STUDIES ON GAS CHLORINATION FOR COLOUR REMOVAL IN TEXTILE DYEING INDUSTRIES IN TAMIL NADU

Submitted to

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ABBREVIATIONS

A	-	Absorbance
ACGIH	-	American Conference of Governmental Industrial Hygienists
AEGLs	-	Acute Exposure Guideline Levels
AFFFBR	-	Anaerobic Fixed Film Fixed Bed Reactor
ALCOA	-	Aluminium Company of America
AOX	-	Adsorbable Organic Halogen
ASP	-	Activated Sludge Process
AVR	-	Automatic Voltage Regulator
BC	-	British Columbia
BDL	-	Below Detectable Limit
BOD	-	Biological Oxygen Demand
CAS	-	Chemical Abstract Service
CETP	-	Common Effluent Treatment Plant
COD	-	Chemical Oxygen Demand
CPCB	-	Central Pollution Control Board
DAF	-	Dissolved Air Flotation
DIN	-	Deutsches Institute for Normung (German Institute of Standards)
DO	-	Dissolved Oxygen
EC	-	Electrical Conductivity
EN	-	European Norm
EPA	-	Environmental Protection Agency
ETP	-	Effluent Treatment Plant
FRP	-	Fibre Glass Reinforced Plastic
GDP	-	Gross Domestic Product
GL	-	Ground Level
h	-	Hour
H_2O_2	-	Hydrogen Peroxide
HCl	-	Hydrochloric Acid

HDPE	-	High Density Poly Ethylene
HOCl	-	Hypochlorous Acid
ID	-	Inner Diameter
IDLH	-	Immediately Dangerous to Life or Health
IS	-	Indian Standards
ISO	-	International Standard Organization
L	-	Litre
m	-	Meter
MBR	-	Membrane Bioreactor
mg/L	-	Milligram per Litre
MINAS	-	Minimal National Standards
mL	-	Milli Litre
MSDS	-	Material Safety Data Sheet
NF	-	Nano Filtration
nm	-	Nano meter
O_3	-	Ozone
OD	-	Outer Diameter
OEHHA	-	Office of Environmental Health Hazard Assessment
OR	-	Oxidation Reduction
OSHA	-	Occupational Safety and Health Administration
PPE	-	Personnel Protective Equipment
ppm	-	Parts per Million
PVC	-	Poly Vinyl Chloride
RED	-	Re-registration Eligibility Document
RMP	-	Risk Management Programme
RO	-	Reverse Osmosis
SHE	-	Safety, Health and Environment
SIPCOT	-	State Industries Promotion Corporation of Tamil Nadu
SMBS	-	Sodium Meta Bi-sulfite
STEL	-	Short-term Exposure Limit
SU	-	Study Units

T	-	Tonne
TDS	-	Total Dissolved Solids
TiO_2	-	Titanium Dioxide
TLV	-	Threshold Limit Value
TNPCB	-	Tamil Nadu Pollution Control Board
TSS	-	Total Suspended Solids
TWA	-	Time Weighted Average
UASB	-	Upflow Anaerobic Sludge Blanket
UF	-	Ultra Filtration
UK	-	United Kingdom
UN	-	United Nation
UNIDO	-	United Nation Industrial Development Organization
US	-	United States
USEPA	-	United States Environmental Protection Agency
ZLD	-	Zero Liquid Discharge

CHAPTER 1

TEXTILE DYEING INDUSTRIES

1.1 General

The Textile Industry plays an important role in Indian Economy. Currently, it contributes to 4% of GDP, 14% of industrial production and over 13.5% of export earnings of India (Textile Ministry, 2009). The Textile Sector in Tamil Nadu contributes well over one-fourth of India's total textile manufacturing meant for domestic consumption as well as for exports. Coimbatore, Tirupur, Salem and Erode is known as textile belt of Tamil Nadu. If Coimbatore is known for cotton production, Tirupur is known for knitting and Erode and Salem are known as the home of textile weavers.

Tirupur popularly known as the 'Baniyan City' contributes about 60-70% of knitwear export from India. The Tirupur Textile Industry makes extensive use of local networking, with the manufacturing process being broken down into specialized 'job-work units' such as knitting, bleaching and dyeing, printing, cutting and sewing carried out on different premises. About 700 units are involved in textile wet processing in and around Tirupur.

Erode which is situated on the bank of the river Cauvery is popular for the handloom products and also home textiles like lungi, towels, etc. About 567 units engaged in cotton/man-made yarn/fabric dyeing and printing are functioning in Erode. These units are concentrated on the banks of river Cauvery and Bhavani in Erode and Bhavani taluks.

1.2 Textile Processing

In the broader sense, the textile industry includes production of yarn (natural/man-made), converting yarn into grey cloth and doing wet-processing of yarn/grey cloth into finished consumer products.

The spinning stage consists of blowing and mixing, carding, combing, drawing, simplex, ring spinning and cone winding. The weaving stage comprises warping, sizing and weaving. The wet processing helps to enhance the appearance, durability and serviceability of fabrics by converting yarn/grey cloth (known as greige goods) into finished consumer goods. The wet processing can be broken down into four stages viz., fabric preparation, dyeing, printing and finishing. A wide range of equipment viz., winch, soft flow, cabinet, cheese, and jigger machines are used in textile wet processing. The wet processing covers singeing (burning to remove loose threads), desizing (removing sizes from the fabric), scouring (immersion in caustic soda to remove impurities), bleaching (using chlorine, hydrogen peroxide or sodium hypochlorite to whiten it), heating, washing, drying, mercerizing (immersion in cold caustic soda to improve affinity of dyes), washing, dyeing, washing, drying, printing, drying and finishing (to obtain wrinkle-free or water repellent cloth) and calendaring. Wet-processing consumes large quantity of water and various types of chemicals (viz., dyes, sodium chloride, soda ash, caustic soda, wetting oil, hydrochloric acid, sulphuric acid, acetic acid, softening agents, fixing agents etc.).

The textile wet processing is associated with a number of environmental problems, since it results in the generation of large quantity of complex and varying characteristic wastewater having unfixed dyes and other organic and inorganic chemicals used in wet processing. The effluents are generally hot, alkaline and coloured by dyes and they lower dissolved oxygen levels in receiving water bodies, threaten aquatic life and damage the aesthetic value as well as the quality of surface water bodies and ground water bodies. In addition, soil fertility might be lost leading to loss of agricultural production.

1.3 Colour Removal in Textile Effluent

A wide variety of dyes viz., Reactive, Acid, Basic, Direct, Disperse, Sulphur and Vat dyes are used in the textile dyeing process. The typical fixation of the textile dyes varies in the range of 40-95%. The textile effluents are highly coloured due to the release of unfixed dye molecules in the dyeing process. Since human eye can readily detect less than 1ppm dye concentration, the coloured textile effluent causes significant aesthetic problem. Also the resistance of the dyes to degradation in biological treatment systems is of concern.

Textile wet processing industries employ several treatment technologies for the 'Colour Removal' in the Textile Effluent. Broadly the treatment technologies for Colour Removal fall under two categories viz., Separation Technologies and Degradation Technologies. The separation technologies include chemical precipitation (using chemical coagulants viz., lime, ferric chloride, alum, ferrous sulphate with addition of polyelectrolytes, if necessary), adsorption (using activated carbon), Ion Exchange Resins and filtration. The oxidation technologies can be classified into chemical and biological oxidation technologies. The biological treatment system employed could be aerobic, anaerobic or combination of both. The chemical oxidation technologies could employ either conventional chemical oxidants like potassium permanganate, chlorine, etc. or advanced oxidation processes like UV irradiation, O_3 and UV/O_3 which are designed to generate powerful hydroxyl radicals that have oxidation potential several times higher than the oxidation potential of conventional chemical oxidants.

The choice of the treatment methods could vary from one industry to the other and the effluent treatment schemes typically could include various physical, chemical, biological or combination of physico-chemical and biological treatment processes, depending upon the degree of treatment to be achieved. Most effluent treatment schemes of Textile Industries in Tamil Nadu have incorporated 'Chemical Precipitation' as treatment technology for colour removal.

1.4 Gas Chlorination in Textile Dyeing Industries in Tamil Nadu

The Textile Wet Processing Industries in Textile Belt of Tamil Nadu have adopted the 'Chemical Precipitation' as the conventional treatment method for Colour Removal for a longer period of time. Chemical coagulants like alum, lime, ferrous chloride and ferric chloride along with polyelectrolytes (if necessary) are added to react with dyes resulting in the separation of dye molecules from the effluent. The dye molecules settle down along with chemical coagulants as chemical sludge in the sedimentation tank. The conventional chemical treatment results in generation of large quantities of chemical sludge which is classified as hazardous waste. About 200 T of sludge per day is generated for treating one lakh litre of textile wastewater. The cost of management and disposal of hazardous sludge has become a problem to the industries. In addition, larger area is required to store the sludges within the premises of the industries and it is also of great concern to the industries.

In order to eliminate the problem of sludge management, at present, some Textile Wet Processing Units in the Textile Belt of Tamil Nadu are adopting 'Gas Chlorination' as Colour Removal Technology instead of the conventional chemical precipitation. The easy availability of gas chlorine in cylinders/tonners and availability of gas chlorinator units locally with cheaper cost encourages the industries to select this technology, since it also eliminates the problem of sludge generation to a major extent.

1.5 Scope and Objectives of the Study

Recently, the Honorable High Court of Madras has directed the Tamil Nadu Pollution Control Board 'to review the use of chlorine and its storage procedures in the industrial sector and to ensure that the best available technology is adopted for colour removal and health of community is not put at risk due to adoption of low-cost substandard solution'. In this context, the Tamil Nadu Pollution Control Board (TNPCB) has mandated the Centre for Environmental Studies, Anna University, Chennai-25 to conduct an expert study on Gas Chlorination in Textile Dyeing Industries, Tamil Nadu in 03.04.2008. The scope of the study included the following three aspects.

1. Review of chlorine use and its storage procedures in the Textile Industries, Tamil Nadu.
2. Review of treatment technologies for colour removal and making suitable recommendations by taking into considerations various factors including community health.
3. Study part shall also address the efficacy of the effluent treatment systems adopting gas chlorination technique provided by the textile dyeing units to the maximum possible extent.

The various tasks to be carried out in the study are as follows:

1. Review the available Literature on National/ International Policies/ Practices/ Regulations/ Laws/ Rules on the use of Chlorine gas in water/ wastewater treatment.
2. Select Ten Study Units mainly located at Erode District and a few units located in Tirupur, and Karur District.
3. Review the storage, handling and usage practices of Chlorine gas in Textile Effluent Treatment systems in the Selected Study Units.
4. Conduct Field Studies on Gas Chlorination in the Study Units and analyze Wastewater/ Ambient Air/ Solid Waste samples for the applicable physico chemical parameters.
5. Arrive at the mass-balance for the Chlorine gas used.

6. Assess the impact of Gas Chlorination treatment residues on the environment and human health using accepted health criteria.
7. Make suitable recommendations on the safety in Chlorine storage and use.
8. Review the Textile Effluent Treatment technologies for colour removal and suitable recommendations.

This report covers the details of the study – methodology, data collected, data interpretation and the recommendations within the scope of the study.

CHAPTER 2

USE OF CHLORINE IN INDUSTRIES

A comprehensive review of literatures on the use of chlorine in industries and the properties of chlorine and its chemical hazards was carried out. In addition, various accidents that have taken place internationally and in India due to chlorine use in industries are presented in this chapter.

2.1 Properties of Chlorine

Chlorine is a member of the halogen family and is the second most reactive non-metallic substance next to fluorine. It is highly reactive, thus almost never found in nature. About 2% of earth's surface material is chlorine, which is in the form of sodium chloride in seawater and natural deposits as carnallite ($KMgCl_3.6H_2O$) and sylvite (KCl). Active volcanoes can emit some chlorine. The general properties of chlorine are presented in Table 2.1.

Table 2.1 General Properties of Chlorine

Sl. No.	Properties	Values
1	Chemical Abstract Service (CAS) Number	7782 – 50 –5
2	UN Number	1017
3	UN Class	2
4	Hazchem code	2XE
5	National Fire Protection Association Hazard Index	
	5.1 Health	3
	5.2 Flammability	0
	5.3 Reactivity	0

Source: IS : 4263 – 1967 Indian Standard Code of Safety for Chlorine.

2.1.1 Physical Properties

Some of the important physical properties of chlorine are presented in Table 2.2.

Table 2.2 Physical Properties of Chlorine

Sl. No.	Description of Properties	Remarks
1	Physical State	Gas as well as liquid
2	Colour	Greening Yellow (gas), Clear amber (liquid)
3	Odour	Characteristic, suffocating
4	Boiling point (Liquefying)	34.6°C (1 atm)
5	Freezing (melting) point	-100.98°C (1atm)
6	Density	3.209 g/L (1 atm, O°C)
7	Vapour pressure	3.617 atm (O°C)
8	Liquid Gas Volume Relationship Ratio	Weight of one volume of liquid Cl_2 equals weight of 457.6 volumes of gas @ O°C and 1 atm
9	Solubility	Soluble in alkalis, but only slightly soluble in water, ~1% @ 9.4°C

Source: IS : 4263 – 1967 Indian Standard Code of Safety for Chlorine

2.1.2 Chemical and Hazardous Properties

In India, chlorine is deemed to be an explosive, when contained in any metal container in a compressed liquefied state, within the meaning of the Indian Explosives Act, 1984. The filling, possession, transport and importation are governed by the Gas Cylinder Rules 1940. The chemical and hazardous properties of chlorine are presented in Table 2.3.

Table 2.3 Chemical and Hazardous Properties of Chlorine

Sl. No.	Properties	Remarks
1	Flammability	Neither liquid nor gaseous chlorine is explosive or flammable, but both react readily with many organic substances which may result in explosion. Chlorine also supports combustion of certain materials.
2	Reactivity 2.1 With Metals	Dry chlorine reacts with aluminium, arsenic, gold, mercury, selenium, tellurium, tin and titanium. Carbon steel ignites above 250°C.
	2.2 With Other elements	Mixtures of chlorine and Hydrogen composed of more than 5% of either component may react with explosive violence. It acts with ammonia, alkalis and alkaline earth metal hydroxides.
	2.3 With Inorganic Compounds	Chlorine has great affinity for Hydrogen. Chlorine reacts with ammonia. Chlorine reacts readily with lime and caustic soda to form hypochlorites.
	2.4 With Organic Compounds	Chlorine reacts with organic compounds to form chlorinated derivatives and Hydrochloric acid. The reactions with Hydrocarbons, alcohols and ethers may become explosive.

Source: IS : 4263 – 1967 Indian Standard Code of Safety for Chlorine

2.2 Hazards Associated with Chlorine

2.2.1 Health Hazards

i) **Respiratory System:** Chlorine gas is primarily a respiratory irritant. If chlorine is inhaled (1-10 ppm), irritation of respiratory system may occur with coughing and breathing difficulty. The effect of chlorine may become more severe for upto 36 h of exposure. Inhalation of higher concentrations (>15ppm) can rapidly lead to respiratory distress with airway constriction and pulmonary edema. Tachypnea, dyspnea, cyanosis, wheezing, rales, a feeling of suffocation and/or hemoptysis may rapidly develop. Exposures to concentrations of 1000 ppm can be fatal even within minutes.

ii) **Eyes:** Low concentrations in air can cause burning discomfort, spasmodic blinking or involuntary closing of eyelids, redness, conjunctivitis and tearing. Corneal burns may occur at high concentrations. Prolonged exposure can cause blindness.

iii) **Skin:** Chlorine's corrosive effects irritate the skin, causing burning pain, inflammation, sweating and blisters. Direct contact with liquid chlorine or concentrated vapour can produce a severe chemical burn similar to a thermal burn.

iv) **Cadiovascular:** Tachycardia and initial hypertension followed by hypotension may occur. After severe exposure, cardiovascular collapse may occur due to lack of oxygen. Children are more vulnerable to chlorine gas than adult.

v) **Metabolic and General:** Insufficient tissue oxygenation can produce acidosis. A major inhalation exposure can produce an unusual form of acid-base imbalance, hyperchloremic metabolic acidosis, caused by an excess of chloride ions in the blood. Other general symptoms may include dizziness, agitation, anxiety, nausea and vomiting.

vi) **Long-term (Chronic) Effects:** The health effects associated with breathing small amounts of chlorine over longer periods of time are not known, but are currently under investigation. Some studies show that workers develop adverse effects from repeated inhalation exposures, but others do not. Chronic exposure has been shown to cause corrosion of teeth. Prolonged exposure to atmospheric chlorine concentration of 5 ppm results in disease of bronchi and a predeposition of tuberculosis. Acne is common in persons exposed for longer periods of time to low concentrations of chlorine and is commonly known as chlorance. Chlorine has not been classified for carcinogenic effects, but the association of cigarette smoking and chlorine fumes may increase the risk of cancer.

vii) **Mechanism of Action of Chlorine:** The mechanism of action of chlorine lies in two different free radical pathways.

a. Chlorine atom which itself is a free radical, when released reacts with other molecules to oxidise them.
b. Indirect generation of reactive oxygen species.

On entering the respiratory tract, chlorine reacts with water forming hydrochloric acid (HCl) and hypochlorous acid (HOCl) ($Cl_2 + H_2O \rightleftharpoons HCl + HOCl$).

Hypochlorous acid is a strong oxidizing agent and on dissolution, it releases hydrochloric acid (HCl) and reactive oxygen species (O). ($HOCl \rightleftharpoons HCl + O$). These react with the surrounding tissue components causing oxidative changes that lead to the generation of pro-inflammatory signals and the initiation of an inflammatory response in the airways. The hydrochloric acid then acts as a secondary irritant.

viii) Reproductive Toxicity Information: Chlorine has not been reported to cause mutagenicity, teratogenicity, embryo toxicity and reproductive toxicity effects in humans.

2.2.2 Explosion Hazard

Since liquid chlorine increases considerably in volume (weight of one volume of liquid chlorine equals weight of 457.6 volumes of gas at 0°C and 1 ppm) when evaporated, hydrostatic rupture in containers, pipelines and other equipment may occur due to buildup of excessive pressure. The danger due to pressure buildup in a heated cylinder leading to an explosion is to be noted.

2.2.3 Fire Hazard

Chlorine is neither explosive nor flammable, like oxygen, it is capable of supporting combustion of certain substances and corrosives. It may react to cause fires or explosions upon contact with turpentine, ether, ammonia gas, illuminating gas, hydrocarbons, hydrogen, powdered metals, saw dust and phosphorous.

2.3 Use of Chlorine

Chlorine was discovered by Sheele in 1774 A.D. and confirmed by Humphery Davy in 1810 A.D., who suggested the name chlorine (Greek word meaning greenish yellow) for the gas. Definitive work on electrolytic generation of chlorine and its liquefaction was done by Michael Faraday in 1830s and the first English patent for an electrolytic chlorine producing cell was given to Charles Watt in 1851. The first permanent liquid chlorine water purification system was installed in Philadelphia in 1913 and Altoona, Pennsylvania was the first city to treat sewage with liquid chlorine in 1914. Chlorine was used as a poisonous gas during the war in 1915 and it was first registered as a disinfectant in drinking water, cooling tower, swimming pool water and sewage treatment by US in the year 1948. Chlor-Alkali industry is involved in the manufacture of chlorine gas. Chlorine gas produced is chilled into a liquid and stored as a liquefied compressed gas to facilitate its transport, handling and usage. The dynamic growth of chlorine chemistry during the industrial development in the twentieth century has resulted in wide application of chlorine all over the world which are as follows:

1. The largest single use of chlorine (~50%) is in the manufacture of PVC, which is used in fabricating flooring, piping, wallpaper, furniture and various household products.
2. Chlorine (~10%) is also extensively used to bleach wood pulp and paper.
3. Chlorine is also widely used as a chemical reagent in the synthesis and manufacture of metallic chlorides, chlorinated solvents, pesticides, pharmaceuticals, detergents and refrigerants.
4. Chlorine is used in water treatment to disinfect drinking water, swimming pools, ornamental pools and aquaria, sewage and wastewater and other types of water reservoirs.
5. It is also used as a disinfectant (microbiocide/ algicide) in food processing systems, pulp and paper systems, commercial and industrial water cooling systems. It is used as a bleaching agent in textile manufacturing.

About 45 million tons (MT) of chlorine is produced annually and demand is 14.495 million tons worldwide. About 10.39 MT of chlorine was produced in Europe during 2006. Germany is the largest chlorine producers accounting for 43.8% of European production. Belgium/ Neatherland account for 13.5% and France occupies the third place and accounts for 12.3% of total chlorine production in Europe. According to specialists, chlorine production will increase at a global rate slightly above 1% per annum. In India, the chlorine production is 2.24 million tons and demand for chlorine is 1.4 million tons (India Markets, 2007).

2.3.1 Accidents Related to Chlorine

The dynamic growth of chlorine chemistry and its wider application all over the world during the industrial development in the twentieth century has proved that chlorine is not only a very useful element, but also a very dangerous element causing many chlorine accidents. Internationally, chlorine gas is the major source of toxic release accidents. The factors mainly responsible are equipment failure, human error and other reasons. The accidental chlorine releases in Minnesota during 1995-2004 was reported as 93. Over half of these accidental releases resulted in evacuations, injuries or both. Except one, all releases have occurred at fixed facilities (eg. Aluminium smelter, recreational pool, oil refinery, etc.).

A significant number of accidents from the use of chlorine gas as a pesticide have been reported by the American Association of Poison Control Centres, the Chlorine Institute, The California Pesticide Illness Surveillance Program and others. Generally, it is reported that most accidents involved maintenance or equipment failure of chlorinator systems in commercial swimming pool, pulp/paper mills, cooling towers, etc. Release of chlorine due to leakage/rupture in chlorine tonner or its valve failure of injection pipe are some of the situations leading to accidents.

Across the ten states in US, some 275 power plants report that they use large amounts of ammonia or chlorine gas. The MHIDAS database showed that 96 chlorine accidents have taken place during the period 1964-1996, which resulted in 39 deaths and injured over 2700 people. About 32% of the accidents were only due to the mechanical failure. National Response Centre, US received reports of 2200 releases of chlorine and 6400 ammonia spills during 1994-2004. Ammonia and chorine were the first and second most commonly reported extremely hazardous substances involved in serious non-transportation industrial accidents. About 518 chlorine release accidents and 562 ammonia release accidents have involved death, injury or evacuation during 1994-1999. Between 1989-2003, 228 occupational inhalation accidents involving chlorine were reported to SWORD database in UK. Of these 69 accidents were estimated to have led to reactive airways dysfunction syndrome (RAPS), a form of irritant induced asthma. The details of some of the chlorine release accidents that have taken place internationally and in India are presented in Annexure I.

CHAPTER 3

TEXTILE INDUSTRIES SELECTED FOR STUDY

3.1 Inventorisation of Textile Dyeing Units

The first step in this study was to select the representative textile dyeing industries in Tirupur, Erode and Karur which use chlorine gas for effluent treatment. For this purpose, an inventorisation of Textile Wet Processing Units adopting Gas Chlorination was carried out with the assistance from TNPCB. Field visits have been made to Erode and Tirupur and the industries were requested to furnish the details about their practices of gas chlorination in the form of questionnaire. At the time of inventorisation, about 30 units in Erode, 1 unit in Karur and 2 units in Tirupur have adopted Gas chlorination. The production capacity, raw materials, process technology, type of machinery/ equipment, type and quality of dyes and other chemicals used are found to vary very widely in the textile units.

Generally the textile units fall under three main categories viz., small, medium and large-scale. The quantity of daily wastewater generation varies widely in the range of 5,000 L to one lakh litres for small and medium scale units and above one lakh litre to several lakh litres for medium and large-scale units. In addition, some Tiny Textile units in Erode generating effluent as low as below 5000 L/day adopt gas chlorination. Also four new CETPs in Tirupur are adopting gas chlorination for treating very large quantity of effluent (as high as several lakh litres/day).

At the end of inventorisation, ten textile units (7 from Erode, 2 from Tirupur and 1 from Karur) were selected for conducting field studies on use of chlorine in effluent treatment. At Erode, 5 units were located at Erode Corporation (B.P.Agraharam, Vairapalayam, R.N.Pudur and Surya Palayam) and the other 2 units were located at SIPCOT and Bhavani. Out of 10 study units selected, 3 units fall under large-scale category (including 1 CETP), 4 units fall under medium-scale category and the other 3 units fall under small-scale category. The industry profiles of the ten Study Units are presented in Table 3.1.

3.2 Treatment Systems of the Study Units (SUs)

As a measure of pollution abatement, the TNPCB has mandated the textile units to implement zero liquid discharge (ZLD) treatment facilities. Thus the textile units adopt primary and main treatment for colour and organics removal followed by RO pretreatment processes by filtration (sand/carbon/micron). The RO system is provided for TDS removal followed by RO reject management system by evaporators (solar/ mechanical).

The treatment systems of the selected SUs are presented in Table 3.2. All the units have adopted gas chlorination as treatment technology for colour removal (Figs. 3.1, 3.2 and 3.3) followed by dechlorination for removal of residual chlorine. Out of 10, only 3 units have adopted biological treatment processes for organics removal. After chlorination/ dechlorination, the Units 1, 3 and 7 have provided Bio-tower, ASP and Bio-enzyme processes for removal of organics (Figs. 3.4 and 3.5).

Out of 10, 7 units have provided RO pretreatment processes by filters (sand/carbon/micron) (Figs. 3.6 and 3.7) and RO system for removal of TDS. In Unit 9, the treated effluent was taken for reuse as salt solution and thus no RO system was provided. In Unit 8, after colour removal the treated effluent was disposed into street sewer. Whereas in Unit 2 (CETP), the RO and evaporator systems were under construction. For the management of RO reject, mechanical evaporators (Fig. 3.8) were provided in 4 units and solar ponds (Figs. 3.19 and 3.10) were available in the other 3 units.

Table 3.1 Profile of Study Units (SU*)

SL. No.	Description	SU 1	SU 2	SU 3	SU 4	SU 5	SU 6	SU 7	SU 8	SU 9	SU 10
1	Category	Large	Large	Large	Medium	Medium	Small	Medium	Small	Small	Medium
2	Production Capacity	315 T/month	25 member units	6T / day	3 T / day	20 T / month	16 T / month	293 T/month	9.3 T/ month	1 T/ month	1.5 T/ month
3	How long chlorine adopted	3 years	6 months	2 years	1 year	1 1/2 years	2 years	6 months	2 years	3 years	2 years

*The actual trade names of the Industries are not used in the identification. Only code names ranging from SU-1 to SU-10 are used.

Table 3.2 Treatment Systems of the Selected Study Units (SUs)

Sl. No.	Study Units	Colour and Organics removal followed by RO pretreatment processes	TDS Management	RO reject Management	Remarks
1	SU 1	Chlorination/Dechlorination, Bio-tower, Filters (sand/ Carbon / Micron)	RO and Nano	Mechanical evaporator	-
2	SU 2	Chlorination/Dechlorination, Tube Settler	RO Plant under construction	Mechanical evaporator under construction	Conducting trial runs
3	SU 3	Chlorination/Dechlorination, ASP, chemical precipitation, Filters (sand / micron)	RO	Mechanical evaporator	-
4	SU 4	Chlorination/Dechlorination, Filters (sand/micron)	RO	Mechanical evaporator	-
5	SU 5	Chlorination/Dechlorination, Filters (sand/micron)	RO	Solar Pond	-
6	SU 6	Chlorination/Dechlorination, Filters (sand/ carbon/ iron)	RO and Nano	Solar Pond	-
7	SU 7	Chlorination/Dechlorination, Bio-enzyme process, filter (sand/ micron)	UF and RO	Solar Pond	-
8	SU 8	Chlorination/Dechlorination, filters (sand)	-	-	Disposal of treated effluent into street drain
9	SU 9	Chlorination/Dechlorination, chemical precipitation, filters (sand/ carbon)	-	-	Recovered salt solution for reuse
10	SU 10	Chlorination/Dechlorination, filters	RO and Nano	Mechanical evaporator	-

Fig.3.1 Collection Tank as Chlorine Reaction Tank

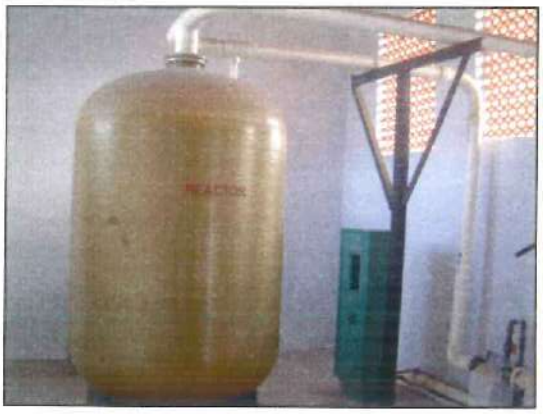


Fig. 3.2 Chlorine Reactor

Fig. 3.3 Chlorination Treatment for Colour Removal

Fig. 3.4 Bio-enzyme Process for Organics Removal

Fig.3.5 ASP for Organics Removal

Fig. 3.6 Sand Filters

Fig.3.7 Nano Filters

Fig.3.8 Mechanical Evaporator

Fig.3.9 Solar Pond

Fig.3.10 Enhanced Solar Evaporation Pond

CHAPTER 4

STORAGE, HANDLING AND USAGE PRACTICES OF CHLORINATION IN THE STUDY UNITS

4.1 Chlorine Tonners/Cylinders

In the Study Units, liquid chlorine is supplied in packages of varying sizes according to the requirements of the customer. The textile units in Erode and Tirupur have widely used Ton containers (or Tonners) of chlorine capacity (normal) 916 kg, with tare weight 625 kg having 12 mm shell thickness and overall length of 206 cm. The diameter of the tonner is 77.4 cm (ID) and 79.8 cm (OD) and the shape of the dome is concave with chime both end inward curved (Fig. 4.1). Few Tiny (printing and tie and dye process) textile units have used chlorine gas cylinders of 100 kg capacity (Fig. 4.2). The tonners and cylinders have bright yellow colours. Generally, all the chlorine tonners were found to have permanent markings of some details such as serial number, tare weight, net weight, chlorine symbol, manufacturer's details, etc. In some tonners, the paint colour was not maintained as bright yellow (Figs. 4.3 & 4.4).

4.2 Vacuum Type Gas Chlorinators

Chlorine is generally stored as liquid in the tonners under pressure. For treating textile effluent, a continuous and constant metered quantity of chlorine gas should be withdrawn from the tonner and chlorine gas should be thoroughly dissolved with the textile effluent. For this purpose, the textile units are providing 'Vacuum Type Gas Chlorinators' which are generally installed on floors or frames nearer to the tonners (Figs. 4.5, 4.6 & 4.7). Normally, flexible copper tubes are used for connecting the chlorine tonner and the chlorinator. The discharge of chlorine gas from the tonner to the chlorinator will take place only when the chlorinator is operating under vacuum condition and thus this system is considered to be safe in the field.

A vacuum break loop or device should be employed whenever chlorine from tonners is absorbed in a liquid (ie. Textile effluent), since there is a tendency for the liquid (ie. Textile effluent) to be sucked back into the chlorine tonner when it is becoming empty which may result in serious accidents. Thus the vacuum type gas chlorinators are provided either with an automatic vacuum regulator (Type 1) or a barometric loop (Type 2) to break the vacuum.

4.2.1 With Automatic Vacuum Regulator

The main components of the gas chlorinator include pressure-reducing valve, automatic vacuum regulator, rotometer / gas flow meter (may be within a cabinet housing, Fig. 4.8) and an injector along with piping systems (generally made up of PVC) for conducting liquids and gases. At first, vacuum is developed in the chlorinator by passing textile wastewater at high pressure (through booster pumps) to an injector. Then chlorine gas at high pressure is discharged from the tonner and its pressure is reduced by passing through pressure-reducing valve and it flows upto the automatic vacuum regulator. The vacuum in the chlorinator further transports the chlorine gas from automatic vacuum regulator to the injector. In the injector, chlorine gas is thoroughly dissolved in textile wastewater and then the concentrated chlorine solution is taken to the desired point of application in the treatment plant. For safety reasons, safety valves like check valve, emergency drain valve, pressure relief valve and vacuum relief valve are also provided in the system. The capacity of gas chlorinator is scaled in kg/ hour. In the textile units, gas chlorinators in the range of 10-50 kg/ hour capacity are widely used. All the three large-scale units (Unit 1, Unit 2 and Unit 3) and one medium-scale unit (Unit 7) have installed Vacuum Type Gas Chlorinators with Automatic Vacuum Regulators. In Unit 3 (CETP), the chlorine gas withdrawal rate from the tonners is very high. Thus an electrically heated evaporator (Fig. 4.9) is provided to vaporize the liquid chlorine discharged from the tonner. Then the chlorine gas is allowed to enter into Vacuum Type Gas Chlorinator.

4.2.2 With Vacuum Break Loop (Barometric Loop)

Almost all the medium and small-scale textile units in Erode have widely provided Vacuum Type Gas Chlorinators with Barometric Vacuum Breaking Loops. The working principle of the gas chlorinator remains the same. However, for preventing back-siphonage (ie. Suckback of the liquid into the chlorine tonner), a barometric loop as a giant upside down 'U' is provided by extending the piping system. The barometric loop might be 10.5 m (35 feet) tall, since an absolute vacuum could pull the water upto 9.87 m

(32.9 feet). A venturi set-up is provided at the end of the barometric loop, just above the chlorine reaction tanks (ie. Syntex tanks) (Figs. 4.10 to 4.14).

4.3 Chlorine Reaction Tanks / Chlorine Reactors

All the units have done the chlorination of textile effluent as batch process. The concentrated chlorine solution from the Vacuum Type Gas Chlorinator is thoroughly mixed with the large quantity of textile effluent that is to be treated in the Chlorine Reaction Tank / Chlorine Reactors. By providing adequate contact time (ie. Detention time / reaction time) for chlorination of textile effluent in the chlorine Reaction Tank, the decolourisation of the effluent is achieved.

The Unit 3 (Fig. 4.15) and Unit 7 have used the raw effluent collection cum equalization tank as Chlorine Reaction Tank. The concentrated chlorine solution is dispersed into the large quantity of effluent through the diffusers provided at the bottom of the tank. In Unit 1, concentrated chlorine solution passes through flash mixer and then disperses into the large quantity of effluent in the clarifier, which is used as chlorine reaction tank.

In Unit 3 (CETP), the raw effluent after equalization is pumped from an equalization tank into the 'Chlorine Reactor' which is known as oxidation-Reduction Reactor (OR Reactor). The chlorine reactor is made up of HDPE piping system, in which 1.49 m dia pipes of 75 m length each in 6 numbers are arranged parallely and they are suitably interconnected (Fig. 4.16). The concentrated chlorine solution is dosed into the piping system at several dosing points and the entire reactor contents are homogenized by recirculating the contents using pumps for adequate contact time.

The medium and small-scale units (Units 4, 5, 6, 8, 9 and 10) have used syntex tanks (normally two interconnected tanks) of capacity 5000 – 10000 L (each) as Chlorine Reaction Tanks. The concentrated chlorine solution is allowed to enter into the syntex tank from the top through a venturi setup, at which the chlorine gas is mixed thoroughly with the textile effluent (Figs. 4.10 to 4.14). Adequate contact time for chlorination of textile effluent is provided by recirculating the contents of the syntex tanks using a pump.

4.4 Storage and Handling Practices

The details of the chlorine cylinder and its accessories are presented in Table 4.1. The textile units generally have placed the chlorine tonners in dry and well-ventilated areas (either open or closed) away from source of heat or danger of fire. The tonners were placed also away from direct sunlight either within a separate storage room (Fig. 4.17) or in an open area (Fig. 4.1, 4.5). However, some small-scale units have placed the tonners under direct sunlight (Fig. 4.18, 4.19).

In some units, the tonners were placed on the elevated floor (Fig. 4.1), where as, in most other units, they were simply also lying on the ground (Fig. 4.19). Only in two units (Unit 1 and 2), the tonners were placed on steel rails slightly above the floor (Fig. 4.1). In most of the units, the empty cylinders were placed separately (Fig. 4.20). The storage area was also found to be away from elevators, and not containing other compressed gas containers, turpentine, ether, anhydrous ammonia, finely divided metals or other inflammable materials. In most textile units, chlorine tonners were transported by hand trucks. In Unit 2 (CETP), electric hoist cranes (Fig. 4.21) were used for handling cylinders. In few units, the tonners were also transported only by manually. In some units, for loading and unloading the chlorine tonners, overhead gantry is provided (Fig. 4.22, 4.23). Except one unit, MSDS was found to be available in all the units.

4.5 Chlorine Leak Handling, Safety and First-aid Measures

For detecting chlorine leak at the locations where chlorine is stored and handled, the textile units have provided either chlorine gas alarm device (Fig. 4.24) (chlorine sensor) or a bottle of ammonia solution or both. Only in few units, leak detection system was provided. In two large-scale units (Unit 1 and Unit 2), 'Chlorine – Tonner Safety Hoods (FRP hood system) (Fig. 4.25 and 4.26) were provided for shielding or enclosing leaky chlorine-tonners. Normally, the textile units have provided caustic lye (Fig. 4.27) for absorbing the chlorine leak. Wind socks for indicating the direction of wind was not found to be available in the textile units.

Safety equipment like gas masks, rubber gloves, personal protective equipment, oxygen administration apparatus (Fig. 4.28, Fig. 4.29), etc. were found to be available in most textile units. Also eyewash shower (Fig. 4.30), emergency kit and first-aid boxes were found to be available in some units only. Instruction boards for handling emergency situations were displayed in few units (Fig. 4.31). Despite the availability of the safety equipment, periodic drills and training classes for workers were not conducted regularly in most textile units.

4.6 Interpretations

Based on the provisions in the Indian National Codes of Practices on chlorine, a set of questions were prepared and the chlorine work practices of the study units were evaluated in response to these questions (Table 4.2). Percentage compliance of textile units to the chlorine work practices was found to be in the range of 35-83%. The storage areas of chlorine tonners in most textile units were found to comply with the recommendations. Generally, the chlorine tonners were found to have permanent markings of some details such as serial no., tare weight, chlorine symbol, manufacturing details etc. Only few textile units have used mechanical devices for handling chlorine tonners, whereas most units used hand trucks.

Generally in the study units, chlorine alarm devices and ammonia solutions were found to be available. Provisions for emergency disposal of chlorine leaks (eg. Alkali solutions) were found to be available in 50% of the study units. Some health and safety equipment devices (eg. gas mask, rubber gloves, PPE, eye wash showers, emergency kits, oxygen administration apparatus) were found to be available in textile units. However appropriate use of these devices and the maintenance of these devices were not paid due attention. Only few textile units have provided first-aid boxes to the workers and displayed instruction boards for handling emergency situations. Despite the availability of some safety equipment devices, the workers lacked training and experience specific to chlorine safe work practices.

Table 4.1 Details of Chlorine Storage and Handling in SUs

Sl. No.	Description		Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
1	Numbers of chlorine tonners/ cylinders	Total	3	8	2	2	2	2	2	1	3	6
		Under use	1	1	1	1	1	1	1	1	1	1
		Empty	2	7	1	1	1	1	1		2	5
2	Vacuum Type Gas Chlorinator Model		With AVR	With AVR	With AVR	With Barometric Loop	With Barometric Loop	With Barometric Loop	With AVR	With Barometric Loop	With Barometric Loop	With Barometric Loop
3	Chlorine Reactor		Clarifier	HDPE Pipe	Collection cum Equalization tank	Syntex tank	Syntex tank	Syntex tank	Collection cum Equalization tank	Systex tank	Syntex tank	Syntex tank
4	Chlorine tonner under use placed at		Away from sunlight	Away from sunlight	Direct sunlight	Away from sunlight	Away from sunlight	Away from sunlight	Away from sunlight	Direct sunlight	Away from sunlight	Away from sunlight
5	Chlorine tonners lying (on ground/ elevated rail)		Elevated rail	Elevated rail	On ground	On ground	On ground	On ground	Elevated rail	On ground	On ground	On ground
6	Transportation of chlorine tonners (Manually/ electric crane/ hand trucks)		Electric crane	Electric crane	Hand trucks	Hand trucks	Electric crane	Hand trucks	Electric crane	Electric crane	Hand trucks	Hand trucks
7	Chlorine gas alarm device or ammonia bottle or both		Chlorine gas alarm	Both	Ammonia bottle	Ammonia bottle	Both	Chlorine gas alarm device	Chlorine gas alarm device	Ammonia bottle	Ammonia bottle	Both
8	Availability of PPE		Eye shower, PPE, Oxygen administer, FRP hood system, First-aid box	Eye shower, PPE, Oxygen administer, FRP hood system, First-aid box	Gas mask	Gas mask	Oxygen administer	Oxygen administer	Available with out water and oxygen	Not available	Oxygen administer	Eye shower, Oxygen administer,
9	Marking and Labelling		Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Table 4.2 Storage, Handling and Usage Practices of Chlorine in SUs – An Evaluation

Sl. No.	Requirement Check List	SU 1	SU 2	SU 3	SU 4	SU 5	SU 6	SU 7	SU 8	SU 9	SU 10	Requirement Compliance Score: (Max.10)
1	Is the storage area dry and ventilated?	✓	✓	✓	✓	×	✓	✓	×	✓	✓	8
	Is the cylinder stored away from direct sunlight?	✓	✓	✓	✓	×	✓	✓	×	✓	✓	8
2	Is it stored away from turpentine, ether, ammonia, and other inflammables?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
3	Are full and empty cylinders stored separately?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
4	Are markings made on the valve end of the cylinders?	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	9
5	Is the warning marked on the cylinder?	×	×	×	×	×	×	×	×	×	×	0
6	Are the containers placed securely on cradles/ with suitable block to prevent rolling?	✓	✓	×	×	×	×	✓	×	×	×	3
7	Is the floor of the storage room atleast 150 mm above the surrounding ground?	×	✓	×	×	×	×	×	×	×	×	1
8	Is chlorine alarm device provided?	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	9
9	Are the cylinders/ ton containers transported by handtrucks?	✓	×	×	✓	✓	✓	×	✓	✓	✓	7
10	Is mechanical device being used for lifting tonne containers?	×	✓	✓	×	×	×	✓	×	×	×	3
11	Is flexible copper tubing used for connecting the cylinder and the piping?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10

Table 4.2 (Contd.)

12	Is a suitable wrench used for opening the valves?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
13	Is a current MSDS available for chlorine cylinder?	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	9
14	Is ammonia solution available to detect leaks?	×	✓	✓	✓	✓	✓	×	✓	✓	✓	8
15	Are provisions for emergency disposal of chlorine available?	✓	✓	✓	×	✓	×	✓	×	×	×	5
16	Is tonners/ cylinders stored in a horizontal/ upright position?	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
17	Is instruction and training regarding protective measures and PPE being given?	✓	✓	✓	×	×	×	✓	×	×	×	4
18	Is a suitable gas mask available for employee?	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	9
19	Are suitable first-aid notices placed at convenient places?	✓	×	×	✓	✓	×	✓	×	×	×	4
20	Are the employees aware of the first-aid treatment procedures?	✓	✓	✓	×	×	×	✓	×	×	×	4
21	Are emergency showers and eye baths available in convenient locations?	✓	✓	✓	✓	✓	×	✓	×	✓	✓	8
22	Is oxygen administration apparatus available?	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	9
23	Are distinctly marked first-aid boxes accessible to the workers?	✓	×	×	×	×	×	×	×	×	×	1
	SU wise Compliance Score (Max.: 23)	19	19	17	14	15	13	18	8	14	14	
	SU wise Compliance Score (%)	83	83	74	61	65	57	78	35	61	61	

Fig. 4.1 Chlorine Tonners

Fig. 4.2 Chlorine Cylinder

Fig. 4.3 Marking and Labelling
(Tonner 1)

Fig. 4.4 Marking and Labelling
(Tonner 2)

Fig. 4.5 Gas Chlorinator (Location 1)

Fig. 4.6 Gas Chlorinator (Location 2)

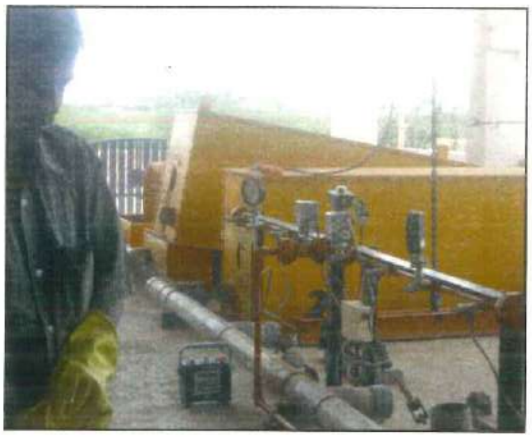


Fig.4.7 Gas Chlorinator (Location 3)

Fig. 4.8 Cabinet Housing for Rotometer

Fig. 4.9 Chlorine Evaporator

Fig. 4.10 Syntex Tank Chlorinator

Fig. 4.11 Barometric Vacuum Break Loop
(Location 1)

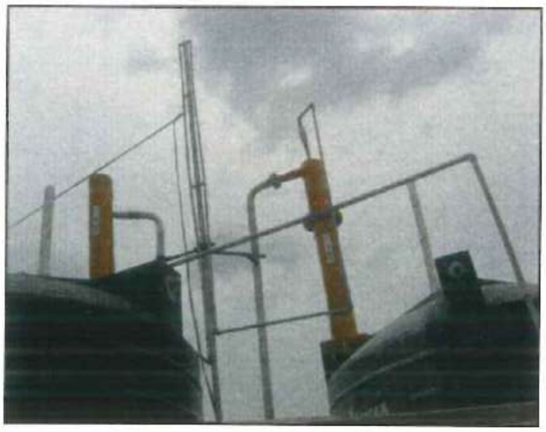


Fig. 4.12 Barometric Vacuum Break Loop
(Location 2)

Fig. 4.13 Barometric Vacuum Break Loop (Location 3)

Fig. 4.14 Barometric Vacuum Break Loop (Location 4)

Fig. 4.15 Collection/ Equalization Tank as Chlorine Reactor

Fig. 4.16 HDPE Piping System as Chlorine Reactor

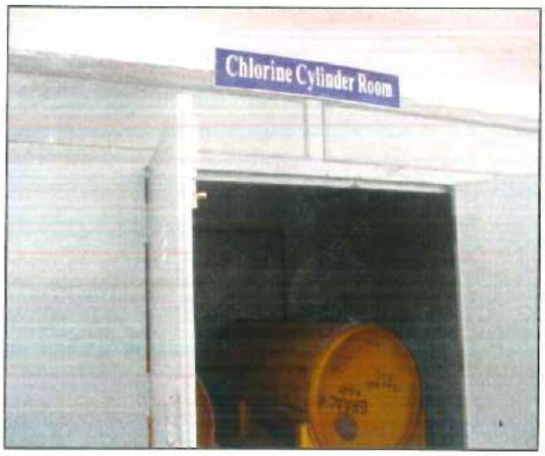


Fig. 4.17 Chlorine Cylinder Room

Fig. 4.18 Chlorine Tonners Exposed to Sunlight (Location 1)

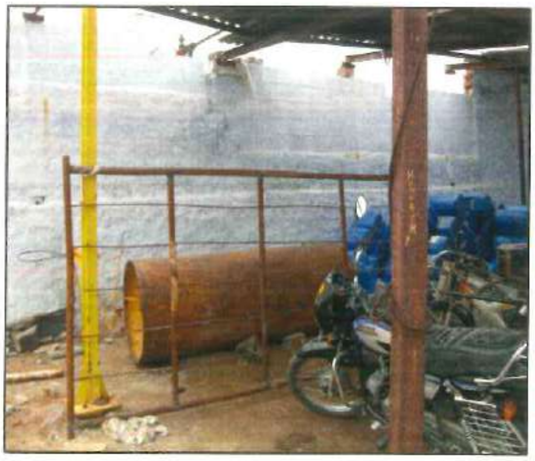


Fig. 4.19 Chlorine Tonners Exposed to Sunlight (Location 2)

Fig. 4.20 Empty Cylinders

Fig. 4.21 Electric Hoist Cranes

Fig. 4.22 Overhead Gantry (View 1)

Fig. 4.23 Overhead Gantry (View 2)

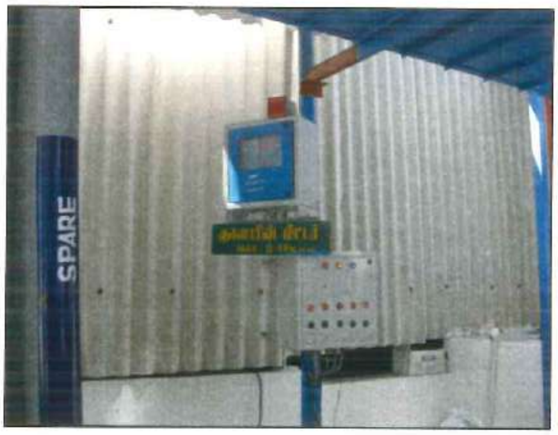


Fig. 4.24 Chlorine Alarm Device

Fig. 4.25 FRP Safety Hood

Fig. 4.26 FRP Hood System

Fig. 4.27 Caustic Lye for Chlorine Absorption

Fig. 4.28 PPE (Model 1)

Fig. 4.29 PPE (Model 2)

Fig. 4.30 Eye Wash Shower

Fig. 4.31 Instruction Boards

CHAPTER 5

STUDIES CONDUCTED ON EFFLUENT TREATMENT IN SELECTED TEXTILE INDUSTRIES

5.1 Planning for the Study

The textile industrial units selected for the study are described in Chapter 3. As a next step, the details were obtained from the industry for supporting the CES study. All the units agreed for the study and promised that the normal operations will be ensured during the study.

1. For each unit, study was conducted with prior intimation to the units.
2. For each unit, the effluent collection points in the ETP/CETP were decided based on the treatment scheme adopted in the unit. The sample collection points were decided by keeping true objectives of the study unit in mind i.e. to focus on the implications of chlorine use in the treatment process. Similarly, the air samples and solid samples collection points were decided.
3. On a particular day, the sample collection will commenced after the industrial operation starts and chlorine is applied in the effluent treatment. Generally, study will go on until a batch/shift operation is completed normally ranging from 10–12 hours.
4. In this study, the well-mixed raw effluent was treated with chlorine gas in a closed/ open reactor. The duration of the reaction varies from 30 min to 12 hours applying chlorine dose depending on the colour intensity. Samples were collected at 5, 10, 30, 60, 90 min at the end of chlorination and after dechlorination.
5. The details of the effluent sampling points for each study units (SU) are indicated in the ETP diagram presented under the respective Study Units.

5.2 Sampling Methodology and Parameters

5.2.1 Effluent Samples

The effluent samples were collected from various parts of the treatment plant in the 10 units. One litre clear Polyethylene (PE) bottles were used to collect the samples for analyzing the physico-chemical parameters. Every sample bottle was labeled with the sample number/points, sample locations, date and time of sampling. Before filling the sample bottle, it was rinsed for 2 or 3 times with water being collected. The collected samples were preserved in icebox and transported to CES laboratory and used for analysis. The following parameters were considered for assessment: pH, colour, TDS, TSS, BOD, COD, AOX residual chlorine and chloride. Effluent samples collections were performed by grab sampling method and its physico-chemical parameters analysis was performed by the Standard Methods as tabulated in the Table 5.1. Each parameter was analysed twice minimum.

Table 5.1 Analytical Methods for Effluents

Sl. No.	Parameter	Analytical Method	Standard Methods
1	Colour	Spectrophotometer (Spectronic ® 20) at 436 nm, 525 nm, 620nm	2120C
2	pH	Potentiometry (pH meter)	4500 –H^+
3	Total Dissolved Solids	Gravimetry	2540 C
4	Total Suspended Solids	Gravimestry	2540 D
5	BOD	3-day BOD test at 27°C	5210
6	COD	Open reflux method	5220
7	AOX	Multi X 2000 AOX Analyzer – AJ Germany	DIN 38409/14
8	Residual Chlorine	Iodometric Titration Method	4500 B
9	Chloride	Argento Metric Titration Method	4500 Cl B

5.2.2 Air Samples for Chlorine Analysis

Air samples were collected manually and also by using chlorine in-situ analyser (Ray make). Manual air sampling was carried out by fixing chlorine methyl orange solution. Before sampling, the wind speed and direction was checked using Anemometer around the sampling area. Once the area was selected, the flow meter was connected to Impinger tube carrying 20 mL of sampling solution and flow meter was adjusted in such a way that it allows only a specified volume of air (1 litre of air/min). The air samples were collected for different time intervals and at different distance from the chlorinator. The analytical method for air sampling is shown in Table 5.2

Table 5.2 Analytical Method for Air Sampling

Parameter	Method	Reference
Air chlorine	1. Methyl orange – 505 nm spectrophotometric method	Indian Standards IS : 5182 – 1982 (Part XIX)
	2. Ray – Chlorine Meter	-

5.2.3 Sludge Samples

Sludges generated from processes such as biological waste treatment and chemical residue were collected in clean airtight polythene bags from selected locations and analysed for AOX. Before loading the sample into the sample cells, it was washed with nitrate wash solution to remove any inorganic chloride present. Then it was analyzed using AOX analyzer.

5.3 Characteristics of Raw Effluent

The wastewater originates from all the operations in the textile process. The wastes consist of washwater after various processes and comprises soluble organic and inorganic substances. The characterization of the raw effluent has been done by collecting composite raw effluent samples from the study units. The samples were analysed for various physico-chemical parameters for the 10 units. A summary of raw effluent characteristics is presented in Table 5.3. The raw effluent was highly coloured due to the usage of various dyes. Mostly the samples were having neutral pH and some were slightly alkaline in nature. The BOD and COD represent the total amount of organic matter present in the water. The BOD and COD values were found to be 115-486 mg/L and 265-1119 mg/L respectively. Raw effluents had a high chloride concentration of 1419 to 14,739 mg/L. The TDS concentration of raw effluent was found to be in the range of 4108 to 9950 mg/L and TSS concentration was in the range of 120 to 787 mg/L. In general the textile industry wastes are of strong colour, high chloride content, high BOD and high COD values. The results also show a large extent of variation from unit to unit and sample to sample.

Table 5.3 Textile Wastewater Characteristics

Sl. No.	Parameter		Study Units
1.	pH		7.0 – 9.6
2.	TDS (mg/L)		4108 – 9950
3.	TSS (mg/L)		120 – 787
4.	BOD (mg/L)		115 – 486
5.	COD (mg/L)		265 – 1119
6.	Chloride (mg/L)		1419 –14,739
7.	Colour (m^{-1})	436 nm	11.3-133.5
		525 nm	7.4 – 45.4
		620 nm	3.4 – 67.7

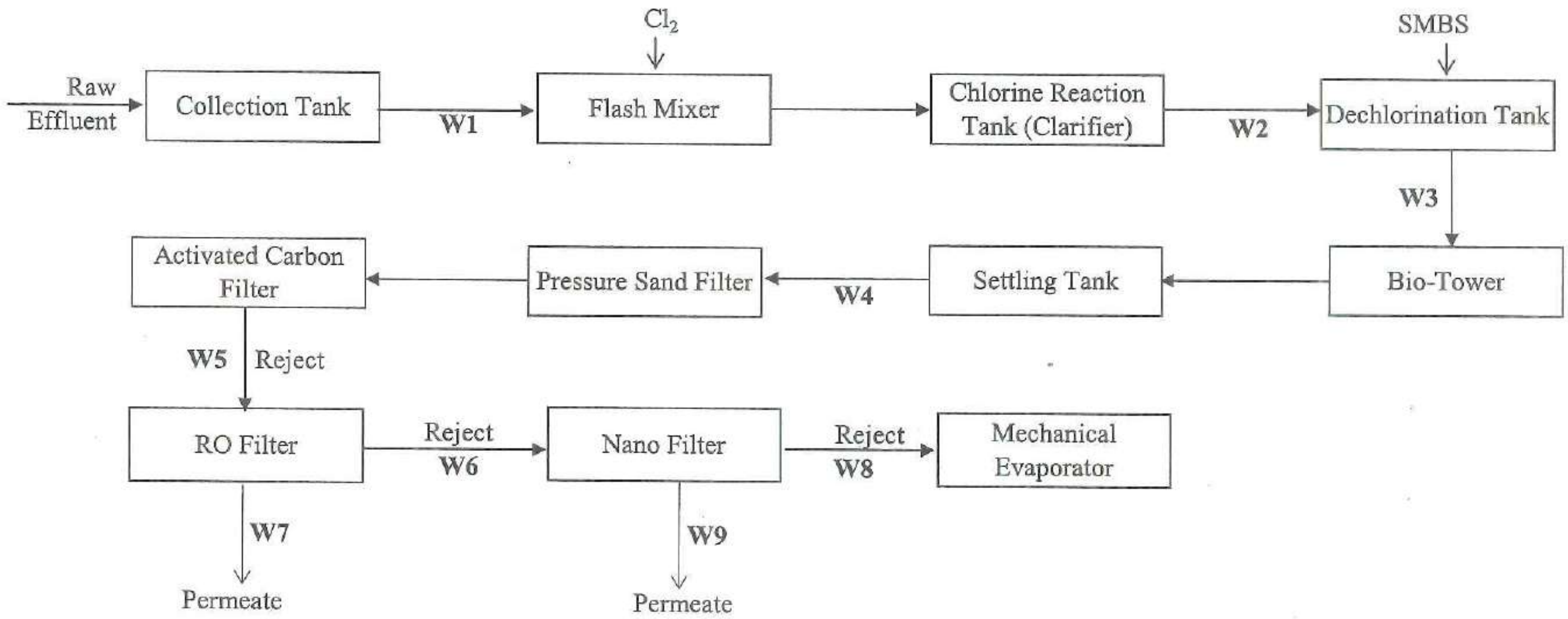
5.4 Study Results

5.4.1 Study Unit 1

The Study Unit 1 (SU-1) is involved in the wet processing of hosiery and yarn. It is a large-scale unit and the industry profile is presented in Table 3.1. The effluent generated in the industry is subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme (Fig.5.1) consists of chlorination and aerobic biological treatment for the removal of colour and organics, RO system for the removal of TDS and NF and mechanical evaporator for RO reject management.

The raw effluent was first subjected to gas chlorination for colour removal. The concentrated chlorine solution passing through the flash mixer was thoroughly dispersed into the large quantity of the effluent in the clarifier (17.64 m^3 capacity), by means of diffusers at the bottom of the tank which is used as chlorine reaction tank. After chlorination, the effluent was subjected to dechlorination by using SMBS for removal of free residual chlorine. The chlorination followed by dechlorination resulted in 77-91% reduction in colour and 35-36% reduction in organics. For the removal of organics, the dechlorinated effluent after pH adjustment was subjected to aeration followed by biological treatment process in the bio-trickling tower. At the end of biological treatment, 83-86% reduction in organics was achieved. After biological treatment, the effluent was taken to the RO system in which the TDS was reduced from 9950 mg/L to less than 288mg/L. The reject from RO system was then subjected to Nano filtration for recovery of brine solution. The reject from Nano filtration was finally taken to evaporation in a mechanical evaporator.

The characterization of the effluent at different stages of treatment is presented in Table 5.4 (except colour and AOX). The colour and AOX details are presented separately in Table 5.5 and 5.6 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.7. In SU 1, Chlorination resulted in percent colour removal in the range of 77-91%.



Note: W1-W9 Effluent Sampling points

FIGURE 5.1 EFFLUENT TREATMENT SCHEME FOR SU-1

TABLE 5.4 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 1)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	9.2	420	1119	9950	786	Nil	3722
2	W2	Chlorination Outlet	6.8	270	868	9312	758	25	4059
3	W3	Dechlorination Outlet	6.9	272	714	9396	699	Nil	4122
4	W4	Bio -Tower Outlet	7.3	72	153	9358	125	Nil	4122
5	W5	Activated Carbon Filter Outlet	7.2	54	96	9364	76	Nil	4121
6	W6	RO Reject	7.5	45	336	26412	24	Nil	10479
7	W7	RO Permeate	7.1	12	12	288	5	Nil	239
8	W8	Nano Reject	7.1	128	1075	35722	5	Nil	18076
9	W9	Nano Permeate	7.2	5	58	45480	2	Nil	15675

TABLE 5.5 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 1)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.385	38.5	0.304	30.4	0.677	67.7	-	-	-
2	W2	Chlorination Outlet	15 min.	0.134	13.4	0.107	10.7	0.072	7.2	65	65	89
			30 min.	0.099	9.9	0.067	6.7	0.068	6.8	74	78	90
3	W3	Dechlorination Outlet		0.090	9.0	0.056	5.6	0.064	6.4	77	82	91

TABLE 5.6 AOX CONCENTRATIONS (SU-1)

Sl. No.	Parameter	End of Chlorination mg/L	End of Dechlorination mg/L	Sludge (mg/kg)	
				Biological	Salt
1	AOX	14	19	163	101

TABLE 5.7 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-1)

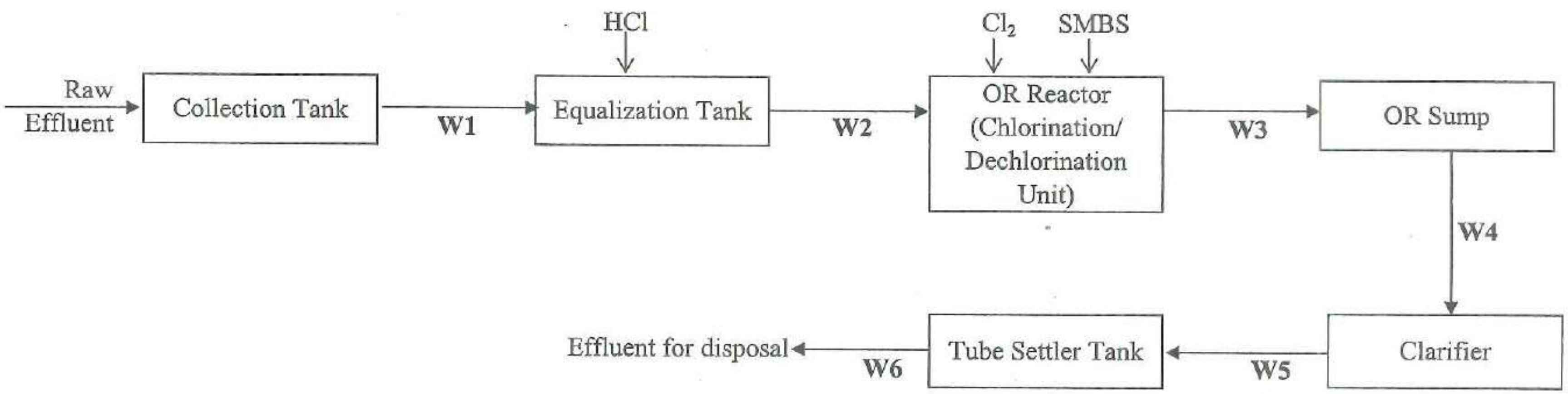
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	4.0	1.9	0.7	0.3	Nil
2	Near Chlorine Reactor	1.8	1.1	0.3	Nil	Nil

5.4.2 Study Unit 2

The Study Unit 2 (SU-2) is a CETP. The effluent treatment scheme (Fig. 5.2) consists of chlorination for removal of colour and organics. The process of chlorination and dechlorination is carried out in Oxidation Reduction Reactor (OR Reactor) followed by removal of solids in the clarifier.

The raw effluent was taken to the equalization tank to get a constant flow rate and uniform pollution load. Then the equalized effluent was pumped into the 'Chlorine Reactor' which was known as OR reactor. The chlorine reactor was made up of HDPE piping system, in which 1.49m dia pipes of 75m length each in 6 numbers were arranged parallely and they were suitably interconnected. The concentrated chlorine solution was dosed into the piping system at several dosing points and the entire reactor contents were homogenized. After chlorination, the effluent was subjected to dechlorination in the same reactor by dosing SMBS for removal of residual chlorine and it was aerated in OR sump. The chlorination/dechlorination resulted in 69-84% reduction in colour and 47-50% reduction in organics. Then the effluent was taken to the clarifier and tube settler in which 55-58% reduction in organics was achieved. Finally it was taken for discharge.

The characterization of the effluent at different stages of treatment is presented in Table 5.8 (except colour and AOX). The colour and AOX details are presented separately in Table 5.9 and 5.10 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.11. In SU 2, Chlorination resulted in percent colour removal in the range of 69-84%.



Note: W1-W6 Effluent Sampling points

FIGURE 5.2 EFFLUENT TREATMENT SCHEME FOR SU-2

TABLE 5.8 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 2)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.3	115	452	8624	560	Nil	3546
2	W2	Equalization Tank Outlet	7.8	100	427	8615	560	Nil	3550
3	W3	Chlorination Outlet	6.3	78	302	8620	474	57	3625
4	W4	Dechlorination Outlet	6.3	61	225	8515	456	Nil	3765
5	W5	Clarifier Outlet	6.4	58	221	8518	12	Nil	3768
6	W6	Tube Settler Outlet	6.5	52	192	8518	284	Nil	3768

TABLE 5.9 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 2)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.201	20.1	0.120	12.0	0.112	11.2	-	-	-
2	W2	Equalization Tank Outlet		0.201	20.1	0.120	12.0	0.112	11.2	-	-	-
3	W3	Chlorination Outlet	15 min.	0.124	12.4	0.078	7.8	0.083	8.3	38	35	26
			30 min.	0.086	8.6	0.059	5.9	0.031	3.1	57	51	72
			45 min.	0.077	7.7	0.054	5.4	0.024	2.4	62	55	79
4	W4	Dechlorination Outlet		0.060	6.0	0.037	3.7	0.018	1.8	70	69	84

TABLE 5.10 AOX CONCENTRATIONS (SU-2)

Sl. No.	Parameter	End of Chlorination mg/L	End of Dechlorination mg/L
1	AOX	18	19

TABLE 5.11 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-2)

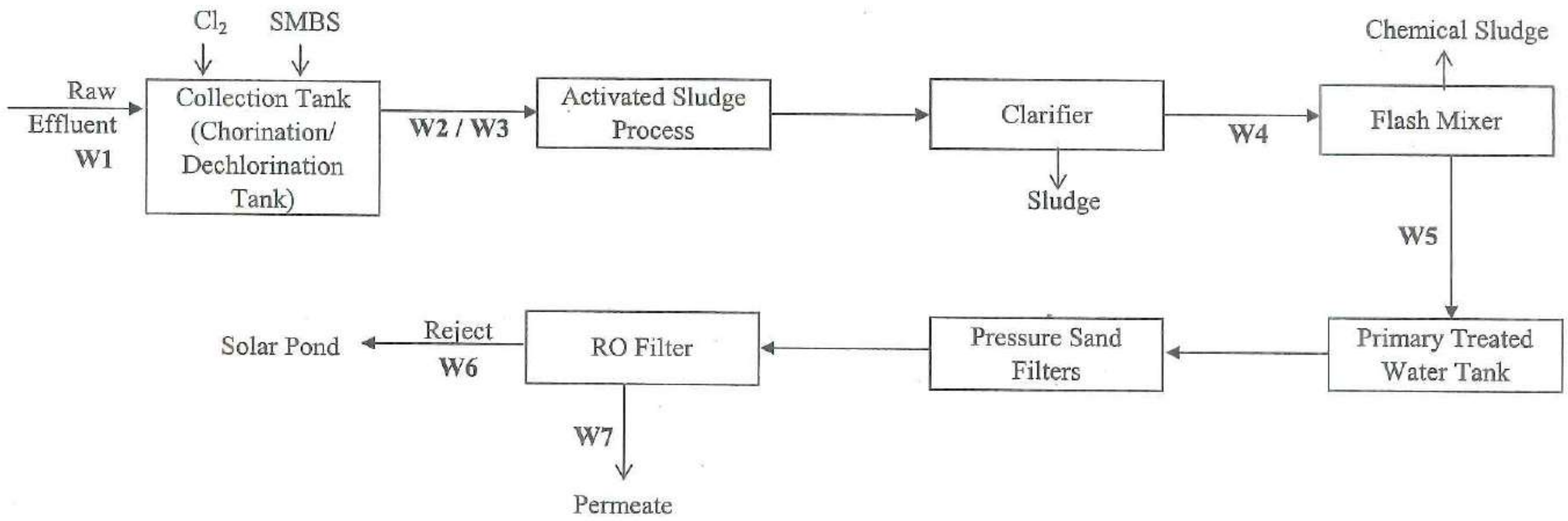
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	4.8	2.3	1.0	0.5	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.3 Study Unit 3

The Study Unit 3 (SU-3) is a major scale industry involved in the production of fabrics. The effluent generated in the industry is subjected to the treatment in the zero liquid discharge facility. The effluent treatment scheme is shown in Fig. 5.3. It consists of chlorination for colour and organics removal and then subjected to biological and chemical treatment processes. Removal of dissolved solids was carried out in the RO system and RO Reject was finally subjected to evaporation in the solar evaporator.

The raw effluent was collected in the collection tank, which was used as chlorination/ dechlorination reaction tank. In the collection tank, the concentrated chlorine solution was dispersed into the large quantity of effluent through the diffusers provided at the bottom of the tank. Then dechlorination was carried out in the same tank by dosing SMBS for the removal of residual chlorine. At the end of chlorination/dechlorination, 31-49% reduction in colour and 18-26% reduction in organics was achieved. Then it was subjected to biological and chemical treatment processes for further removal of colour and organics, which resulted in 85-89% reduction in colour and 85-92% reduction in organics. After biological and chemical treatment processes, the effluent was taken to the RO system for the reduction of TDS in which TDS removal from 6977 mg/L to less than 216mg/L was achieved. Then the RO reject was finally taken to evaporation in the solar evaporator.

The characterization of the effluent at different stages of treatment is presented in Table 5.12 (except colour and AOX). The colour and AOX details are presented separately in Table 5.13 and 5.14 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.15. In SU 3, Chlorination resulted in percent colour removal in the range of 31-49%.



Note: W1-W7 Effluent Sampling points

FIGURE 5.3 EFFLUENT TREATMENT SCHEME FOR SU-3

TABLE 5.12 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNIT (SU - 3)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Raw Effluent	8.5	250	786	6977	787	Nil	2469
2	W2	Chlorination Outlet	8.1	217	650	6448	612	17	2720
3	W3	Dechlorination Outlet	8.1	185	645	6578	572	Nil	2789
4	W4	Clarifier Outlet	7.6	52	168	5537	142	Nil	2663
5	W5	Flash Mixer Outlet	7.4	19	116	5524	48	Nil	2780
6	W6	RO Reject	8.1	60	160	30523	32	Nil	14874
7	W7	RO Permeate	7.4	9	4	216	6	Nil	182

TABLE 5.13 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 3)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.337	33.7	0.243	24.3	0.232	23.2	-	-	-
2	W2	Chlorination Outlet	2 hrs.	0.260	26.0	0.176	17.6	0.139	13.9	23	28	40
			4 hrs.	0.255	25.5	0.174	17.4	0.136	13.6	24	28	41
			6 hrs.	0.250	25.0	0.171	17.1	0.130	13.0	26	30	44
			8 hrs.	0.249	24.9	0.164	16.4	0.128	12.8	26	33	45
			10 hrs.	0.235	23.5	0.159	15.9	0.120	12.0	30	35	48
3	W3	Dechlorination Outlet		0.233	23.3	0.156	15.6	0.118	11.8	31	36	49
4	W4	Clarifier Outlet		0.108	10.8	0.070	7.0	0.054	5.4	68	71	77
5	W5	Flash Mixer Outlet		0.051	5.1	0.031	3.1	0.025	2.5	85	87	89

TABLE 5.14 AOX CONCENTRATIONS (SU 3)

Sl. No.	Parameter	End of Chlorination mg/L	RO Reject mg/L	Chemical Sludge (mg/kg)
1	AOX	2	2	238

TABLE 5.15 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-3)

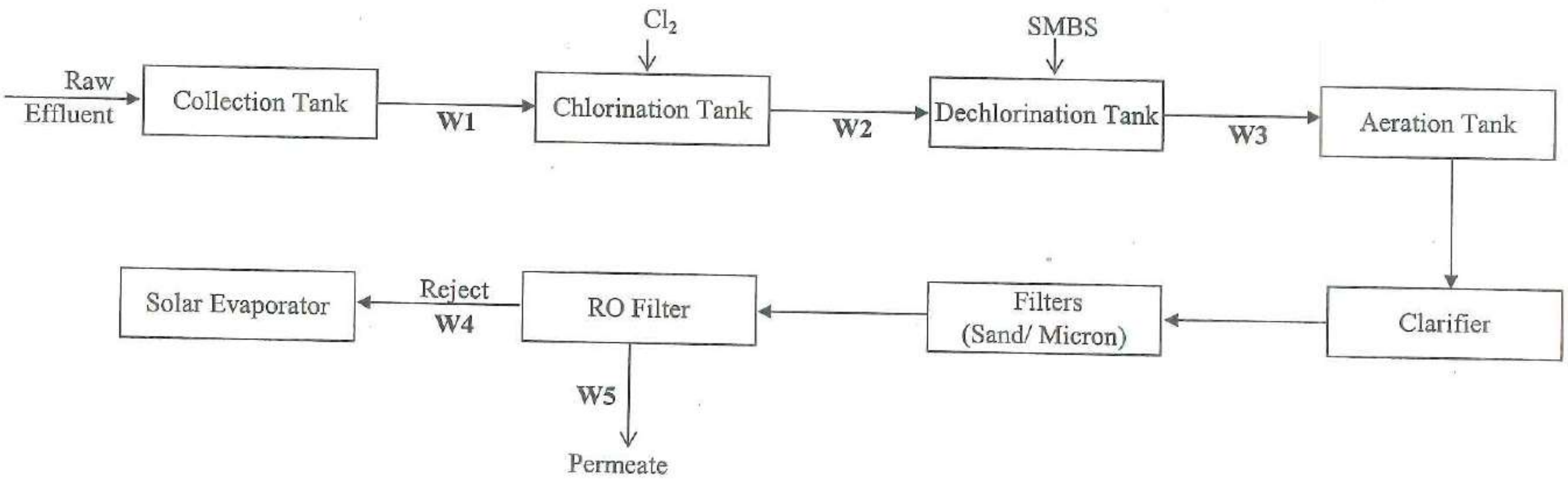
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.2	Nil	Nil	Nil	Nil
2	Near Chlorine Reator	0.3	Nil	Nil	Nil	Nil

5.4.4 Study Unit 4

The Study Unit 4 (SU-4) is a medium scale industry involved in the manufacturing of hosiery cloth. The effluent generated in the industry was subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme (Fig. 5.4) consists of chlorination for colour and organics removal, RO system for TDS removal and solar evaporator for RO Reject management.

The raw effluent was subjected to chlorination for colour removal. The concentrated chlorine solution was allowed to enter into the syntex tank from the top through venturi setup, at which the chlorine gas was mixed thoroughly with the dyeing effluent. Adequate contact time was provided by recirculating the contents of the syntex tanks using a pump. After chlorination, the effluent was subjected to dechlorination using SMBS for removal of residual chlorine. The chlorination/dechlorination resulted in 70-74% reduction in colour and 42-48% reduction in organics. Then the effluent was subjected to aeration and RO pre-treatment processes and was taken to RO system for the reduction of TDS, in which TDS removal from 7020 mg/L to less than 248 mg/L was achieved. The reject from RO system was finally taken to evaporation in the solar evaporator.

The characterization of the effluent at different stages of treatment is presented in Table 5.16 (except colour and AOX). The colour and AOX details are presented separately in Table 5.17 and 5.18 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.19. In SU 4, Chlorination resulted in percent colour removal in the range of 70-74%.



Note: W1-W5 Effluent Sampling points

FIGURE 5.4 EFFLUENT TREATMENT SCHEME FOR SU-4

TABLE 5.16 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 4)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.1	236	588	7020	536	Nil	2613
2	W2	Chlorination Outlet	6.7	152	370	6295	526	32	3110
3	W3	Dechlorination Outlet	6.7	123	340	6850	526	Nil	3252
4	W4	RO Reject	6.7	23	266	26654	24	Nil	9000
5	W5	RO Permeate	6.7	18	20	248	20	Nil	181

TABLE 5.17 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 4)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.131	13.1	0.074	7.4	0.053	5.3	-	-	-
2	W2	Chlorination Outlet	15 min.	0.111	11.1	0.063	6.3	0.044	4.4	15	15	17
			30 min.	0.091	9.1	0.052	5.2	0.033	3.3	31	30	38
			45 min.	0.062	6.2	0.040	4.0	0.029	2.9	53	46	45
3	W3	Dechlorination Outlet		0.036	3.6	0.022	2.2	0.014	1.4	73	70	74

TABLE 5.18 AOX CONCENTRATIONS (SU 4)

Sl. No.	Parameter	End of Chlorination mg/L	End of Dechlorination mg/L
1	AOX	0.33	2

TABLE 5.19 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-4)

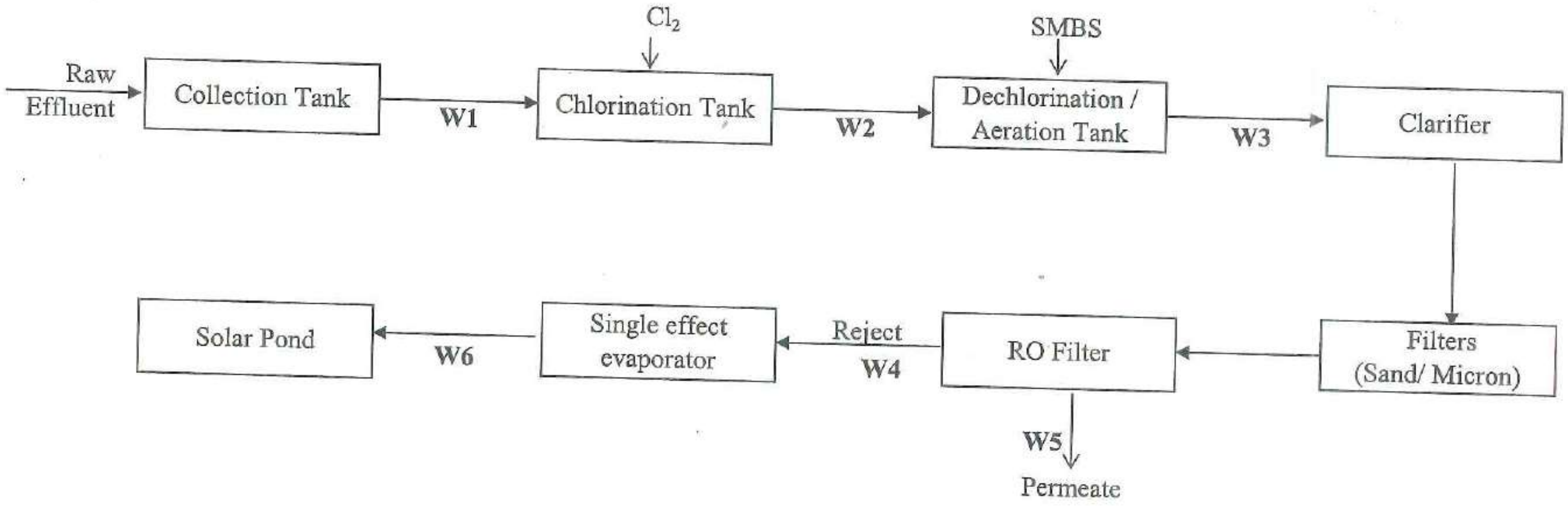
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.7	0.3	Nil	Nil	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.5 Study Unit 5

The Study Unit-5 (SU-5) is a medium scale unit involved in the manufacturing of fabrics. The effluent generated in the industry was subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme was shown in Fig 5.5. The effluent treatment system consists of chlorination for colour and organics removal, RO system for the removal of TDS and mechanical evaporator and Solar Pond for RO reject management.

The raw effluent was subjected to chlorination for colour removal. The concentrated chlorine solution was allowed to enter into the syntex tank from the top through venturi setup, at which the chlorine gas was mixed thoroughly with the textile effluent was provided by recirculating the contents of the syntex tanks using a pump. After chlorination, the effluent was subjected to dechlorination using SMBS for removal of residual chlorine. The chlorination/dechlorination resulted in 89-95% reduction in colour and 51-56% reduction in organics. The effluent was then was taken to RO pre-treatment system and to the RO system for the reduction of TDS, in which TDS was removed from 4108 mg/L to less than 32 mg/L. Then the reject from RO system was finally subjected to evaporation in the mechanical evaporator and solar pond.

The characterization of the effluent at different stages of treatment is presented in Table 5.20 (except colour and AOX). The colour and AOX details are presented separately in Table 5.21 and 5.22 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.23. In SU 5, Chlorination resulted in percent colour removal in the range of 89-95%.



Note: W1-W6 Effluent Sampling points

FIGURE 5.5 EFFLUENT TREATMENT SCHEME FOR SU-5

TABLE 5.20 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 5)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.3	486	840	4108	692	Nil	2567
2	W2	Chlorination tank outlet	6.2	330	500	3564	571	49	3106
3	W3	Dechlorination Tank Outlet	6.3	240	366	3684	548	Nil	3114
4	W4	RO Reject	6.7	56	140	20568	26	Nil	15402
5	W5	RO Permeate	6.3	16	48	32	10	Nil	224
6	W6	Single Effect Evaporator	7.1	10	46	Nil	Nil	Nil	8532

TABLE 5.21 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 5)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Raw Effluent		0.227	22.7	0.188	18.8	0.110	11.0	-	-	-
2	W2	Chlorination Tank Outlet	15 min.	0.054	5.4	0.035	3.5	0.015	1.5	76	81	86
			30 min.	0.033	3.3	0.017	1.7	0.012	1.2	85	91	89
			45 min.	0.026	2.6	0.016	1.6	0.007	0.7	89	91	94
3	W3	Dechlorination Tank Outlet		0.024	2.4	0.015	1.5	0.006	0.6	89	92	95

TABLE 5.22 AOX CONCENTRATIONS (SU-5)

Sl. No.	Parameter	End of Chlorination mg/L	End of Dechlorination mg/L
1	AOX	12	13

TABLE 5.23 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-5)

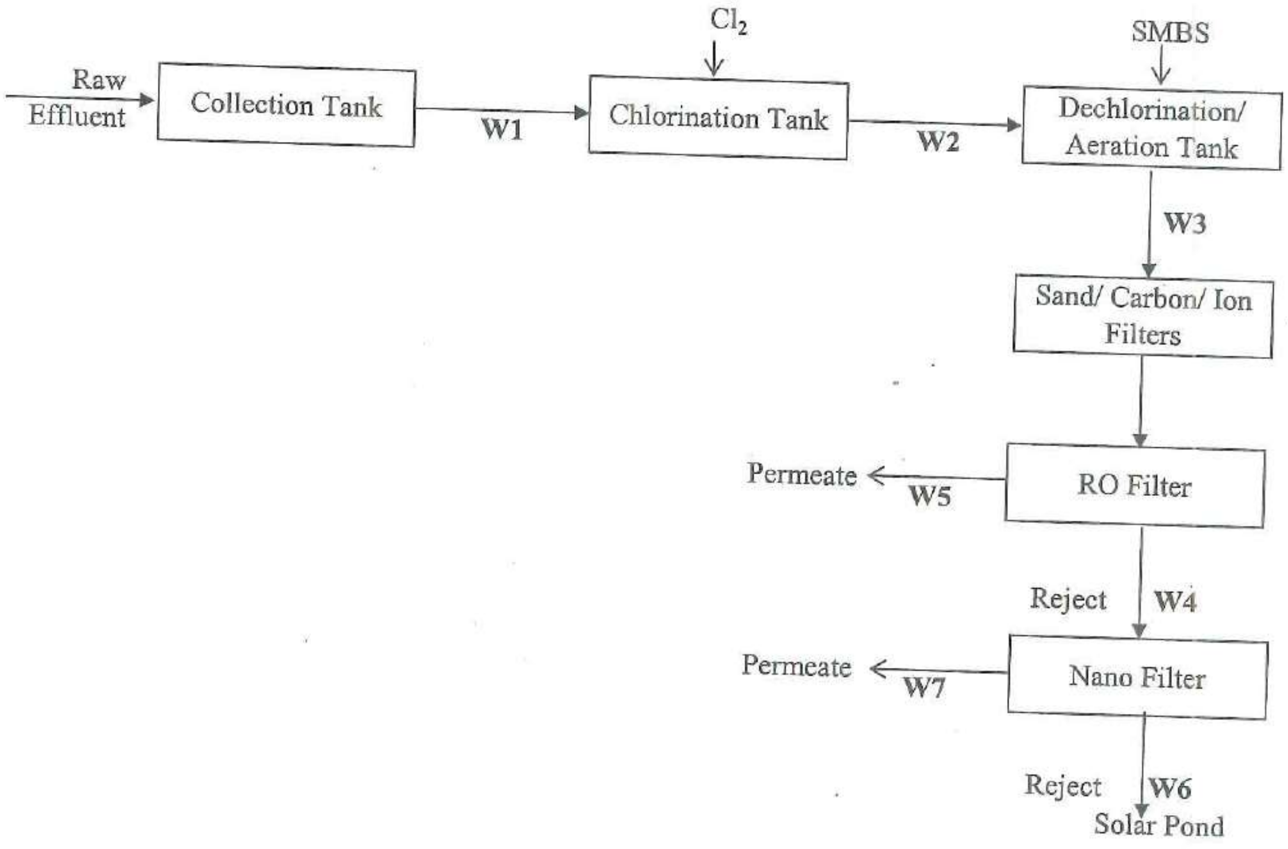
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.3	Nil	Nil	Nil	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.6 Study Unit 6

The Study Unit 6 (SU-6) is a small-scale unit involved in the manufacturing of cotton fabrics. The effluent generated in the industry was subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme was shown in Fig 5.6. The treatment process consists of chlorination for colour and organics removal, RO system for the removal of TDS and NF and Solar Pond for the RO reject management.

The raw effluent was subjected to chlorination for colour removal. The concentrated chlorine solution was allowed to enter into the syntex tank from the top through venturi setup, at which the chlorine gas was mixed thoroughly with the textile effluent. Adequate contact time was provided by recirculating the contents of the syntex tanks using a pump. After chlorination, the effluent was subjected to dechlorination by dosing SMBS for removal of residual chlorine. At the end of chlorination/ dechlorination, 88-98% reduction in colour and 48-50% reduction in organics was achieved. Then the effluent was taken to RO pre-treatment system and RO system for the reduction of TDS, in which TDS removal from 5980 mg/L to 312 mg/L was achieved. The reject from the RO system was subjected to Nano filtration for recovery of brine solution and then the reject from Nano filtration system was finally taken to the solar evaporator for evaporation.

The characterization of the effluent at different stages of treatment is presented in Table 5.24 (except colour and AOX). The colour and AOX details are presented separately in Table 5.25 and 5.26 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.27. In SU 6, Chlorination resulted in percent colour removal in the range of 88-98%.



Note: W1-W7 I Effluent sampling points

FIGURE 5.6 EFFLUENT TREATMENT SCHEME FOR SU-6

TABLE 5.24 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 6)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.6	120	265	5980	134	Nil	2799
2	W2	Chlorination Outlet	6.6	58	148	5740	122	23	2936
3	W3	Dechlorination Outlet	7.3	60	137	5688	112	Nil	2994
4	W4	RO Reject	7.0	40	40	35476	92	Nil	15652
5	W5	RO Permeate	7 .0	24	58	312	5	Nil	206
6	W6	Nano Reject	7 .0	150	540	54128	BDL	Nil	30975
7	W7	Nano Permeate	7.0	10	72	9376	BDL	Nil	19023

TABLE 5.25 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 6)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.146	14.6	0.189	18.9	0.034	3.4	-	-	-
2	W2	Chlorination Outlet	15 min.	0.068	6.8	0.052	5.2	0.018	1.8	53	72	47
			30 min.	0.067	6.7	0.050	5.0	0.006	0.6	54	74	82
			45 min.	0.066	6.6	0.047	4.7	0.004	0.4	55	75	88
3	W3	Dechlorination Outlet		0.012	1.2	0.004	0.4	0.004	0.4	92	98	88

TABLE 5.26 AOX CONCENTRATIONS (SU-6)

Sl. No.	Parameter	End of Dechlorination mg/L	NF Reject mg/L
1	AOX	26	18

TABLE 5.27 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-6)

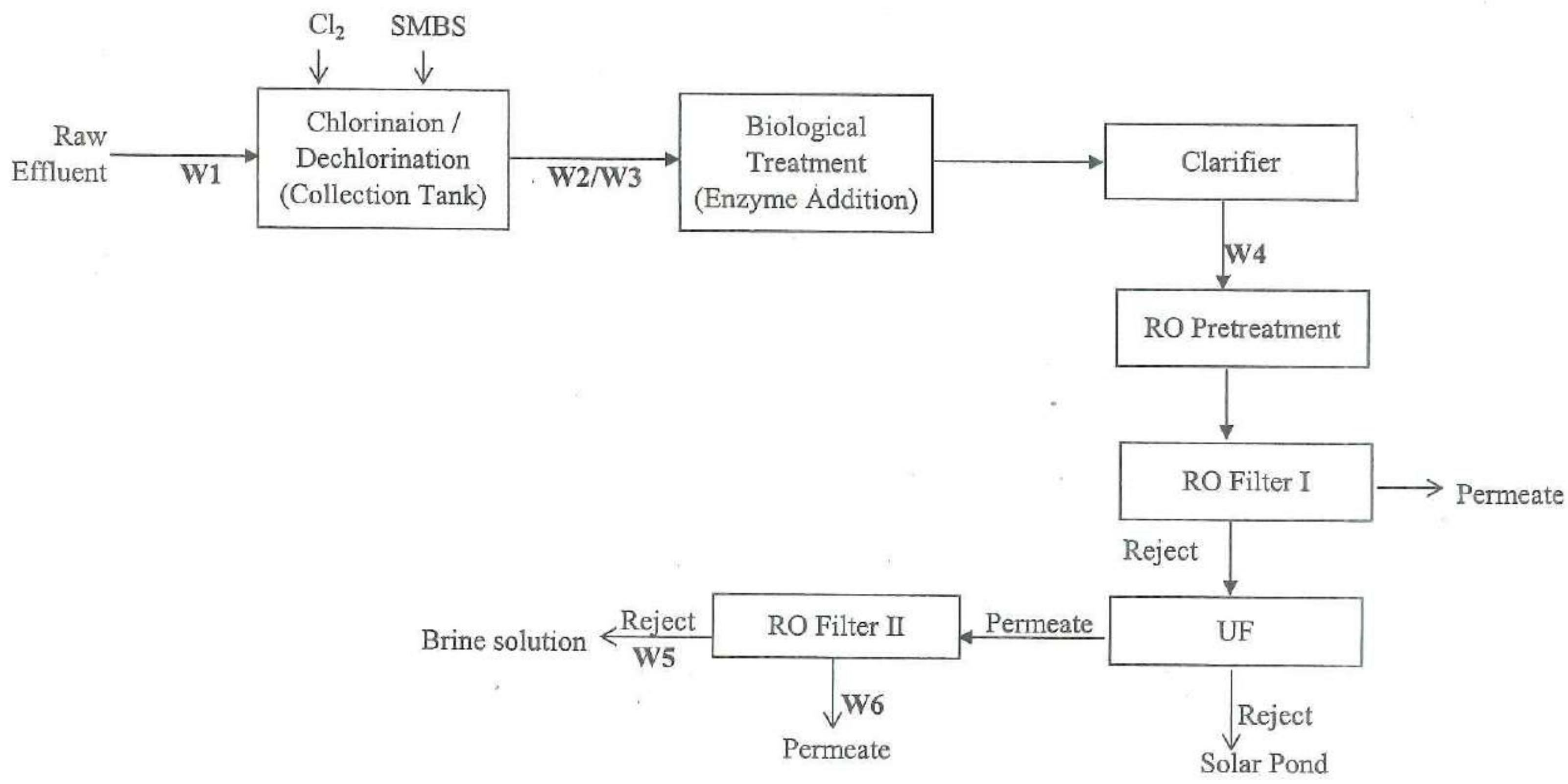
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	3.3	2.1	0.9	0.2	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.7 Study Unit 7

The Study Unit 7 (SU-7) is a medium scale industry involved in the manufacturing of hosiery fabrics and garment dyeing. The effluent generated in the industry was subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme (Fig. 5.7) consists of chlorination for colour removal, biological treatment (enzyme addition) for the removal of organics, RO system for the removal of TDS and solar evaporator for RO Reject management.

The raw effluent was subjected to chlorination for colour removal. The raw effluent was collected in the equalization tank which was also used as a chlorine reaction tank. The concentrated chlorine solution was dispersed into the large quantity of effluent through the diffusers provided at the bottom of the tank. After chlorination, the effluent was subjected to dechlorination in the same collection tank by dosing SMBS for removal of residual chlorine. The chlorination followed by dechlorination resulted in 82-93% reduction in colour and 61-62% reduction in organics. The effluent was then taken to biological treatment process (enzyme addition) for removal of organics in which 74-84% reduction in organics was achieved. After biological treatment, the effluent was subjected to RO pre-treatment process and RO process which reduced the TDS from 7850 - 254 mg/L and it was finally taken to evaporation in the solar evaporator.

The characterization of the effluent at different stages of treatment is presented in Table 5.28 (except colour and AOX). The colour and AOX details are presented separately in Table 5.29 and 5.30 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.31. In SU 7, Chlorination resulted in percent colour removal in the range of 82-93%.



Note: W1-W6 Effluent Sampling points

FIGURE 5.7 EFFLUENT TREATMENT SCHEME FOR SU-7

TABLE 5.28 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 7)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Raw Effluent	7	420	840	7850	345	Nil	3396
2	W2	Collection Tank Outlet (Chlorination Outlet)	6.7	184	360	7784	274	16	3710
3	W3	Collection Tank Outlet (Dechlorination Outlet)	6.8	159	326	7736	252	Nil	3767
4	W4	Clarifier Outlet (after Biological Treatment)	6.9	68	219	7736	106	Nil	3767
5	W5	RO (II) Reject	6	90	360	45429	10	Nil	18724
6	W6	RO (II) Permeate	6.4	22	40	254	6	Nil	278

TABLE 5.29 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 7)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Raw Effluent		0.348	34.8	0.169	16.9	0.121	12.1	-	-	-
2	W2	Collection Tank Outlet (Chlorination Outlet)	30 min.	0.326	32.6	0.157	15.7	0.092	9.2	6	7	24
			1 hr.	0.217	21.7	0.134	13.4	0.090	9.0	38	21	26
			4.5 hrs.	0.033	3.3	0.031	3.1	0.024	2.4	91	82	80
3	W3	Collection Tank Outlet (Dechlorination Outlet)		0.024	2.4	0.030	3.0	0.013	1.3	93	82	89
4	W4	Clarifier Outlet		0.002	0.2	0.001	0.1	0.004	0.4	99	99	97

TABLE 5.30 AOX CONCENTRATIONS (SU-7)

Sl. No.	Parameter	End of Dechlorination mg/L	RO Reject mg/L
1	AOX	40	35

TABLE 5.31 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-7)

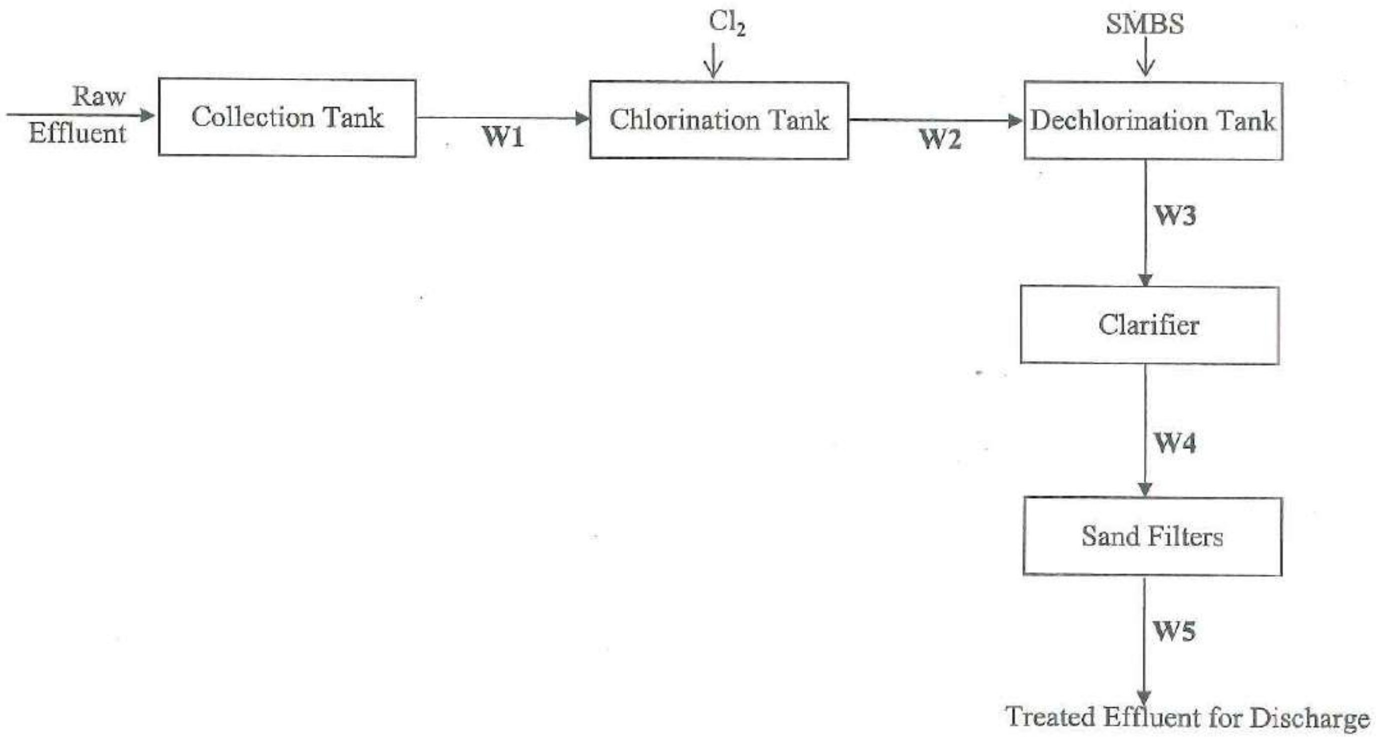
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.4	0.2	Nil	Nil	Nil
2	Near Chlorine Reactor	0.3	Nil	Nil	Nil	Nil

5.4.8 Study Unit 8

The Study Unit 8 (SU-8) is a small-scale unit involved in the manufacturing of hosiery fabrics. The effluent generated in the industry after treatment was discharged into drainage system. There is no ZLD facility. The effluent treatment scheme (Fig. 5.8) consists of chlorination for colour and organics removal, and it was subjected to filtration for solids removal.

The raw effluent was first subjected to chlorination for colour removal. The concentrated chlorine solution was allowed to enter into the syntex tank from the top through a venturi setup, at which the chlorine gas was mixed thoroughly with the textile effluent. Adequate contact time was provided by recirculating the contents of the syntex tanks using a pump. After chlorination, the effluent was subjected to dechlorination by dosing SMBS for the removal of residual chlorine. The chlorination/ dechlorination resulted in 86-94% reduction in colour and 32-35% reduction in organics. The dechlorinated wastewater was then subjected to filtration (sand filters) for removal of solids and finally discharged into the drainage system.

The characterization of the effluent at different stages of treatment is presented in Table 5.32 (except colour and AOX). The colour and AOX details are presented separately in Table 5.33 and 5.34 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.35. In SU 8, Chlorination resulted in percent colour removal in the range of 86-94%.



Note: W1-W5 Effluent Sampling points

FIGURE 5.8 EFFLUENT TREATMENT SCHEME FOR SU-8

TABLE 5.32 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 8)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.3	132	415	6616	356	Nil	1419
2	W2	Chlorination Tank Outlet	7.2	91	296	5979	290	97	1475
3	W3	Dechlorination Tank Outlet	7.6	86	284	5846	289	77	1478
4	W4	Clarifier Outlet	8.0	84	207	5226	192	61	1478
5	W5	Sand Filter Outlet (Treated Effluent for discharge)	8.7	65	170	5226	146	55	1464

TABLE 5.33 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 8)

Sl. No.	Sampling Location No.	Sampling Locations	Colour Measurement						Colour Removal Efficiency (%)		
			436 nm		525 nm		620 nm				
			(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)	0.134	13.4	0.132	13.2	0.143	14.3	-	-	-
2	W2	Chlorination Tank Outlet	0.086	8.6	0.083	8.3	0.058	5.8	36	37	59
3	W3	Dechlorination Tank Outlet	0.010	1.0	0.008	0.8	0.020	2.0	93	94	86

TABLE 5.34 AOX CONCENTRATIONS (SU-8)

Sl. No.	Parameter	End of Dechlorination mg/L	Treated Effluent for Discharge mg/L
1	AOX	29	10

TABLE 5.35 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-8)

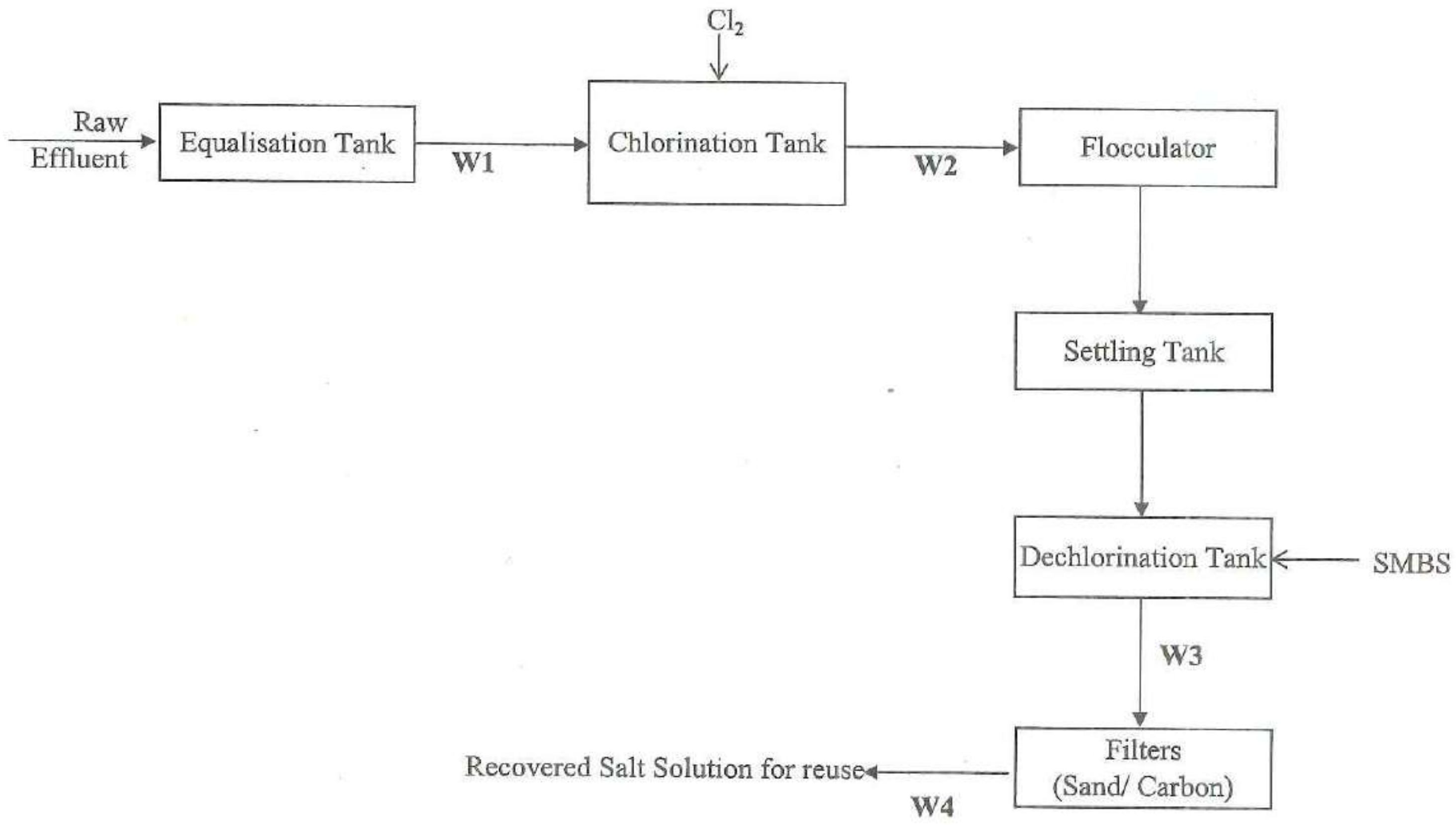
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	3.8	2.9	1.6	0.8	0.2
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.9 Study Unit 9

The Study Unit 9 (SU-9) is a small-scale industry involved in the manufacturing of hosiery and yarn. The effluent generated by the industry was subjected to the treatment in the zero liquid discharge facility using chlorine oxidation and recovering salt solution with no chemical sludge. The effluent treatment scheme (Fig 5.9) consists of chlorination for colour removal and organics removal. The process of chlorination was carried out in the OR Reactor tank and the solids removal was carried out in the flocculator.

The dyeing effluent after equalization was pumped into the OR Reactor tank. The equalized effluent was treated with the oxidation reduction process after initial adjustment of pH and inoculation of catalytic chemicals. Then the chlorinated effluent was passed into the flocculator where polymer / polyelectrolyte were added for removal of solids. Then it was passed into sump via settling tank where dechlorination was carried out by loading Sodium Meta Bi-sulphite. The chlorination / dechlorination resulted in 93-94% reduction in colour and 22-25% reduction in organics. Then the effluent was passed through pressure sand filter and activated carbon filter.

The characterization of the effluent at different stages of treatment is presented in Table 5.36 (except colour and AOX). The colour and AOX details are presented separately in Table 5.37 and 5.38 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.39. In SU 9, Chlorination resulted in percent colour removal in the range of 93-94%.



Note: W1-W4 Effluent Sampling points

FIGURE 5.9 EFFLUENT TREATMENT SCHEME FOR SU-9

TABLE 5.36 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 9)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Equalisation Tank Outlet (Raw Effluent)	9.6	260	440	29948	120	Nil	14739
2	W2	Chlorination outlet	7.6	208	362	28932	98	7	14992
3	W3	Dechlorination Outlet	7.6	196	344	28680	88	Nil	15085
4	W4	Recovered Salt Solution	7.6	196	752	35720	76	Nil	17539

TABLE 5.37 EFFECT OF CHLORINATION IN COLOUR REMOVAL (SU - 9)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		1.335	133.5	0.454	45.4	0.361	36.1	-	-	-
2	W2	Chlorination Outlet	5 min.	1.126	112.6	0.285	28.5	0.136	13.6	16	37	62
			10 min.	0.097	9.7	0.047	4.7	0.036	3.6	93	90	90
			15 min	0.096	9.6	0.040	4.0	0.027	2.7	93	91	93
3	W3	Dechlorination Tank Outlet		0.082	8.2	0.033	3.3	0.024	2.4	94	93	93

TABLE 5.38 AOX CONCENTRATIONS (SU-9)

Sl. No.	Parameter	End of Chlorination mg/L	Recovered salt solution mg/L
1	AOX	14	17

TABLE 5.39 CHLORINE GAS CONCENTRATION IN AIR (ppm) (SU-9)

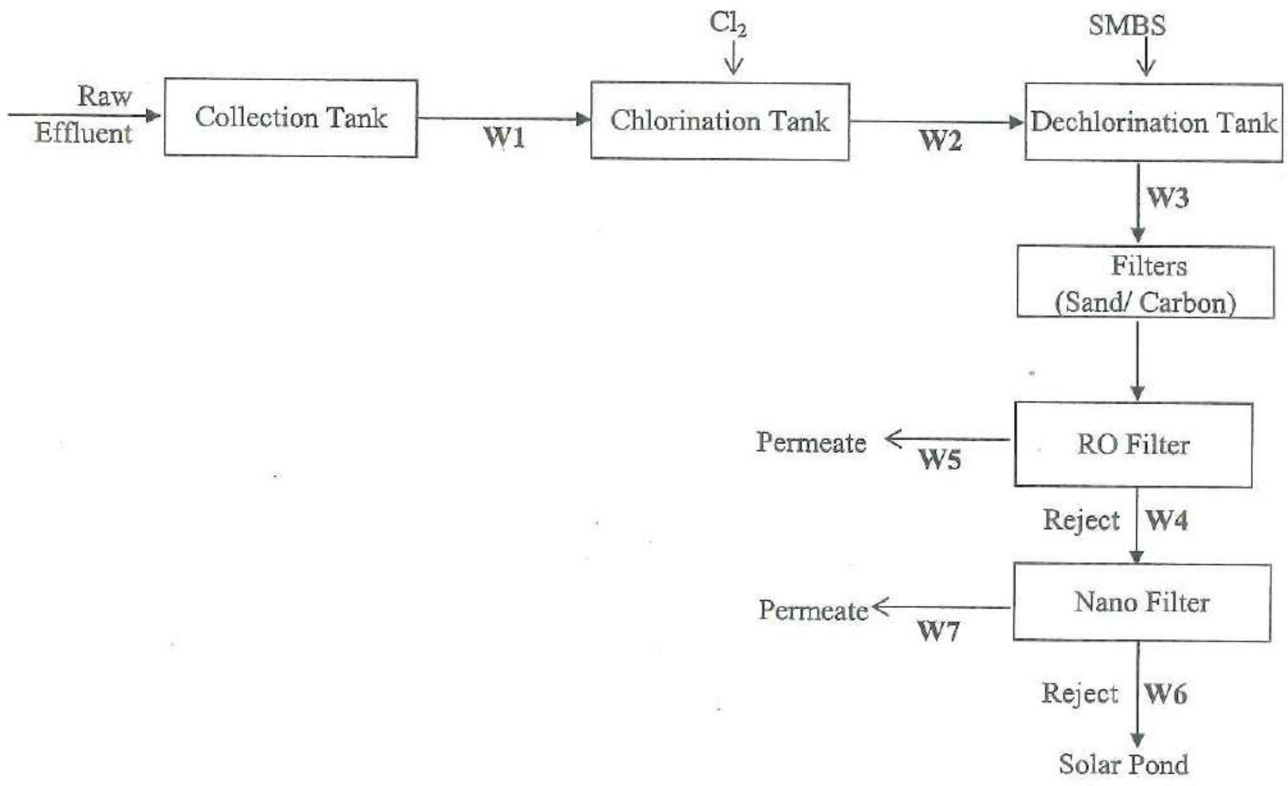
Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.2	Nil	Nil	Nil	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

5.4.10 Study Unit 10

The Study Unit 10 (SU-10) is a medium scale industry involved in the manufacturing of hosiery cloth. The effluent generated in the industry was subjected to treatment in the zero liquid discharge facility. The effluent treatment scheme (Fig. 5.10) consists of chlorination for colour and organics removal, TDS removal in RO system for recovery and reuse of water and solar evaporator for NF reject management.

The raw effluent was first subjected to gas chlorination for colour and organics removal. The concentrated chlorine solution was allowed to enter into the syntex tank from the top through a venturi setup, at which chlorine gas was mixed thoroughly with the dyeing effluent. After chlorination, the effluent was subjected to dechlorination by dosing SMBS for the removal of residual chlorine. The chlorination/ dechlorination resulted in 65 - 70% reduction in colour and 49- 50% reduction in organics. The effluent was taken to RO system for the reduction of TDS in which TDS removal from 5624 to 108 mg/L took place. The reject from the RO system was subjected to Nano filtration for recovery of brine solution and rejects from the Nano filtration system was finally taken to the solar evaporation.

The characterization of the effluent at different stages of treatment is presented in Table 5.40 (except colour and AOX). The colour and AOX details are presented separately in Table 5.41 and 5.42 respectively. The observations on chlorine concentration in air in the unit are presented in Table 5.43. In SU 10, Chlorination resulted in percent colour removal in the range of 65 - 70%.



Note: W1-W7 Effluent Sampling points

FIGURE 5.10 EFFLUENT TREATMENT SCHEME FOR SU-10

TABLE 5.40 CHARACTERISTICS OF EFFLUENT FROM TREATMENT UNITS (SU - 10)

Sl. No.	Sampling Location No.	Sampling Locations	pH	Organics (mg/L)		Solids (mg/L)		Residual Chlorine (mg/L)	Chloride (mg/L)
				BOD	COD	TDS	TSS		
1	W1	Collection Tank Outlet (Raw Effluent)	7.4	380	644	5624	480	Nil	2995
2	W2	Chlorination outlet	6	208	496	5523	362	10	3275
3	W3	Dechlorination Tank Outlet	7.1	194	322	5312	316	Nil	3297
4	W4	RO Reject	6.6	84	144	28752	78	Nil	26376
5	W5	RO Permeate	8	22	57	108	24	Nil	226
6	W6	Nano Reject	6	172	864	35104	BDL	Nil	40112
7	W7	Nano Permeate	6.6	50	122	27124	52	Nil	29162

TABLE 5.41 EFFECTS OF CHLORINATION IN COLOUR REMOVAL (SU - 10)

Sl. No.	Sampling Location No.	Sampling Locations		Colour Measurement						Colour Removal Efficiency (%)		
				436 nm		525 nm		620 nm				
				(A)	(m^{-1})	(A)	(m^{-1})	(A)	(m^{-1})	436 nm	525 nm	620 nm
1	W1	Collection Tank Outlet (Raw Effluent)		0.113	11.3	0.086	8.6	0.073	7.3	-	-	-
2	W2	Chlorination Outlet	15 min.	0.052	5.2	0.034	3.4	0.029	2.9	54	60	60
			30 min.	0.045	4.5	0.033	3.3	0.026	2.6	60	62	64
			45 min.	0.041	4.1	0.029	2.9	0.025	2.5	64	66	66
3	W3	Dechlorination Tank Outlet		0.040	4.0	0.026	2.6	0.022	2.2	65	70	70

TABLE 5.42 AOX CONCENTRATIONS (SU-10)

Sl. No.	Parameter	End of Dechlorination mg/L	Nano Reject mg/L
1	AOX	21	95

TABLE 5.43 CHLORINE CONCENTRATION IN AIR (ppm) (SU-10)

Sl. No.	Sampling Locations	At Source	2m	4m	6m	8m
1	During Dechlorination/ Aeration	0.3	Nil	Nil	Nil	Nil
2	Near Chlorine Reactor	Nil	Nil	Nil	Nil	Nil

CHAPTER 6

HEALTH, SAFETY AND ENVIRONMENTAL (HSE) RISK ASSESSMENT FOR THE TEXTILE UNITS

The use of chlorine gas in textile units to treat the dyeing effluents leads to 3 types of risks:

i) Health Risk

ii) Safety Risk

iii) Environmental Risk

This Chapter outlines the assessment of three types of risks associated with the chlorine use.

6.1 Health Risk Assessment

The treatment of textile wastewater by gas chlorination in chlorine reactors followed by removal of free residual chlorine by dechlorination and aeration leads to emission of chlorine gas into the atmosphere. In order to estimate the health risks from occupational exposure to chlorine in air for the treatment plant workers / operators, the health risk assessment already done was reviewed in this study. As a consequence, the treatment plant workers/ operators are exposed to the chlorine gas emission.

6.1.1 Exposure Assessment

As a first step in the health risk assessment, the exposure assessment was made. The short-term exposure level (ie., 15 min.) concentration of chlorine in the atmospheric air in and around the chlorination unit and dechlorination/ aeration unit was measured in the selected study units during the field studies. The Table 6.1 presents the measured concentration of atmospheric chlorine in the study units (SU 1 to SU 10). They are representative for typical occupational exposure of workers in the textile units.

From Table 6.1, the following inferences are made:

1. As anticipated, the maximum concentration of chlorine in the atmosphere is at the Reactor/ Sump/ Dechlorination unit/ Equalization Tank.

2. Maximum concentrations for the ten study units ranged from 0.2 to 4.8 ppm.
3. Four units out of 10 recorded a concentration ranging from 3.3 to 4.8 ppm.
4. As one move away from the reactor, chlorine concentrations decreased; the chlorine was detected in the air upto a distance of 8 m from the reactor in one study unit.

6.1.2 Dose – Response Assessment

As the next step in the health risk assessment, a comprehensive review of the literature on the Dose-Response Assessment was made. The toxicity literature for chlorine has been comprehensively described by WHO, US EPA, ACGIH, etc. 'The chlorine exposure levels and effects on human' is presented in Table 6.2. The hazard information is described first by route of exposure (inhalation, ingestion and skin contact) and then by duration of exposure (acute, chronic and sub-chronic) in laboratory toxicity studies. For treatment plant workers / operators in textile units, the route of exposure to chlorine is inhalation and the duration of exposure is acute, since gas chlorination is carried out as batch process.

Existing regulations in India under Factories Act, 1948 impose occupational exposure limits for chlorine. Under this Act, the short – term exposure limit (ie., 15 min) and long – term exposure limit (ie., 8 h) are 3 ppm and 1 ppm respectively (Table 6.3). The ACGIH has recommended an 8 h TLV of 0.5 ppm and a 15 minute STEL of 1 ppm (Table 6.4) and IS code (IS : 4263 – 1967) also refers to ACGIH recommendations. Many European countries apply the limit for long-term exposure (8 h) as 0.5 ppm and short-term exposure (15 min.) as 1 ppm. Whereas, a draft proposal of European Directive on Occupational Exposure Limits establishes limit of 0.5 ppm (instead of 1 ppm) for short-term exposure (15 min) to chlorine. US EPA has derived Acute Exposure Guideline levels (AEGLs) and it is presented in Table 6.5.

Out of many such recommendations, the IS : 4263 – 1967 recommendation is considered to be significant as it falls in line with the current international recommendations. Provision made in the Factories Act, 1948 is legally binding.

6.1.3 Risk Characterization

This evaluation was undertaken to determine whether any risk to health of Treatment Plant workers/ operators might be present when they are exposed to chlorine in air during treatment of textile wastewater by gas chlorination. The health risk to the Treatment Plant workers/ operators was characterized by comparing the worst – case actual exposure to the permissible levels.

(a) The short–term exposure (15 min) level concentration of Cl_2 was found to be highest at the dechlorination/ aeration tanks in all the 10 study units. The worst – case actual levels of chlorine exposure in the study units was compared to the short–term exposure limit (STEL) of existing Factories Act (3 ppm), India. Out of 10 units, in 4 units (ie., SU 1, SU 2, SU 6, SU 8), the actual exposure concentration (3.3 – 4.8 ppm) was found to exceed the STEL (3 ppm) and thus actual exposure is posing health risk to the treatment plant workers / operators.

(b) The worst – case actual levels of chlorine exposure was compared to the STEL (1 ppm) of IS guidelines. Out of 10 units, in 4 units (ie., SU1, SU2, SU6, SU8), the actual exposure concentration (3.3 – 4.8 ppm) was found to exceed the STEL of IS guideline and thus actual exposure is posing health risk,to the Treatment Plant workers / operators.

(c) US EPA has derived Acute Exposure Guideline Level-1 (AEGL-1) for 30 min. exposure as 0.5 ppm and above 0.5 ppm, the general population (including susceptible individual) could experience notable discomfort, irritation or certain asymptomatic non-sensory effects, however the effects are reversible upon cessation of exposure. Assuming the duration of exposure of TP workers/ operators at the textile units to the worst-case actual levels of chlorine as 30 min. and comparing to the AEGL-1 guideline value (0.5 ppm), then actual exposure concentration (0.7 – 4.8 ppm) in 5 units (SU 1, SU 2, SU 4, SU 6 and SU 8) was found to exceed AEGL-1 guideline value of 0.5 ppm and thus posing health risk to the Treatment Plant workers / operators.

(d) US EPA has derived Acute Exposure Guideline Level-2 (AEGL-2) for 30 min. exposure as 2.8 ppm and above 2.8 ppm, the general population (including susceptible individual) could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. Assuming the duration of exposure of TP workers/ operators at the textile units to the worst-case actual levels of chlorine as 30 min. and comparing to the AEGL-2 guideline value (2.8 ppm), then actual exposure concentration (3.3 – 4.8 ppm) in 4 units (SU 1, SU 2, SU 6 and SU 8) was found to exceed AEGL-2 guideline value of 2.8 ppm and thus posing health risk to the Treatment Plant workers / operators.

In summary, workers/ operators employed in atleast 40% of the textile units are exposed to chlorine gas beyond permissible levels, posing health risk to such people.

Table 6.1 Concentration of Chlorine in Air in the Study Units

Sl. No.	Study Unit	Source of Chlorine Emission	Chlorine Concentration in ambient air (ppm)	
1	SU 1	Clarifier (Dechlorination / Aeration)	At Clarifier	4
			At 2 m	1.9
			At 4 m	0.7
			At 6 m	0.3
			At 8 m	Nil
2	SU 2	OR Sump (Dechlorination / Aeration)	At OR Sump	4 .8
			At 2 m	2.3
			At 4 m	1.0
			At 6 m	0.5
			At 8 m	Nil
3	SU 3	Equalization Tank (Dechlorination / Aeration)	At Equalization Tank	0.2
			At 2 m	Nil
4	SU 4	Dechlorination / Aeration Unit	At Dechlorination Unit	0.7
			At 2 m	0.3
			At 6 m	Nil
5	SU 5	Dechlorination / Aeration Unit	At Dechlorination Unit	0.3
			At 4 m	Nil
6	SU 6	Dechlorination / Aeration Unit	At Dechlorination Unit	3.3
			At 2 m	2.1
			At 4 m	0.9
			At 6 m	0.2
			At 8 m	Nil

7	SU 7	Equalization Tank	At Equalization Tank	0.4
			At 2 m	0.2
			At 6 m	Nil
8	SU 8	Dechlorination / Aeration Tank	At Dechlorination Tank	3.8
			At 2 m	2.9
			At 4 m	1.6
			At 6 m	0.8
			At 8 m	0.2
9	SU 9	Dechlorination / Aeration	At Dechlorination Tank	0.2
			At 2 m	Nil
10	SU 10	Dechlorination / Aeration	At Dechlorination Tank	0.3
			At 2 m	Nil

Table 6.2 Dose – Response Assessment for Chlorine

Exposure Levels (ppm)	Health Effects
0.1 – 0.3 ppm	Odour Threshold (Varies by individual).
<0.5 ppm	No known acute or chronic effect (STEL, 15 min.).
1 – 3 ppm	May cause mild irritation of eyes, noise and throat.
3 – 5 ppm	Burning in eyes, nose and throat; May cause headache, watering eyes, sneezing, coughing, breathing difficulty, bloody nose and blood-tinged sputum.
5 – 15 ppm	Severe irritation of eyes, nose and respiratory tract
30 – 60 ppm	Immediate breathing difficulty resulting in pulmonary edema (fluid buildup in lungs), possibly causing suffocation and death.
430 ppm	Lethal after 30 minutes.
1000 ppm or more	Fatal after a few breaths.

Source: Chlorine Incident Management, 2006 Version 1, Health Protection Agency

Table 6.3 National Exposure Limits for Chlorine

Sl. No.	Description	The Factories Act, 1948	IS : 4263 – 1967
1	Short-term Exposure Limit STEL, (15 min.)	3 ppm	1 ppm
2	Long-term Exposure Limt TWA, (8 h)	1 ppm	0.5 ppm

Table 6.4 International Exposure Guidelines for Chlorine

Sl. No.	Description	OSHA	ACGIH	NIOSH
1	Short-term Exposure Limit (15 min.)	1 ppm	1 ppm	1 ppm
2	Long-term Exposure Limit (8h)	0.5 ppm	0.5 ppm	0.5 ppm
3	Immediately Dangerous to Life and Health (IDLH)*	N.A.	N.A.	10 ppm or more

* The Immediately Dangerous to Life and Health (IDLH) exposure level is the point at which a person without appropriate respiratory protection could be fatally injured or could suffer irreversible health effects.

Source: Hazardous Substances Fact Sheet, New Jersey Department of Health and Senior Services

Table 6.5 Acute Exposure Guideline Levels

	10 min.	30 min.	60 min.	4h	8h
AEGL – 1	0.5	0.5	0.5	0.5	0.5
AEGL – 2	2.8	2.8	2.0	1.0	0.71

Source: US EPA

6.2 Safety Risk Assessment

The safety risk assessment involves hazard identification and assessing the consequence of such hazards.

6.2.1 Hazard Identification

The hazardous events that could take place in a typical textile unit adopting gas chlorination were identified and the same are presented in Table 6.6. These hazardous events could lead to undesirable consequences eg. release of toxic chlorine gas to air and could result in unique accident scenarios that could endanger the workers and public.

Table 6.6 Hazards in Using Chlorine Gas Cylinders

Sl. No.	Hazard Description
1	Chlorine release from leak of chlorine main cylinder valve, when cylinder is in operation
2	Chlorine release from leak of pigtail tubing (connecting chlorine cylinder to chlorine gas piping)
3	Liquid valve in chlorine cylinder develops a leak
4	Leak at the connection to the vacuum regulators
5	Chlorine gas pressure exceeds normal working gas pressure due to increase in room temperature
6	Fusible plug on cylinder opens and releases chlorine gas
7	Chlorine leak develops in one of chlorinator components ie., pressure relief valve, rotameter, differential regulating valve while it is in operation
8	Chlorine solution leak develops in a chlorine solution line in the building/ outside the building/ at a feed point solution.
9	Chlorine gas line or connection is broken
10	Chlorine solution line is broken

6.2.2 Consequence Analysis

Once the hazardous events are identified, the next step in risk analysis is to analyze their consequences ie., estimating the magnitude of damage to the potential receptors. Many studies have been conducted to assess the consequence of toxic dense chlorine gas release. In all the studies, the effect-zone estimates were predicted for selected accident scenarios. The major findings of such studies are listed in Table 6.7.

One particular study conducted by M/s SPIC is significant. A brief description of the study follows: With the rupture of nozzle, liquid chlorine comes out, immediately vaporizes into air, moves as a dense gas. The rate of release of chlorine from the nozzle varies with time and is dependent on initial temperature and pressure of the cylinder. For a 1 tonne cylinder (at 30°C and 6.3 atmosphere pressure), through a 2.5 cm diameter nozzle, the rate of chlorine release will be 1 kg/ sec. at the instant of failure and gradually decreases to 0.75 kg/sec at 1 min and 0.3 kg/sec at 3 min. However for consequence modelling, the release rate is assumed to be 1 kg/sec, which represents the worst case. The movement of the dense cloud and its dispersion in the atmosphere depend on prevailing meteorological conditions. For the worst case atmospheric conditions that exist during night time with wind speed of 2 m/sec and atmospheric stability class of F, M/s SPIC has predicted that an area of 1000 m radius around the source point is likely to have the ground level (GL) concentration above 25 ppm. It is concluded that the vulnerable zone in which the GL concentration of chlorine exceeding 25 ppm is restricted to 1000 m from the source point during the night time and 800 m during the day time under the worst case condition.

6.2.3 Safety Risk Assessment for Textile Units

From the Table 6.7 and the US EPA study, it is concluded that the vulnerable zone varies according to the nature of hazard. It may be from a few hundred meters to a few kilometers. It is safe to conclude that the worst-case consequence due to a hazard like chlorine cylinder rupture will be that the dangerous concentration of chlorine is likely to reach a distance of atleast 2 km from the release point. This assessment is as per US EPA toxic end point of 3 ppm of chlorine concentration. In the case of textile industries this means that the vulnerable zone might extend beyond the boundary of textile units endangering the public living in the mixed industrial zones in the vicinity of the units. Thus it may be concluded that the catastrophic failures of chlorine tonner might endanger the public and hence the levels of public risk associated with gas chlorination process in textile units is high in Textile belts of Tamil Nadu.

Table 6.7 Studies on Consequence Analysis of One Tonne Chlorine Cylinder

Organization	Modes of Failures	Consequences
M/s.Alcoa Alumina	a) Vessel Failure	Reaches a distance of 270 m downwind before probability of a fatality reaches zero.
	b) 25mm Vessel leak	Reaches a distance of 400 m downwind before probability of a fatality reaches zero.
M/s.IFFCO – ANOLA	a) Catastrophic Failure	Chlorine concentration upto 30 ppm in downwind direction upto 1247 m.
	b) Valve Failure	Chlorine concentration upto 30 ppm at 500 m from source of chlorine release.
M/s. Spic Electric Power Corporation Ltd.	a) Rupture of Cylinder	Vulnerable zone in which chlorine concentration will exceed 25 ppm is restricted to 900 m during nighttime and 832 m during daytime.
	b) Rupture of Nozzle	Vulnerable zone in which chlorine concentration will exceed 25 ppm is restricted to 1000 m during nighttime & 800 m during daytime.
Iyuke *et al*, Water TP, Malaysia	Worst-case scenario	The distances to toxic end point 3 ppm (8.9 km), 10 ppm (5.3 km) and 20 ppm (3.8 km)
E:Dungan, The Chlorine Institute	a) Liquid valve is struck and sheared off.	Depending on atmospheric conditions, the chlorine cloud containing in excess of 25 ppm will travel between 914 m – 3352 m.
	b) Failure of one-inch chlorine gas line.	Depending on atmospheric conditions, the chlorine cloud containing in excess of 25 ppm will travel between 304 m – 1216 m.
US EPA	a) Worst–case release of entire contents in 10 min.	The distances to toxic end point (3 ppm) in Rural (4827 m) and Urban (2092 m).*
	b) Hole in the storage vessel/ Valve failure	The distances to toxic end point (3 ppm) in Rural (less than 161-965 m) and Urban (less than 161-483 m).

***Used in this study for risk assessment.**

6.3 Environmental Risk Assessment

6.3.1 Effects on Water Environment

Some textile units (small-scale / tiny) discharge the treated effluent into street drains and that ultimately results in the discharge of chlorinated effluent into aquatic systems. All chlorine discharged to aqueous environment will be present in the speciated form and the relevant chlorine species will be hypochlorous acid and hypochlorite anion. The hypochlorous acid (HOCl) predominant at pH 5-7 is a more powerful oxidant than hypochlorite ion (OCl^-) and chlorine. Dissociation is poor at pH levels below 6. The half-life of hypochlorite is estimated to be less than 2 hours. The chlorine species will then react with organic materials present in the effluent as well as natural waters and results in the formation of various chlorine by-products. Aqueous chlorine species do not bioaccumulate.

A few study units were found to discharge their effluents after the chlorination/ dechlorination treatment into the street drains which ultimately reach the surface water bodies. In one case, a very high residual chlorine concentration of 55 mg/L was found to be present after the dechlorination process, well above the TNPCB tolerance limits of 1 mg/L. The residual chlorine concentration in the wastewater generally depletes dissolved oxygen in the receiving water body and as such aquatic life gets affected. Residual chlorine may also react with other compounds in the waste stream to form toxic substances which results in acute toxicity.

In the Study Units, at the end of chlorination/ dechlorination, AOX was found to be generated in the range of 2 to 40 mg/L. In India, limit for AOX discharge for industrial effluents is yet to be fixed, whereas in European countries the limit should not exceed 1 mg/L for discharge into surface water. The gas chlorination leads to the formation of chlorine containing decomposition by-products generally represented as AOX. They are family of chemicals produced when chlorine reacts with organic matter in the effluent and produce dangerous chlorinated compounds. The amount of AOX formed may vary depending on the type of dyes and other organics and the chlorine dosages applied. The AOX formed is retained in the RO Reject and finally gets concentrated in the sludge of solar evaporation, which is temporarily stored in the premises of the industrial units.

Presence of AOX in the environment is a worldwide concern since they are persistent, carcinogenic and bioaccumulative and also have adverse effect on flora and fauna in the aquatic system. When the AOX chemicals are concentrated and released in large quantities to receiving water bodies such as lakes and rivers, they can cause chronic toxicity to aquatic organism. Chronic effects may affect an organisms size, growth rate and ability to reproduce. AOX families are toxic to fish and other aquatic organism at low concentration. Formation of chlorine by-products is of great concern because of the potential impact of these compounds on public health and the environment.

6.3.2 Effects on Land

AOX in sludges serve as a marker for levels of anthropogenic compounds, some of which may be persistent pollutants in soil. The sludge samples analysed for AOX in the study units showed a range of 101-238 mg/kg. It is reported that improper disposal will lead to the problem of ground water pollution, changes in soil condition, adverse effects on plants and poor productivity of soil. The chlorination by-product formation will result in rapid changes in photosynthesis, respiration and transpiration of trees as well as changes in the pigment pattern. In the context of soil contamination, some organic halogens may be transformed in the soil to more toxic compounds such as vinyl chloride, which is a known human carcinogen.

6.3.3 Effects on Materials

Dry chlorine gas is non-corrosive but it is highly corrosive in the presence of moisture. Wet chlorine is corrosive to most of metals. Chlorine is also corrosive to polyvinyl chloride pipelines, when chlorine reacts with water, weak solutions of hydrochloric acid and hypochlorous acids are formed which are highly corrosive in nature.

It was reported that in recent tests, chlorine bleach was exposed to samples of commercial-grade copper, cold rolled steel and aluminium. The copper samples discoloured in three hours and showed green corrosion in 24 hours. Aluminium showed signs of corrosion within 24 hours, and on the surface of cold rolled steel rust formed within 30 minutes. A process known as "hydrogen embrittlement" may occur as the chlorine bleach attacks the stainless steel, trapping hydrogen gas in the pores of the metal. Over time, the hydrogen can be released, resulting in weakened metal. It is especially damaging to welded joints.

6.4 Summary

The following are the conclusions made from the study on the Health, Safety and Environmental Risk:

1. The air environment in significant number of industries (40%) contains excessive levels of chlorine gas which may pose health problems to the workers/ operators.
2. The accidental release of chlorine cylinder rupture is likely to affect a distance of atleast 2 km.
3. The AOX formed in chlorine use is present in excessive concentrations both in effluent and sludge. Unless, their disposal is managed scientifically, they will lead to water and soil pollution.

CHAPTER 7

HEALTH, SAFETY AND ENVIRONMENTAL (HSE) RISK MANAGEMENT IN TEXTILE UNITS

7.1 Background Material

In preparing this chapter on 'Health, Safety and Environmental (HSE) Risk Management in Textile Units', the data and information presented in the following chapters have been used:

a) Chapter 4 Storage, Handling and usage practice in the study units.

In this chapter, the current practice of chlorination in the textile units have been reviewed and it is concluded that the safety related practice is far from satisfactory.

b) Chapter 5 Studies conducted on Effluent Treatment in selected Textile Industries.

In this chapter, comprehensive data related to treatment scheme, effect of treatment, air emission, effluent characteristics and sludge characteristics are presented.

c) Chapter 6 Health, Safety and Environmental Risk Assessment.

In this chapter, implications on health of the workers have been presented. In addition, the adverse effects on water environment and land environment have been analysed. Also, the risk to the community due to chlorine gas released is presented. This leads to the conclusion that chlorination practices are potentially hazardous from health and environment points of view.

In over all terms, there is a need to implement measures to improve the Health, Safety and Environmental aspects in the textile units, to the satisfactory level. This chapter outlines measures that are necessary and essential for this purpose.

7.2 Regulatory Requirement

The first and foremost requirement that the textile units are bound to meet is the stipulation provided in the Factories Act, 1948. In India, chlorine is deemed to be an explosive, when contained in any metal container in a compressed or liquefied state, within the meaning of The Indian Explosives Act, 1984. The filling, possession, transport and importation is governed by the Gas Cylinder Rules, 1940.

7.2.1 Factories Act, 1948

The following Sections of the Act are applicable to the textile units in general and the units practicing chlorination in particular.

i) **Section 2(cb) deals with** listing the industries involving hazardous processes, in which the first schedule (No.17) include processes involving chlorine use and explosives use in industries.

ii) **Section 7 deals with** a written notice to be given by the occupier to the Chief Inspector 15 days before he begins to occupy any premises as a factory with the details like name and address of occupier and factory, the number of workers likely to be employed in the factory, etc.

iii) **Section 7A deals with** general duties of the occupier, which state that the occupier should ensure the health, safety and welfare of all workers while they are at work in the factory. The occupier's duty include providing and maintaining safe systems of work in the factory, ensuring safety in connection with the use, handling, storage and transport of substances (eg. Chlorine), providing necessary information about instruction, training and supervision to ensure the health and safety of all workers at work, maintaining all places of work in the factory in a safe condition and monitoring such working environment in the factory. Every occupier should also prepare a written statement of his general policy with respect to the health and safety of the workers at work and should carry out the policy and should also revise the policy.

iv) **Section 11 (Chapter III – Health) deals with** the cleanliness practices that every factory should follow.

v) **Section 13 deals with** providing adequate ventilation and temperature by providing circulation of air, maintaining a comfortable room temperature in every work room by proper design of wall and roof materials and adoption of suitable other measures.

vi) **Section 17 deals with** providing and maintaining sufficient suitable lighting (natural or artificial or both), where workers are working.

vii) **Section 28 deals with** providing Hoist and lifts in the factory with good mechanical construction, sound material and adequate strength, and also it should include marking of safe working load.

viii) **Section 31 deals with** taking effective measures to ensure safety for any machinery or any part in a factory that is operated in a pressure above atmospheric pressure.

ix) **Section 35 deals with** providing suitable goggles for the protection of the eyes of the workers employed in the immediate vicinity of the process.

x) **Section 36 deals with** the precautions that should be taken for dangerous fumes, gas, etc. No person should be allowed to enter any confined space in a factory in which any gas, fume or vapour is likely to be present to such an extent posing risk to persons. The person should take all-practicable measures for entering into the confined space to remove any gas, fume or vapour so as to bring its level within the permissible limits.

xi) **Section 37 deals with** taking all-practicable measures to prevent any explosion in a factory that is containing explosive gas or vapour under pressure greater than atmospheric pressure. The vessel containing explosive substance should not be subjected to any welding, brazing, soldering or cutting operation which involves the application of heat.

xii) **Section 38 deals with** precaution to be taken in case of fire. The factory should provide safe means of escape for all persons in the event of fire and necessary equipment of extinguishing fire and workers should be trained with the means of escape in case of fire.

xiii) **Section 41 B deals with** compulsory disclosure of information by the occupier. All information regarding dangers, health hazards and the measures to overcome such hazards arising from the exposure or handling of the substances should be furnished. The occupier of the factory involving hazardous process should lay down the measures for handling, usage, transportation and storage of hazardous substances inside the factory premises and publicise them to the workers and the general public living in the vicinity.

xiv) **Section 41 C deals with** specific responsibility of the occupier in relation to hazardous processes. The occupier should maintain accurate and up-to-date health records who are exposed to toxic substances. The occupier should appoint persons who posses qualification and experience in handling hazardous substances. The occupier should also provide the medical examination for the worker before he is assigned to the job, while continuing in the job and after he is ceased to work in such job.

xv) **Section 41 F deals with** maximum permissible limits of exposure of toxic substances, the second schedule prescribes the permissible exposure for chlorine as 1 ppm (8 hrs. TWA) and 3 ppm (15 min. STEL).

xvi) **Section 41 G deals with** the workers participation in safety management.

xvii) **Section 41 H deals with** the right of workers to warn about imminent danger.

xviii) **Section 45 (Welfare) deals with** providing and maintaining first aid appliances that are readily accessible during all working hours. Nothing except the prescribed contents shall be kept in the first-aid cupboards.

7.2.2 Gas Cylinder Rules, 2004

The Ministry of Commerce and Industry (Department of Industrial Policy and Promotion) has published *the Gas Cylinder Rules, 2004* in supersession of '*Gas Cylinder Rules, 1981*'. Various rules for filling, possession, import and transport of gas cylinders, markings on cylinders and valves, labelling of cylinders, general precautions, handling and use, loading, unloading and transport of cylinders, storage of cylinders, examination and testing of cylinders, accidents and inquires, etc. are covered in nine chapters in an elaborate manner in the *Gas Cylinder Rules, 2004*. The following Sections of the Act are applicable to textile units practicing gas chlorination.

(i) **Section 3 deals with** filling, possession, import and transport of cylinders. No person should posses any cylinder with any compressed gas unless such cylinder and its valve have been constructed to a type and standard (tonne containers manufactured to BS:1500, IS:2825, Valves manufactured to IS:3224).

(ii) **Section 4 deals with** specifications that the valve fitted to gas cylinder should comply in all respects for industrial gas cylinders, IS:3224.

(iii) **Section 4 deals with** safety relief devices. The chlorine cylinders should not be provided with any safety relief device.

(iv) **Section 6 deals with** markings on cylinders. Every cylinder should be marked with manufacturer's marking and rotation number, cylinder specifications, date of last hydrostatic test, working pressure and test pressure, tare weight and water capacity.

(v) **Section 7 deals with** marking on valve, which include the specification of valve, the year and month of manufacture, manufacturer's symbol, the name or chemical symbol of the gas, Inspector's stamp, etc.

(vi) **Section 8 deals with** identification colours for industrial cylinder as per IS:4379.

(vii) **Section 9 deals with** labelling of cylinders with the name of the gas and the address of the person who filled the gas and attaching a warning.

(viii) **Section 11 deals with** no repairing of seamless gas cylinders under use.

(ix) **Section 12 deals with** no repairing of welded or brazed cylinders.

(x) **Section 13 deals with** prohibition of employment of children (age less than eighteen years) and intoxicated persons for loading, unloading or transport of any compressed gas cylinder.

(xi) **Section 15 deals with** general precautions of maintaining cylinders in good conditions. No oil or lubricant should be used for valve or other fittings of any cylinder. No cylinder shall be subjected to any heat treatment or exposed to a high temperature or to the sun or stored with any other flammable or explosive material. Valves fitted to chlorine shall be provided with securing nut on the outlet. If a leak in the valve cannot be rectified, the cylinder shall be removed to an open space where it is least dangerous to life and property.

(xii) **Section 16 deals with** special precautions to be taken to prevent fire and explosion in any place where gas under pressure in a cylinder is stored, handled or transported.

(xiii) **Section 17 deals with** deputing a competent and experienced person for filling, loading and unloading the cylinders.

(xiv) **Section 18 deals with** handling and using conveyors, trolleys and cradles for moving the cylinders. Cylinders shall not be allowed to fall upon one another. Sliding, dropping or playing with cylinders is prohibited. Cylinders used in horizontal position shall be secured that they cannot roll.

(xv) **Section 20 deals with** transport of cylinder as per provisions laid down in Schedule VI. Cylinder shall not be transported by a bicycle or any other two wheeler. Cylinder should not project in the horizontal plane beyond the sides or ends of the vehicle by which they are transported. There shall not be sharp projections on the inside of the vehicle. Compressed gas cylinders shall not be transported along with any other article of highly flammable or corrosive nature. No lifting magnet shall be used in loading or unloading of cylinders filled with any compressed gas. Proper cradle with chains or wire rope slings shall be used for cranes. No person shall transport any leaky cylinder. Any cylinder containing a flammable or toxic gas, which develops a leak during transport, shall promptly be removed to an isolated open place away from any source of ignition and the person responsible for transportation shall immediately contact the filler.

(xvi) **Section 21 deals with** storage of cylinders.

- → Cylinders shall be stored in a cool, dry, well ventilated place under cover, away from boilers, open flames, steam pipes or any potential sources of heat and such place of storage shall be easily accessible.
- → Toxic gas cylinder shall be separated from flammable gas cylinder.
- → Cylinders shall not be stored under conditions, which will cause them to corrode.
- → Cylinders shall not be stored along with any combustible material.
- → Empty cylinders shall be segregated from the filled ones and care shall be taken that all the valves are tightly shut.

(xvii) **Section 23 deals with** purity of gas. Compressed gases shall be free from impurities, which are like to corrode the metal.

(xviii) **Section 24 deals with** cylinders exposed to fire. Cylinders exposed to fire should not be used.

(xix) **Section 25 deals with** ownership of cylinder.

(xx) **Section 26 deals with** re-testing of cylinder.

(xxi) **Section 27 deals with** owner's record to be kept including cylinder manufacturer's name and the rotation number, the specification number, date of original hydrostatic test, cylinder manufacturer's test and inspection certificate, number and date of letter of approval granted by the Chief Controller.

7.3 Existing National Guidelines

The Bureau of Indian Standards has made comprehensive recommendations covering the safety and health aspects related to chlorination practice in textile industries. The relevant BIS are as follows:

(i) IS : 4263 - 1967

It is important that personnel engaged in a chlorine plant or any activity involving handling of chlorine should understand the hazardous properties of chlorine and should know about the safety and preventive measures. Thus the Indian Standards (IS) Institution had prescribed a code of safety concerning hazards related to chlorine in the code *IS: 4263-1967*. This code describes the properties of chlorine and essential information for the safe handling and use of chlorine which include general preventive measures, emergency measures, first aid and equipment cleaning and repairs guidelines. The modification of the text of this code was made by incorporating the Amendment No.1 (May 2002).

(ii) IS : 10553 (Part I) – 1983

Since chlorine cylinders and drums with liquid chlorine can rupture at temperatures of over 70°C due to building up of internal pressure, special precautions are required to be observed when working with chlorine gas apparatus and chlorine containers. Thus the Indian Standards Institution had approved the draft finalized by the Public Health Engineering Equipment Sectoral Committee regarding the General Guidelines for Chlorination Plants including Handling, Storage and Safety of chlorine cylinders and drums and published the code *IS: 10553 (Part 1)-1983*. The modification of the text was made by the incorporation of the Amendment No.1 (July 1988). This code covers the recommendations for installation of chlorination equipment and container room including handling, storage and safety of cylinders and drums.

(iii) IS : 8198 (Part 6) - 1988

In order to ensure safe handling of cylinders containing liquid chlorine gas, there are several precautions and safe practices which are to be observed by the manufacturers, fillers and users of gas cylinders. Thus the Indian Standard code of Practice for Steel Cylinders for Compressed Gases (Part 6 Liquefied chlorine Gas), *IS: 8198 (Part 6) – 1988* was published in the year 1988 and it was reaffirmed during 2002. This code covers the approved specifications and general guidance for manufacture of chlorine, inspection procedures during manufacture and use, disposal of condemned cylinders, fittings, fillings, marking and labelling, storage, handling, transportation, removing chlorine from cylinders, general precautions, chlorine leaks and records to be maintained at the filling station.

(iv) **IS : 4379 - 1981**

It has become customary to identify the contents of the gas cylinders by marking the cylinders with the name of the gas and chemical formula in addition to colour-marking of the cylinders. The code *IS: 4379-1981* (Reaffirmed 2002) covers the method of marking industrial gas cylinders for identification of the contents.

(v) **IS : 3224 - 2002**

The requirements/ specifications for design, materials, manufacture and testing of new valve fittings for use with refillable steel cylinders for compressed gases are covered in the code *IS: 3224 : 2002*.

7.4 International Organizations Recommendations

At the international level, several organizations have formulated guidelines for safe use of chlorine in industries. Prominent among them are: OSHA, USEPA, Chlorine Institute, US and Work Safe BC, British Columbia. Most of the international guidelines have also been covered under BIS guidelines.

7.5 Guidelines for HSE Risk Management

To minimize the health, safety and Environmental risk due to chlorine hazard, it is necessary for the textile units to follow well established rules/ guidelines made by Factories Act, Gas Cylinder Rules, BIS and various International agencies (OSHA, US EPA, Chlorine Institute and Work Safe BC, British Columbia, Oxychem Hand Book, etc.). As already stated, the BIS recommendations are comprehensive and are almost in line with the current developments at the international level. Using the BIS Guidelines, some selected international guidelines and the present study experience, a set of Guidelines have been prepared (Table 7.1). These guidelines are in simplified version and many provisions in the Factories Act/ Gas Cylinder Rules may also find a place in them. Codes have been used but the provisions in the BIS Codes have been rewritten to highlight the core points. Secondly, it was felt that addition of a few points to the BIS recommendation is necessary to make it more comprehensive. The additional points have been gathered from important international publications already cited. Thirdly, a few recommendations have been added based on the present study experience. In Table 7.1, the resulting guidelines are presented.

Table 7.1 Guidelines For Health, Safety and Environmental Risk Management in Textile Industry

Section 1 Guidelines for Chlorine Leaks and Fire Handling

Sl.. No.	Guidelines	Reference
1.1	**Chlorine Leaks Handling**	
1	Chlorine leaks should be investigated by authorized trained personnel equipped with suitable gas mask. All other persons should be kept away from affected area, until the cause of leak is corrected.	IS:4263 - 1967 IS:8198 (Part 6) 1988
2	Chlorine leaks shall be taken care of immediately.	
3	Corrective measures shall be undertaken by trained men only, wearing proper safety equipment.	
4	Leaky cylinders shall be moved quickly to safe open area.	
5	If the leak is large, all persons in that area shall be warned.	
6	If chlorine is leaking as liquid, cylinders shall be turned so that leaking side is on the top.	
7	Leaks around outlet of valve discharge shall be stopped by closing the valve or tightening the packing gland nut or replacing the gaskets.	
8	Leaks at fusible plugs, valve inlet and cylinder body usually require special handling and emergency equipment.	
9	A leaking cylinder shall not be transported.	
10	Suitable gas masks with eye shield shall be available within easy reach whenever cylinders and containers are handled.	
11	Chlorine is heavier than air, therefore persons shall be instructed to keep above and upwind of the leak.	
12	Water shall never be used on chlorine leak, as it always makes the leak works due to corrosive effect.	
13	A leaking container shall not be immersed into a body of water.	
14	For equipment and piping leaks, supply of chlorine shall be shut-off.	
15	All exhaust mechanisms shall be turned on immediately.	
16	Containers, Piping and Equipment should be checked for leaks daily.	
17	If a minor chlorine leak developing in a transit, in a populated area, excessive quantities of lime should be used. If the leak is extensive, transporting vehicle should move until open country is reached.	
18	A 1 to 4 minute rate of air change is required in an emergency.	Oxychem Hand Book

19	When inside a building, all windows, doors and other openings should be closed and air conditioners and air intake systems should be turned off.	Chlorine Institute, New Jersey Fact Sheet
20	Persons not wearing PPE from area of spill or leak should be evacuated.	
21	If a source of leak is cylinder and the leak cannot be stopped in place, the leaking cylinder should be moved to a safe place in the open air for repair or the cylinder should be allowed to become empty.	
22	For liquid spill, the area should be ventilated and should be washed with water.	
1.2	**Fire Handling**	
1	In case of fire, cylinders and drums containing chlorine shall be protected by spraying with water since the containers can burst at temperature of over 70°C.	IS: 10553 (Part I) 1983, Air gas-MSDS, Chlorine Institute
2	Incipient fire responders should wear eye protection. Structural fire fighters must wear self-contained breathing apparatus and full protective equipment.	
3	If fire is present, chlorine containers and equipment should be moved to safe locations.	

Section 2 Guidelines for First-aid Procedure

Sl. No.	Guidelines	Reference
1	Suitable notices shall be fixed in convenient places regarding first-aid measures.	IS 4263-1967
2	Any worker seriously exposed to chlorine gas shall be removed at once to uncontaminated area.	
3	If breathing has not ceased, patient shall be placed on his back, with head and back elevated and kept warm using blankets. Rest is essential.	
4	If breathing apparently has ceased, artificial respiration shall be started immediately.	
5	Milk may be given in mild cases as a relief from throat irritation.	
6	Nothing shall be given by mouth to an unconscious patient.	
7	If liquid chlorine has contaminated skin or clothing, emergency shower shall be used immediately. Skin areas shall be washed with large quantities of soap and water. No clothing shall be removed immediately.	
8	If eyes are affected, they shall be flushed immediately with running water for atleast 15 minutes.	
9	If a person has swallowed chlorine and is conscious, he shall be immediately made to drink copious amounts of lime water, milk of magnesia or fresh water.	
10	All employees shall be given comprehensive instructions on the use of first-aid equipment.	
11	Properly designed emergency showers and eyebaths shall be provided in convenient locations and they shall be maintained properly.	
12	First-aid boxes shall be marked with its name and provided in readily accessible positions.	
13	Do not apply oils, ointments or medications to the eyes.	Chlorine Safe Work Practices, Air Gas-MSDS, Chlorine Institute
14	Do not attempt to neutralist the chlorine with other chemicals.	
15	Rescuers should not attempt to retrieve victims of exposure to chlorine without adequate personal protective equipment.	
16	If chlorine contaminates the skin, immediately it should be washed be with running water for 15 min or longer.	
17	Victims should be taken for medical attention. They should take label and MSDS to physician or other health personnel with victims.	
18	Never give anything by mouth to an unconscious or convulsing person.	
19	If a person inhaled chlorine, the person should sit in an upright position with the head and truck elevated to a 40-60 degree position.	

20	An individual with a chlorine inhalation continues to be symptomatic after leaving the area of exposure, oxygen therapy is recommended.	
21	If chlorine contact with eyes, the eyelids should be held apart during this period to ensure contact of water with all accessible tissues of the eyes and lids.	
22	If individual is unconscious and vomiting, take steps necessary to protect the airway from obstruction.	

Section 3 Guidelines for Chlorine Containers

Sl. No.	Guidelines	Reference
3.1	**Inspection and Testing**	
1	External body should be sound and free from any defect such as dent, bulge, cut, gouge, corrosion, etc.	IS : 8198 (Part 6) 1988
2	Outlet threads of valves should be in good condition.	
3	Spindle should be sound and not broken.	
4	Gland washers shall be of good quality.	
5	Cylinders shall be tested periodically for hydrostatic retesting at the time of filling by the filler.	
6	Paint colour shall be maintained by periodically repainting them.	
3.2	**Fittings**	
1	Cylinder shall be fitted with a valve conforming to IS : 3224-2002.	IS: 8198 (Part 6) 1988
2	Valve shall be protected by a stout metal cap, securely attached to the body of the cylinder.	
3.3	**Marking and Labelling**	
1	Each cylinder shall have the following permanent markings on the valve end of the cylinder. → Serial No., identification and symbol of the manufacture → Number of the standard to which the cylinder conforms → Test pressure → Date of hydrostatic stretch test with code mark of the station → Water capacity in liters → Tare mass → Working pressure and → Chlorine symbol	IS: 8198 (Part 6) 1988 IS:4263 1967
2	The cylinder valves shall have the following markings → Number of the standard → Chlorine symbol → Test Pressure → Manufacturer's symbol and year of manufacture	

3	Each cylinder shall carry a label tacked to the cylinder, detailing the name of the filling station, name of the gas in capital and warning instruction stipulated by Gas Cylinder Rules. The warning instructions shall be written as follows. **Warning ! CHLORINE!** → Do not change the colour of this cylinder. → This cylinder may not be filled with any gas other than chlorine. → This cylinder should be kept cool. It should not be placed near a stove or any other source of heat, nor be exposed to the sun. → No oil or similar lubricant should be used on the valves or other fittings of this cylinder. → This cylinder should not be stored with any inflammable or explosive material.	
4	The containers should be labelled as - danger; poisonous, corrosive liquid and gas under pressure, can cause eye skin and respiratory tract burns, can support combustion.	Air Gas-MSDS
3.4	**Connections and Valves for removing Chlorine from Cylinders**	
1	Connections shall be made with yoke and adopter.	IS:8198
2	A shut-off valve suitable for liquid Cl_2 service shall be provided at the beginning of stationary piping to simplify the changing of containers.	(Part 6) 1988
3	To unseat valve, end of wrench shall be struck with the help of hand and then opened slowly.	IS:4263-1967
4	If the valve is too tight to open, the packing gland nut shall be slightly opened to free the stem.	
5	Large wrenches shall not be used on valve opening.	
6	Tonne containers are equipped with 2 valves each with an internal eduction pipe. A removal hood is provided to protect the valves from injury.	
7	A flexible connection between the container and the piping should be used. (Annealed copper tubing (9.5 mm outside diameter) suitable for 35.2 kg/cm^2).	
8	A new gasket (lead) should be used when making connection.	
3.5	**Discharge and Gas Flow**	
1	Tonne containers shall be unloaded from a horizontal position, one valve above the other. The upper valve discharges chlorine gas, and the lower liquid chlorine.	IS:4263-1967
2	Cylinders discharge gas when upright, and liquid when inverted.	IS:8198
3	A vacuum break loop or device shall be employed whenever chlorine from cylinders or containers is absorbed in a liquid.	(Part 6) 1988

4	When chlorine is being absorbed in a liquid, there is sometimes a tendency for the liquid to be sucked back into the container as it becomes empty. This may result in serious accidents.	
5	When high rate of gas flow is required, chlorine should be withdrawn as a liquid and converted to gas by means of vaporizer.	
6	Tonne container should be placed in a cradle or carefully blocked during discharge.	

Section 4 Guidelines for Chlorination Plants

Sl. No.	Guidelines	Reference
4.1	**Installation of Chlorination Equipment and Container Room**	
1	Chlorinator and cylinders shall be housed in separate rooms, easily accessible, close to the point of application and convenient for truck loading and safe container handling.	IS:10553 (Part I) 1983
2	The floor shall be flat and atleast 150 mm above the surrounding ground and drainage shall be adequate.	
3	Height of container room shall be atleast 4 m.	
4	Under no circumstances, chlorine gas units shall be housed in basement or below ground level, since chlorine gas is heavy and settles into depressions.	
5	The exits shall lead directly out in the open and doors shall open outward.	
6	There shall be adequate air circulation and cross ventilation in the rooms.	
7	Air entry shall be from above and air exit shall be from below. Exhaust fans shall be provided at floor level.	
8	The blade and motor of exhaust fan shall resist corrosion by chlorine.	
9	Natural ventilation that allows an air change of 10 min is desirable.	
10	Separate and reasonably gas tight enclosures openings to the outdoor shall be provided for housing chlorine-feeding equipment in large installations.	
11	Containers shall rest securely on cradles or on a level rack equipped with adequate safety block to prevent rolling and be slightly elevated from the floor to keep them dry.	
12	Temperature in the installation room shall be within the range of +4 to +40°C.	
13	Chlorine gas cylinders shall not be exposed to direct heat radiations and shall be protected from sun rays.	
14	Electrical installations inside the chlorine gas room shall be limited.	
15	The following information shall be indicated predominantly on the outside entry door. → Chlorine gas dosing apparatus room. → Smoking and handling naked flame prohibited. → Admission restricted.	
16	When chlorine is being absorbed in a liquid to prevent suckback of the liquid into the container, a barometric leg or vacuum breaking device or both should be used.	
17	Atleast two exits should be provided in each rooms	

18	Electrical equipment should be non-sparkling or explosion proof.	Air gas-MSDS, Chlorine Safe Work Practices
19	Storage rooms with floor areas larger than 19 m^2 must have two or more exit doors.	
20	Doors should not be self-locking.	
21	If possible, chlorine containers should be housed in a room separate from the area where chlorination equipment is located.	
22	Each room housing chlorine container or equipment should have a viewing window atleast 30 cm square or larger.	
4.2	**Equipment Cleaning and Repairs**	
1	Equipment and tank cleaning and repairs shall be under the direction of thoroughly trained personnel.	IS:4263 - 1967
2	Workmen shall not attempt to repair chlorine equipment while it is in operation.	
3	Welding, cutting or other work using flame or spark shall not be attempted on chlorine lines or containers until purged with steam and then hot-air-dried.	
4	Immediate drying of a chlorine pipeline or container into which water has been introduced is essential to prevent corrosion.	
5	Workers entering tanks shall be equipped with suitable Personal Protective Equipment. At least one other person shall be observing operations from outside the tanks at all times.	
6	Under no circumstances shall a rescuer enter a tank to remove a victim of overexposure without proper respiratory protection. Another attendant shall be available at all times and the rescuer shall be in view of the outside attendant at all times.	
7	Iron and steel will ignite in chlorine at about 230° C, all welding or burning must only be done after the chlorine equipment is completely emptied and purged with dry air or nitrogen.	Chlorine Safe Work Practices

Section 5 Guidelines for Storage Practices

Sl. No.	Guidelines	Reference
1	Cylinders shall be stored in a dry ventilated place away from heat or danger of fire.	IS:4263-1967
2	Chlorine storage room shall be fireproof.	IS : 8198 (Part 6) 1988
3	Cylinders shall be stored in such a manner so that the oldest stock can be used first.	
4	Full and empty cylinders shall be separated.	
5	Valve protection hoods (stout metal cap) shall be kept always in place, except when cylinder is under use.	
6	Cylinders shall be stored in an upright position. Tonners shall be stored on their sides.	
7	Storage area shall be away from elevators, gangways or ventilating systems.	
8	Storage area shall not contain other compressed gas containers, turpentine, ether, anhydrous ammonia, finely divided metals or other inflammable materials.	
9	All plants shall keep on hand at all times sufficient supply of chlorine cylinders.	
10	Unobstructed access from two opposite entrances should be provided in a chlorine storage area.	
11	Chlorine cylinder temperature should not exceed 125° F (52° C).	New Jersey Fact Sheet, Chlorine Safe Work Practices
12	Do not store chlorine near busy roadways or anywhere else, where vehicles operate. Chlorine reacts with carbon monoxide to produce phosgene, an extremely poisonous gas.	
13	A suitable fan, atleast 15 air changes per hour must ventilate the chlorine storage room.	
14	All ventilating fans must include switches outside the chlorine room.	

Section 6 Guidelines for Handling Practices

Sl. No.	Guidelines	Reference
1	Cylinders shall not be dropped or struck against each violently.	IS : 10553 (Part I) 1983
2	Cylinders shall be moved on properly balanced hand trucks, with a chain or clamp support.	
3	Hoisting of cylinders shall be avoided.	IS:8198 (Part 6) 1988
4	A lifting clamp cradle or carrier shall always be used.	
5	Traveling overhead hoists shall be used to move tonne containers to storage or point of use.	
6	For lifting tonne containers, stationary or movable jib cranes or traveling overhead rail hoists of two tonnes capacity (minimum) and capable of clearing the load atleast two metres above the track rail are suitable.	IS 4263 - 1967
7	Valves shall be opened counter clockwise with a 9.5 mm square-box wrench not over 152 mm long.	
8	Valves on chlorine cylinders should be closed when chlorine is not being withdrawn.	Oxychem Hand Book, Air gas – MSDS
9	To monitor consumption of chlorine at any time, the cylinder should be placed on a scale.	
10	After handling chlorine, hands should be washed thoroughly.	
11	While chlorine handling, eating or drinking should not be done.	

Section 7 Guidelines for General Preventive Measures

Sl. No.	Guidelines	Reference
7.1	**General Preventive Measures**	
1	Layout of area shall be designed with due consideration for adequate natural or mechanical ventilation	IS:4263 - 1967
2	All equipment shall be kept in proper working condition by preventive maintenance.	
3	Heat shall not be applied directly to the cylinder for any reason.	
4	Cylinders shall be handled by properly instructed and trained persons.	
5	Cylinders with defects shall be immediately labeled appropriately and returned to the supplier.	
6	Marking and identification colour of a cylinder shall never be defaced.	
7	If any damage occurs to the cylinder, supplier shall be immediately informed immediately.	
8	When there is a doubt in proper handling of the cylinder, the manufacturer or supplier of the cylinder shall be consulted.	
9	The cylinder shall not be filled with any other gas.	
10	Adequate and suitable Personal Protective Equipment shall be made available at all times.	
11	Chlorine monitoring equipment which continuously samples the air and detects the presence of chlorine should be considered in any storage or operating area where chlorine is released	Chlorine Institute, Oxychem Hand Book, Air gas-MSDS
12	Goggles or rubber gloves, rubber shoes, hat and approved respirator should be used where chlorine concentration exceeds exposure limits.	
13	Only compatible materials should be used for cylinders, process lines, and other chlorine handling equipment. Chrome and aluminium are not suitable materials for use with chlorine.	
14	Empty cylinders should be marked as 'Empty'.	
15	For plant operators, long pants, shirts with sleeves, safety glasses with side shields or goggles approved for use with hazardous chemicals, hard hats and safety shoes should be worn.	
7.2	**Employee Selection and Training**	
1	People suffering from asthma, bronchitis shall not be employed.	IS:4263 - 1967
2	Chest X-ray shall be recommended for all new entrants.	
3	Training classes for both new and old employees shall be conducted periodically to keep them conscious of the hazards and safety measures.	
4	There shall be periodic drill and instructions regarding location, purpose and use of Personal Protective Equipment (PPE), safety showers, eye fountains, first aid kits, etc.	

5	All workers shall be trained to adopt preventive measures (such as fire alarms, shut-down procedures for valves and switches, fire-fighting equipment, use of PPE, first-aid, etc.) in case of emergency.	
7.3	**Eye Protection**	
1	Eye protection devices should always be worn.	IS:4263 – 1967,
2	Workers in an area that contains greater than 0.5 ppm chlorine, must wear eye protection with a tight seal around the eyes or face to prevent chlorine gas entering the eyes.	Chlorine Safe Work Practices
7.4	**Respiratory Protection**	
1	A suitable gas mask shall be available to every employee involved with chlorine handling.	I S:4263 – 1967
2	A respiratory protective equipment shall be carefully maintained and kept in clean, dry, light-proof cabinets properly protected by polyethylene bags.	
3	Equipment used by more than one person shall be sterilized after each use.	
4	No person shall enter chlorine-contaminated area without a respirator.	
5	Respiratory protective devices shall have molded flexible face pieces with transparent windows.	
6	Self-contained breathing apparatus equipped with a cylinder of air or oxygen carried on the body shall be suitable for high concentrations of chlorine in an oxygen deficient atmosphere.	
7	Industrial canister type mask is suitable for moderate concentration of chlorine.	
8	Positive pressure hose mask (blower) is suitable for high concentration of chlorine.	
9	Full-face piece respirators are appropriate for leak control for less than 10 ppm chlorine concentration.	Chlorine Safe Work Practices,
10	Half-face piece respirator with vapour-tight chemical goggles could be used for a small leak below 5 ppm chlorine concentration.	New Jersey Fact Sheet
11	If concentration exceeds 10 ppm, approved self contained breathing apparatus with a full-face piece operated in positive mode should be used.	
12	Escape respirator may only be used for immediate evacuation of the contaminated atmosphere.	

7.5	**Safety Measures**	
1	All operating and storage rooms for chlorine gas appliances and containers shall be fire-proof.	IS: 10553 (Part I) 1983
2	Chlorine storage rooms shall be provided with chlorine gas alarm device which gives out an acoustic or an optical signal when chlorine concentration is reached the set value of 1 mg/m^3 of air in case of a person working in the room and 20 mg/m^3 of air when no human being is inside the room.	
3	The sensor for alarm device shall be placed not higher than 300 mm above the floor of the room.	
4	A bottle of ammonia is essential to detect leaks, etc. in case alarm is not provided.	
5	Cylinder shall be tested at every shift period for leaks by passing over each cylinder and around each valve and pipe connections, a rod with a small cotton-wool swab tied on the end, dipped in an aqueous solution.	
6	In tracing a leak, always start from the cylinder and work down along the line of flow until the leak is found.	
7	At every shift period, chlorine leak shall also be tested by trying to detect the sharp irritating smell of chlorine.	
8	Safety equipment like gas masks, rubber gloves, aprons shall be housed in easily accessible (unlocked) cupboards placed outside the chlorination room.	
9	First-aid box and eye wash fountain shall be provided outside chlorinator room.	
10	Solvents (eg. Petroleum, hydrocarbons, alcohols) shall not be used for clearing parts which come in contact with chlorine.	
11	Safe solvents are chloroform or carbon tetrachloride.	
12	Grease shall never be used where it comes in contact with chlorine	
13	No direct flame shall be applied to chlorine cylinders when heating becomes necessary.	
14	Regular rehearsals including entire testing procedures and wearing of the equipment should be conducted.	
15	Employee should be familiar with MSDS sheet.	Oxychem Hand Book,
16	Emergency response workers who are controlling a serious chlorine leak must have access to full-body protective suits.	Chlorine Safe Work Practices

Section 8 Guidelines for Pollution Control Measures

Sl. No.	Guidelines	Reference
1	Select closed type chlorine reaction tanks instead of open tanks.	Present Study
2	Adopt proper reactor designs for dechlorination/ aeration units to minimize the emission of chlorine gas into the atmosphere.	
3	Optimize the process control parameters for minimizing the emission of chlorine gas into the atmosphere.	
4	Control pH correction before dechlorination in order to minimize chlorine emission into the atmosphere.	
5	Ensure proper management of AOX containing sludge to avoid water and soil pollution.	

CHAPTER 8

COLOUR REMOVAL TECHNOLOGIES IN TEXTILE DYEING INDUSTRIES

8.1 Colour Removal Technologies

Textile Wet Processing industries employ several treatment technologies for colour removal in the textile effluent. Broadly the treatment technologies for colour removal fall under two categories namely viz., Separation technologies and Degradation technologies. The Separation technologies include the following.

1. Chemical precipitation using chemical coagulants (eg. Lime, Alum, Ferrous Sulphate, Ferric chloride, mixture of coagulants, polyelectrolytes.
2. Adsorption (Activated Carbon)
3. Ion exchange resins
4. Membrane separation processes (Ultra filtration, Nano filtration, Reverse Osmosis etc.)

The Degradation technologies can be classified into Biological Oxidation Technologies and Chemical Oxidation Technologies. The following biological treatment systems could be employed.

1. Activated Sludge Process (Conventional)
2. Activated Sludge Process (Extended aeration)
3. Anaerobic Process (UASB)
4. Anaerobic Fixed Film Fixed Bed Reactors (AFFFBR)
5. Membrane Bio-reactors

The Chemical Oxidation Technologies could employ either conventional chemical oxidants (eg. chlorine) or advanced oxidation processes, which generate powerful hydroxyl radicals having oxidation potential several times higher than oxidation potentials of conventional chemical oxidants. The advanced oxidation technologies include the following processes.

1. UV Photolysis, UV/ H_2O_2
2. Ozone, Ozone/ UV, Ozone/ H_2O_2
3. Fenton and Photo Fenton (UV/ Solar)
4. Photocatalysis (UV/ Solar)
5. UV/ Ozone/ TiO_2

A comprehensive review of various colour removal technologies adopted by the textile units in Tamil Nadu (including CETPs implementing ZLD facilities) was carried out. In addition, the published research literatures on performance of numerous treatability studies of various colour removal technologies have been reviewed. The salient features of the literature review and the present study results are presented in this chapter.

8.2 Technologies used in Tamil Nadu

8.2.1 Chemical Precipitation combined with other Physical/Biological Processes

Most of the textile units in Tamil Nadu employ either chemical precipitation or combination of chemical precipitation with other physical/biological processes as the conventional treatment scheme for colour removal. Various types of chemical coagulants (viz., lime, alum, ferrous sulphate, ferric chloride, mixed coagulants) with and without the addition of polyelectrolyte have been used. The combination of chemical precipitation and the polishing sand/carbon filtration processes was reported to be satisfactory in removing colour (max. 99%) and one of the CETPs implementing ZLD facility in Tirupur has adopted this scheme. The chemical precipitation results in generation of large quantities of chemical sludge which is classified as hazardous waste. Chemical precipitation combined with aerobic biological treatment (extended aeration) with the sand/carbon filtration as polishing treatment was also found to be effective in removal of colour (max. 99%), but results in generation of chemical sludge and biological sludge. The combination of chemical treatment (DAF) and the membrane separation processes (micro filtration/nano filtration) was reported to remove colour completely by one of the CETPs implementing ZLD facility in Tirupur. The environmental implications of this technology include not only management of chemical sludge but also the concentrated rejects and the spent membranes from the membrane separation processes.

8.2.2 Biological Treatment combined with other Physical/Biological Processes

The biological treatment (either aerobic or anaerobic alone) was found to be not sufficiently able to remove colour (max 78%). However aerobic biological treatment (ie., extended aeration) followed by resin filtration was reported to be effective in removal of colour (max 99%) and about 10 CETPs are implementing this scheme in their ZLD facilities in Tirupur for treating effluent flow in the range of 3000-11,000m^3/day. The management of biological sludge as well as regenerated spent wash from the resins has become the environmental issues of this technology.

The combination of aerobic biological treatment (membrane bioreactor) and the activated carbon adsorption was reported to produce colourless effluent by a CETP implementing this technology in Tirupur for its ZLD facility and the environmental implication of this technology include generation of biological sludge, spent carbon and spent membranes.

The two-stage anaerobic (UASB) and aerobic (ASP) biological treatment processes was reported to remove colour greater than 90%. However the combination of two-stage anaerobic (AFFFBR) and aerobic (extended aeration) biological treatment processes with polishing sand/carbon filtration processes was found to remove 99% colour. The environmental issues of this technology include management of biological sludge and the spent carbon for disposal.

8.3 Technologies at Research Level (Advanced Oxidation Technologies)

Numerous research works conducted on Treatability studies of simulated textile dyeing wastewaters by various advanced oxidation processes (eg. UV/ Ozone, UV/ Ozone/ TiO_2, UV photofenton, Nano TiO_2) were reported to remove colour satisfactorily. For biologically pretreated textile effluent, the colour removal efficiency was found to be 95% by ozone and 98% by UV/ H_2O_2 processes. However the performance of these techniques need to be demonstrated at the industry scale-level.

8.4 Colour Removal in Study Units using Chlorination

8.4.1 Standards for Discharge of Industrial Effluents

The Bureau of Indian Standards (BIS) has laid down the first set of standards or tolerance limits for discharge of industrial effluents into Inland Surface Waters (IS: 2490 – 1974). These standards were referred as 'Effluent Standards' and they have been notified by GOI under The Environment (Protection) Rules, 1986 (Schedule VI, Rule 3-A). In addition to effluent standards, Minimal National Standards (MINAS) were incorporated in the Environment (Protection) Act, 1986. These standards were considered to be minimum standards for major polluting parameters that specific industry should achieve. The MINAS for textile processing industry specified standards for parameters such as pH and BOD, whereas standards were not specified for colour, SS, TDS, COD, Total Residual Chlorine and AOX.

The Water (Prevention and Control of Pollution) Act, 1974 (Section 17, Clause 3 of Subsection 1) empowers the Tamil Nadu Pollution Control Board (TNPCB) to lay down the effluent standards. Accordingly, TNPCB fixed up effluent standards for discharge of trade/ sewage effluents (Revised order B.P. Ms. No. 30 dt. 21.12.1984) for 35 parameters. However standards for colour and AOX were not specified. The National Standards for discharge of Industrial Effluents for relevant parameters applicable to this study are presented in Table 8.1. The International Organizations prescribed standards for the discharge of colour and AOX containing effluent. The standards for colour prescribed by US EPA (US EPA 110.1), ISO (ISO 7887) and European Standards (DIN EN ISO 7887) are presented in Table 8.2. The colour of textile effluents is characterized by spectral absorption coefficient at three wavelengths (436 nm, 525 nm and 620 nm). The standards prescribed for colour ie., 436 nm, 525 nm and 620 nm are 7 (m^{-1}), 5 (m^{-1}) and 3 (m^{-1}) respectively. The United Nations Industrial Development Organization (US/RAS/92/120) presented AOX limits for discharge of chlorinated effluent into water bodies and it is presented in Table 8.3. The AOX limits for various countries vary in the range of 0.05 mg/L to 5 mg/L. Germany has prescribed the limit for AOX as 0.5 mg/L, whereas France has prescribed the limit for AOX as 5 mg/L.

Table 8.1 Select National Standards for discharge of Industrial Effluents

Sl. No	Parameter	Tolerance Limits for discharge of Trade Effluents into Inland surface waters (TNPCB)	General Effluent Standards for discharge into Inland Surface Water (Environment (Protection) Rules, 1986)	MINAS Standards for Textile Processing Industry
1	pH	5.5-9.0	5.5-9.0	5.5-9.0
2	Suspended Solids (mg/L)	100	100	Not Available
3	Total Dissolved Solids (mg/L)	2100	Not Available	Not Available
4	Total Residual Chlorine (mg/L)	1.0	1.0	Not Available
5	BOD (mg/L)	30 (3 day, 27° C)	30 (3 day, 27° C)	30
6	COD (mg/L)	250	250	Not Available
7	Chlorides (mg/L)	1000	Not Available	Not Available
8	Colour	Not Available	All efforts should be made to remove colour as far as possible	Not Available

Table 8.2 International Effluent Standards for Colour

Sl. No.	Parameter		European and National Standards (DIN EN ISO 7887)	US EPA and Standard Methods (US EPA 110.1)	ISO (ISO 7887)
1	Colour (m^{-1})	436 nm	7	7	7
		525 nm	5	5	5
		620 nm	3	3	3

Table 8.3 AOX Limits for Discharge of Effluents into Surface Water Bodies

Sl. No.	Countries	AOX Limits (mg/L)
1	Argentina	1
2	Austria	0.5
3	France	5
4	Finland	1
5	Germany	0.5
6	Greece	1
7	Ireland	0.05
8	Italy	1
9	Paris	1
10	Switzerland	0.1
11	Zambia	0.5

Source: UNIDO US/RAS/92/120, OSPAR 97/15/1, Annex 12

8.4.2 Colour in Raw Effluent

A comparison of raw effluent characteristics for the 10 Study Units is presented in Table 8.4. The effluents were generally alkaline in nature with pH in the range of 7–9.6, due to addition of salt in the dyeing process. The effluents were either lightly or strongly coloured with colour measurement at three wavelengths (436 nm, 525 nm and 620 nm) in the range of 11.3-133.5 m^{-1} (436 nm), 7.4-45.4 m^{-1} (525nm), 3.4-67.7 m^{-1} (620 nm). BOD and COD were found to vary in the range of 115-486 mg/L and 265-1119 mg/L respectively. The residual chlorine was found to be nil in the raw effluent and the chloride was found to be in the range of 1419-14,739 mg/L. The TDS and TSS were found to be in the range of 4108-9950 mg/L and 120-787 mg/L respectively. High TDS was due to use of salt in the dyeing process. The wide variation in the characteristics of raw effluent might be due to differences in dyeing technology, machinery used, type and quality of dyes and other chemicals used and the dyeing shades of the fabric.

8.4.3 Chemistry of Chlorination for Colour Removal

The chlorine gas dissolved in the effluent will be present in the speciated form and the relevant chlorine species will be hypochlorous acid (HOCl) and hypochlorite anion (OCl^-) as shown in equations 1 and 2. Depending upon the pH of the effluent, the hypochlorous acid and hypochlorite anion formed will react with dyes and will be converted to chloride as shown in equation 3. Also this process may give chlorinated intermediates as disintegrated by-products ie., AOX and unutilized chlorine as residual chlorine.

$$Cl_2 + H_2O \rightarrow HOCl + HCl \quad (1)$$

$$HOCl \rightarrow OCl^- + H^+ \quad (2)$$

$$Dye + HOCl \rightarrow [Degraded\ products] \rightarrow CO_2 + H_2O + Cl^- \quad (3)$$

The Mass Balance for chlorine (per Litre) used in the treatment of textile wastewater for a typical study unit ie. SU-5 is shown in Figure 8.1.

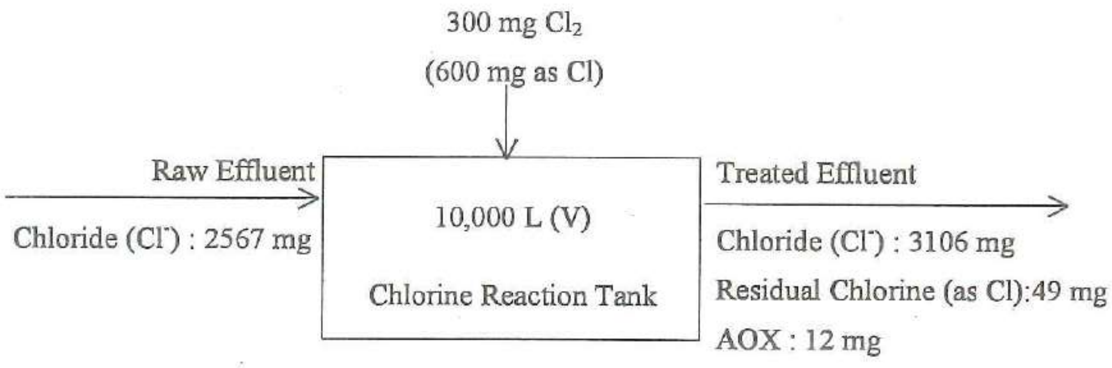


Figure 8.1 Mass Balance for Chlorine (per Litre) (SU 5)

Input	=	2567 (Cl^-) + 600 (as Cl)
	=	3167 mg (as Cl)
Output	=	3106 (Cl^-) + 49 (as Cl) + 12
	=	3167 mg (as Cl)

Mass Balance Calculations (Typical) for Chlorine Reaction Tank

1) Chlorine Dose	=	3 kg/hr for 60 min. duration
	=	3×10^6 mg
2) Volume of Reactor	=	10,000 L
3) Concentration of Chlorine added	=	$\frac{3 \times 10^6}{10,000}$ mg /L = 300 mg/L
4) Concentration of Chlorine added (as Cl)	=	2 x 300 = 600 mg /L
5) Chlorine Concentration in the influent (as Cl^-)	=	2567 mg/L
6) Total (Input)	=	2567 + 600 = 3167 mg/L
7) Chlorine in the outlet of Chlorination Unit (as Cl^-)	=	3106 mg/L
8) AOX in the outlet of Chlorination Unit	=	12 mg/L
9) Residual Chlorine in the outlet of Chlorination Unit (as Cl^-)	=	49 mg/L
9) Total (Output)	=	3106 + 12 + 49 = 3167 mg/L

10) For Perfect Mass Balance,

(6) should be equal to (9) (ie. Input = Output)

8.4.4 Colour Removal Efficiency

All the ten study units (SU 1 – SU 10) have adopted gas chlorination as primary treatment technology for colour removal of textile effluent. Chlorination was carried out as batch process in chlorine reactors which are of open tank types (ie., equalization tank/ clarifier) or closed tank type (ie., syntax tanks). Out of 10 study units, only 3 units (2 large-scale and one medium scale) have provided open tank types, and 6 more units (3 medium scale and 3 small scale) have used syntex tanks as chlorine reactors. The remaining one unit ie., CETP has installed the HDPE piping system (known as OR Reactor) as chlorine reactor.

Since the colour intensity of the raw effluent was widely varying, the textile units have varied the chlorine dose and contact time of chlorination for decolourisation of the textile effluent. The chlorine dose was found to vary in the range of 60-300 mg/L during the field studies in the study units. Most of the study units have provided the contact time of 30-60 min. Whereas only two units (ie., SU 7 and SU 3) have extended the contact time upto 4 h and 12h respectively. Chlorination was followed by dechlorination using SMBS for removing free residual chlorine.

At the end of chlorination/ dechlorination, the colour removal efficiency was found to be in the range of 31-98% in the study units. Out of 10 units, 7 units were found to meet the

International Effluent Standards for colour and the remaining 3 units were not able to meet the International Standards. The wide variation in colour removal efficiency might be due to the differences in the process control parameters of chlorination treatment system and the variation of the types and concentration of dyes in the raw effluent and also the dyeing technology.

8.4.5 Organics and Solids Removal Efficiency

Even though, gas chlorination was effective in the decolourisation of textile effluent, organics removal was not effective. The COD/BOD reduction was found to be only 18-62% at the end of chlorination/ dechlorination. The higher colour removal efficiency might be mainly due to the rupture of chromopheric group in the dye and not due to the oxidation of organics. The BOD/ COD concentration in the treated effluent at the end of chlorination/ dechlorination was found to exceed the TNPCB tolerance limits for discharge of trade effluents into inland surface water. The units SU 1, SU 3 and SU 7 have provided biological treatment process resulting in overall reduction of organics in the range of 74-92%. At the end of chlorination/ dechlorination, the suspended solids removal was found to be in the range of 2-34%. It was found to exceed the TNPCB tolerance limits for discharge of effluents into inland surface water.

8.4.6 Adsorbable Organic Halogens (AOX)

Treatment of textile wastewater by chlorination can be problematic in some circumstances such as the wastewater containing organics. Chlorine can react with organic compounds found in the effluent to produce dangerous chlorinated compounds. The amount of AOX formed may vary depending on the type of dyes and other organics and the chlorine dosages applied. During the end of chlorination/dechlorination, it was found to be generated in the range 2 to 40 mg/L. The AOX formed is retained in the RO reject and finally gets concentrated in the sludge of solar evaporation, which is temporarily stored in the premises of the industrial units. The sludge samples analysed for AOX also confirmed this (163-238 mg/Kg). Generally, AOX values are more in the treated effluent and exceed the standards prescribed by UNIDO.

8.5 Comparison of Technologies

For a comparison of the different technologies for Colour Removal, the following technologies were used:

1) Chlorination Based (Different additional processes)	=	13 units (Sl.Nos. 1 to 7, Table 8.1)
2) Chemical Precipitation Based (Different additional processes)	=	15 units/ Research Studies (Sl.Nos. 8 to 16)
3) Biological Process Based (Different additional processes)	=	16 units/ Research Studies (Sl.Nos. 17 to 28)
4) Advanced Oxidation Technologies	=	12 Research Studies (Sl.Nos. 29 to 31)
5) Electro Chemical Process	=	1 Research Study (Sl.No. 32)
Total		57

Thus, data related to efficiency of colour removal for 57 technologies were used. For comparison purpose, the following criteria were used and the relevant data for each criteria for each technology was collected to the extent possible.

Criteria used for comparison:

1. Colour removal efficiency
2. Nature and amount of Chemicals required
3. Supplementary processes required
4. Environmental implication
5. Cost of treatment.

In Table 8.5, the data related to the 57 units are presented. A critical analysis of the data presented in Table 8.5 will lead to several important inferences:

a) Regarding chlorination practice in Karur/ Tirupur/ Erode

1) The study units in Karur/ Tirupur/ Erode using chlorination could achieve colour removal in the range of 31-98% using chlorination. Out of 10 units, only 7 units could remove colour to meet the International Standards and the remaining 3 units could not meet the standards. It shows that chlorination technology as being practiced in Karur/ Tirupur/ Erode does not guarantee colour removal to meet the International Standards.

2) The chlorination practice results in sludge production which is very small and sludge management is relatively much easier because of the small quantity.

3) The chlorination practice raises important environment related issues:

(i) Air surrounding the chlorine reactors gets contaminated with chlorine gas; in 40% of the units, the contamination is beyond permissible levels. This has a serious health implication for the operators/ workers of the industry.

(ii) The treated effluent and sludge contain AOX in excessive concentrations.

4) Cost of effluent treatment is the lowest in the case of the chlorination practice.

b) Other technologies

Among the other technologies, the biological treatment based technologies (with additional processes) are noteworthy.

1) The biological treatment based technologies do not require any chemical but require electrical energy in the case of aerobic units.

2) They produce sludge but the amount of sludge will be more than that of chlorine based technologies but less than that of physico-chemical technologies. It does not introduce a new chemical in the sludge unlike in the case of chlorine based technologies which generate AOX. Similar is the status of the effluent in which no new chemical is introduced.

3) Regarding colour removal, the efficiency of this technology is comparable to any other technology including the chlorine based technologies.

4) Regarding cost of treatment, precise figures are not available. But when compared to chlorine based technologies, the cost could be about 5 times higher.

5) The physico-chemical based technologies produce large amount of sludge and involves use of chemicals and hence not favoured by many people.

(c) Summary

Since the textile effluent is complex and variable, it is unlikely that a single treatment technology will be suitable for effective colour removal. The comprehensive literature review revealed that appropriate combinations of the physical, chemical and biological treatment processes are effective in removal of colour. The selection of the most appropriate treatment method is influenced by a number of factors related to each effluent characteristic, relative cost, degree of treatment required, process efficiency and its reliability and the environmental implications and health and safety aspects of the treatment processes. Based on the understanding of the State-of Art of the 'best practicable control technology currently available', it is concluded that the combination of biological treatment based technologies with suitable supplementary processes might be considered as an appropriate treatment method for removal of colour. This conclusion is made since it offers the following specific advantages over the chlorination based technologies:

(1) It avoids air pollution and hence is not a health hazard for the workers.

(2) It avoids safety related risks for the workers.

(3) Risk in community health is avoided.

(4) There is no danger of introducing new chemical in water and soil environment.

At the same time, it is also to be noted that biological treatment based technologies offer the following disadvantages:

(1) Sludge management more tedious because of the larger volume.

(2) Cost of treatment is significantly higher.

Over all, the biological treatment based technologies are more environmental friendly, offer comparable efficiency, are free from public health problems; and hence, they are recommended even though the cost of treatment is higher.

Table 8.4 Characteristics of Raw Effluent

Sl. No.	Parameter		SU1	SU2	SU3	SU4	SU5	SU6	SU7	SU8	SU9	SU10	Threshold
1	PH		9.2	7.3	8.5	7.1	7.3	7.6	7	7.3	9.6	7.4	5.5-9.0
2	Colour	436 nm	38.5	20.1	33.7	13.1	22.7	14.6	34.8	13.4	133.5	11.3	7 m^{-1}
		525 nm	30.4	12.0	24.3	7.4	18.8	18.9	16.9	13.2	45.4	8.6	5 m^{-1}
		620 nm	67.7	11.2	23.2	5.3	11.0	3.4	12.1	14.3	36.1	7.3	3 m^{-1}
3	Organics	BOD	420	115	250	236	486	120	420	132	260	380	30 mg/L
		COD	1119	452	786	588	840	265	840	415	440	644	250 mg/L
4	Solids	TSS	786	560	787	536	692	134	345	356	120	480	100 mg/L
		TDS	9950	8624	6977	7020	4108	5980	7850	6616	29,948	5624	2100 mg/L
5	Residual Chlorine		Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1 mg/L
6	Chloride		3722	3546	2469	2613	2567	2799	3396	1419	14739	2995	1000 mg/L

Table No. 8.5 Colour Removal Technologies – A Comparison

Sl. No.	Technologies		Colour Removal Efficiency (%)	Chemicals Required	Supplementary Process Required (if any)	Environmental Implications		Cost (per m³)
1	Chlorination	SU 1	77 – 91	Chlorine (198 ppm), SMBS	Dechlorination / Settling Tank	Chlorine Air Emission	4 ppm	Rs.2-3
						AOX in Effluent	19 mg/L	
		SU 2	69 – 84	Chlorine (117 ppm), SMBS	Dechlorination / Aeration	Chlorine Air Emission	4.8 ppm	
						AOX in Effluent	19 mg/L	
		SU 3	31 – 49	Chlorine (160 ppm), SMBS	Dechlorination / Clarifier	Chlorine Air Emission	0.2 ppm	
						AOX in Effluent	2 mg/L	
		SU 4	70 – 74	Chlorine (300 ppm), SMBS	Dechlorination / Aeration	Chlorine Air Emission	0.7 ppm	
						AOX in Effluent	2 mg/L	
		SU 5	89 - 95	Chlorine (300 ppm), SMBS	Dechlorination / Aeration	Chlorine Air Emission	0.3 ppm	
						AOX in Effluent	13 mg/L	
		SU 6	88 – 98	Chlorine (100 ppm), SMBS	Dechlorination / Aeration	Chlorine Air Emission	3.3 ppm	
						AOX in Effluent	26 mg/L	
						AOX in Nano Reject	18 mg/L	
		SU 7	82 – 93	Chlorine (180 ppm), SMBS	Dechlorination / Clarifier	Chlorine Air Emission	0.4 ppm	
						AOX in Effluent	40 mg/L	
		SU 8	86 – 94	Chlorine (60 ppm), SMBS	Dechlorination	Chlorine Air Emission	3.8 ppm	
						AOX in Effluent	29 mg/L	
						Residual Chlorine in Effluent	55 mg/L	
		SU 9	93 – 94	Chlorine (173 ppm), SMBS	Dechlorination	Chlorine Air Emission	0.2 ppm	
						AOX in Effluent	17 mg/L	
		SU 10	65 – 70	Chlorine (150 ppm), SMBS	Dechlorination / Aeration	Chlorine Air Emission	0.3 ppm	
						AOX in Effluent	21 mg/L	
						AOX in Nano Reject	95 mg/L	

2	Chlorination + Bio-Tower	SU 1	77 – 91	Chlorine (198 ppm), SMBS	Dechlorination/ Settling Tank	Chlorine Air Emission	4 ppm	N.A.
						AOX in Effluent	19 mg/L	
						AOX in Bio Sludge	163 mg/Kg	
						AOX in Salt	101 mg/Kg	
3	Chlorination + ASP + Chemical Precipitation	SU 3	85 – 89	Chlorine (160 ppm), SMBS	Dechlorination, Clarifier	Chlorine Air Emission	0.2 ppm	N.A.
						AOX in Effluent	2 mg/L	
						AOX in RO Reject	2 mg/L	
						AOX in Chemical Sludge	238 mg/Kg	
4	Chlorination + Bio-Enzyme	SU 7	97 – 99	Chlorine (180 ppm), SMBS	Dechlorination, Clarifier	Chlorine Air Emission	0.4 ppm	N.A.
						AOX in Effluent	40 mg/L	
						AOX in RO Reject	35 mg/L	
5	Chlorination + MBR		75	Chlorine (200 ppm), SMBS	Dechlorination, Sludge Processing Units	Biological Sludge		NA
6	Chlorination + MBR + Resin Filter		100	Chlorine (200 ppm), SMBS	Dechlorination, Sludge Processing Units	AOX in effluent, Biological Sludge, Spent resins for disposal		Rs. 40 (ZLD)
7	Dissolved Air Flotation (DAF) + Micron Filtration + Nano Filtration		100	Ferric Alum (400 ppm) + PE (5 ppm)	Evaporator for NF reject	Chemical Sludge, Spent membranes for disposal		Rs.44.90 (ZLD)
8	Ultra Filtration		70-99	Nil	Reject Management Process	Concentrated Reject		N.A.
9	RO Membranes		>97%	Nil	Reject Management Process	Concentrated Reject		N.A.

10	Chemical Precipitation	Lime	40 – 93	Lime 700-1600 mg/L	Clariflocculator, Sludge Processing Units	Chemical Sludge	Rs. 5-6
		Alum	52 – 94	Alum 400-900 mg/L			
		Ferrous Sulphate	14 – 94	Ferrous Sulphate 300-1800mg/L			
		Ferric Chloride	55 – 91	Ferric Chloride 400-900 mg/L			
		Lime + Alum	66 - 99	Lime- 200 - 700 mg/L Alum- 300 - 500 mg/L			
		Lime + Ferrous Sulphate	75 - 88	Lime – 200 - 700 mg/L Ferrous Sulphate-200-600 mg/L			
		Lime + Ferric Chloride	80 - 87	Lime- 200 - 700 mg/L Ferric Chloride-150-500 mg/L			
11	Chemical Precipitation + Pressure Sand Filtration		92 Colourless	Lime, Ferrous Sulphate, Polyelectrolyte	Clariflocculator + Sludge Processing Units	Chemical Sludge	Rs. 30 (ZLD)
12	Chemical Precipitation + Sand Filtration + Granular Activated Carbon		87 - 99	Coagulants	Clariflocculator + Sludge Processing Units	Chemical Sludge, Spent filter media for disposal	Rs.11.69 (1998)
13	Chemical Precipitation + Ozonation		Colourless	Lime, Ferric Chloride, Polyelectrolyte	Clariflocculator + Sludge Processing Units	Chemical Sludge	Rs. 19.18
14	Chemical Precipitation + Sand Filter + Ion Exchange + Carbon Absorption		76	Lime, Ferric Sulphate, Polyelectrolyte	Tube Settler	Chemical Sludge, Spent filter media for disposal	Rs. 34
15	Chemical Precipitation + Sand Filter + Ion Exchange + Carbon Absorption + UF		92	Lime, Ferric Sulphate, Polyelectrolyte	Tube Settler, Solar Pond for UF reject	Chemical Sludge, UF reject for disposal	Rs.52
16	Chemical Precipitation + Extended Aeration		96	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	Rs.11.59 (1998)
17	Chemical Precipitation + Extended Aeration + Sand Filter		96	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	N.A.
18	Chemical Precipitation + Extended Aeration + Sand Filter + Activated Carbon Filter		99	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	Rs.14.3 (1998)

10	Chemical Precipitation	Lime	40 – 93	Lime 700-1600 mg/L	Clariflocculator, Sludge Processing Units	Chemical Sludge	Rs. 5-6
		Alum	52 – 94	Alum 400-900 mg/L			
		Ferrous Sulphate	14 – 94	Ferrous Sulphate 300-1800mg/L			
		Ferric Chloride	55 – 91	Ferric Chloride 400-900 mg/L			
		Lime + Alum	66 - 99	Lime- 200 - 700 mg/L Alum- 300 - 500 mg/L			
		Lime + Ferrous Sulphate	75 - 88	Lime – 200 - 700 mg/L Ferrous Sulphate-200-600 mg/L			
		Lime + Ferric Chloride	80 - 87	Lime- 200 - 700 mg/L Ferric Chloride-150-500 mg/L			
11	Chemical Precipitation + Pressure Sand Filtration		92 Colourless	Lime, Ferrous Sulphate, Polyelectrolyte	Clariflocculator + Sludge Processing Units	Chemical Sludge	Rs. 30 (ZLD)
12	Chemical Precipitation + Sand Filtration + Granular Activated Carbon		87 - 99	Coagulants	Clariflocculator + Sludge Processing Units	Chemical Sludge, Spent filter media for disposal	Rs.11.69 (1998)
13	Chemical Precipitation + Ozonation		Colourless	Lime, Ferric Chloride, Polyelectrolyte	Clariflocculator + Sludge Processing Units	Chemical Sludge	Rs. 19.18
14	Chemical Precipitation + Sand Filter + Ion Exchange + Carbon Absorption		76	Lime, Ferric Sulphate, Polyelectrolyte	Tube Settler	Chemical Sludge, Spent filter media for disposal	Rs. 34
15	Chemical Precipitation + Sand Filter + Ion Exchange + Carbon Absorption + UF		92	Lime, Ferric Sulphate, Polyelectrolyte	Tube Settler, Solar Pond for UF reject	Chemical Sludge, UF reject for disposal	Rs.52
16	Chemical Precipitation + Extended Aeration		96	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	Rs.11.59 (1998)
17	Chemical Precipitation + Extended Aeration + Sand Filter		96	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	N.A.
18	Chemical Precipitation + Extended Aeration + Sand Filter + Activated Carbon Filter		99	Lime – 200 mg/L Alum – 300 mg/L	Clariflocculator + Sludge Processing Units	Chemical Sludge, Biological Sludge	Rs.14.3 (1998)

19	Biological Treatment	ASP	50 – 75	Nil	Clarifier, Sludge Processing Units	Biological Sludge	N.A.
		Anaerobic Reactor	70 - 80	Nil	Clarifier, Sludge Processing Units	Biological Sludge	N.A.
		ASP (Extended aeration)	45 – 70	Nil	Clarifier, Sludge Processing Units	Biological Sludge	N.A.
		Membrane Bio Reactor (MBR)	Light Coloured	Nil	Sludge Processing Units	Biological Sludge, Spent membranes for disposal	N.A.
		Aerobic (White rot fungus)	64 – 96	Nil	Sludge Processing Units	Biological Sludge	N.A.
		UASB	20 – 78	Nil	Sludge Processing Units	N.A.	N.A.
		Anaerobic Fixed Film Fixed Bed Reactor (AFFFBR)	64	Nil	Sludge Processing Units	Biological Sludge	N.A.
20	Extended Aeration + Sand Filter		66	Nil	Clarifier, Sludge Processing Units	Biological Sludge	N.A.
21	Extended Aeration + Sand Filter + Activated Carbon Filter		98	Nil	Clarifier, Sludge Processing Units	Biological Sludge	Rs.7.89 (1998)
22	ASP (extended aeration) + Resin Filter		98 – 99	Nil	Clarifier, Sludge processing Unit, Evaporator	Biological Sludge, Spent resins for disposal	Rs. 46 (ZLD)
23	Membrane Bio-Reactor (MBR) + Activated Carbon Filters		Colourless	Nil	Sludge Processing Units	Biological Spent membranes and Carbon for disposal	Rs. 58.70 (ZLD)
24	AFFFBR + Sand Filter		66	Nil	Sludge Processing Units	Biological Sludge	N.A.
25	AFFFBR + Sand Filter + Activated Carbon Filter		98	Nil	Sludge Processing Units	Biological Sludge	N.A.
26	AFFFBR + Extended Aeration		75	Nil	Sludge Processing Units	Biological Sludge	N.A.
27	AFFFBR + Extended Aeration + Sand Filter		76	Nil	Sludge Processing Units	Biological Sludge	N.A.
28	AFFFBR + Extended Aeration + Sand Filter + Activated Carbon Filter		99	Nil	Sludge Processing Units	Biological Sludge	Rs.8.40 (1998)
29	AFFFBR + Cascade Aeration + Sand Filter + Carbon Filter		99	Nil	Sludge Processing Units	Biological Sludge	Rs. 6.37 (1998)
30	Anaerobic (UASB) + Aeration		92	Nil	Sludge Processing Units	Biological Sludge	N.A.

31	Advanced Oxidation Technologies	Ozone (14–4058 mg/L)	45 – 100	Nil	Nil	Nil	N.A.
		Ozone/ UV	80 – 90	Nil	Nil	Nil	N.A.
		UV/ Ozone/ TiO_2	90 – 99	TiO_2 (0.25 g/L)	Catalyst Separation	Nil	N.A.
		UV- Photofenton	97	Alkalis, Acids, Fe^{2+}, H_2O_2	pH adjustment	Iron sludge	N.A.
		Solar Photofenton	80	Acids, Alkalis, Fe^{2+}, H_2O_2	pH adjustment	Iron sludge	N.A.
		Photocatalysis	73 – 99	Titanium dioxide	Catalyst Separation	Nil	N.A.
		Nano (TiO_2) Photocatalysis	90 – 100	Titanium dioxide (Nano)	Catalyst Separation	Nil	N.A.
32	Advanced Oxidation Technologies of biologically pretreated effluents	Ozone	95	Nil	Nil	Nil	N.A.
		O_3 / H_2O_2	99	Nil	Nil	Nil	N.A.
		UV/ H_2O_2	98	H_2O_2	Nil	Nil	N.A.
		UV	80	Nil	Nil	Nil	N.A.
		Fenton	95	Fe^{2+}, H_2O_2, Acids, Alkalis	pH adjustment	Nil	N.A.
		Photofenton	86	Fe^{2+}, H_2O_2, Acids, Alkalis	pH adjustment	Iron sludge	N.A.
33	Ozonation + Adsorption		99	Nil	Nil	Spent Carbon for disposal	N.A.
34	Electro Chemical Process		90 – 95	Nil	Nil	Iron hydroxide Sludge	N.A.

N.A. – Not Available.

CHAPTER 9

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

9.1 Summary

9.1.1 Background

1. In order to eliminate the problem of sludge management, at present, some Textile Wet Processing Units in the Textile Belt of Tamil Nadu are adopting 'Gas Chlorination' as Colour Removal Technology. The easy availability of gas chlorine in cylinders/tonners and availability of gas chlorinator units locally with cheaper cost encourages the industries to select this technology, since it also eliminates the problem of sludge generation to a major extent.

2. Recently, the Honorable High Court of Madras has directed the Tamil Nadu Pollution Control Board 'to review the use of chlorine and its storage procedures in the industrial sector and to ensure that the best available technology is adopted for colour removal and health of community is not put at risk due to adoption of low-cost substandard solution'. In this context, the Tamil Nadu Pollution Control Board (TNPCB) has mandated the Centre for Environmental Studies, Anna University, Chennai to conduct an expert study on Gas Chlorination in Textile Dyeing Industries, Tamil Nadu in 03.04.2008.

9.1.2 Study on Safety, Health and Environment

1. The first step in this study was to select the representative textile industries in Tirupur, Erode and Karur which use chlorine gas for effluent treatment. For this purpose, an inventorisation of Textile Wet Processing Units adopting Gas Chlorination was carried out with the assistance from TNPCB. At the time of inventorisation, about 30 units in Erode, 1 unit in Karur and 2 units and 4 CETPs in Tirupur have adopted Gas chlorination.

2. At the end of inventorisation, ten textile units (7 from Erode, 2 from Tirupur and 1 from Karur) were selected for conducting field studies on use of chlorine in effluent treatment. Out of 10 study units selected, 3 units fall under large-scale category (including 1 CETP), 4 units fall under medium-scale category and the other 3 units fall under small-scale category.

3. The textile units in Erode and Tirupur have widely used Ton containers (or Tonners) of chlorine capacity (normal) 916 kg, with tare weight 625 kg having 12 mm shell thickness and overall length of 206 cm. Few Tiny (printing and tie and dye process) textile units have used chlorine gas cylinders of 100 kg capacity.

4. Based on the provisions in the Indian National Codes of Practices on chlorine, a set of questions were prepared and the chlorine work practices of the study units were evaluated in response to these questions. Percentage compliance of textile units to the chlorine work practices was found to be in the range of 35-83%. The storage areas of chlorine tonners in most textile units were found to comply with the recommendations. Only few textile units have used mechanical devices for handling chlorine tonners, whereas most units used hand trucks.

5. Generally in the study units, chlorine alarm devices and ammonia solutions were found to be available. Provisions for emergency disposal of chlorine leaks (eg. Alkali solutions) were found to be available in 50% of the study units. Some health and safety equipment devices (eg. gas mask, rubber gloves, PPE, eye wash showers, emergency kits, oxygen administration apparatus) were found to be available in textile units. However, appropriate use and the maintenance of these devices were not paid due attention. Only few textile units have provided first-aid boxes to the workers and displayed instruction boards for handling emergency situations. Despite the availability of some safety equipment devices, the workers lacked training and experience specific to chlorine safe work practices.

6. The effluent samples were collected from various parts of the treatment plant in the 10 units. The following parameters were considered for assessment: pH, colour, TDS, TSS, BOD, COD, AOX, residual chlorine and chloride. Air samples were collected manually and also by using chlorine in-situ analyser. The air samples were collected for different time intervals and at different distances from the chlorinator. Sludges generated from processes such as biological waste treatment and chemical residue were collected in clean airtight polythene bags from selected locations and analysed for AOX.

7. The treatment of textile dyeing wastewater by gas chlorination in chlorine reactors followed by removal of free residual chlorine by dechlorination and aeration leads to emission of chlorine gas into the atmosphere. In order to estimate the health risks from occupational exposure to chlorine in air for the treatment plant workers / operators, the health

risk assessment already done was reviewed in this study. As per the assessment, it is found that the treatment plant workers/ operators are exposed to the chlorine gas emission.

8. The gas chlorination leads to the formation of chlorine containing decomposition by-products generally represented as AOX. They are family of chemicals produced when chlorine reacts with organic matter in the effluent and produce dangerous chlorinated compounds. The amount of AOXs formed may vary depending on the type of dyes and other organics and the chlorine dosages applied. The AOXs formed is retained in the RO Reject and finally gets concentrated in the sludge of solar evaporation, which is temporarily stored in the premises of the industrial units. In the Study Units, at the end of chlorination/ dechlorination, AOX was found to be generated in the range of 2 to 40 mg/L. In India, limit for AOX for effluent discharge is yet to be fixed, whereas in most European countries the limit should not exceed 1 mg/L for discharge into surface water.

9. There is a need to implement measures to improve the Health, Safety and Environmental aspects in the textile units, to the satisfactory level. The first and foremost requirement that the textile units are bound to meet is the stipulation provided in the Factories Act, 1948. In India, chlorine is deemed to be an explosive, when contained in any metal container in a compressed or liquefied state, within the meaning of The Indian Explosives Act, 1984. The filling, possession, transport and importation is governed by the Gas Cylinder Rules, 1940. The Bureau of Indian Standards has made recommendations covering the safety and health aspects related to chlorination practice in textile industries. At the international level, several organizations have formulated guidelines for safe use of chlorine in industries. Prominent among them are: OSHA, US EPA, Chlorine Institute, US and Work Safe BC, British Columbia. Most of the international guidelines have also been covered under BIS guidelines.

9.1.3 Study on Colour Removal Technologies

1. A comprehensive review of various colour removal technologies adopted by the textile units in Tamil Nadu (including CETPs implementing ZLD facilities) was carried out. In addition, the published research literatures on performance of numerous treatability studies of various colour removal technologies have been reviewed.

2. All the ten study units (SU 1 – SU 10) have adopted gas chlorination as primary treatment technology for colour removal of textile effluent. Chlorination was carried out as

batch process in chlorine reactors which are of open tank types (ie., equalization tank/ clarifier) or closed tank type (ie., syntax tanks). Out of 10 study units, only 3 units (2 large-scale and one medium scale) have provided open tank types, and 6 more units (3 medium scale and 3 small scale) have used syntex tanks as chlorine reactors. The remaining one unit ie., CETP has installed the HDPE piping system (known as OR Reactor) as chlorine reactor.

3. At the end of chlorination/ dechlorination, the colour removal efficiency was found to be in the range of 31-98% in the study units. Out of 10 units, 7 units were found to meet the International Effluent Standards for colour and the remaining 3 units were not able to meet the International Standards. The wide variation in colour removal efficiency might be due to the differences in the process control parameters of chlorination treatment system and the variation of the types and concentration of dyes in the raw effluent and also the dyeing technology.

4. The data on efficiency, chemicals and environmental implications and costs, related to 57 colour removal technologies collected and compared.

5. Since the textile effluent is complex and variable, it is unlikely that a single treatment technology will be suitable for effective colour removal. The comprehensive literature review revealed that appropriate combinations of the physical, chemical and biological treatment processes are effective in removal of colour. The selection of the most appropriate treatment method is influenced by a number of factors related to each effluent characteristic, relative cost, degree of treatment required, process efficiency and its reliability and the environmental implications and health and safety aspects of the treatment processes. Based on the review, it is concluded that the combination of biological treatment based technologies with suitable supplementary processes might be considered as an appropriate treatment method for removal of colour. Over all, the biological treatment based technologies are more environmental friendly, offer comparable efficiency, are free from public health problems; and hence, they are recommended even though the cost of treatment is higher.

9.2 Conclusions

Based on the review of literature and on the field studies conducted, the following conclusions are made:

1. The use of chlorine gas for colour removal in textile industries is rare world wide.

2. Compared to other colour removal technologies, the cost of Gas Chlorination Technology is the lowest.

3. The use of chlorine gas for removal of colour in textile dyeing effluents is highly effective in colour removal, but at the same time does not yield desired results under certain conditions. Thus, this technology like any other technology has its own limitations.

4. Gas chlorination for removal of colour results in very minimal sludge generation and thus sludge management is relatively easier because of the small quantity.

5. The use of chlorine gas for colour removal leads to the formation of AOX which is ultimately found in the effluent and sludge in undesirable concentrations. The AOX is a notified pollutant.

6. The practice of Gas Chlorination leads to contamination of air with chlorine gas in normal conditions; in significant number of cases beyond permissible levels posing health risk to the treatment plant operators/ workers.

7. The textile dyeing units practicing Gas Chlorination are located (especially in Erode) in places where there are many residential houses close-by. Gas chlorination involves serious safety and health risks to the plant operators and the surrounding community in the event of accidental release of chlorine due to the container rupture. It is reported in the literature that the impact is estimated to reach atleast 2 km from the plant.

8. The practice of Gas Chlorination in the textile dyeing units need to be regulated to the standard norms in many cases. Well-established rules/ guidelines/ recommendations have been made by Factories Act, Gas Cylinder Rules, BIS and various International Agencies.

9. In general, it has not been possible to completely eliminate the safety risk associated with the use of chlorine gas.

10. There is a great need to create awareness among the industrial units about the implications of using chlorine gas for colour removal.

11. Alternatives for Gas Chlorination Technology for colour removal in textile dyeing industries do exist. An example is the biological treatment based technology along with suitable additional processes. Even though the costs of such alternative

technologies are higher, they are preferable in terms of health, safety and environment compared to Gas Chlorination Technology.

9.3 Recommendations

In view of the conclusions already presented in section 9.2 in this chapter, the following recommendations are made for the Textile Dyeing Units (Large, Medium, Small, Tiny and CETPs) that are located in the Textile Belt of Tamil Nadu:

1. All the textile dyeing units in Tamil Nadu practicing Gas Chlorination must be persuaded to switch over to an alternate technology for removal of colour from the effluents. The exception will be those units which
   - (i) comply with the Safety, Health and Environmental Regulations/ Rules related to the use of chlorine gas, and
   - (ii) are not located in close proximity to the community. It is preferable to ensure that such industries are located atleast 2 km away from the nearest community.
2. For the units allowed to continue with Gas Chlorination, the TNPCB should immediately arrange for training programs to make them familiar with the necessary Safety, Health and Environmental Regulations/ Rules.
3. As per the results obtained from the study, it is recommended that TNPCB may discourage the textile dyeing units in Tamil Nadu in using chlorine gas for colour removal in future.
4. As an alternative to the gas chlorination technology, biological treatment based technologies along with suitable additional processes appear to be promising.

2.2.2009

Director - CES

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ANNEXURE I

CHLORINE RELATED ACCIDENTS

(a) International

During 1970s

- On 30th April 1974 in *Yokkachi, Japan* accident during transshipment of chlorine resulted in injuring 521 people.
- On 14th December 1975, chlorine explosion accident in *Niagara Falls, USA* resulted in the death of 4 people and injuring 176 others.
- In February 1978, chlorine leakage in a rail car transporting chlorine in *Younstown, USA* resulted in the death of 8 people and injured 138 others.
- On 11 November 1979, chlorine leakage during rail transport at *Canada* resulted in evacuation of 20,000 people.

During 1980s

- On 1st June 1981, chlorine release accident in *Geismar, USA* resulted in injuring 125 people.
- On 4th August 1981, an accident involving a rail car transporting chlorine in *Mexico, Montanas* resulted in the death of 28 people, injured 1000 and evacuated 5000 people.
- On 7th September 1986, a train transporting chlorine derailed at *Mississippi*. Two cars ruptured and released chlorine gas, as a result 100 families were evacuated.
- On 7th July, 1987 accident in a rail car transporting chlorine resulted in injuring 200 people, in *USSR, Anna*.

During 1990s

- On 17th January 1990, chlorine release from a truck resulted in causing injury to more than 182 people in *Ahlsfeld, Germany*.
- On 5th January 1991, chlorine was released at a factory for PVC at *Nyon, Switzerland* resulted in evacuation of about 12,000 people.

- On 11th March 1991, an explosion resulting in the release of chlorine gas in a petrochemical industry resulted in the death of 2 people and injured 122 others, in *Catzacoaloas, Mexico*.
- On 6th May 1991, chlorine leakage at a factory in *Henderson, USA* resulted in injuring 55 people and evacuating 15,000 people.
- On 23rd January 1992, chlorine release at a store in *Schkopau, Germany* resulted in injuring 186 people.
- On 15th July 1995 in *Astra, Iran*, a chlorine leakage accident resulted in the death of 3 people and injured 200.
- In January 1996, large chlorine released from rail tanker at *Williams Port Pennsylvania, USA* resulting in evacuating several communities in the area.
- In April 1996, at *Western Montana, USA*, several towns and interstate were closed due to chlorine spill, which lifted after 17 days; 1 person died and over 300 people were hospitalized.
- During January 1997, a transport chlorine accident took place in *Lahore, Pakistan*. About 32 people died, 900 others injured and 1000 people were evacuated.
- In 1997, chlorine leakage during rail transport at *Youngs Town, USA* resulted in 8 deaths and 138 injured.
- On 1st April 1997 in *Salvador, Acajutla* chlorine accident took place in a facility handling washing powder. About 400 people were injured and more then 100 people were evacuated from the area.
- In August 1998, 60 people were hospitalized due to chlorine accident at *Tampa Florida, US.*

During 2000s

- On 14th August 2002, 48000 pounds of chlorine released over 3 hours period during railroad tank car unloading operations at DPC Enterprises, *LP Missouri, USA*. Personal Protective Equipment could not be utilized by the personnel who were trained to use it because the equipment was very close to the spill.
- On 20th July 2003, 4 people were hospitalized during chlorine released at *Honey Well Chemical Plant, Baton Rocye, US.*

- On 28th June 2004, Union Pacific and Burlington *Northern Santa Fe* trains derailed one chlorine car. Three people died and another 50 people were hospitalized because of exposure to the gas.
- On 13th August 2004, people living near a water treatment plant suffered from a chlorine leak in *East China's Jiangsu Province*. More than 70 residents were rushed to hospital.
- On 6th January 2005, 70-80 tons of chlorine gas leaked from wrecked train killing 9 people and injuring 250 at *Graniteville, S.C.South Caroline, USA.*
- On 19th May 2005, chlorine leakage accident in *Puerto Rico, USA* resulted in injuring 200 people and evacuating 1500 people.
- On 6th January 2006, chlorine tank cars were derailed from Norfolk Southern freight train and struck a parked train at Avonadale Mills, a denim textile plant in *Graniteville, S.C.* Nine people died in the accident and nearly 240 people were sickened by gas fumes and 44 people with acute respiratory ailment were kept in the hospital.

(b) Chlorine Accidents in India

In India, even though chlorine is widely used in industries and in water and wastewater treatment plants, the informations available about chlorine release accidents are scanty. The details of some of the chlorine accidents reported in newspapers are presented below.

During 1980s

- In 1985, 2 tons of chlorine leaked at Petrochemical Plant, *Chembur, Mumbai*. One was dead and 140 people were hospitalized.
- On 10th June 1987, an accidental release of chlorine from bonnet of a valve in a chlorine bullet situated in a Chloro-alkali industry took place at *Anandabazar Patrika*. The chlorine release was first noticed at 12 O'clock at night and continued till 3.45 am and at 8.30 am all the studs have failed and the valve was thrown out of its position to give rise to huge spillage of liquid chlorine from the tank. Ultimately at about 5.30 pm, the hole was plugged. About 72 people were affected and a heavy shower for an hour brought relief by arresting to some extent the spreading of gas.

- On 5th May 1989, chlorine leakage at *Britania Chowk* resulted in injury of 200 people.

During 1990s

- In December 1991, chlorine leakage from a pipeline at *Calcutta* injured 200 people.
- In January 1994, chlorie gas transport accident in *Thane District* injured 298 people.

During 2000s

- On 7th December 2007, power failure caused minor leakage of chlorine in *Chemplast Sanmar Ltd., in Mettur, Tamil Nadu.*
- In 2007, at an industrial manufacturing unit of cotton and bandage, *West Bengal*, during chlorination of water in a cistern, chlorine bubbled out of water. Two near by department of the same factory received chlorine at 25 ppm at 1.88 m/s wind velocity.
- On 10th February 2008, a fireman was hospitalized while plugging chlorine leakage from a gas cylinder at a water treatment centre, Athani, Erode, Bhavani Taluk.
- On 5th May 2008, chlorine gas leak in a water filter plant, *Tata Motors, Jamshedpur* resulted in hospitalization of 125-150 people.
- On 11th June 2008, 230 persons (most of them school children and college students) have developed acute breathing problem after inhaling air-containing chlorine around Tumkur City Municipal Council main premises in *Karnataka.*
- On 18th July 2008, about 10 villagers were hospitalized due to chlorine leakage from a chemical plant at Mottur, Karungal Hamlet, *Mettur, Salem.* .
- On 21st November 2008, there was a leakage in *Kilpauk Water Treatment Plant, Chennai.* There was no damage or injury to human lives and this leakage was arrested within 10 minutes.

ANNEXTURE II

TEAM MEMBERS FROM CES

1. Dr. K.Thanasekaran, Director
   Team Leader

2. Dr. S.Kanmani, Assistant Professor & Co-ordinator
   Team Member

3. Dr. K.Palanivelu, Assistant Professor
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   Senior Project Assistant

9. M.Jamesh
   Senior Project Assistant

10. R.Sumathi
    Typist

11. G.Venkatesh
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