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SURPLUS ACTIVATED SLUDGE DISINTEGRATION FOR ADDITIONAL NUTRIENTS REMOVAL

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DEZINTEGRACJA OSADU CZYNNEGO NADMIERNEGO W CELU WZMOŻONEGO USUWANIA SUBSTANCJI POŻYWKOWYCH

Systemy osadu czynnego projektowane z myślą poprawy usuwania związków pożywkowych oparte są na zasadzie wzrostu, w beztlenowych i tlenowych warunkach, mikroorganizmów posiadających wysokie zdolności akumulacji fosforu. Aby uniknąć powrotu dużych ilości zakumulowanego fosforu w procesach kondycjonowania osadów stosowana często jest chemiczna precypitacja. To jednak nie musi przebiegać w ten sposób, ponieważ co najmniej dla części osadu, przed innymi procesami stabilizacji osadów, można przeprowadzić proces jego dezintegracji. Przedstawiona dezintegracja osadu nadmiernego przyczyniała się do usunięcia pokaźnej części związków pożywkowych w formie struwitu. Efektem dezintegracji osadu było uwolnienie jonów metali i destrukcja mikroorganizmów poli-P. Przeprowadzony proces dezintegracji osadu pozwolił na usunięcie przynajmniej 25% fosforu wpływającego z ładunkiem ścieków, bez dodawania związków chemicznych.

Summary

Activated sludge systems designed for enhanced nutrients removal are based on the principle of altering anaerobic and aerobic conditions for growth of microorganisms with a high capacity of phosphorous accumulation. To avoid return of large parts of accumulated phosphorous in the processes of sludge conditioning chemical precipitation is often applied. This can be not be the case, at least for a part, if prior to other processes of sludge handling, the sludge will be disintegrated. It was demonstrated that disintegration of surplus activated sludge permits removal of a substantial part of nutrients in the form of struvite. The effects of sludge disintegration on metals ions release and poly-P destruction were elucidated. Appropriated handling of disintegrated sludge allows for removal of at least 25% of the inflowing phosphorous load without addition of chemicals.

INTRODUCTION

Enhanced biological nutrients removal (EBNR) process from sewage leads to accumulation of most of the phosphorous by specific bacteria. Bacterial biomass in conventional activated sludge systems treating municipal sewage usually contains

2–3% of phosphorous. Designed for nutrients removal activated sludge can accumulate as much as 8% of phosphorous. Usually the microorganisms are exposed to altering anaerobic and aerobic conditions. Finally, phosphorous is removed from the treated sewage with the surplus activated sludge. At large wastewater treatment plants anaerobic sludge digestion is most often applied. The majority of phosphorous is released from the activated sludge flocs in the anaerobic digester. Dewatering of digested sludge results often in return of part of the released phosphates to the main wastewater to be treated.

The aim of this paper is to describe a new concept based on combining surplus sludge disintegration in front of anaerobic digestion, carried out for better sludge digestion, with nutrients removal. Sludge disintegration accelerates phosphorous and metals ions release, and the majority of phosphorous as well as a part of nitrogen can be removed from the system through struvite precipitation.

EXPERIMENTAL METHODS

Activated sludge samples were taken from an EBNR full scale municipal sewage treatment plant. Mechanical disintegration was carried out with a high pressure pump (100 bar), which recirculated sludge, from a 25 dm^3 container, through a 1.2 mm nozzle. To force 25 dm^3 of sludge through the nozzle 3 minutes were required. Disintegration was carried out for 15, 30 and 60 minutes.

Samples of raw and disintegrated surplus activated sludge taken directly from the full scale treatment plant were digested in 2.5 dm^3 glass reactors at constant temperature of 30°C. During 14 days of digestion the amount of phosphates was monitored.

Chemical and microscopic analyses were performed for samples before and after each time of disintegration. All chemical and physical parameters were determined according to the procedures given in Standard Methods for Examination of Water and Wastewater [2].

Concentrations of phosphates were determined in filtrated 0.025 dm^3 samples and spiked with molybdenovanadate reagent (0.001 dm^3). For colorimetric determinations a spectrophotometer HACH DR 4000 was applied.

Dissolved metals were determined in a 0.1 dm^3 sample to which 0.01 dm^3 lanthanum of solution was added before aspirating. Concentrations of potassium, calcium and magnesium were determined with an atomic absorption – AAnalyst 100 Perkin Elmer.

Microscopic investigations were carried out using a microscope of bright field and contrast phase coupled with a camera. The microscope used – Nikon Alphaphot-2 YS2-H coupled with camera Panasonic GP-KR 222 allowed for size measurements by a program Lucia – ScMeas Version 4.51. Samples for microscopic investigations were stained according to the Neisser method.

RESULTS AND DISCUSSION

The activated sludge flocs are agglomerates of bacteria maintained together due to the presence of exopolymers (EPS). These polymers are composed of sugars, amino acids and uronic acids [4]. Adsorptive properties of exopolymers have been well documented especially with respect to biosorption of pollutants. Biosorption studies regarding biological waste water treatment have focused on both the biosorpion of hazardous organic pollutants and DOC onto aerobic and anaerobic biomass [3, 5, 7].

Cloete and Oosthuizen [5] have examined the composition of exopolymers and found that they contained on average between 27% and 30% phosphorous. They suggested that phosphorous removal in activated sludge might be due not only to PAO (Phosphorous Accumulating Organisms), but also by EPS acting as a phosphorous reservoir.

Disintegration of activated sludge flocs means destruction of EPS and bacteria dispersion as well as partial or complete bacteria cells destruction. As a result, release of intracellular organic matter and enzymes present in cells cytosol, as well as destruction of EPS results in increase of dissolved organic matter in the liquid.

The direct effect of release of intracellular and exocellular organic matter can be measured as soluble COD increase.

Already 15 minutes of mechanical activated sludge flocs disintegration resulted in COD increase in the filtrate (filter paper) of 83 mg O_2/dm^3 (from 61 to 144 mg O_2/dm^3) – more than double increase of COD. With and increase of the disintegration time a further increase of COD occurs (Fig. 1).

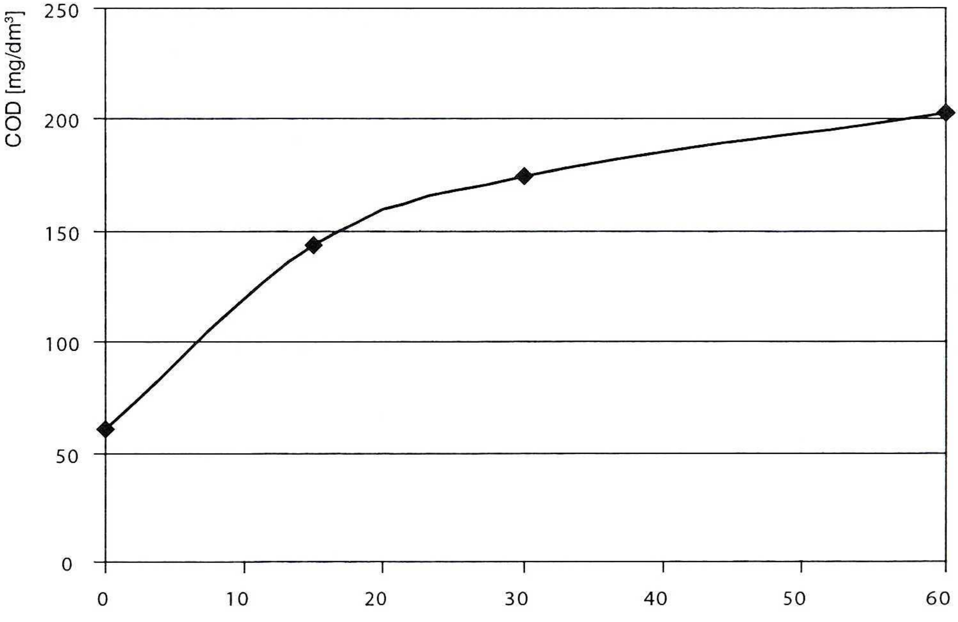

Fig. 1. COD increase due to mechanical disintegration

The disintegration effect with prolonged time was shown on a series of microphotographs (Fig. 2–5).

Fig. 2. Micrograph of raw activated sludge

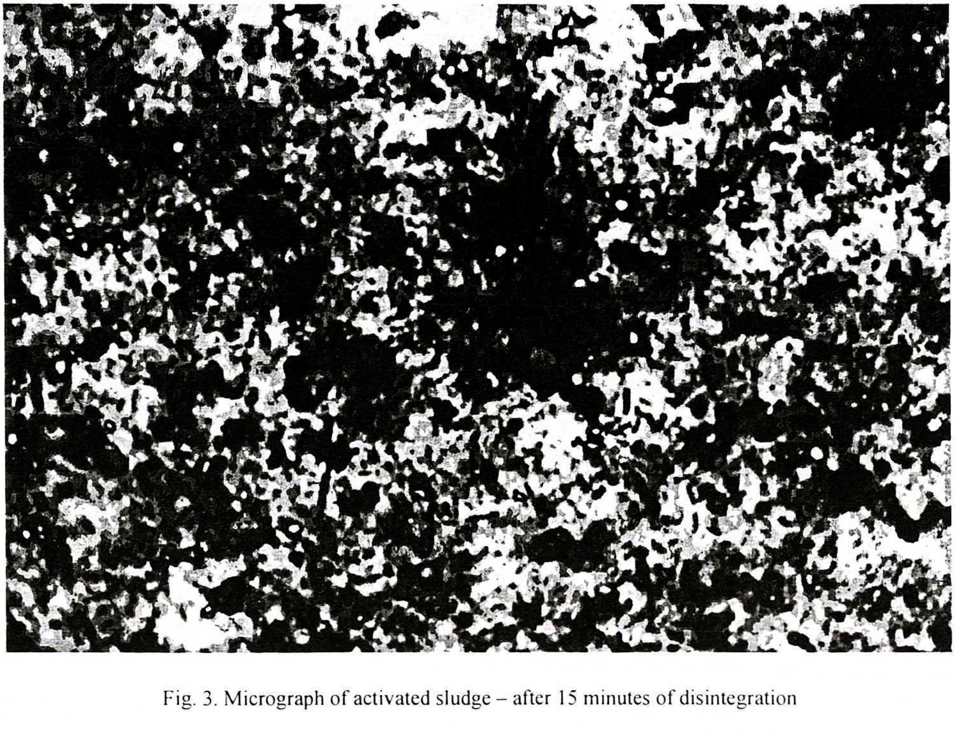

Fig. 3. Micrograph of activated sludge – after 15 minutes of disintegration

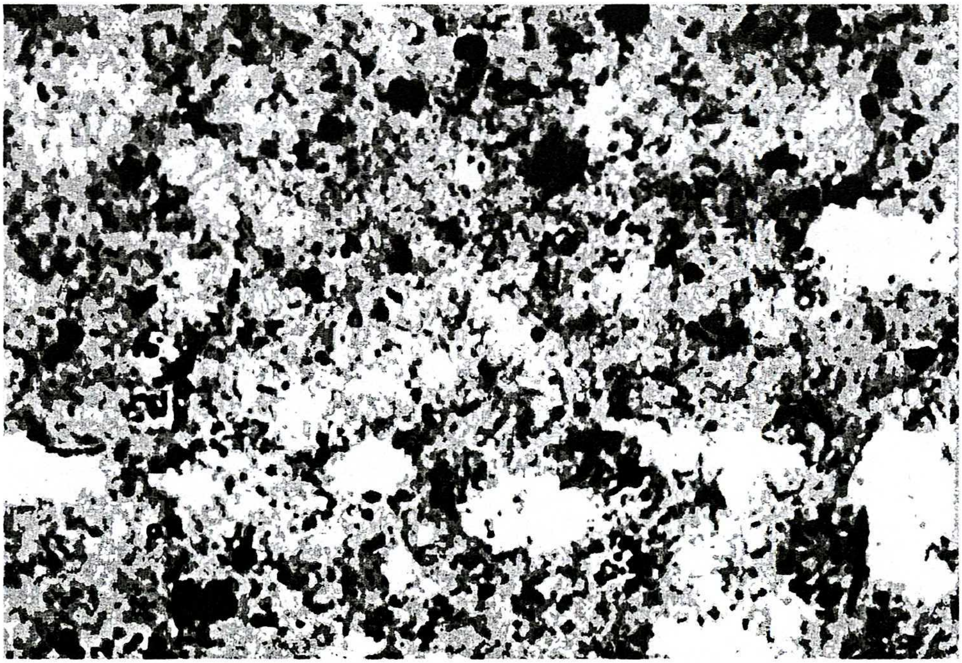

Fig. 4. Micrograph of activated sludge – after 30 minutes of disintegration

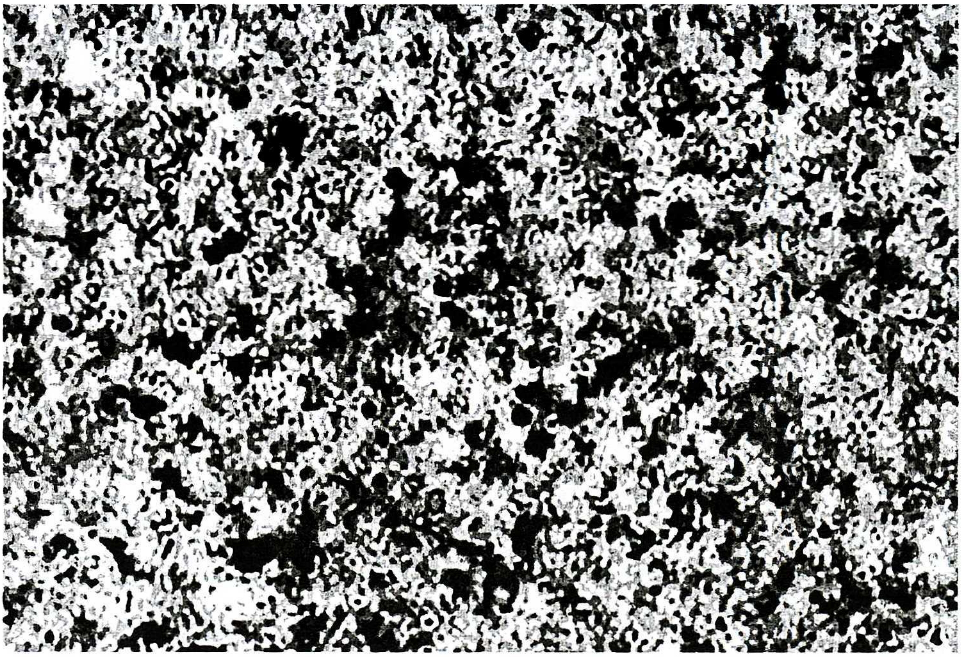

Fig. 5. Micrograph of activated sludge – after 60 minutes of disintegration

The release of organic substances (expressed here as COD) as an effect of activated sludge flocs disintegration leads to a substantial increase of methane production in the sludge anaerobic digestion [6, 9].

Hydrolytic decomposition of polypeptides by freed enzymes results also in nitrogen compounds release. A substantial increase of ammonia and slight increase of nitrites and nitrates concentrations can be observed (Fig. 6).

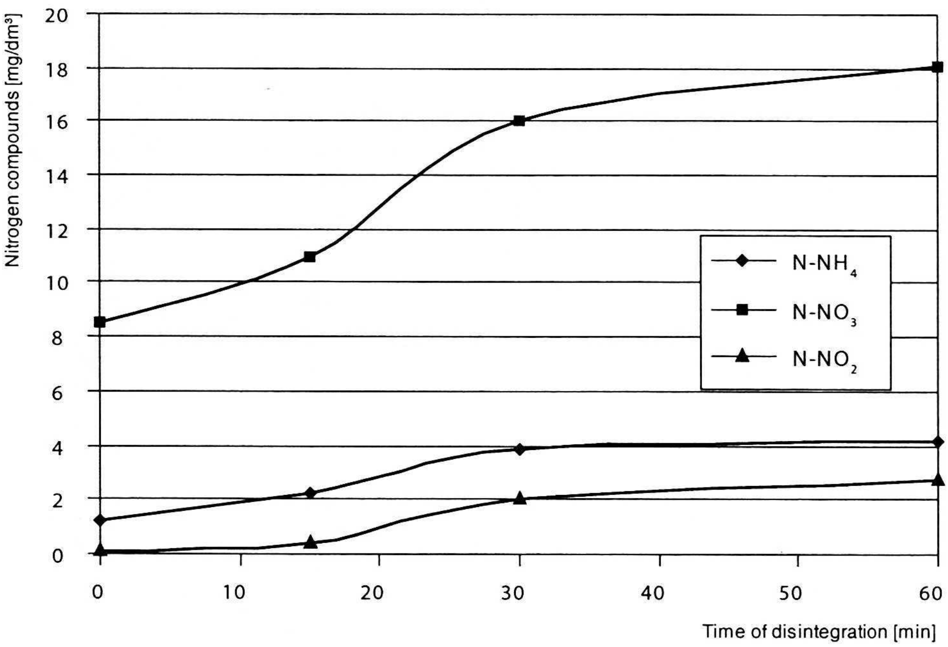

Fig. 6. Changes of nitrogen compounds in relation to the time of mechanical disintegration

However, the most affected by disintegration were the volutins of polyphosphates. After 60 minutes of disintegration the concentration of phosphates in the solution increased from 8.9 mg PO_4/dm^3 to 63.4 mg PO_4/dm^3 (Fig. 7). Most of the phosphates were released already in the first 30 minutes of disintegration. The difference in phosphates concentration between the concentrations measured after the 30 and 60 minutes of disintegration was only 10 mg PO_4/dm^3. The indirect proof of intra and extracellular polyphosphates destruction are the measured increase of magnesium, potassium and calcium ions in the solution (Fig. 8).

The increase of magnesium, potassium and calcium in relation to phosphates was much lower. Therefore, directly after disintegration the ratios of Mg/P and K/P are distinctly different from those given in the literature. After the first 15 minutes of disintegration the ratio of Mg/P was 1.5 and for K/P was 3.1 (Fig. 9). Continuation of disintegration leads to drastic decrease of the aforementioned ratios.

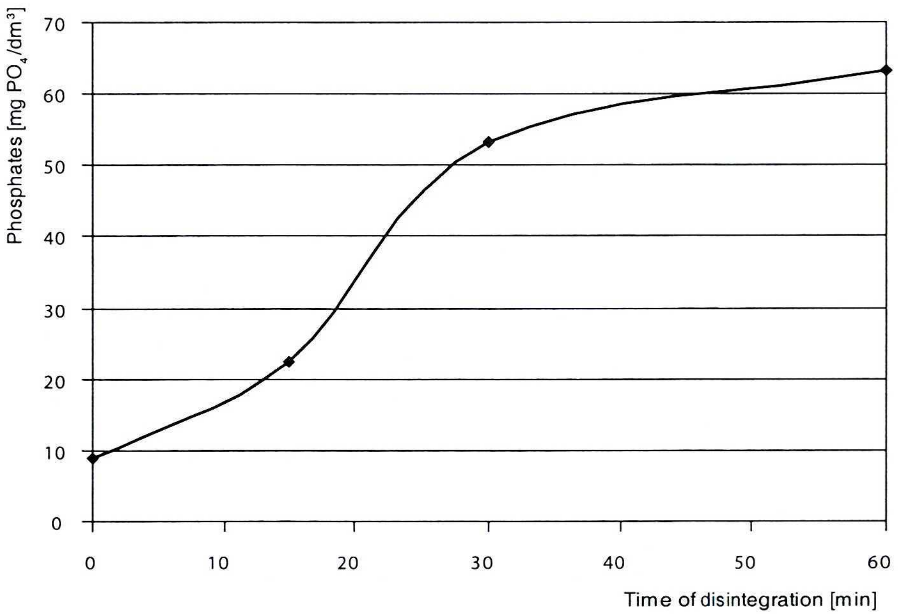

Fig. 7. The effect of sludge disintegration on the phosphates increase in the solution (example)

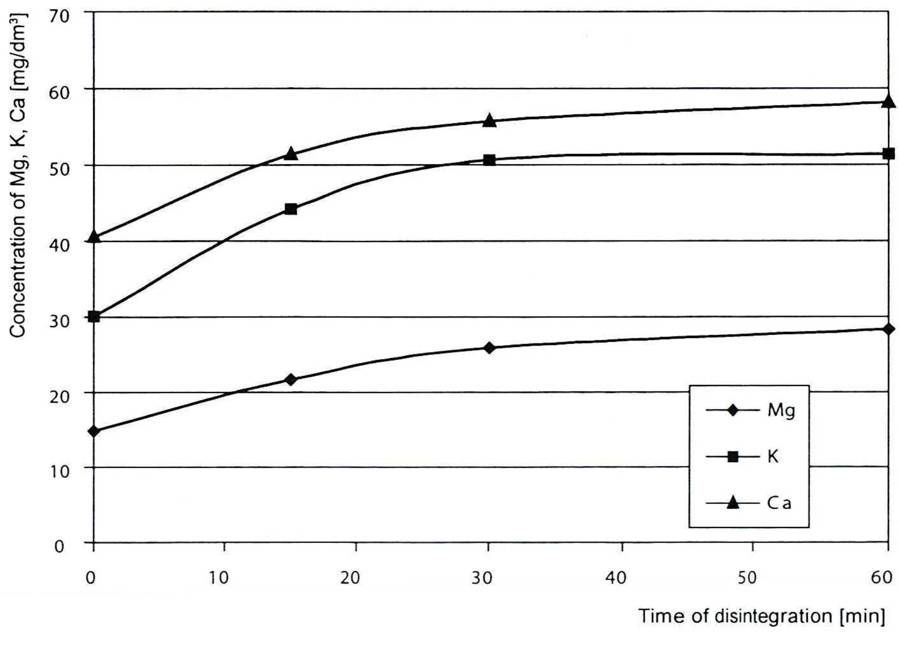

Fig. 8. The effect of disintegration on the release of magnesium, potassium and calcium

Arvin and Kristensen [1] have given the ratio of Mg/P equal to 0.25, and K/P equal to 0.29. A similar ratio for Mg/P = 0.26 was given by Jardin and Popel [8], and Wentzel [11]. A somewhat higher ratio of Mg/P = 0.285 was given by Imai *et al.* [8].

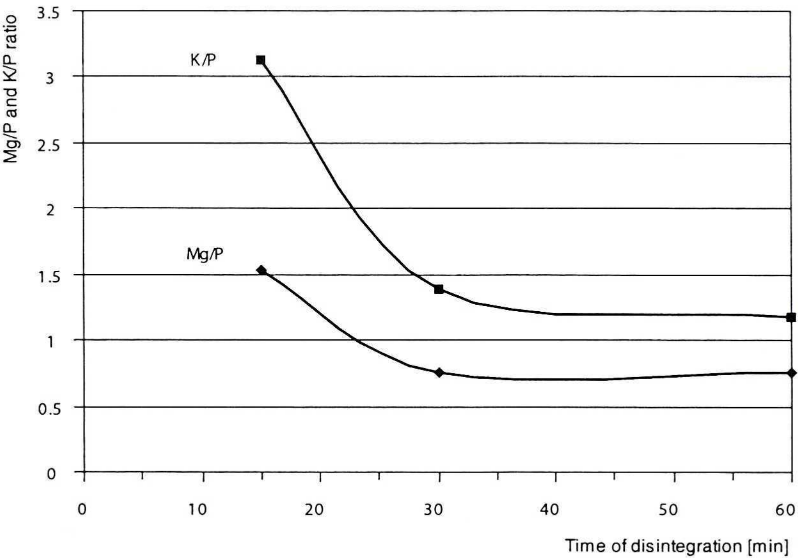

Fig. 9. Changes of the Mg/P and K/P mass ratios with time of disintegration

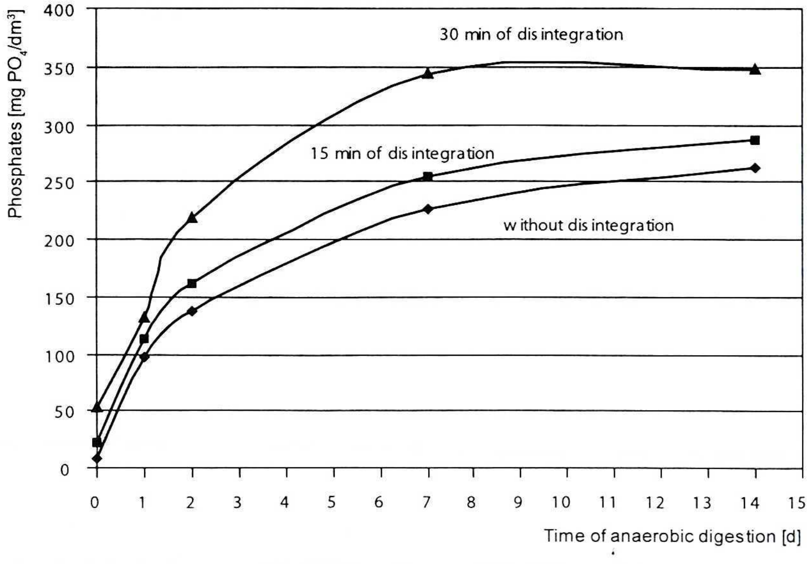

Fig. 10. Hydrolysis of poly-P under anaerobic conditions

The drastic differences in found ratios of Mg/P and K/P and given in the literature can be explained. Evidently the disaggregation of poly-P does not result in immediate release of phosphorous in readily soluble orthophosphates. Only after hydrolysis of the poly-P complex, under anaerobic conditions an increase of simple phosphates is possible.

The effects of anaerobic hydrolysis are shown in Figure 10. With an enormous increase of phosphates to the range of 260 to 350 mg PO_4/dm^3 after 14 days under anaerobic conditions, and a relatively small increase of magnesium and potassium concentration, the ratio of Mg/P and K/P decreased substantially. After 7 days under anaerobic conditions the ratio of Mg/P and K/P was respectively 0.21 and 0.40, decreasing even more after 14 days.

Divagations on the ratios of metal ions (Mg, K, and Ca) to phosphorous have mainly a theoretical importance. For practical reasons of nutrients removal it is important to have an appropriate ratio of magnesium or potassium and phosphates, and ammonia nitrogen in order to fulfill the formula of struvite – $Mg:NH_4:PO_4$, of which the molar ratio is 1:1:1. The mass ratio of $Mg:NH_4:PO_4$ is 0.25:0.19:1. The appropriate ratio of Mg/PO_4 is obtained after keeping the disintegrated sludge under anaerobic conditions, for a short period, as given e.g. in Figure 11 for 1 day. In the examined case about 40 mg P/dm^3 can be removed without an external source of magnesium. Keeping the disintegrated sludge in anaerobic conditions for a longer period, say 7 days, (for hydrolysis of poly-P – see Fig. 10) and adding then deficient magnesium, as much as about 100 mg P/dm^3 can be removed as struvite. Also a part of nitrogen can be efficiently removed.

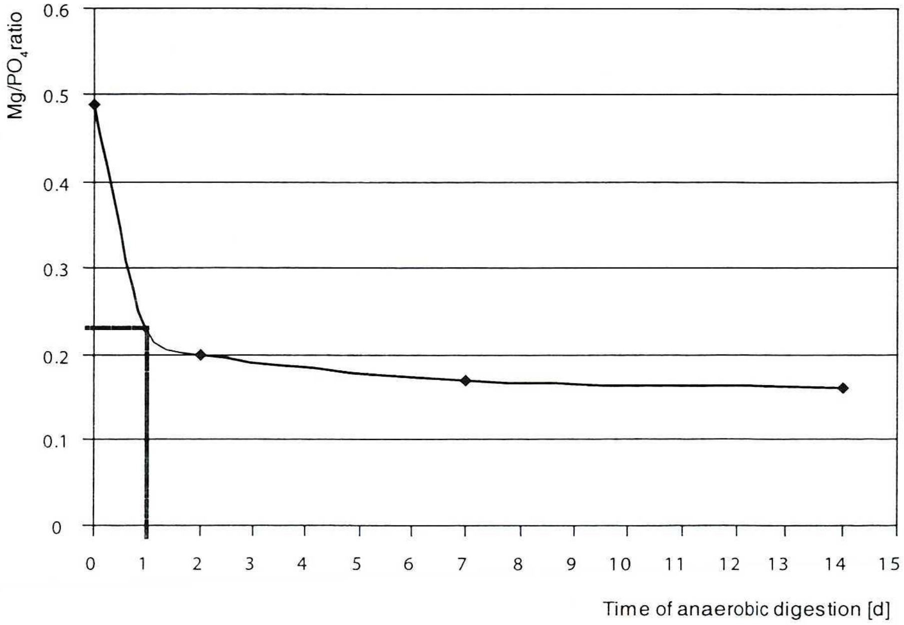

Fig. 11. The effects of anaerobic conditions on the Mg/PO_4 mass ratio in the liquor of disintegrated sludge

The precipitated struvite of which an example is shown in Figure 12 can be easily separated from the disintegrate sludge.

Surplus activated sludge disintegration followed by a short period of storage in anaerobic conditions, permits removal of a substantial part of phosphorous and nitrogen from the side stream. The load of phosphorous removed (as struvite) from the side stream, constitute about 25% or more of the total load of phosphorous in the main stream of inflowing raw sewage.

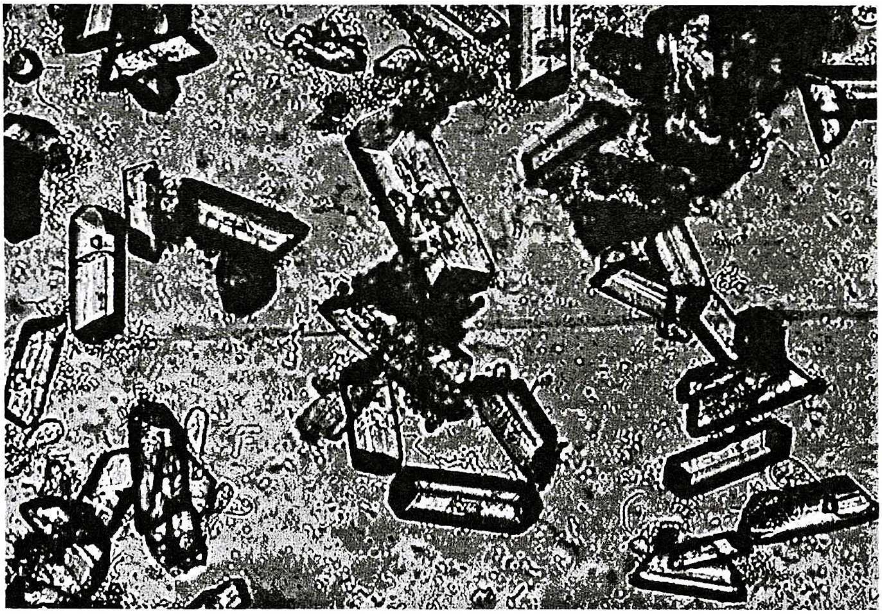

Fig. 12. Precipitated crystals of struvite in liquor of disintegrated sludge for 30 minutes – anaerobic condition

CONCLUSIONS

Although the main aim of surplus activated sludge disintegration is improvement of methane production and sludge mass reduction in the process of anaerobic digestion, there are also possible other advantages. Sludge disintegration followed by short anaerobic condition enables removal of a substantial part of phosphorus and nitrogen in the form of precipitated out struvite. The mechanism and conditions for effective removal of phosphorus and nitrogen from the sewage side stream was elucidated in this paper.

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