International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 13 (2018) pp. 11062-11068

Seasonal Variation of Iron in Underground Drinking Water Sources in and around Moradabad City, Uttar Pradesh, India

Navneet Kumar[1] and D.K.Sinha[2]

[1]Assistant Professor, Department of Chemistry, Teerthanker Mahaveer University, Moradabad, India.
[2]Associate Professor, Department of Chemistry, K.G.K. (P.G.) College, Moradabad, India.

Abstract

Water containing high level of Iron causes staining of clothes and sanitary wares and imparts bitter astringent taste. Taste and odour problems may be caused by filamentous organisms that prey on iron compounds. It is a known fact that Iron in trace amount is essential for nutrition. Twenty samples of underground drinking water from IM2 hand pumps in and around Moradabad city were collected for comparative study and monitoring in the three major seasons of the year namely winter season, summer season and monsoon season. Highest concentrations of iron are reported during summer season and a slightly lower concentration is reported during winter season. Underground drinking water quality with reference to its iron concentration is improved remarkably after the onset of monsoon, however, it is still higher than the recommended standard. Underground drinking water quality management in this reference is the need hour in the area of study.

Keywords: Concentration of iron, drinking water, underground, season.

INTRODUCTION

Iron (Fe) is the second most abundant metallic element in the earth's crust. It exists in water either as ferrous or ferric state, suspended or dissolved. Under reducing conditions, iron occurs in the ferrous state and on exposure to air, ferrous ion is oxidized to ferric state. Iron gives a metallic taste to water causes yellowish red to brown stains on laundry, dishes and plumbing fixtures. In addition, it can clog pumps, sprinkles and other devices (UNEP 1999, Neyaz 2014, Sharma 2017). As per BIS (1991) the desirable and permissible limits of iron in drinking water are 0.3 mg/L and 1.0 mg/L respectively. Beyond 1.0 mg/L taste and appearance of water are affected and it promoted growth of iron bacteria. These bacteria also cause unpleasant odour and taste. Therefore, it is customary that drinking water is always checked for iron content. Routine water quality studies have incorporated estimation of iron as one of the essential parameters (CPCB 2002, Davies 1994, Akanksha 2014, Quarcoo 2015, Kanungo 2017).

Tropical fluvial environment is unique for the strong geochemical fractionation, elemental partitioning and quantitative transportation resulting from its climatic characteristics controlled by heavy seasonal rainfall with long periods of drought and high ambient temperatures (Singh, Munendra 2010, UNESCO 1995). The hydro-geochemical study of this environment can be easily linked with human health aspects that support the development and progress of a newly emerging branch of Earth System Science known as Medical Geology (Deer 1966). A high quality database of a wide range of investigations from the geosphere and biosphere is pertinent and should be, therefore, considered as an essential component of environmental knowledge (Dissanayake and Chandrajith 1999, Ababu 2014, Ghatak 2017).

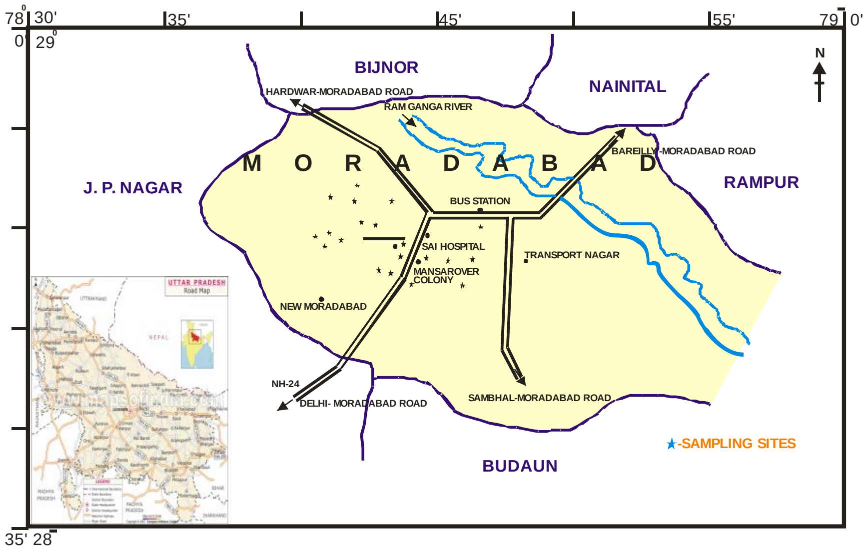

Figure 1: A detailed map of Moradabad district with sampling sites

Iron usually exists in natural water both in ferric and ferrous forms. The form of Iron, however, may be altered as a result of oxidation or reduction or due to the growth of bacteria in the sample during storage (ISI 1983). Usually, the ferric form is predominant in most of the natural waters. Iron in the water may be either in true solution, or in colloidal state or in the form of relatively coarse suspended particles (Grosbois 2007, Prasannakumari 2014, Ahmed 2017). Water containing high level of Iron causes staining of clothes and sanitary wares and imparts bitter astringent taste. Taste and odour problems may be caused by filamentous organisms that prey on iron compounds. It is a known fact that Iron in trace amount is essential for nutrition (Karanth 1997, Lenvik 1978, Faisal 2015, Shinde 2017).

Moradabad is a B class city of western Uttar Pradesh having urban population more than 40 lakhs as per 2001 census. It is extended from Himalaya in north to Chambal river in south. District Bijnor and Nainital are in the north, Rampur in the east, Ganga river in the west and district Budaun is in the north of district Moradabad. Moradabad has seen rapid industrialization and population growth during the last few decades. The major industries are brassware, steelware, paper mills, sugar mills, crushers, dye factories and a number of associated ancillaries. Most of these industries and different kinds of human activities are playing their roles in multiplying the level of water pollution.

Site Location and Climatology

Moradabad is situated at the bank of Ram Ganga river and its altitude from the sea level is about 670 feet. Its latitude and longitude at 28°20', 29°15' and 78°4', 79°E. The plain experiences a humid sub-tropical climate characterized by three prominent seasons; hot summer season (March–June) followed by the monsoon season (July–October) of heavy precipitation and then the cold winter season (November–February). Temperature variation is extreme, ranging from maximum (48^0C) in summer and minimum (3^0C) in winter. A large amount of water is lost into the atmosphere through evapo-transpiration due to less rainy days and large number of sunny days (Rao 1975). The average annual rainfall variation is between 750 and 925 mm/year.

Geology

Lithologically, the Ganga Plain is made-up of interlayered 1–2 m thick fine sand and silty mud deposits showing extensive discontinuous calcrete horizons. Singh (1996) identified two types of lithofacies association: muddy interfluve deposits and sandy interfluve deposits. Muddy interfluve deposits are made up of 0.2–1.0 m thick well sorted silt with extensive calcrete development; 1.0–2.0 m thick highly mottled fine sand deposits with 5–10 cm thick bedded calcrete and shell-bearing mud (Soman 1977, Appelo and Postma 2005, Singh 2010, Alsaffar 2016). Sandy interfluves deposits are made up of 0.5–2.0 m thick lenticular sand bodies representing meandering river deposits and 1.0– 2.0 m thick well sorted silty fine sand representing sheet flood deposits with 10–50 cm thick discontinuous horizons of calcrete (Lehr et al. 1980).

Objectives and Scope

In view of the increased interest in recent years in iron (Fe) concentrations in underground drinking water and impact to human health with reference to recommended standards prescribed by WHO and ISI (WHO 1984, ISI 1983). The present study is focused on factors determining Fe levels in the underground drinking water of IM2 hand pumps in and around Moradabad city of Uttar Pradesh and the identification of appropriate aquifer zones for iron-safe drinking water. The aim of the present work is also to suggest some useful and effective measures for iron concentration in and around Moradabad more specifically in the catchment area of study.

MATERIAL AND METHODS

Sampling

Twenty samples of underground drinking water from IM2 hand pumps in and around Moradabad city were collected for comparative study and monitoring in the three major seasons of the year namely winter season (January 2006), summer season (May 2006) and monsoon season (August 2006). A detailed map of Moradabad district showing sites of sampling collection is presented in Figure-1. A brief description of sampling sites along with apparent water quality is presented in Table 1. These water samples were collected in polyethylene bottles with watertight caps and were acidified in the field with HNO_3 (5 ml/lit of water), which will not affect the dissolved concentrations of metals due to insignificant concentrations of particulate matter in water samples collected during the winter, summer and rainy seasons. In order to avoid any contamination, the samples were transferred to polyethylene bags to avoid direct contact and were stored at 4^0C for preservation till further chemical analysis (APHA 1998, Merck 1974).

Table 1: A brief description of sampling sites alongwith apparent water quality

S.No.	Number and Name of site	Location of site	Depth of boring	Type of source	Apparent water Quality	Use of water
1	I, IM2 Hand pump at Sri Gurdwara, Chandranagar	2 km west to Moradabad collectorate	Approx. 24 meter	Only source of drinking water	Objectionable odour, turns brownish-yellow on standing	Drinking, bathing etc.
2	II, IM2 Hand pump at Singh Mandap, Chandranagar	0.5 km east to site no.I	Approx. 24 meter	Complementary source	Fishy smell, water turns yellowish on standing	Drinking
3	III, IM2 Hand pump at	1.5 km west to	Approx. 27 meter	Only source of	Objectionable odour, turbid,	Drinking,

S.No.	Number and Name of site	Location of site	Depth of boring	Type of source	Apparent water Quality	Use of water
	Patelnagar Mohallah	site no. II		drinking water	water turns yellowish on standing	domestic purposes
4	IV, IM2 Hand pump at Shiv Shakti Vatika, Locoshed	0.5 km east to site no.II	Approx. 24 meter	Complementary source	Objectionable odour, occasionally rusty colour	Drinking, domestic purposes
5	V, IM2 Hand pump at Chau ki Basti, Linepar	Adjacent to Railway Station,	Approx. 26 meter	Only source of drinking water	Fishy smell, turns yellowish-brown and a distinct oily layer on standing	Drinking, domestic purposes
6	VI, IM2 Hand pump at Mata Mandir, Linepar	0.3 km south to Railway Station,	Approx. 24 meter	Complementary source	Objectionable odour, oily layer over the surface on standing	Drinking
7	VII, IM2 Hand pump at Prakashnagar Chauraha	0.2 km south to site no.VI	Approx. 24 meter	Only source of drinking water	Fishy smell, occasionally rusty colour	Drinking
8	VIII, IM2 Hand pump at Linepar Police Station	1.0 km south to site no.VII	Approx. 27 meter	Only source of drinking water	Objectionable odour, turns brownish-yellow on standing	Drinking, bathing etc.
9	I, IM2 Hand pump at Preet Vihar	6 km south-west to Moradabad collectorate	Approx. 34 meter	Only source of water	Odourless, turns yellowish on standing	Drinking, domestic purposes
10	II, IM2 Hand pump at Balmiki Basti	2 km east to site no. I	Approx. 33 meter	Only source of water	Colourless, odourless	Drinking, bathing etc.
11	III, IM2 Hand pump at Balmilki Shiv Mandir, Khushalpur	5 km south-west to Moradabad collectorate	Approx. 35 meter	Only source of water	Colourless, odourless	Drinking, laundering
12	IV, IM2 Hand pump at Ambedkar park, Alkhnanda colony	0.5 km north to site no. III	Approx. 33 meter	Only source of water	Colour of water turns yellowish-brown on standing	Drinking, bathing
13	V, IM2 Hand pump at Bank Colony	1.5 km north to site no. III	Approx. 36 meter	Only source of water	Colourless, odourless	Drinking, domestic purposes
14	VI, IM2 Hand pump at Prathmik Vidyalay, Khushalpur	0.5 km south to site no. V	Approx. 35 meter	Only source of water	Colourless, odourless	Drinking, domestic purposes
15	VII, IM2 Hand pump at Community center, Budh vihar	1.5 km north to Mandi samiti	Approx. 34 meter	Only source of water	Colourless, Fishy smell	Drinking, domestic purposes
16	VIII, IM2 Hand pump at Bamiki Basti, Majhola	1.0 km north to site no VII	Approx. 33 meter	Only source of water	Colourless, odourless	Drinking, bathing etc.
17	IX, IM2 Hand pump at Shiv Mandir , Buddh Vihar	2.5 km east to site no. III	Approx. 33 meter	Only source of water	Colour of water turns pale yellow on standing	Drinking, domestic purposes
18	X, IM2 Hand pump at Police station, Mandi Samiti	7.0 km south to Moradabad collectorate	Approx. 34 meter	Only source of water	Colour of water turns yellowish-brown on standing	Drinking, bathing
19	XI, IM2 Hand pump at Prathmik Kanya Vidyalay, Majhola	1.0 km north-east to site no. X	Approx. 34 meter	Only source of water	Colourless, odourless	Drinking only
20	XII, IM2 Hand pump at Putlighar square, Majhola	1.0 km east to site no. X	Approx. 33 meter	Only source of water	Colour of water turns yellow on standing	Drinking, washing

Analytical Procedure

All samples were filtered by using 0.45 lm cellulose filters. Dissolved Fe concentrations were determined by Varian Liberty Series II Induced Coupled Plasma- Optional Emission Spectrophotometer (ICP-OES) at the Metal Handicraft Service Centre, Moradabad. This is a modern and promising emission technique, which has been used for fast, multi-element analysis. In this technique flame of incandescent plasma of Ar heated inductively by radio frequency energy at 4 to 50 MHz and 2 to 5 KW is used. The energy is transferred to a stream of Ar through an induction coil, whereby temperature up to 10000 K are attained. The sample atoms are subjected to temperatures around 7000 K. Each sample was analyzed in duplicate and mean values were taken as the result. All chemicals of analytical grade and MilliQ water were used. For quality assurance, replicates and analytical blanks were also prepared and analyzed to check the reliability of the data. Analytical precision for all samples were within ±5% in Fe determination (Mishra and Saksena 1993, Trivedi and Goel 1986).

RESULTS AND DISCUSSION

The determined values of Iron in water samples for three seasons are reported in Table 2. The season-wise variation of Iron concentration is graphical presented in Figure-2. The WHO and ICMR standard for iron concentration in water is 0.1mg/lit and permissible limit prescribed by USPH and ISI is 0.3mg/lit (ISI 1983, WHO 1984). High concentrations of iron are reported to be injurious to human health and causes a number of diseases related to stomach. Iron in the form of ferrous is oxidized to ferric imparting a turbidity of water. The results are demonstrated by the minimum and maximum values, average values and statistical evaluations i.e. Standard Deviation (SD), Standard Variance (SV), Standard Error (SE), 95% Confidence Limit (CL) of the iron in underground drinking water sources in and around Moradabad city are presented in Table 1 and description of correlation coefficient (r) is presented in Table 3. The iron values in underground drinking water were recorded from a minimum 0.95 mg/lit at site no.V and maximum 2.61 mg/lit at site no. XVII for winter season as shown in Table 2 along with concentration of average value with 95% CL was found to be 1.561±0.12 respectively. The iron values of winter season showed positive correlation with summer season (r=0.85) which are given in Table 4. The minimum value was 1.75 mg/lit at site no. XIII and maximum value was 3.95 mg/lit at site no. XVII for summer season as shown in Table 2. The average value of iron for summer season with 95% CL was found to be 2.58±0.22 respectively and positive correlation with summer season which are given in Table 4. The high iron content for rainy season was recorded 1.20 mg/lit at site no. XVII and minimum 0.40 mg/lit at site no. X as shown in Table 2. The average value of iron for rainy season with 95% CL was found to be in the range 0.707±0.01. The positive correlation with summer (r=0.75) and winter (r=0.78) respectively which are given in Table 4. Therefore, it may be concluded that the underground drinking water invariably at all the sites for the winter and summer seasons are excessively contaminated with reference to iron metal concentration and it is very alarming. The underground drinking water with reference to iron concentration is moderately contaminated during rainy season (Sundaram et al. 2008, Warren 2001, Kullu 2015).

Table 2: Site-wise and season-wise estimated values of iron with their recommended standards

WHO	0.1	**ISI**	0.3
USPH	0.3	**ICMR**	0.1
Site No.	**Winter Season**	**Summer Season**	**Rainy Season**
1	1.0	2.11	0.60
2	1.90	3.25	0.65
3	1.0	1.92	0.41
4	1.60	3.38	0.91
5	0.95	1.85	0.68
6	1.80	3.85	0.81
7	2.20	3.41	0.95
8	1.0	2.05	0.62
9	1.65	2.15	0.71
10	1.11	1.85	0.40
11	1.03	1.91	0.50
12	1.31	2.31	0.75
13	1.05	1.75	0.65
14	1.05	2.01	0.45
15	2.10	3.15	0.55
16	2.35	3.13	0.95
17	2.61	3.95	1.20
18	2.42	3.03	0.95
19	1.54	2.19	0.65
20	1.55	2.35	0.75

Table 3: Statistical evaluation for iron in different seasons

Season	Min	Max	AV	SD	SV	SE	AV±95% CL
Summer	1.75	3.95	2.58	0.7080	0.5012	0.354	2.58±0.22
Winter	0.95	2.61	1.561	0.5352	0.2864	0.2676	1.561±0.12
Rainy	0.40	1.20	0.707	0.2026	0.0410	0.1013	0.707±0.01

Table 4: Correlation coefficient values for seasonal variation of iron

	Summer	Winter	Rainy
Summer	1		
Winter	0.85	1	
Rainy	0.75	0.78	1

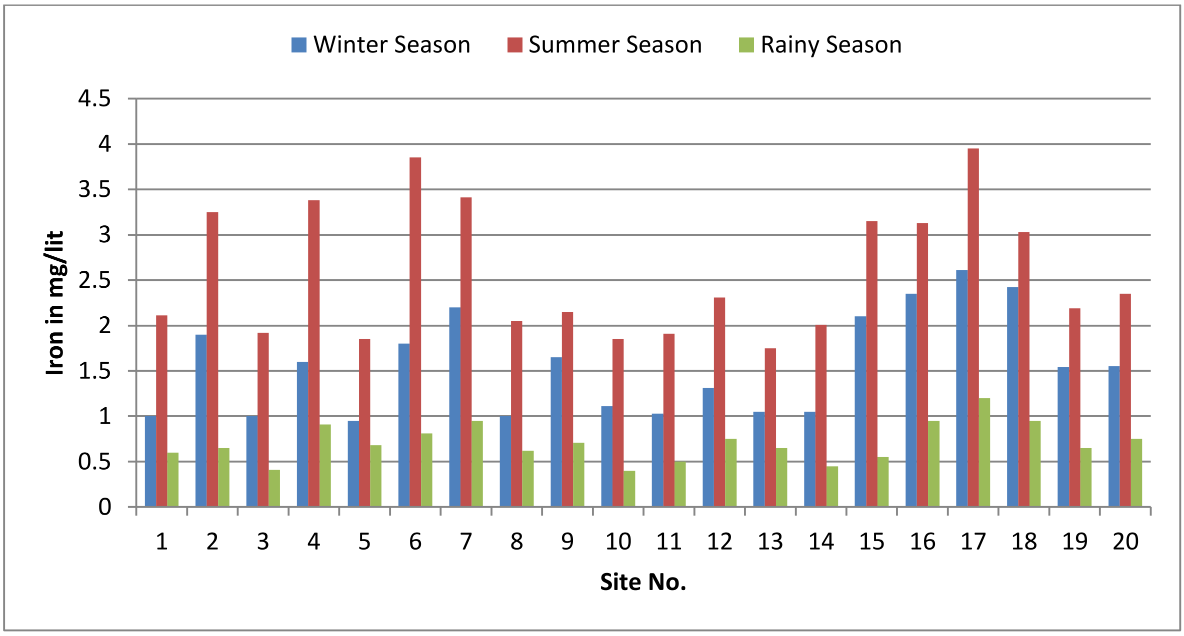

Figure 2: Season-wise graphical presentation of iron concentration

The concentration of iron in groundwater will be higher under more reducing conditions due to bacteriological degradation of organic matter which leads to the formation of various humic and fluvic compounds (Applin and Zhao, 1989; White et. al., 1991). Under reducing condition, the iron from biotite mica and laterites are leached into solution in ferrous state. According to Singhal and Gupta (1999) iron content in groundwater is mainly due to the dissolution of iron oxides. The common method for the removal of iron from water is by aeration followed by sedimentation. In high rainfall zones of India such as Assam, Orissa and Kerala, it is reported that the total iron content ranges from 6.83 to 55 mg/L (Singhal and Gupta, 1999, Singh 2015).

Highest concentrations of iron are reported during summer season and a slightly lower concentration is reported during winter season. Underground drinking water quality with reference to its iron concentration is improved remarkably after the onset of monsoon, however, it is still higher than the recommended standard. Underground drinking water quality management in this reference is the need hour in the area of study.

CONCLUSIONS

The estimated range of iron metal in underground drinking water of IM2 hand pumps in and around Moradabad city for winter, summer, and rains are 0.95-2.61 mg/lit, 1.75-3.95 mg/lit and 0.40-1.20 mg/lit respectively. The underground drinking water is found to be loaded with very high amount of iron during summer and winter season at all the sites of study. The iron concentration is markedly decreased after the onset of monsoon and underground drinking water is moderately contaminated during rainy season with reference to this important parameter.

REFERENCES

[1] Ababu T.Tiruneh et. al. 2014, Evaluation of the risk of heavy metals in sewage sludge intended for agricultural application in Swaziland. International Journal of Environmental Sciences, 5 (1): 197- 216.

[2] Ahmed, Monsef, 2017, Environmental geochemistry of iron, cobalt and nickel metals pollution in surficial bottom sediments of Brullus Lagoon, Egypt, Poll. Res. 36 (3):410-418.

[3] Akanksha et al. 2014, Comparative study of electrode material (iron, aluminium and stainless steel) for treatment of textile industry wastewater, International Journal of Environmental Sciences, 4 (4):519- 531.

[4] Alsaffar, M. S, Jaafar, Suhaimi, M., Kabir, Ahmad, N. 2016, Evaluation of heavy metals in surface water of major rivers in Penang, Malaysia, International Journal of Environmental Sciences, 6 (5): 657-669.

[5] APHA, 1998. Standard Method for the Examination of Water and Wastewater. 20th Edition. APHA, AWWA and WEF.

[6] Appelo, C.A.J. and Postma, D. Geochemistry, 2005. Groundwater and Pollution, 2nd edition. Balkema publishers, Leiden, the Netherlands, 404p.

[7] Applin, K.R. and Zhao. N. 1989. The kinetics of Fe (II) oxidation and well screen encrustation, Ground Water. 27 (2): 168-174.

[8] BIS, 1991. Drinking water specifications. Bureau of Indian Standards, New Delhi.

[9] CPCB, 2002. A report on state of environment Lucknow. Central Pollution Control Board, Ministry of Environment and Forest, Government of India, Delhi.

[10] Davies, J. 1994. The hydrogeochemistry of alluvial aquifers in central Bangladesh. Groundwater Quality in H.Nash and G.J.H. McCall (eds), 17th Special Report, Chapman and Hill, pp 9-18.

[11] Deer WA, Howie RA, Zussman J. 1966. An introduction to the rockforming minerals. Longman Essex, England.

[12] Dissanayake CB, Chandrajith R. 1999. Medical geochemistry of tropical environments. Earth Sci Rev 47:219–258.

[13] Faisal, B.M.R. et. al. 2015, Assessment of heavy metals pollution and natural radioactivity in topsoil of Savar industrial area, Bangladesh, International Journal of Environmental Sciences, 5 (5):964-979.

[14] Ghatak, Biswadeep, et. al. 2017, A study on the heavy metal accumulation in water, soil and vegetable samples in industrial belt of Vellore district, Poll. Res. 36 (3):626-631.

[15] Grosbois C, Courtin-Nomade A, Martin F, Bril H. 2007. Transportation and evolution of trace element bearing phases in stream sediments in a mining-influenced basin (Upper Isle River, France). Appl Geochem 22:2362–2374.

[16] ISI. 1983. Indian standard methods of sampling and test (physical and chemical) methods for water used in industry, p 122.

[17] Kanungo, Tushar Deb, 2017, Relation of groundwater arsenic, iron, and redox sensitive manganese to aquifer type in barak basin, Assam, India, Poll. Res. 36 (2):271-276.

[18] Karanth, K.R. 1997. Groundwater assessment development and management, Tata Mc Graw-Hill, New Delhi, p 720.

[19] Kullu, Bandana and Behera, Niranjan, 2015, Physico-chemical characterization of different age series sponge iron solid waste dumps with respect to reclamation, International Journal of Environmental Sciences, 5 (6): 1052-1060.

[20] Lehr, J.H., Gass, T.E., Pettyjohn, W.A. and De Marre, J. 1980. Domestic Water Treatment. Mc Graw-hill Book Co., New Delhi, 655p.

[21] Lenvik K, Steinnes E, Pappas AC. 1978. Contents of some heavy metals in Norwegian rivers. Nord Hydrol, 9:197–206.

[22] Merck, E. 1974. Testing of Water, Dermstadt, Federal Republic of Germany.

[23] Mishra, S.P. and Saksena, D.N. 1993. Planktonic fauna in relation to physico-chemical characteristics of Gauri Tank at Bhind, M.P. India. Advances in Limnology. Narendra Publishing House. New Delhi, pp. 57-61.

[24] Singh, Munendra, Singh, Amit Kumar, Swati, Srivastava, Nupur, Singh, Sandeep and Chowdhary, A. K. 2010. Arsenic mobility in fluvial environment of the Ganga Plain, northern India, Environmental Earth Sciences, 59 (8):1703–1715

[25] Neyaz , Nikhat, 2014, Application of surface functionalized iron oxide nanomaterials as a nanosorbents in extraction of toxic heavy metals from ground water: A review, International Journal of Environmental Sciences, 4 (4):472-483

[26] Prasannakumari A.A. et. al. 2014, Absorption potential for heavy metals by selected ferns associated with Neyyar River (Kerala), South India, International Journal of Environmental Sciences, 5 (2):270-276.

[27] Quarcoo A. et. al. 2015, Heavy metal levels in fish caught and processed at Lavender – Hill, Accra, International Journal of Environmental Sciences, 5 (4):776-782.

[28] Rao, K.L.1975. India's water wealth. Orient Longman, New Delhi

[29] Sharma, Sangeeta, Kumar, Davender and Pal, Jitender, 2017, Assessment of heavy metal contents

in vegetables grown in the vicinity of sirsa and their effects on human health, Poll. Res. 36 (2):319-328.

[30] Shinde, Pravin, S. and Donde , Snehal, S. 2017, Effect of heavy metal pollution on mangrove(avicennia marina) carbon sequestration Atmithi River, Poll. Res. 36 (4):943-948.

[31] Singh IB (1996) Geological evolution of Ganga Plain—an overview. J Palaeontol Soc India 41:99–137

[32] Singh, P.K, Sharma, J.L, and Singh, S.K., 2015, Determination of important heavy and transition metals in the surface water of the river Ganges by ion chromatography, International Journal of Environmental Sciences, 5 (5): 1022-1029.

[33] Singhal, B.B.S. and Gupta, R.P. 1999. Applied hydrogeology of fractured rocks, Kluwer academic publishers, The Netherlands, p 400.

[34] Soman, K. 1977. Geology of Kerala, published by Geological Society of India, Bangalore, India-560019, 280p.

[35] Sundaram, Leena and Prakasam, V.R. 2008, Distribution of iron in water of Thiruvananthapuram district of Kerala. Indian J. Env. Prot., 28(9): 833-834

[36] Trivedi, R.K. and Goel, P.K. 1986. Chemical and biological methods for water pollution studies, Environmental publication, Karad.

[37] UNEP, 1999. United Nations Environment Program. Global Environment Outlook 2000. Earthscan, U.K.

[38] UNESCO, 1995. A global geochemical database for environmental and resource management. Earth Science 19. UNESCO Publication, Paris.

[39] Warren LA, Haack E.A. 2001. Biogeochemical controls on metal behaviour in freshwater environments. Earth Sci Rev 54:261–320.

[40] White, A.F., Benson, S.M., Yee, A.W., Woiienberg, H.A. and Flexed, S. 1991. Groundwater contamination at Kesterson reservoir, California: geochemical parameters influencing selenium mobility, Water Resource research, 27, 1085-1098.

[41] WHO, 1984. Guidelines for drinking water quality, Recommendation, Geneva.