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Original Research Paper

Tannery Effluent Management vis-a-vis Groundwater Quality in Dindigul, Tamilnadu, India

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ABSTRACT

Groundwater meets more than 2/3rd of drinking and agricultural needs of many villages, towns and cities. But its availability and quality remains vulnerable due to pollution, especially from industrial sectors. Dindigul is one of the major skin/hide processing areas in Tamilnadu which generate ≈ 57 KL of effluent per tonne of material processed with high pollution load (TDS: 7912-11430 mg/L, COD: 3571-7600 mg/L, chloride: 3278-4199 mg/L, BOD: 1475-1686 mg/L, hardness: 1188-2800 mg/L, sodium : 650-2255 mg/L, TSS: 398-1248 mg/L, sulphate: 370-830 mg/L, alkalinity: 200-1476 mg/L and sulphide: 51-296 mg/L). A CETP with a design capacity of 2500 KLD is in operation since 1996 to manage the wastes from tanneries. The capacity utilization of CETP was poor (only 34%) and important parameters (TSS, TDS, chloride, oil & grease, BOD, COD, sulphide and TKN) of the treated effluent fail to meet the prescribed standards for discharge either into inland surface waters or on land for irrigation. As the treated effluent is stored in an earthen pond and allowed to percolate naturally, the groundwater quality (TDS, chloride, sulphate, alkalinity, hardness, calcium and magnesium) of the nearby villages is also affected and fail to meet standards prescribed for drinking water.

INTRODUCTION

Groundwater compliments other aquatic resources in the anthropogenic activities all over the world for many centuries, and in the recent decades its utilization has increased manifolds. In India, most of the irrigation (> 65%) and drinking water (> 85%) needs are met with through groundwater (World Bank 2010) due to non-availability or unsuitability of other sources. With day-by-day increase in pollution and over-exploitation, the groundwater quality could reach critical stage of degradation in coming years, thus, threatening the very basic socio-economic development of the country (Briscoe & Malik 2005, ADB 2007, World Bank 2010, Chakraborti et al. 2011). Recent studies indicate that ≈ 59% of districts in the country are vulnerable in terms of safe drinking water with industrial wastes from highly polluting industries (including tanneries) being the major causative factor (Chhonkar et al. 2000, Mondal et al. 2005, CPCB 2007, CGWB 2008, Vijay Shankar et al. 2011, Wyrwoll 2012). About 3000 tanneries are operating in India to process hides/skins of cow, buffalo, goat and sheep (CPCB 2013). Out of these, ≈ 55% are located in Tamilnadu (Chennai, Ambur, Ranipet, Vaniyambadi, Pernambet, Erode, Trichy and Dindigul). Being in 'small scale' sector and operate mostly in clusters, they opt for 'common effluent treatment plant' (CETP) to manage their wastes. The performance of one such CETP operating in Dindigul (Tamilnadu) and its impact on the groundwater quality of the surrounding areas is dealt here.

MATERIALS AND METHODS

Tanning process: Based on the manufacturing process, the tanneries are grouped into four categories namely (i) Raw to East India (EI) leather: wet or dry salted hides/skins into vegetable tanned semi-finished leather, (ii) Raw to wet-blue: wet or salted hides/skins into chrome tanned semi-finished leather, (iii) Raw to finish: wet or dry salted hides/skins into finished leather and (iv) Semi-finished leather to finished leather: vegetable/chrome tanned semi-finished leather to finished leather. The general process includes four main stages, i.e. pre-tanning, tanning, post-tanning and finishing. A schematic process flow-chart is given in Fig. 1. The whole process is water-intensive and consumes about 30-50 KL per tonne of leather produced of which 95% comes out as wastewater. Also, more than 18 different types of chemicals (≈ 300 kg/ton of hides) are added during the process wherein only 20-25% retained in finished leather and the remaining 75-80% discharged into the effluent stream causing environmental problems. The details of tanning process, wastewater discharge, pollution load, etc. were documented elsewhere (CPCB 1991, Bosnic et al. 2003, CPCB 2013).

Study area: Dindigul town (latitude 10°21' N; longitude 77°57' E) is a part of Vaigai and Pambar sub-basins of Cauvery-Capecomerin basins. Being a water-starved region, its groundwater is under immense stress due to various man-made activities. There are 61 tanneries operating here which

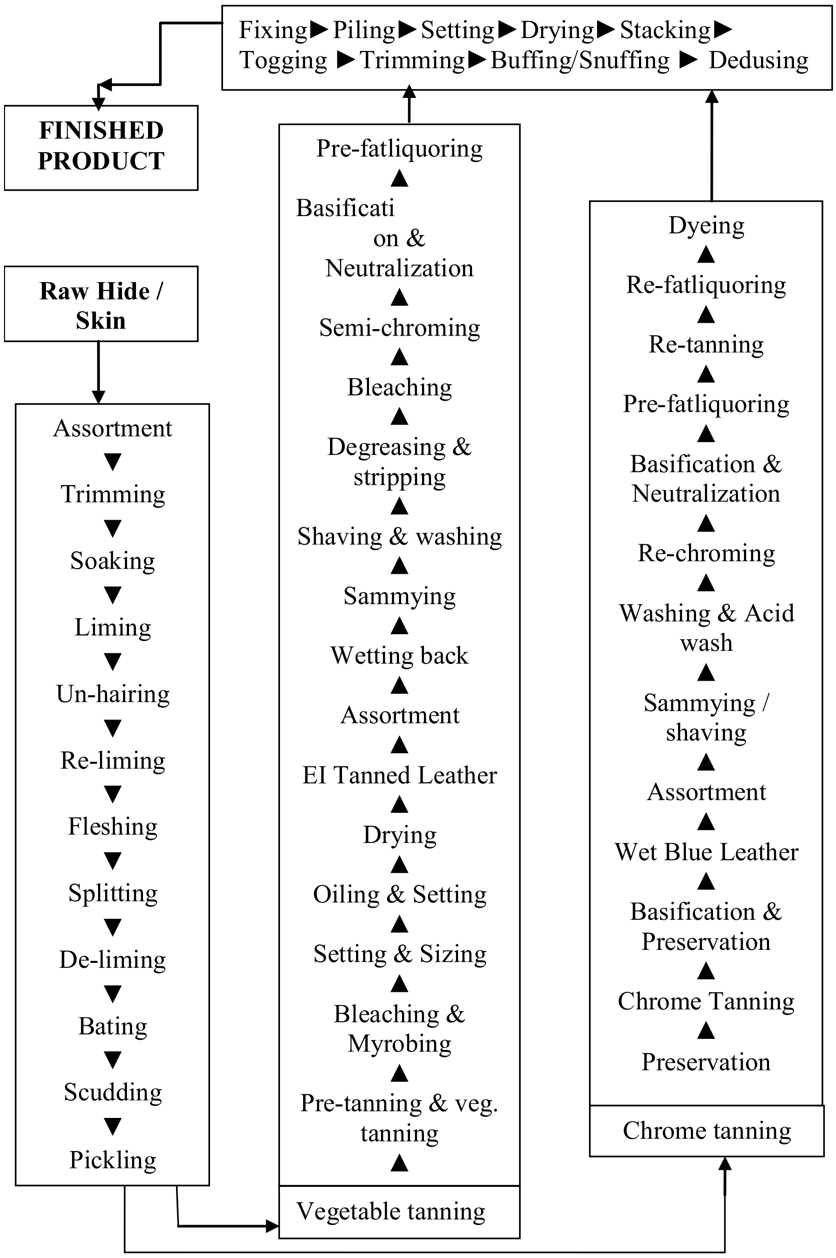

Fig. 1: Schematic flowchart of tanning processes (Source: CPCB 2013).

require huge quantity of water for its activities. They are practicing predominantly vegetable tanning (74%) followed by chrome tanning (17%) and together floated a CETP company (i.e. M/s. Talco-Dindigul Tanners Enviro Control System Pvt. Ltd.) in the year 1996 with a design capacity of 2500 KLD to collect, convey, treat and dispose the industrial wastes.

Sampling: To evaluate the performance of the CETP vis-a-vis the groundwater quality of the nearby areas, composite samples (every 4 hours for 24 hours) were collected during June 2010 and July 2011 from CETP's treatment units (Fig. 2) including sedimentation tank inlet (raw effluent), secondary clarifier outlet (final treated effluent) and earthen storage tank near Pallapatti village where treated effluent is discharged/stored. Simultaneously, groundwater samples (grab) from open-wells situated in nearby villages namely Kudai Paraipatti, Budha Marathupatti, Begum Sahiba Nagar, Kuttiapatti road (Survey No. 183) and Nallandrapuram (Ponmandurai-2nd ward) were collected to study the impact

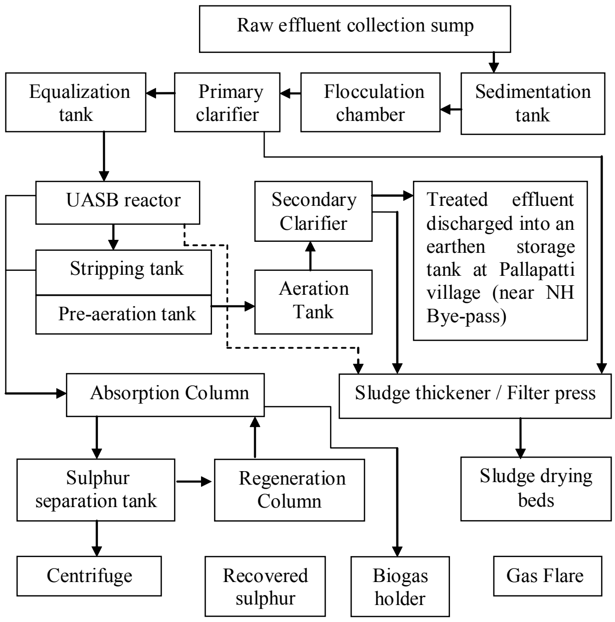

Fig. 2: Schematic flow-chart of CETP (Design capacity (2500 KLD).

of the natural percolation of treated effluent stored in the earthen tank. Sludge samples from CETP were also collected on 28.6.2010 to analyse the characteristics. All the parameters were analysed following standard procedures (APHA 2005). Operational data (effluent inflow, capacity utilization) were sourced from the CETP company.

RESULTS AND DISCUSSION

Environmental safety is a fundamental right enshrined in our constitution to ensure good quality of life for all the citizens as well as other living creatures. To achieve this, various legislations such as Water (Prevention and Control of Pollution) Act 1974, the Air (Prevention and Control of Pollution) Act 1981 and the Environment (Protection) Act 1986 are enacted by the Parliament and are in force for the past few decades. Specific environmental issues are also addressed through many other provisions (of Indian Penal Code, the Criminal Procedure Code, the Factories Act, the Indian Forest Act and the Merchant Shipping Act). Statutory bodies have taken numerous steps for 'safe environment', which include notification of industry-specific standards for discharge of pollutants and development of infrastructure to treat/reduce the pollution load so as to sustain the assimilative and regenerative capabilities of the natural environment. In-spite of all these efforts, the deterioration and degradation of environment in general and aquatic resources in particular are still ubiquitous in the country due to various anthropogenic actions associated with wastewater discharge into sewers, rivers, lakes, ponds or open grounds either treated or untreated and with or without meeting the prescribed standards (Mondal et al. 2005, Mukherjee & Nelliyat 2006, Vyas & Sawant 2007, CPCB 2007, CPCB 2008, CPCB 2009, Nangare et al. 2008, Mondal & Singh 2010, Srikanth Vuppala 2012, Kumar 2013, Tamma Rao et al. 2013).

Dindigul is one of the areas in Tamilnadu where the tanning activity created groundwater contamination and ecosystem damage spread over 100 km^2 (Mondal et al. 2005, CGWB 2008, Mondal & Singh 2010) even though CETP is in place since late nineties. The tanneries here generate effluent to the tune of 3010 KL/day (maximum) from the processing of over 1575 tonnes of hides and skins per month. This indicates the effluent generation of about 57 KL/ tonne of hides/skins processed and indirectly revealing excess consumption of water with reference to the targeted limit of 28 m^3 per tonne (CPCB 2003). Earlier studies estimated effluent generation in the range of 30-40 m^3 per tonne (Bosnic et al. 2003). The overuse of water by tanners could be one of the factors, in addition to the scanty rainfall, limited recharge options and agricultural activities, for the over-exploitation of groundwater resource in this region (CGWB 2008).

The effluent generated from the tanneries are collected, pretreated and conveyed through underground pipelines to the CETP for further treatment. The oil and grease level of 22 mg/L measured at the inlet point of CETP (i.e. sedimentation tank inlet) was above the prescribed standard of 20 mg/L (CPCB 2010), which indicates inadequate pre-treatment provided by the individual member units. The characteristics of raw effluent showed high pollution load (Table 1) in terms of TDS (7912-11430 mg/L), COD (3571-7600 mg/L), chloride (3278-4199 mg/L), BOD (1475-1686 mg/L), hardness (1188-2800 mg/L), sodium (650-2255 mg/L), TSS (398-1248 mg/L), sulphate (370-830 mg/L), alkalinity (200-1476 mg/L) and sulphide (51-296 mg/L). Many tannery clusters in the country (Sahasranaman & Emmanvel 2001, Singh & Rao 2013) showed similar raw effluents characteristics (pH : 5.9-7.7, TDS: 5150-15800 mg/L, BOD: 985-2855 mg/L, COD: 2352-6945 mg/L and sulphides: 62-165 mg/L). Soaking/pickling activities are characterised with effluent having high pollution load and contribute 1/2 of total wastewater generation in the tanning process (CPCB 2013). The low BOD:COD ratio (0.22 to 0.41) of the raw effluent indicated that the wastewater is not fully amenable to biological treatment and the wide variation in the quality of raw effluent collected (Table 1) might be attributed to variations in the process adopted for tanning or leather making (Prasad & Gurunatha Rao 1981).

In the CETP, the raw effluent was subjected to physical, chemical and biological treatments which removed 79-87% of organic and 17-86% of inorganic pollution loads (BOD :

Table 1: Quality of raw and treated effluent of CETP and earthen storage tank near Pallapatti village (Dindigul).

Parameter	Raw Effluent (Sedimentation tank Inlet of CETP)		Treated Effluent (Secondary clarifier outlet of CETP)		Earthen storage tank	Treated effluent discharge standard for CETPs (CPCB 2010)	
	Date: 28.6.10	Date: 14.7.11	Date: 28.6.10	Date: 14.7.11	Date: 14.7.11	Into inland surface waters	On land for irrigation
pH	7.74	7.1	8.04	8.0	8.0	5.5-9.0	
TSS	1248	398	324 (74%)	254 (36%)	435	100	200
TDS	11430	7912	9502 (17%)	6222(21%)	15540	2100	2100
Chloride	4199	3278	3499 (17%)	3278 (0%)	9882	1000	600
O & G	22	-	16 (27%)	-	-	10	10
BOD	1686	1475	214 (87%)	250 (83%)	400	30	100
COD	7600	3571	1280 (83%)	760 (79%)	2020	250	-
Sulphide	296	51	184 (38%)	7 (86%)	-	3	-
TKN	588	385	84 (86%)	206 (46%)	151	100	-
T. Chromium	<0.003	-	<0.003	-	-	2.0	-
Copper	0.844	-	<0.0015	-	-	3.0	-
Zinc	0.654	-	<0.0015	-	-	5.0	-
Lead	0.021	-	<0.015	-	-	0.1	-
Cadmium	<0.0008	-	<0.0008	-	-	1.0	-
Nickel	<0.006	-	<0.006	-	-	3.0	-
Boron	-	0.50	-	0.70	0.6	2.0	2.0

*Performance efficiency (%) of CETP in terms of TSS, TDS, chloride, O&G, BOD, COD and sulphide removal are given in parenthesis
*All values in mg/L except pH

Table 2: Inflow and capacity utilization of CETP during Jan-Dec 2009.

Month	Inflow, KL/month	Avg. Inflow/ day, KL	Capacity utilization (%)	Month	Inflow, KL	Avg. Inflow/ day, KL	Capacity utilization (%)
Jan	35792	1155	46	Jul	24085	777	31
Feb	29769	1063	42	Aug	18249	589	23
Mar	31599	1019	40	Sep	22790	760	30
Apr	25133	838	33	Oct	21373	689	27
May	24390	787	31	Nov	26243	875	35
Jun	25747	858	34	Dec	24841	801	32

83-87%, COD: 79-83%, TSS: 36-74%, TDS: 17-21%, Oil & Grease: 27%, Chloride: 17%, Sulphide: 38-86%, TKN: 46-86%). Govindasamy et al. (2006) observed removal of BOD, COD, TSS and TDS loads upto 97.54%, 93.92%, 97.02% and 18.98% respectively from tannery effluents through physico-chemical/secondary/tertiary treatments in Pallavaram CETP (Chennai). In order to protect the environment, the discharge standards for treated effluent from CETPs were notified (CPCB 2010) and on comparison, the pH was found to be slightly alkaline (8.0-8.04) but within the prescribed standard (5.5-9.0). However, the other important parameters such as TSS, TDS, chloride, oil & grease, BOD, COD, sulphide and TKN were failed to meet the prescribed standards (Table 1). This revealed the unsatisfactory performance of the CETP which might be attributed to poor operation and maintenance as was the case reported earlier from other CETPs in India (CPCB 2005). During 2009, a total quantity of 310,011 KL was received for treatment with an average inflow of 851 KLD indicating only 34 % of CETP's capacity utilization (Table 2) which could also result in under-performance.

The treated effluent from CETP is discharged into an earthen tank for storage and natural percolation and the quality of this tank water was found to be alarming (Table 1) as indicated by the very high concentration of pollutants such as TDS (15540 mg/L), chloride (9882 mg/L), COD (2020 mg/L), TSS (435 mg/L) and BOD (400 mg/L). Due to natural percolation, this wastewater is expected to contaminate the groundwater resource of the nearby areas. The groundwater quality of nearby villages (Table 3) revealed that important parameters (e.g. TDS, chloride, sulphate, alkalinity, hardness, calcium, magnesium) were not meeting the standards prescribed for drinking purpose (IS 10500:2012). Earlier studies carried out in other regions also

Table 3: Groundwater quality of villages located in and around CETP.

Parameter	Sampling Locations (Open Wells) Date of Sampling: June 28, 2010					Indian Standard : Drinking water specifications (IS 10500:2012)	
	Kudai Paraipatti village	Budha Marathupatti	Begum Sahiba Nagar, Kuttiapatti	Survey No. 183 on Kuttiapatti Road	Ponmandurai (ward-2), Nallandrapuram	Requirement (Acceptable Limit)	Permissible Limit in the absence of alternate source
pH	7.84	7.14	7.39	7.01	7.52	6.5-8.5	6.5-8.5
TDS	944	4290	10158	8282	6690	500	2000
Chloride	275	1624	3749	1500	1649	250	1000
Sulphate	69	440	450	400	700	200	400
Alkalinity	100	50	120	60	130	200	600
Total Hardness	450	2500	3500	4000	2200	200	600
Calcium	80	353	922	701	160	75	200
Magnesium	61	394	292	547	437	30	100
Sulphide	<1	<1	<1	<1	<1	0.05	0.05
Fluoride	0.62	0.45	0.68	0.86	0.36	1.0	1.5
Nitrate	0.36	0.53	0.22	0.32	0.36	45	45
Boron	0.56	1.2	1.48	2.24	1.4	0.5	1
Iron	<0.005	0.743	<0.005	0.095	0.387	0.3	0.3
Copper	0.038	<0.0015	<0.0015	1.345	0.413	0.05	1.5
Zinc	<0.0015	<0.0015	<0.0015	0.587	0.495	5	15
Lead	<0.015	<0.015	<0.015	<0.015	<0.015	0.01	0.01
Cadmium	<0.0008	<0.0008	<0.0008	<0.0008	<0.0008	0.003	0.003
Nickel	<0.006	<0.006	<0.006	<0.006	0.166	0.02	0.02
Manganese	<0.0015	<0.0015	0.097	<0.0015	<0.0015	0.1	0.3

All values in mg/L except pH

Table 4: Characteristics of sludge collected from CETP.

Primary Clarifier Sludge		Secondary Clarifier Sludge	
Parameters	Value	Parameters	Value
Cd (mg/g)	0.004	Cd (mg/g)	0.004
Cr (mg/g)	2.61	Cr (mg/g)	0.036
Cu (mg/g)	0.169	Cu (mg/g)	0.015
Ni (mg/g)	0.037	Ni (mg/g)	0.013
Pb (mg/g)	0.044	Pb (mg/g)	0.022
Zn (mg/g)	0.13	Zn (mg/g)	0.026

documented groundwater pollution due to discharge of industrial effluent (CPCB 2007, Vyas & Sawant 2007, Nangare et al. 2008, Kumar 2013, Tamma Rao et al. 2013). This situation has put the human life at risk, as groundwater happens to be the major source of drinking and irrigation in the country (World Bank 2010). The solid wastes generated from the CETP operations particularly the chemical sludge from primary/secondary clarifiers were collected/stored in open areas and this non-scientific practice could also lead to groundwater contamination. Apart from being a hazardous waste (CPCB 2010), its chemical composition (Table 4) indicates the presence of many heavy metals, especially chromium (2610 mg/kg) which causes allergic reactions in human beings (Basketter et al. 2000).

The results of the present study indicate the poor quality of groundwater resource in Dindigul area and found to be unfit for human consumption due to non-compliance of drinking water standards in terms of TDS, chloride, sulphate, alkalinity, hardness, calcium, magnesium, etc. This condition could be clearly attributed to the discharge of tannery (treated) effluent into an earthen tank for storage in-spite of non-compliance with discharge standards and subsequent natural percolation. Therefore, it is imperative to note that the existing CETP infrastructure be put into a better use through (i) technical/functional upgradation (e.g. segregation and treatment of raw effluent based on pollution load, incorporation of 'zero liquid discharge' scheme), (ii) good operational and maintenance practices, (iii) recovery/reuse /recycle of resource (e.g. reuse of RO permeate & recovered chrome/salt) and (iv) strict monitoring/enforcement of legal standards for discharge of treated effluent into inland surface aquatic systems or on land for irrigation.

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