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Reduction of sewage sludge production by combining anaerobic hydrolysis with high pressure homogenization or electrochemical oxidation

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Abstract

Disposal of excess sludge from wastewater treatment plants (WWTPs) is a problem that is becoming more important in last decades: production is rising in all over the world and in the European Union production forecasted for 2010 is about 10 millions of tons.
Traditional disposal of technologies, such as landfill disposal, see disposal and reuse in agriculture were recently limited in the European Union because they are potentially pollutant or dangerous. Rising disposal of techniques, like thermal ones, have high economical and ecological costs, so techniques for reduction of sludge production are very interesting.

Innovative technique for reduction of sludge production can be mainly divided in three categories:

- Physic and thermal techniques (ultrasonication, mechanical treatments, thermal hydrolysis, …)
- Chemical and chemical-physical techniques (oxidation with ozone and other strong oxidants, acid or caustic treatments, …)
- Biological techniques (auto-thermal digestion, enzymes or metabolic uncouplers addition, anaerobic hydrolysis, bacterial predation …).

Even if many of these techniques are studied in literature and some of them (for example ozonation and ultrasonication) are applied in some real scale WWTPs, there are few studies on combination of this technique with biological treatments, in particular way with the ones suitable for little and medium size WWTP.

The main issue of this research activity is to study two chemical-physical techniques not very investigated and applied: mechanical homogenization and electrochemical oxidation.

Mechanical homogenization was studied in literature, but not in combination with biological techniques; electrochemical oxidation with static electric fields is not studied for sludge reduction. Another issue is to study their possible combination with anaerobic hydrolysis, a biological technique derived from OSA technique (Oxidation, Settling, Anaerobic digestion).

Mechanical homogenization is a technique that consists in pressurizing the sludge, even to more than 1000 bars, and forcing it to pass throw an orifice or a valve, where speed increase suddenly, pressure decrease under the vapour pressure and cavitation happens. Important action mechanism includes solid reduction throw hydrolysis of the EPS and oxidation of part of the organic matter. Another important effect of homogenization is the reduction of floc size: after an 80 bar treatment average dimension passes from hundreds of micron to tens. The pressure effect is significant, but not very strong, but increase significantly cellular lysis. The comparison with ultrasonication has shown that action mechanisms are very similar, but the energy needed to obtain the same result is higher for ultrasonication.
Two different range of pressure were tested: at low pressure (3-7 bars) was tested an orifice plate configuration, while ad high pressure (100-1500 bars) was tested a homogenization valve. In both configurations optimal conditions were found: 5 treatments with 7 bars and a plate with a single 2 mm orifice and sludge with 1.5% of solid concentration for low pressure configuration, a single treatment with 600 bars and solids concentration near 3% for high pressure one.

Best results were obtained with high pressure homogenization: COD solubilization was about 10% and TSS reduction about 20%. Low pressure homogenization has shown a direct solid reduction of 5-10%, combined with a simpler management and a more suitability for little WWTPs.
Low pressure homogenization was studied in combination with an aerobic digestion line: TSS reduction was 29-38%, while in the blank line was 19%. High pressure homogenization was successfully tested with aerobic digestion (41% of TSS reduction, blank line had 19%) and with anaerobic digestion: with an SRT of 6.5 days TSS removal was 60% (for blank line was 27%).

Electrochemical oxidation consists in exposing sludge to a low energy electric field for a long time (hours). The most important phenomena that act in sludge reducing are the electrochemical reactions that act both at the electrodes and in the polar sites of flocs (secondary electrodes). For this reason the microstructure of the sludge is simplified, as shown microscopy analysis. Nevertheless there is a partial oxidation of the organic matter and reduction of nitrite. Direct TSS reduction in optimal conditions of about 25%.
Very important were resulted materials of the electrodes: stainless steel can't be used because pitting corrosion increase solid content in treated sludge; best choice is platinum treated titanium. Optimal conditions were higher sludge concentration (even around 3% in solids) and a specific energy of about 5 kWh/m^3. Less important seems to be experiment duration and distance between the electrodes. During some batch tests of combination of electrochemical oxidation with anaerobic hydrolysis, the effects were comparable with high pressure homogenization ones.

Anaerobic hydrolysis is a biological technique that consists in expose the sludge to strong anaerobic condition in absence of substrate. Even many action mechanisms were found: cellular lyses and enzymatic hydrolysis of extra cellular compounds seem to be the most important ones; ionic release in the mixed liquor seems to remark the role of hydrolysis.

In order to better study the effectiveness of combination of anaerobic hydrolysis and other selected techniques, a three lines bench scale WWTP was built. After the transient period, long about 30 days, most of the solid matter was concentrated in the sludge treatment line; nitrogen, phosphate and soluble COD production was high and stable and sludge reduction strong, as reported in the following table.

Table: Effectiveness in sludge removal (mineralization of COD and solubilization of TSS and VSS) during the last 40 days in the bench scale WWTP test. In brackets there is the difference of production from blank line.

	ank line %	**High pressure homogenization %**	**lectrochemical oxidation %**
:OD	54	65 (-26)	66 (-33)
TSS	68	73 (-23)	76 (-34)
VSS	72	74(-19)	78(-31)

The most important operative problem was the difficulty to keep low the nitrate concentration in the anaerobic tank, but this problem depend on the lack of a denitrification stage in the water treatment line: in a larger scale plant this problem can be easily solved.

Both electrochemical oxidation and mechanical homogenization are suitable to apply in a real scale WWTP: positive synergies with traditional and innovative biological treatment were evidenced. Some of the most important phenomena that happen during treatments were supposed and verified, in order to have a future modelling.