International Journal of Research in Advent Technology, Vol. 6, No.5, May 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Water Quality Indices for Assessing Heavy Metals Contamination in Drinking Water Sources of Lachchiwala Gram Panchayat, Dehradun

Snigdha Pundir[1]*, Rakesh Singh[1], Prashant Singh[2], Ravinder Aswal[2], Vikash Kandari[2],.
1. DBS (PG) College, Dehradun
2. DAV (PG) College, Dehradun
**Corresponding Author: snigdha.pundir13@gmail.com*

Abstract- The concentrations of eight heavy metals namely Copper (Cu), Manganese (Mn), Cadmium (Cd), Lead (Pb), Zinc (Zn), Chromium (Cr), Iron (Fe) and Arsenic (As) have been analysed in four different groundwater sources of Lachchiwala Gram Panchayat, Dehradun, (Uttarakhand), India during autumn and winter seasons of 2016. The obtained water quality data further was used to calculate Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI) by comparing it with drinking water quality specifications as per Bureau of Indian Standards, 2012. These indices are helpful in providing an overall quality of the water with regard to presence of heavy metals. Based on calculated results of HPI and HEI the mean HPI values were observed as 2.22 and 43.4 during autumn and winter seasons, respectively. These values were observed to be well below the critical HPI limit i.e., 100. Similarly, mean HEI values were also observed to fall in the Low Metal Evaluation Index range (HEI<10), with its values as 0.89 and 0.99 in autumn and winter seasons, respectively. The results of the study revealed no significant threat of heavy metals pollution in the drinking water sources of Lachchiwala. The study also provides significant information about the water quality status of the studied area and Dehradun.

Index Terms- Heavy metals, Groundwater, Water quality, HPI and HEI.

1. INTRODUCTION

Metals are naturally occurring compounds found in the Earth's crust. Heavy metals are defined as the metals having specific gravity greater than about 4 or 5 g/cm^3 [1]. Heavy metals are required by the body for various biochemical and physiological functions at very low concentrations but can also be highly toxic, if present in high concentration, exceeding their certain threshold limits [2]. The quality of water determines its use for different purposes viz. drinking, bathing, washing, irrigation, etc.

Pollution, considerably affects the quality of water making it unfit for its best designated use. The water is termed polluted when undesirable entities like chemical waste, domestic and municipal sewages, etc, are found to be present in it, and change its quality up to a large extent [3].

Several geogenic processes such as floods, weathering of rocks, atmospheric deposition and various anthropogenic processes affect the quality of drinking water. To determine the suitability of water for consumption, its quality is measured by assessing the physicochemical and biological properties against a set of standards [4]. The provision of safe drinking water depends not only on the quality of water at its source but also on contamination throughout its way to the user and applied practices related to purification and sanitation [5]. Heavy metal contamination of water sources has become a worldwide issue nowadays. Heavy metal pollution is generally related to industrial activities. However, solid and liquid wastes dumping sites and automobiles are also regarded as an important heavy metal pollution source [6]. Drinking water generally contains heavy metals, which are required for our body to function properly, however their higher amounts (more than the prescribed limits) may lead to various health disorders [7]. Improper management of solid waste is also regarded as one of the main cause of environmental pollution and degradation in many cities. In the water supply the metals may be present naturally or due to contamination from corroded pipes and leakages from waste disposal sites [7]. There are many pollution indices that have been developed and applied for assessing the water quality through metal contamination. In a study, twenty drinking water sources of Dehradun district (Uttarakhand) were analyzed for six heavy metals namely, Cu, Mn, Pb, Zn, Cr and Fe during both pre and post-monsoon seasons. The study of Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI) did not indicate any serious threat of heavy metals to the water sources analysed and showed HPI and HEI values below their critical limits of 100 and 20, respectively [8]. Ground water samples taken from hand pumps situated in the Selaqui industrial area of Dehradun district were investigated for heavy metals contamination. The heavy metals concentration in almost all water samples analyzed was found to be within the permissible limits, however it was observed that if the industrial effluents containing heavy metals are drained

regularly in large quantity without proper treatment, then after some years the ground water may get polluted with such toxic heavy metals and subsequently water might not be suitable for drinking purpose [9].

The available literature about heavy metals contamination in drinking water sources of Dehradun district showed that only very few studies have been carried out on such a critical issue. Therefore to fill the gap, present study was planned and carried out in order to assess HPI and HEI in groundwater sources of Lachchiwala Gram Panchayat of Dehradun district.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Lachchiwala Gram Panchayat of Dehradun, Uttarakhand, India. Lachchiwala is a popular tourist place, which is located amidst Sal forest of Dehradun. Ground water samples were collected from four different sites of Lachchiwala Gram Panchayat, Dehradun. The details of GPS coordinates of all study sites were recorded using Global Positioning System (GPS) (Make; Garmin GPSMAP 76CSx) along with elevation above Mean Sea Level (MSL) are shown in Table 1. The map of study area is shown in Figure 1.

Table 1: Details of Drinking Water Sources (sites) of Lachchiwala Gram Panchayat, Dehradun

S. N	Drinking Water Site	Site Code	GPS Coordinates		Elevation above mean sea level (m)
			Latitude	Longitude	
1.	Lachchiwala	S-1	30°11’44.3’’ N	78°07’32.6’’E	497
2.	Missarwala	S-2	30°11’01.8’’ N	78°07’29.3’’ E	488
3.	Missarwala Khurd	S-3	30°10’58.3’’ N	78°07’40.5’’ E	474
4.	Missarwala Kalan	S-4	30°11’06.3’’ N	78°07’18.8’’ E	491

Figure 1: Map showing Sampling Sites

2.2 Sampling Procedure

The groundwater samples were collected from tubewell at each site during autumn (November) and winter (February) seasons in high density polyethylene ‘Tarson’ bottles after 2-3 times rinsing with the samples. For heavy metal analysis the samples were preserved by adding ultra-pure nitric acid (5ml/ L) to minimize adsorption and precipitation by reducing the pH<2. Water samples were transported to the laboratory by maintaining cold chain at 4°C. For determining physico-chemical parameters samples were collected in similar way without adding acid to it and were brought to the lab by maintaining cold chain at 4°C.

2.3 Data Evaluation

The physico-chemical parameters of the groundwater sources i.e., pH, turbidity, total hardness, total alkalinity, chloride and total dissolved solids (TDS) were evaluated by using BIS and APHA protocols and methodology.

The observed values of eight heavy metals namely Cu, Mn, Cd, Pb, Zn, Cr, Fe and As in water samples were compared with drinking water quality standards as laid down by BIS, 2012. The data was further used for the determination of HPI and HEI, respectively.

2.3.1 Heavy Metal Pollution Index (HPI)

Heavy metal pollution index is a powerful tool to assess overall quality of the water with regard to heavy metals [10]. A rating (Wi) is assigned for each selected water quality parameter. The rating system is an arbitrary value from 0 to 1, which can be defined as inversely proportional to the standard permissible value of respective water quality parameter. The water is said to have low heavy metal pollution, when HPI is less than 100 (HPI<100), heavy metal pollution on threshold risk when HPI is equal to 100 (HPI= 100) and the water is unsuitable for consumption, if the heavy metal pollution index value is greater than 100 (HPI>100).

HPI is calculated as follows,

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \quad (1)$$

$$Qi = \sum_{i=1}^{n} \frac{|Mi - Ii|}{Si - Ii} \times 100 \quad (2)$$

Where, Qi is the sub-index of the i^{th} parameter, Wi is the unit weightage of i^{th} parameter, n is the number of

parameters, Mi is the monitored value of i^{th} parameter, Ii is the desirable limit of BIS drinking water i^{th} parameter, Si is the standard value of the i^{th} parameter (permissible limit of BIS drinking water parameter).

2.3.2 Heavy metal Evaluation Index (HEI)

Heavy Metal Evaluation Index (HEI) was initially defined by taking into account possible additive effects of heavy metals on the human health that helps to quickly evaluate the overall quality of drinking water [11].

The index can be calculated using following equation;

$$HEI = \sum_{i=1}^{N} \frac{Ci}{(MAC)} \quad (3)$$

Where HEI is the metal index, C is the concentration of each element in the i^{th} sample, MAC is the maximum allowed concentration for each element and the subscript i is the i^{th} sample. The HEI criteria for samples as follows: Low (HEI<10), Medium (HEI<10-20) and High (HEI>20) was also proposed [12].

3. RESULTS AND DISCUSSION

3.1 Water Quality

The mean values of physico-chemical parameters of the groundwater sources during Autumn and Winter seasons, i.e. pH, turbidity, total hardness, total alkalinity, chloride and total dissolved solids (TDS) are shown in Table 2. All the above mentioned physico-chemical water quality parameters play an important role in determining the overall water quality of any water source. The mean values of pH and TDS in groundwater sources analysed were found within the BIS (2012) limit for drinking water. pH ranged from 7.84 to 8.03 and 7.68 to 7.92 during autumn and winter seasons, respectively. Higher pH of the groundwater can be attributed to the reduction of heavy metal toxicity [13]. TDS varied from 322.4 mg/L to 387.5 mg/L and 350.4 mg/L to 375.8mg/L during autumn and winter seasons, respectively.

Permissible limit for turbidity in drinking water is set as 5 NTU [14]. Turbidity values in analysed water samples ranged from 1.36 NTU to 1.87 NTU during autumn and 0.48 NTU to 1.29 NTU during winter season of the study period.

During autumn season, total hardness was found highest at S-1 site (349mg/L) and lowest at site S-2 (268 mg/L), while, it was 337mg/L (S-1) to 291 mg/L (S-3) during winter season. The overall results analyzed of physico-chemical water quality parameters indicated that the water was found suitable for drinking purpose during the study of both seasons i.e. Autumn and Winter.

3.2 Heavy metal concentration

The water samples were analysed for eight metals, namely, Cu, Mn, Cd, Pb, Zn, Cr, Fe and As from four different groundwater sources of Lachchiwala Gram Panchayat, Dehradun during autumn and winter seasons. The mean values of individual metals for both seasons are given under Table 3. Mn concentration at S-1 in autumn season (2016) was found as (0.541mg/L), which was observed to be higher than its prescribed permissible limit (0.300 mg/L) as per BIS. The other heavy metals analysed were found within their respective permissible limits as per BIS specifications.

The maximum concentration of Cu in drinking water was found at site S-2 in autumn season (0.264 mg/L). Mn concentration was observed to be highest at S-1 site in autumn season as 0.541 mg/L. This high level of Mn than its standard limit of BIS may be attributed to the soil geochemistry of the study area [8.14].

Lead concentration was found maximum at S-1 site in the winter season (0.008 mg/L), however was below the required standard limits for drinking water. Chromium concentrations were observed to be highest at S-1 and S-2 with 0.0037mg/L and 0.0036 mg/L, respectively, which were within permissible limit. Iron was found maximum at S-1 in autumn season (0.1726 mg/L) and lowest at S-3 (0.0019mg/L) during winter season.

Cadmium was only detected at S-3 in autumn season (0.0001mg/L), whereas in winter season Cd was detected in all the sampling sites with highest concentration of 0.0030mg/L at S-3 and lowest 0.0006 mg/L at both S-1 and S-4 sites. Zinc and Arsenic concentrations were not detected at any of the studied site during both seasons.

Table 2: Water Quality Data of Lachchiwala Gram Panchayat, Dehradun for Autumn (A) and Winter (W) Seasons, 2016

		Physico-chemical parameters (Mean values in mg/L)											
		pH		**Turbidity (NTU)**		**Total Hardness (mg/L)**		**Total Alkalinity (mg/L)**		**Chloride (mg/L)**		**Total dissolved solids (mg/L)**	
BIS (IS: 10500) 2012	**DL**	6.5-8.5		1		200		200		250		500	
	PL	6.5-8.5		5		600		600		1000		2000	
WHO	**GV**	7.0-8.5		5		500		-		200		500	
Seasons		**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**
Sampling Sites													
S-1		8.03	7.90	1.87	0.66		337	248	165	4.8	5.8	387.5	371.5
S-2		7.84	7.80	1.36	0.63	268	301	228	176	3.2	4.8	384.7	375.8
S-3		7.84	7.68	1.39	1.29	292	291	206	178	5.6	7.8	322.4	350.4
S-4		7.93	7.92	1.80	0.48	302	321	188	148	4.8	4.7	359.1	373.1
Standard Deviation		0.090	0.11	0.267	0.359	33.97	20.55	26.09	13.74	1.01	1.44	30.19	11.67

*** DL: Desirable Limit, PL: Permissible Limit, GV: Guideline Value**

Table 3: Water Quality Data of Lachchiwala Gram Panchayat, Dehradun for Autumn (A) and Winter (W) seasons, 2016

		Heavy Metals (Mean values in mg/L)															
		Copper (Cu) (mg/L)		**Manganese (Mn) (mg/L)**		**Cadmium (Cd) (mg/L)**		**Lead (Pb) (mg/L)**		**Zinc (Zn) (mg/L)**		**Chromium (Cr) (mg/L)**		**Iron (Fe) (mg/L)**		**Arsenic (As) (mg/L)**	
BIS (IS: 10500) 2012	PL	1.5		0.300		0.003		0.01		15		0.05		0.300		0.05	
WHO	GV	2.0		0.4		0.003		0.01		3.0		0.05		1.0		0.01	
Season																	
Sampling Sites		**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**	**A**	**W**
S-1		0.0692	ND	0.541	ND	ND	0.0006	ND	0.008	ND	ND	ND	0.0037	0.1726	ND	ND	ND
S-2		0.2645	ND	0.170	ND	ND	0.0015	ND	0.001	ND	ND	ND	0.0036	0.0331	ND	ND	ND
S-3		0.1386	ND	0.004	ND	0.0001	0.0030	ND	0.006	ND	ND	ND	ND	0.0019	0.0530	ND	ND
S-4		0.0754	ND	ND	ND	ND	0.0006	ND	0.002	ND	ND	ND	0.0015	0.0335	ND	ND	ND
SD		0.091	0.0	0.254	0.0	0.0	0.001	0.0	0.003	0.0	0.0	0.0	0.0018	0.0763	0.0	0.0	0.0

* ND: Not Detected, DL: Desirable Limit, PL: Permissible Limit, GV: Guideline Value, SD: Standard deviation

3.3 Heavy Metal Pollution Index

The HPI values for all water samples were calculated. The results are given in Table 4 and the variations in both seasons (autumn and winter) are shown in Figure 2.

The HPI values did not show much variation within sampling stations in a month; however the HPI values varied significantly during the two sampling seasons, i.e., autumn and winter as shown in Table 4. S-3 showed higher HPI values as compared to other sampling stations during both the sampling periods with 3.04 and 83.34 in autumn and winter, respectively. Overall HPI results show low heavy metal pollution (HPI<100) in all analysed samples. A recent study on heavy metal contamination in groundwater of Goa mining region, India also revealed similar results with HPI values, which were observed below the critical index limit of 100 [16].

Table 4: Heavy Metal Pollution Index in analyzed water samples

Sampling Station	HPI	
	Autumn Season	Winter Season
S-1	2.98	32.21
S-2	1.39	38.44
S-3	3.04	83.34
S-4	1.47	19.55
Mean value	2.22	43.4

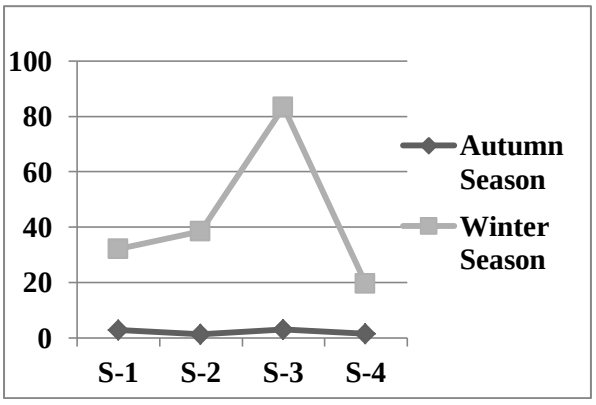

Figure 2: Variation of HPI values in autumn and winter season

3.4 Heavy Metal Evaluation Index (HEI):

The HEI values for all water samples were calculated and the results are given in Table 5 and shown in Figure 3.

The HEI values for all drinking water sources in autumn season were found to be within safe range i.e., less than 10 (low heavy metal risk when HEI<10), with highest at S-1 (2.425) and lowest at S-4 (0.145). However, during winter season highest HEI was observed at S-3 (1.78) and lowest at S-4 (0.43). The HEI values, however were at low heavy metal risk (HEI<10). In a similar study, the heavy metal index values in different drinking water sources of Dehradun, ranged between 6.568 and 0.155 during pre-monsoon and between 1.4428 and 0.1459 during post-monsoon seasons [8].

Table 5: Heavy Metal Evaluation Index in analyzed water samples

Sampling Station	HEI	
	Autumn Season	Winter Season
S-1	2.425	1.07
S-2	0.853	0.67
S-3	0.145	1.78
S-4	0.162	0.43
Mean	0.89	0.99

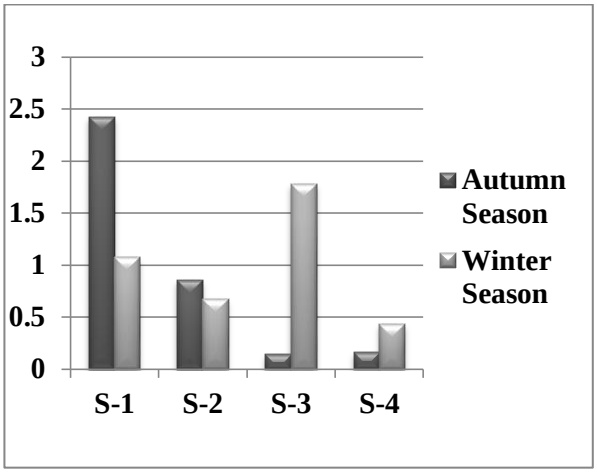

Figure 3: Variation of HEI values in autumn and winter season

4. CONCLUSIONS

Assessment of drinking water sources of Lachchiwala Gram Panchayat, Dehradun, using heavy metal pollution index, concludes that none of the four sources analysed is affected by heavy metal pollution. Thus, the water of the studied sites was found to be suitable for drinking purpose. Though, the HPI and HEI values in the drinking water samples were observed below their critical values but still necessary precautions should be undertaken in order to avoid the contamination of drinking water sources from rapid urbanization, dumping of municipal waste unscientifically, over exploitation of existing water sources, improper pretreatment of raw water before supply and contamination of ground water due to nearby distillery plant and sugar mill of Doiwala, Dehradun.

5. ACKNOWLEDGEMENT
The authors are thankful to Water Technology Initiative Programme, (Department of Science & Technology), Government of India, New Delhi.; Uttarakhand State Council for Science and Technology (UCOST), Dehradun and Uttarakhand Jal Sansthan (UJS), Dehradun for their technical and laboratory support to carry out the study.

REFERENCES

[1] Tamasi, G. & Cini, R., (2004). Heavy metals in drinking waters from Mount Amiata. Possible risks from arsenic for public health in the province of Siena. Science of the Total Environment, 327, 41-51.

Abdullahi K.; Rooyle. (1972): Heavy Metal Contamination of Rivers. Bulletin Geology, 22 (1 & 2) 5-30.

[2] Mohod CV.; Dhote J. (2013): Review of Heavy Metals in Drinking Water and their Effect on Human Health. International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 7.

[3] Alrumman SA.; El-kott AF.; Keshk SMAS. (2016): Water Pollution: Source & Treatment. American Journal of Environmental Engineering, 6(3): 88-98.

[4] Khatri N.; Tyagi S.; (2014): Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. Frontiers in Life Science Volume 8, 2015 - Issue

[5] Mishra S.; Nandeshwar S. (2013). Study to Assess Water Source Sanitation, Water Quality and Water Related Practices at Household Level in Rural Madhya Pradesh. National Journal of Community Medicine. Volume 4, Issue 4.

[6] Abdullahi K, Rooyle (1972) Heavy Metal Contamination of Rivers. Bulletin Geology, 22 (1 & 2) 5-30.

[7] Salem HM.; Eweida EA.; Farag A. (2000): Heavy Metals in Drinking Water and their Environmental Impact on Human Health. ICEHM2000, Cairo University, Egypt, page 542-556.

[8] Gupta A.; Singh R.; Singh P.; Dobhal R. (2016): Heavy Metals in Drinking Water Sources of Dehradun, Using Water Quality Indices. Analytical Chemistry Letters Volume 7, 2017 - Issue 4, Taylor and Francis.

[9] Ramola B.; Singh A. (2013): Heavy Metal Concentrations in Pharmaceutical Effluents of Industrial Area of Dehradun (Uttarakhand), India. Journal of Environmental & Analytical Toxicology. 3:3.

[10] Mohan SV.; Nithila P.; Reddy J. (1996): Estimation of heavy metals in drinking water and development of heavy metal pollution index. Journal of Environmental Science and Health. Part A: Environmental Science and Engineering and Toxicology, Vol. 31, Pages 283-289.

[11] Tamasi G; Cini R. (2004): Heavy metals in drinking waters from Mount Amiata. Possible risks from arsenic for public health in the province of Siena. Science of the Total Environment, 327, 41-51.

[12] Edet AE.; Offiong OE.; (2002): Evaluation of water quality pollution indices for heavy metal contamination monitoring. A study case from Akpabuyo-Odukpani area, Lower Cross River Basin (southeastern Nigeria). GeoJournal, Volume 57, Issue 4, pp 295–304.

[13] Aktar MW.; Paramasivam M.; Ganguly M.; Purkait S.; Sengupta D. (2010): Assessment and occurrence of various heavy metals in surface water of Ganga river around Kolkata: a study for toxicity and ecological impact. Environment Monitoring Assessment 160(1–4):207–213.

[14] BIS (Bureau of Indian Standards) (2012): Indian standard for drinking water — specification, second revision, IS 10500: 2012, Drinking Water Sectional Committee, FAD 25. New Delhi, India.

[15] Brraich OS.; Jangu S. (2015): Evaluation of Water Quality Pollution Indices for Heavy Metal Contamination Monitoring in the Water of Harike Wetland (Ramsar Site), India. International Journal of Scientific and Research Publications, 5(2).

[16] Singh G.; Kamal RK. (2017): Heavy metal contamination and its indexing approach for groundwater of Goa mining region, India. Applied Water Science 7:1479-1485.

[17] American Public Health Association (APHA); American Water Works Association (AWWA); Water Environment Federation (WEF) Standard Methods for the Examination of Water and Wastewater (22nd Edition).

[18] Ali MM.; Ali M.; Islam MS.; Rahman MZ. (2016): Preliminary assessment of heavy metals in water and sediment of Karnaphuli River, Bangladesh. Environmental Nanotechnology, Monitoring & Management. 27-35

[19] Balakrishnan A.; Ramu A. (2016): Evaluation of Heavy Metal Pollution Index (HPI) of Groundwater in and around the Coastal Area of Gulf of Mannar Biosphere and Palk Strait. Journal of Advanced Chemical Sciences 2(3)331-333.

[20] Bartarya SK.; Bahukhandi DK. (2012): Impact Assessment of Urbanization and Industrialization on Surface and Groundwater Quality. Global Journal of Engineering, Design &Technology, 11-22.