Simple physical treatment for the reuse of wastewater from textile industry in the Middle East

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Abstract: In this work, different treatment methods for wastewater from textile washing operations in the Palestinian territories were studied. The goal of the treatment process was to enable the textile industry to reuse the wastewater in textile washing through simple, efficient, and cost-effective methodologies. Actual textile wastewater samples from local textile factories were used and were found to be highly polluted. The study focused on three main processes; sedimentation, coagulation, and adsorption. While sedimentation was found to reduce the total suspended solids (TSS) of the wastewater, coagulation had the additional advantages of lowering the chemical oxygen demand (COD) and achieving higher filtration rates. Four coagulants were tested, ferric chloride, ferrous sulfate plus lime, aluminum sulfate, and aluminum sulfate plus lime. While ferric chloride failed to perform effectively as a coagulant, the other three coagulants were fairly effective. Finally, to further lower the COD of post-coagulation treated water, adsorption using activated carbon was studied. It was found that carbon was effective in reducing the COD of the wastewater using reasonable quantities, where up to 98% COD reduction was achieved using 6 g carbon/L.

Key words: textile, wastewater, treatment, coagulation, sedimentation, adsorption.

Résumé : Cet article présente diverses méthodes de traitement des eaux usées provenant d'opérations de lavage de textiles dans les territoires palestiniens. Le but de ce procédé de traitement était de permettre à l'industrie des textiles de réutiliser les eaux usées du lavage des textiles en utilisant des techniques simples, efficaces et économiques. De vrais échantillons d'eaux usées de textiles provenant des usines de textiles locales ont été utilisés et se sont avérés hautement pollués. L'étude porte sur trois procédés principaux : la sédimentation, la coagulation et l'adsorption. Bien que la sédimentation réduise le TSS dans les eaux usées, la coagulation présentait des avantages additionnels d'abaisser la DCO et d'obtenir des taux de filtration plus élevés. Quatre coagulants ont été mis à l'essai : le chlorure ferrique, le sulfate ferreux avec chaux, le sulfate d'aluminium et le sulfate d'aluminium avec chaux. Alors que le chlorure ferrique n'était pas un coagulant efficace, les trois autres coagulants ont été relativement efficaces. Finalement, l'adsorption sur charbon activé a été examinée afin d'abaisser encore plus la DCO de l'eau traitée après coagulation. En quantités raisonnables, le charbon s'est avéré efficace pour réduire la DCO des eaux usées; une réduction de la DCO atteignant 98 % a été réalisée en utilisant 6 g charbon/L.

Mots clés : textiles, eaux usées, traitement, coagulation, sédimentation, adsorption.

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Introduction

The textile industry produces large amounts of wastewater during all phases of textile production and finishing. Textile washing operations are the most water intensive in textile production. Wastewater from textile washing contains high quantities of chemical residues, which originate from previous textile processing steps, including dyes. The raw materials for the manufacture of dyes are mainly aromatic hydrocarbons (Kent 1974). In addition to dyes, textile wastewater also contains solids, oil, and halogenated organics from processes such as bleaching. Moreover, some compounds may be applied to fibers in processes preceding the final step of washing to improve the properties of fibers. These compounds may be released to the effluent water during washing. Examples of these compounds include surfactants, sizing, coating, and finishing additives. Sizing compounds such as starch contribute to increased biological oxygen demand (BOD) and chemical oxygen demand (COD) of the wastewater stream. Synthetic sizing additives, which are not as biodegradable as starches, can pass through conventional wastewater treatment systems and are often linked to aquatic toxicity in receiving waters (US-AEP 2003). Also, wastewater from textile washing is frequently highly colored and may contain heavy metals such as copper, chromium, and mercury. Many of the aromatic hydrocarbons found in the textile wastewater are either known carcinogens or toxic substances. For example, "basic red 9", a common dye, is toxic and a suspected carcinogen (MSDS 2003).

Because of the hazards associated with the large amounts of textile wastewater, several studies were conducted worldwide resulting in a number of treatment techniques for this wastewater. The complexity of these techniques depends, to a large

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extent, on the intended fate of the treated water and the environmental laws of the country in which it exists (Vandevivere et al. 1998; Tunay et al. 1996; Slokar and Le Marechal 1998; Rott and Minke 1999). Treatment technologies can generally be divided into physico-chemical (coagulation, electrochemical, filtration, ion exchange, adsorption, membrane, and photolysis) and biological methods.

Membranes were used to separate color and hazardous chemicals from textile wastewater. Membrane processes reported for this application are nanofiltration (Tang and Chen 2002; Chen et al. 1997; Sojka-Ledakowicz et al. 1998), ultrafiltration (Marcucci et al. 2002; Ciardelli et al. 2000), and reverse osmosis (Rozzi et al. 1999). Adsorption of dyes was reported using diatomaceous earth (Al-Ghouti et al. 2003) and using activated carbon combined with a membrane process (Rozzi et al. 1999). Similar to adsorption, ion exchange resins were applied to decolorize the textile wastewater and to reduce its COD (Lin and Chen 1997*a*; Karcher et al. 2002). Oxidation using ozone, H_2O_2, and UV was reported to decolorize the wastewater, reduce its COD, and enhance the biodegradability of its toxic chemicals (Ledakowicz et al. 2001; Arslan and Balcioglu 2001; Dogruel et al. 2002; Lin and Lai 2000). Another form of oxidation using the Fenton reagent (H_2O_2 and ferrous sulfate) was reported to be effective in decolorizing the textile wastewater, but not very effective in reducing its COD unless combined with another process such as coagulation (El-Kadri et al. 2002; Kang et al. 2000, 2002). Also, electrochemical oxidation was found to achieve high reduction of COD and BOD (Ciardelli and Ranieri 2001; Vlyssides et al. 1999). Photocatalytic treatment was found effective in decolorizing textile wastewater (Chun and Yizhong 1999; Hachem et al. 2001; Sokmen and Ozkan 2002). Coagulation was studied for the removal of color and turbidity and the reduction of BOD of textile wastewater. Both inorganic coagulants such as alum (Chu 2001; Sapari 1996), $FeCl_3$ (Kim et al. 2003), lime (Georgiou et al. 2003; Mishra et al. 2002), and ferrous sulfate (Georgiou et al. 2003), and organic polymeric coagulants (Mishra et al. 2002) were used. The coagulation process was also studied combined with other techniques such as ion exchange (Lin and Chen 1997*b*) and membrane (Bes-Pia et al. 2002). Biological treatment of textile wastewater was also attempted, although many of the toxic chemicals in this wastewater are known to be hard to biodegrade (Rozzi et al. 1999). Both aerobic (Assadi and Jahangiri 2001; Libra and Sosath 2003; Assadi et al. 2001; Basibuyuk and Forster 1997) and anaerobic (Sen and Demirer 2003; Minke and Rott 1999; Manu and Chaudhari 2002) bio-processing were investigated.

Textile wastewater in Palestinian territories

The clothing and textile industry is one of the key industries in Palestinian territories and the second largest employer in the West Bank and Gaza after construction (PTG 2003). It accounts for 18% of the manufacturing establishments and almost 30% of all manufacturing employment (PTG 2003). Some of the textile manufacturers in Palestinian territories, especially those who make the JEANS© fabrics, also perform textile-washing operations. These operations are needed to fix the dyes on the so-called "pre-washed" fabrics before being sold to the customer. As a case study for wastewater from these washing operations in the Palestinian territories, textile washing operations in the city of Nablus (the largest city in the West Bank) were considered in this study. Textile washing facilities in Nablus wash their fabrics in a series of steps with fresh, potable water used in every step, since the city has no separate "process water" line for industry. In some steps, chemicals are added to the wash water for certain polishing purposes (e.g., enzymes are added for wax removal). No recycle or treatment of the washing wastewater is done in any of these facilities, and wastewater is disposed of into public sewage. Based on data provided by the major textile washing facilities in the city for the amounts of water used per rinse, number of rinses per wash, and number of monthly washes, the total amount of wastewater generated annually by textile washers in Nablus was estimated to be 52 000 m^3/year. Calculations show that this figure is in agreement with the reported global average of 100–500 L wastewater/kg fabric (Karcher et al. 2002). This amount, which is equivalent to the annual drinking water consumption for 1500 habitants in Nablus (based on current average consumption rate), is thrown into public sewage, and is usually rich in toxic materials. The total amount of wastewater produced by textile washers in the Palestinian territory is, obviously, even larger and is therefore a problem requiring serious attention. Private communications with city engineers from Ramallah city (second largest city in West Bank) indicate that about 25% of all wastewater flowing into the city treatment facility comes from textile plants.

The goal of this work was to study simple and efficient techniques for the treatment of textile wastewater, which can be installed by textile washing plants without significant additional cost. Applying such techniques will reduce the net amount of wastewater generated by textile washers, thus reducing the load on public sewage systems, protecting the wastewater biotreatment systems, and, at the same time, enabling the washing facilities to reuse the water and save on their water consumption.

Materials and methods

In this experimental work, actual textile wastewater samples were used. These samples were provided by two of the textile washers in Nablus and were collected from different rinses at different times of the week. The samples were heavily colored and were visibly loaded with solid particles. When the samples were received in our lab, their pH, total suspended solids (TSS), 5-day biological oxygen demand (BOD_5), and chemical oxygen demand (COD) were measured.

Sedimentation tests

Each sedimentation test was performed using a wastewater batch of 8 L. The wastewater was put in a 14 L settling container and mixed for 10 min at 620 r/min for initial homogeneity.

Then, the mixing was stopped and the first sample was taken immediately, which represented the virgin wastewater sample. The sample was taken from a point approximately just bellow the center of the container. The water was then allowed to settle and a second, third, fourth, and fifth sample were taken after 0.5 h, 1.5 h, 3.5 h, and 5 d, respectively. All samples had the same volume (0.5 L) and were taken from the same position in the container. Care was taken not to disturb the water in the container while taking the samples. The samples were then tested to measure their chemical oxygen demand (COD), 5-day biological oxygen demand (BOD_5), and their total suspended solids (TSS), using the standard procedures for these tests that are provided elsewhere (Greenberg et al. 1992).

Coagulation tests using $FeCl_3$

Three containers were filled with 8 L each of wastewater. The solution in each of the three containers was mixed at 620 r/min for 10 min. Mixing was then stopped and $FeCl_3$ was added to each tank to a final $FeCl_3$ concentration in the tanks of 0.1, 1, and 1.8 g/L, respectively. The water was then gently re-mixed at 100 r/min for 30 min. The mixer was then stopped and the first sample was taken immediately. The water was then allowed to settle and samples were taken at 30, 60, 90, and 150 min. For each sample, pH and TSS were measured.

Coagulation tests using aluminum sulfate, lime and ferrous sulfate

Three containers were filled with 8 L each of wastewater. The solution in each of the three tanks was mixed at 620 r/min for 10 min. Coagulants were then added to each tank to give final concentrations of 0.8 g/L aluminum sulfate, 1.5 g/L lime + 1 g/L aluminum sulfate, and 1.5 g/L lime + 1.8 g/L ferrous sulfate, respectively. The solutions were then re-mixed. The pH was measured continuously and adjusted between 5 and 8 by using NaOH and H_2SO_4. After that, the mixers were stopped and the first sample was taken from each container. Then other samples were taken at 30, 60, 90, 150, and 180 min. For each sample, pH, COD, and TSS were measured.

Filtration tests

Four containers were filled with 8 L each of wastewater. The solution in each of the four containers was mixed with a mechanical mixer and a sample was immediately taken from the first container. The second container was allowed to settle for 1/2 h and then a sample was taken. To the third container, 1.5 g/L lime and 1 g/L aluminum sulfate were added and coagulation was performed as described above, then a sample was taken. In the fourth container, coagulation was performed, similar to the third container, but with a post-coagulation settling (sedimentation) for 30 min. All samples were then vacuum-filtered using a 2.5 μm Whatman filter paper. For each sample, the filtration rate was measured.

Adsorption tests

Wastewater that has been partially cleared of suspended solids by coagulation using aluminum sulfate and lime, as described earlier, was subject to adsorption using activated carbon. Four water samples, 0.5 L each, were taken. Activated carbon (Norit, Sigma-Aldrich, Steinheim, Switzerland) was added to the samples yielding a final carbon concentration of 0 (control, no carbon), 1.6, 6, and 30 g/L, respectively. The samples were then mixed at 90 r/min for 1 h. The samples were then allowed to settle for 1/2 h and the carbon was filtered out. The COD of the filtered sample was then measured. Samples were taken in duplicates and the average value was reported.

Results and discussion

Throughout this experimental work, actual industrial textile wastewater samples were used. Since fresh wastewater batches were collected from different washes and for different types of fabrics, the quality of these batches varied. The total suspended solids (TSS) of the fresh wastewater samples was in the range of 320–1600 mg/L with one sample reaching approximately 2500 mg/L. Chemical oxygen demand (COD) ranged from 160 to 1500 mg/L and biological oxygen demand (BOD_5) averaged 170 mg/L. The pH ranged from 6 to 8 with one sample having a pH of 11.5. Others have reported ranges on the same order of magnitude. For example, a Korean textile wastewater had a pH, COD, and TSS of 10.8–11.2, 800–1000 mg/L, and 200–300 mg/L, respectively (Kim et al. 2003), whereas samples from Malaysia had pH, BOD_5, COD, and TSS values of 10.9, 324 mg/L, 2009 mg/L, and 95 mg/L, respectively (Sapari 1996).

The target value for the parameters (COD, BOD_5, and TSS) should depend on the intended fate of the water. The European Union (EU) urban wastewater directive, for example, sets an upper COD limit of 125 mg/L for treated wastewater prior to discharge to rivers (Kiely 1997). As for the BOD_5, rivers are generally considered polluted if the BOD_5 exceeds 5 mg/L (Kiely 1997). In Palestinian territories, Israeli standards for treated wastewater are usually used as guidelines. These standards are close to the EU figures. For practical reasons, since treated wastewater in this study is intended to be reused in another textile washing operation, two goals are kept in mind. First, the amount of suspended solids has to be reduced as much as possible (preferably below 50 mg/L) to produce clear water acceptable for textile washing. Second, the COD has to be minimized (preferably below 125 mg/L) to prevent the accumulation of toxic substances in the water during its reuse and to reduce the mass transfer resistance of dyes and other chemicals to the water during the wash process. To achieve these goals the focus of this work was primarily on simple processes that lower the TSS (sedimentation and coagulation) and the COD (coagulation and adsorption) as discussed next.

Fig. 1. Change in TSS with time during sedimentation.

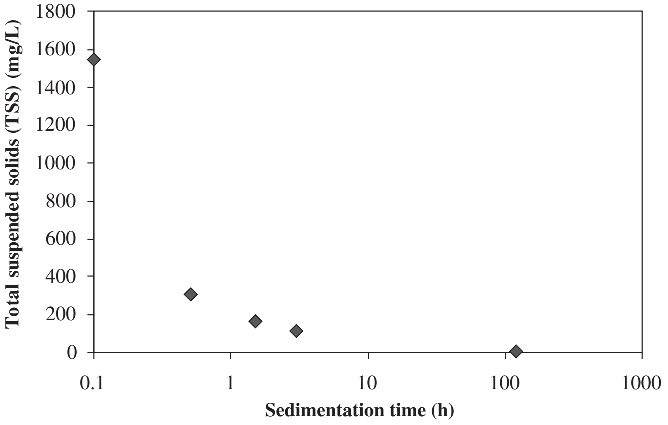
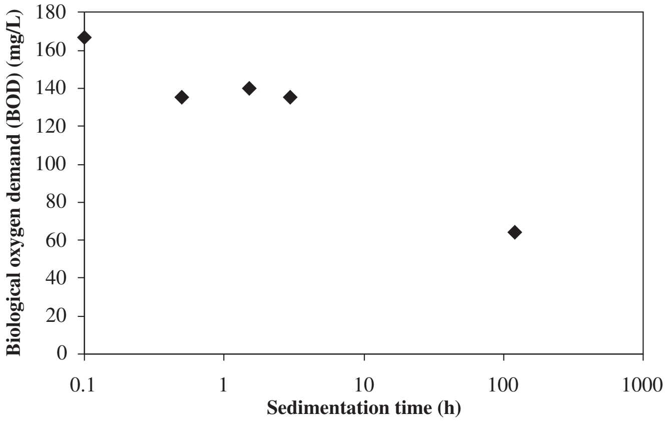


Fig. 2. Change in BOD_5 with time during sedimentation.

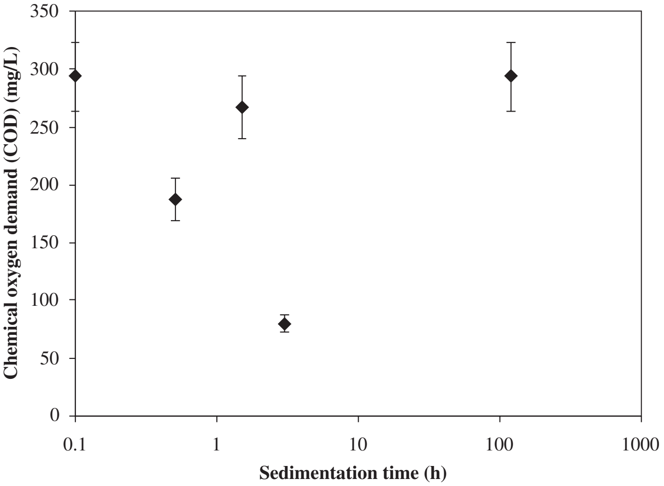


Sedimentation results

Figures 1, 2, and 3 show TSS, BOD_5, and COD, respectively, of textile wash wastewater samples during a simple sedimentation (no coagulants) process. The first sample was taken immediately after the mixing was stopped, whereas the last sample was taken after 5 d of sedimentation. Figures 1 and 2 show a systematic decrease of TSS and BOD_5 over the settling period. The decrease in suspended solids with time is expected as particles settle during the sedimentation, leaving behind a clearer liquid supernatant. It is encouraging to observe from Fig. 1 that 90% of the solids settle out of the solution within the first hour. By the end of the fifth day, an almost clear liquid was obtained.

The reduction in BOD_5, as shown in Fig. 2, although at a lower rate than TSS (16% reduction in the first hour), is also expected. The decrease in BOD_5 with sedimentation indicates that the suspended solids contain a fraction of the biodegradable organic material. Based on differences in the percentage of reduction between TSS and BOD_5 (Figs. 1 and 2), one can conclude that a significant fraction of the biodegradable organic matter is dissolved and cannot be removed by sedimentation alone. This indicates that another treatment method is needed, besides sedimentation, to remove that portion.

Fig. 3. Change in COD with time during sedimentation.



Chemical oxygen demand values in Fig. 3 are generally higher than the corresponding BOD_5 values, which is to be expected. For complex industrial wastewaters, particularly those with high contents of organic non-biodegradable fractions (such as textile wastewater), such a wastewater may register lower BOD_5 than COD (Kiely 1997). Whereas BOD_5 indicates the concentration of biochemical easy-to-decompose substances, COD indicates the concentration of substances that can be readily decomposed "chemically". Like BOD_5, one would expect the COD to drop with settling time due to the removal of solids, which contribute to the COD, from the liquid. However, a non-uniform trend is observed in Fig. 3, which is puzzling. The samples were taken in duplicates that produced the same result indicating that the trend is genuine. A correlation reported by Kiely (1997) shows that $BOD_5 = 0.6$ COD for municipal wastewater, although it does not hold for complex industrial wastewater, particularly industrial wastewater with high contents of organic non-biodegradable fractions. The textile wastewater dealt with in this work may be considered among the latter category. Nonetheless, apparently, this relation holds valid for the first and third data points, yet it is not clear why the COD data follows the trend shown. Another possible explanation for the erratic COD data is the production of volatile fatty acids (such as acetic acids) from the biodegradable sediments under anaerobic conditions. Further testing seems necessary to verify and understand this trend.

Coagulation results

To see if the removal of solids in the case of textile wastewater would be enhanced by using coagulants, a series of tests were performed using several types of coagulating agents. The first coagulant tried was $FeCl_3$. Three tests were performed using 0.1, 1, and 1.8 g $FeCl_3$/L. The fresh wastewater used in the test had a TSS value of 320 mg/L (prior to the addition of $FeCl_3$), which is different than the value for wastewater used in the sedimentation tests (approximately 500 mg/L). This is because a new batch of wastewater was used in the coagulation tests. Figure 4 shows the TSS results for the wastewater using the three

Fig. 4. Change in TSS with time during coagulation using $FeCl_3$.

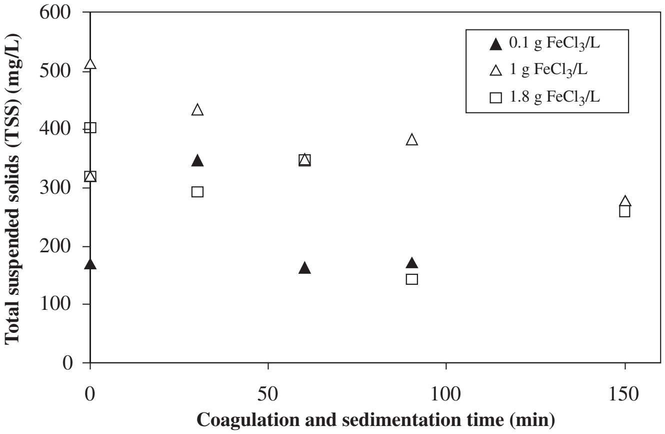
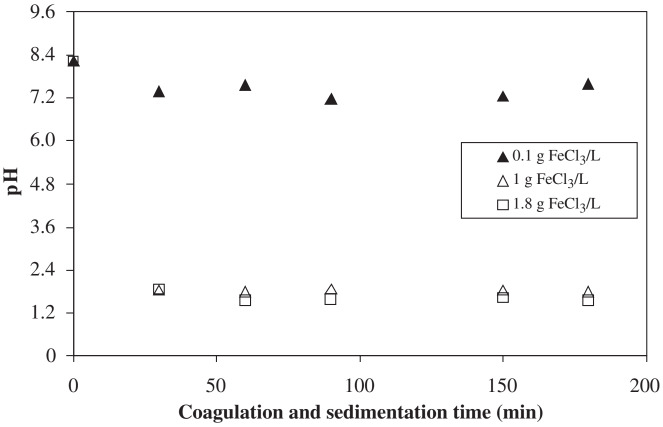


Fig. 5. Change in pH with time during coagulation using $FeCl_3$.



$FeCl_3$ concentrations. The first sample was taken immediately after the mixing was stopped (after adding the $FeCl_3$), whereas the last sample was taken after 2.5 h of sedimentation of the coagulated wastewater. Figure 4 indicates no strong decrease trend in TSS for any of the three samples, unlike the sedimentation tests (Fig. 1). In fact, after 150 min, all three samples seemed to have a TSS value close to where they started. By comparison to the no-coagulation sedimentation case (Fig. 1), it looks like $FeCl_3$ not only failed as a coagulant, but also had a stabilizing effect on the suspended solids in the water. One possible explanation of this is the dramatic drop in pH as a result of adding $FeCl_3$ to a non-pH-controlled solution, as shown in Fig. 5. The more $FeCl_3$ added (1 and 1.8 g/L), the higher the reduction in pH. Ferric chloride acts as an acid in water and gives the hydronium ion, according to the following reactions:

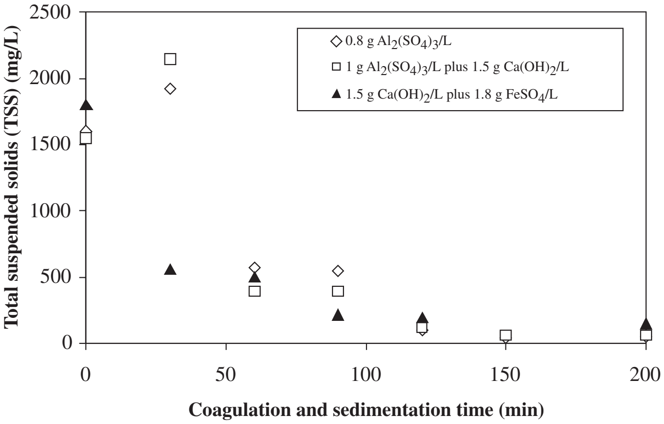
$$[1] \quad FeCl_3 \rightarrow Fe^{+3} + 3Cl^-$$

$$[2] \quad Fe^{+3} + 6H_2O \rightarrow Fe^{+3}(H_2O)_6$$

$$[3] \quad Fe^{+3}(H_2O)_6 + H_2O \rightarrow [Fe(H_2O)_5OH]^{+2} + H_3O^+$$

It seems that this change in solution alkalinity to acidity may have contributed to the stabilization of the solids in solution. There is a report of a similar failure of $FeCl_3$ as a coagulant (CPP 2004), while, on the other hand, others reported a successful application of it as a coagulant (Kim et al. 2003). Another possibility is that the $FeCl_3$ dosage used may have been too high causing particle bridging. As seen in Fig. 4, it appears that the best results for $FeCl_3$ as a coagulant were obtained at the lowest $FeCl_3$ dosage, which may give credit to this explanation.

Fig. 6. Change in TSS with time during coagulation using three coagulants.



Next, three other coagulants were tested. These are (0.8 g $Al_2(SO_4)_3$/L), (1 g $Al_2(SO_4)_3$/L plus 1.5 g $Ca(OH)_2$/L), and (1.5 g $Ca(OH)_2$/L plus 1.8 g $FeSO_4$/L). These will be referred to as “alum”, “alum with lime”, and “lime with ferrous sulfate”, respectively. The fresh wastewater had a TSS value of 903 mg/L (prior to addition of coagulants). The TSS increased to about 1600 upon adding the coagulants. Figure 6 shows the change in TSS for the three coagulants with time. Initially, TSS values for all coagulants increased above 903, due to the addition of the coagulant, but then started to drop dramatically within the first 30 min. Eventually (after 150 min), all three coagulants achieved high TSS reduction rates (90–95%) with alum and alum plus lime showing the best results. During the coagulation process, attempt was made to control the pH of the solutions (using NaOH and H_2SO_4) within the 5–8 range in which the formed hydroxide flocs are insoluble (Kiely 1997). This worked well for alum and alum with lime, but the pH for alum with ferrous sulfate eventually dropped to about 2.5, as shown in Fig. 7. Apparently, this did not affect the performance of alum with ferrous sulfate (as evident in Fig. 6), which is supported by previous findings that the ferrous sulfate’s function, in particular, as a coagulant is not pH dependent (USACE 2004). Despite the small difference in the final TSS values between the case of using the coagulants (Fig. 6) and the no-coagulant sedimentation (Fig. 1), the important advantage of using coagulants over sedimentation is in the systematic reduction of COD as seen in Fig. 8. For all three coagulants used, a clear drop in COD was observed with the most significant drop (about 85%) for alum. Alum with lime also came close, but the drop in COD for ferrous sulfate with lime was the least impressive (45%). In all cases, the systematic reduction was far better than sedimentation alone (Fig. 3).

In addition to COD reduction, another advantage of using a coagulant is that it facilitates the removal of solids from the water by filtration. This is because coagulated flocs are larger in size than their individual particle constituents and, therefore,

Fig. 7. Change in pH with time during coagulation using three coagulants.

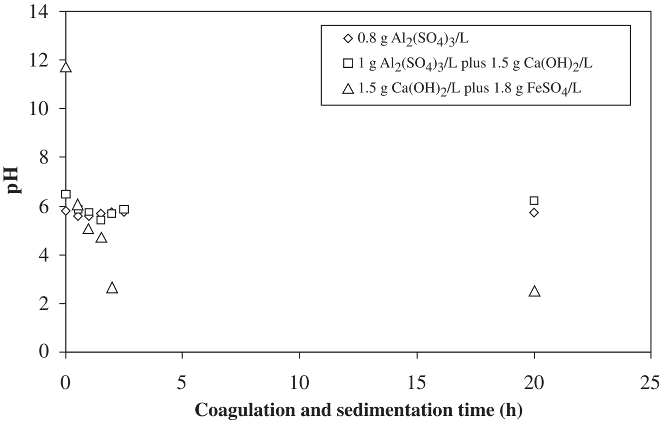
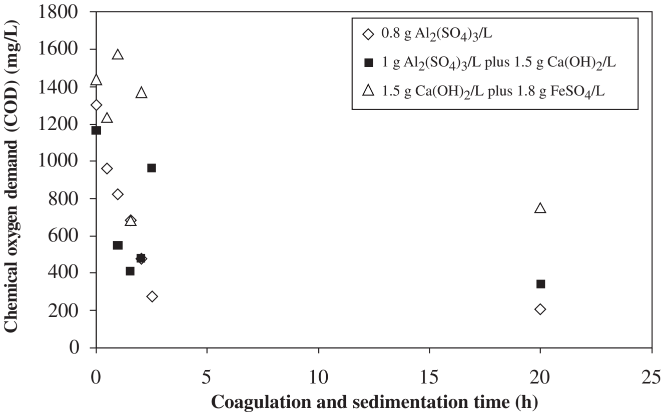


Fig. 8. Change in COD with time during coagulation using three coagulants.



have less tendency to block the filter pores or increase the pressure drop during filtration. To verify the impact of coagulants on filtration in our case, a set of experiments was performed using Whatman filter paper with pore size of 2.5 μm (obviously, Whatman filter paper is not practical for use in the field treatment of textile wastewater, but it was used here for comparison purposes).

Figure 9 shows the filtration rates for three types of treated wastewaters and a fresh textile wastewater. The fastest rate was observed when the solids in the wastewater were coagulated for 1 h (using lime and alum) then allowed to settle for 30 min. Very close to that was the filtration rate when the solution was filtered immediately after 1 h of coagulation time without post-coagulation settling. This indicates that a 1 h coagulation time period was enough to achieve the maximum floc size and no additional floc enlargement was gained by settling. The slowest filtration rate was observed for the non-treated wastewater, as expected. Between these two extremes was the filtration rate for wastewater that was allowed to settle for 30 min, indicating some degree of particle removal during this period (as supported by Fig. 1). The key conclusion from this test is that coagulation helps speed up the filtration rate, mainly through increasing the particle size of suspended solids.

Fig. 9. Filtration rates of different wastewaters using Whatman filter paper size 42 (2.5 μm).

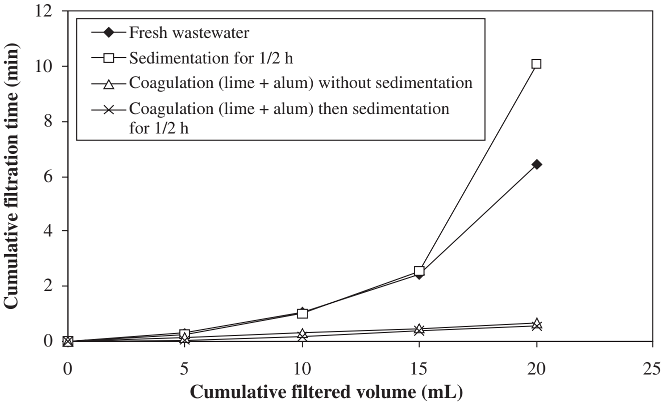
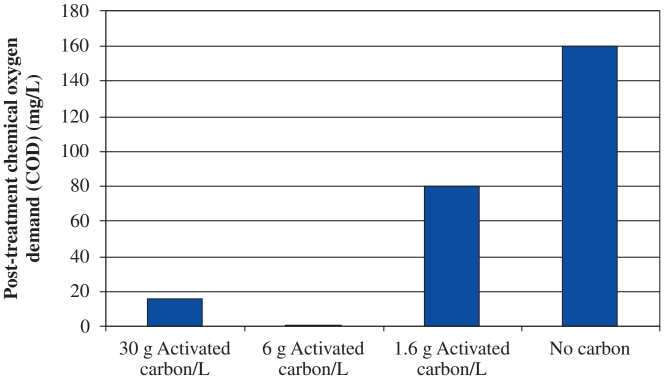


Fig. 10. COD reduction of post-coagulation water after adsorption with activated carbon.



It is worth mentioning here that, if the textile firms were to use the treatment process studied in this work, the primary running cost of the process will be that of the coagulants (in addition to the operating cost of the equipment). Hence, it is important to optimize the dosage of the coagulant. An average of 1 kg of coagulant per cubic metre of wastewater may be needed, as shown in Fig. 6. The cost of such an amount is significant, compared to the cost of fresh water. However, if laws enforcing the treatment of hazardous wastewater (such as textile wastewater) were effected, such cost will be justified.

Adsorption results

Finally, the use of activated carbon adsorption for the reduction of COD was studied. This was prompted by the observation that coagulation, although very encouraging, failed to reduce the COD of treated wastewater to, or below, the desired value of 125 mg/L (Fig. 8). The adsorption step was envisioned as a post-coagulation treatment for further water polishing. So, wastewater that has been initially subjected to coagulation using lime and alum (Fig. 6) was used in the adsorption tests. Three carbon doses were used; 1.6, 6, and 30 g/L, in addition to a "control" (no-carbon) sample. Figure 10 shows the final COD value of the four samples.

A trend of COD reduction with carbon dose is observed in Fig. 10, which is achieved within 1 h of contact with activated carbon, as mentioned earlier. The 6 g carbon sample had lower COD (COD = 2 mg/L) than the 30 g carbon sample (COD = 18 mg/L), although this could be due to experimental error since both values are small and close to each other. However, one can conclude that there is probably no advantage in using a carbon dose larger than 6 g/L and the carbon dose needs to be optimized. Based on these observations, a simple treatment scheme of coagulation using a mixture of lime and alum followed by activated carbon adsorption was sufficient to reduce both turbidity and COD of the textile wastewater, making it feasible to reuse the water.

Conclusions

The goals of this work are multifold. It aims at enabling the textile industry to treat and reuse the wastewater from its textile washing operations using a simple and feasible technology. It also aims at preventing the pollution that results from this wastewater, protecting wastewater treatment facilities, and saving significant quantities of water for other domestic uses. In view of this, the choice of studied technologies was kept to the simplest level to make it easy for the textile industry to accept and implement.

Sedimentation was found to reduce the TSS effectively and, to a less extent, the BOD_5. Yet, the COD was not effectively reduced using this process. The use of coagulants was studied to fill this gap. Ferric chloride ($FeCl_3$) was studied first, but failed to achieve a significant TSS reduction, which is suspected to be due to the pH drop in a non-pH-controlled wastewater. More success was encountered using combinations of small amounts of aluminum sulfate, lime, and ferrous sulfate. In the case of these three coagulants, which were studied in a pH-controlled setting, significant reductions of TSS and COD were achieved. The pH dropped below the target range in the case of ferrous sulfate but did not seem to influence its performance. Coagulation also seemed to improve the filtration rate of the solids out of the treated water, when tested using a 2.5 μm Whatman filter paper, compared to virgin and sedimentation-treated wastewater. This was attributed to the increased size of the flocs thanks to the coagulants.

Adsorption by activated carbon was also studied to complement the coagulation process since coagulation alone could not achieve the targeted COD level of 125 mg/L. Three doses were studied and a dose of 6 g carbon/L was sufficient to reduce the COD to 2 mg/L. Further optimization of the carbon dose is still needed.

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