PHYSICO CHEMICAL ANALYSIS OF TEXTILE INDUSTRIAL EFFLUENTS FROM TIRUPUR CITY, TN, INDIA

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ABSTRACT

The pollution load of the various textiles industrial effluents vary from time to time depends upon the dyes, impurities on the fabrics and other processing chemicals used for the dyeing. Five sampling points were identified from textile industries of Tirupur city, India (E1 to E5) and the study was carried out on the basis of field analysis and characterization studies. The major pollution indicating parameters like COD, BOD, TDS, SS, alkalinity, pH, total hardness, sulfate and chloride levels were analyzed. The effluent was highly turbid and coloured with average organic and inorganic loading. BOD_5/COD ratios ranged from 0.2-0.5 indicates that the effluent contained a large proportion of non-biodegradable organic matter. The effluent also contained high concentration of sulfate, chloride, calcium and magnesium, which are responsible for higher total hardness of effluent. Sample E4 shows high total hardness, alkalinity, pH and conductivity compare to all other effluents is needed much attention to find a suitable technology for the treatment. The effluents from the study area containing pollution indicating parameters considerably higher than the standards stipulated by the governmental authorities. Based on these characteristics, it is suggested that the effluent is not be suitable for discharge directly into aqueous bodies without treatment.

Keywords: Valkalinity, BOD, COD, Dyes, Effluent Characterization, TDS

I. INTRODUCTION

Textile industries are large industrial consumers of water as well as producers of wastewater. Increased demand for textile products, leads to increase in the generation of textile wastewater, which makes the textile industry as a main sources of severe pollution problems worldwide[1, 2]. The process of adding colour to the fibres is known as dyeing which normally requires large volumes of water not only in the dye bath, but also during the rinsing step. The process of dyeing involves the use of different chemicals like salts, metals, surfactants, sulphide and formaldehyde. There are more than 8,000 chemical products associated with the dyeing process and over 100,000 commercially available dyes exist with over 7×10^5 metric tons of dyestuff produced annually[3]. Nearly, 1,000-3,000 m^3 of water is let out after processing about 12-20 tonnes of textiles per day. These effluents are rich in dyes and chemicals, some of which are non-biodegradable and carcinogenic and pose a major threat to health and the environment if not properly treated[4].

Wastewater generated in different production steps of a textile mill have high pH, temperature, detergents, oil, suspended and dissolved solids, dispersants, leveling agents, toxic and non-biodegradable matter, color and alkalinity[5]. Important pollutants in textile effluent are mainly recalcitrant organics, color, toxicants and surfactants, chlorinated compounds (AOX). The textile wastewaters are characterized by extreme fluctuations in many parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), pH and colour[6].

Color in the effluent is one of the most obvious indicators of water pollution and the discharge of highly colored synthetic dye effluents is aesthetically displeasing and can damage the receiving water body by impeding penetration of light[7]. Dyes are recalcitrant molecules which are difficult to degrade biologically. Some of azo dyes are either toxic or mutagenic and carcinogenic[8]. Azo dyes are designed to resist chemical and microbial attacks and to be stable in light and during washing[9].

The diversity in composition of chemical reagents used in textile industries contributes to severe water pollution. A related topic having received considerable interest on the characterization of real time textile effluents from CETPs and dyeing industries at different time intervals. Complete characterization of effluents is essential to identify the suitable treatment method and in turn support the better design of treatment plant.

II. MATERIALS AND METHODS

2.1 Description of study area

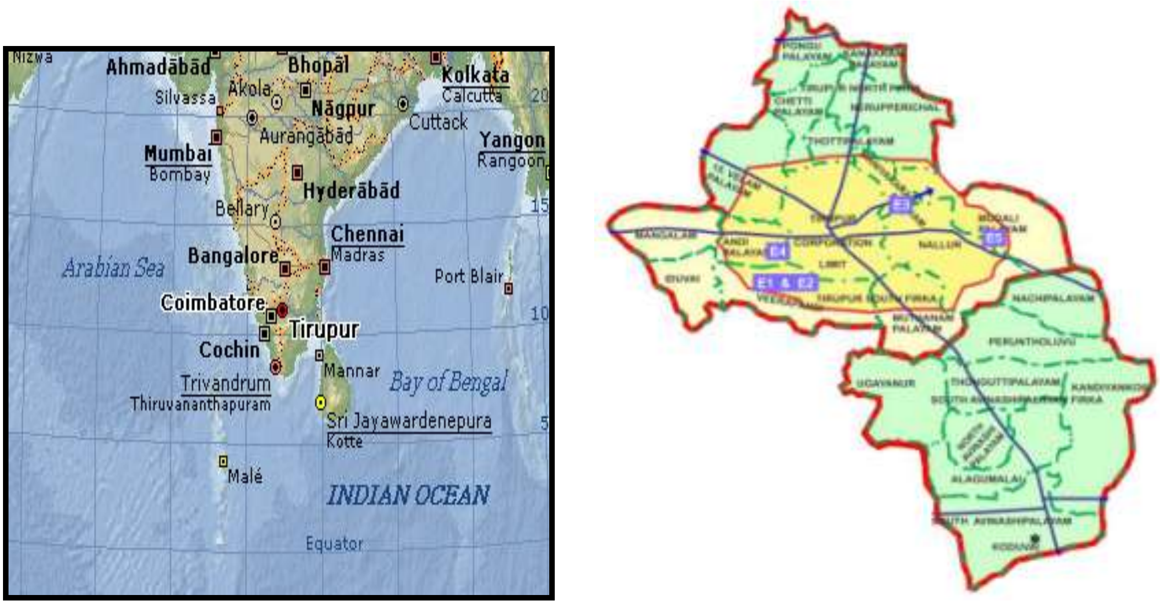

Fig 1.(a) (b)

(a) Tirupur Location map and (b) Sample collecting location at Tirupur city

The study area selected was Tirupur and itis a textile city in the South Indian state of Tamil Nadu, India (Fig.1). Tirupur is the knitwear industry hub of India and the city is now known as the 'Dollar City". This knitwear capital of India has 5 lakhs workers from various parts of India, Sri Lanka and Nepal. In the year 2012 – 2013 the export of knitwear fabric from Tirupur worth Rs.70312 crores.Tirupur, in India, (located 55 km to the east of Coimbatore City, Tamil Nadu) accounts for 90 % of India's cotton knitwear export. There are more than 2500 apparel manufacturing units and 750 dyeing units in Tirupur.

2.2 Sampling sites

Wastewater samples were taken from five textile industrial wastewater outlets, out of three samples from common effluent treatment plant (where the effluent enters into the common effluent treatment plant for the treatment) and two samples from dyeing industries outlets (before the treatment) Table: 1.

Table 1 List of Sampling Sites

Sample No.	Sampling Site
E1*	CETP, Veerapandi, Tirupur
E2*	CETP, Veerapandi, Tirupur
E3	CETP, Mannarai, Tirupur
E4	Sruthi Dyeing, Veerapandi Pirivu, Tiruppur
E5	Texwel Dyeing, SIDCO, Tirupur

* E1 & E2 were taken from same site but during different days

2.3 Instruments and chemicals

The pH of the wastewater samples was determined at the point of sampling using pH meter (Model: ELICO- LI 120). The pH electrode was calibrated using buffers of pH 4.0, 7.0 and 10.0. The electrode was immersed into the wastewater sample and reading was recorded. Conductivity was determined using a conductivity meter (Model: ELICO CM - 180).

Measurement of sulfate concentration was made using UV spectrophotometer (Model: ELICO-BL198 double-beam biospectro-photometer). Hach digestion device (Model: DRB200*:* Digital Reactor Block) and Hach spectrophotometer (Model: DR 3900 Benchtop Spectrophotometer) were also used to measure chemical oxygen demand (COD). For BOD measurement incubator (Model: Everflow Super Delux model) and Hach DO Analyser (Model: HQ430D with LBOD Probe) were used. All chemicals used were of high purity and analytical grade. At all times, fresh regents have been used and great care has been taken to avoid chemical contamination.

2.4 Sample collection, preparation and preservation of sample

Sampling, preparation and preservation precautions have been taken while collecting the effluent samples from the industries. All the samples collected in accordance with standard methods of sampling[10]. Five liter polyethene cans were properly washed with mild detergent and then leached with 1:1 HCl overnight. At the various sampling sites, the containers were rinsed several times with deionized water before the samples were collected at the point of discharge. Wastewater samples were collected from five different sampling sites of the textile dyeing industries for 24 hours after an interval of 4 hours. At each sampling time and sampling site two different sets of wastewater samples (one for COD and the other one for BOD measurement) were taken in two different 1000 mL bottles initially and then poured into other two different five liter cans to be kept for homogenization in order to take time interval composite wastewater samples from each sampling sites in all the working shifts. All wastewater samples were immediately stored in ice box containing well frozen ice cubes until they were taken to the laboratory where they were stored in refrigerator until analysis.

2.5 Analytical procedures

After collection, the samples were analyzed as soon as possible for all the parameters except pH, Electrical conductivity and DO which was measured *in-situ*. Physico-chemical parameters such as DO, pH, TDS, TSS, total alkalinity, total hardness, chloride and sulfate were determined according to standard procedures suitable for wastewater sample[10]. COD and BOD were determined using HACH kit method as per the manufacturer's manual. All data were recorded in triplicates.

III. RESULTS AND DISCUSSION

3.1 Colour

In the present investigation the colour of the untreated effluent was dark brownish to brown. Colour is very important factor for the aquatic life for making food from sun-rays. This photosynthesis activity reduced due to dark colouration is affecting other parameters like temperature D.O. and B.O.D. etc.

3.2 pH

pH is one of the important biotic factor that serves as an index for pollution. The factors like photosynthetic exposure to air, disposal of industrial water and domestic sewage affects pH. The wide narration in the pH value of effluent can affect the rate of biological reaction and survival of various microorganisms. The presence or absence of various ionic species can have direct relation with pH of the effluent. Subsequently such effluent can influence the quality of soil when the effluent is directly exposed to the soil. It is therefore necessary to evaluate effluent with respect to the pH value.

In the present investigation pH values in all of the five effluents sampling sites were found to be alkaline (Fig. 2). The pH values of the untreated effluents were ranged from 8.15 and 10.08. Rao et.al.,[11], also observed the pH of textile industry effluent varied from 5.0 to 11.0. pH value of the effluent was found to be significantly vary depends upon the dyes (acidic, basic and reactive dyes) and the materials (cotton, synthetic, etc.) of dying. For example, high pH denatures the protein fibers (such as wool and silks) and acid dyes (such as azo dyes, triarylmethane and anthraquinone). These dyes are applied to the fabrics along with acid solutions (Table:2)[12].

Table 2: Dyes for Different Fabric Materials [Ghaly et.al., (2014)]

S. No.	Materials	Type of Dyes used
1	Cellulose fibres	Reactive dyes, Direct dyes, Vat dyes, Sulphur dyes and Indigo dyes
2	Protein fibres	Azo dyes, Triarylmethane dyes and Anthraquinone dyes
3	Synthetic fibres	Disperse dyes, Direct dyes and Basic dyes

3.3 Alkalinity

Bicarbonates are directly related to total alkalinity i.e increase in carbonates and bicarbonates increases the total alkalinity. High pH values indicate alkalinity (bicarbonates) problem with sodium ion likely to be the dominant cation. Alkalinity of the effluent samples varied from 1475 mg/L to 5250 mg/L (Fig.2). Higher alkalinity is due to use of chemicals like Na_2CO_3, $NaHCO_3$ and NaOH, surfactants and sodium phosphate.

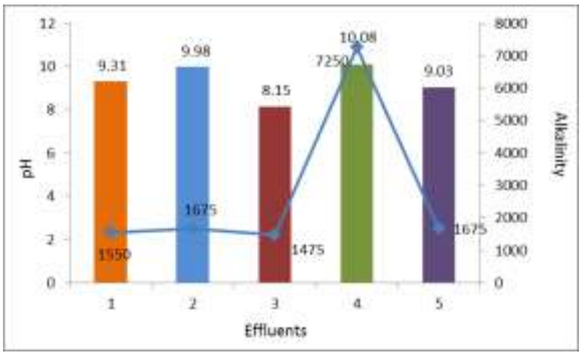

Fig.2 Variation of pH and alkalinity

3.4 Total suspended solids (TSS)

The TSS affect the light intensity of water, suspended solids are the cause of suspended particles inside the water body influencing turbidity and transparency. Devi[13], recorded total plankton, which showed a sterling parallelism with suspended solid. The mean TSS values of the textile effluents E1,E2, E3, E4 and E5 were 6230, 3600, 1800, 1400 and 3000 mg/L respectively (Fig. 3). The TSS values of effluent were found to differ significantly with Industries as well as with sampling days. The increased amount of TSS is due to increased chemical dosing dye fixation and partial dissolution of fibre materials. In other studies the amount of TSS in different textile wastewater samples was found to be in the range of 1020-3680 mg/L which is considerably lower than the results of our findings[14].

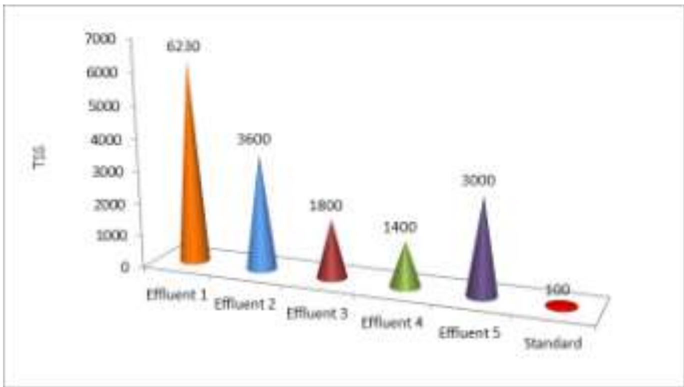

Fig.3 Variation of TSS on effluent samples

3.5 Total Dissolved Solids (TDS)

In the present study the total dissolved solids of untreated effluents E1 to E5 were 7100, 7060, 6120, 13000 mg/L and 7760 mg/L respectively (Fig. 4). The total dissolved solids in sugar mill effluent, tannery waste and textile industries were also reported in the level of 400 - 1650 ppm[15], 1000 - 2850 ppm[16] and 8500 – 15000 ppm[11] respectively. Generally textile industries shows higher TDS value than the other industries mainly due to the fixing, bleaching, dyeing agents, etc used during the processing of the fabrics on different stages.

3.6 Electrical Conductivity (EC)

Generally, electrical conductivity is a measure of the ability of water to pass on electrical current and is affected by the presence of dissolved solids. As the level of total dissolved solids (TDS) raises, the conductivity will also increases[17]. EC was found to be the range from 7.56 mS cm^{-1} to 14.79 mS cm^{-1} (Fig. 4). Water having high EC and TDS values can cause osmotic stress at the root zone of plants which makes it more difficult for a plant to absorb water for growth. Thus increased EC and TDS in irrigation water leads to lower crops production[18]. EC itself is not a human or aquatic health concern but it can serve as an indicator of other water quality problems.

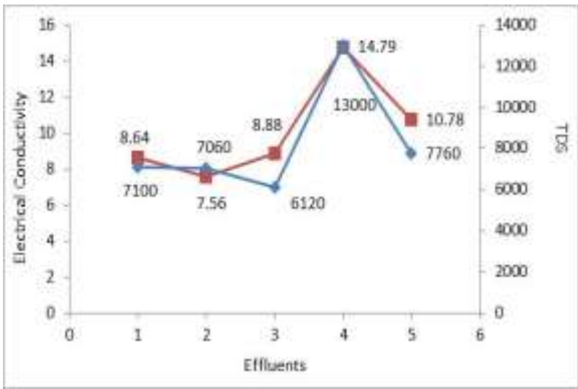

Fig.4 Variation of EC and TDS on effluent

3.7 Hardness

Divalent metallic cations particularly Ca^{+2}, Mg^{+2}, Sr^{+2}, and Fe^{+2} are responsible for hardness in textile effluents. Hardness of the effluent samples (E1 to E5) were found to be varied from 1280 to 3885 mg/L (Fig. 5). According to WHO, the maximum allowable limit of hardness is 500 mg/L. The high levels of hardness were observed in all the effluent samples. The amount of water pollution was found to be higher than the permissible limit (250 mg/L) as per EPA standard[19].

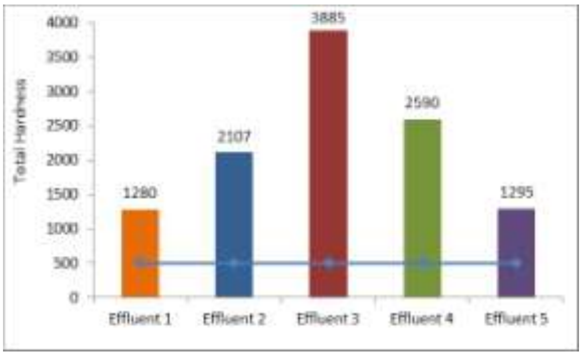

Fig.5 Variation of Total hardness

3.8 Chloride

Chloride (Cl^-) content present in the textile effluents varied from 145 to 1668 mg/L (Fig. 6). Chloride in wastewater comes mostly from raw water taken for dyeing and also it may added as a fixing agents for some of the dyes. Due to the high chloride content of wastewater disposed to the environment, leaf margins become scorched, leaves become smaller and thicker and overall plant growth is reduced. Chloride also contributes to the increase in TDS[20]. Chloride was found to be positively correlated with EC, TDS, TSS, alkalinity and sulfate. This was also good in agreement with our analysis.

3.9 Sulfate

Most natural water supplies contain sulfates (SO_4^{-2}), which is a colorless and odorless compound of sulfur and oxygen and exists as a dissolved salt in water. Sulfates can be more troublesome because they generally occur in greater concentrations. As per Table, the amount of sulfate ions in different textile effluent samples were found to be in the range of 960 - 6300 mg/l. The maximum amount of sulfate ions was found in E4 and that of minimum in E3. According to WHO, the maximum permissible concentration of sulfate is 400 mg/L(Fig. 6). As reported by Agarwal[21] the industrial wastewater containing sulfate ions should not be discharged into any water body from where water is supplied for drinking, as higher concentration of sulfate ions cause taste change in water, have a laxative effect on livestock and humans, and are usually associated with high hardness levels.

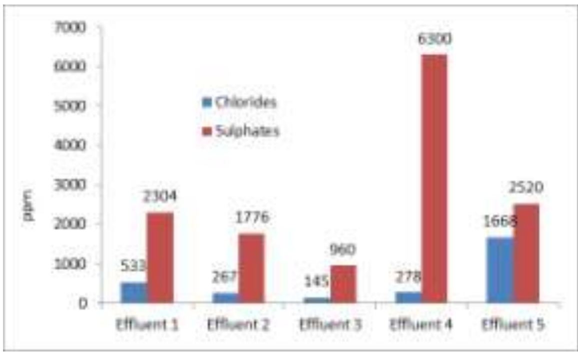

Fig.5 Variation of Chlorides and Sulfate

3.10 Biological Oxygen Demand (BOD)

Textile industries use organic substances as raw materials and high levels of dissolved organic matter consume large amounts of oxygen and increase BOD level, which undergoes anaerobic fermentation processes leading to formation of ammonia and organic acids. Hydrolysis of these acidic materials causes a decrease of water pH values[22]. BOD level of untreated textile effluents is 407 mg/L to 662 mg/L which is higher than the permissible limit (30 mg/L) of CPCB[23] (Fig.7). Increase in BOD which may cause hypoxia conditions with consequent adverse effects on aquatic biota.

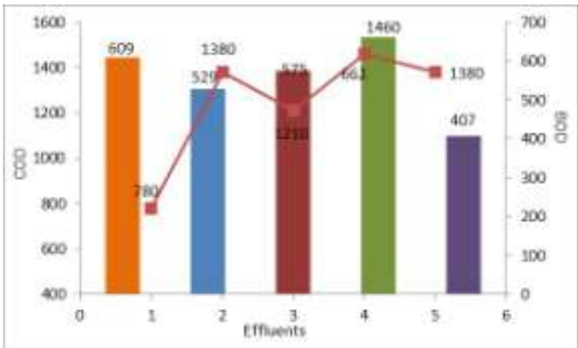

Fig.7 Variation of BOD and COD

3.11 Chemical Oxygen Demand (COD)

The COD levels obtained from the industries shows that detergents, softeners and impurities on the fabrics contributes a significant portion of the COD. Highest COD levels were obtained on dyeing indicating that in addition to fabric impurities removed during scouring or desizing and the contribution of detergents and softeners, residual dyes contributed a large proportion of the COD. COD of untreated textile effluents were varied from 780 mg/L to 1460 mg/L (Fig. 7) and this value of the COD is beyond the permissible limit (250mg/L) of CPCB [23]. This indicates that the effluents were unsuitable for the existence of aquatic organisms due to the reduction of DO content [24].

3.12 Treatment strategy

A BOD_5:COD ratio shows that the effluent consists of different types of organic constituents differing in the rate and ease of biodegradability. BOD_5:COD ratio greater than 0.5 indicates that the effluent contains a large proportion of easily biodegradable organic matter. The BOD_5:COD ratio values ranged from 0.2 – 0.4 indicates the low biodegradability of the textile effluents. The value ranges from 0.4 – 0.5 indicates average biodegradability of the effluent [25,26]. As from the table 3, sample E1 collected from the CETP, Veerapandi can be easily biodegradable and we suggest that the biological treatment process for purification. According to Grau[27], coagulation prior to biological treatment might be advantageous for alkaline wastewaters. But for effluent samples from other places E2 to E4 need both physico chemical treatments such as adsorption, ion-exchange, membrane technology, Electrocoagulation treatments etc. The Effluent sample E5 compulsorily need a physicochemical treatment to meet the CPCB norms before the discharge.

Table 3: BOD:COD ratio

Samples	BOD5:COD ratio
E1	0.78
E2	0.38
E3	0.48
E4	0.45
E5	0.29

IV CONCLUSION

From the present study, it can be concluded that the physicochemical parameters studied such as pH, sulfates, chlorides, alkalinity, hardness, TSS, TDS, EC, BOD and COD for the all untreated textile Industrial effluent samples collected from Tirupur region were found to be quite higher than the recommended values set by the CPCB.

Highest COD levels obtained from the textile industrial samples (E4, E2 & E5) shows that detergents, softeners and impurities on the fabrics contributes a significant portion of the COD. Highest levels of COD on dyeing indicating that in addition to fabric impurities removed during scouring or desizing and the contribution of detergents and softeners, residual dyes contributed a large proportion of the COD. TSS levels were highest on E1 mainly due to solid material removed during bio-stoning. Increase in chloride levels of the effluents for fabric dyeing operations due to high salt levels used to enhance dye exhaustion. Total alkalinity was highest on E4 indicating that the effluent was alkaline (pH=10.08) and lowest on E3 indicating slightly alkaline (pH = 8.15). High total alkalinity levels obtained for effluents as a result of the use of sodium carbonate as a scouring agent and caustic soda for the saponification of waxes, oils and soils during fabric washing operations.

E4 shows higher TDS, alkalinity, pH, conductivity and total hardness compared to all other samples indicates that much attention on suitable treatment methods to convert the non-biodegradable complex structure into biodegradable simple compounds, so as to reduce treatment time, cost and pollution load created. In such a case synergism of combining different treatment methods to find suitable technologies will help us to reach our goal. Waste minimization is of great importance in decreasing pollution load and production costs. Traditional technologies to treat textile wastewater include various combinations of biological, physical, and chemical methods, but these methods require high capital and operating costs. It appears that an ideal treatment process for satisfactory recycling and reuse of textile effluent water should involve the following steps.

1. Characterization of effluents (Discharge of effluents without treatment reflected in the quality of the ground water analysis [28,29]
2. Classification of the effluents on the basis its pollution load
3. A combination method such as (UV/Ozone, EC/Ozone, UV/TiO_2, UV/TiO_2/Ozone, etc) can be adopted suitably to minimize the treatment cost and increase its efficiency[30].

Hence from the results of the present study, physicochemical parameters obtained are higher than CPCB[23] permissible limits suggesting that untreated textile effluents should be treated or it should be diluted before disposal or it can be reused for the dyeing process, so that it does not hamper the environment.

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