Hydrodynamic disintegration of sewage sludge – recovery of organic compounds, biomass deactivation, cell lysis

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Keywords: excess sludge, circular economy, carbon recovery, hydrodynamic disintegration

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One of the new challenges in sewage sludge management is acting in accordance with the rules of circular economy. The example of such action is recovery of soluble biodegradable organic compounds from activated sludge flocs and using them as a substrate for intensification of nutrient removal form wastewater. In order to release soluble organic compounds the disintegration of excess sludge can be used. The idea of this process is the destruction of sludge structure and the change of its physicochemical properties using the additional energy. Although many papers document a positive effect of the application of disintegrated sludge as a source of organic carbon for facilitation of N and P removal from sewage (Yan *et al.,* 2015; Xu *et al.*, 2016), according to some reports, such a measure can lead to the worsening of the quality of treated wastewater (Meng *et al.,* 2013). It is therefore important to have a tool that would allow for the assessment of the possibility of worsening the quality of treated wastewater prior to the application of disintegrated sludge as a source of organic carbon. The paper will present study results aimed at the determination whether such tool can be the analysis of changes in sludge properties, particularly focused on the assessment of deactivation and lysis of microorganisms.

In the experiment, 8 series were conducted (Table 1). Each series involved observations for 5 samples of disintegrated excess sludge differing in the amount of energy used in the disintegration process (70-350 kJ/L) and for a sample of raw sludge. The amount of energy used in the disintegration process is expressed as energy density (ε_L), i.e. the amount of energy relating to 1 L of disintegrated sludge. This parameter was selected because it was necessary to maintain the amount of energy used in the disintegration process in different series of the experiment at a constant level. Thickened excess sludge disintegration was conducted in a lab device containing a multi-use rotor driven by a motor with a power of P=2.2 kW, revolutions n= 2800/min, installed in a 10 L tank.

Table 1. Main assumptions of the experiment

Partial experimental objectives	Their implementation	Series number
Analysis of release of organic compounds from activated sludge flocs	Determination of the disintegration degree (DD). Observations of changes in SCOD and VFA concentrations in sludge liquid	SI-SVIII
Changes in the structure of activated sludge flocs	Microscope observations	SIV-SVIII
Analysis of cell deactivation and lysis	Oxygen uptake rate tests (OUR). Observations of changes in DNA concentration in sludge liquid	SV-SVIII

Data presented in Fig. 1 show that for DD not exceeding approximately 5%, disintegration of excess sludge led to an increase in the activity of microorganisms. In a range of DD values from approximately 5 to approximately 30%, progressing deactivation of microorganisms was observed, still not accompanied by cell lysis, or the process was relatively unimportant in relation to breaking activated sludge flocs. The distribution of $DNA_{\varepsilon L}/DNA_0$ values suggests that DD ≈ 30% can be considered a threshold the exceedance of which results in intensive cell lysis. It was accompanied by an approximately 100% decrease in the activity of microorganisms. Observations provided in Table 2 suggest that in the case of lack of intensive cell lysis as a result of the disintegration process, the disintegrated sludge proved to be an appropriate source of organic carbon for facilitating removal of nutrient from wastewater. Otherwise, the application of disintegrated sludge led to the disruption of the nitrification process and worsening the quality of wastewater in reference to COD. A decrease in the respiratory activity of microorganisms can be considered as the "warning signal" preceding the occurrence of intensive cell lysis.

The study showed that the preliminary assessment of potential worsening of the quality of treated wastewater in the case of use of disintegrated sludge in the sewage line of the wastewater treatment plant can employ indices $OUR_{\varepsilon L}/OUR_0$, and $DNA_{\varepsilon L}/DNA_0$ determined based on appropriate parallel OUR tests and analysis of DNA concentration in sludge liquid.

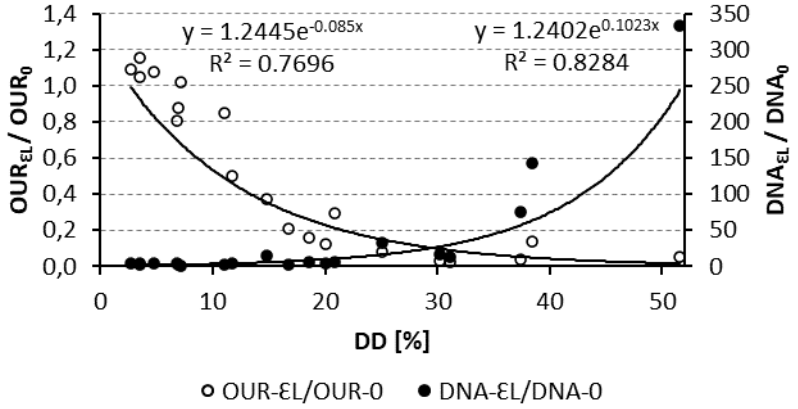

Figure 1. Effect of the degree of disintegration on biomass deactivation ($OUR_{\varepsilon L}/OUR_0$) and cell lysis ($DNA_{\varepsilon L}/DNA_0$)

Table 2. Changes in properties of excess sludge depending on energy density at which the disintegration process was conducted, and effect of use of disintegrated sludge on the efficiency of wastewater treatment.

Observations		Energy density used in the process of disintegration of excess sludge (kJ/L)				
		70	140	210	280	350
Changes in properties of disintegrated sludge - this study						
Organic compounds release:						
SCOD/VFA	-	14.65±5.21	11.10±2.55	11.87±7.38	10.41±1.87	14.36±2.83
DD	%	3.98±1.39	7.12±1.90	14.61±3.11	24.94±6.22	37.64±6.56
Deactivation of microorganisms:						
$OUR_{\varepsilon L}/OUR_0$	-	1.08±0.06	0.90±0.12	0.34±0.12	0.13±0.03	0.04±0.01
Cell lysis:						
$DNA_{\varepsilon L}/DNA_0$	-	2.46±1.33	2.85±0.94	7.00±5.20	46.76±65.52	109.74±151.54
Change in the efficiency of wastewater treatment in reference to the system operating with no dosing of disintegrated sludge (Zubrowska-Sudol and Walczak 2015; 2022)						
C, N and P removal:						
$\Delta\eta_{COD}$	%	at a similar level			–4.6	n.r.a.
$\Delta\eta_{TN}$	%	+16.1	+26.7	+17.8	–12.8	n.r.a.
$\Delta\eta_{TP}$	%	+70.3	+65.7	+63.1	+63.1	n.r.a.

n.r.a. no research available

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Acknowledgements

The study was performed as a part of research project “Disintegration of activated sludge as a method to obtain alternative source of organic compounds for biological nutrient removal from wastewater” (No. N N523 736840), financed by National Science Centre (Poland).