DOI: 10.2478/v10216-011-0031-x ECOL CHEM ENG S. 2012;19(3):415-421

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HYGIENISATION OF SURPLUS ACTIVATED SLUDGE BY HYDRODYNAMIC CAVITATION

HIGIENIZACJA OSADU CZYNNEGO NADMIERNEGO W PROCESIE KAWITACJI HYDRODYNAMICZNEJ

Abstract: The success of an effective process of disintegration is the application of physical or chemical methods of the destruction of the cell wall which consequently becomes fragmented and the intracellular matters are released into the surrounding liquid. The purpose of the conducted experiments was to demonstrate possibilities of application of the hydrodynamic in the bacteriological hygienisation of surplus activated sludge. The confirmation of the effectiveness of the bactericidal activity of hydrodynamic cavitation was the number of bacteria grown on agars before and after hygienisation process. Selective and basic beddings have been used in the research. The bacterial culture has lasted approximately 24 to 48 hours. After the period of incubation the colonies produced have been counted and initially identified. Based on the microbiological analyses a significant reduction in an overall number of bacteria and pathogenic bacteria belonging to the family *Enterobacteriaceae* and to the pathogenic species *Staphylococcus* has been noticed. The overall number of bacteria decrease about 80% after 45 minutes of disintegration of surplus activated sludge. Pathogenic bacteria belonging to the family *Enterobacteriaceae*: lactose-positive and lactose-negative decrease about 93% and 92%, respectively. Reducing the number of *Salmonella* bacteria was 100% after 45 minutes of disintegration processes. Reduction bacteria of species *Staphylococcus* were about 93% for mannitolo-positive and 92% for mannitolo-negative.

Keywords: disintegration of surplus activated sludge, hydrodynamic cavitation, hygienisation

The success of an effective process of disintegration is the application of physical or chemical methods of the destruction of the cell wall which consequently becomes fragmented and the intracellular matters are released into the surrounding liquid.

The product can be utilized both as a substrate in aerobic as well as anaerobic biological processes. The application of disintegration technology into the sludge treatment process leads to reduced sludge quantities and markedly improves sludge quality.

Several disintegration processes are developed: mechanical: hydrodynamic cavitation, ultrasound, homogenizer, stirred ball mills; thermal hydrolysis (autoclave or steam heating), wet oxidation; chemical: use of enzymes, alkaline/acid hydrolysis; biological: thermophilic aerobic/anaerobic pretreatment. These disintegration methods are common for activated

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sludge stabilization, resulting in solubilization of sludge volatile matter and the production of biogas [1]. Positive effects were shown for thermal pretreatment [2-4], addition of enzymes [5, 6], ozonation [7-9], chemical solubilization by acidification [10] or alkaline hydrolysis [11, 12], and mechanical and ultrasonic sludge disintegration [13-20]. One of the disintegration method is hydrodynamic cavitation. Hydrodynamic cavitation results in formation of cavities (bubbles) filled with a vapour - gas mixture inside the flowing liquid, or at the boundary of a constriction devices due to rapid local pressure drop. Subsequently, the pressure recovers down the constriction (valve or nozzle) and causes cavities to collapse. The collapse of cavitation bubbles is defined as implosion and the forces associated with results in mechanical and physicochemical effects. The physical effects include the production of shear forces, shock waves, generating local high temperatures and pressures, whereas the chemical effects result into the generation of radicals *eg* formation of reactive hydrogen atoms and hydroxyl radicals which recombine to form hydrogen peroxide [21-23].

Although the methods of disintegration are different in character, they all aim to achieve partial or complete lysis of bacteria cells disintegration leads to reduced microorganisms quantities. The purpose of the conducted experiments was to demonstrate possibilities of application of the hydrodynamic disintegration in the bacteriological hygienisation of surplus activated sludge.

Materials and methods

Material and experimental installation

Surplus activated sludge samples were taken from an *Enhanced Biological Nutrient Removal* (EBNR) full scale municipal sewage treatment plant. The treatment plant was designed for the flow of 120 00 m³/d. For the time being, the amount of flowing sewage is *ca* 90 000 m³/d, sewage retention time *ca* 14 days and concentration of activated sludge in the bioreactor 4320÷4640 mg/dm³.

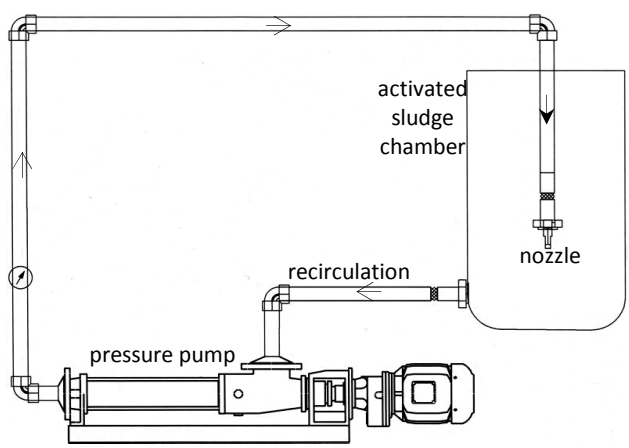

Fig. 1. Scheme of the experimental installation

Hydrodynamic disintegration was executed with the application of a pressure pump (12 bar), which recirculated sludge from a 25 dm^3 container, through a constructed cavitation nozzle. The process was carried out for 15, 30 and 45 minutes. Scheme of the experimental installation is shown in Figure 1.

Microbiological methods

Selective and basic beddings have been used in the research. For cultivation methods of microorganisms the following mediums were used:

- Nutrient agar
- MacConkey agar
- Chapman agar
- Salmonella/Shigella agar (SS)

The bacterial cultures were incubated at 37ºC and have lasted approximately 24 to 48 hours. After the period of incubation the colonies produced have been counted and initially identified.

For *in vitro* diagnosis of some bacteria, the API 20E tests (of BioMerieux) which are a semi-quantitative micromethod, serving for assessment of the enzymatic activity were used.

Surplus activated sludge samples characterized by a high abundance of bacteria. Therefore, before plating was performed dilutions of the test material from 10^{-1} to 10^{-10}. The investigations presented here were performed 5 times in 5 stages.

The number of bacteria in 1 cm^3 of surplus activated sludge was calculated according to PN-EN ISO 6222:2004.

Results and discussion

The confirmation of the effectiveness of the bactericidal activity of hydrodynamic cavitation was the number of bacteria grown on agars before and after hygienisation process.

According to the methodology used, the process of hydrodynamic disintegration was carried out for 15, 30 and 45 minutes. The prolonged time of hygienisation by hydrodynamic disintegration results in a decrease of overall number of bacteria. After 45 minutes disruption of bacteria the quantity decrease of 80% (Fig. 2).

The use of hydrodynamic cavitation for the bacterial indicator of sanitary assessment of sewage sludge showed the devastating effects and decrease number bacteria of the genus *Salmonella*. Reducing the number of *Salmonella* bacteria was 100% after 45 minutes of disintegration processes (Fig. 3). Cavitation has also resulted in the reduction of *Shigella* sp. sticks by 96% (Fig. 3).

Hydrodynamic cavitation caused reduction of pathogenic bacteria belonging to the family *Enterobacteriaceae*: lactose-positive and lactose-negative decrease about 93% and 92%, respectively (Fig. 4).

Hygienisation process has also contributed to the reduction of bacteria of the genus *Staphylococcus*, those pathogenic for humans (mannitolo-positive) and non-pathogenic (mannitolo-negative). Reducing the number of *Staphylococcus* mannitolo-positive and mannitolo-negative after 45 minutes of disintegration processes was 93% and 92%, respectively (Fig. 5).

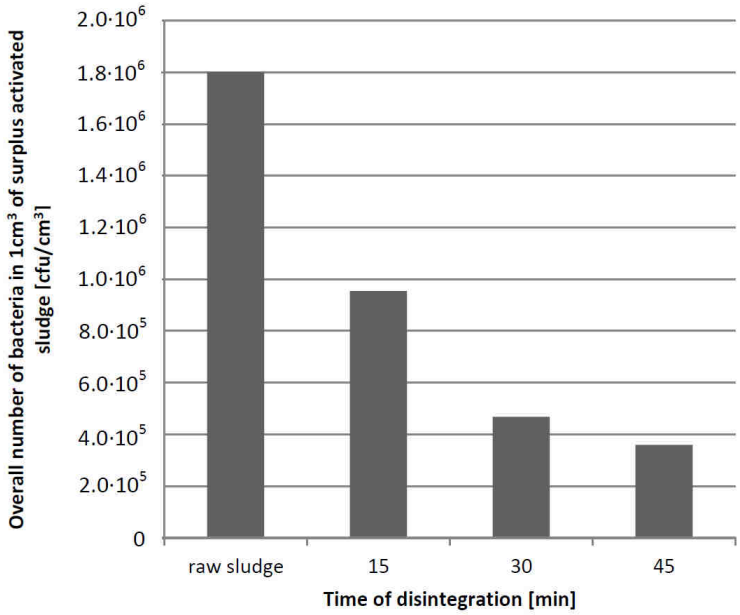

Fig. 2. Overall number of bacteria in 1 cm^3 of surplus activated sludge before and after hygienisation process

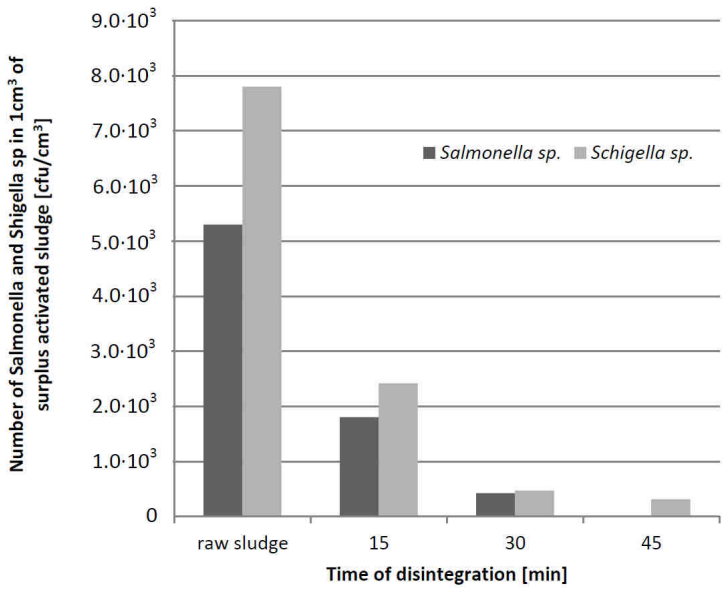

Fig. 3. Number of *Salmonella* and *Shigella* sp. in 1 cm^3 of surplus activated sludge before and after hygienisation process

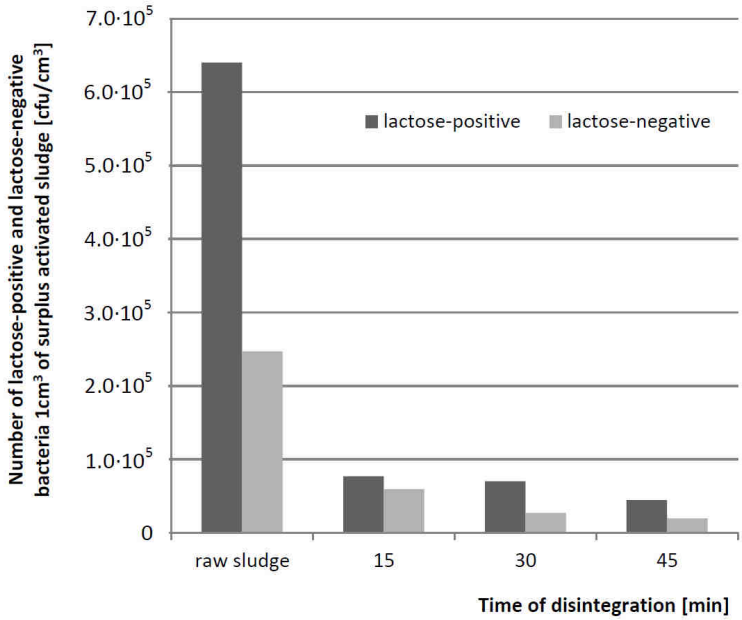

Fig. 4. Number of lactose-positive and lactose-negative bacteria 1 cm^3 of surplus activated sludge before and after hygienisation process

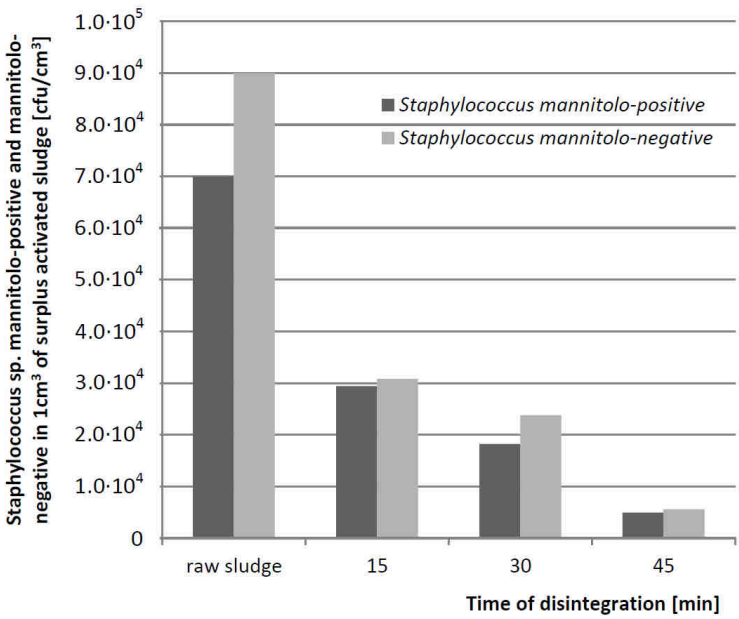

Fig. 5. Number of *Staphylococcus* sp. mannitolo-positive and mannitolo-negative in 1 cm^3 of surplus activated sludge before and after hygienisation process

The effect of cell disruption (hygienisation process) depends on time of disintegration, environment, age, type and form of microorganisms (vegetative form, spores) and age of the culture. The death of bacteria by lysis of cells under the influence of hydrodynamic cavitation is a function of logarithmic time of them actions. Generally, the more vulnerable are young cultures, but each organism has a different sensitivity associated with the duration of action. There are, in fact significant differences in sensitivity between the types of organisms and even different species within the genera.

Conclusions

Based on the microbiological analyses a significant reduction in an overall number of bacteria and pathogenic bacteria belonging to the family *Enterobacteriaceae* and to the pathogenic species *Staphylococcus* has been noticed. The overall number of bacteria decrease about 80% after 45 minutes of disintegration of surplus activated sludge. Pathogenic bacteria belonging to the family *Enterobacteriaceae*: lactose-positive and lactose-negative decrease about 93% and 92%, respectively. Reducing the number of *Salmonella* bacteria was 100% after 45 minutes of disintegration processes. Reduction bacteria of species *Staphylococcus* were about 93% for mannitolo-positive and 92% for mannitolo-negative.

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HIGIENIZACJA OSADU CZYNNEGO NADMIERNEGO W PROCESIE KAWITACJI HYDRODYNAMICZNEJ

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Abstrakt: Skuteczność procesu dezintegracji wynika z fizycznych lub chemicznych metod destrukcji ściany komórkowej, co w konsekwencji prowadzi do jej fragmentacji i uwalniania wewnątrzkomórkowych substancji do otaczającej fazy płynnej. Celem przeprowadzonych badań było wykazanie możliwości zastosowania kawitacji hydrodynamicznej do bakteriologicznej higienizacji osadu czynnego nadmiernego. Potwierdzeniem skuteczności bakteriobójczego działania kawitacji hydrodynamicznej była liczba bakterii rosnących na agarach przed i po procesie higienizacji. Do badań użyto podłoży podstawowych i selektywnych. Hodowla kultur bakteryjnych trwała 24 i 48 godzin. Po czasie inkubacji kultury zostały policzone i poddane wstępnej identyfikacji. Na podstawie przeprowadzonych analiz stwierdzono redukcję ogólnej liczby bakterii o ok. 80% po 45 minutach dezintegracji osadu czynnego nadmiernego. Patogenne bakterie należące do rodziny *Enterobacteriaceae* uległy redukcji: laktozo-dodatnie o ok. 93%, a laktozo-ujemne o ok. 92%. Bakterie z rodzaju *Salmonella* uległy całkowitemu zniszczeniu. Liczba bakterii z rodzaju *Staphylococcus* zmniejszyła się o 93% w przypadku mannitolo-dodatnich i o 92% w przypadku mannitolo-ujemnych.

Słowa kluczowe: dezintegracja osadu czynnego nadmiernego, kawitacja hydrodynamiczna, higienizacja osadu