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Advanced (Ozone) and Conventional (Biological) Techniques for the Disinfection of UASB Treated Effluent

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Abstract: Anaerobic treatment did not eliminate the enteric pathogens (total coliform, fecal coliform, fecal streptococci, *Salmonella* and *E. coli*) in effluent and requires post treatment. In this study, an attempt was made to treat Upflow Anaerobic Sludge Blanket (UASB) reactor treated effluent by ozone (O_3) and conventional polishing processes (oxidation ponds, diffused aeration and sunlight). Ozonation at the rate of 300 mg h^{-1} resulted in optimal pathogen removal of 99% at 30 min ozonation time. The same removal efficiency was achieved at the ozonation time of 20 min when 2 ft effluent head was maintained, by reducing the diameter of reactor column, due to enhanced liquid-gas contact. As far as the conventional techniques were concerned, three parallel lab scale oxidation ponds were developed. Spectacular algal growth was achieved due to the presence of nitrogen and phosphorous in the treated effluent. Dissolved Oxygen (DO) content of water was increased to the saturation level due to photosynthesis. At retention time of 2 days, more than 99% removal of pathogens was achieved. Other conventional methods sunlight irradiation and diffused aeration failed to give any significant results.

Key words: UASB treated effluent, pathogens, disinfection, ozonation, sunlight, oxidation ponds

INTRODUCTION

Traditionally, the indicator bacteria (total coliform, fecal coliform, *E. coli*, *Salmonella* and fecal *Streptococcus*) have been considered the principal parameter for evaluating the microbiological quality of treated water. These pathogens can cause diseases like cholera, cryptosporidiosis, diarrhea, giardiasis and typhoid fever. Every year around 4 million people die from water borne diseases. Only typhoid fever causes approximately 1.7 million of deaths worldwide (WHO, 1996).

Anaerobic treatment technology is now overwhelmingly used to treat the wastewater (Annachhatre and Amatya, 2000). However, this technique has not been proved effective to disinfect the effluent due to short retention time for treatment. Combined with a proper post-treatment, anaerobic treatment provides a sustainable and appropriate method for providing a good quality effluent. It is being used successfully in tropical countries and there are some encouraging results from subtropical and temperate regions (El-Gohary and Nasr, 1999). The post treatment options include conventional as well as advanced oxidation processes (AOPs) like ozonation. The concept behind AOPs is the exposure to strong oxidizing agents like free hydroxyl radicals (Glaze *et al*., 1987).

The goal of ozone use in aquaculture is disinfection, removal of dissolved organic and inorganic waste, enhanced nitrification and control of suspended solids. Ozone effectively destroys bacteria, viruses, fungi, algae and protozoa by disrupting cell membrane function. It enters the cell and destroys the nuclear chemistry of the cell (Liltved and Landfald, 1995; Summerfelt and Hochheimer, 1997). Owsley (1991) reported that O_3 treatment of infectious bacteria in water was effective as a disinfectant at dose of 0.2 mg L^{-1} at retention time of 10 min.

When organisms are exposed to sunlight, the photosensitizers react with oxygen molecules to produce highly reactive oxygen species, resulting in breakage of DNA strands of microorganisms. For bacteria, the process is reversible as the bacteria may again become viable if conditions allow cells to be repaired. Whereas, viruses are unable to repair DNA damage and are therefore sensitive to optical inactivation (Wegelin *et al*., 1994; McGuigan *et al*., 1999; Kehoe *et al*., 2001). Conroy *et al*. (1996) exposed water samples to full sunlight and confirmed that sunlight had bactericidal effect on turbid water, with reductions in the initial

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bacterial count of over 10^3 CFU mL^{-1}. The disinfection was attributed to pasteurization effects rather than ultraviolet light.

Pathogen removal in oxidation pond systems is ascribed to a number of natural decay processes including: (a) DNA damage caused by the UV component of solar radiation (Curtis *et al*., 1992a); (b) photo-oxidation (Curtis *et al*., 1992b); (c) bactericidal effects of algal growth (Parhad and Rao, 1974) and (d) starvation due to lack of nutrients or carbon source. These processes are highly dependent on environmental factors such as, pH, DO, temperature, solar radiation, algal biomass and nutrient concentrations (Frijns and Lexmond, 1991). According to Alaerts *et al*. (1990) temperature and retention times are more determining factors.

The present study was aimed to monitor the effectiveness of ozone and conventional post treatment options for disinfection. Efforts were made to optimize the doses and retention time of ozone and conventional processes for the their maximum removal efficiency.

MATERIALS AND METHODS

Bubble column reactor: The ozonation was carried out in bubble column type reactors of varied dimensions (Fig. 1). The internal diameters of the reactors were 3 and 5 cm, respectively. A JQ-6M PURETECH model ozone generator was used. The ozone produced by using simple air was bubbled into the reactor by means of a diffuser at a rate of 300 mg h^{-1} to disinfect the sample of UASB treated effluent. The retention time (ozonation time) was varied from 10 to 35 min. Ozone treated effluent was sampled at regular time intervals for the determination of the pathogens.

Conventional treatment set up: Algal based polishing set-up was consisted of three parallel lab scale oxidation ponds of dimension 30×30 cm (Fig. 2). Marvelous growth of two types of algal species *Ulthrox* and *Microspora* was observed (Fig. 3). The system was operated at an ambient temperature during the month of December. A lab scale diffused aeration reactor of total volume 13.5 L with an aeration chamber of 9 L and a clarifier portion of 4.5 L was used to disinfect treated effluent (Fig. 4). Air was sparged through effluent using an assembly of six diffusers holding them 1.5 cm above the bottom of the reactor. A schematic of conventional oxidation processes is shown in Fig. 5.

In algal ponds, retention time varied from 1 to 5 days for disinfection of effluent. While for aeration process, DO was varied from 5 to 8 mg L^{-1} at an ambient temperature (18°C). Diffused aeration experiments were carried out in continuous mode for a retention time of 6 h.

Analytical methods: Wastewater was characterized for the microbiological parameters such as total coliform, fecal coliform, fecal streptococci, *Salmonella* and *E. coli* of influent and effluent in accordance with Standard Methods for the Examination of Water and Wastewater (APHA, 1998).

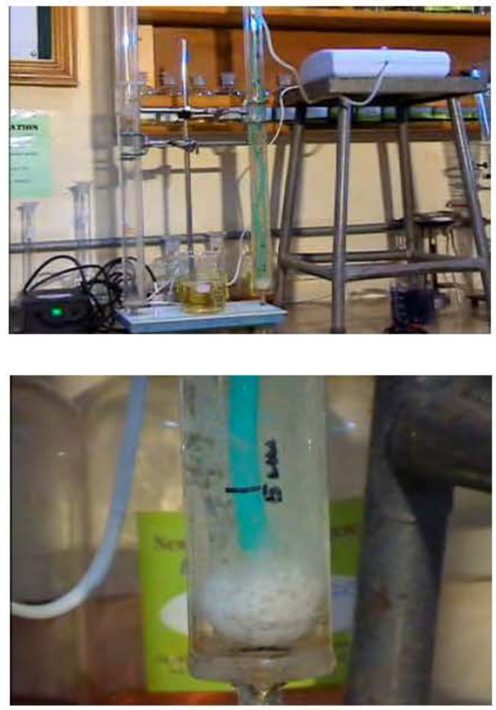

Fig. 1: Lab scale bubble column reactors of varied dimensions

Fig. 2: Laboratory scale algal ponds

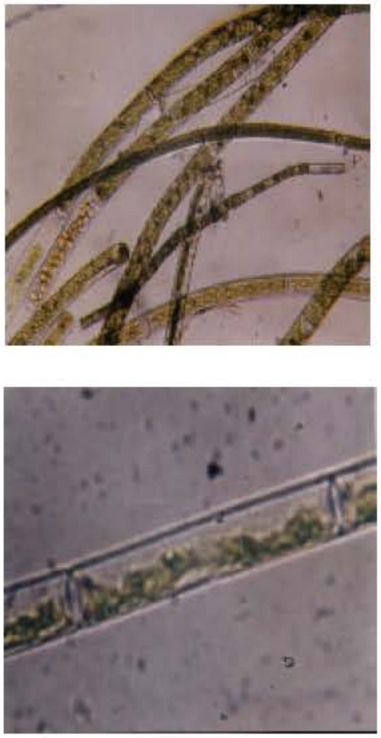

Fig. 3: Microscopic snaps of the algal species

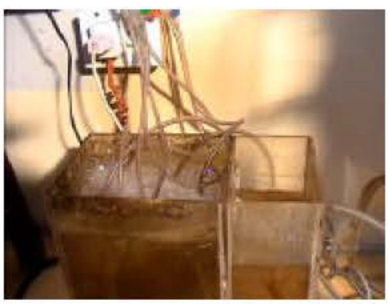

Fig. 4: Photograph of aeration assembly

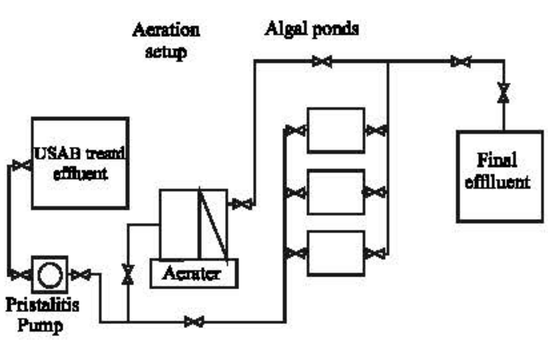

Fig. 5: Schematic of conventional post treatment set up

RESULTS AND DISCUSSION

Ozone was found to be effective in reducing the population of several groups of bacteria (Fig. 6). Ozone killed microorganisms by disrupting the nuclear chemistry of the microorganism's cell (Liltved and Landfald, 1995; Summerfelt and Hochheimer, 1997). Population of pathogens (fecal coliform, *Salmonella*, fecal *Streptococcus* and *E. coli*) was reduced by more than 99% at 30 min ozonation, when water column height was 1 foot. The same removal efficiency was achieved at the bubbling time of 20 min (Fig. 6b) by doubling the water column height (A decrease in the diameter of the reactor doubled the water column height). An increase in column height enhanced the bubble-gas contact time resulting in better mass transfer. Since the concentration of ozone generated either from air or pure oxygen is very low, the mass transfer efficiency is of extreme importance for optimal performance of ozonation process (Metcalf and Eddy, 2003).

The results of the conventional treatment methods are depicted in Fig. 7-9. Figure 7 shows the removal efficiencies of the algal ponds. At retention time of 2 days, more than 99% removal of pathogens was achieved.

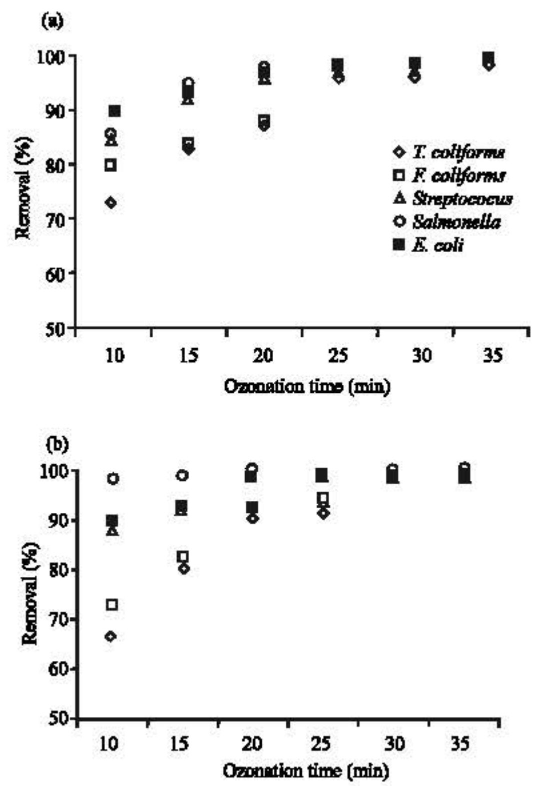

Fig. 6: Effect of various water column heights (a) 1 ft, (b) 2 ft on ozonation for pathogens removal

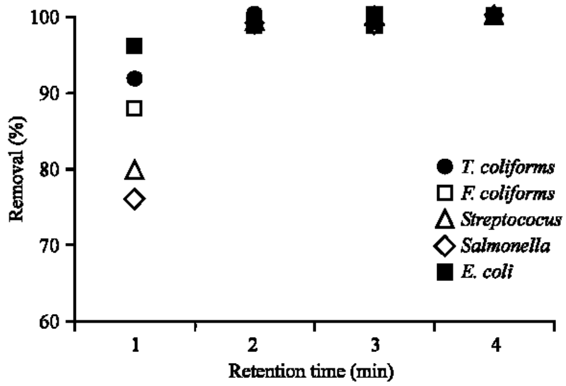

Fig. 7: Pathogen removal (%) by algae at different retention times

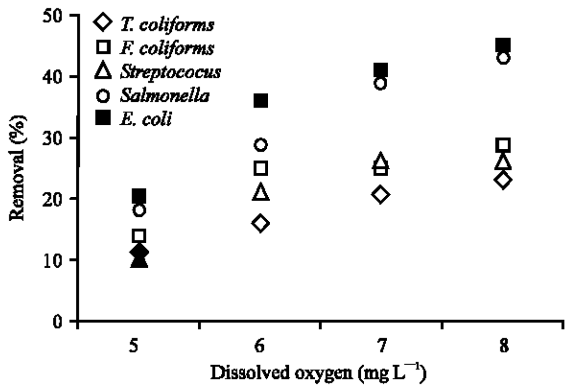

Fig. 8: Pathogen removal (%) by varied Dissolved Oxygen (DO) concentration at 18°C

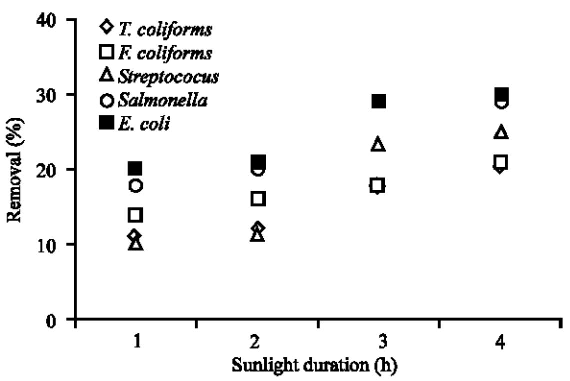

Fig. 9: Pathogen removal (%) by sunlight

However, complete disinfection was achieved at retention time of 4 days. Many workers (Khan and Ahmad, 1992; Mezrioui and Baleux, 1994) also reported the removal of total and fecal coliforms and fecal *Streptococci* up to 99.9% in algal ponds with a retention time of 5 days under subtropical conditions. The lower retention time achieved in the present study is may be due to the pretreatment of wastewater by UASB reactor, which enhanced algal growth due to the presence of nitrogen and phosphorous. Higher disinfection efficiency of algal ponds could be explained due to high dissolved oxygen because of algal photosynthesis, release of toxins by algae, increased light penetration and antibacterial substances produced by algal cells (Bian and Li, 1992).

Other conventional methods, sunlight and diffused aeration, were not appeared to be effective treatment techniques (Fig. 8 and 9). The removal efficiencies were about 45 and 33%, respectively.

CONCLUSION

The following conclusions can be drawn from this study:

- Disinfection by ozone yielded high rate of elimination of all pathogens aimed in this study. Mass transfer of ozone appeared to be the governing factor for the optimization of ozone dose. Thirty three percent reduction in the ozonation time and dose was achieved by doubling the reactor column height for the same volume of the sample.
- Amongst conventional methods, treatment through algal ponds emerged to be the most suitable, cheapest and sustainable option for the disinfection of UASB treated effluent as it eliminated 99.9% of pathogens with a retention time of only two days. Without any addition of nutrient or consumption of electricity.

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