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Treatment of Primary Settled Wastewater Using Anaerobic Sequencing Batch Reactor Seeded with Activated EM

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Abstract
The biologic treatment process using effective microorganisms (EM) in an anaerobic sequencing batch reactor (ASBR) for primary settled wastewater treatment was investigated. Activated EM was formed from raw EM to increase its efficiency by ensuring that the microorganisms were in an exponential phase of growth. A bench-scale ASBR (volume 2.6 l) was seeded with activated EM and the characteristics of the influent and effluent wastewater were investigated under different temperatures and reaction times. This system achieved good removal efficiency for all the analyzed parameters. The removal efficiency of the chemical oxygen demand (COD), soluble COD, biochemical oxygen demand, total suspended solids, ammonia, and total phosphorus increased with increasing reaction time and temperature, and reached 72.1%, 61.5%, 75.7%, 80.9%, 50.4%, and 62.5% respectively, at a reaction time of 24 h and at 35 °C. The system showed good removal of total coliform and salmonella and a reduction in ammonia and sulfate-reducing bacteria. Biogas can also be obtained using this system.

Keywords: Anaerobic treatment; ASBR; Effective microorganisms; Pathogens; Wastewater treatment

1. Introduction

Organic matter, suspended solids, and nutrients are among the main constituents that should be removed from municipal wastewater . Reduction of organic matter, which can be accomplished with biological treatments, must occur before wastewater is discharged into waterways. Suspended solids that settle in a water body and reduce the cross sectional area of waterways may be problematic (Metcalf & Eddy, 2003). Although colloidal particles do not settle readily, they do cause turbidity . To resolve these problems, wastewater should undergo sedimentation treatment prior to discharge (Metcalf & Eddy, 2003). Excessive nutrients such as nitrogen and phosphorus often lead to significant algal growth. These nutrients become oxygen demanding materials when the algae die and settle to the bottom (Metcalf & Eddy, 2003). Depending on the level of nutrients and local regulations; physical, chemical and/or biological treatment may be used. Ideally, the treatment to remove organic matter, suspended solids and excessive nutrients should be a modification of an existing low-cost treatment process with a short startup period. From the point of view of cost, anaerobic treatment process is preferred, because it does not require large inputs of energy beyond those energy can be obtained by generating biogas. There are three main reactions in anaerobic processes: fermentation, acetogenesis, and methanogenesis (David, 2006). Notably, the rate of growth should be balanced and pH must be regulated in anaerobic treatment (David, 2006). Anaerobic fermentation can occur in a pH of 5.0 to 9.0; however, bacterial methane operates in a much narrower range of 6.5 to 7.6, with an optimum value of approximately 7.0 (David, 2006).

In this study, a new biological treatment process that uses effective microorganisms (EM) to treat primary settled wastewater in an anaerobic environment was investigated. EM is a brown to dark brown liquid solution and consists of naturally beneficial microorganisms that are not pathogenic, genetically engineered or modified, or chemically synthesized (Nour El-Din, 2008). EM, which is produced through a fermentation process, is primarily used by mixing it with or applying it to other organic materials (Nour El-Din, 2008). EM was developed for agricultural use as an alternative to chemical fertilizers. However, unlike chemical fertilizers, the purpose of EM is to increase the number of beneficial microorganisms in the soil (EMRO, 2012). Although the development of EM began in the 1960s, the first commercial product did not appear until 1982 (EMRO, 2012). The potential of naturally-occurring microbes and their ability for coexistence were identified and developed by Dr. Teruo Eliga, Professor of Horticulture at the University of the Ryukyus in Okinawa, Japan. EM contains three basic groups of microorganisms: lactic acid bacteria (*Lactobacillus* and *Pediococcus*), yeast (*Saccharomyces*), and phototrophic bacteria (Rashid and West, 2006). Namsivayam et al. (2011) used EM to reduce alkalinity, total dissolved solids, biological oxygen demand (BOD), and chemical oxygen demand (COD) of domestic sewage under standard conditions. All the parameters that were tested showed distinct reduction; however, total heterotrophic bacterial and yeast population increased. The result of the experiment performed by Namsivayam et al. (2011) shows that EM can improve the effectiveness of domestic waste treatment . Rashid and West (2006) showed that after three months, an application of EM combined with duckweed grown in a dairy wastewater stabilization pond significantly reduced NH_4–N, total Phosphorus , and BOD, compared to control treatment . Okuda and Higa (1997) reported that the application of EM to wastewater reduced toxicity .

During this study, a bench-scale anaerobic sequencing batch reactor (ASBR) was seeded with activated effective microorganisms. The ASBR process can be considered as a suspended growth process with reaction and solid-liquid separation occurring in the same vessel (Metcalf & Eddy, 2003). ASBR was examined in a laboratory at temperatures ranging from 5 to 25 °C, while treating a nonfat dry milk synthetic substrate with a COD concentration of 600 mg/l. The organic loading of the process was changed by selecting a hydraulic retention time ranging from 6 to 24 h. At 25 °C, 92 to 98 percent COD removal was achieved at volumetric loadings of 1.2 to 2.4 kg COD/m^3.d (Metcalf & Eddy, 2003). The removal of COD, soluble chemical oxygen demand (sCOD), BOD, total suspended solids (TSS), ammonia, and total phosphorous (TP) were investigated using this system. *Total coliform and salmonella were also investigated to show the effect of the system on the removal of pathogens. The ability of the system to produce biogas was determined by examining* the existence of methane-forming bacteria, while the ability of the system to remove odor was determined by investigating the decrease in the amount of sulfate-reducing bacteria (SRB).

2. Experimental procedure

Activated EM was prepared by mixing a certain dose of EM with primary settled wastewater for a period of one week. The activation of EM is required to ensure that the growth rate of the microorganisms is in the exponential rather than the lag phase during the treatment process. Activation of EM to the exponential phase will result in good removal efficiencies compared with using raw EM under similar conditions. A bench-scale system consisting of a 20 × 13 × 10 cm antibacterial plastic tank (volume 2.6 l) was used. The experiment focused on the effect of reaction time and temperature. The mixing rate and the settling time (2 h) were constant during the experiment. ASBR was seeded with activated EM (12.5 % activated EM by volume) and operated under different reaction times but with a constant settling time of 2 h per cycle. The influent wastewater was primary settled municipal wastewater obtained from the Zenin wastewater treatment plant in Giza, Egypt. All wastewater analytical methods used in this experiment conformed to standard American methods for the examination of water and wastewater (2005), and all results were obtained in duplicate.

The first step was to determine a suitable dose for the preparation of activated EM. Different doses (2.5 ml/l, 7.5 ml/l, 10 ml/l, 20 ml/l, and 30 ml/l) of raw EM were applied to primary settled wastewater and then left in an anaerobic complete-mix reactor for 1 week at 27 ± 2 °C. One week is the period recommended by the manufacturers of EM (Nour El-Din, 2008). Then, different doses of the prepared activated EM were used to seed the ASBR for investigating their performance on the removal of COD, BOD, and TSS with a reaction time of 6 h. The highest removal efficiencies of COD, BOD_5, and TSS were obtained at 27 °C with an EM dose of 10 ml/l and a retention time of 6 h, as shown in Figures 1, 2, and 3.

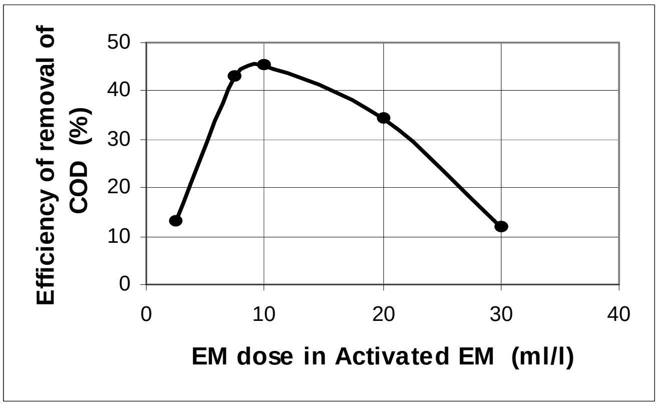

Figure 1. Removal efficiency of COD versus different EM doses

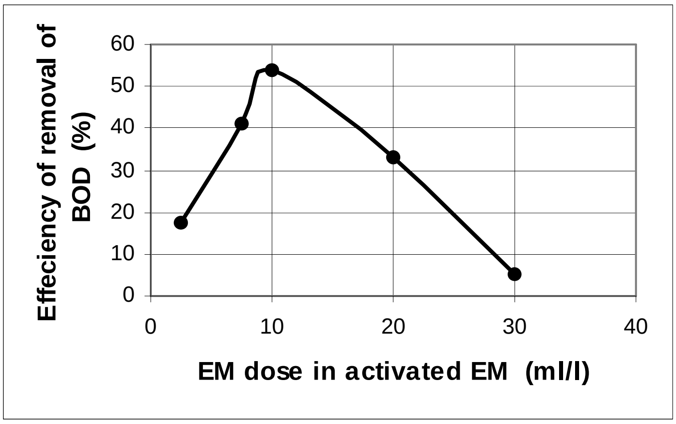

Figure 2. Removal efficiency of BOD_5 versus different EM doses

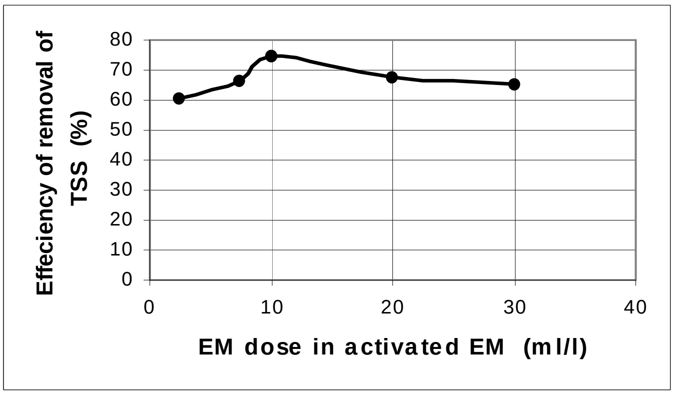

Figure 3. Removal efficiency of TSS versus different EM doses

3. Results and Discussion

3.1. Effect of Different Reaction Times at Different Temperatures

ASBR seeded with activated EM with an EM dose of 10 ml/l was examined at 15 ± 2 °C and 35 ± 2 °C to simulate winter and summer temperature conditions and under different reaction times (6, 10, 16, 20, and 24 h). The removal efficiency of COD, sCOD, and BOD_5 increased with reaction time, as shown in Figures 4–9. This indicates that the growth rate of the microorganisms in the reactor at retention times between 6 and 24 h followed the exponential growth phase. Further increase in the retention time may lead to the stationary phase, wherein the growth rate of microorganisms equals the death rate. The system showed good removal efficiency of TSS due to (1) consumption of an organic portion of the TSS during the treatment process, and (2) settling of a portion of TSS during the settling phase. The decrease in the effluent wastewater turbidity with increasing retention time indicates that additional filtration facilities may not be required when using a higher reaction time. The system also showed good removal efficiencies for both ammonia and TP. The removal of ammonia may be due to the growth of anaerobic ammonium-oxidizing (anammox) bacteria, which can convert ammonia and nitrite gas to nitrogen gas under an anaerobic environment. The decrease in phosphorus levels may be due to the use of phosphorus by microorganisms during metabolism. On comparing the results obtained under different temperatures, it can be concluded that the removal efficiencies for all parameters at a temperature of 35 °C are much higher than those for the same parameters at 15 °C. These results are consistent with the literature (Nour El-Din, 2008).

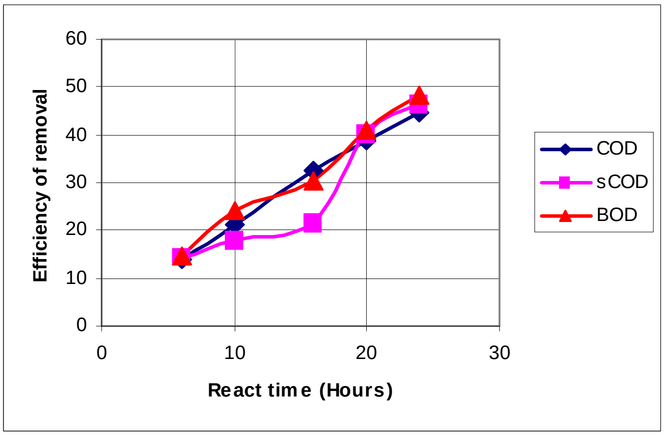

Figure 4. COD, sCOD, and BOD_5 removal efficiency for different reaction times at 15 °C

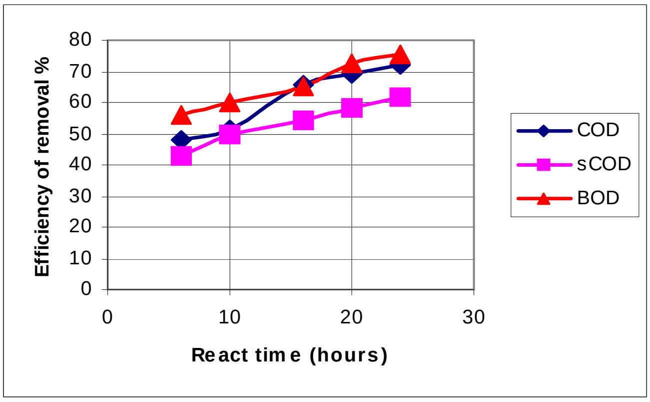

Figure 5. COD, sCOD, and BOD_5 removal efficiency for different reaction times at 35 °C

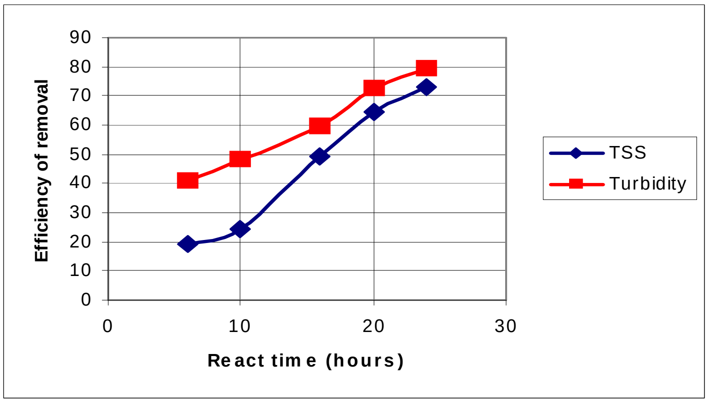

Figure 6. TSS and turbidity removal efficiency for different reaction times at 15 °C

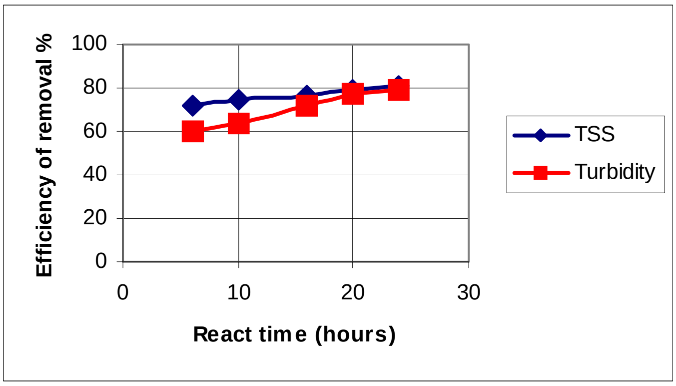

Figure 7. TSS and turbidity removal efficiency for different reaction times at 35 °C

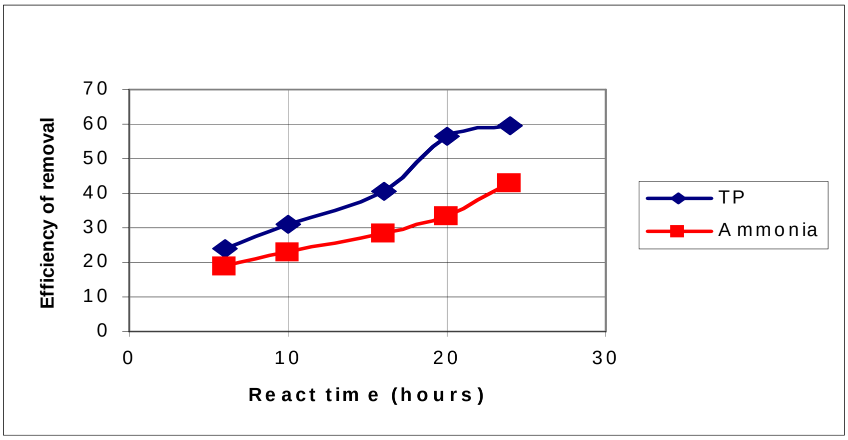

Figure 8. Ammonia and TP removal efficiency for different reaction times at 15 °C

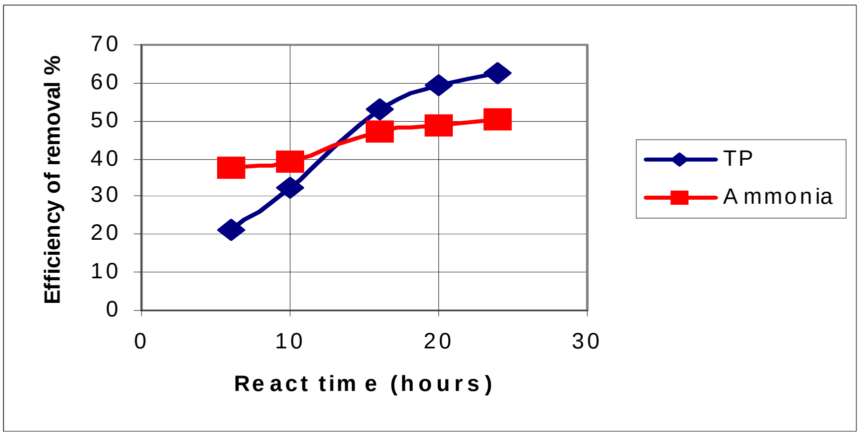

Figure 9. Ammonia and TP removal efficiency for different reaction times at 35 °C

3.2. Microbial Load in Activated EM

A total bacterial count was performed for the activated EM used in the system. The total bacterial and fungal counts in the activated EM, as shown in Table 1, indicate that there was a microbial load. This strongly indicates that biological treatment was the main reason for the removal of the different parameters.

Table 1. Total bacterial and fungal count at 22 °C and 37 °C

Parameter	At 22 ° C	At 37 ° C
Total bacterial count (CFU/ml)	2×10^3	1.5×10^3
Total fungal count (CFU/100ml)	1.2×10^3	

3.3. Effect of Using Activated EM on Total Coliform and Salmonella

Total coliform and salmonella were measured in the influent and effluent wastewater after a reaction time of 24 h at a temperature of 35 °C. The results for total coliform and salmonella are shown in Table 2. From these results, it is evident that a reduction of 98.6% occurred for total coliform and that salmonella was not detected in the effluent. This leads to the conclusion that use of EM can result in partial disinfection of wastewater.

Table 2. Total coliform and salmonella in influent and effluent wastewater

Parameter	Influent	Effluent
Total coliform (CFU/100ml)	1.1×10^5	1.5×10^3
Salmonella (CFU/ml)	1×10^2	Not detected

3.4. Methane-Forming Bacteria and Sulfate-Reducing Bacteria

Methane-forming bacteria inside the reactor were investigated by taking samples from the reactor after a reaction time of 24 h at 35 °C. SRB were also determined in the influent and effluent wastewater after the treatment process at a reaction time of 24 h and a temperature of 35 °C. The result obtained for the methane-forming bacteria was 1.2×10^3 CFU/100 ml, which proves the ability of the system to form biogas. The results in Table 3 show a reduction of SRB in the effluent, which indicates a reduction in hydrogen sulfide. Hydrogen sulfide is a toxic waste product of SRB, and its rotten egg odor is often a marker for the presence of sulfate-reducing bacteria (Gerardi, 2009; Pepper and Gerba, 2004).

Table 3. SRB in influent and effluent wastewater (reaction time of 24 h at 35 ° C)

Parameter	Influent	Effluent
SRB (CFU/100ml)	1.8×10^3	2.1×10^2

4. Conclusions

The conclusions obtained on treatment of primary settled wastewater using activated EM in ASBR are as follows;

1) In the preparation of activated EM, the EM dose that achieved the best treatment efficiency was 10 ml/l.
2) The chemical, physical, and biological parameters obtained after the treatment of primary settled wastewater, at a reaction time of 24 h and temperature of 35 °C, showed that the use of EM technology in such treatments is successful.
3) The treatment process at a reaction time of 24 h and at a temperature of 35 ° C showed significant reduction in total coliform and salmonella; therefore, it can be concluded that EM can cause partial disinfection of wastewater.
4) The use of activated EM with the primary settled wastewater in the treatment process resulted in significant reduction in bad odors by decreasing the levels of ammonia and hydrogen sulfide.
5) The system used in the treatment process can produce biogas. However, the amount of biogas that can be produced requires further research.

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