OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

20425

Distr.
LIMITED

ID/WG.536/7(SPEC.)
16 November 1993

United Nations Industrial Development Organization

Original: ENGLISH

Eleventh Session of the Leather and
Leather Products Industry Panel

Nairobi, Kenya, 29 November-3 December 1993

SETTING UP TANNERY EFFLUENT TREATMENT PLANTS IN INDIA - PRACTICAL EXPERIENCE AND LESSONS LEARNT*

Prepared by

S. Rajamani
UNIDO Consultant

---

* The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

V.93-90270

TABLE OF CONTENTS

		Page
1.	Introduction.....	3
2.	Location of tanneries and characteristics of effluent.....	4
3.	Pollution control standards and effluent management.....	8
	3.1 Individual effluent treatment plants.....	8
	3.2 Common effluent treatment plants.....	10
	3.3 Scattered small-scale units.....	11
4.	Treatment technologies adopted in India.....	11
5.	Experiences and lessons learnt in setting up treatment plants.....	14
	5.1 Treatment plant capacities.....	14
	5.2 Consultancy firms and design of treatment plants.....	14
	5.3 Selection of site and appropriate treatment technology.....	15
	5.4 Cost estimate and financing.....	16
	5.5 Equipment and material of construction.....	17
	5.6 Operation and maintenance problems.....	17
6.	Views and suggestions.....	20
	References.....	21

1. INTRODUCTION

Indian tanning industry is one of the oldest and fastest growing industries. There are more than 2500 tanneries located in different centres with a total processing capacity of 600,000 tons of hides and skins per year. The total wastewater discharge from these tanneries is about 80,000 cubic metre per day. More than 90% tanneries are in small and medium scale sector with processing capacities of less than 3 tons of hides/skins per day. They follow traditional practices, mostly unorganized and unplanned on environmental pollution control aspects.

Tannery waste management has become a matter of increasing concern in India. Setting up of an effluent treatment plant is a difficult task in view of the complex nature of the tannery effluents. Main constraints are unpredictable seasonal and daily variations in quality and volume of tannery effluent discharge, selection of appropriate technology, finance for high capital investment, high operational and maintenance cost, frequent power failures and breakdowns, inadequate trained manpower for operation and maintenance, sludge disposal problems, difficulty in meeting pollution control standards and absence of an acceptable formula in sharing the operation and maintenance costs of Common Effluent Treatment (CET) plants.

Large and medium scale isolated tanneries with sufficient land area and financial capacities have set up independent effluent treatment plants. Tanneries located in clusters and not having enough land and financial capacity to put up individual effluent treatment units need to set up Common Effluent Treatment (CET) plants. It has been organized to set up 30 CET plants covering 1500 tanneries and they are under various stages of implementation. UNIDO sponsored CET plant is being set up for a tannery cluster in Pallavaram near Madras city.

2. LOCATION OF TANNERIES AND CHARACTERISTICS OF EFFLUENT

The tanneries in India process sheep and goat skins, and cow and buffalo hides. They practice both vegetable tanning using barks, nuts and vegetable tan extract and chrome tanning using Basic Chromium Sulphate (BCS) and other chemicals. In order to easily draw large quantity of water required for the tanning processes, most of the tanneries are located near the river banks (i.e Ganges river system in North India and Palar river system in South India) as shown in Fig 1.

Volume and characteristics of wastewater discharge vary from process to process, tannery to tannery and time to time. The operations in a tannery are done in batches and discharge of wastewater is also intermittent.

The characteristics of sectional and composite tannery wastewater are given in Table 1. The spent soak liquor is olive green in colour and contains soluble proteins like albumin and has an obnoxious smell. Suspended matters like dirt, dung and blood adhering to the hides and skins are discharged with the soak liquor. Since large quantity of salt (i.e. 100% on hide/skin weight) in the form of sodium chloride is used as a preservative, the salinity of soak liquor is very high and the chloride content varies from 15,000 to 30,000 mg/l (as Cl^-).

Wastewater from other beamhouse operations namely liming, deliming, bating etc., is alkaline and contains decomposable organic matter, hair, lime, suspended/dissolved impurities, sulphide and high BOD in the range of 2000-5000 mg/l. This is mainly due to the poor quality of calcium hydroxide and other chemicals used in excess quantity without proper control in the beam house operations.

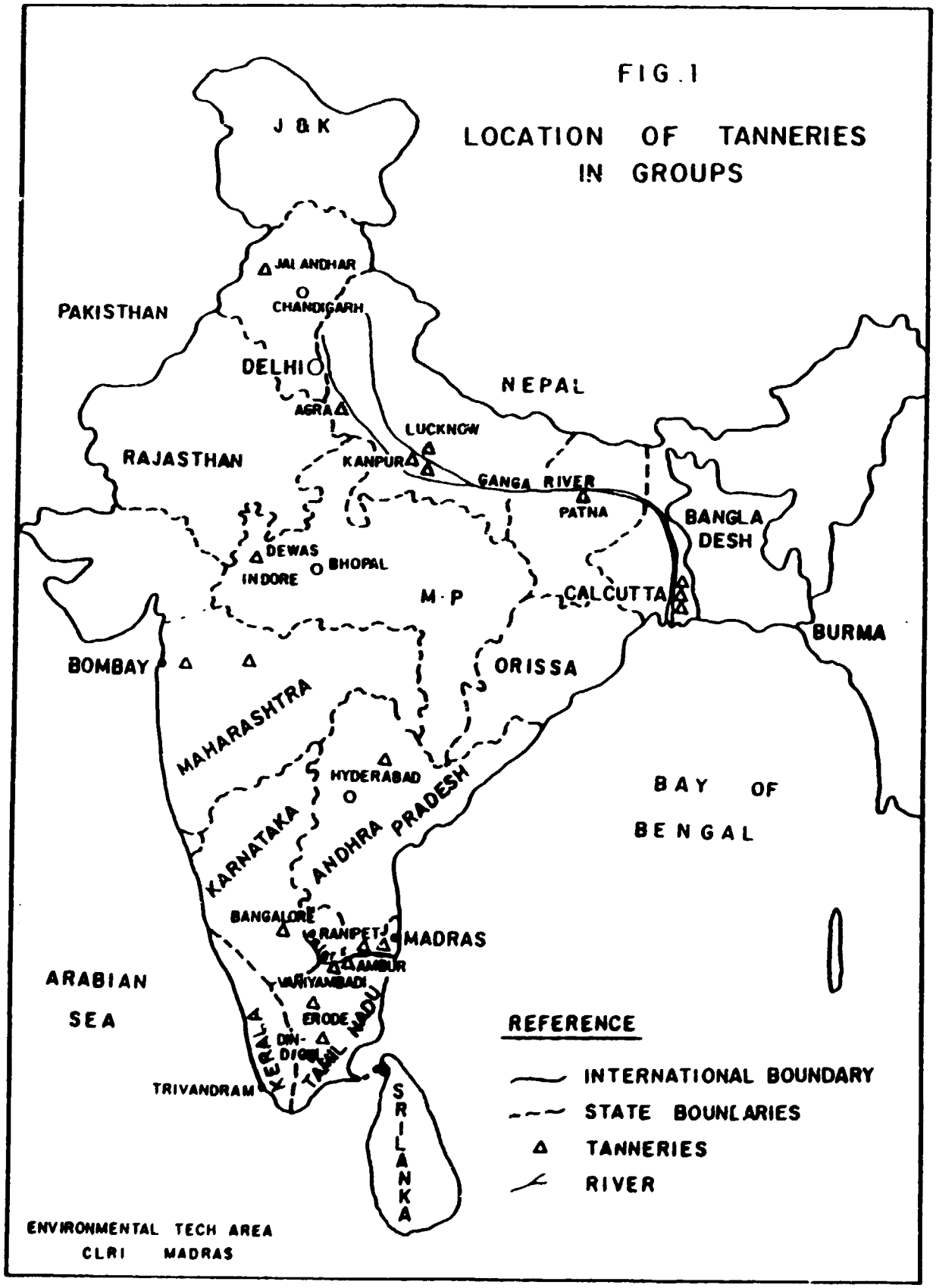
FIG.1
LOCATION OF TANNERIES IN GROUPS
J & K
JALANDHAR
CHANDIGARH
PAKISTHAN
DELHI
NEPAL
AGRA
LUCKNOW
RAJASTHAN
KANPUR
GANGA RIVER
PATNA
BANGLA DESH
DEWAS
INDORE
BHOPAL
M·P
CALCUTTA
BURMA
BOMBAY
ORISSA
MAHARASHTRA
HYDERABAD
BAY OF BENGAL
KARNATAKA
ANDHRA PRADESH
BANGALORE
RANIPET
MADRAS
AMBUR
ARABIAN SEA
VANIYAMBADI
ERODE
KERALA
DIN-DIGUL
TAMIL NADU
TRIVANDRAM
SRILANKA
REFERENCE
INTERNATIONAL BOUNDARY
STATE BOUNDARIES
TANNERIES
RIVER
ENVIRONMENTAL TECH AREA
CLRI MADRAS

Table 1: Characteristics of tannery wastewater

Parameter	Soaking	Liming	Deliming	Pickling	Chrome Tanning	Dyeing Fatliquor& Wet finish	Composite (including washings)
Vol of effluent in m3/ton of hides/skins	6-9	3-4	1-2	0.5-1	1-2	1-2	30-40
pH	7.5-8.0	10.0-12.8	7.0-9.0	2.0-3.0	2.5-4.0	3.5-4.5	7.0-9.0
BOD	1100-2500	5000-10000	1000-3000	400-700	350-800	1000-2000	1000-3000
COD	3000-6000	10000-25000	2500-7000	1000-3000	1000-2500	2500-7000	2500-8000
Total solids	35000-55000	30000-50000	4000-10000	35000-70000	30000-60000	4000-10000	15000-25000
Dissolved soilds	32000-48000	24000-30000	2500-6000	34000-67000	29000-57500	3400-9000	13000-21000
Suspended solids	3000-7000	6000-20000	1500-4000	1000-3000	1000-2500	600-1000	2000-4000
Chlorides as Cl	15000-30000	4000-8000	1000-2000	20000-30000	15000-25000	500-1000	6000-9500
Total Chromium as Cr	-	-	-	-	2000-5000	40-100	100-250

Note: All values except pH are expressed in mg/l.

Wastewater from tan-yard operations namely pickling, vegetable tanning, chrome tanning, fatliquoring etc. is acidic and coloured. The wastewater from vegetable tanning process contains highly polluting organic matter since many tanneries use barks and nuts for tanning in pits. The wastewater from chrome tanning contains large amount of chromium since only 50 to 70% chromium applied in the form of Basic Chromium Sulphate (BCS) is taken by leather and the balance is discharged as waste. It is estimated that 40,000 tons of BCS is used in Indian tanneries per year and about 15,000 tons of chromium in terms of BCS is discharged as waste in the effluent. This causes difficulties in effluent treatment and sludge disposal. Pollutional loads in tannery wastewater per ton of hides/skins process are given in Table 2.

Table 2: Average pollution loads in tannery wastewater per tonne of hides/skins processed

Sl. No.	Pollutional parameter	Pollutional load in kilograms
1.	Biological Oxygen Demand (BOD) 5 days @ 20°C	70
2.	Chemical Oxygen Demand (COD)	180
3.	Chlorides (as Cl)	270
4.	Dissolved solids	600
5.	Suspended solids	100
6.	Sulphides (as S)	4
7.	Total chromium (as Cr)	6

3. POLLUTION CONTROL STANDARDS AND EFFLUENT MANAGEMENT

According to the present Indian environmental pollution control regulations, the tanneries are obliged to set up effluent treatment systems either individually or collectively and the treated effluent shall meet the pollution control standards (i.e. BOD 30 mg/l, COD 250 mg/l, Total Dissolved Solids 2100 mg/l, Chlorides as Cl 1000 mg/l, Chromium as Cr 2 mg/l, Suspended Solids 100 mg/l etc for discharge into inland surface waters) as detailed in Table 3.

The tanneries in India can be grouped into four major categories for effluent treatment management.

i. Large and medium scale tanneries with adequate land, finance and managerial capacity to set up individual effluent treatment plants.

ii. Tanneries located in clusters and do not have adequate land to set up individual effluent treatment units but feasible to set up Common Effluent Treatment (CET) plants.

iii. Cluster of tanneries in cities like Calcutta, Jalandhar, Bombay etc where there is no scope even for CET plants due to non-availability of adequate land, public resistance from the surrounding area, other socioeconomic aspects etc.

iv. Scattered small scale tanneries which neither can set up individual effluent treatment plants nor be included in a CET system.

3.1 Individual Effluent Treatment Plants

Large and medium scale isolated tanneries numbering about 100 have already set up individual effluent treatment plants in their respective tanneries. The treatment capacities of these plants range from 50 to 1,000 cubic metre/day.

Table 3 : Bureau of Indian Standard tolerance limits for tannery effluents

(BIS : 2490 - PART 3 - 1985)

Important characteristics	Tolerance limits for industrial effluents discharged		
	Into Inland surface waters	Into public sewers	Onland for irrigation
Colour and odour	Absent	--	Absent
pH	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0
Suspended solids	100	600	200
Biochemical Oxygen Demand (BOD) 5 days@20^{o}C	30	350	100
Chemical Oxygen Demand (COD)	250	--	--
Total dissolved solids	2100	2100	2100
Chlorides as Cl	1000	1000	600
Total chromium as Cr	2	2	2
Hexavalent chromium as Cr	0.1	0.1	0.1
Sulphide as S	2	2	2
Sodium, percent	-	60	60
Boron as B	2	2	2
Oil and Grease	10	20	10

Note : 1. All values except pH and Sodium are expressed in mg/l

2. Refer concerned Central/State Pollution Control Board for specific standards.

3.2 Common Effluent Treatment Plants

Tanneries in clusters wherever feasible need to put up CET plants. It has been organized by various agencies to set up nearly 30 CET plants to cover the needs of about 1500 small and medium scale units. The treatment capacity of CET plants ranges from 1,000 to 36,000 cubic metre per day. The CET plants in Vaniyambadi tannery cluster in Tamilnadu State and Leather Complex in Punjab state have already been commissioned. The CET project at Pallavaram near Madras city sponsored by UNIDO and CET plants at Ambur, Ranipet etc in Tamilnadu State, Kanpur in Uttar Pradesh State and Bangalore in Karnataka State are under various stages of implementation.

The CET plant concept envisage pretreatment of effluent at the individual tanneries. The minimum requirements of pretreatment are screening and grit removal. In many of the clusters, inadequate land space is the main constraint even to provide pretreatment facilities in individual tanneries. Generally after screening, effluent from the tanneries is collected through a common drain leading to the CET plant.

Prerequisite to set up a CET plant is establishment of an industrial co-operative society by the concerned tanneries of the cluster to be benefited. The co-operative society is responsible both for construction of the CET plant and also for its day-to-day operation and maintenance. The capital cost of the CET plant is shared by the tanneries based on their average production capacities. Financial assistance to the extent of 20 to 25% from the Central Government and 20 to 25% from the concerned State Government on capital investment is provided as grant to the CET plants. Tanneries contribute 10 to 20% of the capital investment and the balance is borrowed as loan from banks at an interest rate ranging from 16 to 22% per annum.

3.3 Scattered Small Scale Units

There are few important tannery clusters like in Calcutta city where there are more than 500 units in number but land space is often inadequate even to lay a common drainage and central primary treatment system. In many towns public sewer system is not available. Even if available, the public sewers are not designed to carry the large volume of tannery effluent with high pollutional load. Further, the tanneries in few towns like in Jalandhar City are scattered and surrounded by residential and other commercial units and often face public objections for the continued existence. In case of these tanning centers, the only environmentally satisfactory solution is to relocate the tanneries to a common industrial site at a satisfactory distance from the city area with combined drainage facilities for tannery effluent and CET plant. The new location need be planned as an exclusive industrial estate for tanning with grouping of different processes. However, relocation of this traditional industry is an enormous and time consuming task. An industrial estate with CET plant in Jalandhar has been recently established for tanneries and other leather units. A major industrial estate is proposed for the relocation of tanneries in Calcutta.

4. TREATMENT TECHNOLOGIES ADOPTED IN INDIA

Treatment technologies commonly adopted under Indian conditions comprises of four steps namely:

i. Segregation of certain sectional waste streams like soak liquor, chrome liquor etc or mixing of suitable sectional wastewater from different processes;

ii. Primary treatment in individual tanneries or in a centralized place wherever CET plant is established;

iii. Secondary biological anaerobic/aerobic treatment; and

iv. Disposal of solid wastes from the treatment plant.

The primary treatment units are mostly similar, either equalisation cum settling tank with sludge drying beds or separate equalisation tank and settling tank with sludge drying beds. Few tanneries in Kanpur have implemented chrome recovery and reuse system. A full scale chrome recovery system, sponsored by UNIDO is being implemented in Pallavaram tannery cluster near Madras city. Secondary biological treatment combinations depend upon the location, availability of land and final mode of treated effluent disposal.

The following three secondary biological treatment combinations are widely adopted in India.

i. Anaerobic lagoon followed by aerated lagoon;

ii. Anaerobic lagoon followed by extended aeration;

iii. Two-stage activated sludge process or extended aeration system.

A typical combination of various treatment processes are shown in Fig 2.

Upflow Anaerobic Sludge Blanket (UASB) system for a CET plant in Kanpur, Upflow Anaerobic Contact Filter for a CET plant in Ambur town, Dissolved Air Floating system in a few tanneries in Tamilnadu State are also being adopted.

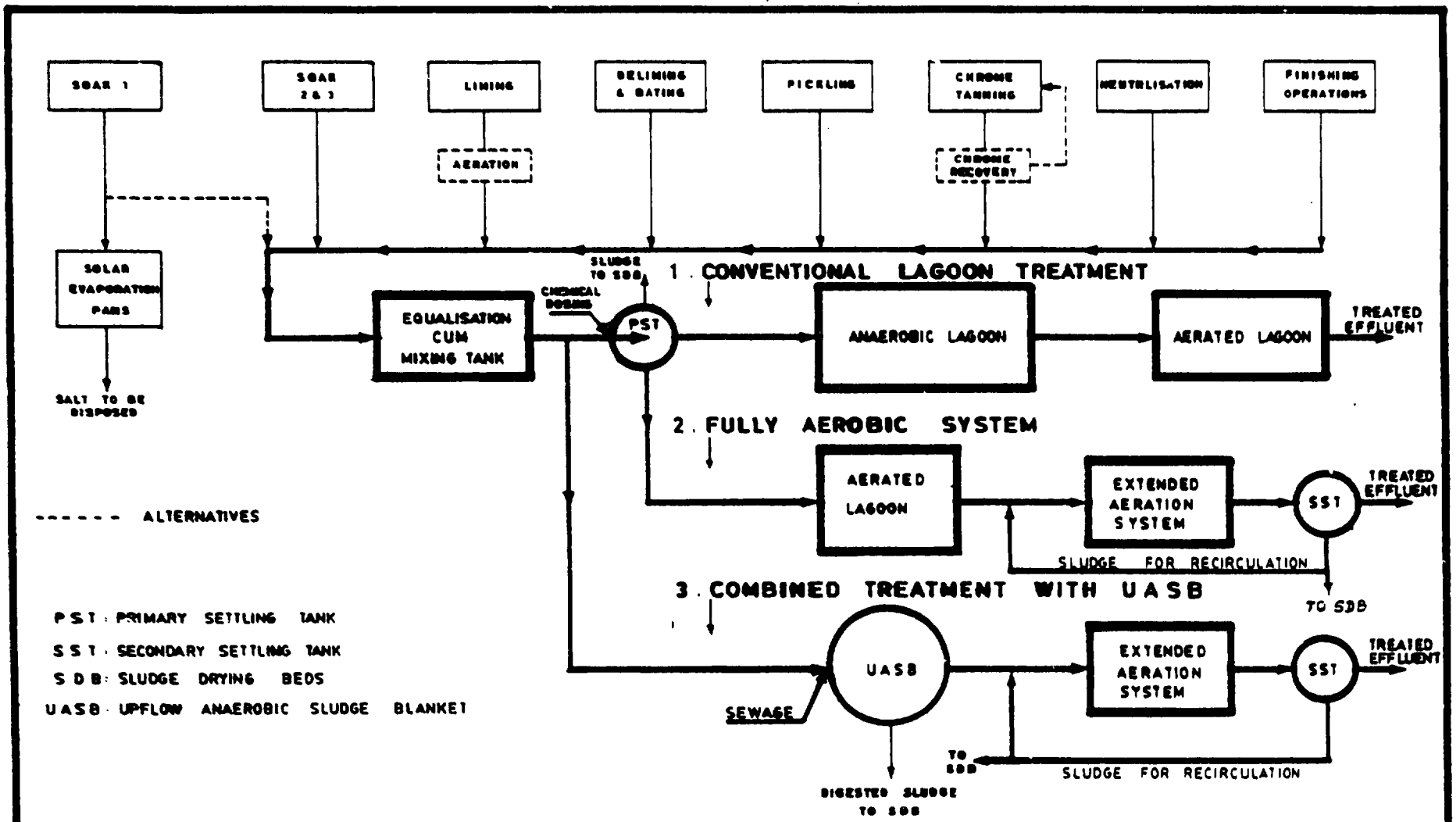

FIG.2 TANNERY EFFLUENT TREATMENT SYSTEMS

5. EXPERIENCES AND LESSONS LEARNT IN SETTING UP TREATMENT PLANTS

5.1 Treatment Plant Capacities

The volume of wastewater discharge and characteristics vary from process to process and tannery to tannery. Hence, detailed inventory and survey of the tanneries including their future plan are required before designing every plant. Most of the effluent treatment plants particularly CET plants in India are either under utilized or under designed. For instance, the CET plant at Vaniyambadi in Tamilnadu State is designed and set up to treat 3,000 cubic metre/day of effluent from 80 tanneries. Currently about 50 tanneries are connected to the CET plant and the other 30 units would be connected in future. But the effluent discharge from the 50 tanneries itself is about 2,500 cubic metre/day and would be more than 4,000 cubic metre/day when all the 80 tanneries are connected to the CET plant. This excess discharge of about 1,000 cubic metre/day of effluent is due to increase in production by about 50% during the planning and implementation period of about 6 years.

Near Jalandhar town in North India a leather complex has been set up recently. A CET plant with 4,500 cubic metre/day has been designed in three modules. The first module with treatment capacity of 1,500 cubic metre/day was constructed and commissioned by the end of 1992 but only about 200 cubic metre/day of effluent from 2 to 3 tanneries is discharged to the CET plant due to delay in the development and relocation of the tanneries to the complex. The CET plant is being operated for less than 20% of its capacity for the past one year, causing operational problems and financial crises.

5.2 Consultancy Firms and Design of Treatment Plants

Many environmental engineering consultancy firms are involved in the design and setting of tannery effluent plants in India. Most of these firms have experience only with the design

and execution of drainage and treatment system for domestic sewage. As the tannery effluent is complex in nature, variable in quality and quantity, knowledge and experience in the tanning process, effluent characteristics and treatment technology would be necessary. For instance, one of the CET plants in South India was designed and constructed without an equalization system. This caused shock and over loading of the primary clarifier, accumulation of sludge in the anaerobic lagoon, over loading in the aerobic biological treatment unit etc. The CET system has been reviewed and an equalization cum mixing tank is being constructed as an additional activity.

5.3 Selection of Site and Appropriate Treatment Technology

Selection of site and treatment technology need thorough study on techno-economic aspects including topography, capital investment, final mode of treated effluent, operation and maintenance cost, land requirement, availability of skilled manpower, influence of the treatment cost on the production of leather etc.

Anaerobic lagoon treatment has been recommended in South India as first stage biological treatment for the segregated effluent discharged from isolated tanneries located outside the cities and processing mostly vegetable tanning in pits and partly chrome tanning. The segregated tannery effluent stream excludes soaking and pickling liquors to minimize the concentration of chlorides and sulphates. But anaerobic lagoons are adopted indiscriminately for treating effluents from all types of chrome tanneries without proper study and segregation of salt containing streams. For example, an anaerobic lagoon with a huge capacity of 40,000 cubic metre in a land area of 15,000 sq.metre was designed and constructed in one of CET plants for treating the effluent discharged mostly from chrome tanneries. The problems of conversion of sulphate into sulphide in the anaerobic lagoon, contribution of COD load and increase in oxygen requirement in the post-aerobic treatment have not been taken

into account in the CET plant design. In addition, this anaerobic lagoon is constructed as a single compartment and will likely to cause problems in operation and maintenance particularly in desludging, emptying the lagoon etc.

Highly sophisticated treatment units like dissolved air flotation system have been set up in few units. Though this system has got certain merits like less land area requirement, improved dissolved oxygen content in the effluent etc, high operational and maintenance cost, frequent replacement of the mechanical parts, corrosion problems, non-availability of skilled manpower etc led to its discontinuance in certain cases.

5.4 Cost Estimate and Financing

The capital cost of an effluent treatment plant depends upon the type of treatment technology, location, final mode of disposal etc. Capital cost for implementing 1,000 cubic metre/day capacity effluent treatment plant would range from 0.5 to 1.0 million US Dollars as per April 1993 rates. Treatment cost of 1,000 cubic metre effluent including operation and maintenance cost, financial cost etc would range from 250 to 750 US Dollars. Cost estimate for the effluent plants are made on capital investment of the plants and annual operation and maintenance for utilization of its designed capacity without provision for escalation, repayment of loan, depreciation, time and cost involved in initial standardization of the process, actual utilization of the plant etc. In view of this most of the projects cost estimates have become unrealistic and ended with revisions. The interest rates for the loan for setting up CET plants are in the range of 16 to 22% per annum. The high interest rate results in high treatment cost and constraints in repayment of loan. Proper techno-economic studies were not carried out in many of the CET plants taking into account of the long term survival of small scale units particularly the units processing raw hides/skins into semi finished leather.

5.5 Equipments & Materials of Construction

Selection of suitable equipments and materials for construction is an important factor. Though most of the mechanical and electrical items for the setting up of effluent plants are manufactured in India, few items need improved design and quality in view of the special requirements in the treatment of tannery effluents. Some of the identified items are

i. Special mechanical rotary screens/sieve arrangements.

ii. Mechanical sludge dewatering systems.

iii. Efficient aeration systems for biological treatment.

Due to unsuitable selection of equipments like conventional bar screens, fixed type aerators etc the desired performance efficiencies could not be achieved in some of the treatment plants.

5.6 Operation & Maintenance Problems

The important problems faced in the operation and maintenance effluent treatment systems are

* Many tanneries use hard water available from their own open or bore wells, poor quality lime with high amount of suspended solids and other chemicals which adversely affect the effluent quality particularly in terms of TDS, chlorides and suspended solids.

* Major variations in the production capacity and effluent discharge which results in under utilization or over loading of the treatment system.

* Few tanneries totally modify the process after implementation of the effluent treatment system (i.e.

from vegetable tanning to chrome tanning, processing from wet blue to finishing instead of raw to finishing and vice versa) and resulted in major change in the quality and quantity of effluent and maintenance of effluent treatment plant.

* Use of toxic and excess non-biodegradable chemicals, preservatives and other inorganic chemicals supplied under commercial name, often vary the quality of effluent and affect the biological treatment systems.

* Discharge of solid waste like fleshing, vegetable tan barks, leather pieces in the wastewater drain leading to effluent treatment plant without proper control.

* Choking and overflowing of the sewer are common occurrences. These are due to poor pretreatment arrangements in the individual tanneries and in some cases, the design of drainage system was not properly done considering the peak flows and other variations.

* Mixing of rain water with tannery effluent often cause- over loading of treatment units in the absence of by-pass arrangements.

* Non-segregation of certain specified streams like soak liquor, pickle liquor, chrome liquor etc from the main waste stream which are originally designed for separate treatment.

* Improper equalisation of the wastewater from various sectional operations, chemical dosing, primary clarification, removal of sludge, operation of sludge dewatering system etc cause often over loading of biological treatment units.

* Insufficient nutrient supply, improper maintenance in recirculation of active sludge and control of MLSS in the

extended aeration/activated sludge processes often affects performance efficiency.

* Operation and maintenance of the treatment units with unskilled manpower who has no knowledge and experience in the tannery effluent system.

* Supply of uninterrupted power supply to the effluent treatment plants is one of the main constraints. Though few CET plants are having alternative power supply arrangement using diesel generators, providing continuous power is often faced with problems when main power supply breaks down for a long period of more than 4 to 6 hours. In addition, the energy supplied from diesel generators is costly.

* Disposal of chrome containing sludge which accumulates in large quantities in the effluent treatment area is another major problem in the absence of proper utilization/disposal methods. It is estimated that about 100,000 tons of partially dried sludge would be generated per year when all the CET plants started functioning.

* Constraints in the sharing of cost towards the operation and maintenance of CET plants by the tanneries in the absence of suitable and acceptable formula.

* Some of the pollution control standards like parameters for Total Dissolved Solids (2100 mg/l), Chlorides (1000 mg/l) etc are unrealistic. For instance, the quality of ground water in some of the tannery area is so deteriorated that if the ground water is directly pumped and discharged outside the tannery without using for the process it will not meet the pollution control standards in terms of dissolved solids and chlorides.

6 VIEWS AND SUGGESTIONS

Tannery effluent is complex in nature. The treatment and disposal of tannery wastewater to meet the pollution control standards is a difficult task and require specialized technological input from experienced and knowledgeable experts. Lack of participation, involvement and awareness among the tanners on the overall planning, selection treatment technology, implementation, operation and maintenance aspects etc. Tne setting up of treatment plants for tannery effluents were under-estimated in many cases resulting serious problems in operation and maintenance. Considering the design efficiencies, the field performance efficiencies of most of the treatment plants are low.

The tanners are mostly conservative in nature and they believe what they see and do not disclose what they do. Though some of the cleaner technologies like chrome recovery and reuse, solid waste utilization etc are developed and adopted by few units, they are yet to become popular. Major programmes for demonstration and wide dissemination are considered necessary.

The tannery effluent treatment plants are either under utilized or under designed with more than 25% difference between the designed capacity and utilization. Organized planning, proper techno-economic feasibility study, continued training and demonstration are necessary not only for tanners and technical staff in the operation and maintenance but also to the pollution control agencies in association with organizations like Central Leather Research Institute (CLRI), United Nations Industrial Development Organization (UNIDO) etc.

REFERENCES

1. Tannery effluents treatment by activated sludge process.
S. Rajamani and W. Madhavakrishna.
Leather Science 1983.

2. Tannery effluents - Methods of treatment control.
S. Rajamani
Commonwealth Science Council, Regional Workshop, Madras, India 1986

3. Environmental Impact Assessment and Effluent Management in Leather Industries.
S. Rajamani, w. Madhavakrishna and G. Thyagarajan.
National Convention of Institution of Engineers, Environmental Engineering Wing, Nainital, India 1987

4. Inventory of tanneries and effluent analysis for a combined effluent treatment system.
S. Rajamani and S.N. Gupta
Indo-Dutch Workshop, Kanpur, India 1989

5. Tannery effluent treatment system in achieving pollution control standards.
S. Rajamani, W. Madhavakrishna and A. Raman
Regional seminar on quality through Standards BIS
Ambur, India 1988

6. Clean technology in the leather industry - "Chrome recovery and reuse".
S. Rajamani, S.N. Gupta, R.B. Mitra, J.E. Schaapman and H.H.A. Pelckmans.
Paper presented in International Water Pollution Control Federation Conference held in Washington, DC, USA Oct 1990

7. Anaerobic treatment of tannery effluents.
S. Rajamani.
Paper presented in the UNIDO sponsored Expert Group Meeting in pollution control in the tannery industry in the South East Asia Region, Madras, India 15-17 February 1991.

8. Treatment of combined tannery effluent with Upflow Anaerobic Sludge Blanket (UASB) System.
S. Rajamani, K.V. Raghavan, G. Thyagarajan, J.E. Schaapman and Abdullah Khan.
Paper presented in International Water Pollution Control Federation Conference held in Toronto, Canada, Oct 1991.

9. Chrome recovery and reuse in tanneries.
S. Rajamani, R. Suthantharajan, E. Ravindranath, K.V. Raghavan, G. Thyagarajan and J.E. Schaapman.
Paper presented in Enviro Tech 91 4th International Conference & Exhibition held at Nehru Center, Bombay from Oct 28-Nov 2, 1991.

10. Chrome recovery and reuse in India
S. Rajamani, S.N. Gupta, R.B. Mitra, J.E. Schaapman and H.H.A. Pelckmans.
Paper published in the American Journal of Water Environment and Technology Jan 1992 issue.