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Seasonal variation on physico-chemical parameters and trace metals in groundwater of an industrial area of north Chennai, India

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Abstract

Seasonal variation on physico-chemical parameters and trace metals of groundwater in and around Ambattur industrial area, Chennai were determined. The hydrochemical investigation revealed that the seasonal effect does not change the order of abundance of cations and anions but it does change the concentration of various ions present in the groundwater. Alkali metals (Na^+, K^+) and strong acids (Cl^-, SO_4^{2-}) are dominating over alkaline earth metals (Ca^{2+}, Mg^{2+}) and weak acids (HCO_3^-, CO_3^{2-}) for both seasons. Statistical analysis indicates the highest positive correlation exists between EC and Cl with correlation co-efficient of 0.97 and 0.96 during pre and post-monsoon respectively. Nitrate concentration in the groundwater ranges from 2 to 258 mg/l during pre-monsoon. in the case of post-monsoon, it ranges from 0 to 230 mg/L. During post-monsoon period, nitrate concentration decreased in many wells that are located mostly inside the industrial area. However, it has increased in the residential area, reflecting that the leaching of nitrate from the open sewerage lines. Groundwater in the study area is generally hard, fresh to brackish and low alkaline nature. The unsuitability of groundwater for drinking was identified in few places due to high total hardness and TDS. Fluoride is within the permissible limit for human consumption as per international standards.

Keywords: Water quality, groundwater, Chennai, Ambattur industrial area, India

Introduction

Industrial areas are the target especially for the environmental auditing. The environmental impact of human activity on the groundwater is considered as one of the major hazard in the modern days. Rapid urbanization and increased industrial activities has resulted in the degradation of water quality. The effluents discharged from industries and sewage water is the main contaminants of groundwater. The chemical budget of major ions and heavy metals are important in determining the quality of groundwater. Groundwater with low pH values can cause gastrointestinal disorder and this water cannot be used for drinking purposes. Contamination of groundwater by heavy metals has been given much attention due to their low biodegradability and toxic effects (Kaplay & Patode, 2004; Rima Chatterjee *et al.*, 2010). Study of chemical budget of major ions gains importance since it explains the origin of the ions in groundwater and the level of the contamination by natural as well as anthropogenic sources (Subba Rao, 2006). In this study, major ions are determined so as to draw a conclusion on the source of origin of these ions whether it is natural or anthropogenic.

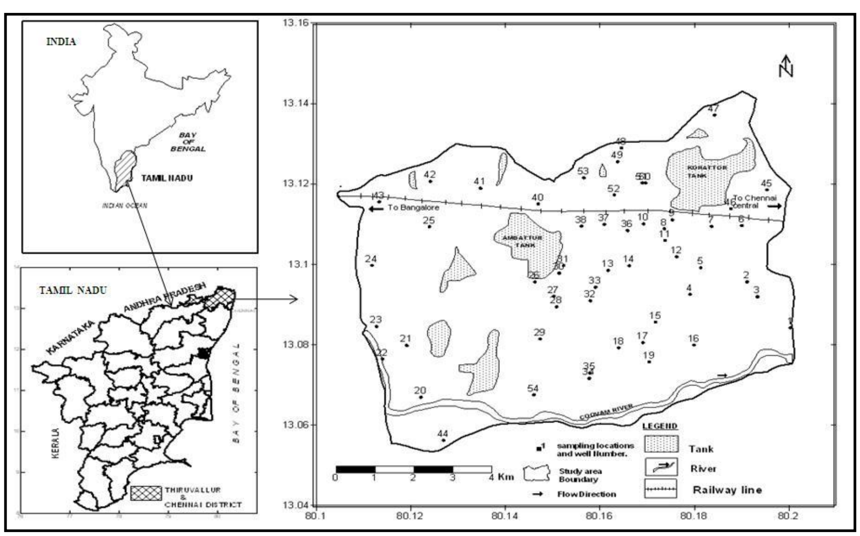
Study area

The study area is a sub-urban area of Chennai Metropolitan city and located NW of the city. The extent of study area is about 72 Sq. km. falling N-latitudes 13º03'01'' to 13º20'58'' and E-Longitudes 80º06'00'' to 80º39'58'' (Fig.1). The study area is covered by Survey of India toposheet No.66C/4, in the state of Tamil Nadu, India. The predominant industrial units are engineering industries which involves metal handling such as cutting, milling, shaping and producing different scrap metals, mainly iron. An offshoot of engineering industry is the electroplating industries specialized in different metal coatings. Next to major industries are the chemical industries mainly paint and chemicals

Methodology

Groundwater samples were collected from 54 representative open wells during May'2007 and Jan'2008 from investigated area. Samples were collected in new 1-

Fig.1. Location map of study area



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L HDPE bottles pre-washed with dilute hydrochloric acid and rinsed three to four times with the water sample before filling it to capacity and then labeled accordingly. The samples were stored at a temperature below 4°C prior to analysis in the laboratory. For collection, preservation and analysis of the samples, the standard methods (APHA, 1995) were followed. Trace metals were determined by Graphite Furnace Atomic Absorption Spectrophotometer (Perkin-Elmer AAnalyst 700). Multi element Perkin-Elmer standard solutions were used for the estimation of Trace metals. All the parameters are expressed in milligrams per litre (mg/L), except pH (units). The ion-balance error computed on each set of complete analysis of water sample was observed to be within the acceptability range of ± 5%. Results were compared with the WHO's water quality safe limit for drinking purpose.

Table 1. Details of analytical methodology and basic statistics of groundwater samples collected from the study area

Variables	Units	Detection limit	Premonsoon(May-2007)			Postmonsoon(Jan-2008)		
			Minimum	Maximum	Mean	Minimum	Maximum	Mean
pH		-	6.15	8.22	7.18	6.41	8.11	7.30
EC	µmhos/ cm	-	410	7630	2434	225	5910	1986
TH	mg/l	5	100	2620	494	85	2360	476
Ca	mg/l	2	12	656	95	14	280	90.
Mg	mg/l	1	2	238	62	6	403	60
Na	mg/l	1	35	910	314	12	900	246
K	mg/l	1	BDL	155	26	2	105	21
HCO_3	mg/l	6	48	782	324	36	1037	378
Cl	mg/l	4	35	2399	481	21	1576	361
SO_4	mg/l	5	18	900	236	9	640	176
NO_3	mg/l	0.05	BDL	258	52	BDL	230	55
F	mg/l	0.10	0.20	1.46	0.70	0.23	1.50	0.77
TDS	mg/l	10	242	5225	1629	131	3923	1351
Cu	mg/l	0.005	BDL	0.10	0.02	BDL	0.07	0.01
Pb	mg/l	0.020	BDL	0.40	0.15	BDL	0.23	0.08
Zn	mg/l	0.005	BDL	0.44	0.07	BDL	0.89	0.03
Ni	mg/l	0.010	BDL	0.18	0.01	BDL	0.04	0.01
Cd	mg/l	0.005	BDL	0.21	0.02	BDL	0.02	0.01
Cr	mg/l	0.005	BDL	0.59	0.04	BDL	0.33	0.03
Mn	mg/l	0.010	BDL	5.35	0.58	BDL	2.20	0.27
Fe	mg/l	0.010	BDL	6.63	0.51	BDL	4.88	0.22

BDL. Below detection limit

Results and discussion

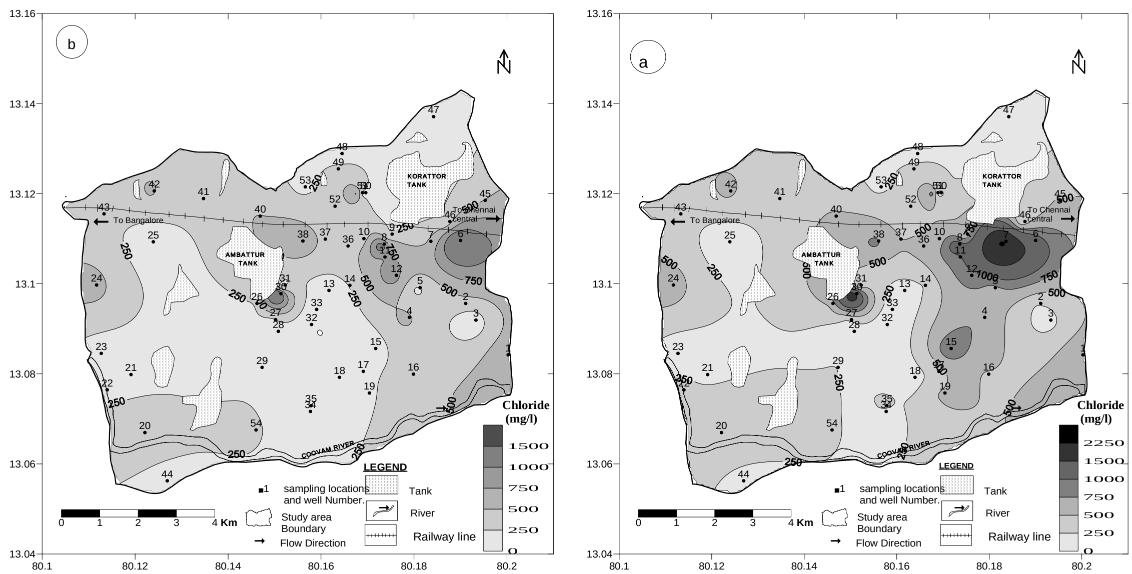
In the study area all the water quality parameters showed a wide variation in space and time. The spatial variation was mainly due to the groundwater contamination due to anthropogenic sources such as industry, and the open domestic sewerage system. In addition, surface water resources like tanks and river influence the quality of water through groundwater recharge. Temporal variations were due to seasonal influences mainly, the effect of rainfall. The data analyses revealed that most of the parameters showed a substantial decrease after monsoon. However, concentration of nitrate increased in many wells during postmonsoon periods. The statistical parameters such as minimum, maximum, mean of groundwater are presented in Table 1 for both premonsoon and postmonsoon. To know the distribution pattern of different elements and to demarcate the higher concentration zone, the contour maps for various elements were also generated, discussed and presented.

In the study area, pH value ranged from 6.15 to 8.22 with an average value of 7.18 during premonsoon and 6.41 to 8.11 with an average value of 7.18 during post monsoon period and most of the wells showed pH in the alkaline range during premonsoon (May 2007). During the postmonsoon period of January 2008, many wells in the industrial area showed higher pH values compared to the premonsoon values.

Electrical Conductivity of water is a good indicator of pollution as most of the soluble pollutants exist as ions in water. During premonsoon period, EC values ranged from 410 to 7630 µS/cm at 25ºC and the ground water quality in the study area is found to be equivalent to freshwater in about 7.5 % of the sample analyzed as indicated by low EC value (<750 µS/cm at 25^0 C). In about 48 % of the wells, EC varies between 751- 2250 µS/cm at 25^0 C and 13% of the well varies between 2251-3000 µS/cm at 25^0C indicating that the ground water is slightly mineralized and about 31.5% of the wells, EC is more than 3000 µS/cm at 25^0C indicating that the ground water is highly mineralized. During the post monsoon period of January 2008, EC values were comparatively less in most of the wells and it is ranged between 225 and 5910 µS/cm at 25^0C. However, it increased in 8 wells; this could be due to the occurrence of more anthropogenic pollution during the post-monsoon period. The wells located in the northwest and western areas have EC values less than 1000 µS/cm at 25º C except one well.

As per the TDS classification (Fetters, 1990), most of the groundwater samples collected during premonsoon and postmonsoon periods belong to brackish type (TDS>1,000 mg/l). TDS more than 3000 mg/l was observed in the wells close to industries, where the majority of industries are mainly engaged in paint and chemicals and other area is the landfill site. TDS values when compared with WHO's permissible limit reveals that 68.5 % and 55.5 % of the samples were unfit for drinking

Fig 2 Distribution of chloride (a) during premonsoon period of May-2007 (b) postmonsoon period of January 2008



and other domestic purposes during pre and postmonsoon respectively. TDS is more likely to be increased due to the disposal of untreated waste from the industries. Total hardness of groundwater varied between 100 and 2620 mg/l as $CaCO_3$ during the premonsoon period (May 2007). During the post-monsoon period (January 2008), it varied between 85 and 2360 mg/L as $CaCO_3$. Classification of groundwater based on total hardness shows that a majority of groundwater samples fall in the hard water category.

During pre-monsoon, the concentration of cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} ions ranged from 12 to 656; 2 to 238; 35 to 910; 0 to 155 mg/L with a mean of 95.96, 62.07, 314.44 and 26.25 mg/L respectively. The ionic concentrations (based on mmol/L) are 20.14, 21.24, 55.66 and 2.96%. The order of abundance is $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$. But during post-monsoon the concentration of cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} ranged from 14 to 280; 6 to 403; 12 to 900; 2 to 105 mg/L with a mean of 90.33; 60.90; 246.81 and 21.66 mg/L respectively. The ionic concentrations (based on mmol/L) are 24.30, 25.17; 47.33; and 3.20%. The order of abundance is $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$. The seasonal effect does not change the order of abundance of cations but it does change the concentration of various ions. Similarly in the case of anions during premonsoon, HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-} ranged from 48 to 782; 35 to 2400; 18 to 900 and 0 to 258 mg/L with a mean of 324.23, 480.11, 235.65 and 52.51 mg/ L respectively. The ionic concentrations (based on mmol/L) are 27.55, 47.99, 20.52 and 3.94%. The order of abundance is $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-}$. During postmonsoon HCO_3^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-} ranged from 36 to 1037; 21 to 1576; 9 to 640 and 0 to 230 mg/L with a mean of 378.87, 361.39, 176.98 and 55.25 mg/L respectively. The ionic concentrations (based on mmol/L) are 34.41, 42.67, 17.49, and 4.84% respectively. The order of abundance is $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-}$.

The distribution of chloride is shown in Fig.2 (a) and Fig.2 (b) for pre and post-monsoon respectively. The trend of Chloride contours clearly show that the contamination level is possibly moving towards eastern & southeastern direction. During premonsoon period, chloride values of 28 wells exceed the desirable limit of 250 mg/L, while during postmonsoon period chloride values of 35 wells exceed the desirable limit. However, it has increased in 7 wells; this could be due to the occurrence of more anthropogenic pollution during the post monsoon period. Analysis of the data reveals that in all the samples higher values of chloride is associated with higher values of EC.

The spatial distribution of nitrate during pre and postmonsoon is illustrated in Fig.3 (a) and Fig.3(b) respectively. During the postmonsoon period, nitrate concentration decreased in many wells, which are mostly inside the industrial area. However, it has also increased in the residential area which could be due to the leaching of nitrate from the open sewerage lines. This indicates that domestic waste leads to more nitrate problem than the industries reflecting the lack of sufficient sanitary facilities due to uncontrolled urbanization.

Trace metals

The variation in the concentration of trace metals (Cu, Pb, Zn, Ni, Cd, Cr, Mn and Fe) in both pre and postmonsoon in the groundwater of the study area was evaluated. Cu values range from 0.00 to 0.103 mg/L with an average value of 0.025 mg/L during premonsoon. However, during the post-monsoon, the values range from 0.00 to 0.072 with a mean of 0.006. During both pre and postmonsoon, the concentration of Cu is well within the WHO permissible limit of 1.5 mg/l. In the case of iron, out of 54 stations, Fe value crosses the WHO limit in 5 stations during both the monsoon periods and the values ranges from 0.00 to 6.630 mg/L with a mean of 0.596 mg/L during premonsoon and post monsoon demonstrates 0.00 to 4.879 with a mean of 0.522 mg/L. Though there is a seasonal variation in the concentration of Fe values, the wells which are very close to the industries and southern part shows higher values and the highest value is recorded in station no. 35 in both the

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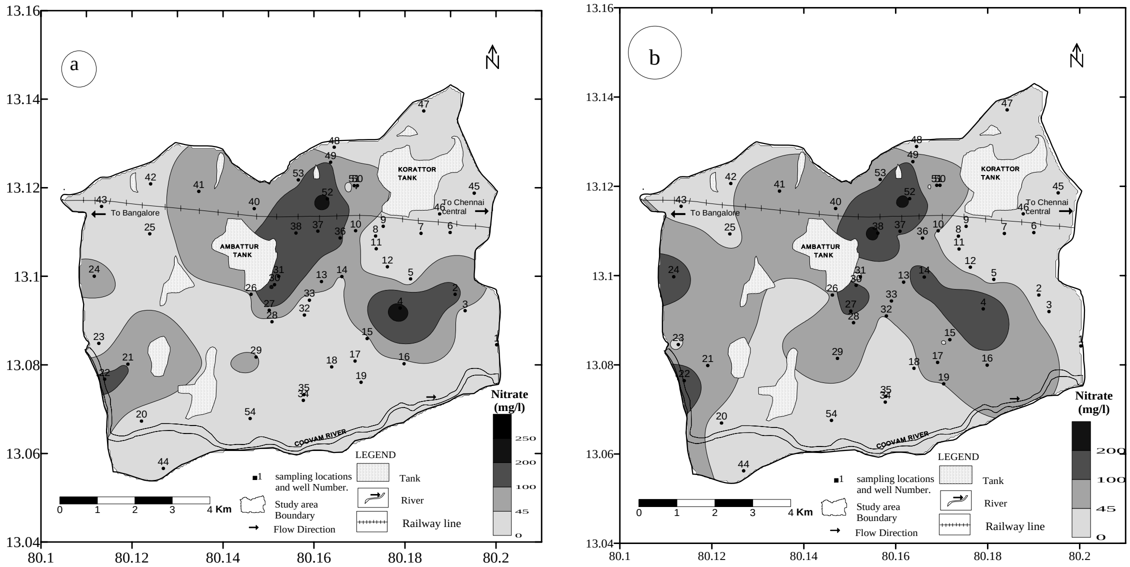
Fig .3. Distribution of Nitrate (a) during premonsoon period of May-2007 (b) post-monsoon period of January-2008



seasons. Since in this region, the predominant industrial units are engineering industries, which involves cutting, milling, sizing and producing different size and shape of scrap metal chiefly iron. Hence, the high Fe concentration in these waters could be attributed mainly to the anthropogenic activities rather the soil-water interaction. Pb values during premonsoon ranges from 0.00 to 0.436 with a mean of 0.163 mg/L and the values during postmonsoon ranges from 0.00 to 0.194 with a mean of 0.054 mg/L. Lead is usually found in low concentration in natural waters because Pb containing minerals are less soluble in water. Concentration of lead in natural water increases mainly through anthropogenic activities. Forty six wells during premonsoon and forty four wells during postmonsoon crosses the WHO limit of 0.01 mg/L. The presence of appreciable quantity of lead in ground water of the study area indicates that the industrialization and urbanization has resulted in severe contamination of ground water.

Conclusion

The hydrochemical investigation of groundwater in and around Ambattur industrial area reveals that 68.5% of samples during premonsoon and 55.5% of the samples during postmonsoon were unfit for drinking and other domestic purposes on the basis of TDS. The trend of TDS contours clearly show that the contamination level is possibly moving towards eastern & southeastern direction. During postmonsoon period nitrate concentration decreased in many wells which are mostly inside the industrial area. However it has increased in the residential area, which could be due to the leaching of nitrate from the open sewerage lines. This indicates that domestic waste leads to more nitrate problem than the industries and suggests lack of sufficient sanitary facilities due to uncontrolled urbanization. The highest correlation was found between EC and Chloride. The high content of Cl^- and Na^+ would have originated from the industrial wastes mainly from paint and chemical industries. Trace metal study indicates that during both pre and postmonsoon, concentration of Fe was high in many stations. Pb, Mn and Cr found to be high in the southern part of the study area. The findings clearly indicate that the ground water of the study area is heavily polluted especially with toxic heavy metals besides high TDS and other inorganic major constituents and the spread of pollution is towards the southern & south eastern direction. The findings of the study also indicate the need for proper industrial planning and the safe disposal of industrial and urban waste, which would otherwise lead to severe environmental degradation.

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