EXCESS ACTIVATED SLUDGE QUANTITY MINIMIZATION.

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INTRODUCTION

The activated sludge is the most widely used biological waste water treatment process. Independently of the activated sludge process applied, there is always a certain amount of excess sludge produced. Even at very low organic sludge load there is a yield coefficient of about 0.4. For conventional activated sludge with a load of about 0.5 g BOD/g.d, the yield coefficient can be as high as 0.8. Advanced biological nutrients removal process, most often are supported with chemical precipitation of phosphorous, and thus in spite of very low sludge organic loads, the excess sludge amount can be substantial.

Treatment and disposal of excess sludge from waste water treatment plants is costly, while simple land fill or direct agriculture application methods can no longer be used. Therefore sludge minimization is at present of paramount importance. An overview of possible to be applied methods of sludge minimization was given by Wei at al. (2003).

Different strategies are currently developed for sludge amount reduction, like; disintegration of bacteria cells, chemical uncoupling mechanism or predation of bacteria. Disintegration or lysis of bacteria cells will release cell contents into the medium, thus providing an autochthonous substrate that contribute to organic loading of the activated sludge. This autochthonous organic substrate is reused in microbial metabolism, and a portion of carbon is liberated as products of respiration. A portion however, is used for growth denominated as cryptic growth (Mason et al., 1986).

Lysis of cells is performed by different methods; e.g. hydrodynamic disintegration, thermal, freezing, oxidation, or using acids or alkali. Among the various methods on the basis of lysis-cryptic growth sludge ozonation for reducing sludge production has been successfully applied in practice.

Chemical uncoupling mechanism occur if respiratory control did not exist and instead the biosynthetic process is rate limiting. Therefore, excess free energy would be directed away from anabolism so that the production of biomass can be reduced. Chemical uncouplers, such as 2,4-dinitrophenol (dNP), para-nitrophenol (pNP), pentachlorophenol (PCP) and 3,3',4',5-tetrachlorosalicylanilide (TCS) as mentioned by Wei et al. (2003), have recently found attention. In the present publication, preliminary results of the use of para-nitrophenol (pNP), and meta-chlorophenol have been presented.

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Sludge disintegration sometimes is understood as activated sludge flocs dispersion. Really sludge dispersion can lead to minimization sludge yield. This however, is most often a pseudo-yield minimization. Dispersion results in loosing of the floc structure and releasing free bacteria, which are spilled over the weirs of the secondary settling tank. Also, filamentous micro-organisms cause the settling properties to deteriorate. Such conditions can be the result of the presence of sulfide (Nielsen and Keiding, 1998) or toxic substances.

Oxidation with ozone (Yasui i Shibata, 1994) or chlorine is an another possibility for sludge yield minimization. Ozonation is a costly method and can lead to higher COD values in the effluent. Although chlorinating is much less costly, and a reduction of 65 % sludge production can be achieved (Saby et al., 2002) it results in sludge poor settleability, sludge dispersion and worsening the results of treatment.

Another approach to minimize the sludge yield was presented by Saby et al., (2003). Introduction of an anoxic tank on the sludge recirculation stream, in which an oxidation reduction potential is lowered to a level of -250 mV resulted in a sludge reduction efficiency up to 58 %. That extremely simple solution was however, not satisfactorily explained. The explanation given is that under a low ORP or anoxic conditions, sludge decay is accelerated effectively, which facilitates the sludge disintegration and solubilization so that sludge yield is reduced. That aforementioned explanation was repeated in the follow up paper of Chen et al., (2003).

In order to explain the effects of sludge disintegration and dispersion some results of hydrodynamic sludge disintegration and dispersion observed at an industrial wastewater treatment plant are also given.

METHODOLOGY AND MATERIALS

The process of chemical activated sludge disintegration was investigated in laboratory batch reactors. Activated sludge was taken from an existing municipal wastewater treatment plant, but synthetic sewage was used as the substrate. The synthetic sewage of a COD value in the range between 490 - 540 mg O_2/l, was added at a rate allowing for a 24 hour HRT. Two different loads have been investigated. The different organic loads of 0.1 and 0.035 g/g.d were obtained as a result of different mixed liquor suspended solids concentration, namely 2.58 and 7.42 g/l. For practical reasons in the two series of experiments the 10 liters reactors have had an effective volume of 5.6 and 7.3 liters.

In each series three reactors were supplied in parallel, one with synthetic sewage only, second with the addition of para-nitrophenol, and the third one with the addition of meta-cholrophenol. The used concentration of para-nitrophenol was between 10 and 100 mg/l, and that of meta-cholrophenol 20 mg/l.

Daily measurements of COD, pH, temperature, ORP and dissolved oxygen have been done. The concentration of activated sludge was measured only at the beginning and at the end of the experiments (one week).

All determinations have been done according to the Standard Methods (1992).

For activated sludge disintegration a special designed cavitaion nozzle, working under a pressure of 12 bars, was used.

RESULTS AND DISCUSSION

Addition of 20 mg/l of meta-chorophenol in the first week of investigations has allowed for a 92 % reduction of sludge production. (Fig. 1). Measured COD of the treated sewage have not shown any deterioration of the effects of substrate removal. (Fig. 2).

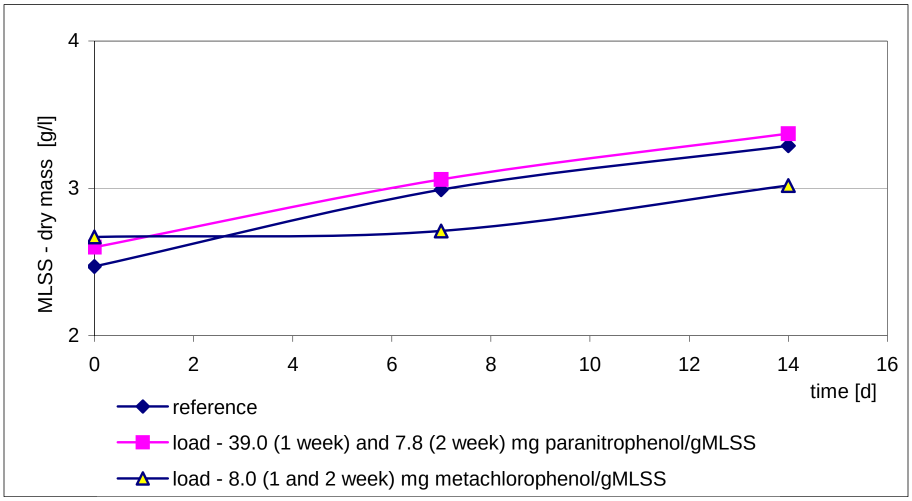

Fig. 1. Effects of the addition of para-nitrophenol or meta-chlorophenol on the activated sludge dry mass concentration.

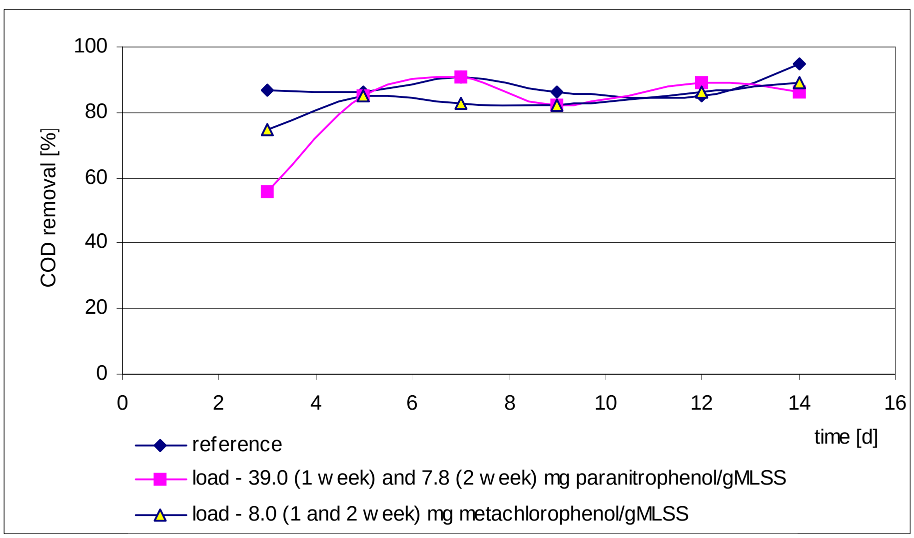

Fig. 2. The effects of para-nitrophenol or meta-chlorophenol addition on COD removal. (Series I).

Lowering the dose of meta-chlorophenol in relation to the sludge concentration also the effects of sludge production reduction were lower. Due to the higher concentration of MLSS in the second series of experiments, form 2.58. to 7.42 g/l, the effective load of meta-chorophenol was respectively 8.0 and 2.7 g $_{\text{meta-chlorophenol}}$/g.MLSS. With the lower load of meta-chlorphenol in the second series the sludge production decrease was only 65 %.

The effects of COD removal have been somewhat lower for the samples with added metachlorophenol. (Fig. 3). However, the results of COD removal for paranitrophenol added have been higher in comparison to the blank run.

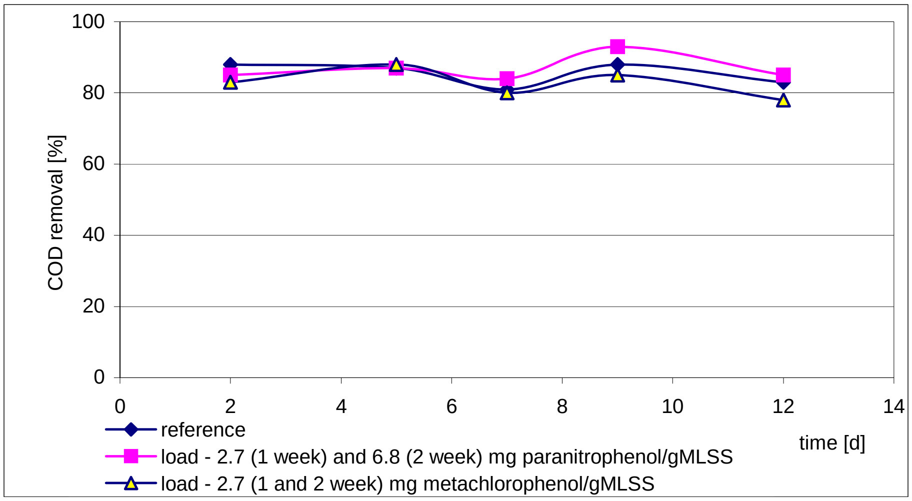

Fig. 3. The effects of para-nitrophenol or meta-chlorophenol addition on COD removal. (Series II).

Para-nitrophenol was less effective in sludge production reduction. With a very high concentration in the feed - the synthetic sewage of 100 mg/l, the effects have been only about 12 % . (Fig. 1). It could be stated that the effects of sludge production reduction have been negligible. In addition, in contrary to meta-chlorophenol, para-nitrophenol affected negatively the effects of substrate removal. Also the treated sewage has become yellow and the activated sludge has darkened. For this reason the dose of para-nitrophenol was lowered distinctively to 10 mg/l, in the second week of the first series of experiments, resulting in a load of 7.8 $g_{\text{para-nitrophenol}}$/g MLSS. With the higher concentration of activated sludge in the second series, and the concentration in the feed of 20 mg/l, but the load was even lower and rated 2.7 $g_{\text{para-nitrophenol}}$/g MLSS.

In the second series the effects of added para-nitrophenole on sludge production reduction were (as expected) even lower.

Addition of the investigated chemicals for activated sludge production reduction has also affected the treated sludge quality in terms of turbidity and presence in effluent of dispersed microorganisms. A microscopic photo of the activated sludge effluent from the reference (blank) experiment and that with added para-nitrophenol (20 mg/l) is shown below.

Partial disintegration of activated sludge as a result of chemicals addition (Fig. 4.) can also mean a pseudo excess sludge reduction due to discharge of a part of solids with treated waste water to the recipient.

(a) Microscopic picture of the activated sludge effluent without chemicals

(b) Microscopic picture of the activated sludge effluent with added para-nitrophenol

Fig. 4. Visualized effluent quality from the (a) reference activated sludge process (without any added chemicals) and (b) from the experiments with para-nitrophenol addition.

The presence of some chemicals in industrial effluents, can also cause activated sludge floc dispersion, like in the case of phenolic waste water treatment (Fig. 5). The excess sludge produced in many cases of industrial waste water treatment can therefore be extremely low.

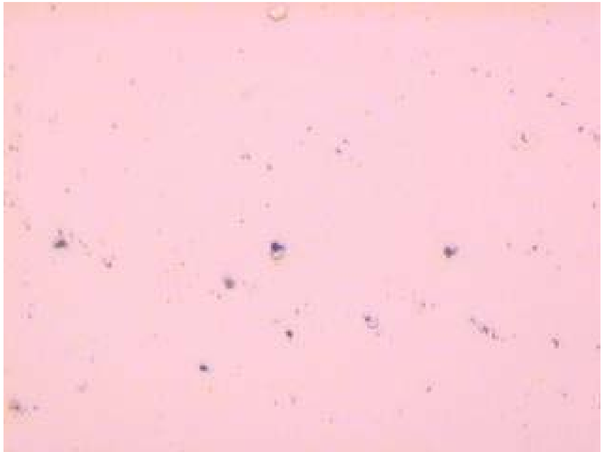

Fig. 5. Dispersed microorganisms and mineral particles in the effluent from a biological phenolic wastewater treatment process.

Recently attention is given to mechanical or sonically disintegration for activated sludge production minimization. The effects of disintegration of activated sludge on sludge production minimization however, are limited mainly due to the effects of cryptic-growth. In specific cases, especially with very high concentration of the biomass the effects of disintegration can be distinct. A side effect is the dispersion and disruption of bacteria overflowing the weirs of the secondary settling tanks. Below a picture of disintegrated activated sludge is given to show the potential of pseudo-sludge production minimization. (Fig. 6).

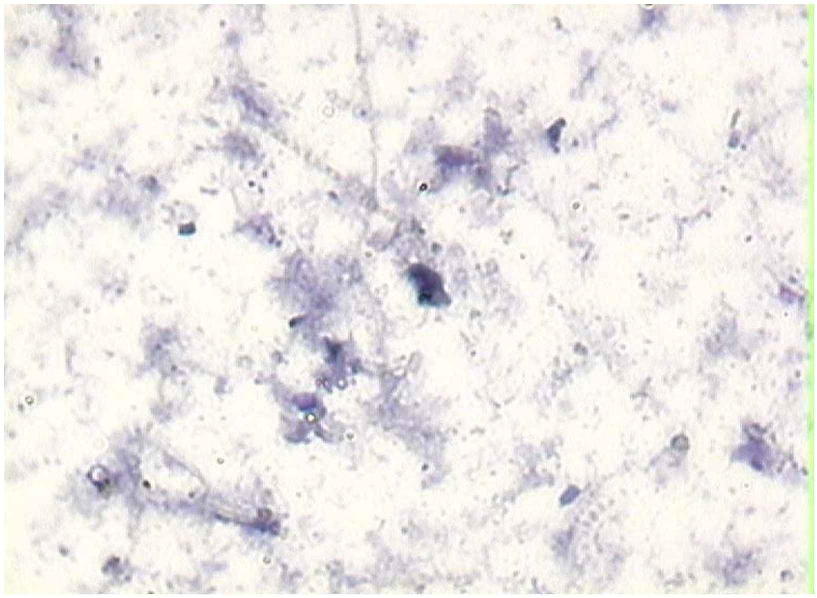

Fig. 6. Disintegrated hydro-mechanically activated sludge.

Activated sludge disintegration has however, multiple other positive effects on the overall wastewater treatment process including sludge handling. In combination with anaerobic sludge digestion there is a definitely positive effect on the sludge amount and quality as well as on biogas production. (Suschka et al. 2006).

The effects on sludge amount reduction in the process of anaerobic digestion as an effect of partial sludge disintegration are limited to a difference of about 5 -8 % in comparison to a reference sample. Disruption of bacteria cells results in a liquor COD increase of above 30 %, what means a higher load of organic substrate to be added to the digester. This results in a substantial increase of produced biogas. In our experiments the addition of 20 % in volume of disintegrated activated sludge to the digester has given a gas production in volume and yield in comparison to removed organic matter in the order of 48 % (Fig. 6 and 7).

Disintegration of activated sludge in combination with anaerobic sludge digestion is also advantageous in terms of filamentous micro-organisms eradication.

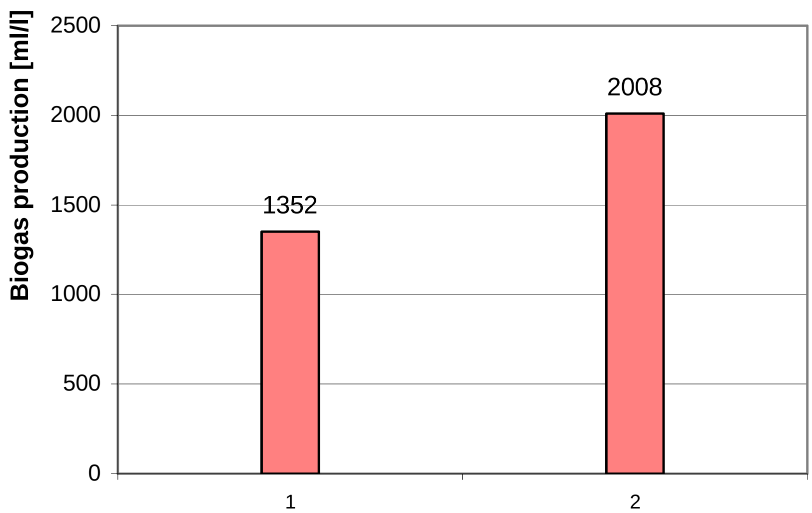

Fig. 6. Effects of anaerobic digestion for 17 days of (1) activated sludge (blank) and (2) with addition of 20 % disintegrated sludge.

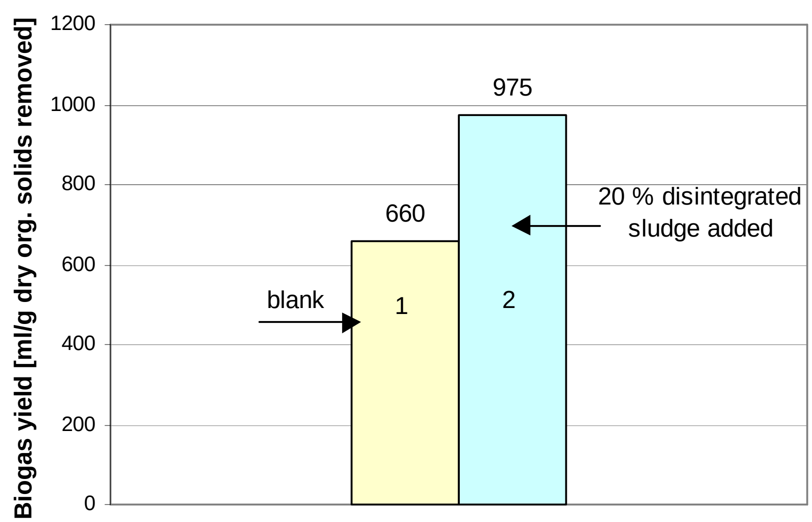

Fig. 7. Biogas yield increase by 48 % , as an effect of disintegrated activated sludge addition.

CONCLUSIONS

Reduction of excess activated sludge production is imperative for wastewater treatment costs minimization. It is often repeated the costs of sludge handling are amounting about 60 % of the total cost. In the present work attention was given to the possibilities of addition of chemical uncouplers.

As shown the effects on sludge minimization can be distinct. There are also some side effects like treated wastewater quality deterioration. The long-term effects of chemicals addition is at present an open question, and much more experiments are required.

In the present work attention was also raised on sludge dispersion and achieved pseudo sludge production reduction. Dispersion can be the result of added purposely chemicals or due the presence of some chemical in industrial wastewater.

The most promising approach to sludge production minimization seems sludge disintegration independently on the technique applied. Apart from distinct sludge production minimization possible to be achieved, the accompanying effects on e.g. sludge digestion make the sludge disintegration process a very promising technology.

REFERENCES

APHA, (1992) Standard Methods for Water and Wastewater Examinantion, 17th ed. Amer. Public Health Assoc, Washington D.C. ...

Chen G-H., An K-J., Brois E and Djafer M., (2003), Possible cause of excess sludge reduction in an oxic-settling-anaerobic activated sludge process (OSA process). 37, 16, 3855-3866

Mason ..C.A., Hamer G. and Bryers J.D., (1986), The death and lysis of microorganism in environmental processes. FEMS Microbiol. Rev. 39, 373-401...

Nielsen P.H. a. Keiding K., (1998), Disintegration of activated sludge in presence of sulfide. Wat. Res. 32, 2, 313-320

Saby S., Djafer M. a. Chen G-H., (2002), Feasibility of using a chlorination step to reduce excess sludge in activated sludge process. Wat Res. 36, 3, 656-666

Saby S., Djafer M. a. Chen G-H., (2003), Effect of low ORP in anoxic sludge zone on excess sludge production in oxic-settling-anoxic activated sludge process. Wat. Res. 37, 1, 11-20

Suschka J., Grubel K and Machnicka A., (2006) Możliwość intensyfikacji procesu fermentacji beztlenowej osadów ściekowych poprzez dezintegrację osadu czynnego w procesie kawitacji mechanicznej. Gaz, Woda i Technika sanitarna (in press)

Yasui i H. and Shibata M., (1994), An innovative approach to reduce excess sludge production in the activated sludge process. Wat Sci Tech. 30, 9, 11-20

Wei Y., Van Houten R., Borger A., Eikelboom D., Fan Y. (2003) Minimization of Excess sludge production for biological wastewater treatment, Wat. Res., 37, 4453-4467.