International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 9, pp: 742-752 www.ijaem.net ISSN: 2395-5252

# Chemical treatments of Effluents from Agro-Based Paper Mill in Uttarakhand State of India

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Date of Submission: 15-11-2020 Date of Acceptance: 30-11-2020

**ABSTRACT:** The pulp and paper industries discharge large amount of effluent as wastewater in the surrounding streams thereby causing serious health and environmental problems. These large quantities of effluents need to be treated after characterization prior to their disposal. Physicochemical characteristics of effluents from an agro-based paper mills located in Uttarakhand state of India were analyzed in terms of pH, colour, TS, TDS, TSS, turbidity, BOD, COD, and AOX. The results demonstrated markedly higher values of all physicochemical parameters of effluents from various processing units of the paper mill than the permissible limit thus necessitating appropriate treatment prior to their discharge in the environment. In the present paper several types of coagulant viz. Ferric chloride, lime, alum and Ferric chloride with poly acryl amide(PAM) have been examined for their effectiveness of reducing chemical load of the effluent.

**KEYWORDS:** Effluents, coagulants, paper mill, BOD, COD, AOX

## I. INTRODUCTION

The pulp and paper industry is ranked as the third world's largest consumer of water consequently producing high amounts of waste waters [1].The natural raw material used for the processes are wood, cellulose, fibres, vegetables, rice husk, and waste-paper. It is established fact the effluent characteristics vary according to the process applied and chemicals used by industries during different processes [2]. Organic material and suspended solid contents are generally considered major pollutants of pulp and paper industry effluents [3]. Pollution of groundwater due to disposal of industrial and municipal effluents in water bodies is a major concern for habitants in cities and around the industrial clusters in India [4]. The paper mill effluent exhibit high biological oxygen demand (BOD) and chemical oxygen demand (COD) due to organics like, lignin, terpenes, cellulose, tannins, resin acids, fatty acids, phenolic compounds, coal and chlorinated organic compounds. Inorganics like sodium, calcium, silicates, sulphur and its compounds, Aluminium oxide ($Al_2O_3$), ferric oxide ($Fe_2O_3$), muds, grits, [5]. Discharge of such harmful chemical compounds into the environment, some of which are toxic, mutagenic, persistent, bio-accumulating and thus causing numerous harmful disturbance in biological system has the potential to disrupt the structure and functioning of the natural ecosystem [6]. Among the paper making processes, pulping especially chemical pulping generates waste water which contains wood debris and soluble wood materials. Similarly bleaching generates toxic substance as it utilizes chlorine for brightening the pulp [7]. There are many chemicals in paper mill effluent known to be toxic to animals and humans and proved to be genotoxic and carcinogenic. Tetra chloro dibenzo-dioxin (TCDD) found in paper mill effluent and one of the most toxic chemicals is a very aggressive carcinogen that also impairs reproductive health and may cause sterility. It is most commonly consumed by eating contaminated fish or drinking contaminated water. Some other toxins like nitrogen, nitrite, chlorides, transition metals, chelating agents and dioxins found in paper mill effluent have been proved to cause ailing effect to not only aquatic animals but humans also. Drinking contaminated water causes ulceration of internal organ linings, severe diarrhea, and if left untreated can prove to be fatal [8].The colloidal or suspended solids has a deleterious effect on the receiving streams as anaerobic decomposition of these solids consumes dissolved oxygen in the water and in turn affects adversly the aquatic life [9]. For the pollution abetment, it becomes essential to assess the physiochemical parameters of effluent and to evolve appropriate treatment measures accordingly to minimize the pollution load for their reuse in irrigation, industries and other purposes. The high volume of effluent discharge and associated economic constraints has made it mandatory for paper industries to treat the effluent to the extent till it comes within the norms of regulatory bodies.

## II. MATERIALS AND METHODS

### Chemical and Analytical

All the chemicals used were of analytical grade and referred to Sd fine chem, Ranbaxy, All the reagents and test solutions were prepared in triple distilled water and preserved in Schott Duran bottle. The laboratory glass used, were washed with detergents and rinsed with distilled water and then oven dried at 200$^0$C prior to use. The pH of the effluent samples was measured by using microprocessor digital pH meter (Remi).The turbidity of effluent samples was measured by using turbidity meter and the readings were recorded as nephlometric turbidity unit (NTU).

The pulp and paper mill selected for the study is located at 29° 12' 37.5156" N, 78° 57' 42.5880" E in the state of Uttarakhand, India. The mill (installed capacity of 100 tpd) adopts soda pulping process for pulp production using 8-10% caustic (NaOH) charge for wheat straw and 12-14% for bagasse during pulping.

### Collection of effluent samples

Samples from different streams were collected hourly for six hours and then mixed to make it composite for laboratory study from Agro based Mill of U.K (India).Effluent samples from different streams i.e. chlorination (C), extraction (E), combined bleach plant (CBP) and combined effluent (CE), were collected hourly for six hours from the Mill and then mixed to make it composite for laboratory study. The effluent samples were collected during summer (May, 2015) and winter (January, 2016) to observe any change in the characteristics of the effluent. Furthermore, the samples were acidified with nitric acid and gallons containing samples were preserved in refrigerator at 4$^0$C till further analysis.

### Physicochemical Characterization of Effluents

Effluents samples collected from various sections of processing units of the paper mill were subjected to physicochemical analysis according to standard methods [10, 11]. The pH of effluent samples was measured at the site of collection using microprocessor based pH meter (Labtronics).Colour of the samples was analyzed by spectrophotometric method. Turbidity of the effluent was measured by using turbidity meter (Hach 2100AN). The remaining effluent characteristics parameter, i.e., total solid (TS), total suspended solid (TSS), total dissolved solid (TDS), BOD and COD were determined volumetrically/ titrimetrically as per standard methods. AOX were measured with AOX analyzer (Analytic Jena-Multi X2000). All tests and measurements were carried out in triplicates in order to access the repeatability of the results.

## III. RESULT AND DISCUSSION

**Table 1: Physicochemical values of effluents from processing stages of the paper mill**

| Parameter | C- Stage | E- Stage | Combined bleach Effluent (CBE- Stage) | Combined Effluent(CE-Stage/primary clarifier inlet) |
|---|---|---|---|---|
| **pH** | 2.55±0.045 | 9.25±0.02 | 6.18±0.03 | 9.8±0.05 |
| **COD (ppm)** | 935.35±0.060 | 1125.61±0.06 | 705.52±0.40 | 2000.55±1.15 |
| **BOD (ppm)** | 170.32±4.35 | 670.42±1.06 | 625.35±8.80 | 655.75±2.31 |
| **TS (ppm)** | 2172.25±4.01 | 2785.79±6.56 | 2387.14±7.20 | 1980.65±11.55 |
| **TSS (ppm)** | 401±5.31 | 315.44±3.34 | 381.50±1.01 | 330.65±2.67 |
| **TDS (ppm)** | 1771.25±2.01 | 2470.35±3.29 | 2005.64±6.65 | 1650±9.97 |
| **Colour ( PCU)** | 410±0.060 | 1121±0.06 | 1845±0.40 | 2802±1.15 |
| **AOX (ppm)** | 40.82±0.38 | 26.05±0.39 | 24.62±0.15 | 14.98±0.50 |
| **Turbidity (NTU)** | 73.22±1.32 | 95.55±1.01 | 106.23±0.67 | 349.37±0.68 |

It is evident from the results of physicochemical analysis of effluents from different processing units presented in **table 1** that values of all the studied parameters vary to a great extent across the processing stages. The mean value of pH varied from 2.55±0.045 to 9.8±0.05 across the four different stages which may be due to the different process and chemicals used at various stage of processing. Effluent from different processing units may have both acidic and alkaline nature. In this study, effluent from chlorination section showed minimum mean value of pH which is in highly acidic range due to the formation of organic acids while processing. In fact, reactions of chlorine with water at chlorination stage lead to formation of hypochlorous acid and hydrochloric acid. The low pH of C-stage effluents may be due to dissociation of hypochlorous acid into hydrogen ion and hypochlorite ion. The highest pH value of effluents from CE unit may be due to the addition of alkali at this stage for the precipitation of total solids which produces hydroxyl ions in water thereby raising the pH of effluent making it alkaline in nature [12]. The effluent from CE unit recorded the pH value of 9.8 which is slightly higher than WHO prescribed tolerance limit of pH value for the paper industry effluent as 6 to 9 [13].Colour of effluents or wastewaters depend on concentration of lignin which come up due to the presence of low and high molecular weight chlorinated organic compound produced during different processing stages like pulping, bleaching and alkali extraction as the lignin degradation products [14-16]. The colour of the effluent from all the four processing stages measured in PCU showed considerable variation ranging from 410±0.060 to 2802±1.15 PCU. Data presented in table 1 revealed that CE effluent exhibited highest colour value followed by E, CBP and C stage. The darkest colour of CE effluent of the paper mill may be due to presence of some amount of black liquor. The colour of effluent has impact on its aesthetics, transparency and gas solubility [17].

The mean total Solids (TS) concentrations in effluents from C, E, CBE and CE units ranged from1980.65±11.55 to 2785.79±6.56 ppm respectively (Table 1). The lowest TS were found in effluent from the CE unit whereas effluent discharge at E unit showed the highest TS. Such effluents get warmed rapidly and hold more heat which is unfavorable for aquatic lives that are adapted to survive at a lower temperature. Total dissolved solid (TDS) was highest for discharge at E unit (2470.35±3.29 ppm) followed by CBE (2005.64±6.65 ppm) and C (1771.25±2.01 ppm) units. Effluents from CE unit however recorded the lowest (1650.67±9.97 ppm) TDS.

The observed values of TDS in discharge from all the processing units were higher than the WHO maximum permissible limit of 500 ppm (500 mg/L) for the discharge of wastewater into surface water. Effluents with higher TDS discharged in water bodies may increase salinity of water thereby making it unfit for irrigation and drinking purposes. Consumption of water with high TDS are reported to cause detrimental impact on alimentary canal, respiratory system, nervous system, coronary system besides, causing miscarriage and cancer [18].

Total suspended solids are usually referred to the undissolved matters including fibres, inorganic fillers, pigments, etc. present in the waste water. The mean TSS contents of effluents from different points C, E, CBE and CE varied from 315.44±3.34 to 401.35±5.31 ppm. The highest TSS was found in effluents from CE unit followed by CBE and E units whereas C unit effluent recorded the lowest TSS. The TSS values measured at all the four discharge points are higher than the WHO maximum limit of 100 ppm (100 mg/L) for discharge of waste water to surface water bodies. Effluent discharge at E unit recorded the lowest TSS.

Turbidity in wastewater is due to the presence of insoluble matters, soluble coloured compounds, and plankton measured either as a reduction in the intensity of transmitted light or as an increase in the intensity of scattered light, is an important parameter for the assessment of effluent quality [19]. The mean value of turbidity of effluents from C, E, CBE and CE streams has been found as 73.22±1.32, 95.55±1.01, 106.23±0.67 and 349.37±0.68 NTU indicating maximum and minimum turbidity in effluents from CE and C streams respectively (Table 1). Higher turbidity reduces the amount of light penetrating the water, which reduces photosynthesis and the production of dissolved oxygen. The results clearly indicated the elevated turbidity in effluents at all processing units and are higher than the WHO standard limits of 5 NTU and should ideally below 1 NTU [20]. Biological oxygen demand (BOD) signifies the amount of oxygen required for microbial degradation of organic matter as well as the self purification capacity of the water body. It is a measure of the organic pollution load of effluents thus quantifies the dissolved oxygen levels. The mean values of BOD for effluents at C, E, CBE and CE units ranged from 170.32±4.35 to 670.42±1.06 ppm. Highest BOD value was found for the effluent from E unit and lowest for that from C unit. However all the values are higher than IS prescribed limit of 100 ppm (100 mg/l) for safe disposal of effluents. The high BOD and low oxygen content of effluent affect survival of gill breathing animals of the receiving water body [21].

Chemical oxygen demand (COD) is the amount of oxygen required to breakdown both organic and inorganic matter and is one of important parameters for assessing pollution load of effluents. The mean value of BOD for effluents at C, E, CBE and CE units was found as in the range of 705.52±0.40 to 2000.55±1.15ppm with maximum and minimum values for effluent of CE and CBE units respectively. The value obtained for effluents of all units are greater than the acceptable limits of 350 mg/l [22] thereby suggesting their toxic nature which may be due to high chemical concentration along with the presence of biologically resistant organic substances [23,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 9, pp: 742-752 www.ijaem.net ISSN: 2395-5252

24].The adsorb able organic halides (AOX) is the quantification of organically bound chlorine compounds such as dioxins and furans, chlorinated phenolic compounds etc. present in the effluents discharged from bleaching sections, where chlorine-based chemicals are used [25].

The CE unit that includes bleach plant effluent, excess backwater from paper machine and the discharge from entire processing units contributes to darkest colour, higher COD along with higher TDS, TSS and turbidity as well. Colour in effluent of CE unit is mainly due to lignin, its derivatives and polymerized tannins which are mostly discharged from the pulping, bleaching and recovery sections. Higher COD in CE effluents is due to presence of highly non-biodegradable lignin, phenol compounds and various toxic substances [26, 27]. Results also indicate that the effluent from E-unit is more polluted than that of from C and CBE units owing to high TS, TDS, BOD and COD. The higher level of colour in the bleach effluent of E unit is indicative of high lignin content extracted out with alkali. Nevertheless, colour of effluents from different processing units of the mill may be due to the presence of low and high molecular weight chlorinated organic compounds generated during pulping and bleaching of pulp. The physicochemical values of effluents from various processing units were found to be higher than permissible limits before discharge [28, 29].

**Treatment of pulp and paper mill effluent (Coagulation/flocculation study)**

In this experiment, the effect of ferric chloride, lime, and alum on COD, BOD, TS, TDS, TSS, Color, AOX and turbidity at each stage of effluent was studied with respect to different amount of chemical doses (100, 300, 500 ppm), pH (~7), revolution (50, 100 and 150 rpm) and retention time intervals (30, 80, and 130 min). A stock solution of 10g/L of ferric chloride, alum and lime was prepared and different doses of 100, 300 and 500 ppm respectively were taken out from this stock solution. For experiment of ferric chloride, alum and lime, total 27 runs were performed for which, 250 ml conical flasks were filled with 100 ml of effluent with different chemical doses.

Treatment with combination of poly acryl amide (PAM) with ferric chloride was done in another set of experiment. In this set of experiment, combination of PAM and ferric chloride was undertaken at the optimum conditions in order to assess the effects of combined treatment on pollution reduction in terms of all the physicochemical parameters.10ppm dose of PAM with optimized dose of ferric chloride at the optimum condition (rpm, RT) in 250ml conical flasks which were filled with 100ml bleach effluent and combined effluent from different sections of the mill. Here the experiments were conducted in triplicate in order to assess the repeatability of the results. The pH of the samples was then adjusted to 7 with the help of 1 N NaOH and 1 N $H_2SO_4$. Effluent was then subjected to mixing at different rotation and retention time as mentioned above. The treated samples were filtered and analyzed for COD, Color, AOX and other parameters as per APHA and CPPA standard methods.

**Ferric chloride treatment**

It is well known that in aqueous medium, ferric chloride hydrolyzes to form positively charged ions and polymeric ions that have a very large surface area and they tend to absorb onto surface of negatively charged colouring organic matter and forms insoluble precipitates which eventually which eventually settle down as sludge [30, 31]. The chemical treatment with $FeCl_3$ was carried out under optimum condition of 100 ppm dose, 150 rpm and 80 minutes retention time at C-stage, the optimum condition of dose 500ppm, 50 rpm and Rt.30 minutes for E-stage, 300ppm dose, 150 rpm and 80 minutes retention time for CBE-stage and under optimum condition with a dose of 500 ppm at 100 rpm for 130 minutes retention time for CE-stage. The reduction efficiency of the treatment is presented in the following table.

**Table 2: Reduction (%) with the $FeCl_3$ treatment**

| parameters | C -Stage | E-Stage | CBE -Stage | CE-Stage |
|---|---|---|---|---|
| COD (ppm) | 81.17 | 91.94 | 85.48 | 77.53 |
| BOD (ppm) | 58.68 | 52.65 | 56.33 | 59.61 |
| TS (ppm) | 24.62 | 19.78 | 16.74 | 23.89 |
| TSS( ppm) | 30.57 | 19.76 | 26.00 | 12.47 |
| TDS (ppm) | 22.80 | 19.78 | 14.97 | 26.16 |
| Colour (PCU) | 53.51 | 73.38 | 54.16 | 68.80 |
| AOX (ppm) | 49.53 | 47.79 | 27.43 | 63.28 |
| Turbidity(NTU) | 56.84 | 47.94 | 51.37 | 60.99 |

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 9, pp: 742-752 www.ijaem.net ISSN: 2395-5252

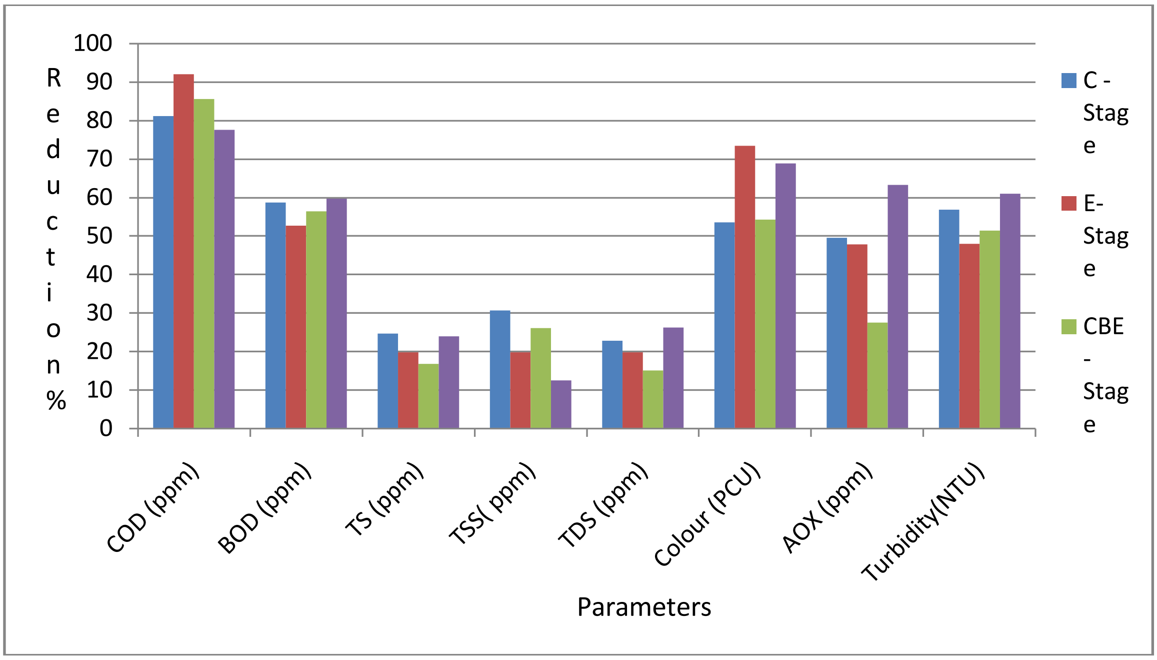


**Fig 1: Reduction (%) with the $FeCl_3$ treatment**

From table 2.0 and fig.1, it is amply clear that the reduction in COD (ppm) is 81.17%, 91.94%, 85.48% and 77.53% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in BOD (ppm) is 58.68%, 52.65%, 56.33% and 59.61% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in color (PCU) is 53.51%, 73.38%, 54.16% and 68.80% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in AOX (ppm) is 49.53%, 47.79%, 27.43% and 63.28%for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in TS (ppm) is 24.62%, 19.78%, 16.74% and 23.89% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in TSS (ppm) is 30.57%, 19.76%, 26.00% and 12.47% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in TDS (ppm) is 22.80%, 19.78%, 14.97% and 26.16% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in Turbidity (NTU) is 56.84 %, 47.94%, 51.37% and 60.99% for the all four stages named C-, E- CBE-, and CE- respectively. The results obtained are very much in conformity with the expectation and hence this treatment may be used as pre treatment step for reduction in the mentioned parameters to reduce the inlet pollution load that would lead to overall reduction in chemical and energy consumption along with improvement in efficiency of effluent treatment plant. The $Fe^{3+}$ ion is similar to $Al^{3+}$ in its strong tendency to complex with $OH^-$ ions and in terms of valence. The fact that iron compounds are highly colored generally precludes their usage in papermaking applications, but for water treatment they can offer a less expensive alternative compared to aluminum salts

**Lime Treatment**

Lime having great potential as a colour reducing chemical, easy availability and being cost effective is natural selection for the purpose. Lime is considered better decolourising agent due to precipitation of calcium salts of weak organic acid produced by chemical separation and fragmentation of lignin during pulping and bleaching. The treatment of wastewater from pulp and paper mills takes advantage of the fact that large amounts of calcium oxide are routinely combined with water and then converted to calcium carbonate during the process of regeneration of the pulping chemicals that are used for kraft cooking of the fibers which is known as massive lime strategy [32].

The chemical treatment with lime was carried out under optimum condition of dose100ppm, rpm 150, RT 80minutes at C-stage, dose500ppm, rpm50, RT 30minutes at E-stage, dose 300ppm, rpm150, and RT 80minutes for CBE-stage and dose500ppm, rpm100, RT 130min for CE-stage. The reduction efficiency of the treatment is presented in the following table.

| parameters | C -Stage | E-Stage | CBE -Stage | CE-Stage |
|---|---|---|---|---|
| COD (ppm) | 73.48 | 85.93 | 76.11 | 74.74 |
| BOD (ppm) | 46.71 | 60.45 | 55.95 | 59.55 |
| TS (ppm) | 22.91 | 16.00 | 23.65 | 20.45 |
| TSS( ppm) | 19.70 | 14.30 | 32.52 | 29.70 |
| TDS (ppm) | 24.67 | 16.31 | 16.91 | 21.50 |
| Colour (PCU) | 51.50 | 82.47 | 70.60 | 89.34 |
| AOX (ppm) | 47.77 | 46.10 | 28.71 | 36.31 |
| Turbidity(NTU) | 33.08 | 23.37 | 30.97 | 38.38 |

**Table 2: Reduction (%) with the lime treatment**

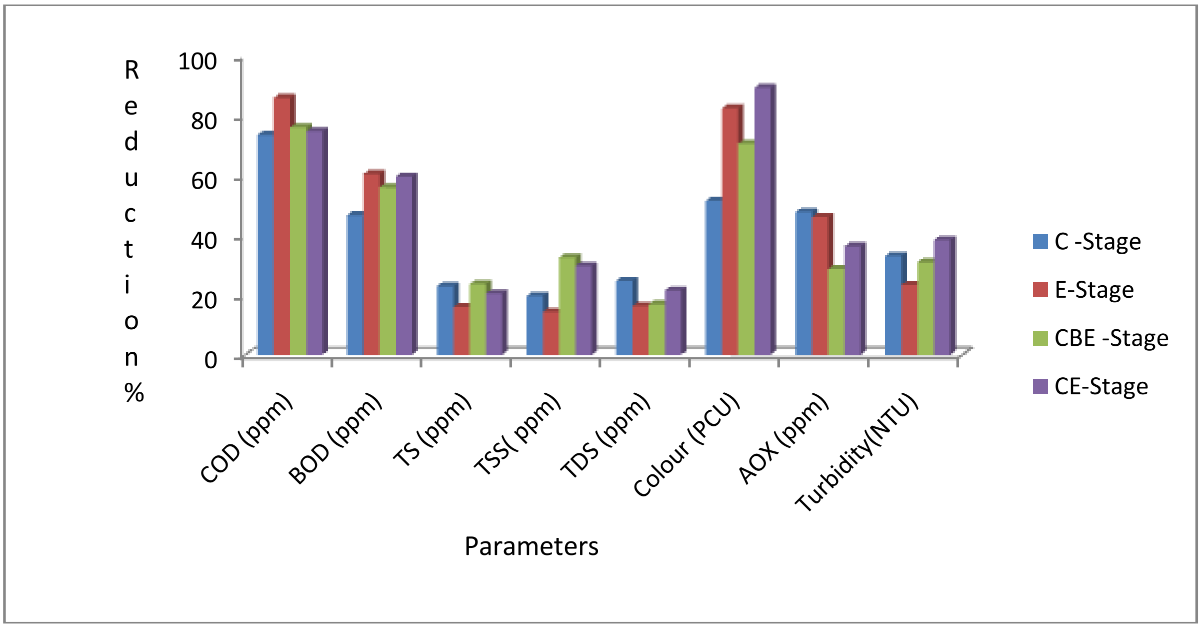


**Fig 2: Reduction (%) with the lime treatment**

Table 3.0 and fig2, indicates that the reduction in COD (ppm) is 73.48%, 85.93%, 76.11% and 74.74 % for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in BOD (ppm) is 46.71%, 60.45%, 55.95% and 59.55% for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in color (PCU) is 51.50%, 82.47%, 70.60% and 89.34%for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in AOX (ppm) is 47.77%, 46.10%, 28.71% and 36.31%for the all four stages named C-, E- CBE-, and CE- respectively. Reduction in TS(ppm) is 22.91%,16.00% ,23.65%and 20.45%for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TSS (ppm) is 19.70%, 14.30%, 32.52% and 29.70%for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TDS (ppm) is 24.67%, 16.31%, 16.91% and 21.50% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in Turbidity (NTU) is 33.08%, 23.37%, 30.97% and 38.38%for all the four stages named C-, E- CBE-, and CE- respectively. Notably, lime is found to be more efficient in terms of colour reduction capacity which validates the fact of being good decolourising agent, similar is the opinion of various researchers regarding its efficacy in terms of pollution load reduction.

**Alum Treatment**

It has been found that most of the reported research work used aluminium, ferrous salts and its polyelectrolyte for the coagulation/ flocculation process, to remove the toxic organic materials from the wastewater in order to make it amenable to secondary treatment, like wet air oxidation (WO) or biological treatment. The treatment was performed under optimum condition of at 100 ppm dose, 50 rpm for 80 minutes retention time at C-stage, 500 ppm dose, 50rpm for 30 minutes retention time at E-stage, 300 ppm dose, 150rpm for 80 minutes retention time for CBE-stage and 500 ppm dose, 100rpm for 130 minutes retention time for CE-stage. The reduction efficiency of the treatment is presented in the following table.

**Table 4: Reduction (%) with the Alum treatment**

| parameters | C -Stage | E-Stage | CBE -Stage | CE-Stage |
|---|---|---|---|---|
| COD (ppm) | 83.49 | 90.56 | 86.37 | 78.75 |
| BOD (ppm) | 60.95 | 46.86 | 57.23 | 71.46 |
| TS (ppm) | 29.54 | 20.46 | 25.19 | 42.16 |
| TSS( ppm) | 21.36 | 19.97 | 32.98 | 20.59 |
| TDS (ppm) | 31.92 | 20.52 | 24.71 | 41.50 |
| Colour (PCU) | 77.00 | 91.60 | 82.39 | 84.62 |
| AOX (ppm) | 33.17 | 50.67 | 37.85 | 54.93 |
| Turbidity(NTU) | 62.68 | 63.30 | 59.10 | 63.77 |

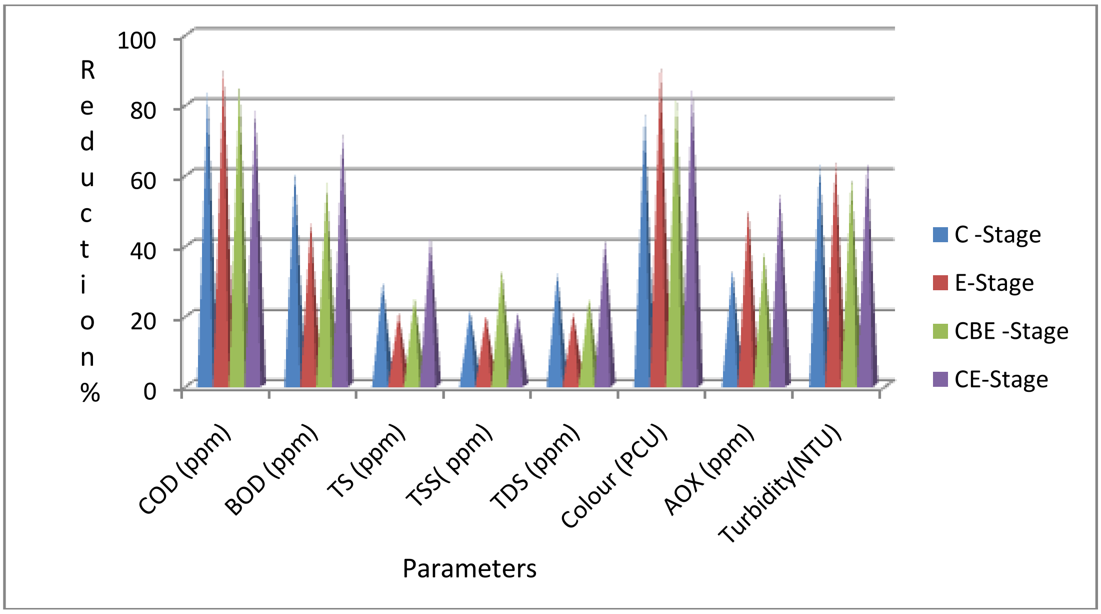


**Fig 3: Reduction (%) with the Alum treatment**

From table 4.0 and fig3, it is obvious that the reduction in COD (ppm) is 83.49%, 90.56%, 86.37% and 78.75% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in BOD (ppm) is 60.95%, 46.86%, 57.23% and 71.46% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in color (PCU) is 77.00%, 91.60%, 82.39% and 84.62% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in AOX (ppm) is 33.17%, 50.67%, 37.85% and 54.93% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TS (ppm) is 29.54%, 20.46%, 25.19% and 42.16% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TSS (ppm) is 21.36%, 19.97%, 32.98% and 20.59% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TDS (ppm) is 31.92%, 20.52%, 24.71% and 41.50% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in Turbidity (NTU) is 62.68%, 63.30%, 59.10% and 63.77% for all the four stages named C-, E- CBE-, and CE- respectively. Although economical, in comparison to other methods, the precipitation method has other associated drawbacks like dewatering and disposal of the generated sludge. However, coagulation/flocculation can be used as an effective primary treatment method to remove much of the, COD, BOD, Colour, toxicity and other parameters. This treatment will make the secondary treatment cost effective as well as efficient in the removal of residual toxic organic compounds which signifies the role of alum for pre treatment and post treatment for the pollution load reduction and obviously is in consonance with the findings of the previous researchers regarding its pollution load reducibility in the respective stages.

**Ferric chloride and Poly acryl amide Treatment**

The main function of flocculants, which consist of very high mass poly electrolytes, usually having a cationic charge, is to collect small agglomerates into large agglomerates. The agglomerates formed by means of flocculants tend to be stronger and more shear-resistant than agglomerates brought about just by charge neutralization. In flocculation process, destabilized particles produced by various coagulants stiff into heavy particles which can be separated from waste water, that is why flocculent can be used individually as well as in combination with coagulant. Similar studies were carried out by previous researchers [33]. The treatment was carried out with 10 ppm dose of PAM mixed with the optimised doses of 100 ppm $FeCl_3$ at 150rpm and 80 minutes retention time at C-stage, 500 ppm dose, 50rpm for 30 minutes retention time at E-stage, at 300 ppm dose, 150rpm for 80 minutes retention time for CBE-stage and 500 ppm dose, 100rpm for 130 minutes retention time for CE-stage. The reduction efficiency of the treatment is presented in the following table.

**Table 5: Reduction (%) with the $FeCl_3$+PAM treatment**

| parameters | C-Stage | E-Stage | CBE -Stage | CE-Stage |
|---|---|---|---|---|
| COD (ppm) | 78.70 | 87.20 | 79.23 | 83.72 |
| BOD (ppm) | 51.74 | 74.37 | 57.58 | 56.96 |
| TS (ppm) | 27.95 | 20.21 | 32.58 | 30.77 |
| TSS( ppm) | 28.43 | 23.74 | 37.77 | 32.16 |
| TDS (ppm) | 27.85 | 19.76 | 31.59 | 30.37 |
| Colour (PCU) | 50.84 | 89.23 | 70.69 | 78.78 |
| AOX (ppm) | 50.98 | 50.28 | 37.25 | 49.04 |
| Turbidity(NTU) | 43.25 | 32.43 | 32.65 | 61.45 |

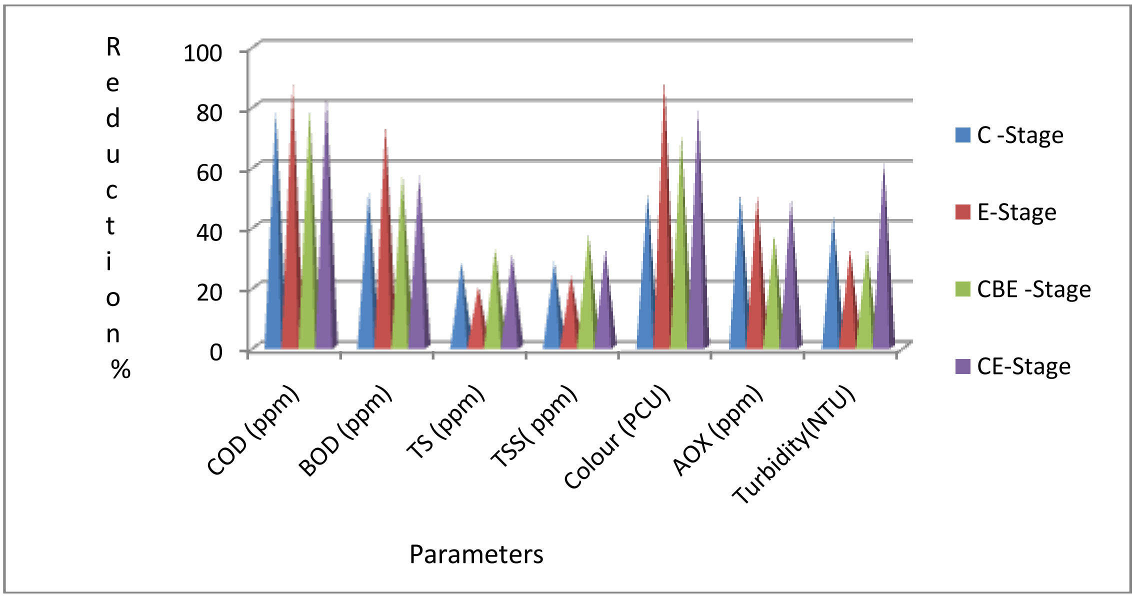


**Fig 4: Reduction (%) with $FeCl_3$+PAM treatment**

From table 5.0 and fig4, it is amply clear that the reduction in COD (ppm) is 78.70%, 87.20%, 79.23% and 83.72 % for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in BOD (ppm) is 51.74%, 74.37%, 57.58% and 56.96 % for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in color (PCU) is 50.84%, 89.23%, 70.69 % and 78.78% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in AOX (ppm) is 50.98%, 50.28%, 37.25% and 49.04% for all the four stages named C-, E- CBE-, and CE-respectively. Reduction in TS (ppm) is 27.95%, 20.21%, 32.58% and 30.77% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TSS (ppm) is 28.43%, 23.74%, 37.77% and 32.16% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in TDS (ppm) is 27.85%, 19.76%, 31.59% and 30.37% for all the four stages named C-, E- CBE-, and CE- respectively. Reduction in Turbidity (NTU) is 43.25%, 32.43%, 32.65% and 61.45% for all the four stages named C-, E- CBE-, and CE- respectively. Thus, with combining the poly acryl amide with $FeCl_3$ makes the reducibility even better than chemical used in isolation which again is in conformity with the view of the researchers worked for similar purposes.

## IV. CONCLUSION:

The chemical treatment with coagulation method is an easy and relatively economical method for the treatment of effluent. Reduction efficiencies of $FeCl_3$, lime, alum, and $FeCl_3$+PAM in reduction of parameters viz. COD, BOD, TS, TDS, TSS, Color, AOX and turbidity were determined for the effluents of all the four stages from the selected mill. Results indicated a significant reduction in COD with all the chemical treatments with an average > 80% reduction; however, alum was found to be the most effective followed by ferric chloride considering overall conditions of the mill. In terms of colour reduction, the combined chemical treatment with $FeCl_3$+PAM was found to be the most effective followed by the lime. Furthermore, alum was found to be the most efficient in reducing the chlorinated organic halides (AOX) where reduction was more than 90% followed by $FeCl_3$+ PAM. As far as other physicochemical parameters are concerned the reduction percentage with the chemical treatments can be assumed appreciably significant that lies in the range of 10 to 60% depending on the different stages. Conclusively, use of these chemicals as pre treatment steps not only reduce the pollution loads, but will also help paper mills in reducing the operating cost of subsequent activated sludge process widely used for treatment of effluent to meet the discharge standards. Secondly, the optimized treatment conditions as evolved through the study for the agro-based paper mill could successfully be used in prediction of their toxicity and effective management and will also help in formulation of proper strategies to counter the pollution load borne by paper mill effluents prior to their disposal into the environment.

## V. ACKNOWLEDGEMENT

Author is grateful to the Director, CPPRI, Saharanpur, UP and the Director, Forest Research Institute Dehradun for providing necessary analytical facilities.Help and cooperation rendered by paper mill personnel towards collection of effluent samples and relevant technical information and production statistics of the mill is thankfully acknowledged.

**Conflict of interest:** None declared.

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