Asian Journal of Water, Environment and Pollution, Vol. 3, No. 2, pp. 101-105.

Research Note

Low Frequencies Ultrasonic Treatment of Sludge

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Received May 28, 2005; revised and accepted February 1, 2006

Abstract: In the present investigation, ultrasonic (US) irradiation treatment technology has been adopted. The mechanism of action (cavitation and sonochemical reaction) of ultrasonic radiation is such that it acts as a potential tool for enhanced biodegradation and sonodegradation of waste and also recovery of resources from treated waste. In ultrasonic waste treatment technology the frequency of US and treatment time is a significant factor in determining optimal reaction conditions. The optimum frequency is substrate specific and low frequency is suitable for sewage sludge treatment. So we opted low frequency (35 kHz and 130 kHz) ultrasonic treatment over varying intervals of time to find out the possibilities to change the quality of sludge by ultrasonic irradiation. Primary sludge characterization parameters i.e. pH, conductivity, chemical oxygen demand (COD), total solid content, total nitrogen and total phosphorus were measured. Ultrasonic pre-treatment was carried out for 5, 10, 20 and 30 min. each (t_1-t_4). Under following treatment, temperature rise, increase in the amount of soluble chemical oxygen demand (SCOD), total nitrogen and phosphorus were analyzed. Both control and treated samples (t_1-t_4) were analysed side by side. Very little change in total nitrogen was observed but significant decline level of phosphorus in samples were seen with increase of time of treatment. These data may provide useful information in the way to solve water and soil pollution by ultrasonic treatment.

Key words: Sludge, ultrasonic pre-treatment, nitrogen and phosphorus.

Introduction

Wastewater sludge are conditioned with polymers to enhance the efficiency of dewatering with presses and centrifuges, but the relationship between fluid dynamics and the polymer/sludge interaction has been shown to be critical in mixing and conditioning performance (Gronroos et al., 2005; Mokrini et al., 1997). It is becoming a growing problem worldwide with its focus on the megacities. In its untreated or sub-treated form, disposal of sludge is undesirable for several reasons. First, the biological decomposition of the organic materials in sludge consumes oxygen and thus reduces the quantity available in the receiving waters for the aquatic life. The decomposition also produces large quantities of malodorous gases. Secondly, the numerous pathogenic microorganisms in untreated sludge are health hazards to human being. Third, its toxic compounds, especially heavy metals, poly aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) being recalcitrant can be dangerous to biota (Jorgensen et al., 1999; Donnelly et al., 1989) and finally the presence of phosphates and nitrogen may lead to eutrophication (Inca et al., 2001). In the case of treatment of sewage sludge having high organic contents, anaerobic digestion is the most preferred technique for stabilization resulting in the reduction of sludge volatile solid and production of biogas. Conventional anaerobic degradation is not efficient because it has rate limiting very first step 'hydrolysis' besides acetogenesis and methanogesis. Due to this, overall process becomes slow. Therefore, to break the rate-limiting step 'hydrolysis' and to enhance the anaerobic degradation process, pre-treatment of sludge by ultrasound, chemical or/and a thermal treatment is a

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possible solution. The pretreatment of waste activated sludge by ultrasonic disintegration has been undertaken in order to improve the anaerobic sludge stabilization. Early report states that, the impact of different ultrasound intensities (41-3217 kHz) and treatment times was examined and it was observed that ultrasonic sludge disintegration is most effective at low ultrasound frequencies and hydromechanical shear forces produced by ultrasonic cavitation are predominantly responsible for sludge disintegration (Tiehm et al., 2001). In this present study, the ultrasound frequency within a range from 35 to 130 kHz, the impact of different ultrasound intensities and treatment times were examined. Sludge disintegration was most significant at low frequencies. Low-frequency ultrasound creates large cavitation bubbles which upon collapse initiate powerful jet streams exerting strong shear forces in the liquid. This work aims to investigate new potential uses of ultrasound in sludge treatment for the depletion level of phosphorus. Short sonication times results in sludge floc deagglomeration without the destruction of bacterial cells. Longer sonication brought about the break-up of cell walls, the sludge solids were disintegrated and dissolved organic compounds were released.

Material and Methods

Sludge sample of sewage were collected from Thermal Power Plant, Indraprastha Estate, New Delhi. In order to characterize this sample pH, electric conductivity, total solid content (gm/l), COD (mg/l), total nitrogen and total phosphorus were measured. This was followed by ultrasonic treatment at four different duration of time (5-30 min.) using ELMA multi frequency ultrasonic bath (according to manufacture instruction). The sonication of sludge was performed in borosilicate glass vessel (250 ml). During sonication, sludge sample were stirred and the temperature was maintained at 25 +3 °C by thermostated jackets.

Ultrasonic pre-treatment specifications were taken as under (Hua Inez et al., 1997).

Treatment time (min.)	:	5(t_1), 10(t_2), 20(t_3) and 30(t_4). Sample volume 100 ml.
US Frequency	:	35 kHz and 130 kHz.
US Power	:	250 W.
US Intensity	:	Power supplied per transducer area (50.95 watt per sq. cm)
US Density	:	Power supplied per sample volume (2500 watt per lit)
US Dose	:	Energy supplied per sample volume (j/l)

pH and electric conductivity of sample were measured by electrode based probe (water and soil analysis kit, Electronics India, model 161E), the rise in temperature of sample on ultrasonic treatment was measured by mercury filled thermometer, total nitrogen was measured by Kjeldahl method (Kjeldahl, 1883; Trivedy et al., 1984) (Figure 2) and total phosphorus was measured by stannous chloride method (Figure 3).

Results and Discussion

The results of the present study are based on the induced physiochemical effects due to ultrasonic irradiation of sludge. Low-frequency ultrasound creates large cavitations bubbles which upon collapse initiate powerful jet streams exerting strong shear forces in the liquid. The decreasing sludge disintegration efficiency observed at higher frequencies was attributed to smaller cavitations bubbles which do not allow the initiation of such strong shear forces. This is the decomposition of the flocculent structures within the sludge and/or breaking down of the microorganisms embodied in the sludge. Short sonication times resulted in sludge floc deagglomeration without the destruction of bacteria cells. Longer sonication brought about the break-up of cell walls. It is anticipated that ultrasonic shock waves hits the microbial cell walls. These large bubbles upon implosion give high mechanical effect, which leads to disintegration of microbial cells. Temperature rise in each sample with the increase in treatment of time. Particulate sludge material was broken down into smaller pieces. We also measured the highest degree of disintegration at 35 kHz. The significant increase of the COD was attributed to the breakup of microbial cells leading to the release of intracellular material (Tiehm et al., 2001).

The efficiency of sludge disintegration decreased with increasing frequency (Figure 1). Total Kjeldahl nitrogen (TKN) were realised. TKN concentration was determined in the whole sludge and in the supernatant using the normalised method. This measure represents organic nitrogen and ammonia. Microbial cells were broken due to ultrasound. Intracellular compounds were released into the liquid phase and were made soluble. So ultrasounds led to a nitrogen release. Figure 2 shows nitrogen concentration via different times of ultrasonic (35 kHz and 130 kHz) treatment. On the whole sludge, total nitrogen (TKN) was constant. This means that ultrasound did not lead to a nitrogen mineralisation or volatilisation. For a specific energy increase due to ultrasonic treatment, the quantity of organic nitrogen in particles decrease and organic nitrogen concentration in soluble phase and ammonia concentration increased. Thus organic nitrogen was made soluble. Very little organic nitrogen was transformed into ammonium. Nitrogen is mainly in proteins or amino acids. Proteins were made soluble but were not completely degraded. Activated sludge not containing significant numbers of denitrifying, polyphosphate [poly (P)]-accumulating bacteria was grown in a fill-and-draw system and exposed to alternating anaerobic and aerobic periods. During the aerobic period, poly(P) accumulated up to 100 mg of P of (dry) weight (Van Niel et al., 1998). When portions of the sludge were treated with low frequency ultrasonic waves, the intracellular poly(P) was degraded and released as orthophosphate (Figure 3). Total dissolved solid; Using ultrasound did not change total matter quantity. Total solids concentration (TS) was constant. Thus ultrasound, in terms of energy input, did not induce an evaporation phenomenon. Figure 4 shows total dissolved solid under ultrasonic treatment (35 kHz and 130 kHz). The total mineral solid content and the total organic solids content were almost constant. Thus ultrasound did not induce a mineralisation phenomenon. However, the solid content of soluble (supernatant of centrifugation) and particulate (solids of centrifugation) parts varied with specific supplied energy. Soluble matter concentration increased, whereas particulate matter concentration decreased. Thus, ultrasound led to a solubilisation phenomenon of not only organic solids but also of mineral solids. Solubilisation of mineral matter was very low, In fact, total solid solubilisation (STS) increased with energy input.

Comparative observations were taken at different time intervals at constant temperature (40°C). The concentration of COD, nitrogen and phosphorous was estimated (Figure 4). No significant difference in concentration of COD, N and P was observed. Thus low frequency ultrasonic treatment of sludge is powerful method for pollution degradation. The impact of ultrasound waves on liquid cause the periodical compression and rarefaction of medium. Cavitation occurs above a certain intensity threshold, when gas bubbles are created which first grow in size before

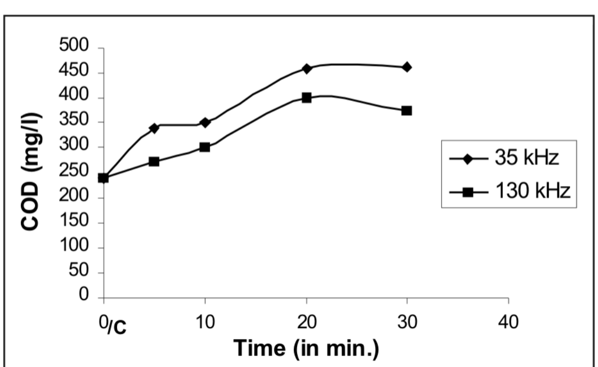

Figure 1: Influence of ultrasonic (35 kHz and 130 kHz) dose on COD (mg/l) of sludge.

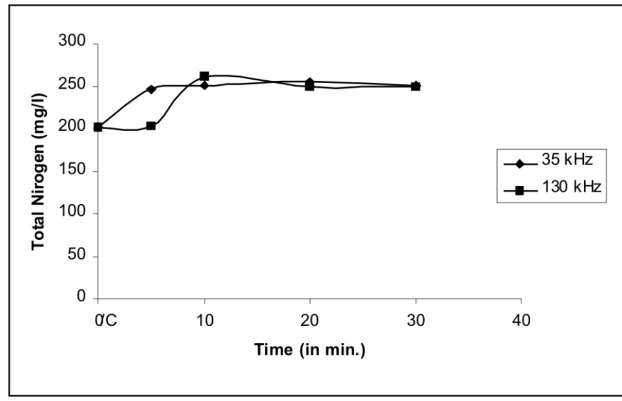

Figure 2: Total nitrogen (mg/l) under influence of ultrasonic treatment (35 kHz and 130 kHz) of sludge.

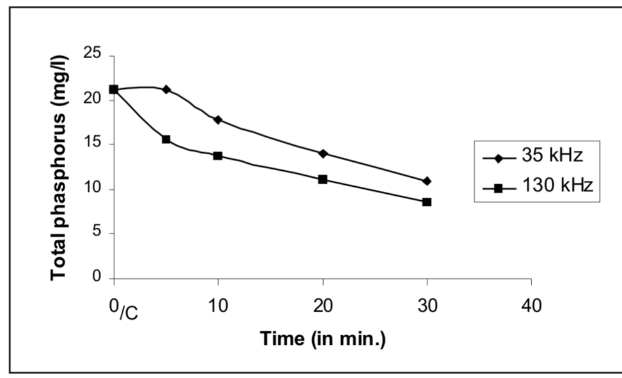

Figure 3: Total phosphorus (mg/l) under influence of ultrasonic treatment (35 kHz and 130 kHz) of sludge.

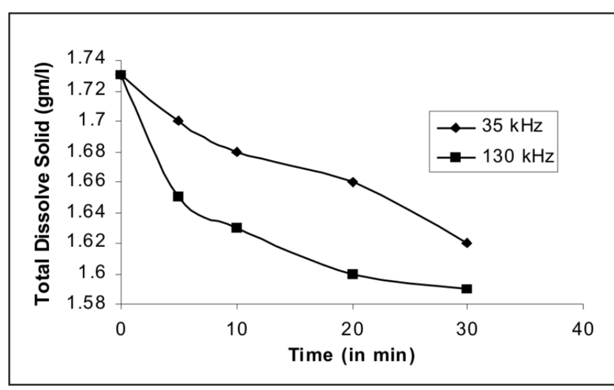

Figure 4: Total dissolved solid under ultrasonic treatment (35 kHz and 130 kHz).

violently collapsing within few microseconds. The violent collapse produces very powerful hydromechanical shear forces in the bulk liquid surrounding the bubble. It has been shown (Harrison, 1991) that macromolecules with molecular mass above 40,000 are disrupted by the hydromechanical shear forces produced by ultrasonic cavitation. The temperature and pressure inside the collapsing cavitation bubbles rise up to about 5000 K and several hundred atmosphere. These extreme condition can lead to the thermal destruction of compound present in the cavitation bubbles and to the generation of very reactive hydroxyl radicals (Mason, 1991; Young, 1989). In this way sonochemical reactions can degrade volatile pollutants by pyrolytic processes inside the cavitation bubbles and non-volatile pollutants by hydroxyl radical reactions in the bulk liquid (Petrier and Francony, 1997; Thiehm, 1999). While sonochemical degradation processes can occur in a broad ultrasound frequency range from 20 kHz up to about 1 MHz the highest efficiency of sonochemical reaction was observed at >100 kHz (Hua and Haffmann, 1997; Petrier and Francony, 1997). Both the hydromechanical shear forces and the sonochemical effects can contribute to the ultrasonic disintegration of sewage sludge.

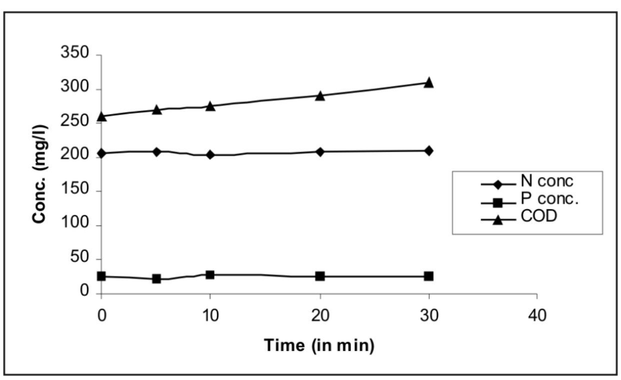

Figure 5: Comparative analysis of temp. (40° C) on the conc. of phosphorus, nitrogen and COD (in mg/l) at different times.

Conclusions

Our experiments are oriented towards waste degradation through an alternative advanced oxidation technology. The wastes under study are of different sludge, which have an adverse environmental impact. Our effort is to modify toxic and bulky sludge into least offensive and environmentally acceptable form. Low frequency ultrasonic pre-treatment (35 kHz, 250 W) of sludge generates mechanical and radical effects due to acoustic cavitation and sonochemical reaction, which destroy the floc structure of sludge and disrupt the cell wall of microorganisms. Microbial cell disruption leads to significant release of soluble organic intracellular compounds into the aqueous phase resulting in increased COD. Cells were broken due to ultrasound. Intracellular compounds were released into the liquid phase and were made soluble. So ultrasounds led to a nitrogen release. Using ultrasound did not change total matter quantity. Total solids concentration (TS) was constant. Total phosphorus increase in aqueous phase in the form of orthophosphate. High temperature and pressure due to cavitation generate highly reactive oxidizing hydroxyl radicals which mediate sonochemical reaction.

Acknowledgement

Funding for this project by University Grants Commission (UGC) is gratefully acknowledged.

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