 10.5.2, 10.5.7). There are many adaptation measures that could be applied in various parts of Asia to minimise the impacts of climate change on water resources, several of which address the existing inefficiency in the use of water: modernisation of existing irrigation schemes and demand management aimed at optimising physical and economic efficiency in the use of water resources and recycled water in water-stressed countries; public investment policies that improve access to available water resources, encourage integrated water management and respect for the environment, and promote better practices for the sensible use of water in agriculture; the use of water to meet non-potable water demands. After treatment, recycled water can also be used to create or enhance wetlands and riparian habitats. (WGII 10.5.2)

CONCLUSION

Groundwater is becoming scare day by day not only alarming in India, but also its becoming a global problem. The depletion of groundwater is caused due to natural and anthropogenic activities. Climate change influences the global hydrological cycle which in turn impacts the groundwater recharge rate and resulting in the depletion. Not only climate change but the strategy to mitigate climate change like afforestation also leads to ground water depletion due to evapotranspiration hence in some cases climate change shows doubled effect on the ground water resources. Due to great stress on the quantification of the effect of climate change on groundwater, various models were developed and researched like climate models, hydrological models weather models, and also recordings of GRACE satellite were combined with hydrological models to remove the variability and for better estimation of groundwater depletion. With time the models were improved refined so that they can be used as perfect simulator of the climate condition to forecast the ground water depletion rate in future, so as to predict what extent of mitigation strategies are to be adopted according to the damage incurred. The climate change affects the groundwater both directly and indirectly which is the main reason for study becoming complicated and less research being done in this area. The output of the model is reintroduced as an input to the other model this leads to bias in exactly studying the effect of climate change on groundwater. The three R's principle of Reduce, Reuse and Recycle has to be followed for effective ground water management.

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ERRORS INVOLVED IN THE ESTIMATION OF GROUNDWATER QUALITY INDEX

Prashant Jha[a], Ankit Agrahari[b] and Alok Sinha[c]
[a,b] B.Tech. Students, Department of Environmental Science and Engineering, ISM, Dhanbad
[c]Assistant Professor, Department of Environmental Science and Engineering, ISM, Dhanbad
E-mail: aloksinha11@yahoo.com

ABSTRACT

Groundwater quality index (GWQI) is a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality. It may act as a decision tool for water quality managers. Unavailability of all the data may introduce errors in the estimation of water quality depending upon the weight factor and quality factor of the parameter for which data is not available. This may lead to underestimation or overestimation of the water quality. This paper attempts to highlight the type of errors involved in calculation of WQI when parameters of different weights and quality factors are not available.

1.0 INTRODUCTION

Groundwater is a vital natural resource for the reliable and economic provision of potable water supply in both the urban and rural environment. It thus plays a fundamental role in human well-being, as well as that of some aquatic and terrestrial ecosystems. Groundwater is getting contaminated due to extraction of minerals, agricultural activity, leaching of solid waste disposal. Several industrial activities such as metal, timber, tanneries also cause the degradation of quality of water. As a result, more and more groundwater is becoming unfit for drinking (Reza and Singh, 2010).

Groundwater pollution hazard assessments are needed for clearer appreciation of the actions needed to protect groundwater quality, and should become an essential component of environmental best practice. Groundwater pollution hazard assessment should prompt municipal authorities or environmental regulators to take both preventive actions (to avoid futurepollution) and corrective actions (to control the pollution threat posed by existing and past activities).

Water pollution affects human health which in turn hampers economic and social progress. The evaluation of groundwater quantity and quality and establishing data base is important for future water resource planning & management. WQI is a technique used to quantify and classify the suitability of water for drinking purposes. It takes into account the collective effect of different water quality parameters on the overall water quality. It mathematically transforms a large number of water quality data into a single number and thus is a very simple and effective tool to convey information about the quality of groundwater. It brings about a transparency in the understanding of water quality by integrating complex data into a single number which denotes the water quality status (Sharma and Patel, 2010; Rajankar et. al. 2009; Sonawane and Shrivastava, 2010; Kavitha and Elangovan, 2010).

2.0 CONCEPT OF GROUND WATER QUALITY INDEX (GWQI)

Water quality problems have been a factor in determining human welfare (Simoes *et al.*, 2008). A tremendous growth in the manufacture and use of synthetic chemicals for agriculture and animal husbandry, to increase food production, causes the degradation of water resources. Many of these activities have contaminated water supplies, due to insecticide and herbicide runoff from agricultural land, and industrial discharges into surface waters (Manahan, 2000).

Water quality index (WQI) attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Bordalo *et al.*, 2001). They are intended to provide a simple and understandable tool for managers and decision makers on the quality and possible uses of a given water body. It may be possible to understand their interactions and to assess the sustainability of the environment by measuring as many parameters as possible that define the system (Jonnalagadda & Mhere, 2001).

The weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters. The formulation for weight calculation is given by the equation:

$w_i = K/s_i$ (1)

where, w_i : unit weight for the i^{th} parameter

s_i : recommended standard for parameter and i = 1, 2, 3…, 16; and

K : constant of proportionality

The WQI calculation involves the following steps:

a) First, the calculation of the quality rating for each of the water quality parameters; and
b) Second, a summation of these sub-indices in the overall index.

The individual quality rating is given by the expression as:

$q_i = 100(v_i/s_i)$ (2)

where, v_i: measured value of the i^{th} parameter in water sample under consideration

s_i: standard or permissible limit for the i^{th} parameter

The WQI is calculated using the following equation:

$WQI = [(\Sigma q_i w_i/\Sigma w_i)]$ (3)

The WQI was used to classify the surface water according to the pollution level where 100 represent the highest water quality (Haris & Omar, 2007). The water quality can be categorized with different ranges, which is presented as Table 2.3.

Table 2.1: Water quality index scale (*Source*: Sindu & Sharma, 2007)

Range	**Water quality**
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very poor
>100	Unsuitable

The evaluation of groundwater quality can also be determined cusing the following formulae (Asadi et al., 2007):

$WQI = \text{Antilog} [\Sigma W^n{}_{n=1} \text{Log}_{10} q_n]$ (4)

Where W is Weightage factor (W) is computed using the following equation

Wn = K / Sn (5)

and K, Proportionality constant is derived from,

$K = [1 / (\Sigma^n{}_{n=1} 1/Si)]$ (6)

Sn and Si are the WHO / ICMR standard values of the water quality parameter

Quality rating (q) is calculated using the formula,

qni = {[(Vactual – Videal) / (Vstandard – Videal)] * 100} (7)

where,

qni = Quality rating of ith parameter for a total of n water quality parameters

Vactual = Value of the water quality parameter obtained from laboratory analysis

Videal = Value of that water quality parameter can be obtained from the standard tables.

Vstandard = WHO / ICMR standard of the water quality parameter

The quality of water can be interpreted from Table 2.1. The evaluation of GWQI first involves the identification of the different parameters that are being considered in determining the water quality. The two components that determine the value are the weight factor and the quality factor of the individual parameters. The weight factor in general is determined by the permissible standards for the parameters. Lesser the standard, higher is the weight factor. Generally, the WHO standards or the IS standards are considered for the calculations. The quality factor depends on the observed concentration of the various parameters. Different formulae have been devised for the evaluation of the index. Hence, the range for drinking suitability may vary depending on the scale used for calculation. The groundwater quality parameters of importance includes pH, E.C., TDS, hardness, alkalinity, chloride, sulphate, Calcium, Potassium, sodium, Iron, Magnesium, nitrate, fluoride, D.O., B.O.D., C.O.D. and specific Heavy Metals. Pathogenic contamination may also be evaluated if threat may be there. Since the water quality index represent the quality by a single number, errors may be involved if sufficient parameters are not involved for the estimation of groundwater quality (Sharma and Patel, 2010; Rajankar et. al. 2009; Sonawane and Shrivastava, 2010; Kavitha and Elangovan, 2010).

3.0 ERRORS INVOLVED IN THE CALCULATION OF GWQI

This study analyzes the error involved in the calculation of GWQI due to non-availability of data. The data obtained from the analysis of groundwater quality was obtained for different parameters. The GWQI was then calculated by considering different number of parameters ignoring a particular parameter, and noting its effect on the value of GWQI. This was repeated by eliminating different parameters so as to study the effect on the GWQI due to non-availability of data for a particular parameter.

The GWQI was calculated by using above mentioned formulas. For both the cases, the GWQI was initially calculated using 9 parameters namely TDS, hardness, chloride, sulphate, sodium, nitrate, pH, alkalinity and fluoride. The parameters were eliminated step by step in the following manner:

a) Increasing order of weight factor
b) Decreasing order of weight factor
c) Increasing order of quality factor
d) Decreasing order of quality factor

The corresponding change in GWQI was analyzed for each of the above cases keeping in mind the following classification for the given ranges of WQI values :

3.1 Removing Pollutant with Low Weight Factors

When we remove the parameter having lower values of weight factors the maximum deviation in the WQI on using Eq. 3 for WQI calculation is -1.1% and the WQI goes up from 92.9 to 93.9 (Table 3.1, Fig 3.1). Hence the WQI may be underestimated if parameters with low weight factors are ignored, though the impact is not significant. When Eq. 4 is used for calculation of WQI, when parameters having low weight factors are not considered the error involved in estimation of WQI is 9.9756% when only three parameters are considered. This may lead to over estimation of Water Quality (Table 3.2, Fig 3.2).

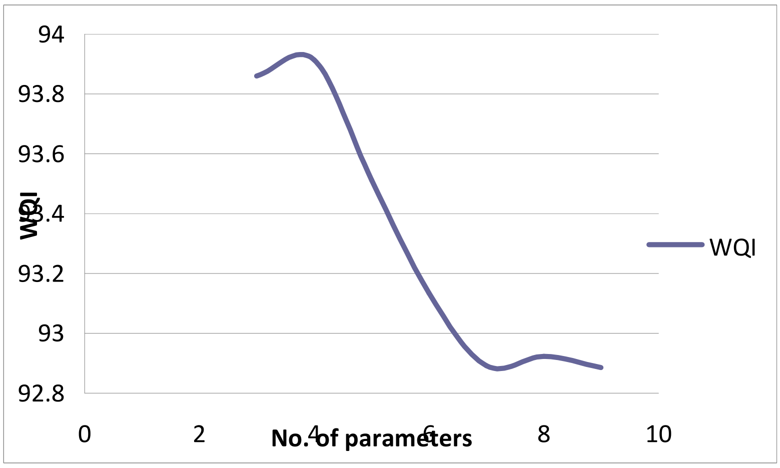

Figure 3.1: Impact on WQI on Removing Pollutant with Low Weight Factors (Eq. 3)

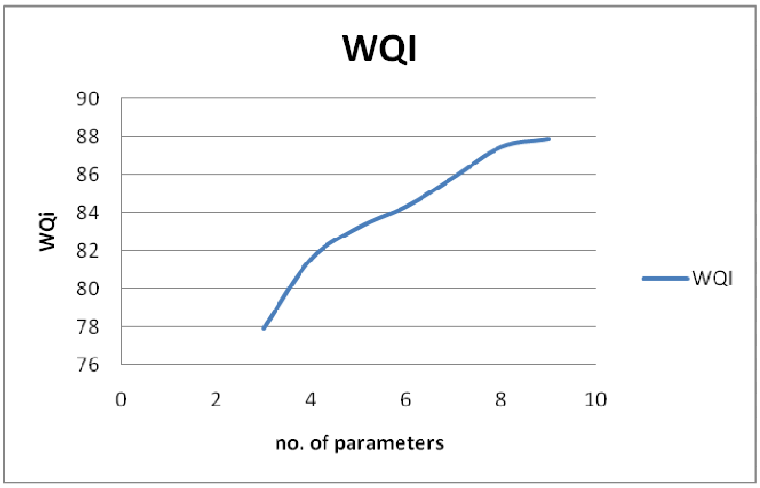

Figure 3.2: Impact on WQI on Removing Pollutant with Low Weight Factors (Eq. 4)

3.2 Removing Pollutant with High Weight Factors

While non-consideration of parameters with high weight factors (by eq. 3) may significantly impact the WQI which may with overestimation of WQI if we consider 6 parameters and it can also lead to underestimation of the WQI if 7 parameters are considered in this case (Table 3.3, Fig. 3.3). The percent error involved in calculation of WQI varies from -88.4587 to +52.4028. This variation may be regarded to the decrease in the total weight of the factors considered. When Eq. 4 is used for calculation of WQI, the water quality index is seriously impacted with total error of 86.854% when only 3 parameters are considered which may lead to overestimation of WQI (Table 3.4, Fig 3.4).

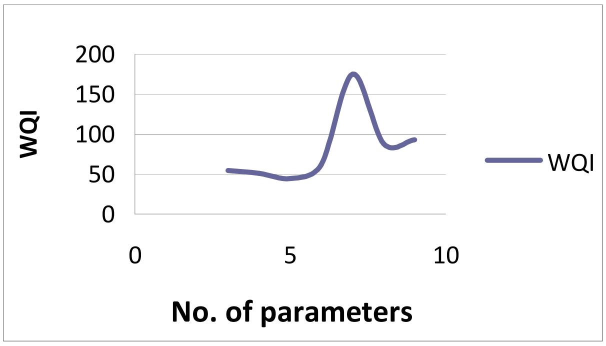

Figure 3.3: Impact on WQI on Removing Pollutant with High Weight Factors (Eq. 3)

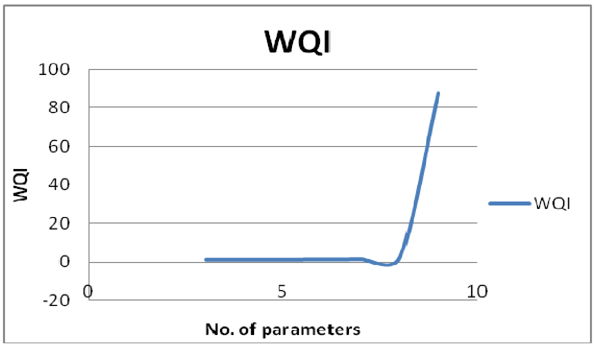

Figure 3.4: Impact on WQI on Removing Pollutant with High Weight Factors (Eq. 4)

3.3 Removing Pollutant with Low Quality Factors

If the parameters having high values of quality factors are removed the impact on the WQI (by Eq. 3) is not significant if more than 4 parameters are considered but when only 3 factors are considered for calculation of WQI, the water quality may be underestimated and the % Error may be as high as 156.9% (Table 3.5, Fig. 3.5). When Eq. 4 is used for calculation of

WQI and parameters with low quality factors are not considered then an error of 86.666% may be incorporated and the water quality may be underestimated.

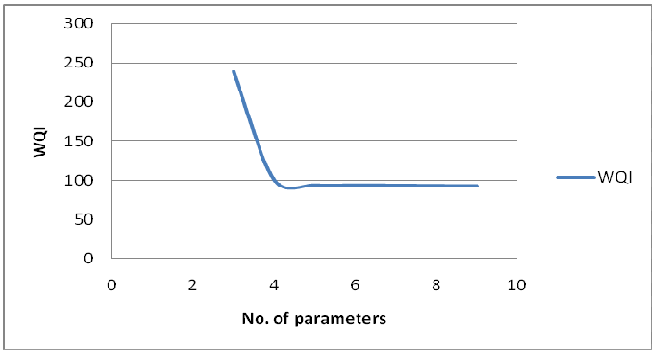

Figure 3.5: Impact on WQI on Removing Pollutant with Low Quality Factors (Eq. 3)

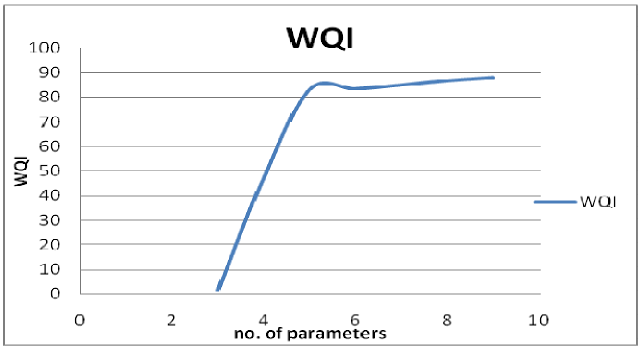

Figure 3.6: Impact on WQI on Removing Pollutant with Low Quality Factors (Eq. 4)

3.4 Removing Pollutant with High Quality Factors

Non consideration of parameters having high quality factor may result in over estimation of Water Quality with a maximum percentage error of 69.2% in this case (by Eq. 3). This may lead to over estimation of water quality in this case if less than 6 parameters are considered (Table 3.7, Fig. 3.7). When using Eq. 4 for calculation of WQI and on non availability of parameters having high quality factors, the water quality may be highly overestimated with a % Error of 86.839% when only four parameters with low quality factors are considered (Table 3.8, Fig. 3.8).

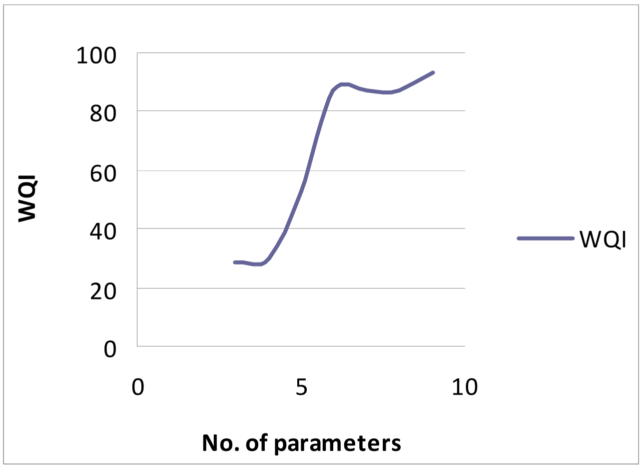

Figure 3.7: Impact on WQI on Removing Pollutant with High Quality Factors (Eq. 3)

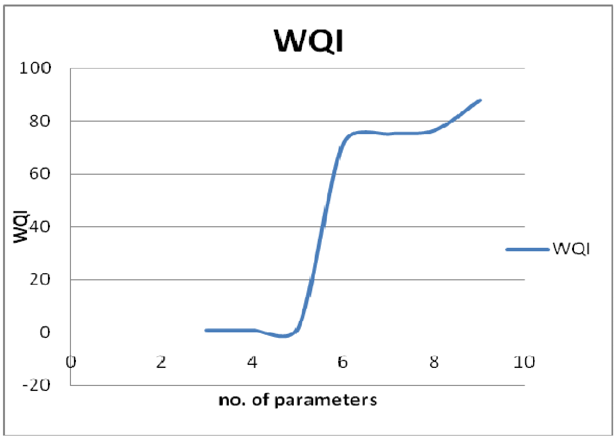

Figure 3.8: Impact on WQI on Removing Pollutant with High Quality Factors (Eq. 4)

4.0 CONCLUSIONS

Based on the above study we can conclude that

- The error involved in calculating WQI is not significantly related to the number of parameters whose concentrations are not known or for which data are not considered. Maximum Error is introduced when considering 7 parameters (-88.46%) where as the error is +43.1 % when only 3 parameters are considered.
- It can be concluded that WQI is more reliable and accurate as a larger number of parameters are available in its formulation. At the same time, it can be concluded that the WQI values can be calculated with marginal error when data for some of the pollutants which are not biased towards either high or low concentration are not available.
- The error introduced in calculating WQI is more acute when data for the parameters having high sub index values are not considered. When Eq. 3 is used for calculating WQI the water quality may be overestimated where as it can be underestimated when Eq. 4 is used for calculation of WQI.
- The error involved in deriving WQI values when data for the parameters with low sub index values are not available indicates a highly polluted environment to be less polluted. This may bring result in underestimation of water quality.
- The errors introduced in calculating WQI are marginal when the data of the parameters having highest and lowest sub index values are not considered simultaneously.

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Table 3.1: Impact on WQI on Removing Pollutant with Low Weight Factors (by Eq. 3)

Parameter	V (actual)	V std	Qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
TDS	520	1000	52	0.0012	0.0624	NC	NC	NC	NC	NC	NC
Hardness	310	300	103.33	0.004	0.4133	0.4133	NC	NC	NC	NC	NC
Chloride	107	250	42.8	0.0048	0.2054	0.2054	0.2054	NC	NC	NC	NC
Sulphate	39	250	15.6	0.0048	0.0749	0.0749	0.0749	0.0749	NC	NC	NC
Sodium	56	200	28	0.006	0.168	0.168	0.168	0.168	0.168	NC	NC
Alkalinity	119	120	99.17	0.01	0.9917	0.9917	0.9917	0.9917	0.9917	0.9917	NC
Nitrate	160	50	320	0.0241	7.712	7.712	7.712	7.712	7.712	7.712	7.712
pH	7.82	8.5	54.67	0.1417	7.7467	7.7467	7.7467	7.7467	7.7467	7.7467	7.7467
Fluoride	1.41	1.5	94	0.8033	75.5102	75.5102	75.5102	75.5102	75.5102	75.5102	75.5102
Summation				1	92.8846	92.8222	92.4089	92.2035	92.1286	91.9606	90.9689
Total weight					1	0.9988	0.9948	0.99	0.9852	0.9792	0.9692
WQI					92.8846	92.9337	92.8919	93.1348	93.5126	93.914	93.8598
% error						-0.0529	-0.0078	-0.2694	-0.6761	-1.1082	-1.0499

Table 3.2: Impact on WQI on Removing Pollutant with Low Weight Factors (by Eq. 4)

Parameter	*V actual*	*V std*	*qi*	*Qi=Log qi*	*Wi*	*WiQi*	*WiQi (8 para)*	*WiQi (7 para)*	*WiQi (6 para)*	*WiQi (5 para)*	*WiQi (4 para)*	*WiQi (3 para)*
TDS	520	1000	52	1.716003	0.0012	0.00206	NC	NC	NC	NC	NC	NC
Hardness	310	300	103.33	2.014226	0.004	0.00806	0.00806	NC	NC	NC	NC	NC
Chloride	107	250	42.8	1.631444	0.0048	0.00783	0.00783	0.00783	NC	NC	NC	NC
Sulphate	39	250	15.6	1.193125	0.0048	0.00573	0.00573	0.00573	0.00573	NC	NC	NC
Sodium	56	200	28	1.447158	0.006	0.00868	0.00868	0.00868	0.00868	0.00868	NC	NC
Alkalinity	119	120	99.17	1.99638	0.01	0.01996	0.01996	0.01996	0.01996	0.01996	0.01996	NC
Nitrate	160	50	320	2.50515	0.0241	0.06037	0.06037	0.06037	0.06037	0.06037	0.06037	0.06037
pH	7.82	8.5	54.67	1.737749	0.1417	0.24624	0.24624	0.24624	0.24624	0.24624	0.24624	0.24624
Fluoride	1.41	1.5	94	1.973128	0.8033	1.58501	1.58501	1.58501	1.58501	1.58501	1.58501	1.58501
Sum					1	1.94395	1.94189	1.93383	1.926	1.92027	1.91159	1.89163
Total weight						1	0.9988	0.9948	0.99	0.9852	0.9792	0.9692
WQI						87.8916	87.4759	85.868	84.3336	83.2288	81.5813	77.916
% error							0.4158	2.0236	3.5581	4.6629	6.3103	9.9756

Table 3.3: Impact on WQI on Removing Pollutant with High Weight Factors (Eq. 3)

Parameter	V (actual)	V std	Qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Fluoride	1.41	1.5	94	0.8033	75.5102	NC	NC	NC	NC	NC	NC
pH	7.82	8.5	54.67	0.1417	7.7467	7.7467	NC	NC	NC	NC	NC
Nitrate	160	50	320	0.0241	7.712	7.712	7.712	NC	NC	NC	NC
Alkalinity	119	120	99.17	0.01	0.9917	0.9917	0.9917	0.9917	NC	NC	NC
Sodium	56	200	28	0.006	0.168	0.168	0.168	0.168	0.168	NC	NC
Chloride	107	250	42.8	0.0048	0.2054	0.2054	0.2054	0.2054	0.2054	0.2054	NC
Sulphate	39	250	15.6	0.0048	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749
Hardness	310	300	103.33	0.004	0.4133	0.4133	0.4133	0.4133	0.4133	0.4133	0.4133
TDS	520	1000	52	0.0012	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624
Sum					92.8846	17.3744	9.6277	1.9157	0.924	0.756	0.5506
Total wt.					1	0.1967	0.055	0.0309	0.0209	0.0149	0.0101
WQI					92.8846	88.3294	175.0491	61.9968	44.2105	50.7382	54.5148
% error						4.9041	-88.4587	33.2540	52.4028	45.3750	41.3090

Table 3.4: Impact on WQI on Removing Pollutant with High Weight Factors (Eq. 4)

Parameter	V actual	V std	qi	Qi=Log qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Fluoride	1.41	1.5	94	1.973128	0.8033	1.58501	NC	NC	NC	NC	NC	NC
pH	7.82	8.5	54.67	1.737749	0.1417	0.24624	0.24624	NC	NC	NC	NC	NC
Nitrate	160	50	320	2.50515	0.0241	0.06037	0.06037	0.06037	NC	NC	NC	NC
Alkalinity	119	120	99.17	1.99638	0.01	0.01996	0.01996	0.01996	0.01996	NC	NC	NC
Sodium	56	200	28	1.447158	0.006	0.00868	0.00868	0.00868	0.00868	0.00868	NC	NC
Chloride	107	250	42.8	1.631444	0.0048	0.00783	0.00783	0.00783	0.00783	0.00783	0.00783	NC
Sulphate	39	250	15.6	1.193125	0.0048	0.00573	0.00573	0.00573	0.00573	0.00573	0.00573	0.00573
Hardness	310	300	103.33	2.014226	0.004	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806
TDS	520	1000	52	1.716003	0.0012	0.00206	0.00206	0.00206	0.00206	0.00206	0.00206	0.00206
Sum						1.94395	0.35893	0.11269	0.05232	0.03236	0.02367	0.01584
Total weight						1	0.1967	0.055	0.0309	0.0209	0.0149	0.0101
WQI						87.8916	2.28525	1.29627	1.12803	1.07735	1.05602	1.03715
% error							85.606	86.595	86.764	86.814	86.836	86.854

Table 3.5: Impact of WQI on Removing Pollutant with Low Quality Factors (Eq. 3)

Parameter	V (actual)	V std	Qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Sulphate	39	250	15.6	0.0048	0.0749	NC	NC	NC	NC	NC	NC
Sodium	56	200	28	0.006	0.168	0.168	NC	NC	NC	NC	NC
Chloride	107	250	42.8	0.0048	0.2054	0.2054	0.2054	NC	NC	NC	NC
TDS	520	1000	52	0.0012	0.0624	0.0624	0.0624	0.0624	NC	NC	NC
pH	7.82	8.5	54.67	0.1417	7.7467	7.7467	7.7467	7.7467	7.7467	NC	NC
Fluoride	1.41	1.5	94	0.8033	75.5102	75.5102	75.5102	75.5102	75.5102	75.5102	NC
Alkalinity	119	120	99.17	0.01	0.9917	0.9917	0.9917	0.9917	0.9917	0.9917	0.9917
Hardness	310	300	103.33	0.004	0.4133	0.4133	0.4133	0.4133	0.4133	0.4133	0.4133
Nitrate	160	50	320	0.0241	7.712	7.712	7.712	7.712	7.712	7.712	7.712
Summation				1	92.8846	92.8097	92.6417	92.4363	92.3739	84.6272	9.117
Total weight					1	0.9952	0.9892	0.9844	0.9832	0.8415	0.0382
WQI					92.8846	93.2573	93.6532	93.9012	93.9523	100.5671	238.6649
% error						-0.4012	-0.8275	-1.0945	-1.495	-8.271	-156.9478

Table 3.6: Impact of WQI on Removing Pollutant with Low Quality Factors (Eq. 4)

Parameter	V (actual)	V std	qi	Qi=Log qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Sulphate	39	250	15.6	1.193125	0.0048	0.00573	NC	NC	NC	NC	NC	NC
Sodium	56	200	28	1.447158	0.006	0.00868	0.00868	NC	NC	NC	NC	NC
Chloride	107	250	42.8	1.631444	0.0048	0.00783	0.00783	0.00783	NC	NC	NC	NC
TDS	520	1000	52	1.716003	0.0012	0.00206	0.00206	0.00206	0.00206	NC	NC	NC
pH	7.82	8.5	54.67	1.737749	0.1417	0.24624	0.24624	0.24624	0.24624	0.24624	NC	NC
Fluoride	1.41	1.5	94	1.973128	0.8033	1.58501	1.58501	1.58501	1.58501	1.58501	1.58501	NC
Alkalinity	119	120	99.17	1.99638	0.01	0.01996	0.01996	0.01996	0.01996	0.01996	0.01996	0.01996
Hardness	310	300	103.33	2.014226	0.004	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806
Nitrate	160	50	320	2.50515	0.0241	0.06037	0.06037	0.06037	0.06037	0.06037	0.06037	0.06037
Sum					1	1.94395	1.93822	1.92954	1.92171	1.91965	1.67341	0.08839
Total weight						1	0.9952	0.9892	0.9844	0.9832	0.8415	0.0382
WQI						87.8916	86.7402	85.0232	83.5039	83.1089	47.142	1.22573
% error							1.1514	2.8684	4.3878	4.7827	40.75	86.666

Table 3.7: Impact of WQI on Removing Pollutant with High Quality Factors (Eq. 3)

Parameter	V (actual)	V std	Qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Nitrate	160	50	320	0.0241	7.712	NC	NC	NC	NC	NC	NC
Hardness	310	300	103.33	0.004	0.4133	0.4133	NC	NC	NC	NC	NC
Alkalinity	119	120	99.17	0.01	0.9917	0.9917	0.9917	NC	NC	NC	NC
Fluoride	1.41	1.5	94	0.8033	75.5102	75.5102	75.5102	75.5102	NC	NC	NC
pH	7.82	8.5	54.67	0.1417	7.7467	7.7467	7.7467	7.7467	7.7467	NC	NC
TDS	520	1000	52	0.0012	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	NC
Chloride	107	250	42.8	0.0048	0.2054	0.2054	0.2054	0.2054	0.2054	0.2054	0.2054
Sodium	56	200	28	0.006	0.168	0.168	0.168	0.168	0.168	0.168	0.168
Sulphate	39	250	15.6	0.0048	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749
Summation				1	92.8846	85.1726	84.7593	83.7676	8.2574	0.5107	0.4483
Total weight					1	0.9759	0.9719	0.9619	0.1586	0.0169	0.0157
WQI					92.8846	87.276	87.2099	87.0876	52.0643	30.2189	28.5541
% error						6.0382	6.1094	6.2411	43.9473	67.4662	69.2585

Table 3.8: Impact of WQI on Removing Pollutant with High Quality Factors (Eq. 4)

Parameter	V actual	V std	qi	Qi=Log qi	Wi	WiQi	WiQi (8 para)	WiQi (7 para)	WiQi (6 para)	WiQi (5 para)	WiQi (4 para)	WiQi (3 para)
Nitrate	160	50	320	2.50515	0.0241	0.06037	NC	NC	NC	NC	NC	NC
Hardness	310	300	103.33	2.014226	0.004	0.00806	0.00806	NC	NC	NC	NC	NC
Alkalinity	119	120	99.17	1.99638	0.01	0.01996	0.01996	0.01996	NC	NC	NC	NC
Fluoride	1.41	1.5	94	1.973128	0.8033	1.58501	1.58501	1.58501	1.58501	NC	NC	NC
pH	7.82	8.5	54.67	1.737749	0.1417	0.24624	0.24624	0.24624	0.24624	0.24624	NC	NC
TDS	520	1000	52	1.716003	0.0012	0.00206	0.00206	0.00206	0.00206	0.00206	0.00206	NC
Chloride	107	250	42.8	1.631444	0.0048	0.00783	0.00783	0.00783	0.00783	0.00783	0.00783	0.00783
Sodium	56	200	28	1.447158	0.006	0.00868	0.00868	0.00868	0.00868	0.00868	0.00868	0.00868
Sulphate	39	250	15.6	1.193125	0.0048	0.00573	0.00573	0.00573	0.00573	0.00573	0.00573	0.00573
Sum					1	1.94395	1.88357	1.87552	1.85555	0.27054	0.0243	0.02224
Total weight						1	0.9759	0.9719	0.9619	0.1586	0.0169	0.0157
WQI						87.8916	76.4845	75.0787	71.7055	1.8644	1.05755	1.05255
% error							11.407	12.813	16.186	86.027	86.834	86.839

SOLID WASTES IN CONSTRUCTION

Vikas Srivastava[1], Rakesh Kumar[2], Satyendra Nath[3],B. K. Mishra[4] and P. K. Mehta[2]
1. Assistant Professor, Civil Engg. Department, SHIATS (Formerly AAI-DU), Allahabad - 211007.E-mail: vikas_mes@rediffmail.com
2. Associate Professor, Civil Engg. Department, MNNIT, Allahabad - 211004.
3. Assistant Professor, Environmental Science Department, SHIATS (Formerly AAI-DU), Allahabad - 211007.
4. Assistant Professor, Department of Environmental Engineering and Science, ISM, Dhanbad - 211007.

ABSTRACT

The pollution of the environment and the associated ill effects have become cause of serious concern due to advancement in science and technology and industrial revolution, whose nature and character is changing with each major development. Disposal issue of waste products is a challenge for the community. Some of these materials are not biodegradable and often leads to disposal crisis and environmental pollution. Construction sector's major contribution towards preservation of environment and sustainable development lies in recycling and reuse of the waste material. Different types of wastes can be used as supplementary material, as an alternative of conventional material in construction activities. Of late, the inclusion of different types of by-products in cement based materials and in aggregate has become a common practice. By substitution of wastes as supplementary material an economical construction can be achieved, in addition to reducing the threat of environmental hazard. In this paper an attempt is made to highlightthe scope of utilization of several solid wastes as supplementary materials and their properties in various construction activities.

1. INTRODUCTION

Thousands of tons of agricultural residue and industrial by products are produced every year, as such study of their characteristics and possible applications become a priority**.** Fly ash is finely divided residue resulting from the combustion of powdered coal and is transported from the combustion fire box through the boiler by the flue gases into precipitators. The amount of ash produced from coal or lignite burnt in power plants varies greatly depending on the source of coal, its preparation and washing procedure employed. Fly ash produced may be upto 20% or even more of the coal burnt. The fly ash obtained from boilers employing mechanical collectors alone is coarser than those obtained using electro static precipitators. The nature of fly ash depends on the source of the coal and its composition, the type of fuel used the boiler operations, the type of precipitators used etc. As per estimates in India more than 100 million tons fly ash is produced every year, which is increasing day by day.The use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali – aggregate reaction and enhances sulphate resistance besides being economically and ecologically beneficial (Helmuth, 1987). The other solid wastes are rice husk, aggregates, e – wastes, waste glass etc.

2. WASTES USED IN CONSTRUCTION

The generation of solid wastes is a serious environmental problem. Different wastes viz. fly ash, rice husk, recycled aggregates, e-wastes and waste glass, can effectively be used in construction to overcome the problems cited above besides resulting, in general, safer, economical, durable and eco-friendly construction. In the present paper the scope and advantages of utilization of fly ash (FA), rice husk ash (RHA), recycled aggregates (RCA), e-wastes and waste glass (WG) in construction is discussed.

2.1. Fly Ash

Around 140 million tons of fly ash get accumulated every year at the thermal power stations in India. Internationally, fly ash is considered as a byproduct which can be used for many applications. Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash it is removed from the bottom of the furnace. In this case it is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata (Oner and Yildiz 2005, Li and Zhao 2003, Jiang et al. 2004). Fly ash consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy (amorphous) in nature. The carbonaceous material in fly ash is composed of angular particles.

The particle size distribution of most bituminous coal fly ashes is generally similar to that of silt (less than a 0.075 mm or No. 200 sieve). The specific gravity of fly ash usually ranges from 2.1 to 3.0, while its specific surface area (measured by the Blaine air permeability method) may range from 170 to 1000 m^2/kg. The color of fly ash can vary from tan to gray to black, depending on the amount of unburned carbon in the ash. The lighter the color, lower the carbon content. Lignite or sub bituminous fly ashes are usually light tan to buff in color, indicating relatively low amounts of carbon as well as the presence of some lime or calcium. Bituminous fly ashes are usually some shade of gray, with the lighter shades of gray generally indicating a higher quality of ash (Oner and Yildiz 2005).

Some of the engineering properties of fly ash that are of particular interest, when fly ash is used as an admixture in Plane Cement Concrete (PCC) mixes, include fineness, Loss on Ignition (LOI), chemical composition, moisture content, and pozzolanic activity. Fineness is the primary physical characteristic of fly ash that relates to pozzolanic activity. As the fineness increases, the pozzolanic activity can be expected to increase.

It is reported that, when replacing up to 40 percent of the Portland cement in concrete, all Class F fly ashes and most Class C fly ashes increase the time of setting. However, some Class C fly ashes may have little effect on, or possibly even decrease, the time of setting. Delays in setting time will probably be more pronounced, compared with conventional concrete mixes, during the cold months (Li and Zhao 2003).

2.2 Rice Husk Ash

Rice Husk Ash (RHA) is another promising pozzolanic material with high reactivity. Addition of rice husk ash in concrete makes it durable and improves its properties. Rice husk is an agricultural residue obtained from the rice grains and about 110 million tons is produced in the world (Boating and Skeete 1990). About 4.88 million tons of rice husk is produced in India annually. Thus, there is a good potential to make use of RHA as a valuable pozzolanic material (James and Rao 1986). Mehta in 1973 investigated the effect of pyro-processing on pozzolanic reactivity of RHA (Mehta 1994). The ash produced by controlled burning of the rice husk between 550ºC - 700 ºC for one hour transforms the silica content of the ash into amorphous phase (James and Rao 1986, Hwang and Wu 1989). The reactivity of amorphous silica is directly propotional to the specific surface area of the ash (Tangchirapat et al 2008, Chindaprasirt, and Jaturapitakkul 2007). The ash so produced is pulvarised or ground to required fineness and mixed with cement to produce blended cement. Hwang and Wu (1989) observed that at 400 ºC, polysaccrides begin to depolymerize. Above 400 ºC, dehydration of sugar units occurs. At 700 ºC, the sugar units decompose. At temperatures above 700 ºC, the unsaturated products react together and form a highly reactive carbonic residue. It is also reported that higher the burning temperature, the greater is the percentage of silica in the ash.

2.3 Recycled Aggregate

The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum out of which 7-8 million tons are concrete and brick waste (Hansen 1992, Oikonomou2005). This huge quantity of waste can effectively be used in construction industry. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal. Aggregates composed of recycled concrete generally have a lower specific gravity and a higher absorption than conventional gravel aggregate. New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action. The compressive strength depends on the compressive strength of the original concrete and the water-cement ratio of the new concrete. It has been found that concrete made with recycled concrete aggregate has at least two-thirds the compressive strength of natural aggregate concrete. .

It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving, which gives best particle size distribution. The amount of fine particles (<4.75mm) after recycling of demolished were in the order of 5-20% depending upon the original grade of demolished concrete. The best quality natural aggregate can be obtained by primary, secondary & tertiary crushing whereas the same can be obtained after primary & secondary crushing in case of recycled aggregate. The single crushing process is also effective in the case of recycled aggregate (Oikonomou2005). The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from crushed rock. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete. The specific gravity (saturated surface dry condition) of recycled concrete aggregate (RCA) is generally in the range of 2.35 - 2.58 which is lower in comparison to natural aggregates. Since the RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from 3.05% to 7.40%, which is relatively higher than that of the natural aggregates. Since, the water absorption characteristics of recycled aggregates is higher, it is advisable to maintain saturated surface dry (SSD) conditions of aggregates before start of the mixing operations. The loose bulk density of recycled aggregate is lower than that of natural aggregate, except recycled aggregate, which is obtained from demolished newly constructed culvert. Recycled aggregate passed through the sieve of 4.75mm due to which voids increased in rotted condition. The lower value of loose bulk density of recycled aggregate may be attributed to its higher porosity than that of natural aggregate (Hansen, 1992). The recycled aggregate is relatively weaker than the natural aggregate against mechanical actions. The crushing and impact values of recycled aggregate satisfy the BIS specifications.

2.4 E - Waste

E-waste is a term used to cover almost all types of electrical and electronic equipment (EEE) that has or could enter the waste stream. Although e-waste is a general term, it can be considered to cover TVs, computers, mobile phones, white goods (e.g. fridges, washing machines, dryers etc), home entertainment and stereo systems, toys, toasters, kettles – almost any household or business item with circuitry or electrical components with power or battery supply. Using the personal computer (PC) as an example – a normal Cathode Ray Tube (CRT) computer monitor contains many valuable but also many toxic substances. One of these toxic substances is cadmium (Cd), which is used in rechargeable computer batteries and contacts and switches in older CRT monitors. A pile of 500 computers contains 717kg of lead, 1.36kg of cadmium, 863 grams of chromium and 287 grams of mercury – all poisonous metals. CRT tubes contain average of 4 pounds of lead Thousands of children throughout the India are attending schools that were built on or near toxic waste sites, with increased risk of developing asthma, cancer, learning disorders and other diseases linked to environmental pollutants. If e-waste is disposed of in landfills, burned outdoors or recycled in other inappropriate ways, toxic substances might contaminate the air, water and soil, affecting the life of all living creatures. These are not eco-friendly processes as they pollute the land and the air. Study of the thermal behavior of the polymers namely polyethylene, polypropylene, polystyrene show that these polymers get softened easily without any evolution of gas around 130-140°C. For The plastic waste inhibits good binding property. For use, the aggregate is generally heated to around 170°C and the shredded plastic waste (size between 2.36 mm and

4.75 mm) is added. Plastic gets softened and coats over the aggregate. The mix of aggregate and plastic is compacted and cooled. The block thus prepared becomes very hard and shows compressive strength not less than 130 MPa and binding strength of 50 MPa. This shows that the binding strength of the polymer is good (IRC: 48-1972). The polymer coated aggregate soaked in water for 72 hours shows no stripping at all. This shows that the coated plastic material sticks well with the surface of the aggregate.

2.5 Waste Glass

Glass is produced in several forms viz., container glass (bottles, jars), flat glass (windows, windscreens, mirrors, shoe cases etc), bulb glass (light globes), cathode ray tube glass (TV screens, monitors, etc), all of them have a limited life and need to be reused/recycled in order to avoid environmental problems that would be created if they were to be dumped or sent to landfill. Glass is a unique inert material that could be recycled many times without changing its chemical properties. Waste glass can be used in construction industry as partial replacement of aggregate, besides recycling and in landfills.

Specific gravity of waste glass is about 2.5 which is slightly lower than that of natural aggregate. The water absorption of waste glass is about 0.4% which is substantially lower than that of substantial aggregate (Turgut and Yalhizade 2009).

3. USES OF WASTES

Smaller pieces of concrete is used as gravel for new road construction projects. Sub-base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt poured over it [16]. Crushed recycled concrete can also be used as the dry aggregate for brand new concrete if it is free of contaminants. Larger pieces of crushed concrete, such as riprap, can be used for erosion control. With proper quality control at the crushing facility, well graded and aesthetically pleasing materials can be provided as a substitute for landscaping stone.

In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength of the road. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with organic synthetic polymers like plastics. Polymer modified bitumen is emerging as one of the important construction materials for flexible pavements. Use of plastic waste in the construction of flexible pavement is gaining importance because of the several reasons. The polymer modified bitumen show better properties for road construction and plastics waste, otherwise considered to be a pollution menace, can find its use in this process and this can help solving the problem of pollution because most of the plastic waste is polymers. Plastic waste can be used in road construction as filling material in base and as a binder material in pavement.

The use of the recycled glass as aggregate in concrete has become popular in modern times. Recent research findings have shown that concrete made with recycled glass aggregates have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates. Secondary markets for glass recycling may include: Glass in ceramic sanitary ware production; Glass as a flux agent in brick manufacture; Glass in astroturf and related applications (e.g. top dressing, root zone) material ;Glass as an aggregate. Glass aggregate, a mix of colors crushed to a small size, is substituted for many construction and utility projects in place of pea gravel or crushed rock. Glass aggregate is not sharp to handle. Common applications are as pipe bedding--placed around sewer, storm water or drinking water pipes to transfer weight from the surface and protect the pipe. Another common use would be as fill to bring the level of a concrete floor even with a foundation.

One of the area identified its bulk utilization of fly ash is in construction of roads and embankments. Central Road Research Institute (CRRI), New Delhi, chosen as the 'Nodal Agency' for this activity, has undertaken many demonstration projects. Fly ash may be used in different element of road such as pavement, embankment and as filling material in base. In cement concrete pavement cement can be replaced by fly ash up-to 40% by weight. Use of fly ash in concrete pavements improves the strength and durability of the pavement while it reduces the construction costs. Class C fly ash has been used as substitute for cement in the concrete, and Class F fly ash, while not cementitious, acts as a pozzolana to enhance the long term strength and durability of concrete. In addition, fly ash increases the workability of the concrete and usually reduces the water demand. The resulting concrete typically has a higher ultimate strength, and is denser, providing resistance to infiltration from deicers. Normally use of fly ash slightly retards the setting time of concrete, but it is compensated by reduction in the admixture dosage to maintain the same workability. Use of fly ash in road works results in reduction in construction cost by about 10 to 20 per cent. Typically cost of borrow soil varies from about Rs.100 to 200 per cubic metre. Fly ash is available free of cost at the power plant and hence only transportation cost, laying and rolling cost are there in case of fly ash (Jiang et al. 2004).

4. CONCLUSION

Different types of wastes require space, time and money for proper disposal. Even then, the pollution is unavoidable. These wastes can be used in different construction activities. The reuse of wastes leads to saving of environment and natural resources. Also, the reuse makes the construction economical without compromising the quality of construction.

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TOXIC HEAVY METALS IN GROUNDWATER OF DHANBAD DISTRICT, JHARKHAND, INDIA

Indrajit Kumar Singh[1]*, Rajeshwar Singh and Amarjeet Kumar Singh
[1]Department of Applied Geology, Indian School of Mines, Dhanbad-826 004
*Corresponding author e-mail: iksinghism@yahoo.co.in

ABSTRACT

Twenty ground water samples from eastern part of Dhanbad District, has been analyzed for some toxic metals that include Cd, Cu, Fe, Mn, Ni, Pb and Zn. Higher concentration of toxic heavy metals, *viz.* Fe, Mn, Cu is noticed which has a bearing on soil and human consumption.

Key words: Ground Water, Dhanbad, Coalfield, Heavy Metals and Water geochemistry.

INTRODUCTION:

Ground water is an essential and vital resource for human life and economic world. Though, major part of the Earth is covered with water but the quantum of fresh water required for various human activities is rather limited. With the continuing growth and concentration of population, developmental activities and industries in Dhanbad District, the ground water is being exploited indiscriminately and is used for various purposes, irrespective of its qualitative suitability. The study forms the eastern part of Dhanbad district, which is built up on a Precambrian rocks mainly consists of Chhotanagpur gneissic complex, and other sedimentary rocks such as sandstone, shale in addition to coal[1] (Fig-1). In the present study an attempt has been made to assess the concentrations of some of the important toxic metals in the ground water of this important coal belt.

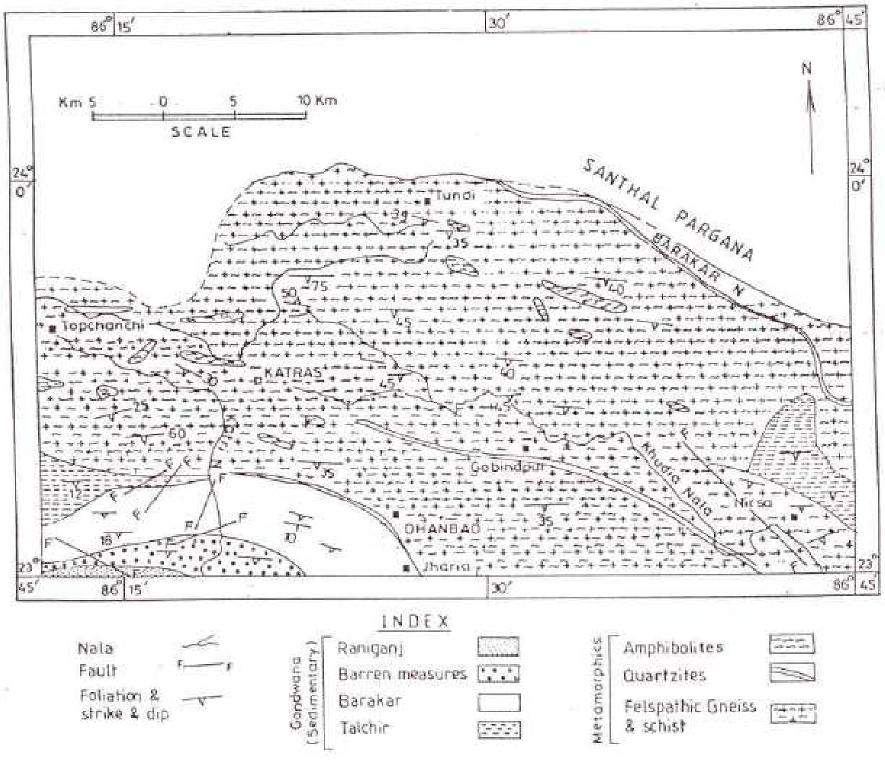

Fig. 1 Showing geological map of Eastern Dhanbad

Water samples from eight dug wells and twelve tube wells (Fig-2) have been systematically collected and analyzed for Cd, Cu, Fe, Mn, Ni, Pb, and Zn using Atomic Absorption Spectrophotometer (AAS), following standard analytical methods[2]. The concentrations of various toxic heavy metals are presented in Table-1.

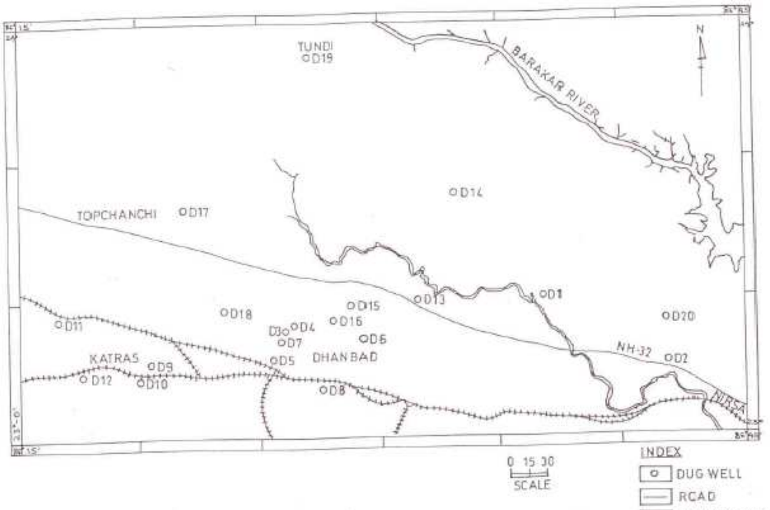

FIG. 2 LOCATION MAP OF THE SAMPLING WELLS

Table 1 Concentrations (mg/l) of toxic heavy metals in groundwater of Dhanbad District.

Survey points	Source of water	Cadmium	Copper	Iron	Manganese	Nickel	Lead	Zinc
D-1	DW	BDL	0.015	0.027	0.085	BDL	BDL	0.054
D-2	TW	BDL	0.002	0.9	0.006	BDL	0.008	0.103
D-3	TW	BDL	0.005	1.6	0.012	BDL	0.003	0.079
D-4	TW	BDL	0.003	3.5	0.005	BDL	0.009	0.005
D-5	TW	BDL	0.010	1.8	0.018	BDL	0.007	0.212
D-6	TW	BDL	0.020	6.9	0.041	BDL	0.013	0.087
D-7	TW	BDL	0.011	5.5	0.032	BDL	BDL	0.105
D-8	TW	0.0015	0.007	1.7	0.018	BDL	BDL	0.113
D-9	TW	BDL	0.002	0.09	0.007	BDL	0.006	0.009
D-10	DW	BDL	0.003	0.06	0.111	BDL	0.015	0.121
D-11	DW	0.0003	0.004	0.07	0.056	BDL	0.0005	0.062
D-12	TW	BDL	0.052	1.2	0.041	BDL	0.032	0.086
D-13	DW	BDL	0.007	0.112	0.072	BDL	0.0007	0.070
D-14	TW	0.0014	0.011	0.10	0.018	BDL	BDL	0.047
D-15	DW	BDL	0.022	0.09	0.008	BDL	BDL	0.083
D-16	TW	BDL	0.008	BDL	BDL	BDL	0.016	0.057
D-17	DW	0.0002	0.022	0.025	0.064	BDL	0.0004	0.183
D-18	DW	BDL	0.005	0.15	0.101	BDL	0.023	0.430
D-19	DW	BDL	0.006	0.185	0.017	BDL	0.028	0.079
D-20	TW	0.0012	0.005	0.07	0.030	BDL	0.092	0.063

Explanations:DW-dug Well, TW- Tube Well, BDL- Below detectable Limits

Quality comparison with drinking water standard[3, 4] are shown in Table-2. It is clear from the Table-2 that Cd, Ni, Pb and Zn parameters are within the range of permissible limits in almost all sampling points. However, Fe, Mn and Cu were found to exceed permissible limits in eight, two and one samples respectively (Table-2).

Table 2 Quality comparison of groundwater of Dhanbad area with drinking water standards.

Toxic heavy metals	WHO (1984) Highest desirable (mg/l)	Standards Max. permissible (mg/l)	ISI (1983) Highest desirable (mg/l)	Standards Max. permissible (mg/l)	Numbers of samples exceeding permissible limits.
Cd	0.005		0.01	No relaxation	Nil
Cu	1.0		0.05	1.5	01
Fe	0.3	1.0	0.05	1.5	08
Mn	0.1		0.1	0.5	02
Ni	No guide line value set				
Pb	0.05		0.1	No relaxation	Nil
Zn	5.0	15.0	5.0	15.0	Nil

Because of relatively high abundance of Fe in rocks of the Earth's crust, ranks fourth by weight (5.63 percent) [5] and its geochemical mobility, iron normally occurs in almost all kinds of ground water in appreciable quantity[6]. However, man made factors can locally raise the iron concentration in the groundwater, main sources being use of Fe-bearing metallic pipes and machine especially in the coal mining areas such as Dhanbad. In the present investigation, the water samples from tube wells numbered as D-2, D-3, D-4, D-5, D-6, D-7, D-8 and D-12, which show higher concentration iron (Table-1). The source of higher enrichment of iron could be traced either due to the presence of dissolved iron appears to coal mining and its related activities. Further, under reducing conditions the solubility of iron-bearing minerals (siderite/ marcacite) increases, leading to the enrichment of dissolved iron in groundwater. Iron is found in most drinks and foods. It is an essential component of several cofactors including hemoglobin and the cytochromes. The recommended daily intake is 10mg for men 18mg for women.

Because life is develop in the presence of all the elements and elements are required for healthy development of living tissues within a zoological system, it's over supply produces toxic effects while depletion leads to deficiency. Lower concentration of Cd, Cu, Mn and Ni has no adverse effects on the health while deficiency of iron may causes anaemic problems in women. Deficiency of zinc may lead to retarded growth, sexual infantilism in teen-age individuals and impaired wound healing. While zinc deficiency also leads to rash diarrohea and respiratory infections.[7]

Mobilization of manganese in groundwater occurs due to reduction (both chemically and bacterially) of Mn^{4+} in to Mn^{2+} soluble from.[8] Slightly higher concentration of Mn is found in dug well waters of D-10 and D-18 (Table-1). These samples are especially from major anthropogenic source like coal mining and coal combustion[9].

Manganese is an essential trace elements forming part of several important enzyme systems involved in protein and energy metabolism and in mucolysacchride formation. The recommended daily allowance for adults is at least 1.2 mg., but insufficient dietary manganese may result in abnormal carbohydrate metabolism and impaired insulin production in humans.

The presence of Cu, Fe, Mn, Pb and Zn in the ground waters of Dhanbad district is reported as a preliminary information, an immediate quality monitoring of ground water in this area is needed to know the exact trend, source and degree of quality deterioration, which enables one to take precautionary measures to overcome future environmental degradation in this predominantly coal mining belt.

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IMPACT OF OPENCAST COAL MINING ON WATER RESOURCES – A CASE STUDY

A. Jamal, R.P.Singh and Abhay Kumar Ranjan
Department of Mining Engineering,
Institute of Technology,
Banaras Hindu University,
Varanasi - 221005 (U.P.), India.

ABSTRACT

Pure coal is an inert material as far as quality and quantity of water is concerned in mine. However, the occurrence of impurities as inorganic minerals in coal changes the quality of water significantly. In underground coal mines, the water is always in acidic range. However, in case of opencast mine the quality of water ranging from alkaline to acidic in various overburden and coal benches respectively. The quality of water in main sump is also less acidic than water in sump near coal face. This variation in quality of water indicates that the active minerals present in coal and associated rocks are responsible for changing the quality of water in a coal mining complex. A case study is discussed in this paper to assess the impact of mining on water resources and its remedial measures.

Coal seam in Singrauli Coal Field is deposited during Permian period (Damuda Series of Gondwana System). This series contains five seams separated with each other mainly by sandstone, shale and fired clay. Barakar sandstone and coal seams are porous and permeable in nature due to primary and secondary permeability. Hence, they act as good aquifers. These strata are most active chemically and affect the quality of sump water significantly. The paper also determines the **acid production potential** and **acid neutralization potential** of coal and associated rocks. The study conclude that low sulphur in coal and significant **acid production potential** of Barakar sandstone are responsible for relatively better water quality in surface mine in comparison to underground coal mines.

INTRODUCTION

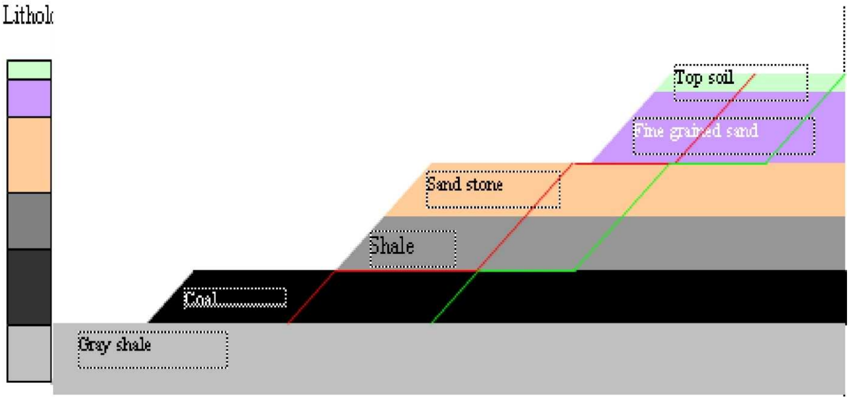
Singrauli town, known for coal based power generation plants, has a population of over 12 lakh with huge quantity of coal at shallow depth. The coal mining is started in this area as early as 1857. However, the continuous mining was started from Jhingurdah and Gorbi mine since 1965 & 1971 respectively. It present population is increasing due to coming up of of India largest power plant of 3216 MW capacity by Reliance & several other power plants and industries by Birla, Essan, etc. besides active mining by Northern Coalfields Ltd.

As a result of mining and power plant activities in the area, the major problem is availability of potable and industrial water for population and industries both. The active mining not only depleting the ground water quantity but degradation of water quality is also a major threat in the area. Mining in different stratigraphic horizons discharging alkaline and acid water as well. The acidic water of Gorbi (abandoned), Amlori and Jhingurdah opencast projects have high concentration of iron, sulphate, and the total dissolved solids. The pH value is also in acidic range.

Geological set up

All major rocks types including sedimentary and igneous are found in and around the Singrauli district.

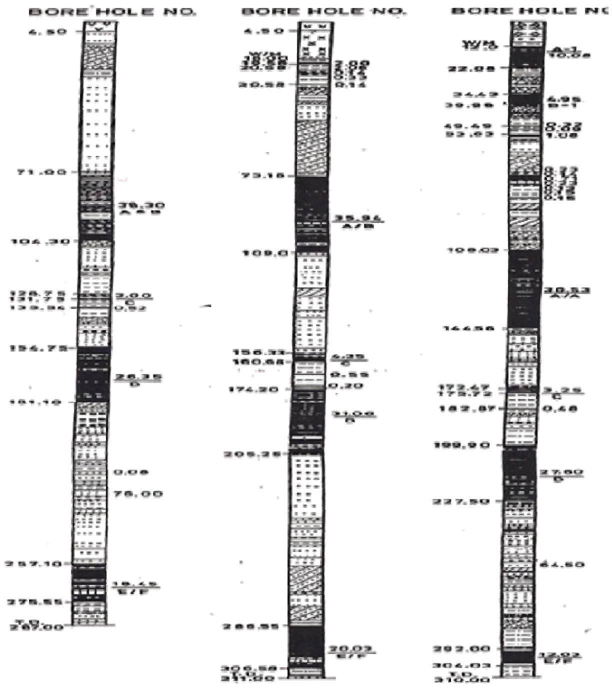
The various rock types in coal fields are shown as modal in Model 1.



Model 1: Common associated rocks with coal seams.

The various litho units with various thickness are shown in Plot 2. The lithic piles shows a pre hindrance of sandstone dominated cycles. The northern limit of the singrauli is defined by a long East-West trending fault. The adjoining rocks are Talchir or Bijawars. Out of two basins, Moher sub- basin is most potential. It is flanked by Talchir sediments in East and west and lineated to north by prominent east-west fault. In this basin, the beds have a general NW-SE trend in the western part and this strike severs to nearly east-west along Amlori-Nigahi-Jayant block. Moher sub-basin shows a broad basinal structure with uneven undulation on its libs. There are two seams (Jhingurdah top seam, Jhingurdah bottom seam) in Ranigang formation and 6 seams (Pan Pahri, Khadia seam, Parewa top seam, Parewa bottom seam, Turra seam & Kota seam) of Barakar formation. There is local faults also in the mines of Singrauli. (Raja Rao, C.S. 1983. Bulletins of the Geological Survey of India, Series A, No.45, Coalfields of India, Vol III, pp 130-133.)

Several faults in the coal field are major source of contaminated water in the mine. Besides this, sandstone is the bulk overburden and main source of ground water for mine and potable water both. The gentle dip does not pose any problematic flooding of the opencast projects. However, water quality deterioration is the major issue.



Plot 2: Bore hole litholog of coal field.

Hydrogeology

The coalfield experiences a tropical monsoon type of climate. The summer and winter temperature is highly variable and fluctuates from 46^0 C in summer to 5^0C in winter. The area enjoys a heavy monsoon and annual rainfall varies between 1250 mm to 1500 mm.

The ground and hilly area is mostly covered with forest of Kendu, Mahua, Bija, Amla. The flat terrain is used for cultivation. A brief of surface water quality and ground water scenario is given below:

a) Surface water

The singrauli coalfield is located in the drainage area of the Son and Rihand River. The north flowing streams in the Moher scarp are a join the Bijul river which is a tributary of Son. The South flowing streams mostly join the Kachmi, a tributary of Rihand. Some tributary directly debounche into Rihand reservoir or join the Balia nala directly. Among the north flowing streams , the Mirhauli nala is important. Turra and Mudwani nalas are seasonal. In Amelia area, the Pararwar and Bondha nalas with semi-perennial flows are important. The water from different mines are received by these nallas. Kachni, Bijul and Balia nalas received the mine effluent from different projects. Some projects directly discharge their effluent into Rihand reservoir. There is water treatment plant in some mines also

Surface and ground water samples from the area were analysed. The data shown in Tables 1 & 2.

Table 1: Physico-chemical characteristics of mine water in Amlori coal mine.

Water quantity parameters	Water Sampling Sites				Tolerance limits as per GSR: (Inland Surface Water
	NAW$_1$	NAW$_2$	NAW$_3$	NAW$_4$	
Colour	Yellowish	Yellowish	Light Yellow	Yellowish	Shall be colourless
Odour	Pungent	Pungent	Pungent	Pungent	Shall be odourless
Temp0C	32.1 – 33.3	32 – 32.8	31.2 – 32.3	31.4 – 31.8	Shall not exceed 5°C above the receiving water temperature
pH	5.14 – 5.21	5.26 – 5.32	5.64 – 5.72	5.82 – 5.87	5.5-9.0
TSS	210 - 219	223-234	198-204	211-221	100
TDS	1217-1229	1113-1127	1518-1528	915-927	2100
SO$_4$	813-827	915-934	806-819	726-739	1000
Fe	2.01-2.03	1.98-2.04	1.06-2.14	1.12-1.19	3.0
Ca	46.4-48.2	35-39	33-41	22.8-25.4	
Na	55.2-57.6	61.2-67.8	44.8-48.4	58.7-62.2	
Mg	49-56	37-47	43-52	57-69	
K	23-34	33-39	16-21	66-72	
CO$_3$	BDL	BDL	BDL	BDL	
HCO$_3$	BDL	BDL	BDL	BDL	

Table 2: Physico-chemical characteristics of mine water in Jhingurdah coal mine.

Water quantity parameters	Water Sampling Sites				Tolerance limits as per GSR: (Inland Surface Water
	NAW$_1$	NAW$_2$	NAW$_3$	NAW$_4$	
Colour	Yellowish	Yellowish	Light Yellow	Yellowish	Shall be colourless
Odour	Pungent	Pungent	Pungent	Pungent	Shall be odourless
Temp0C	32.1 – 33.3	32 – 32.8	31.2 – 32.3	31.4 – 31.8	Shall not exceed 5°C above the receiving water temperature
pH	5.36-5.45	5.32-5.39	5.44-5.52	5.76-5.81	5.5-9.0
TSS	210-219	223-234	198-204	211-221	100
TDS	1217-1229	1113-1127	1518-1528	915-927	2100
SO$_4$	831-839	925-941	816-827	706-708	1000
Fe	1.01-1.09	2.38-2.47	1.10-1.24	1.32-1.41	3.0
Ca	46.4-48.2	35-39	33-41	22.8-25.4	
Na	55.2-57.6	61.2-67.8	44.8-48.4	58.7-62.2	
Mg	49-56	37-47	43-52	57-69	
K	23-34	33-39	16-21	66-72	
CO$_3$	BDL	BDL	BDL	BDL	
HCO$_3$	BDL	BDL	BDL	BDL	

All values are in mg/L except pH, colour, temperature and odour.

BDL – Below Detection Limit.

It may be observed from tables that the pH of water discharged from various locations in mine are below or above the recommended permissible limit of industrial effluent discharge. The pH value of water in this mine varies between 5.14 and 5.87. The lowest pH value of mine water was observed at the old sump, where it varies between 5.14 and 5.21. The concentration of TDS in mine water are within the permissible limit of industrial discharge and the highest concentration of TDS was observed in the water seeping from working coal face. The concentration of TDS in the water discharged from coal face varies from 1518mg/L to 1528mg/L.

The concentrations of iron and sulphate are within the permissible limit and varies from 726 mg/L to 934 mg/L being highest in mine water of new sump, where it lies between 915 mg/L and 934 mg/L. The concentration of iron in mine water varies from 1.06 mg/L to 2.04 mg/L being highest in old sump. All other water quality parameters are within the permissible limit.

On the basis of water quality results, it was concluded that there is a mild problem of acid mine drainage in this coal mine and requires implementation of proper management to save the fresh water in and around the mining area.

Jhingurdah coal mine

The physic-chemical characteristic of mine water available in Jhingurdah coal mine is summarized in table 2.

It may be observed from table and figure that pH value of water in this mine varies from 5.32 to 5.81 which is very near to the recommended permissible limit. The lowest pH value was observed in water of new sump, where it is between 5.32 and 5.39, which is beyond the recommended permissible limit and is an objectionable water quality parameters. The concentration of TSS is highest in water of main sump where it varies between 223 mg/L to 1528 mg/L.

The TDS concentration in mine water varies between 915 mg/L and 1528 mg/L, which are within the recommended permissible limit of industrial effluent discharge. The highest concentrations of TDS were observed in water from working coal faces where it varies from 1518 mg/L to 1528 mg/L.

The concentration of sulphate and iron in mine water are within the recommended permissible limit. The concentration of sulphate in mine water varies between 706 mg/L and 941 mg/L. Almost same concentration was observed in main sump where it varies from 925 mg/L to 941 mg/L. The iron concentration in mine water varies between 1.01 mg/L to 2.47 mg/L, which is within the permissible

b) Ground water scenario

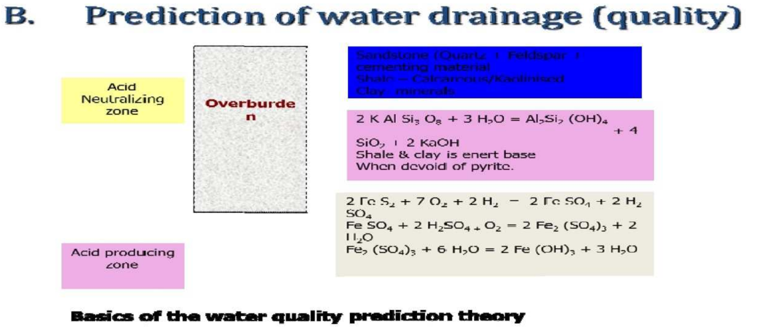
Both unconfined and confined aquifer systems are existing in these mines due to multi seam nature of formations. This can be seen from Plot 1 also as bore hole litho logs.

The sandstone above Khadia seam is unconfined while sandstone occurring as inter burden are confined system up to Turra Seam, which is a working seam in many mines. Faults and fractures in mines create connectivity between sandstone and coal seams and water seepage through seams has been observed.

Management of water quality

Result of water quality analysis discussed above conclude that water in all mentioned coal mines are acidic and suffering with high concentration TDS, shulphate, iron and low pH value. Waters of these mines are continuous by discharged into near by nallas. Various methods proposed for the treatment of waste water are economically unfeasible in many mines. A few mines are using limestone for the management of waste water. A more feasible method for neutralization of acid water and reduction of other pollutants has been suggested in subsequent paragraphs.

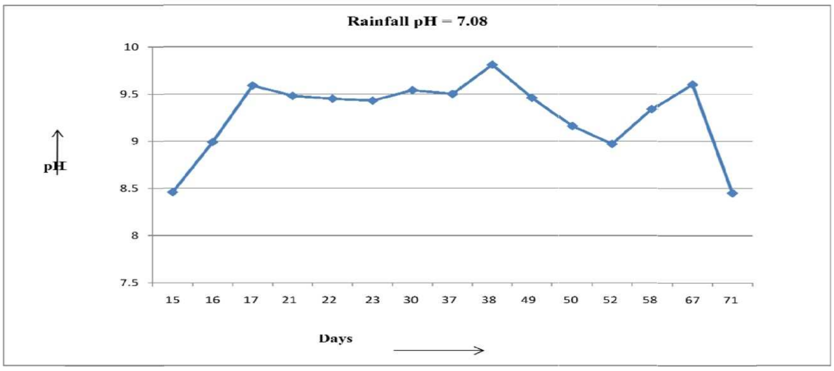
It may be observed from above water assessment that acid mine drainage and other suspended and dissolved solids are threat for surface water quality in the areas. Some improvement in water quality can be made by knowing the geo-environmental characteristics of coal and associated rocks. The theory for acid water neutralisation is explain in below diagram:


B. Prediction of water drainage (quality)

Basics of the water quality prediction theory

For knowing the contribution of various rocks (Sandstone of various types) an coal leaching test were conducted. The observation are shown as figures 1 to 10 .

Figure 1: Kinetic test : Fine grained Sandstone



It may be observed from above figure that sandstone can be used for neutralisation of acid water of coal mines. Keeping in view, the above information it is suggested that diversion of acid water effluent through rocks having high neutralisation capacity for acid water may be an option for control of acid water and other pollutants in coal mines . However, the contribution of various rocks
and coal can be determined or predicted in polluting the water at laboratory scale. By simple leaching model, various rocks of the area may be tested for knowing their contribution in generation of pH, TDS etc before suggesting channel or diversion through rocks for treatment of waste water.

CONCLUSION AND FIELD APPLICATION

Pure coal is an inert material as far as quality and quantity of water is concerned in mine. However, the occurrence of impurities as inorganic minerals in coal changes the quality of water significantly. In underground coal mines, the water is always in acidic range. However, in case of opencast mine the quality of water ranging from alkaline to acidic in various overburden and coal benches respectively. The quality of water in main sump is also less acidic than water in sump near coal face. This variation in quality of water indicates that the active minerals present in coal and associated rocks are responsible for changing the quality of water in a coal mining complex. A case study is discussed in this paper to assess the impact of mining on water resources and its remedial measures.

Coal seam in Singrauli Coal Field is deposited during Permian period (Damuda Series of Gondwana System). This series contains five seams separated with each other mainly by sandstone, shale and fired clay. Barakar sandstone and coal seams are porous and permeable in nature due to primary and secondary permeability. Hence, they act as good aquifers. These strata are most active chemically and affect the quality of sump water significantly. The paper also determines the acid production potential and acid neutralization potential of coal and associated rocks. The study conclude that low sulphur in coal and significant acid production potential of Barakar sandstone are responsible for relatively better water quality in surface mine in comparison to underground coal mines.

In coal area, the characteristics of coal and associated rocks must be thoroughly investigated to prepare a water management plan with minimum impact on environment and in economic way.

ACKNOWLEDGEMENT

The authors are thankful to council of scientific and industrial research New Delhi for providing financial assistance to work on this project. The special thank are due to personnel of Northern Coalfields Limited for helping in sample collection and valuable discussion.

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QUALITY ASSESSMENT OF SURFACE WATER RESOURCES OF PRATAPGARH DISTRICT, UTTAR PRADESH

Ashwani Kumar Tiwari*, Mukesh Kumar Mahato, Abhay Kumar Singh
CSIR-Central Institute of Mining and Fuel Research,
Barwa Road, Dhanbad-826015

ABSTRACT

In order to assess the suitability of water for irrigation uses, the chemical characteristic of surface water resources in Pratapgarh district have been analyzed and evaluated. For this purpose, 25 water samples from rivers, ponds and canals were collected and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS),turbidity, major cations (Ca^{2+}, Mg^{2+}, Na^{+} , K^{+}) and major anions (HCO_3^- , F^-, Cl^-, NO_3^-, SO_4^{2-}). pH of the analyzed samples indicates mild alkaline nature of the water samples. Total dissolved solids of 80% of analyzed surface water samples were falling in the category of fresh water and 20% in the category of brackish water. HCO_3^- and Cl^- are dominant anions and Na^+ and Ca^{2+} as the dominant cation in the water chemistry of the Pratapgarh surface water resources. Parameter like residual sodium carbonate (RSC), permeability index (PI), percent sodium (%Na), sodium adsorption ratio (SAR) were calculated and plotted to understand the water quality and utilitarian aspect of surface water for irrigation uses. The calculated parameters show that the majority of the surface water samples are suitable for irrigation uses. The higher salinity and %Na restrict the suitability of the water at few sites.

Keyword: Pratapgarh**,** surface water quality, major Ions, salinity hazard, SAR, RSC.

INTRODUCTION

Water is the most important input required for plant growth and in agricultural production. Bulk weight of all living organisms consists of 80 to 90% of water. Water need for plant growth is met with soil water storage in plant root zone. Under raided conditions, soil water storage is continuously replenished with natural rainfall. However, irrigation is essential in arid and semi-arid climates to maintain soil water storage at an optimum level to get higher yield. Therefore, irrigation can be defined as replenishment of soil water storage in plant root zone through methods other than natural precipitation. All water sources used in irrigation contain impurities and dissolved salts irrespective of whether they are surface or underground water. However, quality of water has meaning only with respect to its particular use. Water which can be considered good quality for household use may not be ideal for irrigation uses. In agriculture, water quality is related to its effects on soils, crops and management necessary to compensate problems linked to water quality. It is very important to note that many problems of soil degradation like salinity, soil permeability, toxicity etc. can be related to irrigation water quality.The chemical parameters of surface water play significant role in classifying and assessing water quality. Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) can be used as criteria in the classification of water for a particular purpose. Considering the individual concentration may not find its suitability for other purposes and better result can be obtained only by considering the combination chemistry of all the ions rather than individual or paired ionic characters (Handa 1965; Hem 1985). The objective of the present study was to assess the hydro-chemical characteristics of the surface water of Pratapgarh district and its suitability for irrigation uses.

STUDY AREA

Pratapgarh district lies between $25^0$34'N and $26^0$11'N latitudes and $81^0$19'E and $82^0$27'E longitudes and the total geographical area of the district is 3,730 km^2 with a population of 27,31,174 (**Fig 1**).It is one of the oldest districts of Uttar Pradesh that came into existence in the year 1858. The annual rainfall of the district varies from 905 to1300 mm, 20-59 % of annual rainfall occurs during the month of June, July and August. The Sai is one of the most important rivers, goes through the heartland of the Pratapgarh and flows towards west-east. This river irrigates northern and southern parts of Pratapgarh district. The surface elevation is

137 meters from Sea level. The climate of this area is characterized by hot dry summer and cold dry winter. The main activity carried out in this area is agriculture and the district ranked as the top producer of *Phyllanthus emblica* (Aonla fruit). It is a multi-purpose fruit, is extremely rich in vitamin C, help cure gastro-intestinal disorders. It is exported all over India and also other parts of the world. The other important crops grown in different seasons are rice, bajra, maize, arhar, urad in kharif; wheat, gram and pea in rabi and urd and moong in zaid. Sugarcane, potato and mustard are important cash crops in the study area.

SAMPLING AND ANALYSIS

For the assessment of water quality of Pratapgarh district, a systematic sampling was carried out during June 2009. Representative 25 surface water samples from river, ponds and canals water were collected from rural and town areas (**Fig. 1**). The analysis of surface water samples were carried out in the laboratory at Central Institute of Mining and Fuel Research, Dhanbad as per Standard Methods (APHA, 1985). pH and electrical conductivity values were measured in the field using a portable conductivity and pH meter. In the laboratory, the water samples were filtered through 0.45 µm Millipore membrane filters to separate suspended sediments. Acid titration and molybdosilicate methods were used to determine the concentration of bicarbonate and dissolved silica, respectively. Concentration of major anions (F^-, Cl^-, NO_3^- and SO_4^{2-}) were determined by ion chromatograph (Dionex DX-120) using anion (AS12A/AG12) columns coupled to an self-regenerating suppressor (ASRS) in recycle mode. Concentration of major cations (Ca^+, Mg^{2+}, Na^+ and K^+) were determined by flame atomic absorption spectrophotometer (VARIAN-AA280 FS).

RESULT AND DISCUSSION

The results include the hydro-chemical analysis of 25 surface water samples collected from the study area (**Table 1**).

In situ measured pH of the analyzed samples varied from 6.8 to 9.8 and the average pH was found to be 8.0 indicating mildly acidic to alkaline nature of the surface water samples in study area. The EC ranged from 234 to 3270 µS cm-^{1} with an average value of 869 µS cm-^{1}. Concentration of total dissolved solids (TDS) in the surface water of the study area ranged from 203 to 2044 mg l^{-1} with an average value of 669 mg l^{-1} (Table 1). The large variation in the EC, TDS and ionic concentration in the surface water of the area may be attributed to variation in geo-chemical processes and anthropogenic activities

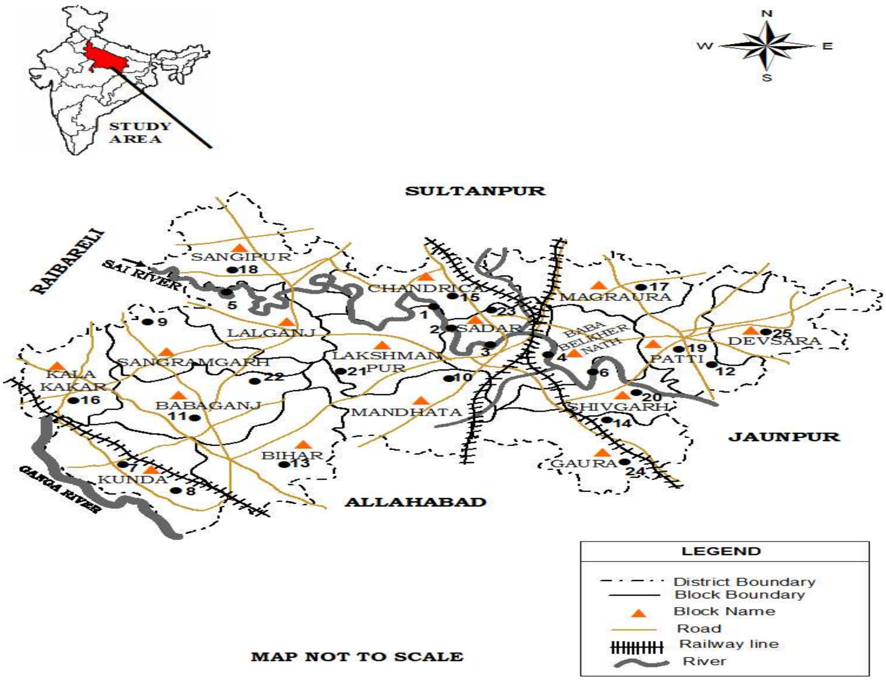

Figure1. Location map of Pratapgarh district and sampling site

Table 1. Physico-chemical characteristics of surface water of Pratapgarh district.

S.N	***Sample Location***	***pH***	***EC***	***TDS***	***Turb.***	***F***	***Cl***	HCO_3	SO_4	NO_3	***Si***	***Ca***	***Mg***	***Na***	***K***	***% Na***	***RSC***	***SAR***	***PI***
	RIVER SAMPLES																		
1	Pandeypur	8.2	373	331	11.4	0.42	23.8	195	22.8	5.9	12.1	23.3	12.9	29.8	5.1	39.1	2.08	1.23	87.6
2	Pratapgarh City Start	7.5	351	329	12.7	0.30	28.0	186	25.7	5.4	11.1	24.1	12.5	30.3	5.6	39.5	1.93	1.25	86.3
3	Pratapgarh City Mid	8.5	1037	839	3.0	1.11	80.0	457	40.0	17.8	30.0	48.4	32.2	122.2	10.4	52.5	4.94	3.34	77.6
4	Pratapgarh City End	7.3	358	333	10.3	0.42	26.5	192	24.9	5.0	11.3	24.4	12.5	30.1	5.5	39.2	2.02	1.24	86.8
5	Kalapur	8.2	808	665	11.6	0.89	76.0	335	37.9	12.2	38.3	36.3	28.4	90.2	10.4	50.2	3.40	2.72	77.6
6	Basirpur	8.1	537	403	1.9	0.73	32.0	220	26.6	1.9	17.0	30.5	19.2	49.2	6.4	42.6	2.05	1.72	77.1
	POND SAMPLES																		
7	Maharupur	8.4	826	656	4.3	2.09	56.0	369	23.8	12.2	26.0	40.2	26.9	89.0	10.7	49.5	3.92	2.66	78.2
8	Bahadurpur	7.9	950	832	74.4	1.09	355.9	113	39.3	26.7	27.4	79.7	57.6	123.5	8.2	39.0	-2.54	2.57	47.8
9	Bhatari	7.8	810	498	1.4	0.64	78.0	247	5.9	28.0	37.6	37.0	36.1	24.8	2.8	19.3	1.62	0.70	52.5
10	Saray Narayan	7.8	2140	1346	7.3	0.37	667.0	242	58.9	1.3	32.8	96.7	115.5	125.5	5.7	28.1	-3.26	2.04	37.7
11	Rampur	8.3	860	790	6.2	2.68	37.9	516	8.9	28.1	21.1	26.3	45.0	90.1	13.6	45.9	5.93	2.47	76.4
12	Bahuta	9.8	2270	2044	263.0	3.62	52.0	1290	68.5	7.9	46.6	16.8	13.2	541.4	4.1	92.5	20.18	23.99	110.5
13	Rajangarh	8.4	1627	1365	52.9	1.00	152.0	775	14.0	69.7	35.6	82.3	70.1	134.5	30.8	40.2	7.73	2.63	59.9
14	Chandpur	8.6	1559	1129	6.0	3.38	169.9	564	41.2	31.8	0.2	36.2	27.2	224.4	30.4	72.3	7.21	6.87	92.7
15	Adharpur	7.4	341	262	54.6	0.55	36.0	68	16.6	62.2	7.6	23.5	16.6	18.6	12.7	30.8	-0.17	0.72	55.6
16	Lala Bazar	8.0	803	536	2.2	0.57	44.0	304	16.0	8.5	32.3	60.0	35.5	26.9	8.5	19.0	2.01	0.68	48.0
17	Mangraura	8.0	602	564	78.0	2.80	76.5	313	12.2	10.5	10.2	24.0	15.5	85.4	14.4	62.3	3.89	3.34	96.7
	CANAL SAMPLES																		
18	Samaspur	6.8	377	283	342.0	0.64	34.0	86	53.7	20.5	8.8	20.3	8.5	43.6	7.0	54.8	0.55	2.05	85.4
19	Sarsatpur	7.3	234	213	199.0	0.37	12.0	121	14.6	0.8	15.4	32.2	9.6	3.5	3.1	8.8	0.78	0.14	61.1
20	Bhojemau	8.3	457	287	2.0	0.64	12.0	175	18.4	1.7	19.6	28.7	12.5	14.5	3.5	22.6	1.63	0.57	75.2
21	Manikpur	8.1	1367	857	34.7	2.35	195.9	274	103.8	46.8	26.9	55.7	31.8	88.8	30.7	46.3	1.78	2.35	64.6
22	Lodipur	7.4	238	209	130.0	0.40	2.3	132	14.8	2.3	15.8	25.6	9.4	3.3	2.8	9.5	1.13	0.14	73.6
23	Pratapgarh	8.5	2180	1457	7.5	2.55	359.9	507	66.8	42.8	24.8	66.5	38.5	320.0	28.1	69.3	5.05	7.73	82.4
24	Savansa	7.7	321	203	9.0	0.59	10.0	113	16.9	3.6	12.1	31.2	10.1	3.5	2.4	8.2	0.65	0.14	59.6
25	Fatehpur	7.5	311	299	57.0	0.72	3.8	198	14.8	2.9	11.6	33.6	12.7	18.6	2.8	24.4	1.88	0.69	74.0

Major ion Chemistry

Among major cations, sodium was the dominant ions representing on average 54% of total cations. Calcium and magnesium ions were of secondary importance, representing on average 23% and 16% of total cations, respectively. Potassium was least dominant cation and representing 6% of the total cations (**Figure 2a**). The order of cation abundance was $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$. Among the major anions, bicarbonate was generally dominant and representing on average 67% of the total anions. Chloride is the second dominant anion, representing on an average 22% of the total anions. Sulfate and nitrate were less dominant ions and contributing 7% and 4% to the total anions respectively (**Figure 2b**). Fluoride is the least dominant anion and comprising 0.25% of the total anions. The order of anions abundance in the surface was found as $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}>F^{-}$.

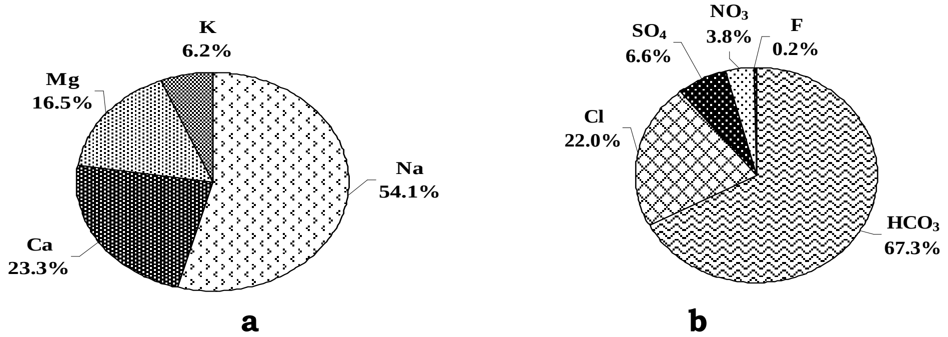

Figure 2. Percentage contribution of (a) cations to the total cationic balance (TZ^+) and (b) contribution of anions to the total anions charge balance (TZ^-)

SUITABILITY FOR IRRIGATION USE

The water quality evaluation in the area of study is carried out to determine their suitability for agriculture purposes. The suitability of the surface water for irrigation is contingent on the effects on the mineral constituents of the water on both the plant and the soil. In fact, salts can be highly harmful. They can limit growth of plant physically, by restricting the taking up of water through modification of osmotic processes. Also salt may damage plant growth chemically by the effect of toxic substance upon metabolic processes. Salinity, sodicity and toxicity generally need to be considered for evaluation of the suitability quality of surface water for irrigation (Shainberg and Oster, 1976; Todd, 1980). Parameter such as percent sodium (%Na), sodium absorption ratio (SAR), residual sodium carbonate (RSC) and permeability index (PI) have been computed by following equations:

SAR = $Na/[(Ca+Mg)/2]^{0.5}$ (i)
Na% = $Na+K/(Ca+Mg+Na+K) \times 100$ (ii)
RSC = $(CO_3+HCO_3) - (Ca+ Mg)$ (iii)
PI = $(Na + \sqrt{}HCO_3)/ (Ca + Mg + Na) \times 100$ (iv)

All concentrations are in meq l^{-1}

High salt concentration (high EC) in water leads to formation saline soil, while high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium absorption ratio (SAR). The calculated value of SAR in the study area ranges from 0.1 to 24.0 (avg. 3.0). The plot of data on US salinity diagram (USSL 1954) in which EC is taken as salinity hazard and SAR as alkalinity hazard shows that 40% of the samples fall in C2S1 categories indicating good to permissible quality of water for irrigation uses (**Fig. 3**). Due to low sodium and medium salinity, water of C2S1 class can be used for irrigation purpose on almost all soil with little danger of sodium problem. About 40% of the samples falls in the categories C3S1, indicating high salinity and low alkali water. High salinity water (C3) can not be used on soils with restricted and requires special management of salinity control. Such water can be used to irrigate salt- tolerant and semi-tolerant crop under favorable drainage conditions. Plotted points of two samples fall in the C1S1, two in the C3S2 and one in the C3S4 zones in salinity diagram. Medium alkali (S2) water will present an appreciable sodium hazard in fine texture soils having high cations exchange capacity especially under low leaching condition. This water can be used on coarse or organic soils with good permeability. Very high alkali (S4) water generally is not suitable for irrigation.

Percent sodium (Na %) is widely used for evaluation the suitability of water quality for irrigation (Wilcox, 1955). High percentage of Na^+ with respect to (Ca^{2+}, Mg^{2+}, Na^+) in irrigation water, causes deflocculating and impairing of soil permeability (Singh et al., 2008). The Indian Standard (BIS, 1991) recommends maximum sodium percentage (%Na) of 60% for irrigation water. The percent sodium in the study area ranged from 8.2 to 92.5 % (average 40.2%). The plot of analytical data on the Wilcox (1955) diagram relating EC and %Na show that water samples fall in all classes. About 84% of the water samples are excellent to good, good to permissible quality, which may be used for irrigation purposes without any hazard (**Fig. 4**). About 16% water samples have high sodium percent (above 60%) and are not suitable for irrigation purposes.

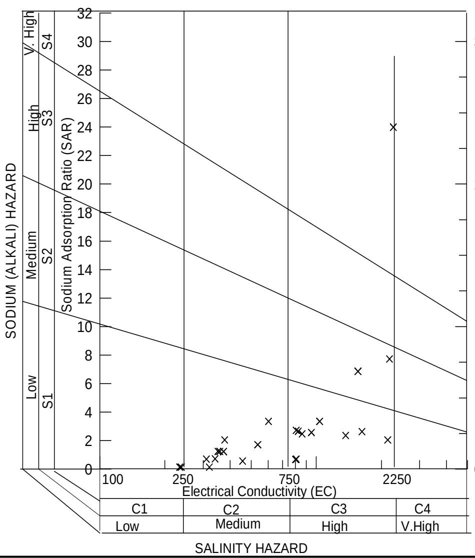

Figure 3. US salinity diagram for classification of irrigation water (USSL 1954)

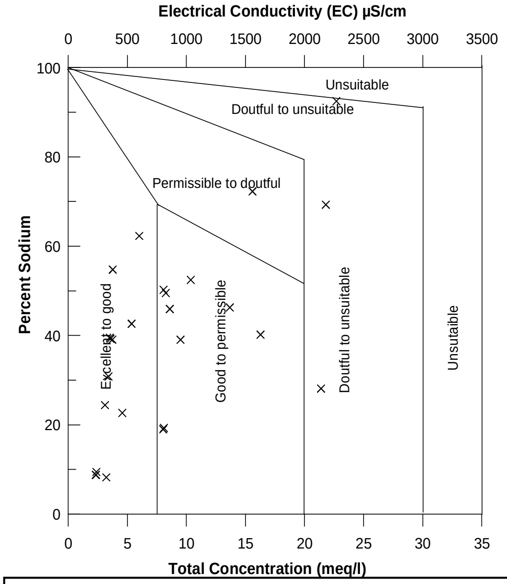

Figure 4: Wilcox diagram relating Electrical Conductivity and Sodium Percentage

The quantity of HCO_3^- and CO_3^- in excess of alkaline earths (Ca^{2+}+Mg^{2+}) expressed as residual sodium carbonate (RSC) also influences the suitability of water for irrigation (Eaton, 1950; Richards, 1954). The anions HCO_3^- and CO_3^- in the irrigation water tend to precipitation calcium and magnesium ions in the soil resulting in increase in the proportion of the sodium ions (Karanth, 1989). RSC was considered to be indicative of sodicity hazard in water. Irrigation water having RSC value >5 meq l^{-1} is considered as harmful to growth of plant, while water with RSC value above 2.5 meq l^{-1} are not considered suitable for irrigation. In most of analyzed surface water samples (64%), RSC values were below 2.5 meq $l^{-1}$and water is found suitable for irrigation uses. However, RSC values are higher than the 2.5 and 5.0 meq l^{-1} respectively in 16% and 20% of the analyzed surface water samples, suggesting marginally suitable to unsuitable for irrigation purpose.

Soil permeability is affected by long-term use of water rich in Na^+, Ca^{2+}, Mg^{2+}, and HCO_3. Doneen (1964) classified irrigation water in three PI classes. Class-I and Class-II water types are suitable for irrigation with 75% or more of maximum permeability, while Class-III type of water, with 25% of maximum permeability, are unsuitable for irrigation. Plotting the data on Donnen's chart indicate that the 40% percent of the water samples fall in Class–I and 56% in Class-II in the Doneen's chart implying that the water is of good quality for irrigation purposes with 75% or more of maximum permeability (Domenico and Schwartz, 1990). However, only one surface water sample belongs to Class-III, i.e. unsuitable category (**Fig. 5**).

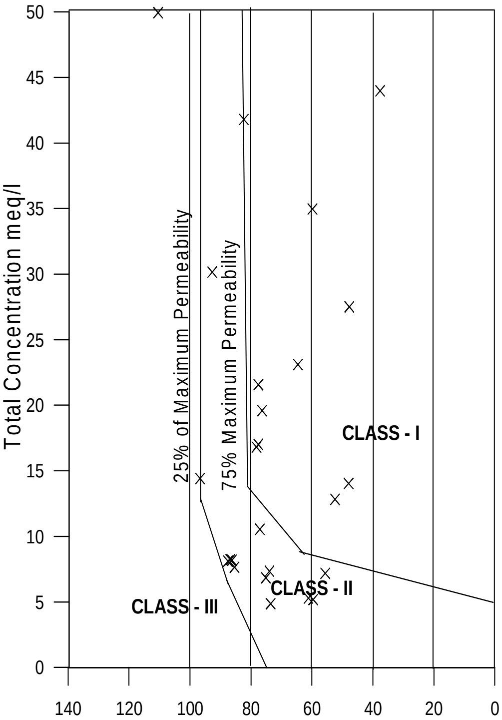

Figure 5: Doneen classification of water for irrigation uses on the basis of Permeability Index

CONCLUSION

The chemistry of the surface water is dominant by HCO_3^- and Cl^- in anionic and Na^+ and Ca^{2+} in the cationic composition. The surface water of this area is very much affected by various natural and anthropogenic sources. The source of these may be the agricultural wastes and domestic sewage disposals. The quality assessment of water for irrigation uses show that only 48% of the surface water can be used in irrigation without any treatment, considering all the calculated parameters like salinity hazard, sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and permeability index (PI). However, the water can be used for irrigation after proper implementation of the water and soil management plan in the study area.

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A STUDY OF IMPACT OF CLIMATE CHANGE ON WATER RESOURCES: -A REVIEW

Ram Kishor Singh & Anil Kumar#
National Institute of Foundry & Forge Technology, Hatia, Ranchi- 834003
Email: singhramkishor@gmail.com
#corresponding address: akiitk_70@rediffmail.com

ABSTRACT

Climate change is a big environmental challenge which has a great impact on global water resources. Observational records and climate projections provide enough evidence that freshwater resources are vulnerable to climate change and its consequences for human societies and ecosystems. Due to the changing world climate now became a global challenge for planning a long- term water system and its management. Extensive studies required and established a relation on hydrology and water resources which include plan management, operation management, environmental protection & ecological balance. It has a close relationship with industry, agriculture, city development and economic fields. Irrigated agriculture was affected to impacts of climate change which leads to the temperature and precipitation changes. This paper deals the impact of climate change on the strategies of water resources and hydrological phenomena.

Key words: Climate change, Water resources, Hydrology, Ecosystem

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QUALITY ASSESSMENT OF GROUND WATER IN DOMESTIC USE IN THE CITIES OF MIZORAM

Laltlankima[1], Shiva Kumar[1*], K.B. Singh[2], D.Chandrasekharam[3]
[1]Department of Geology, Mizoram University, Aizawl- 796001
[2]Department of Chemistry, Govt. Zirtiri Residential Science College, Aizawl- 796001
[3]Deparment of Earth Science, IIT Mumbai- 440076

ABSTRACT

Mizoram is one of the seven sister states in the north-eastern region of India. It is hilly state yet is one of the most urbanized states in the Country. The supply of potable water is mainly maintained by the Public Health Engineering Department (PHED) of Government of Mizoram. The Department sets different water projects to meet the requirements of potable water of the people but due to fast growth rate and urbanization the supply always fail to meet the demand. Therefore, the people are bound to depend on the alternative sources of potable water *i.e.* tuikhurs, which is artificially fabricated small pits to collect seepage water and hand pumps, which are very limited in number. Therefore, the use of tuikhurs as an alternative source of potable water is the common practice in the state as a whole.

The quality assessment of this water seems to be mandatory as people are using it without any treatment whereas the supply water through PHED undergoes some treatments before distribution.

The aim of the work is to assess the quality of potable water of three district headquarters of Mizoram, they are Aizawl, the capital city, Saiha, situated at the southernmost tip of the state and Champhai, the city at the eastern boundary of the state and to compare the quality of such water by physic-chemical and bacteriological analyses. Various field surveys were conducted in pre-monsoon season of 2011 in Aizawl, Champhai and Saiha towns and samples from different sources were collected. Physico-chemical tests performed were pH, EC, TDS, Turbidity, Total alkalinity, Total Hardness, Total Iron and Fluoride. Most Probable Number (MPN) of total coliform and faecal coliform are also measured. Further some of the water samples were also tested on ICP-AES for elements present in traces. pH, TDS and EC were measured by Pen type digital instruments(Eutech Instruments), total hardness was measured by Water Testing Kit (Transchem AgritechLtd.) and arsenic concentration was determined in-situ using an arsenic kit (Merckoquant Chemicals, Germany).

Most of tuikhur water is found to be good as per WHO and ISI standard, however, Champhai samples are found to be more alkaline than the other two cities and fluoride contents are consistently on lower side. The metals viz. Na, K, Mg, Ca are well within the recommended range mentioned by the WHO and ISI while AS, Fe, Mn are below detection limit (BLD). The phenomenon of adsorption seems to be responsible for the lower contents of metal in the water samples. Ca contents are higher than Mg in all the samples for which these tests were performed. The dominance of shale in Bhuban Formation is mostly observed and therefore most of aquifers are also argillaceous in composition. Potassium is slightly higher than the sodium contents in some samples suggesting the argillaceous composition of

aquifers, on the contrary, the higher Na content is suggestive of the sandy nature of the aquifers. The phenomenon of adsorption seems to be responsible for lower contents of metals and heavy metals.

GEOPHYSICAL EXPRESSION OF NATURAL RECHARGE IN DIVERSIFIED GEOLOGICAL TERRAINS

Upendra K. Singh
Department of Applied Geophysics, Indian School of Mines, Dhanbad-826 004, India
Correspondence: upendra_bhu1@rediffmail.com
Phone: +91-326-2235606, Fax: +91-326-2296563

ABSTRACT

Behavior of the Dar-Zarrouk (DR) parameters i.e. longitudinal conductance, transverse resistance, longitudinal resistivity, and transverse resistivity has been compared with the behavior of the natural recharge in two diversified geological terrains. Patterns of the geophysical parameters and those of natural recharge have been analyzed and a qualitative relation in their behavior was recognized. Graphical comparison of the geophysical and hydrogeological parameters clearly illustrates a qualitative relationship between the two parameters. Use of such qualitative relation in the field of ground water exploration and management studies is explained. A modest beginning is attempted to arrive at a quantitative relation between natural recharge and DR parameters.

ARSENIC IN THE CENTRAL GANGETIC PLAIN REGIONS OF INDIA

AL Ramanathan [1], Manoj Kumar[1], Parijat Tripathi [1], Alok Kumar [1], Pankaj Kumar [2], Prosun Bhattacharya[3] and Manish Kumar[4]
1.School of Environmental Sciences, JNU, New Delhi, India
2. University of Tsukuba, Japan
3. KTH-, Royal Institute of Technology, Stockholm, SWEDEN Tejpur University, Assam , India
4. University of Tejpiur Assaom

ABSTRACT

Arsenic in groundwater is a major public health issue affecting over millions rural inhabitants across Indian subcontinent. They rely on shallow groundwater sources as their main source of drinking water for rural population. Groundwater from these areas contain few tens of time higher value prescribed for the World Health Organization's guideline value for arsenic in drinking water .Alluvial aquifers rich in Arsenic is an environmental and human health issue . Arsenic in the Gangetic plain have been slowly poisoned the groundwater used for drinking and agriculture. Arsenic concentration in the region varies from below detection limit up to as high as 200-250µg/L. The As was very high near the river basin. The concentration of As near an inland lake was also very high. Concentration of As were found to be moderate to low in the interior flood plains between these two basins. The groundwater shows that intermediate and deeper aquifers have more As compared to As in Shallow aquifers. It is observed that As concentration in ground water is comparatively higher than the surface water .As concentrations is also very low in some locations. The sulphate concentration in groundwater was low as compared to surface water. These aquifers are at risk, due to geochemical changes happening there in which oxidized and reduced waters mix, and where the amount of sulphate available for microbial reduction seem to be limited. This study also high lights the comparison between tube well platform color and the level of As from the wells to validate platform color. We used platform colors to indicate the safe well water in As. affected regions

CONTAMINATION OF SOIL AND WATER BY NATURAL HEAVY METALS ORIGINATING FROM ULTRAMAFIC ROCKS (SERPENTINE SOIL)

Adarsh Kumar* and S.K. Maiti
Indian School of Mines
Department of Environmental Science and Engineering
Centre of Mining Environment, Dhanbad-826001(Jharkhand)

ABSTRACT

Heavy metals originating from the ultramafic rocks (serpentine soil) is the natural source of contamination for the soil and ground water. The elevated level of chromium and nickel resulting from the serpentine soil is the major area of concern. Chromium exists in nature in trivalent and hexavalent form but Cr (VI) is 50-100 times more carcinogenic than Cr (III). The elevated level of Manganese oxide oxidises the Cr (III) to Cr (VI) whereas Cr (VI) is reduced to Cr (III) by organic matter, Fe (II) and sulphites. Chromium varies from 634-125,000 mg kg^{-1} in serpentine soil and 0-117 µg L^{-1} in fresh water which is highly toxic, carcinogenic and mutagenic for human and animal health. Other heavy metals such as Co, Fe, Zn, Cu, Pb, Mn is also found in adequate amount which further enhances the toxicity of the soil, surface water and ground water.

The low porosity and water holding capacity of such soil is the major source of leaching of heavy metals which further contaminate the ground water. The serpentine soil is nutrient deficient and exhibit low level of nitrogen, phosphorus, potassium and Ca/Mg ratio. Furthermore, high level of heavy metals makes the area more unfavourable for the plant growth. It is difficult to identify the critical level of toxic elements, but Ni and Cr above 50-100 ppm is toxic and detrimental for the plant growth. It is found that; plant uptake of chromium is less than nickel. As some of the naturally occurring endemic grasses and plants can accumulate a high level of heavy metals in their roots, leaves and stem, these hyper accumulating plants is used for phytoremediation and phytomining purpose.

An overview of this literature review discussing about the concentration of the heavy metals present and leaching out from the serpentine soil, mobility and possible remediation techniques is presented in this paper.

Keywords: Serpentine soil, Ground water, Heavy metals, Chromium and Nickel.

IMPACT ASSESSMENT OF GROUND WATER QUALITY STATUS USING WATER QUALITY INDEX METHOD OF COAL MINING AREA.

Arabinda Behera*, Gaurav Jatav* and Dr. Vipin Kumar**
Department of Environmental Science & Engineering
Indian School of Mines,
Dhanbad - 826 004, Jharkhand, India
E-mail:arabindabehera3@gmail.com, gauravmaxim@gmail.com

ABSTRACT

More than 90% of the rural people use ground water for domestic and drinking purposes. As quality of drinking water is directly related to public health, an attempt has been made to understand the ground water quality by using water quality index (WQI). WQI a technique of rating water quality is an effective tool to assess spatial changes in ground water quality. Water samples were collected from open and tube wells during post-monsoon season surrounding of Jharia coal mines (Block I) and analysed for various water quality parameters by adopting APHA standard methods. The open and tube wells from which the samples were collected are extensively used for drinking water purpose. So, Indian Standards for drinking water IS-10500 was used for the development of WQI. The values of WQI have been mainly affected by the concentration of hardness and sulphates. Some the heavy metals like iron, manganese, zinc and lead are the cause of concern as they were found to be beyond the limits.

Key words: Ground water, spatial variation, WQI.

INTEGRATED GEOPHYSICAL APPROACH FOR GROUND WATER EXPLORATION

Upendra K. Singh*, S. B. Singh
Department of Applied Geophysics, Indian School of Mines, Dhanbad-826 004, India National Geophysical Research Institute, Uppal Road, Hyderabad-500 606, India
Correspondence: upendra_bhu1@rediffmail.com
Phone: +91-326-2235606, Fax: +91-326-2296563

ABSTRACT
Delineation of ground water resources in hard rock terrains is one of the important topics to be treated with a more advanced approach than simple one-dimensional attitude, particularly when looking for deeper water saturated horizons. The present study introduces an integrated geophysical approach to identify structural features such as fractures, weak zone and intrusive bodies that can control and host potable ground water at greater depths. The study is conducted in an area of about 8 km2 along east cost of Tamil Nadu, which has been identifies as a major rain shadow zone. Geophysical measurements (resistivity, magnetic and electromagnetic techniques) were carried out in very close grid pattern. The sensitivity of each technique to different rock properties has been considered to resolve the problem. A major weak zone running in SW-NE direction is demarcated that is characterized by many intrusive dyke bodies. The conductivity distributions at different depth throw light on many structural features. The varying thickness of weathered rock calculated from the horizontal loop electromagnetic and deep resistivity sounding (DRS) for entire area reflects the extension of weathering associated with dyke implements geo-electric section obtained through DRS studies concentrated mainly along the week zone have shown in the occurrence potable ground water resource.

REMEDIATION OF HEXAVALENT CHROMIUM BY HIGH CARBON IRON FILINGS

Gaurav kr. Yadav[1], Dr.Alok Sinha[2]
Department of Environmental science and Engineering
Indian School of Mines, Dhanbad 826004

ABSTRACT
Chromium compounds are used in various industries (e.g. textile dying, tanneries, metallurgy, metal electroplating and wood preserving). Large quantities of chromium are discharged into the environment due to improper disposal and lack of treatment of wastewater, from these industries. Wastewater rejected by the industries often contains chromium at concentrations above local discharge limit.

Remediation of groundwater contaminated with Cr(VI) may involve pumping the contaminated groundwater on surface and passing through a treatment chain which may include physical, chemical or biological processes like chemical precipitation, coagulation, flocculation, adsorption, reverse osmosis, activated sludge process, membrane separation processes, bioremediation etc. Conventional methods like ASP and UASB may result in high Cr(VI) in their effluent and sludge. Pump and treat methods of treatment of groundwater may prove to be costly as it involves pumping of water and then treatment and again pumping the groundwater back to subsurface. Hence the current trend is moving towards the in-situ treatment of groundwater. Use of Zero-Valent Iron (ZVI) & High Carbon Iron Filings (HCIF) as reactive medium for in-situ treatment of groundwater is one of the most promising techniques because of low cost, easy availability and ability to degrading contaminants. Zero-valent iron (Fe^0) based permeable reactive barriers (PRBs) have been recognized as a viable and cost-effective technology for *in-situ* remediation of groundwater contaminated with redox active inorganics (such as chromate, nitrate, and uranate) as well as chlorinated organic. Zero-valent iron could potentially stabilize several elements in contaminated soil, because its oxidation would cause minor changes in pH, and provide effective surfaces for sorption of both cations and anions. Hexavalent chromium Cr(VI)), which is a strong oxidant, a potential carcinogen and more mobile in soils and aquifers, is transformed to trivalent chromium (Cr(III)), which is less hazardous and less water soluble and associated with solids.

Keywords: chromium, zero- valent iron, hexavalent chromium.

ASSESSMENT OF GROUND WATER QUALITY STATUS BY USING WATER QUALITY INDEX METHOD IN AND AROUND INDIAN SCHOOL OF MINES, DHANBAD, JHARKHAND, INDIA

Arun Kumar, Ravi Makawana and Prasoon Kumar Singh
Department of ESE, Indian School of Mines, Dhanbad, Jharkhand, India
Email: pks0506@yahoo.co.in, ismarunkumar@gmail.com

ABSTRACT

Groundwater quality assessment is important to ensure sustainable safe use of water. However describing the overall water quality in and around Indian School of Mines is difficult due to the spatial variability of multiple contaminants and wide range of indicators that could be measured. The study was carried out by collecting fifteen ground water samples (open wells and bore wells) during monsoon, post monsoon and winter season. The present investigation and objective of this study was focused on the determination of physicochemical parameters, and to examine the quality of ground water and its suitability for domestic purposes by using water quality index (WQI). WQI, a technique of rating water quality, is an effective tool to assess spatial and temporal changes in ground water quality. The sampling sites showed physicochemical parameters within the water quality standards and quality of water is good & fit for drinking purpose. From the Water Quality Index it is inferred that despite the mining and heavy industry, the quality of water is predominantly good to excellent.

Keywords: Ground Water, Seasonal Variation, Water Quality Index.

AN EXACT SOLUTION OF PLANE MAGNETOHYDRODYNAMIC VISCOUS FLUID FLOW THROUGH POROUS MEDIA

Dr. Manoj Kumar
Department of Physics, J.N.College
Ranchi-4, Jharkhand, India
E-mail: profmanoj@rediffmail.com

ABSTRACT

The geometric theory in the studies of flow machinery furnishes the possible information of flow field and structures in general, simplifying the mathematical complexities to a greater extent. In recent years, the flow of fluid through porous media has become an important topic because of recovery of crude oil from the pores of reservoir rocks. In this case, Darcy's law represents the gross effect. Meanwhile, there has been a renewed interest in studying magnetohydrodynamic (MHD) flow and heat transfer in porous media because of the effect of magnetic fields on the performance of many systems.

In present paper plane steady MHD flow of viscous incompressible fluid with infinite electrical conductivity through porous media has been considered. Governing equations for the flow are:

$\operatorname{div} \mathbf{V} = 0$

$$\rho[(\mathbf{V}.\operatorname{grad}\mathbf{V})\mathbf{V}] = -\operatorname{grad} p + \eta\nabla^2\mathbf{V} + \mu\mathbf{J}\times\mathbf{H} - \frac{\eta}{k}\mathbf{V}$$

$$\operatorname{curl}(\mathbf{V}\times\mathbf{H}) = \mathbf{0} \text{ and } \operatorname{div}\mathbf{H} = 0$$

where,

$\mathbf{V}$= velocity vector, $\mathbf{H}$= magnetic field vector, $\mathbf{J}$ = curl $\mathbf{H}$= current density vector,
p = fluid pressure, ρ = fluid density, η = coefficient of viscosity,
μ = magnetic permeability, k = permeability of medium.

A new system of flow equations has been obtained in the case of constantly inclined magnetic field. A system of orthogonal curvilinear coordinates in the plane of flow has been taken. Lastly, the solutions have been obtained when the streamlines and their orthogonal trajectories generate isometric net.

AN INTRODUCTORY APPROACH TO GROUND WATER CONTAMINATION IN INDIA.

Pratibha Gautam
Department of Environmental Science & Engineering
Indian School of Mines, Dhanbad - 826 004, Jharkhand
E-mail:gautampratibha.19@gmail.com

ABSTRACT

Everything existing on this earth needs water. As the population over this world is increasing day by day, the demand for clean water for drinking, industrial and agricultural purpose is also increasing exponentially. Ground water is assumed as the most reliable source of water to fulfil this increased requirement of clean water for various purposes. Ground water is the only natural resource which is found at every part of this earth though its availability varies at each place depending on many factors like rainfall and geological formation (distribution of aquifers).

In natural form ground water is generally found more pure than surface water but due to urbanization the quality of ground water is degrading these days which is a matter of serious concern. There are a number of physical and chemical processes by which contaminates are getting in to the ground water and making it unfit for human consumption and other purposes. Human activities are mainly responsible for this ground water contamination. In India Salinity, Nitrate, Arsenic, Fluoride and Iron are recognized as the major contaminants of ground water. Many studies have revealed that ground water contamination is reaching to an alarming situation in various parts of India and creating health problems. Therefore to protect the environment and for maintaining human uses of groundwater especially for ensuring safe drinking water it is important to regulate the groundwater quality and protect it from contamination.

So this topic has been chosen for the study so that mechanism and possible sources of ground water contamination can be understood. Status of ground water contamination in India and major contaminant of ground water sources are also described in this paper as per the Indian scenario.

Key words: Ground water, contamination, aquifer.

CHANGE DETECTION STUDY OF LAND USE PATTERNS OF JHARIA COALFIELD REGION, JHARKHAND

Ravi Makawana, Arun Kumar .V and Prasoon Kumar Singh
Department of Environmental Science & Engineering
Indian School of Mines, Dhanbad-826004
Jharkhand, INDIA
(Email: pks0506@yahoo.co.in)

ABSTRACT

Land use/land cover change detection in the form of maps and statistical data is very vital for spatial planning, management and utilization of land. Remote Sensing and Geographic Information System (GIS) have been used in order to study land use / land cover changes.

The aim of this study is to detect land use changes between 1925 to 2008 using Topographic maps (prepared by Survey of India), Aerial photographs, satellite images of IRS LISS IV MX Satellite Imagery (2008-09).

The study has produced a land use/ land cover map of Jharia coal field at five (1925, 1974, 1987, 1993, 2004, 2008) point of time in order to detect the changes that have taken place in the agriculture area, mining area and water bodies. Land use changes have been detected by image processing method in ERDAS IMAGING 9.3, ArcGIS 9.3. Monitoring of land use/land cover changes help to plan development activities such as major schemes and for community requirements. Time period of 1925- 2008 shows some major land use changes.

Keywords: Land use, Land cover, Change Detection, ArcGIS9.3, ERDAS IMAGINE 9.3.


DEPARTMENT OF ELECTRONICS & INSTRUMENTATION
ENVIRONMENTAL SCIENCE & ENGINEERING
खनन पर्यावरण केन्द्र
CENTRE OF MINING ENVIRONMENT