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EVALUATION OF GROUNDWATER QUALITY USING CONTAMINATION INDEX IN LUDHIANA, PUNJAB (INDIA)

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ABSTRACT

Groundwater samples were collected from villages Wallipur, Kumkalan, Malewal, Lubangarh, Jainpur and Malikpur of Ludhiana district located near Budha Nallah during pre-monsoon and post-monsoon season during the year 2011. Samples were analysed for heavy metals including arsenic, boron, chromium, copper, iron, magnesium, manganese and lead using I-Cap to find contamination index. The results showed that the concentration of heavy metals ranged between 0.00-42.76 mg/L and 0.00-31.89 mg/L for pre-monsoon and post-monsoon season respectively. Among the examined heavy metal constituents, magnesium has the highest mean value of 18.34 mg/L followed by manganese 0.095 mg/L while copper remained the least 0.004 mg/L for pre-monsoon. Also, magnesium recorded the highest standard deviation 9.11 mg/L, followed by manganese 0.099 mg/L while lead recorded the least value of 0.002 mg/L for pre-monsoon. Similarly, magnesium recorded highest mean value of 18.23 mg/L and chromium 0.002 mg/L with least mean for post-monsoon. The computed contaminated index ranged between -2.90 to 2.02 for pre-monsoon and -3.93 to 1.76 for post-monsoon. The highest contamination index value was recorded at location S18 (Malikpur) for pre-monsoon and S12 (Lubangarh) for post-monsoon while location S11 (Lubangarh) and S6 (Wallipur) recorded the lowest contamination value for pre-monsoon and post-monsoon season respectively in the study area. The study recommended treatment, proper maintenance and compliance to the specification according to the International Standard (WHO, 2006)

INTRODUCTION

Punjab state is situated in the north-eastern region of India, covering area of about 50 thousands square kilometers and has a population of around 28 millions. Punjab state is one of the most productive agricultural regions, where the agricultural area is cultivated with the help of extensive irrigation using the ground water and the canal water from Beas and Sutlej rivers. Groundwater is the major source of drinking and other domestic water uses in Ludhiana. It is the most reliable source of drinking water supply in the community. In order to meet the demand of water supply of the city, ground water is being pumped through deep tube wells and shallow hand pumps without any systematic planning. This over- explo-

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itation is depleting the ground water resource. The problem is further aggravated by lack of ground water recharge because of diversion of agricultural land to urban sector. Thus, the fast growing urbanization, industrialization and other developmental activities have brought a variable water crisis. The rapid industrialization in Ludhiana, though contributed to economic development, has resulted in heavy losses to economic welfare in terms of effects on agricultural activities, human health and ecosystem at large through air and water pollution. Water pollution is caused by industrial effluents of agro and non-agro based industries and sewage water containing urban and domestic wastages. Water pollution by non-agricultural sources is caused by discharge of effluents of paper, medicine, textile/hoisery industries and contaminants releases through metallurgical operations. The cause of the groundwater pollution is untreated or partially treated sewage water and discharges from agro-based manufacturing industries and the major ion concentrations in groundwater pollution were Pb, Cr, Mn, Fe, Ni, S and Cd besides extremely high quantities of phosphorous, nitrogen and sulphide compounds. Solid and liquid wastes emanating from the industrial activities are the inevitable by-products of manufacturing process. The town which earned the name of Manchester of Punjab landed into dubious distinction of being one of the most polluted human settlements in the country (Gill and Arora 2010). Azad *et al.*, (1984) studied the nature of potentially toxic elements and their concentration in the effluents emanating from two groups of industries-first involved in the manufactu- ring of metallic products such as cycles, their spare parts and electroplating, and the second group comprising processing of textiles, woolens and dyes. Analysis of these effluents revealed that, in general, Pb, Cd and Ni were more in effluents of industries manufacturing metallic products compared to textile and woolen industries. The mean Pb, cd and Ni concentration in effluents was 2.5, 1.44 and 7.5 times higher in first type of industries than that in effluents from second type of industries. Dhillon and Dhillon (1991) studied about heavy metals and stated that Arsenic (As) is another toxic element which was detected in alluvial aquifers of Punjab whose concentration varied from 35 - 688 µg/L and its average concentration of As in I, II and III agro-climatic zones of the Punjab state was 23.4, 24.1 and 76.8 µg/L respectively. Khurana *et al.*, (2003) studied about the chemical analysis of sewage water samples collected from different locations of an open drain, commonly known as 'Budha Nala", downstream from the entry into Ludhiana city revealed that the concentration of metals in the drain increases manifold as it passes through Ludhiana city. The mean concentration of all the toxic elements such as Fe, Zn, As, Pb, Ni and Cr in the sewage water samples collected at the entry point were 0.03, 0.04, 0.005, 0.004, 0.002 and 0.001 mg/L which increased to 10.8, 0.78, 2.10, 0.075, 0.28 and 0.26 mg/L respectively in the samples collected from about 15 km downstream of entry point. This is because the number of industries pouring their untreated effluents increased as the distance downstream increased. This implies that the open Budha Nala drain, which is a natural fresh water stream before its entry into Ludhiana city, turns into highly polluted sewage channel when it passes through the interior of the city receiving effluents from various types of industries on its way. Dheri *et al.*, (2007) conducted study and showed that the concentration of Pb, Cr, Cd and Ni were not only significantly higher in water samples of Budha Nallah drain but also in those collected from shallow hand-pumps located within its vicinity of 200 m as compared to deep tubewell water. The mean concentration of Pb, Cr, Cd and Ni in drain water was 21, 13.3 , 700 and 2200 times higher than their respective values in tubewell water. Similarly their concentrations in shallow hand-pumps were 18, 80, 88 and 210 times higher than deep tubewell water. Akoteyon (2012) evaluated 15 groundwater samples from 15 locations around landfills in Igando-Lagos, Nigeria during dry season. Samples were analyzed for heavy metals including (Iron, Lead, Manganese, Copper, Chromium, Cadmium and Zinc) according to standard method. The quality of groundwater samples of the study area was assessed based on contamination index (i.e., factors of single component that exceed the maximum permissible concentration of water quality parameter according to WHO standard).The adopted WHO standard showed that only Chromium was found to be within the maximum permissible limit of drinking water quality in the study area. The computed contaminated index ranged between 15.4-432.06. The highest contamination index value was recorded at location G5 while location G9 recorded the lowest contamination value in the study area.

MATERIALS AND METHODS

The study region was Ludhiana, the largest city in Punjab, both in terms of area and population as shown in Fig. 1. It lies between latitude 30055'N and longitude 75054'E. The Municipal Corporation limit of city is spread over an area of 141 sq. km. The population of the city within the Municipal Corporation area is estimated at 34.0 lakhs. The climate of Ludhiana is semi arid with maximum mean temperature reaching upto 42.8 °C and minimum mean temperature is as below as 11.8 °C. Ludhiana city was founded on a ridge of Budha Nallah a tributory of river Sutlej. The untreated sewage of the city is discharged into Budha Nallah. In addition to the city sewage, the nallah receives the treated, partially treated and untreated toxic effluents from a multitude of industries located in Ludhiana city. As a result of perennial flow of sewage in Budha Nallah, it has become an open sewer. The Budha Nallah falls into river Sutlej near village Wallipur after traversing about 55 km from its originating point at Machhiwara. For the present investigation, villages Wallipur, Kumkalan, Malewal, Lubangarh, Jainpur and Malikpur along Budha Nallah were selected for groundwater quality analysis along Budha Nallah.

Groundwater samples were collected from various villages of Ludhiana district located near Budha Nallah within the vicinity of 1.0 km during the year 2011. Six samples from village Wallipur, two samples from each village Kumkalan, Malewal, Jainpur and Malikpur and four samples from village Lubangarh were taken from tubewells located on both sides of Budha Nallah during pre-monsoon and post-monsoon seasons. The samples were collected during first fortnight of June (Pre-monsoon) and first fortnight of October (Post-monsoon). Before collection of water sample, each tube well was run for about 10 to 15 minutes to ensure the removal of stored water in the pump assembly and suction pipe. Water sample was then collected in a 1.0 litre plastic bottle after rinsing it with the running water. These bottles were then stored in an icebox and transported to the laboratory for analysis where these were kept in a refrigerator. The chemical analysis of groundwater samples collected was analyzed for sixteen heavy metals with the help of I-Cap.

The quality of groundwater can be assessed with

Fig. 1 Map of Punjab State, India

the use or calculation of environmental factors and indices, which include a wide range of parameters. Such factors may become valuable tool for the assessment of environmental condition of an area. According to Backman *et al*., (1998), contamination index is defined as Eq. 1 and 2:

$$C_d = \sum_{i=1}^{n} Cf_i \qquad (1)$$

where

$$C_{fi} = C_{Ai} - C_{Ni} / C_{Ni} \qquad (2)$$

where, C_d = contamination index; C_{fi} = contamination factor of the i-th component, C_{Ai} = analytical value of the i-th component and C_{Ni} = upper permissible concentration of the i-th component. Contamination index (Cd) is calculated individually for each water sample, as a sum of the contaminant factors of single component that exceed the maximum contaminant levels. Hence, contamination index summarized the combinational effects of several quality parameters, that may have harmful consequences to human health/the environment. The value scale for contamination index consists of 3 ranges; $C_d < 1$ (low contamination), $1 < C_d < 3$ (medium contamination) and $C_d > 3$ (high contamination).

RESULTS AND DISCUSSION

The level of the heavy metal constituents in groundwater samples (Table 1) shows that in all the sampling locations, arsenic exceeded the BIS standard limit in 7 locations (i.e., $S1\text{-}_{3,7\text{-}8,\,12\text{ and }14}$) during pre-monsoon and 3 locations (i.e., $S_{3,\,10\text{-}11}$) during post-monsoon. Manganese was found to be above the maximum permissible limit of BIS standard in only 5 locations (i.e., $S1\text{-}_{3,\,13\text{ and }18}$) and 4 locations ($S_{9\text{-}12}$) during pre-monsoon and post-monsoon respectively. Lead exceeded the BIS standard limit in all the sampling locations except S_{11} during pre-monsoon while magnesium was found to be above the maximum permissible limit of BIS standard in 2 sampling locations (i.e. S13 and 18) and (i.e. $S_{12\text{ and }17}$) during pre-monsoon and post-monsoon respectively. It was discovered that copper, chromium, iron and boron were found to be within the BIS standard limit in all the sampling locations. The perusal of Table 2 presents the statistics of heavy metal constituents in groundwater of the study area. The result shows that the mean concentration of the examined parameters (arsenic, manganese, lead, magnesium, copper, chromium, iron and boron) ranged between 0.002-0.033, 0.013-0.286, 0.009-0.016, 6.848-42.76, 0.00-0.009, 0.00-0.008, 0.00-0.048 and 0.022-0.212 mg/L respectively for pre-monsoon and 0.00-0.016, 0.002-0.468, 0.00-0.006, 8.17-31.89, 0.001-0.023, 0.00-0.003, 0.001-0.069 and 0.033-0.320 mg/L respectively for post-monsoon. Among the examined heavy metal constituents, magnesium has the highest mean value of 18.34 mg/L followed by manganese 0.095 mg/L while copper remained the least 0.004 mg/L for pre-monsoon. Also, magnesium recorded the highest standard deviation 9.113 mg/L, followed by manganese 0.099 mg/L while lead recorded the least value of 0.002 mg/L for pre-monsoon. Similarly, magnesium recorded highest mean value of 18.23 mg/L and chromium 0.002 mg/L with least mean for post-monsoon. On the pattern of the relative variation, the result of the coefficient of variation (C.V) shows that all the examined variables are heterogeneous. Manganese and iron for example tops the list with a value of 104.2% and 150.0% for pre-monsoon and post-monsoon respectively. The computed contamination index for the sampling locations shows that location S18 (Malikpur) has the highest contamination index, followed by location S13 (Lubangarh), S3 (Wallipur) and S2 (Wallipur) while location S1 (Wallipur) recorded the lowest value of contamination index for pre-monsoon and for post-monsoon, S12 (Lubangarh) recorded the highest contamination index as a result of the presence of As, Mn, Pb, Mg and B being the contamination parameters as shown in Fig. 3 and 4. Further, the BIS standard limit for drinking water quality adopted to adjudge the suitability of groundwater for human drinking in the study area showed that all the parameters examined with the exception of copper, chromium, iron and boron was found to be above the maximum permissible limit for drinking water standard at some sampling locations both for pre-monsoon and post-monsoon. High arsenic levels were noticed in water samples at locations S1, S2 and S3 of village Wallipur (Table 1) during the pre-monsoon.

Water containing arsenic shows deleterious effect on human health. It can cause stomach pain, nausea, vomiting; diarrhea; numbness in hands and feet; partial paralysis; and even blindness. Studies have also shown that excessive dissolved manganese concentrations in groundwater result in taste and precipitation problems. Similarly, heavy metals such as magnesium, lead and manganese have also been reported at excessive levels in groundwater in parts of Ludhiana due to the addition of effluents from electroplating, dye and finishing units, vanaspati and chemical industries brought through Budha Nallah. Lead is a naturally occurring heavy metal. The presence of lead in water can result in health effects including neurological damage, reduced IQ, anemia, and nerve disorders, among others.

CONCLUSION AND RECOMENDATIONS

The present study evaluated groundwater samples from 6 locations around Budha Nallah within the vicinity of 1.0 km in Ludhiana district, Punjab during pre-monsoon and post-monsoon seasons. Samples were analyzed for heavy metals including (As, Mn, Pb, Mg, Cu, Cr, Fe and B) according to BIS standard method. The quality of groundwater samples of the study area was assessed based on contamination index (i.e., factors of single component that exceed the maximum permissible concentration of water quality parameter according to BIS standard).The adopted BIS

Table 1 Concentration of heavy metals (mg/L) in groundwater samples within vicinity of 1.0 Km of Budha Nallah in Ludhiana district.

Village	Sampling location	Elements (mg/L)							
		As	Mn	Pb	Mg	Cu	Cr	Fe	B
Wallipur	S1*	0.029	0.148	0.011	13.91	0.003	0.003	0.021	0.146
	S1**	0.004	0.076	0.002	17.38	0.014	0.001	0.005	0.145
	S2*	0.032	0.166	0.011	11.87	0.002	0.004	0.028	0.126
	S2**	0.004	0.037	0.003	21.26	0.002	0.002	0.009	0.177
	S3*	0.033	0.109	0.014	20.56	0.003	0.000	0.033	0.179
	S3**	0.016	0.049	0.001	8.60	0.005	0.003	0.014	0.071
	S4*	0.006	0.069	0.011	10.60	0.009	0.004	0.012	0.086
	S4**	0.001	0.048	0.000	13.40	0.003	0.002	0.003	0.100
	S5*	0.008	0.064	0.014	8.01	0.009	0.001	0.048	0.080
	S5**	0.006	0.027	0.001	14.14	0.008	0.002	0.001	0.095
	S6*	0.008	0.091	0.014	16.47	0.005	0.007	0.005	0.105
	S6**	0.001	0.020	0.001	13.88	0.001	0.002	0.003	0.103
Kumkalan	S7*	0.011	0.013	0.015	22.86	0.004	0.003	0.002	0.022
	S7**	0.001	0.010	0.006	14.48	0.004	0.002	0.003	0.033
	S8*	0.011	0.015	0.011	12.51	0.002	0.010	0.012	0.054
	S8**	0.001	0.040	0.008	15.61	0.023	0.002	0.069	0.043
Malewal	S9*	0.009	0.022	0.015	20.38	0.008	0.005	0.005	0.057
	S9**	0.002	0.373	0.002	15.63	0.007	0.002	0.029	0.111
	S10*	0.009	0.022	0.016	21.0	0.008	0.004	0.004	0.054
	S10**	0.012	0.185	0.005	18.25	0.006	0.001	0.043	0.071
Lubangarh	S11*	0.004	0.050	0.009	6.848	0.002	0.007	0.034	0.034
	S11**	0.016	0.273	0.002	8.170	0.011	0.002	0.012	0.065
	S12*	0.011	0.028	0.012	13.69	0.006	0.000	0.001	0.031
	S12**	0.001	0.468	0.003	31.31	0.011	0.001	0.008	0.320
	S13*	0.002	0.387	0.011	42.76	0.001	0.008	0.009	0.146
	S13**	0.002	0.002	0.005	28.39	0.005	0.001	0.003	0.158
	S14*	0.005	0.069	0.011	19.08	0.001	0.005	0.019	0.040
	S14**	0.001	0.017	0.006	16.28	0.004	0.001	0.002	0.042
Jainpur	S15*	0.007	0.048	0.011	16.57	0.002	0.002	0.031	0.081
	S15**	0.001	0.021	0.003	17.42	0.004	0.002	0.002	0.077
	S16*	0.005	0.076	0.011	17.86	0.008	0.003	0.019	0.064
	S16**	0.001	0.009	0.006	20.23	0.003	0.001	0.001	0.047
Malikpur	S17*	0.003	0.044	0.012	17.99	0.000	0.001	0.022	0.083
	S17**	0.000	0.082	0.005	31.89	0.004	0.000	0.005	0.138
	S18*	0.011	0.286	0.015	37.20	0.004	0.000	0.000	0.212
	S18**	0.001	0.014	0.006	21.75	0.003	0.000	0.001	0.056
BIS Std: 2004-05, (IS:10500)		0.01	0.1	0.01	30.0	0.05	0.05	0.3	0.5

* Pre-Monsoon ** Post-Monsoon

Table 2. Descriptive statistics of heavy metals in groundwater and BIS standard limits.

Parameter (mg L^{-1})	Range	Mean	Std. Dev	Coefficient of variation (%)	BIS Std:2004-05, (IS:10500)
As*	0.002-0.033	0.011	0.010	90.91	0.01
As**	0.000-0.016	0.044	0.005	11.36	
Mn*	0.013-0.286	0.095	0.099	104.2	0.1
Mn**	0.002-0.468	0.097	0.137	141.2	
Pb*	0.009-0.016	0.012	0.002	16.67	0.01
Pb**	0.000-0.006	0.004	0.002	50.0	
Mg*	6.848-42.76	18.34	9.113	49.69	30.0
Mg**	8.17-31.89	18.23	6.740	36.97	
Cu*	0.000-0.009	0.004	0.003	75.0	0.05
Cu**	0.001-0.023	0.007	0.005	71.43	
Cr*	0.000-0.008	0.004	0.003	75.0	0.05
Cr**	0.000-0.003	0.002	0.001	50.0	
Fe*	0.000-0.048	0.017	0.014	82.35	0.3
Fe**	0.001-0.069	0.012	0.018	150.0	
B*	0.022-0.212	0.089	0.054	60.67	0.5
B**	0.033-0.320	0.103	0.069	66.99	

* Pre-Monsoon ** Post-Monsoon

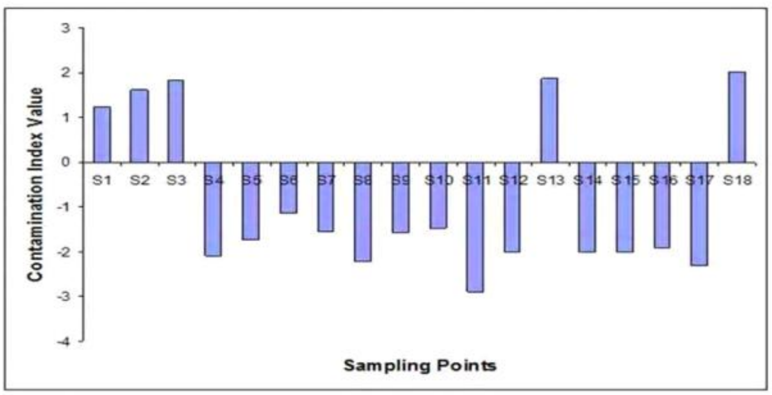

Fig. 3 Contamination index for the sampling locations (Pre-Monsoon)

standard showed that only copper, chromium, iron and boron was found to be within the maximum permissible limit of drinking water quality in the study area. The computed contaminated index ranged between -2.90 to 2.02 for pre-monsoon and -3.93 to 1.76 for post-monsoon. The highest contamination index value was recorded at location S18 (Malikpur) for pre-monsoon and S12 (Lubangarh) for post-monsoon while location S11 (Lubangarh) and S6 (Wallipur) recorded the lowest contamination value for pre-monsoon and post-monsoon season respectively in the study area.

The study recommended that, industrial effluent should be treated before it is been discharged into the Budha Nallah. This will safeguard the health of the people especially those that depend on groundwater source for drinking purpose. Strict laws should be imposed on the industries which release their effluents directly into the water. Regular monitoring of small scale industries which are also a major contributor for polluting the surface water and ultimately contaminates the ground water. Educating the people about the various problems specially the labour class that works in industries will also help to clean the

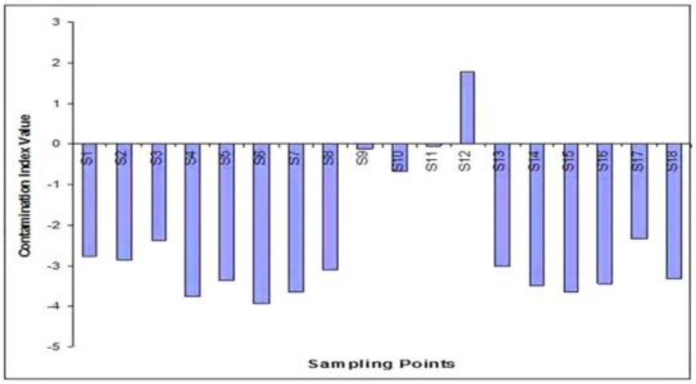

Fig. 4 Contamination index for the sampling locations (Post-Monsoon)

environment as the best way to manage the environment, is to manage ourselves.

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