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Ministry of Water Resources, River Development and Ganga Rejuvenation
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भू-जल न्यूज़

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Ground Water Pollution by Industrial Clusters

भू-जल न्यूज़

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Editorial

Pollution caused by industries has alarming consequences. During 2009-10, Central Pollution Control Board (CPCB) in collaboration with IIT Delhi carried out comprehensive environmental assessment of environmental parameters including groundwater quality in eighty eight industrial clusters and rated them on the concept of Comprehensive Environmental Pollution index(CEPI). Central Ground Water Board in turn carried out detailed ground water quality studies in all the industrial clusters identified by CPCB. These studies by CGWB serve as a yardstick to monitor and evaluate the extent of ground water pollution and also recommend measures that need to be taken to undo/alleviate the damage already done.

Pollution caused by industries is a matter of grave concern and the present issue of Bhujal News is devoted entirely to the topic. Ten papers have been compiled on some of the studies carried out by CGWB in the industrial clusters**.** Ravi Kumar Gumma etal in their paper 'Ground water quality in industrial clusters of Greater Hyderabad, Telangana' have highlighted the extent of groundwater contamination in six industrial clusters of Hyderabad **.I**t has **also** been stated that the proposed plan of smart cities should encompass the provisions for proper industrial and sanitary infrastructure. The paper 'Ground water quality around industrial cluster in Ratlam (M.P.) India' by Kulshreshtha etal describes groundwater quality in industrial cluster in Ratlam based on analysis of 62 groundwater samples collected in April,2013. On the basis of the analytical data, hydrochemical facies and nature of rock-water interaction of groundwater has been brought out to explain the mechanisms controlling the water chemistry of the area. In their paper on groundwater quality at village Bhaneda Khemchand, block Nanauta, district Saharanpur, UP' Ram Prakashet al have shown how the organic waste discharged from the surrounding industries has impacted ground water quality indicated in terms of high BOD & COD. The paper by Dr A Mukherjee is a review paper which has not elaborated about pollution caused by some specific industry but which stresses on probable ground water pollution due to committed industrialization in Chhattisgarh if proper precaution aided by scientific study is not undertaken. The paper ‘Study on water quality trends in groundwater of Digboi, Assam’by Radhapyari etal attempts to illustrate the water quality trends of Digboi in Tinsukia district, where one of the oldest and largest refinery in Asia the “Digboi Refinery”is located. The study also indicated that the concentration of some parameters changed with season. The paper ‘Occurrence of high Chromium in parts of industrial area in Unnao district, Uttar Pradesh’ by Shrivastava etal presents an interesting study on the occurrence of harmful hexavalent chromium in the groundwater in the industrial area of Unnao dist. from the effluents discharged into some drains in its vicinity. Due to this, the quality of groundwater is being affected adversely. The paper ‘Groundwater quality & temporal variation in the industrial clusters of Panipat city, Haryana by Jain etal presents an interesting study on spatial and temporal changes in groundwater quality in and around Panipat city in the light of heavy industrialization of several types of industries in the area. Quality characteristics of groundwater in the area in terms of its physicochemical quality and trace metal contents has been presented for years 2014 and 2016. The paper ‘Impacts of industrialization on water quality of Korba city’ by Dewangan etal describe impact of industrialization/coal burning on water quality of Korba block. The paper has incorporated good amount of field data relating to the quality parameters (physicochemical and trace metals) of the surface water as well as groundwater in the vicinity of coal mines/burning sites in and around Korba city. Finally the paper ‘Groundwater pollution along Najafgarh drain, NCT, Delhi by Kapoor etal is based on exhaustive field data about the status of chemical quality of groundwater resulting in its pollution along the Najafgarh drain in NCT, Delhi due to a variety of industrial activities in the area. The conclusions drawn at the end presents a grave picture and there is urgent need for proactive action to combat pollution.

G C Pati
Editor

Groundwater quality in industrial clusters of Greater Hyderabad, Telangana

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Abstract

Rapid industrialization incommensurate with proper infrastructure resulted in haphazard and unregulated industrial growth in the country. An attempt has been made to know the extent of groundwater contamination in six industrial clusters of Hyderabad to understand the impact of industrial as well as anthropogenic activity on the urban aquifers. A total of 48 groundwater samples, 34 during pre monsoon, 14 during post monsoon period were collected and analyzed for 11 constituents (pH, EC, TH, Ca^{2+}, Mg^{2+}, CO_3^-, HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}, and F^-). In addition, another 34 samples, 25 during Pre-Monsoon and 11 during post monsoon period were collected for trace elemental analysis (Mn, Zn, Cr, Co, Cd, Cu, Ni & Fe). High EC, Cl^-, SO_4^{2-} values have been observed along with high concentration of Manganese (Mn) & Cadmium (Cd) in all six industrial clusters indicating the pollution of groundwater due to industrial effluents. The occurrence of Nitrate in groundwater above the permissible limit indicate the anthropogenic contamination of groundwater. There is an urgent need to enforce strict regulatory measures and opt for high end treatment facilities to mitigate the issue and to stop further damage to groundwater quality. There is also a need that the proposed plan of smart cities should encompass the provisions for proper industrial and sanitary infrastructure including waste water treatment facilities and other measures to protect groundwater.

Key words: Groundwater contamination, Industrial cluster, Hyderabad

1. Introduction

In nature groundwater gains different inorganic elements through complex water-rock interactions and may become enriched with various ions rendering the water unsuitable for drinking purpose. The groundwater quality deterioration is more prevalent in urban areas due to cumulative effects of different sources of contamination like domestic, industrial and other factors. In India, over 50 % of urban water requirement is met from groundwater (CGWB, 2013). Discharge of untreated sewage in water courses is the main water polluting source for both surface and groundwater in India. The impetus given to industrialization witnessed fast paced industrial growth in the country. This has also led to severe groundwater pollution due to improper discharge facilities and lack of holistic approach in resource management. Unlike surface water, groundwater contamination is irreversible. Among such pollutants, nitrate is the most common pollutant. Nitrate is a source of nitrogen and nitrate is formed due to natural reactions of atmospheric nitrogen with rain water as part of nitrogen cycle and significant amount of it enters the soil during rainfall. Nitrate is a non-lithological source and in natural conditions unpolluted groundwater contains <5 mg/L of nitrate (Karanath1987). It is of particular concern due its direct correlation with urbanization process, development and infrastructural facilities.

Hyderabad, the capital city of newly formed state of Telangana witnessed industrial growth since mid-seventies. Discharge of untreated industrial effluents has resulted in severe groundwater contamination in and around industrial clusters of Hyderabad. Inadequate treatment facilities at source, lack of holistic approach and planning has further deteriorated the situation. In order to assess the groundwater pollution in the industrial clusters of Telangana identified by Central Pollution Control Board (CPCB), groundwater samples were collected and analyzed from six industrial clusters located in Kukapalli, Patancheru, Bolarum, Jeedimetla, Katedan and Uppal of Greater Hyderabad. **(Fig 1)**

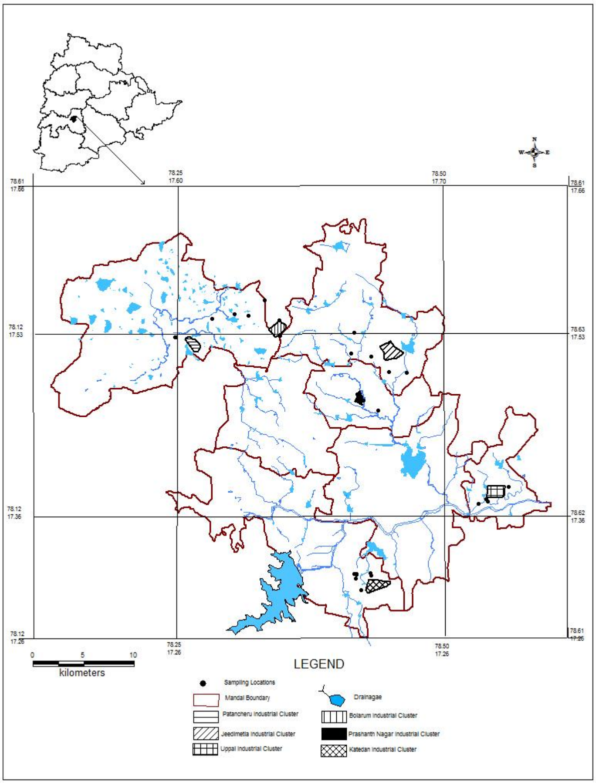


Fig-1: Location of Industrial Clusters in and around Greater Hyderabad

2. **Area**

The study had been carried out in 6 industrial clusters Viz., Patancheru, Bolarum, Jeedimetla, Prashantinagar, Uppal and Katedan industrial areas of Greater Hyderabad (Fig-1). Greater Hyderabad is one of the largest metropolitan areas of India and is spread over an area of 778 sq.kms comprising Municipal Corporation Hyderabad (MCH), ten peripheral municipalities, Secunderabad Cantonment and Osmania University. It has a population of 7.7 million people as per 2011 census data. Hyderabad experiences semi arid tropical climatic conditions. The mean annual rainfall is 884 mm recorded in 50 rainy days. The south west monsoon contributes 74% of annual rainfall and north east monsoon contributes 14%. The main geomorphic units are residual hills, pediments, inselbergs, pediplains and valley fills. The River Musi, a tributary of Krishna River, with a gradient of 2 m per km flows from west to east and most of the streams are ephemeral in nature. Hyderabad is endowed with a number of natural and artificial lakes. The Patancheru industrial area is drained by Nakkavagu and Peda vagu streams which join into Manjira, a tributary of Godavari River. The Bolarum industrial area is drained by seasonal streams like Pamulavagu. The Prashanth nagar industrial area is situated along the Kukatpalli nala. The major bulk of inflows of this nallah estimated at 70 MLD drain into the Hussain sagar lake of which 55 MLD is domestic sewage and 15 MLD is from industrial effluents. The catchment area has major industrial areas like Kukatpally, Balanagar, Sanathnagar and Jeedimetla. Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) has initiated a project to divert the Kukatpally nala from flowing into Hussainsagar lake. The Uppal industrial area is situated upstream of the Musi.

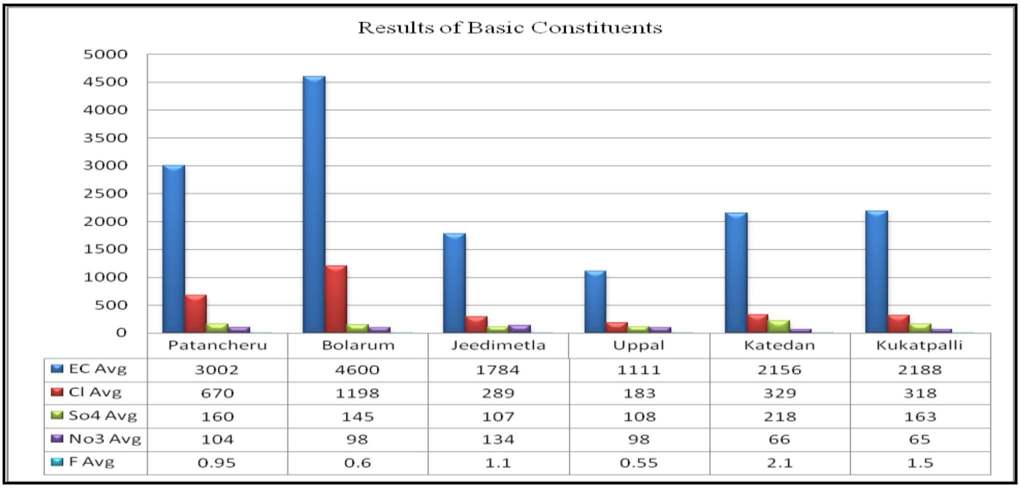
The area forms part of the Pre-Cambrian peninsular shield and is underlain by the Archaean crystalline complex, comprising of granites intruded by dolerite dykes. The thickness of the weathered zone varies from 5-25 m and discharges generally vary from negligible to 5 lps. In general, the shallow fractures are more productive than the deeper ones. Groundwater occurs under phreatic conditions in weathered zone and under semi-confined to confined conditions in the fractured zones. The depth to water level is observed in between 5 and 20 m but on an average it is around 10 m.

3. Method of Study:

Groundwater samples were collected from the 6 industrial clusters located in different parts of Greater Hyderabad. Groundwater sampling is mainly done to assess the effects of industrial as well as anthropogenic contamination. All the above industrial areas are surrounded by human settlements. Groundwater is also being extensively utilized by adjoining urban settlements for domestic purposes. A total of 48 samples, 34 during pre-monsoon and 14 during post-monsoon period were collected and analyzed for 11 constituents. The samples were analyzed in Regional Chemical Laboratory of Central Ground Water Board using standard methods (APHA, 1998). The constituents determined were pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^-), bicarbonate (HCO_3^-), chloride (Cl^-), nitrate (NO_3^-), sulphate (SO_4^{2-}) and fluoride (F-). The data precision was tested using the cations and anion charge balance method, with precision of + or –5 %. (pH, EC, TH, Ca^{2+}, Mg^{2+}, CO_3^-, HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}, and F-). In addition, another 34 samples, 25 during Pre-Monsoon and 11during post monsoon period were collected and analyzed for trace element analysis (Mn, Zn, Cr, Co, Cd, Cu, Ni & Fe).

4. Results and Discussions:

The analytical results were compiled and processed for each cluster. The extent of contamination in industrial clusters is evident from high concentrations of EC (7780 µcm/s in Patancheru, 6600 µcm/s in Bolarum, 3147 µcm/s in Katedan and 3083 µcm/s in Prashanthnagar), Nitrate (217 mg/L in Patancheru, 136 mg/L in Bolarum, 240 mg/L in Jeedimela, 300 mg/L in Uppal and 128 mg/L in Katedan and 107 mg/L in Prashanthnagar), Chloride (2340 mg/L in Patancheru, 2021 mg/L in Bolarum) (**Fig-2 and Table-1**). High values of certain trace elements (**Fig-3 and Table-2**) indicate the industrial contamination. The number of samples showing basic and trace elements more than permissible limits of drinking water standards as prescribed by BIS (IS 10500 : 2012) and highest value observed in respect of all six industrial clusters are shown in **Table- 3 & 4** respectively. The waters are mainly of Ca^{2+}-Mg^{2+} - Cl^- SO_4^{2-} type in all six industrial clusters **(Fig-4)**.



	Patancheru	Bolarum	Jeedimetla	Uppal	Katedan	Kukatpalli
EC Avg	3002	4600	1784	1111	2156	2188
Cl Avg	670	1198	289	183	329	318
So4 Avg	160	145	107	108	218	163
No3 Avg	104	98	134	98	66	65
F Avg	0.95	0.6	1.1	0.55	2.1	1.5

Fig-2: Concentrations of Basic constituents

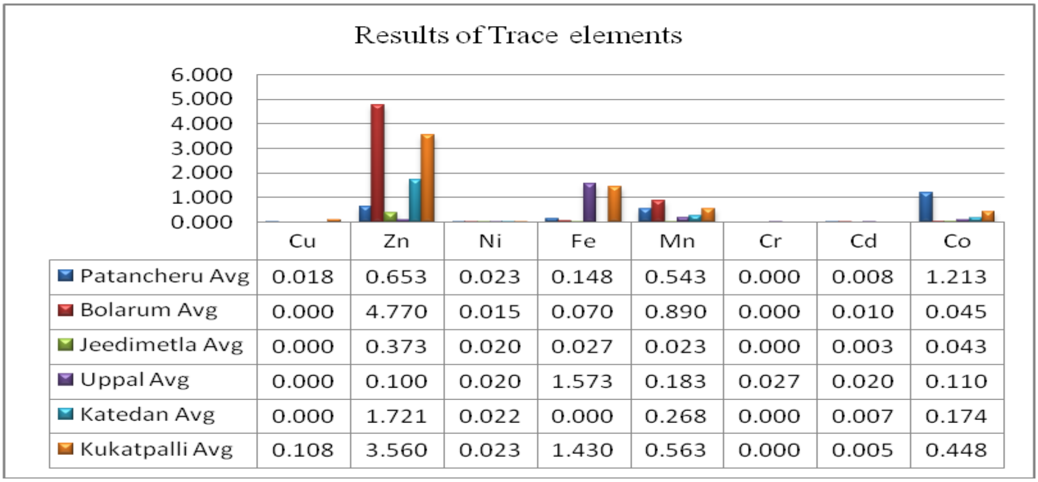


Fig-3: Concentration of Trace elements

Table-1: Minimum, Maximum and Average of basic parameters in six industrial clusters

Industrial Cluster / Parameter		Patancheru	Bolarum	Jeedimetla	Uppal	Katedan	Kukatpalli
EC (µS/cm)	Min	1150	3200	1060	977	600	1118
	Max	7780	6630	2930	2520	3147	3083
	Avg	3002	4600	1784	1111	2156	2188
Cl^- (mg/L)	Min	149	553	145	145	67	149
	Max	2340	2021	525	553	510	581
	Avg	670	1198	289	183	329	318
SO_4^{2-} (mg/L)	Min	58	96	53	83	49	1
	Max	259	259	163	253	451	450
	Avg	160	145	107	108	218	163
NO_3^- (mg/L)	Min	0	78	45	10	0.06	10
	Max	217	136	240	300	128	107
	Avg	104	98	134	98	66	65
F- (mg/L)	Min	0.6	0.3	0.5	0.4	1.05	0.85
	Max	1.8	1	1.9	1.1	4.29	2.38
	Avg	0.95	0.6	1.1	0.55	2.1	1.5

Table-2 Minimum, Maximum and Average of Trace elements in six industrial clusters

Industrial Cluster	Parameter	Cu	Zn	Ni	Fe	Mn	Cr	Cd	Co
		(mg/L)							
Patancheru	Min	0.07	0.7	0.02	0.02	0.07	0.0	0.01	0.13
	Max	0.07	1.42	0.03	0.34	1.06	0.0	0.01	4.27
	Avg	0.018	0.653	0.023	0.148	0.543	0.0	0.008	1.213
Bolarum	Min	0.0	0.0	0.010	0.0	0.50	0.0	0.0	0.04
	Max	0.0	9.54	0.02	0.14	1.28	0.0	0.02	0.05
	Avg	0.0	4.77	0.015	0.07	0.89	0.0	0.01	0.045
Jeedimetla	Min	0.0	0.05	0.01	0.0	0.01	0.0	0.0	0.04
	Max	0.0	1.07	0.03	0.08	0.34	0.0	0.01	0.05
	Avg	0.0	0.373	0.02	0.027	0.023	0.0	0.003	0.043
Uppal	Min	0.0	0.0	0.01	0.13	0.02	0.0	0.0	0.11
	Max	0.0	0.3	0.03	4.27	0.34	0.08	0.03	0.11
	Avg	0.0	0.10	0.02	1.573	0.183	0.027	0.020	0.11
Katedan	Min	0.0	0.02	0.01	0.0	0.01	0.0	0.0	0.070
	Max	0.0	8.50	0.04	0.0	0.990	0.0	0.020	1.700
	Avg	0.0	1.721	0.022	0.000	0.268	0.0	0.007	0.174
Kukatpalli	Min	0.0	0.000	0.010	0.000	0.010	0.0	0.0	0.0
	Max	0.38	13.910	0.040	3.860	1.690	0.0	0.010	1.700
	Avg	0.108	3.560	0.023	1.430	0.563	0.0	0.005	0.448

Table-3: The highest values observed & no. of samples with concentration more than permissible limit of basic constituents as per drinking water standards (BIS)

Industrial Cluster		Patancheru		Bolarum		Jeedimetla		Uppal		Katedan		Kukatpalli	
		A	B*	A	B*	A	B*	A	B*	A	B*	A	B*
pH		1	6	0		0		0		2	6.4	0	
EC	(µS/cm)	2	7780	3	6630	0	2930	0		2	3147	1	3083
TDS	(mg/L)	3	1620	2	3978	0		0		0		0	
Cl^-	(mg/L)	1	2340	2	2021	0		0				0	
SO_4^{2-}	(mg/L)									1	451	1	450
Ca^{2+}	(mg/L)	2	377	2	545	0		0		3	313	1	248
Mg^{2+}	(mg/L)	5	165	3	233	6	107	1	102	8	122	3	114
TH	(mg/L)	3	1620	2	2320	1	900	1	820	6	1100	2	1090
NO_3^-	(mg/L)	4	149	3	136	7	240	2	300	6	128	3	107
F-	(mg/L)	1	1.8	0		1	1.8	0		6	4.3	2	4.3

A* Number of samples with more than permissible limit
B*Highest value observed

Table-4: The highest values observed in respect of Trace elements & no. of samples with concentration more than permissible limit as per drinking water standards (BIS)										
Industrial Cluster	No. of samples		Cu	Zn	Ni	Fe	Mn	Cr	Cd	Co
			(mg/L)							
Patancheru	4	A*	0	0	0	1	2	0	0	0
		B*	0	0	0	0.34	1.06	0	0	0
Bolarum	2	A*	0	0	0	0	2	0	1	0
		B*	0	0	0	0	1.28	0	0.02	0
Jeedimetla	3	A*	0	0	0	0	0	0	0	0
		B*	0	0	0	0	0	0	0	0
Uppal	3	A*	0	0	0	2	1	0	1	0
		B*	0	0	0	4.27	0.34	0	0.03	0
Katedan	9	A*	0	0	0	0	2	0	1	0
		B*	0	0	0	0	0.99	0	0.02	0
Kukatpalli	4	A*	0	0	0	1	1	0	0	0
		B*	0	0	0	1.86	1.69	0	0	0
A* Number of samples with more than permissible limit B*Highest value observed										

4.1 Patancheru Industrial Cluster: A number of Pharmaceutical industries with more than 90 manufacturers (Beijer et al. 2013) have been functioning since 1977 in this cluster. Since 1989, waste water from these facilities is being treated in a common effluent treatment plant (CETP) called Patancheru Effluent Tech Limited (PETL). However, the treated and untreated effluents from the industries are being discharged in Nakkavagu and Pedavagu streams. Patancheru-Bollaram cluster was banned for further projects in 2010 by Ministry of Forests and Environment (MoEF) due to investigations conducted by the Central Pollution Control Board (CPCB). In 2013 this ban was re-imposed by the MoEF. Industrial clusters with CEPI score > 70 have been identified as critically polluted areas. Instead of reduction, the CEPI-score for pollution gradually increased over the years (Reddy 2013). The Nakkavagu stream that flows through the industrial estate in Patancheru bears the brunt of waste disposal of over 100 industries. This, once clean, stream was used by surrounding villages for irrigation and drinking purposes. The estate, which consists of paint, plastic, chemical and bulk drug industries routinely dump their waste into the stream.

A total of 6 samples were analyzed for basic constituents and 4 samples were analyzed for trace elements in and around this industrial cluster. High EC values ranging from 1150 µS/cm to 7780 (µS/cm) with an average of 3002 µS/cm were observed. The water is of mixed type representing the predominance of Na^{2+}-K^{2+} - Cl^{-} SO_4^{2-} than Ca^{2+}-Mg^{2+} - Cl^{-} SO_4^{2-} (Fig-5). The Villages Sultanpur & Krishnareddipeta shows high EC, chloride and nitrate concentrations in groundwater. The presence of high chloride along with high concentration of manganese (Mn) & cadmium (Cd) indicate the pollution of groundwater due to the industrial effluents. The other trace elements like nickel (Ni), chromium (Cr), zinc (Zn) were within the permissible limits. The concentration of cadmium (0.05 mg/L) was observed during post-monsoon period. The occurrence of nitrate beyond the permissible limit in the groundwater indicates the anthropogenic effects on groundwater.

***4.2 Bolarum Industrial Cluster*:** Bolaram has an Industrial development area and has many small and medium scale industries like pharmaceutical units that manufacture bulk drugs. There are around 40 industries in this area. Pamulavagu, a tributary of Nakkavagu carries treated and untreated effluents from this bolarum industrial area. A total of 3 groundwater samples for basic constituents and 2 samples for trace elements were analyzed. High EC values were observed from groundwater samples of Bolarum industrial area. The EC ranged from 3200 (µS/cm) (minimum) to 6630 (µS/cm) (max) with an average of 4600 µS/cm. The presence of high chloride along with high concentration of manganese (Mn) & cadmium (Cd) indicate the pollution of groundwater due to industrial effluents. The other trace elements like nickel (Ni), chromium (cr), zinc (Zn) were within the permissible limits. Cadmium (0.05 mg/L) in groundwater is observed during Post-Monsoon period. The water is of mixed type representing the predominance of Ca^{2+}-Mg^{2+}-Cl^{-} SO_4^{2-} and Na^{+}-K^{+} - Cl^{-} SO_4^{2-} **(Fig-5).** The occurrence of high nitrate in the groundwater beyond permissible limits indicates the anthropogenic effects on groundwater.

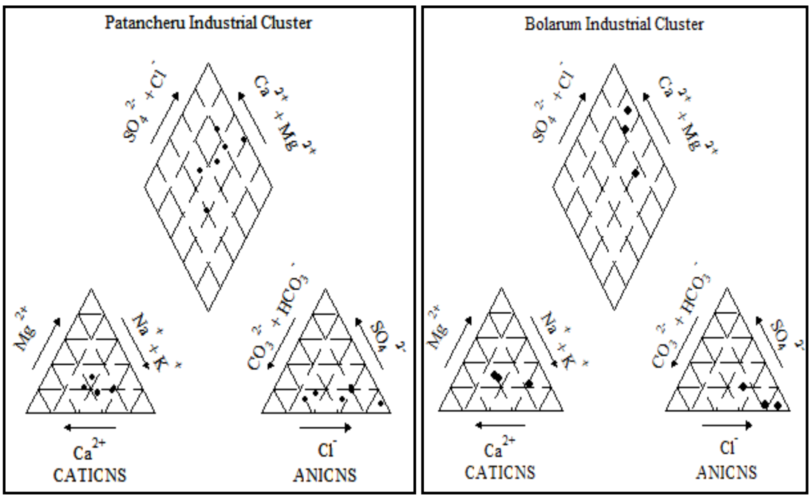


Fig-5: Piper–Trilinear diagram of Patancheru and Bolarum Industrial Clusters

***4.3 Jeedimetla Industrial Cluster*: ** The main industries are those of machine tools, pharmaceuticals, electrics, textiles and chemicals. A total of 7 samples were analyzed for basic constituents and 3 samples were analyzed for trace elements in and around this industrial cluster. The water is of mixed type representing the predominance of Ca^{2+}-Mg^{2+} - Cl^{-} SO_4^{2-} and Na^{+}-K^{+} - Cl^{-} SO_4^{2-} **(Fig-6)**. The EC ranged from 1060 (µS/cm) (minimum) to 2930 (µS/cm) (max) with an average of 1784 (µS/cm). The presence of high chloride along with high concentration of manganese (Mn) & cadmium (Cd) indicate the pollution of groundwater due to industrial effluents. The other trace elements like nikel (Ni), chromium (Cr), zinc (Zn) were within the permissible limits. The occurrence of high nitrate in the groundwater beyond permissible limits may be due to anthropogenic activity. The Jeedimetla Effluent Treatment Limited [JETL] set up its Combined Waste Water Treatment Plant [CWWTP] at Jeedimetla industrial area to prevent pollution by treating industrial effluents to environmentally acceptable norms.

***4.4 Uppal Industrial Cluster*: ** This cluster features food and agro products manufacturing units apart from other small scale industries. A total of 4 samples were analyzed for basic constituents and 3 samples were analyzed for trace elements in and around this industrial cluster. The water is of predominantly Na^{+}-K^{+} - Cl^{-} SO_4^{2-} type (**Fig-6)**. The EC ranged from 977 (µS/cm) (minimum) to 2520 (µS/cm) (max) with an average of 1111 (µS/cm). The presence of high concentration of Manganese (Mn) & Cadmium (Cd) indicate the pollution of groundwater due to industrial effluents. The other trace elements like Nickel (Ni), Chromium (Cr), Zinc (Zn) were within the permissible limits. High concentration of Fe (7.17 mg/L) was observed in IDA, Uppal. The occurrence of high nitrate in groundwater beyond permissible limits indicates the anthropogenic influence on groundwater.

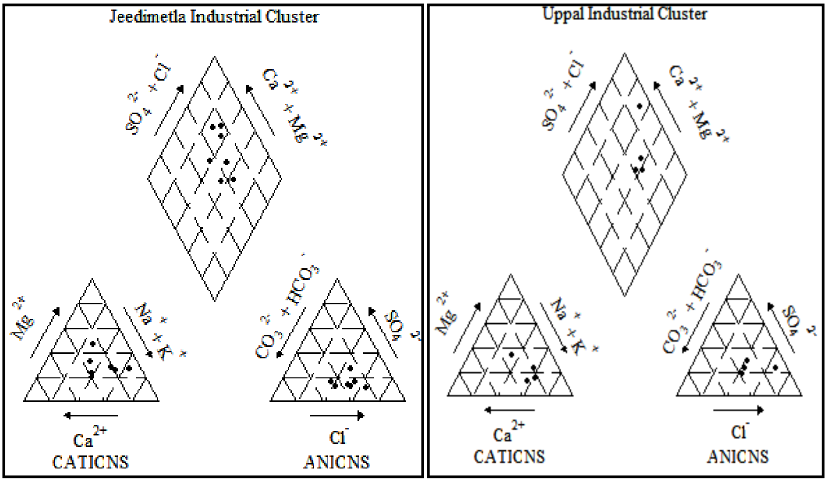


Fig-6: Piper–Trilinear diagram of Jeedimetla and Uppal Industrial Clusters

4.5 Katedan Industrial Cluster: The industrial area located in Rajender Nagar mandal, has many agro and food products industries, chemical and plastic, colour and polymer manufacturing units. A total of 10 samples were analyzed for basic constituents and 9 samples for trace elements. The water is of mixed type representing the predominance of Ca^{2+}-Mg^{2+} - Cl^- SO_4^{2-} and Na^+-K^+ - Cl^- SO_4^{2-} **(Fig-7**). The EC ranged from 600 (µS/cm) (minimum) to 3147 (max) with an average of 2156 (µS/cm). The occurrence of high chloride and sulphate along with high concentration of manganese (Mn) & cadmium (Cd) indicate the pollution of groundwater from the industrial effluents. The other trace elements like Nickel (Ni), Chromium (Cr), Zinc (Zn) were within the permissible limits. High occurrence of nitrate in groundwater beyond permissible limits indicates the anthropogenic influence on groundwater.

4.6 Prashanthnagar/Kukatpalli industrial Cluster**:** A total of 4 samples were analyzed for basic constituents and 4 samples for trace elements. The water is of mixed type representing the predominance of Ca^{2+}-Mg^{2+} - Cl^- SO_4^{2-} type **(Fig-7**). The EC ranged from 1118 (µS/cm) (minimum) to 3083 (µS/cm) (max) with an average of 2188 (µS/cm) The presence of high Chloride and Sulphate along with high concentration of Manganese (Mn) & Cadmium (Cd) indicate the pollution of groundwater from the industrial effluents. High concentration of Zn (13.91 mg/L) is observed in IDPL, Balanagar, adjacent to the Kukatapalli/Prashanthnagar industrial area. The occurrence of high concentration of nitrate indicates the anthropogenic effect on groundwater.

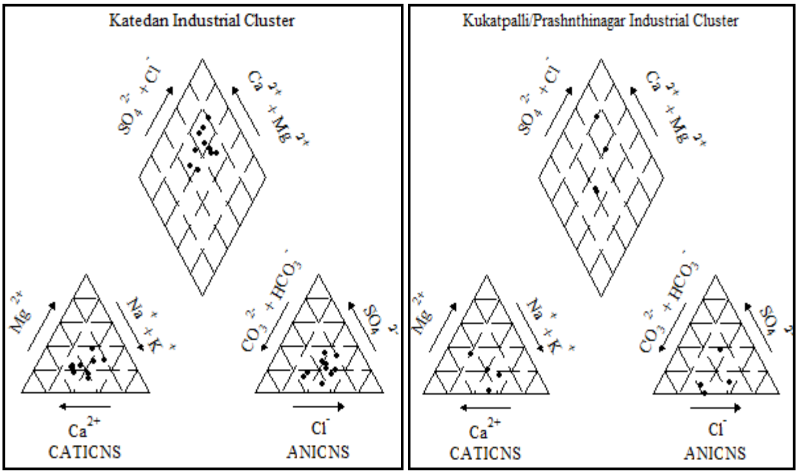


Fig-7: Piper–Trilinear diagram of Katedan and Kukatpalli Industrial Clusters

5. Conclusions and Recommendations:

(i) It is observed that groundwater is contaminated due to industrial as well as domestic effluents in all six industrial clusters in Greater Hyderabad.

(ii) Inadequate treatment facilities at the source led to untreated industrial effluents finding its way into the streams and aquifers, thus contaminating groundwater.

(iii) There is a need for periodical monitoring of groundwater quality including complete organic and trace elemental analysis with enhanced monitoring stations in and around these industrial clusters.

(iv) There is also a need that the proposed plan of smart cities should encompass the provisions for proper industrial and sanitary infrastructure including waste water treatment facilities and other measures to protect the groundwater resource.

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References

1. APHA, 1998, Standard methods for the examination of water and waste water (22nd edition), NW Washington, DC: American Public Health Association
2. CGWB, 2013 CGWB (2013) Master Plan for artificial recharge in India, Govt. of India, Unpublished report.
3. Karanth, KR 1987, Groundwater assessment, development and Management, Tata Mc-Graw Hill Publishing Company.
4. Indian Standard Drinking Water Standards - Specification (Second Revision) ICS 13.060.20, Bureau of Indian Standards, Manak Bhawan, 9 Bahadur shah Zafar Marg, New Delhi.
5. Patancheru-Bollaram Industrial Cluster, Water & Mega Cities, www.waterandmegacities.org /patancheru-bollaram-industrial-cluster
6. S.J. Reddy 2013 (http//www.downtoearth.org.in/content/polluters-under-moef-scanner)

Groundwater quality around industrial cluster in Ratlam (M.P.) India

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Abstract

Ratlam city has been identified as one of country's 22 most severely polluted areas by Central Pollution Control Board. Central Ground Water Board through its network of Regional Offices initiated a detailed survey of groundwater quality of the industrial clusters/areas across India. The study consisted of field survey which included collection of groundwater samples covering the industrial area and surrounding villages and laboratory investigations. This was aimed at evaluating major ions; establishing hydro-chemical facies and determining their suitability for drinking, irrigation and other uses by local inhabitants. The study revealed that the quality of groundwater surrounding the industrial area of Ratlam has deteriorated significantly as many of the chemical constituents in most samples exceeded the maximum permissible limit prescribed by BIS (10050:2012).

1. Introduction

Ratlam district of MP has emerged as an important industrial city of Malwa Region, therefore, reports on ecological impacts and contamination due to industrial development are frequent from this region. A decade ago, Central Ground Water Board, NCR, Bhopal conducted a comprehensive study regarding groundwater pollution due to industrial development around Ratlam district, MP. The results of the study were published in July1998 by Central Ground Water Board, NCR, Bhopal. The study revealed the presence of very high level of pollutants like Nitrate, Chloride and Sulphate in groundwater. It was found that in some locations, the colour of ground/surface water was reddish-brown with bad odour which could directly be linked to source of industrial effluent. The study concluded that industries of Ratlam had severely contaminated surface and groundwater in the region comprising Dosigoan, Ghatala, Bajankhedi, Jadwasa Khurd and Jadwasa Kalan villages **(Goel, 1998).** Central Ground Water Board (CGWB) decided to reassess groundwater quality in the polluted industrial clusters identified by CPCB. The present study in Ratlam Industrial cluster was the part of that programme..

1.1 Geomorphology

The whole Ratlam district lies on Malwa plateau. The general scene is of undulating country sloping towards north and marked by series of high hills and valleys. There are isolated hills that attain prominence in the southeast of the district and near the western margins of the plateau. In the west hills are dissected and slopes into the narrow valleys of seasonal steams of Mahi. Geomorphology of Ratlam district can be divided into five divisions.1.The Malwa plateau in the east 2.The plateau of Sailana 3.The western hills of Sailana 4.The Chambal valley 5.The Mahi valley.

1.2 Drainage

Ratlam district falls under Ganga and Mahi river basins. The tributaries of Chambal river drain about 70 % of the area of the district. Southwest part of the district is drained by the Mahi River and it tributaries. The type of drainage in general is dendritic developed on Deccan Trap basaltic rocks. The Chambal River flows in the northeast part of the district. The important tributaries of Chambal River in the district are Kshipra, Maleni and Pingla rivers. The Mahi River flows in the southwest part of the district. The Mahi River is a consequent river, which originate from Dhar district. The main tributaries of the Mahi River are Bageri, Jammer, Karan, Pundia, Bunad Pampavati and Telni.

2. Methodology

The principal author made a visit to the study area and collected water samples through several open dug wells and bore wells within the periphery of Ratlam Industrial area in the month of April-2013.The samples were collected after filtration as per guidelines of APHA in one-litre pre-rinsed airtight polythene bottles and sealed with wax. A total 62 water samples were collected.. The samples were analyzed in the Regional Chemical Laboratory of Bhopal for basic parameters and selective heavy metals which included Fe, Zn, Mn, Cd, Ni, Cr, Pb *& Cu*.

The pH and EC values were determined in situ with the help of portable pH-meter and EC-meter whereas other constituents were determined in the laboratory by using different volumetric methods such as Flame-photometer (Systonics-128), Spectrophotometer (Shimadzu, UV-1201). The heavy metals analysis was carried out by using Atomic Absorption Spectrophotometer (GBC-Avanta).The observed ion-balance-error computed on each set of water sample was within the range of acceptability (± 5%). **Annexure–I** shows the list of sampling points. Geographical locations of sampling points are shown in **Fig-1**.

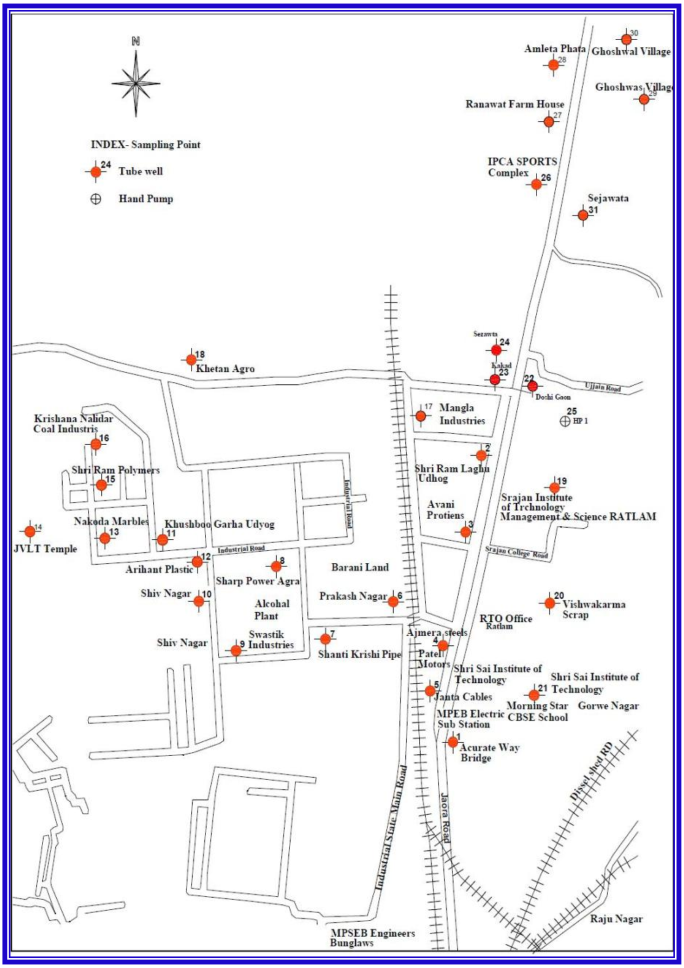

Fig-1: *Map of Ratlam Industrial Area along with locations of sampling points.*

3. Results & Discussion

3.1 Suitability of groundwater for drinking and general domestic use

One of the main objectives of the groundwater quality monitoring is to assess the suitability for drinking purposes. Bureau of Indian Standards **(BIS)** formerly known as Indian Standard Institute (ISI) vide its official document IS: 10500:2012, Second edition (ICS 13.060.20) has recommended the quality standards for drinking purpose and these have been used for finding the suitability of groundwater. Based on BIS prescribed limits for different parameters, the groundwater quality around Ratlam Industrial Area has been described. **Annexure II** contains water quality data for supporting the following statements:

The Earth's temperature and that of groundwater too depends on depth. It usually stays within a narrow range year-round. In the present study, temperature of the water samples were recorded at the sampling sites between 23rd April to 26th April, 2013. Groundwater of Industrial Areas of Ratlam did not show significant fluctuation in temperature since all the values were between 23.5 to 27.5^{0}C. There was a distinctive salty or brackish taste in a few samples which might be caused by high chloride or sulfate content. A couple of locations reported disagreeable odour (Metallic smell). This may be due to presence of minerals, such as iron or copper that may be present naturally or introduced by anthropogenic activities.

Accurate documentation of water color is important as it indicates source of water and density of pollutants. In the present investigation, the true color of the water samples was documented after removing all suspended material. It was observed that despite significant differences in composition, fourteen sampling-points constituting 46.66% of the samples had yellowish brown to reddish brown color**.(Fig. 2)** Potential causes of discoloration may be correlated with untreated effluent interjected into lower horizons of soils through landfills/lagoons by industries in the area.

Fig 2:Colored samples collected from the study area
The red, yellow and brown colors indicate various degree of pollution

Environmental Pollution reports on Ratlam Industrial area published by various government and non-government organizations have reported that the groundwater in some parts of Ratlam and 12 other adjoining villages such as Dosigaon, Ghatala, Bajankhedi, Jadwasakala and Kurd. have become yellowish brown to reddish brown in color. Alcohol Plant, Jayant Vitamins, Steller Drugs and IPCA Laboratory, the Sajjan Chemicals have largely been blamed for this. A study conducted by Saha & Sharma (2006) while working with Indian Institute of Soil Science(IISS), Bhopal also

identified yellowish to reddish brown colored groundwater samples from five villages adjoining Ratlam Industrial area namely Ghatala, Bhajankheda, Jadwasa, Bhatuni, and Dosigaon with spectrometric absorbance between 0.123 to 0.956 at 400 nm wavelength. The study further pointed out that there was a striking similarity in spectral absorbance characteristics as well as high contents of chemical oxygen demand (COD), sulphate and chloride between groundwater of the affected villages and collected effluent from an Alcohol Plant operating in nearby industrial area. This indicates that effluents from the Alcohol plant might be one of the sources of groundwater contamination in the area.

The pH value ranged in between 6.82 to 9.81 and five locations namely TW_3 (9.02)**,** TW_{11} (9.05)**,** TW_{27} (8.68)**,** TW_{28} (8.64) and TW_{29} (9.81) had pH > 8.5 whereas four out of thirty-one locations namely TW_5 (6.82), TW_6 (6.92), TW_{14} (6.87) and TW_{17} (6.79) had pH values less than neutral i.e. 7. The presence of extremely alkaline groundwater in some locations [TW_3 (9.02)**,** TW_{11} (9.05)**,** TW_{27} (8.68)**,** TW_{28} (8.64) and TW_{29} (9.81)**]** may be attributed to carbonate minerals found in precipitated sedimentary rock. **(*Table* 1)**. It was observed that Industrial Areas of Ratlam and its bordering villages had EC ranging from 861 to 7934 (Avg. 3105) µS/cm at 25^0C indicating the quality of groundwater has been gravely contaminated and belongs to extremely poor quality. All the locations examined across the study area had EC values greater than BIS acceptable limit i.e. 750 µS/cm at 25^0C, accounting for the fact that more than 50% locations registered EC values greater than BIS maximum permissible limit i.e. 3000 µS/cm at 25^0C with highest as 7934 µS/cm at 25^0C in $TW_{18.}$The high EC in above mentioned wells may be attributed to accumulation of salts from wastes/ untreated effluents containing trace metals and other pollutants drained by different industries into the adjacent land thereby polluting groundwater.

Generally for most water systems, carbonates (CO_3^{2-}) are least predominant ions whereas bicarbonates (HCO_3^-) are the dominant anions. More than 50% of groundwater in the study area had carbonate ions with maximum concentration of 96 mg/l in TW_{29} location. A comparison of the findings with the BIS recommended level of bicarbonate (200 mg/l) indicated that industrial areas of Ratlam have not been influenced by the presence of bicarbonate as 90.30% locations did not have HCO_3^- ions >200 mg/l. The chloride concentration in the examined samples varied in between 57 (TW_{29}**)** to 2269(TW_3) mg/l **(Annexure II)**. The results pertaining to chloride study suggested that Industrial Areas of Ratlam and its bordering villages has great threat of Chloride pollution since 26 out of 31 examined points (83.87%) had chloride concentration greater than BIS permissible limit (250mg/l). The area was vulnerable to Sulphate pollution in groundwater since 19 out of 31 locations(61.29 %) reported SO_4^{2-} concentration more than BIS acceptable limit (200 mg/l) with minimum at 12 mg/l in Ghoshwash Village (TW_{29}) and maximum at 1510 mg/l in Swastik Industries, Sector-C (TW_9).

It is evident from the Table-1 that 10 out of 31 locations had high NO_3^- concentration (> 45 mg/l). Nitrates are harmful and can result in the "blue-baby syndrome" in which babies and pregnant women are at higher risk to the adverse effects of high nitrates. This study revealed **(Annexure II)** that the area was free of fluoride contamination of groundwater. Phosphate concentration in the study area had marked variation between 0.00 to 2.19 mg/l.

About 77.41% of the samples had calcium content greater than specified guideline of BIS (75 mg/l) with a minimum of 32 mg/l in IPCA Sport Complex (TW_{25}) and Sejawta Village(TW_{31}) whereas maximum concentration of 808 mg/l was reported in the premises of Avani Proteins (TW_3). The high amount of calcium in waters may be related to accumulation of salts from wastes/ untreated effluents containing trace metals and other pollutants drained by different industries into the adjacent land thereby polluting groundwater. An overview of data pertaining to magnesium concentration **(Annexure II)** revealed that about 87.09% samples could not meet the BIS prescribed criteria (30 mg/l). The groundwater samples belonging to area under study can be classified as hard to very hard for household use. The optimum range of hardness for household use is from 75 to 150 mg/l. If excessive hardness is confirmed (greater than 300 mg/L of $CaCO_3$), treating of water becomes necessary. An overview of the data indicated that the groundwater in and around Ratlam Industrial Area might be categorized as hard to very hard for drinking purpose as twenty nine out of thirty-one locations were found to contain Total Hardness greater than 200 mg/l which is the desirable limit set by BIS (2012).

Mean concentration of sodium in the study area was calculated as 186 with highest as 430 mg/l in TW_7 (Shanti Krishi Pipe, Sector-A) and minimum at 2 mg/l in TW_{22} (Doshi Village) respectively. Significant variations in potassium concentration has been recorded as high as 19.3 mg/l at HP1whereas TW_{18} had minimum concentration of 0.80 mg/l (Table 1). Concentration of silica ranges from 53 mg/l in TW_{14} (JVL Temple) to 2 mg/l in TW_{30} (Sejawta Village) respectively with mean value of 39 mg/l.

3.2 Chemistry of selected heavy metals

The distribution profile of heavy metals in groundwater samples collected from Industrial Area of Ratlam and its surrounding villages have been depicted in **Annexure II**.

Groundwater in industrial Areas of Ratlam and its surrounding villages do not appear to be sensitive to contamination with iron since all the observations were below the prescribed desirable limit (1mg/l) of BIS with maximum at 0.029 in $TW_{1.}$ Similarly concentrations of zinc, manganese, copper and nickel are also reported below the prescribed limits of BIS in all locations. Only one location was found to be polluted with chromium where its concentration has been found 0.142 mg/l which is 2.84 times greater than BIS maximum permissible limit (0.05 mg/l). Groundwater of Ratlam and its bordering villages indicated cadmium and lead contamination vulnerability. About 96.77 % samples (highest, 0.045 mg/l) reported cadmium concentration higher than BIS acceptable limit(0.003 mg/l) and 93.54% samples (highest, 0.168 mg/l)**,** reported lead concentrations higher than BIS acceptable Limit(0.01mg/l)

3.3 Suitability of water for irrigation purpose

The chemical data of all the water samples pertaining to Industrial Areas of Ratlam and its bordering villages, was plotted on U.S. Salinity Laboratory diagram **(Fig 3)**. U.S. Salinity Laboratory diagram classify waters for irrigation purpose based on electrical conductivity (µS/cm at 25^{0}C) and sodium adsorption ration (SAR) {Wilcox (1948)}. It is evident from the diagram that 48% of the wells were falling in the class C_4-S_1 (Very High Salinity & Low Sodium). The waters from these wells may be used occasionally under very special conditions by mixing this water with low EC water. Very high salinity tolerant crops should be grown. These waters have little/no danger of the development of sodium hazard due to low SAR values. It is noteworthy here that use of water with conductivity values above 2,250 µ mhos/cm is an exception and very few instances can be cited where such water have been used successfully.

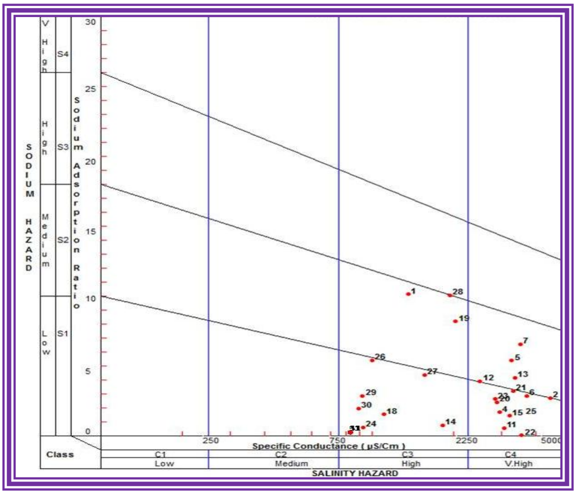

Fig 3: USSL Diagram of study area Showing Water Quality for Irrigation Purpose

Note: (*) tagged water samples not included in the USSL diagram due to limitat
software program, however their respective positions verified and discussed on the b
EC and calculated SAR values.

More salt tolerant crops can be grown with highly saline water only when the water is used copiously and the subsoil drainage is good (USDA Handbook 60, 1968)**.** The eight locations representing TW_{14}(14), TW_{18} (18), TW_{24}(24), TW_{26}(26) TW_{27}(27) TW_{29}(29) TW_{30}(30) and TW_{31}(31) were grouped under **C_3-S_1 (**High Salinity & Low Sodium) class suggesting that the water can be used on soils with good drainage. Class C_4-S_2 (Very High Salinity & Moderate Sodium) was reported in 16.12% of wells which means the water may produce an appreciable amount of sodium hazard in fine textured soils having high CEC (Cation Exchange Capacity) and low leaching conditions. Therefore it is not suitable for irrigation at all, but may be used occasionally under very special conditions by mixing this water with low EC water. Very high salinity tolerant crops should be grown in such areas. Three locations representing TW_1(1), TW_{19} (19) and TW_{28}(28) were grouped under **C_3-S_2** (High Salinity & Moderate Sodium) class, which means that these water can be used on soils with good drainage. Special management practices are required for salinity control. Salt tolerance crops may be grown.

3.4 Geochemical Classification (Hydro-Chemical Facies)

The results of the hydro chemical analysis of water samples pertaining to Industrial Areas of Ratlam and its bordering villages were plotted on Hill – Piper trilinear diagram to know the hydro-chemical facies **(Fig 4).** It was found that about 74.19 % of the samples of Ratlam Industrial Area were Alkaline earth-Chloride type (Ca-Mg-Cl) or Calcium – Chloride type of water which means these had permanent hardness since the concentration of calcium and magnesium cations exceeded sodium and potassium cations .Simultaneously the concentrations of SO_4^{2-} and Cl^- anions collectively were reported to be high as compared to CO_3^{2-} and HCO_3^- anions. The waters belonging to TW_{29}(29) and **TW_{30}(30)** locations were found to be of Alkaline earth-Bicarbonate type (Ca-Mg-HCO_3) or Calcium – Bicarbonate type of water which means these waters had temporary hardness since the concentration of calcium and magnesium cations exceeded sodium and potassium cations. Simultaneously the concentrations of CO_3^{2-} and HCO_3^- anions together were reported to be high as compared to SO_4^{2-} and Cl^- anions. The remaining 21.29% samples were found to be Alkali earth-Chloride type (Na-K-Cl) or Sodium– Chloride type which means these are saline in nature and had permanent hardness since the concentration of sodium and potassium cations exceeded calcium and magnesium cations and the concentrations of SO_4^{2-} and Cl^- anions together were reported to be high as compared to CO_3^{2-} and HCO_3^- anions together.

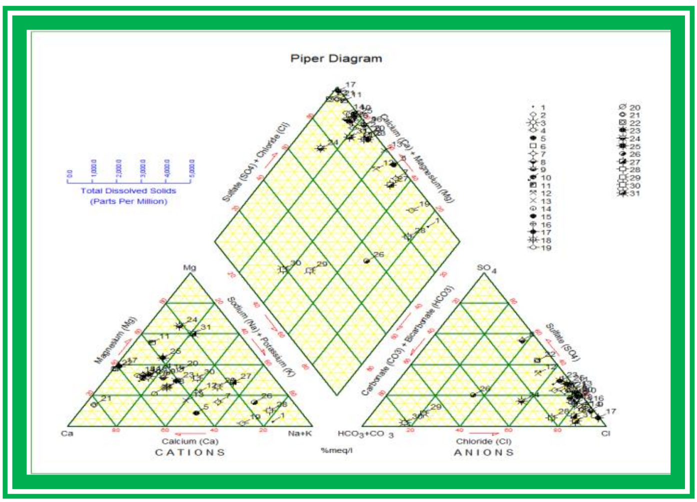

Fig 4: Piper Diagram showing Hydro-chemical Facies of Waters collected from

4. Mechanisms controlling water chemistry

Gibbs (1970) has proposed a chemical diagram for mechanisms controlling chemistry of groundwater which helps in understanding the relationship of the chemical components of with their respective aquifer lithologies. The diagram has different zones based on the water contribution of recharging precipitation, rock/ mineral weathering and evaporation/ crystallization on the hydrochemistry. The discretion of the origin of the lithology has been explained by the following assumptions **(Day *et. al*., 1998):**

(1) Atmospheric precipitation dominant waters should come from rocks which contain dominantly Na^+ and K^+, which are less soluble and producing only small quantities of TDS with moderate to high Na/ Ca+Na ratio.
(2) Rock dominant waters (mineral weathering processes) show high concentration of Ca^{2+} and Mg^{2+} and HCO_3^- resulting in moderate TDS and moderate Na/ Ca+Na ratio.
(3) Evaporation dominant waters show high concentration of Na^+ and Cl^- ions and low concentration Ca^{2+} and Mg^{2+} ions due to calcite precipitation resulting in high TDS and high Na/ Ca+Na ratio.

Gibbs used two ratios in his diagrams, representing the **Ratio-I** for cations [(Na+K)/(Na+K+Ca)] and **Ratio-II** for anions [Cl/(Cl+ HCO3)] as a function of TDS which are widely employed to assess the functional sources of dissolved chemical constituents in water.

One of the major short comings with the **Gibb's (1970)** diagram is that there is no place for waters which have been affected by domestic/industrial contamination or other sources of hydrochemical enrichment other than the three sources outlined above since many studies have shown origin of the lithology away from the three major factors, namely, precipitation dominance, rock-water interaction and evaporation-crystallization. It is probably on account of this reason that the diagram is often used together with other hydrochemical assessment diagrams such as Piper, Wilcox etc. integrated with multivariate statistical analyses.

Lastly, to know the mechanisms controlling groundwater chemistry and relationship of the chemical components of water with their respective aquifers, the chemical data pertaining to Industrial Areas of Ratlam and its bordering villages, was plotted on Gibb's diagram **(Figure 5 & 6). Gibb's ratio-1 (Cations)** ranged from 0.013 to 0.877 with an average 0.453 whereas **Gibb's ratio-2 (Anions)** varied from 0.162 to 0.987 with an average of 0.837 respectively. It is interesting to note that the results show a different phenomenon which is responsible for the chemical budget of the waters belonging to Industrial Areas of Ratlam since majority of the values plotted away from the three major factors, namely, precipitation dominance, rock-water interaction and evaporation-crystallization This clearly demonstrates that apart from the natural source, artificial factor,

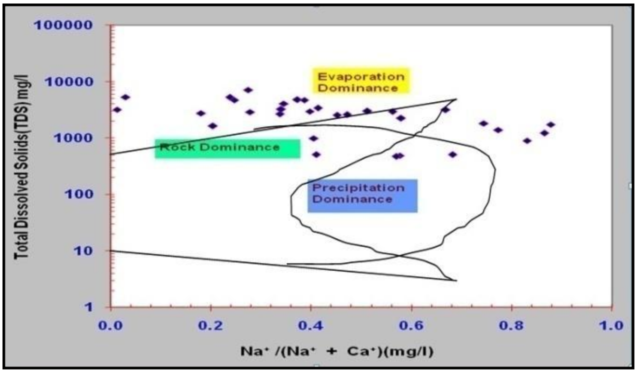

Fig 5: Gibb's Diagram illustrating the mechanism controlling groundwater chemistry (Ratio-I, Cations)

namely, anthropogenic activity have decided the dominance of the ions resulting in drastic change in chemical composition of groundwater.

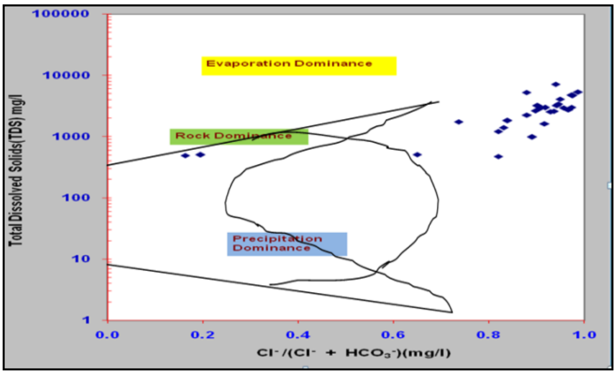

Fig 6: Gibb's Diagram illustrating the mechanism controlling groundwater chemistry (Ratio-II, Anions)

5. Conclusion

It may be concisely stated that people residing in and around Ratlam Industrial area are consuming groundwater that is not up to the BIS standards. Published literature and present study have shown that wastes from industries have polluted the groundwater very critically in Dosigoan, Ghatala, Bajankhedi, Jadwasa Khurd and Jadwasa Kalan villages and many other localities across the industrial areas of Ratlam. The continuous industrialization since last 80 years has posed a great threat for surrounding environment of the district. In all the places visited by the principal *author*, residents of the villages were quite aware of the danger in groundwater. They have to walk a great distance from Ratlam to get potable water. For bathing, washing and irrigation, people are still using the contaminated water. Thus it is imperative for the concerned authorities to take action.

Acknowledgement

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References

1. **APHA, (1995):** Standards Methods for the examination of water and wastewater.
2. **BIS (2012):** Drinking water specifications, Bureau of Indian Standards, Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi, IS 10500.
3. **Day, J. A., Dallas H. F. and Wackernagel A. (1998):** Delineation of management region for South African rivers based on water chemistry. Aquatic Ecosystem Health and Management, 1,183-197.
4. **Gibbs, R. J. (1970):** Mechanism controlling world water chemistry. Science, 170, 1088-1090.
5. **Goel, D. K.(1998):** Impact of Industrial Pollution on the Quality of Ground Water in parts of Ratlam District, MP. A report published by Central Ground Water Board, NCR, Bhopal, July, 1998.
6. **Piper, A. M. (1944):** A graphical procedure in the geochemical interpretation of water analysis. Am. Geophys. Union Trans., v25, pp 914-928.
7. **Saha, J.K. and Sharma, A. K. (2006):** Impact of the use of polluted irrigation water on soil quality and crop productivity near Ratlam and Nagda industrial area.IISS-1, Indian Institute of Soil Science, Babi Bagh,Bhopal, pp. 26.
8. **USDA Handbook 60(1968):** Diagnosis and Improvement of Saline and Alkali Soils. Indian Edition. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
9. **Wilcox, L. V. (1948):** The quality of Water for irrigation use. , US Department of Agriculture Bull., 1962, 40.Wiley and Sons. New York: 1015 Pp. **www.**blacksmithinstitute.org.

Annexure –I List of the Locations of Collecting Water Samples

S.No.	Location	Sample code	Temp. ^oC	Date of Collection	Well Address
1	Accurate Way Bridge	TW_1	24.5	23-04-2013	Well is situated in front of industry on Ratlam-Jowra Rd.
2	Shri Ram Laghu Uddhyog, Plot No.A-69, Industrial Area	TW_2	24	23-04-2013	Well is situated in the premises of industry on Ratlam-Jowra Rd.
3	Avani Proteins, Plot No. A-73, Industrial Area	TW_3	25	23-04-2013	Well is situated in the premises of industry.
4	Maruti Suzuki(Patel Motors), Plot No. 76-CPE, Industrial Area	TW_4	25.5	23-04-2013	Well is situated in the premises of industry.
5	Janta Cables, Plot No.77,Industrial Area	TW_5	27.5	23-04-2013	Well is situated in the premises of industry.
6	Prakash Nagar, Sector-A, Industrial Area.	TW_6	25.5	23-04-2013	Well (Nagar Palika's Well) is situated on barren land of Prakash Nagar at Innovative Sport Crossing .
7	Shanti Krishi Pipe, Sector-A, Industrial Area.	TW_7	23.5	23-04-2013	Well is situated in the premises of industry.
8	Sharp Power Agra, Sector-C, Industrial Area	TW_8	27	24-04-2013	Well is situated in the premises of industry.
9	Swastik Industries, Plot No.32-33, Sector-C, industrial Area	TW_9	27.5	24-04-2013	Well is situated in the premises of industry.
10	Shiv Nagar	TW_{10}	28	24-04-2013	Well(Govt. Well) is situated in the vicinity of colony Shiv Nagar located behind Alcohol Plant.
11	Khushboo Garhe Uddhyog, Plot No.261, Sector-C, Industrial Area	TW_{11}	27.5	24-04-2013	Well is situated in the premises of industry.
12	Arihant Plastic, Plot No. 85, Scetor-C, Industrial Area.	TW_{12}	27	24-04-2013	Well is situated in the premises of industry.

13	**Nakoda Mabbles, Plot No L/19, Sector-C, Industrial Area.**	**TW_{13}**	**27.5**	**24-04-2013**	Well is situated in the premises of industry.
14	**JVL Temple**	**TW_{14}**	**26.5**	**24-04-2013**	Well is situated in the premises of Temple.
15	**Shri Ram Polymers**	**TW_{15}**	**23.5**	**24-04-2013**	Well is situated in the premises of industry behind JVL Company Ltd.
16	**Kishna Nalidar Coal Industries, Plot No. 66-B, Sector-C**	**TW_{16}**	**25**	**24-04-2013**	Well is situated in the premises of industry.
17	**Mangla Industries, Plot No. 67-C, Sector-B**	**TW_{17}**	**24.5**	**24-04-2013**	Well is situated in the premises of industry.
18	**Khetan Agro(A unit of Khetan Chemicals & Fertilizes), Sejawta**	**TW_{18}**	**27.5**	**25-04-2013**	Well is located in the premises of industry which is situated in TAPPA Village (Sejawta).
19	**Sajjan Institute of Technology, Management & Science, Gourab Nagar.**	**TW_{19}**	**24.5**	**25-04-2013**	Well is situated in the premises of institute, Gourab Nagar.
20	**Vishwakarma Scrap Traders, Gourab Nagar**	**TW_{20}**	**25.5**	**25-04-2013**	Well is situated in the premises of industry, Gourab Nagar.
21	**Shri Sai Institute of Technology, Gourab Nagar**	**TW_{21}**	**27.5**	**25-04-2013**	Well is situated in the premises of institute, Gourab Nagar.
22	**Doshi Village**	**TW_{22}**	**26.5**	**25-04-2013**	Well is situated in front of Govt. Primary School, Doshi Village.
23	**Doshi Village**	**TW_{23}**	**24.5**	**25-04-2013**	Well is situated in the premises of Govt. Horticulture Nursery, Doshi Village.
24	**Sejawata Village**	**TW_{24}**	**23.5**	**25-04-2013**	Well is situated in front of Shantilal Agrawal's(MLA) house.
25	**Doshi Village**	**HP_1**	**27.5**	**25-04-2013**	Well is situated in front of Kantilal Devdra's house near to Shiv Mandir.
26	**IPCA Sport Complex**	**TW_{25}**	**27**	**25-04-2013**	Well is situated inside campus on Ratlam - Jaowra Rd.

27	**Ranawat Farm House**	**TW_{26}**	**24.5**	**25-04-2013**	Well is situated inside Farm House on Ratlam -Joura Rd.
28	**Amlela Phanta**	**TW_{27}**	**27.5**	**26-04-2013**	Well is situated in front of Chintaharan Hanuman Mandir acrossing Ratlam-Joawra road.
29	**Ghoshwash Village**	**TW_{28}**	**24.5**	**26-04-2013**	Welll (Owner- Shri Samrath Malwiya)is situated in the vicinity of Ghohswas Village behind IPCA laboratory.
30	**Ghoshwash Village**	**TW_{29}**	**245**	**26-04-2013**	Well is situated inside Hariyana- Alwar-Ratlam Dhaba on Ratlam-Joawra Rd.
31	**Sejawata Village**	**TW_{30}**	**26.5**	**26-04-2013**	Well is situated near Deshi Wine shop.
TW=Tube Well, HP= Hand Pump					

Annexure -I1: CHEMICAL ANALYSIS RESULTS SHOWING MAJOR IONS CONCENTRATIONS IN THE STUDY AREA.

S.No.	pH	EC (µS/cm at 25^0C)	$CO3^{-2}$	$HCO3^{-1}$	Cl^{-1}	$SO4^{-2}$	$NO3^{-1}$	F^{-1}	$PO4^{-3}$	TH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SiO_2	Fe	Zn	Mn	Cd	Cu	Ni	Cr	Pb
1	7.53	1355	0	67	305	175	10	0.9	0	120	40	5	255	0.9	18	0.03	0.095	0.000	0.033	0.007	0.000	0.001	0.168
2	8.24	4530	12	67	1234	375	68	0.3	0	1700	488	117	255	2.3	34	0.008	0.027	0.000	0.042	0.009	0.000	0.002	0.095
3	9.02	7934	36	146	2269	500	19	0.5	1.63	3300	808	311	300	5.6	51	0.01	0.038	0.05	0.045	0.007	0.004	0.005	0.000
4	8.25	2950	12	85	745	200	55	0.5	1.87	1180	264	126	130	4	43	0.01	0.035	0.000	0.039	0.003	0.000	0.000	0.098
5	6.82	3270	0	37	801	315	37	0.7	2.18	840	280	34	355	4.9	43	0.01	0.032	0.000	0.035	0.003	0.000	0.000	0.000
6	6.92	3790	0	55	950	350	48	0.4	2.1	1360	348	119	240	5.6	41	0.01	0.039	0.000	0.033	0.006	0.000	0.000	0.075
7	8.24	3520	12	92	851	370	18	0.4	1.49	820	216	68	430	4	46	0.005	0.026	0.000	0.028	0.000	0.000	0.000	0.096
8	8.33	5830	60	104	752	1510	37	0.8	2.07	2500	612	236	185	5.1	45	0.009	0.047	0.02	0.000	0.006	0.008	0.000	0.106
9	7.55	5330	0	43	1603	250	17	0.3	1.97	2040	480	204	280	4.8	45	0.008	0.043	0.00	0.022	0.007	0.000	0.000	0.133
10	8.27	5220	12	37	1433	475	50	0.2	0.29	2220	560	199	180	2.8	45	0.007	0.024	0.00	0.021	0.006	0.000	0.142	0.124
11	9.05	3060	0	24	695	350	52	0.4	0	1310	216	187	45	2.5	22	0.001	0.015	0.00	0.017	0.004	0.000	0.000	0.14
12	8.38	2500	48	67	489	420	12	0.6	0	720	176	68	240	2.1	46	0.000	0.011	0.00	0.019	0.003	0.000	0.000	0.141
13	8.05	3350	0	24	865	375	37	0.3	0	1000	288	68	300	2.5	48	0.000	0.023	0.00	0.022	0.001	0.000	0.000	0.134
14	6.87	1814	0	43	468	80	25	0.8	2.19	800	200	73	48	3.1	53	0.000	0.026	0.00	0.024	0.001	0.000	0.000	0.139
15	8.23	3210	12	79	766	250	94	0.7	2.19	1340	320	131	118	5.4	47	0.000	0.025	0.00	0.027	0.001	0.000	0.000	0.141
16	7.51	5250	0	43	1525	350	54	0.9	0.15	2000	440	219	275	2.1	41	0.003	0.013	0.07	0.028	0.006	0.000	0.000	0.136
17	6.94	5940	0	24	1844	150	24	0.4	0.02	2500	604	241	16	2.4	45	0.005	0.014	0.000	0.021	0.005	0.000	0.000	0.128
18	7.92	1101	0	37	298	75	28	0.5	0.03	400	104	34	70	0.8	3	0.000	0.008	0.000	0.013	0.000	0.000	0.000	0.097
19	8.29	2030	12	92	475	225	14	0.7	0	300	112	5	325	1	32	0.000	0.017	0.000	0.01	0.000	0.000	0.000	0.099
20	7.62	2880	0	49	709	250	19	0.4	1.96	1020	200	126	175	3.4	50	0.000	0.021	0.000	0.008	0.000	0.000	0.000	0.094
21	7.99	3310	0	73	808	350	19	0.2	1.53	1100	376	39	243	4.5	36	0.000	0.023	0.000	0.013	0.001	0.000	0.000	0.121

Annexure -I1: CHEMICAL ANALYSIS RESULTS SHOWING MAJOR IONS CONCENTRATIONS IN THE STUDY AREA.

S.No.	pH	EC (µS/cm at 25^0C)	$CO3^{-2}$	$HCO3^{-1}$	Cl^{-1}	$SO4^{-2}$	$NO3^{-1}$	F^{-1}	$PO4^{-3}$	TH	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	SiO_2	Fe	Zn	Mn	Cd	Cu	Ni	Cr	Pb
22	8.25	3560	24	43	390	450	68	0.4	0	1120	280	102	2	1.7	44	0.000	0.004	0.000	0.011	0.000	0.000	0.000	0.123
23	8.31	2830	12	49	645	390	57	1.0	0	995	232	101	190	1.1	41	0.000	0.002	0.000	0.013	0.001	0.000	0.000	0.118
24	8.32	925	24	104	191	75	5	0.8	0	400	40	73	27	0.8	45	0.000	0.000	0.000	0.013	0.001	0.000	0.000	0.112
25	7.23	3590	0	49	794	425	220	0.7	0	1500	280	195	125	19.3	48	0.000	0.000	0.000	0.017	0.000	0.000	0.000	0.119
26	8.41	1001	24	214	121	95	40	1.4	0	160	32	19	156	1	42	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.12
27	7.73	1555	0	92	447	50	21	1.3	0	360	56	54	189	1.6	38	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.137
28	8.68	1932	24	183	511	52	27	1.0	0	220	48	24	340	3	42	0.000	0.000	0.000	0.02	0.004	0.000	0.000	0.153
29	8.64	921	60	293	71	40	35	1.0	0	240	48	29	101	1.5	37	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.162
30	9.81	890	96	293	57	12	38	0.7	0	280	56	34	75	1.2	48	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.168
	7.77	861	0	55	248	13	26	0.4	0	340	32	63	41	1.2	2	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.134

Impact of organic industrial pollutants on groundwater quality at village Bhaneda Khemchand, Block Nanauta, District Saharanpur, UP

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Abstract

Water pollution is the contamination of water bodies e.g. lakes, rivers, oceans, aquifers and groundwater. This form of environmental degradation occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds. Organic water pollutants include detergents, disinfection by-products such as chloroform found in chemically disinfected drinking water, food processing waste which can include oxygen-demanding substances, fats and grease, insecticides and herbicides, a huge range of organo halides and other chemical compounds, petroleum hydrocarbons including fuels (gasoline, diesel fuel, jet fuels, and fuel oil) and lubricants (motor oil), and fuel combustion byproducts, volatile organic compounds such as industrial solvents emitted as a result of improper storage etc. The organic waste discharged from the surrounding industries has impacted groundwater quality indicated in terms of BOD as high as 74 mg/l & COD as high as 880 mg/l in groundwater of the area.

1.Introduction

Water pollution affects the entire biosphere – plants and organisms living in these bodies of water. In almost all cases the effect is damaging not only to individual species and population, but also to the natural biological communities. Water pollution is a major global problem which requires monitoring and evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells).

The village Bhaneda Khemchand has 850 voters & 200 houses (approx) and most of drinking water requirement is met through groundwater using Hand pumps, IM II & Submersible Hand pumps (depth varies from 150 feet to max 300 feet) . No piped water supply is available in the village. Krishnainadi passes through village Bhaneda Khemchand, and meets Hindon & Kali at Barnava in Baghpat. The Krishnainadi carries the effluents of Kisan Sahkari Chini Mill & Distillary and SMC Foods Ltd (a Milk Product Factory) situated about 3 km north of Bhaneda Khemchand village. The nadi containing the industrial effluents is depicted in F**ig-1.**

1.1Hydrogeology of area

Saharanpur district lies in the northern most part of the Uttar Pradesh. The village Bhaneda Khemchand where the quality assessment has been carried out falls in the central part of Nanauta block of the District Saharanpur. Two industries namely Kisan Sahkari Chini Mill

& Distillery and Sri Madusudan Ghee are located North and NNW of village within 4-kilometer.

Figure-1 Krishnai nadi before entering the village Bhaneda Khemchand

1.2 Geology

The area exhibits distinct hydrogeological conditions due to its variegated geological settings. The area is underlain by Quarternary sediments overlying Siwaliks group of formations. The general stratigraphic sequence of the formations met within the area is presented below in **table-1**.

Table-1 Regional stratigraphic sequence of the area

Formations	Age	Geology
Younger alluvial plain in declining flood plains.	Recent	Sands & clays
Older alluvial mains (including Bhabar & Tarai).	Upper pleistocene to recent	Boulder, pebbles gravel, sands, silt and
Upper Siwaliks	Upper Pliocene- middle pleistocene	Sand stone with boulders cobbles, conglomerate and
Middle Siwaliks	Middle miocene to lower Pliocene	Sand stone with associated clays and pebbles beds.

The area is underlain by Older alluvium comprising of chiefly pebbles, gravel, sands, silt of various grades and clay. The older alluvial plains show flat to undulating topography characterised by sediments brought by rivers Yamuna and Ganga.

1.3Depth to water level

The pre-monsoon depth to water level in the block ranged from ranged from 3.46 mbgl (Nanauta block) to 9.45 mbgl (Jaroda Panda). The water level in the eastern part of the block is deeper, greater than 5 mbgl whereas in the western part of the block shallower water levels are observed(less than 5.0 mbgl). The northwestern corner of the block also shows deeper water levels.

On the basis of trend of depth to water contours in the area, the water level in and around the village may be extrapolated to vary between 5 mbgl and 7.0 mbgl.

1.4 Water Table Elevation

The Water table elevation map has been prepared by utilising the reduced level of the premonsoon depth to water level in the area. The contour interval has been kept as 5m between two successive contours. The perusal of the map shows that the general groundwater flow direction in the area and specifically around the village in question is from North to South. The Water table elevation map is presented below as **Fig 2**.

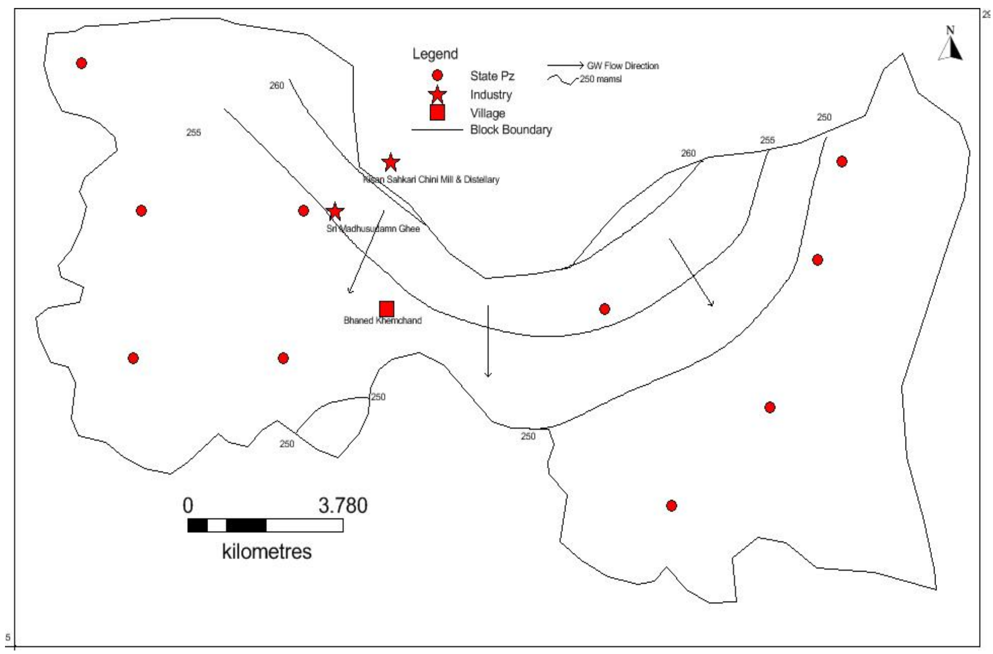

Fig 2: Map showing water table elevation around village Bhaneda Khemchand

2. Sample Collection & Methodology

A total of 20 samples were collected from six locations in the village Bhaneda Khemchand as per Standard Methods in polythene bottles. The samples for BOD COD were collected in Glass bottles. Samples for trace metals were collected & treated with 1:1 Nitric acid at sampling sites. A few parameters along with samples brought by the villagers were analyzed on the spot for pH, EC TDS .A brief introduction was given to the villagers regarding the quality of water of the area on the basis of the analyses done on the spot. For other parameters, the samples were analyzed in details as per standard methods (APHA) in the Chemical Lab of CGWB, NR, Lucknow. The location, latitude and longitude were recorded on the spot using digital high quality GPS of Gramin make. **Table 2** shows the list of sampling points. **Fig 3** depicts the sampling points in Baneda Khemchand village.

Table 2: Details of groundwater samples collected from Bhaneda Khemchand village

S. No.	Location	LONGITUDE			LATITUDE			Source ofsample
1	In the house of Gram Pradhan	77^{0}	26 '	37.97 "	29^{0}	40 '	59.18 "	Private H/P
2	Prathamikvidyalaya	77^{0}	26 '	37.09"	29^{0}	40 '	58.12 "	H/P IM-II
3	Infront of Sh. Janaru house, near pulia	77^{0}	26 '	44.44 "	29^{0}	40 '	57.41 "	H/P IM-II
4	Infront of Dr Satpal Ex Pradhan house	77^{0}	26 '	44.93 "	29^{0}	40 '	54.10"	H/P IM-II
5	In the house of Dr Satpal Ex Pradhan	77^{0}	26 '	44.93 "	29^{0}	40 '	53.10"	Submersible pump
6	In the house of Sh. Raju, near bridge	77^{0}	26 '	43.53 "	29^{0}	40 '	51.19 "	Private H/P

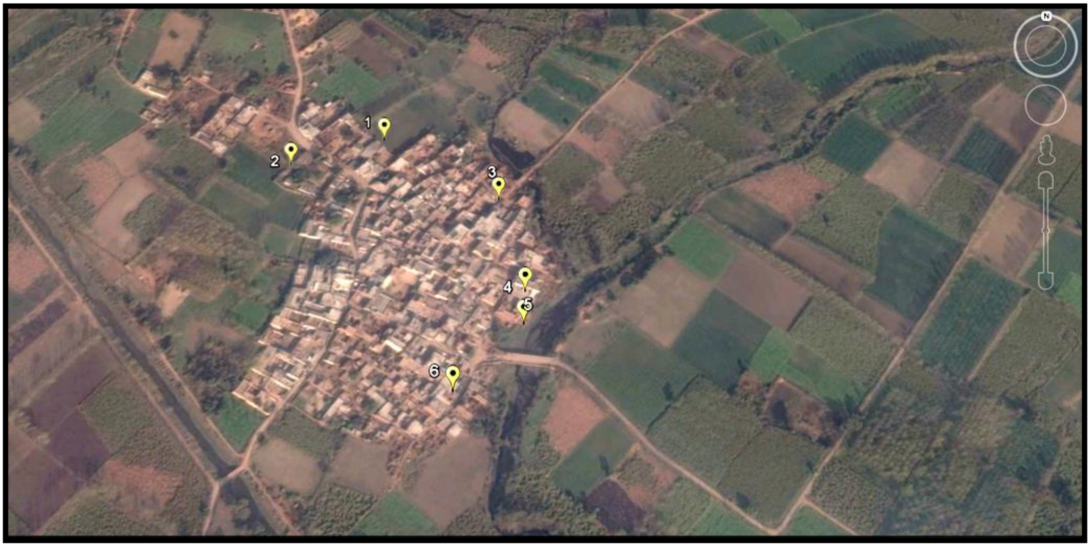

Fig-3 Location Map of sampling Points in BhaneraKhemchand Village, Nanauta Block, Saharanpur District, UP

Major drains directly discharge effluent in to the Krishnainadi. The impact of the effluent in the phreatic aquifer around the village Bhaneda Khemchand, is shown in **Figures 4 & 5**) -

Figure 4 & 5 Water immediately and after thirty minutes of withdrawal from Hand pump

3. Results

The results of groundwater sampling done for Heavy Metals, Basic Parameters and Chemical Oxygen Demand and Biochemical Oxygen Demands are given in tables 3, 4 & 5 respectively.

Table 3:Chemical analysis results for heavy metals in groundwater samples from Bhaneda Khemchand village

Sample No	Iron	Manganese	Lead	Cadmium	Silver	Copper	Zinc
1	0.450	0.305	Nd	Nd	Nd	0.024	1.320
2	1.800	0.410	0.002	Nd	Nd	0.031	1.080
3	1.200	0.200	Nd	Nd	Nd	0.013	1.450
4	1.550	0.305	0.003	Nd	Nd	0.028	1.210
6	2.800	0.829	0.004	Nd	Nd	0.016	1.870

Concentration in mg/l

Table 4:**Chemical analysis results for major parameters in groundwater samples from Bhaneda Khemchand village**

SN	pH	EC μS/cm	CO_3	HCO_3	Cl	F	NO_3	SO_4	TH	Ca	Mg	Na	K	SiO_2	PO_4
1	7.147	1010	0	476	21	0.61	8.5	59	305	84	23	83	7.1	42	nd
2	7.371	740	0	360	14	0.55	0.4	42	270	60	29	33	6.1	42	nd
3	7.683	550	0	299	11	0.28	0.3	3.2	185	38	22	31	5.7	38	nd
4	7.483	720	0	360	11	0.46	0.6	37	245	64	21	44	6.2	41	nd
5	7.007	2120	0	848	96	0.64	20	190	700	154	77	80	108	52	nd
6	6.899	2400	0	903	135	0.37	10	240	800	170	91	120	77	47	nd

Concentration in mg/l except for pH & EC

Table-5: **BOD & COD in groundwater samples from Bhaneda Khemchand Village**

Sample No	BOD	COD
1	74	730
3	38	880
4	60	200
6	70	160

Concentration in mg/l

3.1 Discussions (based on Groundwater quality results)

It has been observed that all the basic chemical parameters (pH, EC, CO_3, HCO_3, Cl, NO_3, SO_4, F, TH, Ca, Mg, Na, K & PO_4) are within the acceptable limits of BIS(IS:10500-2012). The heavy metals (Manganese, Iron, Copper, Cadmium, Zinc, Lead, Silver) analysis show that concentration of Iron and Manganese in most groundwater samples are more than the permissible limits (>1 mg/l for Fe as per BIS; IS:10500-2012). The high concentration of iron & manganese in the water may be due to geogenic contamination.

Biochemical Oxygen Demand (BOD) is a measure of the quantity of dissolved oxygen in milligrams per litre necessary for the decomposition of organic matter by microorganisms such as bacteria. The presence of BOD > 3 mg/l is unsuitable for drinking purposes (IS: 2296, 1982, **Annexure I**).In the area it ranges from **38 to 74** mg/l showing that the contamination of groundwater by the industrial effluent is dominated by organic contamination.

COD is generally not found in groundwater and it is measure of the amount of biologically active substances such as bacteria & biologically inactive organic matter in water. It is the oxygen equivalent of the total organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant such as dichromate. In the village Bhaneda Khemchand, it ranges from **160 to 880** mg/l. The presence of organic matter is also visible in the samples depicted in figures **3 & 4**. The industrial effluent disposal limit of COD to inland surface water is 250 mg/l max **(Annexure II)**. The high value of COD in groundwater of village Bhaneda Khemchand indicates the organic pollution by industrial effluents that are being discharged by nearby industries.

BOD and COD are two common measures of water quality that reflect the degree of organic matter pollution of a water body. It is generally not present in groundwater however leaching of organic matter to groundwater increases the BOD & COD values.

It has been observed that the Hand pumps, IM II & Submersible Hand pumps up to the depth of 300 feet was found to be highly contaminated by organic matters and in few cases water was found to be yellow coloured.

3.2 Main Sources of Pollution

The major water polluting industries situated in the catchment area of the krishnainadi and discharging effluent during its course near BhanedaKhemchand village are Kishan Sahkari Chini Mill & distillery and SMC Foods which are located within 3 km(approx.) towards North direction of the village.The pollutants are organic in nature as there is no increase in concentration of inorganic constituents / metallic parameters in groundwater of the village whereas oxygen demand (Chemical / Biochemical) has increased abnormally.

4. Conclusion:

As the upper phreatic zone up to 300 feet is being contaminated by the organic pollutants, the deeper aquifer beyond 300 ft should be used for drinking water. Though there is no piped water supply for drinking/ domestic purpose, the villagers should be provided with deep tube well for potable drinking water.

The industries in the nearby area should have proper and working Effluent Treatment Plant(ETP) to avoid further contamination of groundwater in deeper aquifers.

The river near Bhaneda Khemchand village should be properly lined to avoid the leaching of pollutant organic matters to the phreatic aquifer.

The Krishnai nadi can be revived only if arrangements are made to release fresh water at various points from canals in to the river.

Acknowledgement

The authors are thankful to the Chairman, CGWB, and Regional Director CGWB, NR, Lucknow for allowing the above study. They are also thankful to their fellow Hydrogeologists for helping in preparation of this paper.

References

1. APHA, Standard Methods for the Examination of Waste and Wastewater, 19th ed., American Public Health Association, Washington, DC. , 1995
2. BIS IS: 10500 Indian Standard Drinking Water Specification, Second revision. Bureau of Indian Standards, New Delhi, India, 2012
3. BIS IS: 2296 Indian Standard Drinking Water Specification, Second revision. Bureau of Indian Standards, New Delhi, India, 1982

Annexure - 1

Water Quality Standards (IS: 2296, 1982)

SN.	**Characteristics**	***Designated best use***				
		A	**B**	**C**	**D**	**E**
1	Dissolved Oxygen (DO)mg/I, min	6	5	4	4	-
2	BiochemicalOxygendemand(BOD)mg/I, max	2	3	3	-	-
3	Total coliform organisms (MPN/100ml, max)	50	500	5,000	-	-
4	Total dissolved solids, mg/I, max.	-	-	-	-	2,100

Class-A: Drinking Water Source without conventional treatment but after disinfection.

Class-B: Outdoor bathing.

Class-C: Drinking water source after conventional treatment and disinfection.

Class-D: Propagation of Wild life and Fisheries.

Class-E: Irrigation, Industrial Cooling.

Annexure -II

General Standards for discharge of Environmental Pollutants Part A - Effluent (EPA Rule 1986, Schedule -VI)

Parameter	**Standards**			
	Inland surface water	**Public Sewers**	**Land for irrigation**	**Marine coastal areas**
BOD(mg/l)	30	350	100	100
COD(mg/l)	250	-	-	250

Study on water quality trends in groundwater of Digboi, Assam

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Abstract

Water is the most vital element for the survival of life on earth. Industrial establishments are generally associated with the exploitation of nature and its negative impact on the surrounding areas. Water has become one of the emerging environmental issues. Issues of water quantity, quality and water stress are the three major concerns and are vital to the quality of life on earth. Monitoring of water quality facilitates evaluation of nature and extent of pollution, effectiveness of pollution control measures, water quality trends, prioritization of pollution control efforts and in planning water conservation measures. The present study attempts to illustrate the water quality trends of Digboi in Tinsukia district, Assam where one of the oldest and largest refineries in Asia i.e. the "*Digboi Refinery*"is located. Various physico-chemical parameters viz. pH, turbidity, total dissolved solids, electrical conductivity, alkalinity, hardness, nitrate, chloride, sulphate, fluoride, sodium, potassium and total iron content were analyzed. Among the various parameters recorded, total dissolved solids varied from 15.7 mgL^{-1} to 577 mgL^{-1}; pH ranged from 5.67 to 8.4; electrical conductivity varied from 28.9 µs cm^{-1} to 1155 µs cm^{-1}; chloride values from 10.63 mgL^{-1} to 77.8 mgL^{-1} ; total alkalinity varied from 30.7 mgL^{-1} to 207 mg L-1; total hardness from 52.0 mgL^{-1} to 300.0 mgL^{-1}; sulphate values varied from 1.60 mgL^{-1} to 47.8 mgL^{-1}; nitrate from 0.5 mgL^{-1} to 2.9 mgL^{-1} ; fluoride values ranged from 0.06 mgL^{-1} to 0.68 mgL^{-1}; sodium from 1.39 mgL^{-1} to 56.4 mgL^{-1}; potassium value from 0.40 mgL^{-1} to 22.9 mgL^{-1}; while iron values ranged from 0.11 mgL^{-1} to 4.40 mgL^{-1}.

Keywords: Industrial cluster; Water quality trends; Digboi; Assam; Digboi Refinery.

1. Introduction

Industrial establishments are generally associated with the exploitation of nature and its negative impact on the surrounding areas. The Upper Assam Basin is a poly history basin from where hydrocarbons are being produced for more than a century (Mandal et al 2013). When the British discovered the presence of oil in Digboi area of Tinsukia district, Upper Assam in the year 1825, people could hardly think of its hazardous impact on surrounding forest and water resources and agricultural lands. In 1857, Goodenough of Mckillop Stewart and Company, a Britain-based firm, began drilling in the area, the first successful attempt for extracting oil in Asia. It is said by legends that the town "Digboi" was named after Goodenough's constant urgings to his workforce "*Dig boy, dig*" (Thakuria 2001). Digboi [**Fig1**] was declared as one of the problem areas in the country due to the impact of industrial effluents and emission from Digboi Refinery. The Digboi refinery is run by the Indian Oil Corporation which is the largest commercial enterprise of India. The refinery

produces 650,000 metric tonnes of crude oil every year and its products include high quality wax and important petrochemicals. It produces the conventional products such as LPG, Motor Spirit, Mineral Turpentine Oil, Superior Kerosine, High Speed Diesel, Light Diesel Oil, Furnace Oil, Bitumen, and Raw Petroleum Coke besides producing some speciality products such as Solar Oil, Jute Batching Oil and most importantly Paraffin Wax. (www.iocl.com/aboutus/digboirefinery.aspx). Even though the company has their own effluent treatment plant (ETP), it is seen to have little effect on the control of pollution in the region. Thus, the hundred year old refinery has been a major cause of pollution to the nearby areas. In this connection, the Pollution Control Board, Assam served a closure notice on the Refinery on February 12, 2001, under section 33A of the Water (Prevention and Control of Pollution) Act 1974 for releasing highly toxic effluents including oil and grease into water bodies. Digboi refinery is located in north eastern part of Assam in Tinsukia district. It occupies parts of north and southern flanks of Digboi hill at Digboi. The hill trends in ENE-WSW to NE-SW direction. The area falls in the Survey of India toposheet No. 83 M/11. Digboi is well connected by rail and road with rest of the country.
The objective of this paper is to study the groundwater quality trends in Digboi, Assam during 2007 to 2014. A detailed study by CGWB during 2001-2002 is again discussed in the paper. Further, various work carried out by other researchers in the field related to water quality in Digboi, Assam are studied and their findings are incorporated in the paper.

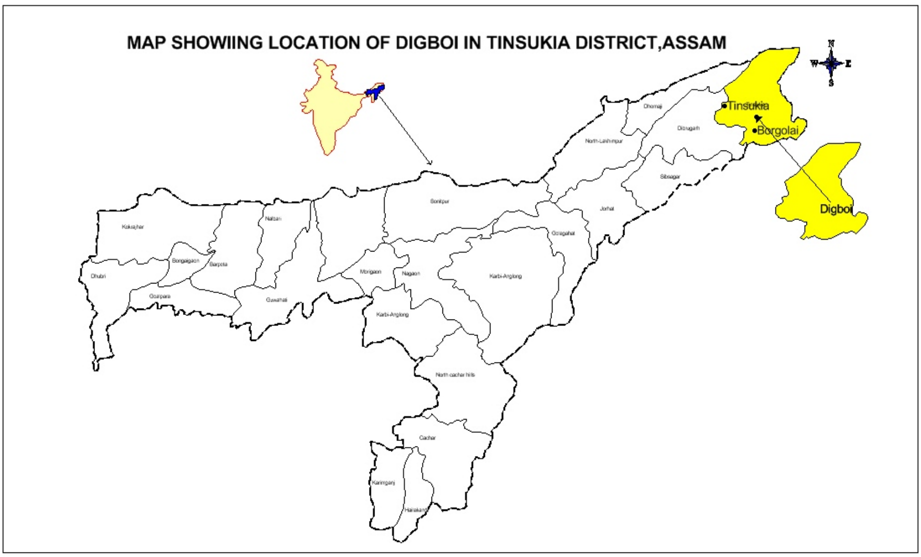

Fig 1. Location map of Digboi, Tinsukia district, Assam

1.1 Hydrogeology of the area

Groundwater occurs under unconfined to semi-confined condition in unconsolidated sediments and semi-confined condition in semi-consolidated sediments. Groundwater flow follows the surface topography of the area and is towards NW in north and S to SW in south of Digboi. From available data, groundwater flow gradient is calculated as 1.956 m/km in NW and 1.17-2.93 m/km in SSW directions. Depth to water levels of dug wells ranged from 1 to 7m bgl (average 2 to 4 m) during lean period. Piezometric levels at shallow depth ranged from 2 to 3 m bgl and at deeper depth structures show 3 to 13 m bgl. Two National Hydrograph stations (NHS) monitored by Central Ground Water Board at Digboi town situated in Tertiary sediments with a very thin veneer of alluvium shows a declining trend of about 1-2 meter during the last decade. Groundwater fluctuation is recorded to be 3.22m bgl at Digboi (NHS) area during 2014 for alluvial formation which indicates high infiltration character of underlying formations [**Fig2]**. Tinsukia National Hydrograph station (NHS) has shown High Iron Concentration with high Water Level Fluctuation **[Fig.3A]** but in Digboi National Hydrograph station (NHS) there is no symmetrical relation with Iron and WL fluctuations **[Fig.3B].**

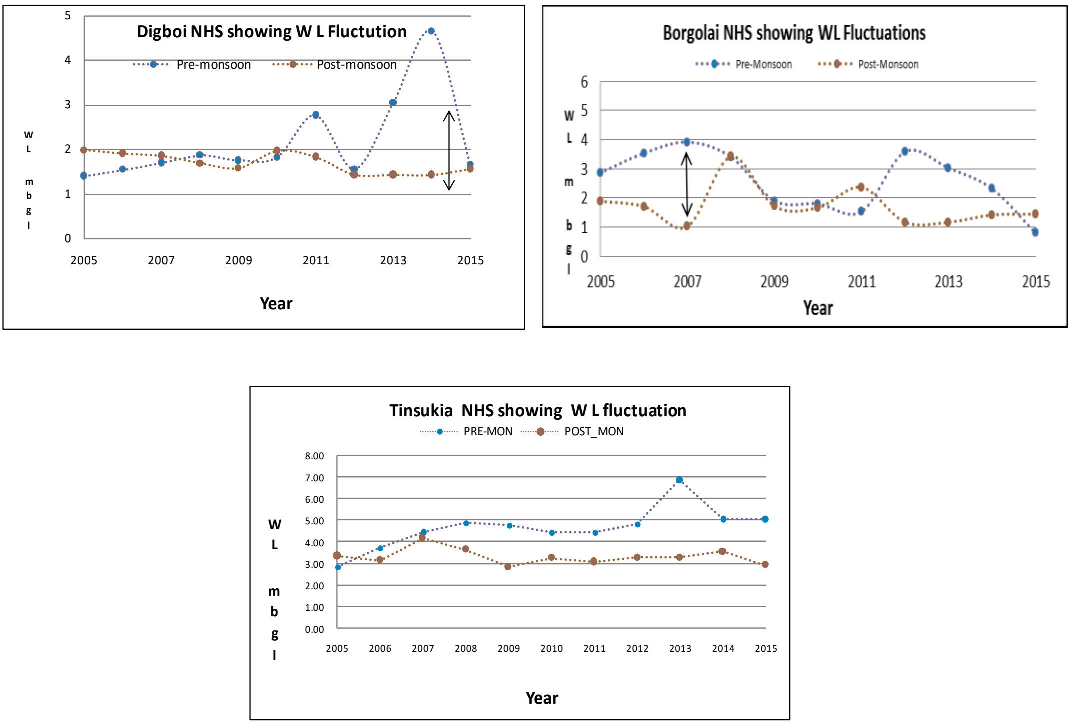

Fig 2: Diagram showing Water level fluctuation

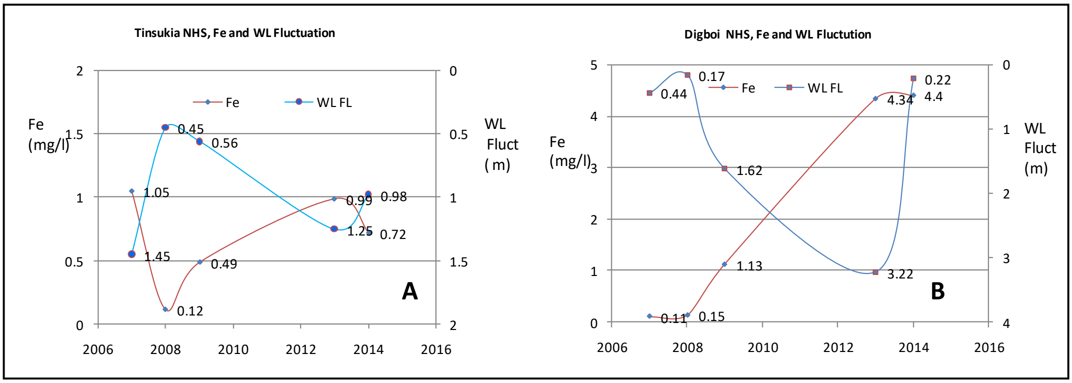

Fig. 3. (A) Relationship between water level fluctuation (WL) and iron (Fe) in Tinsukia district; (B) relationship between water level fluctuation (WL) and iron (Fe) in Digboi district

2. Literature review on groundwater quality studies of Digboi area

Periodic monitoring of water quality is of utmost importance in pollution prone areas to assess the change in quality of water with time so that planning for alternative sources of potable water can be made thereby reducing the long term health effects to the public. Various studies have been carried out to find out the effects of industrial effluents to groundwater quality. Sahoo et al.(2013) studied the effects of underground disposal of formation water in 15 disposal wells of 3 oil fields in Assam and concluded that the groundwater quality in the oil fields of Dibrugarh and Tinsukia districts of Assam have not been contaminated due to underground disposal of formation water in this area with the prevailing practice of disposal. Prakash et al. (2011) studied the impact of waste water discharge in groundwater in and around Digboi. It was observed that the COD content was very high in all the study area where waste water from refinery was collected in the pit-dug wells (**Table 1**). Further Bordoloi et al. (2015) studied the correlation between different water parameters and phytoplankton data in which high value of COD was reported. Central Ground Water Board, North Eastern Region had taken up some important studies such as “Feasibility Report on Assessment of Ground Water Potential for Construction of Deep Tubewell in Digboi Refinery Area” in 2001-2002 **(Annexure- I)** and “A short term study of Ground Water flow regime in the surrounding area of the Sludge Pit within Refinery Complex, Digboi, District - Tinsukia, Assam” in 1993. The studies revealed that groundwater quality was contaminated with metal and heavy metal viz. iron, manganese and lead.

Table 1. Values of pH, EC and Chemical Oxygen Demand (COD) of various type of source in Digboi, Assam				
Type of Source	**pH**	**Electrical Conductivity (EC, µS cm^{-1})**	**Chemical Oxygen Demand (COD, mg L^{-1})**	**Reference**
Effluent receiving stream (S1)	9.4	392.2	216.8	[Bordoloi et al. (2015)]
Refinery discharge, Dug well 1	6.79	994	4600	[Prakash et al. (2011)]
Refinery discharge, Dug well 2	3.02	2130	6400	[Prakash et al. (2011)]
Refinery discharge, Dug well 3	2.03	5740	5040	[Prakash et al. (2011)]

3. Analysis of groundwater samples for potability study

Analysis of samples was carried out as per the standard practice stipulated by APHA guidelines. The parameters analysed were pH, conductivity, turbidity, alkalinity (CaCO3), TDS, chloride, total hardness, calcium, magnesium, sulphate, nitrate, sodium, potassium, fluoride and iron.The water samples were collected from three monitoring wells viz. Digboi, Tinsukia and Borgolai for five years.(**Table 2**)

The analysed values were compared with BIS guidelines and it was observed that the physico-chemical parameters of water samples collected from different wells in and around Digboi during five years i.e.2007, 2008, 2009, 2013 and 2014 showed pH in the range 5.67 to 8.4. It was observed that most of the samples collected were alkaline in nature except in few locations. The electrical conductivity was found to vary in the range of 28.9 µs cm^{-1} to 1155 µs cm^{-1}. It was observed that the sample from Borgolai showed the lowest electrical conductivity. The values of TDS were found to be in the range of 15.7 mgL^{-1} to 577 mgL^{-1} while the nitrate values ranged from 0.5 mgL^{-1} to 2.9 mgL^{-1}. Fluoride values ranged from 0.06 mgL^{-1} to 0.68 mgL^{-1}; sodium ranged from 1.39 mgL^{-1} to 56.4 mgL^{-1}; potassium value ranged from 0.40 mgL^{-1} to 22.9 mgL^{-1}; chloride values ranged from 10.63 mgL^{-1} to 77.8 mgL^{-1}. The values of total hardness ranged from 52.0 mgL^{-1} to 300.0 mgL^{-1}. The values of all the physico-chemical parameters viz. pH, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), Total hardness (TH), carbonate (CO_3^{-2}), bicarbonate (HCO_3^-), chloride (Cl^-), fluoride (F^-), nitrate (NO_3^-)and sulphate (SO_4^{-2}) are well within the permissible limits of BIS.

The concentration of iron in most of the wells was above the permissible limits and ranged from 0.11 mgL^{-1} to 4.40 mgL^{-1} (maximum permissible limit is 1.0 mg/L BIS,2012,**Fig 4**).

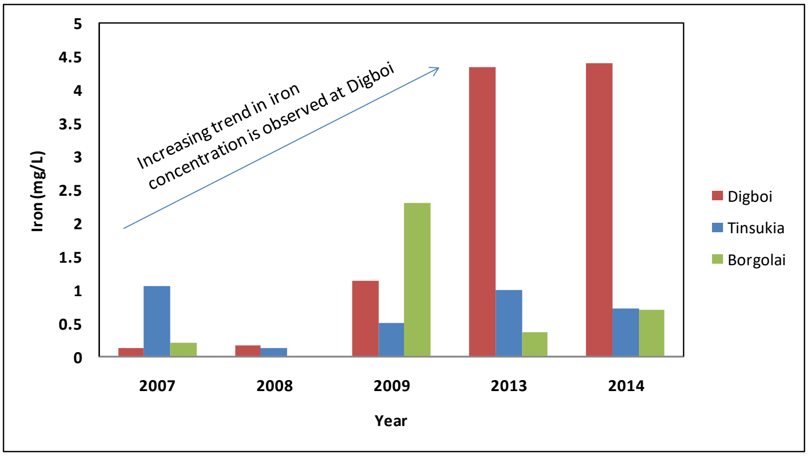

Fig 4. Histograms showing trends of iron contamination in Digboi, Tinsukia district, Assam

Concentration of Cd, Cr and Zn are within the permissible limit. However the concentration of lead (Pb), iron (Fe) and manganese (Mn) in some dug wells under examination were found to be above the prescribed maximum permissible limit. **(Table 3)** Hence, it is evident that there are no sharp changes in chemical constituents in groundwater of Digboi except slight increase in values of some parameters. Further, from the literature survey, the presence of heavy metals in groundwater in and around Digboi is confirmed which needs thorough research by carrying out regular monitoring and assessment of the wells and by increasing the number of sampling points located at Digboi.

4. Conclusion

The analysis of groundwater in Digboi and nearby areas and its comparison with data from previous studies carried out by CGWB and others revealed that groundwater quality in respect of physicochemical parameters in Digboi is deteriorating slowly with the passage of time. The trace heavy metal analysis of groundwater from monitoring wells indicates their concentration above the maximum permissible limits in some locations. The high concentration of iron above the permissible limit prescribed by Indian Standard is observed in groundwater samples collected during pre-monsoon season where volume of water is very less. However, concentration of iron in the same area will be lesser during monsoon season.

Previous studies also point to the high concentration of Mn & Pb in groundwater samples which may be attributed to leakage from unprotective domestic sewage and industrial effluents as most of the heavy metals and in particular the lead metal is generated from street dust. There is a need for immediate attention to restore the water quality in this area.

References

1. APHA (2012), Standard method for the examination of the water and wastewater. 22nd edition, American Public Health Association, New York, U.S.A
2. BIS (2012),Indian Standard Drinking Water –Specification(Second Revision) IS 10500: 2012
3. Bordoloi D, Baruah PP., (2015), Phytoplankton diversity in Digboi oil refinery effluent receiving stream of Assam, India, Bangladesh J. Bot. 44(2), pp 163-175.
4. Centre for Environment Education(1997),A Directory, North East, NGOs in Environment Education in North East India:, Chapter IV, Exploring Environmental Movements in Assam: Some Case Studies, p 91.
5. CGWB(1993): A short term study of ground water flow regime in the surrounding area of the sludge pit within refinery complex, Digboi, District -Tinsukia, Assam
6. CGWB (2001): Feasibility report on assessment of ground water potential for construction of deep tubewell in Digboi Refinery area, technical report: series c, no. 11/2001
7. CPCB(1995). Ground Water Quality in Problem Areas: status report. New Delhi: CPCB, Ministry of Environment and Forests
8. The Indian oil, the Energy of India. https://www.iocl.com/aboutus/digboirefinery.aspx
9. Kumar P, Sanyal S., Sinha R., Sukhdev P., (2007), Accounting for freshwater quality in india, gaisp (green accounting for indian states project), Monograph 8
10. Mandal K, Dasgupta R (2013) Upper assam basin and its basinal depositional history, 10th biennial international conference & exposition, p292
11. Prakash. R,. Srivastava S.K,. Rastogi R, Singh K.,. Bhartariya K.G (2011) Ground water pollution & preventive measures in some cities of India. CGWB,NR, Workshop on Management Techniques in Ground Water Stressed Urban Areas, At Lucknow, p 20-25
12. Sahoo B.N.,.Baruah D.C (2013), Investigation of the effect of formation water disposal on ground water in oil fields of Assam, India, Int. J Appl. Sci Biotechnol, 2, pp 49-58.
13. Thakuria. N.,(2001 April 15) Down to earth, Paying for Pollution, http://www.downtoearth.org.in/ news/paying-for-pollution-16083.

Table 2. Values of physico-chemical parameters in groundwater samples collected from monitoring wells located in and around Digboi, Tinsukia district, Assam for the years 2007, 2008, 2009, 2013 and 2014.

Parameter	DIGBOI					TINSUKIA					BORGOLAI				
	2007	*2008*	*2009*	*2013*	*2014*	*2007*	*2008*	*2009*	*2013*	*2014*	*2007*	*2008*	*2009*	*2013*	*2014*
PH	8.2	8.4	8.09	8.3	8.2	7.3	8.03	7.88	8.3	8.02	5.67	-	8.02	8.1	6.3
Conductivity (µmho cm^{-1}) at 25°C	283	283	85	299	287	825	887	39	856	234	1155	-	78	233	28.9
Turbidity (NTU)	-	-	-	-	BDL	-	-	-	-	1.3	-	-	-	-	1.2
TDS (mg L^{-1})	184	181	55.25	139	132	398	577	25.35	454	112	561	-	50.7	123	15.7
T-alkalinity (mg L^{-1})	85.4	158	79.95	100	68	176	195	36.9	168	80	207	-	30.7	44	36
Cl (mg L^{-1})	21.2	42.5	14.18	25.8	56	77	77.8	10.63	69.4	17.9	56	-	14.18	25.8	21.8
Sulphate (mg L^{-1})	19	19	6	9.92	1.62	-	90	3	47.84	13.2	-	-	8	18.2	1.6
Nitrate (mg L^{-1})	-	-	-	2.2	1.4	-	-	-	0.5	2.9	-	-	-	1.2	1.5
F (mg L^{-1})	BDL	BDL	BDL	0.6	BDL	0.18	BDL	BDL	0.68	0.46	0.54	-	BDL	0.74	0.06
Ca (mg L^{-1})	26	22	12	38.4	14.4	64	92	12	60.8	28.8	22	-	12	8	14.4
Mg (mg L^{-1})	8.5	8.2	41.25	2.91	3.9	3.0	17	28.7	12.6	6.80	3	-	20	11.6	30.1
T-Hardness (mg L^{-1})	100	95	195	108	52	160	300	145	204	100	70	-	110	68	160
Na (mg L^{-1})	-	-	-	2.9	34.1	-	-	-	56.4	8.18	-	-	-	13.6	1.39
K (mg L^{-1})	-	-	-	0.4	6.9	-	-	-	22.9	4.97	-	-	-	5.56	1.40
Iron (mg L^{-1})	0.11	0.15	1.13	4.34	4.4	1.05	0.12	0.49	0.99	0.72	0.19	-	2.3	0.36	0.7

Table 3. Concentration of trace elements in water samples in Digboi, Tinsukia district, Assam						
Year	**Lead** (mg L^{-1})	**Iron** (mg L^{-1})	**Cadmium** (mg L^{-1})	**Chromium** (mg L^{-1})	**Manganese** (mg L^{-1})	**Zinc** (mg L^{-1})
2002	0.14	3.14	0.07	0.02	10.13	3.28
2007	0.016	3.06	-	-	0.80	NA
2013	ND	2.16	-	-	-	0.26

Annexure I: Values of physico-chemical parameters in groundwater samples collected from monitoring wells located in and around Digboi, Tinsukia district, Assam for the years 2001-2002															
Parameters	**Hawkinspara**			**Kalibari**			**Missionpara**			**Golai**			**Borbil**		
	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01	May'02	Jan'02	Sep'01
pH	8.5	9.2	7.1	6.5	6.7	7.4	6.8	6.2	7.3	6.7	6	7.2	6.6	6.7	7.2
Turbidity (NTU)	1.11	-	-	5.0	-	-	12.5	-	-	3.44	-	-	21.9	-	-
EC (µmho cm^{-1}) at 25°C	3.52	411	380	296	353	325	315	346	330	237	353	290	179	210	195
T-Hardness (mg L^{-1})	8.2	40	8	56.42	96	18	125.58	200	38	49.14	136	20	56.48	124	14
Ca (mg L^{-1})	3.79	28.4	6	13.85	50	10	21.88	140	26	13.85	82	14	8.82	Nil	8
T-Alkalinity (mg L^{-1})	124	24	40	74.8	126	12	148.2	208	24	46.2	96	8	90.2	126	12
Chloride (mg L^{-1})	1.61	26	4	42.02	63	54	9.69	53	14	38.25	34	34	12.93	21	20
Phosphate (mg L^{-1})	BDL	-	-	BDL	-	-	BDL	-	-	BDL	-	-	BDL	-	-
Fluoride (mg L^{-1})	BDL	0.1	-	BDL	0.1	-	BDL	0.1	-	BDL	0.03	-	BDL	0.2	-
TDS (mg L^{-1})	196	230.4	210	205	504	350	221	144	205	196	130	165	156	106.5	139
Iron (mg L^{-1})	0.21	-	-	0.51	-	-	0.99	-	-	0.21	-	-	3.14	-	-
Sulphate (mg L^{-1})	-	-	12	-	-	32	-	-	28	-	-	22	-	-	18
angnesium (mg L^{-1})	-	-	2	-	-	8	-	-	12	-	-	6	-	-	6

Possible groundwater pollution from committed industrialization in Chhattisgarh State: "Prevention is better than cure"

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Abstract

The major industrial activities which will see expansion in near future in Chhattisgarh State are Iron and Steel industry, Mining and Thermal Power Projects. These industries release toxics which pollute air, water and soil. The present paper gives some facts and figures of pollution caused by industries in Chhattisgarh. It is an attempt to put a word of caution before the onset of such industries so that proper preventive strategies can be adopted to protect the groundwater with the principle "prevention is better than cure". Of all the systems of environment which get polluted, groundwater needs the most protection since pollution of aquifers is irreversible. It is recommended that pollution prevention measures should go hand in hand with industrial development strategies.

1. Introduction

The road map sketched and policy adopted by Chhattisgarh State has been able to attract large investment for committed industrial development in near future in Chhattisgarh. These developmental activities are bound to change the environmental conditions of the State. Therefore a balance has to be maintained between developmental activities and environment protection through proper management practices. Since groundwater is the main source of drinking water and irrigation water in the State hence protection of groundwater from possible pollution has to be ensured through foresight and solid scientific data base.

The major industrial activities of forth coming years in the State are Iron and Steel industry, Mining and Thermal power projects. Coal based thermal power stations generate huge quantity of fly ash. Coal mining is associated with acid mine discharge and steel plants are source of fallout dust with heavy metals. The toxic substances thus released pollutes air, water and soil. The present paper is an attempt to put a word of caution before the onset of such industries so that proper preventive strategies can be adopted to protect the groundwater with the principle "prevention is better than cure".

2. Groundwater scenario of Chhattisgarh

The occurrence of groundwater in the state has been classified into six major provenances (Mukherjee and Tewari, 2006). Two crystalline provinces, Proterozoic sedimentary province and Gondwana semi-consolidated sedimentary province which occupy nearly 58%, 27% and 12% of the area of the state respectively (CGWB, 2006). The understanding of inherent aquifer characteristics of these areas is essential to understand the vulnerability of aquifer system. The overall groundwater development in the State is still around 30% and there are large areas with perennially shallow groundwater levels (www.cgwb.gov.in). Unconfined aquifers are still widely being used as source of drinking water. The groundwater ,by and large is potable except for sporadic anthropogenic pollution noticed along the industrial belts of Raipur, Bhilai-Durg, Korba and Rajnandgaon areas of the State (Patel et al, 2006; Pandey et al, 2008, 2013 ; Pandey and Srivastava,2000).

3. Major industries and related groundwater pollution

The State is having major industrial activities in the form of Steel plants at Bhilai and Raigarh, Aluminium plant at Korba, Thermal power plants at Korba, Sipat, Tamnar and Bhilai, Cement plants in Raipur, Durg, Champa and Bastar districts. Coal mines are present in Korba, Raigarh, Sarguja and Koria districts, Iron ore mines at Bailadila (Dantewada district) and Delli-Rajhara (Balod District), limestone-dolomite mines in Bastar, Durg, Bilaspur,Raipur and Champa districts and Bauxite mines at Bodal-Daldali (Kabirdham district), Mainpat and near Amarkantak(Surguja district). Apart from these, other medium scale significant industries (Table-1) include paper and chemical industries of Raipur, Bilaspur, Mahasamund, Durg, Dhamtari, Champa and Rajnandgaon districts. Sporadic local groundwater pollution due to these industrial activities has been reported from these areas.

Table-1 Industrial units of Chhattisgarh

Sl No.	Category	Existing Units	Proposed Units
1	Steel Industries	58	4
2	Engineering Units	07	
3	Cement Industries	14	
4	Chemical Industries	34	
5	Solvent and Food Industries	35	
6	Yarn & Fabrics	07	
7	Paper, Plywood and others	10	
8	Thermal power plant	04	40

Mercury (Hg) pollution has been reported from from soil, surface water and groundwater in 3-10 km radius of integrated Bhilai Steel Plant (BSP) . The plant with production capacity of 3.1MT steel has 10 coke ovens for production of metallurgical coke by combustion of coal for manufacturing of steel. In Indian coal the average concentration of Hg is 0.272 ppm and it varies from 0.17 to 0.32 ppm. A German study shows for every 1000kg of coke production, 0.01 to 0.03g Hg is released. Toxicological effects of elemental Hg (Hg^0) exposure include respiratory and renal failures, cardiac arrest and cerebral oedema. Bhilai- Durg Township is the largest urban area of the state population wise. Fallout of Hg through dust over soil near vicinity of steel plant is reported elsewhere in range of 60-836g/km^2/month. A Study in Bhilai area found groundwater and soil contained Hg beyond standard limit, average of 0.44ppm and 16.58 ppm respectively (Koshle, et al,2008, Parvez et al 2010). Another study shows many fold increase in Hg content in groundwater when data of 1997 is compared with that of 2006 in the vicinity of BSP. (Parvez et al 2010). All the bio-receptors in the area have shown higher Hg presence compared to prescribed standards.

Lead (Pb) pollution has also been detected in groundwater, surface water and soil around BSP. Pb is highly toxic and accumulates on soil due to its immobility. Pb can be released due to combustion of coal and smelting of iron ore, limestone/dolomite. Thus steel plants and cement plants are potential polluters. A study revealed Pb contamination in range of 3-52ppb in groundwater in Bhilai area (Patel et al 2006). Since Pb is not bio-degradable, it accumulates in soil and becomes a source for groundwater pollution. Pandey & Srivastava (2000) reported Pb, Cd and Cyanide contamination beyond standard limit in Somni Nala watershed from where the BSP effluent outflows.

The thermal power plants(TPP) are producer of large quantity of SO_2. The CPCB estimated 183 tonnes of SO_2 emission per day from Korba industrial area along with generation of 21000 tons of fly ash. Acid rains have been reported from Korba area. CPCB also reported high Zn and F contamination in groundwater in Korba area The fly ash is rich in B, Cd, Be, Cu, Zn, Pb, As, U, Hg and other heavy metals. These toxic elements leach out from fly ash ponds to contaminate the surface and groundwater. The ash is alkaline in nature and increases the alkalinity of soil. According to an estimate of CPCB 1 acre of land is required for ash pond for production of every mw of electricity. Thus 1500 acres of land is required for ash pond in Korba area for upcoming TPP. In the Korba area to generate 1500mw of electricity, 21000 tones/day of ash is produced by combustion of 50000 tonnes of coal. Such large area in and around industrial unit can be a potential site for groundwater pollution.

Coal mining in Chhattisgarh State is presently the largest mining sector activity. Studies undertaken by CMPDI found that different toxic metals like As, Hg, Cr, Ni were released from coal and mine spoil heaps in Damodar Valley. By locating the coal washeries near mines, water pollution problems get worse. The acid mine recharge liquid effluents from coal handling plants, workshops and suspended particles from these industrial units adversely effective the aquatic environment. The cement plants and its captive limestone mines in the state generate fine dust which contains metals and non metals as source of water pollution.

3.1 Upcoming industries in Chhattisgarh and groundwater

Thermal power plants: Chhattisgarh power developers have made an investment commitment worth Rs 1,58,000 crore . This will help add 39,500 mw through 40 power projects. These projects will be executed phase-wise in the next few years. The list reveals upcoming 15 new projects of 17000 mw capacity in Janjgir-Champa district followed by Raigarh district where 12 projects of around 14000 mw capacity are proposed. In Korba district additional 4700 mw capacity projects and 2500 mw capacity projects are proposed in Sarguja district .

Out of proposed 40 new Thermal Power Plants, 27 are coming up in two districts. The entire Champa district and part of Raigarh district is occupied by karstic aquifer. The groundwater levels in the karst terrain of these two districts are generally found deep. Vulnerability of karstic aquifer is well known; therefore utmost care should be taken for site selection and proper deigning of ash ponds in these districts. Korba and Sarguja districts are occupied by Gondwana rocks and granitic rocks where groundwater levels remain shallow which provide higher possibility of contamination through percolation.

Steel plants: The proposed mega steel plants of Bastar- Dantewara district at Dilli-Mili, Geedam , Nagarnar and Lonadiguda is going to expose one of the least developed, shallow groundwater region of state to possible contamination as experienced in Bhilai- Durg area.

Coal mining: The upcoming 39500 mw thermal power plants and mega steel plants are going to use coal from Korba, Raigarh, Surguja and Koriya districts. These districts are already suffering the consequences of coal mining for existing thermal power plant and steel plants. Additional mining from existing mines or new coal mines without proper management strategies will add more stress on air, soil and water.

4. Possible strategies for prevention of groundwater contamination

- Going with the philosophy "awareness is safety", large data bank and knowledge club has to be created about air, soil and water pollution existing around the super thermal power stations and mega steel projects of world and the remedial measures adopted worldwide.
- Micro level hydrogeological and environmental study through independent group has to be carried out at each proposed location of super thermal power station and mega steel project to generate first hand data base. All mega projects must have R&D division on environmental aspects.
- State sponsored groundwater monitoring mechanisms (quantitative and qualitative), should be established by strengthening the district level and state level monitoring stations. Latest available technology should be used to detect the pollution parameters.
- Proper aquifer wise groundwater management plan has to be worked out at local level and highest level task force has to be constituted to implement the management plan.
- Empowered Regulatory Authorities has to be appointed and measures like Model bill of groundwater regulation has to be enacted in the State immediately.

5. Conclusion

"Prevention is better than cure" should be the strategy to protect groundwater in the upcoming industrial zones of Chhattisgarh. So far groundwater in the state is by and large potable and being used for drinking without any purification. Since the groundwater levels are shallow in many areas it can be polluted fast. Coal based thermal power stations generate huge quantity of fly ash while coal mining is associated with acid mine discharge and steel plants are source of fallout dust with heavy metals. The toxic released pollutes air, water and soil. Aquifer pollution is irreversible. It is therefore recommended that pollution prevention measures should go hand in hand with industrial development strategies.

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Reference-

1. CGWB 2006 State Report on "Hydrogeology of Chhattisgarh",184 p.
2. Koshle,A, Y. Pervez , Tiwari R P and Pervez, S 2008-Environmental pathways and distribution pattern of total mercury among soils and groundwater matrices around an integrated steel plant in India. Jour. Sci.& Ind. Res, v 67:523-530
3. Mukherjee, A and Tewari, D. 2006- Emerging challenges in groundwater resource management before newly created state with special reference to Chhattisgarh, In proceeding on 12th National Symposium on Hydrology, Nov.14-15, In Romani et.al, Edt. Ground water Governance,73- 82, published by Capital publishing company, New Delhi.
4. Pandey P K, Verma Y, Choubey S, Pandey M and Chandrakhar -2008 Biosorptive removal of cadmium from contaminated groundwater and industrial effluents,Bioresource Technology, v 99(10): 4420–4427
5. Pandey P K, Pandey M and Chakraborty M- 2013 Fluoride Mobilization Due to Coal Mining in Parts of Chhattisgarh Journal of Environmental Protection, 2013, 4, 385-388, doi.org/10.4236/jep.2013.44046
6. Pandey S K and Shrivastava, P K-2000,Contamination of Pb, Cd and CN in ground water of Somni stream watershed ,district Durg, MP, In proceeding -workshop on strategy for groundwater development in M.P, by CGWB Raipur, p T6-6-14.
7. Patel K.S., Shrivas K., Holmann P. and N. Jakubowski -2006 A survey of lead pollution in Chhattisgarh State, central India, Environmental Geochemistry and Health v 28:11–17, DOI: 10.1007/s10653-005-9006-0
8. Pervez, S. Koshle A., and Y. Pervez 2010 Study of spatiotemporal variation of atmospheric mercury and its human exposure around an integrated steel plant, India. Atmos. Chem. Phys,v10: 5535–5549, doi:10.5194/acp-10-5535-2010

Occurrence of high Chromium in parts of industrial area in Unnao district , Uttar Pradesh

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Abstract

Chromium naturally occurs in rocks, animals, plants, soil and in volcanic dust and gases. It comes in several different forms including trivalent Chromium and hexavalent Chromium. Trivalent Chromium is often referred to as Chromium(III) and is an essential nutrient for the body. Hexavalent Chromium or Chromium(VI), is generally used or produced in industrial processes and has been demonstrated to be a human carcinogen when inhaled. Water insoluble Chromium (III) compounds and chromium metal are not considered a health hazard, while the toxicity and carcinogenic properties of Chromium (VI) have been known for a long time. In India BIS (2012) has recommended a limit of 0.05 mg/l Chromium as Cr(VI) in drinking water in view of its severe toxicity. In 2012, a total of 69 samples for Cr(VI) were collected from the groundwater, surface water and effluents in some parts of Unnao industrial area, in polypropylene bottles and were kept in ice box during transportation. For total Chromium, the samples were also treated with (1:1) analytical grade Nitric acid. These samples were analyzed for the estimation of total & hexavalent Chromium following the methodology laid down in Standard Methods for Water and Waste Water Analysis. It has been observed that Chromium (total) has been found in groundwater and surface water at few places in study area of Unnao district with positive correlation. The Effluent samples near CEPT at Dahi-Chowki has recorded total Chromium as 3984 microgram/l. Mirza tannery drain, recorded total Chromium as 4455 microgram/l. In groundwater samples high values of Hexavalent Chromium have been found near J R Inter College, Dharamkanta (602 µg/l); Shivnagar (141 µg/l); Maduwasi (102µg/l); Masnagar (54 µg/l); Dakari (50 µg/l) and Lauikhera (45 µg/l) areas in Unnao. It has been observed that in Dharamkata area, fresh dumping of industrial solid waste containing Chromium salts is impacting groundwater quality in phreatic aquifer of the area.

Keywords: Hexavalent Chromium, Industrial solid waste, Groundwater pollution

1. Introduction

Hexavalent Chromium is a compound form of the metallic element Chromium. Chromium naturally occurs in rocks, animals, plants, soil and in volcanic dust and gases. It comes in several different forms including trivalent Chromium and hexavalent Chromium. Trivalent Chromium is often referred to as Chromium (III) and is an essential nutrient for the body. Hexavalent Chromium, or Chromium (VI), is generally used or produced in industrial processes and has been demonstrated to be a human carcinogen when inhaled.

The mechanism(s) of Cr(VI)induced carcinogenicity is not completely understood. The toxicity of chromium within the cell may result from damage to cellular components during the hexavalent to trivalent chromium reduction process, by generation of free radicals, including DNA damage. Recent studies indicate biological relevance of non-oxidative mechanisms in Cr(VI) carcinogenesis (Zhitkovich, Song *et al.* 2001).

The presence of Hexavalent chromium in groundwater due to tannery solid wastes has been reported in different parts. (Kalicharan et al. 2010 & Ram Prakash et al. 2012). The chromium compounds (Cr III & Cr VI) leach to groundwater body depending on the initial concentration, gradient flow direction and presence of effluent. (Hem, J.D.1991& Lloyd, J. W. et al. 1985). The high values of Cr VI beyond the permissible limits of 0.05 mg/l have been found to affect the human health adversely. The dissolved metals and ions play a very important role in various physiological processes in the flora and fauna of the habitat. If present in higher or low concentration than the required limit, it can cause unusual effects or diseases. The health effects of Chromium to toxicity, dermatitis, ulcer; Copper to liver damage, CNS irritation; Iron to haemochromatosis; Lead to paralysis, toxicity, anaemia, mental disorders; Zinc to syndromes, retarded growth, immunity, anemia are well reported(BIS 2012). In the present study, details of high concentration of Chromium VI found in groundwater of some industrial areas of Unnao district in Uttar Pradesh and its adverse impacts on the water quality are described.

1.1 *Study Area*

The Unnao district has in general a flat topography. However, there are two different topographical features viz. low and upland areas. Lowland lies along the Ganga river to the west and along the Sai River to the extreme north and east. It belongs to the flood plains of the rivers and is subjected to frequent floods. The upland is generally not liable to flooding and extends to the boundaries of the district from North West to south east between the high banks of the above rivers. The maximum elevation in the district is 128.73 meters above mean sea level near Safipur Sarsoi. The master slope of the district is from NE to SW. The Ganga forms the western and southern boundary to the district and the Sai for the greater part of its course, forms the northern and eastern boundary. The other important drainage channels of the district are namely, Kalyani, Khar, Loni & Marahi that are the tributaries of the river Ganga. The area is comprised of new to older alluvial deposits. The depth to water level varies between 5.0 mbgl to 10mbgl. The area experiences heavy rainfall of about 852 mm during which various solid wastes get dissolved in surface water and later percolate to groundwater bodies.

2. Sources of Chromium in the environment

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100 mg/l Chromium compounds are found in the environment due to erosion of Chromium-containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg, in sea water 5 to 800 µg/l, and in rivers and lakes 26 µg/l to 5.2 mg/l (Hem, J.D.1991).

3. Effects of high Chromium on human health

Water insoluble Chromium (III) compounds and Chromium metal are not considered a health hazard, while the toxicity and carcinogenic properties of Chromium (VI) have been known for a long time. The acute oral toxicity for Chromium(VI) ranges between 50 and 150 µg/kg. In the human body, Chromium (VI) is reduced by several mechanisms to Chromium(III) already present in the blood before it enters the cells. The Chromium (III) is excreted from the body, whereas the chromate ion is transferred into the cell by a transport mechanism, by which also sulfate and phosphate ions enter the cell. The acute toxicity of Chromium(VI) is due to its strong oxidation properties. After it reaches the blood stream, it damages the kidneys, the liver and blood cells through oxidation reactions. Hemolytic, renal and liver failures are the results of these damages. Aggressive dialysis can improve the situation (Franchini and Mutti 1988 &Kolaciski, Kostrzewski *et al.* 1999).

Three mechanisms have been proposed to describe the genotoxicity of Chromium(VI). The first mechanism includes highly reactive hydroxyl radicals and other reactive radicals which are by products of the reduction of Chromium (VI) to Chromium (III). The second process includes the direct binding of Chromium (V), produced by reduction in the cell, and Chromium (IV) compounds to the DNA. The last mechanism attributed the genotoxicity to the binding to the DNA of the end product of the Chromium (III) reduction (Samitz 1970).

Chromates are often used to manufacture leather products, paints, cement, mortar and anti-corrosives. Contact with products containing chromates can lead to allergic contact dermatitis and irritant dermatitis, resulting in ulceration of the skin, sometimes referred to as "chrome ulcers". This condition is often found in workers that have been exposed to strong chromate solutions in electroplating, tanning and chrome-producing manufacturers (EPA 1998).

4. Collection of water samples and methodology

A total of 47 samples were collected from hand pumps (depth approx. 10 m) & Tube wells (depth approx. 30m), surface water and effluents in the area during May-June 2012 Samples were collected in pretreated 1 litre Polypropylene (TORSON) bottles and were treated with analytical grade Hydrochloric acid. These samples were analyzed for the estimation of total & hexavalent Chromium, pH & electrical conductivity All the chemicals used were of analytical reagent grade. The standard stock Cr(VI) solutions was prepared by weighing 2.8287 g of Potassium dichromate in one liter double distilled water and it was further diluted to desired concentrations containing 20, 40, 50, 60, 80, 100, and 200 mg/L of chromium (VI) in aqueous phase standard solutions. The estimation of hexavalent chromium was carried out by using Diphenyl carbazide method as per standard methods (APHA 22nd edition). The analytical data is given in Table -1.

5. Results and discussions

In India, BIS (2012) has recommended 0.05 mg/l Chromium in drinking water in view of its severe toxicity. It has been found that the concentration of Chromium & Electrical Conductivity in some samples of groundwater / surface water are higher than the permissible limit as per BIS (IS:10500,2012) (Table-1). The perusal of of data indicate that Chromium (total) has been found in groundwater & surface water in higher concentration at few places in the study area of Unnao district. The effluent samples near CEPT at DahiChowki has recorded total Chromium as 3984 microgram/l. Mirza tannery drain recorded total Chromium as 4455 microgram/l. The effluents containing high Chromium coming out from various tanneries present in the area mostly infiltrate through unlined drains which may pollute groundwater of the area. Locations of various surface water and groundwater samples are depicted in **Fig-1.**

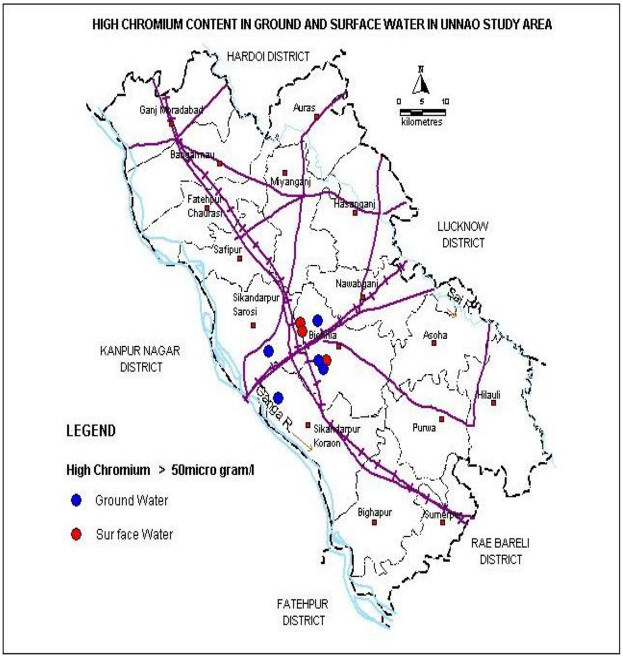

Fig-1: Sample locations with high Chromium content

In groundwater samples, high values of Hexavalent Chromium have been found near J R Inter College, Dharamkanta (602 µg/l); Shivnagar (141 µg/l); Maduwasi (102µg/l); Masnagar (54 µg/l); Dakari (50 µg/l) and Lauikhera (45 µg/l) areas in Unnao. The total chromium has also been found in shallow groundwater. Though in many places hexavalent chromium has not been detected but total chromium has been found to be quite high, which may be due to reduction of chromium (VI) to chromium(III) during passage through the topsoil having reducing conditions.

It has been observed that in Dharamkata area, fresh dumping of industrial solid waste containing Chromium salts is being carried out. **Fig-2** shows one of the water pit dumped with Chromium salts. The whole area near J R Inter college, Dharamkanta showed yellow patches of Chromium salts on the outer walls of the buildings. The Table -1 depicts that in Dharamkata area near J R Inter college, high values of Chromium have been detected in surface water body and also in the shallow tube wells which indicate that the Chromium wastes have leached to the shallow groundwater of the area and if it is not checked, it may deteriorate the deeper groundwater system as well.

Fig-2:Contaminated Surface Water due to Chromium wastes dump

6. Conclusion

The presence of Chromium (total) in surface as well as in groundwater indicate that industrial solid wastes/effluents is polluting groundwater through surface water.However the quantum and the affected area at present is very small though it has started polluting the groundwater. The presence of hexavalent Chromium recorded in groundwater of Dharmkanta, near Unnao bypass area is due to the dumping of industrial solid wastes nearby, on the road. These solid wastes containing Chromium salts if leached to the shallow groundwater can be a matter of concern as it may further deteriorate the deeper groundwater system. This shows that the spread of Chromium in groundwater is in lateral as well as in downward directions.

Table -1 : Ground Water Quality of Study Area in Unnao Distt, UP

SN	Location	Type	pH	EC in µs/cm	Cr VI in µg/l	Total Cr in µg/l
1	Left Effluent Benther	Eff	7.67	1310	ND	1
2	Right Effluent Benther	Eff	7.78	4000	ND	6
3	Mixed EfflceptBenther	Eff	7.61	1860	ND	_
4	TW near CEPT	SP	7.52	668	ND	_
5	J S slaughter house	Eff	7.62	698	ND	11
6	Benthar	IMII	7.22	746	ND	6
7	Lauikhera	DW	8.01	5860	ND	45
8	Gaya prasad, laukhera	IMII	7.25	4170	ND	31
9	Sambhu, Laukhera	IMII	7.42	781	ND	0
10	Manglal, Laukhera	IMII	7.28	982	1.39	2
11	Sushil, laukhera	HP	7.26	763	ND	11
12	JagannathJalimkhera	Dw	7.38	2030	ND	26
13	RamkumarJalimkhera	HP	7.21	1630	ND	26
14	JagawathJalimkhera	HP	7.17	1490	ND	26
15	Raj bhadur, Dakari	HP	6.98	6120	ND	50
16	Mahesh Singh, Dakari	HP	7.02	3330	ND	_
17	Khadibhawan, Shuklaganj	HP	7.44	1880	ND	_
18	Ayurwedik hospital, maswari	IM II	7.06	2050	ND	_
19	Maduwasi	IM II	7.46	4310	ND	_
20	Drain in side, Maduwasi	Drain	7.72	1710	ND	_
21	Sankarsingh,Maduwasi	IM II	6.94	3040	0.21	_
22	Horilal,Maduwasi	IM II	7.34	1860	ND	102
23	Kanyavidyalay,Maduwasi	IM II	7.18	4600	ND	

24	Mirza tannery drain, unnao	Drain	7.58	1330	ND	4455
25	Unnao distillery	Drain	7.98	795	ND	31
26	MunnaAwasthi, Rishinagar	HP	7.08	1664	ND	16
27	New Krishna sweet	IM II	7.42	902	ND	35
28	DC Dwedi, Risinagar	HP	7.85	1204	ND	6
29	JL Dwedi, Risinagar	HP	7.65	1440	ND	20
30	Pal Traders,Subasnagar	HP	7.64	1227	ND	16
31	Hanuman Temple Ambikapuram	IM II	7.72	643	ND	16
32	VinodRathor,Suklaganj	HP	7.48	1664	ND	16
33	JHS Singrausi, Darmkanta	IM II	7.7	888	ND	11
34	JAR Inter college, Daramkanta	SW	7.76	3516	2070	4012
35	JAR Inter college, Daramkanta	TW	7.76	2985	352	602
36	Pintu Gupta, Shivnagar	HP	7.9	3552	ND	141
37	Eff CEPT, DahiChowki	Eff	7.29	7398	ND	3984
38	Eff CEPT, DahiChowki	Eff	7.26	19706	ND	3310
39	CEPT, DahiChowki	IM II	7.6	1758	ND	21
40	Garhi, Nr tower	HP	7.52	1068	ND	16
41	Jhanjhari	DW	7.71	2726	ND	21
42	Central School	IM II	7.74	674	ND	45
43	Masnagar	IM II	7.49	1262	ND	54
44	Masnagarinvillage	DW	7.26	2738	ND	21
45	Masnagaronroad	DW	7.06	952	ND	11
46	CEPT,	Eff	7.08	23482	ND	–
47	J S slaughter house	Eff	7.87	1782	ND	–

ND= Not Detected

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References:

1. American Public Health Association (2012) Standard methods for examination of water and waste water, 22ndedn.,Wasington, DC.
2. BIS (2012) IS: 10500 Indian Standard: Drinking Water–Specification, first revision. Bureau of Indian Standards, New Delhi, India.
3. EPA (1998). "Toxicological Review of Trivalent Chromium. CAS No. 16065-83-1. In support of Summary Information on the Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency, Washington, D.C."
4. Franchini, I. and A. Mutti (1988). "Selected toxicological aspects of chromium(VI) compounds." Science of the Total Environment 71(3): 379-87.
5. Hem, J.D.(1991) Study and interpretation of chemical characteristics of natural waters. Book 2254, 3rdedn. Scientific Publishers, Jodhpur, India.
6. Kolaciski, Z., P. Kostrzewski, et al. (1999). "Acute potassium dichromate poisoning: a toxicokinetic case study." Journal of Toxicology - Clinical Toxicology 37(6): 785-91.
7. Kali Charan, Ram Prakash & Kiran Singh [2010];Ground Water Contamination in Industrial Area, Unnao District, Govt Of India, Ministry Of Water Resources, CGWB, Technical Report.
8. Lloyd, J. W. and Heathcote, J. A. (1985), Natural Inorganic Hydrochemistry in Relation to Groundwater. An Introduction. Oxford University Press, New York. 294p.
9. Ram Prakash and S K Srivastava (2012), Chromium contamination in groundwater in some parts of Unnao District, UP. Govt of India, Ministry Of Water Resources, CGWB, Technical Report.
10. Samitz, M. H. (1970). "Ascorbic acid in the prevention and treatment of toxic effects from chromates." ActaDermato-Venereologica 50(1): 59-64.
11. Supriya Singh, AlkaTripathi, S K Srivastava and Ram Prakash(2013), Biosorption of Chromium (VI) on FicusRacemosa Bark Powder, International Journal of Chemistry and Applications, Volume 5, Number 4 pp. 237-249.

12. WHO (1984) Guidelines for drinking water quality. World Health Organisation, Geneva.
13. Zhitkovich, A., Y. Song, et al. (2001). "Non-oxidative mechanisms are responsible for the induction of mutagenesis by reduction of Cr(VI) with cysteine: role of ternary DNA adducts in Cr(III)-dependent mutagenesis." Biochemistry 40(2): 549-60.

Groundwater quality & temporal variation in the industrial clusters of Panipat city, Haryana

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Abstract

Industrialisation is one of the specific human activities of significant concern for protection of groundwater quality and the management of groundwater resources. Its growing trend has important overall implications for freshwater use specifically for the development, protection and management of groundwater in urban environments. Panipat city is situated on Shershah Suri Marg, 90 km north of National Capital, New Delhi and falls under the National Capital Region. The city has made unprecedented progress and the activities related to various industrial units such as dyeing, textile processing and foundries etc. coupled with rapid and haphazard urbanization has resulted in groundwater pollution. A study was carried out by CGWB in 2014 to assess groundwater quality in industrial clusters of Panipat city and in continuation a repeat study of the area has been carried out in February 2016. This paper is based on reassessment of groundwater quality of identified contaminated pockets so as to outline the management actions that may be necessary to ensure different levels of modifications so that groundwater quality is maintained.

1. Introduction

Panipat city is well known for textiles and carpets. It is situated on Shershah Suri Marg, 90 km north of National Capital, New Delhi and falls under the National Capital Region. The city forms a part of the Indo-Ganga alluvial plain and total geographical area of the City is about 58 sq. km. It falls in parts of Survey of India topo-sheet No. 53C/15. The normal annual rainfall of the city is 680 mm. National Fertilizer Limited, Sugar Mill, Thermal Power Plant, Oil Refinery are some of the large/major important industrial units located in and around the city. A large number of dyeing units, handloom textiles and printing units are also scattered all over the city.

Exploratory drilling by Central Ground Water Board has revealed the presence of three aquifer groups in the city down to depth of 460 m. The entire water supply to the city is being met from groundwater through tube wells installed by the government water supply agency and the industries tapping predominantly the first aquifer. The excessive extraction of groundwater for drinking/domestic usage and industrial sector has resulted in significant decline in water levels, ranging from 1.26 m/yr to 1.34 m/yr. The Panipat block has been categorized as 'Over-exploited' with stage of groundwater development at 178 % (Ground Water Resource Assessment 2011).

Dense industrialization set up of various industrial units such as dyeing, textile processing and foundries etc. coupled with rapid and haphazard urbanization has resulted in groundwater pollution in Panipat city. A study was carried out by CGWB in 2014 to assess groundwater quality in Industrial clusters of Panipat city and in continuation a repeat study of the area has been carried out in February 2016. This paper is based on reassessment of groundwater quality of identified contaminated pockets so as to outline the management actions that may be necessary to ensure different levels of modifications so that groundwater quality is maintained.

2. Major ions

Chemistry of water is controlled by interaction between solute and aquifer solids and overlying land use. The determination of major ions and heavy metals gives an idea on general hydrochemistry of the groundwater with respect to the groundwater development by various stake holders for drinking/domestic, agricultural and industrial usages.

The results of the analysis of groundwater samples carried out in 2016 following APHA, 2012 indicate that there is significant variation in the groundwater quality at different sites/locations. The minimum and maximum concentrations of chemical constituents in groundwater are given in **Table 1**.

The pH of groundwater varies from 7.55 to 8.30 and majority of groundwater sample shows average value less than 8, indicating that the groundwater in the city area is slightly alkaline in nature. Electrical conductance is a measure of total dissolved solids in groundwater samples in relation to inorganic constituents and in general is an indicator of water quality in relation to inorganic constituents. It ranges between 638 and 1702 micromhos/cm at 25^{0}C. 83% samples show EC variation from 1000 to 2000 micromhos/cm. As EC values in major part of the city is less than 2000 micromhos/cm, it indicates that groundwater in Panipat city, by and large, is fresh with respect to dissolved solids.

Table 1: Range of chemical constituents in groundwater in Panipat

Parameters	Minimum	Maximum
pH	7.55	8.3
EC (µmhos /cm at 25°C)	638	1702
CO_3	NIL	NIL
HCO_3 (mg/l)	292	660
Cl (mg/l)	17	128
SO_4 (mg/l)	106	325
NO_3 (mg/l)	0.1	6
F (mg/l)	0.96	14.30
PO_4 (mg/l)	0.11	0.58
Ca (mg/l)	16	49
Mg (mg/l)	7.5	111
Na (mg/l)	122	360
K (mg/l)	3.5	8.5
SiO_2 (mg/l)	10	21
Total Hardness As $CaCO_3$ (mg/l)	92	564

Carbonate is absent in all the groundwater samples. The concentrations of bicarbonate ranged between 292 and 660 mg/l; it shows that the groundwater is slightly alkaline in nature. Chloride concentration varies from 17 to 128mg/l. These values are well within the BIS, 2012 permissible limits for drinking purposes. Overall sulphate values vary from 106 to 325 mg/l concentrations and are well within the maximum prescribed limit of 400 mg/l. In general, nitrate concentration is within the desirable limit of 45 mg/l and vary from 0.10 to 6 mg/l. Fluoride concentrations vary between 0.96 and 4.25 mg/l. 83% of the groundwater samples have fluoride concentration beyond the permissible limit of 1.5 mg/l. Very high concentration of Fluoride (14.30 mg/l) has been observed in a groundwater sample at Thermal Power Plant. The sampling point was situated near to Ash Disposal Plant. The phosphate concentration varies from 0.11 mg/l to 0.58mg/l. The higher concentration may be due to percolation of stagnant water from nearby cesspool.

Calcium and Magnesium, in general are found to be well within the maximum prescribed limits of 200 and 100 mg/l respectively. The Calcium concentration ranged from 16 to 49 mg/l whereas Magnesium concentration ranged from 7.50 to 111 mg/l. The magnesium concentration is exceeding only at HUDA-12, where it is found to be 111 mg/l. Calcium and magnesium along with carbonates, sulphates and chlorides make the water hard both temporarily and permanently. The total hardness (as $CaCO_3$) is found to be well within the permissible limit of 600 mg/l and ranged between 92 to 564 mg/l. The sodium concentration varies between 122 to 360 mg/l. Potassium concentration, has been found to be between 3.5 and 8.5 mg/l.

3. Type of Water

In general the groundwater is found to be mixed character type with 83% samples of Mixed Type character where Sodium (Na^+) are dominant cations while bicarbonate (HCO_3) followed by Sulphate(SO_4) are the dominant anions. It indicates that these waters are of Na-HCO_3- SO_4 type. One sample representing inhabited area shows characteristic Na-HCO_3 type waters, which indicates that alkali metals exceed alkaline earth metals. These waters are inordinately soft in proportion to their content of dissolved solids.

4. Heavy Metals

Rocks yield various heavy metals when degraded by weathering, but nature has effective methods of handling it. Exposure of man to heavy metal from natural sources is generally negligible. Air pollutants such as particle settling on water, acid rain dissolving metallic dust and runoff from polluted soil can also contribute to heavy metals load of water. The use of phosphate fertilizers has shown to enhance leaching of cadmium from soil, which reaches the groundwater. The domestic sludge and solid waste contain high concentration of Cu, Pb, Ni, Zn, Cr, Cd, Mn etc. Medium to high levels of Cu, Fe, Mn, Zn, Cr, Cd etc. have been found in some of the fertilizers. Leaching from these fertilizers can contribute to the increased concentration of these metals in groundwater. The common sources of heavy metals in groundwater are geological weathering, industrial processing of mines and minerals, industrial effluents- steel, petroleum refining, pulp and paper, fertilizers etc, animal and human excreta, sludge, solid waste and agricultural activities

Heavy metals namely Arsenic, Copper, Cadmium, Iron, Lead, Manganese and Zinc were determined to ascertain the extent of groundwater contamination in the Panipat Industrial cluster **(Table 2)**. Lead has not been detected in any of the samples of groundwater while Copper and Zinc are generally observed in low concentrations. Arsenic was found to be below detection limit in all samples collected from Panipat Industrial Cluster.

Iron (Fe) is present in 40% of groundwater samples. Iron ranged between 0.0557 to 4.968 mg/l. At two locations namely Oil Refinery (0.6448 mg/l), Babail Road (4.968 mg/l) iron concentrations is found to be beyond the desirable limit set by BIS, 2012 for drinking water. Manganese (Mn) above BIS, 2012 permissible limit (0.3 mg/l) has been observed at one location, namely, Rojhla TW (0.565mg/l). Cadmium (Cd) concentration is generally low except in one sample of Rojhla TW(0.0032mg/l) where it is slightly higher than the permissible limit 0.003mg/l set by BIS, 2012 in drinking water. Results indicate that the groundwater is slightly contaminated with Cadmium.

Table 2: Concentrations of Heavy Metal Ions in Water Samples of Panipat City

S. No.	Location	Cd	Cu	Mn	Pb	Zn	Fe	As
		<---mg/l-------------------------->						
1	**Matsya Bhawan**	BDL	BDL	0.018	BDL	0.0314	-	-
2	**Indira Colony**	BDL	0.0054	0.0222	BDL	0.0738	0.0557	BDL
3	**Jatel Road**	BDL	0.0172	0.037	BDL	0.1382	-	-
4	**Sewah Industrial Cluster**	0.0012	BDL	0.065	BDL	0.23	0.0549	BDL
5	**HUDA-12**	BDL	BDL	0.2592	BDL	0.0352	-	-
6	**Plot No. 260 Sector-29 Part II (PN 260)**	BDL	BDL	0.0816	BDL	0.1216	-	-
7	**Babail Road**	0.0006	BDL	0.0158	BDL	0.0166	4.968	BDL
8	**Rohila**	0.0032	BDL	0.565	BDL	0.156	0.0767	BDL
9	**Refinery PPMC**	-	-	-	-	-	0.6448	BDL
10	**HUDA - Flora Chowk**	-	-	-	-	-	0.1487	0.003

5. Suitability for Drinking

Salinity, nitrate, sulphate, fluoride, hardness and heavy metals are some of the vital quality parameters that are normally considered for evaluating the suitability of drinking water. BIS, 2012 have assigned desirable and permissible concentration limits for these constituents in drinking water. It is found that the groundwater is suitable for drinking at most of the places with few exceptions where fluoride and iron is high. Thus this groundwater should be used after suitable treatment. These waters can also be used after blending with good quality water.

6. Suitability for Irrigation

The suitability of groundwater for irrigation is assessed based on Salinity commuted in terms of EC, Sodium Adsorption Ratio (SAR) and Residual sodium carbonate (RSC) values of waters. High EC water causes salinity hazard, high SAR causes sodium hazard and high RSC causes Alkali hazard of irrigation groundwater. Salinity in terms of EC varies from 638µS/cm to 1702 µS/cm in the study area. Use of this groundwater on well drained soils may not cause salinity hazards.

Alkali hazards of irrigation groundwater are estimated through the computation of Residual sodium carbonate (RSC) or as Eaton index and waters with RSC below 1.25 me/l are termed safe, those with RSC between 1.25 – 2.5me/l as marginal and waters with RSC more than 2.5 me/l as unsafe for irrigation use. In the area of study, RSC values are high and generally range from -3.47meq/l (at HUDA-12) to 8.37 meq/l (at Thermal Power Plant). Such waters (Except HUDA-12) are not suitable for customary irrigation as these may cause alkali hazards. However, these waters can be used for irrigation for salt tolerant crops on soils with adequate permeability along with suitable soil amendment.

Plot of USSL diagram (Fig 2) used for the classification of irrigation waters indicated that (50%) groundwater of study area falls under classes C_3S_3. Continuous use of such waters may lead to high salinity and high sodic hazards. Some of groundwater falls under $C2S_1$, $C3S_1$ $C3S_2$, such water may lead to medium to high salinity and low to medium sodicity when used for normal irrigation practices.

7. Temporal variation in groundwater quality

In 2016 the samples were collected from same locations where one or more parameter were found to be above BIS, 2012 permissible limit during the study carried out in 2014(Ground Water Pollution In The Industrial Clusters Of Panipat City, Haryana). The results of physico-chemical parameters determined in 2016 have been tabulated against values obtained in 2014 **(Table 3**).

Table 3: Variation in Chemical Parameters in GroundWater Samples, Panipat City

S. No.	Location	Year	E.C. In µmhos /cm at 25°C	HCO3 in mg/l	Cl in mg/l	SO4 in mg/l	NO3 in mg/l	F in mg/l	Ca in mg/l	Mg in mg/l	Na in mg/l	K in mg/l	Total Hardness in mg/l
1	Thermal Power Plant (TPP)	**2014**	2191	670	133	400	0.38	11.58	27	17	485	9	137
		2016	1666	625	76	145	0.5	14.3	25	7.5	331	8.5	92
3	Plot No. 260 Sector-29 Part II	**2014**	2720	418	562	350	17	0.52	165	167	188	9	1098
		2016	1373	464	69	275	0.6	2.25	16	17	315	3.5	113
4	HUDA 12	**2014**	1545	442	197	185	16	1.51	59	55	219	5	372
		2016	1480	476	118	285	1	0.96	43	111	144	8.5	564
5	Bhainswal	**2014**	568	323	21	32	0	1.92	27	2.4	116	2	78
		2016	638	292	17	106	0.5	1.95	21	17	122	3.5	123

There is improvement in water quality in general with respect to salinity, chloride sulphate, calcium, magnesium, sodium, potassium and hardness with time but there are a few exceptions. Salinity has increased at Bainswal while sulphate and hardness has increased with time at HUDA 12. There is not much change in water quality with respect to nitrate. Fluoride concentration has increased with time at all locations with exception at HUDA 12 where it has decreased considerably. Cause of fluoride in the area is found to be associated with its proximity to ash disposal plant.

No substantial change has been observed in respect to Cadmium, Copper and Zinc while there is slight improvement in water quality from 2014 to 2016 with respect to Lead and Iron.

On comparing the diagrammatic representation of water type on hill piper diagrams **(Fig 1)** it is found that in 2014 in general the groundwater is found to be mixed character type with majority of samples Ca-Mg-HCO3 followed by Ca-Mg-Cl-SO4 with isolated cases of Na-Cl or Na-SO4 type. But in 2016 , 50% samples are of Na-HCO3-SO4 type with isolated cases of Na-HCO3-Cl-SO4 indicating base exchange reaction.

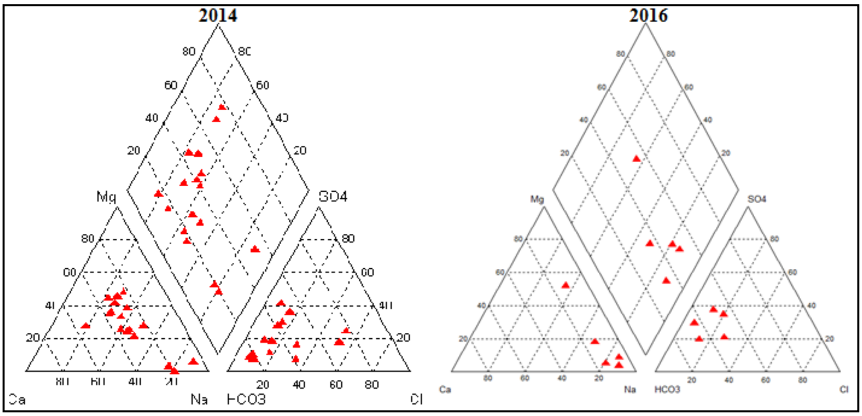

Fig 1 Hill Piper Diagram

The comparison of diagrammatic representation of EC with respect to SAR on USSL plot **(Fig 2)** is also indicative of considerable change in water quality of shallow aquifer with reference to irrigational use. The sodic character of groundwater has increased from 2014 to 2016 as number of samples falling in S2 and S3 class have increased. There is slight improvement in sodicity in tube well water at Thermal Power Plant.

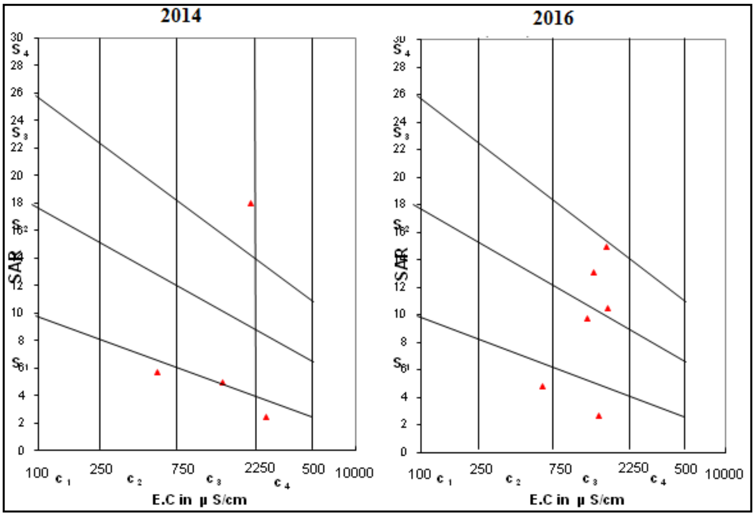

Fig 2 USSL Plot

8. Summary & suggestions

In Panipat city, dense industrialization set up for various industrial units such as dyeing, textile processing and foundries etc. coupled with rapid and haphazard urbanization has resulted in groundwater pollution. Study indicates that aquifers are polluted by fluoride and heavy metals such as Iron, Manganese and Cadmium at some locations. These locations are confined in the proximity of thermal power plant, oil refinery and Rojhla in the industrial clusters of HUDA. These industries are discharging their wastewater/effluents either on road side eucalyptus plantations, drains or on open ground/soil surface. In industrial area, it has been observed that water flowing through storm/drainage is of varied colors, which certainly will contribute to groundwater contamination. The groundwater pollution is not confined to one particular part of the city but is scattered in nature due to industrial set up in various clusters at various locations. Due to the presence of fluoride and heavy metal like iron and manganese in groundwater aquifers, it can be used for drinking purposes only after proper treatment. However, these waters can be used for irrigation for salt tolerant crops on soils with adequate permeability along with suitable soil amendments due to high RSC values. Continuous use of such waters may lead to high salinity and high sodic hazards or may lead to medium to high salinity and low to medium sodicity when used for normal irrigation practices.

There is improvement in water quality in general with respect to salinity, chloride, sulphate, calcium, magnesium, sodium, potassium and hardness with time but there are a few exceptions. There is not much change in water quality with respect to nitrate. Fluoride concentration has increased with time at all locations. Cause of fluoride in the area is found to be associated with its proximity to ash disposal plant. Not much change in water quality is observed with respect to Cadmium, Copper and Zinc while there is slight improvement in water quality with respect to Lead and Iron from 2014 to 2016.

Keeping in view, the industrial development in the Panipat city, which is very high and dense, it is proposed that industries which are prone to pollution should be shifted completely from small industrial clusters/residential areas to the newly developed industrial sectors, so that groundwater contamination could be checked in a more effective manner. Every industry (small or large) should be directed to install ETP in its premises to overcome the water contamination. Effective drainage system should be developed in newly created/developed industrial sectors, so that impoundage of wastewater could be stopped, as it may affect the groundwater quality right in its vicinity. Concerned agencies should regularly check and monitor the chemical quality of the effluents produced by industries before these are discharged out of the industrial premises and take strict action against the industrial unit found violating norms/guidelines. Roof top rainwater harvesting in large and medium industries should be made mandatory to augment groundwater recharge. This will not only increase the availability of groundwater but will also dilute the pollutants.

REFERENCES

1. APHA, 2012, Standard Methods for the Examination of Water and Wastewater, Washington, USA.
2. Bureau of Indian Standards for drinking waters BIS: 10500:2012.
3. CGWB, NWR, Chandigarh, Ground Water Year Book of Haryana State, 2014.
4. Handa, B.K., 1975, Natural Waters, Their Geochemistry, Pollution and Treatment with a Chapter on the Use of Saline Water, Technical Manual No.2.
5. Hem, J. D., 1970, Study and interpretation of chemical characteristics of natural waters, USGS, WSP.
6. Singh, Shailendra, 2014, Ground Water Pollution In The Industrial Clusters Of Panipat City, Haryana, CGWB unpublished report.

Impacts of industrialization on water quality of Korba city

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Abstract

In this work, the groundwater and surface water contamination in a huge coal burning site of the country, Korba, Chhattisgarh state, Central India is described. To know the suitability of water for domestic and agricultural use the collected water samples were analyzed for the physicochemical parameters (pH, Conductivity), major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3, Cl^{-}, NO_3^{-}, SO_4^{2-}, F^{-}), Total Hardness (TH) ,Total Alkalinity (TA) and heavy metals (Mn, Fe, Zn, Co, Ni, Cu, Cd and Pb) by the standard method given in APHA. Obtained values were compared with IS-2012: 10500: drinking water standard. The study reveals that by and large the groundwater and surface water are suitable for drinking purpose. However, instances of contamination is observed in isolated patches in the study area that may be due to anthropogenic activity like industrialization, civilization etc.

1. Introduction

Korba is known as the power hub of Chhattisgarh state. Huge reserves of coal are found in this area. Several coal mines, thermal power plants and aluminum industries are running in this region. Coal, a fossil fuel, is the largest source of energy for the generation of electricity worldwide. On the other hand, it is one of the largest worldwide anthropogenic sources of green house gases, acids, metals, organic compounds, etc. The ash content of coal is >30% and found to be contaminated with toxic inorganic and organic compounds (Sarkar et.al, 2006 & Sahu et.al, 2009). The thermal power plants generate power as well as fly ash due to combustion of coal. The industrial effluents are being discharged at various points in the surrounding area. The fly ashes, ore flushing and other chemical effluents generated from the industries are let out in dumping sites like ponds, tanks etc. which is discharged in to the surface water drains as a final liquid effluent containing various kinds of pollutants. Suitability of groundwater for drinking, irrigation and industrial purposes depends upon its quality. Changes in groundwater quality are due to variation in climatic conditions, residence time of water with aquifer materials and inputs from soil during percolation of water (CGWB, 2010). Many hydro geochemical processes have been highlighted in the control of the chemical composition of groundwater like carbonates, silicates weathering and ion exchange (Mitra et. Al, 2007 & Subba Rao, 2008). Several land and water-based human activities are causing pollution of this precious resource (Shankar et.al, 2011 & World Bank, 2010). The groundwater as well as surface water is seriously deteriorating due to rapid industrialization and urbanization.

1.1 Climate, soils and crops

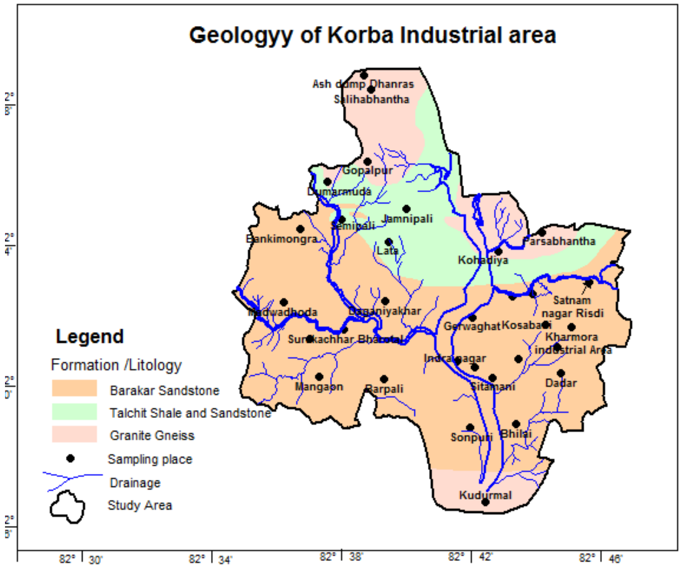
The climate of Korba city is sub tropical and south east monsoon is the main source of rains. The average annual rain fall is approximately 1200 mm. The soils of the study area are mostly of loamy and sandy type. Kharif is the main cropping season and Paddy is the main crop followed by wheat, maize and jawar. The pulses, oil seeds, fruits, vegetables, mirch, masala and sugarcane etc. are also grown in the area.

1.2 Drainage and geomorphology

The area is mainly drained by Hasdeo river and its tributaries. The Hasdeo River flows from north to south in the centre of the city. The Belgirinala and Dengunala both are important water bodies of city, flowing through Nehru nagar, Parshabhata, Belgiribasti, Rungara, Bhadrapara, Lalghat, Chhatghat and Kohadiya from east to west. All these streams join to the main river at confluence point due North and North East of Korba space town. The drainage exhibits dendritic to sub-dendritic pattern in the area with more or less same drainage density. Geomorphologically the area displays Structural Plains, Pediment/Pediplain and Denudational Hills. Overall the topography in the area varies between 300 m to 1021 m amsl.

2. Geology and Hydrogeology

Geologically the investigated area is underlain by formations ranging in age from Archean to Proterozoic. Barakar sandstone which is lateritic at places occupies the major portion of the area. However in the north western portion of the area around Jaminipali, Somanipali, Agarkhar and Sumedha pinkish to grayish, medium to coarse grained porphyritic granite occurs.



The groundwater in these formations occurs under semi-confined and confined conditions. The average thickness of the weathered portion in the area is around 15 m and in some places it goes up to 30 m. The occurrences of fractures at depth in the area are not common and wherever they occur are less potential from groundwater point of view. In general the discharge varies from 0.5 to 3 lps. Therefore, the development in these formations is mostly by way of dug wells ranging in depth between 6.02 to 12.0 mbgl with the depth of water level varying between 4.00 to 10.00 mbgl. The depth of bore wells drilled in that area varies between 50 to 200 mbgl.

3. Study Area

The study area covers about 280 sq. km. and is situated in the south-central part of Korba district. It falls in the Survey of India Topo Sheet Nos. 64J/11 and 64J/15 (1:50000 Scale) between latitudes 22^0 20’ to 22^0 25’N and longitudes 84^0 40’ to 82^0 45’N. Korba town which is the headquarters of Korba district falls in the study area. It is bounded by Pali block in the west, Katghora in the north-west and Kartala block in the east.

4. **Materials and method**

In the present investigation seventy five (75) water samples were collected from different sources (13-Dug well, 30-Hand pump and 32-Surface water) distributed in different locations of Korba. The analysis has been done in the laboratory of Central Ground Water Board, Chhattisgarh by adopting standard methods as prescribed in APHA – 19^{th} Edition 1995.

5. Results and discussion

The detailed chemical analysis data of Korba Industrial area is given in **Tables-1& 2**. In case of dug well water the pH varies between 5.5 to 7.8. The groundwater is neutral to alkaline in dug well zone. However, in few locations groundwater has been found to be acidic as in case of a dug well each in Bhilai , Dadar, Pondibahar and Kharmora . In case of hand pump water samples, the pH values range from 5.9 to 8.2. In most of the hand pumps groundwater is alkaline in nature while in few locations viz. Kudurmal and Bhilai pH (> 7.0) were also observed in study area. The highest pH value of 8.2 has been observed in the groundwater sample of a hand pump at Satnam nagar. Over all the groundwater of Korba is mostly neutral to slightly alkaline in nature, except in few locations where it is acidic in nature. It may be attributed to mining activity going on around the Korba area. In surface water samples, the pH value varies between 5.6 and 8.0 which indicate that the surface water is also slightly neutral to alkaline in nature though, in some locations it is obviously acidic in nature.

The conductivity in water from dug well vary between 139 to 1795 µS/cm at 25^oC. In most of the samples from dug wells, the electrical conductivity(EC) value is less except in Indira nagar and Kudurmal where EC is 1795 µS/cm and 1533 µS/cm respectively. In samples from hand pump, conductivity value ranges from 80 to 1668 µS/cm at 25 ^oC. The highest value has been observed in handpump water at Kudurmal i.e. 1515 µS/cm at 25^oC. In surface water samples the EC values vary between 100 to 710 µS/cm at 25^oC.

Bicarbonate concentration in dug well water samples ranges from 6 to 348 mg/l. In hand pump water samples, it ranges between 6 to 744 mg/l. The highest bicarbonate concentration 744 mg/l is observed at Kudurmal and at rest of the locations it is within BIS limit. In surface water samples it is in between 12 mg/l at Satnam nagar (lowest) to 262 mg/l at Parsabhata (highest).

In dug well water samples chloride concentration ranges from 11 to 243 mg/l. In hand pump water samples chloride concentration varies from 7 to 156 mg/l. The highest value was recorded at Kudurmal, whereas lowest value was recorded at Barpali. Chloride concentration in surfaces water samples ranges from 7.0 to 98.0 mg/l.

In samples from dug well zone, fluoride concentration range from 0.1 to 2.0 mg/l and in samples from hand pump zone, fluoride concentration vary from 0.2 to 2.6 mg/l. The locations where high concentration of fluoride in groundwater have been reported are Dhanras HP (2.6 mg/l), Kudurmal DW (2.6 mg/l), Kudurmal HP (1.75 mg/l). Locations where high fluoride are observed in surface water are NTPC Power City (5.7), followed by ash dyke water (3.5), Chhatghat SW (3.3), Satnamnagar SW (3.1), Bhaiskhatal SW (2.6), Kudurmal DW (2.6), Kudurmal HP (1.75), and Parsabhata SW (1.5 mg/l).

Table: 1. Physico-chemical parameters in ground and surface water of Korba city

Parameter	Dug well (n=13)		Hand pump (n=30)		Surface water (n=32)		IS 10500 :2012
	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Range
pH	5.5-7.8	6.9	5.9-8.2	7.2	5.6-8	7.7	6.5-8.5
EC (µS/cm)	139-1795	491.5	80-1668	384.8	100-710	248	-
CO_3^{2-} (mg/l)	0	0	0	0	0	0	-
HCO_3^- (mg/l)	6-348	106.6	6-744	139.8	12-262	77.3	200-600
Cl^- (mg/l)	11-243	61.5	7-156	37.2	7-98	24.5	250-1000
F^- (mg/l)	0.1-2	0.5	0.2-2.6	0.5	0.1-5.7	1.5	1.0-1.5
SO_4^{2-} (mg/l)	0-148	42.5	0-53	11.0	0-125	28.2	200-400
SiO_2 (mg/l)	1-11.9	4.9	1-11.9	4.9	0-11.8	4.3	-
PO_4^{3-} (mg/l)	0.16-0.57	0.4	0.14-1.01	0.4	0.1-1.25	0.4	-
NO_3^- (mg/l)	0-215	25.9	0-105	17.0	0-101	11.7	45
Na^+ (mg/l)	8-116	46.1	2.5-162.1	29.7	1.8-100.4	24.7	-
K^+ (mg/l)	0.3-41	10.7	0.4-13.3	4.7	1.8-36.3	9.6	-
Ca^{2+} (mg/l)	4-94	30.2	2-82	29.7	2-36	16.8	75-200
Mg^{2+} (mg/l)	2-74	11.8	1-66	9.7	1-12	5.5	30-100
TH (mg/l)	20-545	122.3	10-480	118.8	15-125	65.2	200-600

Table: 2. Heavy metals in ground and surface water of Korba city							
Parameter	**Dug well (n=13)**		**Hand pump (n=30)**		**Surface water (n=32)**		**IS 10500 :2012**
	Min-Max	**Mean**	**Min-Max**	**Mean**	**Min-Max**	**Mean**	**Range**
Pb (mg/l)	0-0.28	0.03	0-0.06	0.02	0-0.25	0.05	0.05
Fe (mg/l)	0.01-1.2	0.30	0.01-9.8	2.33	0.1-1.4	0.72	0.3
Mn (mg/l)	0-0.4	0.09	0-0.7	0.18	0-1.09	0.27	0.1-0.3
Cu (mg/l)	0-1.5	0.15	0-0.3	0.05	0-2	0.61	0.05-1.5
Zn (mg/l)	0-1.8	0.47	0-4.2	0.61	0-2.12	0.42	5-15
Cr (mg/l)	0-0.08	0.01	0-0.13	0.01	0-0.07	0.02	0.05
Cd (mg/l)	0-0.04	0.01	0-0.03	0.00	0-0.03	0.01	0.003

The high fluoride concentration have been observed in surface water samples in different locations of Dengu nalla and Belgiri nalla which are carrying effluents of Aluminum plant and Thermal power plant. These nallas finally join the Hasdeo River and very high fluoride has also been recorded at the effluent confluence point. The high Fluoride concentration in groundwater is also observed at few locations in the study area. The factory effluents from various plants contribute high fluoride in surface water. The geological formation may also have influences on the concentration of fluoride in groundwater in the study area. Consumption of high fluoride water causes fluorosis and other diseases (Handa, 1997).

In dug well water the nitrate concentration varies from 0 to 215 mg/l. In few samples from dug wells ,high concentration of nitrate, (above the BIS permissible limit of 45mg/l) has been observed in the study area. The dug well locations where very high concentration has been recorded are Gewraghat (NO_3^- 215 mg/l), Indiranagar (200), Bhilai (110), Dadar (100), and Pondibhata (100 mg/l). Presence of high nitrate in shallow aquifer in isolated patches is due to unhygienic surrounding prevailing around the well. In hand pump water nitrate concentration varies from 0 to 105 mg/l. At few locations i.e. Gewraghat, Surakachar, Bhilai and Kosabari higher concentration of nitrate in the order of 90, 70, 57 and 50 mg/l has been observed respectively. High nitrate in hand pumps indicate that pollution has leached in deeper levels of groundwater as well. Consumption of water with high concentration of nitrate (> 45 mg/l) may lead to blue baby syndrome (Kar et.al, 2002 & BIS, 1997 &2010)

The sulphate concentration in Korba town has been reported to be within the desirable limits. In case of dug well water, the sulphate concentration varies from 0 to 148 mg/l whereas in hand pump water, the sulphate concentration varies from 0 and 53 mg/l. In surface water samples, sulphate concentration varies from 0 to 125 mg/l.

In study area, the phosphate concentration varies from 0.14 to 1.01 mg/l in dug well water. In hand pumps it is observed between 0.16 to 0.57 mg/l and the highest concentration of 0.57 mg/l was recorded at Gopalpur hand pump which is situated near the ash pond. In surface water, phosphate concentration varies from 0.1 to 1.25 mg/l.

Sodium concentration varies from 8 to 116 mg/l in dug well water. In hand pump water lowest value observed was 2.5 mg/l at Mangaon and Sonpuri, whereas the highest value recorded was 162.1 mg/l at Kudurmal, which is exceptionally high. In rest of the water samples values have been observed to be less than 100mg/l. In Surface water samples minimum sodium concentration has been recorded as 1.8 mg/l at Satnam nagar whereas the highest concentration of 100.4 mg/l is observed at Parsabhata. Over all sodium concentration is low in study area.

In dug well water samples, the lowest potassium concentration observed is 0.3mg/l at Gopalpur and highest value has been observed as 41 mg/l at Indira nagar. In case of hand pump water samples, potassium concentration was lowest at 0.4 mg/l in Lata and highest 13.3 mg/l at Bhilai. In surface water samples it varied from 1.8 to 36.3 mg/l.

In study area calcium is predominant cation in all kind of water, whether it is surface or groundwater. In dug well water calcium concentration varies from 4 to 94 mg/l and in hand pump water calcium concentration varies from 2 to 82 mg/l. In surface water calcium concentration varies from 2 to 36 mg/l. In general calcium level is less than the permissible limit of 200 mg/l (BIS) in all kind of water.

The highest magnesium concentration in groundwater have been observed at Indira nagar 74 mg/l and Kudurmal 59 mg/l. In rest of the samples it is < 20mg/l, which indicate magnesium is low in concentration in shallow aquifers. In deep aquifers, magnesium concentration vary from 1 to 66 mg/l. In surface water samples magnesium concentration vary from 1 to 12 mg/l. In general magnesium concentration in all kinds of water is less than the BIS permissible limit (100mg/l) for the drinking water purpose.

5.1 Heavy Metals

The analytical results of heavy metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) of groundwater and surface water are presented in **Table -2.**

Iron is a major pollutant in the study area. It has been found that iron occur in almost all kinds of water samples. The maximum limit of iron in potable water is 1 mg/l as per BIS recommendation. In water from dug wells iron content is found relatively in lower concentration i.e. it varies from 0.01 to 1.2 mg/l. Only in few wells iron content is beyond the BIS permissible value. In case of hand pumps water is severely affected with iron and its concentration varies from 0.01 to 9.8 mg/l. In surface water iron content varies from 0.1 to 1.4 mg/l.

In some water samples, manganese has been observed to be more than the BIS recommended limit of 0.30 mg/l. In dug well water samples, manganese concentration is observed in between 0 to 0.4 mg/l and in hand pump water its concentration varies from 0 to 0.7 mg/l. In surface water manganese concentration varies from 0.0 to 1.09 mg/l and the highest value of 2.0 mg/l is obtained in NTPC power city. In another water sample from ash pond at Dhanras manganese is recorded as 1 mg/l. In few river water samples, manganese concentration was recorded greater than 0.3 mg/l which is due to anthropogenic activity.

Copper is an essential element for human beings. The desirable and permissible limit of copper in drinking water are 0.05 to 1.5 mg/l respectively. The highest concentration of copper has been recorded as 1.5 mg/l in dug well water near ABC coal washeries, at Chakabuda. Copper has also been found in groundwater samples collected from Barpali (0.06 mg/l) and Bhilai (0.05 mg/l). In rest of the dug wells, it is recorded below the maximum desirable limit. In hand pump water, high concentration has been observed in Balgeri nalla (0.3 mg/l), Surakachar mining area (0.25 mg/l) and SBS colony (0.12mg/l). In surface water copper content is observed between 0 to 2 mg/l.

Zinc is also an essential and beneficial element for human growth and metabolism. Zinc imparts an undesirable astringent taste to water at threshold concentration of about 4 mg/l (as zinc sulfate). Water containing zinc at concentrations in excess of 3–5 mg/l may appear opalescent and develop a greasy film on boiling (Todd, 1976). The desirable limit for zinc is 5 mg/l and maximum permissible limit is 15 mg/l for drinking water as per BIS recommendation. Zinc is a vital growth element for plants and animals but at elevated levels it is toxic to some species of aquatic life (Karanth, 1997). Zinc in water may also result from industrial waste pollution. The FAO-recommended maximum level for zinc in irrigation water is 2.0 mg/l. The US EPA primary drinking water standard is 5 mg/l. In study area zinc content in surface water is in between 0 to 2.12 mg/l. The zinc concentrations in surface water are generally within the permissible limit. In groundwater of dug well zone and hand pump water, zinc is observed below the BIS recommended limit for drinking water purpose.

Lead is a very toxic element which accumulates in the skeletal structure of man and animals. Its maximum permissible limit is 0.05 mg/l and beyond this limit it can be toxic and create solvency diseases, infection in gastrointestinal track, paralysis, mental confusion and visual disturbances such as anaemia etc. The lead concentration in dug well water varies from 0 to 0.28 mg/l and in hand pump water it varies from 0 to 0.06 mg/l which indicates that at some locations in groundwater the lead concentration is beyond the BIS recommended limit. In some of the surface water samples,it is also recorded beyond the permissible limit. In surface water the lead concentration varies from 0 to 0.25 mg/l.

Chromium concentration in dug well water varies from 0 to 0.08 mg/l and in water from hand pumps it varies from 0 to 0.13, which indicate that at some locations in groundwater the chromium concentration is beyond the BIS recommended limit. Similarly in surface water the chromium concentration varies from 0 to 0.07 mg/l which again show that in some of the surface water samples, it beyond the permissible limit. Chromium concentration in small amount is essential to mammals but in excess (0.05 mg/l as maximum permissible limit fixed by BIS, WHO, ICMR) can cause digestive problems, intestinal diseases, carcinogenic acuity (cancer), cutaneous and nasal mucous membrane ulcers and dermatitis etc.

Cadmium is an undesirable element and even in low concentrations can cause lung, kidney and pancreatic diseases. It interferes with enzymes and causes a painful disease called Itai-Itai of bone. In dug well water cadmium varies from 0 to 0.04 mg/l and in hand pumps water it varies from 0 to 0.03 mg/l. This indicates that at some locations the cadmium concentration in groundwater is beyond the BIS recommended limit. In surface water the cadmium concentration varies from 0 to 0.03 mg/l, which indicates its occurrence beyond permissible limits at places.

6. Conclusion

The groundwater of study area is slightly alkaline in nature except in some locations where it is acidic. The groundwater is suitable for drinking and domestic purposes except at few places where instances of contamination have been observed. The high fluoride concentration has been observed in some surface water bodies where the industrial effluents are discharged. The occurrence of some trace elements beyond the prescribed limit set by BIS in both groundwater as well as surface water at few locations also indicate contamination; however, in rest of the area the water is potable.

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References

1. APHA, 1995, "Standard Methods for The Examination of Water And Wastewater (19th Ed.)". Washington, Dc: American Public Association.
2. BIS, 1997, Drinking water standards of BIS 10500.
3. BIS, 2012, Drinking water standards of BIS 10500.
4. CGWB, 2010, Ground Water Quality in Shallow Aquifers of India, Central Ground Water Board, Ministry of water Resources, Government of India.
5. Goodarzi, F. Huggins, F.E. and Sanei, H., 2008, Assessment of elements, speciation of As, Cr, Ni and emitted Hg for a Canadian power plant burning bituminous coal, International Journal of Coal Geology, 74, 1-12.
6. Handa, B.K., 1997, Hydro Chemical Zones of India, Proc.
7. Kar, S. Khan, D.K. and Santra, S.C., 2002, Ground water nitrate concentration and its impact on human health: a review. Everyman's Science, 37, 35-40.
8. Mitra, B.K., Sasaki, C. Enari, K. and Matsuyama.Fujita, N.M., 2007, Suitability Assessment of Shallow Groundwater for Agriculture In Sand Dune Area of Northwest Honshu Island, Apan. Applied Ecology and Environmental Research, 5, 177-188.
9. Nielson, N. And Nielson, G., 2000, The essential handbook of groundwater sampling, CRC Press, Boca Raton, USA.
10. Palmer, C.A. and Lyons, P. C., 1996, Selected elements in major minerals from bituminous coal as determined by INAA: implications for removing environmentally sensitive elements from coal, International Journal of Coal Geology, 32, 151-166.
11. Sarkar, A., RumaRano, Udaybhanu, G. and Basu, A.K., 2006, A comprehensive characterisation of fly ash from a thermal power plant in Eastern India Fuel Processing Technology, 87, 259-277.
12. Sahu, S.K., Bhangare, R.C., Ajmal, P.Y., Sharma, S. Pandit, G.G. and Puranik, V.D., 2009, Characterization and quantification of persistent organic pollutants

in fly ash from coal fuelled thermal power stations in India, Microchemical Journal, 92, 92-96.

13. Subba Rao, N., 2008, Factors Controlling The Salinity in Groundwater in Parts of Guntur District, Andhra Pradesh, India. Environmental Monitoring and Assessment, 138, 327-341.

14. Shankar, P.S.V. Kulkarni, H. And Krishnan, S., 2011, India's groundwater challenge and the way forward. Economic and Political Weekly, EPW.

15. World Bank, 2010, World Bank Deep wells and prudence: Towards pragmatic action for addressing groundwater overexploitation in India.

16. WHO, 2004, Guidelines for Drinking Water Quality, Vol. 1, Recommendation, France, 181 p.

17. Yudovich, Ya.E. and Ketris, M.P., 2005, Mercury in coal: a review Part 2. Coal use and environmental problems, International Journal of Coal Geology, 62, 135-165.

18. Yudovich, Ya.E. and Ketris, M.P., 2006, Selenium in coal: A review, International Journal of Coal Geology, 67, 112-126.

19. Yudovich, Y.E. and Ketris, M.P., 2006, Chlorine in coal: A review, International Journal of Coal Geology, 67, 127-144.

Groundwater pollution along Najafgarh drain, NCT, Delhi

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State Unit Office, Delhi

Abstract

The Najafgarh drain is one of the very old drains originating from Rajasthan/Haryana as a rivulet. Najafgarh Drain Basin has been identified as one of the critically polluted areas as per the report of Central Pollution Control Board. The Najafgarh drain receives waste water through various outlets and from all sources like domestic, agriculture and industrial. It is the biggest drain of NCT Delhi discharging around 1800 mld of waste water into river Yamuna. It contributes about 60% of the total waste water that gets discharged from Delhi into river Yamuna. It traverses a length of 62 Km before joining the river Yamuna at Wazirabad after passing through Southwest, West, Northwest and North districts of NCT Delhi. Apart from domestic waste, the drain also carries effluents from industrial areas. The drain water is contaminated to a considerable level. A special study of Najafgarh drain basin was taken up during 2011-12 with a view to evaluate the intensity of pollution due to direct inflow of untreated sewage in the drain and its impact on groundwater. The study has revealed that concentration of various ions in the groundwater samples are beyond permissible limits as prescribed by BIS (2012) for drinking water. The groundwater in the aquifers along the Najafgarh drain is contaminated in stretches and the area is not suitable for any large scale groundwater development.

1. Introduction

Najafgarh drain basin occupies an area of 832 sq. km. out of total area of 1483 sq.km. of Delhi. Najafgarh drain is continuation of the rain fed Sahibi River (which originates in Jaipur, Rajasthan passing through Alwar, Rajasthan and Gurgaon, Haryana) and an elongation of the Najafgarh Jheel. Najafgarh Jheel the largest surface water body in Delhi, which had original spread of about 22.5 sq.km. is now constricted to just 6.0 sq.km. The Najafgarh drain enters Delhi near Dhansa, Southwest corner of Delhi and spills its overflow in the Najafgarh Jheel (lake) basin. It traverses a length of 62 km before joining the river Yamuna (**Fig 1**). Thus nearly 60% length of the Najafgarh drain flows through Southwest district of NCT, Delhi. The stretch of the Najafgarh drain through Southwest and part of West district is unlined while stretch of the drain through Northwest and remaining part of West district is lined. The drain finally joins the river Yamuna flowing in the eastern part of Delhi.

Yamuna is the major river stretching across 22 km along NCT Delhi. . The two barrages in NCT, Delhi are located on upstream and downstream end of River Yamuna at Wazirabad and Okhla respectively. No fresh water is released from the upstream barrage at Wazirabad while a large quantity of waste water from domestic, industrial and agricultural activities is discharged on its downstream through 19 drains into the river

Yamuna. This stretch is highly polluted and has considerable impact on surface and groundwater systems of the NCT, Delhi. The colour of river water is bluish/ greenish, which changes to dark grey downstream where Najafgarh drain joins the river Yamuna.

The drainage of Delhi is divided into three main drainage zones in respect of pollution outfalls 1) Najafgarh Drain Basin, 2) Trans Yamuna Drain Basin and 3) Okhla Sewage Treatment Plant (STP) catchment. Najafgarh Drain is the major contributor of pollution load into Yamuna River. The total outflow of Najafagrh Drain is around 1800 mld.

This paper discusses the groundwater pollution study of Najafgarh drain, Delhi taken up under Annual Action Plan 2011-12 of State Unit Office, Delhi with the objective of evaluating the intensity of pollution due to direct inflow of untreated sewage from surrounding areas and its impact on groundwater quality.

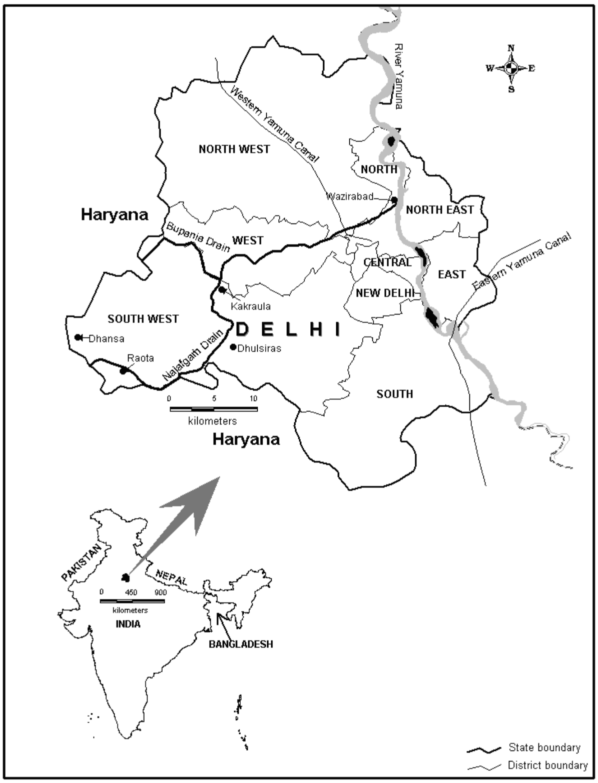

Fig 1: Map of Delhi showing Najafgarh drain

2. Status of waste water treatment

There are two major sources of pollution: domestic and industrial. Normally 80% of water supply is generated as sewage. Before entry of Najafgarh Drain in Delhi, the drain receives sewage from many towns and colonies such as Gurgaon etc. As per "Action Plan – Abatement of Pollution in Critically Polluted areas of Najafgarh Drain Basin" prepared by DPCC (2011), the capacity of Sewage Treatment Plants operational in the catchment area of Najafgarh drain is only around 1100 mld. Unauthorized residential colonies alongside the drain have not been laid with proper sewerage network and untreated waste water from these colonies is contributing to deteriorated water quality of the drain. There are a total of 47 drains outfalling in Najafgarh drain basin. In addition to domestic waste water, the drain also carries industrial effluents from the industrial areas viz. Wazirpur, Lawrence Road, Najafgarh Road, Kirti Nagar, Naraina, Mayapuri and Anand Parvat. The basin of the Najafgarh drain also possess agriculture areas. Agriculture wastes is also contributed to it especially during rainy season. Najafgarh drain also receives surplus fresh water through Western Yamuna Canal.

The effluents from industries engaged in activities of pickling, dyeing, electroplating etc. in the industrial area as well as non industrial area falling in the catchment of Najafgarh Drain are the main sources of water pollution. The waste water discharged by these industries have exceeded the acceptable limits of pH & TDS. Though these industries have CETP, there is no provision for controlling the TDS. (Delhi Pollution Control Committee, 2011)

There are 19 industrial areas whose waste water reaches the Najafgarh drain **(Table- 1**). As per Delhi Master Plan 2021, 20 new industrial areas have been earmarked for redevelopment. Industrial areas falling in the catchment area of Najafgarh Drain are Anand Parbat, Samaipur Badli, Sultanpur Mazra, Hastsal Pocket-A, Naresh Park Extn, Libaspur, Peeragarhi Village, Khyala, Hastsal Pocket D, Shalimar Village, Nawada, Rithala, Swarn Park Mundka, Haiderpur, Dabri and Basai Darapur.

Table 1: List of industrial areas with the industries whose waste water flows into Najafgarh Drain

North Zone		**Types of Industries**
1.	G.T. Karnal Road Industrial Area	Engineering, Electronics, Plastics, Wire units, Hosiery, Chemical Units & other Small scale units.
2.	Rajasthani Udyog Nagar Industrial Area	Engineering, Textiles, Hosiery, Plastics and Automobiles etc.
3.	S.M.A. Industrial Area	Engineering, Plastics, Chemical Units
4.	S.S.I. Industrial Area	Engineering, Plastics, Chemical Units, Hosiery units
5.	Wazirpur Industrial Area	Engineering, Plastics, Chemical, Dyes, Textiles, Paints, Steel Rolling, Pickling Units
6.	Lawrance Road Industrial	Engineering, Plastics, Textile, Paint, Steel rolling and other small scale Units
7.	Udyog Nagar Industrial Area	Engineering, Plastic and other Small Scale units.
8.	D.S.I.D.C. –Sheds Nangloi	Plastics, Engineering, Textiles, Wire Units and Hosiery units etc.
9.	Mangol Puri Industrial Area	Engineering, Textiles, Plastics, Automobile and other Small Scale Industries.
1	Badli Industrial Area	Textiles, Electronics, Engineering, Plastics, Soap

10.		and Detergents, Wire units, Small scale chemical units, Hosiery, Clothes stitching, Dyeing and Printing units.
11.	Narela Industrial Area	Engineering, Textiles, Plastics etc.
12.	Bawana Industrial Area	Food processing, Drug & pharmaceutical, Electronics & telecommunication etc.
South Zone		
1.	Okhla Industrial Area, Ph-I & Ph-II	Textile, Engineering, Plastics, Electronics, Wooden furniture, Sanitary fittings, Soap and Detergents, Wire units, Small scale chemical units, Hosiery, Clothes stitching, Dyeing and Printing units.
West Zone		
1.	Naraina Industrial Area, Ph-I & Ph-II	Medium industries about 500 Nos. Mostly Engineering
2.	Mayapuri Industrial Area, Ph-I & Ph-II	Engineering, Plastics, Tyre and Rubber Industry, Small scale units.
3.	Tilak Nagar Industrial Area	Engineering, Plastics etc.
4.	Kirti Nagar Industrial Area	Engineering, Steel Industries, Automobiles, Chemical plants, Wood based furniture etc.
5.	D.F.L. Industrial Area, Moti Nagar	Engineering, Steel Industry, Chemical units, Vegetable Oil Textiles, Plastics, Hosiery etc.
6.	Najafgarh Road Industrial Area	Engineering, Plastics, Rubber processing, Paint, Hosiery, Textile, Chemical, Chlorine, Sodium Hydroxide, Vegetable Oil, Pesticides Units

(After Delhi Pollution Control Committee, 2011)

Out of the proposed 15 Nos of CETPs for treatment of waste water generated by the industrial areas of Delhi, only ten have been constructed and are operational. One more CETP at Narela industrial area has been constructed by DSIDC, which is also operational. Wastewater from all CETPs except for Jhilmil & Friends Colony enters into Najafgarh Drain.

3. Geology and hydrogeology

The subsurface formations present in the area in the vicinity of the drain have alternate fluvial and aeolian sands distributed sporadically. The sediments are comprised of predominately silt with medium to fine sand and clay. The alluvial deposits are of Pleistocene age with interbedded, lenticular and inter-fingering deposits of silty sand, clay and kankar. The proportion of finer sediments is more in depth range of 0 to 45 meters below ground level, nearly 60% is fine sand in composition and rest is made up of a mixture of silt and clay. The aeolian sands are underlain by Delhi Quartzite of Proterozoic Age.

Groundwater in the area occurs under unconfined conditions in phreatic zones and under confined/semi confined conditions in the deeper aquifers. Throughout the Southwest district and major part of West district, the depth to bedrock below Najafgarh drain and its adjacent area is in the range of 200-300 meters below ground level (**Fig 2**)).

As the drain in its middle part takes a bend from N-S orientation to nearly E-W direction and flows eastwards to join river Yamuna (**Fig 3**), it gradually moves towards surface exposures of hard rocks which can be observed at a few places, and as such gradually the depth to bedrock below the drain and its adjacent areas decreases from 200-300 mbgl towards west to less than 100 mbgl and the location where the drain joins river Yamuna, the depth to bedrock is in the range of 10-30 m. bgl only (Plate 2). The rock is comprised of grey coloured quartzite which is thickly bedded hard & compact and is intruded locally by pegmatites and quartz veins, often interbedded with mica schists.

The depth to water level in the areas adjacent to the Najafgarh drain varies in the range of 2.2 to 17.90 meters below ground level. The shallower depth to water level is noticed in the upstream parts of the drain where it enters Delhi and in the most downstream parts of the drain where it meets the river Yamuna. The relatively deeper water levels are found in the middle stretches of the drain. The depth to groundwater levels monitored in the pre monsoon and post monsoon period are given in **Table 2**.

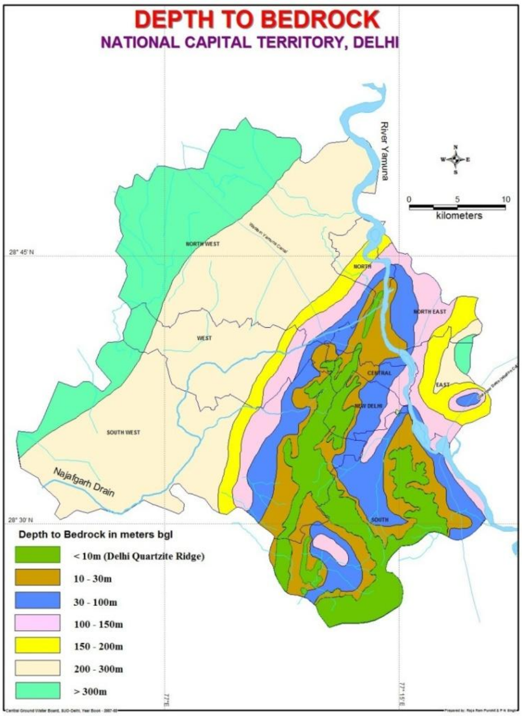

Fig 2: Map showing Depth to bedrock

Table 2: Depth to groundwater level along Najafgarh drain				
Sl.No.	**Name of Station**	**Type of Well**	**Depth to Water level May, 2011 (m bgl)**	**Depth to Water level Nov 2011 (m bgl)**
1	Galibpur	Pz	2.98	2.28
2	Raota	DW	3.51	2.77
3	Deorala	Pz	2.2	2.43
4	Jhuljhuli	DW	2.77	2.6
5	Daryapurkhurd	Pz	4.86	4.55
6	Daulatpur	Pz	17.05	16.38
7	Chawla	Pz	13.22	13.20
8	Dwarka Sec 16	Pz	14.80	15.24
9	Dwarka Sec 20	Pz	12.62	11.52
10	Shikarpur	Pz	12.02	11.15
11	Bapraula	DW	3.5	2.8
12	Tilangpur	DW	7.17	4.87
13	Punjabi Bagh	Pz	17.65	17.90
14	Vikaspuri	Pz	10.25	10.85
15	Ashok Vihar IV	Pz	10.43	10.51
16	Kingsway Camp	Pz	4.50	4.13
17	Delhi University	Pz	5.32	5.28
18	Tagore Garden	Pz	7.69	6.67
19	Najafgarh	Pz	15.97	17.32

4. Groundwater quality

During the field visits, samples were collected mainly from hand pumps from the areas adjacent to the drain to know the probable impact of the Najafgarh drain on groundwater quality. Acid treated samples were collected for trace element/ heavy metal analysis and normal samples for major element analysis. The sampling locations are shown in **Fig 3**. Spatial distribution of various chemical constituents in groundwater was studied to observe the distribution pattern of various chemical constituents in space.

The analysis of groundwater samples for major and trace inorganic dissolved constituents was carried out as per Standard methods. The results of chemical analyses of major ions and heavy metals are given in **Tables 3 and 4** respectively. For the present study, standards prescribed by BIS (IS 10500:2012) for drinking water have been used for evaluation of water quality for domestic use.

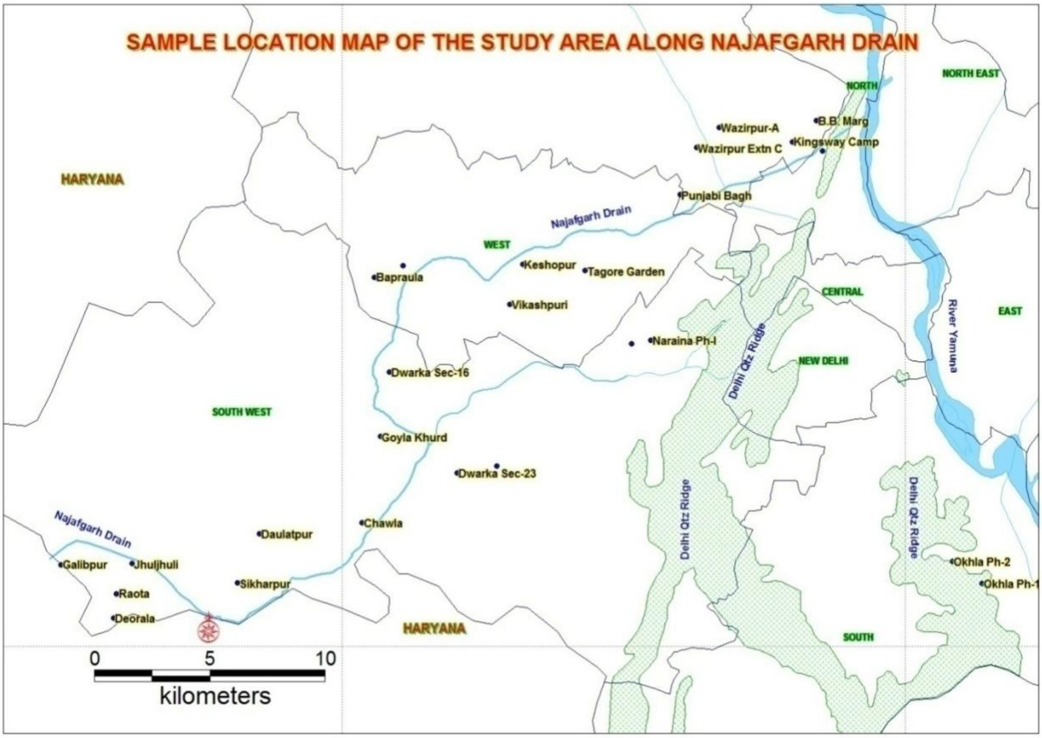

Fig 3: Map showing sampling locations of the study area

Table 3:Chemical Analysis of water samples along Najafgarh Drain, May 2011																
S. No.	**Location**	**Type of sample**	**pH**	**E.C. micro mhos/cm. at 25^0 C**	**Values in mg/l**											
					CO_3	**HCO3**	**Cl**	**SO_4**	**NO_3**	**F**	**Ca**	**Mg**	**Na**	**K**	**Total Hardness as $CaCO_3$**
1	Galibpur	T.W	7.6	6100	0	134	2077	175	90	0.7	169	236	859	36	133
2	Raota	H.P	8.02	7380	0	322	2390	495	75	0.78	43	145	1618	1	706
3	Jhuljhuli	D.W	7.85	10700	0	107	3905	635	141	0.17	432	300	1815	97	2314
4	Deorala	T.W	8	6440	0	107	2210	140	144	0.59	141	162	1102	4.8	1069
5	Sikharpur	T.W	8.05	3770	0	148	764	650	15	0.43	110	102	550	9	696
6	Daulatpur	T.W	8.15	320	0	107	42	18	4.52	0.2	35	14	10	2.7	147
7	Chawla	T.W	7.75	4030	0	107	1112	335	16	0.62	185	124	485	7.9	1020
8	Dwarka Sec-23	T.W	7.48	7730	0	228	2806	nd	1.79	0.12	354	307	920	5.6	2148
9	Dwarka SPG	T.W	8.5	1370	66	167	306	9	14	0.37	12	17	277	1.6	98
10	Goyla Khurd	T.W	8.15	1130	0	188	222	nd	45	0.6	31	55	115	8.6	304
11	Dwarka Sec-16	T.W	8.42	1600	66	242	306	45	20	1.06	7.8	29	305	6.5	137
12	Bapraula	T.W	7.95	6450	0	497	1615	835	59	1.3	75	162	1318	12	853
13	Tilangpur Kotla	D.W	8.32	2780	82	779	403	55	107	2.39	12	33	623	3	167
14	Vikashpuri	T.W	8.05	1400	0	389	236	nd	43	1.59	27	33	227	5	206
15	Keshopur	T.W	7.75	2700	0	376	598	168	39	0.97	55	27	395	8.4	500
16	Tagore Garden	T.W	7.9	205	0	94	21	nd	2.15	0.14	27	7.2	3	1.8	98
17	Punjabi Bagh	T.W	8.41	2830	66	349	438	396	16	2.12	16	36	578	6	186
18	Kingsway Camp	T.W	7.81	4210	0	550	1125	65	12	2.7	55	81	756	8.9	471
19	Delhi University	T.W	7.56	3300	0	148	813	335	81	0.53	200	79	400	1.8	824
20	B.B. Marg	T.W	8.18	1240	0	403	188	21	54	4.14	24	24	238	3.5	157

Table 4: Heavy Metal analysis of water samples along Najafgarh Drain, May 2011							
Sl. No.	**Location**	**Values in mg/l**					
		Cd	**Cu**	**Mn**	**Pb**	**Zn**	**Fe**
1	Galibpur	nd	0.02	0.04	0.17	1.99	1.23
2	Raota	nd	0.01	0.05	0.14	1.63	1.65
3	Jhuljhuli	nd	nd	0.03	0.09	0.03	0.27
4	Deorala	nd	0.02	0.01	0.14	0.27	5.07
5	Sikharpur	nd	0.01	0.26	0.09	0.07	0.13
6	Daulatpur	nd	nd	nd	ND	nd	nd
7	Chawla	0.01	0.01	0.07	0.16	0.15	0.76
8	Dwarka Sec-23	0.02	nd	0.09	0.19	0.43	0.48
9	Dwarka SPG	nd	nd	nd	ND	0.25	0.04
10	Goyla Khurd	nd	nd	0.13	0.03	0.06	nd
11	Dwarka Sec-16	nd	nd	0.01	0.05	0.06	nd
12	Bapraula	0.01	0.01	0.05	0.03	0.04	1.68
13	Tilangpur Kotla	nd	nd	nd	0.15	0.03	0.41
14	Vikashpuri	nd	nd	nd	0.03	0.02	0.09
15	Keshopur	nd	nd	0.01	ND	0.08	0.17
16	Tagore Garden	nd	nd	nd	0.05	0.22	0.04
17	Punjabi Bagh	nd	0.13	0.07	ND	0.36	4.71
18	Kingsway Camp	nd	nd	0.06	0.06	0.06	0.9
19	Delhi University	nd	nd	0.02	0.08	0.13	0.3
20	B.B. Marg	nd	nd	nd	ND	0.15	0.13
21	Wazirpur Extn C	ND	0.005	0.09	0.029	0.1578	0.081
22	Wazirpur-A	ND	0.012	0.0178	0.066	1.537	0.082
ND-Not determined, nd-not detectable							

4.1 Major Elements

Constituent wise number of water samples falling in different categories and their comparison with BIS standards, their maximum and minimum values are tabulated in Table 5.

Table 5: Constituent wise number of groundwater samples falling in different categories

S No	Constituent	Min. Value (mg/lit)	Max. Value (mg/lit)	Number of samples		
				Below Desirable limit	Between Desirable & Permissible Limits	Beyond Maximum Permissible Limit
1	Chloride	21	3905	5	7	8
2	Sulphate	9	835	13	3	4
3	Nitrate	1.79	144	11		9
4	Calcium	7.8	432	12	5	3
5	Magnesium	7.2	307	6	6	8
6	Fluoride	0.2	4.14	13	2	5

As salinity appears to be a major problem in groundwater of NCT Delhi, it is important to examine the pattern of variation of electrical conductivity in the aquifers along the Najafgarh drain. Electrical conductivity of groundwater has been found to vary from 205-10700 µS/cm at 25^{o}C. The maximum value of 10700 µS/cm was recorded at Jhuljhuli. About 50% of the samples analyzed fall under unsuitable class having EC more than 3000 µS/cm. The variation in Electrical Conductivity of the groundwater with respect to the sampling locations is shown in **Fig. 4 & Fig 5**. Initial stretch of the Najafgarh Drain has higher salinity in comparison to other parts. In middle stretch, EC values showed decrease as the sampling locations are located near the places where Ganda Nala joins Najafgarh Drain. Later part of the drain has comparatively lower values of EC.

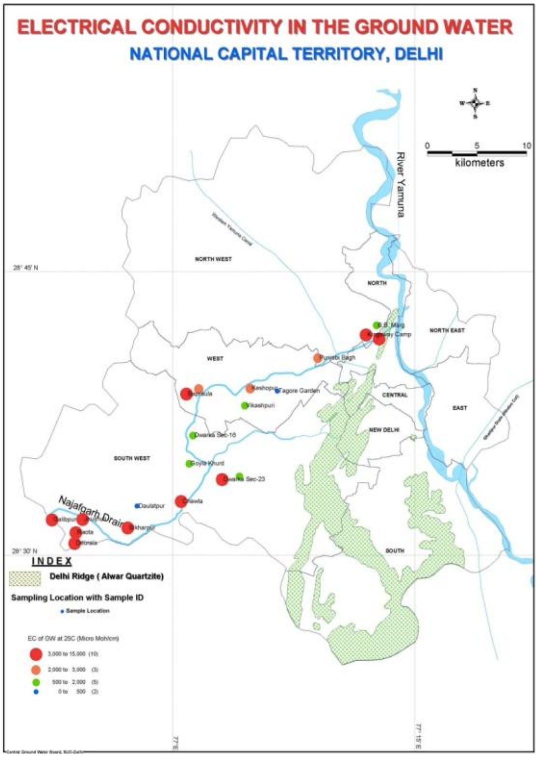

Fig 4 : EC in groundwater along Najafgarh Drain

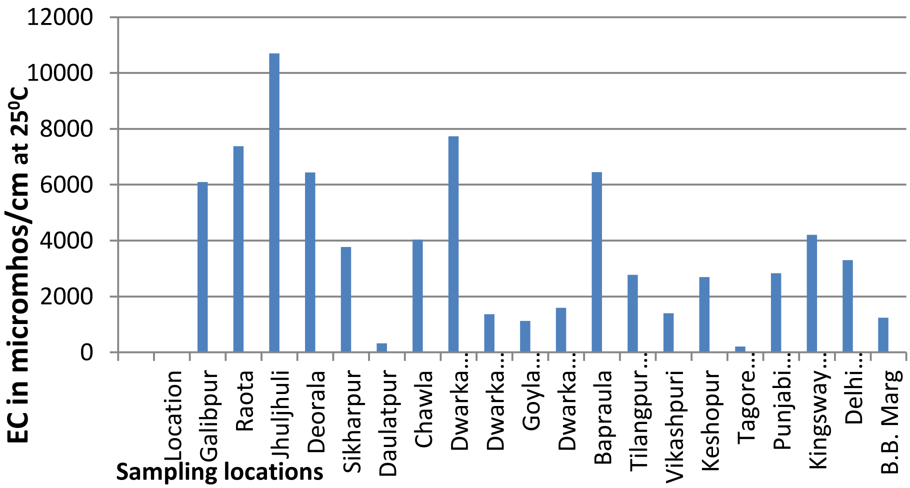

Fig. 5: Concentration of EC in groundwater in different sampling locations

Concentration of chloride in groundwater samples varies from 21 to 3905 mg/litre. In 35% of groundwater samples, chloride concentration exceeds the desirable limit (250 mg/litre) and in 40% of the samples, chloride concentration exceeds the permissible limit (1000 mg/litre). Pattern of chloride distribution is similar to that of Electrical conductivity. Initial stretch has higher chloride concentration than the later part of the drain. The variation in concentration of chloride in groundwater with respect to the sampling locations is shown in **Fig 6 & Fig 7**.

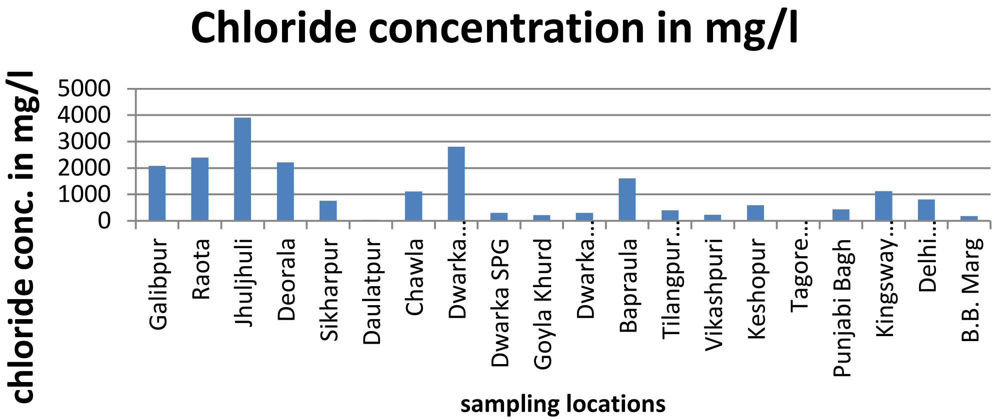

Fig. 6: Concentration of chloride in groundwater in different sampling locations

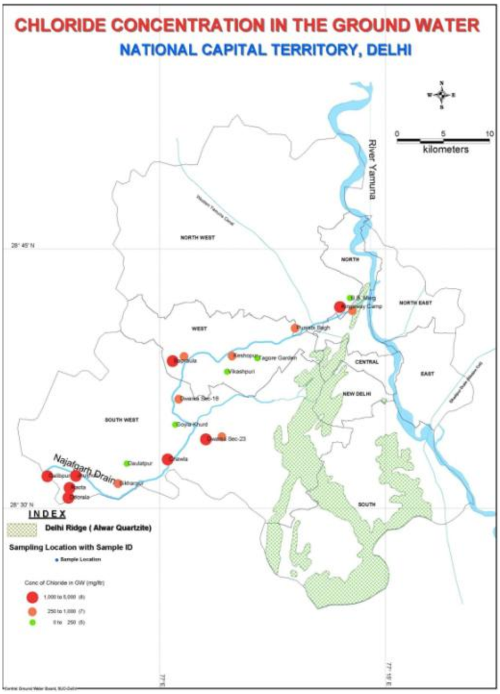

Fig 7 : Chloride in groundwater along Najafgarh Drain

Sulphate was detected in almost all the groundwater samples collected for analysis. The concentration of sulphate in groundwater varied from 9 to 835 mg/litre. Maximum concentration of sulphate was observed at Bapraula. The concentration of sulphate in 15% of groundwater samples exceeded the desirable limit (200 mg/litter). In 20% groundwater samples, concentration of sulphate was beyond permissible limit (400 mg/litre). The variation in concentration of sulphate in groundwater with respect to the sampling locations is shown in **Fig. 8**.

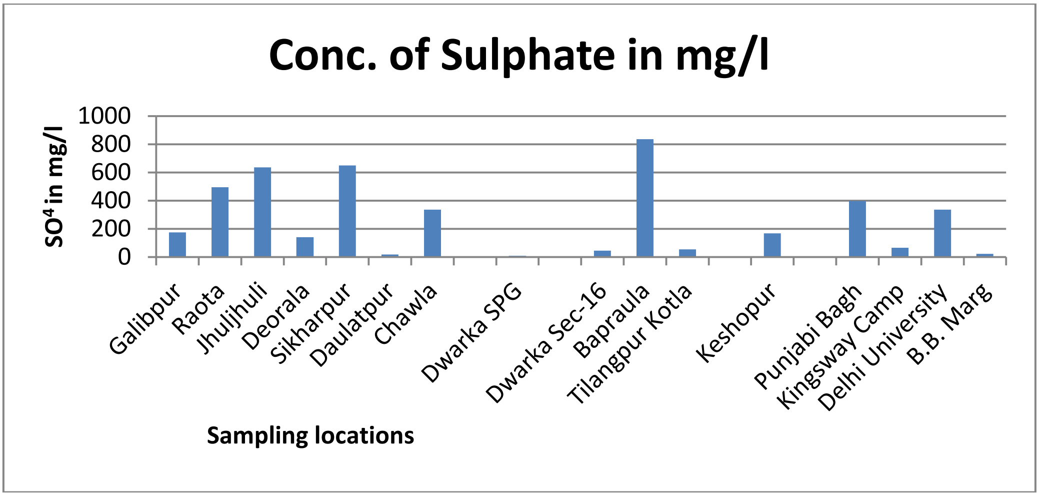

Fig. 8: Concentration of sulphate in groundwater in different sampling locations

Values of magnesium have been reported in the range of 7.2 to 307 mg/l. In 40% of the samples, the value of magnesium exceeded the permissible limit. Only 30% of samples have shown magnesium value within the desirable limit of drinking water standards. The variation of magnesium concentration in groundwater with respect to the sampling locations is shown in **Fig.9**. It is observed that magnesium concentration in groundwater is more in the samples close to the drain and it was reduced at larger distance from the drain. The higher concentration of magnesium could be on account of localized greater influx of magnesium into groundwater from the effluents from the drain. The effect of migration is seen up to a distance of about 1.5 km.

Values of calcium in groundwater samples have been found to vary from 7.8 to 432 mg/litre. Around 60% of the samples have concentration of calcium below desirable limit of 75 mg/litre. Only in 15% of groundwater samples (at 3 locations namely Jhuljhuli, Dwarka Sec-23 and Delhi University), concentration of calcium was found to be above permissible limit of 200 mg/litre. The variation of calcium concentration in groundwater with respect to the sampling locations is shown in **Fig. 10**. Concentration of calcium in groundwater has been found to be high in the samples close to the drain. The higher concentration of calcium could be on account of localized greater influx of calcium into groundwater from the effluents from the drain. The effect of migration is seen up to a distance of about 1.5 km only on either side of drain.

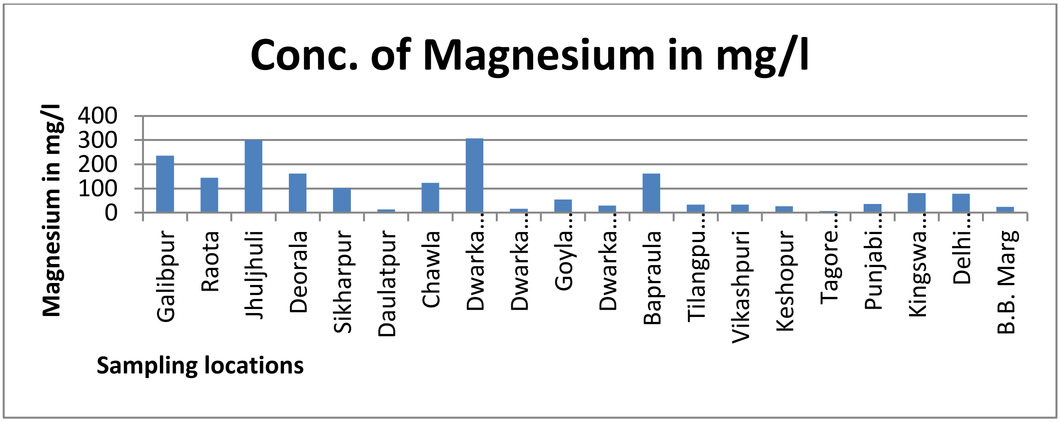

Fig. 9: Concentration of magnesium in groundwater in different sampling locations

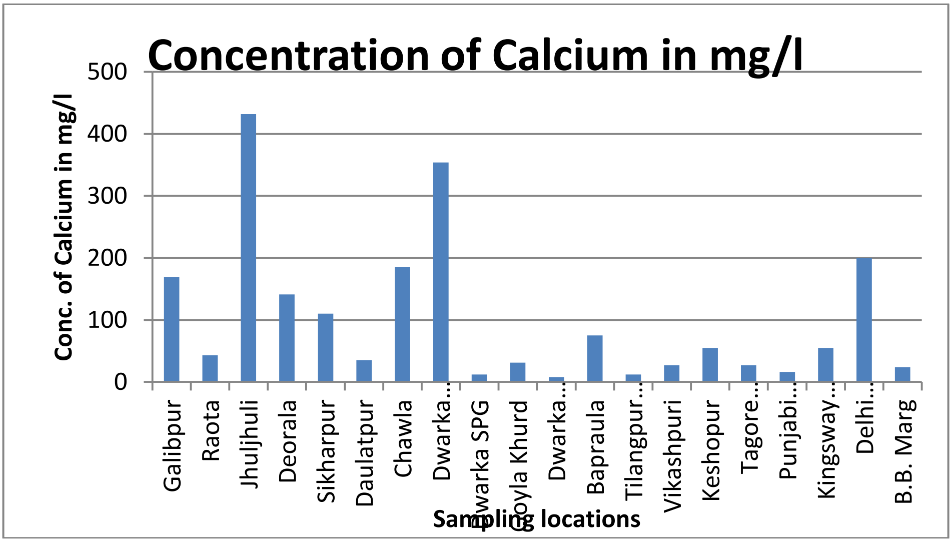

Fig. 10: Concentration of calcium in groundwater in different sampling locations

Fluoride was detected in almost all the groundwater samples (Table-3). The concentration of fluoride in groundwater samples has been found to vary from 0.2 to 4.14 mg/litre. Fluoride concentration was observed to be below desirable limit in 65% of samples. Around 10% of samples had Fluoride concentration above desirable limit (1.0 mg/litre) and within permissible limit. Fluoride concentration above permissible limit (1.5 mg/litre) was observed in 25% of samples. The variation in concentration of fluoride in groundwater with respect to the sampling locations is shown in **Fig. 11 & 12.**

Initial stretch of the drain has lower fluoride values. Higher values are seen in samples after the confluence of Bapraula drain and Ganda nala with Najafgarh drain. Both the nalas, particularly Bapraula drain receive industrial effluents as discharge. Fluoride in groundwater is generally geogenic in origin but in this part of Delhi, it appears that anthropogenic activity is also contributing to higher concentration of fluoride in groundwater.

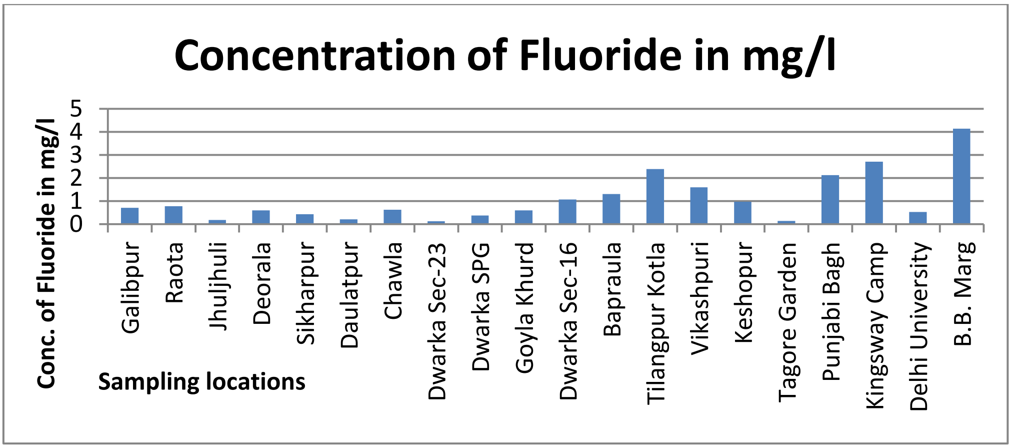

Fig. 11: Concentration of fluoride in groundwater in different sampling locations

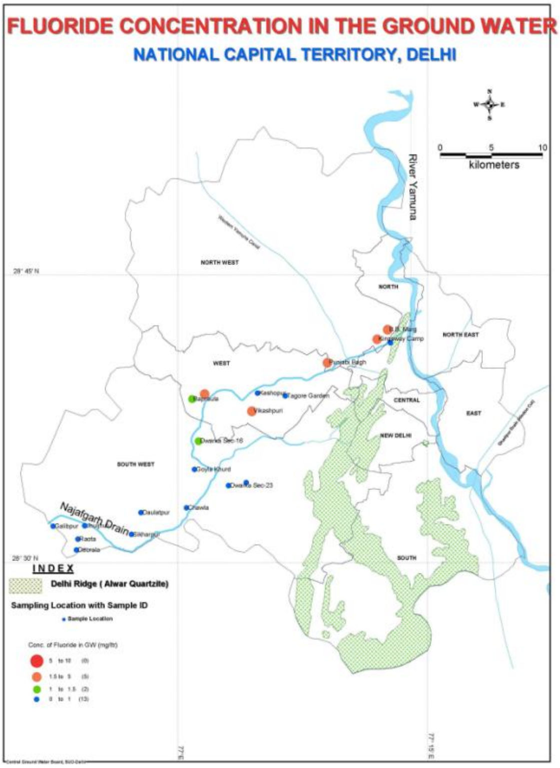

Fig 12:Fluoride in groundwater along Najafgarh Drain

Concentration of Nitrate in groundwater samples varied from 1.79 to 144 mg/litre. Highest concentration of 144 mg/l has been observed at Deorala. Around 45% of the samples have nitrate concentration above desirable limit of 45 mg/litre. The variation in concentration of nitrate in groundwater with respect to the sampling locations is shown in **Fig. 13 & 14**. Nitrate concentration is more in the initial stretch of the Najafgarh drain and then reducing upto confluence of Ganda nala thus indicating that the domestic waste discharges may be more in the initial reaches of Najafgarh drain. Further downstream the concentration again increases due to the contribution of domestic/STP waste discharges from Ganda nala/ Bapraula drain,

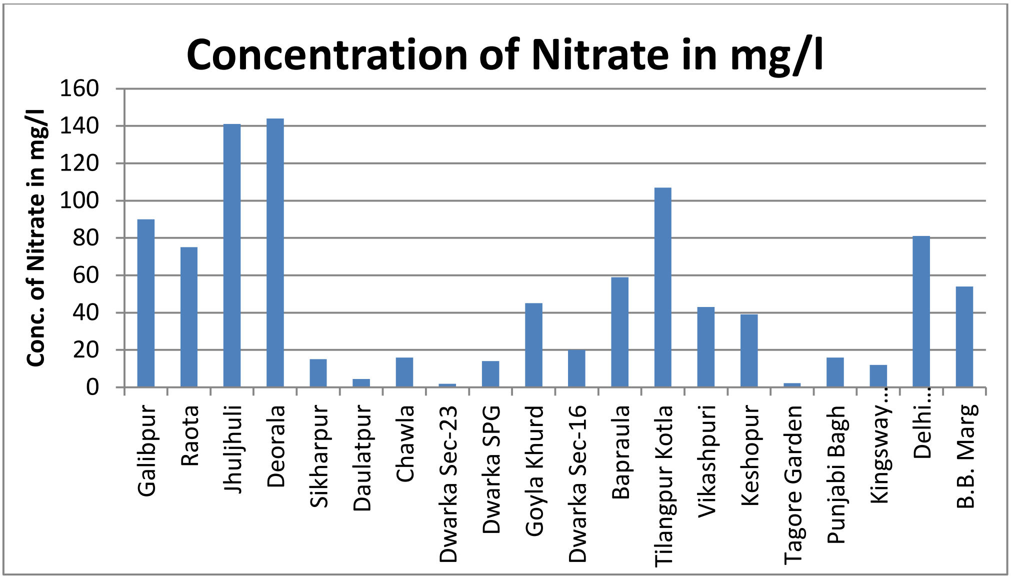

Fig. 13: Concentration of Nitrate in groundwater in different sampling locations

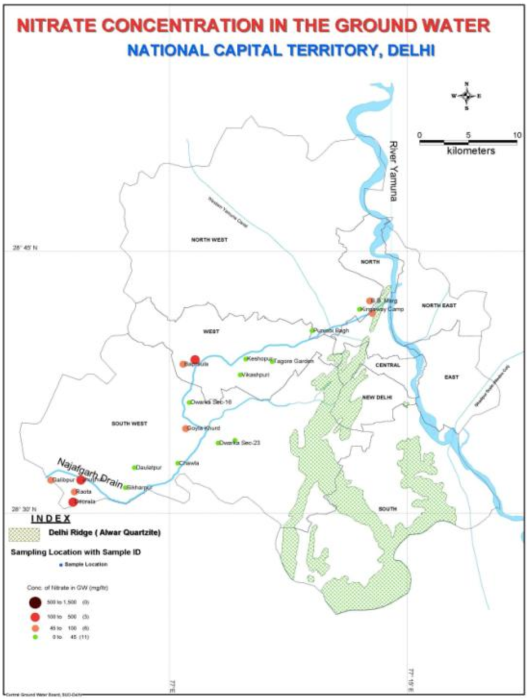

Fig 14 : Nitrate in groundwater along Najafgarh Drain

4.2 Heavy Metals

Constituent wise percentages of water samples falling in different categories as compared with BIS standards for heavy metals and their maximum and minimum values are given in **Table 6.**

Table 6: Constituent wise number of groundwater samples falling in different categories of heavy metal concentrations

S No	Heavy metal	Min. Value (mg/l)	Max. Value (mg/l)	Number of samples			
				Below Desirable limit	Between Desirable & Permissible Limits	Beyond Maximum Permissible limit	Below Detectable limit
1	Zinc	0.02	1.99	21	0	0	1
2	Lead	0.029	0.19	0	0	17	0
3	Copper	0.005	0.13	8	2	0	12
4	Cadmium	0.01	0.02	17	-	3	0
5	Manganese	0.002	0.26	14	2	0	6
6	Iron	0.007	5.07	11	3	5	3

Lead concentration has been observed to vary between 0.029 to 0.19 mg/l. Highest concentration of lead with value of 0.19 mg/l was observed at Dwarka Sector 23. Excess concentration of lead beyond permissible limit of 0.01 mg/l was detected in all the groundwater samples. The bar graph showing lead concentration in groundwater with respect to different sampling locations is shown in **Fig. 15 & 16**. Higher lead concentration has been observed in the initial reaches of Najafgarh drain and after the confluence of Bapraula drain, which may be due to discharge of industrial effluents into the nala.

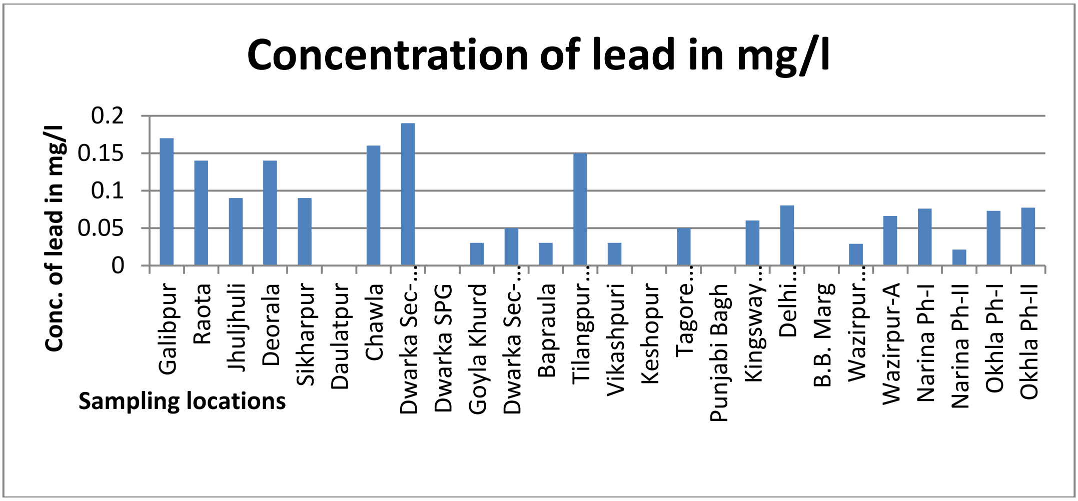

Fig. 15: Concentration of Lead in groundwater in different sampling locations

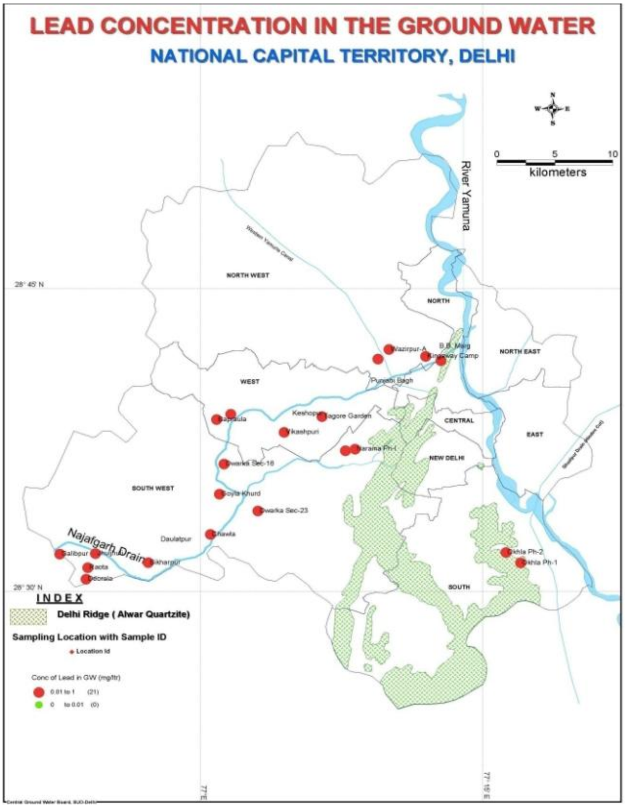

Fig 16 : Lead in groundwater along Najafgarh Drain

The concentration of iron in groundwater samples ranged from 0.04 to 5.07 mg/l. In 23% of the samples, concentration of iron was found to be beyond permissible limit of 1.0 mg/l. The geogenic phenomenon in conjunction with the anthropogenic sources could have led to enrichment of iron in groundwater of shallow aquifers adjacent to the drain. The variation in concentration of iron in groundwater with respect to the sampling locations is shown in Fig. 17.

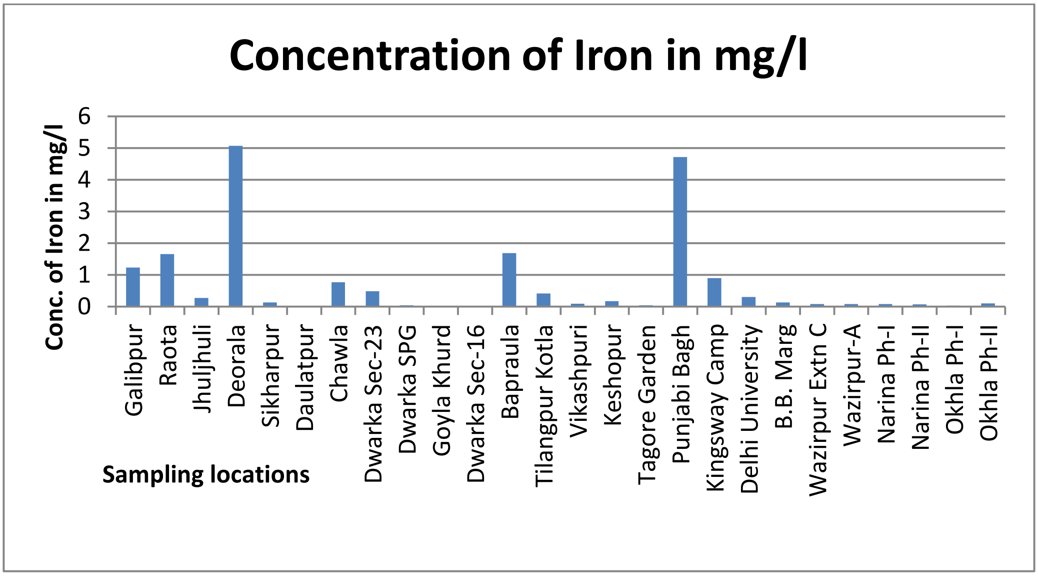

Fig. 17: Concentration of Iron in groundwater in different sampling locations

The desirable limit of Cadmium in groundwater is 0.003 mg/l and no relaxation in the permissible limit has been recommended as per BIS, 2012. Cadmium had been detected only in three groundwater samples. The concentration of cadmium in shallow aquifers varied from 0.01 to 0.02 mg/l. The variation of cadmium concentration in groundwater with respect to the sampling locations is shown in **Fig. 18 & 19.**

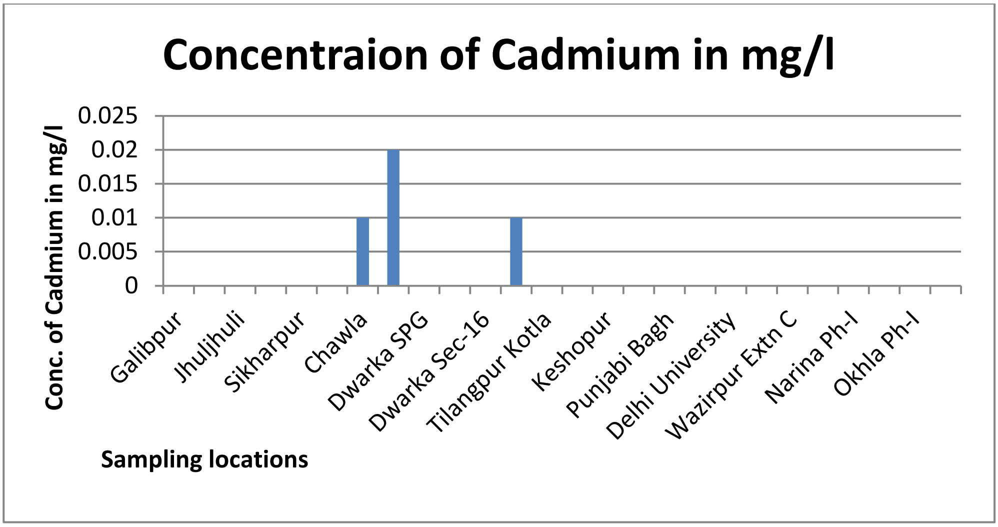

Fig. 18: Concentration of Cadmium in groundwater in different sampling locations

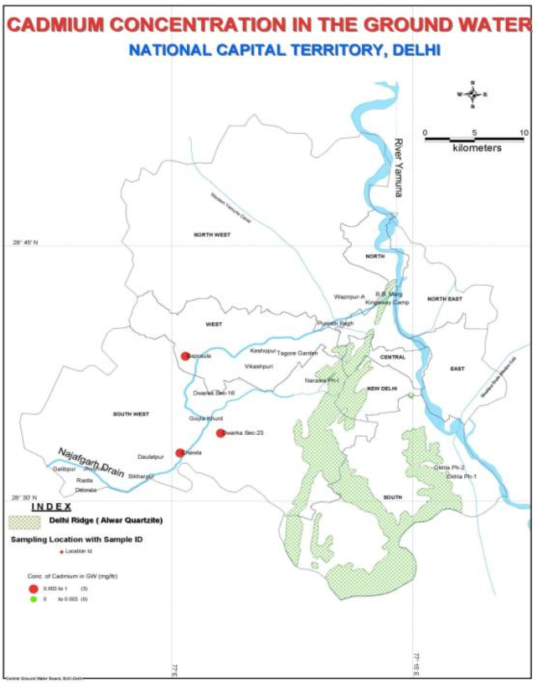

Fig 19 : Cadmium in groundwater along Najafgarh Drain

4.3 Change in groundwater quality over the years

The assessment of groundwater quality in shallow aquifer in the vicinity of Najafgarh drain of NCT Delhi was previously carried out by CGWB earlier during Annual Action Plan 2004-05 wherein the effects of recharge from the water being carried by the drain was reported. It was also reported that the fresh water thickness along the drain was more in unlined section of the drain which is also evident from the fact that water becomes more saline on moving away from the drain. However, the shallow aquifer in the vicinity of the drain was contaminated in stretches.

The chemical analysis results of the present study were compared with those during the earlier study. Although the sampling points of the two studies are not exactly the same, the overall changes in the concentration of some of the elements are tabulated below in Table 7. On comparing the values, it has been observed that the concentrations of majority of ions as well as the number of samples beyond permissible limit have increased.

Table 7 : Comparison of the concentration of chemical results

Parameters	Concentration Range (mg/l)		No. of samples beyond permissible limits	
	2004-05	2011-12	2004-05	2011-12
Magnesium	21-238	7.2-307	5	8
Calcium	13-290	7.8-432	1	3
Fluoride	0.21-7.14	0.2-4.14	5	5
Nitrate	0.2-261	1.79-144	6	9
Sulphate	25-1140	9-835	2	4
Chloride	113-1548	21-3905	2	8
Cadmium	0.002-0.011	0.00-0.02	1	3
Copper	0.001-0.073	0.005-0.13	0	0
Manganese	0.01-1.2	0.002-0.26	2	0
Lead	0.014-0.08	0.029-0.19	5	17
Zinc	0.004-8	0.02-1.99	0	0
Iron	0.2-4.9	0.007-5.07	Majority of the samples (88%)	5

5. Conclusion

(i) Najafgarh drain carries 60% of the effluents in Delhi and major part of it is unlined. The drain water is contaminated to a considerable level . A good number of samples showed magnesium, fluoride and nitrate concentration in groundwater to be beyond the permissible limit of drinking water. The contamination of groundwater is more in the initial reaches of Najafgarh drain and after the confluence of Bupanla and Ganda nala with Najafgarh drain. The relatively higher concentration in the initial stretch is due to the drain being unlined and in the lower reaches it may be due to relatively porous nature of the soil or damaged and leaking lining of the canal.

(ii) In the aquifers adjacent to the earlier stretch of the drain, mostly in South West district part of NCT Delhi, the calcium and magnesium concentrations in groundwater showed similarity in their variation with respect to the sampling locations. In aquifers adjacent to the later part of the drain, often contradictory trends in occurrence of calcium and magnesium have been observed. Since the number of subsidiary drains joining Najafgarh drain is substantial in later part of the drain, the anthropogenic influence on the concentration of cations (Calcium and Magnesium) in later part of the drain is more prominent. In middle stretch of the Najafgarh drain, where subsidiary drains join Najafgarh drain at close intervals, the nitrate concentration in groundwater has been observed to be beyond permissible limit.

(iii) Electrical conductivity and chloride showed classic similarity pointing to the fact that salinity is mainly chloride anion controlled. The higher salinity in groundwater could be both because of longer retention time of groundwater and lack of flushing and in very shallow water level area,it could be on account of repeated oxidation and evaporation.

(iv) Fluoride in groundwater is generally geogenic in origin but in some parts of the study area, it appears to be due to anthropogenic reasons.

(v) Nitrate above the desirable limits is observed in the entire area upto 1.5 km on either side of the Najafgarh drain. The reason being recharge to groundwater from domestic discharge water flowing in the drain

(vi) Lead concentration beyond permissible limits is observed in 50% of the samples indicating the treated industrial effluents being released into the drain.

(vii) Cadmium concentration beyond permissible limit is observed in 15% of the samples indicating untreated industrial effluents being released into the drain and then migration in groundwater due to recharge from the nala.

(viii) The effect of contaminant migration is seen on both sides upto 1.5 to 2 km from Najafgarh drain and upto 1-1.5 km on either side of the minor nalas joining the Najafgarh drain.

References

1. Bureau of Indian Standards, 2004, Drinking Water Specification –IS 10500;2004.
2. Central Ground Water Board & Central Pollution Control Board, 2000, Status of Ground Water Quality & Pollution Aspects in NCT, Delhi.
3. Central Pollution Control Board, 2004, Report on “Status of sewerage and sewage treatment plants in Delhi.
4. Central Ground Water Board, 2011, Ground Water Quality of NCT, Delhi.
5. Central Ground Water Board, 2012, Report on Ground Water Management Studies along Najafgarh Drain, NCT, Delhi.
6. Delhi Pollution Control Committee, 2011, Action Plan – Abatement of Pollution in Critically Polluted Area. Delhi Master Plan, 2021.

Assessment of groundwater quality in industrial clusters of Karnataka notified by Central Ground Water Board

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Abstract

Central Pollution Control Board (CPCB), Govt. of India has notified eighty eight polluted industrial clusters in India with an aim to centrally monitor and evaluate the status of the damage to various environmental components including groundwater quality based on Comprehensive Environmental Pollution Index (CEPI). Five of these industrial clusters are located in Karnataka. They are namely Mangalore in Dakshina Kannada district, Bhadravathi in Shimoga district, Raichur in Raichur district, Bidar in Bidar district and Peenya in Bangalore Urban district

Groundwater sampling was carried out by Central Ground Water Board (CGWB) during pre monsoon period of 2011 from the existing groundwater abstraction structures to assess the groundwater quality scenario in and around the notified industrial clusters of Karnataka. These samples were analyzed for routine chemical parameters and heavy metals and this paper deals with site specific groundwater quality scenario. The results of the chemical analysis show that none of the clusters of Karnataka fall under very critically polluted category in terms of groundwater contaminants. As per Bureau of Indian Standards drinking water specification IS 10500: 2012, heavy metal like Nickel is within the permissible limit in all the five clusters. Localized contamination of groundwater by industrial waste is detected from two locations at Bhadravathi (with Manganese 0.50 mg/l and 0.56 mg/l) and Bidar (with Chloride 2912 mg/l and 1562 mg/l). Nitrate above permissible limit ranges from (48- 206) mg/l which is observed from four locations in Peenya and from one location each from Raichur and Bhadravathi industrial clusters which may be due to leachate percolation from unscientific disposal of municipal waste or from sewage and septic pipes leakage. Prioritizing planning needs and measures with detailed reappraisal studies for improving the overall scenario of groundwater quality is recommended.

Key words: industrial clusters, groundwater quality, planning needs, improve

1. Introduction

Although industrialization is inevitable, various devastating ecological and human disasters have continuously occurred over the years implicating industries as the major contributor to environmental degradation and pollution processes of various magnitudes (Salisu Dan'azumi et. al, 2010). According to United Nations World Water Assessment Programme (WWAP, 2006), the impact of industrialization on water quality is more than its withdrawal as managing large volumes of wastewater from industries is a major challenge for users. While there is scope for reclamation of industrial wastewater to make it reusable, but in majority of the cases most effluent is returned directly to the water cycle often without adequate treatment thereby polluting the groundwater. The degree of pollution is dependent on various factors like volumes of effluents and the concentrations of hazardous substances they contain, combined with the mode of disposal and the vulnerability of the underlying groundwater (Morris B.L et al, 2003).

Central Pollution Control Board (CPCB), Ministry of Environment and Forest, Government of India in association with Indian Institute of Technology, New Delhi took up a study to identify polluted industrial clusters or areas in the country to take concerted action and to centrally monitor and improve the current status of the environmental components such as air and water quality data (both surface and groundwater), the ecological damage it causes and visual environmental conditions. Environmental assessment of industrial clusters across the country was done based on Comprehensive Environmental Pollution Index (CEPI) with an aim of identifying polluted industrial clusters and prioritizing planning needs for improving the quality of environment. CEPI is a rational number to characterize the environmental quality at a given location following the algorithm of source, pathway and receptor along with the standard designated calculations which captures the various health dimensions of environment including air, water and land. The assessment carried out has been documented in the form of a report entitled "Comprehensive Environmental Assessment of Industrial Clusters" wherein a total of 88 industrial areas or clusters have been notified of which five industrial clusters (**Fig 1)** fall in Karnataka. The report (CPCB report, 2009) has concluded that the industrial clusters having aggregated CEPI score (with air, water and land components) of 70 and above should be considered as critically polluted, cluster with score of 60-70 should be considered as severely polluted areas. The overall CEPI is presented in the alpha-numeric form stating the score along with the status of Air, Water and Land environment in terms of subscript as critical (c) / severe (s)/ normal (n). In this paper, the status of groundwater is discussed only as other components like air; surface water and land are outside the ambit. Based on this notification, CPCB has earmarked the following classification for Karnataka based on CEPI score **(Table 1**).

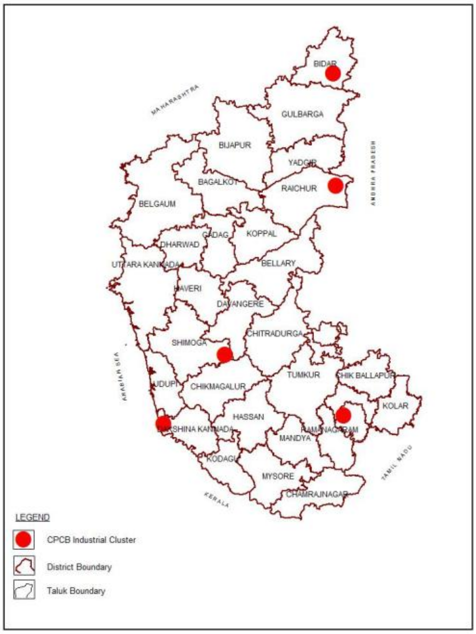

Fig 1: Location of various industrial clusters in Karnataka

Table 1: Notified industrial clusters of Karnataka with CEPI score and classification

Sl. No.	Industrial Clusters/District	Air (A)	Water (W) includes Surface water	Land (L) includes soil and groundwater	CEPI score	Cumulative status	Classification for soil and groundwater
1	Mangalore in Dakshina Kannada district	61.75	57.75	54.0	73.68	Ac_Ws_Ls	Severe
2	Bhadravathi# in Shimoga district	62.75	56.50	45.50	72.33	Ac_Ws_Ln	Severe
3	Raichur in Raichur district	59.75	46.50	44.50	68.07	As_Wn_Ln	Normal
4	Bidar in Bidar district	58.75	49.00	44.00	67.64	As_Wn_Ln	Normal
5	Peenya in Bangalore Urban district	56.75	46.00	42.00	65.11	As_Wn_Ln	Normal

(Source: CPCB report, 2009, # includes existing critically polluted areas)

2. Results and Discussion

In order to assess the groundwater conditions in and around the notified industrial clusters, Central Ground Water Board, South Western Region, Bangalore took up groundwater sampling for pollution studies (CGWB Report, 2013). Samples were collected from existing groundwater abstraction structures in and around the industrial clusters and were analyzed for routine chemical parameters and heavy metals at Regional Chemical Laboratory, Central Ground Water Board, Bangalore. The details of these studies are discussed.

2.1 Mangalore

Mangalore is one of the important town of Dakshina Kannada district and is called as the gate way to Karnataka due to the presence of New Mangalore Port Trust which is an all weather port. Imports through Mangalore (Panambur) harbour include crude oil, edible oil, LPG, and timber. Special Economic Zones like the Mangalore Special Economic Zone (MSEZ) is designed as a multi product SEZ catering to various industries like petrochemical, manufacturing, service, trading and warehousing industry. According to Ministry of Micro, Small, Medium Enterprise (MSME) report on Brief Industrial Profile of Dakshina Kannada district, the main industries are Mangalore Chemicals and Fertilizers Ltd.(MCF), Kudremukh Iron Ore Company Ltd. (KIOCL), Mangalore Refinery and Petrochemicals Ltd. (MRPL), BASF India Pvt. Ltd, Bharati Shipyard Limited and Total Oil India Limited (ELF Gas). To evaluate the groundwater pollution level, groundwater samples (normal & acidified) were collected from five industrial areas for chemical analysis and the results are presented in Table 2.

Table 2: Chemical analysis result of Mangalore industrial area

	Ind Area -1	Ind Area-2	Ind Area-3	Ind Area-4	Ind Area-5
pH	8.2	8	8.1	8.2	8.2
Specific Conduct. in µS/cm at 25°C	370	360	120	190	140
C03 - -	0	0	0	0	0
HC03 -	43	37	31	37	18
CI -	57	85	14	28	21
N03	48	12	3.2	13	8
S04-	18	10	4	10	12
F -	0.1	0.1	0.1	0.05	0.1
Ca ++	44	40	8	16	8
Mg ++	5	5	2	2	5
TH	130	120	30	50	40
Na +	18	23.4	11	12.1	10.5

K +	7.2	3.2	1	14.9	1.6
Mn	0.002	0.001	0.002	0.001	0.001
Cu	0.001	0.002	0.001	0.001	0.002
Ni	0.002	0.001	0.001	0.001	0.001

The results show that all major cations / anions and heavy metal are found within the permissible limits as per BIS drinking water specification, IS 10500:2012 and the extent of industrial groundwater pollution is not severe. Only one sample at Industrial Area -1 has higher value of 48 mg/l of Nitrate which is more than the permissible limit of 45 mg/l.

2.2 Bhadravathi

Bhadravathi taluk of Shimoga district comprises mainly of factories like Vishveshwaraiah Iron & Steel Plant, M.S.P.L. Gases Ltd. under Steel Authority of India and the Mysore Paper Mills (MSME report on Brief Industrial Profile of Shimoga district). Six samples were collected during May 2011. The results (Table 3) show that there are some indications of groundwater pollution which may be both of geogenic and anthropogenic sources. Highest pH value of 8.8 is observed in Ujjainipura and Nitrate content of 206 mg/l is detected at Hanumanthappa. In Surgithoppu and Anchaneya locality Manganese content is found 0.50 mg/l and 0.56 mg/l respectively which is more than the permissible limit as per BIS, 10500, 2012. Generally deeper aquifer with anaerobic condition gives rise to Iron and Manganese in groundwater (Paul M. Kohl, et.al, 2006) but its detection near the industrial cluster more likely links its genesis to waste discharge or Industrial effluent (Srivastava. S.K, et. al, 2008).

Table-3: Chemical analysis results of Bhadravathi Industrial area

		Locations					
Location		Surgithoppu	Anchaneya	Anchaneya	Ujjainipura	Maruthi Nagar	Hanumanthappa Colony
pH		7.9	8.1	8.1	8.8	8.6	8.6
Specific Conduct. in µS/cm at 25°C		1070	960	920	430	1060	1290
$C0_3^{--}$	**Concentration in**	0	0	0	21	25	15
$HC0_3^{-}$		238	256	171	37	226	207
CI^{-}		220	163	178	85	178	142
$N0_3$		2	1	0.3	5	1.3	206

$S0_4^-$	**mg/l**	20	30	58	14	58	72
F^-		0.5	0.5	0.4	0.3	0.3	0.2
Ca^{++}		72	64	36	24	48	120
Mg^{++}		61	46	63	7	48	61
TH		430	350	350	90	320	550
Na^+		41	55	43	29	48.4	39
K^+		6.3	4.1	7.6	49	80.3	5.1
Mn		0.5	0.56	0.22	0.007	0.001	0.001
Cu		0.002	0.001	0.002	0.001	0.001	0.003
Ni		0.001	0.001	0.001	0.002	0.001	0.001

2.3 Raichur

The major industries in Raichur taluk of Raichur district are M/s Karnataka Power Corporation Ltd., Shakthinagar (Thermal Power Station), Raichur Solvent, Raichur General Oil Seeds Grower Co-operative Society Ltd., Farooq Anwar Company Raichur Mysore Petro Chemical Ltd., Raichur Vishal Cotspin Ltd (MSME report on Brief Industrial Profile of Raichur district) . Totally four acidified groundwater samples were collected from Shaktinagar industrial area, which is the major industrial hub of the taluk. The analysis results for heavy metals are shown in **Table 4**, which indicate that the heavy metal content in these samples are within the permissible limits. Only one sample was analyzed for Basic analysis with nitrate concentration of 156 mg/l, which is higher than the permissible limit of 45 mg/l.

Table-4: Chemical analysis results in Raichur industrial area

Sl. No	**Location**	**Mn**	**Cu**	**Ni**
		Concentration in mg/l		
1	Shakti Nagar	0.02	0.001	0.011
2	Opp Thermal Power Station	0.002	0.002	0.002
3	Mysore Petrochemical Ltd	0.001	0.003	0.004
4	Viswanath Reddy & Company	0.003	0.001	0.001

2.4 Bidar

The prominent industries in Bidar are Maruthi Organics Limited, Mahatma Gandhi Sahakari Sakkare Karkhane Niyamity, Gauri Industries Limited, Yenepoya minerals & Granites Pvt. Limited and Jade Holdings Pvt. Ltd (MSME report on Brief Industrial Profile of Bidar district). Four samples were collected for chemical analysis (Table 5) which shows that at two locations namely near Satwik Drugs Ltd and Nirumodh Kendra parameters such EC, Sulphate, Calcium, Magnesium, Chloride and Total Hardness are beyond permissible limits as per BIS standards of 2012. Chloride ion in groundwater is an indicator of anthropogenic inputs because there are very less known source of chloride in nature. (Srivastava.S.K, et.al, 2008). The high level of Specific conductance and total hardness in groundwater is probably due to discharge from polluting industries and untreated waste. (Tahir MA and Bhatti MA, 1994). Thus, localized contamination of groundwater due to industrial activity is observed.

Table-5: Chemical analysis results in Bidar Industrial area

Parameters	Location			
	Opp-Satwik Drugs Ltd	Opp to vivimind lan Ind unit I	Side of Bidar Nirumodh Kendra	In front of Gampa Alcoats Ltd
pH	6.9	7.7	7.3	8.2
Specific Conduct. in µS/cm at 25°C	10560	970	5800	410
$C0_3^{--}$	0	0	0	0
$HC0_3^{-}$	445	134	128	110
CI^{-}	2911	206	1562	57
$N0_3$	23	25	19	5
$S0_4^{-}$	760	52	542	20
F^{-}	0.2	0.16	0.1	0.6
Ca^{++}	600	56	440	24
Mg^{++}	605	58	242	17
TH	4000	380	2100	130
Na^{+}	581	43	361	30.4
K^{+}	5.8	1.3	5.8	1.4
Mn	0.001	0.002	0.001	0.001
Cu	0.098	0.002	0.001	0.001
Ni	0.002	0.001	0.001	0.001

2.5 Peenya

The Peenya industrial area covering an area of 40 sq km lies in the northern part of Bangalore city (M.S. Nagaraja Gupta and Sadashivaiah. C,2014). It is one of the largest and oldest industrial areas of Southeast India having enclave of industrial units like chemical, pharmaceutical, plating, metal, leather, and allied industries (MSME report on Brief Industrial Profile of Bangalore urban district, 2012).

Groundwater samples were collected from four bore wells in and around the industrial area during May 2011. The analyzed results (Table 6) indicated that pH values ranges from 8.1 to 8.7. The high alkaline nature of groundwater can be associated with the canning industries (Nancy. J. Shell, 1992) located in the industrial hub. Four locations are showing nitrate above the permissible limit (49 mg/l to 79 mg/l) owing its origin due to contamination from municipal waste or leakage from sewage. Remaining parameters are all within permissible limits and the extent of pollution is not so severe.

Table-6: Chemical analysis results in Peenya Industrial area

	Location				
Parameters	**Balaji nagar**	**Kalika nagara 2nd stage**	**Vindhymana nagara 2nd cross**	**Corporation Park**	**Gowari concrck Blocks**
pH	8.7	8.1	8.1	8.5	8.4
Specific Conduct. in μS/cm at 25°C	1020	1280	1060	640	900
$C0_3^{--}$	27	0	0	15	12
$HC0_3^-$	92	183	165	146	153
CI^-	213	249	178	78	128
$N0_3$	49	58.5	79	24	74
$S0_4^-$	30	82	68	32	52
F^-	0.18	0.25	0.22	0.22	0.24
Ca^{++}	92	60	64	48	60
Mg^{++}	39	92	63	22	48
TH	390	530	420	210	350
Na^+	38	41	43	36	41
K^+	22.7	12.7	9.2	19.8	5.3
Mn	0.002	0.002	0.001	0.001	0.001
Cu	0.001	0.001	0.001	0.002	0.002
Ni	0.007	0.001	0.002	0.001	0.001

3 Conclusion and Recommendations

On perusal of the chemical analysis results, it is found that none of the clusters of Karnataka falls under "very critically polluted" in terms of concentration of groundwater contaminants. Localized contamination of groundwater is observed only from Bhadravathi and Bidar industrial areas. Heavy metal like Nickel is within the permissible limit (BIS 10500: 2012) in all clusters except Manganese (in Bhadravathi). Nitrate value range from 48-206 mg/l and are reported from four locations in Peenya and from one location respectively from Bhadravathi and Raichur industrial cluster areas owing its origin to pollution from unscientific disposal of municipal waste and from sewage. Parameters such as EC, Sulphate, Calcium, Magnesium and Total Hardness are above permissible limit in Bidar area only, probably suggesting the ill affect of industrial activity on groundwater. In Peenya, alkaline water suggests the adverse impact of canning industries on local groundwater regime.

As the clusters are normal to severely polluted, pollution control measures should be implemented and areas should be kept under surveillance. Environment (Protection) Act, 1986 which enjoins upon the Central Government to take such measures, as it deems necessary and expedient for the purpose of protecting and improving the quality of environment. Strict regulations should be enforced to control the effluents.

The deterioration of groundwater quality due to blooming industrial and various anthropogenic activities can be tracked by continuous monitoring of groundwater quality and quantity, using modern technologies or tools like GIS showing spatial distribution of various water quality parameters which will also be helpful for policy makers. In order to meet the potability of groundwater, continuous and effective treatment methods combined with constant monitoring and surveillance is essential. Artificial Recharge schemes can also be implemented in feasible areas to improve the groundwater quality, as groundwater pollution is localized in nature.

Dissemination and sharing of data by various State and Central Government organizations on familiar platform and common issues will improve the overall scenario. Awareness campaign and sensitizing the people on water pollution and other aspects will pave way for better management of this precious resource. To delineate the spatial boundaries as well as the extent of eco-geological damages, further reappraisal study may be proposed in the critically notified industrial clusters to reach a consensus for a remedial action plan that will help in pollution abatement and to restore the environmental quality of respective industrial clusters.

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References:

1. Brief Industrial Profile of Bangalore urban district Report by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India, August, 2012 (http://dcmsme.gov.in/)
2. Brief Industrial Profile of Bidar district Report by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India (http://dcmsme.gov.in/).
3. Brief Industrial Profile of Dakshina Kannada district Report by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India (http://dcmsme.gov.in/)
4. Brief Industrial Profile of Raichur district Report by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India (http://dcmsme.gov.in/dips).
5. Brief Industrial Profile of Shimoga district Report by Ministry of Micro, Small and Medium Enterprises (MSME), Govt. of India (http://dcmsme.gov.in/)
6. Comprehensive Environmental Assessment of Industrial Clusters Report by Central Pollution Control Board 2009, Ministry of Environment and Forests, Govt. of India.
7. M.S. Nagaraja Gupta and Sadashivaiah. C, 2014, Assessment of water quality in Peenya industrial area, Bangalore, International Journal of Research in Engineering and Technology, Volume: 03, Special Issue: 06, p 52-60
8. Morris, BL., Lawrence, AR., Chilton, PJ, Adams, B, Calow, R and Klinck, B.A. 2003, Groundwater and its susceptibility to degradation: A global assessment of the problems and options for management. Early Warning and Assessment Report Series, RS, 03-3. United Nations Environment Programme, Nairobi, Kenya.
9. Nancy. J. Shell, 1992, Industrial Pollution Control: Issues and Techniques. John Wiley & Sons, 15-Sep-1992, 416 p.
10. Paul M. Kohl, Steven J. Medlar, 2006, Occurrence of Manganese in Drinking Water and Manganese Control, American Water Works Association, 2006, 184 p.
11. Report on Pollution by Industrial clusters in Karnataka, 2013, Central Ground Water Board, SWR, Bangalore, Ministry of Water Resources, Govt. of India.
12. Salisu Dan'azumi and Mustapha Hassan Bichi., 2010, Industrial Pollution and Implication on Source of Water Supply in Kano, Nigeria, International Journal of Engineering & Technology IJET-IJENS Vol:10 No:01, pp 76-81.
13. Srivastava,S.K & Ramanathan,A.L, 2008, Hydrogeochemical studies around the Bhalswa Landfill, Delhi, India, Groundwater for sustainable development: Problem, perspective and challenge by Prosun Bhattacharya, AL Ramanathan, Arun B. Mukherjee, Jochen Bundschuh, D. Chandrasekharam, A.K. Keshari, CRC Press, 09-Apr-2008 , 484 p

14. Tahir M A, Bhatti M A, 1994, Survey of Drinking Water Quality in the Rural Areas of Rawalpindi District. In Proceeding of Pakistan Council of Res. in Water Resources, Islamabad.
15. WWAP. 2006, Water: a shared responsibility. The United Nations World Water Development Report 2. UN-WATER/WWAP/2006/3 UNESCO, Paris and Berghahn Books, New York.46p.