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Treatment of wastewater resulting from paper industry using integrated coagulation, sedimentation and filtration process

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ABSTRACT

A study has been done on the treatment of effluent wastewater resulting from pulp and paper mills using the integrated coagulation, sedimentation and filtration process. Three of the most effective coagulants have been evaluated: alum, ferric chloride, and poly aluminum chloride (PAC) for the chemical precipitation stage and geotextile filter for the filtration process. The optimum dose of alum, ferric chloride, and PAC used were 25 ppm, 5 ppm, and 100 ppm, respectively, which reduce COD by 80%, 81%, and 82% and reduced TSS by 97%, 96%, 95% respectively. A comparison between the three chemicals in performance, dose, price and sourcing was done. As a result, ferric chloride with a dose of 5 ppm was the best coagulant which was used as primary treatment. The effect of using geotextile filter as secondary processed treatment by plain or chemical coagulation was also tested and evaluated. Results showed that using a geotextile filter as a slow rate filter after plain sedimentation provides realistic and better operational results, with a running time of up to 13 and 6.5 days before reaching 100% clogging at a filtration rate of 2 and 5 $m^3/m^2/d$ respectively. While using geotextile filter after chemical precipitation increase the running time of the filter up to 16.5 and 7.6 days before reaching 100% clogging at a filtration rate of 2 and 5 $m^3/m^2/d$ respectively. The results also showed that using plain sedimentation before geotextile filtration yields good results without the need to add an expensive chemical coagulant, as the COD removal ratio reaches to 85 and 90% at filtration rate of 5 and 2 $m^3/m^2/d$ respectively and the TSS removal ratio reaches to 100%.

Keywords: Alum, chemical precipitation, coagulation, filtration, geotextile, PAC, paper industry wastewater and waste treatment.

INTRODUCTION

It is well known that the pulp and paper industry is one of the major consumers of non-renewable energy, such as fossil fuels and electricity, in addition to the massive use of wood and water for manufacturing, discharging significant quantities of pollutants into the environment (Wan et al., 2022). After primary metals and chemicals, pulp and paper production generates the third-largest amount of wastewater which represents 42% of the world's industrial effluent (Sharma et al., 2022; Savant et al., 2006; Ashrafi et al., 2015). The global market for wastewater treatment in the pulp and paper sector is expected to increase from $983.9 million in 2012 to $1.569 billion in 2020, according to an analysis by Frost and Sullivan (Toczyłowska-Mamińska, 2017).

Total suspended solids (TSS), and chemical oxygen demand (COD) are examples of common contaminants found in wastewater from paper and pulp industry (Javeed et al., 2023). The typical characterises of wastewater from paper and pulp industry are shown in Table 1 (Toczyłowska-Mamińska, 2017; Wagle et al., 2020). Characteristics may be changed according to operating condition, number of water cycles in operation system, and characteristics of paper wastes.

Toczyłowska-Mamińska (2017) stated that manufacturing process of paper from wood pulp includes three main steps; pulping, bleaching and papermaking. The first step; pulping (mechanical, hybrid or chemical methods), which requires separating the cellulose fibres from the primary source, typically wood chips. Pulping processes range from the physical separation of fibres using mechanical pulping, to chemical degradation and removal of lignin to release the fibres. Bleaching step, as chemical pulps are generally used for high-quality paper or personal product uses, the pulp may be bleached to enhance brightness, whiteness and perceived cleanliness. The last step; papermaking step, this step where the paper manufacturing process begins. Typical characteristics of mechanical and chemical pulping process effluents and pulp and paper mills effluents are summarized in Table 1.

Bajpai, (2014) reported that waste paper is an important raw material that can be reused and has an economic value that can be used in the process of manufacturing of many paper types. In order for waste paper to be recycled, it needs to go through some processing stages. These stages include pulping, sieving, washing and flotation, deink, bleaching and finally paper making process (Thompson, 2004). Most Paper industry in Egypt depend on recycled paper by using waste paper and cartons, which is sorted, shredded and mixed with hot water and chemicals, then the paste is spread on sheets and dried at high temperature. Wastewater resulting from stages of paper industry is collected through channels located beneath those stages, and it is not separated individually; rather, it is handled by collecting and treating it all at once.

Wastewater from pulp and paper is the subject of much research utilizing various treatment techniques. Chemical, physical, and biological treatments are some of these techniques. As a result of the shortcomings of the earlier techniques, which included their high cost, their restrictions, and the challenge of integrating biological approaches as small units within factories due to the strict working conditions and follow-up requirements they require. Other reaches were treated with sedimentation and then filtration, which produced treated water of high quality at a reasonable cost. In order to achieve high-quality treated wastewater, a research of water and pulp wastewater was conducted utilizing chemical and plain sedimentation as the first stage and geotextile filtering as the second. It is possible to use this treated wastewater for street washing and irrigation (Ash, n.d.; Civil, n.d.; Paranhos et al., 2023), filtration (Moo-young and Tucker, 2002; Science, 2023) and Cleaning Water Bodies (Bhatia, 2023).

Fiber-containing wastewater from the pulp and paper industries might present unique challenges for the separation of solids from liquids. Most solid-liquid separation systems struggle to operate when they have to produce high-quality water, filter out particles, run continuously, and remove large volumes of fiber. Chemical coagulation followed by filtration is an effective technique for treating wastewater with a high concentration of suspended particles. Most studies and real-world examples have shown that coagulation will reduce pollution loads and produce adequate water recovery (Ahmad et al., 2008; Al-Malack et al., 1999; Aguilar et al., 2002; Holt et al., 2002) (Georgiou et al., 2003; Al-Mutairi et al., 2004). Other studies refer using geotextile membrane as filter media which gave high quality of treated water (Science, 2023; BM and U, 2016). In addition to alum and ferric chloride, poly aluminium chloride is used as coagulants in water and wastewater treatment and in some other applications. Their mode of action is typically described in terms of two separate mechanisms: inclusion of impurities in an amorphous hydroxide precipitate known as flocculation and charge neutralisation of negatively charged colloids by cationic hydrolysis products (Duan and Gregory, 2003). The relative importance of these mechanisms depends on factors such as coagulant type and coagulant dosage.

Therefore, the purpose of this research was to study the effect of using chemical precipitation using three different types pf coagulants (Alum, Ferric chloride and Poly aluminium chloride) with varying concentrations for treatment of wastewater resulting from paper industry. Another purpose is to studying the performance of the geotextile filter for completing the treatment process under varied filtration rates.

MATERIALS AND METHODS

In the following subsections a description of used materials, experimental models, sampling, the experimental program and methods of analysis will be illustrated.

Characteristics of the paper mill wastewater

The wastewater used in this study was collected from the effluent wastewater from paper mill factory called "Mino Bardi" factory, located in Qwesna city (Menoufia governorate, Egypt). Due to the difficulty of obtaining raw untreated wastewater from the factory, the original samples of wastewater were collected from the effluent

Table 1. Typical characteristics of mechanical and chemical pulping process effluents and pulp and paper mills effluents

For mechanical and chemical pulping process effluents		For pulp and paper mills effluents	
Chemical composition	concentration in ppm (mg/l)	Chemical composition	Concentration in ppm (mg/l)
COD	500–115000	COD	480–4450
TSS	800–1000	TSS	800–1000
pH	6.3–6.8	pH	6.1–8.3
Lignin	11000–25000	BOD_5	120-4000
Sulfate	3–5100	Sulfates	241
Sulfite	50–4800	Chlorides	80–980
Sulfides	1–270	Phosphates	155–470
Acetic acid	235–10400	Volatile fatty acids	950
Resin acids	3.2–550	Acetic acid	200
Chlorides	13.9–38.5	Propionic acid	98
Total acids	5	Butyric acid	36
Phenols	17–800	Total polyphenols	48
Peroxide	0–1000	Total dissolved solids	395–2500
Furfural	0–1140	Cellulose	1200
Terpenes	0.1–25000	Butyric acid	36
2-Propanol	0–18	Total polyphenols	48
Methanol	90–12000	N	Ranged from 10 to 350 according to process
Ethanol	0–3200	SS	120–4000
Abietic acid	4.3–5.2	Color (Pt-Co)	Ranged from 4000 to 5000
Oleic acid	5.3–14.5	Conductivity μs/cm	1365
β-Sitosterol	2.2	T/L mg/L Tannic acid	33
Tannins	2730		

pipe of treated wastewater from the factory into the public sewer network. The treatment process inside the factory including removal of higher percentage of TSS using Flotation unit followed by disk filter unit. In order to increase the solid content to simulate the raw wastewater, the original samples were mixed with chopped carton in the laboratory. Table 2 shows the properties of both the original and the synthetic wastewater used in the present study. The parameters were measured according to the Standard Methods for the Examination of Water and Wastewater (Sandiford, 2009). Wastewater produced from paper industry acquires a content of dissolved solids from the processes that occur within the factory, whether in the manufacturing stages or in the stages of water reuse within the factory. It has been clarified that the water sample taken from the factory was treated water, and the content of suspended solids was increased only by using shredded cardboard, which gives the impression of an increase beyond the usual level.

Wastewater characteristics produced from the paper industry vary from one factory to another and even daily within the same factory according to several factors indicated below:

1. Manufacturing method.
2. The number of recycle times for water before it is disposed of.
3. The chemicals used in manufacturing (Retention Aids that improve drainage and increase retention of fine particles.)The nature of the materials used in manufacturing that includes newspapers, recycled paper and other.

Coagulants

Three of most popular coagulants have been used as follows:

1. Alum)$Al_2(SO_4)_3.18H_2O$ (with density of 1.725 g/cm^3 and molar mass of 474.39 g/mol in dry state and about 666.5 g/mol in wetted state
2. Ferric chloride ($FeCl_3$) with density of 2.9 g/cm^3 and molar mass of 162.2 g/mol

3. Poly aluminium chloride (PAC 18 %) with density of 1.37 g/cm^3 and Molar mass of 80.45 g/mol

Equipment used

Jar test procedures were performed with the conventional jar apparatus (I.S.CO.SRL-MILANO, model JF/F) shown in Figure 1 using 6 glasses with volume of 1000 ml. Coagulants were added with different concentrations (5, 10, 25, 50,100,200, 400, 600, 800, 1000, 1200 mg/L) and keeping other variables constant like stirred velocity, stirred time and sedimentation time. Samples were stirred for a period of 2 min at 200 rpm. It was followed by a further slow mixing of 15 min at 40 rpm. The flocs formed were allowed to settle for 30 min, then clarified water was analysed for TSS and COD conc.

Preparation and setting

Two steel tanks were used with dimension 100 × 100 cm and 100 cm depth equipped with variable speed stirrer fixed on the top and clear side Figure 2 For the following purposes

1. The first tank is used to prepare the synthetic samples with chopped carton, coagulant addition, and rapid mixing.
2. The second tank is used to gentle mixing and settling for 30 min.

Figure 1. Jar test apparatus

Filtration apparatus

The filtration apparatus used in this study made from acrylic material with cross-section of (10 × 10) cm and 130 cm height shown in Figure 3. The filtration reactor consists of:

1. 10 cm from bottom under drainage system
2. 10 cm of small gravel (passed from sieve size 5and retained on sieve size 10)
3. Geotextile media with different density (300 – 400 –………– 1100 – 1200) gsm
4. Water distributer at height 10 cm from top
5. Submersible pump (DL-3000) for high flow rate

Table 2. Properties of original and synthetic wastewater (paper and pulp wastewater mixed with chopped carton)

Chemical composition	Original sample concentration in ppm (mg/l)	Synthetic sample concentration in ppm (mg/l)
COD	720–790	1000–1500
TSS	345–375	800–1000
Total nitrogen	---	14
TS	---	1200
Turbidity	---	160
CL^-	---	150
pH	---	6.7
Electrical conductivity	---	9.82 S m^{-1}
Fe	---	0.7819
Manganese	---	0.2429
Magnesium	---	0.2995
Lead	---	0.0244
Chromium	---	0.0004
Barium	---	0.1556
Cadmium	---	0.0279
Nickel	---	0.1244
Cobalt	---	0.0147
Arsenic	---	0.0347

Figure 2. Settling tank used

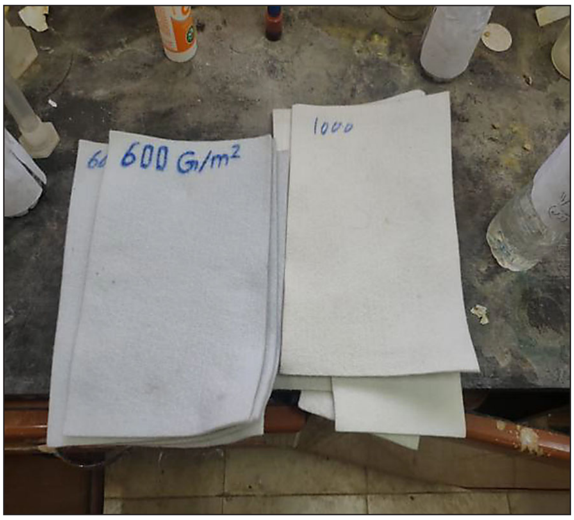

Figure 4. Geotextile filters

up to 2000 l/h rate and scientific dry pump (watson marlow) for small flow rate up to 220 rpm
6. Hoses, valves and supports

Geotextile filter

During this study geotextile filters with different density (300 – 400 –...– 1100 – 1200 gsm) were used, which is supplied from non-woven technical textiles factory called EGYPTEX that located in Badrasheen city (Giza governorate, Egypt) shown in Figure 4.

EXPERIMENTAL PROCEDURE

First stage (chemical precipitation)

This stage aims to study the effect of coagulant type and dose on pollutants removal. Jar test procedures were performed using 800 ml wastewater samples. Different concentration of three types of coagulant (5, 10, 25, 50,100, 200, 400, 600, 800, 1000 and 1200 mg/L) were tested. The selected coagulant dosage was added to 800 mL of wastewater and it was stirred for a period of 2 min at 200 rpm. And followed by a further slow mixing of 15 min at 40 rpm (Wong et al., 2006). After that settling were allowed for 30 min. After settling, TSS and COD conc. were determined.

Second stage (membrane filtration preceded by chemical precipitation)

In this stage, the geotextile membrane filtration efficiency was studied to complete the treatment of wastewater after chemical precipitation. Rates of filtration and membrane density were studied and membrane life time and head losses was recorded in addition to removal efficiency of TSS and COD.

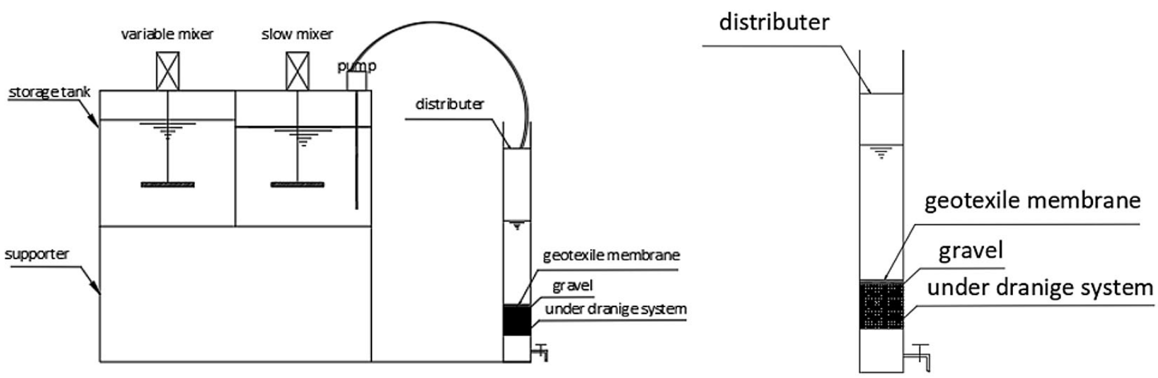

Figure 3. Filtration apparatus

Third stage (membrane filtration preceded by plain sedimentation)

In this stage the geotextile membrane filtration efficiency was studied to treat wastewater after plain sedimentation for 30 min retention time. This stage aims to comparing the final efficiency of TSS and COD removal from paper effluent wastewater using (plain sedimentation + membrane filtration) versus (chemical precipitation + membrane filtration)

RESULTS AND DISCUSSION

First stage (chemical precipitation)

Effect of using coagulants with small dose

In this stage small doses of each coagulants (5 – 10 – 25 – 50 – 100) ppm have been used, the COD and TSS removal ratio was recorded in Figure 5 and Figure 6. It is noticeable that the optimum concentrations of alum, ferric chloride, and PAC are 20 ppm, 5 ppm, and 100 ppm, respectively, which reduce COD by 80%, 79%, and 77% and TSS by 97%, 98%, and 96% respectively which agree with results from other researches (Wong et al., 2006) (Ahmad et al., 2008). The figure illustrates the COD removal ratios of 79%, 75%, and 73% for alum, ferric chloride, and PAC respectively at zero coagulant content (no chemicals are added). In order of sequence, the removal ratio only increased by 5% with the addition of coagulant, indicating a slight increase in the COD removal ratio and an improvement in filter lifespan. The following paragraph presents a comparison between the use of chemical coagulant and plain sedimentation, taking into consideration Egyptian code and economic constraints.

Effect of using coagulants with high dose

This trials aim to study using high doses of chemicals only (200 – 400 – 600 – 800 – 1000 – 1200 mg/l) in case of no further stages of treatment needed. Results of these trials showed that, there was no significant increase in the removal efficiency of COD or TSS as shown in Figure 7 and 8, in addition to the high cost of chemical and large amounts of resulting sludge. Therefore, it was crucial to determine the optimum dosage in order to minimize the chemicals cost and obtain the optimum performance in treatment process. The optimum dosage of coagulant is defined as a value above which there is no significant increase in removal efficiency with further addition of the coagulant (Zainol et al., 2011) (Daud et al., 2015)

Evaluating the coagulant type and dosage and its impact on the treatment cost

The amount of produced sludge resulting from chemical precipitation is related to the amount of formed flocs. Calculation of mass of produced chemical flocs resulting from each chemical coagulant can be determined as the following (Metcalf and Eddy, 2003):

a) Mass of Alum flocs

- $Al_2(SO_4)_3.18H_2O + 3\ Ca\ (HCO_3)_2 \rightarrow 2\ Al\ (OH)_3 + 3\ CaSO_4 + 6\ CO_2 + 18\ H_2O$

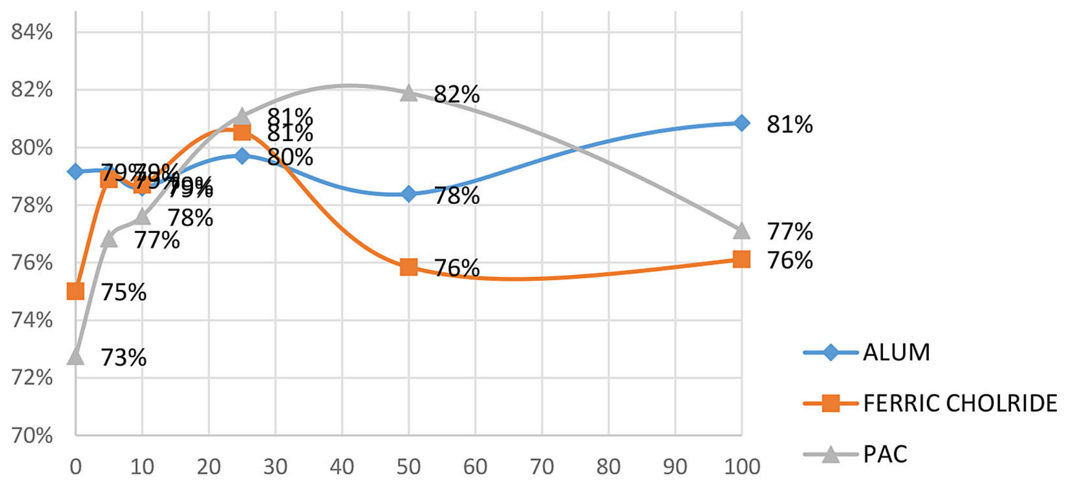

Figure 5. COD removal ratio with different small concentration of coagulant

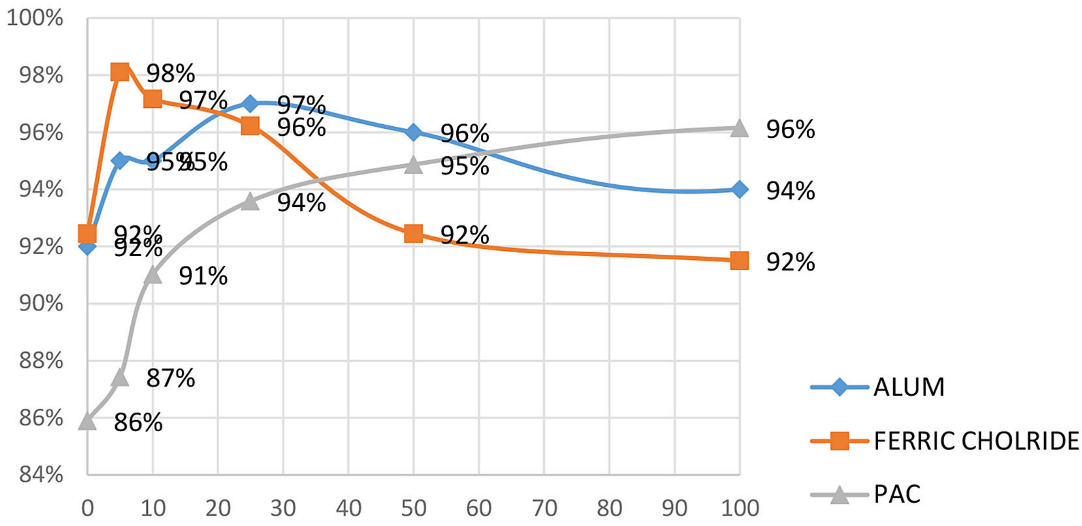

Figure 6. TSS removal ratio with different small concentration of coagulant

- 666.5 g/mol + ... → 156 g/mol + ...
- Mass of produced flocs from alum = alum dose ·(156/666.5) = 25·(156/666.5) = 5.85 mg/l

b) Mass of Ferric chloride flocs

- 2 $FeCl_3$ + 3 Ca $(HCO_3)_2$ → 2 Fe $(OH)_3$ + 3 $CaCl_2$ + 6 CO_2
  324.4 g/mol + ... → 213.8 g/mol + ...
- Mass of produced flocs from ferric chloride = dose·(213.8/324.4) = 5·(213.8/324.4) = 3.3 mg/l

c) Mass of Poly aluminum chloride (PAC) flocs

PAC + 3 Ca $(HCO_3)_2$ → 2 Al $(OH)_3$ + ...
80.45 g/mol + ... → 156 g/mol + ...

- Mass of produced flocs from PAC = dose ·(156/80.45) = 100·(156/80.45) = 193.9 mg/l

Table 3 shows a comparison between the three coagulants with reference to coagulant dose, unit price, total cost of used chemicals and the mass of produced flocs. Results showed that, 5 ppm dose of ferric chloride is the best coagulant in terms of highest removal efficiency, lowest total cost of chemical and lowest production of sludge

Second stage (membrane filtration preceded by gravity sedimentation)

Effect of filter density

In this stage wastewater was allowed to settle for 30 min before passing through a geotextile membrane filter with different density (gsm). The experimental results show that the 500 gsm filter gives the higher removal ratio of about 94% of TSS and 68% COD conc. as shown in Figure 9. Sadashiva in his study on domestic wastewater treatment using filters with density of more than 500 gsm, approximately give the same results, because equivalent opening size remain constant after 400 gsm filter according to manufacture specification in EGYPTEX factory which range from 0.074 to 0.088 mm.

Table 3. A comparison between three coagulants with optimum dose of each

Coagulant	Alum	Ferric chloride	PAC
Optimum Dose (ppm, g/m^3)	25	5	100
Unit coagulant price (L.E)/kg	20	80	20
Total cost of chemical used (L.E)/m^3 of wastewater	$= \frac{25}{1000}*20 = 0.50$ /m^3	$= \frac{5}{1000}*80 = 0.40$ /m^3	$= \frac{100}{1000}*20 = 2$ /m^3
Availability	Available	Available	Less Available
Mass of produced flocs related to the used dose (mg/l)	5.85	3.3	193.9
Best choice	second	first	third

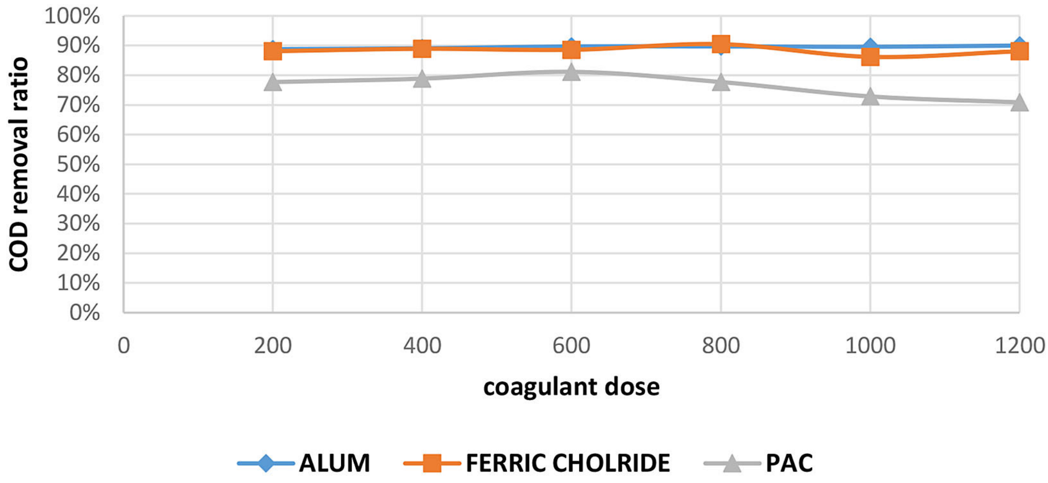

Figure 7. COD removal ratio with different high concentration of coagulant

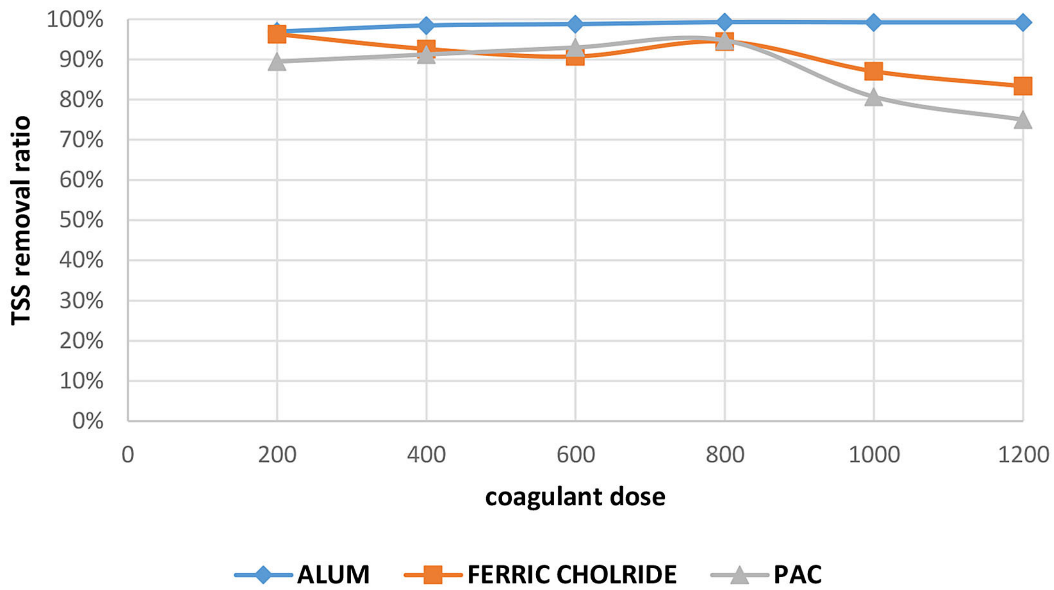

Figure 8. TSS removal ratio with different high concentration of coagulant

Effect of filtration rate on clogging time of filter

When using 500 gsm filter at different filtration rates, the filter life time was recorded as shown in Figure 10. Results showed that there is an inverse relationship between clogging time and rate of filtration.

Experiments have been done on different filtration rates ranging from 2 to 150 $m^3/m^2/d$ in geotextile filter with density 500 gsm. Experiments shows that using high filtration rates similar to rapid sand filter (100–150) $m^3/m^2/d$ lead to rapid blockage of the filter occurs as a result of the accumulation of suspended solids in filter medium pores, which is equivalent to the loss in the head of the maximum permissible height (1 m) within a period not exceeding 2–3 hours which is not commensurate with realistic operating conditions.

In contrast when using low filtration rates such as slow sand filters (2–5) $m^3/m^2/d$, the filter clogging time ranges between 7–13 days. That is because rates of filtration from the filter layers are equal to rates of income discharge, therefore, it is preferable to use the geotextile filter in wastewater treatment from the paper industry in range of the slow filtration rates, because it gives positive results with the longest possible operating period.

According to faure clogging time defined that maximum water head loss acceptable in the geotextile which has to be determined in the previous experiments the allowable head losses was 1 m

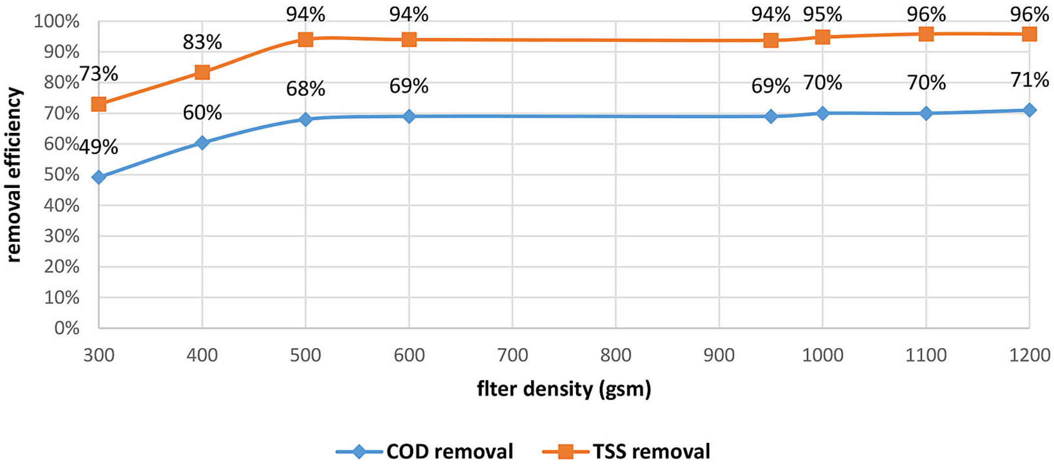

Figure 9. TSS and COD removal ratio versus filter density

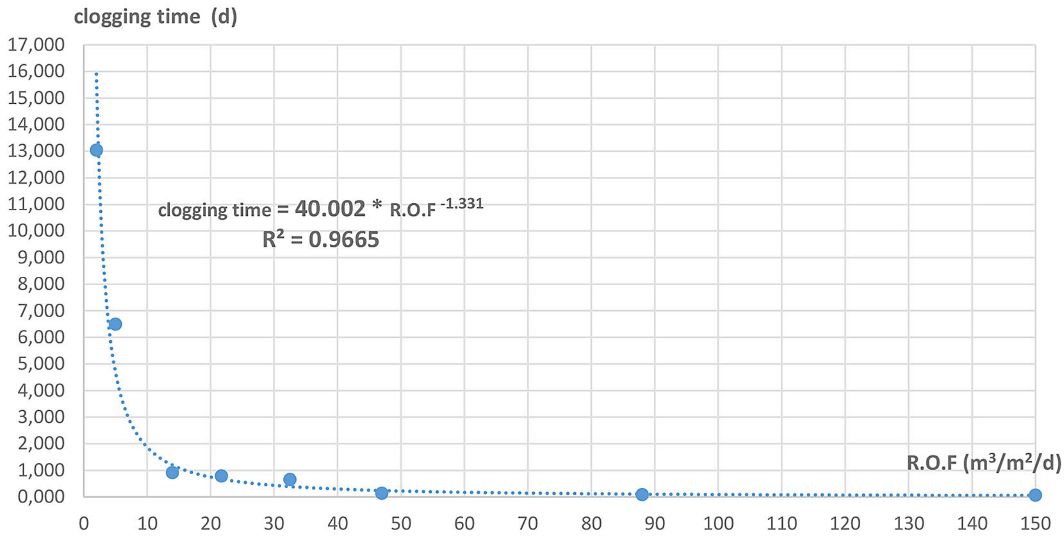

Figure 10. Relation between filter clogging time and rate of filtration

which occurs because of most of the filter's pores clogging as shown in Figure 11 and as a result, it needs to be cleaned or replaced. (Palmeira, 2020).

Relation between head losses and life time

In the first days, it is noticed that the height of the water above the filter is equal to zero, due to the increase in water column above filter (membrane), after a few days, the filter begins to clog, and thus the losses through the filter increase and the water level rises above the filter until it reaches to 1 m in 13 day for 2 $m^3/m^2/d$ filtration rate and 6.50 day for 5 $m^3/m^2/d$ filtration rate (As shown in Figure 12).

On the contrary, the removal efficiency decrease significantly in the first days until the dirty skin layer begins to appear on the surface of the filter, which in turn helps in the filtering process and improves the removal efficiency of COD until it reaches to 85 and 90% for 5 and 2 $m^3/m^2/d$) and TSS removal ratio reaches to 100% (as shown in Figure 13 and 14)

Third stage (membrane filtration preceded by chemical precipitation)

Form the result of first and second stages 5 ppm of ferric chloride achieved the best results and 2 and 5 $m^3/m^2/d$ rate of filtration were the best in efficiency and operation, so the third stage had been done to study the effect of using chemical sedimentation on the filter efficiency and its life time. According to result shown in Figure 15, it was recorded that filter life time reaches to 16.5 day for 2 $m^3/m^2/d$ filtration rate

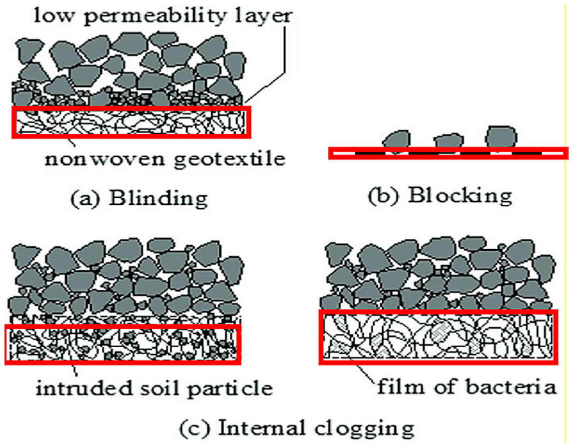

Figure 11. Filter clogging steps

and 7.6 day for 5 m³/m²/d filtration rate achieving an increase of filter life time by 20% after chemical sedimentation. The COD removal (Figure 16) ratio increase to 90% and 95% for 5 and 2 m³/m²/d and 100% TSS removal ratio (as shown in Figure 17 and 18).

Comparison between filter efficiency processed by gravity settling vs. chemical sedimentation

From the previous laboratory results, a comparison between membrane filtration preceded by plain sedimentation and membrane filtration precede by chemical precipitation in terms of many factors like treatment efficiency, treatment cost, treated water quality and treated water use (as shown in Table 4). It has been shown that the use of geotextile filter in wastewater treatment from the paper industry for slow filtration rates (2–5) m³/m²/day after plain sedimentation reach a life time of about 13 days and 6.5 days respectively. The COD removal ratio reach to 95% and 86% respectively and TSS removal ratio reach to

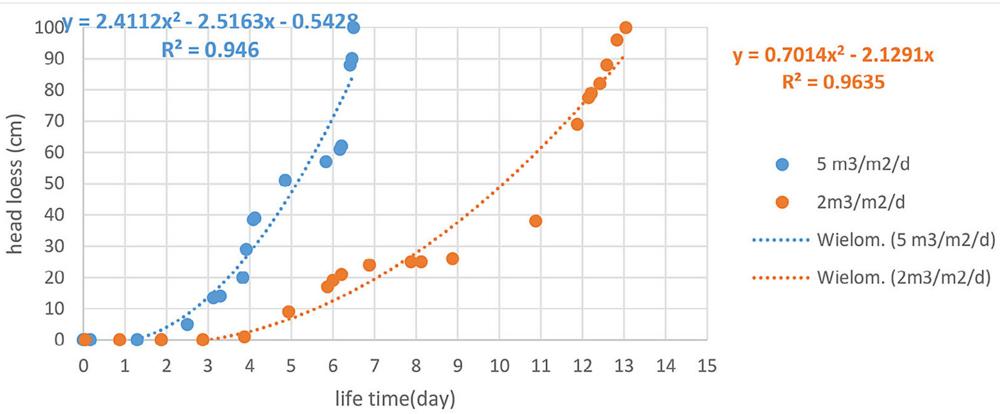

Figure 12. Relation between filter life time and head losses at different filtration rates

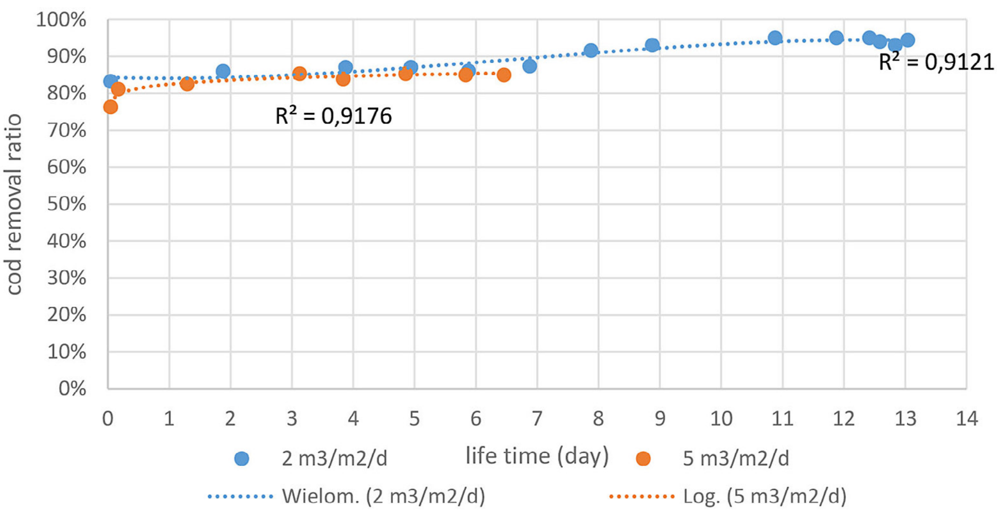

Figure 13. Relation between COD removal ratio with life time for different filtration rates

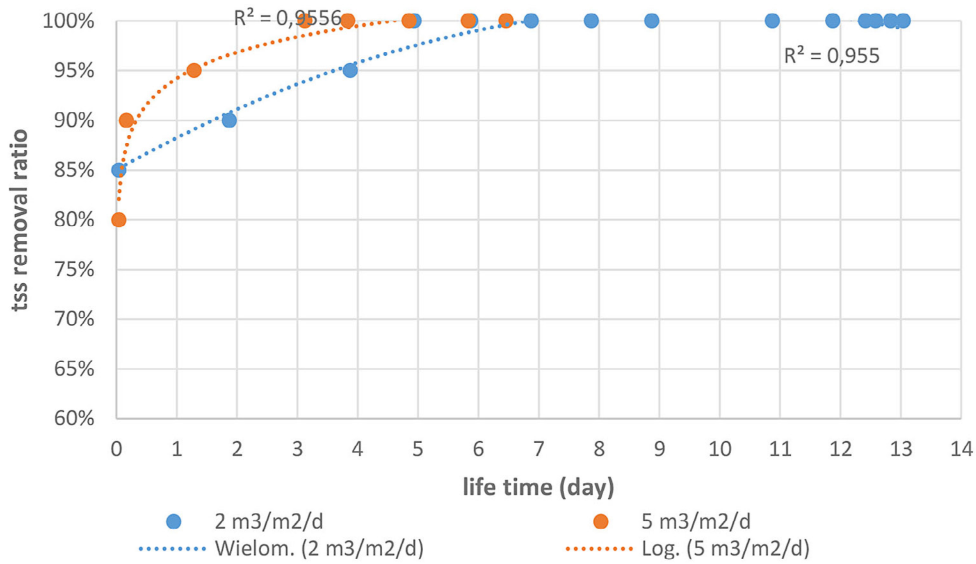

Figure 14. Relation between TSS removal ratio and life time for different filtration rates

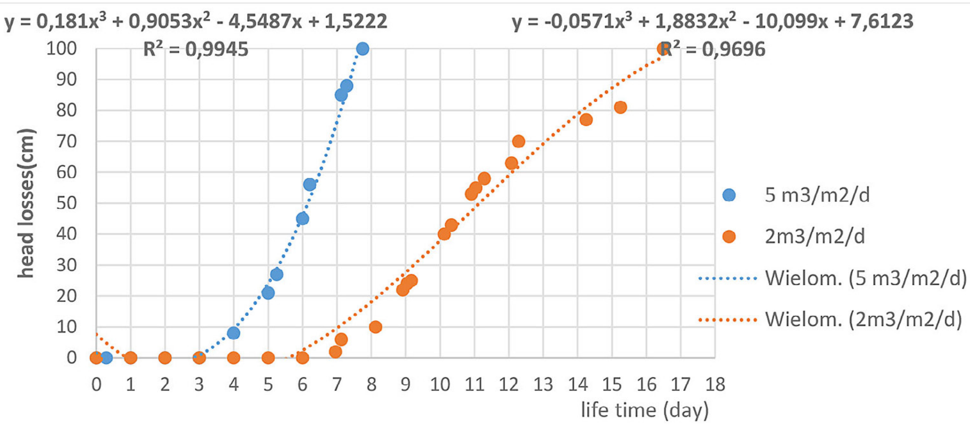

Figure 15. Relation between filter life time and head losses for slow filtration rates after chemical sedimentation

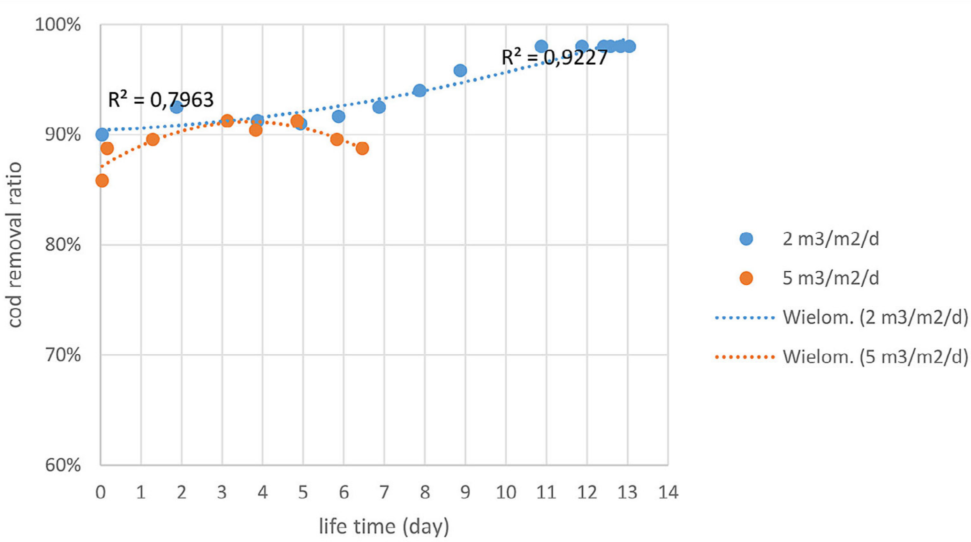

Figure 16. Relation between COD removal ratio with life time for slow filtration rates after chemical sedimentation

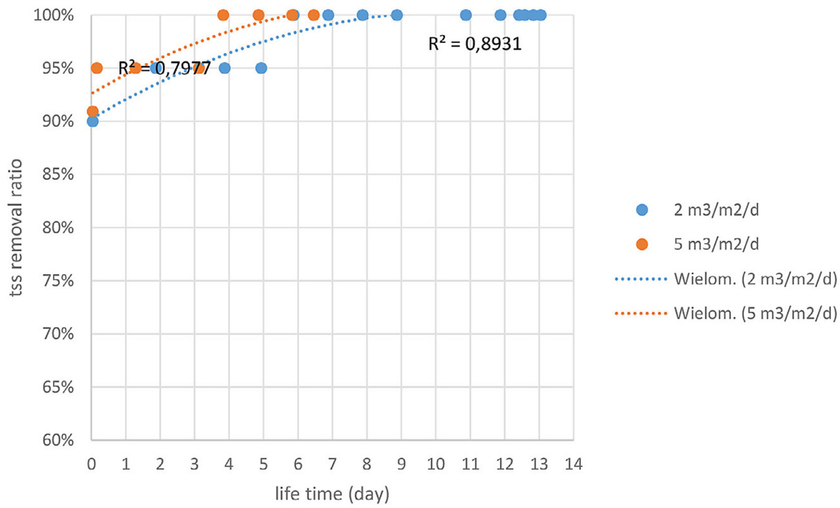

Figure 17. Relation between TSS removal ratio with life time for slow filtration rates after chemical sedimentation

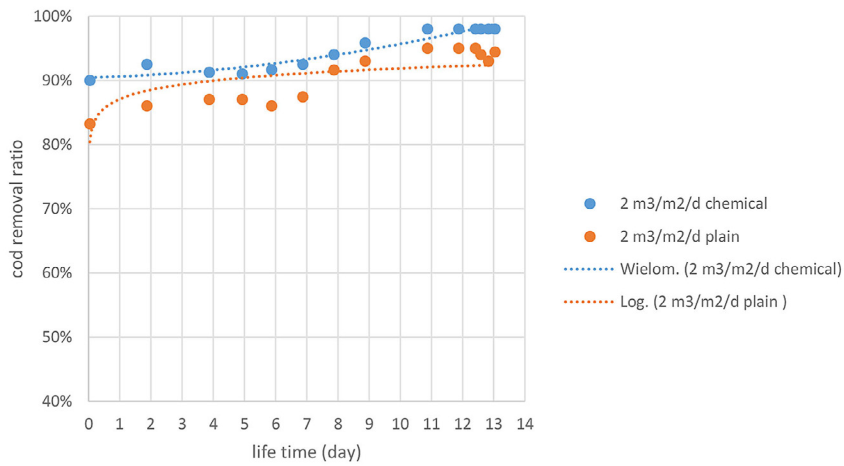

Figure 18. Relation between filter life time and cod removal ratio for 2 m^3/m^2/day filtration rate after plain and chemical sedimentation

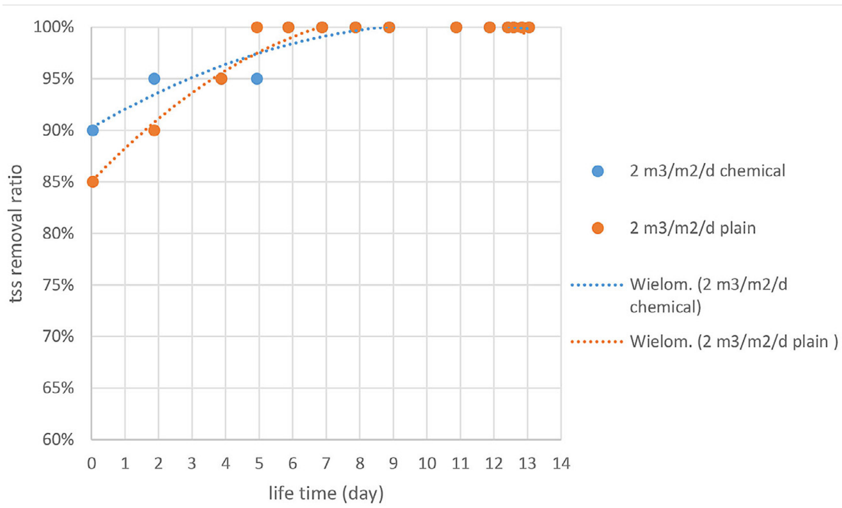

Figure 19. Relation between filter life time and TSS removal ratio for 2 m^3/m^2/day filtration rate after plain and chemical sedimentation

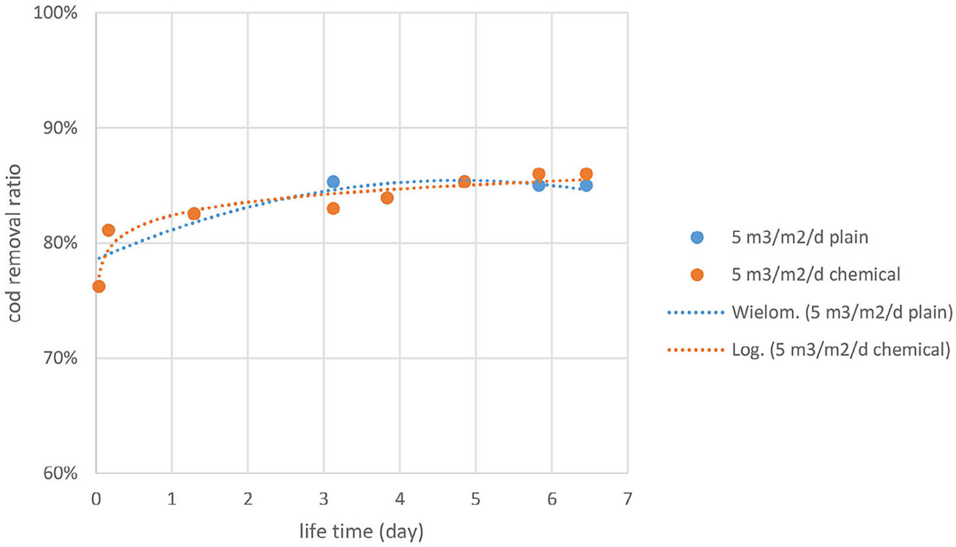

Figure 20. Relation between filter life time and cod removal ratio for 5 m^3/m^2/day filtration rate after plain and chemical sedimentation

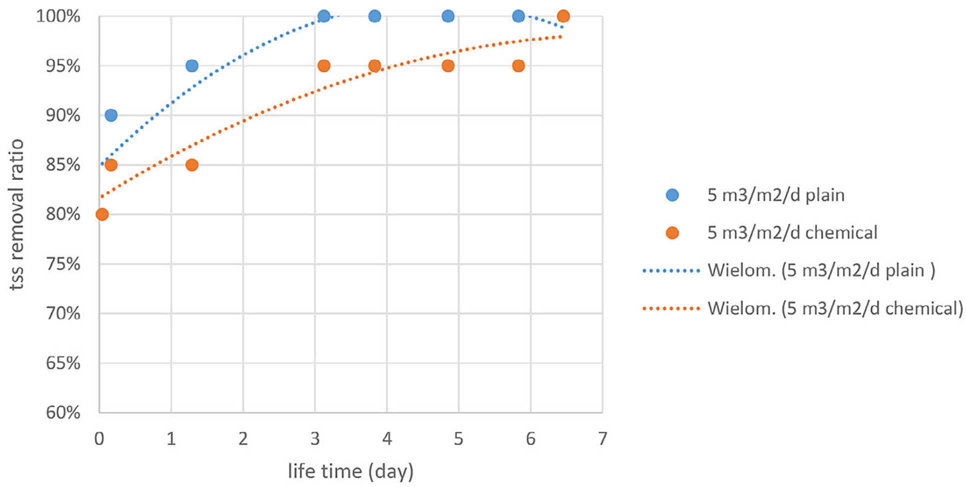

Figure 21. Relation between filter life time and TSS removal ratio for 5 m^3/m^2/day filtration rate after plain and chemical sedimentation

Table 4. Comparison between plain sedimentation, chemical sedimentation, membrane filtration preceded by plain sedimentation and membrane filtration preceded by chemical sedimentation for wastewater treatment from paper and pulp industry

Comparison	Chemical sedimentation only	Membrane filtration preceded by plain sedimentation	Membrane filtration preceded by chemical sedimentation
Best experiment condition	5 ppm ferric chloride for 30 min sedimentation	30 min plain sedimentation and 500 gsm geotextile filter	5 ppm ferric chloride for 30 min sedimentation and 500 gsm geotextile filter
TSS removal ratio	95%	100%	100%
COD removal ratio	79%	90%	95%
Filter clogging time	Not used	13 days and 6.5 days for slow filtration rates (2–5) m^3/m^2/day respectively	16.5 days and 7.60 days for slow filtration rates (2–5) m^3/m^2/day respectively
Treatment cost (L.E/m^3)	0.45	0.8	1
Use after treatment according to Egyptian environmental laws44/2000	Third group	First group	First group

100% for both filtration rate at the end of filter life time. While using of geotextile filter in wastewater treatment from the paper after chemical sedimentation increase life time of filer by 20% which reach to 16.50 days and 7.6 days respectively for (2–5) m^3/m^2/day filtration rates and COD removal ratio reach to 95% and 90% respectively and TSS removal ratio which reach to 100% for both filtration rate at the end of filter life time (as shown in Figure 18, 19, 20 and 21)

Mehmood et al (2019) examine the plain sedimentation as a pre-treatment before physico-chemical treatment process for pulp and paper industrial effluent. He concluded that the removal efficiency of TSS and COD was about 29% 14.5% respectively. When TSS removal ratio decrease in the settling stage, rapid accumulation of SS on the surface of filters occurred, hence accelerated the clogging action of the filter pores. This is explain the reason of long life time of filter following chemical precipitation comparing to filter following plain settling.

CONCLUSIONS

From the results obtained during the present study it is concluded that:

1. Ferric chloride is the best coagulant type in removal efficiency of COD and TSS which reach to 81% and 96% respectively with minimum total cost of chemicals of about 0.40 L.E/m^3 for chemical sedimentation of wastewater resulting from paper industry.
2. Using chemical sedimentation as a single stage for treat wastewater produced from paper and pulp industry yields acceptable results, but the treated wastewater cannot be used for irrigation, in addition to the high cost of the chemical substance.
3. A 500 gsm geotextile filter gave higher COD and TSS removal ratio which reached 68% and 94% respectively, while using filters with gsm more than 500 approximately give the same results which it is not economic because equivalent opening size remain constant after 400 gsm filter according to manufacture specification in EGYPTEX factory which range from 0.074 to 0.088 mm.
4. Using the geotextile filter in wastewater treatment from the paper industry in range of the slow filtration rates (2–5) m^3/m^2/day after plain sedimentation, gives positive results with filter life time reach to 13 days and 6.5 days respectively and the COD removal ratio reach to 95% and 86% respectively and TSS removal ratio which reach to 100 % for both filtration rate at the end of filter life time.
5. Using the geotextile filter in wastewater treatment from the paper industry after chemical sedimentation increase life time of filer by 20% which reach to 16.50 days and 7.6 days respectively for (2–5) m^3/m^2/day filtration rates and COD removal ratio reach to 95% and 90% respectively and TSS removal ratio which reach to 100% for both filtration rate at the end of filter life time.
6. The results also showed that using plain sedimentation before geotextile filtration yields good results without the need to add an expensive chemical coagulant, as the COD removal ratio reaches to 85 and 90% at filtration rate of 5 and 2 m^3/m^2/d respectively and the TSS removal ratio reaches to 100%.

A future study on number of geotextile filter layer, ability to recover used membrane and treatment of different industrial wastewater with geotextile filter layer should be done

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