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Assessment of heavy metal pollution index of groundwater in Arani Taluk of Tamil Nadu, South India

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ABSTRACT

The groundwater suitability is based on hydrogeochemical features water quality based on the seasonal variations were determined. Groundwater samples were collected in the Arani Taluk of Tamil Nadu, South India, and trace metals were determined to characterize and evaluate water quality. Trace metals such as Zn, Pb, Mn, Ni, Co, Fe, Cu, Cr were analyzed for the premonsoon and postmonsoon seasons. Using a GIS spatial distribution map was prepared. The spatial distribution map of water quality studies concerning trace metals shows that the water has a higher concentration of heavy metals and the results of Heavy metal pollution index (HPI) also substantiates the fact and many groundwater samples were found to show higher values than the allowed limit concerning heavy metal contamination.

***Key words**: Groundwater, Hydrogeochemistry, Heavy metal pollution index, Trace metals*

Introduction

The explosive change in the demography, especially in the developing countries like India, made stress on the water resources. In view of the importance in the present scenario, many researchers investigate on the variation in the hydrochemical properties including the cause and origin of the contaminants and variable spatial pollution loads in the groundwater. In developing countries, like India, urban and industrial sectors have shown remarkable growth which induces migration followed by settlements in the newly formed urban sprawls (Mosaferi *et al.*, 2014; Khatri and Tyagi, 2015; Talalaj and Biedka, 2016; Yihdego, 2017; Teta and Hikwa, 2017; Odiyo and Makungo (2018).

Hence the problem owing to anthropogenic activity on the hydrological system can be considered as multi-dimensional and complex as there are wide variety of contaminants and its intricate subsequent chemical reactions with soil/rock yields various constituents to groundwater. Hence detailed scientific evaluation of geochemical characteristics of trace elements in groundwater has become highly essential in the present scenario of rapid urbanization and industrialization. Further, heavy metal contamination to water resources has been given much attention by researchers due to their low biodegradability and adverse impact caused due to bioaccumulation as well as its toxic effects on the food chain (*Li et al.*, 2017; Nasehetal, 2018).

From the point of view of trace elements level and its impact of contaminants, detailed evaluation of the above factors becomes pertinent in order to identify the specific sources of pollution and for effective water management. Hence in the present study, geochemical scientific applications have been effectively used to characterize the hydrogeochemical nature of the water resources in the region. Further, spatial analysis using GIS has been applied to delineate the zones which have significant impact on the groundwater of the region.

Study Area

The study area, Arani is located in the northern part of Tiruvannamalai district, Tamil Nadu, South India and geographically lies between N-latitudes 12°40′12′′ and E-Longitudes 79°17′08′′(Fig. 1). There are many isolated hillocks and tor complexes and the geology of the region comprises of Charnockite, Gneiss, Granite, Sandstone, Shale, Sand, Silt and Alluvium. The region enjoys Discontinuous unconfined to semi confined aquifers in fissured formations. In the present work, Arani is so chosen since it houses many industries including large scale, small scale and tiny industries. In this region, Industries are located at random and not concentrated at one location. There is a blend of industrial and residential areas. The effluents from the textile and other industries in the study area have significant impact on the groundwater of the region.

Methodology

In the present study, groundwater samples are collected following random sampling technique and the sampling stations are chosen in a near grid pattern. Samples were collected at 44 locations in the study area representing pre-monsoon and post-monsoon periods in order to evaluate the variations in the terrace metals level present in the of groundwater due to seasonal impact. Standard methods were followed in the collection of the groundwater samples, preservation techniques and for sample analysis (Hem, 1985; APHA, 1995). Trace metals were determined using atomic absorption spectrophotometer (AAnalyst 700; Perkin–Elmer).

Results and Discussion

Trace metal Geochemistry

The concentration of heavy metals in the groundwa-

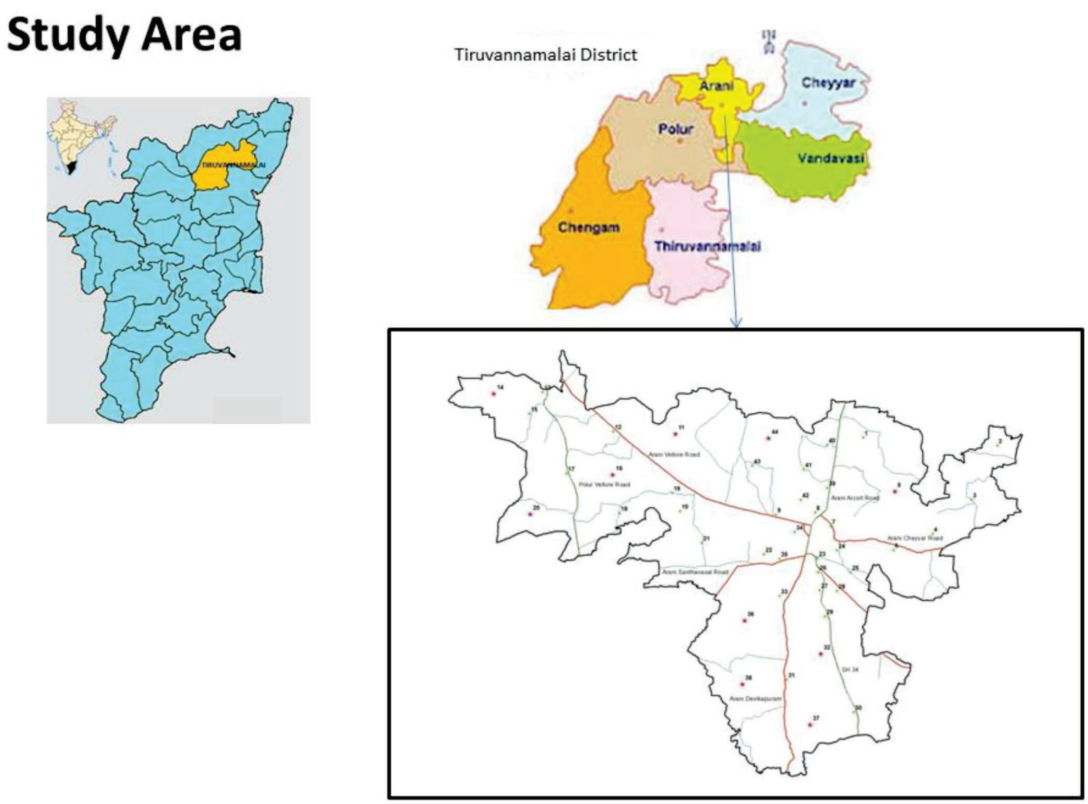

Fig. 1. Study area map illustrating the sample locations

ter of the study area is determined and presented in Table 1. Seasonal variation in the concentration of trace metals was evaluated in the groundwater of the region. During premonsoon, Cu values ranges from 0.002 to 0.043 with a mean value of 0.014mg/L. For postmonsoon, the values are found to vary from 0.003 to 0.087 with an average value of 0.017. Results of Cu shows that the concentration of this metal in the groundwater is well within the maximum permissible limit of 1.5 mg/L (IS, 2012) but some of the values are found to be greater than the desirable limit of 0.05 mg/L during postmonsoon. Spatial distribution map (Fig. 2a) illustrates that the study area is found to have low concentration of copper indicating that these wells are not affected with respect to this metal ion. Spatial distribution map of postmonsoon (Fig.2b) illustrates that the southern part of the study area is found to have the higher concentration of copper in the range of 0.053 to 0.087 mg/L indicating that these wells are slightly affected with respect to this metal ion as the values are found to be greater than the desirable limit of 0.05 mg/L. Most of the wells in the northern, eastern and western part of the region have moderate concentration of copper values not exceeding the desirable limit of 0.05 mg/L.

The concentration of zinc during premonsoon varies from 0.010 to 5.42 with a mean value of 0.822 mg/L and in the case of postmonsoon, the values range from 0.017 to 2.976 with an average value of 0.443 mg/L. The value of Zn during both monsoon periods is found to be within the desirable limit of 5 mg/L. The mean values of Ni during premonsoon and postmonsoon are 0.071 and 0.044 mg/L respectively which is higher than the permissible limit of 0.02 mg/L and in the case of Mn, the average values are 0.605 and 0.526 mg/L during premonsoon and postmonsoon periods. The results clearly shows that the groundwater of the region is contaminated with these metals and the spatial map of Ni during premonsoon and postmonsoon illustrates that some of the wells falling in the central and southern parts of the study area are highly contaminated with this metal as the values ranges from 0.09 to 0.14 mg/L and 0.05 to 0.26 mg/L, respectively (Fig.3a & 3b). Similarly, the values of Iron also illustrate higher values in most of the sampling stations and the average value during pre and postmonsoon

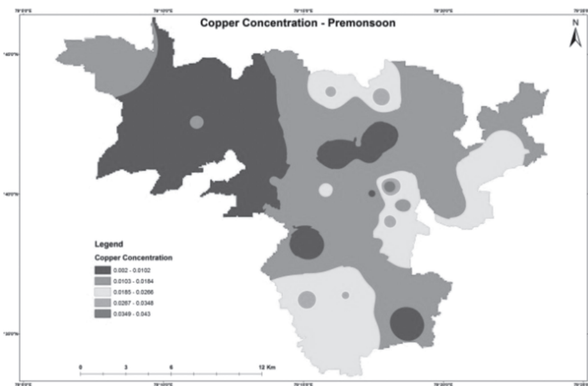

Fig. 2a. Spatial distribution map of Copper during premonsoon

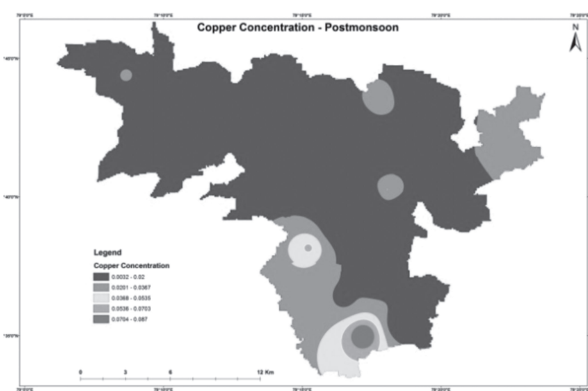

Fig. 2b. Spatial distribution map of Copper during postmonsoon

Table 1. Summary statistics of trace metals

Trace metals (mg/L)	Premonsoon			Postmonsoon		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Zn	0.010	5.420	0.822	0.017	2.976	0.443
Pb	0.003	0.080	0.032	0.000	0.049	0.017
Mn	0.003	4.820	0.605	0.017	2.816	0.526
Ni	0.006	0.440	0.071	0.002	0.264	0.044
Co	0.001	0.025	0.011	0.002	0.112	0.018
Fe	0.002	0.980	0.139	0.004	0.596	0.047
Cu	0.002	0.043	0.014	0.003	0.087	0.017
Cr	0.006	0.184	0.076	0.000	0.113	0.042

are 0.139 and 0.047mg/L. In the case of Chromium, the concentration of Cr in many of the stations is found to be higherthan the maximum permitted limit of 0.05 mg/L. The average value during premonsoon and postmonsoon is 0.076 and 0.042 mg/L respectively. During premonsoon, Spatial distribution map of Cr (Fig. 4a) illustrates that the study area is found to have higher concentration of chromium indicating that these wells are affected with respect to this metal ion. Contour map shows that the wells falling in the eastern, southwestern and a small zone in the southern part are found to have higher concentration of Cr in the range of 0.077 to 0.184 mg/L. In the case of postmonsoon, spatial distribution map shows that the wells falling in the eastern, central and southwestern part of the study area are found to have high values of Cr ranges from 0.045 to 0.112 mg/L (Fig.4b).

A Pb value during premonsoon is ranging from 0.003 to 0.08 with a mean of 0.03 mg/L and the values of postmonsoon ranges from 0.0003 to 0.049 with a mean of 0.017. Many of the groundwater samples in the region show Pb values higher than the permitted limit of 0.01mg/L (Fig.5a &5b). The untreated effluents from the textile and dyeing industries in the region would have attributed to the higher concentration of heavy metals in the groundwater of the region. As the concentration of Cr and Pb are found to be high in the groundwater samples of the region, the higher content of these metals may create health hazards and hence the water could not be classified as suitable for drinking purposes.

Heavy metal pollution index (HPI)

In the present study, Heavy metal pollution index (HPI) was used to evaluate the suitability of groundwater for drinking purpose. HPI was calculated using the following equation (Mohan *et al.*, 1996, Prasad and Sangita, 2008)

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

Wi represents the unit weightage of the ith heavy metal; Qi is a sub-index of the heavy metal and n is

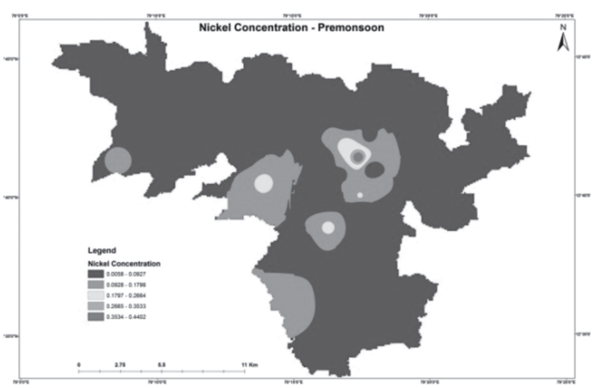

Fig.3a. Spatial distribution map of Nickel during premonsoon

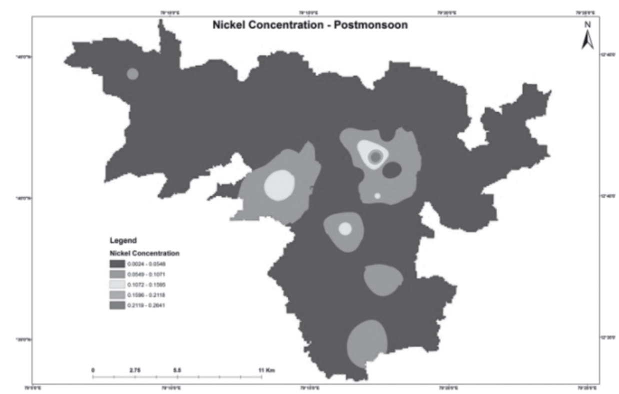

Fig. 3b. Spatial distribution map of Nickel during postmonsoon

Table 2. HPI calculations for ground water, based on Indian drinking water standards (Indian Standard 2012, 10500) - premonsoon

Heavy metals (in ppb)	Mean concentration (Mi)	Maximum permitted limit (Si)	Desirable limit (Ii)	Unit weightage (Wi)	Sub index (Qi)	Wi x Qi	HPI (mean)
Zn	821.81	15000	5000	0.00000667	41.8	0.0028	301.99
Pb	31.87	10	No relaxation	0.1	319	31.8707	
Mn	605.26	300	100	0.00333333	253	0.8421	
Ni	70.71	20	No relaxation	0.05	354	17.6776	
Fe	139.03	300	No relaxation	0.00333333	46.3	0.1545	
Cu	14.17	1500	50	0.00066667	2.47	0.0016	
Cr	75.62	50	No relaxation	0.02	151	3.0248	

ΣWi =0.1774 ΣWiQi=53.5709

the number of heavy metals measured in the study.

Qi is calculated using the following equation.

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

where, M_i represents the estimated concentration of the ith heavy metal, I_i is the maximum desirable value of the ith heavy metal (2004) wherein Si is the maximum permissible limit and in the present study, Indian standard specifications for water is applied (IS,1991). W_i is evaluated from the inverse proportional of the permissible value of the ith heavy metal (Mohan *et al.*, 1996). In general, the critical pollution index value is 100. In Table 4a & b,

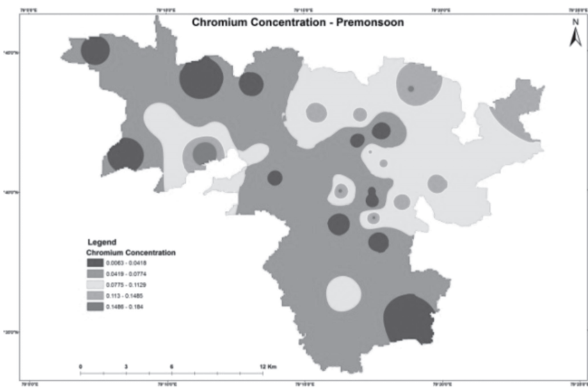

Fig.4a. Spatial distribution map of Chromium during premonsoon

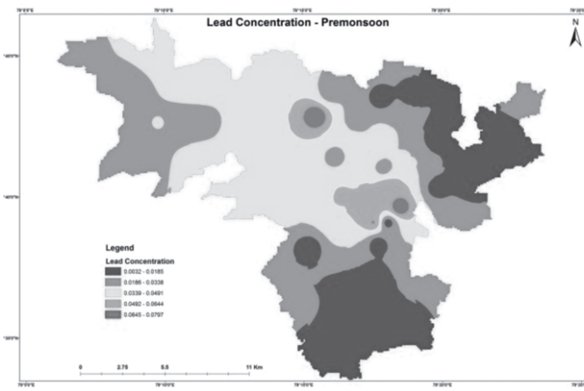

Fig. 5a. Spatial distribution map of Lead during premonsoon

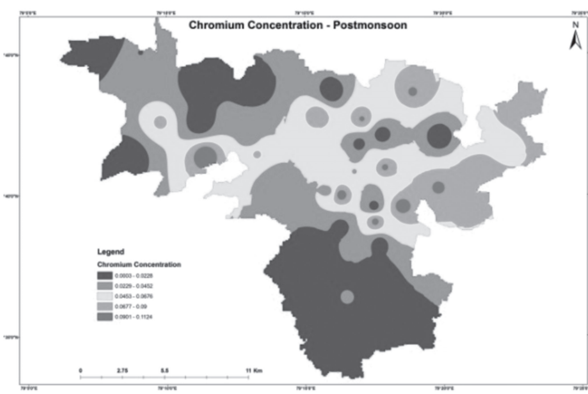

Fig. 4b. Spatial distribution of Chromium during Postmonsoon

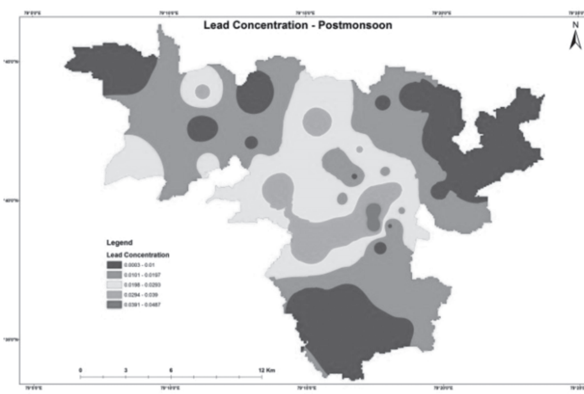

Fig.5b. Spatial distribution map of Lead during postmonsoon

Table 3. HPI calculations for ground water, based on Indian drinking water standards (Indian Standard 2012, 10500) - postmonsoon

Heavy metals (inppb)	Mean concentration (Mi)	Maximum permitted limit (Si)	Desirable limit (Ii)	Unit weightage (Wi)	Sub index (Qi)	Wi x Qi	HPI (mean)
Zn	442.55	15000	5000	0.0000667	45.6	0.0030	174.17
Pb	17.49	10	No relaxation	0.1	175	17.4919	
Mn	526.11	300	100	0.00333333	213	0.7102	
Ni	43.80	20	No relaxation	0.05	219	10.9493	
Fe	46.94	300	No relaxation	0.00333333	15.6	0.0522	
Cu	19.80	1500	50	0.00066667	2.08	0.0014	
Cr	42.24	50	No relaxation	0.02	84.5	1.6897	

ΣWi =0.1774 ΣWiQi=30.8977

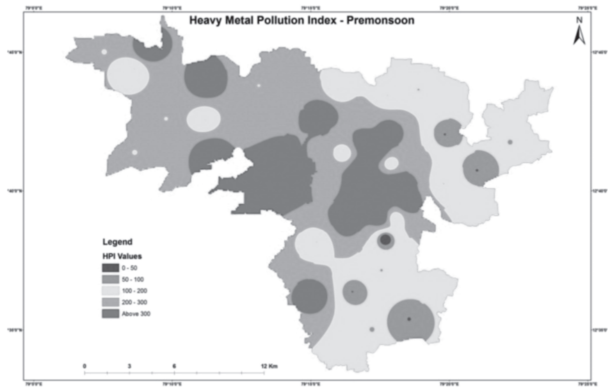

Fig 6a. Heavy Metal Pollution Index – Premonsoon

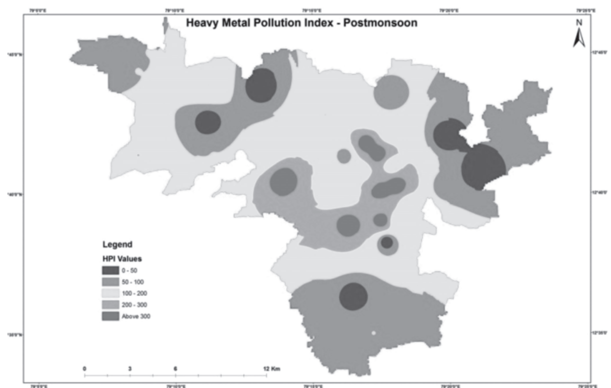

Fig 6b. Heavy Metal Pollution Index – Postmonsoon

HPI was calculated using the mean values of each metal (Mi) with unit weightage (Wi) and standard permissible values (Si) for premonsoon and postmonsoon periods.

Results of HPI values at each sampling station for premonsoon show (Table 2) that the values range from 45.10 to 865.6 with a mean value of 302.45. In the case of postmonsoon (Table 3), the HPI values vary from 26.02 to 548.45 with an average value of 174.4. It is observed that during both monsoon periods, none of the HPI values were found to fall under low or middle class (HPI < 15 or HPI < 15-30). All the groundwater samples fall under high class viz., HPI > 30. Further most of the sampling stations show values greater than critical pollution index value of 100. Spatial distribution diagram (Fig.6a & 6b) illustrate that the middle part of the study area is significantly affected with higher rate of contamination of trace metals. The study area is famed with the variety of industries and the region is known to be conglomerated with cluster of rice mills and dying industries. Dyeing of textiles is one of the basic requirements for the production of variety of textiles and the dyeing industry uses many metals to get colored complexes. This may be attributed to the higher value of heavy metals in the groundwater of the study area.

Conclusion

In the present research, Trace element assessment of groundwater quality of the study area has been evaluated and the results are summarized the results indicates that Chromium, Lead and Nickel are found to have higher concentration than the permissible limits in many of the groundwater samples which has been confirmed by the Heavy metal pollution index which also indicates that many of the samples are found to have values greater than the critical value of 100.

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