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Groundwater Quality Assessment around Tanneries at Tiruchirappalli, India

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Abstract: Water as a resource, fundamental amenity and universal solvent is shared by inhabitants. The tanning industry is one of the oldest industries in India. The tanning industry is an especially large contributor of pollutants to water resources. Concentration of pollutants more than their permissible limits in potable water leads to health problems, such as water-borne diseases like fluorosis, typhoid, jaundice, cholera, premature baby and other problems, especially in infants. The water samples were taken from the villages Sembattu and Gundur and there are twelve numbers of tanneries working in this area. Various physicochemical parameters such as pH, electrical conductivity, chloride (Cl), total hardness $CaCO_3$ (TH), nitrate (NO_3), sulphate (SO_4) and alkalinity have been analysed. In the analyses, chloride and hardness content in groundwater were on higher side compared with Bureau of Indian Standard (BIS) and World Health Organization (WHO) standards but the level of sulphate was within permissible limit. It is evident that groundwater quality is gradually getting deteriorated and it may deteriorate further with time. The results envisaged that the quality of groundwater around tanneries areas is poor, and is not suitable for drinking purpose and can only be used after proper treatment.

Key words: Groundwater quality, groundwater pollution, tanneries, physicochemical parameters.

Introduction

Groundwater is really a mixture of waters from many sources of different ages. The age of a particular sample is the average age of all the constituent components. The age of groundwater increases with depth. Groundwater is actually a complex, generally dilute, chemical solution. The chemical composition is derived mainly from the dissolution of minerals in the soil and the rocks. Rainfall itself is a dilute chemical solution and contributes significant proportions of some constituents in groundwater. The natural groundwater quality varies with local hydrogeological conditions. In its passage from recharge area to the aquifer, groundwater may dissolve substances that it encounters or it may deposit some of its constituents along the way depending on the pH of the groundwater (Tien, 2009). Groundwater is an essential and vital component of our life support system. The groundwater resources are being utilized for drinking, irrigation and industrial purposes. Generally groundwater was free from contamination. Before the industrial revolution, the main risk to groundwater quality was from bacteria and viruses. However, due to rapid growth of population, urbanization, industrialization and agriculture activities, groundwater resources are under stress. In many surface aquifers, domestic sewage and industrial effluents are the chief polluting sources, and surface runoff is a seasonal phenomenon that is largely influenced by the climate prevailing in the basin (Giridharan et al., 2009). Increased settlement of human population in urban areas has resulted in enhancement of buildings, roads,

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vehicles, factories, urban sewage and storm drains, smoke and dust, and garbage hazards which lead to severe surface, groundwater and air pollution (Subba Rao, 1997; Swarna Latha, 2010).

The era of unlimited fresh water supply is coming to an end due to pollution of water sources owing to the increasing discharge of large volume of waste water and toxic nature of wastes. Much of the health hazards in developing countries is largely due to lack of the safe drinking water (Sonawane, 2010). Chloride ion Cl^-, sulphate ion SO_4^{2-}, nitrate ion NO_3^-, and carbonate ion CO_3^{2-} occur as anions in groundwater. Sulphate contents in water may be due to natural sources as well as anthropogenic sources (Venkatesan, 2009). Concentration of pollutants more than their permissible limits in drinking water leads to health problems such as water-borne diseases like fluorosis, typhoid, jaundice, cholera, premature baby and other problems, especially in infants (Prakash, 2006). According to WHO organization, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it (Ramakrishnaiah, 2009). The tanning industry is one of the oldest industries in India. The tanning industry is an especially large contributor of chromium pollution to water resources. It is estimated that in India alone, about 2000 to 3200 tons of elemental chromium escape into the environment annually from the tanning industries, with a chromium concentration ranging between 2000 and 5000 mg L^{-1} in the effluent compared to the recommended permissible limit of 2 mg L^{-1}(Kumar, 2010).

The environment is under increasing pressure from liquid wastes emanating from the leather industry. These are inevitable by-products of the leather manufacturing process and cause significant pollution unless treated in some way prior to discharge (Bosnic, 2000). Groundwater is one of the main sources of drinking and irrigation water for Tamil Nadu. Any groundwater that has already been contaminated due to improper industrial and tannery waste water disposal or handling practices needs to be remediated. At the same time, future occurrence of groundwater contamination must be prevented by designing the tannery waste disposal facilities that can effectively contain the wastes that are being disposed. Groundwater is an important resource to act as a natural storage that can buffer against shortages of surface water (Kan, 2012). The main objective of our present work is analysis of the groundwater quality due to tannery effluent discharged around Sembattu and Gundur villages located in Tiruchirappalli to Pudukoattai main road. Groundwater samples were collected in and around Sembatty and Gundur villages and compared with the groundwater qualities like pH, electrical conductivity, chloride (Cl), total hardness $CaCO_3$ (TH), nitrate (NO_3), sulphate (SO_4) and alkalinity with World Health Organization (WHO) and Bureau of Indian Standard (BIS) standards to conclude the effect of tannery effluent discharge on the groundwater quality for its suitability in drinking purpose.

Methods

Study Area

Tiruchirappalli metropolitan city is located at the Central part of Tamil Nadu about 300 km south of Chennai, India. The city currently covers an area of 146.90 sq.km and it lies at an altitude of 78 m above sea level. The population increased greatly, from 7,52,066 in 2001 to 8,26,636 in 2006 with the population density of about 5320 per sq.km. The water samples were taken from the villages Sembattu and Gundur. In these two villages 12 numbers of tanneries are working. These are situated in the area nearby the Trichirappalli International Airport on Pudhukottai Road. The tanneries draw the water from bore wells locally and also from distant places for their requirements, but they discharge the effluent locally. In some local ponds the effluents are stored and appear to be dark in colour, and during rainy seasons these are carried away to distant places and pollute the groundwater elsewhere. Ten Samples were collected in bottles from the dug wells in and around the tanneries situated in two villages Sembattu and Gundur. The bottles are clear and clean having 1000 mL capacity each. After taking the sample these were carefully closed with lid. For the purpose of testing the chromium each sample was added with 1 mL of nitric acid to prevent the evaporation of chromium before taking sample in the sample bottle. The location of sample stations is shown in the location map (Figure 1).

Sampling Procedure

From the study area, ten dug wells were chosen for sample collection. The representative sampling sites were chosen in order to cover various anthropogenic activities including waste disposal. The sample containers (polypropylene) were pre-cleaned by soaking in 2 mol L^{-1} HNO_3 for 24 h and washed with deionized

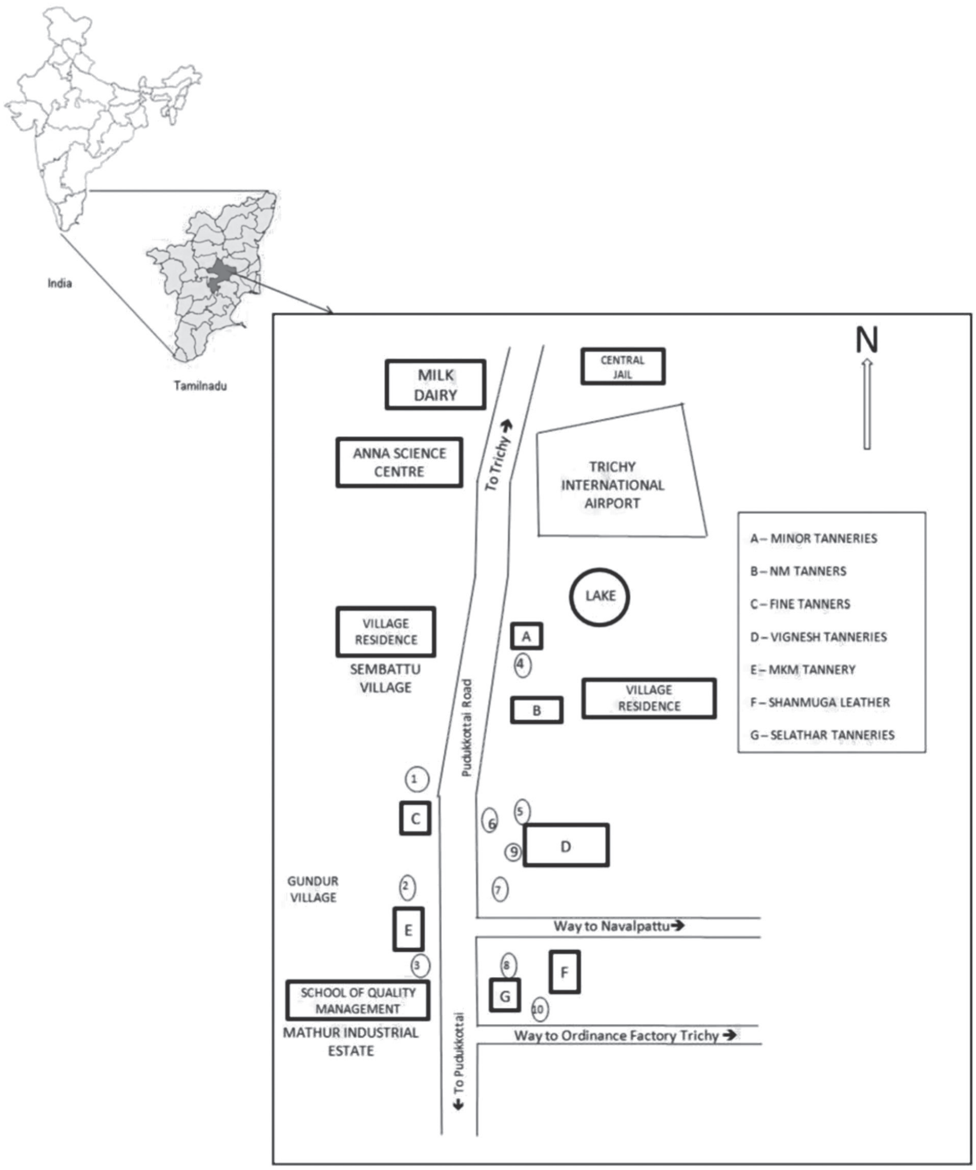

Figure 1: Map showing location and sampling points collected in the study area.

water three to four times. Before collecting samples, the containers were rinsed with the samples. Groundwater samples were collected from the wells at 10 cm below the static water level using a water sampler. The sampling depth of 10 cm below the water level was chosen to avoid any suspended matter entering into the container. The samples were kept in ice boxes and transported into the laboratory and stored at 4 °C until analysis.

The physico-chemical parameters like pH, EC, total hardness, chloride, sulphate, nitrate, fluoride and alkalinity were also estimated as per standard methods (APHA, 2005). The volumetric procedure called Mohr's method was used to determine chlorides in samples. This depends upon the precipitation of silver chlorides (AgCl) by the addition of a standard solution of silver nitrate ($AgNO_3$) to the sample in the presence of potassium chromate (K_2CrO_4) which is the indicator capable of demonstrating the slightest excess of $AgNO_3$ to reach the end point. A reddish brown precipitate of silver chromate ($AgCrO_4$) was formed which shows that all the chloride has been precipitated. The EDTA method was considered to be most accurate for determination of hardness as compared with soap test. In EDTA method, the total hardness is measured by titrating against Ethylene Diamine Tetra Acidic acid (EDTA) or it is sodium salt so as to form stable complex ions with the calcium (Ca^{++}) or magnesium (Mg^{++}) ions in water.

Sulphate ions have been precipitated in HCl medium with $BaCl_2$ to form barium sulphate crystals of uniform size. Light by the precipitate has been measured using a (spectrophotometer) Nephlo turbidity meter (Sabal, 2008).

Results and Discussion

Water need for drinking and domestic purposes should be chemically safe and free from undesirable physical properties such as colour, turbidity and should have a no unpleasant taste and odour. The predominant pH range is between 6.6 and 8.6, which is safe for drinking. In groundwater, hardness is generally due to the presence of bicarbonate, chloride and sulphates of calcium and magnesium. Hardwater is generally believed to have no harmful effect on human being and the cardio vascular diseases are reported to be confined from the areas of softwater than those having hardwaters. It may, however, cause encrustations in water supply structures and has adverse effects on domestic use such as reducing the effectiveness of cleaning solution. Analytical results of different samples collected in and around tanneries from study area of Sembattu and Gundur villages have been mentioned in Table 1.

The pH is expressed as a number ranging from 0 to 14. The number is an expression of the concentration of H^+ ion in the solution. The value of pH with respect to the study area was found in the range of 7.6 to 8.3. The maximum value of pH was found in sample 8 towards south of Nnavalpattu Road and minimum pH (7.6) was observed in sample 7 towards north of Navalpattu Road in Guntur village (Table 1 and Figure 2). According to ISI (1982) pH should be between 6.5 and 8.5. The excess range of pH affects taste and corrosion in water supply system. The pH was found to be within the permissible limit. Salinity is the saltiness or dissolved salt contents of a water body. Salt content is an important factor in water use. Salinity can be technically defined as the total mass in grams of all the dissolved substances per kilogram of water. Electrical conductivity is a numerical expression of ability of an aqueous solution to carry electrical current.

BIS has recommended a drinking water standard for total dissolved solids a limit of 500 mg L^{-1} (corresponding to about EC of 750 µS cm^{-1} at 25 °C) that can be extended to a TDS of 2000 mg L^{-1} (corresponding to about 3000 µS cm^{-1} at 25 °C) in case of no alternate source. Water having TDS more than 2000 mg L^{-1} are not suitable for drinking uses. Minimum (1780) in location 6 and maximum (1900) in location 4 was reported in villages (Table 1 and Figure 3). Chloride is present in all natural waters, predominantly at low concentrations. It is highly soluble in water and moves unreservedly with water through soil and rock. BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg L^{-1} of chloride

Table 1: Groundwater quality around tanneries

Sample location	*Parameters*						
	pH	*Electrical conductivity (EC)*	*Chloride (Cl)*	*Total hardness ($CaCO_3$) (TH)*	*Nitrate (NO_3)*	*Sulphate (SO_4)*	*Alkalinity as $CaCO_3$*
Sample 1	7.8	1800	350	590	71	30	340
Sample 2	8.1	1810	355	580	70	31	350
Sample 3	7.9	1865	360	600	75	33	360
Sample 4	8.2	1900	348	548	72	29	351
Sample 5	7.7	1820	347	550	69	28	345
Sample 6	7.9	1780	319	640	68	27	350
Sample 7	7.6	1790	358	520	73	30	352
Sample 8	8.3	1805	360	535	74	31	338
Sample 9	8.1	1845	365	600	77	32	362
Sample 10	8.0	1790	327	645	72	29	360
Average	7.9	1820	348	580	72	30	351

Except EC (µS cm^{-1} at 25 °C), all values are in mg L^{-1}.

in drinking water. The concentration of chloride (in mg L^{-1}) in groundwater from observation wells have been used to illustrate the distribution patterns of chloride in different ranges of suitability. Chloride varied from 319 to 368 mg L^{-1}. The highest value of chloride in groundwater samples was observed in location 9. The average value of chloride in groundwater samples was 351 mg L^{-1}. It is evident from Table 1 and Figure 4 that all the samples have chloride values greater than 250 mg L^{-1}. Higher content of chlorides gives salty taste to water. This excess value leads to taste, indigestion, affected palatability and corrosion in water supply.

Hardness of water is not a specific component but is a variable and complex mixture of cations and anions. Total hardness (TH) varied from 520 to 645 mg L^{-1}. The highest value of total hardness (TH) in groundwater samples was observed in location 10. WHO recommended safe permissible limit for hardness i.e., 100-500 mg L^{-1}. In groundwater, hardness is mainly due to carbonates, bicarbonates, sulphates and chlorides of Ca and Mg (Table 1 and Figure 5). Higher range of hardness may cause urinary concretions, kidney/ stomach disorder.

As per the BIS Standard for drinking water the maximum desirable limit of nitrate concentration in groundwater is 45 mg L^{-1} with no higher value. The occurrences of nitrate in groundwater was beyond permissible limit (45 mg L^{-1}) and varied from 68 to 77 mg L^{-1}. The highest value of nitrate in groundwater samples was observed in location 9. The average value of nitrate in groundwater samples was 73 mg L^{-1}. Though nitrate is considered comparatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of matheomoglobinemia particularly to infants. The specified limits are not to be exceeded in public water supply. The limit is exceeded, hence water is considered to be unfit for human consumption (Table 1 and Figure 6).

Sulphates are a component of tannery effluent, emanating from the use of sulphuric acid or products with a high (sodium) sulphate content. The sulphate values range from 27 to 33 mg L^{-1} in the groundwater samples nearby tannery industries. The sulphate values of groundwater are shown in Figure 7. The sulphate values are within permissible values as per BIS (up to 250 mg L^{-1}). Excess value causes gastrointestinal irritation. More concentration (750 mg L^{-1}) with Mg causes laxative effect. Alkalinity ranged from minimum (338 mg L^{-1}) in location 8 to maximum (362 mg L^{-1}) in location 9 in south and north of Navalpattu Road (Table 1 and Figure 8). As per the BIS Standard for drinking water the Alkalinity of most water samples was found to be out of permissible limit 200 mg L^{-1}; elevated value of alkalinity gives an objectionable taste to water.

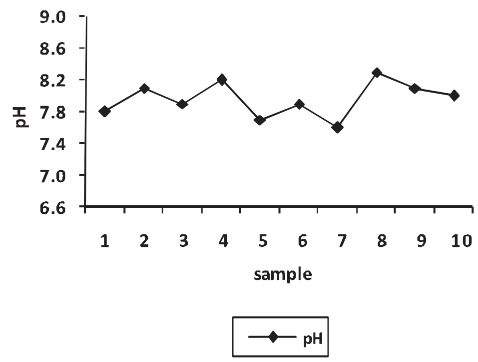

Figure 2: pH variation in groundwater samples.

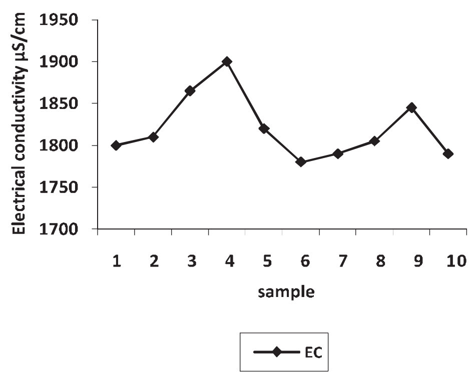

Figure 3: Electrical conductivity variation in groundwater samples.

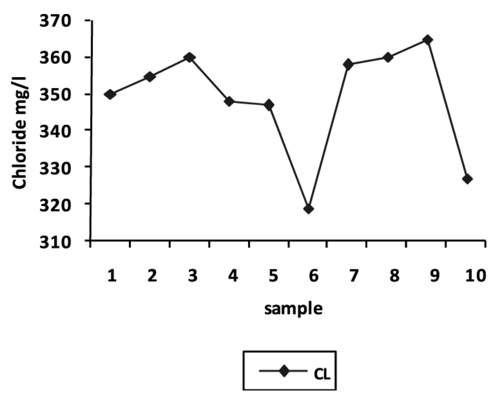

Figure 4: Chloride variation in groundwater samples.

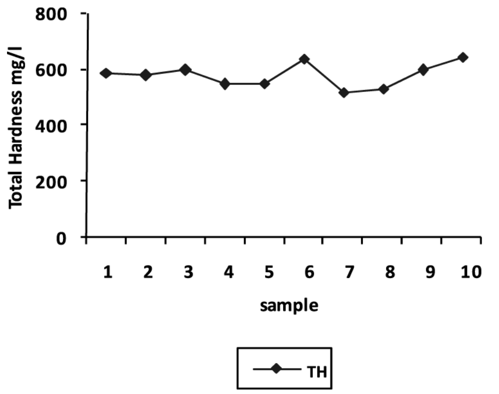

Figure 5: Total hardness variation in groundwater samples.

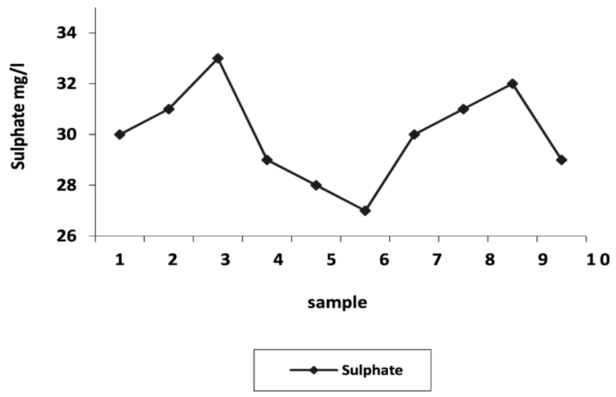

Figure 7: Sulphate variation in groundwater samples.

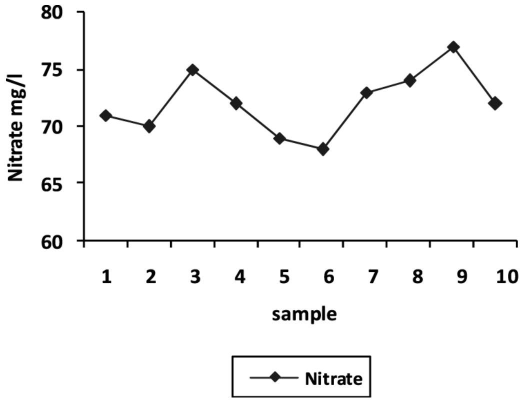

Figure 6: Nitrate variation in groundwater samples.

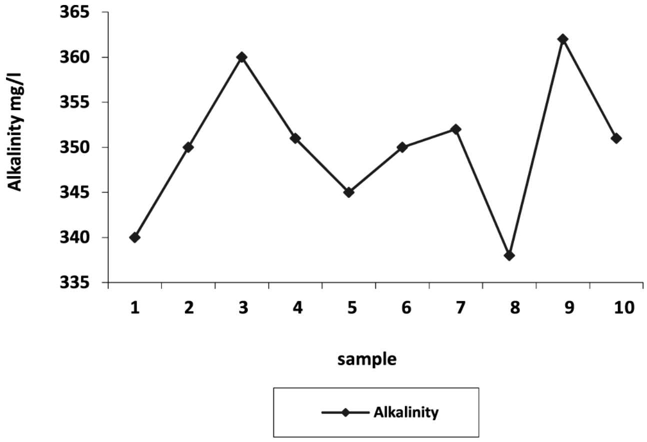

Figure 8: Alkalinity variation in groundwater samples.

Conclusions

Groundwater is a precious natural resource. It forms an important part of the hydrologic cycle. In comparison with the surface water pollution, the groundwater contamination is very difficult to control. The groundwater in and around tannery industries were analyzed. From the analysis, chloride and hardness content in groundwater were on higher side compared with BIS and WHO standards but the level of sulphate was within permissible limit. It is evident that groundwater quality is gradually getting deteriorated and it may deteriorate further with time. But further tests must be undertaken for other pollutants to evaluate the groundwater as used for potable water. So public should be made aware of the water quality importance and hygienic conditions before use. Also it is necessary to implement certain remedial measures.

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Contents