Assessing the changes in groundwater quality around tanneries: the Chennai example (India)

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Abstract A study was carried out with the aim of assessing the groundwater quality with respect to chromium around tanneries in a part of Chennai, southern India. The wastes from these tanneries are treated in the common effluent treatment plant (CETP) and released to open drains that join the Adyar River flowing nearby. Water samples were collected from 22 locations in March 2010 and analysed for chromium content. The chromium concentration in groundwater was compared with the study carried out in 2008. EC ranged from 985 to 5344 μS/cm and was at permissible levels in only 5.3% of groundwater samples. The chromium concentration ranged from 5 to 35 μg/L which was within the maximum permissible limit of 50 μg/L (Bureau of Indian Standards for drinking water quality). A general pattern of high concentration in the northeastern part of the study area was found where the tanning industries and CETP are located. The CETP started functioning in 1995 in this area after stringent rules were imposed to treat the effluent before its disposal. However, before 1995, effluent with high concentration of many ions was released to open drains without proper treatment. In 2008, the chromium concentration in the study area ranged from 4 to 990 μg/L while EC ranged from 584 to 6690 μS/cm. Due to the functioning of the CETP, the chromium in groundwater has decreased, as evident from the studies in 2008 and 2010. However, the quality of groundwater based on EC is still poor, which may be because the CETP removes chromium effectively as it is a potentially-toxic heavy metal, rather than decreasing the concentration of all the ions in groundwater. Hence, it is essential to remove the TDS and to frequently monitor the groundwater quality at regular intervals.

Key words leather industry; tannery pollution; chromium; electrical conductivity; total dissolved solids; Chennai, India

INTRODUCTION

Groundwater pollution is of major concern in any country as most of the world's population relies on groundwater for their freshwater. Due to a tremendous increase in industrial activities in the last few decades, a number of environmental problems have been reported in several developing countries. Tanneries are among those industries that affect groundwater quality as they use a variety of chemicals, such as sodium chloride, sodium sulphate, chromium sulphate, vegetable oils, lime and dyes. They also use large quantities of water during the tanning process. In India, there are more than 1200 tanneries of which the Tamil Nadu state accounts for more than 75% (Tamil Nadu Social Development Report, 2000). The tanneries in Tamil Nadu are located in Chromepet, Chennai, the capital of Tamil Nadu state, some towns (Ranipet, Ambur, Vaniyambadi) located about 120 km west of Chennai and in Dindigul, approx. 400 km south of Chennai. The large-scale tanneries send the effluent to the common effluent treatment plant (CETP) where it is treated. However, it is generally found that these treatment plants are mainly aimed at removing chromium, which is a potentially-toxic heavy metal, rather than reducing the total dissolved solids (TDS) in the effluent. Thus the effluent released by these treatment plants has high concentrations of most of the ions that come from the chemicals used during the tanning process. The treated effluent from these industries pollutes the surface water and groundwater in the adjacent areas, thereby leading to deterioration of the water quality.

This study was carried out in and around Chromepet area where the groundwater, which was of good quality even at 9–12 m depth, has been reported to have become salty (Tamil Nadu Social Development Report, 2000). Salinity in groundwater is a major problem around tanneries and is due to the use of large amounts of sodium and calcium salts in the tanning processes (Mondal *et al*., 2005). In addition, concentrations of heavy metals such as copper, cadmium, chromium, zinc, iron and lead significantly greater than the Bureau of Indian Standards (BIS) limit are also present in groundwater around tanneries in Vellore, Dindugal and Kancheepuram districts of Tamil Nadu (Ravichandran, 2009). Bhattacharya (2004) reported that the tanneries in and around Chromepet and the nearby Pallavaram area have discharged the effluents into open drains. The Chromepet area got its name from the "chrome tanning" process practiced here. The effluent resulting from these leather tanning industries has been sent to the CETP located at Pallavaram since 1995 (Govindasamy *et al*., 2006) where it is treated and then disposed of into open drains that join the Adyar River located to the west side (Brindha *et al*. 2009, 2010; Brindha & Elango 2012).

A study carried out in 2008 reported chromium concentrations in groundwater of up to 1 mg/L, which is above the permissible limit of 50 µg/L in drinking water (BIS, 1993). The people in this area depend on piped water supplied by the Government for domestic use. There are also private wells that cater for the needs of the local population. Hence, it is important to study the groundwater quality of this area, especially with regard to chromium. Thus, this study was carried out in and around Chromepet area of Chennai with the aim of assessing the groundwater quality with regard to chromium.

STUDY AREA

The study area forms a part of the major city of Chennai, Tamil Nadu, India. Samples were collected from Chromepet and Pallavaram areas (Fig. 1) where small-scale and large-scale tanneries are located. This area is located 13 km from the Bay of Bengal. The climate is of low humidity and high temperature. The temperature in summer ranges from 38°C to 42°C (May to June) and in winter from 18°C to 34°C (October to December). The average annual rainfall is 1200 mm. The northeast and southwest (July to September) monsoons contribute to 54% and 36%, respectively, of annual rainfall. The land use consists mainly of compact settlements, roads, schools, colleges and industries. Topographically this region slopes gently towards the east.

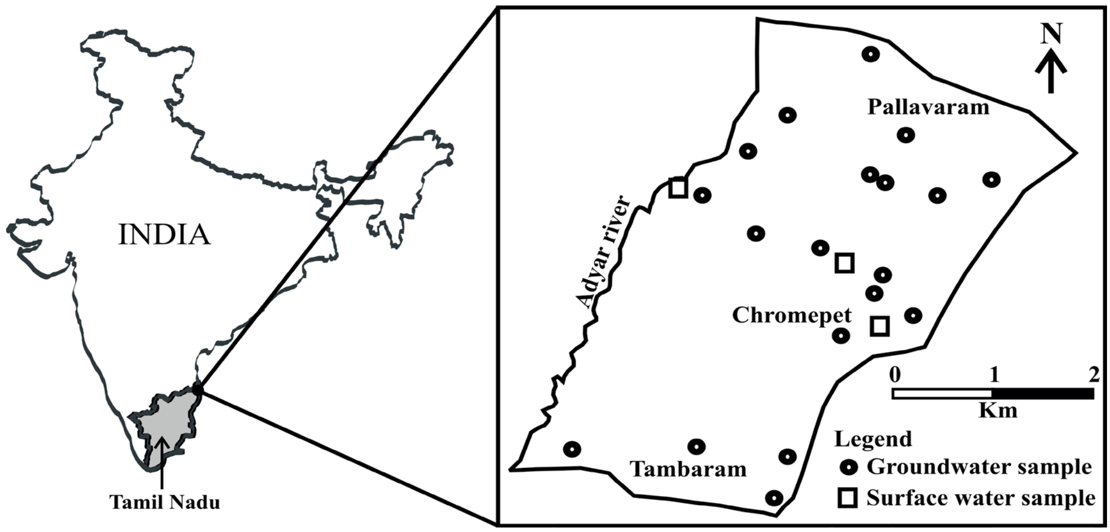

Fig. 1 Location of the study area.

Geology and hydrogeology

The region is mostly comprised of Archean crystalline rocks at the basement and they outcrop in the west and also in the Adyar River bed. The Archean crystalline rocks include charnokites and gneisses, and are generally weathered at the top. The depth and intensity of weathering in general varies from 4 to 15 m. The weathered rocks are overlain by a thin soil cover and also by thin deposits of alluvium, especially along the river. The alluvium generally consists of sand, silt and clay in different proportions. The thickness of the soil/alluvium occurring above the basement crystalline rocks varies from 3 to 5 m.

Groundwater occurs in this area under unconfined conditions both in the upper soil and the lower weathered/ fractured crystalline rocks. Bore wells in this region extend down to 100 m. Transmissivity varies between 6 and 872 m^2/day, and the storativity between 2.9×10^{-4} and 4.5×10^{-3} (CGWB, 2008). Wells in the crystalline formation generally yield up to 7 L/s (CGWB, 2008).

MATERIALS AND METHODS

A well inventory survey was carried out in the study area and the electrical conductivity (EC) of water samples was measured. Nineteen groundwater samples and three surface water samples, which included two lake water and one river water sample, were collected in March 2010 (Fig. 1). The topographic elevation of where water levels were measured was recorded by global positioning system (GPS; TRIMBLE Geoexplorer 3). Groundwater level was recorded using a water level indicator (Solinst 101). Groundwater and surface water samples were collected in plastic bottles of 500 mL capacity that had been cleaned with 1:1 HNO_3 and then rinsed with double-distilled water. During sampling, the bottles were rinsed with the groundwater to be sampled before filling with the sample. Parameters such as pH and EC were measured in the field using a multi-parameter portable instrument (YSI 556). Total dissolved solids (TDS) in groundwater was calculated using the formula: TDS (mg/L) = EC (µS/cm) × 0.64. The groundwater samples were analysed for chromium using a Perkin Elmer Atomic Spectrometer (Analyst 800). Standards of 1, 0.5 and 0.1 mg/L were used for calibration. A visit to a tannery in this area was also carried out to understand the tanning process.

RESULTS AND DISCUSSION

Groundwater level in this area ranged from 8.5 to 31 m a.m.s.l. during this study. The general quality of groundwater can be assessed by the pH, EC and TDS, which is discussed briefly. The minimum, maximum, mean and standard deviation of various parameters are given in Table 1.

Table 1 Statistical summary of various parameters measured in groundwater in 2008 and 2010.

Parameter	2008 (*n* = 36)*				2010 (*n* = 19)				Treated effluent from CETP*
	Min	Max	Mean	Standard deviation	Min	Max	Mean	Standard deviation	
pH	7.3	8	7.6	0.2	6.6	8	7.5	0.3	7.9
EC (µS/cm)	584	6690	2327	1214	985	5344	2820	1263	9197
TDS (mg/L)	374	4282	1489	777	630	3420	1805	808	5886
Chromium (µg/L)	4	990	481	328	5	35	12	8	90

*(Brindha & Elango, 2012)

pH

The pH ranges from 6.6 to 8, with a mean of 7.5. Most of the groundwater samples were slightly alkaline in nature. The Bureau of Indian Standards for drinking water quality (BIS, 1993) recommend a pH limit of 6.5 to 8.5 in water used for domestic purposes; all groundwater samples fall within this range. The lake samples had pH of 7.7 and 8.9, while the river had a pH of 8.85, all being alkaline. The spatial variation in pH in groundwater and surface water samples is given in Fig. 2. The pH of treated effluent collected from the CETP was 7.9 (Brindha & Elango, 2012).

Electrical conductivity

EC gives a general idea of the major ion composition in the measured samples. Groundwater EC ranged from 985 to 5344 µS/cm (Table 1). Groundwater was classified based on EC; levels were permissible in 5.3% and not permissible in 57.9% of sampling locations, while 36.8% were in the hazardous category. The spatial variation in EC is shown in Fig. 3. The highest EC of 5344 µS/cm was observed in a well located close to the effluent treatment plant; thus the impact of the treated effluent on the groundwater quality could be observed in this area. Also, the northeastern parts where the tanneries are located have groundwater with higher EC than the other areas.

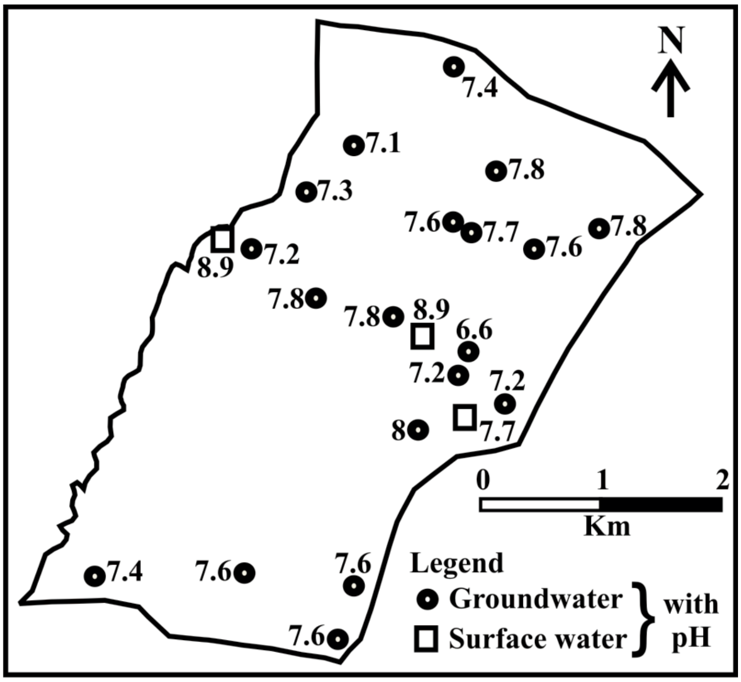

Fig. 2 Spatial variation in pH of groundwater.

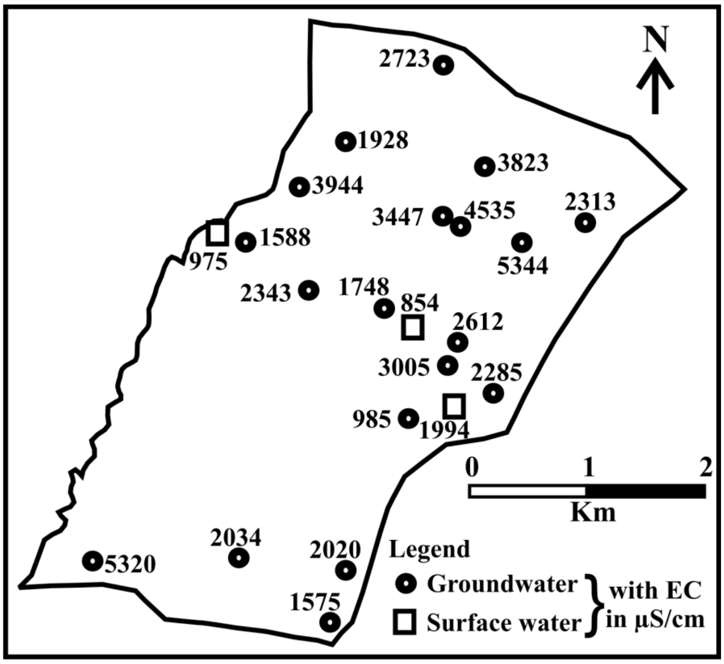

Fig. 3 Spatial variation in EC (µS/cm) of groundwater.

Total dissolved solids

Groundwater TDS was classified based on Freeze & Cherry (1979) and David & DeWeist (1966) to determine its nature. Most of the groundwater samples in this area were brackish, i.e. between 1000 mg/L to 10000 mg/L (94.7%) and one sample was fresh (5.3%) water type, i.e. less than 1000 mg/L as per Freeze & Cherry (1979). According to David & DeWeist (1966) classification, none of the groundwater samples were desirable for drinking (<500 mg/L) while only 5.3% were permissible for drinking (500–1000 mg/L). The spatial variation in TDS (mg/L) is shown in Fig. 4.

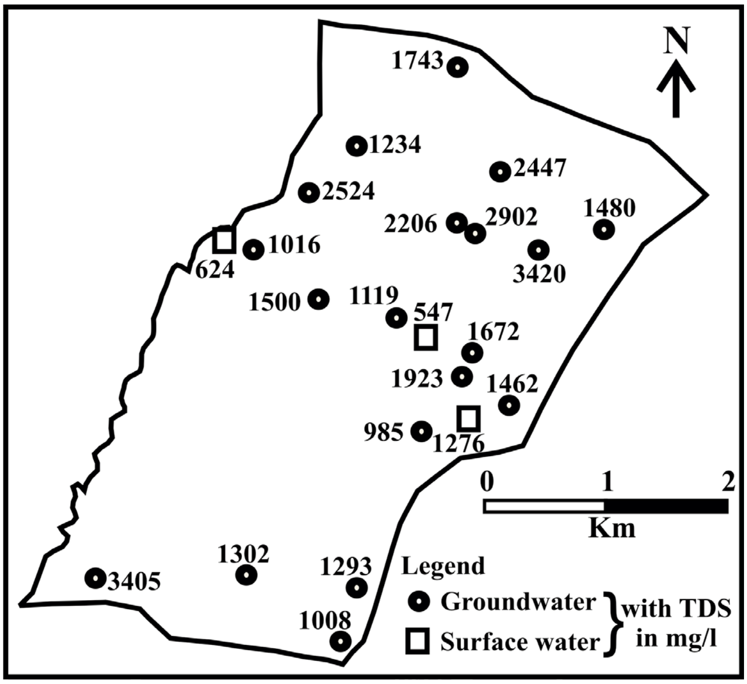

Fig. 4 Spatial variation in TDS (mg/L) of groundwater.

Chromium

Groundwater chromium concentrations ranged between 5 and 35 μg/L, with a mean of 12 μg/L. Chromium concentrations were 4 and 6 μg/L in the lake water samples and 4 μg/L in the river water sample. The chromium concentration in groundwater (Fig. 5) was relatively high in the northeastern part of the study area where the CETP and tanneries are located. Chrome tanning, which is practiced widely because the processing time is less than in vegetable tanning, uses chromium in the form of chrome sulphate that strengthens the leather and makes it water repellent. The excess chromium remaining after the tanning processes gets washed-off and combines with the effluent. This effluent is treated in the CETP and chromium is removed by chemical precipitation before the wastewater is released to open drains. The higher concentration of chromium near the CETP is due to leaching of the treated effluent from this plant to the groundwater. According to the standards specified by BIS (1993), the maximum permissible limit of chromium in drinking water is 50 μg/L. However, none of the groundwater samples exceeded the permissible limit. In 2008, the chromium concentration in the study area was reported to range from 4 to 990 μg/L (Brindha & Elango, 2012). The groundwater quality with respect to chromium has improved significantly due to the removal of chromium from the effluent by CETP.

CONCLUSION

This study was carried out in the Chromepet area, Chennai, southern India, where a number of tanneries are located. The aim was to assess the chromium concentration in the groundwater and to determine whether the current levels are hazardous. EC of groundwater was between 985 and 5344 μS/cm (mean 2820 μS/cm). Of the 19 groundwater samples collected, 95% were brackish based on TDS and unsuitable for drinking based on EC. The maximum concentration of chromium was 35 μg/L which is within the maximum permissible limit of 50 μg/L. The EC, TDS and chromium are high in the northeast of the area where the CETP discharges the treated effluent in open drains. The groundwater quality with respect to chromium has improved relative to results obtained in 2008. The residents of this area are well aware of the contamination of the groundwater and therefore depend on other sources of water for cooking purposes. However, from an environmental

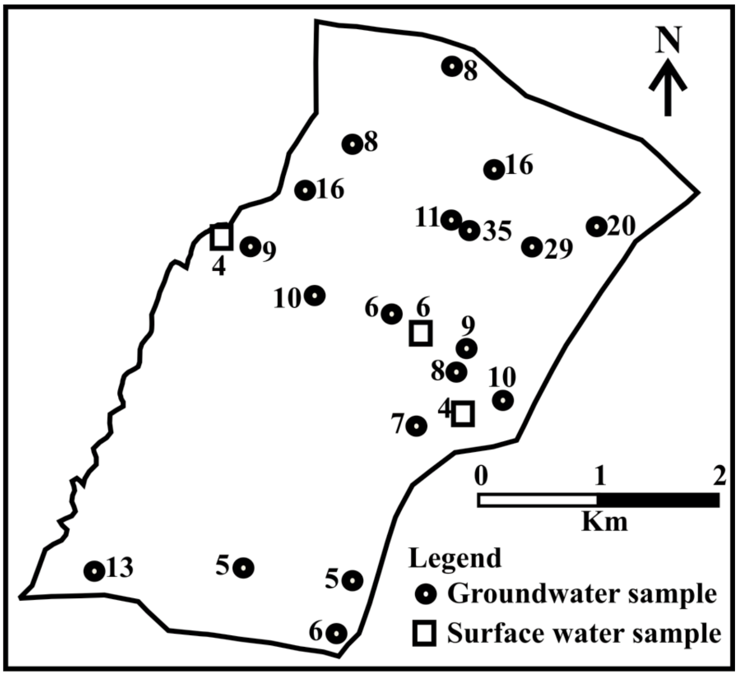

Fig. 5 Spatial variation in chromium concentration (µg/L) in groundwater.

point of view it is essential to improve the quality of groundwater by increasing the removal of TDS from the effluent treated in the CETP.

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