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Integrated Adsorption–Coagulation and Naofiltration of Textile Effluent Using Three-stage Filtration Unit

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Abstract

Treatment of textile effluent using biomaterials extracted from the waste materials has gained attention nowadays.This research mainly aims to treat textile effluent csollected from the discharge unit using three-stage treatment process. Primary tank contains matrices made of coarse crab shell, luffa sponge and carbon pieces. Second treatment tank consists of magnetic composites made of activated carbon and chitosan. Combined adsorption-coagulation process is followed at the second under different optimized operational parameters such as pH, solute concentration, solvent concentration, temperature, etc. Tertiary treatment tank contains nanofibers made of HTCC where the final treatment and removal of micropollutant occurs. Physiochemical analyses of pre- and post-treatmented effluent at each stage of treatment are carried out to examine the quality of treatment tanks and the results are discussed.

1. Introduction

The textile industry is one of the important industrial sectors which has significant economic value. India has a widespread network of textile industries throughout the country, i.e., approx. 10,000 garment industries and about 2,100 bleaching and dyeing industries (Nagajyothi et al, 2010). Quantity of textile effluent is comparatively high when compared to other industries and the quantity of organic compounds are also considerably high that cannot be easily removed by in single step. This characteristic may be due to the high quantity of dyestuffs, surfactants, and additives. Several physiochemical parameters used to qualify water are also highly altered in textile effluent and it is usually characterized by strongly colored, high TSS, fluctuating pH and it differs according to the type of dyes used, high temperature, high COD, BOD, etc. (Mondal et al, 2011; Garg et al, 2008). Textile effluent generally contains 20 to 50% of reactive dyes, 30 to 40% of sulphur dyes, 5 to 10% of azoic dyes, 5 to 20% of vat dyes and 7 to 20% of disperse acid dyes, 2 to 3% of basic dyes and 1 to 2% of pigment dyes (Ghaly et al, 2015; http://www.dyespigments.com/textile dyes.html).

When such threatful effluent contacts nearby water bodies, it ultimately affects the aesthetic nature and also hinders the sunlight and oxygen to reach the deep living aquatic biota and stops the photosynthetic activity. As a result, the ecosystem is completely destroyed (Namasivayam et al, 2001). Therefore, removal of toxic materials from the effluent is indispensible. With the advancement in technology, several methods are followed for effluent treatment such as adsorption (O'Neill et al, 1999); Bansal et al, (2005) and Eliassen. and Bennet, (1967) coagulation/ flocculation/precipitation; Nabi Bidhendi et al, (2007) polyelectrolyte; (Anjaneyulee et al, (2005) biological process; Babel S and Opiso (2007) ionizing/gamma radiation. Considering many advantages, among these techniques, this research aims to treat textile effluent using combined adsorption-coagulation and nanofiltration methods due its cost-effectiveness and time-efficiency.

In this research, three consecutive stages, i.e., primary, secondary and tertiary treatment were followed to treat original textile effluent. Primary treatment is a primary stage where coarse matrixes made of chitosan, luffa sponge and activated carbon were used to separate large and visible contaminants from the effluent. In secondary treatment, the actual treatment occurs by adsoption-coagulation using magnetic composites made of chitosan and activated carbon under optimized conditions; therefore, they can be easily scaled up from laboratory to industry scale. Tertiary treatment includes disinfection and removal of the remaining micropollutants by nanofiltration made of HTCC.

2. Materials and Methods

2.1. Collection of the Effluent

The effluent sample was collected from the final outlet discharge unit in and around Tiruppur, Tamil Nadu. The samples were collected in non-reactive and hygienic plastic containers and carried to the laboratory for analysis and further treatment procedures

2.2. Analysis of samples

For the collected samples, different physiochemical analyses such as pH, turbidity, EC, TDS, TSS, COD, etc., were analyzed from the standard methods (Arnold *et al.,* 1992). Hardness of effluent was estimated by EDTA titrimetric method (Arnold *et al*., 1992) and chloride and sulphates determined using Argentometric and Volumetric methods as stated by Rump & Krist, 1992.

2. 3. Experimental Setup

In this research, the three-stage treatment method was followed which contains primary, secondary, and tertiary treatment unit.

3. Results and Discussion

Experimental setup is shown in table, which contains inlet, primary treatment tank, secondary treatment tank, nanofiltraion unit, and collector.

3.1 Primary treatment tank

The lab setup of the primary settlement tank is cylindrical in shape. The height and width of the tank are 30 and 20, respectively. The primary tank is tightly packed with coarse crab shells, luffa sponge, and coarse carbon rods. The height of the matrix is about 20 cm. On the top of the tank there is an inlet tube. At a time, the tank was filled with 5 liters of effluent. The main intention at this stage is to trap and remove organic and inorganic solids between the matrixes by sedimentation. The effluent is again collected at the bottom of the tank and transferred to the secondary tank using peristaltic pump for further process. During this process, coarse materials from the raw effluent are removed which can block the pipes and sewer lines. Effluent retention time in the primary treatment tank was 8 hours.

3.2 Secondary treatment

In this stage, magnetic composite made of activated carbon and chitosan were used to treat the effluent through single step adsorption-coagulation method. pH of the unit fixed to 6, composite concentration as 4g/l, temperature of the unit as about 75C for the duration of 90 min and the The speed rotation was optimized to 100rpm for constant adsorption and coagulation, because above that speed the disturbance and redispersion of the floc may occur. The main aim of secondary treatment is to further reduce the organic, i.e., BOD and COD and other toxic substances untreated in the effluent after the primary treatment, and therefore to satisfy the standards fixed for textile effluent before discharging into surface waters such as rivers and lakes.

Coagulation is one of the most important treatment methods of dye-containing wastewater due to its cost-effectiveness (Anjaneyulu et al., 2005; Golob et al., 2005) and is accomplished by the adding opposite charge to that of the colloidal particles in the media. Using coagulation pigmented or dyed water can be discolored including wide variety of dyes. These days, coagulation using biopolymers is widely applied and an efficient method for industrial wastewater treatment. Chitosan acts as a promising bioflocculant that can be used for removing both particulate and dissolved substances in waste water (Renault et al., 2009). Among several biopolymers, chitosan is widely used in coagulation process of wastewater treatment due to its advantage of being a non-toxic and non-corrosive material and therefore it is safe to handle (Bolto and Gregory, 2007; Bratby, 2007). The protonization of amino groups in chitosan makes it positively charged in the solution and makes it very effective material for coagulation through different kinds of binding applications. Numerous works also evidenced that chitosan can also involved in a dual mechanism of coagulation by charge neutralisation and flocculation by bridging mechanism (No and Meyers, 2000; Guibal and Roussy, 2007).

Adsorption is a surface phenomenon for removing organic and inorganic pollutants from the medium. Absorbable solutes in the effluents when contact the adsorbent with a highly porous surface, liquid–solid intermolecular forces of attraction will result in deposition of some of the solute molecules from the water the solid surface of adsorbent. This method fulfilled many researchers need of treating and removing pollutants, both organic and inorganic, from the wastewater. These days, activated carbon is widely used for adsorption process since they posses high degree of porosity and an extended surface area (Bansal and Goyal, 2005). Organic pollutants including pesticides, herbicides, aromatic solvents, polynuclear aromatics, chlorinated aromatics, phenolics, chlorinated solvents, high-molecular-weight (HMW) aliphatic acids and aromatic acids, HMW amines and aromatic amines, fuels, esters, ethers, alcohols, surfactants, and soluble organic dyes can be adsorbed onto the activated carbon surface. Usually, adsorption process will be carried out after various physicochemical treatment steps such as coagulation/clarification, filtration, and dissolved air flotation, etc.

In this research, one step treatment of textile effluent by integrating adsorption and coagulation methods were carried out. Chitosan from crab shell was used as a coagulant and activated carbon from luffa sponge was used as an adsorbent.

Adsorption and coagulation process gained the attention of researchers due to its time-, money-, cost-effectiveness. Several studies evidenced the advantages of adsorption-coagulation method as follows. Stukenberg (1975) in his research treated wastewater in single step using adsorption-coagulation. Asadullah and Rathnasiri (2015) treated palm oil effluent using adsorption-coagulation method and also stated that separate adsorption or coagulation process is not the effective method for effluent treatment but a combined coagulation-adsorption processes are the most effective one. Reactive dyes in the synthetic wastewater were treated by a combined coagulation/ carbon adsorption process by Papic et al. Jessica Margaret Younker (2015) in her research also clearly inferred the advantage of using integrated coagulation-adsorption for the treatment of oily waste water. Shen et al, 2002 also used organo-bentonite for adsorption-flocculation method to remove phenol from the water. Shah et al (2013) in their work evidenced the advantages of coagulation-adsorption hybrid process in the treatment of dye and pigmented waste water. Asad and Rathnasiri (2015) also used coagulation and adsorption process for treating palm oil effluent. Also Dziubek and Kowal (2008) treated waste water by coagulation-adsorption using dolomite.

Results of this research also clearly infer that integrated adsorption-coagulation method using magnetic composites in secondary treatment is very effective in removing organic and inorganic pollutants from the textile effluent may be due to the synergistic effect of coagulation and adsorption processes.

3. 3. Tertiary treatment

Seconday treated textile effluent as finally passed into the nanofiltration unit and physiochemical analyses of post-treated water was carried out.

Nanofiltration is a pressure-driven membrane process for liquid-phase separations where molecules are removed by both sieving mechanism and charge effect between membrane and ions in water (Thanuttamavong et al., 2001, 2002) and it has more advantages than reverse osmosis in terms of lower energy consumption and higher flux rates as reported by (Cadotte et al., 1988; Gozalvez et al., 2002). Studies of Ledakowicz et al., (2001), Ahmad et al., (2002), etc., also reported in their work the efficiency of nanofiber in dye removal from textile wastewater.

4. Physiochemical characterization of textile effluent

Freshly collected sample from the outlet was used for various physiochemical analysis and the results of pre- and post-treated effluents are shown in Table 1. Several physiochemical studies were carried out in order to examine the treatment rate at primary and secondary tanks. Throughout the experiment, effluent retention time in the primary treatment tank was optimized to 8 hours and was then slowly collected for the secondary treatment.

4.1. Colour

One of the major problems faced by the textile industry is the colour. Colour of the effluent is a straightforward indication for pollution level and discharge of intensely coloured effluent has drastic effects on the receiving water directly (Rajeswari *et al.,* 2013). Thus when discharged untreated, it may reduce the rate of photosynthesis of the aquatic life which in turn affects other parameters like temperature, DO, and BOD. In this study, the freshly collected effluent was brownish black in colour and the colour units were found to be 5200 on Pt-Co scale. Studies of Alaguprathana and Poonkothai , 2015; Ogunlaja and Aemere, (2009); and Arul *et al.* (2011) also evidenced the same color of the textile effluent. Therefore, the value proved that the effluent was highly colored due to synthetic different dyes used at the time of processing. Temperature and pH of the effluent may also cause high coloured since they do not allow the chromophore group to disintegrate during dyeing process; Table 1 shows the primary, secondary, and tertiary treated waters, respectively. We can observe significant reduction in the color of effluent after the adsorption process by magnetic composites when compared to the raw effluent. Therefore, the experimental setup was effective in reducing the color of the effluent. After primary treatment, there was no significant change in the color; but after secondary treatment, the color changed from brownish black to pale colored. Finally, after nanofiltration, the water was transparent. Robinson et al, 2001; Namasivayam et al, 2004; Bhattacharyya K.G, 2003, etc., also evidenced that adsorption is the efficient process to remove color from the textile dye.

4.2. **pH**

Determining pH of the effluent is very important during the treatment process because the chemical reactions are greatly controlled by ionic nature of the solution. pH is the main biotic factor and is also an index for pollution(Buckly, 1992). Therefore, little change in pH could greatly affect the biological reaction and also the life of various microorganisms. Various ionic species of the textile effluent of the effluent can be identified by the acidic and basic natures of the effluent. Difference in pH also changes the soil permeability that may contaminate underground water resources (Sukumaran et al, 2008; Edmund, 1998).

Table 1, shows the pH value of raw, primary and secondary treated textile effluent. Raw effluent was highly alkaline with pH 10.7, which was higher than the BIS limit, i.e., 5.5 to 9, as reported by Thorat and Wagh (1999) and Sivakumar *et al.* (2011), etc., due to the presence of acidic, basic, and reactive dyes. pH of the primary treated water was found to be unaltered but after the secondary treatment pH of the effluent significantly reduced to 7.8 which is more or less neutral and was within the BIS limit, After tertiary treatment, nanofiltration, pH of the nanofiber was about 7.2.

4.3. **Total Hardness**

Divalent metallic cations such as Ca+2, Mg+2, Sr+2 and Fe+2 are the reasons for the amount hardness in textile effluents. According to BIS, the maximum acceptable limit of hardness is 250 mg/L, whereas hardness of the freshly collected raw effluent was found to be 712 mg/L. Therefore, we can observe that the total hardness of the effluent is several fold significantly high than the permissible limit; this may lead to precipitation of most of the dyes on the surface of water and thereof the water becomes highly turbid and polluted more. Ohioma *et al.* (2009) also obtained similar results. Table 1 shows the total hardness of the effluent after primary, secondary, and tertiary treatments and we can infer that there is no or very least amount of treatment had occurred at primary treatment, i.e., hardness reduced from 712 to 698 mg/L, whereas significant treatment had occurred in secondary and tertiary treatments, viz., total hardness reduced from 698 to 312 mg/l after due to effective adsorption of magnetic composites and finally it reduced to 103 mg/l after nanofiltration. Similar results were also evidenced by Abdulaziz et al, 2016; Kurapati Srinivas, 2016; Seyed Shahin Homaeigoha, 2011, etc., that nanofibers can effectively reduce hardness of the water.

4. 4. **Alkalinity**

Alkalinity of the water is the ability of water to resist pH change upon addition of acid, i.e., acid-neutralizing capability (Mohabansi *et al.,* 2011). Alkalinity has buffering capacity on the water systems and it is the must be monitored in all effluents. High alkalinity may be due to the presence of weak and strong base such as carbonates, bicarbonates, hydroxides, borates, phosphates, silicates, etc., used while processing and dying. Alkalinity of the freshly collected effluent was about 1430 mg/l, whereas the BIS allowed alkalinity of the textile effluent is 200 to 600 mg/L, therefore alkalinity was fivefold higher in the effluent, which was also evidenced by Mohabansi *et al.* (2011). Effluent with high alkalinity when discharged untreated it will affect the mucous membrane of grazing animals and thus may lead to metabolic alkalosis.

Alkalinity of the wastewater greatly reduced at the secondary treatment from 1430 to 531 mg/L, i.e., about 70 % of the treatment occured; after nanofiltration, the alkalinity of the effluent reduced to 27mg/L.

4.5. Biological Oxygen Demand (BOD)

Effluent from the textile industries contains many organic substances because large amount synthetic dyes used for coloring and processing contain more amounts of organic components that can consume large amounts of oxygen which in turn increases the BOD level. With increased BOD level, anaerobic fermentation occurs that leads to the formation of ammonia and organic acids and reduce the pH of water bodies. Moreover, increase in BOD leads to microbial oxygen demand causes reducing DO which may induce hypoxia conditions with subsequent adverse effects on aquatic biota (Goel, 1997). 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. According to BIS, the permissible amount of BOD is 100 mg/L. BOD of the freshly collected effluent was about 970 mg/L, which was several folds higher than the permissible limit. Table 1shows BOD of the raw, primary treated and secondary treated effluent. After the primary treatment BOD decreased from 892 to 697mg/l and after the secondary treatment, BOD value was about 92 mg/L, which falls below the permitted BIS value, 100 mg/L; and finally, BOD of the effluent reduced to 36 mg/L after nanofiltration. From the results, we can infer that using the experimental setup of this research, BOD of the effluent can be greatly reduced.

4.6. Chemical Oxygen Demand (COD)

High level of COD in the effluent may be due to softeners, detergents, some impurities from the fabrics while processing, etc; therefore, COD represents the organic strength of the effluent (Kolhe and Pawar, 2011). COD of raw effluent collected was about 1500 mg/L and the permissible limit as per BIS is 250mg/L. 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 (Mohabansi et al, 2011).

From Table 1, we can see that there was approximately 20 % decrease in the COD of the effluent after the primary treatment, i.e., COD reduced from 8690 to 6937 mg/L. The decrease in both COD and BOD at this stage may be due to trapping of organic molecules responsible for the height BOD and COD within the matrixes. After the secondary treatment, there was significant reduction in the COD, i.e., 336 mg/L. After tertiary treatment, BOD of the effluent notably reduced to 93 mg/L Thereof, at the end of the treatment, the COD of the effluent falls below the BIS permissible limit.

4.7. Total Dissolved Solids (TDS)

Effluent from textile industries generally shows higher TDS when compared to other effluents, because of fixing, bleaching, and using dyeing agents, etc., while processing the fabrics at different stages. Due to high TDS, salinity of the water may alter which in turn disturbs the organisms in aquatic ecosystem. TDS of raw effluent was found to be 10800 mg/L, whereas the fixed BIS permissible amount is 2100 mg/L.

TDS value after the primary treatment of effluent found to be considerably reduced from 9120 to 4050 mg/L, about 30 % of treatment, as shown in table. After the secondary and tertiary treatments, TDS reduced from 4050 to 2019 and then to 600 mg/L, respectively. Therefore, a combination of sedimentation and primary, secondary, tertiary treatments was very effective in reducing the TDS of textile effluent.

4.7. Total suspended solids (TSS)

The reason for increased TSS in the effluent may be due to chemicals used during dye fixation and partial dissolution of fibre materials. TSS of the effluent increases due to high content of carbonates, bicarbonates, chlorides, phosphates and nitrates of Ca, Mg, Na, K, organic matter, salt and other particles. The value of TSS may differ with respect to different types of dye industries. High TSS decreases the light intensity of water, and thereby influences turbidity and transparency of the water, and finally it depletes the oxygen level in water system that in turn affects other parameters. TSS of freshly collected effluent from the industrial outlet was 3072 mg/L which was also evidenced by Ajao *et al.* (2011) and Mohabansi *et al.* (2011). As per BIS limit, the permissible limit of TSS in effluent is 100–150 mg/L, as shown in table. Therefore, the effluent was polluted several folds. There was about 55% of treatment occurred at the primary tank, from 3072 to 993 mg/L, because at this stage several suspended solids may get trapped between the matrixes. After secondary and tertiary treatments, TSS of the effluent greatly reduced to 92 and 26 mg/L, respectively.

4.9. **Electrical Conductivity**

The electrical conductivity of the water does not have any direct influence on human or aquatic health, but it is an indicator of other water quality problems.

The electric conductivity of the water sample indicates the total concentration of the ionized constituents of water and is also a measure that determines the ability of water to pass on the electrical current. It also indirectly measures charge carrying species or molecules in the effluents (Sultana et al., 2009). Conductivity of the water increases with an increase in the total dissolved solids (TDS) (Gnanachandrasamy et al, 2012). Water with high electrical conductivity can cause osmotic stress for the plants at the root parts thereby adsorption of nutrient and water is restricted which greatly lowers the crops production (Mojiri et al, 2011). The commonly used units for measuring electrical conductivity of water are: µS/cm (micro Siemens/cm) or mS/cm (milli-Siemens), where 1 mS = 1000 µS [http://www.smart-fertilizer.com/articles/electrical-conductivity].

Electric conductivity of the freshly collected sample was found to be 9700 µS cm^{-1}. The BIS standard of electric conductivity for the textile effluent is 1400 µS cm^{-1}. After primary treatment, electrical conductivity decreased from 9700 to 8240 µS cm^{-1}, because of the adsorption by the matrices. After the secondary treatment, it significantly decreased to 1203 µS cm^{-1}, which confirmed the effective removal of dissolved solids in effluent by the composites. Eventually, after the tertiary treatment, electrical conductivity of the effluent was about 500 µS cm^{-1}, which was remarkably within the BIS value.

4.10. **Phosphate**

High amount of phosphate loading in to the lake or surface water ecosystem will increase the aging process the water ecosystem Because, phosphate will stimulate the growth of organisms in the ecosystem. Therefore, an imbalance in the nutrient and material cycling process may occur (Ricklefs, 1993) which leads to eutrophication. During which aquatic plants and algae will grow tremendously than the normal and block the surface of the water that inhibits entry of sunlight and oxygen into the lower levels. Therefore, removal of phosphate is of essence.

Amount of phosphate in the collected effluent was about 9.17mg/l. Primary treatment had no significant role in the removal of phosphate, but after the secondary treatment, the amount of phospahte in the effluent was about 1.59 mg/l, which is threefold decreased. After tertiary treatment, the phosphate level was about, 0.3mg/l which was severalfold decreased, below the standard limit fixed for textile effluent, i.e., 5mg/l. Therefore, the experimental setup was effective in removing the phosphate from the textile effluent.

4.11. **Nitrates**

Since textile industries use high concentrations of dyes with ammonium nitrogen, textile effluents contain nitrates more than the permissible amount. Along with phosphorus, nitrate can also induce eutrophication (Howarth et al. 1998; Meybeck & Helmer 1989; Smayda 1990). Nitrate can also cause the methemoglobinemia in infants.

The concentrations of nitrates in raw textile effluent were found to be 15mg/l, whereas the BIS allowed permissible limit is about 10mg. After the primary treatment, there was no significant reduction In the nitrate concentration; but after the secondary and the tertiary treatments, the concentrations of nitrates were 6 and 3mg/l, respectively, which was under the BIS permissible limits.

4.12. **Zinc**

Zinc in the effluent when contacts the environment causes drastic effects. Plants exposed to zinc are readily prone to zinc toxicity and when human or animals exposed to the effluent with high zinc concentration, it may cause muscular pain and even intestinal hemorrhage as reported by Honda et al., 1997; Jordao et al., 2002. In this research the effluent collected contained about 10- zinc when untreated and after the secondary and tertiary treatments it was reduced to 4 and 1mg/l, respectively. Therefore primary and secondary had a significant role in removing the zinc from the effluent.

4.13. **Chromium**

Chromium can cause toxicity in both plants and animals. Water bodies contaminated with chromium can directly affect the vegetation. Increased amount of chromium when contact the nearer water bodies can drastically affect vegetations. It can also cause skin ulcer, convulsions, kidney and liver damage in human. Moreover, it can generate all types of genetic effects in the intact cells and in the mammals in vivo (Khe´rici-Bousnoubra et al., 2009). It has also been reported that intensive exposure to Cr compounds may lead to lung cancer in man (Jordao et al., 2002). Freshly collected textile effluent had 5mg of chromium, whereas the limited BIS amount is about 0.1mg/l. After secondary treatment, the level decreased to 0.1 and after tertiary treatment only trace amount of chromium was recorded.

4.13. **Chloride**

High content of chloride in textile effluent is majorly chlorine compounds, e.g., hydrochloric acid, hypochloric acid and chlorine gas at different processes such as bleaching, washing and disinfecting agents (Nosheen et al., 2000). When effluent with high chloride contacts any aquatic medium, in spite of destroying microbiota [USEPA, 1999], plants and trees nearby will get affected Rhoades, 2011); the leaf margins of the plants become scorched, smaller and thicker. High chloride content can also the increase in TDS [Hayase et al., 2000], which in turn increases electric conductivity, TDS, TSS, sulfate and alkalinity of the water body.

Chloride content in the collected effluent was 889 mg/L, which is above the permissible limit, i.e., 250 mg/L according to BIS. From the table, we can observe that primary treatment was not effective to remove chloride from the effluent, whereas secondary treatment, i.e., magnetic composites can effectively reduce the chlorine content from 889 to 187 mg/L, i.e., 80 % of treatment occurred at secondary treatment tank, whereas further reduction of chloride about 91 mg/L was carried out by nanofilter.

4.15. **Sulfate**

Textile effluent contains sulfate ions derived during washing and processing. Usually, they are colorless and odorless sulfur and oxygen compounds and exist in water as a dissolved salt. When the effluent with high amount of sulphate reaches nearby groundwater or some water bodies, it may change the taste of water, cause death to all freshwater aquatic organisms since they are salt intolerant. Raw effluent collected from the discharge site contained about 1050 mg/L of sulfate. From the results, we can observe that primary treatment is not effective in removing sulfate molecules, i.e., no or least amount of decrease in sulfate concentration, whereas secondary treatment was very effective and the value decreased to 391 mg/L, which falls under the permissible concentration fixed by BIS, 400 mg/L. Tertiary treatment effectively reduced sulfate upto 20%, i.e, from 391 to 109 mg/L.

4.16. **Oil and Grease**

Oil and grease content in the textile effluent may be due to mat finishing or color finishing processes. High amount of oil and grease when discharged into water bodies, it may form a layer, and lead to drastic environmental issues due to limited light and oxygen into water bodies which in turn photosynthesis of the aquatic organism may block and results in death [CPCB, 1990].Therefore, removal of oil and grease from the effluent before discharged in to the water bodies is indispensible.

Raw effluent collected from the discharge site contained 18 mg/L oil and grease, whereas BIS permitted level is 10 mg/L and thus the treatment was carried out. After the primary treatment, effluent contained 14 mg/L of oil and grease and after secondary treatment it was greatly reduced to 0.9 mg/L; after tertiary treatment, effluent contained no oil and grease.

4.17. **Microbial Count**

Harmful pathogens in the effluent include protozans, coliform bacteria and viruses. In this study quantitative microbial growth from the freshly collected effluent was 12.6 x10 CFU/ml, which was significantly high when compared to the allowed BIS value, 10 CFU/100ml. As shown in results, microbial count did was more or less similar after the primary treatment, whereas after the secondary treatment, there was considerable amount of reduction in the microbial colonies. i.e., from 11.6 x10 CFU/ml to 9x10 CFU/ml, the removal may be due to antimicrobial and adsorbing properties of activated carbon and chitosan. There was tremendous reduction in the microbial count after the treatment with HTCC nanofibers, microbial count at the end of the treatment was found to be 0.1x10 CFU/ml.

From the results, we can conclude that textile effluent can be effectively treated using the experimental setup of this research. Primary treatment tank was set up to remove large-sized pollutants that can hinder the treatment quality of secondary and tertiary treatments. Besides removing the pollutants, at the end of primary treatment, some of the physiochemical properties of the treated effluent had greatly changed, i.e., TSS, BOD, and TDS of the effluent decreased 60, 30, 35 %, respectively, whereas other physiochemical parameters were also remarkably reduced. Similar results were also obtained by Rajeswari, 2015; Flörke, 2013; EPA, 1997, etc.

In secondary treatment, using magnetic composites, through coagulation-adsorption process, most of the micropollutans in the effluent and color were found to be reduced. Several studies evidenced that both the chitosan and activated carbon are the best coagulant and adsorbent, respectively, and effectively used in treating the effluent as follows: Ariffi et al, 2009; Guibal and Roussy, 2007; Barron Zambrano et al, 2010; ignat et al, 2012; Dotto and Pinto et al, 2011, and so on used chitosan in different forms to treat textile effluent and for removing color. Similarly, Rahman et al, 2012; Syafalni et al, 2012; Majedi et al, 2014; Hussain et al, 2015, and so on evidenced successful application of activated carbon in textile effluent treatment. Results of this study also confirmed that using the composites, dyes with different charges, positive, negative, and disperse, were removed successfully. In order to increase the quality of treatment, nanofiltration of the effluent was carried which further decreased the pollutants and the microbial count was significantly reduced. Feng et al, 2013; Svobodová et al, 2011; Qu et al, 2013; Asmatulu et al, 2013 and so on also evidenced that nanofibers can be effectively used for removing micro-pollutants from the effluent. Besides nanofibers as a disinfect, they also completely adsorbed the color of the effluent.

Conclusion

This research aims at the treatment of raw textile effluent collected from Tiruppur, Tamilnadu Characterizations of freshly collected sample were carried out followed by the treatment process. Lab-scale effluent treatment was done using three stage treatment units, namely (1) primary treatment—using luffa sponge, carbon pieces and coarse crab shell; (2) secondary treatment—coagulation-adsorption by magnetic chitosan and activated carbon composites (3) tertiary treatment—disinfection and removal of micropollutants using HTCC nanofibers. Physiochemical analyses of post-treated water at each stage were done and the results were tabulated. From the results, we can infer that at each stage, the quality of water increased, i.e., COD, BOD, TSS, TDS, sulfate and chloride concentration, oil and grease concentration, etc., were gradually reduced and finally the physiochemical parameters of the completely treated water followed BIS standards. Therefore, a combination of adsorption-coagulation and nanofiltration method can be an efficient method for treating textile effluent.

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Table 1 Physiochemical analyses of raw and treated effluent at each stage with BIS allowed parameter values

S.No	Physiochemical Parameters	BIS (mg/l)	Raw (mg/l)	Primary (mg/l)	Secondary (mg/l)	Tertiary (mg/l)
1	**Color**					
2	**pH**	7.5	10.7	10.7	7.8	7.1
3	**Total Hardness**	500	712	698	312	103
4	**Alkalinity**	200	1430	1430	531	127
5	**Biological Oxygen Demand (BOD)**	100	892	697	92	36
6	**Chemical Oxygen Demand**	250	8690	6937	336	93

	(COD)					
7	**Total Dissolved Solids (TDS)**	2100	10800	4050	2019	600
8	**Total suspended solids (TSS)**	100	3072	993	92	26
9	**Electrical Conductivity** (μScm^{-1})	1400	9700	8240	1203	500
10	**Phosphate**	5	9.17	9.17	1.59	0.3
11	**Nitrates**	10	15	15	6	3
12	**Zinc**	5	10	10	4	-
13	**Chromium**	0.1	5	5	0.1	-
14	**Chloride**	250	889	889	187	91
16	**Sulfate**	400	1050	1050	1050	109
17	**Oil and Grease**	10	18	14	0.9	Nil
18	**Microbial Count** (CFU/ml)	10	12.6	12.6	9	0.1