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Ground water quality in environmentally degraded localities of Panipat city, India

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Abstract: *A systematic physico-chemical analysis of the groundwater at 41 different locations in Panipat city (Haryana), India has been taken up to evaluate its suitability for domestic purposes. The data revealed considerable variations in the water samples with respect to chemical composition. For the analyzed water samples pH, EC, TDS, TA, TH, Na^+, K^+, Ca^{2+}, HCO_3^-, Cl^-, SO_4^{2-} and F^- varied from 6.6-7.5, 0.09-3.28 mmhoS cm^{-1}, 700-2100 mg l^{-1}, 245-1054 mg l^{-1} (as $CaCO_3$), 153-520 mg l^{-1} (as $CaCO_3$), 57-560 mg l^{-1}, 5-22 mg l^{-1}, 36-95 mg l^{-1}, 298-1285 mg l^{-1}, 60-311 mg l^{-1}, 17-786 mg l^{-1}, 0.24-9.27 mg l^{-1} respectively. All samples have high concentration of dissolved salts and all the samples were hard to very hard. Correlation coefficient "r" analysis has been worked out among different water quality parameters. The study shows a positive and significant, correlation of electrical conductivity with total dissolved salts (r = 0.979), total hardness (r = 0.507), sulphate (r = 0.453), total alkalinity(r = 0.725). Total hardness is positively and significantly correlated with magnesium(r = 0.833) and sulphate (r = 0.687). Where as total alkalinity was found to be positively and significantly correlated with bicarbonate (r = 0.992). Fluoride was higher than permissible limits in most of the samples.*

Key words: *Ground water, Panipat, Physico-chemical analysis, Correlation coefficient*
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Introduction

Groundwater is the major source of water supply for domestic purposes in the urban as well as in rural parts of India. Various reasons for this include non-availability of potable surface water and a general belief that groundwater is pure and safer than surface water due to earth covering. Presence of more than 200 chemical constituents in groundwater has been documented including approximately 175 organic and more than 50 inorganic and radionucleotides. The sources of these chemicals are both natural and anthropogenic. USEPA (Khaiwal and Garg, 2006) has detected volatile organic compounds (VOCs) in 466 randomly selected public groundwater supply systems. Those occurring most often were trichloroethylene and tetrachloroethylene. In the less developed countries, contamination of water supplies by organic compounds is of minor concern, or of no concern at all. In such places the major health problems are the result of inorganic chemicals contamination, poor sanitary conditions and illness brought about by pathogenic organisms. Once the groundwater at a site is degraded, it may remain as unusable or even hazardous condition for decades or centuries. The typically low velocity of groundwater prevents a great deal of mixing and dilution, consequently, a contaminant plume may maintain a high concentration as it slowly moves from points of recharge to zone of discharge (Pattyjohns, 1979).

Water soluble substances that are dumped, spilled, spread or stored on the land surface eventually may infiltrate. Groundwater can also become contaminated by the disposal of fluids through wells and, in lime stone terrains, through sinkholes directly into aquifers. Likewise, infiltration of contaminated surface water has caused groundwater contamination in several places. Irrigation tends to increase the mineral content of both surface and groundwater. The degree of severity in such cases is related to hydrologic properties of the aquifer, the type and amount of waste, disposal method and climate. Another cause of groundwater quality deterioration is excessive pumping out, which may precipitate the migration of more mineralized water from the surrounding strata to the well. Various studies (Kaul *et al.,* 1999; Khaiwal and Garg, 2006; Yadav and Lata, 2003; Meenakshi *et al.,* 2004; Prakash and Somashekar, 2006; Bishnoi and Arora, 2007; Shailaja and Jhonson, 2007) carried out in the past have reported the presence of excessive fluoride, arsenic, nitrate, sulphate, heavy metals, salinity, hardness, pesticides *etc.* from different parts of India. It has been reported that 77% of urban population and only 31% of rural population in India has access to potable water.

Panipat is one of the fastest industrializing cities of Haryana (India) with an approximate population of 5, 00,000. The area is semi-arid with low and erratic precipitation. Most of the rainfall is received from July to September during monsoon. The area is characterized by extreme temperatures in winter and summer and high wind velocity during summer. The subsoil water is stored in sand and gravel beds. The depth of water table varies from 5 to 25 meters in different aquifers. Hand pumps can easily be installed in study area and extensively used to pump out the water. Panipat has more than 2500 cloth/thread dye houses along with a thermal power station and petroleum refinery. These industries produce more than 2 million litre per day (MLD) wastewater. More than 90% industries do not treat wastewater due to prohibitive costs. Yamuna river passes near to Panipat but due to stringent regulations industries are not allowed to dispose wastewater in it. So these industries dispose wastewater on land. Some of the industries inject wastewater (untreated or partially treated) into ground water. This

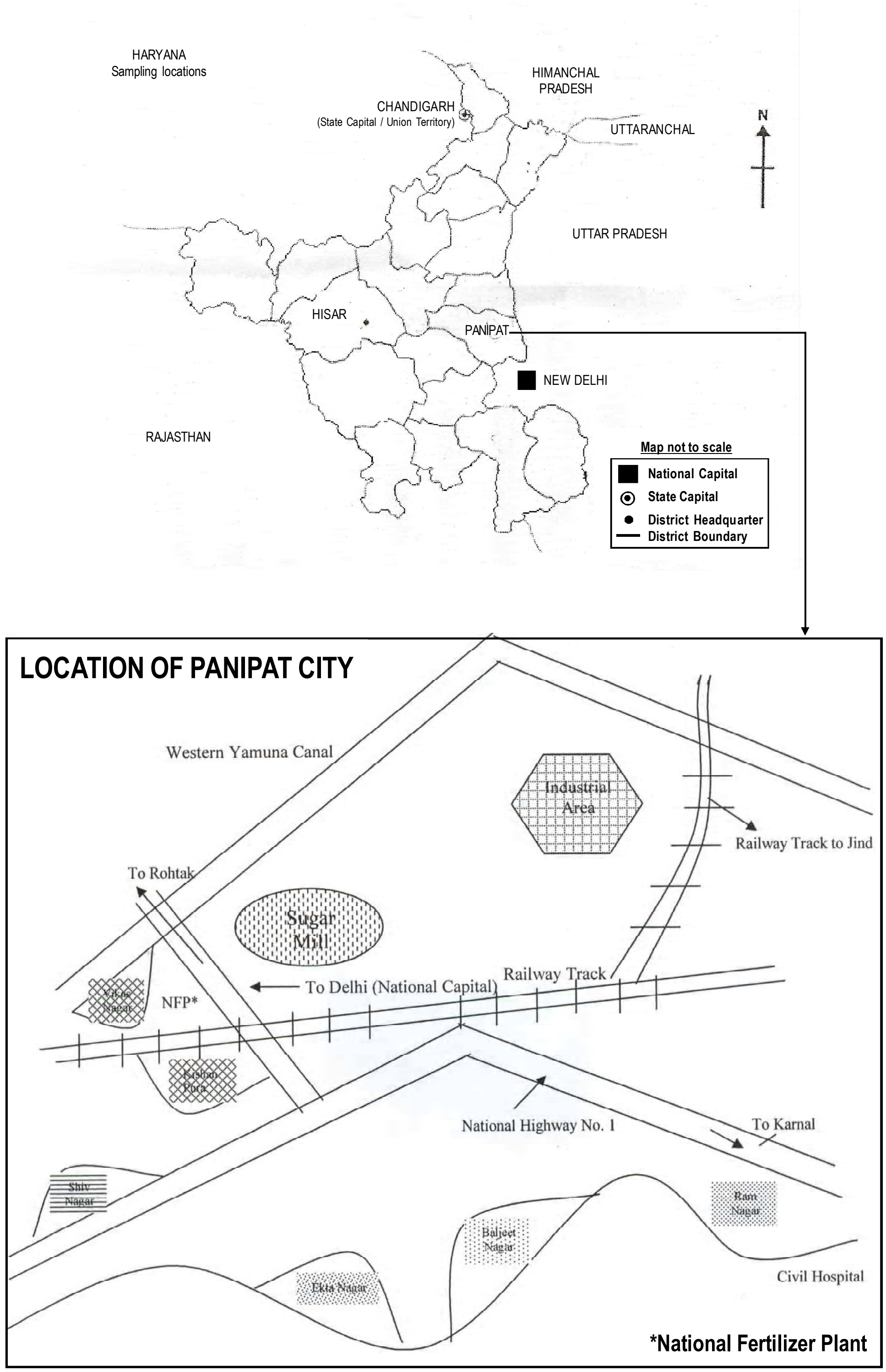

Fig. 1: Map of study site

unscientific disposal of wastewater is contaminating the groundwater of Panipat city. Populace in unauthorized urban areas is dependent on groundwater for their drinking and other domestic needs. A bibliographic survey has shown that yet no detailed study on groundwater quality has been undertaken in this fast developing town of Haryana. So the objective of this study was to assess the groundwater quality in Panipat city with a view to generate baseline data for future research and to help the policy makers to formulate strategies for alternate water supply sources.

Materials and Methods

Present study was undertaken in six localities, *viz*. Baljeet Nagar, Ekta Nagar, Ram Nagar, Shiv Nagar, Kishan Pura and Vikas Nagar. The approximate population of the localities is 90,000. The residents of these localities depend on ground water for their domestic, commercial and industrial requirements due to non-availability of erratic surface water supply. Majority of the installations (Hand pumps) are private and shallow.

A total of 41 water samples (SP-1 to SP 41) were collected form privately owned manually operated hand pumps. Only those installations were selected for sampling whose water is used for domestic purposes. The details of samples collected from each locality are given in Table 1.

The pH and EC of the samples were measured on the spot at the time of sample collection using portable equipments (Eutech Cybernatics Model pH scan meter and Eutech Cybernatics Model TDS scan meter). Physico-chemical analysis was conducted following the standard methods (APHA, 2005). The analyzed parameters include color, taste, odour, pH, electrical conductivity (EC), total hardness (TH), total alkalinity (TA), sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, sulphate and fluoride. The results obtained were reproducible within ±3% error limit. Statistical analysis was carried out on computer using the statistical package for social sciences (SPSS) programme.

Results and Discussion

The availability and chemical quality of groundwater are closely related to precipitation. As a general rule, the least mineralized water, both in streams and underground, occurs in areas of greater amount of rainfall. Inland precipitation decreases, water supplies diminish, and the quality deteriorates. The composition of water bearing rocks exerts a strong influence on groundwater quality and thus, the solubility of the rocks may override the role of precipitation. In India, out of total water balance, 70 percent are used for agriculture, 25 percent for industry and remaining 5 percent are used for drinking purposes. The demand for country's water supply at present is 30 cubic km. This would increase to 52 cubic km in 2025. The demand is not only due to population but also due to improvement in living standards. The use of water resources due to the development of industry, power, engineering, transport, urbanization and intensification of agriculture exerts greater qualitative and quantitative impacts on the hydro-geological regimes of inland water.

Table - 1: Ground water sampling sites in Panipat city

Name of site	Sample number
Baljeet Nagar	SP – 1 to SP – 8
Ekta Vihar	SP – 9 to SP – 15
Ram Nagar	SP – 16 to SP - 29
Shiv Nagar	SP – 30 to SP – 34
Kishan Pura	SP – 35
Vikas Nagar	SP – 36 to SP - 41

At some studied localities groundwater was coloured but free from odour. The taste was slightly to moderately brackish in most of the private installation. A comparison of the physico-chemical characteristics of the studied water samples has been made with WHO (1971) and ISI (1983) standards (Table 2). The data revealed that there were considerable physico-chemical variations in the examined samples not only in the samples collected from the different localities, but even in the samples collected from the same locality.

In Table 2, a comparison of groundwater quality of the area under study with drinking water standards (ISI, 1993 and WHO, 1971) is presented. The data revealed considerable variations in the water samples with respect to chemical composition. On comparing the pH of underground water in the studied localities, it has been observed that pH at all the studied locations fall with in the WHO acceptable limits. There has been a large variation in electrical conductivity (0.09-3.28 mmhoS cm^{-1}). In accordance with EC and TDS values also varied from 700 to 2100 mg l^{-1}. According to the salinity classification of groundwater (Rabinove *et al.,* 1958) ground water was non-saline at six locations, slightly saline at 35 locations (Table 3). TDS content was higher than the WHO acceptable limits at all the studied locations.

Total hardness is one of the most important properties of drinking water. Hardness may causes urolithiasis (Chari and Lavanya, 1994). Total hardness in the studies localities of Panipat city varied from 153-520 mgl^{-1}. According to Durfor and Becker (1964) classification, groundwater was very hard to hard at all the studied locations (Table 4). Calcium content of studied samples was within the maximum limit as prescribed by ISI, but was higher at some locations than WHO permissible limit of 75 mgl^{-1}. The magnesium content ranged from 6 to 93 mg l^{-1} with a mean value of 34.2 ± 21.03 mg l^{-1}. Except sixth location, magnesium content was with in WHO prescribed limits.

The WHO acceptable limit for total alkalinity was 200 mg l^{-1} $CaCO_3$), but BIS has extended this limit to 600 mgl^{-1} in case of non-availability of alternate water sources. In this study, total alkalinity ranged from 245 to 1054 mg l^{-1}, which was higher than WHO limits in all the studied samples. Carbonate was absent in all samples. But bicarbonate was present in significant quantities. The bicarbonate content ranged from 298 to 1285 mg l^{-1} which is much higher than WHO limit of 30 mgl^{-1} at all the studied locations.

Table - 2: Comparison of groundwater quality of the study area with drinking water standards (ISI and WHO), (n= 41)

Parameter	Values in samples			ISI standards (1983)		WHO standards (1971)
	Minimum	Maximum	Mean ± SE	Acceptable limit	Maximum limit	
pH	6.6	7.5	7.02 ± 0.03	7.0-8.5	6.5-9.2	8.0-8.5
EC (mmhos cm^{-1})	0.09	3.28	2.36 ± 0.11	- ***	-	-
TDS (mg l^{-1})	600	2100	1524 ± 65.96	500	1500	500
TA (mg l^{-1})	245	1054	588 ± 36.4	200	600	200
TH (mg l^{-1})	152	520	297 ± 14.93	200	600	100
Na^+ (mg l^{-1})	57	560	214 ± 21.3	-	-	50
K^+ (mg l^{-1})	5	22	11.4 ± 0.66	-	-	-
Ca^{2+} (mg l^{-1})	6	95	64 ± 2.90	75	200	75
Mg^{2+} (mg l^{-1})	6	93	34.2 ± 3.30	200	400	50
CO_3^{2-} (mg l^{-1})	0	0	0	75	200	75
HCO_3^-(mg l^{-1})	298	1285	718 ± 45.5	30	-	150
Cl^- (mg l^{-1})	60	311	166 ± 11.7	200	1000	200
SO_4^{2-} (mg l^{-1})	17	786	323 ± 31.0	200	400	200
F^- (mg l^{-1})	0.24	9.27	3.1 ± 0.39	1.0	1.5	1.0

-*** = Standards are not available

Table - 3: Classification of groundwater on the basis of salinity (n= 41)

Classification	Salinity range (mg l^{-1})	No. of samples	Reference
Non-saline	< 1,000	6 (14.6)*	USSLS (1954)
Slightly saline	1,000 - 3,000	35 (85.4)*	
Moderately saline	3,000 - 10,000	None	
Very saline	> 10,000	None	

* = Parentheses indicates the percentage

Table - 4: Classification of groundwater on the basis of total hardness (n= 41)

Total hardness range (as $CaCO_3$) in mg l^{-1}	Description	No. of samples	Reference
0-60	Soft	None	USPHS (1954)
61-120	Moderately hard	None	
121-180	Hard	4 (9.8)*	
> 180	Very hard	37 (90.2)*	

* = Parentheses indicates the percentage

Table - 5: Correlation coefficient values of water quality parameters (n = 41)

	pH	EC	TDS	TH	TAx	Cl^-	SO_4^{2-}	HCO_3^-	F^-	Na^+	K^+	Ca^{2+}	Mg^{2+}
pH	1.00	-.792**	-.799**	-.371*	-.651**	-.204	-.334*	-.647**	0.091	-.480**	-.446**	-.477**	-.200
EC		1.00	.979**	.507**	.725**	.303	.453**	.730**	-.223	.546**	.525**	.376**	.352*
TDS			1.00	.512**	.740**	.340*	.449**	.746**	-.236	.558**	.536**	.410**	.337*
TH				1.00	.023	.059	.687**	.035	-.198	.196	.150	.256	.833**
TA					1.00	.247	-0.24	.992**	-.252	.326*	.681**	.197	-0.92
Cl^-						1.00	-.211	.223	-.106	.072	-.037	.127	.027
SO_4^{2-}							1.00	.007	-.022	.617**	.080	.217	.596**
HCO_3^-								1.00	-.247	.363*	.673**	.186	-.077
F^-									1.00	.121	-.284	-0.16	-.093
Na^+										1.00	.165	.211	.156
K^+											1.00	.232	-.033
Ca^{2+}												1.00	-.028
Mg^{2+}													1.00

** = Significant at $p \leq 0.01$ level (Two-tailed significance)

* = Significant at $p \leq 0.05$ level (Two-tailed significance); -ve sign indicate the inverse correlation between two parameters

Sodium and potassium are naturally occurring elements of groundwater. Industrial and domestic wastes also add sodium to groundwater. It is one of the major contributors to salinity of water (Chari and Lavanya, 1994). The concentration of sodium in the studied samples varied from 57 to 560 mg l^{-1}. The sodium content has been found to be higher than WHO permissible limit (50 mg l^{-1}) at all the studied locations. The potassium content ranged from 5-22 mgl^{-1}.

Chloride in excess (>250 mgl^{-1}) imparts a salty taste to water and people who are not accustomed to high chloride can be subjected to laxative effects (Ravi Parkash and Krishna Rao, 1989). The chloride in the groundwater may be contributed from minerals like apatite, mica, and hornblende also from the liquid inclusions in the igneous rocks (Das and Malik, 1988). The chloride content in the studied area ranged from 60-311 mg l^{-1}.

In 13 locations, chloride content was higher than the WHO limit. The sulphate although may be present in sedimentary rocks and in minor quantities in igneous rocks, are largely recycled from the atmosphere. Thus concentration of sulphate may occur in wide ranges in the nature. Higher concentrations of sulphate in drinking water may cause purgation of alimentary canal with magnesium, when it is more than 30 mg l^{-1}. The sulphate content ranged from 17-786 mg l^{-1} with a mean value of 323±198 mg l^{-1} in the present study. Nair *et al.* (2006) studied the Groundwater quality of north-east Libya. Water quality index (WQI) of the studied samples revealed that well water of Albayda and Shahat were good for drinking and were only slightly polluted, whereas those of El-Marj, Ras al-Hilal and Derna were moderately polluted. However, the well water of Susa was excessively polluted and was unsuitable for drinking. Prakash and Somashekar (2006), studied the Groundwater quality of Anekal Taluk, Bangalore and reported. The results indicated the water quality os not suitable for drinking purposes at several locations. Bishnoi and Arora (2007) studied the groundwater quality in rural area of Rohtak district and concluded that most of the samples did not comply with WHO standards. Overall water quality was found unsatisfactory for drinking purposes.

To observe the relationship among various physico-chemical parameters, Karl Pearson correlation analysis was performed and correlation matrix so emerged is given in Table 5.

The data showed that EC was significantly and positively correlated with TDS, TH, TA, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+} and F^- suggesting that TDS, TH, TA, SO_4^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+} and F^- greatly influenced the electrical conductivity. Total hardness was positively and significantly correlated with Mg^{2+} and SO_4^{2-}. This shows the dependence of total hardness on magnesium and sulphate concentration in studied localities of Panipat city. This is also in accordance with earlier studies (Gupta *et al.*, 1994; Garg *et al.*, 1998).

TA was significantly and positively correlated with HCO_3^- and K^+. SO_4^{2-} was significantly and positively correlated with Na^+ and Mg^{2+}. Fluoride and chloride were not significantly correlated with any of the analyzed parameters.

On the basis of present physico-chemical analysis of groundwater of Panipat city localities, it has been concluded that groundwater quality in the studied zone of the city varies from locality to locality. Higher values of certain chemical constituents at certain locations indicate that the groundwater on those specific locations is not suitable for drinking purposes as such. These high values of certain inorganics may be due to geological reasons, unplanned sewage system and dumping of solid waste etc. So it is suggested that any groundwater source in the suggested area should be analyzed before use for its suitability for domestic purposes. The results also suggest that the contamination problem is not alarming at present but groundwater quality may deteriorate with time. Therefore proper care should be taken to avoid any groundwater contamination. The industrialists should be advised to dispose the industrial waste after proper treatment and municipal authorities should also be advised to properly manage the sewage water to avoid the contamination of ground water. General public should be directed to install deep hand-pumps or use properly treated surface water for drinking purposes.

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