GROUNDWATER POLLUTION IN URBAN AREAS AND ITS EFFECT ON GROUNDWATER REGIME

D. K. CHADHA
Central Ground Water Board, New Delhi

S.R. TAMTA
Central Ground Water Board, Faridabad

Abstract *The causes and nature of various inorganic, organic and metallic constituents of wells in major cities in India were investigated in a detailed industrialisation and urbanisation study. The inorganic, organic and heavy metal constituents including colour unit frequently exceeded the WHO/BIS standards for drinking water. Groundwater chemical constituents were measured over a field season programme in monitoring wells placed strategically in relation to city wastes drainage, industrial drains and spread. Results indicate that rapid urbanisation and industrialisation are major source of the inorganic, organic and heavy metals in the groundwater and the inputs are markedly dependent on wet drains resulting in surge of the chemical constituents into the groundwater. Pollution of groundwater due to urbanisation and. industrialisation were investigated in Pali, Jodhpur and Kota towns in Rajasthan; Ranipeth, Amber and Vaniyambadi towns in North-Arcot-Ambedkar district in Tamil Nadu; Gorakhpur, Kanpur, Mathura, and Agra in UP, Nagpur in Maharastra, and Chaliyar river banks in Kerala. The types of pollutants generally encountered are biological, toxic metals, and chemical compounds of health hazards. Case histories are illustrated from Hyderabad and Visakhapatnam in Andhra Pradesh, Bhopal and Ratlam in Madhya Pradesh, Ghaziabad and Noida in Uttar Pradesh and Ludhiana in Punjab.*

INTRODUCTION

Urbanisation and industrialisation, has led to large scale consumption of surface and groundwater resources. As a result the discharge of sewage and other industrial wastes has also increased considerably. Most of the industries are concentrated around cities and towns due to their strategic location. The concentration of industries causes multiple pollution problems to surface and groundwater resources. When industrial effluents pollute surface water, the effects of pollution are felt immediately. In case of groundwater, the effects of pollution is slow due to non-turbulent mixing, and considerable lapse of time for the discharged industrial effluents in mixing with groundwater. The exact concentration of constituents of effluents in water is depended upon volume of discharge and manufacturing processes (CGWB, 2000).

The problems of portability related to inorganic constituents in groundwater are largely being overwhelmed by contamination resulting from organic pollution. Water quality is a vital factor in assessing groundwater resources as well as in study of hydrochemical environment and evolution. Little is known about the medical effects on human being of many of the constituents found in groundwater. Pollution of groundwater by aliphatic and aromatic organic compounds including pesticides, insecticides has been reported. Toxicity and carcinogenicity of organic compounds have been tentatively classified as known or suspected human and mammalian carcinogens. Serious cumulative systematic poisoning, rapid fatal poison, brain damage, toxicity, dermatitis, increase in blood cholesterol and blood pressure; skin, kidney, nerve, and liver damages; circulatory system problem, increased risk of cancer, thyroid problem, bone disease, delay in physical and mental development in children, blue baby syndrome, hair and finger nail loss, numbness in fingers or toes; are some of the known health hazardous effects of heavy metals in drinking water. Acceptable standards vary from country to country depending upon economic prosperity, climate, geographic location. The standards tend to change with time a medical information becomes available. Hence any set of standards can only be considered as guide.

The present paper pertains to work undertaken by CGWB in areas of Hyderabad and Visakhapatnam (CGWB, 2000), Bhopal (Hussain and Gupta, 1999), Ratlam (Goel, 1998), Noida (Tamta, 1999), and Ludhiana (CGWB, 1998). The investigated areas characterize the Indian cities and are relatively urbanised. The objectives of the study were to identify the relationship between urban drainage and accumulation of pollutants in groundwater hence drinking water supplies from the wells. For this evaluation it was necessary to understand in detail the temporal nature of the passage of pollutants from the point source through the soil to the groundwater and the nature of the plumes that develop in the groundwater system

CASE HISTORY-I

Hyderabad and Visakhapatnam, Andhra Pradesh

Hyderabad

The population of Hyderabad City has increased more than six folds from 5 lakhs inhabitants in 1901 to 31.5 lakh in 1991. The present estimated population of Hyderabad city including nine municipalities is around 57 lakh. Total domestic requirement of water to the city is around 798 MLD, industrial demand 200 MLD and Non-domestic demand 70 MLD towards the institutions, railways, hotels and public places.

The peripherals of Hyderabad and surrounding municipal towns of Hyderabad City are highly concentrated with industries discharging hazardous liquid gaseous and solid wastes. In Hyderabad urban area, areas around Bollaram, Jeedimetla, Sanathnagar, Kukatpally and L.B. Nagar, the groundwater contains high EC, Chloride, Nitrate and Sulphate beyond permissible limits, Cadmium and chromium are also found to be more than permissible limits in Jeedimetla, Mangalhat and Ranigunj areas.

Central Ground Water Board, to study the quality of groundwater in Hyderabad city and surrounding municipalities, had collected 314 samples from shallow bore wells, 3 surface water samples and 2 seepage samples. The samples were analysed in the chemical laboratory of CGWB, SR. The ranges of different chemical constituents are given in Tables 1 and 2.

Table 1 Concentration of trace elements in groundwater in localities of Hyderabad city

Sr. No.	Constituents	Range mg/l	Drinking water standards mg/l
1	Cu	0.0335-0.5887	0.05
2	Cd	0.0026-0.0159	0.01
3	Zn	0.0195-1.1048	5.00
4	Fe	0.0682-2.6660	0.30
5	Mn	0.0084-3.3934	0.10

Table 2 Ranges of different Chemical Constituents in and around Hyderabad city.

Sr. No.	Constituents	Range		General Range	BSI Standards	
		Min	Max		Desirable	Permissible
1	pH	6.5	8.7	6.9-7.7	6.5-8.5	No relaxation
2	Electrical Conductivity In μS/cm at 25°C	200	7500	700-3000	750	3000
3	Total Hardness (mg/l)	70	2780	150-1000	300	600
4	Calcium (mg/l)	14	720	50-300	75	200
5	Magnesium (mg/l)	3.6	272	10.120	30	100
6	Chloride (mg/l)	3.5	1766	50.600	250	1000
7	Sulphate (mg/l)	4.8	1392	25.450	200	400
8	Nitrate (mg/l)	1.2	760	10.300	45	100
9	Fluoride (mg/l)	0.17	3.3	0.5-1.7	1.0	1.5

Visakhapatnam

The population of Visakhapatanam city has increased from 70243 inhabitants in 1941 to 822000 in 1991. It is estimated that by the end of 1998 about 10.75 lakhs inhabitants were present in the city. The present water supply in Visakhapatnam is 94 LPCD against 181 LPCD. The Visakhapatnam municipal corporation is augmenting the water supply through 75 pilot groundwater schemes spread through the city. Central Ground Water Board collected 316 water sample from bore-wells, dug-wells, surface reservoirs, streams, springs, industrial effluents.

In Visakhapatnam urban areas, Nitrates and Chlorides are potential indicators of urban and domestic pollution in thickly populated areas. In industrial areas, groundwater is highly polluted initially due to seawater ingress and secondly by industrial effluent being drained into the sea without much treatment. Trace elements like Cr, Mn, Fe, Pb and Cd are found to be beyond permissible limits in groundwater of Mindi and R. Venkatapuram areas. The particular of the range of the chemical constituents, BSI standards are shown in the Tables 3 and 4.

Table 3 Concentration of Trace Elements in groundwater in some localities of Visakhapatnam

Sr. No.	Constituents	Range, mg/l	Drinking water standards, mg/l
1	COD	0.0-264	NS
2	Cd	0.30-0.72	0.01
3	Zn	0.01-3.22	5.00
4	Pb	0.18-0.19	0.30

Table 4 Ranges of different Chemical Constituents in and around Visakhapatanam

Sr. No.	Constituents	Range		General Range	BSI Standards	
		Min	Max		Desirable	Permissible
1	pH	3.6	8.9	7-8.5	6.5-8.5	No relaxation
2	Electrical conductivity µS/cm at 25°C	100	181000	750-3000	750 (equivalent to 500 mg/l TDS)	3000 (equivalent to 2000 mg/l TDS)
3	Total Hardness (mg/l)	35	37930	200-500	300	600
4	Calcium (mg/l)	8	1403	50-100	75	200
5	Magnesium (mg/l)	1	8361	10-60	30	100
6	Chloride (mg/l)	11	54041	50-200	250	1000
7	Nitrate (mg/l)	0	556	20-100	45	100
8	Fluoride (mg/l)	0.01	12.4	0.2-1.0	1.0	1.5
9	Sulphate (mg/l)	1	16080	25-100	200	400

CASE HISTORY-II

Bhopal and Ratlam, Madhya Pradesh.

Bhopal

Bhopal city includes 56 municipal wards spread over an area of 296 Km^2. The population has increased tremendously after Bhopal became the capital of Madhya Pradesh. It has increased from 1,85,000 in 1961 to 10,63,622 in 1991. The projected population for 1998 was 14,35,000.

The major requirement of drinking water supply is met from surface water sources, namely Upper and lower lakes and Kolar reservoir. Besides, about 350 tube wells and a few large diameter dug wells and hand pumps also meet the requirement. In addition, unaccounted privately owned dug wells and bore-wells installed in individual house holds, housing colonies, industries and business complexes also cater to the requirement. The total water supply available to Bhopal city both from surface and groundwater sources is 233 MLD against water demand of 281 MLD. Thus, the present water supply falls short of 48 MLD.

The chemical quality of surface water bodies, mainly Upper and Lower lakes play vital role in assessing impact of urbanisation on them and also on quality of groundwater in adjacent area. Regular inflow of untreated sewage in the lakes through unlined and open drains has produced high magnitude of nutrients. As a result excessive growth of aquatic plants has taken place in the lake waters. This has resulted in eutrophication and hyper-eutrophication of Upper and Lower lakes, which have made them, polluted. Other undesirable human activities like washing of clothes, vehicles, disposal of domestic wastes and agricultural residues and religious activities like immersion of idols and Tazias (only in Upper lake) are also making the lake waters polluted. The chemical analyses substantiate the above phenomenon. The means of disposal untreated sewage into the lakes is also leading to pollution of groundwater.

In Govindpura industrial area, disposal of untreated industrial effuent of Adarsh Electroplating Works contains very high concentration of Iron, Zinc, Chromium, and Cadmium. Electrical conductivity of this industrial effluent has been measured to be 64000 micro-Siemens/cm. The continuation of disposal of such effluent through unlined drain will be very dangerous in future for the quality of groundwater in nearby areas. There is urgent need to control such pollution of groundwater.

From Bhopal city, 16 groundwater samples were collected from dug-wells, hand pumps, tube-wells in alluvium, deccan trap, Vindhyan sandstone formation and also some water samples from Upper and Lower lake, Patra nala, for heavy metal analyses and 160 samples for general constituents and the results of the groundwater samplers are given in Tables 5 and 6.

Table 5 Trace elements analysis of selected water samples collected from Bhopal city.

Sr. No.	Constituents	Range mg/l	Drinking water standards mg/l
1	Cu	0.01-0.19	0.05
2	Cd	0.01-0.05	0.01
3	Zn	0.05-1.16	5.00
4	Pb	1.10-0.34	0.05
5	Mn	0.01-0.39	0.10
6	Cr	0.01-0.13	0.05
7	Fe	0.05-0.60	0.30
8	Ni	0.01-0.04	NS
9	Co	0.51-0.74	NS
10	Sr	0.33-1.43	NS

Table 6 Ranges of different chemical constituents in and around Bhopal city.

Sr. No.	Constituents	Range		General Range	BSI Standards	
		Min	Max		Desirable	Permissible
1	pH	6.88	8.40	7.25-8.00	6.5-8.5	No relaxation
2	Electrical Conductivity In μS/cm at 25°C	396-	3910	500-2000	750	3000
3	Total Hardness (mg/l)	120-	900	250-850	300	600
4	Calcium (mg/l)	32	272	80-200	75	200
5	Magnesium (mg/l)	10	89	25-75	30	100
6	Chloride (mg/l)	21	645	35-250	250	1000
7	Sulphate (mg/l)	8	285	20-90	200	400
8	Nitrate (mg/l)	6	215	10-100	45	100
9	Fluoride (mg/l)	0.05	4.05	0.3-0.60	1.0	1.5

RATLAM

Ratlam is an industrial town in western Madhya Pradesh. Occurrence of reddish-brown coloured groundwater in hand pumps and dug-wells spreading over an area of 76 Km^2 in Ratlam town were investigated which established a strong correlation between the groundwater and industrial effluents with respect to Nitrate, Chloride and Sulphate. The colour, though not established for want of analysis, was suspected to be due to dissolution of Azo-dyes. In same localised pockets, the groundwater of deeper aquifer below 60-m bgl is also showing sign of colour pollution. The colour of the groundwater in industrial area and also in rural area was of reddish colour with brownish tinge whereas in the groundwater of Ratlam town, it was colourless. During the field investigation, it was noted that the brownish red colour of the groundwater was similar to the red colour matter spreading on soil in the premises of Sajjan Chemicals Ltd. However, no effluent was flowing at the time of investigation due to closure of industries, but the soil of the drain was red and similar to that of red colour of groundwater.

The colour and turbidity of the groundwater samples at some places varies between 585-860 Hazen and 5.5-6.2 NTU, respectively. To verify the colour of groundwater, iron content was determined in these water samples. The iron content in the groundwater samples was insignificant and the maximum concentration determined was 0.04 mg/l, which cannot impart colour to the groundwater. The colour of the effluent of alcohol plant was dark brown and opaque. The effluent of alcohol brewery sugar plants is always brown with very high-suspended organic matter. These effluents are biodegradable, and therefore, cannot impart permanent colour except high salt content to receiving waters. The colour, though not established for want of analysis, was suspected to be due to dissolution of Azo-dyes. In some localised pockets, the groundwater of deeper aquifer below 60-m bgl was also showing sign of colour pollution. Azo-dye contain naphthalene rings, one or two SO_3-H groups to render the dyes water soluble and several -OH and NH_2 groups for colour variation and fastness. The colour caused by organic compound imparts no suspension or turbidity on storage of samples, and the colour disappears on treatment of the samples with activated charcoal.

50 water samples were collected from hand pump, tube wells, and dug-wells for major ions, minor ions, heavy metals, colour, and turbidity analysis.

Table 7 Iron and Cadmium in groundwater collected from Ratlam city

Sr.No.	Constituents	Range mg/l	Drinking water standards mg/l
1	Cd	0.00-1.00	0.01
2	Fe	1. 00-40	0.30

Table 8 Colour and turbidity in groundwater in Ratlam study area

Location	Type	Colour, Hazon	Turbidity NTU
Dosigaon	D.W.	860	6.2
Jadwasa Kala	H.P.	585	5.5

Table 9 Ranges of different chemical constituents in and around Ratlam city

Sr. No.	Constituents	Range and average		BSI Standards	
		Range	Average	Desirable	Permissible
1	pH	7.06-7.65	7.35	6.5-8.5	No relaxation
2	Electrical Conductivity in µS/cm at 25°C	760-6080	2050	750	3000
3	Total Hardness (mg/l)	170-2400	655	300	600
4	Calcium (mg/l)	46-576	170	75	200
5	Magnesium (mg/l)	10-233	56	30	100
6	Chloride (mg/l)	760-6080	417	250	1000
7	Sulphate (mg/l)	10-500	105	200	400
8	Nitrate (mg/l)	16-350	101	45	100
9	Sodium (mg/l)	22-405	166	NS	NS
10	Fluoride (mg/l)	0.47-1.98	1.23	1.0	1.5

CASE HISTORY-III

Ghaziabad and Noida, Uttar Pradesh

Ghaziabad

A news item on 'The subterranean river of poison' was published in the 'Times of India' dated Feb. 7, 1999, which stated that a tube-well in a factory located in south side of G.T. road industrial area, Ghaziabad, was yielding yellow coloured water. The District Headquarters, Ghaziabad, is located in the extreme western part of the district. The study area, covering approximately 2 sq.km. is located in the Southern part of the Ghaziabad town, in the east of Hindon river. The area is bounded by National Highway No. 24 in the South and railway line running in northwest -southeast direction in the North. One main drain flows through the area in northeast -southwest direction.

An investigation was, therefore, conducted in and around the above said industrial area to decipher the groundwater pollution by industries located in the area. The well, where yellow coloured water had been reported, is located in Suruchi Dyeing Unit adjacent to Plot No. 35 belonging to M/S Global Spin Weaver Ltd. The study area is underlain by alluvial sediments of quaternary age. A thick coarse sand bed mixed with gravel is occurring at depth range of 40-75 m bgl, which acts as a good aquifer and all tube wells present in the area are tapping only this aquifer.

In order to study the groundwater pollution in the area, 16 water samples were collected from various locations in the study area. Electrical conductivity of groundwater where pollution was reported, was found to be more than 2000 micro-siemens/cm at 25°C and conductivity values decrease away from this pollution zone. A perusal of data shows that all the major, minor and heavy metals are well with in the permissible limits of drinking water quality as per the norms of IS: 10500 of 1991, except the water sample of polluted groundwater. A samples of groundwater from the reported tube-well was got analysed at Sri Ram Institute for

Industrial Research and p-Nitrophenol was reported to be 0.54 mg/lit, which is much in excess of the permissible limit (0.001 mg/lit). P-Nitrophenol is an intermediate compound produced during the synthesis of paracetamol, manufactured by M/S Global Spin & Weaver Ltd. Organic compounds have been tentatively classified as known or suspected human and mammalian carcinogens.

Table 10 Trace elements analyses of selected water samples collected from Gazhiabad city

Sr. No.	Constituents	Range mg/l	Drinking water standards mg/l
1	Cu	0.002-0.006	0.05
2	Cd	0.00-0.001	0.01
3	Zn	0.009-2.079	5.00
4	Pb	0.006-0.019	0.05
5	Mn	0.146-0.290	0.10
6	Cr	0.000-0.031	0.05
7	Fe	0.037-0.425	0.30
8	Co	0.004-0.030	NS
9	Sr	0.134-0.248	NS

Table 11 Ranges of different Chemical Constituents in and around from Ghaziabad city

Sr. No.	Constituents	Range		General Range	BSI Standards	
		Min	Max		Desirable	Permissible
1	pH	6.85	7.6	7.1-7.5	6.5-8.5	No relaxation
2	Electrical Conductivity μS/cm at 25°C	938	3050	1100-1700	750	3000
3	Total Hardness (mg/l)	298	575	350-575	300	600
4	Calcium (mg/l)	66	148	60-125	75	200
5	Magnesium (mg/l)	32	57	33-55	30	100
6	Chloride (mg/l)	47	396	107-221	250	1000
7	Sulphate (mg/l)	54	746	54-225	200	400
8	Nitrate (mg/l)	2.6	87	5-10	45	100
9	Fluoride (mg/l)	0.5	0.71	0.5-0.7	1.0	1.5
10	Phosphate (mg/l)	0.01	0.26	0.01-0.03	NS	NS
11	p-Nitrophenol (mg/l)	-	0.54	-	-	0.001

Noida

Based on a public litigation case pertaining to pollution of groundwater in Noida, Central Ground Water Board investigated the pollution of groundwater resulting from a drain passing through the Noida residential colony. Though the drain originates in Shahdra but it enters the colony at Chilla regulator above Okhla barrage. Fine-grained sand intermixed with layer of clay and silt has been identified as potential granular zone.

Groundwater samples were collected from both the banks of Chilla drain covering an area of about 100 m wide from the banks and 5 km stretch along the drain. Drain water samples were also collected at entrance point of Chilla regulator and at downstream of the drain. Groundwater samples from hand pump (35-70 feet) were generally coloured whereas those collected from tube-wells (70-250 feet) were colourless though they too turned brownish on storage. Analysis of water samples for major ions, minor ions, and heavy metals conclusively established pollution of shallow water aquifer.

Table 12 Iron and Manganese content of groundwater in Noida residential area along the drain originating at Chilla regulator above Okhala.

Sr. No.	Constituents (mg/l)	Drain water	Shallow aquifer (33-70 ft)	Deep aquifer (70-250 ft)	Drinking water standards, mg/l
1	Fe	5.55-7.50	1.5-4.59	0.01-0.55	0.01
2	Mn	0.25-0.35	0.92-1.65	0.01-0.43	0.30

CASE HISTORY -IV

Ludhiana

Central Ground Water Board, NWR, Chandigarh, conducted a specific study adding hydrogeological input, into a lot of work done by many institutions reporting industrial pollution of groundwater in Ludhiana city. This study on urban hydrogeology illustrates that Ludhiana city occupies an area of 165 km^2 and is inhabited by 20 lakh people. Out of 1311 industries, 104 are generating hazardous wastes. The present supply of water to the city is based upon deep tube-wells (60-100 m) and the total number of such tube-wells is more than 200.

The city is underlain by Indus-Ganga alluvium of quaternary age. There are four well-marked granular zones, 6-14 m thick, separated by thick clay beds. The first potential granular zone is deciphered at 32-45m where Cd, CN, Cr^{+6}, and Pb from surface industrial effluents pollute groundwater. A comparison of the results of the samples, collected from Ludhiana city during 1992 and again during 1994, reveals sharp increase in concentration of CN, TH, and Na in almost all site wells.

Table 13 Ranges of different chemical constituents in and around Ludhiana city

Sr. No.	Constituents	Range		BSI Standards	
		Shallow aquifer 32-45 m	Deep aquifer 62-75 m	Desirable	Permissible
1	pH	6.6-8.2	7.5-7.9	6.5-8.5	No relaxation
2	Electrical Conductivity μS/cm at 25°C	333-1633	102-308	750 (Equivalent to 500 mg/l TDS)	3000 (Equivalent to 2000 mg/l TDS)
3	Total Hardness (mg/l)	333-1633	102-308	300	600
4	Calcium (mg/l)	83-349	47-114	75	200
5	Magnesium (mg/l)	31-185	1.2-53	30	100
6	Chloride (mg/l)	38-408	10-264	250	1000
7	Nitrate (mg/l)	60-317	1.0-16	45	100
8	Fluoride (mg/l)	0.44-1.8	0.41-0.84	1.0	1.5

Table 14 Trace elements analyses of selected water samples collected from Ludhiana city

Sr. No.	Constituents	Range		Drinking water standards, mg/l
		Shallow aquifer	Deep aquifer	
1	Cd	ND-0.021	ND	0.01
2	Pb	ND-0.52	ND-0.030	0.05
3	Cr	ND-1.60	ND	0.05
4	As	ND-0.071	ND	0.50
5	Ni	ND-0.05	ND	NS
6	CN	ND-0.51	ND-0.029	NS

CONCLUSIONS

Central Groundwater Board has been monitoring groundwater quality all over the country under various investigation programmes including pollution of groundwater occurring as a result of municipal, agriculture and industrial wastes; oil fields and mining wastes; septic tanks, cesspools and sea water intrusion. The types of pollutants generally encountered are of biological, toxic, radioactive nature and chemical compounds, which are health hazards. It is high time that a control over the source of pollution would help in restricting the spread of the contaminants through the aquifer. Groundwater restoration methods include physical containment techniques, hydrodynamic control, withdrawal and treatment, biodegradation etc. But little or no work has been done effectively on scientific basis except in the field of treatment of effluents.

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