STUDY OF TREATMENT OF LAUNDRY WASTEWATER

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ABSTRACT:

Water has always played a major role in the industrial laundry operations, due to large quantity of universal solvent required for the effective laundering of industrial garments and other textile goods. On an average a laundry uses 15L of water to process 1kg of work and discharges a total of 400m^3 of waste water daily. Treatment of this kind of waste water is particularly difficult because of high surfactant content. It also contains various organic and inorganic loads generated by the soil that has been washed out. The main importance is to treat the laundry water in order to remove various impurities in water and also reduce the COD value of the washes laundry water to a permissible limit. There are various pre-treatment methods used to purify the industrial laundry waste water before it is discharged. The tested treatment method systems are as follows: physio-chemical pre-treatment like Coagulation, Flocculation and Dissolved Air Floatation, Sand filtration, Ozonation, Granular Activation carbon filtration, Cross flow Ultrafiltration, Mobile composite material and adsorption. The most feasible methods which can be used on lab scale are Ultrafiltration, Coagulation, Nano filtration, Adsorption .Analysis of pH; TSS, COD, BOD, turbidity, conductivity etc. can be performed to check reuse of laundry waste water. This work deals with study of treatment of laundry wastewater using a combination of various methods.

KEYWORDS: Surfactants, COD, Nano filtration, Ultrafiltration, Adsorption.

INTRODUCTION

Water treatment is vital for reducing the impact of numerous chemicals that are released to the natural water sources (e.g. ponds, lakes and rivers) from a wide variety of industrial and domestic applications. Pollution of water has a huge impact on the environment. Surfactants are a group of chemicals with cleansing properties. Generally, surfactants consist of a polar group and a non poplar group. The polar group is soluble in water in water thereby making it water soluble (hydrophilic), and the polar group is insoluble in water, ie hydrophobic. Therefore, surfactants are combination of the hydrophilic and hydrophobic. They are widely used in household and industrial purposes. The majority usage is found in shampoos and detergents and in industries like textiles, paints, polymers, mining. Surfactants have the ability to remove both water-soluble components and non-water-soluble soils. The surfactants are widely used in the cleaning detergents, textie, polymer, oil recovery pesticide, pharmaceutical, mining, pulp, paper and paint, industries. The waste water from these industries consists a large amount of surfactants which cannot be directly disposed of in the water streams, which may affect the marine life. On an average a laundry uses 15 litres of water to clean 1 kg load of cloth and discharges 400m ^{3} waste water. Therefore, recycling this waste water would help in limiting the consumption of clean water. The harmful effects on aquatic life would be minimised. Surfactants on mixing with the soil may degrade the quality of soil. Therefore it is necessary to reduce the surfactant concentration in the waste waters (Ali khosravanipour mostafazadeh, 2019) .There are three major types of surfactants—ionic, non ionic, and amphoteric. Among the ionic surfactants, sodium alkyl sulfonates are among the most used ionic surfactants in a wide range of detergents—dishwashing liquids, shampoos, shaving foams, powders .Linear alkyl benzene sulfonates(LAS),alkylethoxysulphates, benzylalkyl sulphonates (BAS), alkylphenol ethoxylates, and ammonium compounds are the most frequently used commercial surfactants. (SALAGER, 2002) The most widely used systems for laundry wastewater treatment are conventional methods such as Ultrafiltration, Nanofiltration, Ion exchange, Electrocoagulation, Electrooxidation. Different methods of pre-treatment are used to treat the industrial laundry wastewater before it is discharged. The complexity of pre- treatment varies from location depending on the size of the facility, the volume of water and chemicals and other materials consumed the type and usage of products used by the customers. (Sandeep kumar Tripathi, 2003) One of the most widely used pre-treatments of industrial laundry wastewater consists of coagulation and flocculation followed by Dissolved Air Flotation (DAF).Coagulation is a well-known treatment which, by addition of a chemical (such as Al^{3+} and Fe^{3+} salts or organic polymers), destabilises small particles in suspension. Such particles – after electrical neutralisation – tend to gather and form coagulated flocs of 20–50 μm in size. Flocculation reagents, consisting of long-chain polymers polyelectrolytes, reinforce the floc formation and cohesion. Flotation allows then to separate the flocs from the liquid; as solid/liquid separation system, flotation is preferred to settling being the coagulums very light.Coagulation is a well-known treatment which, by addition of a chemical (such as Al^{3+} and Fe^{3+} salts or organic polymers), destabilises small particles in suspension. Such particles – after electrical neutralisation – tend to gather and form coagulated flocs of 20–50 μm in size. Flocculation reagents, consisting of long-chain polymers polyelectrolytes, help the floc formation and cohesion. Thus, the choice of a surfactant for a laundering product depends on numerous factors such as temperature, type of fabric, foam level desired, builders used (phosphate or non-phosphate), the product form (liquid, concentrated powder) and the process of making.

2. LITERATURE REVIEW

Louis et al. (2001) have studied the types of surfactant in which classification of surfactant is done. A surfactant molecule consists of two parts. One part is water loving (hydrophilic) and the other is hydrophobic. There are four main types of surfactants: anionic, nonionic, cationic and amphoteric surfactants. Anionic surfactants have the negative charge (-COO-, -SO3-, -SO4-) in the polar group. Soaps, alkylbenzenesulfonates, fatty alcohol sulfates are all anionic agents. Whereas the cationic surfactants carry a positive charge in their polar group, dimethyl distearyl ammonium chloride is an example of this category. In non-ionic surfactants, they have a polar group that cannot be ionized in an aqueous solution. The hydrophobic part consists of the fatty chain. The hydrophilic part contains non ionizable atoms. Amphoteric substances consists of unit forming a dipolar ion. Linear alkylbenzene sulfonates (LAS) have extensively replaced alkylbenzene sulfonates (ABS) for biodegradability reasons. Methyl ester sulphonates, alkyl poly glucoside are bio-degradable, renewable, easily synthesis but are relatively expensive. (Tan, 2001)

Canan et al (2004) have studied the removal of the surfactants using the Adsorption technique and Microfiltration. Adsorption was carried out using the Activated Charcoal (AC). Linear Alkyl Benzene sulphonates and Cetyl triammonium bromide were used. Adsorption was used as a preliminary treatment followed by the secondary treatment of Microfiltration. The effect of temperature and the transmembrane pressure were also studied. Firstly batch experiments were carried out. AC was added to 100 ml of the sample for 120 min at 30°C and then the solution was filtered using whattman filter paper. Secondly, continous set of experiment was performed. For this a tank of 20 L in volume was filled with the water sample. Then, PAC was added in known concentrations in order to achieve adsorption. 0.2 mm cellulose acetate sheet was used to filter the water and this filter was placed in the steel microfiltration unit.The continuous flow experiment yielded a greater amount of surfactant removal than the batch experiments. The effect of pressure was studied, which showed that increasing the pressure, reduced the rejection rate. LABS concentration decreased from 80% to 44% at 200 kPa. Temperature however didn't show any significant changes from 20°C to 40°C. Also as the pore membrane size increased, the rejection rate decreased. Therefore, it was observed that Microfiltration resulted in greater Surfactant removal and continous flow experiments showed good results than the batch experiments. (Canan Akbil Basar, 2004)

Ciabatti et al. (2009) have studied various methods like Dissolved Air Floatation (DAF), Ultrafiltration (UF), Adsorption on GAC and Ozonation to study the parameters of the laundry waste water. The Surfactants used for the study included non-ionic surfactant BIAS (Bismuth Active Substances) and anionic surfactant MBAS (Methylene blue active substances). The primary coagulant used was the polyaluminium chloride (PAC). This treatment accounted for about 45% COD removal efficiency, whereas the overall reduction efficiency was about 87%. Results obtained from the process were as follows: COD was reduced from 602 mg/l to 140 mg/l in case of GAC and 81 in case of UF respectively. TSS was reduced from 166 mg/l to 4 mg/l (98%) for GAC and 2.5 mg/l for UF respectively. Turbidity reduction was found to be 110 NTU to 1.1 NTU (98%) and 0.8 NTU for GAC and UF processes respectively. (Ciabatti, 2009)

Boyko et al. (2013) have studied the effects of activated carbon on surfactant removal. They have studied the different parameters of surfactant removal by adsorption. Activated charcoal was obtained from peach stones, asphalts, coal tar and pitch. Further they have measured the amount of surfactant by UV spectrophotometer. Higher surface area of peach stones showed greater efficiency of 61 % than the natural asphalite (50%).. Effect of pH in particular was found by presence of oxygen. Maximum removal efficiency was found at pH 6-7 which was adjusted by adding HCl and NaOH and AC was obatained from peach stones. Amount of carbon also influenced the removal of sulphonic compounds. Less amount of carbon resulted in steep slope on the adsorbed detergent. (Boyko Tsyntsarski, 2014)

E.Terechova et al. (2014) have studied the process of combined chemical coagulation-flocculation/UV photolysis treatment for anionic surfactant Linear Alkyl benzene Sulphonates (LAS). The coagulants used were Mineral Ash, $ZnCl_2$ and Praestol. Coagulants were added to 400ml of the sample water and then allowed to mix for 5 minutes. The supernantant was then passed for the treatment of photolysis. High pressure mercury lamp was used as the light source for photolysis. Volume of water was 200 ml. The effect of solution pH in UV photolysis was also investigated. The results found after chemical coagulation-flocculation had a LAS removal efficiency of 74.58% and COD removal of 70.12%. The pH reduced from 9 to 8.In case of UV photolysis LAS concentration was decreased from 3-10 mg/l to 2 mg/l when the pH was 6.0 but it was further reduced to 0.5 mg/l when the pH increased to 8. The product after photolysis mainly involved non-toxic components (CO_2 and H_2O) and also no secondary pollutants were generated after the treatment. (E L Terechova, 2014)

Mohammed et al. (2014) have studied electrochemical oxidation process for the treatment of the waste water. The physicochemical features of the wastewater (e.g.,electrolyte solution, initial concentration of the water) also affect the electrochemical oxidation process.. High pH however increases the efficiency of the process. Under the optimal conditions the removal efficiencies of the textile wastewater by electrochemical oxidation were 78% of COD and 92% of turbidity. The energy and electrode consumptions at the optimum conditions were calculated to be 0.7 kWh/kg COD and 0.2 kg Fe/kg COD, respectively. Treatment of landfill leachate (with an initial COD value of 1414 mg/l) showed 68% efficiency when the run time was about 4 hours. Olive oil mill waste water when subjected to electrolysis shows 99.85% turbidity decrement and COD reduction to 99.59% (From 41000 mg/l to 167 mg/l) (Mohammed J K Bashir, 2014)

Eddy et al. (2016) have studied the removal of the anionic surfactant from cleaning in place water (CIP water). The steps they incorporated were Nano filtration followed by Moving Bed Reactor (MBR). This process is also known as Advanced Oxidation Process (AOP). The first step splits the wash water into high and low concentrated stream. The second step involves the treatment of permeate of Nano filtration in MBR. The permeate contains BOD, COD and traces of detergent. PCI tubular membranes were used in Nano filtration setup.NF was performed until the permeate recovery was about 90%.The MBR unit contains of flat sheet membranes and the reactor has a volume of 11 m^3 of water. The MLSS concentration was about 10 g/l. Maximum removal efficiency was observed at pH-5 and room temperature with a pressure of 50 bar. After running the process for 80 days the final COD concentration obtained was 50-100 mg/l. (Eddy Linclau, 2016)

Beata et al. (2016) have studied the application of “sunlight” to decompose the dissolved organic matter, using the anionic surfactant sodium dodecyl sulfate (SDS) and the nonionic surfactant, phenylpolyethylene glycol. The decomposition time for non –ionic surfactant is 6hours. The source of the light used was the mercury lamp (250 W) along with six quartz tubes. The solution of SDS used was about 46 ml mixed in water and along with pH-=2 and 68% nitric acid. UV assisted digestion with the addition of hydrogen peroxide at pH=2 is an effective method for the degradation of organic compounds. The results obtained showed that this technique might prove a useful solution similar to that of hydrogen peroxide oxidation followed by UV treatment. (Bielecka, 2016)

Mattia et al. (2017), have studied the environmental impact of different detergents used in the industrial laundry processes. Three different detergents and three different methods were used to study the results on the environment: ReCiPe, CED (Cumulative energy demand), and IPCC 2007. The Life assessment cycle (LCA) method analysed the household detergents. Subsequently, the contribution of detergents to environmental impacts of industrial continuous batch washing (CBW) machine laundary system is investigated. Different Ultrafiltration polymeric and ceramic membranes, RO membranes, have been studied. Overall reduction was about 40 %, there by indicating the minimal harmful impact on the environment and hazardous results on humans. Thereby waste water could be recycled. (Mattia Giagnorio, 2017)

Shashank et al. (2017) have studied the removal of sodium dodecylbenzenesulfonate (SDBS), an anionic surfactant by batch foam fractionation. The concentration of surfactant in water was up to six times the critical micelle concentration (CMC). Foam fractionation was performed with SDBS solutions having concentrations of 500, 1000, 2000 and 3000 mg dm^3. Salt used was NaCl. The feed solution was slowly poured into the column from the top. Air was sparged with a flow rate in the range of 0.4 − 1.6 dm^3 min^{-1}. Each experiment was run for 7 h. Samples of the aqueous phase were collected at every 1hr interval. The concentration of SDBS in the aqueous phase was measured by a UV-Visible spectro photometer. 5cm^3sample was collected. In the presence of NaCl in the feed solution, reductions in the surfactant recovery and separation efficiency were observed. Both of these parameters decreased with the increasing salt concentration. (Shashank Shekhar Srinet, 2017)

Fu J et al. (2018) have studied the effluent concentration of Linear Alkylbenzene Sulphonates(LAS) and Benzyl Alkonium Chloride(BAC). The processes under study were anaerobic-oxic treatment process (A/O) and cyclic activated sludge technology process(CAST). The total concentrations of LASs in influent were from 19.2 to 1889 μg/L. The total concentrations of BACs were lower than those of LASs, with the concentration ranging from 0.00935 to1.85 μg/L respectively Samples were collected in 1 litre glass bottles and then transferred to laboratory with low temperature of about 4°C. The removal efficiency was more in the advanced oxidation process (97.9-100%) as compared to the CAST process (95.1-100%). The study showed that LAS was removed efficiently if subjected to the aerobic treatment process. However BAC was removed in the biological and the CAST process respectively. Both the process had an efficiency greater than 83% without any changes in parameters. For CAST treatment process surfactants can be degraded to a great extent under aerobic conditions. They also studied the seasonal variations on the removal efficiencies and it was concluded removal efficiencies of surfactants in autumn were a little higher than those in winter. (Fu-Jie Zhua, 2018)

Slawomira et.al (2018) have studied the application of the Moving bed Bio-Reactor (MBBR) for the treatment if the laundry waste water. Anionic, Non-Ionic and sum of the Anionic and the Non-Ionic surfactant was studied. The parameters under the study were BOD and COD and the wastewater contains chemicals used during wet washing and impurities removed from the linens. The research included tests of a two-stage moving bed bio reactor (MBBR), Veolia company, with two reactors filled with carriers Kaldnes K5 (specific area – 800 m^2 /m^3) and a total capacity of 260 dm^3, were used under aerobic conditions. The source of activated sludge for MBBR was the communal wastewater treatment plant. The raw laundry contained high concentrations of surfactants (anionic and nonionic), a low content of total nitrogen and slightly elevated levels of phosphorus. The initial COD was obtained in the range of 727-944 and the BOD_5 was obtained in the range of 335-542 mg O_2/L .Concentrations of ammonium nitrogen, nitrate nitrogen and orthophosphates were below the lower limits (0.2, 0.2 and 0.04 mg/L, respectively). After treatment value of BOD was 7–21 mg O_2/L while COD values varied in the range from 36 to 118 mg O_2/L. Removal efficiencies of 90% were observed in three successive measurements. Removal efficiencies on the level of 90% were reached after 43 days.The surfactants removal efficiency was equal to 79–99% for anionic,88–99% for nonionic ones and 85–96% for the sum of anionic and nonionic surfactants. The highest content of surfactants removal in treated wastewater was observed in 82 days. (Sławomira Bering, 2018)

Zhenmin et al. (2018) have studied the anaerobic membrane bioreactor (AnMBR) designed to decompose the organic matters and convert organic nitrogen . Thus they are accumulated in the supernatant. After the anaerobic treatment, microaeration was performed and lastly the effect of various bacteria on the degradation process was studied. The surfactants under the study were the anionic surfactants namely, Sodium lauryl sulphates and sodium lauryl polyoxyethylene ether sulphate. The influent COD was about 12000 mg/l. Using only anaerobic treatment the COD removal was about 25-40% and along with using the microaeration the efficiency increased to 40-70%. Introduced microaeration effectively decreased the concentration of surfactants from 9000 mg/L to 2000 mg/l. The bacterias such as *Aquamicrobium*, *Flaviflexus*, *Pseudomonas* and *Thiopseudomonas* helped in the degradation of the surfactants. (Zhenmin Cheng, 2018)

Ali et al. (2019) have analysed the removal of surfactant of nonylphenol ethoxylates. They went through the process of ultrafiltration to first get the filtrate and then divided into three samples for further treatment by adsorption (GAC- Granular Activated Carbon), nanofiltration(NF) and electro-oxidation/electrocoagulation(EO/EC). Parameters under the study were COD, pH, Conductivity, TSS and turbidity. Ultrafiltration was done using PES membrane (Polyether Sulphone) which gave a recovery of 80% filtrate. COD and turbidity reductions were found to be up to 88% and 98% respectively. The adsorbate used on first sample was granular activated carbon (GAC) which gave a COD reduction from 628 mg/l to 201 mg/l (approx. 70%). Also there was a slight change in pH from 9.2 to 9. Conductivity was reduced from 715µS/cm to 651 µS/cm. Significant decrease was found in TSS parameter from 60 mg/l to 1-2 mg/l. After performing Nanofiltration on second sample COD was reduced from 628 mg/l to 80 mg/l. Conductivity was reduced from 715µS/cm to 256 µS/cm. Electro-oxidation and electrocoagulation were performed on the filtrate obtained from both UF and NF samples. EO/EC on UF resulted in COD reduction from 628 mg/l to

110 mg/l but there was a drastic increase in conductivity from 715 µS/cm to 4900 µS/cm and in case of NF COD was reduced from 628 mg/l to 167 mg/l and for conductivity there was again an increase from 715 µS/cm to 6940 µS/cm. Also turbidity was decreased from 71 NTU to 16 NTU. (Ali Khosravanipour Mostafazadeha, 2019)

Hany M. et al. (2019) have studied the adsorption of surfactants on zero valent iron(nZVI). Synthesis of nZVI includes transmission electron micrography (TEM),Field emission scanning electron microscopy(FE-SEM) , X-ray diffraction spectroscopy (XRD), BET surface area determination and zeta potential of the nZVI. Nano-ZVI is used as adsorbent for removingcationic surfactant, Hexadecylpyridinium chloride surfactant (HPDCL) and anionic surfactant, sodium dodecylbenzene sulphonate(DBS). The technique including microbiology treatment , chemical and electro chemical oxidation, foam separation, ion exchange and membrane separation, coagulation, and various adsorption methods. The effect of different experimental parameters such as the amount of nZVI, the initial surfactant concentration, pH, shaking speed, and temperature on the system performance have been studied. Removal efficiency of HDPCl up to 99% and of DBS up to 93 % was obtained. The removal efficiency increased as the temperature of the solution was increased. Also the shaking speed increased the removal efficiency. (Hany M. Abd El-Lateef, 2019)

Hemamalini et al. (2019) have investigated TiO_2 nanoparticles to remove the surfactants from produced water. Nevertheless, an excessive loading of TiO_2 nanoparticles beyond 2 weight % had deteriorated the membrane performances. The operating conditions were the pH and the air flow rate. Considering these correlations optimum conditions for the process were determined at the pH of 6.00 and ABFR of 0.41 L/min. By switching on the UV-A radiation, the membrane flux and surfactant rejection measured in terms of percent COD removal were enhanced with the increase of TiO_2 loading in membrane until reaching 2 wt%. Beyond this the increased loading of the TiO_2 membrane decreased the efficiency of the treatment. (Hemamalini Rawindran, 2019)

3. Materials and Methodology

3.1 Materials

Material requirement comprised of water samples, chemicals and instruments used for testing. All the materials were used at Tesla Innovation Center at Taloja. Basic materials was different types of feed water which were

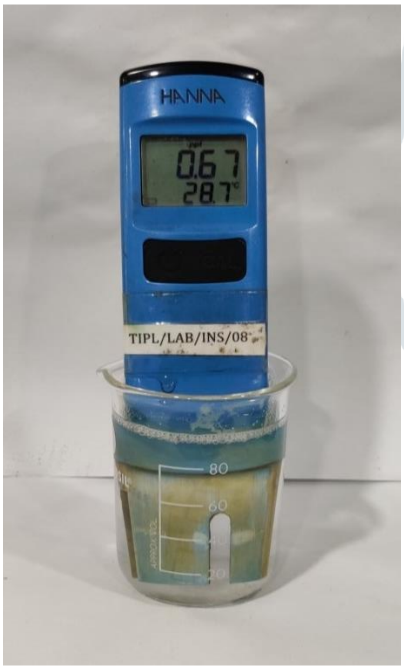
1. Synthetic Water- This water was prepared in the laboratory with different detergent concentration. 1000ppm and 1500ppm were the two different concentrations used for preparing synthetic water. 10 litres of sample was created in the lab of each concentration and was then tested.
2. Residential Greywater- This water was collected from a colleague's house which was then transported to the testing facility. 25 litres of sample was taken to the center. This water was collected as per the family's daily washing needs.

3. Laundry Greywater- The water was collected from a local washing company and was taken from their first load for utmost detergent concentration. 10 litres of sample was collected for testing and had high range of COD values.

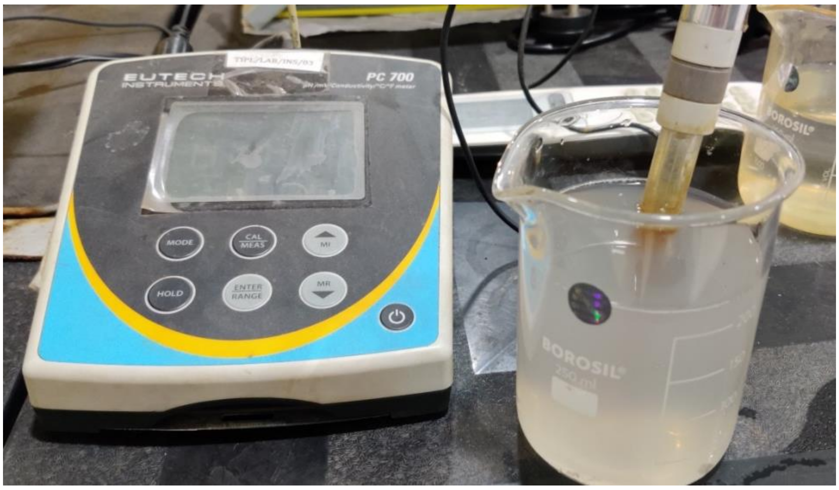
Other materials required were different chemicals which were coagulants such as Ferrous Sulphate ($FeSO_4$), Ferric Chloride ($FeCl_3$), Poly Aluminium Chloride (PAC) and Alum. Also for titration FAS was used. For treating pH hydrochloric acid (HCl) and lime ($Ca(OH)_2$) was used. For adsorption the main ingredient to be used was Activated Carbon (AC).

Also quite a few instruments were provided by Tesla Innovation Center which were used in testing different parameters, which were

1. pH meter- used for measuring the pH of the water.
2. TDS meter- used for measuring TDS of the water.
3. Turbidity meter- calibrated turbidity meter was provided for measuring turbidity of the water.
4. COD vials- this was a chemical mixture of Potassium dichromate ($K_2Cr_2O_7$), Mercury Sulphate ($HgSO_4$) conc. HCl and distilled water all together put into the vial for testing. It was then titrated against 0.1N FAS solution for giving the correct COD value.



TDS Meter **Turbidity meter** **Turbidity Bottle**



pH meter

3.2 Methodology Adopted

Different methods were tried and tested for different types of feed water and then finally a combination of methods was decided for laundry water. All the methods were analysed not only on the basis of their efficiency but also their economic value and then finalised for its usage. Following methods were used as a single method or as a combination,

1. Chemical Precipitation-

500ml of sample was collected and pH was tested. If pH was above 9 then proceed with addition of coagulant either was add lime in appropriate quantity to reach the given pH. The sample was then compared with addition of different coagulants namely Ferrous Sulphate ($FeSO_4$), Ferric Chloride ($FeCl_3$), Poly Aluminium Chloride (PAC) and Alum. Then reduction in parameters was tested and the one with most reduction of parameters was chosen. Also if there is only one parameter to be considered for testing, then based on that alone the coagulants were chosen.

2. Chemical Precipitation + Detox-

After precipitation,that is treating with chosen coagulant the water is then transferred to a detox machine which is a prerequisite for this method. A detox machine is a combination of ozonation and photolysis of the water. The water is filled in the tank and then it is pumped into a reactor where ozonation takes place and then it is recycled for a few minutes which is then passed for photolysis by passing it through a UV light reactor. It is generally used to remove the odour of the water and then killing the bacteria present along with reduction in COD values. But its setup is quite costly.

3. Adsorption-

A small tubular reactor is filled with Activated Carbon of desired volume for sample to be retained and is stopped at one end with a stop cork. The carbon is first washed with sample for the carbon to get accustomed. The water sample is then added to just submerge the carbon in it and a retention time of 15 minutes is given for the adsorption action to take place. Then it is collected from the bottom by opening the stop cork and then tested for its parameters.

4. Aerobic Treatment-

500 ml sample is taken and 500ml of activated sludge is added to it in a container. The activated sludge is activated by aeration and then added to it. The mixture is then mixed well and a sample is taken for parameter testing for any changes and then put for aeration for minimum of 6 hours. To take to even greater efficiency it can further be kept for 8 and 12 hours respectively. But after 6 hours interval a sample is taken to check the reduction in parameters. Also a combined treatment method of chemical precipitation, aerobic treatment and adsorption was performed keeping the above procedure same.

4. Results and Discussion

4.A Effect of feed concentration

Two different synthetic water samples of 1000 ppm and 1500 ppm were prepared. The effect of the samples is detected on the basis of the final results obtained after coagulation. The parameters used for the comparison include the pH and COD.

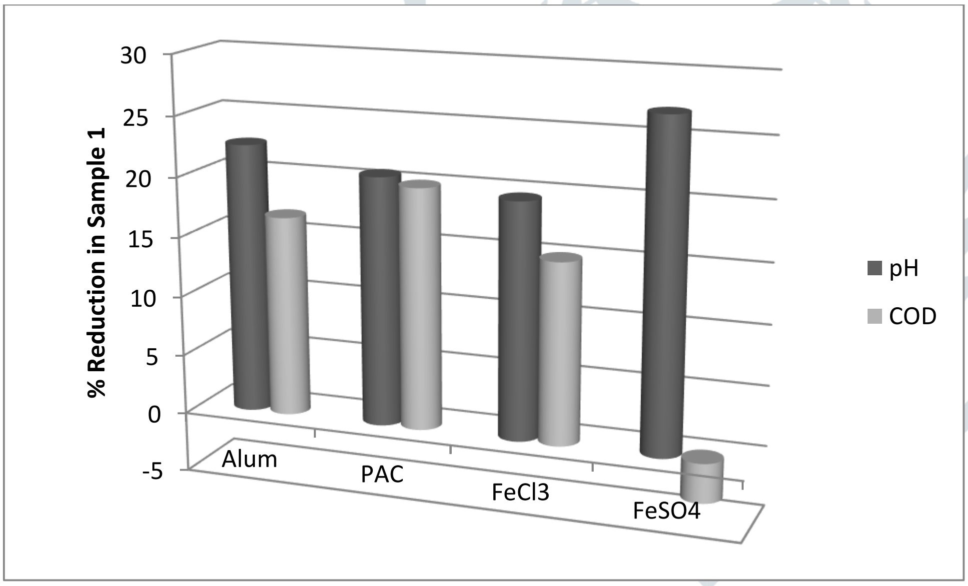


Fig 3.A.1 Sample 1 % reduction

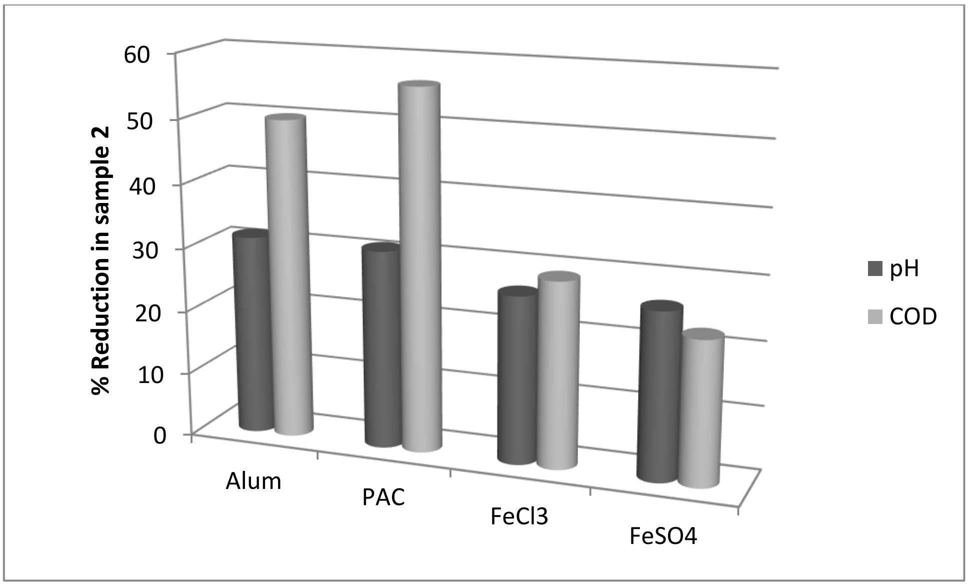


Fig 3.A.2 Sample 2% reduction

The following graphs indicate that the increased reduction efficiency is obtained when the feed concentration is more, keeping the coagulants same. Thus, it is concluded that decreased feed concentration shows more reduction in the pH, whereas more feed concentration shows greater COD removal.

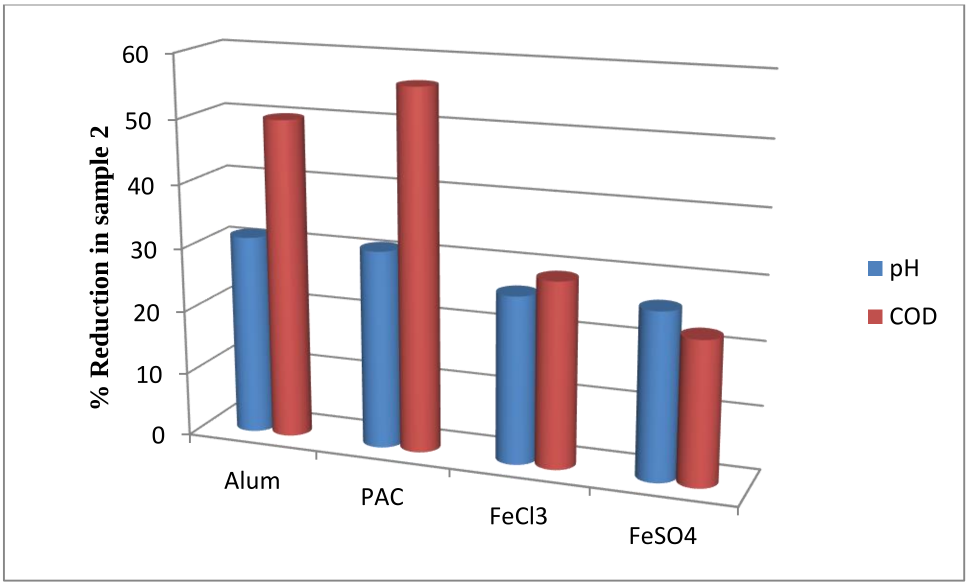
4.B. Effect of Coagulants

A) **SYNTHETIC FEED WATER**

The initial parameters of the feed water are:

Parameter	Sample 1(1000 ppm)	Sample 2(1500 ppm)
pH	9.33	9.92
COD (mg/l)	499.5	665.6
TDS (ppm)	670	960
Turbidity (NTU)	30.4	54.6

Four coagulants were used to treat the samples of the synthetic feed water. The coagulants used were PAC, Alum, $FeCl_3$ and $FeSO_4$. There has been an increase in the TDS and the turbidity values for all the coagulants because of the precipitant obtained. And therefore the parameters for comparison are pH and COD. The % reduction in the pH and COD values are shown graphically. PAC showed a reduction of about 52.5%.



Thus it was concluded that for the treatment of the synthetic water, PAC was the best coagulant.

B) RESIDENTIAL GREY WATER

Three coagulants (Alum, PAC, $FeCl_3$) were used for the study. The comparison between the COD and the Turbidity is shown.

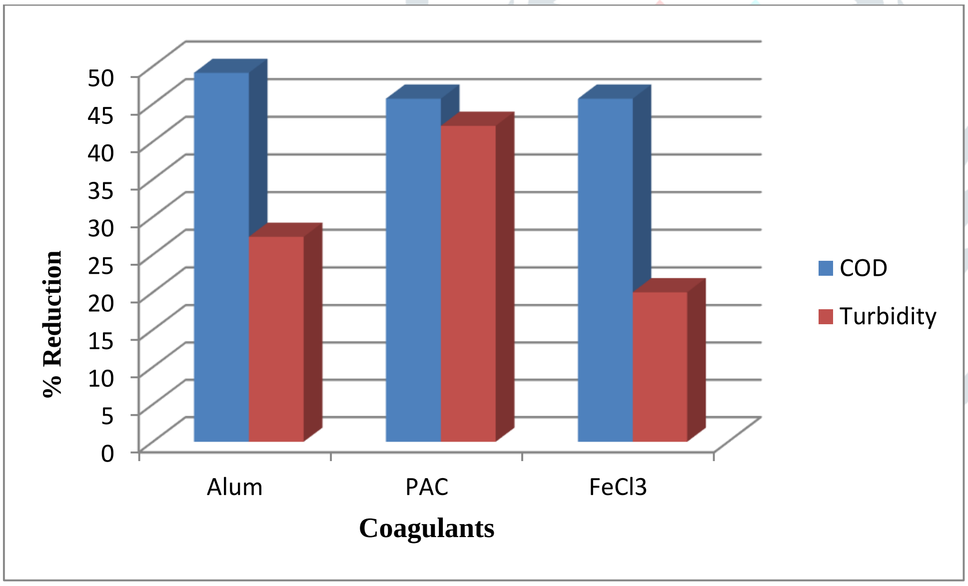


Fig 4.B Effect of Coagulants on Residential Water

Even though PAC didn't show maximum reduction in the COD value, the supernatant obtained from PAC was less turbid as compared to the other; hence PAC was chosen as the key coagulant.

C) LAUNDRY GREY WATER

Actual laundry waste water was obtained. The pre-treatment of chemical precipitation was done using the three coagulants. The coagulants used were the same as those used in the laundry water treatment. However in this case the parameters under observation were pH, COD, TDS and turbidity. The initial parameters of the water are:

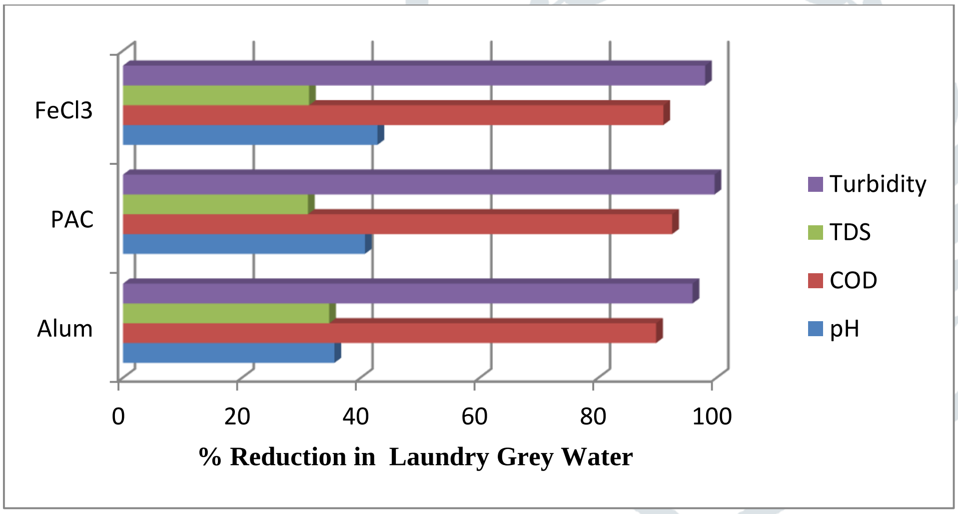
Table C.1: Feed parameters

PARAMETERS	FEED
pH	11.86
COD	12230.4
TDS	5590
Turbidity	1335

After the addition of suitable amount of poly and a settling time, the results obtained are as follows:

Table C.2: Chemical Precipitation

PARAMETERS	PAC	Alum	$FeCl_3$
pH	7.03	7.64	6.78
COD	915.2	1248	1098.24
TDS	3850	3650	3840
Turbidity	4.33	54	25.7



4.C. Effect of Methodology used

A) **Synthetic water Sample**

Four methods were performed on the synthetic water sample. The parameters of 1500 ppm were considered. The % reduction in the parameters is displayed in the graph below.

Methodology	% Reduction			
	pH	COD	TDS	Turbidity
Chemical Precipitation	31.048	56.25	TDS increased	Turbidity increased
Detox	7.9	50.51	4.39	26.94

Adsorption	5.9	74.18	TDS increased	22.28
Chemical Precipitation + Adsorption	19.69	60	TDS increased	84.25

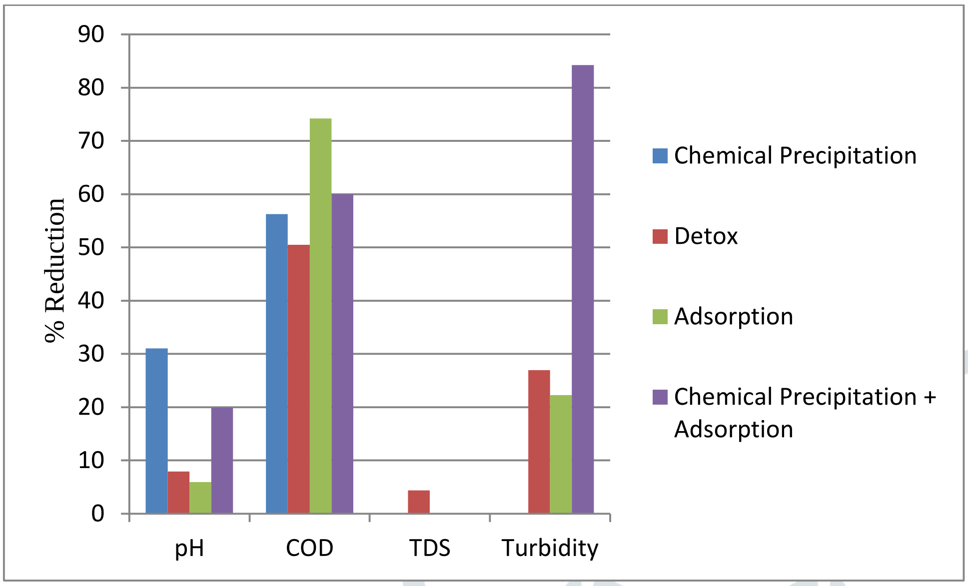


Fig 4.C Effect of different methods on synthetic water

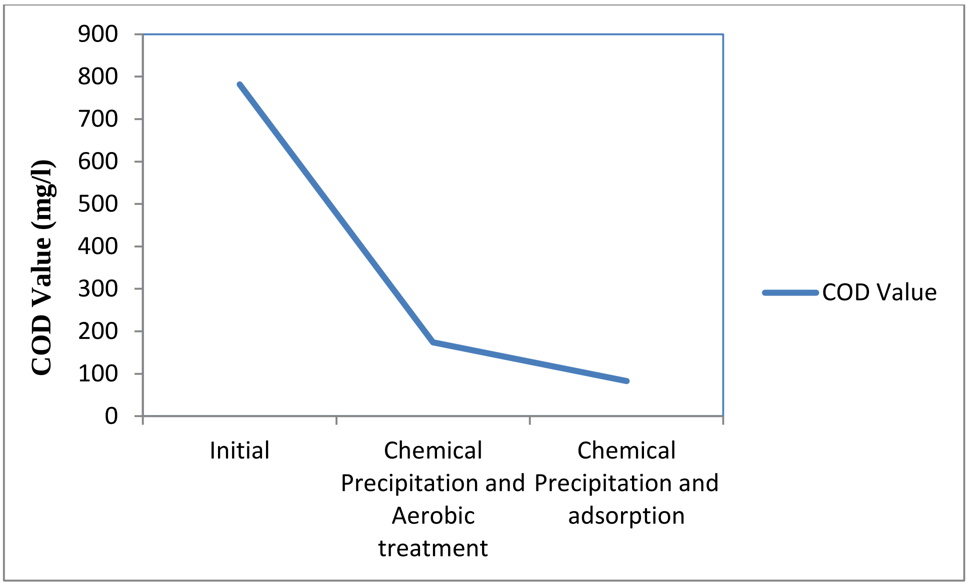
The above graph indicates that the combined method of Chemical precipitation and adsorption showed enhanced results in all the parameters. However, it also indicates that the adsorption technique resulted in the increase of the TDS value of the water. Also adsorption alone resulted in the maximum COD removal (74%), but since it was a novel technique it is adopted at the end.

B) Residential Sample Water

For determining the effect of methodology the two series of methods were compared. The pre-treatment of Chemical Precipitation remained the same.

a. Chemical Precipitation- Aerobic treatment
b. Chemical Precipitation – Adsorption

The parameter under the consideration was only the COD.



Thus the graph shows that the combined result of the Chemical precipitation showed greater removal efficiency in the COD value. Also, Aerobic treatment could be used as an intermediate step for the COD removal. The COD removal efficiency was about 74.74% for aerobic treatment and 87.95 % for Adsorption respectively. And the overall turbidity removal was 85% for Aerobic treatment and 91.75% for adsorption. Thus from the above mentioned two procedures it was observed that the combination of the Chemical Precipitation and Adsorption shows enhanced results.

C. Laundry Grey water

For treating the laundry water, two series of methods were used.

a. Chemical Precipitation – Adsorption
b. Chemical Precipitation – Aerobic Treatment – Adsorption

The coagulant used was the PAC for chemical precipitation

The results obtained after treatment step 1:

Table C.1: Final parameters after Adsorption

PARAMETERS	FEED	AFTER PRECIPITATION	AFTER ADSORPTION
pH	11.86	7.6	7.79
COD (mg/l)	12230.4	1248	299.59
TDS	5590	3950	3420
Turbidity (NTU)	1335	2.41	2.37

The result obtained after treatment step 2:

Table C.2: Final parameter after Aerobic treatment and Adsorption

PARAMETERS	FEED	AFTER PRECIPITATION	AFTER AEROBIC TREATMENT	AFTER ADSORPTION
pH	11.86	7.6	8.20	7.9
COD (mg/l)	12230.4	1248	133.12	16.64
TDS	5590	3950	1030	990
Turbidity (NTU)	1335	2.41	2.24	3.33

Comparison among the different methods;

Methodology	% Reduction			
	pH	COD	TDS	Turbidity
Chemical Precipitation	31.04	56.25	TDS increased	Turbidity increased
Detox	7.9	50.51	4.39	26.94
Adsorption	5.9	74.18	TDS increased	22.28
Chemical Precipitation + Adsorption	34.31	97.55	38.81	99.82
Chemical Precipitation + Aerobic Treatment	-	77.7	-	-
Chemical Precipitation + Aerobic Treatment + Adsorption	33.3	99.86	82.28	99.75

The COD removal efficiency was 89.79% and the turbidity decreased drastically from 1335 NTU to 4.33 NTU (99.67%) in case of PAC, hence PAC was the key coagulant used. The initial COD level of 12230.4 mg/l was reduced to 1248 mg/l by chemical precipitation, to 133.12 mg/l by Aerobic treatment and finally to 16.64 through Adsorption. The COD lowered from 12230.4 mg/l to 16.64 mg/l at the final step (99.86% removal). The turbidity removal from these processes was about 99.75%, out of which the turbidity varied from 1335 NTU (Initial) to 2.41 NTU (through Chemical Precipitation), to 2.24 NTU (through aerobic treatment) and again slightly increased during the adsorption technique to 3.33 NTU. The pH always remained in the range if 7.8 to 8.3 during the entire process. The Total Dissolved Solids (TDS) reduced from 3950 ppm to 900 ppm (77.215%) during the entire procedure.

4. Conclusion

In this study, different methods of treatment of Chemical precipitation, Aerobic treatment, Adsorption were used for removing various impurities from the greywater. Chemical precipitation was the common preliminary step for all the types of water. Among all the coagulants PAC was the most effective one.

Ozonation method was not being brought into use because this produced excessive foam and also this was not economically feasible because of the ozone generator. For synthetic water, however a combined method of chemical precipitation and adsorption reduced the COD from 715 mg/l to 132.62 mg/l (81.45%), turbidity from 148 to 23.3NTU (84.25%) but increased the TDS in the water. The above method produced enhanced results but since adsorption is a novel technique and the replacement of the activated carbon frequently would result in reduction in the efficiency. Therefore an intermediate step of Aerobic treatment prior to adsorption was carried out.

The COD lowered from 12230.4 mg/l to 16.64 mg/l at the final step (99.86% removal). The turbidity removal from these processes was about 99.75%. Thus, it was concluded that the treatment procedure combining the Chemical Precipitation, Aerobic treatment and Adsorption was the most effective and economical in treating the laundry waste water. Since the TDS obtained is greater than the specified range this water cannot be used for drinking. However the other parameters obtained after the treatment were in the range specified by the WHO, therefore the treated water was fit for reuse in toilet flushing, Car washing irrigation and even watering of plants. However further treatment like RO/UV filtration would help in reducing the TDS values which would then making the water usable but would increase the cost of treatment.

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