THE INTENSIFICATION OF SEWAGE SLUDGE ANAEROBIC DIGESTION BY PARTIAL DISINTEGRATION OF SURPLUS ACTIVATED SLUDGE AND FOAM.

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ABSTRACT
Large quantities of sludge are produced in biological wastewater treatment. Sludge has a high putrescibility and therefore has to be stabilizsed in order to enable an environmentally safe utilization or disposal.
The anaerobic digestion is the standard technique to stabilize the sludge. Digestion produces biogas and reduces the amount of organic matter. The amount of excess sludge production from wastewater treatment plants is continuously increasing. Therefore, minimization of excess sludge is becoming more and more important.
The aim of bacterial cell disintegration is the release of the cell contents as an aqueous extract. Mechanical disintegration can activate the biological hydrolysis process and therefore, significantly increase the stabilization rate of the secondary sludge. It has been shown that when subjecting the sludge to 30 min of mechanical disintegration, the COD concentration in the supernatant increased from 61 mg/l to more than 144 mg/l in activated sludge and from 68 to more than 688 mg/l in foam.
This study presents an application of mechanical disintegration on sewage sludge (mainly surplus activated sludge) and foam to enhance biodegradability and biogas yield in anaerobic digestion.

KEYWORDS
Mechanical disintegration, anaerobic digestion, activated sludge, foam.

INTRODUCTION

With the higher standards of wastewater treatment and sewage sludge utilization the higher requirements for effectiveness of employed processes are also set. Furthermore, the quantity and the characteristics of sewage sludge and particularly the presence of questionable sludge (i.e. floating, bulking activated sludge) cause significant problems connected with costs and conditions of utilization (Wolny and Kamizela, 2003).

The growing quantities of sludge generated in urban areas require innovative treatment processes that are capable of achieving significant cuts in mass and volume. Technologies that combine efficient sludge mass and volume reductions with the production of reusable sludge products at competitive costs represent the most desirable solutions.

Wastewater treatment processes based on low sludge loading rates and with both anaerobic, anoxic and aerobic zones, give sludge with low energy content and often poor sedimentation characteristics. Through sludge disintegration the flocs structure of the sludge is changed, bacteria cells are opened and the cell content is released. The dissolved components are readily degradable in a digestion process. In addition the dewaterability is increased.

Anaerobic digestion is the most often applied process for stabilization of sewage sludge at medium and large wastewater treatment plants. Mass reduction, methane production, and improved dewatering properties of the fermented sludge are important features of anaerobic digestion (Tiehm et al., 1997). A part of the biomass can be decomposed into liquid and finally becomes methane and carbon dioxide (Yin et al., 2004).

The anaerobic stabilization is a slow process. Therefore, long residence times in the fermenters and large fermenter volumes are required. Anaerobic degradation of particulate material and macromolecules is considered to follow a sequence of four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. In the case of sewage sludge digestion, the biological hydrolysis has been identified as the rate limiting step. Therefore, the pretreatment of sewage sludge by mechanical disintegration can improve the subsequent anaerobic digestion. However, there is a lack of information as to how different degrees of sludge disintegration impact on the digestion process (Yoon et al., 2004; Tiehm et al., 2001).

On account of carbon removal in the form of methane and carbon dioxide, the end product shows a substantially better biological stability than the unfermented material. Therefore, land-fill disposal and limited agricultural use as a fertilizer are possible. A disadvantage of the fermentation technique is the slow degradation rate of sewage sludge (Tiehm et al., 1997). Conventional residence times in anaerobic digesters are about 20 days, requiring large fermenters. Sludge hydrolysis is the rate limiting step of anaerobic digestion. The degree of degradation of organic matter varies between 25% and 60 % (Grönroos et al., 2005).

The anaerobic digestion of disintegrated biosolids enables advanced sludge stabilization due to the enhanced reduction of organic matter. Moreover, the residual sludge quantity can be slashed by another 30-40% (total sludge reduction up to 60%). The rate-limiting step in the anaerobic digestion process is the initial hydrolysis phase. When sludge disintegration is employed, this reaction is accelerated. Hence, the sludge retention time in the anaerobic digestion reactor can be cut from the standard 15-20 days to below 15 days. As a consequence, the digester volume can be reduced, which leads to savings in investment and operating costs. The operating costs are influenced through; (a) lower demand on reactor heating, and (b) the oxidation and conversion of refractory COD (of complex organic structures) to BOD (biodegradable low-molecular compounds, e.g. formic acid or acidic acid), providing higher biogas yields and hence increased power generation from biogas. Finally, due to the destruction of filamentous flocs (responsible for water retention in the sludge) during disintegration, the dewatering properties of the residual sludge are improved

Basically, the disintegration process is accomplished by the application of physical or chemical methods to break down cell walls. Thus, cell walls are fragmented and intracellular compounds are released. The product can be utilized both as a substrate in aerobic and anaerobic biological processes. Several disintegration processes are developed: <u>mechanical</u>: ultrasound, homogenizer, stirred ball mills; <u>thermal</u>: thermal hydrolysis (autoclave or steam heating), wet oxidation; <u>chemical</u>: use of enzymes, alkaline/acid hydrolysis; <u>biological</u>: thermophilic aerobe/ anaerobe pretreatment.

The anaerobic digestion rate and the biodegradability of sludge solids can be improved by sludge treatment resulting in solids solubilization. Positive effects were shown for thermal pretreatment (Tanaka et al., 1997, Stuckey & McCarty, 1984; Li & Noike, 1992), addition of enzymes (Thomas et al., 1993; Knapp & Howell, 1978), ozonation (Weemaes et al., 2000; Yasui & Shibata, 1994), chemical solubilization by acidification (Gaudy et al., 1971; Woodard & Wukasch, 1994) or alkaline hydrolysis (Mukherjee & Levine, 1992), and mechanical sludge disintegration (Müller et al., 1998; Kopp et al., 1997). The inclusion of disintegration technology into the sludge treatment process leads to reduced sludge quantities and markedly improved sludge quality.

EXPERIMENTAL METHODS

For the carried out experiments the material used (surplus activated sludge and foam) was taken from a municipal sewage treatment plant working as enhanced biological nutrient removal plant. Activated sludge samples as well as foam samples were taken from different sectors of the biological process units.

Mechanical disintegration was executed with a high pressure pump (100 bar), which recirculated sludge, from a 25 litre container, through a 1.2 mm nozzle. To force 25 litre of sludge through the nozzle 3 minutes were required. Disintegration was carried out for 15, 30 and 60 minutes. The achieved recirculation rate was 5, 10 and 20.

Samples of disintegrated sludge or foam in admixture with surplus activated sludge taken direct from the full scale treatment plant have been digested in 2.5 liters glass bottles at constant temperature of 30 ^{o}C. The disintegrated activated sludge constituted 20 % in volume, and foam 20 and 40 % in volume. During 14 days of digestion the amount of produced biogas was daily monitored.

Chemical and microscopic analyses were performed for samples before sludge or foam disintegration and also at the end of anaerobic digestion. All chemical and physical parameters were determined according to the procedures given in Standard Methods for Examination of Water and Wastewater (19^{th} ed.). For colorimetric determinations a spectrophotometer HACH DR 4000 was applied. Concentration of potassium and magnesium were determined on an atomic absorption analysis instrument - AAnalyst 100 Perkin Elmer.

RESULTS AND DISCUSSION

Mechanical disintegration of raw activated sludge resulted in transfer of organic substances from the sludge solids into the aqueous (liquid) phase, and was demonstrated by an increase of COD (Fig. 1). Already after 15 minutes of activated sludge mechanical disintegration an increase of COD of 83 mg O_2/l was measured (from 61 to 144 mg O_2/l). It is therefore a more than a double increase of COD. With an increase of the time of disintegration a further increase of COD occurs.

In consequence of bacterial cells destruction in the process of disintegration not only organic matter was released but also phosphates, stored in the cells as poly-P. The "shoot out" poly-P stored in the form of volutine are later hydrolyzed and appear in the liquid as phosphates. The increase of phosphates concentration in the liquid after desintegration of activated sludge or foam was shown in Fig. 2. In the case of activated sludge an increase from 9 to 63 m PO_4/l , and in the case of foam an increase from 25 to 419 mg PO_4/l was measured.

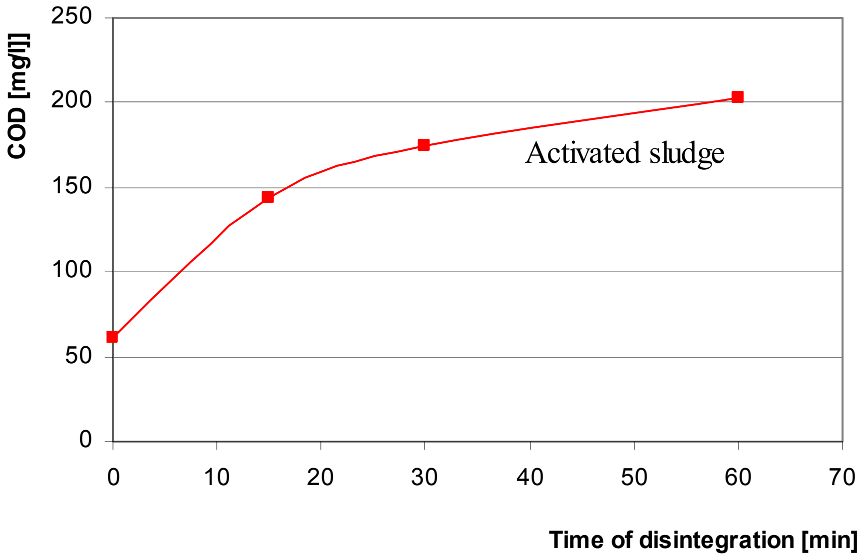

Fig. 1. The influence of the time of activated sludge disintegration on COD release.

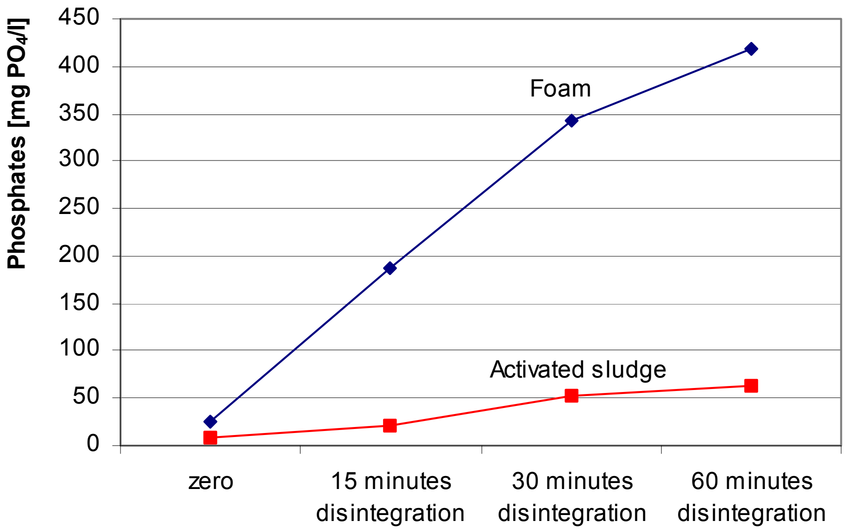

Fig. 2. Changes of phosphates concentration in the liquid after activated sludge or foam disintegration.

As a consequence of bacteria structure fragmentation the enzyme cytosoles are released affecting hydrolytic decomposition of polypeptides, resulting further ions release. In addition the very high pressure applied (100 bars) and prolonged time of disintegration causes destruction of peptides bonds.

Additional application of ultrasound disintegration resulted in further destruction of cell walls and increased release of organic matter and phosphates. The effects of COD and phosphates release due to ultrasound foam disintegration was presented in Fig. 3. The phosphates concentration increased of 162 mg PO_4/l in comparison to the sample mechanically disintegrated for 30 minutes. If compared to 60 minutes of mechanical disintegration (fig. 2), an additional increase of 76,5 mg PO_4/l was measured.

The results of addition of 20 % in volume of disintegrated sludge on the effects of sludge anaerobic digestion was shown in Fig. 4. An about twice increase in gas production was observed. After 14 days of anaerobic conditions the amount of produced gas was 283 ml, while in the sample with added disintegrated sludge (20 %) the amount of produced gas was 514 ml.

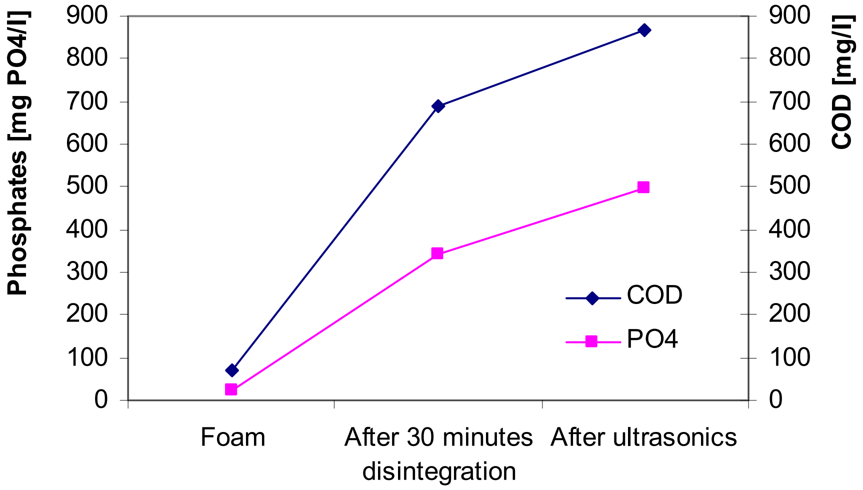

Fig. 3. The effect of additional ultrasound foam disintegration on release of phosphates and COD.

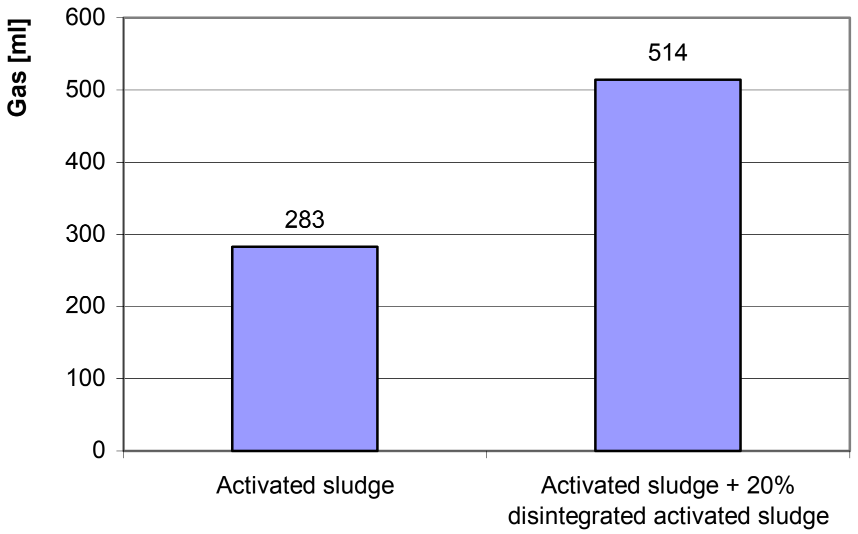

Fig. 4. Gas production after 14 days of anaerobic digestion.

Addition of 20 % in volume of disintegrated foam to an activated sludge sample subject to anaerobic digestion, the gas production in 14 days was 1616 ml. This is about six times as much as obtained if only activated sludge was digested. Comparing the gas production of samples with the addition of 20 % of disintegrated sludge and 20 % of disintegrated foam there was a three times higher gas production. Increase in the amount of added disintegrated foam to the sludge sample resulted in a biogas production of 2020 ml. The results are shown in Fig. 5.

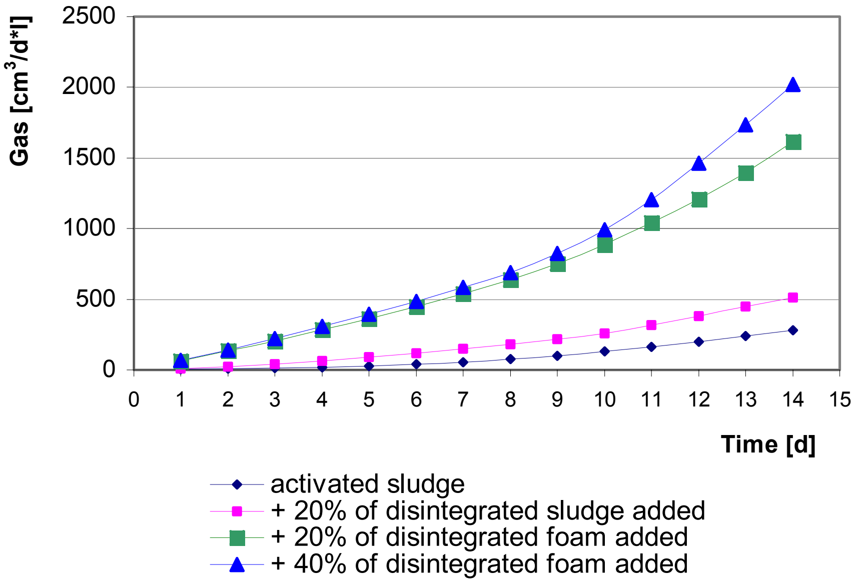

Fig. 5. Gas production after 14 days digestion of samples of activated sludge with and without addition of a part of disintegrated activated sludge or foam

The measure increase of produced gas by a factor of three is comparable to the COD increase (from 174 to 688 mg O_2/l) after 30 minutes of activated sludge or foam disintegration

CONCLUSIONS

Our experiments have clearly demonstrated that mechanical and/or ultrasound activated sludge disintegration could positively affect sludge anaerobic digestion. Due to sludge disintegration, organic compounds were transferred from the sludge solids into the aqueous phase resulting in an enhanced biodegradability. Therefore disintegration of sewage sludge is a promising method to enhance anaerobic digestion rates and lead to reduce the volume of sludge digesters. The addition of disintegrated surplus activated sludge and/or foam to the process of sludge anaerobic digestion can lead to markedly better effects of sludge handling at wastewater treatment plants. In the case of disintegrated activated sludge and/or foam addition to the process of anaerobic digestion it is possible to achieve an even twice a higher production of biogas.

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