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IMPACT OF INDUSTRIALIZATION ON GROUNDWATER QUALITY - A CASE STUDY OF BADDI-BAROTIWALA INDUSTRIAL BELT, DISTT. SOLAN, HIMACHAL PRADESH, INDIA

KAMALDEEP, MADHURI S. RISHI, NARESH KOCHHAR AND NIBEDITA GHOSH

Department of Environment Science, Panjab University, Chandigarh, India

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ABSTRACT

The present study endeavors to identify the groundwater contamination problems in Baddi-Barotiwala Industrial belt of District Solan, Himachal Pradesh, India. The dense unplanned industrial establishments have negatively affected the groundwater quality in the study area. Groundwater samples from 44 different locations and sources were collected and subjected to standard analytical techniques for physico-chemical analysis. The results obtained were compared with the Bureau of Indian Standards (BIS: IS: 10500, 2003) guidelines for drinking water suitability in relation to possible health hazards. From the heavy metal analysis it can be inferred that high concentrations of Fe, Cu, Pb and Mn has rendered the groundwater unsuitable for drinking purposes. The disposal of untreated effluents from various industrial units may be the source of groundwater contamination in the area of concern. It is indicative that the quality of groundwater is deteriorating with the ever increasing menace of industrialization in this solace of heavenly abode.

INTRODUCTION

Water constitutes 50-97% of the weight of all plants and animals and about 70% of the weight of human body and hence is essential for the survival of all forms of life on earth (Buchholz, 1998). Due to increasing contamination and scarcity of surface water resources, a major stress has been shifted to groundwater resources. Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). In many countries, the wastewater is released into rivers, lakes and other water bodies. This further leads to many environmental issues including eutrophication, depletion of dissolved oxygen fish mortality (Rosenberg, 1985). Therefore, the unchecked and uncontrolled disposal of wastewater into water bodies is degrading the water resources and ultimately affects the public health. Water pollution becomes a serious concern when it involves poisoning of drinking water. With increasing population and growing industrial practices, no natural resource has given rise to deeper concern than good clean water. With the advent of industrialization not only surface water but ground water has also been degraded up to a level at which it has become unsuitable for human consumption. Due to recent industrialization and ever

***Address for correspondence : Email :** kamaldeep07@gmail.com

increasing urbanization, the quality of groundwater has become a matter of major concern because of heavy metal contamination (Mance 1987; Aiyesanmi *et al.* 2004; Amajor 1986; Ezeigbo 1989; Calderon 2000; Jha *et al.* 1990; Ramesh *et al.* 2000). Contamination of water by trace metals is a serious health issue. Studies have shown that heavy metal toxicity leads to cardiovascular, neurological and renal problems (Vallee and Ulmer 1972; Jarup 2002; Packham 1996). The main health hazards caused by chemical pollution of water are due to presence of nitrates fluorides, arsenic, cadmium, lead and other toxic metals (Nemerow, 1978). There are several well known catastrophic episodes of poisoning due to some toxic trace elements in drinking water. Therefore, preventing health risks from heavy metals requires regular of water quality and identification of trace metal contamination sources.

Over exploitation and unplanned development of ground water can disturb the dynamic ecological balance and leads to depletion and salinization of aquifers (Poland, 1961). According to Hart and Stander (1972) the population explosion, increased industrialization, agricultural development and recreational activities, all lead to corresponding increase in volume of effluents and diversity of pollutants, discharged into natural environment. It is pertinent to know that the harmful chemicals released from the industries as waste products enter the life chain by polluting the different components of environment which are common natural resources of mankind (Giddings, 1973)

The industrial belt of Baddi-Barotiwala, district Solan, Himachal Pradesh was chosen as target area to assess the effects of industrial pollution on groundwater quality as this area has boomed with much unplanned industrial development in the last few decades. This will help in proper management of water resources and further help to curtail deterioration of water quality in the study area.

Description of the Study Area

Solan is one of the south-western districts of Himachal Pradesh. District Solan came into existence on 1st September, 1972. It ranks 9th among the districts of the state with an area of 1936 sq. km. (3.48% of total state area). It is known as the industrial and commercial district of Himachal Pradesh. It has attracted large industrial investment with Baddi, Barotiwala, Nalagarh and Parwanoo being home to most of the industries. District Solan lies between North Latitude 30°44′53″ to 31°22′01″ and East Longitude 76°36′10″ to 77°15′14″.The average elevation of the district ranges between 300-3000 m above mean sea level. The Baddi-Barotiwala region lies in the lap of outer Himalayas forming part of Siwaliks.

Industrial Development

The local inhabitants mainly depend on agriculture for their subsistence. Large and small scale industrial development however has taken place randomly all over the district; especially rapid industrial development is taking place in areas adjoining Punjab plains viz. at Nalagarh valley within the Nagar Panchayat of Baddi and Gram Panchayats of Barotiwala, Gulurawala, Sandholi, Thana, Bhud areas. List of important industrial units in the study area is given in Table 1.

Hydrogeology

Hydro geologically, the unconsolidated valley fill or alluvial formation occurring in the valley area; semi-consolidated formations belonging to Siwalik Group and older consolidated hard rocks, form aquifer in the district. Major parts of the district are hilly and mountainous with highly dissected and undulating terrain. These areas are underlain by semi-consolidated and consolidated hard rocks of Tertiary and Proterozoic period. Groundwater potential in such areas is very low due to its hydro geomorphic set up. In the study area, the groundwater occurs in porous unconsolidated alluvial formation comprising, sand, silt, gravel, cobbles/pebbles. Groundwater occurs both under phreatic and confined conditions. Wells and tube wells are the main groundwater abstraction structures.

Groundwater Resources

Rainfall is the major source of recharge to ground water. Other sources are seepage from the rivers, irrigated fields and inflow from upland areas. The discharge from ground water mainly takes place from wells and tube wells. The groundwater level in the valley of river Sirsa is shallow and varies on an average from 5.5 meters to 6.3 meters near the riverbed and increases towards the hills. The tributaries like Balad Nadi, Ratta Nadi remain dry except monsoon season and groundwater is the only water source for domestic, agricultural and industrial use.

MATERIALS AND METHODS

Forty four samples were collected from different locations and sources like hand pumps, tube wells and dug wells in the study area. Good quality standard sampling bottles were used for collecting the water samples. Parameters like pH, EC and TDS were determined in the field itself at time of sample collection using the portable water and soil analysis kit. Rest of the physico chemical parameters including heavy metals (Fe, Cu, Cr, Cd, Mn, Pb, Zn, Ni) were immediately determined in the laboratory following the standard procedures (APHA, 1995). The results obtained were compared with the Bureau of Indian Standards (BIS: IS: 10500, 2003) guidelines for drinking water suitability in relation to possible health hazards.

RESULTS AND DISCUSSION

Forty four samples from different locations and sources of groundwater were analyzed for twenty three physico chemical parameters including eight heavy metals. The tabulated form of results for physicochemical analysis and critical water quality parameters along with their permissible limits (BIS: IS: 10500, 2003) are given in Table 1 and 2.

pH: The pH in the samples studied ranged between 7.3 and 8.8. This shows the water is slightly alkaline in nature and is well within the prescribed limits of 6.5 and 8.5.

Alkalinity : Alkalinity due to CO_3 is present in 22% of the samples tested with 24mg/L as the minimum value and 108mg/L as the maximum value observed. HCO_3 is present in all the samples showing the minimum value of 110mg/L and maximum value of 1123mg/L. The alkalinity at two locations has crossed the permissible limit of 600mg/L (BIS, 2003). This can impart unpleasant taste to water and can be deleterious to humans in presence of high pH, hardness and TDS.

Iron: Twenty seven percent of water samples tested crossed the desirable limit of 0.3mg/L as prescribed by BIS (2003), rendering these samples unsuitable for drinking water purposes (Fig. 1). Iron in traces is essential for nutrition. However, while chronically consuming large amounts of iron can lead to a condition known as iron overload; this condition is usually the result of a gene mutation. Left untreated, iron overload can lead to hemochromatosis, a severe disease that can damage the body's organs. Early symptoms include fatigue, weight loss and joint pain, but if hemochromatosis is not treated, it can lead to heart disease, liver problems and diabetes.

Lead: Lead concentration exceeds the permissible limit of 0.05mg/L in 5% samples (Fig 2). Lead toxicity can cause burning in mouth, severe inflammation of gastrointestinal tract with vomiting and diarrhea, chronic paralysis, mental confusion and anemia.

Copper: Water sample from six locations i.e. 13% of total samples (Fig. 3) have been found non potable due to high concentrations of copper. High concentrations of copper in drinking water can cause liver damage, irritation of central nervous system and depression.

Manganese : Manganese is found above desirable limit in 18% samples (Fig. 4). Excess of manganese in drinking water supplies causes change in appetite and reduction in metabolism of iron to form hemoglobin.

Inter Relationship between Various Chemical Parameters

Study of inter relationship between various chemical

Table 1. Number of Industrial Units in the Study Area

Area	No. of industries under Water Act, 1974 (as on 15.09.2007)	No. of industries with ETP's	Industries without ETP's	Main types of industries
Baddi- Barotiwala	985	173 (43 under installa-ation making total 216)	769	Textile, dyeing, pharma, chemicals formulation, pulp & paper, pesticides
Nalagarh	667	124 (61 under installa-tion making total 185)	482	Textile dyeing, pharma, chemicals formulation, distillery & engineering
Total	1652	401	1251	

(Source: Baddi Barotiwala Nalagarh Development Authority, 2007)

Table 1.

Parameter	Min. Value	Max. Value	Desirable limit	Permissible Limit
pH	7.30	8.8	6.5	8.5
CO3	24 (mg/L)	108(mg/L)	-	-
HCO3	110(mg/L)	1123(mg/L)	-	-
Cl	7.1(mg/L)	184(mg/L)	250(mg/L)	1000(mg/L)
SO4	6(mg/L)	265(mg/L)	200(mg/L)	400(mg/L)
NO3	0.62(mg/L)	48(mg/L)	45(mg/L)	No Relaxation
F	0.03(mg/L)	10(mg/L)	1.0(mg/L)	1.5(mg/L)
Ca	10(mg/L)	142(mg/L)	75(mg/L)	200(mg/L)
Mg	1.2(mg/L)	49(mg/L)	30(mg/L)	100(mg/L)
TH	45(mg/L)	370(mg/L)	300(mg/L)	600(mg/L)
Na	15(mg/L)	640(mg/L)	-	-
K	1.6(mg/L)	49(mg/L)	-	-
Fe	0.04(mg/L)	2.87(mg/L)	0.30(mg/L)	1.0(mg/L)
Cu	0.001(mg/L)	0.238(mg/L)	0.05(mg/L)	1.5(mg/L)
Pb	0.011(mg/L)	0.062(mg/L)	0.05(mg/L)	No Relaxation
Zn	0.020(mg/L)	6.550(mg/L)	5(mg/L)	15(mg/L)
Ni	0.015(mg/L)	0.087(mg/L)	-	-
Mn	0.003(mg/L)	16.42(mg/L)	0.10(mg/L)	0.30(mg/L)

(BIS: IS: 10500, 2003)

Table 2. Heavy Metal Analysis of Water Samples

S. No.	Parameter	BIS Permissible Limit	No. of Samples Exceeding Permissible Limit	Percentage of Samples Exceeding Permissible Limit
1	Fe	0.3 mg/L	12	27%
2	Cu	0.05mg/L	6	13%
3	Pb	0.05mg/L	2	5%
4	Mn	0.10mg/L	8	18%

species present in the water is the most important aspect of hydrochemistry. Statistical relationships like correlation between various ions present in the waters of the study area were studied using Minitab 15 version. The results of the correlation studies are discussed below.

HCO_3--Ca^{2+} and HCO_3--Mg^{2+}: The results show that there is a positive correlation of bicarbonate ions with both calcium and magnesium ions (Fig. 5).

Na^+_- Cl^-: Study of statistical relationship between Na+-Cl- depicts a strong positive correlation between the two (Fig. 6). The sodium ions predominates the chloride ions in the groundwater of the study area. This indicates that there are some additional sources of sodium ions apart from the common sources.

Ca_2^+-Mg^{2+}: A negative correlation between calcium and magnesium ions is indicated in the groundwater. Magnesium ions are strongly dominated by calcium ions (Fig. 7).

Fe-Pb and Fe-Zn : There is a positive correlation of iron with lead and zinc ions i.e. iron is the dominant species over lead & zinc and the concentration of zinc and lead ions increases with the increase in the concentration of iron ions in the water samples (Fig. 8).

CONCLUSIONS AND RECOMMENDATIONS

The findings from the chemical analysis indicate that the groundwater is alarmingly getting contaminated by heavy metals due to industrialization in the study area. The groundwater samples collected from the vicinity of various industrial units show high concentrations of one or more heavy metals. This can be directly responsible for the ill health of the people residing there. In order to improve the quality of groundwater and to check its further deterioration due to heavy metal contamination in the study area, it is essential to strictly initiate potential measures to check the pollution caused by untreated industrial effluents.

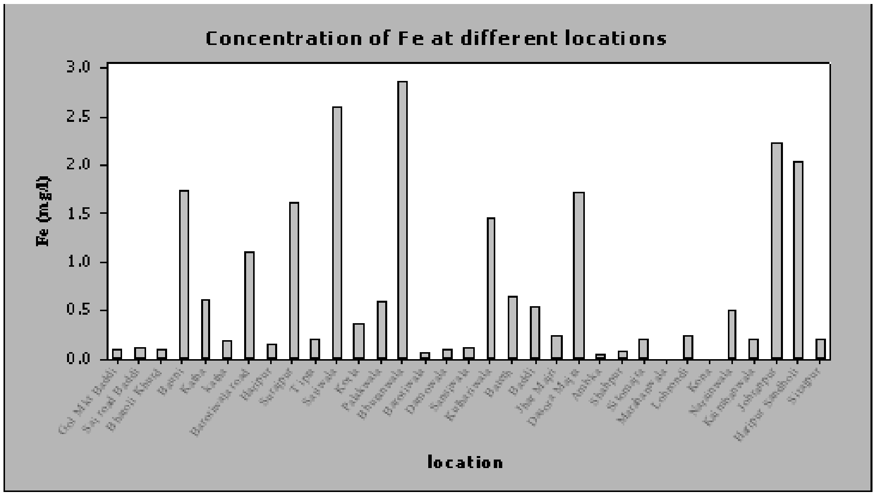

Fig. 1 Concentration of Fe in water samples at different locations

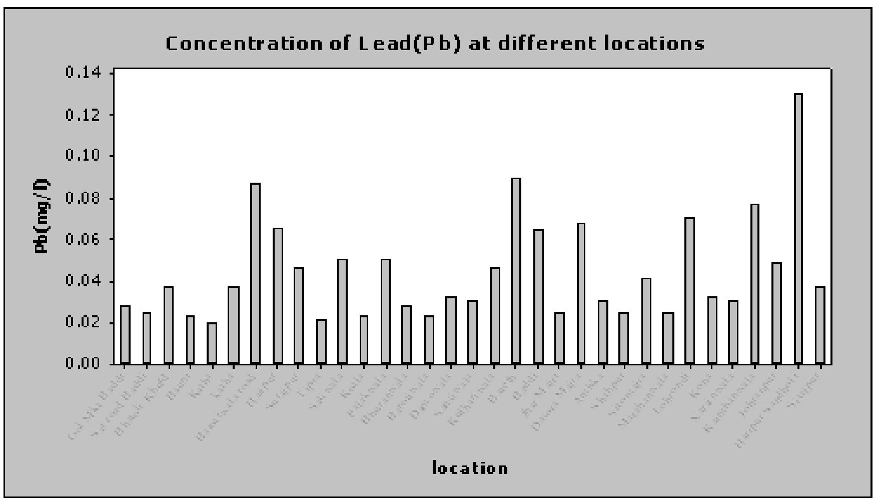

Fig. 2 Concentration of Pb in water samples at different locations

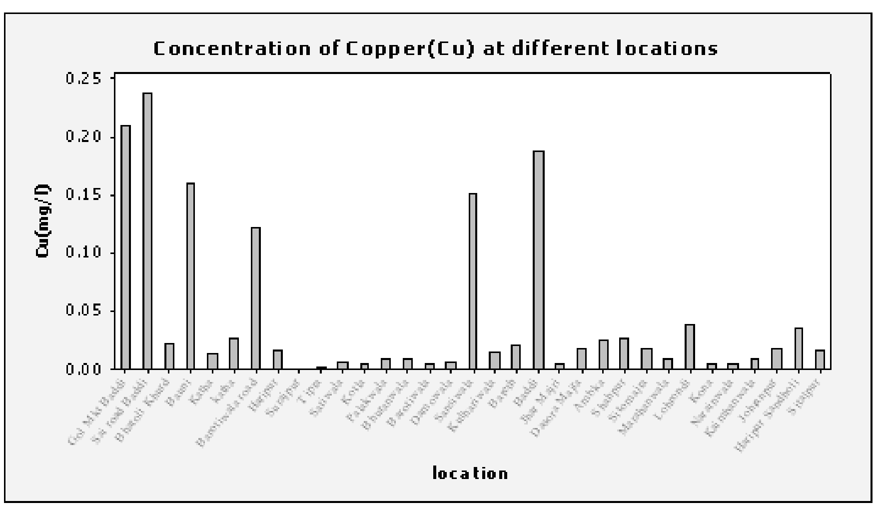

Fig. 3 Concentration of Cu in water samples at different locations

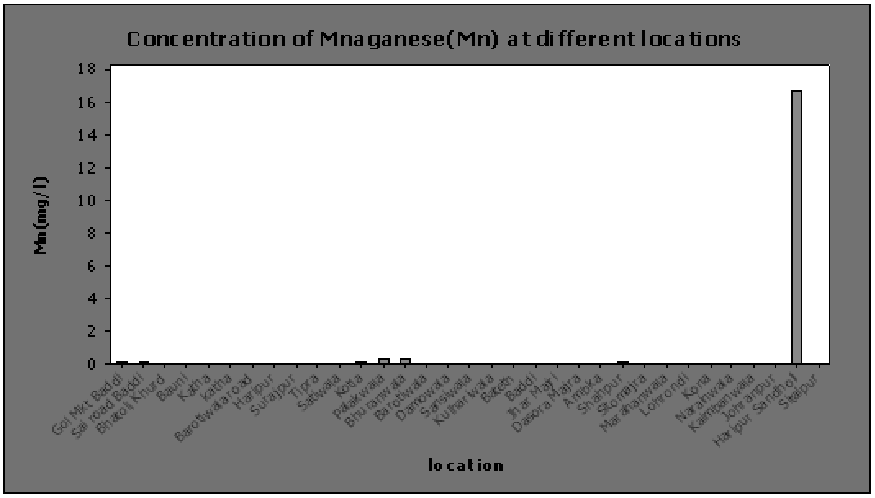

Fig. 4 Concentration of Mn in water samples at different locations

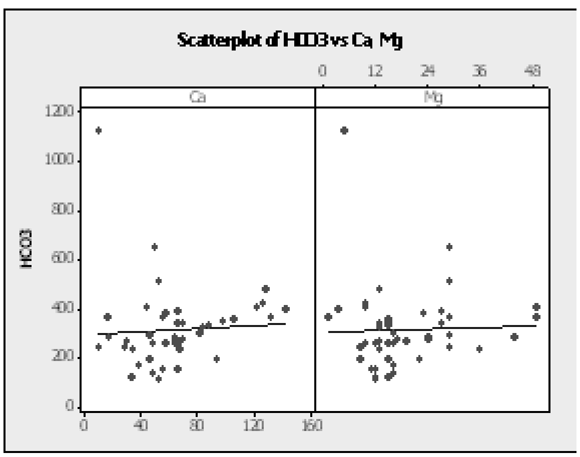

Fig. 5 Correlation of HCO_3 with Ca and Mg

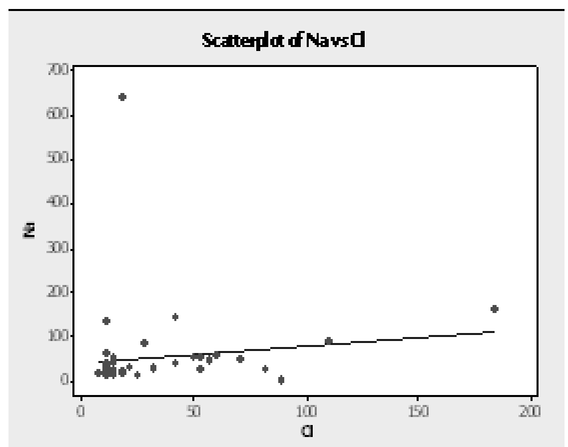

Fig. 6 Correlation of Na with Cl

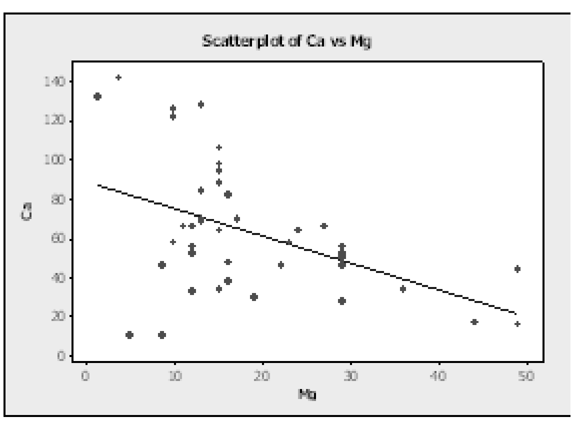

Fig. 7 Correlation of Ca with Mg

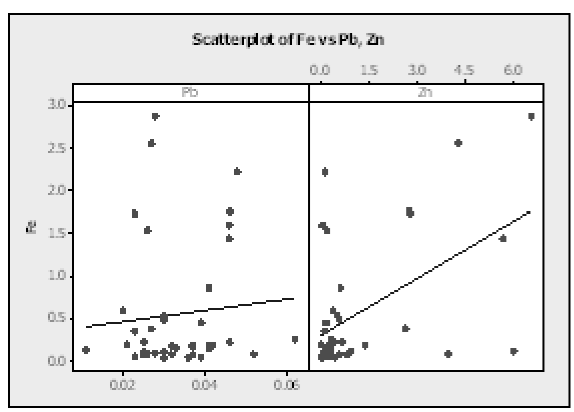

Fig. 8 Correlation of Fe with Pb and Zn

Regular groundwater quality monitoring is also essential to keep a check on the quality of water by establishing various observation wells in the study area. Common water treatment plants are recommended in the area to provide potable drinking water supplies to the local population.

REFERENCES

Aiyesanmi, A.F., Ipinmoroti, K.O. and Adeeyinwo, C.E. 2004. Baseline geochemical characteristics of groundwater within Okitipupa South-East belt of the bituminous sands field of Nigeria. *International Journal of Environmental Studies.* 61 : 49–57.

Amajor, L.I. 1986. Geochemical characteristics of groundwater in Port Harcourt and environs *Proc. NIWASA Symposium. Ikeja, Lagos.* 366-374.

American Public Health Association, 1995. *Standard Methods for Examination of Water and Waste Water*, 18th Edition, APHA, Washington, D.C., USA.

Anonymous 2007. Report by Baddi-Barotiwala Nalagarh Development Authority.

Barman, S. C., Sahu, R. K., Bhargava, S. K. and Chatterjee, C. 2000. Distribution of heavy metals in wheat, mustard and grown in the field irrigated with industrial effluent. *Bulletin of Environmental Contamination and Toxicology.* 64 : 489-496.

Buchholz, R.A. 1998. Principles of Environmental Management. *The Greening of Business*, 2_{nd}. Prentice- Hall, London, UK.

Bureau of Indian Standards (BIS). 2003. Indian standards, specification for drinking water, fifth reprint, Manak Bhawan, New Delhi. p-9

Calderon, R.L. 2000. The epidemiology of chemical contaminants of drinking water. *Food and Chemical Toxicology.* 38 : 13-20.

Central Pollution Control Board, HPSPCB. 1997. Zoning atlas for siting of industries (based on environmental considerations) - Solan District (Himachal Pradesh). EMAPS/5/1997-98. Environmental planning and mapping series. Delhi and Shimla.

Ezeigbo, H.I. 1989. Geological and hydrological influences on the Nigeria environment. *Water Resources.* 1 : 37 - 44.

Fakayode, S.O. 2005. Impact of industrial effluents on water quality of the receiving Alaro River in Ibadan, Nigeria. *Ajeam-Ragee.* (10) :1-13.

Giddings, C.J. 1973. *Chemistry, Man and Environment Changes*. Canfield press, San Francisco, 472.

Hart, O.O. and Stander, G.J. 1972. The effective utilization of physico-chemically treated effluents. *Prog. Water Technology*. 95-102.

Jarup, L. 2002. Cadmium overload and toxicity. *Nephrology Dialysis Transplantation.* 17 (Suppl. 2) : 35-39.

Jha, P. K., Subramanian, V., Sitasawad, R., and Van Grieken, R. 1990. Heavy metals in water and sediments of the Yamuna River (a tributary of the Ganga). *Science of the Total Environment.* 95 : 7-27.

Karanth, K.R. 1987. *Groundwater Assessment Development and Management*. Tata McGraw Hill Ltd, New Delhi. pp 77-89.

Mance, G. 1987. *Pollution Threats of Heavy Metals In Aquatic Environment*. London: Elsevier.

Mukherjee, S. and Nelliyat, P. 2006. Groundwater pollution and emerging environmental challenges of industrial effluents irrigation: A case study of Mettupalayam Taluk, Tamilnadu. pp 34-37.

Nemerow, N.L.1978. *Industrial Water Pollution Origins, Characteristics and Treatment*. Addison- Wesley Publishing Company, 738.

Packham, R.F. 1996. *Drinking water Quality and Health.* UK: The Royal Society of Chemistry. 52–65

Ramesh, R., Ramanathan, A. L., Ramesh, S., Purvaja, R. and Subramanian, V. 2000. Distribution of rare earth elements in the surficial sediments of the Himalaya river system. *Geochemical Journal.* 34 : 295–319.

Rosenberg, R. 1985. Eutrophication-the future marine coastal nuisance. *Marine Pollution Bulletin.* 16 (6) : pp 227-231

Vallee, B. and Ulmer, D.O. 1972. Biochemical effects of mercury, cadmium and lead. *Annual Review of Biochemistry.* 41 :91-128.