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Research Article

EXPERIMENTAL STUDY OF TEXTILE WASTEWATER TREATMENT USING HIGH VALENT OXIDANTS

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A B S T R A C T

The problems created by textile wastewater getting more serious concern especially in developing countries. This is due to the low biodegradation of dyes and chemicals used in the commercial textile are hazardous and dangerous to the environment. Due to the low biodegradation of dyes, the conventional biological treatment process is not very effective in treating dye waste. To overcome these problems, the research for environment-friendly and low-cost treatment is essential. This experimental study is carried out to find the quality of dyeing wastewater in the textile industry by assessing the physiochemical characteristics and heavy metal concentration. For this study, fifty liters of dyeing wastewater is collected from a dyeing unit at Tirupur. Ferrate is a potential water treatment chemical used for treating dyeing wastewater due to its dual functions as an oxidant and a coagulant. High valent oxidants such as ferrate (IV), ferrate (V) and ferrate (VI) are added to the dyeing wastewater from the textile industry and various pollutants are removed. The treatment is done for a period of 15 days and the parameters are recorded for consecutive days (1, 5, 10 and 15). On comparing the three oxidants, ferrate (VI) proved to be very effective in reducing the concentrations of tested parameters.

INTRODUCTION

Nowadays Textile industry is one of the major industries in the world that provide employees with no required special skills and play a major role in the economy of many countries. The three different types of fibers used in the manufacturing of various textile products are cellulose fibers, protein fibers and synthetic fibers. Each type of fiber is dyed with different types of dyes. Cellulose fibers are dyed using reactive dyes, direct dyes, naphthol dyes and indigo dyes. Protein fibers are used to dye process in the form of acid dyes and lanaset dyes.

Synthetic fibers are dyed using disperse dyes, basic dyes and direct dyes. The textile industry utilizes various chemicals and a large amount of water during the production process. About 200 liters of water is used to produce 1 kg of textile. The water is mainly used for the application of chemicals onto the fibers and rinsing the final products. The wastewater produced during this process contains a large amount of dyes and chemicals containing trace metals such as Cr, Fe, Cu, Ni, Pb and Zn which are capable of harming the environment and human health.

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The textile wastewater can create causes of hemorrhage, ulceration of skin, nausea, skin irritation and dermatitis. The chemical present in the water block the sunlight and increase the BOD thereby inhibiting photosynthesis and reoxygenation process [5]. The residual dyes from the textile industries are considered to have a wide variety of organic pollutants introduced into the natural water sources that are toxic to aquatic life. Thus, wastewater from the dyeing process of the textile industry is treated with high valent oxidants such as ferrate (IV), ferrate (V) and ferrate (VI) for the reduction of undesirable parameters. The respective ferrate (IV), ferrate (V) and ferrate (VI) are sodium ferrate (IV) (Na4Feo4), potassium ferrate (K3FeO4) and potassium ferrate (K2FeO4).

MATERIAL

Characteristics of Wastewater

Tirupur is located on the bank of Noyyal River. It is the one of the major textile industrial zones and knitwear hub contributing to 90% of total cotton knitwear exports from India, which is 50 km away from the east of Coimbatore city and is spread over 160 Km2 and it was an agricultural town with irrigated farms and the boom in the textile industry led to an interwoven network of the small scale units leading to the growth of the city into a major textile hub. The last 40 years so far long have complained of pollution and depletion of Groundwater from the site. The wastewater was collected from the site in a 60 liters plastic container and transported to the laboratory and stored in the refrigerator before being analyzed and tested. The textile wastewaters effluents generally mix with surface water or runoff water; it has been forming a prime cause of large quantity of wastewater generation. The characteristics of wastewater generated reflect and change the nature of surface water as well as reducing the groundwater quality. The chemical analysis of wastewater shows that the result was analyzed the various parameters and it's having high concentrations. The chemical characteristic of wastewater has a presence of the highly toxic substance and it will create a problem in aquatic environmental or drastic changes and the threat to high in the ecosystem. The characteristics of raw wastewater collected from Tirupur at Coimbatore. When the result to be compared to the BIS standard as shown in table 1.

Table 1 Parameters of Untreated wastewater

Parameters	Untreated wastewater	BIS Standards
pH	7.8	5.5 – 9
Total solids mg/l	4000	450
Total dissolved solids mg/l	2500	2100
Total suspended solids mg/l	1500	100
BOD mg/l	50.65	30
COD mg/l	2800	250
Chloride mg/l	2659.5	1000
Total hardness mg/l	850	0.1
Chromium ppm	5.83	3
Copper ppm	11.27	2
Iron ppm	8.62	5
Lead ppm	8.87	3
Zinc ppm	10.57	3
Nickel ppm	9.84	3

Chemical water treatment

As the name suggests, this treatment involves the use of chemicals in the water. Chlorine, an oxidizing chemical, is used to kill bacteria which decompose water by adding contaminants to it. Another oxidizing agent used for purifying the wastewater is ozone. Neutralization is the technique where an acid or base is added to bring the water to its natural pH of 7[13]. Chemicals are used to prevent the control of the bacteria reproducing from the water, thus making the water pure [3].

Coagulation

The test was conducted by adding 1 L wastewater to 1 L beakers and places them in multiple stirrers and starts the motor of the stirrer. The graded dosage of 0.2-1.8 mg/l was added to ferrate (IV), ferrate (V) and ferrates (VI) are added to the samples respectively [6]. Agitate at 100 rpm and the speed of paddles is reduced to 40 rpm for 10 minutes. Visible flocs are appeared and settled for 20 minutes. The optimum dosage of ferrate (IV), ferrate (V) and ferrate (VI) are 1 mg/l, 0.6 mg/l and 0.8 mg/l respectively. The optimum dosage of ferrate was taken by better results as the oxidant [9], [16],[22].

Oxidation process

Oxidation is the process in which the oxygen is added or hydrogen is removed from the compound [20]. This alters the properties of the wastewater thus positive impact is created in the treatment of wastewater. Several characteristics such as BOD, COD and heavy metals are efficiently reduced.

Table 2 properties of ferrate

S.No	Properties	Sodium Ferrate (IV)	Potassium Ferrate (V)	Potassium Ferrate (VI)
1.	Standard formula	Na_4FeO_4	K_3FeO_4	K_2FeO_4
2.	Appearance	Reddish brown	Red-purple	Reddish-brown
3.	Melting point	Decomposes	Decomposes	Decomposes at 198^{o}C
4.	Boiling point	Decomposes	Decomposes	Decomposes
5.	Density	2.74 g/cm^3	2.76 g/cm^3	2.829 g/cm^3
6.	Solubility in water	Very soluble	Soluble	Soluble(slowly decomposes when pH is high)
7.	Flash point	Non-flammable	Non-flammable	Non-flammable

These three high valet oxidants are Ferrate (IV) Sodium Ferrate (Na4FeO4), Ferrate (V) Potassium Ferrate (K3FeO4) and Ferrate (VI) Potassium Ferrate (K2FeO4). The present study is carried out using all three oxidants after finding the result. Sedimentation tank models were used to analyze wastewater characteristics concerning time. The wastewater samples are segregated into three batches each for Ferrate (IV), Ferrate (V) and Ferrate (VI)[11],[18]. These Ferrate salts are added in the dosage levels of 1mg/l, 0.6mg/l and 0.8mg/l respectively [1]. After the addition of these oxidants, the samples are tested for the consecutive days of 1st day, 5th day and 10th day.

The Various dosages can adopt in the chemical oxidants.

Ferrate (IV)

Sodium Ferrate (Na4FeO4) is used as a Ferrate IV which appears to be red-purple as shown in fig 1(a). It is easily soluble with water and non-flammable. Under extreme temperature conditions, the Ferrate IV decomposes. It is a highly powerful oxidizing agent [7],[15],[18],[20].

Fig 2 (a) Ferrate (IV)

Ferrate (V)

otassium Ferrate (K3FeO4) is used as a Ferrate V which appears to be in purple in color and available salt format as shown in fig 1(b). The density ranges from 2.7g/cm3 to 2.9g/cm3. Under extreme temperature conditions, the Ferrate IV decomposes. It is a powerful oxidizing agent [9].

Fig 2 (b) Ferrate (V)

Ferrate (VI)

Potassium Ferrate (K2FeO4) is used as a Ferrate VI which is reddish-purple and available in a salt format as shown in fig 1(c). The density of the salt is 2.829g/cm3. It is a soluble in water and an odorless substance that slowly decomposes when the pH is high. It is an eco-friendly oxidation substance and a non- flammable substance [2], [4],[8],[12]. In many researchers, Ferrate (VI) used as an alternative to the existing coagulant because it is an easily available and eco-friendly material for both water treatments as well as wastewater treatment. Ferrate (VI) is normally used in the disinfection process. It is partially degrading and oxidization of organic and inorganic content; it can be removed by suspended or colloidal particulate materials during the treatment process.

Fig 2 (c) Ferrate (VI)

Instrument analysis

He raw and the ferrate oxidized samples were scanned by using Atomic absorption spectrophotometer. In this equipment, samples were analyzed for different heavy metals and trace Metals such as Cr, Fe, Cu, Ni, Pb and Zn [10],[20]. These metals are present in the wastewater, which is capable of increasing the toxic substance and create environmental pollution issues. These samples were scanned by different wavelengths corresponding to only one element, and the width of an absorption line.

Physical and chemical analysis of Wastewater

Normally, any type of wastewater has been analyzed in physical and chemical characteristics study. In this paper, wastewater was analyzed for pH, Total solids, Total dissolved solids, Total suspended solids, BOD, COD, Chloride, Total hardness based on standard methods [14],[16], [17],[18].

EXPERIMENTS AND DISCUSSIONS

He wastewater samples are segregated into three batches each for Ferrate (IV), Ferrate (V) and Ferrate (VI). These Ferrate salts are added in the dosage levels of 1mg/l, 0.6mg/l and 0.8mg/l respectively. After the addition of these oxidants, the samples are tested for the consecutive days of 1st, 5th, 10th, and 15th day.

The characteristics of the textile wastewater sample after the addition of oxidation are presented in Table 3. Three different high valent oxidation compounds, namely Ferrate (IV), (V), (VI) was used for identifying the optimum removal efficiency of toxic compounds from the wastewater. These oxidants were made to react with wastewater for a period of 15 days, where the maximum removal efficiency was observed when Ferrate VI was used because of its very high valent oxidation property, in comparison with other oxidants. The optimum characteristics of pH, Total solids, Total dissolved solids, Total suspended solids, BOD, COD, Chloride, Total hardness Cr, Fe, Cu, Ni, Pb and Zn are respectively 6.5, 2250 mg/l, 1800 mg/l ,450 mg/l ,37.5 mg/l , 1840 mg/l ,1790.73 mg/l 595, 2.06 mg/l, 3.51 mg/l, 3.08 mg/l , 4.23 mg/l , 5.11 mg/l and 3.26 mg/l.

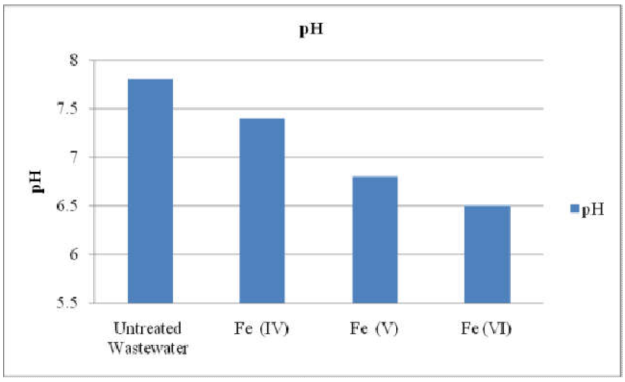

Fig 1 pH for Fifteenth Day Results after the Addition of Oxidants

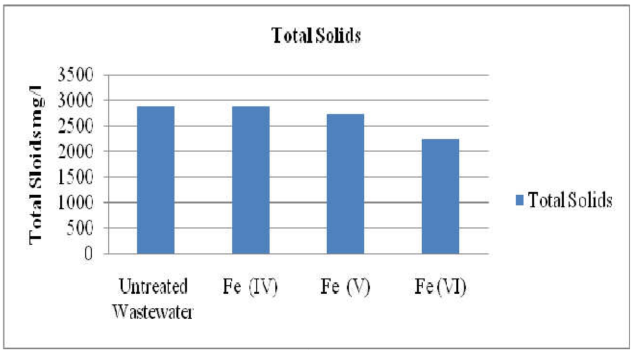

Fig 2 Total Solids for Fifteenth Day Results after the Addition of Oxidants

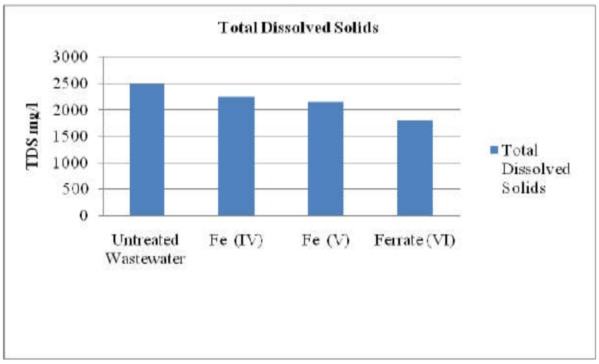

Fig 3 Total Solids for Fifteenth Day Results after the Addition of Oxidants

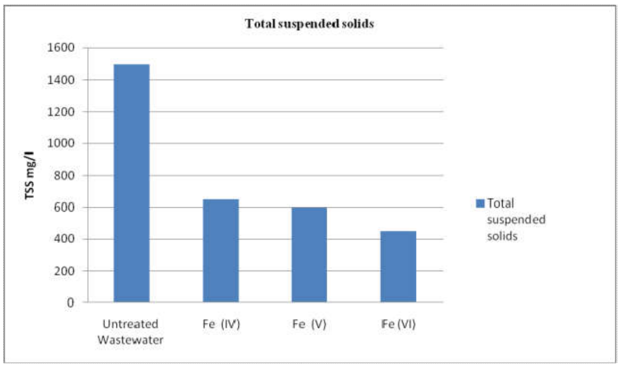

Fig 4 Total Solids for Fifteenth Day Results after the Addition of Oxidants

Table 3 1st , 5th, 10th, and 15th days after the addition of Ferrate (iv),(v),(vi) oxidants

S.NO	PARAMETER	1st day Ferrate			5th day Ferrate			10th day Ferrate			15th day Ferrate		
		(IV)	(V)	(VI)	(IV)	(V)	(VI)	(IV)	(V)	(VI)	(IV)	(V)	(VI)
1.	pH	7.8	7.6	6.8	7.6	7.4	6.7	7.6	7.1	6.7	7.4	6.8	6.5
2.	Total solids mg/l	4000	4500	3850	3850	4000	3800	3500	3600	3100	2900	2750	2250
3.	Total dissolved solids mg/l	3000	3500	2900	2900	3100	2950	2750	2700	2450	2250	2150	1800
4.	Total suspended solids mg/l	1000	1000	950	950	900	850	750	800	650	650	600	450
5.	BOD mg/l	50.5	50.2	48.45	49.2	49.7	47.9	46.4	47.55	45.6	39.8	40.1	37.5
6.	COD mg/l	2720	2720	2560	2640	2560	2480	2480	2400	2320	2160	2000	1840
7.	Chloride mg/l	2482.2	2411.28	2304.9	2322.63	2216.25	2127.60	2251.71	2127.6	2021.22	2038.95	1985.76	1790.73
8.	Total hardness mg/l	830	820	800	805	790	765	750	715	690	685	650	595
9.	Chromium ppm	5.75	4.5	3.75	5.34	4.14	3.26	5.12	3.07	2.98	4.45	2.89	2.06
10.	Copper ppm	9.0	6.66	11.0	7.3	6.57	8.7	6.94	6.21	6.87	6.12	5.73	3.51
11.	Iron ppm	8.5	7.0	5.0	6.39	5.69	4.2	5.84	5.07	3.72	5.13	4.76	3.08
12.	Lead ppm	5.75	8.5	6.75	5.75	8.5	6.75	5.21	6.74	5.83	4.92	6.15	4.23
13.	Zinc ppm	10.28	7.142	8.14	9.21	6.74	7.24	8.17	5.87	6.48	7.09	5.24	5.11
14.	Nickel ppm	9.67	7.33	7.16	8.24	6.94	8.87	7.54	6.05	7.21	7.01	5.72	3.26

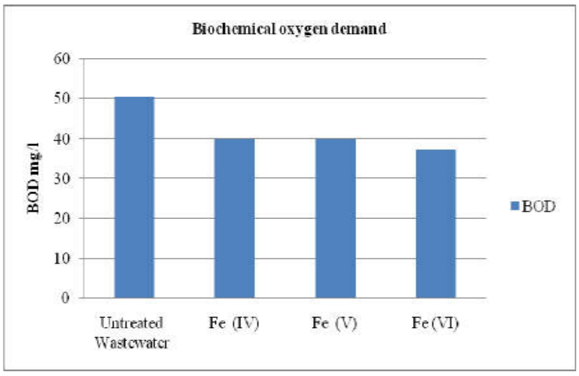

Fig 5 BOD for Fifteenth Day Results after the Addition of Oxidants

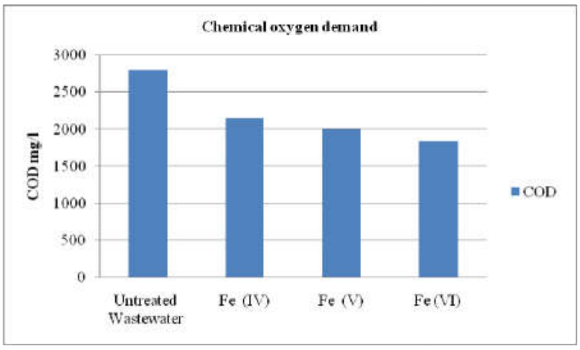

Fig 6 COD for Fifteenth Day Results after the Addition of Oxidants

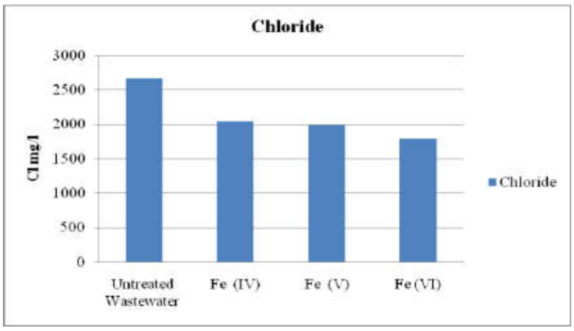

Fig 7 Chloride for Fifteenth Day Results after the Addition of Oxidants

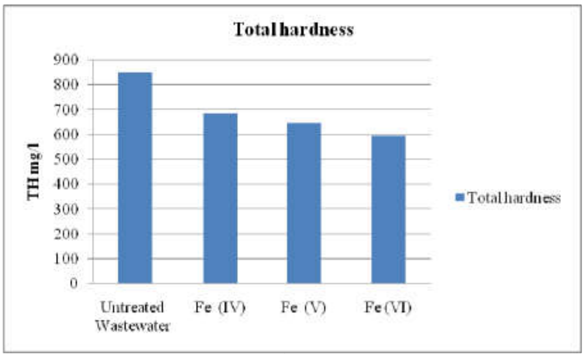

Fig 8 Total Hardness for Fifteenth Day Results after the Addition of Oxidants

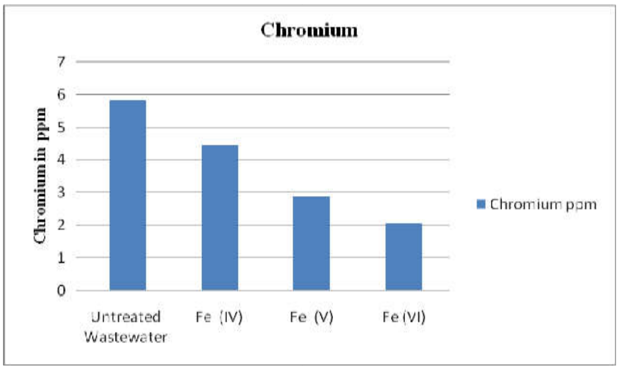

Fig 9 Chromium for Fifteenth Day Results after the Addition of Oxidants

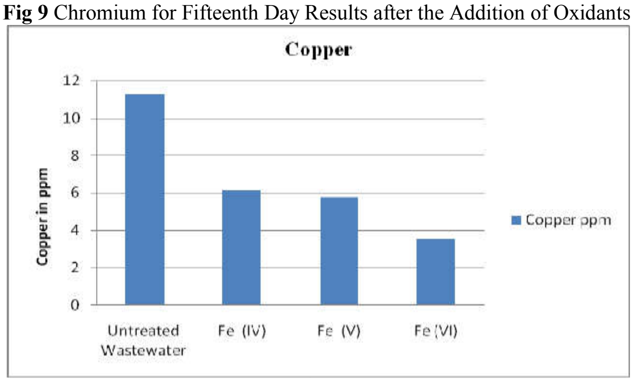

Fig 10 Copper for Fifteenth Day Results after the Addition of Oxidants

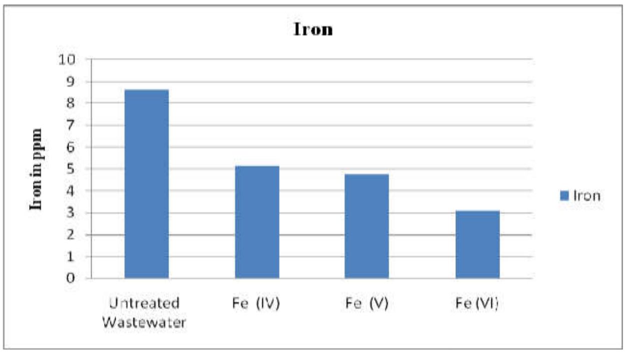

Fig 11 Iron for Fifteenth Day Results after the Addition of Oxidants

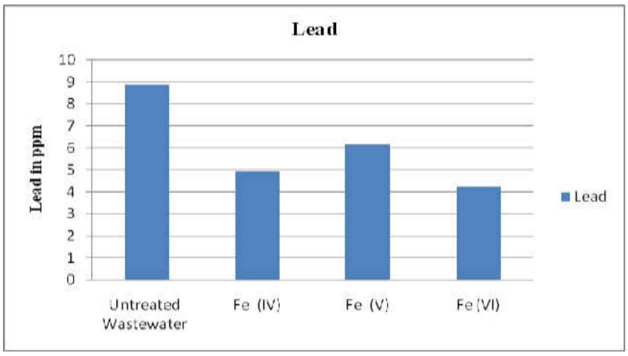

Fig 12 Lead for Fifteenth Day Results after the Addition of Oxidants

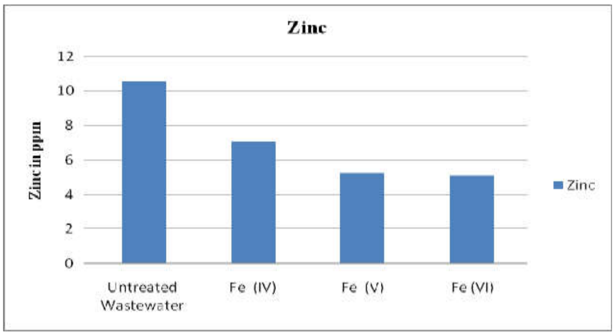

Fig 13 Zinc for Fifteenth Day Results after the Addition of Oxidants

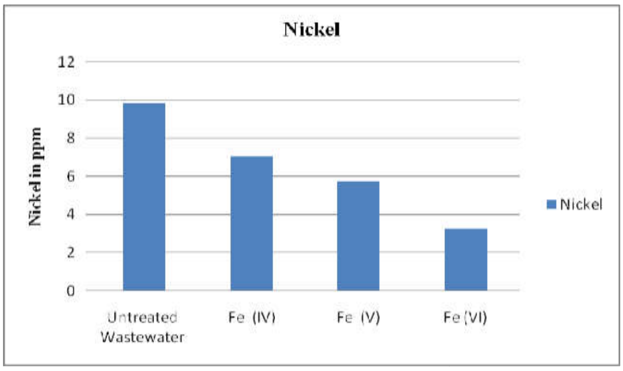

Fig 14 Nickel for Fifteenth Day Results after the Addition of Oxidants

Determination of detention period by using high valent oxidant

The above experiment process is repeated by using ferrate IV, ferrate V& ferrate VI as a natural oxidant agent. It is obtained from the eco-friendly and high oxidation materials, which are constraint to measure the detention period and removal efficiency of textile wastewater by using high oxidizing agents. Different oxidizing chemicals were used such as Ferrate IV, Ferrate V and Ferrate VI is varied as 1st, 5th, 10th and 15th days is carried out by sedimentation tank process.

Effect of detention period on Removal of chemicals using high valent oxidant

It is observed that the average detention time is fifteen days for varied ferrate IV, ferrate V and FerrateVI is carried out. The optimum detention period of wastewater is fifteen days of ferrate VI, the removal efficiency of Wastewater from 70 to 20% are TSS < Cu < Ni < Cr < Fe < Pb < Zn < TS < COD < Cl< TH < TDS < pH.

Finally, the removal efficiency of textile wastewater is carried out by varying the detention period for ferrate VI, it is achieved better performance when comparing to others. This will reduce chemical dosage and sludge production, therefore results in a low-cost treatment process and reducing a cost of treatment. The following results were shown in table 3.

CONCLUSION

The reduction rates of tested parameters are higher for ferrate (VI) when compared to ferrate (IV) and ferrate (V). This study reveals that high valent ferrate can diminish the disagreeable smell. The colored compounds are oxidized hence the color also diminishes after the treatment. The optimum result is obtained by using low concentrations of ferrate in wastewater treatment.

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