Assessment of influence of addition of potassium drilling fluid on potassium content in activated sludge in wastewater treatment process in SBR reactors

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Abstract. The activated sludge is described as a complex biological system composed of microorganisms. Within this system, processes of both physical and biochemical nature undergo, resulting in the purification of wastewater as well as industrial sewage. Recent researches indicate also on a possibility of co-treatment via activated sludge of used drilling fluids. As a result of wastewater treatment, sewage sludge is being formed, which according to its composition may become a waste to dispose or a product for natural reuse. The hereby paper presents the influence on potassium content in the activated sludge of addition of used drilling fluids (volume ranging from 0.25% to 4% of the volume of treated wastewater), which may have an impact on the final natural use of sludge.

1. Introduction

Neutralisation of waste via activated sludge is a method used as a technology for wastewater treatment, implement worldwide for almost a century. The activated sludge is composed of microorganisms’ clusters, which with an appropriate oxygen supply can decompose organic substances of wastewater into simple solid inorganic compounds. Via activated sludge usage and creation of aerobic, anaerobic, and oxygen deficiency conditions alternatively, carbon compounds, as well as those biogenic, i.e. nitrogen and phosphorus are effectively removed [1-3]. The method of purification with the use of activated sludge is predominantly used to treat municipal wastewater, yet also those of industrial origin [4-6].

Recent researches indicate also on the possibility of co-treatment via activated sludge of used drilling fluids. Babko’s paper [7] presents a comparison of the influence of two types, polymer, and potassium-polymer, drilling fluids on the level of treatment of wastewater and eucaryotic organisms of activated sludge. The most important conclusions were that the polymer-potassium drilling fluids in doses of 1% and 3% contributed to an acceleration of the tempo of reduction of suspended solids, and that polymer drilling fluids did not stimulate the abovementioned process in any of dose. The addition of a 3% polymer drilling fluid increased the tempo of COD removal approximately twice. Furthermore, the addition of any of the aforementioned drilling fluids had no negative impact on the tempo of the removal of N-NH$_3$ however, did increase it approximately 20% in the case of TN removal in the laboratory SBR reactors.

Sewage sludge remaining post wastewater treatment, depending on its composition, may become a disposable waste or a product for natural reuse. Sludges characterised by a high fertilising value may
be used for fertilisation or reclamation of degenerated lands. The fertilising value of the sludge is determined by the content of the main nutrients essential for plants, i.e. nitrogen, phosphorus, potassium, magnesium, calcium, and microelements. The soil-forming features of sludges result mainly from the high content of the organic fraction in it, which is a rich and nutrient environment for microorganisms’ activity and humus-producing substances [8,9]. Fertilisation of soil with sludge under pot experiment conditions conducted by Szwedziak [8] proved an increase in the growth of pea plant in relation to the control variant without fertilisation. In the research conducted by Kujawska et al. the composition of soil-forming mixtures with sludges combined with mineral drilling waste has been proposed. Those mixtures are highly organic matters, their reaction and C to N ratio are optimal for the growth of the majority of plants [12].

Therefore, sludge should be perceived also as a valuable organic fertiliser because it is composed of trace elements and organic matter. Sludge contains vital nutrients, such as nitrogen and a significant amount of phosphorus, however low amount of potassium [13-15]. Recently, an increase in the amount of sludge produced may be observed, which leads also to the construction of new sewage treatment plants, as well as modernisation of already existing ones.

Sludge contains a variety of nutrients indispensable for plants. Table 1 presents a comparison of the content of macro elements (nitrogen, phosphorus, potassium, carbon, sulphur) in exemplary sludge without the addition of drilling fluids [10,11].

Table 1. Characteristics of the activated sludge.

| Designation               | Unit    | Value |
|---------------------------|---------|-------|
| Humidity                  | %       | 24,4  |
| Dry matter                | %       | 25,6  |
| Organic matter            | % DM    | 36,8  |
| Mineral substances        | % DM    | 61,2  |
| Reaction                  | pH      | 12,5  |
| Total nitrogen            | % DM    | 4,1   |
| Ammonium nitrogen         | % DM    | 2,1   |
| Total phosphorus          | % DM    | 1,03  |
| Calcium                   | % DM    | 8,50  |
| Magnesium                 | % DM    | 3,7   |
| Potassium                 | % DM    | 0,68  |

A possibility of co-treatment of used in mining processes fluids via activated sludge will influence the content of potassium in the sludge. Especially, the addition of used polymer-potassium drilling fluids may cause a significant increase in potassium content in the sludge; worth noticing is the fact that those are the most used drilling fluids in Poland. The hereinafter paper presents the level of potassium accumulation, depending on the age of activated sludge and the amount of used drilling fluid.

2. Materials and methods

The laboratory set used for the experiment consisted of 6 SBR reactors. Each reactor was composed of:

- chamber
- mixing system
- aeration system
- temperature-regulating system
The reactors’ chambers were made of glass vessels in the cylindrical shape and a total capacity of 1600 ml each. The system was divided into two sets, each operating 3 bioreaction chambers.

The mixing system facilitated smooth regulation of the mixer’s rotation, in a range from 1 to 250 rotations per min\(^{-1}\). Electric motors have been used for servicing the mixing system. One motor was used for 3 chambers to operate. One mixing system consisted of three mixers.

The aeration system facilitated the provision of a required amount of air and its regulation separately for each chamber.

Using a model of sewage treatment plant SBR type, have been conducted researches aiming at assessment of the level of accumulation of potassium on the activated sludge during co-treatment of used drilling fluids with municipal wastewater. The experiment was conducted in six chambers (cylinders) simultaneously, maintaining a constant operational regime for each. Reactors had a 12-hours-long working cycle (two per 24-hours), according to a fixed schedule. The duration of each phase was set to obtain the best quality of wastewater in bioreactors outlets. One of the most vital factors, in that case, was a selection of time for sedimentation, to facilitate the transfer of a suitable amount of treated sewage from the bioreactor, and on the other hand, the time should not be too long to prevent secondary flotation and stratification of sludge, which result in an increased amount of suspended solids in the outlet. Furthermore, too long sedimentation time may lead to secondary releasing of biogenic substances from the activated sludge to already treated wastewater. The duration of particular phases of the cycle shall be regulated via a time control.

For the purpose of the experiment, the activated sludge and raw wastewater drawn from the Municipal Wastewater Treatment Plant “Hajdów” in Lublin were used. The aforementioned facility is one of the major plants in Poland and is located in the eastern part of the city. It is an advanced biological-mechanical treatment plant, where a method of treatment via activated sludge is implemented. The treatment plant is fed by the municipality of Lublin and Świdnik, as well as other, minor nearby localities. In recent years, the average daily amount of wastewaters input was approximately 65,000 m\(^3\), being less than half of its intended maximal daily output capacity.

The input mixture in the SBR laboratory reactors was composed of activated sludge (process factor) of volume 1.2 dm\(^3\) and raw wastewater (source of organic matter/culture medium) – 0.4 dm\(^3\). In a decantation phase, treated wastewater of volume of 0.4 dm\(^3\) was discharged. In a replenish phase, each time 0.4 dm\(^3\) of raw wastewater was introduced. Each of the reactors operated at a constant temperature of 20 ± 0.5°C. Serving as an addition, polymer-potassium drilling fluid from Maćkowice well was used (with a specification provided in Table 2).

### Table 2. Basic properties of the polymer-potassium scrubber used (average values from 3 replicates).

| Designation       | Unit   | Value           |
|-------------------|--------|-----------------|
| Solid suspensions | g/ml   | 732 ±41         |
| Reaction          | pH     | 8.86 ±0.10      |
| TOC               | [%]    | 2.56 % ±0.20    |
| Total nitrogen    | [%]    | 0.02% ±0.01     |
| COD               | mg/dm\(^3\) | 17886.20 ±325.75 |
| BOD mg/dm\(^3\)  | mg/dm\(^3\) | 24.15 ±0.69    |

The dosing of drilling fluids during the experiments was planned as follows:

- Chamber K1 – control, reference samples for chambers 2-6 – drilling fluid addition 0.00%
- Chamber K2 – drilling fluid addition 0.25% of the volume
- Chamber K3 – 0.50% vol.
• Chamber K4 – 1.00% vol.
• Chamber K5 – 2.00% vol.
• Chamber K6 – 4.00% vol.

Chemical analyses were conducted once per 24-hours (every two working cycles of SBR). The experiment duration was 15 days. The concentration of potassium in the individual chambers was determined by ICP-OES Ultrace 238 (Jobin Yvon Horriba France) using a direct calibration method after microwave digestion (Multiwave 3000, Anton Paar). The samples (1 g) were digested in an acid mixture of HNO₃: HCl (5:2). The digestion process lasted 45 min at 180°C and the pressure of 18 bars. Ba concentrations were determined at wavelengths (766.49 nm). Detection limits for particular metals did not exceed 10 ppb.

2.1 Statistical analysis.
The data were also statistically analysed through correlation analysis Pearson’s (r) to investigate the signification between the duration of the experiment and the concentration of potassium. When interpreting the results of the correlation studies, the criteria of the dependency force adopted by Bam et al. (2011), which assumes that the correlation coefficient r > 0.7 indicates a strong relationship between the two parameters, while values in the range 0.5–0.7 indicate a moderate relationship between them.

3. Results
On the basis of findings from the conducted researches, the introduction of drilling fluid together with municipal wastewater into the chambers filled with the activated sludge had an impact on the potassium content in the activated sludge. That influence was dependent upon the amount of added drilling fluid, as well as the length of the operational cycle of the chamber. In chamber No. 1, where no drilling fluid was introduced, any significant changes concerning potassium (in the amount of 51.2 mg/l ±1.0) content was not observed. The most notable change was recorded in chamber No. 6, where for 15 days the content of potassium increased to 831 mg/l do 888 mg/l. Figure 1 presents the aforementioned findings. In chamber No. 6, the addition of drilling fluid was 4% of the volume of introduced wastewater.

![Figure 1. Content of potassium in the activated sludge in the chamber 6 within 15 days.](image-url)
The content of potassium in each chamber at the end of the experiment differed significantly, which was a result of a diverse amount of drilling fluid addition in each chamber. Figure 2 explains that relation.

![Graph of potassium content in chambers K1-K6 after 15 days](image)

**Figure 2.** Content of potassium in chambers K1-K6 after 15 days.

Graphs present clearly the influence of drilling fluid addition on the change in the content of potassium in the output from the SBR chambers. In each case, together with an increase in the addition of drilling fluid, as well as in the duration of the experiment, the content of potassium in the output increased. Table 3 gathers together the total results of the experiment.

**Table 3.** Percentage of potassium in separate bioreactors (mg/l) on individual days from 1 to 15.

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| K1| 51,4| 51,3| 51,2| 51,4| 51,5| 51,7| 52,2| 52  | 51,8| 51,4| 51,2| 50,5| 50,2| 50,5| 51  |
| K2| 138 | 139 | 144 | 146 | 148 | 149 | 150 | 151 | 150 | 149 | 152 | 153 | 154 | 155 | 154 |
| K3| 193 | 193 | 194 | 194 | 195 | 197 | 200 | 201 | 205 | 204 | 208 | 209 | 210 | 210 | 210 |
| K4| 344 | 346 | 344 | 339 | 340 | 345 | 346 | 348 | 349 | 350 | 350 | 355 | 356 | 355 | 357 |
| K5| 712 | 720 | 745 | 748 | 749 | 752 | 751 | 755 | 758 | 758 | 757 | 760 | 761 | 761 | 762 |
| K6| 831 | 845 | 855 | 858 | 859 | 864 | 865 | 872 | 871 | 875 | 875 | 879 | 880 | 885 | 888 |

The conducted correlation analysis between the duration of the experiment and the content of potassium has proved a strong positive correlation. Day 1. was an exception, as a moderate negative correlation was observed, see table 4.
4. Conclusions
The conducted research has confirmed that the implementation of the laboratory bioreactor type SBR enabled to recreate conditions of the bioreactors treating municipal wastewater via a method of activated sludge. Facilitated also co-treatment of polymer-potassium drilling fluids.

On the basis of the analysis of the results, conclusions that introduction into bioreactors of diverse doses of drilling fluids influences the content of potassium were made. The age of activated sludge also had an impact on the obtained results. Together with an increase in the addition of drilling fluid, as well as in the duration of the experiment, increased the content of potassium.

Sludges are characterised by very good physical features and relatively high content of basic nutrients. The increase in the content of potassium additionally improves those properties. Concerning the fertilisation process, they may be used in agriculture however, the basic restriction in their usage may be an excess content of heavy metals, which may significantly restrain or even completely prevent their usage in relation to their susceptibility to bioaccumulation.

References
[1] Bodik I, Kratochwil K, Herdova B, Tapia G and Gasparikova E 2002 Municipal wastewater treatment in the anaerobic-aerobic baffled filter at ambient temperature. Wat. Sci. Tech. 46(8) pp 127-135
[2] Kujawska J and Wojcik Oliveira K 2020 Ecotoxicological assessment of the soilfertilized with sewage sludge Present Environment and Sustainable Development 2020 14(1) pp 131-146
[3] Drewnowski J, Remiszewska-Skwarek A, Duda S and Łagó G 2019 Aeration Process in Bioreactors as the Main Energy Consumer in a Wastewater Treatment Plant. Review of Solutions and Methods of Process Optimization Processes 7(5) p. 311 doi:10.3390/pr7050311
[4] Brucculera M, Bolzonella D, Battistoni P and Cecchi F 2005 Treatment of mixed municipal and winery wastewaters in a conventional activated sludge process: a case study Wat. Sci. Tech. 51 (1) pp 89-98
[5] Czechowska-Kosacka A, Cel W, Kujawska J and Wróbel K Alternative fuel production based on sewage sludge generated in the municipal wastewater treatment 2015 Rocz Ochr Sr. 17(1) p 24
[6] Babko R, Jaromin-Gleń K, Łagód G, Pawłowska M and Pawłowski A 2014 Effect of drilling mud addition on activated sludge and processes in sequencing batch reactors Desalin Water Treat 57(3) 1490-1498 doi: 10.1080/19443994.2015.1033137

[7] Babko R, Jaromin-Gleń K, Łagód G, Danko Y, Kuzmina T, Pawłowska M and Pawłowski A 2017 Short-term Influence of Two Types of Drilling Fluids on Wastewater Treatment Rate and Eukaryotic Organisms of Activated Sludge in Sequencing Batch Reactors J. Environ. Qual. 46(4) pp 714-721

[8] Szwedziak K and Woźniak A 2005 Wpływ nawożenia osadem czynnym na przyrost biomasy grochu Infrastruktura i ekologia terenów wiejskich 2005 2 pp 113-119

[9] Franz M 2008 Phosphate fertilizer from sewage sludge ash (SSA) Waste Manag 28(10) pp. 1809-1818 doi: 10.1016/j.wasman.2007.08.011

[10] Pescod M B 1992 Wastewater treatment and use in agriculture Food and Agriculture Organization of the United Nations p 125

[11] Kandiah A 1990 Water quality management for sustainable agricultural development Nat. Resour. Forum 14 (1) pp. 22-32

[12] Kujawska J and Pawłowska M 2018 Effects of soil-like materials mix from drill cuttings, sewage sludge and sawdust on the growth of Trifolium pratense L. and transfer of heavy metals J. Ecol. Eng. 19 pp 225-230

[13] Maćkowiak C and Igras J 2005 Skład chemiczny osadów ściekowych i odpadów przemysłu spożywczego o znaczeniu nawozowym Inżynieria Ekologiczna 10 pp 70-77

[14] Grobelak A, Stepień W and Kacprzak M 2016 Osady ściekowe jako składnik nawozów i substytutów gleb Inżynieria Ekologiczna 48 pp 52-60

[15] Kulikowska D and Bilicka K 2009 Analiza przemian materii biologicznej i związków azotu podczas kompostowania osadów ściekowych Czasopismo techniczne. Środowisko 11 pp 101-110