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MONITORING THE SUBSTANTIAL METAL ANALYSIS AND HMPI IN GROUNDWATER FROM VILLAGE AND NEARBY DEVELOPED AREAS OF KANNUR REGION: A GIS STUDY

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ABSTRACT

The present study was conducted on heavy metal pollution of groundwater in Kannur district. Totally 25 groundwater samples were collected from different village and nearby developed areas in 2019. The spatial variation of heavy metals were analyzed for Fe> Pb>Mn>Zn in AAS. The heavy metal analysis results were compared with the BIS and the APHA standards for drinking and public health. The spatial interpolation techniques such as inverse distance method were used to prepare heavy metal distribution map with the help of ArcGIS10.3. The mean heavy metal pollution index (HMPI) for each sampling site reflected highest pollution in Iron. The present study reveals that most of the sampling sites were obtained below the critical pollution index limit. The high values of HMPI were found in Mattanur and Alakkode. However, iron concentration exceeding the desirable limit in many areas without affecting the pollution. The low concentration of other metals zinc, manganese and lead found in few areas were highly polluted nearby industrial operations and representing human-induced pollution. Overall conclusions of the study should be taken seriously by the concerned water resource management authorities in order to control the metal pollution in the groundwater.

KEY WORDS : Groundwater, GIS, HPI, Kannur, Metal analysis.

INTRODUCTION

In world 2.5% of the water is non-saline fresh water. It is utilized for drinking for quite a while and simple wellspring of consumable water and furthermore its virtue has made with improvement of human progress has put genuine inquiries to the protected utilization of groundwater for drinking purpose (Thangavelu *et al.,* 2019). In various factors, for example, environment, soil qualities, rock types, geography, human exercises on the ground and so forth forces a few impacts on the nature of water (Thangavelu, 2013). Heavy metal pollution represents an important environmental problem due to its toxic effects and bioaccumulation throughout the food chain. The main sources of heavy metal pollution include electroplating, painting and surface treatment industries (Boateng *et al.,* 2016).

Several authors have listed their studies in heavy metal work. Zhang, (2017) have been presented the trace elements (Fe, Zn, Cu and Mn) for biological consumption but they lead to several health issues when they are excess or deficient in water. Few toxic elements are always having an adverse effect on humans at any dose level. Origin and source of the heavy metals in groundwater are from both point source and non-point source Tiwari *et al.,* (2016; Chaturvedi *et al.,* (2018) and Abou Zakhem (2014) have studied to assess the groundwater in relation to how industrial agricultural and urban activity of the north east part of Damascus City affect the groundwater by leaching of heavy metals from the sewage water treatment station. The study conducted on distribution and heavy metal pollution index of heavy metals in water of the Yellow river in China. For the analysis surface water sample were collected in two different seasons and the concentration of heavy metals were determined using heavy metal pollution index (Sener *et al.,* 2017). The effect of pollution level is higher in normal season than the drought season. The consumption of water with this elevated chromium concentration cause serious health problems. Amongst the pollutants contaminating water bodies, metals play very long last effect on the wetland ecosystems (Pal *et al.,* 2017).

Selvam *et al.,* (2015) have assessed the heavy metal pollution using GIS and pollution indices in agriculture is necessary in order to understand the contamination. The spatial distribution of Zn, Cr, Cd and Pb revealed that the contaminations are related to the land use and influence of anthropogenic pollution and soil properties (Carr *et al.,* 2010). High metal contents were found near industrial area and agglomeration. The study helped in development of a water and sediment pollution prevention strategy (Sapna *et al*., 2020b). Tiwari *et al.,* (2015) have studied the water quality by GIS and HPI model in a coal mining area scarcity of a clean and potable water has emerged and became one of the most serious developmental issues in part of Bengal. The use and discharge of chemical agents, such as heavy metals, as a result of anthropogenic activities, affects the normal variation and distribution pattern of heavy metals (Paul *et al.,* 2019). The direct sources of the heavy metal ions are food and water and, indirect sources are industrial activities and traffic (Shuanxi *et al.,* 2010). Some heavy metals such as Cu, Fe, Mn, Ni and Zn are compulsory micronutrients for flora - fauna and microbes. The quantity of copper compounds in nature is minimal. The present study is to monitoring the substantial metal analysis and heavy metal pollution index (HPI) of selected rural and nearby industrial areas in Kannur district using GIS techniques.

MATERIALS AND METHODS

Study area

Kannur region is surrounded by Kasaragod locale toward the north, Kozhikode region toward the south and Wayanad region to the south-east. The east district is limited by the Western Ghats, which shapes the boundary with Karnataka state area of Kodagu. The area is border by the Western Ghats in the East, Kozhikode and Wayanad regions, in the South, Lakshadweep Sea in the West and Kasaragod district in the North. The district can be isolated into three land regions high nations, midlands and swamps. It covers a territory of 2966 sq.km and it lies between 11°40' 10'' and 12° 20' 30'' Northern latitudes, and 75°10' 20'' and 75°56' 40'' Eastern longitudes. The topography of the region lies between 50-60m above the sea level (Figure 1).

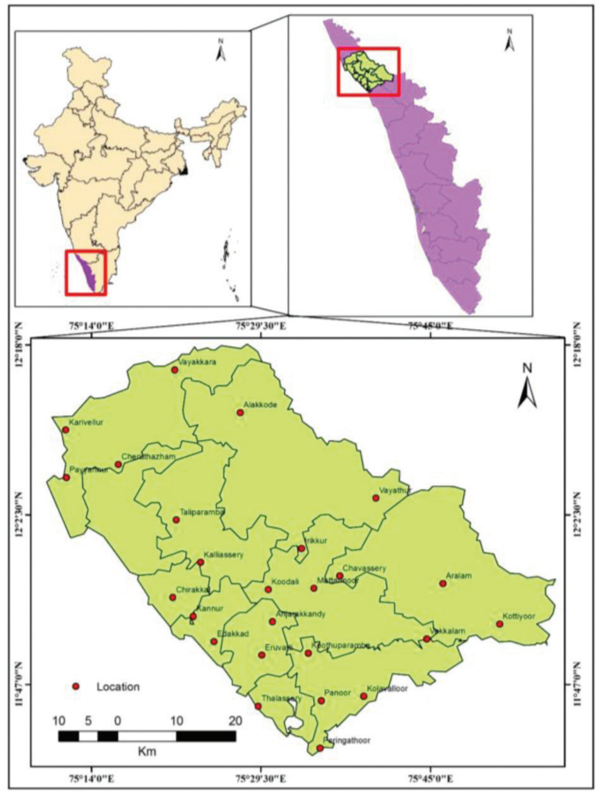

Fig 1. Study area map of Kannur district

The area has a sticky environment with an abusive hot season from March to the furthest limit of May. It is trailed by the Southwest storm, which consistent to September. October and November structure the post rainstorm season. Maximum temperature is above 35 °C and least temperature is about 20 °C and yearly normal precipitation is 34 - 38 mm. There are three distinct rock formation of the district are crystalline, basement laterite, coastal alluvium. The average annual rainfall of the district 275.52 mm and more than 65% of annual rainfall occurs during the four monsoon months. There are laterite soils, earthy colored hydromorphic soil, costal waterway alluvium, and woodland loamy soil.

Sample collection and analysis

The present study 25 groundwater samples were collected from different bore five taluks such as Thalassery, Kannur, Iritty, Taliparamba and Payyanur in provincial regions and close to modern regions in the year of 2019 respectively. Water samples were stored in refrigerator and later analyzed using standard method samples was preserved using Concentration of HNO_3 after filtration. The analysis was carried out for physico-chemical and heavy metal parameters ((ZN, Mn, Pb, and Fe) per the standard methods of (APHA, 1995). The concentration of heavy metal in groundwater is determined using Atomic Absorption spectroscopy (AAS) and atomic emission spectroscopy (AES) is a spectroanalytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation by free atoms in the gaseous state. Atomic absorption spectroscopy is based on absorption of light by free metallic ions. In analytical chemistry the technique is used for determining the concentration of a particular element in a sample to be analyzed. The digested samples were analyzed in triplicates with the average concentration of metals being displayed in mg/L by the Bureau of Indian Standards (BIS, 2012).

Heavy Metal Pollution Index (HMPI)

Heavy metal pollution index (HMPI), is a rating method and an effective tool to assess the water quality with respect to heavy metals. HMPI is a method that rates the aggregate influence of individual heavy metal on the overall quality of water. The HMPI shows overall quality of water with respect to content of heavy metals. The critical HMPI value is 100. The weighted arithmetic average of the concentrations was used to calculate HMPI values using the Eq. 1 given by (. (Panigrahy *et al.*, 2015)

$$\text{HPI} = \sum_{i=1}^{n} \frac{Wi * Qi}{\text{Wi}} \quad .. (1)$$

Where, Wi is the unit weightage defined as reciprocal value of Si where Si is the maximum permissible limit for drinking water given by BIS (2012), and n is the number of parameters considered. Qi is the sub-index of the ith parameter, and calculated by Eq. 2

$$\text{Qi} = \sum_{i=1}^{n} \frac{Mi * 100}{\text{Si}} \quad .. (2)$$

Where, Mi is the monitored value of heavy metal, Si is the standard value of the ith parameter, in ppm (μg/l). The higher the concentration of a metal compared to its respective maximum permissible limit (Si), the worse the quality of the water.

RESULTS AND DISCUSSION

Summary statistics analysis of groundwater quality

Statistical analysis infers properties of a population, for example by testing hypotheses and deriving estimates. It is assumed that the observed data set is sampled from a larger population. The overall mean of heavy metal contamination in ground water of the Kannur district varies from (0-1.382). The mean value of Kannur district (0.308) which is greater The mean concentration is very low in Aralam, Edakkad, Eruvatti, Chirakkal, Panoor, Peringathoor and Erikkoor.

The heavy metal range varies from 0 - 4.63 which implies that the distribution of heavy metal in ground water is spatially not uniform and which again support above observation that heavy metal content in ground water is not even. From these result it is inferred that a uniform strategy cannot be applied to remove the ground water in drinking or agriculture purpose for which a better analysis tool is necessary for decision makers. The higher value of standard deviation in Koothuparamba (2.209), Chavassery (2.039), Thalassery (1.341), and Kottiyoor (1.391) when compared with Vayakkara, Thaliparamba, Alakkode, Eruvatti, Panoor and Chirakkal. This statistical analysis shows that Chavassery is indicated the presence of large number of industries and discharge of effluent into ground water. Chavassery has the highest metal pollution with respect to other. Vayakkara, Karivellur, Edakkad, Eruvatti and, Chirakkal has very low variance when comparing with Koothuparamba and Kolavellur. Moderate places include Cheruthazhm, Thalassery and Kottiyoor. The higher value in Chavassery and Koothuparamba indicate the pollution level in that area. Among all the places Chirakkal and Kalliasery has the very low value of zero.

Cheruthazham and Edakkad have the highest value of kurtosis. The moderate skeweness shows at Thaliparamba, Alakkode, Vayathur, Chavassery, Anjarakkandy, Thalassery, Kottiyoor, Peringathoor and Mattannoor. Vayathur, Chavassery and Alakkode have the value of 1.983, 1.972 and 1.988 respectively. The very low negative value indicates the Panoor has very low level of pollution compared to other area. The moderate value of kurtosis was observed in Thaliparamba, Alakkode, Vayathur, Chavassery and Kottiyoor. The very low negative value can be seen in the area such as Vekkalam, and Kannur. The value becomes negative at Koodali, Eruvatti, Kannur, Panoor, Vekkalam and Kalliassery. The main source of heavy etals in ground water is considered to be commercial and industrial leaks. A wide variety of both organic and inorganic pollutant has been found in aquifers underlying commercial and industrial activities. Ore mining and metal processing facilities are the reason behind presence of metals in ground water of anthropogenic activities.

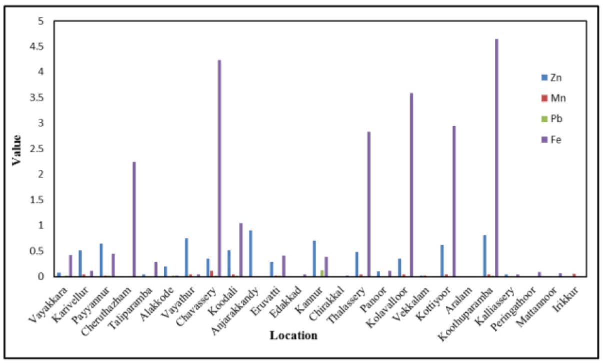

Fig. 2. Summary statistical analysis of groundwater heavy metal analysis

Assessment of groundwater quality of the heavy metal contamination

Iron (Fe)

The maximum permissible limit of Iron for drinking water given by BIS 0.3 mg per liter Iron concentration in the groundwater table trains from 0 to 4.6 mg per liter. Most of the samples exceeds the limit of 0.3 indicate the presence of Iron concentration in the groundwater of Kannur district. High concentration than Aralam (0), Chirakkal (0.01), Alakkode (0.062), Irikkur (0.02), Peringat (0.025), and less than Chavassery (1.117), Cheruthazham (0.56), Koodali (0.407) and Eruvatti (0.184). There are four zones depending upon the Iron content. The area having concentration 0.0007-1.16207 is very low Fe content. The majority of the places were observed in low concentration of Fe including Vayakkara, Alakkode, Karivelloor, Peringathoor, Vekkalam, Aralam and Alakoode. Some areas have concentration ranges from 1.16208-2.32406 indicating low concentration of Iron among collected ground water samples observed Anjarakkandy, Panoor, Eruvatti and Cheruthazham were the places having the range of concentration as shown in Figure 3.

Moderate concentration of iron can be found in area of Kottiyoor and Mattanoor. High concentration areas were observed in Koothuparamba, Chavassery and Kolavelloor indicate the Iron pollution in that area. The industrial activities in that area cause the high concentration of Fe in the ground water. Iron in excessive quantity in water can harm skin cells, leading to infection and wrinkles. Moreover, such water is not healthier for drinking. Iron is not hazardous to health, but it is considered a secondary or aesthetic contaminant. Essential for good health, iron helps transport oxygen in the blood. Most tap water in the United States supplies approximately 5 percent of the dietary requirement for iron.

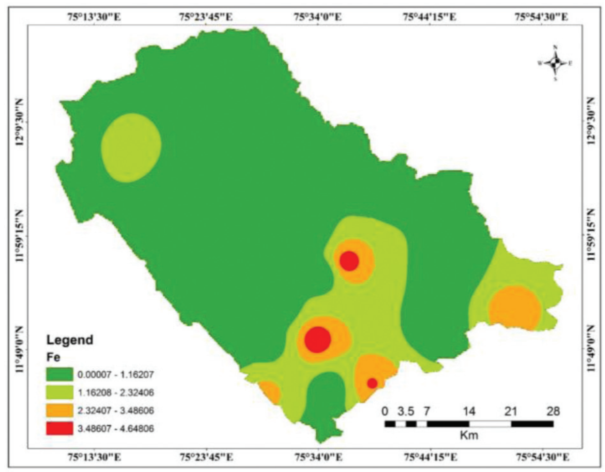

Fig. 3. Spatial distribution map of Fe

Lead (Pb)

The maximum concentration of Lead ion is often taken as an important parameter deciding the suitability of water for drinking water. In the present investigation low concentrations of lead is observed the major portion of the Kannur district. The maximum permissible level of lead in drinking water is 0.01 mg/l by BIS standard exceeding that limit cause serious health issues. The water that contains more than 0.01 mg/l is not suitable for drinking water. Aralam, Vayakkara, Anjarakkandy, Iritty, Chirakkal, Thalassery and Vekkalam have lead concentration ranges between 0-0.00249 mg/l. Some places including Payannur, Karivellur, Panoor Kolaveloor and Thaliparamba were presented low concentration of lead with a range of 0.00249-0.00498 mg/l. The moderate range of 0.00498-0.00748 mg/l was found at Eruvatti and Thaliparamba which indicates that there is no lead pollution in that area. And also gives that the industrial activities in that area are not affecting the drinking water quality. But when the range changes from 0.00749-0.00999 mg/l, there is a chance of having lead pollution in that area as shown in Figure 4.

In Kannur, the concentration of lead is at 0.01 mg/l which is the maximum permissible limit of lead in drinking water and the industrial activity in that area results in the serious health issues arising from drinking water. Lead can enter drinking water when plumbing materials that contain lead corrode, especially where the water has high acidity or low mineral content that corrodes pipes and fixtures. The most common sources of lead in drinking water are lead pipes, faucets, and fixtures. In homes with lead pipes that connect the home to the water main, also known as lead services lines, these pipes are typically the most significant source of lead in the water. In children, low levels of exposure have been linked to damage to the central and peripheral nervous system, learning disabilities, shorter stature, impaired hearing, and impaired formation and function of blood cells. Hence, the necessary action should take place in order to reduce the concentration in ground water.

Manganese (Mn)

Manganese (Mn) cause primarily due to the human activities. The ground water sample collected from Chavassery has the highest concentration of manganese ranges from 0.0004 - 0.10975. The permissible limit of Mn in drinking water given by BIS is 0.1 mg/l, except Chavassery all the samples fall under this limit due to anthropogenic activities in the site. The very low concentration of Mn can be seen in the range 0.00004-0.02744 mg/l in Aralam, Cheruthazham, Payyannur, Vayakkara and Eruvatti. The industrial activities do not affect the ground water quality as shown in Figure 5. The low concentration of lead with a range from 0.02745-0.05488mg/l was observed in some areas of Kannur district. The area such as Kolavelloor and Kottiyoor fall under this range indicate the low metal pollution. But in cases of Karivellur, Vayathur, Koothuparamba, Thalassery and Irikkur more concentration in water sample ranges from 0.05489-0.08231 mg/which indicates that there may be chances of pollution. The effect can be neglected by controlling of industrial discharges. Higher concentration of Mn can be found at a range from 0.08232-0.10975 mg/l at the sight of Chavassery. The Mn pollution is more in that area due to activities done by industries. Excessive exposure or intake may lead to a condition known as magnesium, a neurodegenerative disorder that causes dopaminergic neuronal death and symptoms similar to Parkinson's disease.

Zinc (Zn)

Zinc (Zn) concentration of groundwater sample shows the range between 0.00017-0.89811 mg/l. The average concentration of 25 samples was found below the permissible limit. The maximum permissible limit of zinc in drinking water is 5mg per liter. The pH concentration may at a range between 6-7 mg/l which will cause corrosion in pipe and can release toxic metals such as zinc and lead into water. As per BIS standard manganese quality of water should be below the range of 5 mg per litre above which course serious health problems by drinking the polluted water. Aralam, Mattannur, Irikkur, Edakkad, Cheruthazham and Vekkalam were observed the very low concentration of zinc at a range from 0.00017-0.22465 mg/l. The industrial activities in that area won't affect the groundwater

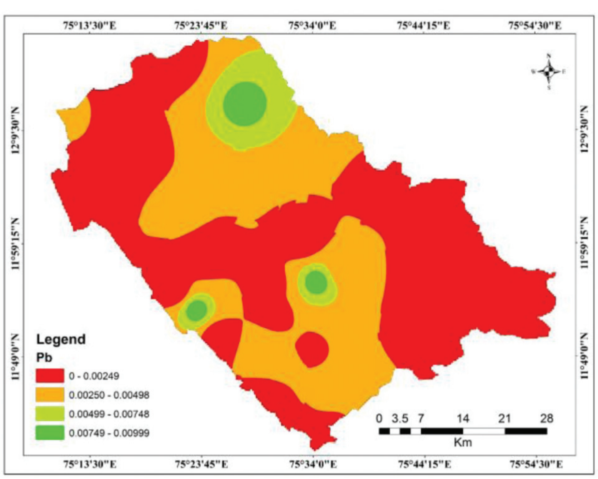

Fig. 4. Spatial distribution map of Pb

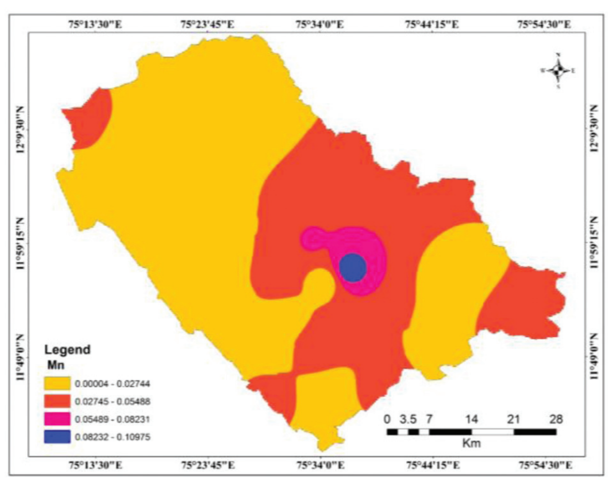

Fig. 5. Spatial distribution map of Mn

quality .The low concentration of zinc can be found at the range of 0.22466-0.44913 mg/l in Alakkode and Chavassery areas. The moderate concentration found in Thalassery, Koodali and Karivellur indicate the chances of pollution in study area. Higher concentration of zinc can be found at a range of 0.6763-0.8981. The area for under this range are Vayathur, Payyanur, Koothuparamba and Kannur indicates that the chances of pollution in future. The main reason behind this is the activities done by industries .Necessary action should take place in order to control the effect in future higher concentration of zinc is found at Koothuparamba and the low concentration at Salem among all collected water samples as shown in figure 6. Water with a zinc concentration of more than 5 mg/l may start to be become chalky in appearance with a detectable deterioration in taste. Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include loss of appetite, diarrhea, and headaches, kidney and stomach damage, and other side effects.

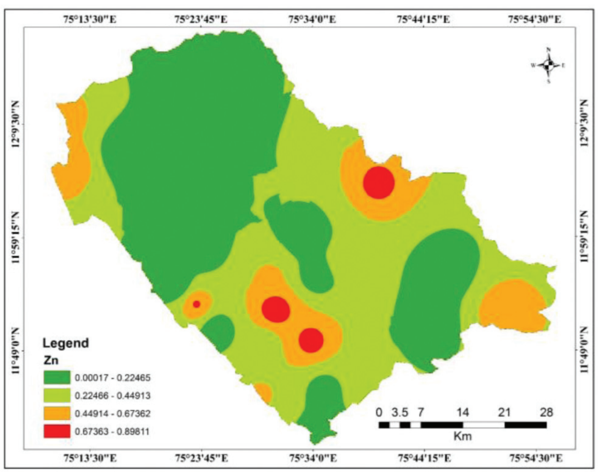

Fig. 6. Spatial distribution map of Zn

Heavy Metal Pollution Index

The concentration of heavy metal analysis were analyzed and completed in 25 groundwater samples. The concentration of heavy metal is maximum level at Mattannur because it contains industries which carry waste discharged from most of the chemical and fertilizer industries and also from residential areas of the city. Except Iron and all other heavy metals such as Zinc, Magnesium and Lead inside the municipality zone were below maximum permissible limit of drinking water quality given by BIS. The distance from industrial areas to the groundwater quality has greater influences as the distance is low the concentration of heavy metal in the groundwater is high. Iron level can be seen at a higher concentration in the most of places of Kannur district. The concentration of zinc, manganese and lead work found within permissible limit for drinking water quality at all sites. The table provided details of calculating heavy metal pollution index (HMPI), water index (Wi) and quality index (Qi). The critical value of heavy metal pollution index is 100 (Milivojevic, 2016). The HMPI values were calculated in different sampling to assess the pollution load in selected site as shown in Figure 7.

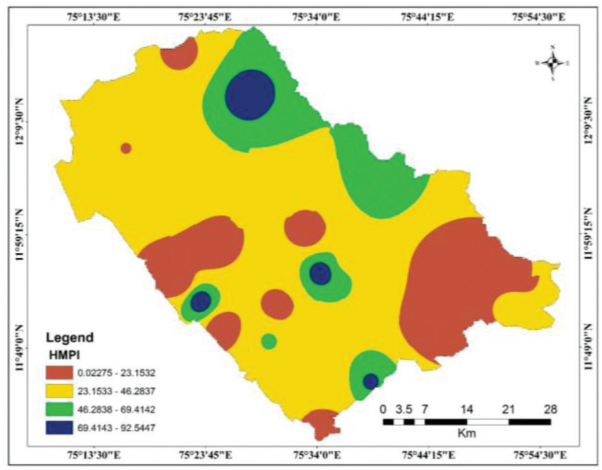

Fig. 7. Spatial distribution map of HMPI

The very low ranges of HMPI were obtained Aralam, Edakkad, Kalliassery, Chirakkal, Irikkur, Vekkalam, Anjarakkandy and Peringathur. It indicates that majority of the places are safe from metal pollution. The low range areas of (23.15-46.28) Vayakkara, Cheruthazham, Kottiyor, Koothuparamba, Chavassery, Karivellur, Panoor and Thaliparamba were observed safe for drinking purpose whereas. The moderate concentration of HMPI can be seen in the range of (46.82-69.04) at Vayathur which indicates the possibility of pollution in future scenario. The high range of (69.41- 92.54) areas were obtained Mattanur and Alakode which indicates the pollution due to industrial seepage in nearby areas as shown in (Table 1, 2, 3, 4 & 5). The HMPI value for all the samples were below the critical index limit. Mattannur area was presented highest pollution due to industrial and wastewater discharge. When the chemicals and fertilizers get into groundwater through seepage and it become a unsafe and unfit for human use.

Table 1. Heavy Metal Pollution Index of GW1

Parameters	Permissible Limit by BIS (mg/I) (Si)	Weightage *Wi =1/si*	Subindex *QI= n*	*Wi x Qi*
ZN (Mi=0.08)	5	0.2	1.6	0.32
Mn (Mi=0.01)	0.01	10	10	100
Pb (Mi=0.001)	0.01	100	200	2000
Fe (0.42)	0..3	3.33	11.75	39.1275
		Wi =113.53		HPI=18.844

Table 2. Heavy Metal Pollution Index of GW4

Parameters	Permissible Limit by BIS (mg/I) (Si)	Weightage *Wi = 1/si*	Subindex *QI= n*	*Wi x Qi*
ZN (Mi=0.01)	5	0.2	0.2	0.04
Mn (Mi=0.01)	0.1	10	10	100
Pb (Mi=0)	0.01	100	0	0
Fe (Mi=2.25)	0.3	3.33	750	2497.5
		Wi = 113.53		HPI = 22.87

Table 3. Heavy Metal Pollution Index of GW6

Parameters	Permissible Limit by BIS (mg/I) (Si)	Weightage Wi =1/si	Subindex QI= n	*Wi x Qi*
ZN (Mi=0.2))	5	0.2	4	0.8
Mn(Mi=0.05)	0.1	10	50	500
Pb(Mi=0.009)	0.01	100	90	9000
Fe(Mi=0.05)	0.3	3.33	16.66	2497.5
		Wi =113.53		HPI=84.17

Table 4. Heavy Metal Pollution Index of GW9

Parameters	Permissible Limit by BIS (mg/I) (Si)	Weightage Wi =1/si	Subindex QI= n	Wi x Qi
ZN (Mi=0.51)	5	0.2	10.2	2.04
Mn (Mi=0.05)	0.1	10	50	500
Pb (Mi=0.001)	0.01	100	10	1000
Fe (Mi=1.05)	0.3	3.33	350	1165.5
		Wi =113.53		HPI=23.49

Table 5. Heavy Metal Pollution Index of GW10

Parameters	Permissible Limit by BIS (mg/I) (Si)	Weightage Wi =1/si	Subindex QI= n	Wi × Qi
ZN (Mi=0.9)	5	0.2	100	20
Mn (Mi=0)	0.01	10	0	0
Pb (Mi=0.001)	0.01	100	10	1000
Fe (0.01)	0..3	3.33	3.33	11.0889
		Wi =113.53		HPI=9.08

CONCLUSION

The present study reveals that most of the sampling sites were obtained below the critical pollution index limit. The high values of HMPI were found in Mattanur and Alakkode. Mattanur area has the highest concentrations which fall under near critical value due to the leakage of industrial, chemical and fertilizer into the ground water. It is unsafe for drinking water and also it may lead to serious health problems to human. The study also shows that Aralam were reported any form of pollution and it is due to lack of major threatening activities. This indicates the effect of industrial zone, agriculture and urban activity. It also shows that the groundwater areas are likely more affected by leaching of heavy metal from industrial activities. However, iron concentration exceeding the desirable limit in many areas without effecting the pollution. The low concentration of other metals zinc, manganese and lead found in few areas were highly polluted nearby industrial operations and representing human-induced pollution. Overall of the study should be taken earnestly by the concerned water resource management authorities in order to control the metal pollution in the groundwater.

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