Need of Groundwater Management in Tannery Belt: A Scenario about Dindigul Town, Tamil Nadu

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Introduction

The earth without water is difficult to imagine. There is evidence that the life on the earth originated in water. Today, water is continuously getting polluted from many different sources. These include untreated sewage, industrial discharge, and leakage from oil storage tanks, mine drainage, pesticides and seawater intrusion etc (Cartwright and McComas, 1968; Merkel, 1972; Fink and Aulenbach, 1974; Ebraheem et al. 1990; Rao and Gupta, 2000; Barker et al. 2001; Ghosh Bobba, 2002; Saxena et al. 2004; Mondal et al. 2005; Tariq et al. 2005; Sarwade et al. 2007; Venugopal et al. 2008; Mondal et al. 2010). The process of groundwater pollution is complicated one and quite different from that of surface water pollution. It means once groundwater is polluted, it is so difficult to bring to its original position. Tannery is also one industry, which is continuously polluting the groundwater systems and also eco-systems in all over India as well as world wide (Sule and Ingle, 1996; Jordao et al. 1997; Cassano et al. 1999; Khwaja, et al. 2001; Bajza and Vrcek, 2001; Rao et al. 2002; Gagneten and Ceresoli, 2004; Apte et al. 2005; Leghouchi et al. 2009; Vankar et al. 2009). Most of the tanneries in India (see Fig. 1) are located near the riverbanks i.e. Ganges river in North India and Palar river in South India (CLRI, 1990), because it needs a large amount of fresh water to process hides and skins. Various chemicals are used to process the raw materials in tannery industries, which causes the surface water as well as groundwater pollution . Such type of problem is also faced in and around Dindigul town and its impact is discussed here.

Tanning Industry: Indian Scenario

There are about 1083 tanneries in India with a total installed processing capacity of 62.05 million hides and 161.34 skins (Paul Basker, 2000). Tamil Nadu, West Bengal and Uttar Pradesh states together claim 88.40 percent of the tannery units in this country (Fig. 2). Statistic shows that more than 50% tanneries are located in Tamil Nadu, India.

Fig.1. Location of major tannery clusters in India.

Tanneries in Tamil Nadu

Tannery industries in Tamilnadu are mainly concentrated in places like Ranipet, Ambur, Vaniambadi and Pernambet of North Arcot Ambedkar district. The other tanning centres in the state include Erdoe, Salem, Vellore, Dindigul, Tiruchirapalli, Pallavaram, Madhavaram, Coimbatore and Madras. The tanneries in Vaniamvadi, Ambur, Trichy and Dindigul process mostly goat or sheepskins while the tanneries in Ranipet, Pernambet, Erode and Pallavarm undertake tanning of hides. Location wise distribution of the tannery is shown in Fig.3, this figure shows that more than 70% tanneries are located at Ranipet, Vanaiyambadi, Dindigul, Ambur and Chrompet. More than 14% tanneries are at Pernambet and Erode. There are less than 16% tanneries located at the other places.

Impact of Tanneries in and Around Dindigul Town

There are about 80 functional tanneries in and around Dindigul town, Tamil Nadu, India with a capacity to process about 200 MT hides and skins as leather. It was estimated that about 76,400- 85,600 kg of leather was produced in Dindigul town every day (Paul Basker, 2000). The concentration of tanneries can be found along Madurai, Batla Gundu and Ponmandurai roads. The tanning industries commenced in 1939. The process of tanning involves the use of large amount of fresh water and various chemicals. The various chemicals used in tanning are lime, sodium carbonate, sodium bi-carbonate, common salt, sodium sulphate, chrome sulphate, fat, liquors, vegetable oils and dyes etc.

This industry is one of the major consumers of fresh water and most of the

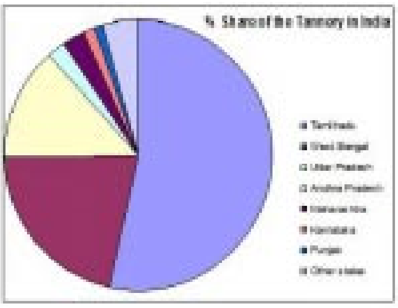

Fig.2. Distribution of the tannery in India

water is discharged as wastewater. The quantity of total wastewater discharged for 100 kg of skins and hides processed varies from 3000 to 3200 litres. Common salt (NaCl) is the biggest polluting material in the tanning industry. For every 10 tonnes of salted hides and skins processed, 2-3 tonnes of salt is removed and in addition another one ton of salt is removed, while pickling. The amount of wastewater generated by these tanneries is approximately from 2.5-3.0 MLD (million litres per day) with TDS level of 20, 000-25,000 mg/l on the surface, which in turn is collected in irrigation ponds (Mondal et al. 2005). These collection ponds act as a source of pollution. The pollution penetrated vertically down and polluted the groundwater system. It pollutes the groundwater and makes it unfit for drinking, irrigation and for general consumption (WHO, 1984). It is established that a single tannery can cause the pollution of groundwater around the radius of 7 to 8 km (Bhaskaran, 1977). Used salts lime, sludge, spent bark, tan liquor sludge, fat, primary and biological sludges, protein, pig bristles, tail and body hair, tanned trimmings and shavings are the main solid wastes from the tanneries.

Barker et al. (2001) used electrical imaging technique for delineation of contamined groundwater zones due to the tannery effluents. Five images were measured at Pudhupatty and Ponnimanturai areas situated about 5 km west of Dindigul town but it was within the tannery clusters. One image, out of them, measured directly at the base of the Pudhupatty tank (a typical section shown in Fig. 4), a large holding reservoir into which polluted water from the tanneries was discharged. At the time of the survey, the tank was dry and its surface appeared to comprise thin salty clay. Here the sub-surface was characterized by low resistivities, with values of less than 10 Ω-m being seen at the surface and values of less than 50 Ω-m being apparent down to depths of 15 m or more. A survey (in April 2001) showed that the surface water at Pudhupatty tank contains 15, 000 mg/l of TDS, which indicates high contamination of groundwater in that village. The study showed that the resistivity of shallow regolith (weathered zones) might be expected to be <50 Ω-m. Since the water table was shallow and the regolith was largely saturated, any resistivity much below 20 Ω-m will indicate groundwater contamination, in absence of any clay material. Out of the five images, four had shown that the top 10–15 m of regolith has resistivity of <10 Ω-m, with top 5 m having a resistivity of less than 4 Ω-m. This had clearly indicated that the soil was strongly contaminated.

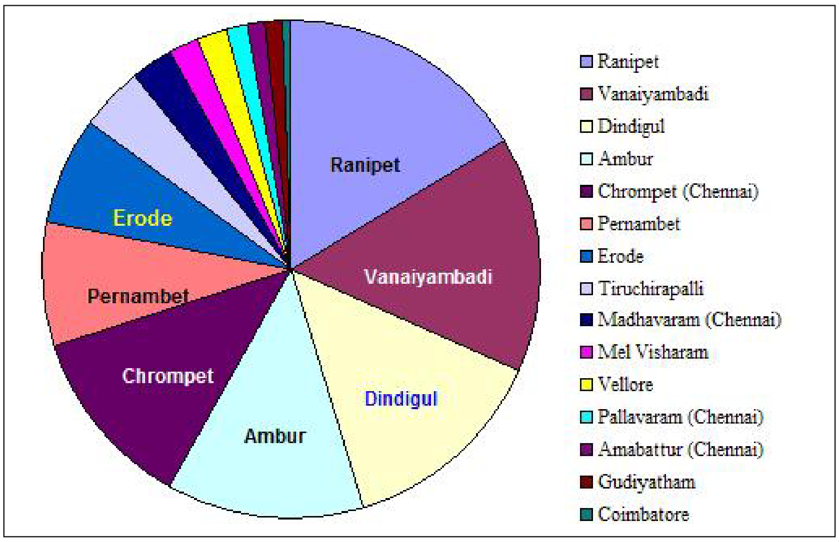

Fig.3. Distribution of the tannery in Tamil Nadu.

For the evaluation of groundwater quality, 106 water samples were collected during January 2001(Mondal et al. 2005) from the represented dug wells and dug-cum-bore wells distributed throughout the area. Methods of collection and analysis of water samples followed are essentially the same as given by APHA (1985) and Brown et al. (1974). The concentration of cations such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}) and Potassium (K^{+}), and anions such as Bicarbonate (HCO_3^-), Sulphate (SO_4^{2-}), Chloride (Cl^-) and Nitrate (NO_3^-) in the groundwater had been studied. Apart from these constituents, pH, electrical conductivity (EC), total dissolved solid and total hardness (TH as $CaCO_3$) were also studied. The values of TDS varied from 349 to17, 000 mg/l with mean of 2,496 mg/l. The isoclines of TDS were also shown in Fig. 5. The values of the above constituent were more than the permissible limit (WHO, 1984) in and around the tannery cluster compared to other parts of the area. The trend of TDS contours clearly showed that the contamination level was possibly moving along the river course. The same trends were obtained for the chemical constituents of Na^+, Cl^- and SO_4^{2-} etc. The correlation of these constituents with the EC had been carried out. The highest correlation was observed between EC and chloride with a correlation coefficient of 0.99. Progressive reduction in correlation coefficients for Mg^{2+}, (Na^++K^+), Ca^{2+} and SO_4^{2-} were observed as 0.91, 0.87, 0.86 and 0.56, respectively. It indicated that the quality of groundwater in this area under investigation was deteriorated mainly due to extensive use of salt (NaCl) in the leather industries.

As we know that the prime cause of chromium pollution in groundwater was chromite (Cr_2O_4), an ore of chromium. Chromium is used for making dyes which are used in the tannery industry. Recently, in February 2009, 29 groundwater samples were collected from the representative dug and dug-cum-bore wells in and around the tannery clusters, Dindigul, Tamil Nadu. Chromium was analyzed by Atomic Adsorption Spectrometry (AAS) technique

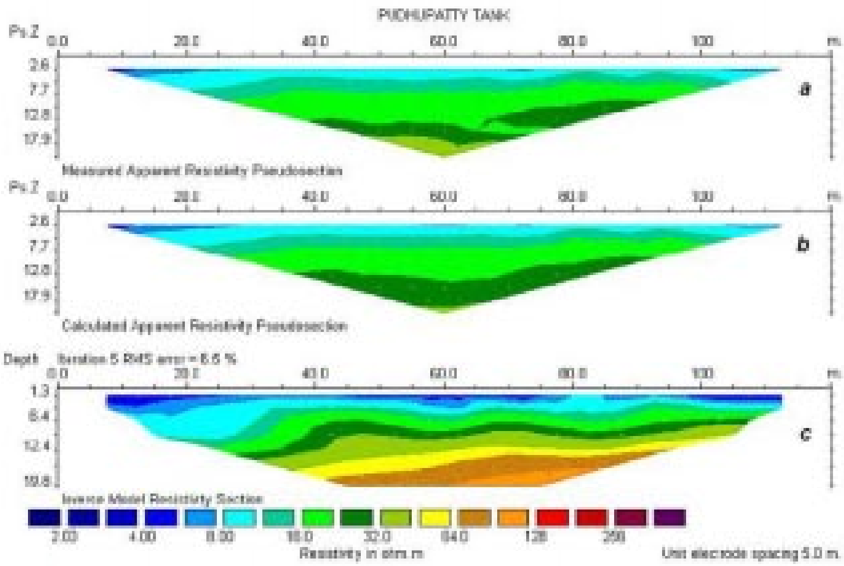

Fig.4. Electrical image at Pudhupatty tank of Dindigul (*after* Barker et al. 2001).

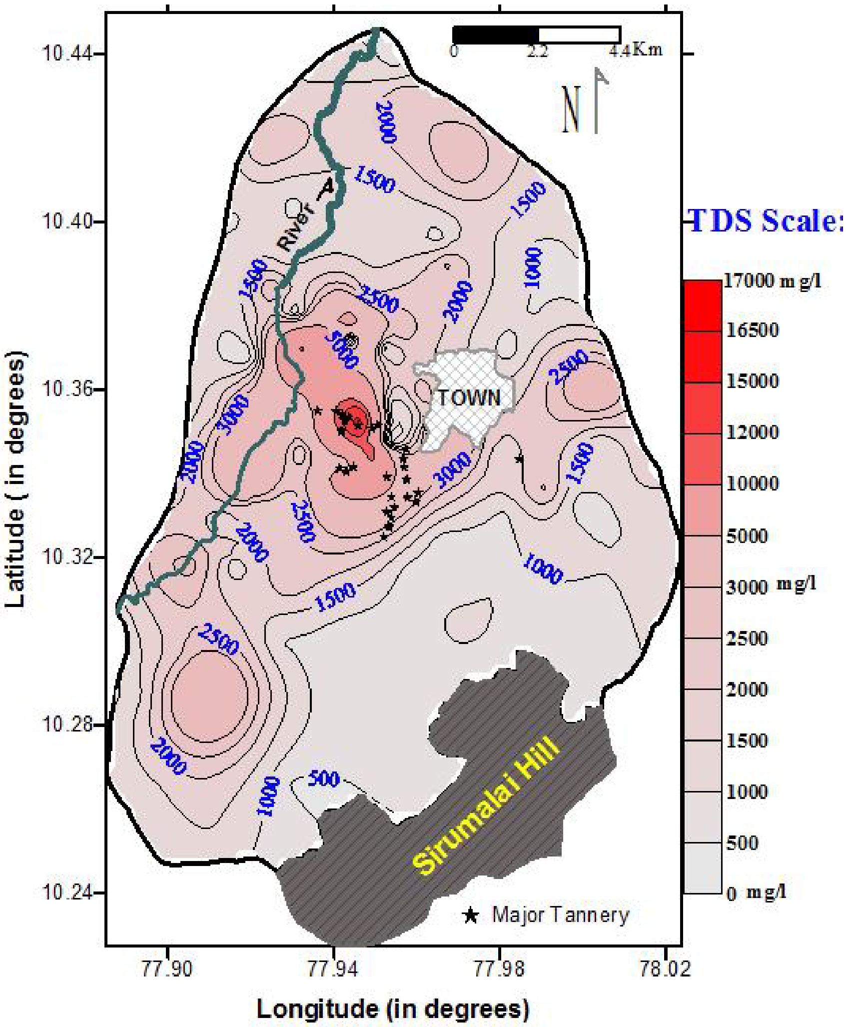

Fig.5. TDS contours (mg/l, January 2001, *after* Mondal et al. 2005).

at Vitro Laboratory, Hyderabad, India. The results reveal that the harmful hexavalent chromium (Cr^{+6}) was obtained below the permissible limit (50 µg/L). Gravity, permeability and wetness of the aquifer material and miscibility of the pollutant in groundwater controlled the mobility of pollutants. Fairly high incidence of rainfall (901.51 mm annually) intercepted by consecutive drought years is characteristic of the study area. Pollutant impregnated materials, e.g., solid and liquid wastes, leaching through weathered granite infiltrated into the substratum and reached the water table. The percolation by seepage water is a slow process and likely attains greater mobility in wet seasons with the lapse of time. Since most of the effluents of tanneries were discharged into streams/ tanks, chromium was mostly washed off and the amount retained on the bottom of streams/tanks was minimal. This could be one of the reasons for its low concentration in shallow aquifers (in open wells). The other reason could be that in recent years pre-treatment of effluent made the Cr concentration to a minimum level. The results of analysis however showed other concentrations (i.e. Mg^{2+}: 22-1854 mg/L, Na^{+}: 43-6046 mg/L, Cl^{-}: 57-13652 mg/L and SO_4^{2-}: 25-7154 mg/L etc) harmful for drinking and irrigation purposes. Although samples for chromium had been collected from groundwater, it had been found that the maximum concentration of trivalent chromium (Cr^{3+}) was 530 µg/L. A contour map was also prepared for Cr^{3+} (see Fig. 6) which indicated tannery clusters affected by Cr^{3+} plume more than the permissible limit of 50 µg/L (WHO, 1984).

These 80 functional tanneries employ about 3000 workers out of a population of nearly 2 lakhs. In 13 villages, as many as 1,090 houses had been damaged due to tannery pollution. Local people also are suffering from different diseases like eye irritation and exacerbation of skin disorders. Kidney degeneration and testicular atrophy have also been observed, while excessive intake of drinking water containing high sodium chloride has been reported to produce hypertension, excess chromium causes respiratory trouble and liver problems as chromium is known as carcinogenic agent (Peace Trust, 2000).

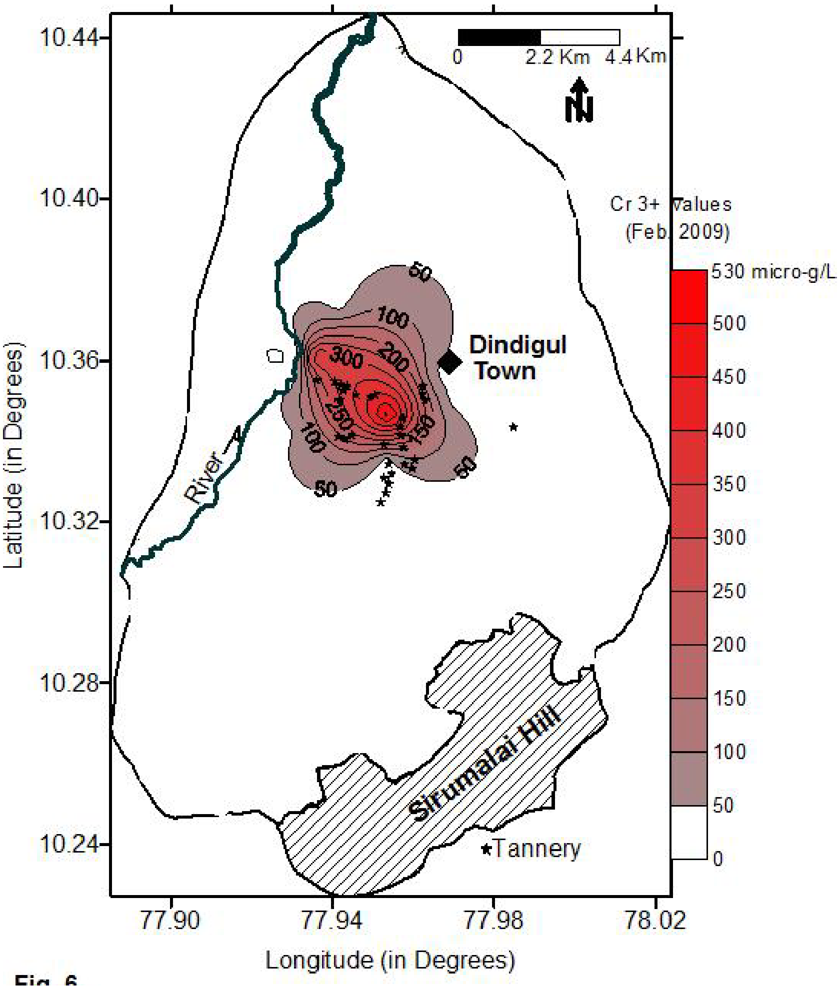

Fig. 6. Cr-contours map (in µg/l, February 2009).

Ecosystem damaged in Dindigul Town

Tannery pollution has spread over about 100 km^2 in and around Dindigul town (Mondal et al. 2005). The ecosystem is also damaged due to untreated effluents from the tannery industries. Groundwater in shallow dug well emits foul smell and colour has also become dark. The use of various chemicals generated toxic effluents, out of which 30 percent were absorbed with help of the existing technology (i.e. CEPT). But the rest were let out into the open land, canal, and nearby tanks etc. Apart from the chemical effluents, solid waste was generated for hide processed. No technology was in place to handle the solid wastes. Solid wastes, including sludge and animal fleshing and hair, are either dumped into the barren land, irrigation land, open land or are buried in trenches. The irrigation land has also lost its fertility (see Fig. 7).

Fig.7. Showing degradation of soil fertility at Ponni-manturai.

Hydrogeological Status in and around Dindigul Town

The area is characterized by undulating topography generally sloping towards north and northwest. The highest elevation (altitude) in the hilly area (Sirumalai hill) is of order of 1350 m (amsl). But it varies from 360 m (amsl) in southern parts to 240 m in the northern parts of the area. There is no existing perennial stream. Runoff from precipitation within the area ends in small streams flowing towards main river Kodaganar (see Fig. 5). The average annual rainfall is in the order of 901.51 mm from the period of 1971-2008. Geologically, the area includes Achaean granites and gneisses. Black cotton soil and red sandy soil predominate in the area. The thickness of soil varies from 0.52 m to 5.35 m, but thickness of the weathered zone varies from 3.1 to 26.6 m (Mondal, 2005). The thickness of weathered zone varies from place to place within the area, but this shallow zone may not be a reliable source for large demands of groundwater. Weathered zone facilitates the movement and storage of groundwater and through a network of joints, faults and lineaments, which form conspicuous structural features. Apart from the structural controls on the groundwater movement, the terrain is covered with pediment and buried pediment at southern and western sides of the area. Another dominant formation is the charnokite, which is found in the extreme southern and southeastern part of the Sirumalai hill. Groundwater is extracted through dug wells, dug-cum-bore wells and bore wells for different purposes. The water level contours and flow direction were prepared with the use of Surfer version 8.00, February 11, 2002 Surface Mapping System, Golden Software, Inc. using a kriging method considering 48 water levels collected from the monitoring wells (shown in Fig. 8) during September 2001. The general trend of groundwater motion under the shallow aquifer is in a north and northwest directions.

Methods for the Reversal of Damages

Common Effluent Treatment Plant (CEPT): The tannery effluent from 36 tanneries in Dindigul was brought to the Common Effluent Treatment Plant (CETP),

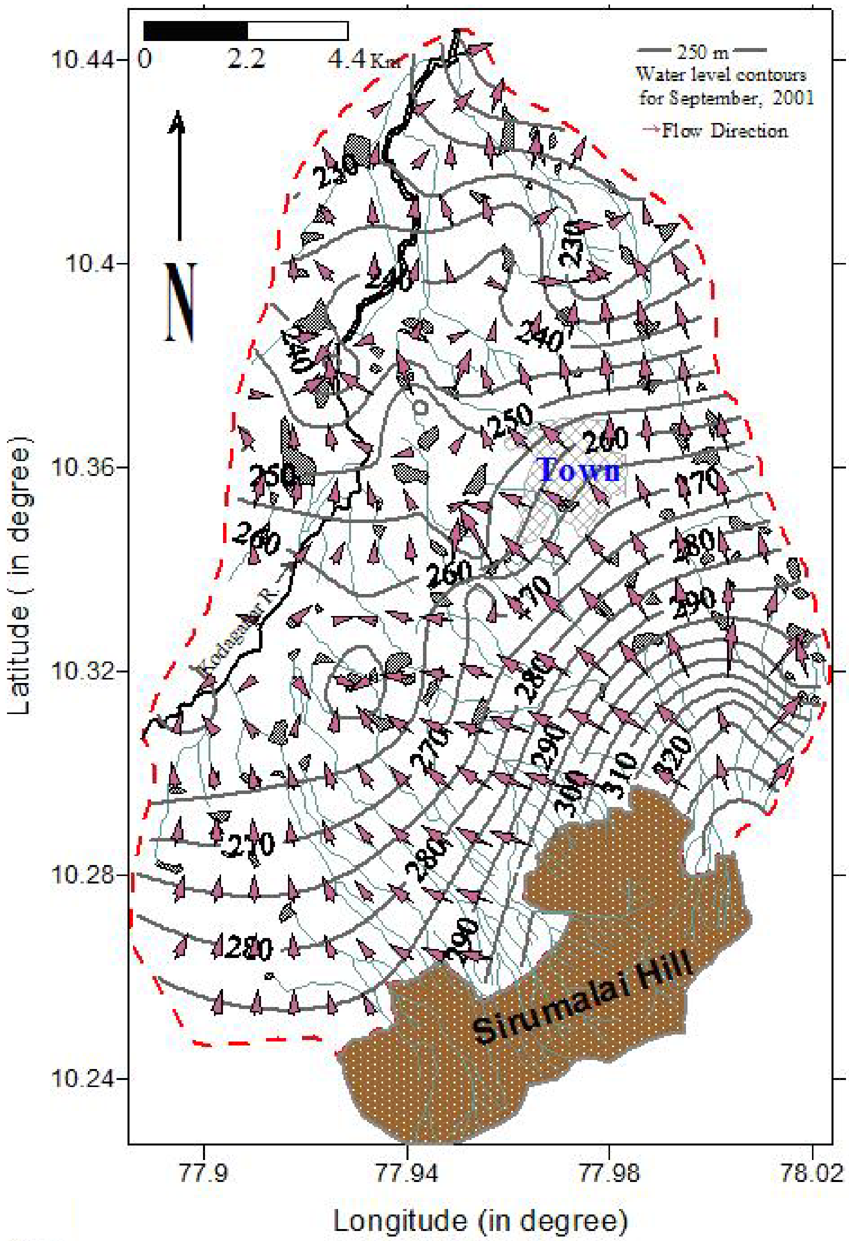

Fig.8. Water level contours (m, amsl) and flow direction (September 2001)

via underground pipes through gravity flow and discharged into an equalization tank. The equalized waste is screened through bar screens having rectangular bars with a clear spacing of 20 to 50 mm positioned at 15° to the vertical. The screened waste is now sent through a grit channel to remove particles with specific gravity 2.6. When the degrited wastewater is coagulated with lime in a mixing tank and flocculated before sending it for sedimentation. The Primary Settling Tank (PST) removes settleable solids along with flocculated solids from wastewater. Now the wastewater is sent to an anaerobic lagoon to reduce the high BOD of organic wastes having a detention time of 10 days.

However, these adjustments could not possibly result in any appreciable reduction in TDS and Cl^- in the final effluent, which is mainly due to inorganic dissolved solids. Hence tertiary treatment is needed for the effluent coming out of the secondary clarifier to reduce the following parameter concentrations i.e. TDS, Cl^- and SO_4^{2-}. In order to effect the reduction in these values to within tolerance limits a combination of dual medium filtration followed by ultra filtration and reverse osmosis.

Tertiary treatment suggested: A three-step process consisting of granular media filtration, ultra filtration followed by reverse osmosis has been suggested for the effluent coming out of the CETP. They are discussed below.

Granular media filtration: The total suspended solids is first removed as a pre-treatment to Ultra Filtration (UF) and Reverse Osmosis (RO) to prevent clogging problems in the membranes. Since total suspended solids down flow dual medium filter with the possible combination of anthracite and sand could be used. This could result in reduced suspended solids by as much as 80 to 90%. This is essential for the smooth functioning of ultra filtration and reverse osmosis.

Ultra Filtration (UF): Ultra filtration systems are pressure driven membrane operations that use porous membranes for the removal of mostly colloidal material and some dissolved material. These systems use driving pressures of 1034 KN/m^2 to remove colloidal material with molecular weight in excess of 5000. This results in color and turbidity removal from wastewater. It is used typically in re-purification applications as a pre-treatment step for reverse osmosis. Ultra filtration is capable of concentrating bacteria, some proteins, some dyes, and constituents that have a larger molecular weight of greater than 10,000 Dalton. It is only somewhat dependent upon the charge of the particle and is much more concerned with the size of the particle. Ultra filtration is typically not effective at separating organic streams. But it is functioned as (1) regenerates exhausted solutions making it possible to reuse them in the process and (2) purifies wastewater, making it possible to reuse the same water in the process or discharge it clean and pure into the environment.

Reverse Osmosis (RO): The membrane consists of several thin layers or sheets of film that are bonded together and rolled in a spiral configuration around a plastic tube. This is also known as a Thin Film Composite (TFC membrane). A high quality RO membrane is "semi-permeable", which means that it allows water to pass through but prevents dissolved particles (i.e., mineral, chemical contaminant and even smallest bacteria etc) from passing through. Reverse osmosis is the reversal of the natural flow of osmosis. In a water purification system, the goal is not to dilute the salt solution, but to separate the pure water from the salt and other contaminants. When the natural osmotic flow is reversed, water from the salt solution is forced through the membrane in the opposite direction by application of pressure. Through this process, we are able to produce pure water by screening out the salts and other contaminants.

The reverse osmosis process cannot go on indefinitely without removing the contaminants. Ultimately the membrane could become clogged by salt and other impurities, requiring increasingly greater pressure to force water through the membrane. To solve this problem, the membranes are configured to split the feed water into two streams. One part is to be purified and the other part to wash away the particles rejected by the membrane. 5µ sediment pre-filter and a 2µ carbon pre-filter remove suspended solids, chlorine, organic chemicals and anything larger than 2µ. The water then proceeds to the Reverse Osmosis membrane. Its pores are so tiny (about 6/10,000th of a micron or 1/50,000th of an inch), it removes more contaminants from the water, including viruses and bacteria.

Chemical methods for treating polluted water: An inexpensive method to treat polluted water using sunlight in combination with catalysts such as Titanium Dioxide (TiO_2) has been developed at the Department of Chemistry and Biochemistry, University of Texas at Arlington, US. The department has also developed a technique to treat chromium pollution using a conducting polymer called polypyrrole. This TiO_2 technique can be used for bulk organic and inorganic pollutants. TiO_2 absorbs light and generates hydroxyl radicals. These radicals are highly reactive and oxidizing. When they come into contact with organic molecules they break up the latter. The second process using conducting polymer is based on redox chemistry. When light hits the catalyst particles, electrons are generated. These highly reducing electrons immobilize the pollutant and reduce, say the highly polluting Chromium (VI) to the more harmless Chromium (III). To describe the process in another way, when the polymer is transferred to the pollutant, the pollutant is reduced and the polymer is oxidized. The polymer can be recycled and used again.

Watershed development: Adoption of suitable location specific water harvesting technologies in tannery-polluted regions will help in the recharging of groundwater. Groundwater available zones are identified for sustainability of groundwater development. The important points to be considered here are identification of the areas for locating suitable artificial recharge structures and construction of artificial recharge structures in the most appropriate sites and also monitoring the groundwater quality for observing the impact of artificial recharge structures like percolation ponds, check dams, etc.

Check dams: Small earth dams are, semi-circular or curved banks of earth, generally not more than 3 m in height and 60 m in length. They are built by manual labour and repaired periodically by the user community.

Percolation tank: Percolation tank has come to be recognized; as a dependable mode not only for rainwater harvesting but also for augmenting groundwater recharge in the hard rock terrain. Percolation tank is more or less similar to check dams, with a fairly large; storage reservoir. Percolation tanks are artificially created surface water bodies, sub-merging a land area with adequate permeability to facilitate surface run-off to recharge the groundwater.

Need for Groundwater Management

In the early 1980s, ignoring warnings about pollution, the industry pursued business growth as the demand for leather increased worldwide. The Central Government helped it along with its export policy. To meet the demand, tanners switched from the traditional eco-friendly process using tree bark and vegetable extracts to a chromium-based process using over 200 chemicals that reduced the time and space required for tanning. It causes groundwater pollution due to disposal of untreated effluents not only Dindigul but also in Jalandhar, Agra, Kunpur, Lucknow, Patna, Kolkata, Pewas, Rajkot, Warangal, Palar, Ranipet, Ambur, Vaniyambadi, Erode and other towns in India. Now a day there is a lot of water scarcity. People are not getting fresh water at proper time and proper places. Question has come about Water Security. Therefore, we have present duty to safe the water in terms of quantity as well as quality, and bring the damaged groundwater systems to its original position after doing extensive research. For a sustainable, economic development and management of damaged/polluted groundwater resources, a systematic evaluation through an integrated approach, is imperative. Initially, the hydrogeological, geophysical and hydrochemical studies have to carry out in the spoiled aquifers for acquiring required data. Finally, groundwater numerical model is to be prepared with integrating these data depending upon all input and output stresses on the groundwater system. Then these models help us for proper management of groundwater resources in the damaged aquifers in terns of quantity and quality to bring to its original position.

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