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Chemical Treatment for Mixed Wastewater in Small Communities in Egypt

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Authors' contributions

This work was carried out in collaboration between all authors. Author AMH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author RE managed the experimental work and the literature searches. Authors BEH and REH reviewed both the study design and the paper manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Applying advanced oxidation process, by Fenton's reaction, to treat mixed wastewater. The study focused on treatment of domestic sewage mixed with industrial wastewater generated from sugar industry.
Study Design: The research focused on studying the optimum dose of hydrogen peroxide and the retention time to treat influent fresh mixed wastewater samples, which include domestic sewage and industrial wastewater. The used fresh mixed wastewater samples were collected from the influent of El-Hawamdya wastewater treatment plant. El-Hawamdya wastewater treatment plant is located in Abu-Seir village in Giza, Egypt.
Methodology: The plant contains units of primary sedimentation tanks, trickling filter and final settling tanks and chlorine dose often added before disposal of the treated wastewater. The plant daily capacity is about 20,000 m^3/d. The input wastewater includes about 76% of domestic sewage

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and 22% of sugar industry's wastewater plus 2% from small industries. The applied experiments were determined in order to achieve, both, efficiency and economical benefit.

Results: Based on the experimental work program executed in this research, and limited to the tested materials and testing procedures, it has been found that the overall optimum dose for H_2O_2 is 1.5 mg/l with a 20 minutes retention time.

Conclusion: It has been concluded that the chemical treatment, by Fenton reaction, can be used for treatment of fresh raw mixed wastewater, under the circumstances of the study, with acceptable efficiency and suitable cost.

Keywords: Chemical treatment of mixed wastewater; Fenton reaction; wastewater treatment in small communities; sugar industry wastewater treatment.

1. INTRODUCTION

Municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids [1-2]. It has been found that the efficiency of treatment of sewage in some Egyptian villages is relatively small, especially with the presence of industrial wastewater along with domestic sewage, treatment of wastewater becomes more difficult and traditional treatment is less efficient. The objectives of wastewater treatment include: reduction of biological oxygen demand (BOD), reduction of suspended solids (SS), destruction of pathogens and removal of nutrients, toxic compounds, non-biodegradable compounds and dissolved solids, [3]. Relatively simple domestic wastewater treatment technologies can be provided to maintain low cost sanitation and environmentally sound disposal while beneficially reuse the treated wastewater [4]. Biological treatment by trickling filters has certain limitations [5], so it was not included in this research. Volatile suspended solids (VSS) are those solids (mg/l) which can be oxidized to gas at 550 C^o. Most organic compounds are oxidized to CO_2 and HO at that temperature; inorganic compounds remain as ash [6]. A previous study in Alexandria, Egypt, focused on enhancing the mixed wastewater treatment using cyanobacteria [7]. The traditional treatment could be less efficient and slower than chemical treatment in case of mixed wastewater, so it was found that chemical treatment would give higher efficiency if we used it beside traditional treatment. Also, because of the increasing interest in developing alternative method for improving the treatment of sewage, advanced chemical oxidation technologies (AOTs) was applied [8] as a successful technique which can degrade the non-biodegradable substance. The molecules of the organic substance break in a small amount with a higher percentage of oxygen in form of alcohols, carboxylic acids, etc. Oxidation of organic substance with oxygen in their molecules will be much easier than the other ones. This is the main concept in chemical oxidation process. Oxidation with ozone or hydrogen peroxide has been found to be an important alternative to chlorination because the oxidation doesn't result in toxic chlorinated organic compounds [9]. Fenton reaction is considered as one of the most successful process in advanced chemical oxidation. Therefore, Chemical treatment by Fenton oxidization process had been studied in this research.

The oxidation of organic and natural substrates by iron(II) and hydrogen peroxide is called the "Fenton chemistry", as it was first described by H. J. H. Fenton who first observed the oxidation process of tartaric acid by H_2O_2 in the occurrence of ferrous iron ions [10]. Alternatively, the name of "Fenton Reaction" or "Fenton reagent" is frequently used. We know that the Fenton reagent defined as a mixture of hydrogen peroxide and ferrous iron happens to be accepted as one of the most effective techniques for the oxidation of organic and natural toxins.

The Fenton reagent has recently been known for more than a century but their application as an oxidizing process for destroying harmful organics was not applied until the later nineteen sixties [11-12]. Following this time comprehensive inspections showed that the Fenton reagent is effective in treating various industrial sewage components including aromatic amines [13], an extensive variety of dyes [14-15] pesticides [16-17] surfactants [18], explosives [13] as well as many other substances. Consequently, the Fenton reagent has been applied to treat many different wastes such as those associated with the textile industry, chemical substance manufacturing, refinery and energy terminals, engine and steel cleaning etc. [19].

The Fenton reagent can also effectively be applied for destruction of toxic wastes and non-biodegradable effluents to render them more suitable for secondary biological treatment [3]. Additionally, the value of Fenton reaction has been long recognized among others in food chemistry [20]. Fenton 1894, [21], gave the Fenton's reagent. Fenton's reagent is a mixture of H_2O_2 and ferrous iron, which generates hydroxyl radicals. The ferrous iron (Fe++) initiates and catalyzes the decomposition of H_2O_2, leading to the generation of hydroxyl radicals. The technology of such radicals involves a complex response sequence in an aqueous solution [22]. H_2O_2 can behave as an OH scavenger as well as a radical initiator [23]. Generally, Fenton's oxidation process is pH adjustment, oxidation response, neutralization and coagulation for precipitation. Therefore, the organic substances are removed in two stages of the oxidation [24]. A continuous photo-Fenton process for the degradation of gaseous dichloromethane (DCM) can be used [25]. Solar photocatalytic destruction of the azo absorb dyes acid orange 24 using a photo Fenton reaction advertised by solar energy was used [26]. The degradation of different commercial reactive chemical dyes by using solar light assisted Fenton and photo-Fenton reaction was investigated [27]. Photocatalytic organic content reduction of two selected synthetic wastewaters from the textile dyeing industry was studied by the use of heterogeneous and homogeneous photocatalytic methods under solar irradiation, at a pilot plant range at the Plata program Solar de Almeria [28]. The scavenging effect of Phosphate and bicarbonate anions on the degradation of organic and natural pollutants through the Fenton process may be relatively reduced by the requirement of the application of this Technique at relatively low pH [29].

2. EXPERIMENTAL WORK

2.1 Wastewater Sampling

Fresh mixed wastewater samples used were taken from outfall of wastewater treatment plant located in El-Hawamdya. El-Hawamdya wastewater treatment plant is located in Abu-Seir village in Giza, Egypt. The plant contains units of primary sedimentation tanks, trickling filter, final settling tanks, and contact tank. Its daily capacity is about 20,000 m^3/d. The influent is a mixed domestic and industrial wastewater. The industrial part comes from Sugar industry, which raises the organic content in the influent wastewater, significantly. The measured characteristics of wastewater are listed in the Table 1.

Table 1. The measured characteristics of the fresh wastewater

Polluted parameter	Quantity
COD (mg/L)	730
BOD (mg/L)	395
TSS (mg/L)	308
pH	9.73

2.2 Experimental Set-up

For Fenton reaction the material used in this study include Ferrous Sulfate Heptahydrate ($FeSO_4.7H_2O$) which is used as a catalyst. It was provided from El-shark El-Awsat Company for Chemicals, Cairo. Also, Hydrogen Peroxide solution (50% w/w) was provided from El-shark El/Awsat Company for Chemicals. In addition, three conical glass, one liter, flasks were used. A burette and a stopwatch were, also, used.

2.3 Procedure

The investigation was based on the different doses of H_2O_2 and the reaction time. To perform this experimental study, three conical flasks were used. First four liters of fresh wastewater are mixed well together, and then samples were taken from it to measure the main biological, chemical, and physical parameters before the treatment by Fenton reaction, which was mentioned in Table 1 previously. Then the three flasks were filled by fresh wastewater samples one liter each one. A fixed dose of 0.025 mg Fe^{+2} (ferrous sulfate) was first added to the flasks. After that, three different doses of H_2O_2 were applied to the fresh wastewater samples directly, without primary treatment. The Hydrogen Peroxide (H_2O_2) was applied with doses of 0.5, 1.0, and 1.5 mg/l. Each sample was treated for three different retention times of 10, 20, and 30 minutes. This arrangement produced nine different samples. Each sample was tested for Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS), and pH value.

2.4 Analytical Method

The experiments were carried out in the laboratory of the El-Hawamdya wastewater treatment plant, which located in Abu-Seir village in Giza, Egypt. The chemical oxygen demand

(COD) was determined by using a Bioblock (COD) Analyzer, which depends on the method of acidic oxidation by dichromate. The pH was measured by pH meter; this device is calibrated and adjusted using standard solutions. The total suspended solids (TSS) were determined by using solid filtration device, dryer and sensitive electrical balance according to the standard method. And finally, Biological Oxygen Demand (BOD) measurement indirectly determines the concentration of organic matter in wastewater by measuring amount of dissolved oxygen used by the bacteria to oxidize the organic matter for five days under controlled incubation at 20°C.

3. RESULTS AND DISCUSSION

3.1 Technical Evaluation

In order to investigate the optimum dose of H_2O_2 and the optimum retention time for COD, BOD, and TSS removal, a series of experiments were carried out at different Hydrogen Peroxide initial concentrations. The percentages of COD, BOD, and TSS removal have been determined throughout the reaction period of 10, 20, and 30 minutes.

COD removal efficiency at different doses and different retention times were calculated, analyzed, and presented. In order to obtain the optimal time, the investigation was carried out at various H_2O_2 doses. Fig. 1 shows the relation between the COD removal efficiency and the H_2O_2 doses throughout different times of 10, 20, and 30 minutes. The figure indicates that, generally, increasing dose of H_2O_2 with increasing the time enhanced the COD removal efficiency. But, one result behaved differently. This odd result may be attributable to the presence of some experimental errors during the calibration, treatment, or measuring.

On the other hand, in order to obtain the optimal retention time of reaction, the investigation was carried out at various H_2O_2 doses. Fig. 2 shows the relation between the BOD_5 removal efficiency and the H_2O_2 retention times at different doses.

Fig. 2 illustrates that the higher the dose of H_2O_2, the higher the effluent BOD_5 removal efficiency obtained. Also it shows that increasing time leads to decrease the effluent BOD_5 and increasing BOD_5 removal efficiency.

Fig. 3 shows the relation between retention time and TSS removal efficiency at Different H_2O_2 Doses. To determine the optimum treatment time, giving maximum efficiency of removal of the suspended materials, different doses of Hydrogen Peroxide were used. The tested doses were 0.5, 1.0, and 1.5 mg/l, at retention times of 0, 10, and 30 minutes.

Fig. 3 illuminates the comparison between these three doses throughout various times. The figure indicates that 0.5 mg/l H_2O_2 curve is giving the best efficiency according to the amount of removal of TSS after treatment process. The optimum result occurs at retention time equal to 30 minutes. It should be noted here that although the curve, which mentioned above is considered the best in terms of the efficiency of removal of TSS after treatment process, but the differences between the three curves are minor differences.

Fig. 4 shows the relation between the effluent pH & different doses of H_2O_2 (0.5, 1 and 1.5 mg/l). The pH value ranged between 6.02 and 9.73 at retention times of 30 minutes. These results indicate that the H_2O_2 dose significantly affects pH value. But, a 0.5 mg/l H_2O_2 dose, was enough to deal with the alkalinity of fresh mixed wastewater samples.

3.2 Cost Estimate

A brief cost comparison between chemical and biological procedures has been presented. The major evaluation parameters are the electricity consumption per 1 m^3 of mixed raw wastewater, the required area in m^2 per 1 m^3/d of mixed raw wastewater, and the workers productivity in terms of m^3/worker. The estimates are given in Table 2. The table shows that, in spite of the relatively higher cost of the Fenton's reaction, it can compete successfully with other traditional biological treatment methods.

Table 2. Economical comparison

	Treatment by Fenton's reaction	Extended aeration	Oxidation ditch
Electricity consumed (kW/h/m^3)	0.065	0.440	0.412
Land space (m^2/m^3)	0.289	3.671	6.839
Worker production (m^3/Worker)	109	240	210

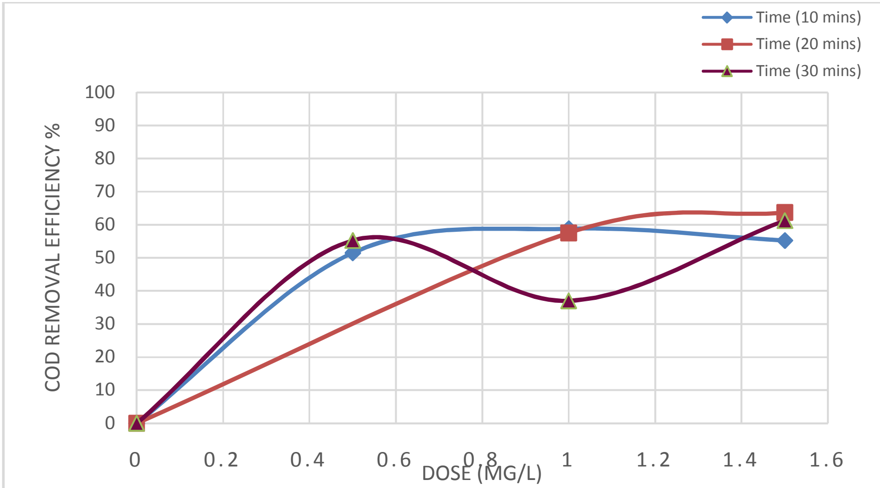

Fig. 1. Effect of H_2O_2 dose variation on COD removal efficiency at different retention times

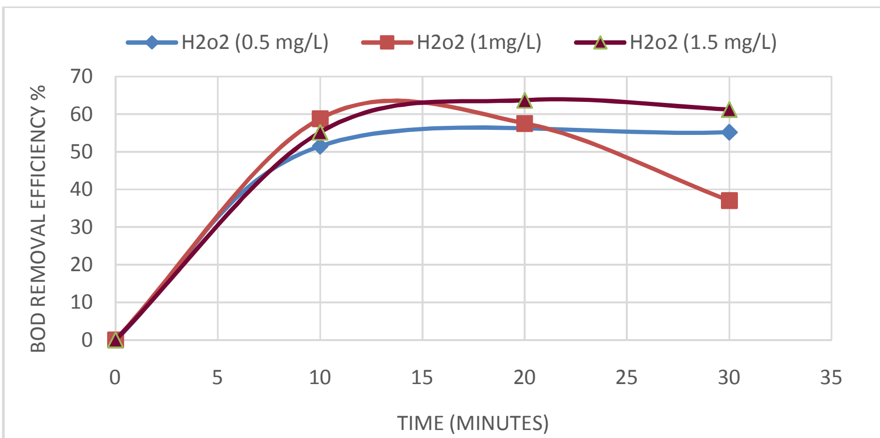

Fig. 2. Effect of retention time variation on BOD removal efficiency at different H_2O_2 doses

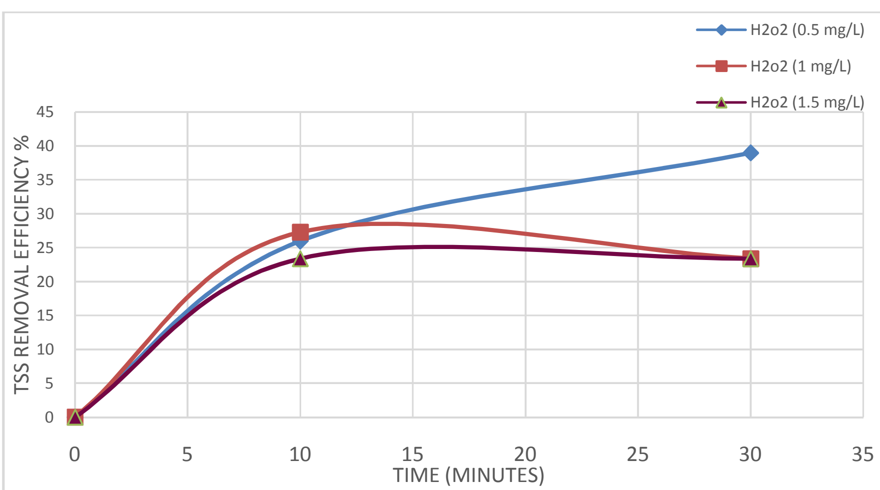

Fig. 3. Effect of retention time variation on TSS removal efficiency at different H_2O_2 doses

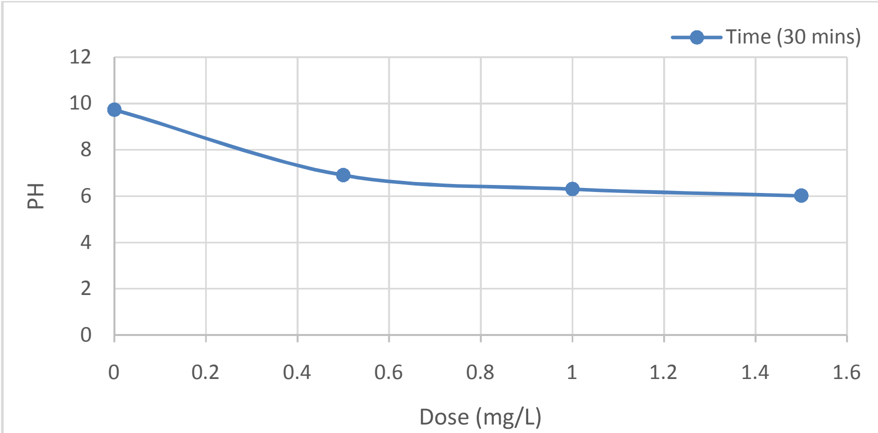

Fig. 4. pH value at different doses of H_2O_2 with 30 minutes retention time

4. CONCLUSION

The research studied the effect of H_2O_2 dose variation with the retention time on enhancing the BOD, COD, and TSS removal efficiency, and pH value. The main target was to investigate the suitability of using Fenton reaction in treatment of mixed domestic- industrial wastewater in the small communities in Egypt. These tests were executed to achieve, both, efficiency and economical benefit. Based on the experimental work program executed in this research, and limited to the tested materials and testing procedures, the following conclusions can be achieved:

- Fenton reaction can be used in the treatment of mixed domestic-industrial wastewater with great variation in organic matter content.
- Due to the, relatively, high cost of treatment by Fenton reaction technology, The reaction can be used in small communities and limited to the villages that contains small industries.
- The removal efficiency of COD ranged between 36.98% and 63.7%, at treatment of raw mixed wastewater with Hydrogen Peroxide (H_2O_2) with different doses ranged between 0.5 and 1.5 mg/l, for retention times ranged between 10 and 30 minutes.
- The optimum COD removal efficiency of 63.70% can be achieved by treatment of mixed wastewater with 1.5 mg/l H_2O_2 dose for 20 minutes.
- The COD removal efficiency can be enhanced by applying the Fenton reaction to primary treated mixed wastewater instead of fresh mixed wastewater.
- The removal efficiency of BOD ranged between 22.53% and 55.44%, at treatment of mixed wastewater with Hydrogen Peroxide (H_2O_2) with different doses ranged between 0.5 and 1.5 mg/l, for retention times ranged between 10 and 30 minutes.
- The maximum BOD removal efficiency of 55.44% can be achieved by treatment of mixed wastewater with 1.5 mg/l H_2O_2 dose for 30 minutes.
- The BOD removal efficiency can be enhanced by applying the Fenton reaction to primary treated mixed wastewater instead of fresh mixed wastewater.
- The removal efficiency of TSS ranged between 23.38% and 38.96%, at treatment of mixed wastewater with Hydrogen Peroxide (H_2O_2) with different doses ranged between 0.5 and 1.5 mg/l, for retention times ranged between 10 and 30 minutes.
- The maximum TSS removal efficiency of 38.96% can be achieved by treatment of mixed wastewater with 0.5 mg/l H_2O_2 dose for 30 minutes.
- The TSS removal efficiency can be enhanced by applying the Fenton reaction to primary treated mixed wastewater instead of fresh mixed wastewater.
- The effluent pH value after treatment process for retention time of 30 minutes ranged between 6.02 and 6.91.
- The optimum pH value of 6.9 was achieved at H_2O_2 dose of 0.5 mg/l.

- In spite of the relatively higher cost of the Fenton's reaction, it can compete successfully with other traditional biological treatment methods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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