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Research Paper

Physico-Chemical Parameters of Textile Dyeing Effluent and Its Impacts with Casestudy

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Abstract: *This study focused on the quality of textile dyeing effluent by analyze the physico-chemical parameters such as colour, pH, total hardness, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), turbidity, chlorides, sulphides, silica, calcium, iron, oil and grease of the effluent. The results of the analysis were correlated with the water quality standards of BIS (Bureau of Indian Standard). It was confirmed that all the parameters studied above guideline permissible limits excluding calcium, sulphide and iron. Also this paper included the case study of textile dyeing industry, Tirupur district, Tamilnadu, India and its impacts with suggestions and policies in terms to reduce pollution load on environment.*

Keywords: Effluent, physico-chemical parameters, case study, impacts, suggestions.

Introduction

Clothing and textiles, after agriculture, is the basic requirement of human being. India has a large network of textile industries of varying competence. In terms of its production and employment, the textile industry is one of the largest industries in the world[1]. India's second largest employment producing area is textile industry and about 35 million people both skilled and unskilled get direct employment as a result vast development in textiles. India's leading and oldest industrial sectors about 81% of total industries are located in Tamil Nadu, Gujarat, Punjab and Maharashtra[2] and estimating about 20% of the total industrial production. In the year 2010-11 India furnished a large production of textile about 325 lakh bales[3]. According to Ministry of Textiles, 2,500 textile weaving factories and 4,135 textile finishing factories are functioning in India. Textile industry plays a major role in Indian economical growth because in the year 2010, the share of textiles in total exports was 11.04% hence it partially fulfills the Indian economical thrust. The cynical effect of textile industry is, consuming dyes particularly harmful synthetic dye such as azo dyes for dyeing and coloring process. Ancient time's natural dyes are typically applied for dyeing process though these processes provided a limited range of colors on fabrics and it appears dull shade so these dyes are not much attractive by the people. The negative aspect of using natural dyes on fabric is easily faded when exposed to sunlight and washing as a result the synthetic dyes are successfully entered into the industrial market particularly textile industry. Synthetic dyes are complex substances most of them have produce an adverse effects on all forms of livings like soil, water, flora, fauna, livestock and human population.

Approximately calculating that 80,000 tons of dyes used in various industries such as food processing industries, cosmetics, paper mills etc but the textile division alone consumes about 60% of total dye production[4] for coloring a variety of fabrics and about 10–15% of unspent dyes are let out into the clean water bodies which makes the water highly coloured and polluted, typically with a concentration range 10–200 ppm[5,6].

Large quantities of water are needed for textile processing, dyeing and printing. Among these various processes, dyeing process includes fixing dyes on fabrics, washing etc requires more water[7] and it consumes 16% of total water usage depending on the type of dyes used and this dyeing sector contributes to 15% - 20% of the total waste water flow. According to WHO nearly 80% of water is polluted in developing country due to the dumping of domestic waste into aquatic bodies. Particularly in India almost 70% of the water has become polluted due to the discharge of domestic sewage and industrial effluents into natural water source, such as rivers, streams as well as lakes[8]. The colour, concentration of trace metals, nature of dyes, and characteristics of effluent vary from industry to industry based on the water utilization and every day manufacturing goods[9]. Major pollutants released from the textile industries are from the several of their wet-processing operations like scouring, bleaching, mercerizing and dyeing[10]. Cotton fabric production process and related water pollutants given in Table 1.

Table 1: Fabric production process and related water pollutants

Fabric production process	Water pollutants
Singering, Desizing	High BOD and total solids(TS)
Scouring	High BOD, total solids, alkalinity & temperature
Bleaching, Mercerizing	High BOD, total solids and alkaline wastewater
Heat-setting	Low BOD, low solids, alkaline wastewater
Dyeing, Printing & Finishing	-
Wasted dyes, Wastewater	High BOD, COD, TDS, TSS & TS

In textile manufacturing process, the industry uses a various chemicals such as sulphur, naphthol, vat dyes, nitrates, acetic acid, soaps, enzymes, chromium compounds and heavy metals like copper, arsenic, lead, cadmium, mercury, nickel, and cobalt and certain auxiliary chemicals. In addition to that harmful chemicals present in the water may be formaldehyde based dye fixing agents, chlorinated stain removers, hydro carbon based softeners, non bio degradable dyeing chemicals. Most of these chemicals are not retained in the finished products, but are discharged as wastewater. As a result, textile wastewater contain strong color, high temperature, more turbidity, broadly fluctuating pH, high COD and BOD concentration, large amount of suspended solids and total dissolved solids due to the presence of different pollutants within water environment[11]. Also these effluents are toxic and detrimental to environment and human health directly or indirectly Table 2.

Table 2: Chemicals used in textile processing and its adverse effects of unsafe disposal

Chemicals	Example	Cynical impacts
Detergents: Non-ionic detergent	Nonyl-Phenol Ethoylates	Non bio-degradable, generates toxic metabolites & highly poisonous to fish
Stain remover	Solvents like CCl_4	Ozone depletion (ten times more than CFC)
Rust stain remover	Oxalic acid	Toxic to aquatic organisms & increases COD
Sequestering agent	Polyphosphates like Trisodium Polyphosohate, Sodium hexameta phosphate etc.	Causes turbidity, increases TDS & prevents sunlight into water bodies hence hinders photosynthesis process
Printing gums	Pentachlorophenol	Dermatitis, liver, kidney damage & Carcinogenic
Fixing agent	Formaldehyde and Benzedrine	Harmful to all livings so internationally banned
Bleaching compounds	Chlorine powder	Itching and harmful to skin
Dyeing agents	Amino acid liberating groups	Carcinogenic so internationally banned

The present work is aimed to study physicochemical parameters of textile dyeing effluents and its impacts on environment with case study. The results of effluent correlated with BIS limits. Thus, the characteristics study of the effluent is important to determine its reprocessing of contaminated water by safe and appropriate techniques due to its high water consumption[12].

Area of study
The textile dyeing effluent is collected from the Textile city Tirupur, It is a Kongu Nadu region of Tamil Nadu, India for the present work.

Case Study
In the modernized world, industrialization is indispensable and considered to be a key role for the development of nation's wealth in terms of domestic employment and legal relationship between the countries by exchange of material goods. But the drawback of industrialization is pollution where the untreated effluents by all possible sources such as textile dyeing, leather tanning, paper and pulp processing, sugar manufacturing, etc. discharged directly into land or water bodies and polluting the surroundings. The one of the best example for polluted city in Tamilnadu is Tirupur. Tirupur is spread over 27.20 sq. kms and the seventh largest city in Tamil Nadu and 50kms from Coimbatore district, the Manchester of Southern India. The first knitting trade in Tirupur was started by Mr. Gulam Kadar in the year 1937. Today Tirupur is one of the leading cotton knitwear manufacturing swarm in South India both for overseas market and the domestic market and almost 80 per cent of India's cotton knitwear exports happening from Tirupur. Hence Tirupur is also called as the Knitwear city, Banian city, Small Japan, Dollar city[13] and T-Shirt city. There are 6,250 units involved in various operations of the textile industry and it includes 4900 knitting and stitching units, around 736 dyeing and bleaching units, 300 printing units, 100 embroidery units and 200 units catering to compacting, raising and calendering.

Among these units, the bleaching and dyeing units in textile processing are the two major units that require a large amount of water and the water requirement for dyeing process is around 106 liters/kg. However most of the water used by these units is `non- consumptive' and it is discharged as effluent after processing. For the last three decades the dyeing units located in and around Tirupur have polluting the "Noyyal", a non-perennial river that ends in the Cauvery, near Karur by discharging the harmful effluents into the river. Noyyal includes two major dam Orathuppalayam, Near Chennimalai, Tirupur district and Aathupalayam Dam, Near Vellakoil, Karur district specially constructed in the aim of irrigation about 20,000 acres of land in Tirupur and Karur districts. During the period 1980's the villages in the region of Noyyal river basin was a productive land for paddy, sugarcane, cotton, turmeric, banana, oil seeds etc. At present the river Noyyal and Orathuppalayam dam is a place for dumping of toxic effluent as a result the water is said to be dead or black water. In addition, about 1500 tonnes of colouring agents are used each year, nearly 75,000 m^3 of textile effluents are being let out into the river Noyyal every day and into various sewage systems[14]. (Figure 1)

The untreated waste water effluent near the point of disposal, create foul smell [15] so people are living near the sampling site more disturbed. According to TNPCB the total dissolved solids (TDS) in the water discharged into the river should not be more than 2,100 parts per million (ppm) but the TDS level of water in the Orathupalayam dam area is above 9,000 ppm. During summer the level of TDS is high and also local groundwater is becoming brackish and significantly harder due to more water evaporation for the past two decades. In detail, higher concentrations of pollutants mainly organic matter in river water cause an increase in biological oxygen demand[15], chemical oxygen demand, total dissolved solids, total suspended solids as a result the water is unfit for drinking, irrigation[16] or any other purposes and the people in Noyyal river basin are very much frustrated due to large consumption of contaminated waste water.

Figure 1: Textile industrial waste water spreading on land and aquatic system

Almost all major industries possess their own treatment facilities for decontaminate the industrial effluents excluding small scale industries as their profit is meager. Therefore in India there are adequate proof and datas available regarding mismanagement of Industrial waste[17-19]. There are some common industrial effluent treatment methods[20] available for waste water treatment includes physical, chemical and biological methods (Table 3). The spotlight of these methods are, first converting the colored compounds in water into sludge and solid supports finally it completely devastated the dye molecule. Moreover reverse osmosis process and biological methods may also be considered to clean the polluted water. During water treatment process, instead of using hypochlorite, peracetic acid is a suitable alternative and environmentally friendly bleaching chemical because it is easily decomposes to oxygen and acetic acid, which is completely biodegradable[21].

Table 3: Common effluent treatment methods

Physical treatment	Chemical treatment	Biological treatment
Sedimentation	Neutralization	Stabilization
Filtration	Reduction	Aerated lagoons
Floatation	Oxidation	Trickling filters
Foam fractionation	Catalysis	Activated sludge
Coagulation	Ion Exchange	Anaerobic digestion
Reverse osmosis	Electrolysis	Fungal treatment
Solvent extraction	Flocculation	Stabilization
Ionization radiation	-	-
Adsorption	-	-
Incineration	-	-
Distillation	-	-
Membrane treatment	-	-

There are several government policies and private organizations available to reduce the dumping of effluent into water bodies and cleaning of contaminated water by suitable treatment methods. According to the Water (Prevention and Control of Pollution) Act of 1974, all textile and dyeing industries are necessary to get permission to discharge its effluent into water systems. As per the order of Madras High Court, Zero Liquid Discharge (ZLD) should be strictly followed in Tirupur knitwear cluster during the effluent treatment process. From 2004 onwards, the local volunteer organization like Siruthuli is taking more efforts to protect the clean water resource. Moreover out of the 736 units, 278 are treating 38 MLD of effluents through 20 Common Effluent Treatment Plants (CEPTs) and more than 400 are treating 45 MLD of effluents through Individual Effluent Treatment Plants (IETPs). Presently Government has initiated to clean the river which is a good impact to the people living in tirupur area but it has to be finished quickly and to monitor continuously. But the main solution regarding this issue is the authorities will not permit any more new processing industries in and around Tirupur region.

Material and Methods

The effluent sample was collected in cleaned plastic container and it was subjected to physico- chemical parameters by using standard procedures[22-26]. The methodology of this study is represented in Table 4.

Table 4: Methodology of the study using standard procedures

Physico-chemical parameters	Methods
Colour , Hazen	Spectrophotometer, Merck
pH at 30^0 C	pH meter, Merck
Total Hardness	Complexometric titration
BOD, mg/l	Incubating the sample at 30^0C for 5 days followed by titration
COD, mg/l	Closed reflux method
TDS, mg/l	Gravimetric, oven drying at 105° C
TSS, mg/l	Gravimetric, oven drying at 105° C
Turbidity, NTU	Nephlometer
Chlorides, as Cl-, mg/l	Argentometric titration
Sulphides, as S2-, mg/l	Iodometric method
Silica, as SiO2, mg/l	Spectrophotometer, Merck
Calcium, as Ca, mg/l	Complexometric titration
Iron, as Fe, mg/l	Spectrophotometer, Merck
Oil and grease, mg/l	Partition-gravimetric method

Results and Discussion

It is important to study all features of the textile effluent to improve environmental performance and also to sustain considerable quality of the individual companies. The physico- chemical parameters of textile effluent have been analyzed and the experimental results compared with standard BIS limits. The results of the analysis are presented in Table 5.

Table 5: Results of the physico - chemical parameters of textile effluent and compared with BIS limits

Parameters	Observed Values	BIS Limits
Colour , Hazen	5200	25
pH at 30^0 C	8.66	5.5-9
Total Hardness	970	500
BOD, mg/l	970	100
COD, mg/l	3080	250
TDS, mg/l	242220	2,100
TSS, mg/l	7116	100
Turbidity, NTU	81.5	10
Chlorides, as Cl-, mg/l	42487	600
Sulphides, as S2-, mg/l	0.46	2
Silica, as SiO2, mg/l	1087	250
Calcium, as Ca, mg/l	172.3	200
Iron, as Fe, mg/l	0.16	3
Oil and grease, mg/l	18	10

Colour

Colour of the effluent is one of the major problems in textile industry and it is widely accepted primary pollutant in wastewater. In fact colour in the effluent is easily visible to human eyes even at very low concentration and no one likes the appearance of dirty water. The effluent selected for the present study is brownish green colour and colour units were found to be 5200 on Pt-Co scale. This value indicates that the effluent was highly colored due to presence of different dyes, colour producing compounds and metals, pH of the effluent and temperature during dyeing and bleaching of fabrics. Sometimes the factors, pH and temperature makes the water highly coloured because that do not allow the chromophore group to disintegrate during dyeing process. Colour diminishes the photosynthesis activity of aquatic life and it affects other parameters such as DO, BOD etc. In general colour is difficult to remove by the conventional treatment methods. Hence adsorption process by activated carbon is one of best method to remove colour in the effluent.

pH

The acidic and basic nature of the effluent can be identified by pH value and it is also determines the presence or absence of various ionic species of the textile effluent. In general the majority of the chemical reactions are controlled by altering the value of pH. For example most of the metals become soluble in water at low pH and insoluble at high pH. From table 5, pH of the sample was found to be 8.66 which are alkaline may be due to nature of dyes such as acidic, basic and reactive dyes and the materials like cotton, synthetic, etc. of dying used for dyeing process (Table 6). The toxicity of water also gets increased due to changing the value of water pH for example water with pH value of about 10 are exceptional and may be a sign of pollution by strong bases such as NaOH and $Ca(OH)_2$[27]. Hence low or high strength of the pH in effluent can affect the quality of clean water and alters the rate of biological reaction with survival of various microorganisms. The strength of the pH also alters the soil permeability which results in contaminating underground water resources[28]. As a result it is necessary to evaluate the effluent with respect to pH value then it can be neutralized with acidic or basic solution.

Total Hardness

Divalent metallic cations particularly Ca^{+2}, Mg^{+2}, Sr^{+2} and Fe^{+2} are accountable for hardness in textile effluents. Hardness of the effluent samples was observed as 970 mg/L. According to WHO, the maximum acceptable limit of hardness is 500 mg/L. The total hardness of samples is above the permissible limit which indicates that the water is hard and most of the dyes get precipitated as a result the water is highly turbid and more polluted. Therefore, the water softening method is carried out before its discharge into the receiving bodies.

Biological Oxygen Demand (BOD)

The BOD is due to the presence of organic contaminants of textile effluents in water bodies. The low or nil BOD shows good quality water, whereas a high BOD indicates the water is highly contaminated and not suggested for drinking purposes. The experimental data of present work shows 970 mg/L BOD. It is found to be exceeds the permissible limit. It is suggested that, the effluent water undergoes anaerobic fermentation processes as a result formation of ammonia and organic acids. Hydrolysis of these acidic materials causes a decrease of pH value which in turn changes the water as more acidic. Moreover increase in BOD leads to microbial oxygen demand causes reducing DO which may induce hypoxia conditions with subsequent adverse effects on aquatic biota[30]. BOD, COD and DO are interrelated when higher COD in effluent induces the BOD as a result it consumes more oxygen in the water hence aquatic organisms become suffocate, and die.

Chemical Oxygen Demand (COD)

From table 1, the maximum COD value was recorded as 3080 mg/L. Commonly, organic strength of the effluent can be identified by COD values. Increases in COD can be due to huge amount of industrial wastes such as detergents, softeners, non biodegradable dyeing chemicals, formaldehyde based dye fixing agents etc. Higher concentration of COD in water implies toxic conditions and the presence of biologically resistant organic substances. Hence the effluent is incompatible for the survival of water living organisms due to the reduction of DO content[31].

Total Dissolved Solids (TDS)

From the experiment, the amount of substance dissolved into the effluent is 242220 mg/L. Generally textile industries shows higher TDS value than the other industries mainly due to the fixing, bleaching and dyeing agents used for fabric processing on different stages. The high TDS value of water not recommended for drinking and irrigation purposes as it may cause salinity problem.

Total suspended solids (TSS)

It consists of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, organic matter, salt and other particles. The TSS value of effluent was found to be 7116 mg/L which is beyond the permissible limit. The highest amount of TSS is due to increased suspended particles in effluent which shows increasing turbidity of water bodies and it depletes the oxygen level in water system as a result disturbing the process of food chain in aquatic medium.

Turbidity

The cloudiness nature of water measured in Nephelometric turbidity unit. Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates. It is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Higher the intensity of scattered lights higher the turbidity. The value for turbidity is recorded as 81.5 NTU which have been found to be higher than the BIS limit. Some cases colour, more total suspended solids and oily scum incorporate with colloidal matter increases the turbidity which gives bad appearance and foul smell. Moreover it prevents the penetration of sunlight and oxygen transfer process with marine water as a result the process of photosynthesis is hindered. Thus turbidity should be measured and treated carefully before their final disposal.

Chloride

In the present study the amount of chloride was recorded as 42487 mg/L which exceeds the BIS limits. The high value of chloride may be due to use of chlorine compounds such as hydrochloric acid, hypochloric acid and chlorine gas in various processes[32] like bleaching, washing and disinfecting agents. Excess chloride (> 250 mg/L) gives a salty taste to water and people who are more consumption of high chloride water may be subjected to adverse effects and also it leads to high corrosiveness to metallic pipes. Mainly high chloride water destroy some microorganisms which are necessary to maintain food chains in aquatic life[33] and it was found to be favour to EC, TDS, TSS, alkalinity and sulfate. Hence avoid the excess usage of chlorine in textile processing.

Silica

The higher value of silica is recorded as 1087 mg/L and these values have been commonly accepted as a measure of pollution effect. In excess of silica makes water turbid and increases salinity problem as a result the water is unfit for domestic and irrigation purposes. Therefore the effluent water should be treated before it is discharged into the water bodies.

Sulphides, Calcium and Iron

In the present investigation, sulphides, calcium and iron in textile effluents are measured as 0.46, 172.3 and 0.16 mg/L respectively. These values are lower than the permissible limits.

Oil and Grease

It is defined as a group of related materials rather than a specific chemical compound extractable by certain solvents, such as hexane[34-36]. They are non-polar and hydrophobic in nature[36]. From table 1, oil and grease value is recorded as 18 mg/L which is quite higher than BIS limits. The presence of oil and grease in water bodies leads to the formation of oil layer, which causes significant environmental problem such as reduction of light penetration into water system therefore photosynthesis process for water living organism is hindered. Besides, it prevents transfer of oxygen from atmosphere to water medium as a result reduces the amount of dissolved oxygen (DO) at the bottom of the water bodies[37] and disturbs the process of food chain in the aquatic life. In animals, oil coating can eradicate the padding properties of fur and feathers. Thus detergents spill over water to remove oil layer but it creates foaming, and can harm to invertebrates and fish as they are a major source of phosphates. Hence oil and grease in water is a major environmental problem, therefore several strategies adopted for minimal usage in textile processing and treated cautiously before their final disposal into water bodies.

Conclusion

In Tamilnadu, particularly in Tirupur the textile industries are growing fast due to its several advantages but on the other hand it is one of the root causes for environmental pollution. In general, the textile industry releases an ample of pollutants from all stages in the processing of fibers and fabrics. Amongst various industries, Central Pollution Control Board has listed the dye and dye intermediates industry as one of the profoundly polluting industries[38]. The present study clearly enlightens the physico-chemical parameters of the textile effluent, which is highly useful to analyze the nature and types of pollutant concentration present in the effluent and this study gives an idea to treat the effluent by suitable treatment methods. Based on the above experimental evidences it is concluded that all the parameters are high in concentration than the standards given by BIS except calcium, sulfide, and iron. Hence the higher values are considered to be threatening to environment as a result it is suggested that the dumping of effluents without ideal treatment should be avoided. Constant monitoring of water quality and adopted policies by CPCB is necessary to avoid further dreadful conditions. The central pollution control board in coordinating with state board is planning to dump all dying effluents into deep sea through pipe line from Tirupur and working out the cost analysis. Our state government may possibly involve in feasible studies and may allot funds for the proposal which may a permanent solution for both the people of Tirupur area and manufacturers of garments. By and large the finding of the studies implies that the effluents are toxic in nature and needed imperative treatment before disposal on water bodies to create pollution less and Eco-friendly environment in the region of all textile cities.

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