DISINTEGRATION OF TANNERY SLUDGE BY ACOUSTIC CAVITATION-AN APPROACH FOR SLUDGE MANAGEMENT

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ABSTRACT

The sludge biomass, composed largely of organic matter 60-90%(W/V), is contained within the cell wall membranes of microbial cells. It was found that the pressure pulses produced by an ultrasonic homogeniser significantly influenced the degree of disintegration of the cells containing the waste. The mechanical sludge disintegration was investigated with an ultrasonic homogeniser operated at a frequency of 20 kHz with different energy intensities. The influence of sludge solids content on the disintegration of the sludge also was investigated. It was found that the influence of mechanical disintegration on particle size cannot fully describe the release of organic material into the sludge water. The release of organic material into the sludge water can best be estimated by the chemical oxygen demand (COD) and by protein release. The degree of disintegration, as indicated by COD and protein release, increased significantly when the energy intensity applied with the ultrasonic homogenizer was increased.

INTRODUCTION

The effluent treatment plants in the leather processing industry produce large amounts of sludge after primary and secondary treatments. It is estimated that processing 1000 Kg of skin/hide, around 100 Kg and 60 Kg of the dry solids are released into the primary and the secondary treatments, respectively. The primary sludge resulting from settling after chemical dosing is inorganic and usually of high density. Secondary sludge resulting from microbial degradation consists of primarily organic matter and it occupies a larger volume. The traditional method of sludge management involves taking the biomass of the secondary sludge to solar drying beds where it gets dried and then dumping it in secured landfills. Due to the traditional disposal of the sludge by land filling etc., the problems are increasing with restrictions for the creation of such secured land sites. Alternative methods like biological digestion systems require hydraulic retention times of about 20-30 days resulting in accumulation and in increased volume of the sludge.

A different method of mechanical disintegration of the sludge materials has been thoroughly reviewed.[1] Active research is taking place to use the best technique, which can disintegrate the biomass as well as be energy efficient. It has been considered that the application of an ultrasonic homogeniser has the potential for maximum disintegration and also for large-scale applications. In sludge handling and disposal systems, disintegration of secondary sludge is a critical need. To improve the digestion efficiency, the dewatering characteristics of the sludge, and the amount of sludge that has to be disposed of, an additional disintegration step has to be done to solublize and convert slowly biodegradable compounds into readily degradable compounds.[2,3]

For large scale disintegration, mechanical methods seems to be the most popular to obtain intracellular compounds such as proteins or enzymes.[4,8,9] In the present study, it is aimed to make the organic material of the tannery sludge available for degradation in an anaerobic process. Degradation of tannery sludge in an anaerobic process requires more than 20 days even to achieve a degradation of about 40%.[12] This is because the cell wall interferes with the degradation process.[3] A mechanical device like an ultrasonic homogeniser, which produces high mechanical shear forces, is expected to disintegrate the bacterial cell. When a pressure differences exist across the cell and exceeds the cell wall rupture pressure, the microbial cell will disintegrate.[10] When this occurs, the intracellular organic compounds are released and are made available for further biological degradation. Thus, the quantity of digested sludge gets reduced and the quantity of biogas released is increased.[5,11,13] The use of an ultrasonic homogeniser in the treatment of tannery sludge has not been studied so far. Hence, an attempt has been made to exploit the high shear force and massive pressure fluctua-

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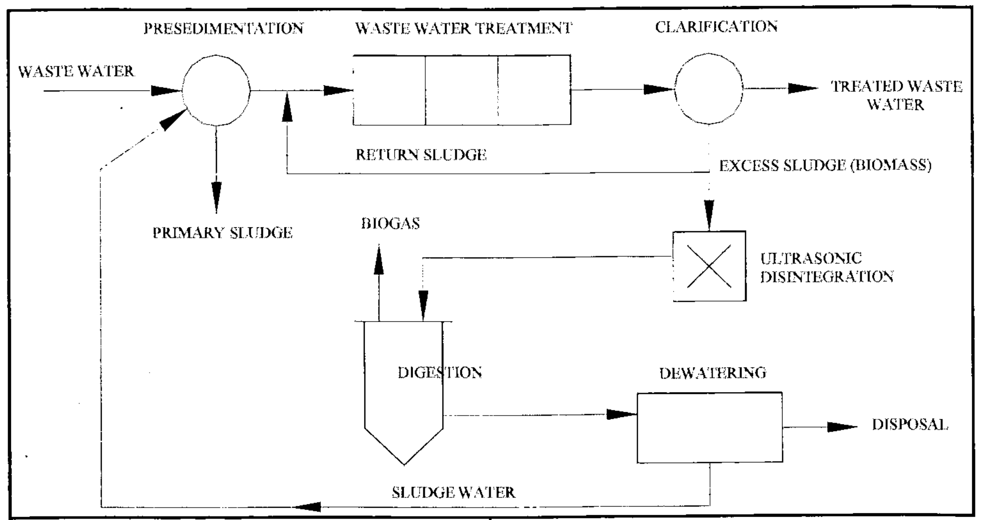

Figure 1. - Flow chart of waste sludge treatment using ultrasonic homogeniser in effluent treatment plant

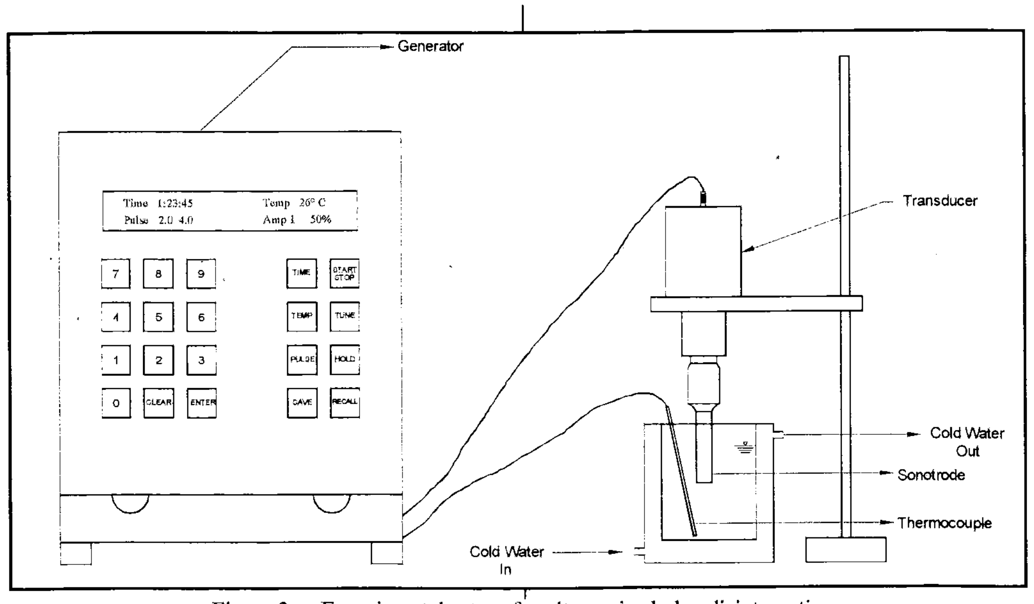

Figure 2. - Experimental set up for ultrasonic sludge disintegration

tions in acoustic cavitation to disintegrate the tannery sludge. The flowchart of the treatment plant and the stage at which the ultrasonic homogeniser was introduced is shown in Figure 1. It is not known whether the microbes survive sonication for further treatment, since there is more than adequate energy to lyse the cell. It may be necessary to recharge the sonicated sludge with microbes for further degradation.

EXPERIMENTAL

Laboratory tests were conducted using waste sludge from a tannery effluent treatment plant. The sludge was collected before the sludge thickening process. In order to remove sand, dust and extra cellular proteins from the sludge it was washed repeatedly with tap water. The washed supernatants were analysed for protein content and it was repeated till no absorbance of UV from the supernatant. The washed sludge is mixed with tap water with different solid contents and taken for studies. The different solid content ranges to 9 g/kg, 15 g/kg and 21 g/kg total solids (TS). These sludges were disintegrated by an ultrasonic homogeniser (Sonics vibra cell™, USA) with 2 operational parameters. One with different intensities and the other one is duration of comminution. A batch size of 300 ml sludge in a jacketed vessel was disintegrated and the sludge temperature was maintained at 20 ± 1°C to see the disintegration effect due to mechanical stress alone. A typical experimental set up for disintegration is shown in Figure 2.

The degree of disintegration was estimated by protein release and chemical oxygen demand by the reported procedure.[6,7] To determine the protein release, the disintegrated sludge was filtered with Whatman filter paper number 1 and

analyzed for protein content using Shimadzu UV visible spectrophotometer at 640 nm. The chemical oxygen demand describes the release of organic substance by mechanical disintegration. The total chemical oxygen demand (COD_{alk}) is usually determined by alkaline hydrolysis. Further the degree of disintegration shown by COD increase can be calculated[3] using the equation 1.

$$DD_{COD} = \frac{COD_t - COD_{ut}}{COD_{alk} - COD_{ut}} \quad (1)$$

The energy input for the disintegration process to achieve a certain degree of disintegration is given by the specific energy. This can be determined by equation 2.

$$E_{spec} = \frac{P \cdot t}{V \cdot TS} \quad (2)$$

The energy input is determined from the applied power (P) of the ultrasonic homogeniser, the contact time (t). The stressed solid mass can be detected by measuring the volume (V) and the total solid content (TS).

The particle size distribution was determined with a laser scanner (Symptec GmbH, Germany).

RESULTS AND DISCUSSION

Particle size analysis and degree of disintegration (DD_{COD})

Figure 3 shows that an increase in energy input leads to a decrease in particle size. The most rapid particle size reduction takes place at energy levels less than 3000 kJ/kg. With energy input greater than 6000 kj/kg, only small changes in particle size take place. The release of organic substances into the sludge water, as indicated by the COD, increases

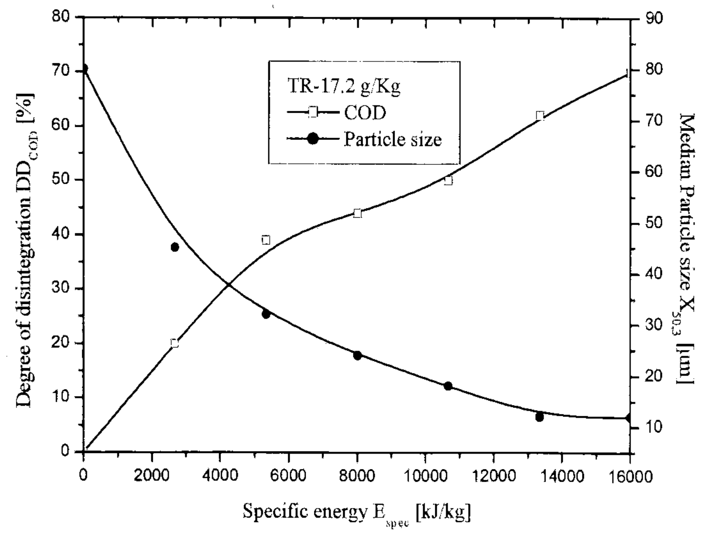

Figure 3. - Median particle size and degree of disintegration for an ultrasonic homogeniser

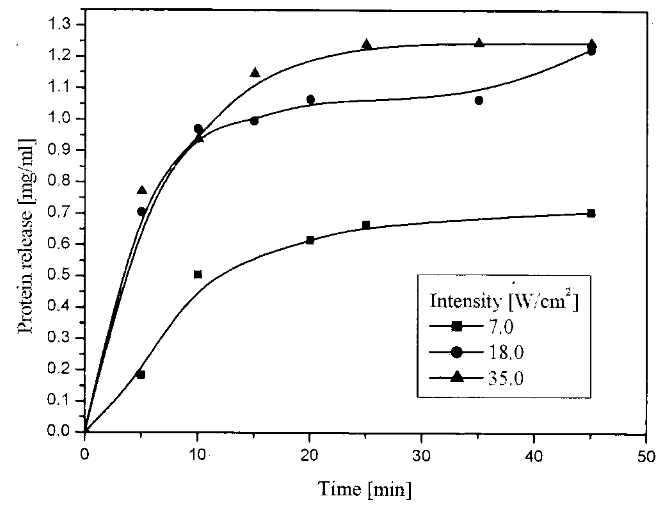

Figure 4. - Kinetics of protein increase with respect to applied intensity

with increasing energy input. The treatment at higher energy has an obvious influence on the reachable level of COD. With a low release of organic material, there will not be significant improvement in anaerobic digestion.[12] So for improved anaerobic digestion, a high degree of disintegration is needed.

Influence of energy intensity on the kinetics of protein release

Energy intensity is one of the major factors influencing protein release. This can be determined from the relationship between the power of the homogeniser and the surface area of the sonotrode. In Figure 4, the protein release with respect to time shows a maximum protein release of 0.7 mg/ml after 45 minutes at a low ultrasound intensity of 7 W/cm². At higher intensity of 35 W/cm², a maximum of 1.2 mg/ml of protein is released after 25 minutes. This suggests that when the ultrasound intensity is high and the cavitation

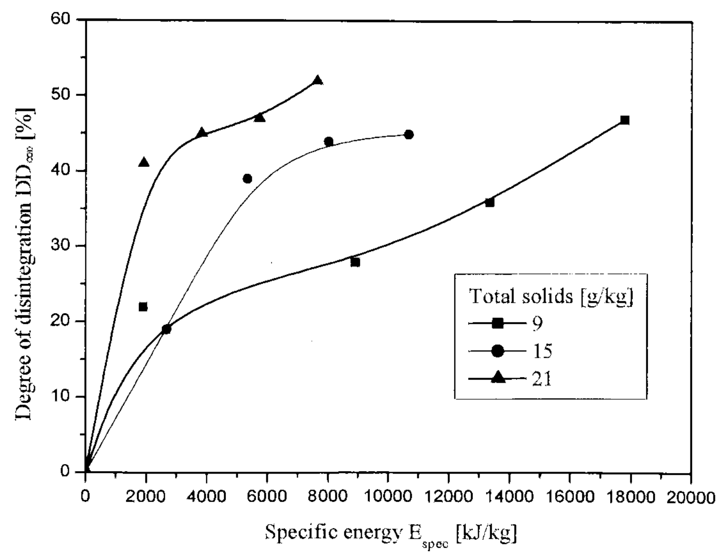

Figure 5. - Energy demand for disintegration of different solid content sludge

bbles are higher, the microbial cell rupture is greater.

fluence of solids concentration and energy consumpon in sludge disintegration

lid concentration is one of the important factors of disingration. In Figure 5 sludge with higher solids shows maxum release of COD at lower energy level. This means that e probability of the cell getting exposed to cavitating bubes is more even at lower energy level.

Conclusions

he disintegration with ultrasonic homogeniser is possible r tannery sludge to enhance the degradation of an anaeroc process in tannery effluent treatment plant. To determine e degree of disintegration, COD and protein release were alysed. From this study it was noticed that increasing the lid content facilitates faster disintegration even at lesser ergy input. Further studies for the treatment of the soniated sludge are under way in our laboratory. It is not known hether the microbes would survive sonication since there more than adequate energy to lyse the cell. It may be ecessary to recharge the sonicated sludge with microbes r further degradation.

Acknowledgement

he authors wish to thank Dr. T. Ramasami, Director, entral Leather Research Institute, Adyar, Chennai for his terest in this work.

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