Arsenic Contamination of Groundwater in Vallanadu Region of Tuticorin District, Tamilnadu, India

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Abstract

The study area covers downstream of Thambraparani River about 400 Km^2 of Tuticorin and Tirunelveli districts of Tamilnadu. Thirty six groundwater samples have been collected and analysed for major ions, iron and arsenic. The arsenic concentration varies between 0.003 to 0.017 mg/l. The slightly high concentration of arsenic is found at Kilpattam and northern Vallanadu located near Thambraparani river sites and at Akanayakkanpatti, Melpuvani and kilpuvani located away from Thambraparani, but connected with lineaments which may facilitated the migration of arsenic from pre-monsoon. Kilpattam site to other isolated sites located at lithological boundaries. At present the main source of arsenic is identified from pesticides used for agriculture activities and automobile diesel wastage materials directly discharged into the course of Thambraparani especially at the upstream side. Though the arsenic content of groundwater is slightly higher >0.01 mg/l, it is recommended to curtail the used arsenic bearing pesticides for agriculture activities and usage of arsenic filters at the sites of pumping stations of Thambraparani drinking water system and at effluents sites of automobile and industrial sites at upstream area of Thambraparani river.

KEYWORDS: Groundwater quality, Arsenic contamination, Tuticorin Thambraparani river, Pesticides, Automobile wastage.

Introduction

Over exposure to arsenic is one of the most widespread Medical geology problems affecting more than one hundred million people in Bangladesh, India, China, Europe, Africa and North and South America. Arsenic, a metalloid, occurs naturally, being the twentieth most abundant element in earth's crust and is a component of more than 245 minerals. The inorganic forms consisting mostly of arsenite and arsenate compounds are toxic to human health. Humans are exposed to arsenic primarily from air, food and water. Arsenic is a minor constituent of some common minerals, and dissolved arsenic concentrations greater than 1 μg/L are common in groundwater. In some aquifers and under certain conditions, much greater arsenic concentrations can be found, and concentrations above 10 μg/L are not uncommon. However, elevated arsenic level in drinking water is the major cause of arsenic toxicity in the world. Reports of arsenic contamination in water are available from more than 30 countries in the world. In India, though cases of arsenic toxicity including liver fibrosis due to drinking of arsenic contaminated water were reported from Chandigarh in early 1978, occurrence of large number of cases of arsenic induced skin lesions were reported from Kolkata, West Bengal in 1984. Oxidation technologies that effectively convert arsenite to arsenate include the use of ozone, chlorine, and hydrogen peroxide (U.S. EPA, 1999). Oxidation of arsenite into arsenate has also proven effective in the presence of manganese oxide and iron oxide (Bajpai and Chaudhuri, 1999; Wang et al., 2000). Vallanadu is a major panchayat in the Tuticorin District of Tamilnadu. The study area **(Fig.1)** is comprised of the toposheet no. 58H/13 and 58H/14 of 1: 50,000 scales published by the Survey of India in the year 1969. Vallanadu lies about 30Km west of Tuticorin, which has both rail and Airbase connections. The district receives the rain under the influence of both southwest and northeast monsoons. The rainfall was gradually increases towards south, west and north and attains a maximum around Kayattar (722.5 mm) and Kovilpatti (734.8 mm) in the northwestern part. The district enjoys a hot tropical climate. The high relative humidity prevails throughout the year between 60 and 75%. The annual mean minimum and maximum temperature are 23°C and 40°C respectively.

Geology of the study area

Rocks of the Proterozoic to Archaean age are extensively exposed in the various parts of the State. The sediments ranging in age from the Gondwanas to Recent are mostly confined to the eastern coast. The crystalline rocks exposed in this part of the peninsular shield include the rocks of the Charnockite Group, the Khondalite Group and gneisses and schists, traversed by ultramafic, basic, granite and syenite intrusives. About 90% of the district is made up of crystalline rocks of Proterozoic group comprising of Charnockites, Garnetiferous biotite gneiss, Quartzite etc., Kurumalai and Vallanadu hillocks are structural features. Few inselbergs are seen in the plain. Pediments, rocky pediments, buried pediments and valley fills are the other landforms in the district. The Vallanadu area is a high grade metamorphic terrain of almandine amphibolite to granulite facies. The area is essentially comprised of different lithotypes i.e., quartzites, calc-silicate rocks, Khondalites, Composite gneisses, Cordierite gneiesses, charnockites, Grey granites and pink granites and veins of pyroxene granulites and amphibolites. Khondalites of vallanadu area of Kerala Khondalite Belt (KKB) are represented by pelitic, Semipelitic, psammitic and calcareous members. The distribution of various lithotypes of the area is shown in (**Fig.2**). Arsenic content is not reported from the lithounits of the study area or it is below detectable limit.

METHODOLOGY

Thirty six groundwater samples were collected from various locations in pre-monsoon and post monsoon of each. The water samples were collected in 200 ml plastic bottles for trace elements analysed and another1000 ml for major cation and anion study, which were corked immediately to make them airtight. Samples were acidified with concentrated nitric acid (HNO_{3}) for determination of trace elements to prevent any reaction. The physical parameters such as pH, EC, TDS and temperature were measured in the field. The major cations and anions were analysed at Spic Research Centre, Tuticorin and Trace elements analysed at NGRI, Hyderabad, using ICP-MS.

Water resource in the study area

Surface water

The river originating from the Western Ghats of Tamil Nadu is a major river draining the study area. It is perennial in nature and flooding is generated in heavy rainfall period only. The Chittar river, a tributary of Tambraparani river joint at Sivalaperi.

Groundwater potential Scenario of the study area

The geology of the area is mainly composed of hard rocks and the fractured and well jointed nature of the rocks provide good amount of groundwater. Comparatively the gneissic rocks are with high groundwater potential owing to the weathering and fracturing for a considerable depth. Charnockites are low in water potential but well jointed, sheared Charnockites are good for groundwater potential. Quartzites are mostly granular, well jointed, cracked and fissured and these properties are reasons behind Groundwater potential of quartzites. The open wells of the area vary in depth from 10 to 40 meters. The important aquifer systems in the district are constituted by (i) unconsolidated and semi-consolidated formations and (ii) weathered and fractured crystalline rocks. The porous formations in the district include sandstones and clays of recent to sub-recent and tertiary age (quaternary). The recent formations comprising mainly sands, clays and gravels are confined to major drainage courses in the district. The maximum thickness of alluvium is 45.0m bgl; whereas the average thickness is about 25.0m. Ground water occurs under water table and confined conditions in these formations and is being developed by means of dug wells and filter points11, 12. The productive zones are encountered in the depth range of 29.5 to 62m bgl. Alluvium, which forms a good aquifer system along the Tambraparani river bed which is one of the major sources of water supply to the villages. The water bearing properties of crystalline formations which lack primary porosity depend on the extent of development of secondary intergranular porosity. The occurrence and movement of ground water in these rocks are under unconfined conditions in the joints and fissures and dependent on the nature and extent of pores and interconnection of fractures zones. The yield characteristics of wells vary considerably depending on the topographic set-up, lithology and nature of weathering.

Hydrogeochemistry

Hydrogeochemistry of groundwater is a dynamic process, which undergoes a constant change with reference to time and space. The geochemical quality of groundwater is also related to the nature of host rock as well as the overlying rock types. Geochemical character of groundwater is an essential component of scientific management of existing groundwater resources. In the present study an attempt has been made to identify the suitability of existing groundwater with reference to drinking, domestic, industrial and irrigational needs. The quality of groundwater is as important as its quantity. All groundwater contains dissolved solids in solution that are derived from the location due to movement of the water. In order to carry out the objectives water samples collected from different locations are analysed to evaluate groundwater quality. The collection and testing of water samples is a very important operation in any water quality study. To analyse the groundwater quality, the groundwater should be collected in one liter capacity polythene bottles after rinsing the bottle with the water, which is to be sampled and the sample collected and sealed tightly. Sample should be collected from a well, only after it has been pumped for sometimes, otherwise non-representative samples of stagnant or contaminated water may be obtained. Water samples have been collected from the existing bore wells and open well sources in 36 locations of the study area. Water samples have been analysed for major cations such as Ca, Mg, Na, and K and anions – CO3, HCO3, SO4 and Cl and TDS, pH etc.

Results and Discussion
Total Dissolved Solids

Total dissolved solids of the ground water estimated for following locations are above 1000mg/l, namely Vallanadu south (Loc. no.1), Vallanadu north (Loc.no.2), Ariyakulam (Loc.no.3), Thiyagarayanagar (Loc.no.5), Kilpattam (Loc.no.10), Papayapuram (Loc.no.12), Melapalamadai (Loc.no.13), Sivalaperi (Loc.no.15), Maruvathalai (Loc.no.17&18), Savalaperi (Loc.no.19&20), Puliyampatti (Loc.no.21&22), Lakshmipuram (Loc.no.24&25), Akanayakkanpatti (Loc.no.28) and Kilpuvani (Loc.no.32). While TDS is below 1000 mg/l, in other areas like KTC nagar (Loc.no.4), Rajagopalapuram (Loc.no.6), Muthur (Loc.no.7&), Thiruthu (Loc.no.9), Melpattam (Loc.no.11), Rajavallipuram (Loc.no.14), Sivalaperi (Loc.no.16), Puliyampatti (Loc.no.23), Akanayakkanpatti (Loc.no.26&27), Melpuvani (Loc.no.29,30&31), Kilpuvani (Loc.no.33), Singathakurichi (Loc.no.35) and Kasilingapuram (Loc.no.36), all above water indicate their suitable nature for drinking and domestic purposes.

Groundwater Hardness

If the hardness is too low the water can be quite corrosive leaching copper and lead out of plumbing pipes. With very low hardness there would also be low levels of beneficial ions in the water, especially calcium and magnesium. If hardness is too high it can have an unpleasant taste, can dry out skin and cause scaling on fixtures and throughout the water distribution system. This scaling is undesirable because it begins to decrease the efficiency of plumbing systems, which results in greater power consumption and increased costs. With reference to BIS, Indian Standards (IS 10500:1991) desirable limit up to 300 mg/l, permissible limit up to 600 mg/l. (Table 1).

Arsenic concentration at Kilpattam in the pre-monsoon (**Fig.3**) and five places at Vallanadu north, Kilpattam, Akanayakkanpatti, Melpuvani and Kilpuvani in the post monsoon (**Fig.4**), where its concentration exceeded permissible limit of 0.01 mg/l (Table 3). In rest of places the concentration of arsenic is in the range from 0.03 to 0.009 mg/l in the pre-monsoon and 0.003 to 0.007 mg/l in the post monsoon. The Arsenic compounds are found both in tri and pentavalent forms in ground water, of which trivalent is more hazardous than the latter. The permissible limit of arsenic in drinking water is 0.01 mg/l (10 ppb/l) and if consumption exceeds this limit and exposed for a long period, it may lead to many health hazards like gastro intestinal tract ulcers, various skin ulcers and tumors. Arsenic is a naturally occurring trace element found in rocks, soils and the water in contact with them. It has been recognized as a toxic element and is considered a human health hazard. As per the BIS Standard for drinking water the maximum permissible limit of Arsenic concentration in ground water is 0.01 mg/l. In 2010, the jointFAO/WHO committee on food additives (WHO, 2010) withdrew the previous established provisional tolerable weekly intake (PTWI) of Arsenic, i.e. 15 μg/kg body weights (equivalent to 2.1 μg/kg body weight/per day). This was becausethe benchmark dose for a 0.5 % increased incidence of lung cancer (BMDL 0.5)was determined to be 3.0 μg Arsenic/kg body weight/day (2–7 μg/kg bodyweight/day), based on the range of estimated total dietary exposure. Iron concentration is widely distributed with various proportions in the study area. In about 100% of samples Fe concentration is exceeded the permissible limit of 0.3 mg/l in pre-monsoon and post monsoon (Table 2) (**Fig.5 and 6** respectively). Iron, the second most abundant element by weight in the earth's crust, is normally present in ground water in the ferrous form (Fe++), which is a soluble state and easily oxidized to trivalent ferric iron (Fe+++). Aeration of iron can affect the quality of both ground water and surface water. Iron rich ground water would affect the soil drainage with the deposition of ferric hydroxide on the surface. Dissolution of iron occurs as a result of oxidation and decrease of pH.

The high content of the arsenic in groundwater may be attributed to the common occurrence of pyrite, pyrhotite, magnatite and ilmenite-iron bearing minerals in gneisses and charnockites of the study area. The relative low values of dissolved iron (<0.7 mg/l) in the middle Ganga plains (i.e. Uttarpradesh and Bihar) compared to higher values in the West Bengal (upto 36 mg/l) and Bangladesh (upto 30 mg/l0 indicate that the middle Ganga plain environment may not be sufficiently reducing to mobile iron and arsenic in groundwater (nickson et al. 1998). In the study area the weathering and large limestone quarry activities might have released the iron in the groundwater so as to form the reducing water environment which the facilitated releasing of arsenic content in groundwater. In general, As and Fe concentration is decreasing from top to bottom in sediment samples of diesel locomotive works hole ranges with a mean of 4-8 mg/kg and mean of 361 mg/kg respectively are reported from Varanasi environs of Ganga river basin (Janardhan Raju, 2012). On considering environs of the study area, the source of arsenic there is four possibilities.

1. Arsenic containing pesticides (sodium arsenite or lead arsenate.
2. Arsenic dusts and gases, released during cement manufacture and mining waste dusts.
3. Paper manufacturing unit and textile unit, pH-mediated industrial effluents and tailing ponds (Swapna Mukherjee, 2011).
4. Arsenic bearing automobile diesel wastage materials normally fed into the Thambraparani river, since it is a lowest contour of the area.

The above source areas are situated in the upstream side of the study area. During the pre-monsoon period, arsenic concentration is located at Kilpattam site where Thambraparani river is showing meandering site and join with Chithar river. But during the post monsoon the arsenic concentration are located at five locations of lithological contact boundaries of granite/gneisses; gneiss and charnockite and also along Thambraparani river course. The concentration of arsenic seems to be migrated from Kilpattam area to the other areas like northern Vallanadu, Kilpuvani, Melpuvani and akanayakkanpatti during the rainy season through the lineaments during the post monsoon period.

Conclusion:

The slightly high arsenic content of groundwater in isolated locations are mainly due to migration of arsenic along Thambraparani river and along the lineaments so as to concentrate at lithological contacts. The arsenic main sources are usage of pesticides in the upland agricultural activity and from automobile diesel waste effluent discharge into the Thambraparani river course. Since arsenic content of lithology of the study area and surrounding environs are below detectable limits, not reported in earlier rocks analyses. It seems mining activities and cement industries are not causative factors for arsenic contaminants of Thambraparani river sites and adjoining sites connected with lineaments. Since textile and paper industries in the upstream site of Thambraparani are very few, their contributions to arsenic contamination are very less. All types of arsenic exposure can cause kidney and liver damage and in most severe exposure there is erythrocyte hemolysis (Swapna mukherjee, 2011). One sign of acute exposure is edema of the eyelids and gastrointestinal irritation and both central and peripheral neuropathies frequently occur. During chronic intoxication "garlic breath", skin sensitivity, dermatitis and keratitus frequently occur. It is recommended to invest in an arsenic water filter or low cost chemical pockets for reducing arsenic content can be used. If drinking water contains arsenic, looks for an alternative source of water, which has no arsenic contaminants. It is also recommended to educate the farmers not to use arsenic bearing pesticides for agriculture activities and also to execute arsenic filters at effluent discharge sites of industrial and automobile activities and at the sites of pumping stations for Thambraparani drinking water system.

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Table -1 Groundwater hardness classification of the study area

Hardness (mg/l)	Water Class	Sample location nos.
0 - 75	Soft	6,7, 11,27, 30, 34, 35, 36
75 – 150	Moderately hard	8, 14, 16, 31, 33
150 – 300	Hard	9, 23, 29
>300	Very hard	1, 2, 3, 4, 5, 10, 12, 13, 15, 17, 18, 19, 20, 21, 22, 24, 25, 26, 28, 32

Table- 2. Distribution of Iron concentration in groundwater (mg/l)

Sl. No.	Iron concentration range	Pre-monsoon		Post monsoon	
		No. of samples	Percentage	No. of samples	Percentage
1	<0.3	Nil	-	Nil	-
2	>0.3	36	100	36	100

Table- 3. Distribution of Arsenic concentration in groundwater (mg/l)

Sl. No.	Iron concentration range	Pre-monsoon		Post monsoon	
		No. of samples	Percentage	No. of samples	Percentage
1	<0.01	34	97.22	31	86.11
2	>0.01	1	2.78	5	13.89

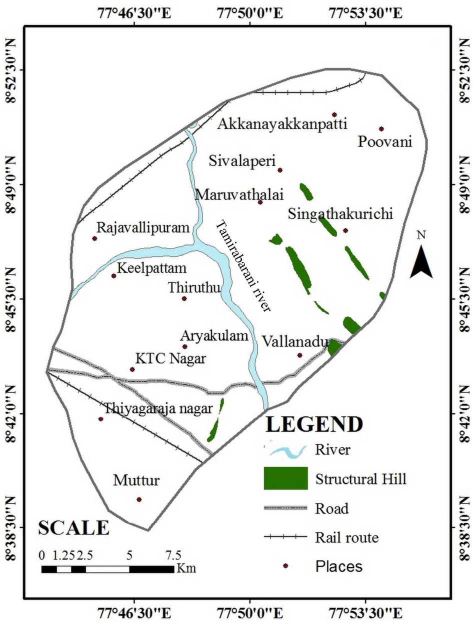

Figure – 1

Map showing water sample locations of the study area

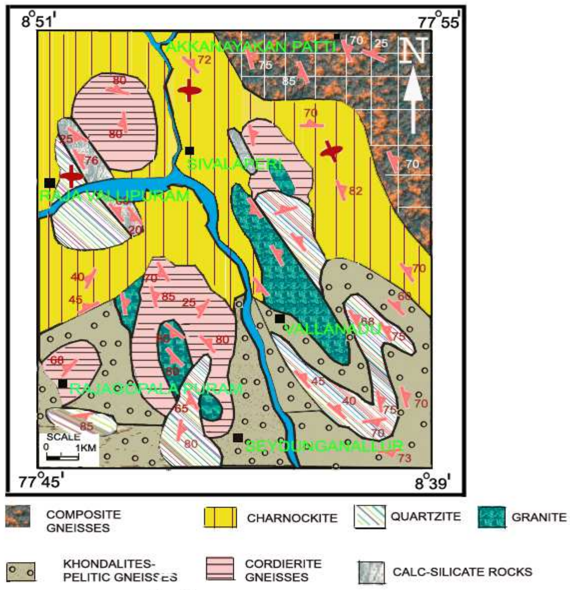

Fig.2

Geological Map of the study area

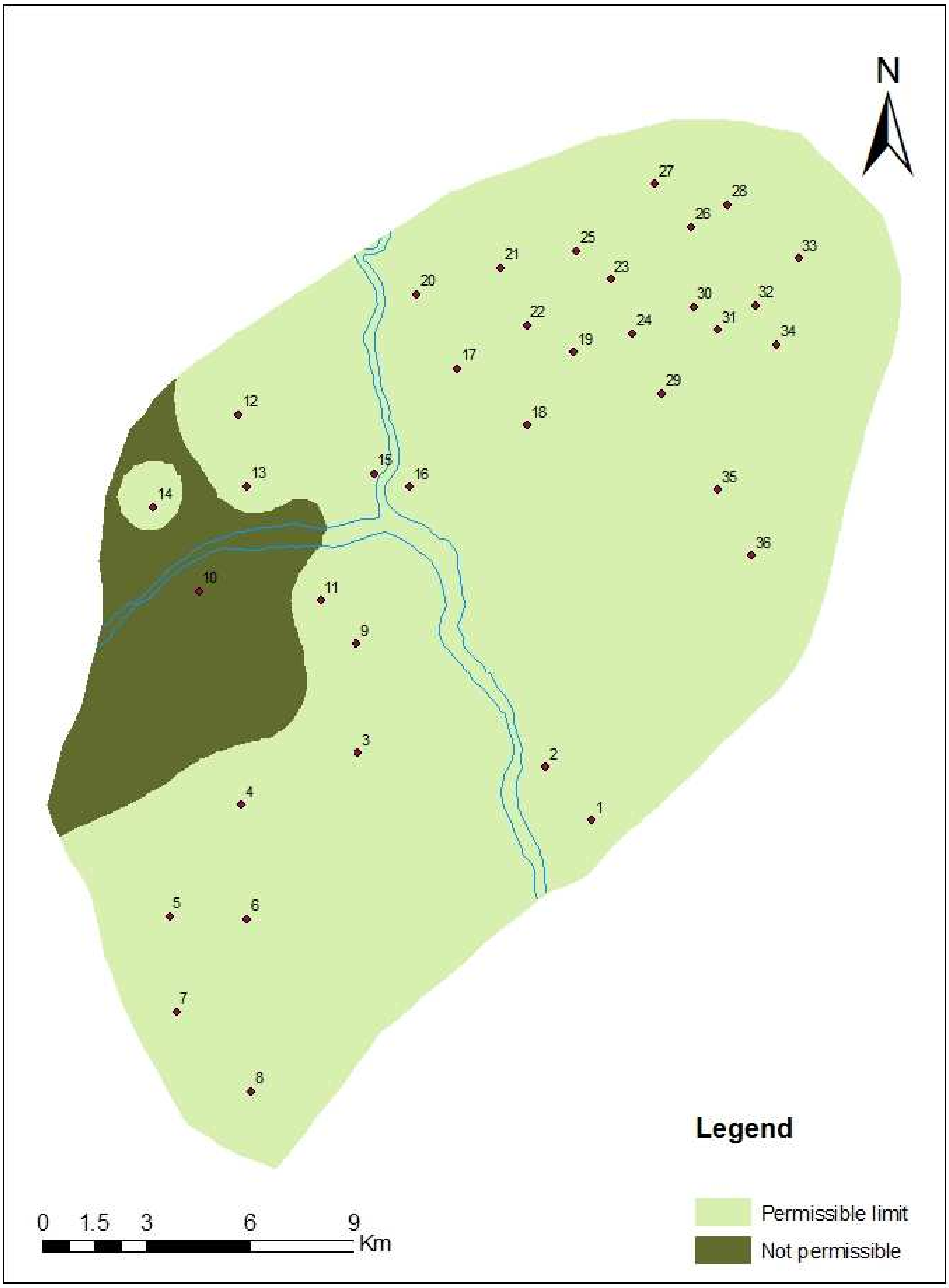

Figure-3. Arsenic distribution in groundwater sample (Pre-monsoon)

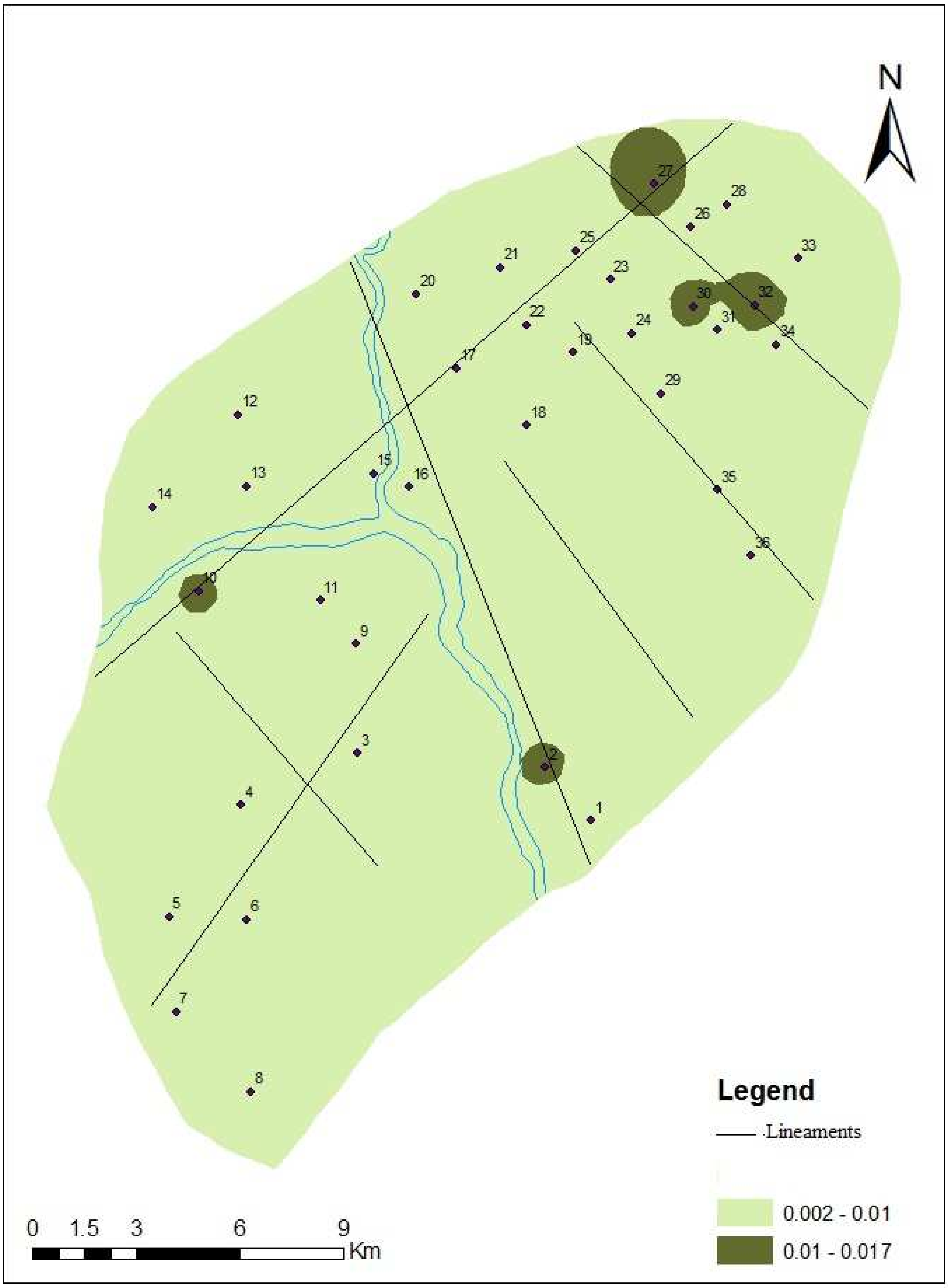

Figure-4. Arsenic distribution in groundwater sample (Post monsoon)

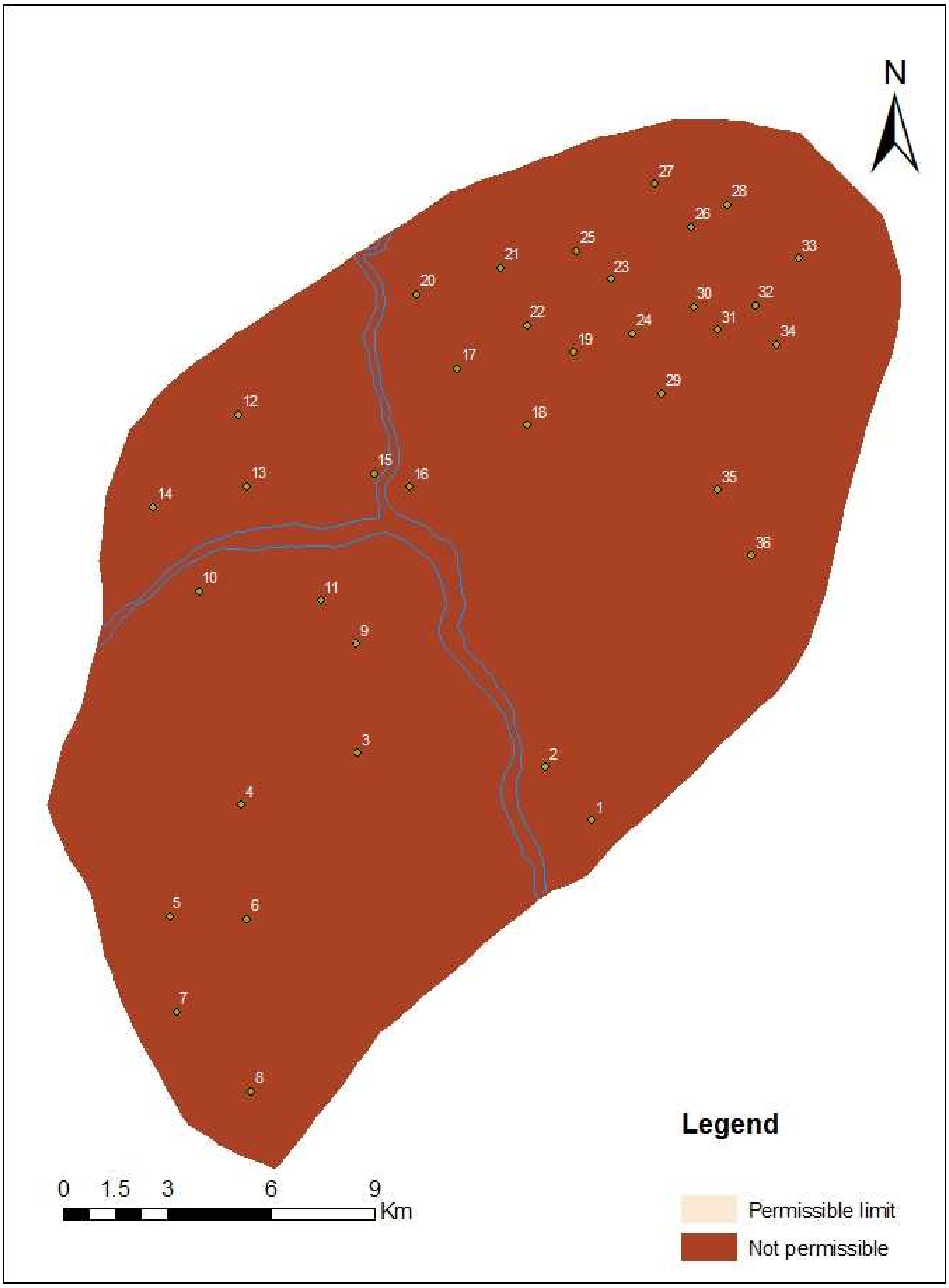

Figure-5. Iron distribution in groundwater sample (Pre-monsoon)

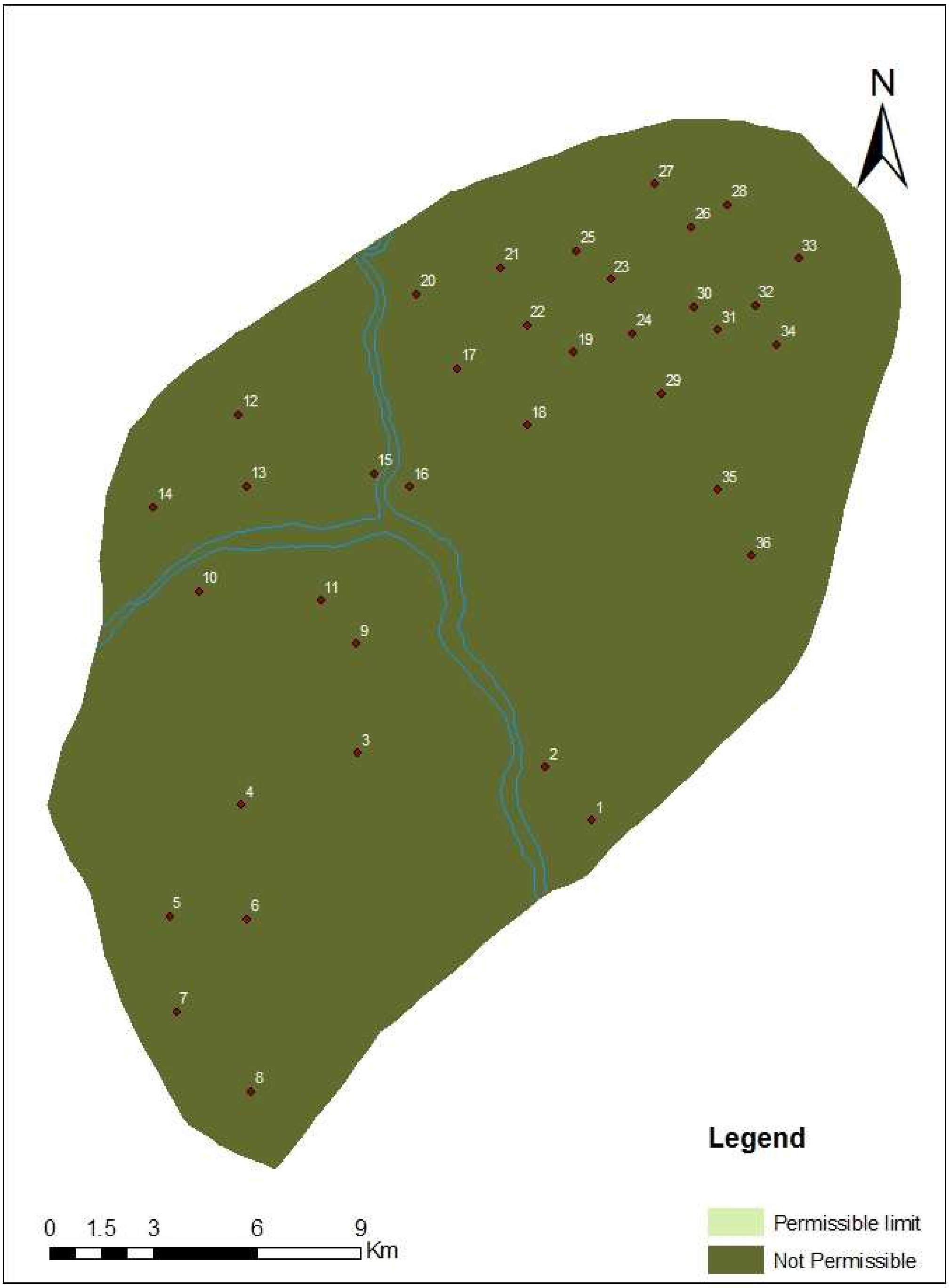

Figure-6. Iron distribution in groundwater sample (Post monsoon)