



Improvement of Final Settling Tanks Performance by Using Chemical Additions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors made equal contributions in problem analysis, validation, calibration of model, reviewing and editing. All authors supervised the manuscript. All authors wrote the original draft. All authors read and approved the final manuscript.

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ABSTRACT

Biological treatment in wastewater treatment plants WWTPs consists of two main tanks, aeration tank and final settling tank. Aeration process using in return activated sludge system is very costly and it is required to operate WWTPs with low dissolved oxygen (DO) concentration in aeration process without risking poor effluent quality. To apply this study, a plant model for the addition of chemicals must be made with the necessary calibration of this model. Laboratory experiments were started between November 2017 and June 2018. This paper will discuss the impact of DO concentration on sludge properties by using a pilot plant model WWTP and find the optimum doses of Hydrogen peroxide H_2O_2 concentration with using low DO concentration to achieve good sedimentation. In this study the DO set-point was changed every 3 weeks between 0.5 mg/l and 4.5 mg/l for a few months. Experiments were carried out to The optimal ratio and dosage of H_2O_2 / Fe^{+2} was 5 as 30/6 mg/l. BOD, COD, TSS and VSS removal efficiency by using H_2O_2 / Fe^{+2} were 91%, 89% 90% & 89%, respectively with DO = 1.5 mg/l at an increased rates were 21.3%, 25.4%,

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20% & 12.7%, respectively. Results of paper proves that the addition of optimum H₂O₂ will save 2 mg/l of DO concentration and providing a high cost of using electricity and mechanical equipment compared to the non-use of H₂O₂.

Keywords: Wastewater treatment plants (WWTPs); sludge properties; chemical additions; hydrogen peroxide (H₂O₂); dissolved oxygen (DO) concentration.

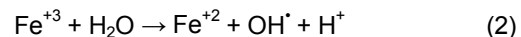
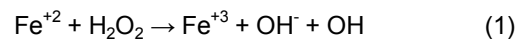
1. INTRODUCTION

1.1 Return Activated Sludge Process

Wastewater is a combination of solids and water. Pollution (Solids) represents 0.1% and water represents 99.9%. Wastewater must be treated to remove solids which threats to human health [1]. Conventional wastewater treatment consists of a consequently stages of physical, chemical, and biological processes for removing organic dissolved and suspended matters [2]. Return activated sludge process (ASP) is an aerobic biological treatment used to decrease the organic matters in wastewater by converting dissolved organic matters into their own biomass [3]. Wastewater treatment in activated sludge system poses a challenge all over the world [4]. Stabilization of waste activated sludge (WAS) is a vital phase for the reuse or disposal [5]. The activated sludge system consists of two main units, the aeration tank and the final clarifier [6]. The efficiency of the activated sludge system depends on physical and biological characteristics of flocs [7]. Aeration tank works to provide the organics with dissolved oxygen (DO) to convert soluble organics into biomass. The flocs in wastewater are allowed to separate and settle down from the effluent water. Final clarifier allows settling to the bottom, allowing clear wastewater to leave the tank. The MLSS may be removed from the bottom of the tank [3]. Many investigations have been done on activated sludge and the effects of factors on this system [8]. In the past, the DO concentration has generally been kept high at the plant (> 5 mg/l) as it has been thought to give better effluent quality [9]. During later years, many efforts have been made to reduce the DO concentration to (2:3) mg/l. In this study the DO set-point was changed every 3 weeks between 0.5 and 4.5 mg/l for 7 months. The other tank is final clarifier which has two primary functions; clarification and thickening. Clarification process is the process which separate solids from the liquid wastewater and thickening process is the moving of sludge particles to the bottom of the tank [10].

1.2 Hydrogen Peroxide (H₂O₂)

Wastewater treatment is divided to three alternatives: (a) advanced biological processes, which may be able to treat high organic loads; (b) advanced chemical processes; (c) or a combination of both [11]. Despite biological purification in wastewater treatment plants, wastewater must also be subjected to additional purification processes such as hydrogen peroxide additions with fixed doses of iron sulphate [12]. Chemical processes such as; hydrogen peroxide additions has been used successfully to increase of BOD & COD removal efficiency. Hydrogen peroxide (H₂O₂) releases a lot of oxygen atoms to increase treatment efficiency. The dose may be ranged between (25-50) mg/l H₂O₂ increase treatment efficiency [13]. H₂O₂ can be used alone or with catalysts, such as iron (Fe⁺² or Fe⁺³) to oxidize BOD/COD compounds in wastewaters [14]. Doses of H₂O₂ are (25-100) mg/L; the cost can often be parallel to savings in coagulant use [15]. In the common Fenton process (Reaction 1), the Fe⁺³ ions are formed. Under the effect of UV light, photo reduction from Fe⁺³ ions to Fe⁺² is run; moreover, the additional OH[•] radicals are formed (Reaction 2) [16]. The cost of using hydrogen peroxide can save coagulant use. Laboratory experiments were conducted to best conditions for Fenton reaction with different H₂O₂ and salts of iron and the best ratio between H₂O₂/ Fe⁺² was 5, respectively [17]. Conversion Fe⁺² to Fe⁺³ which help in the process of oxidation, remove color in the effluent wastewater [18].



2. MATERIALS AND METHODS

2.1 Pilot Plant Model

Physicochemical studies in this paper are essential to evaluate the effect of DO doses and effect of H₂O₂ additions on activated sludge system [19]. To apply this study, a pilot plant model for the addition of chemicals must be made with the necessary calibration of this model. As shown in Fig. 1, plant model was started from

November 2nd, 2017 as shown in these following steps;

1. Pilot plant model was determined to select design flow rate (Q) equals 840 liters per day as 210 liters each six hours (One Cycle) and the pilot plant was controlled as a continuous flow system.
2. The model was located beside the primary sedimentation tank of Zeinen WWTP for easy wastewater transfer to the system and the model consists of three separate tanks: feeding tank, aeration tank and final sedimentation tank.
3. Feeding tank is located a head of the system's biological treatment units and contains 0.5 m³ of water coming from primary settling tank.
4. This tank is a rectangular shape and dimensions of the aeration tank are as follows (0.55 x 0.74 x 0.52) m and the active depth of the tank is 0.52 m and it is where the influent and the returned activated sludge are mixed.
5. The raw wastewater flow rate (from feeding tank) was set at 0.58 L/min., the excess sludge supposed to be taken out from the tank intermittently based on the sludge retention time calculations.
6. Sludge is returned to the aeration tank for 1 minute each 10 minutes to calibrate the model with second plant of Zeinen WWTP.
7. Samples were collected from the pilot plant which located at Zeinen WWTP in Giza, Egypt in the first step, all samples which used for this study were collected from

primary tank where located in at Zeinen WWTP.

8. Different doses of dissolved oxygen were performed in aeration tank of pilot plant and DO doses were varied between 0.5 mg/l: 4.5 mg/l.

2.2 Different Doses of Dissolved Oxygen (Do) in Aeration Tank of Model

Samples were collected from the pilot plant which located at Zenien WWTP in (Giza, Egypt) as the first step. Different doses of dissolved oxygen were performed in aeration tank of pilot plant and DO doses were varied between 0.5 mg/l: 4.5 mg/l. The best efficiency of organics removal was appeared, and knows the optimum DO dose was guide to the best efficiency of final clarifier. In this system, nine (DO) concentrations were carried out in pilot plant and DO concentration was changed between 0.5 mg/l: 4.5 mg/l approximately every 3 weeks. The DO concentration at the end of the aeration tank was generally varied from between 0.5 mg/l: 4.5 mg/l to ensure good treatment efficiency and good settling properties. In pilot plant, high efficiency must be resulted with reduction of the aeration intensity to save energy. Experiments were performed to conclude the effective of the best ratio of H₂O₂ /Fe⁺² ions on improvement of treatment efficiency in final clarifier. The ratio of H₂O₂ /Fe⁺² was 5 as 30/6, respectively [20]. Finally, the results of this experimental work are compared with the recorded values of observation, then the pilot plant model is ready for simulation and the flowchart of the steps of experimental work is shown in Fig. 2.

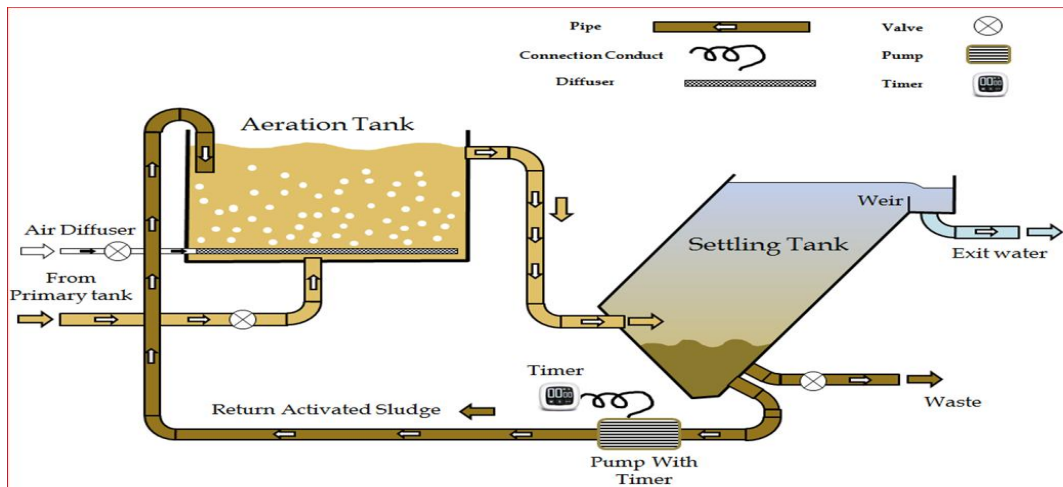


Fig. 1. Schematic diagram of the pilot plant model

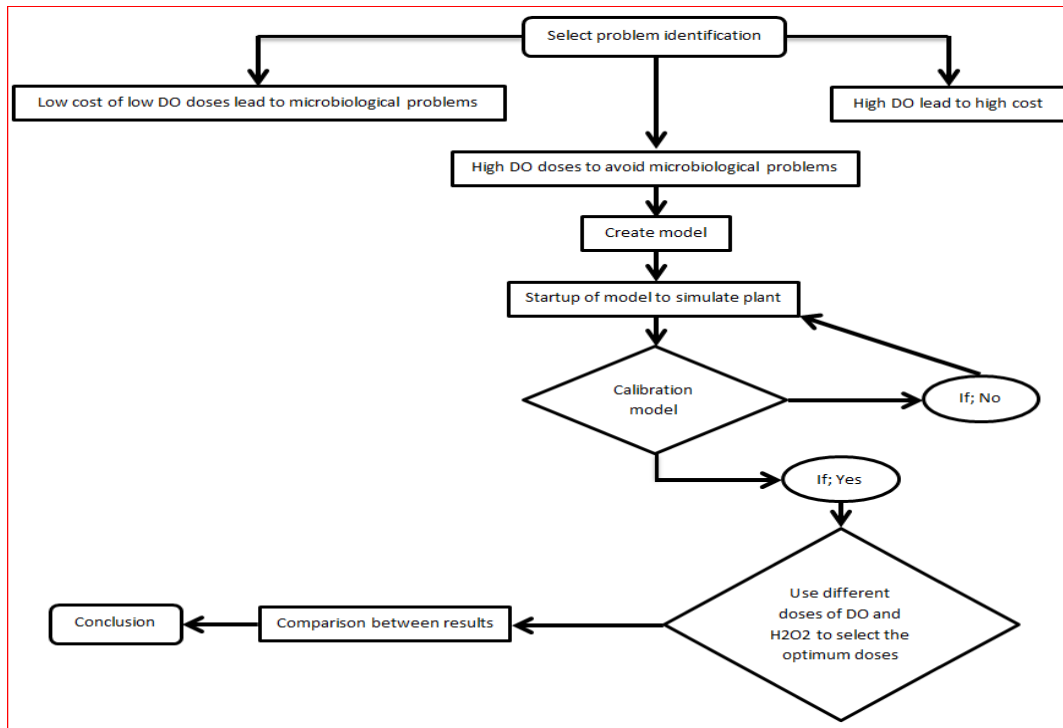


Fig. 2. The work program flow chart

2.3 The Optimum Doses of H_2O_2/Fe^{+2}

After laboratory experiments, ferrous sulphate is better than ferrous ammonium sulphate. Using chemical addition such as ferric sulfate is an important to increase treatment efficiency [16]. Ferrous sulphate and ferrous ammonium sulphate are cheaper compared with other chemicals. But ferrous sulphate does not make color in wastewater as shown in Fig. 3, so using ferrous sulphate are better than ferrous ammonium sulphate. From previous studies, the optimum dose of H_2O_2/Fe^{+2} is 5. Experiments were carried out in Zenien laboratory to find the optimum doses of DO concentration with different doses of H_2O_2 concentrations. The

optimal ratio and dosage of H_2O_2/Fe^{+2} was 5 as 30/6 mg/l.

3. RESULTS AND DISCUSSION

3.1 The Effect of Dissolved Oxygen (Do) on the Treatment Efficiency

In the pilot plant model, during the period mentioned above, different doses of DO were used and their effect on treatment efficiency was observed as shown in Fig. 4 during this period, sudden increases in DO concentration gave higher efficiency of effluent. Efficiency of BOD_5 , COD, TSS and VSS removal increases slowly after 2.5 mg/l up to 4.5 mg/l.



Fig. 3. Ferrous sulphate and ferrous ammonium sulphate

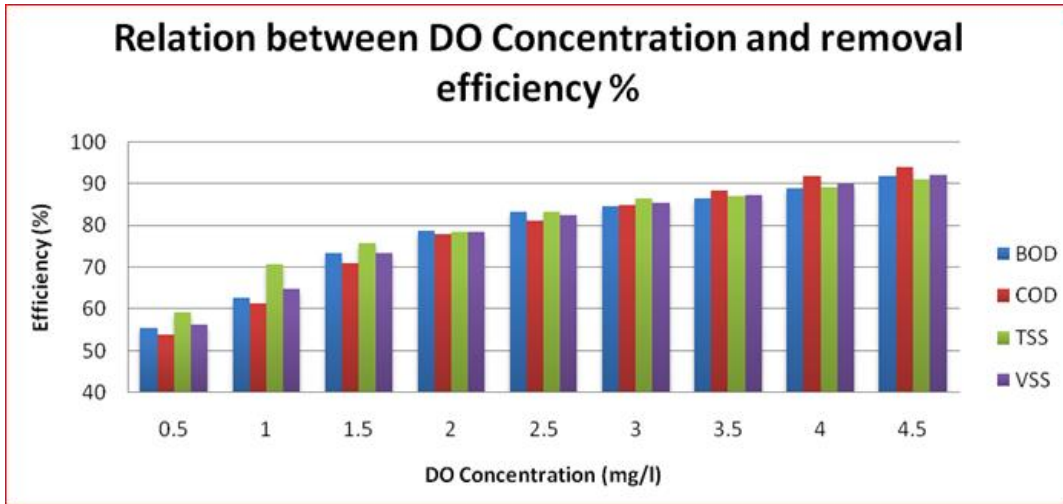


Fig. 4. Relation between DO concentration and treatment efficiency

3.2 Treatment Efficiency with and without Addition of H₂O₂

Because of the lower concentration DO doses give less treatment efficiency [21]; their results

were compared with the results after addition of hydrogen peroxide with the same concentration of DO, and the results of this experimental part in the following Table 1.

Table 1. Treatment efficiency with and without chemicals

Case of treatment	DO (mg/l)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	VSS (mg/l)
Without Chemicals	0.5	61.0	53.0	68.0	64.0
	1.0	66.0	60.0	71.0	72.0
	1.5	75.0	71.0	75.0	79.0
Optimum dose of H ₂ O ₂ /Fe ⁺² is 5 as 30/6	0.5	69.0	62.0	72.0	69.0
	1.0	75.0	69.0	74.0	78.0
	1.5	91.0	89.0	90.0	89.0
Incremental Efficiency %	-	21.3	25.4	20.0	12.7

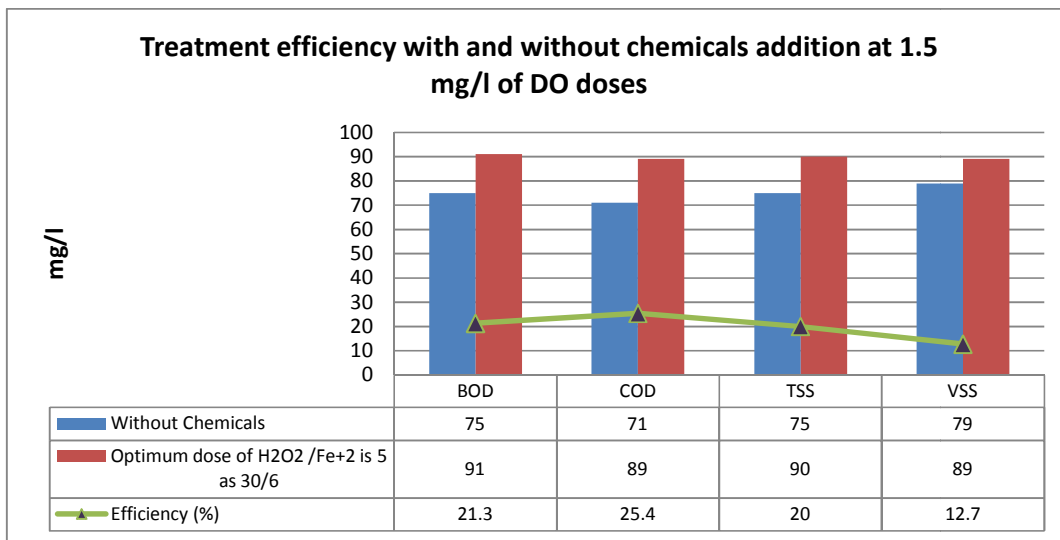


Fig. 5. Treatment efficiency with and without chemicals H₂O₂ addition at 1.5 mg/l of DO doses

For example at 1.5 mg/l without using H₂O₂, treatment efficiency in the system was not efficient as a result of using H₂O₂ as shown in Fig. 5, treatment efficiency of BOD, COD, TSS and VSS increased by 21.3%, 25.4%, 20.0% and 12.7% respectively.

4. CONCLUSION

Addition of H₂O₂ and a Fenton's reagent with DO concentration is a technique to strengthen aerobic sludge. The removal efficiency of (BOD, COD, TSS, and VSS) increased significantly after increasing DO doses. The DO concentrations were more effective up to 2.5 mg/l. It should be noted that the incremental of DO concentration after 2.5 mg O₂/l up to 4.5 mg O₂/l is not economical according to cost of aeration system compared with the incremental of DO concentration from 0.5 mg O₂/l to 2.5 mg O₂/l. The optimal range of DO varies between (2.5-3.5) mg O₂/l for any aeration tank in activated sludge system; not high cost in terms of electrical and mechanical and high efficiency. After using H₂O₂ that can be drawn from this study are:

1. In this experiment, the optimal ratio of H₂O₂/iron salts was observed using a ratio of 5 as 30/6 mg/l.
2. BOD, COD, TSS, VSS removal efficiency were improved by 21.3%, 25.4%, 20.0% and 12.7% respectively after using H₂O₂/Fe⁺² with DO = 1.5 mg/l.
3. At optimum condition (DO=2.5 mg/l), BOD & COD removal efficiency was 83.30% and 81.23% respectively.
4. At optimum condition (DO=2.5 mg/l), TSS & VSS removal efficiency was 83.17% and 82.87% respectively.
5. BOD and COD removal efficiency were increased under the optimal conditions of H₂O₂ /Fe⁺² with (DO=1.5 mg/l) by 21.3% and 25.4% higher than the treatment without using H₂O₂ /Fe⁺² for the same DO concentration.
6. The addition of optimum H₂O₂ /Fe⁺² = 5 with (DO=1.5 mg/l) was equivalent using aeration system with (DO=3.5 mg/l) without H₂O₂ /Fe⁺² for wastewater treatment, this means saving 2 mg/l and providing a high cost of using electricity and mechanical equipment compared to the non-use of H₂O₂ in this treatment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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