

Full Length Research Paper

Evaluating the efficiency of a textile wastewater treatment plant located in Oshodi, Lagos

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The major part of textile processes is based on chemical reactions carried out in aqueous heterogeneous systems which eventually generates effluents of extremely variable composition and constitute an environmental risk of major concern. This study, focused on investigating the characteristic of effluent from textile industry which generates about 1577 m³ wastes per day and the effectiveness of the wastewater treatment technique practised. Wastewater samples were collected at four different outlets within the company premises twice within two months (November and December). The ranges of the physico-chemical parameters studied were as follows: pH 7.12 - 12.99, temperature 28.33 - 64.00 °C, total solids (TS) 2000 – 31800 mgL⁻¹, total suspended solids (TSS) 300 – 780 mgL⁻¹, dissolved oxygen (DO) N.D - 1.50 mgL⁻¹, chemical oxygen demand (COD) N.D – 350 mgL⁻¹, oil and grease 160 – 2370 mgL⁻¹, Chlorides 21 - 1064 mgL⁻¹, Sulphide 1060 – 1400 mgL⁻¹, Chromium (Cr) 0.09 - 0.67 mgL⁻¹, Cadmium (Cd) 0.04 - 0.31 mgL⁻¹ and lead (Pd) N.D - 0.35 mgL⁻¹. The percentage removal was also determined for each investigated parameters with values ranging as follows: TS; 15.1 - 86.5%, TSS; 46.4 - 51.3%, oil and grease; 35.0 - 92.9%, chloride; 27.6 - 65.5%, sulphide; 18.5 - 24.3%, heavy metals (Cr, Cd and Pd); 2.9 - 86.6%, temperature; 27.9 - 55.7%, pH; 20.3 - 45.2%

Key words: Textile processes, wastewater, effluents, treatment plant, removal efficiency, physico-chemical.

INTRODUCTION

Rapid industrial development and growth of cities throughout the world especially in the developing world have led to the recognition and increasing understanding of the relationship between pollution, public health and the environment at large (WHO, 1982). Generally, industries produce more pollutants than does any other segment of the society, hence it has been observed that the pollution load contributed by a small-scale industry like a textile industry may be equal to that of the sewage from a large city (Agarwark, 1999). The industrial revolution of the early 19th century gave great impetus to the factors that brought dramatic changes in the earth's waters. Ever since then, the human impact on Earth waters has increasingly been detrimental to human survival.

The textile industry is one of the rapidly growing sectors of Africa economy. It has the capacity to reduce

unemployment due its large labour demands. Its processes are based on chemical reactions in liquid medium, thereby generating large volume of toxic wastewater. Some of the major processes include: Sizing- saturation of mainly hydrophobic wraps by high viscosity macromolecular solution using sizes like starch and desizing- removal of sizes from fabric using strong chemicals such as acids, bases or oxidizing agents (Babu et al., 2007). Other important processes include bleaching-treatment of cotton and polyester to achieve a white absorbent fabric that is suitable for dyeing, printing and finishing (Babu et al., 2007). The bleaching process uses oxidizing agents like chlorine and hydrogen peroxides. Dyeing and printing are achieved by the use of various types and colour of dye such as azo dyes and sulphur dyes.

Untreated water near the point of disposal, create foul smell and bad odour (Kullkarni, 1997). High levels of pollutants mainly organic matter in river water cause an increase in biological oxygen demand (Kullkarni, 1997), chemical oxygen demand, total dissolved solids, total suspended solids and make water unsuitable for drinking,

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Table 1. Possible treatments for cotton textile wastes and their associated advantages and disadvantages.

Processes	Advantages	Disadvantages	References
Biodegradation	Rates of elimination by oxidizable Substances about 90%.	Low biodegradability of Dyes.	Pala and Tokat, 2002; Ledakowicz et al., 2001.
Coagulation– Flocculation	Elimination of insoluble dyes.	Production of sludge. blocking filter	Gaehr et al., 1994.
Adsorption on activated carbon	Suspended solids and organic substances well reduced.	Cost of activated carbon.	Arslan et al., 2000.
Ozone treatment	Good decolourization.	No reduction of the COD.	Adams et al., 1995; Scott and Ollis, 1995.
Electrochemical Processes	Capacity of adaptation to different volumes and pollution loads.	Iron hydroxide sludge.	Lin and Peng, 1994; Lin and Chen, 1997.
Reverse osmosis	Removal of all mineral salts, hydrolyzes reactive dyes and chemical auxiliaries.	High pressure.	Ghayeni et al., 1998.
Nanofiltration	Separation of organic compounds of low molecular weight and divalent ions from monovalent salts. Treatment of high concentrations.	-----	Erswell et al., 1998; Xu et al., 1999; Akbari et al., 2002; Tang and Chen, 2002.
Ultrafiltration– Microfiltration	Low pressure.	Insufficient quality of the treated wastewater.	Watters et al., 1991; Rott and Mike, 1999; Ciardelli and Ranieri, 2001; Ghayeni et al., 1998.

Babu et al. (2007).

irrigation (Hari et al., 1994) or any other use.

The impact and contribution to pollution by industries depend on process technology, size, nature of products, characteristic and complexity of waste discharged (FEPA, 1991). Water pollution is of grave consequence because both terrestrial and aquatic life may be poisoned; it may cause disease due to the presence of some hazardous substance, may distort the water quality, add odours and significantly, hinders economic activities. If textile waste water, not properly treated is released into the environment, it can introduce metals (Cr and Cd) and organochlorine compounds which can bio-accumulate in fishes in receiving streams. These fishes can have harmful effect on human when consumed. Dye residue and degraded starch render the water unfit for drinking because they reduce its quality by imposing colour and odour on water. Hot effluent also affects dissolved oxygen (DO), which in turn affects the aquatic environment of living organisms in such streams.

Textile wastewater treatment for industrial reuse or disposal remains as a complicated problem due to several reasons. Among them are:

- 1) Non-biodegradable nature of organic dye stuffs present in the effluent.
- 2) Higher levels of chemical oxygen demand (COD), biological oxygen demand (BOD) and total dissolved solids (TDS) content of the waste water.

Thus, any adopted treatment system, especially with respect to primary treatment, should be able to address these issues. The two major processes responsible for

textile wastewater pollution are dyeing and finishing processes because they involve the use of wide range of chemicals and dyestuffs, which generally are organic compounds of complex structure. Textile wastewater includes a large variety of dyes and chemicals additions that make the environmental challenge for textile industry not only as liquid waste but also in its chemical composition (Venceslau et al., 1994). For example, to dye 1 kg of cotton with reactive dyes, 0.6 - 0.8 kg of NaCl, 30 - 60 g of dyestuff, and 70 - 150 L of water are required (Chakraborty et al., 2005). More than 80,000 tonnes of reactive dyes are produced and consumed each year. Once the dyeing operation is over, the various treatment baths are drained, including the highly coloured dye bath, which has high concentrations of salt and organic substances. The wastewater must be treated before reuse or disposal. As far as textile wastewater treatment for industrial reuse and disposal is concerned, colour removal, reduction of Total Suspended Solids (TSS), BOD and COD are the main problems to be addressed in the primary treatment. Most commonly utilized primary treatment processes are:

- i) Conventional physico-chemical treatment utilizing lime and ferrous/alum.
- ii) Conventional biological treatment with aeration to reduce BOD and COD.
- iii) Chlorination.
- iv) Ozonation (with/without ultra violet irradiation).

However, certain problems are associated with these treatment techniques (Table 1).

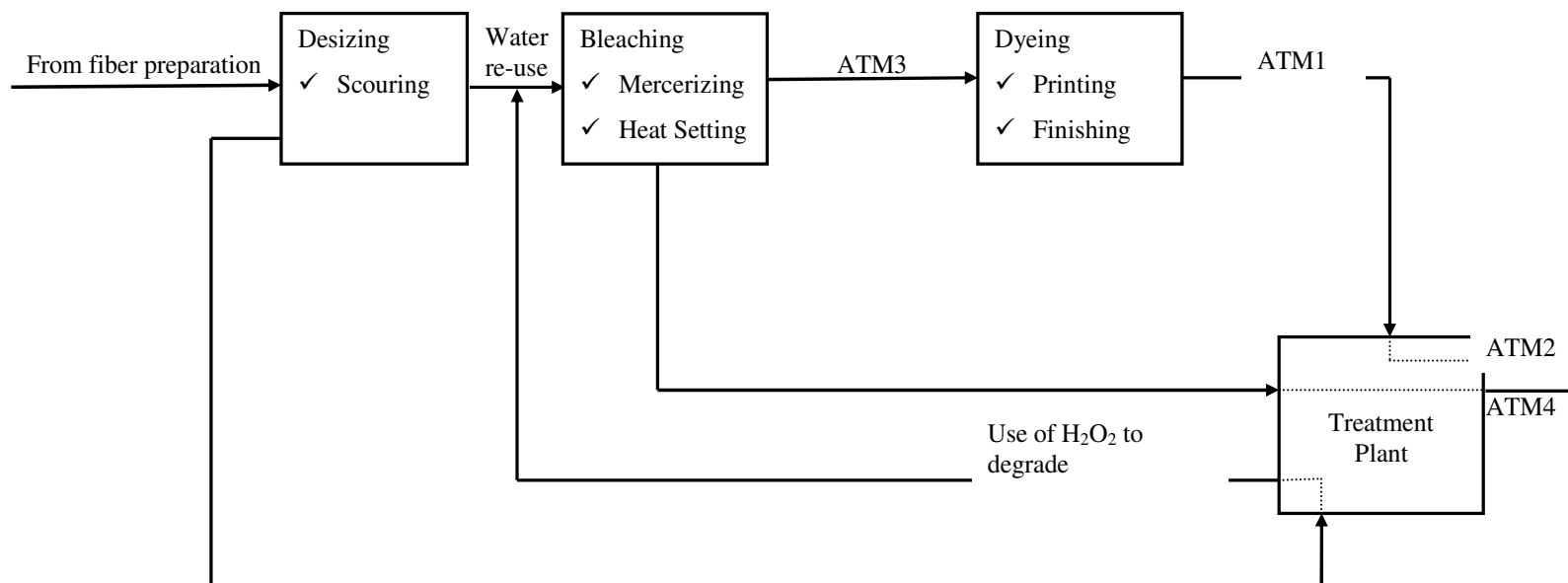


Figure 1. Process and sampling points layout.

Table 2. Operational data for the Textile Manufacturing Company, Oshodi, Lagos State.

Information (Amount of material)	Data
Sized	12.5 tons per day
Desized	12.5 tons per day
Kiered	12.5 tons per day
Bleached	55000 tons per day
Mercerized	55000 tons per day
Dyed	55000 tons per day
Printed	55000 tons per day
Waste volume	1577m ³ per day
Capacity of plant	180m ³ per hour

The company investigated is a textile manufacturing

company, located in Oshodi, a densely populated area of Lagos state, Nigeria. The company is manufacturing various cotton fabrics which involved processes such as spinning, sizing and desizing, scouring, bleaching, dyeing and printing. The production plant drains directly into the treatment plant. Recycling and water conservation were practised by the company as at the time of sampling and conventional primary treatment of wastewater was practised. Samples, raw and treated wastewater were taken from four sampling outlets which are from inlet and outlet of the dyeing and printing process and also inlet and outlet of the scouring and bleaching process (Figure 1).

The physico-chemical status of these wastewater samples (ATM 1, ATM 2, ATM 3 and ATM 4) were investigated, compared with reference standard and the efficiency of the treatment plant

treatment plant determined.

MATERIALS AND METHODS

Description of sampling area

The study area is a Textile Manufacturing Company located in Oshodi, Lagos, Nigeria. It generates 1577 m³ per day of effluent and is equipped with a treatment plant of 180 m³ per hour capacity (Table 2).

Sampling design

Grab samples were collected from 9.30 am to 4.30 pm, that is, 7 h, on an hourly basis to form a composite sample. Samplings were carried out on the 29th November, 2001 and 5th December, 2001. Four effluent samples were collected to represent different activities at different locations within the Textile Company. The description of sampling points/locations and their corresponding activities

Table 3. Site description for the sampling points.

Site	Description
ATM 1	Untreated dyeing, printing effluent.
ATM 2	Treated dyeing, printing effluent.
ATM 3	Untreated bleaching, scouring effluent.
ATM 4	Treated bleaching, scouring effluent.

are shown in Table 3.

Quality assurance

Samples for organics, such as dissolved oxygen (DO), chemical oxygen demand (COD) and oil and grease were collected using glassware while that for trace metals and other parameters were collected in plastic container. These containers (plastic and glass ware) were soaked in 1M HNO₃ overnight (Onianwa, 2001) and washed with teepol, a laboratory detergent, rinsed with tap water and finally with deionised water. Parameter such as temperature, pH, and flow rate were determined on the field while dissolved oxygen (do) and oil and grease were fixed and determined later in the laboratory.

Standard calibration

Standard solution of known concentration was prepared and determine for metal analysis .Blank analysis were carried out for dissolved oxygen (do), chemical oxygen demand (cod), chloride, sulphide and metal analysis for correction of error. chemical oxygen demand (cod) was also done on potassium hydrogen phthalate solution which is a standard, having a value that should not be less than 500 mgL⁻¹.

Chemical analysis

pH: pH of the samples was determined using pH meter which has been initially standardized by using buffer solutions of known value before analysis .

Temperature

Temperature was measured using portable calibrated mercury thermometer (EPA, 1998) at the collection point.

Total solid (TS)

Total solid (TS) was determined gravimetrically by evaporating a known volume of water sample to dryness in a pre-weighed crucible on a steam bath at 105°C (APHA-AWWA-WPCF, 1985).

Total suspended solids (TSS)

Total suspended solids consist of silt, clay, fine particles of organic and inorganic matter. TSS was determined by filtering a known amount of sample through a pre-weighed filter paper. The filter paper was then dried at 103 - 105°C. TSS was determined by using the following formula (Anon, 1992);

$$\text{TSS mgL}^{-1} = (\text{final} - \text{initial wt.}) (\text{amount of sample taken})^{-1} \times 1000$$

Dissolved oxygen (DO)

Dissolved oxygen (DO) was determined by Winkler's titration.

Chemical oxygen demand (COD)

The COD is determined by titration with (0.25 M) ferrous sulphate, using 1:10 phenanthroline (United Kingdom, Dept. of Environ., 1974).

Oil and grease

Oil and greases form a surface film over water and prevent the atmosphere with water and thus interferes with the self-purification of water (Roy, 1996). Oil and Grease was determined using wet procedure. The samples (100 ml) were extracted with three different n-hexane volume (30, 25 and 25 ml). The n-hexane was removed by distillation on water bath. An aliquot was taken in UV cell and its absorbance was recorded against pure n-Hexane. A series of standards were prepared from the reference oil obtained from same plant and a calibration graph drawn (United Kingdom, Department of Environment, 1987).

Chloride

The Chloride (Cl⁻) was determined by Mohr's titration. Twenty millilitre of sample was placed in a conical flask and pH adjusted to between 6 - 8 with small amount of (0.1 M) calcium carbonate solution. One millilitre of potassium chromate solution prepared by dissolving 50 g of potassium chromate in a minimum of distilled water was added and the solution was titrated with (0.0141 M) silver nitrate solution with constant stirring.

Heavy metals

Heavy metal was determined by digesting a known volume of water sample with analytical grade HNO₃. The digested sample was filtered into a 20 ml standard flask, made up to the mark with distilled-deionized water and stored in a nitric acid pre-washed polyethylene bottle in the refrigerator prior to the chemical analysis. The water extracts was analyzed for metals (Pb, Cd and Cr) by atomic absorption spectrometer (Perkin Elmer model 2380). Each sample was analyzed twice and the average of the results was reported. General laboratory quality assurance measures were always observed to prevent sample contamination and instrumental errors. The water used throughout the experiment was distilled twice in an all glass distiller before it was deionized (APHA, 1992).

RESULTS AND DISCUSSION

Table 4 shows the major processes involved in textile manufacturing and the nature of waste-water generated. For environmental impact assessment auditing, the accurate idea of the composition of effluents is very important. This is so because wastewater or industrial effluents contain various pollutants that may alter the quality of the receiving water and the environment at large (Larry et al., 1991).

The operational data of the investigated textile manufacturing company shows that it processes only cotton of which 12.5 tons of materials were sized and

Table 4. Nature of textile effluent.

Textile process	Chemicals used	Nature of effluent
Desizing and scouring	Strong mineral acid and bases.	Degraded sizes, fibres impurities, pesticides (used for cotton growing), heat and penta chlorophenol (PCP) (used as size preservatives).
Bleaching	Sodium hypochlorite, sodium chlorite or hydrogen peroxide (H_2O_2).	Organochlorine compounds, water and oxygen (from H_2O_2 decomposition).
Dyeing	Azo dye, sulphur dye.	Sulphur, coloured dye residue, heat.

Table 5. Result of physico-chemical characteristic of effluent.

Parameter	ATM 1	ATM 2	ATM 3	ATM 4	Range	FEPA discharge limit	Mean
Colour	Blue black	Light yellow	Light yellow	Very light yellow	-	NONE	-
Odour	-	-	Pungent	Pungent	-	NONE	-
pH	12.99	7.12	9.40	7.49	7.12-12.99	6-9	9.25±2.69
Flow rate	-	110	-	100	100-110		105±7.07
Temperature ($^{\circ}C$)	64.00	28.33	61.50	44.33	28.33-64.00	<40 $^{\circ}C$	49.54±16.62
TS (mgL^{-1})	14800	2000	31800	27000	2000-31800	2000	18900±13347.16
TSS (mgL^{-1})	560	300	780	380	300-780	30	505±213.15
DO (mgL^{-1})	N.D	1.50	N.D	N.D	N.D-1.50		1.50±0.00
COD (mgL^{-1})	350	200	N.D	N.D	N.D-350	50	275±106.07
Oil and grease (mgL^{-1})	2240	160	2370	1540	160-2370	20	1577.5±1012.86
Chloride (mgL^{-1})	1064.0	367.5	29.0	21.0	21-1064	2000	370.38±489.80
Sulphide (mgL^{-1})	1400	1060	1300	1060	1060-1400	-	1205±172.34
Cr (mgL^{-1})	0.67	0.09	0.32	0.13	0.09-0.67	0.10	0.30±0.26
Cd (mgL^{-1})	0.15	0.04	0.31	0.17	0.04-0.31	0.01	0.17±0.11
Pd (mgL^{-1})	N.D	N.D	0.35	0.34	N.D-0.35	0.05	0.35±0.01

Key: TS; Total solids, TSS; total suspended solids, DO; dissolved oxygen, COD; chemical oxygen demand, Cr; chromium, Cd; cadmium; Pd, lead.

de-sized per day. 55000 tons of materials are bleached, mercerized, dyed and printed per year. The textile processes produce 1577 m³ of effluent per day, based on 7 h per day and 26 working days per month.

Major pollutants in textile wastewaters are high suspended solids, chemical oxygen demand, heat, colour, acidity and other soluble substances (Dae-Hee et al., 1999).

A detailed physico-chemical status is shown in Table 5. The pH was measured using Orion 370 pH meter, with mean value of 9.25 ± 2.69. The pH of the untreated dyeing and printing effluent (ATM 1) and untreated bleaching and scouring effluent ATM 3) were 12.99 and 9.40 respectively, both higher than Federal Environmental Protection Agency (FEPA) discharge limit of pH 6 - 9. This is as a result of application of chemicals such as caustic soda for mercerizing cotton yarn and vat dye for dyeing. Processes such as de-sizing and scouring, done before bleaching might also be responsible for the basic nature of the waste water. Chemicals like soda ash and hydrogen peroxide used for scouring tends to increase pH. The pH of both treated dyeing and printing (ATM 2)

and treated bleaching and scouring (ATM 4) were 7.12 and 7.49 respectively. These values were within the Federal Environmental Protection Agency (FEPA) discharge limit for textile industry (pH 6 - 9). These reductions in pH values are achieved by the addition of chemicals like sulphuric acid and hydrochloric acid in the treatment plant. The temperature of the treated dyeing and printing effluent (ATM 2) of 28.33 $^{\circ}C$ was within FEPA's standard of less than 40 $^{\circ}C$ while that of the treated bleaching and scouring effluent (ATM 4) was above FEPA's standard as shown in Table 5.

For suspended solids, perusal of the results from Table 5 shows ATM 2 and ATM 4 to be 300 and 380 mgL^{-1} respectively. These values were higher than FEPA's standard of 30 mgL^{-1} . ATM 2 had a value of 2000 mgL^{-1} for Total Solid which was exactly the value for FEPA's discharge limit while ATM 4 value of 27000 mgL^{-1} was above FEPA's standard. The huge difference in the values of ATM 2 and ATM 4 was due to the fact that ATM 1 which is the untreated dyeing and printing effluent was taken through a process of treatment to remove sludge while ATM 3, untreated bleaching effluent was not. It has

Table 6. Result of simple correlation analysis for trace metal, TSS, COD with TS.

Parameter	Cr	Cd	Pb	COD	TSS
Cd	-0.02				
Pd	-1.00	1.00			
COD	1.00	1.00	-		
TSS	0.08	0.90	1.00	1.00	
TS	9.40×10^{-5}	0.93	1.00	1.00	0.68

been reported that industrial effluents have grossly polluted, virtually all streams flowing through industrial estate in Lagos, with vivid example such as Shasha and Iya-Alaro streams which are perpetually coloured, smelly, murky and devoid of aquatic life (Ajayi and Osibanjo, 1981). ATM 1 which was coloured before treatment (Blue black) as shown in Table 5 had its colour removed. Improved colour removal by biological treatment can be achieved by adding activated powdered carbon as catalyst to aeration basins in activated sludge system (EPA, 1978).

For heavy metals, lead (Pd) was not detected in two samples namely, ATM 1 and ATM 2. Table 5 shows Chromium (Cr) having the highest concentration of 0.67 mgL^{-1} in ATM 1. This because chromium is often used for oxidation in cotton dyeing and for chemical fixation in wool dyeing. FEPA recommended discharge limit for chromium is 0.1 mgL^{-1} . Chromium toxicity damages the liver, lungs and causes organ haemorrhages, though is an essential trace nutrient and a vital component for glucose tolerance factor (WHO, 1988). The reduction from 0.67 mgL^{-1} (ATM 1) to 0.09 mgL^{-1} (ATM 2) was achieved firstly by conversion of soluble hexavalent chromium (Cr^{6+}) to insoluble chromic form (Cr^{3+}) and then it was precipitated as hydroxide followed by removal as sludge. Chromium (Cr), cadmium (Cd) and lead (Pd) concentrations in treated effluents, that is, ATM 2 and ATM 4 were within FEPA's discharge limit.

The chemical oxygen demand (COD) ranged from N.D – 350 mgL^{-1} . High COD values could be due to high organic load as shown by TS and TSS values (Osibanjo and Adie, 2007). Chemical oxygen demand (COD) value for ATM 4 of N.D was within FEPA's discharge limit of 50 mgL^{-1} . COD was strongly correlated to total solids and total suspended solids (1.00) (Table 6). This affirmed the linear relationship between solids and COD. Dissolved oxygen (DO) was not detected in almost all the samples except ATM 2 which had a low value of 1.5 mgL^{-1} . The value for oil and grease for ATM 2 (160 mgL^{-1}) and ATM 4 (1540 mgL^{-1}) were higher compared to FEPA discharge limit. The chloride value for ATM 2 (367.5 mgL^{-1}) and ATM 4 (21 mgL^{-1}) were within the FEPA's dis-

charge limit for industrial effluent of 2000 mgL^{-1} . Source of chloride includes acids, sodium chlorite and sodium hyperchlorite. Sulphide values were very high.

The treatment process involves three main steps, namely:

- 1) Coagulation (additions of iron salts to form precipitate).
- 2) Aeration (application of oxygen to form sludge).
- 3) Filtration (removal of sludge) (Figure 2).

The result of percentage removal for investigated parameters is has shown in Table 7. TS have values of 86.8 and 15.1% for ATM 2 and ATM 4 respectively. The low percentage removal for ATM 4 was probably due to a slight technical fault at the activated sludge section as at the time of sampling. The percentage removal for COD was 42.9%, with actual value (200 mgL^{-1}) well above FEPA discharge of 50 mgL^{-1} . This value can be improved on by adsorbing the wastewater on activated carbon after chemical treatment. Oil and grease has the highest percentage reduction of 92.9% for ATM 2. The percentage reduction for Heavy metal was between 2.9 to 86.6%. Cr has the highest percentage removal of 86.6% which is due to effective coagulation ion while Pd has the lowest percentage removal of 2.9%. The concentration of Cd and Pd in ATM 2 and ATM 4 are all above FEPA Effluent discharge limit. Chloride has percentage reduction of 65.5% corresponding to an actual concentration of 367.5 mgL^{-1} , which is well below FEPA Effluent discharge limit.

Conclusion and Recommendation

One of the sources of surface and ground water pollution is discharge of partially treated wastewater directly into the surface water bodies. The results of physico-chemical parameters for treated wastewaters and percentage removal obtained from this study indicate that the wastewater treatment technique as practised by the company is inadequate to remove all the pollution loads generated.

In order to improve on efficiency of the wastewater treatment plant, the following technical and economical options can be adopted:

- i. Practice of batch activated sludge; to effectively remove COD, BOD and colours.
- ii. Replacement of hypochlorite with environmentally friendly/safe alternative, e.g. Peracetic acid, which decomposes to oxygen and acetic acid, which is completely biodegradable (Rott and Minke, 1999).
- iii. Increase capacity of treatment plant.
- iv. Combination of two or more techniques.
- v. Use of a one-step preparatory process for desizing, scouring and bleaching to reduce wastewater volume (Slokar and Majcen, 1997).

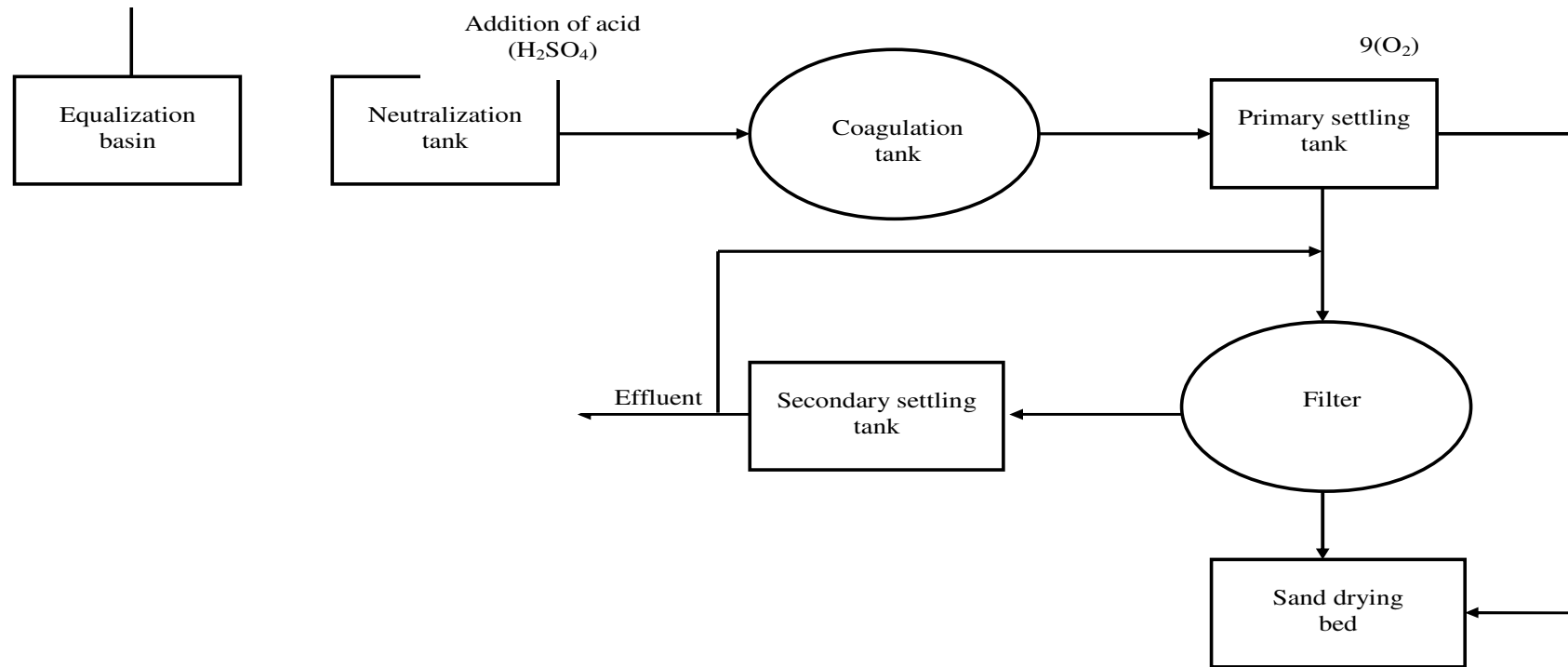


Figure 2. A flow diagram for treatment of wastewater within the company.

Table 7. Percentage reduction of treatment plant.

Parameter	Percentage reduction for dyeing and printing process	Percentage reduction for bleaching and scouring process
pH	45.2	20.3
Temp	55.7	27.9
TS	86.8	15.1
TSS	46.4	51.3
COD	42.9	-
Oil and grease	92.9	35.0
Cl	65.5	27.6
Sulphide	24.3	18.5
Cr	86.6	59.4
Cd	73.3	45.2
Pd	-	2.9

vi. Use of electrochemical mercerization (scouring) and bleaching of textile, which does require the conventional caustic soda, acids and bleaching agent.

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