International Journal of New Technology and Research (IJNTR)
ISSN: 2454-4116, Volume-8, Issue-3, March 2022 Pages 04-11

Assessment of Heavy Metal &Health Risk in Ground Water, Industrial Area Jodhpur Rajasthan

Dr. Prerna Mathuria, Preety Pandey, Prmod Kumar Verma, Dr Shailendra Singh

***Abstract*— Jodhpur is a town and district of Rajasthan (India) Coordinates at Latitude 26° 15' 49.9068'' N-Longitude73° 0' 32.2452'' The present investigation was taken up to evaluate the heavy metal concentrations in the ground water of Industrial Area in Jodhpur Rajasthan. The concentration of six eco-toxic metals such as copper, zinc, Manganese, iron, nickel, and lead were analyzed for 39 groundwater sampling stations in the study area using atomic absorption spectrometer. The results showed that two metals ion, viz. Nickel, and lead exceeded the concentration limit of BIS (2012) in most of the water samples indicating severe human health hazard. The single-factor pollution index (Ii) and compound pollution index (CPI) value of these two metals were very high, i.e., much greater than 1 The other metal concentrations were found within the safe permissible ranges.Heavy metal pollution index is an effective method of rating and ascertaining the water quality with respect to heavy metals. An index value of 100 is considered to be critical, and on the basis of mean concentration, this value in the study area was observed to be 391 which is considerably higher than the stipulated critical index value. 87.17%of the groundwater samples are seen to be having an index far above the critical figure of 100.The study results revealed that both the geogenic and anthropologic activities influenced the groundwater system of the area. This study has massive relevance in designing control measures and action plans for reducing the pollutant influx into the groundwater. Prompt enforcement of environmental protection laws is needed to prevent continuous pollution of the area.**

***Index Terms*— Jodhpur industrial Area, Groundwater, Heavy Metal, Pollution Index, Risk Assessment, Toxicity.**

I. Introduction

The groundwater is considered the largest source of drinking and irrigation purposes water for most of the lower-middle-income and developing countries. About 97% of the world's unfrozen fresh water found beneath the earth's surface as groundwater. Heavy metals pollution in groundwater is increasing rapidly with the rapid agricultural expansion and urbanization. Heavy metals as a type of insistent toxic pollutants are non-biodegradable in the environment. Thus, the residual trace metals in the water environment are threatening human health [3,4]. The major sources of trace metals in the groundwater are atmospheric precipitation, agricultural wastes, discharge of industrial wastewater, agro-pesticides leaching, and urban sewage, mineral mining. [5] Grading water quality indicators largely depends on indicator concentration and the rate of relative toxicity, numerous water quality indices were proposed for the assessment of water quality based on heavy metals [16, 17]. One of these indices is the heavy metal pollution index (HMPI). This method considered the maximum acceptable limit and maximum permissible limit of each heavy metal for water quality classification. According to current regulatory guidelines, several heavy metals are now being considered under the nonrelaxation category [18]. Hence, HMPI cannot be calculated using the latest regulatory guidelines. This study aims to assess the heavy metals contamination in groundwater in industrial area Jodhpur as well as focuses on risks of heavy metal contamination in groundwater.

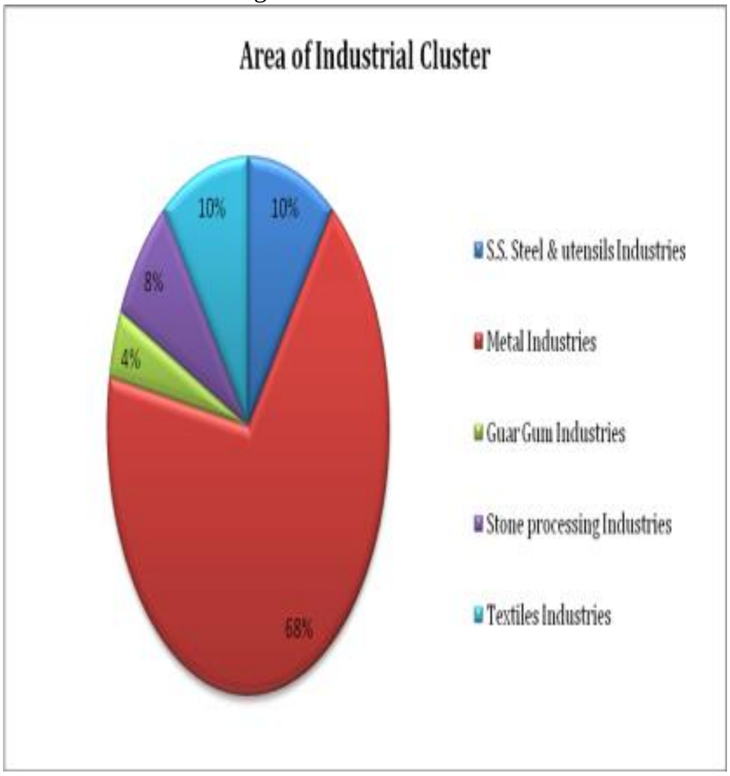

Fig1: Details of main industrial clusters in Jodhpur

Dr. Prerna Mathuria, Preety Pandey, Prmod Kumar Verma, Dr Shailendra Singh

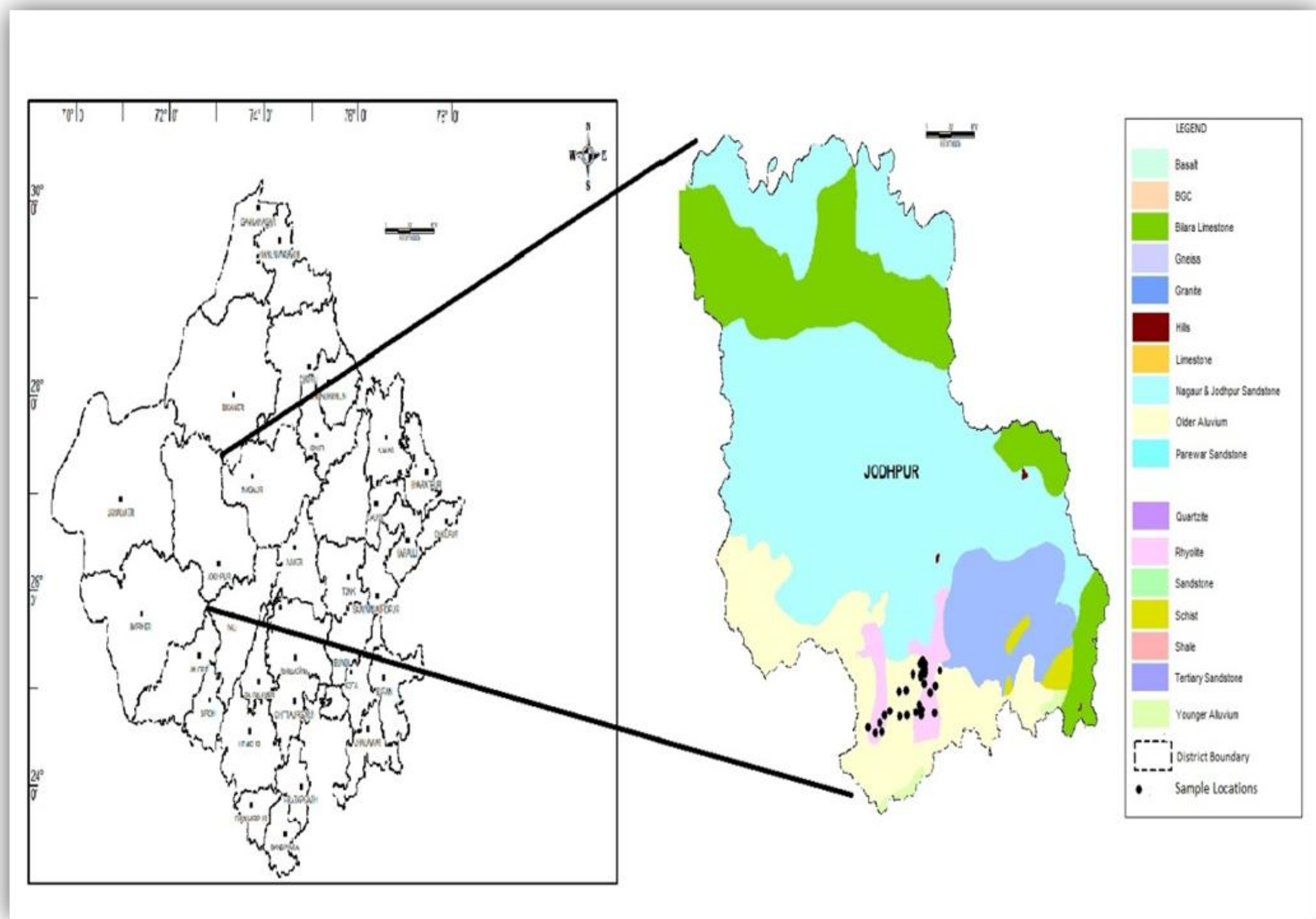

Fig.2: Location Map of The study Area with type of Aquifer and sample locations

II. Materials and Methods of Analysis

A total of 39 Sambles of ground water were collected from seven selected sampling sites Jodhpur Industrial area in june 2020for the present investigation.Before sample collection, bottles were washed with 50% HNO_3 and rinsed with distilled water. After pumping the wells for 15–20 min. then samples were collected and filtered to avoid contamination .For metal analysis, samples were preserved by acidified with concentrated AR grade HNO_3.The targeted heavy metals have been analysed using atomic absorption spectrometer (P G Instrument-UK AA8000) as per the standard method (APHA, 2012).The instrument was calibrated initially before preparation of calibration graph.

Risk calculation of heavy metal pollution

Two types of risk assessment methods of trace heavy metal pollution were used to assess the heavy metal pollution in the groundwater in the study area, which is shown below:

Single-Factor Pollution Index (I_i)

Single-factor pollution index (I_i) is used to evaluate how a single heavy metal pollutes groundwater at a sampling station:

$$I_i = C_i/S_i \qquad (1)$$

Where Ci is the measured content of contaminant i in groundwater water (mg/L), and Si is the evaluation standard of pollutant i in groundwater (mg/L). Here, we followed the BIS guideline value (2012). When I i is >1, the content of that heavy metal exceeds the standard [23]. The results of the single-factor pollution index of heavy metals in groundwater in the study zone are shown in Table 4 and 5.

Compound pollution index (CPI)

Compound pollution index (CPI) was used to evaluate the heavy trace metal pollution in water, which is expressed as follows equation (2):

$$CPI=\sum_{i=1}^{n} Ii/m \qquad (2)$$

Where Ii is a single-factor index of heavy metal and m is the number of heavy metal types. CPI < 1 indicates no heavy metal contamination in water samples, CPI$\geq$1 indicates heavy metal contamination [7].The results were shown in Table 4 and 5

Heavy Metal Pollution Index

The heavy trace metal pollution index (HMPI) model has been recognized by assigning the weightage (Wi) for a particular parameter and selecting the groundwater parameter on which the index has to be based. The rating is nearly 0 to 1, and its selection reveals the consequence of each water quality parameter. It can be defined as inversely proportional to the suggested standard (Si) for each parameter [24, 25]. The concentration limits (i.e., the highest permissible value for drinking water (Si) and maximum desirable value (I i) for each parameter) were taken from the WHO standard (2011). The heavy metal pollution index (HPI) was used for assigning a rating or weightage (Wi) for each particular parameter, is calculated using Equation (3) [24]

$$HMPI = \sum_{i=1}^{n} WiQi / \sum_{i=1}^{n} Wi \qquad (3)$$

Where $\mathbf{W_i}$is the unit weight of the ith parameter, Q_i is the subindex of the ith parameter, and n is the number of parameters. The sub-index Q_i is calculated by,

$$Qi = \sum_{i=1}^{n} Mi - Si / Si — Ii$$

Where M_i , I_i, and S_i donate for the 'monitored value,' 'ideal value' and 'standard values' of the ith parameter respectively. The negative sign (−) denotes a numerical difference between the two values, ignoring the algebraic sign.

III. RESULTS AND DISCUSSION

Trace metals and metalloids, among an extensive limit of contaminations, are steady of a health concern due to their toxicity capacities at a very little concentration and can show an opposing effect on living existences, and tendency to bioaccumulation in lipids and tissues of biotic over time [35]. These metals such as, Pb, Hg, Cd, As, Ni and Co have no useful effects in the body system, moreover, long time exposure may cause more acute interruptions in the normal operations of the human organ systems where the metals deposited [36]. Though some trace metals like Cu, Zn, Fe, and Mn, as micronutrients, are required by the body in limited amounts for metabolic actions, and the same elements, at higher amounts can cause opposing health effects [37]. The key anthropogenic sources of trace metals in groundwater are natural matters leached into the soil or rocks, residue from agrochemicals, controlled release from the sewage treatment plant and industrial run-off, and unrestrained releases or escape from landfill spot and chemical accidents or calamities.

The major sources of Nickel discharge in Jodhpur industrial area are the textile & chrome industries BIS (2012) has prescribed the acceptable limit of 0.02 ppm of nickel in drinking Water and no relaxation beyond the desirable limit has been recommended. The drinking water containing high levels of Ni can lead to headaches; gastrointestinal manifestations; respiratory manifestations; lung fibrosis; cardiovascular diseases; lung cancer; nasal cancer; epigenetic effects. The concentration of nickel has been found to vary from 0.0011 to 0.0.186 ppm.

Mn is an element vital to the proper working of humans, animals, and plant metabolism, as it is obligatory for the operative of several cellular enzymes and can aid to activate hydrolyses, kinesis, transferases, decarboxylases. But excessive consumption of Mn-rich water then showed neural symptoms that are alike Parkinson's disease [41]. Memory damage, hallucinations, disorientation, and impulsive instability also concerns by manganese overdose [42]

Iron (Fe) is the burning issue of rural drinking water in Bangladesh. Although a low level of iron is essential in the human diet and plant metabolism and cannot do much harm, it encourages objectionable bacterial growth ('iron bacteria') inside a waterworks and supply system, resulting in the deposition of a slushy coating on the piping [44]. Besides, high iron content (over 0.3 mg/L) leads to an excess which can cause stomach problems, vomiting, diabetes, nausea, and hemochromatosis [45].

Copper (Cu) is an indispensable element in animals and plants which shows a significant role in metabolism. Temporary exposure to Cu in potable water can lead to gastrointestinal suffering, longtime exposure can lead to copper toxicsis, which results in liver and kidney damage, anemia, hepatic cirrhosis, and deterioration of the basal ganglia [46]. An excess of copper in aquatic environments is seriously harmful to fish and other aquatic lives [47].

Zinc (Zn) is a naturally occurring trace element and an essential nutrient for body metabolism and development, particularly for newborns and young children. However, drinking water containing high levels of Zn can lead to stomach cramps, neurological problems, vomiting; and chronic exposure to Zn is liable for depressed copper consumption, iron shortage, depressed levels of HDL cholesterol [48]Lead (Pb) is another present toxic trace metal and substantial public health concern in the environment [43]. It can cause different biochemical effects when exposed to it for a relatively short time duration These effects may comprise interfering with red-blood-cell chemistry, delays in usual physical and mental growth in an infant, hearing and learning capacities of children, scarcity in attention span, kidney disease, stroke, cancer, and rises in the blood pressure of adults [51).BIS (2012), the acceptable limit of lead in drinking water is 0.01 ppm and no relaxation in the permissible limit has been recommended. Table 1 and 2 shows the concentration of heavy metals present in groundwater sources collected from a different station in sampling sites. The concentration of Pb was the higher in all water samples with almost total samples exceeding the maximum Permissible limit (PAL) and one of the samples having the highest concentration 0.2004 The mean concentration of this metal is .051 with a standard deviation of ±.037 (Table 2). The quality of the source of water may be the reason for the variation of Pb concentration noticeable in the water samples, which is linked to the quality of treatment of the water sources. It was observed that 66.66% of the samples surpassed the PAL limits set by BIS for Ni, with the highest concentration noticeable in Sample 0.186(mg/L) [43]. The mean value of Ni is .041 mg/L with a standard deviation of ±1.036. The other metal concentrations remained within the safe ranges.

Table1
: Concentration (mg/L) of analyzed metals

Sample	Cu	Mn	Ni	Pb	Zn	Fe
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Sample/1	0.0051	0.0009	0.0353	0.0134	0.0045	0.0141
Sample/2	0.004	0.0009	0.0311	0.0054	0.0049	0.0141
Sample/3	0.0082	0.0051	0.0606	0.0299	0.0068	0.0377
Sample/4	0.0104	0.0065	0.0648	0.0561	0.0058	0.0478
Sample/5	0.0125	0.0079	0.0754	0.0652	0.007	0.0494
Sample/6	0.0019	0.0002	0.0102	0.0054	0.0039	0.0039
Sample/7	0.0178	0.0134	0.1051	0.1238	0.0079	0.0764
Sample/8	0.0093	0.0099	0.05	0.0472	0.0066	0.036
Sample/9	0.0104	0.0085	0.0648	0.0561	0.0077	0.0562
Sample/10	0.0156	0.0252	0.069	0.0561	0.0077	0.0528
Sample/11	0.0083	0.003	0.0387	0.0439	0.0057	0.0312
Sample/12	0.003	0.0003	0.0059	0.0153	0.002	0.0108
Sample/13	0.0051	0.0037	0.0141	0.0246	0.0016	0.0568
Sample/14	0.0041	0.0016	0.0161	0.0538	0.0171	0.0125
Sample/15	0.0083	0.0065	0.0243	0.0743	0.0041	0.1044
Sample/16	0.0051	0.0023	0.0284	0.064	0.0033	0.0244
Sample/17	0.0073	0.0037	0.0387	0.0849	0.0055	0.0329
Sample/18	0.0179	0.0107	0.0202	0.0538	0.0404	0.038
Sample/19	0.0019	0.0515	0.0059	0.0341	0.0063	0.0397
Sample/20	0.0051	0.003	0.0243	0.0538	0.0033	0.0159
Sample/21	0.0085	0.0169	0.0054	0.0158	0.0186	0.01466
Sample/22	0.0053	0.000	0.0076	0.0158	0.0034	0.00142
Sample/23	0.1364	1.428	0.0888	0.0777	0.0578	0.01397
Sample/24	0.0161	0.0087	0.1	0.0907	0.0078	0.00756
Sample/25	0.0214	0.0114	0.0622	0.0714	0.0471	0.01483
Sample/26	0.0161	0.0152	0.06	0.0842	0.0228	0.283
Sample/27	0.0161	0.0076	0.0184	0.0524	0.0404	0.01994
Sample/28	0.0096	0.0027	0.0293	0.0401	0.0053	0.00301
Sample/29	0.0118	0.032	0.0337	0.0524	0.0076	0.00301
Sample/30	0.0311	0.0297	0.186	0.2004	0.0757	0.416
Sample/31	0.0032	0.0122	0.0075	0.0116	0.007	0.0472
Sample/32	0.0043	0.0006	0.0204	0.0185	0.0022	0.0105
Sample/33	0.0021	0.000	0.0118	0.0047	0.0015	0.0105
Sample/34	0.0065	0.0099	0.0075	0.0116	0.0241	0.035
Sample/35	0.0098	0.0052	0.0355	0.0761	0.0049	0.0263
Sample/36	0.1136	0.0099	0.0011	0.0255	0.0647	0.0835
Sample/37	0.1306	0.027	0.0747	0.0985	0.0324	0.1485
Sample/38	0.0142	0.1675	0.0182	0.0326	0.0318	0.0887
Sample/39	0.0229	0.041	0.0312	0.0397	0.0679	1.49

Table 2: Destructive statistics of metals parameter

Metal	Mean	Minimum Conc.	Maximum Conc.	Stdv	BIS Standard (2012)	
					Acceptable	Permissible
Zinc	0.01731	0.0045	0.0679	0.020421	5.0	15
Lead	0.05079	0.0047	0.2004	0.037498	.01	NR
Copper	0.018997	0.0019	0.1364	0.031895	.015	1.5
Nickel	0.040569	0.0011	0.186	0.036266	.02	NR
Manganese	0.051033	0	1.428	0.225043	0.1	0.3
Iron	0.089041	0.00142	1.49	0.239998	0.3	1.0

Pearson's correlation matrix

The Pearson's correlation matrix of analyzing groundwater metal parameters is presented in Table 3. In some cases, the dissimilarity matrix value for the same pair of parameters is observed. The statistical result showed that copper (Cu) is strongly positively correlated with manganese (Mn), and Znic (Zn). On the other hand, Nickel (Ni) with Lead (Pb), and Zinc (Zn) with Iron (Fe) are significantly positively correlated with each other. Other metals are not significantly correlated with each other. This matrix Table would provide important information to evaluate the water quality of the study areas.

Table 3: Pearson's correlation matrix for tested metals in groundwater

	Cu	*Mn*	*Ni*	*Pb*	*Zn*	*Fe*
Cu	1					
Mn	0.602981	1				
Ni	0.273108	0.216526	1			
Pb	0.282062	0.12347	0.857102	1		
Zn	0.603846	0.354751	0.331302	0.396095	1	
Fe	0.089477	-0.02385	0.157839	0.176044	0.532629	1

Risk Assessment of Heavy Metal Pollution in Groundwater

Two methods viz, single-factor pollution index (I i) and compound pollution index (CPI) uses for the risk assessment of heavy metal contamination in groundwater. When Ii is greater than1, the concentration of the heavy metal exceeds the standard guideline [23]. The results of the single-factor pollution index of heavy metals in groundwater in the study areas are showed in using Table 4 and 5. The Ii values for Pb in 91.23% of samples >>1, indicating Pb contents significantly exceeded the standard value. The mean value of Ii for Pb is 5.08, which is very higher than 1. Thus, the metal contents in water samples could significantly affect the heavy metal pollution index value. Same as Lead (Pb), another metal, Nickel (Ni) has a high level with a mean value of 2.03, which is higher than the standard value. Nickel is very toxic and highly poisonous to humans and plants. Also the Ii values of copper metal are greater than 1 for 30% of samples. The mean value of Cu 1.27 (>1). The results revealed that the other metals such as, Fe, Mn and Zn have a lower value of Ii (<1). The concentration of those metals in groundwater samples of the study area remains in the range of BIS guidelines (2012). Table 5 indicated the summary of the total result of the single-factor pollution index (I_i) for the sampling sites. Besides, same as single-factor pollution index (I_i), the value of compound pollution index (CPI) is below 1 indicating no metal pollution occurred in water. The CPI value of 69.23%water samples is higher than 1, showing the degree of trace metal pollution

Table 4: Values of single-factor pollution index (I_i) and compound pollution index (CPI) to assessment degree of heavy metal pollution in groundwater

Sample	Cu	Mn	Ni	Pb	Zn	Fe	CPI
S/1	0.34	0.01	1.77	1.3	0.001	0.05	0.58
S/2	0.27	0.01	1.56	0.5	0.001	0.05	0.40
S/3	0.55	0.05	3.03	3.0	0.001	0.13	1.12
S/4	0.69	0.07	3.24	5.6	0.001	0.16	1.63
S/5	0.83	0.08	3.77	6.5	0.001	0.16	1.89
S/6	0.13	0.00	0.51	0.5	0.001	0.01	0.20
S/7	1.19	0.13	5.26	12.4	0.002	0.25	3.20

S/8	0.62	0.10	2.50	4.7	0.001	0.12	1.34
S/9	0.69	0.09	3.24	5.6	0.002	0.19	1.64
S/10	1.04	0.25	3.45	5.6	0.002	0.18	1.75
S/11	0.55	0.03	1.94	4.4	0.001	0.10	1.17
S/12	0.20	0.00	0.30	1.5	0.000	0.04	0.34
S/13	0.34	0.04	0.71	2.5	0.000	0.19	0.62
S/14	0.27	0.02	0.81	5.4	0.003	0.04	1.09
S/15	0.55	0.07	1.22	7.4	0.001	0.35	1.60
S/16	0.34	0.02	1.42	6.4	0.001	0.08	1.38
S/17	0.49	0.04	1.94	8.5	0.001	0.11	1.84
S/18	1.19	0.11	1.01	5.4	0.008	0.13	1.30
S/19	0.13	0.52	0.30	3.4	0.001	0.13	0.75
S/20	0.34	0.03	1.22	5.4	0.001	0.05	1.17
S/21	0.57	0.17	0.27	1.6	0.004	0.05	0.44
S/22	0.35	0.00	0.38	1.6	0.001	0.00	0.39
S/23	9.09	14.28	4.44	7.8	0.012	0.05	5.94
S/24	1.07	0.09	5.00	9.1	0.002	0.03	2.54
S/25	1.43	0.11	3.11	7.1	0.009	0.05	1.97
S/26	1.07	0.15	3.00	8.4	0.005	0.94	2.27
S/27	1.07	0.08	0.92	5.2	0.008	0.07	1.23
S/28	0.64	0.03	1.47	4.0	0.001	0.01	1.03
S/29	0.79	0.32	1.69	5.2	0.002	0.01	1.34
S/30	2.07	0.30	9.30	20.0	0.015	1.39	5.52
S/31	0.21	0.12	0.38	1.2	0.001	0.16	0.34
S/32	0.29	0.01	1.02	1.9	0.000	0.04	0.53
S/33	0.14	0.00	0.59	0.5	0.000	0.04	0.21
S/34	0.43	0.10	0.38	1.2	0.005	0.12	0.36
S/35	0.65	0.05	1.78	7.6	0.001	0.09	1.70
S/36	7.57	0.10	0.06	2.6	0.013	0.28	1.76
S/37	8.71	0.27	3.74	9.9	0.006	0.50	3.84
S/38	0.95	1.68	0.91	3.3	0.006	0.30	1.18
S/39	1.53	0.41	1.56	4.0	0.014	4.97	2.07

Table 5: Summery of single-factor pollution index (I_i) and water categorization

Results	Cu	Mn	Ni	Pb	Zn	Fe
No. of samples exceeding I<1	12	02	26	36	00	02
% of samples exceeding I>1	30.76	5.12	66.66	91.23	00	5.12
Category	MP	LP	HP	HP	NP	NP

HP-highly polluted; MP- moderately polluted; LP- low polluted

Heavy metal pollution Index

Heavy metal pollution index (HMPI)is used to evaluate heavy metal contamination in groundwater samples for the study area. That index value is a single-valued and unit less figure. The value of index is presented in Table 6. The minimum and maximum values of HMPI are 55.22 and 391 respectively. The results of HMPI index revealed that there are 12.82% of samples medium and 87.17% are highly contaminated. The high HMPI may be due to wastewater from industrial and agricultural activities The HMPI index values for most of the samples of the study area were found higher than the critical pollution index

Table-6Summery of Heavy Metal pollution index and water categorization

HMPI	Category	no of samples	%of Samples
<45	Low	Nil	NIL
45-90	Moderate	5	12.82%

>90	High	34	87.17%

IV. Conclusions -

The analysis results showed that there were Three (3) metals viz. Lead (Pb), Nickel (Ni), and copper Cu) that exceeded the permissible limits of the WHO standard in most of the groundwater samples. The single-factor pollution index (Ii) and compound pollution index (CPI) values of these three metals were very high i.e., greater than 1. Other metal concentrations remained in the safe ranges. Heavy metal pollution index, showed that most of the water samples have a medium to a high level of metal pollution occurred. The maximum water samples were contaminated by Cu Ni, and Pb with high concentrations. The results revealed that on average 12.82, and 81.17% of samples were medium, and high risk from heavy metal. The study revealed that about 800% of the total samples were highly contaminated by trace heavy metals. it observed that the regional groundwater system was contaminated by geogenic and anthropologic activities in the area. The heavy metal pollution indices showed the reliability in characterizing the groundwater contamination concerning heavy metals. Groundwater monitoring is imperative for ensuring its sustainable management. It is important to develop methods that reduce the complexity of data to understandable numbers that managers and policymakers can readily use. The study findings can help for further planning of potential remediation measures.

References

[1] Zahid A (2015) Groundwater management aspects in Bangladesh. Technical Report, Center for Water and Environment, Bangladesh Water Development Board.

[2] Morris BL, Lawrence ARL, Chilton PJC, Adam B, Calow RC, et al. (2003) Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management. Early Warning and Assessment Report Series, RS 03-3. United Nations Environment Programme, Nairobi, Kenya 126.

[3] Wang J, Chen S, Xia T (2010) Environmental risk assessment of heavy metals in Bohai Sea, North China. Procedia Environmental Sciences 2:1632-1642.

[4] Muhammad S, Shah MT, Khan S (2011) Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. Microchemical Journal 98: 334-343.

[5] Liu L, Lv J, Xu G (2013) uniformly dispersed CdS nanoparticles sensitized TiO2 nanotube arrays with enhanced visible light photocatalytic activity and stability. Journal of Solid State Chemistry 208:27-34.

[6] Zheng X, Li B, Zhu B (2010) Crayfish carapace micro-powder (CCM): a novel and efficient adsorbent for heavy metal ion removal from wastewater. Water 2: 257-272

[7] . 7. Zhong S, Geng H, Zhang F, Liu Z, Wang T, et al. (2015) Risk Assessment and Prediction of Heavy Metal Pollution in Groundwater and River Sediment: A Case Study of a Typical Agricultural Irrigation Area in Northeast China. Int J Anal Chem 921539.

[8] Yuan X, Zhang L, Li J, Wang C, Ji J (2014) Sediment properties and heavy metal pollution assessment in the river, estuary, and lake environments of a fluvial plain, China. Catena 119: 52-60.

[9] Zahra A, Hashmi MZ, Malik RN, Ahmed Z (2014) Enrichment and geo-accumulation of heavy metals and risk assessment of sediments of the KurangNallah-feeding tributary of the Rawal Lake Reservoir, Pakistan. Science of the Total Environment 470-471: 925-933.

[10] Wang H, Nie L, Xu Y, Du C, Zhang T, et al. (2018) Effects of highway-related pollutant on the groundwater quality of turfy swamps in the Changbai Mountain Area. Int. J. Environ. Res. Public Health 15:1652.

[11] Withanachchi S, Ghambashidze G, Kunchulia I, Urushadze T, Ploeger A (2018) Water quality in surface water: A preliminary assessment of heavy metal contamination of the Mashavera River, Georgia. Int. J. Environ. Res. Public Health 15: 621

[12] Bodrud-Doza M, Islam ARMT, Ahmed F, Das S, Saha N, et al. (2016) Characterization of groundwater quality using water evaluation indices, multivariate statistics and geostatistics in central Bangladesh. Water Sci 30:19-40.

[13] Kim S, Eom S, Kim H-J, Lee JJ, Choi G, et al. (2018) Association between maternal exposure to major phthalates, heavy metals, and persistent organic pollutants, and the neurodevelopmental performances of their children at 1 to 2 years of age- CHECK cohort study. Sci. Total Environ 624: 377-384

[14] Reyes-Toscano CA, Alfaro-Cuevas-Villanueva R, CortésMartínez R, Morton-Bermea O, Hernández-Álvarez E, et al. (2020) Hydrogeochemical characteristics and assessment of drinking water quality in the urban area of Zamora, Mexico. Water 12: 556.

[15] Amiri V, Rezaei M, Sohrabi N (2014) Groundwater quality assessment using entropy weighted water quality index (EWQI) in Lenjanat, Iran. Environ. Earth Sci 72: 3479-3490.

[16] Chaturvedi A, Bhattacharjee S, Mondal GC, Kumar V, Singh PK, et al. (2019) Exploring new correlation between hazard index and heavy metal pollution index in groundwater. Ecol. Indic 97: 239-246.

[17] Rezaei A, Hassani H, Hassani S, Jabbari N, FardMousavi SB, et al. (2019) Evaluation of ground water quality and heavy metal pollution indices in Bazman basin, southeastern Iran. Groundw. Sustain. Dev 9: 100245.

[18] Mukherjee I, Singh UK, Singh RP, Kumari D, Jha PK, et al. (2020) Characterization of heavy metal pollution in an anthropogenically and geologically influenced semi-arid region of east India and assessment of ecological and human health risks. Sci. Total Environ 705: 135801.

[19] Sawut R, Kasim N, Maihemuti B, Hu L, Abliz A, et al. (2018) Pollution characteristics and health risk assessment of heavy metals in the vegetable bases of northwest China. Sci. Total Environ 642: 864-878.

[20] Maskooni EK, Naseri-Rad M, Berndtsson R, Nakagawa K (2020) Use of Heavy Metal Content and Modified Water Quality Index to Assess Groundwater Quality in a Semiarid Area. Water 12: 1115.

[21] BBS (Bangladesh Bureau of Statistics) Annual report. Ministry of Planning.Dhaka. 2018.

[22] US-APHA (2005) Standard methods for the examination of the water and waste water, 21st edn. APHA (American Public Health Association), AWWA, WPCF, Washington, DC 1134.

[23] Wang P, Zhao Z-Z, Wang J-G, Zhang Z-W, Zhang Z-C (2011) Distribution characteristic and potential ecological risk assessment of heavy metals in latosol in the Western area of Hainan island. Journal of Anhui Agricultural Sciences 9: 5210-5339.

[24] Mohan SV, Nithila P, Reddy SJ (1996) Estimation of heavy metal in drinking water and development of heavy metal pollution index. J Environ Sci Health A31: 283-289.

[25] Bhuiyan M, Bodrud-Doza M, Islam, ARM, Rakib M, et al. (2016) Assessment of groundwater quality of Lakshimpur district of Bangladesh using water quality indices, geostatistical methods, and multivariate analysis. Environmental Earth Sciences 75: 23.

[26] Prasad B, Bose JM (2001) Evaluation of the heavy metal pollution index for surface and spring water near a limestone mining area of the lower Himalayas. Environ Geol 41: 183- 188.

[27] 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). Geo Journal 5: 295-304.

[28] Backman B, Bodis D, Lahermo P, Rapant S, Tarvainen T (1997) Application of a groundwater contamination index in Finland and Slovakia. Environ Geol 36: 55-64

[29] Liu S, Zhang Y, Bi S, Zhang X, Li X, et al. (2015) Heavy metals distribution and environmental quality assessment for sediments of the southern coast of the Shandong Peninsula, China. Mar. Pollut. Bull100:483-488.

[30] 3Vu CT, Lin C, Shern C-C, Yeh G, Le VG, et al. (2017) Contamination, ecological risk, and source apportionment of heavy metals in sediments and water of a contaminated river in Taiwan. Ecol. Indic 82: 32-42.

[31] Sharifi Z, Hossaini SMT, Renella G (2016) Risk assessment for sediment and stream water polluted by heavy metals released by a municipal solid waste composting plant. J. Geochem. Explor169: 202-210.

[32] Wen X, Lu J, Wu J, Lin Y, Luo Y (2019) Influence of coastal groundwater salinization on the distribution and risks of heavy metals. Sci. Total Environ 652: 267-277
[33] Wang N, Wang A, Kong L, He M (2018) Calculation and application of Sb toxicity coefficient for potential ecological risk assessment. Sci. Total Environ 610-611: 167-174.
[34] Hakanson L (1980) An ecological risk index for aquatic pollution control. A sedimentological approach. Water Res14: 975-1001.
[35] Malik LA, Bashir A, Qureashi A (9006) Detection and removal of heavy metal ions: a review. Environ ChemLett 17: 1495-1521.
[36] Mominul MI, Karim MR, Zheng X, Li X (2018) Heavy Metal and Metalloid Pollution of Soil, Water and Foods in Bangladesh: A Critical Review. Int. J. Environ. Res. Public Health 15: 2825.
[37] Wang C, Yang Y, Wu N (2019) Combined toxicity of pyrethroid insecticides and heavy metals: a review. Environ ChemLett 1693-1706.
[38] Zhou W, Long W, Xu T (2019) Organic ligands unexpectedly increase the toxicity of chromium (III) for luminescent bacteria. Environ ChemLett. 17:1849-1855.
[39] Slooff W (1989) Integrated criteria document chromium. Bilthoven, Netherlands, National Institute of Public Health and Environmental Protection, Report no 758701002.
[40] Shrivastava R, Upreti R, Seth P, Chaturvedi U (2002) Effects of chromium on the immune system. Immunol. Med. Microbiol 34: 1-7.
[41] Kondakis XG (1989) possible health effects of high manganese concentration in drinking water. Archives of Environmental Health 44: 175-178
[42] Dorman DC (2000) Neurotoxicity of manganese chloride in neonatal and adult CD rats following sub chronic (21- day) high-dose oral exposure. Journal of Applied Toxicology 20: 179-187.
[43] WHO (2011) Guidelines for Drinking-Water Quality. 4th ed. Geneva: World Health Organization https://www.who.int/ water_sanitation_health/
[44] CanDNHW (1990) Nutrition recommendations. The report of the Scientific Review Committee, Department of National Health and Welfare (Canada), DSS Cat.no. H49-42/1990E, Ottawa; https://catalogue.nla.gov.au/Record/1785247
[45] Toyokuni S (2009) Role of iron in carcinogenesis: cancer as a ferrotoxic disease. Cancer Sci 100: 9-16.
[46] 46. Harris ZL, Gitlin JD (1996) Genetic and molecular basis for copper toxicity. Am. J. Clin. Nutr 63: 836-841.
[47] Ali H, Khan E (2018) Bioaccumulation of non-essential hazardous heavy metals and metalloids in freshwater fish. Risk to human health. Environ Chem Lett16: 903-917.
[48] Hooper PL (1980) Zinc lowers high-density lipoproteincholesterol levels. J. Am. Med. Assoc. 244: 1960.
[49] Friberg L Nordberg GF, Vouk VB (1986) Handbook of the toxicology of metals. Vol. II. eBook ISBN: 9780123973399, Amsterdam: Elsevier 130-184.
[50] Krajnc EI (1987) Cadmium - Effects. Integrated criteria document, National Institute of Public Healthand Environmental Protection, Bilthoven, Report No. 758476004. 51. Moore MR (1988) Hematologicaleffects of lead. Science of the total environment 71: 419-431.