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A sustainable solution to treat textile effluent by employing combined coagulation, oxidation and ultrafiltration techniques

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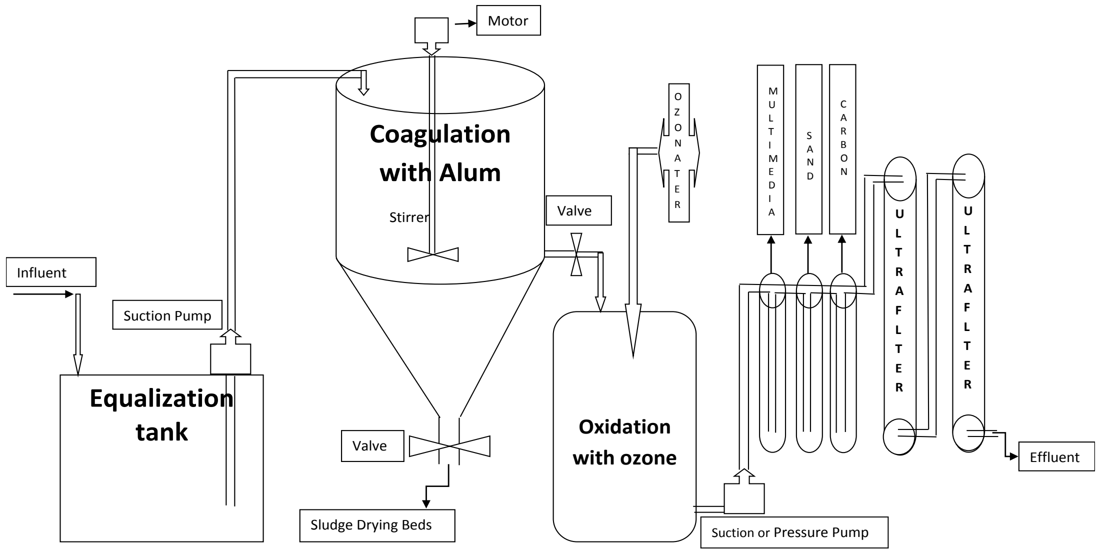
GRAPHICAL ABSTRACT



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ABSTRACT

Presently, Pakistan is the 8th largest exporter of textile products in the world and this sector is considered the backbone of Pakistan's economy. Due to intensified use of dyes, chemicals, and water, the textile sector is also listed as the highest contributor to environmental pollution. Therefore, to approach the demand of new global trend towards sustainability, the textile industry along with others need to focus on resource recovery and reuse. The present study was therefore planned for the treatment of textile effluent composed from 04 textile mill samples. The textile effluent is treated by employing coagulation, ozone oxidation, and ultrafiltration techniques. All the samples exceeded the standard limits as given in Sindh Environmental Quality Standard (SEQS 2016). Each individual treatment provided promising results in terms of reduction in pollution load. Overall findings revealed a remarkable decrease in total suspended solid (TSS) (96 %), total dissolved solid (TDS) (78 %), chemical oxygen demand (COD) (93 %), Biological Oxygen Demand-BOD (93 %), oil & grease (96 %) and heavy metals (HM) (98 %). It is suggested that combined techniques are the best option for textile effluent treatment.

1. Introduction

It has been estimated that due to urbanization, industrialization, and uncontrolled population growth the global water demand has been increased 600 % in the past century. Unfortunately, 52 % of the human population is currently facing water scarcity (Kang et al. 2020). Being the backbone of Pakistan's economy textile sector is playing a vital role in providing employment to 38 % of people and a significant share of foreign exchange. Simultaneously, the textile sector alone is contributing significantly i.e. 51 % in producing highly polluted effluent and discharging untreated or poorly treated effluent Qaiser et al. (2019). Undoubtedly textile effluent streams contain an exceedingly fluctuating pH, a high temperature, COD, BOD, and substantial amounts of suspended solids and heavy metals. These pollutants are

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associated with adverse effects on human health and affects the environment. If treated adequately the health and environment associated hazards could be minimized. Such a process will also help in providing a source of clean recycled water (Azhar et al. 2019; Kang et al. 2020). Textile industrial units in the province of Sindh need to fulfill the legal requirements set by Sindh Environmental Protection Agency (SEPA) as per standards set in Sindh Environmental Quality Standards (Self-Monitoring and Reporting by Industry) Rules, 2014. The effluent priority parameters for textile industries are effluent flow, Temperature, pH, BOD_5, COD, TSS, TDS, copper, and chromium (SMART rules 2014).

The limits of these parameters are given in Sindh Environmental Quality Standards (SEQS) 2016 by SEPA (Table 1, SMART rules 2014; SEQS 2016). Currently various techniques such as flocculation, adsorption, precipitation, oxidation have already been developed and been widely used with or without some modifications in treating the effluents Soares et al. (2006); Wang et al. (2009a); Ozer et al. (2006); Shi et al. (2007). Since wastewater treatment technologies play a key role in the sustainable development, therefore; present study was intended to protect the ecosystem by effective treatment but also for subsequent reuse of the treated effluent for irrigation purposes and other industrial processes (BilalUddin et al. 2015). The study planned to assess the stepwise application of coagulation, ozone oxidation, and ultrafiltration on textile effluent. Here aluminum sulfate (AS), and Ozone were utilized as an effective coagulant, oxidation agents. Thus, the objective of the study is to reduce the pollution load of textile effluent by employing a combination of coagulation, oxidation, and ultrafiltration and assess the efficiency in terms of removing BOD, COD, TDS, TSS, Oil & grease, and heavy metals.

2. Materials and methods

2.1. Sample Collection

Samples were collected in pre-cleaned poly-propylene bottles from four different locations in triplicate i.e. Liberty Textile Mill main drain, Norus Chowrangi SITE, Vita Chowrangi Korangi Industrial Area main drain, and Murtaza Chowrangi Korangi main drain. An equal volume of each individual sample was thoroughly mixed and homogenize with each other to make a composite sample. The characterization of individual and composite samples was carried out by following standard methods for the Examination of Water & Wastewater, APHA (2017). To determine Cd, Cu, Fe, Zn, and Cr a Hitachi Model Z-5000 Atomic Absorption Spectrometry (AAS) was used. Cd and Cr were analyzed by electro-thermal (EC) AAS technique, Whereas, Fe, Cu and Zn were determined through Flame AAS technique. The details of standards calibration curve and instrument conditions are mentioned elsewhere (Shahid et al. (2018).

2.2. Wastewater treatment

Textile effluent was treated by combined coagulation, ozone oxidation and ultrafiltration methods as shown in the flow diagram (Fig.1).

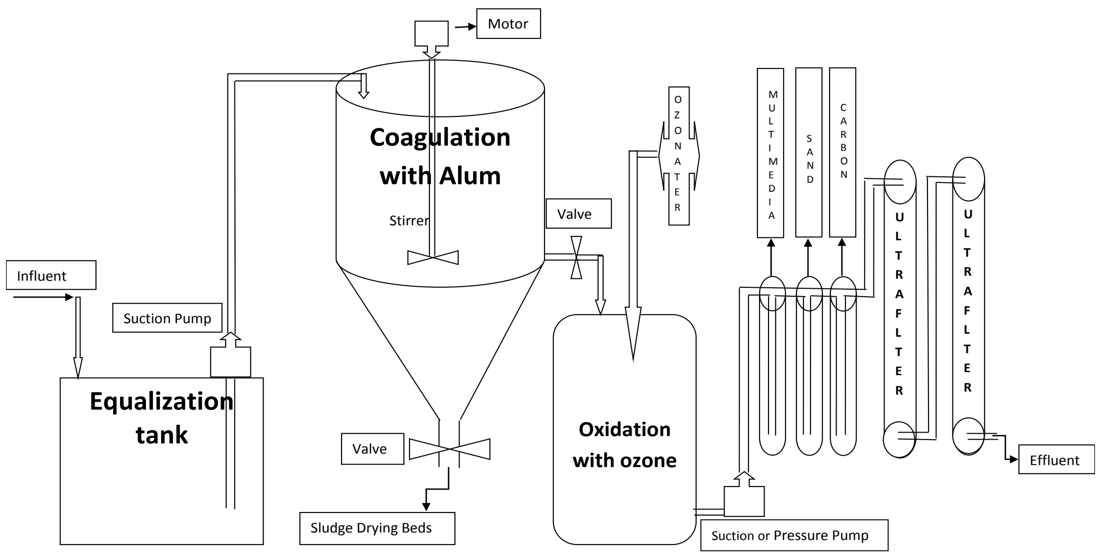

Fig. 1. The flow diagram of combined textile effluent treatment plant at Center for Environmental Studies, PCSIR Laboratories Complex Karachi.

Table 1. Characterization of textile effluents samples.

Parameter	Unit	Textile effluent sample				Composite sample	SEQS limits into Inland water
		01	02	03	04		
pH	-	11.6	11.1	10.9	10.6	10.7	6 – 10
TSS	mg/l	472	495	510	480	475	150
TDS	mg/l	7130	7359	6989	7023	7200	3500
COD	mg/l	2120	2187	2018	2092	2085	150
BOD	mg/l	1078	992	1089	1020	1010	80
Oil & grease	mg/l	28.3	31.9	28	23	24	10
Surfactants	mg/L	30.5	36.0	28.8	34.5	34.2	20
Cd	mg/l	0.001	0.001	ND	0.05	0.03	0.1
Cu	mg/l	0.007	1.37	5.14	2.66	3.55	1.0
Cr	mg/l	1.53	1.86	1.66	1.2	1.54	1.0
Fe	mg/l	1.08	1.16	1.86	2.00	1.90	2.0
Zn	mg/l	2.36	3.21	3.65	4.00	3.86	5.0

2.2.1. Coagulation process

Textile wastewater samples were coagulated with commercial-grade aluminum sulfate. 5 L textile wastewater samples were taken in five glass beakers and doses ranging from 2, 4, 6, 8 and 10 gm of aluminum sulfate were added separately. Mixtures of effluents and coagulants were stirred for rapid mixing for 2 min at 100 rpm, followed by slow mixing at 20 rpm for 15 min. After mixing flocks were allowed to settle for 30 min. Subsequently, the supernatant was withdrawn with syringes (Abhishek et al. 2016; Ashok et al. 2016; Amel et al. 2017).

2.2.2. Oxidation process

The oxidation process was carried out with filtrate from coagulation at the dose of 8 grams. The 5 L filtrate was divided into five clean glass beakers equally and treated with different doses of ozone i.e. 0.2 mg/L, 0.4 mg/L, 0.6 mg/L, 0.8 mg/L, and 1.0 mg/L.

2.2.3. Ultrafiltration

The resultant solution from oxidation at the dose of 0.8 mg/L ozone was passed through ultra-filters (Specification: pore size=1 micron, Maximum feed flow rate= 1.8, Maximum operating temperature= 50 °C, Microfiltration elements= polysulfone) as shown in Fig.1.

3. Results and discussion

The physicochemical parameters of the raw textile effluents clearly revealed a very high pollution load in terms of TSS, COD, and BOD (Table 1) (Rafiqul Islam and Mostafa. 2018, 2020; Qaiser et al. (2019)). The treatment of textile effluents is necessary to protect the ecosystem and enable subsequent recycling of the treated effluent for irrigation purposes or reuse within the textile factory processes. In the present study, the treatment of textile effluent was carried by employing coagulation, ozone oxidation, and ultrafiltration as displayed in the flow chat (Fig. 1). The efficiency of all three treatments was assessed in terms of BOD, COD, TDS, TSS, oil & grease, and the most common toxic heavy metals found in textile effluent such as cadmium, chromium, copper, zinc, and iron (Sharaddha et al. 2017).

3.1. Coagulation process

In scientific research literature chemically induced coagulation is found to be the most frequently applied efficient and economical method to remove pollutants from industrial effluents (Deepa. 2016; Prasenjit et al. 2017). Coagulant improves precipitation efficiency by inducing destabilization of the colloidal particles in the water which subsequently form aggregates. In various studies, it has been reported that the coagulants reduce a load of subsequent treatment by primarily improve the removal rate of BOD, COD (Rafiqul Islam and Mostafa. 2018, 2020). Likewise, in this study aluminum sulfate (AS) was used as a coagulant and found sufficiently effective (Fig. 2). It has been evaluated that increasing doses of aluminum sulfate found more effective in terms of reduction in pollutant load. The low to medium dose from 2 g to 6 g per 5 L have pollutant removal efficiency below 50 %. However, with 8 g per 5 L dose of aluminum sulfate, optimum decrease in TSS (66.3 %), TDS (31.5 %), COD (49.8 %), BOD (53.9 %), oil & grease (58.3 %) and Surfactants (62.5 %) were recorded. Whereas, very little improvement was noted with 10g dose (Fig. 2). Similar findings were reprted in the literature (Aleem et al. 2016; Rfiqul Islam and Mostafa. 2020).

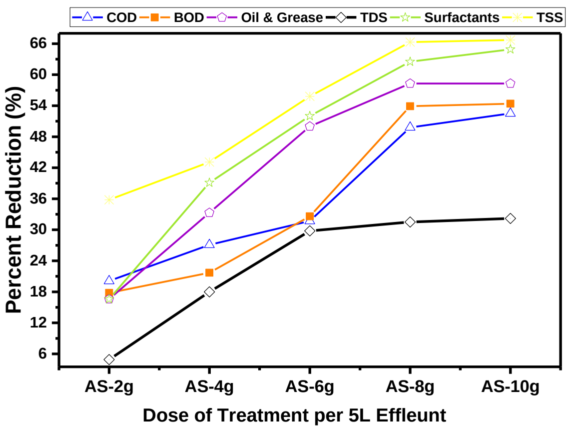

Fig. 2. The effect of Aluminum Sulfate different doses on pollutants removal efficiency.

The influence of coagulant dosage on removal of metals was also studied and it was noted that AS had a good to moderate effect on the removal of trace metals i.e. 40.8 % Cu, 33.3 % Cd, 23.3 % Cr, Fe 36.8 %, and 53.3 % Zn at the optimized dose of 8 g per 5 L (Fig. 3). It should be noted here that the priority parameters remained above the SEQS limits after the coagulation process i.e. TDS (4932 mg/L), TSS (160 mg/L), COD (1036 mg/L), BOD (465 mg/L), Cu (2.1mg/L) and Cr (1.18 mg/L). It is necessary to treat the effluent further and combine other treatment options with coagulation such as oxidation and ultrafiltration .

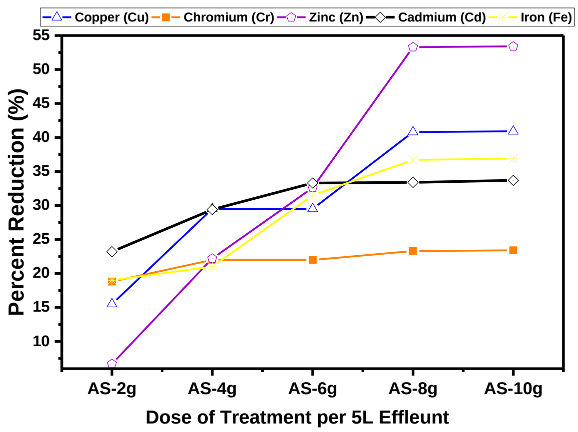

Fig. 3. The effect of aluminum sulfate different doses on heavy metals removal efficiency.

3.2. Oxidation /ozonation process

In recent years a vast number of pollutants including surfactants, natural fatty acids, and polychlorinated biphenyls, etc. have been identified as emerging pollutants in wastewater Rahman et al. (2016). In order to remove these pollutants, researchers attempted ozonation and advanced oxidation processes (Fagbenro et al. 2014; Mohamadreza et al. 2015; Vasilica et al. 2015; Wafa et al. 2015). Shraddha and colleagues (2017) claimed ozone as a powerful oxidant to remove toxic synthetic compounds, odor, and turbidity in water and wastewater. They further explained that ozone in dissolved form reacts with a large number of organic compounds either by direct oxidation as molecular ozone or by the indirect reaction through the formation of secondary oxidants like hydroxyl radical, resulted in a decrease in the color of effluent. It has been evident from the findings that coagulation followed by ozone oxidation caused a significant decrease in pollution load from 25 to 83 % (Table 2). The optimum results were obtained from the 0.8 mg/L ozone treatment dose. The removal percent recorded for TSS (53 %), TDS (25 %), COD (39 %), BOD (42 %), Oil & Grease (47%) and Surfactants (50 %) at 0.8 mg/L dose (Fig. 4). Similarly, it was noted that ozone oxidation have good to excellent effect on the removal of heavy metals i.e. 83 % Cu, 81 % Cd, 82 % Cr, 80 % Fe and 73 % Zn at the dose of 0.8 mg/L (Table 2). Even after the oxidation process, few parameters remain above the SEQS limits i.e. TDS (3699 mg/L), COD (632 mg/L) and BOD (270 mg/L, Table 2). Therefore another process such as ultrafiltration is required to obtain sustainable and acceptable results.

3.3. Ultrafiltration process

In the UF process semi-permeable membrane allows passing water and solutes of low molecular weight while retained suspended solids and solutes of high molecular weight. After ozone oxidation treatment, Ultrafiltration technique was employed, as shown in the flow diagram (Fig. 1). Results showed a marked decrease in COD (132 mg/L), BOD (73 mg/L), TDS (1590 mg/L) values, and heavy metals i.e Cd, Cu, Cr, Fe, and Zn were removed 89% on average well below SEQS limits (Table 2, Fig. 5). Similar findings were also reported by onur and inam onur et al. (2019); Inam et al. (2013). They claimed high removal efficiency for COD and TSS by employing ultrafiltration technique for the treatment of wastewater, while investigating the efficiency of UF based treatment process for highly concentrated oily wastewaters achieved very high removal performances of BOD, COD and TOC. In another study by using advanced UF hollow fiber membranes, Salahi and his colleagues reported removal of 83.1%, 96.3%, and 99.7% for COD, TOC and oil & grease, respectively (Salahi et al. 2015). In addition, Elorm et al. (2020) also described some advantages of membrane filtration techniques such as low space and labor requirements and highly effective in terms of TSS and pathogens removal.

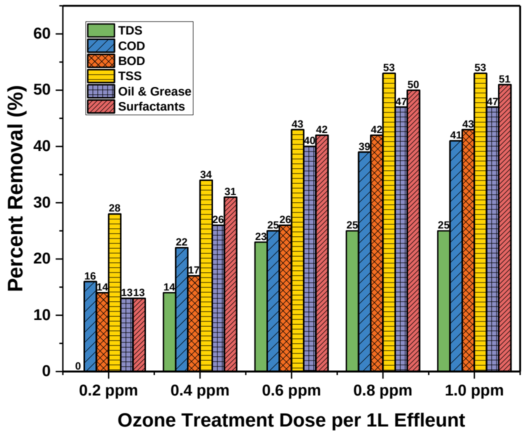

Fig. 4. The effect of ozone different doses on pollutants removal efficiency.

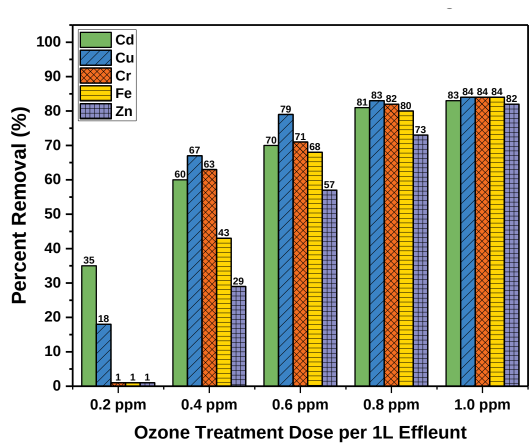

Fig. 5. The effect of ozone different doses on Heavy Metals removal efficiency.

Table 2. Results achieved after ultrafiltration.

Parameters	Unit	Composite sample, mg/L	Ozone treated effluent, mg/L	Ultrafiltration, mg/L	Removal %	
					Ultrafiltration	Overall
pH	-	10.7	7.50	6.8	-	-
TSS	mg/l	475	75.2	18	76	96
TDS	mg/l	7200	3699	1590	57	78
COD	mg/l	2085	632	132	79	93
BOD	mg/l	1010	270	73	73	93
Grease and oil	mg/l	24	5.3	0.95	82	96
Surfactant	mg/l	34.2	6.4	1.66	74	95
Cadmium (Cd)	mg/l	0.03	0.004	Not Detected	100	100
Copper (Cu)	mg/l	3.55	0.357	0.03	91	99
Chromium (Cr)	mg/l	1.54	0.213	0.03	87	98
Iron (Fe)	mg/l	1.90	0.241	0.05	79	97
Zinc (Zn)	mg/l	3.86	0.487	0.03	94	99

4. Conclusions

On the basis of overall results it may be concluded that the combination of these processes was effective in maximum reduction of TDS (78 %), TSS (96 %), COD (93 %), BOD (96 %), oil & grease (96 %), surfactants (95 %) and metals (98 %) from textile effluent (Tabl 2 and Fig. 6). It has also been observed that the coagulation followed by ozone oxidation is sufficient to reduce heavy metals below SEQS limits. However, other parameters like TDS, TSS, COD and BOD need a combination of coagulation, ozone oxidation and ultrafiltration to achieve sustainable results.

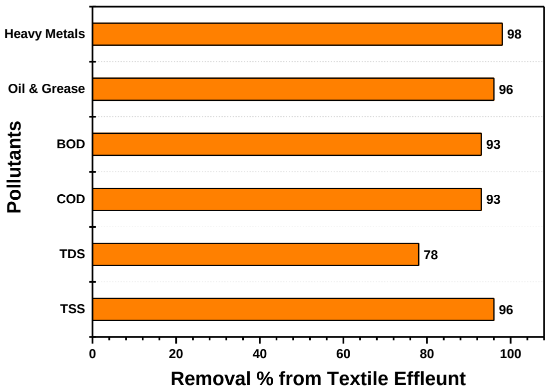

Fig. 6. The combined efficacy of coagulation, oxidation and ultrafiltration for removal of pollutants from textile effluent.

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