



Determination of heavy metal pollution index of ground water of village Wallipur in Ludhiana district

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Abstract: The objective of the study was to reveal the seasonal variations in the groundwater quality with respect to heavy metals contamination near Buddha Nullah in Ludhiana district. To get the extent of trace metals contamination, groundwater samples from tube wells were randomly collected from 16 different points on both sides along the course of Buddha Nullah from areas of Bhamian Kalan, Khasi Kalan and Wallipur Kalan villages of Ludhiana district during first fortnight of June (Pre-monsoon), first fortnight of November (Post-monsoon) and first fortnight of January (Winter season) during the year 2013-14. The concentrations of toxic and heavy metals such as metalloids B, As, Pb; alkaline earth metals Mg, Ca; alkali metals Na, K; transition metals Cr, Mn, Fe, Cu, Zn, Cd and non metal S were determined. The heavy metal pollution index (HPI) was calculated. Most of the parameters were found within permissible limit of BIS, 2004. The average values of concentration of Ca, Cr, Mn, As and Pb for pre-monsoon season was higher than average concentration of post-monsoon and winter season. Overall HPI calculated based on the mean concentration of the heavy metals was found to be 18.11, 15.32 and 16.10 for pre-monsoon, post-monsoon and winter season, respectively, which was below the critical pollution index value of 100. The study recommended proper treatment to the sewage water which is being discharged into the Buddha Nullah.

Keywords: Buddha Nullah, Groundwater pollution, Heavy metal pollution index, Ludhiana

INTRODUCTION

The water unsafe for human consumption and/or hygienic purposes represents a significant health risk for the exposed population. Those at the greatest risk of waterborne disease are infants and young children, the elderly and the people living under unsanitary conditions (WHO Std. 2006). Globally, nearly a billion people still lack access to improved sources of drinking water, and about 2.5 billion lack improved sanitation and an estimated 2,000 children under the age of five die every day from diarrhoeal diseases and of these some 1,800 deaths are linked to water, sanitation and hygiene (UNICEF, 2013). The deterioration of groundwater quality could be attributed to the anthropogenic as well as natural causes. Urban and industrial sectors not only utilize the available water but also discharge a considerable amount of wastewater. In Punjab and the rest of India, the most important anthropogenic factor responsible for groundwater pollution is urban and industrial wastewater which carries the trace elements like arsenic (As), chemicals like cyanide and harmful pesticides. This wastewater is often not treated before its release into sewerage drains. The most common disposal of wastewater is its use as crop irrigation. Direct release of untreated effluents to land and water bodies can potentially

contaminate air, surface, groundwater as well as soils, and eventually the crops. Present discharge of sewage in Ludhiana is 636 million litre per day (MLD) whereas sewage treatment plants (STPs) of capacity 466 MLD are in operation (PPCB proceedings, 2016). Trace metal contaminations are important due to their potential toxicity for the environment and human beings (Gueu *et al.*, 2007; Lee *et al.*, 2007; Adams *et al.*, 2008; Vinodhini and Narayanan, 2008). Monitoring and assessment of the water pollution has become a very critical area of study because of direct implications of water pollution on the aquatic life and the human beings. Large industries include those in the production of gold, aluminium, fertilizer, pulp and paper, textiles and chlor-alkali, as well as automotive engineering industries and electroplating units, which are a major hazardous waste source, are included with the large/medium industries for assessment. Among small-scale industries, chemicals, textiles, dyes/pigments, pesticides and leather tannings are selected as potential hazardous wastes (Misra and Pandey, 2005). A recent study (Dheri *et al.*, 2007) showed that the concentration of lead (Pb), chromium (Cr), cadmium (Cd) and nickel (Ni) were not only significantly higher in water samples of Buddha Nullah drain but also in those collected from shallow hand-pumps located within its vicinity of 200 m as compared to

deep tubewell water. The contamination of groundwater by heavy metals is a serious ecological problem as some of them like As (0.05 mg/l maximum permissible limit) and Pb (0.05 mg/l maximum permissible limit) are toxic even at low concentrations and are non-degradable and can be bio-accumulated through food chain (Kar et al., 2008). The spatial study of heavy metals by using heavy metal pollution index would be helpful in identifying and quantifying trends in water quality (Prasad and Kumari, 2008; Reza and Singh, 2010) and can provide the accumulated information and assessments in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions. In view of rationale presented, the study was planned to assess the groundwater pollution near the Buddha Nullah.

MATERIALS AND METHODS

Location: The study area Wallipur village is located in Ludhiana district of Punjab State. It lies approximately between 30° 51' 10" to 30° 57' 20" N latitude and 75° 46' 00" to 75° 56' 20" E longitude. The average height above mean sea level is 247 m. Ludhiana district has a population of more than 3.4 million (Census of India, 2011). Ludhiana city was founded on a ridge of Buddha Nullah a tributary of river Sutlej and approximately 170 MLD untreated sewage of the city is discharged into Buddha Nullah (PPCB proceedings, 2016). In addition, to the city sewage, the Nullah receives the treated, partially treated and untreated toxic effluents from a multitude industries located in Ludhiana city. As a result of perennial flow of sewage in Buddha Nullah, it has become an open sewer. The Buddha Nullah confluence into river Sutlej near village Wallipur after travelling about 55 km from its originating point at Machhiwara (Jindal and Sharma, 2011).

Collection of samples: Sixteen groundwater samples from different tubewells were collected from village Wallipur of Ludhiana district along both sides of Buddha Nullah (Fig. 1). The groundwater samples were collected during first fortnight of June (Pre-monsoon), first fortnight of November (Post-monsoon) and first fortnight of January (Winter season) during the year

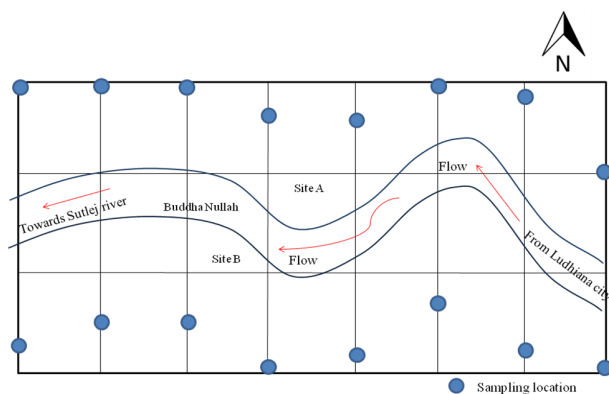


Fig. 1. Sampling location of the study area.

Table 1. Concentration of toxic metals (mg/l) in groundwater samples located within vicinity of 1.0 km along both sides of Buddha Nullah in village Wallipur (Pre-Monsoon).

Element	Sampling Site A								Sampling Site B							
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
Arsenic	0.025	0.021	0.025	0.000	0.002	0.009	0.025	0.003	0.002	0.027	0.051	0.000	0.003	0.020	0.001	0.003
Magnesium	10.60	14.96	6.660	21.41	7.399	9.425	9.764	12.35	42.48	33.00	44.35	23.31	37.31	29.87	28.84	1.857
Manganese	0.675	0.591	0.253	0.831	0.005	0.254	0.244	0.205	0.510	0.401	0.889	0.011	1.221	0.236	0.020	0.006
Lead	0.008	0.008	0.004	0.002	0.003	0.002	0.008	0.008	0.017	0.013	0.017	0.014	0.007	0.009	0.011	0.000
Boron	0.131	0.179	0.148	0.602	0.178	0.157	0.157	0.113	0.244	0.287	0.388	0.230	0.375	0.283	0.292	0.074
Calcium	78.83	71.78	39.99	89.47	33.61	48.22	37.26	43.51	95.18	69.63	100.1	46.23	114.6	94.21	61.20	6.986
Cadmium	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000
Chromium	0.008	0.013	0.009	0.065	0.003	0.005	0.009	0.007	0.006	0.003	0.007	0.005	0.007	0.001	0.001	0.003
Copper	0.002	0.001	0.002	0.000	0.001	0.001	0.000	0.000	0.005	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Iron	0.066	0.174	0.067	0.920	0.072	0.079	0.060	0.011	0.440	0.128	0.097	0.128	0.138	0.093	0.003	0.005
Sulphur	13.16	38.75	11.14	37.59	15.98	4.457	11.32	11.47	78.43	16.94	15.15	7.730	27.10	28.76	10.50	0.469
Zinc	0.006	0.004	0.000	0.003	0.000	0.004	0.001	0.001	0.045	0.002	0.004	0.000	0.066	0.003	0.000	0.015
Potassium	4.329	4.189	2.465	2.162	4.321	2.773	2.041	2.221	38.90	18.73	28.31	4.529	15.39	6.699	5.478	1.108
Sodium	4.357	22.15	6.016	26.06	4.523	22.95	8.961	9.090	171.7	114.6	153.5	23.29	136.3	43.45	61.08	4.442

Table 2. Concentration of toxic metals (mg/l) in groundwater samples located within vicinity of 1.0 km along both sides of Buddha Nullah in village Wallipur (Post-Monsoon).

Element	Sampling Site A										Sampling Site B					
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
Arsenic	0.006	0.000	0.006	0.001	0.005	0.002	0.007	0.004	0.002	0.021	0.001	0.022	0.009	0.000	0.000	0.002
Magnesium	40.51	12.35	28.16	26.12	14.51	7.829	8.609	10.09	59.70	35.79	18.66	30.25	32.89	37.78	16.00	18.25
Manganese	0.353	0.009	0.663	0.355	0.174	0.007	0.157	0.028	0.568	0.782	0.037	0.431	0.642	0.045	0.031	0.009
Lead	0.004	0.005	0.006	0.005	0.005	0.007	0.006	0.007	0.008	0.013	0.007	0.007	0.009	0.010	0.006	0.008
Boron	0.145	0.207	0.375	0.363	0.237	0.201	0.173	0.267	0.521	0.422	0.337	0.371	0.444	0.357	0.239	0.228
Calcium	22.07	24.20	84.74	64.22	41.97	26.57	32.49	32.80	130.20	78.16	33.00	68.38	97.28	76.03	31.37	32.26
Cadmium	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001
Chromium	0.006	0.002	0.011	0.008	0.005	0.003	0.002	0.004	0.003	0.006	0.011	0.002	0.005	0.004	0.002	0.003
Copper	0.009	0.014	0.027	0.039	0.028	0.009	0.012	0.008	0.002	0.020	0.036	0.025	0.023	0.023	0.008	0.017
Iron	0.081	0.084	0.186	0.139	0.139	0.144	0.118	0.198	0.179	0.421	0.139	0.139	0.172	0.157	0.139	0.225
Sulphur	17.34	10.99	65.25	41.83	17.40	16.69	5.166	4.070	70.370	4.117	14.260	14.65	16.36	9.335	25.93	33.02
Zinc	0.026	0.018	0.029	0.085	0.035	0.029	0.024	0.024	0.031	0.055	0.029	0.024	0.030	0.031	0.023	0.040
Potassium	9.070	10.86	36.52	17.02	12.61	9.480	8.338	9.963	46.74	28.77	13.93	19.05	20.07	15.60	13.32	12.67
Sodium	5.855	16.85	42.29	39.69	13.48	11.79	11.15	16.89	264.1	158.1	37.03	125.9	142.7	57.42	40.63	43.58

Table 3. Concentration of toxic metals (mg/l) in groundwater samples located within vicinity of 1.0 km along both sides of Buddha Nullah in village Wallipur (Winter Season).

Element	Sampling Site A										Sampling Site B					
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
Arsenic	0.033	0.002	0.007	0.001	0.001	0.003	0.003	0.001	0.026	0.005	0.017	0.001	0.001	0.006	0.002	0.002
Magnesium	25.87	27.31	6.30	15.32	8.762	2.700	9.091	9.628	29.75	42.70	41.35	5.432	10.91	24.17	5.518	18.17
Manganese	0.097	0.015	0.216	0.004	0.272	0.052	0.079	0.161	0.141	0.282	0.493	0.031	0.361	0.278	0.030	0.008
Lead	0.003	0.003	0.000	0.001	0.003	0.003	0.002	0.004	0.001	0.002	0.001	0.000	0.003	0.003	0.000	0.000
Boron	0.312	0.218	0.061	0.202	0.072	0.022	0.058	0.061	0.263	0.420	0.325	0.063	0.095	0.187	0.066	0.267
Calcium	32.13	20.41	23.48	16.94	33.67	14.80	24.56	26.65	29.10	45.93	41.03	13.65	29.38	29.49	13.31	19.74
Cadmium	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Chromium	0.000	0.004	0.002	0.002	0.001	0.002	0.001	0.002	0.001	0.002	0.002	0.003	0.002	0.003	0.004	0.003
Copper	0.003	0.003	0.001	0.002	0.003	0.002	0.003	0.003	0.002	0.002	0.004	0.003	0.003	0.003	0.002	0.001
Iron	0.070	0.028	0.080	0.003	0.006	0.013	0.048	0.029	0.068	0.469	0.0329	1.956	0.053	0.074	1.953	0.007
Sulphur	31.55	9.595	7.705	10.57	27.68	1.456	8.832	8.140	18.19	2.467	36.88	8.297	14.91	26.51	8.993	28.38
Zinc	0.003	0.000	0.032	0.001	0.058	0.003	0.002	0.002	0.001	0.015	0.025	0.001	0.245	0.086	0.003	0.001
Potassium	13.57	5.663	2.719	3.678	2.791	0.872	1.794	2.105	15.23	26.01	14.73	0.884	3.286	5.344	0.975	4.455
Sodium	93.00	13.68	3.343	15.27	9.753	2.929	3.363	7.211	101.7	162.9	159.7	5.562	34.72	25.10	5.948	58.15

Table 4. Descriptive statistics of heavy metals in groundwater, BIS standard limits.

Parameter (mg/l)	Mean, mg/l	Std. Dev	Coefficient of variation (%)	BIS Std: 2004 (IS:10500)
Pre-monsoon				
Arsenic	0.0136	0.014	104.6	0.01
Manganese	0.3970	0.350	88.2	0.1
Lead	0.0082	0.005	61.9	0.01
Boron	0.2399	0.128	53.5	0.5
Copper	0.0013	0.001	91.7	0.05
Post-monsoon				
Arsenic	0.0055	0.007	120.1	0.01
Manganese	0.2682	0.266	99.2	0.1
Lead	0.0071	0.002	30.6	0.01
Boron	0.3054	0.105	34.3	0.5
Copper	0.0188	0.010	55.1	0.05
Winter season				
Arsenic	0.0069	0.010	136.2	0.01
Manganese	0.1575	0.142	89.8	0.1
Lead	0.0018	0.001	73.6	0.01
Boron	0.1683	0.118	70.3	0.5
Copper	0.0025	0.001	31.6	0.05

2013-14. The spacing between each sampling site was approximately 1.0 km from each other. 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 deep freezer. The samples were then analyzed for toxic and heavy metals *viz.* boron (B), sodium (Na), magnesium (Mg), sulphur (S), potassium (K), calcium (Ca), chromium (Cr), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), lead (Pb) using inductively coupled argon plasma atomic emission spectroscopy (ICAP-AES).

Calculations: The quality of groundwater was assessed by using heavy metal pollution index. Heavy metal pollution index (HPI) is a method of rating which shows the composite influence of individual heavy metal on the overall quality of water and it is an effective tool to characterize the ground water pollution as it combines several parameters to arrive at a particular value which can be compared with the critical value to assess the level of pollution load. In Table 5 the methodology of HPI calculation has been presented in detail. Mean concentrations of the five heavy metals were used for the HPI determination. The rating is a value between 0 and 1 and it is an arbitrary value between 0 and 1 and its selection depends upon the importance of individual quality concentrations in a comparative way or it can be assessed by making values inversely proportional to the recommended standard (S_i) for the corresponding parameter (Horton 1965; Mohan *et al.* 1996). Water quality and its suitability for drinking purpose can be examined by determining its quality index (Mohan *et al.*, 1996; Prasad and Kumari, 2008; Prasad and Mondal, 2008).

$$HPI = \frac{\sum_{i=1}^n W_i \times Q_i}{\sum_{i=1}^n W_i} \dots \dots \dots (1)$$

Where W_i = Unit Weightage of i^{th} parameters, Q_i = sub index of the i^{th} parameter, n = is the number of parameters considered. Weighted arithmetic index method was used for calculation of HPI. The weightage (W_i) was taken as the inverse of standard permissible value (S_i). The sub-index of (Q_i) of the parameter was calculated by

$$Q_i = \sum_{i=1}^n \frac{|M_i - I_i|}{(S_i - I_i)} \dots \dots \dots (2)$$

Where,
 M_i = is the monitored value of heavy metal of i^{th} parameter
 I_i = Ideal value of the i^{th} parameter
 S_i = Standard permissible value of i^{th} parameter
 The quantity ($M_i - I_i$) indicates numerical difference of the two values, ignoring the algebraic sign; that is the absolute value. Generally, the critical heavy metal pollution index value is 100 (Prasad and Bose, 2001).

RESULTS AND DISCUSSION

Chemical analysis of groundwater samples in village Wallipur (Pre-Monsoon): The groundwater samples were analyzed for toxic and heavy metals. The mean and maximum value of concentration of As in groundwater was found out to be 0.0136 mg/l and 0.051 mg/l, respectively, with a standard deviation of 0.014. Of the total samples, its concentration in 37.5 % samples was found to be more than the maximum permissible limit of 0.01 mg/l. Similar results were also reported by Hundal *et al.*, 2009. The mean and maximum value of concentration of Ca was found to be 64.42 mg/l and 114.6 mg/l, respectively and in 37.5 % samples, concentration of Ca was more than the maximum permissible limit of 75 mg/l whereas the mean and maximum value of concentration of Mn was 0.397 mg/l and 1.221 mg/l, respectively which was more

Table 5. Mean HPI of the groundwater samples for pre-monsoon, post-monsoon and winter season.

Parameter	Mean Value (Mi) (mg/l)	Standard permissible value (Si) (mg/l)	Highest desirable value (Ii) (mg/l)	Unit weight age (Wi)	Sub Index (Qi)	Wi X Qi	HPI
Pre-monsoon season							
Arsenic	0.0136	0.05	0.01	20.00	8.91	178.13	18.11
Manganese	0.3970	0.3	0.1	3.33	148.5	495.	
Lead	0.0082	0.05	0.01	20.00	4.53	90.62	
Boron	0.2399	1	0.5	1.00	52.03	52.03	
Copper	0.0013	1	0.05	1.00	5.13	5.132	
				$\Sigma Wi= 45.33$	$\Sigma Wi \times Qi=820.90$		
Post-monsoon season							
Arsenic	0.0055	0.05	0.01	20.00	11.25	225	15.32
Manganese	0.2682	0.3	0.1	3.33	84.09	280.31	
Lead	0.0071	0.05	0.01	20.00	7.344	146.88	
Boron	0.3054	1	0.5	1.00	38.91	38.91	
Copper	0.0188	1	0.05	1.00	3.289	3.29	
				$\Sigma Wi= 45.33$	$\Sigma Wi \times Qi=694.39$		
Winter season							
Arsenic	0.0069	0.05	0.01	20.00	7.66	153.2	16.10
Manganese	0.1575	0.3	0.1	3.33	28.75	95.83	
Lead	0.0018	0.05	0.01	20.00	20.47	409.4	
Boron	0.1683	1	0.5	1.00	66.35	66.35	
Copper	0.0025	1	0.05	1.00	5	5	
				$\Sigma Wi= 45.33$	$\Sigma Wi \times Qi=729.78$		

than the maximum permissible limit of 0.1 mg/l and similar trend was observed in Pb. The concentration of Mn and Pb was more than maximum permissible limit in 75 % and 31.2 % samples. The standard deviation was 0.350 and 0.005 for Mn and Pb, respectively. The mean and maximum value of B was found out to be 0.239 mg/l and 0.608 mg/l which was higher than the maximum permissible limit of 0.5 mg/l. Toxic metals like S, Zn, Cd was found to be below maximum permissible limits in all the samples whereas Fe was found to be more than maximum permissible limit of 0.3 mg/l in one sample and Mg was found to be more than permissible limit (30 mg/l) in 25 % samples (Table 1). These results are supported by many other studies who found high level of heavy and toxic metal concentrations (Kalicharan 2007; Kaur *et al.*, 2014; Garg *et al.*, 2015).

Chemical analysis of groundwater samples in village Wallipur (Post-Monsoon): During post monsoon season, the mean and maximum value of concentration of As in groundwater was found out to be 0.0055 mg/l and 0.022 mg/l, respectively, with a standard deviation of 0.007. In 12.5 % samples, concentration of As was more than permissible limit whereas the mean and maximum concentration of Mn was found to be 0.27 mg/l and 0.78 mg/l, respectively and in 56.25 % samples, its concentration was more than the maximum permissible limit of 0.1 mg/l. The standard deviation for Mn was found to be 0.266. The mean and maximum value of concentration of Ca was 54.73 mg/l and 130.2 mg/l, respectively and in 25 % samples, concentration of Ca was found to be more than maximum permissible limit. Similarly, the mean and maximum value of concentration of Pb was 0.007 mg/l and 0.013

mg/l, respectively, with a standard deviation of 0.002. The maximum value was higher than the maximum permissible limit of 0.01 mg/l. The maximum value of B was found out to be 0.521 mg/l which was higher than the maximum permissible limit of 0.50 mg/l. Toxic metals like S, Zn, Cd was found to be below maximum permissible limits in all the samples whereas Fe was found to be more than maximum permissible limit of 0.3 mg/l in one sample and Mg was found to be more than permissible limit (30 mg/l) in 31 % of total samples (Table 2). The mean concentration of As, Mn, Pb, S, Zn and Ca were less than the concentration during pre-monsoon season which may be due to dilution from recharge contribution from diluted Nullah water.

Chemical analysis of groundwater samples in village Wallipur (Winter Season): During winter season, the mean and maximum value of concentration of As in groundwater was found out to be 0.0069 mg/l and 0.033 mg/l, respectively, with a standard deviation of 0.01. In 19 % samples, concentration of As was more than permissible limit whereas the mean and maximum concentration of Mn was found to be 0.16 mg/l and 0.49 mg/l, respectively and in 50 % samples, its concentration was more than the maximum permissible limit of 0.1 mg/l. The standard deviation for Mn was found to be 0.142. The mean and maximum value of concentration of Ca was 25.90 mg/l and 45.93 mg/l, respectively but in none of the samples it was found to be above maximum permissible limit. Similarly, the mean and maximum value of concentration of Pb was 0.0018 mg/l and 0.004 mg/l, respectively, with a standard deviation of 0.001. In all samples, it was below maximum permissible limit of 0.01 mg/l. The

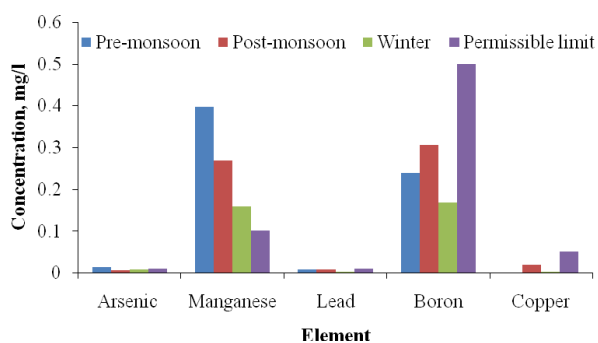


Fig. 2. Average concentration of heavy metals (As, Mn, Pb, B and Cu) in Pre-monsoon, Post-monsoon and winter season.

mean and maximum value of B was found out to be 0.016 and 0.42 mg/l which was less than the maximum permissible limit of 0.50 mg/l. Toxic metals like S, Zn, Cd was found to be below maximum permissible limits in all the samples whereas Fe was found to be more than maximum permissible limit of 0.3 mg/l in two samples and Mg was found to be more than permissible limit (30 mg/l) in one sample (Table 3).

Comparison between chemical analysis of pre-monsoon, post-monsoon and winter season groundwater samples in village Wallipur:

The pre-monsoon, post-monsoon and winter season groundwater samples were analyzed for toxic and heavy metals concentration as shown in Tables 1, 2 and 3. The results of average concentration of heavy metals (mg/l) for pre-monsoon, post-monsoon and winter season are presented in Fig. 2. Perusal of the Fig. 2 revealed that the average values of concentration of B and Fe for post-monsoon season was higher than the pre-monsoon and winter seasons but the average concentration of As, Zn, Cd, Pb and Mn for pre-monsoon season was higher than average concentration of post-monsoon and winter season. This may be due to the fact that during post monsoon season, diluted water due to runoff from Buddha Nullah has entered in to ground as recharge component.

Quite higher concentration of heavy and toxic metals were measured in the groundwater, which may be attributed to the discharge of industrial effluents from dyeing, electroplating, woolen industries, domestic and agricultural waste and other anthropogenic activities around the Buddha Nullah which leads to groundwater pollution in adjoining areas.

Statistics of heavy metals in groundwater: The descriptive statistics of heavy metals in groundwater for pre-monsoon, post-monsoon, winter season and Bureau of Indian Standards (BIS, 2004) limits are presented in Table 4. For pre-monsoon season, among the examined variables, Mn, Ca has the highest mean (0.397 mg/l) followed by B (0.239 mg/l), As (0.013 mg/l), Pb (0.008 mg/l) and Cu (0.001 mg/l). Also, Mn recorded the highest standard deviation of 0.350 mg/l, this is followed by B, As, Pb and Cu. For post-

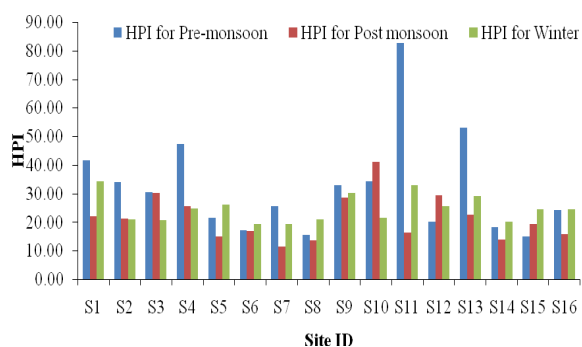


Fig. 3. HPI for pre-monsoon, post-monsoon and winter season at different groundwater sampling sites.

monsoon and winter season, B recorded the highest mean and Mn recorded highest standard deviation. The standard deviation shows that the pollution degree in this area was uniform. On the pattern of the relative variation, the result of the coefficient of variation (C.V.) showed that all the examined variables are heterogeneous. Arsenic for example tops the list with a value of 104.6% for pre-monsoon, 120.1 % for post-monsoon and 136.2 % for winter season, respectively. The mean values of As and Pb for pre-monsoon and post-monsoon season were at par with the maximum permissible limit of BIS (2004). Similarly, the mean value of Mn was higher than the maximum permissible limit of BIS (2004), for pre-monsoon, post-monsoon and winter season as shown in Table 4. The mean value of B and Cu was less than the maximum permissible limit.

In order to calculate the HPI of the water, the mean concentration values of the selected metal (As, Mn, Pb, B and Cu) have been taken into account (Prasad and Mondal, 2008). HPI was also calculated separately for each sampling location to compare the pollution load and assess the groundwater quality of the selected sites (Fig. 3). The critical pollution index value, above which the overall pollution level should be considered unacceptable, is 100 (Prasad and Kumari, 2008; Prasad and Mondal, 2008). Overall HPI for the groundwater samples was found to be 18.11, 15.32 and 16.10 for pre-monsoon, post-monsoon and winter season, respectively (Table 5). The highest HPI was 82.56 at site S11, 40.93 at site S10 and 34.14 at site 1 for pre-monsoon, post-monsoon and winter season, respectively. Results revealed that the HPI for post-monsoon and winter season was less than pre-monsoon which may be due to rainfall contribution to Nullah water which contributes to groundwater. The similar results were also reported by Nazari and Sobhanardakani (2015); Nasrabadi (2015); Sobhanardakani (2016). Overall HPI value indicated that the groundwater quality in village Wallipur on both sides of Buddha Nullah is not critically polluted with respect to these heavy metals during pre-monsoon, post-monsoon and winter season.

Conclusion

The present study revealed the maximum values of concentration of Ca, Cr, Mn, As and Pb in groundwater sample during the pre-monsoon and post-monsoon to be higher than the maximum permissible limit. Though the water was not found to be critically polluted with respect to heavy metals, the situation is still a matter of concern as concentrations of most of the metals were found to be above the desirable maximum value prescribed for the water by BIS (2004). Overall Heavy Metal Pollution index (HPI) calculated based on the mean concentration of the heavy metals for pre-monsoon, post-monsoon and winter season was below the critical pollution index value of 100 for groundwater near Buddha Nullah.

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