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CHANGES IN SLUDGE QUALITY AT THE WATER TREATMENT PLANTS

JAKOŚĆ OSADÓW POWSTAJĄCYCH W PROCESACH UZDATNIANIA WODY

A b s t r a c t

This paper presents the variability of the quantity and specific composition of the sludge produced at two different surface water treatment plants – the Raba water treatment plant (WTP), collecting water from an artificial reservoir; and the Rudawa WTP, collecting running surface water. The authors analyzed the differences in the amount and characteristics of sludge and tried to relate them to specific technological systems in use at the treatment plants. The paper mainly focuses on heavy metals removed from the water and then trapped in the sludge. The aim of the work was to describe changes that involved both the quantity of sludge and its characteristics, especially with respect to its further disposal (e.g. heavy metals, etc.). Additionally, some aspects of an activated carbon dosing regime and its impact on a heavy metal content in sludge were discussed.

Keywords: *sludge processing*, *water treatment*, *sludge disposal*, *sustainable development*

S t r e s z c z e n i e

Artykuł przedstawia zagadnienia zmienności ilości i specyficznego składu osadów powstających przy uzdatnianiu wody powierzchniowej na przykładzie dwóch Zakładów Uzdatniania Wody: ZUW Raba pobierającego wodę ze zbiornika i ZUW Rudawa pobierającego wodę z rzeki. Analizowano różnice w ilości i specyfice osadów w powiązaniu z układami technologicznymi porównywanych Zakładów Uzdatniania Wody. Szczególną uwagę zwrócono na metale ciężkie usunięte z wody, a następnie zatrzymane w osadzie. Rezultatem prac było określenie zmian, które dotyczyły zarówno ilości osadu, jak i jego charakterystyki, szczególnie w zakresie czynników warunkujących jego dalsze zagospodarowanie (np. zawartość metali ciężkich). Wykazano także wpływ sposobu dawkowania węgla aktywnego na zawartość metali ciężkich w osadzie.

Słowa kluczowe: *przeróbka osadów*, *uzdatnianie wody*, *zagospodarowanie osadów*, *zrównoważony rozwój*

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1. Introduction

Changes in Polish legislation after accession to the European Union stipulated the reorientation of views on the operation of water treatment plants, particularly on issues related to the quality of the sludge produced at the water treatment plants and methods for its processing [3–5]. The higher efficiency of pollutant removal, accompanied by the more stringent requirements placed on methods of disposal of the final sludge, forced the majority of the existing water treatment plants to upgrade sludge processing lines. The demand for sustainable development in municipalities, which has been launched on a global scale, includes great interest in the proper processing of sludge [10, 11]. The main goal of this study was to check whether sludge origin has an impact on its final handling at the water treatment plant, with a special emphasis on heavy metal content in the sludge. The water treatment plants (WTPs) described in the paper serve a community of approx. 1 million inhabitants. The article presents the problem of variability in the composition of the sludge produced by two surface water treatment plants – the Raba WTP, withdrawing water from the water reservoir; and the Rudawa WTP, collecting water from the river. The aim of the work was to determine seasonal changes in both sludge quantity and its characteristics, especially in terms of the factors determining its further disposal, i.e. a heavy metal content. Additionally, the authors determined an impact of the way activated carbon is dosed on the heavy metal content in sludge [8, 12].

The production of drinking water is usually carried out through the coagulation of water with hydrolyzing metal salts such as aluminum sulfate (‘alum’) or ferric chloride (‘ferric’). This process is effective at removing turbidity, color, and micro-organisms, but it also results in a waste by-product, such as the coagulant precipitates and particles aggregated together in the form of ‘flocs’. They settle in a form of sludge that can be thickened, centrifuged or filtered prior to its ultimate disposal; these dewatering procedures reduce the final volume of the waste stream. Since the mid-1950s, activated carbon has been widely introduced into water treatment technology to improve water taste and remove odour.

Removal of solid aggregates from water is influenced by numerous factors, including structural configuration, a density difference between solid and liquid phases, as well as the use of dewatering mechanisms. However, from an operational perspective, it is useful to understand how such practical parameters as a coagulant dose and the process pH affect dewatering performance, or sludge ‘dewaterability’. A phenomenological theory developed by Landman, White et al. provides a rigorous approach to modeling the dewatering behaviour of compressible materials, and has been adopted to model various dewatering unit operations [2, 6, 7]. Selection of the right sludge treatment process has now become one of the most important operational problems, this has an adverse impact on the financial situation of water utilities. The continuous demand for higher water quality results in the production of larger amounts of sludge (both by volume and dry weight) as a waste product of the treatment process. As the sludge mass is the difference between the mass of solid particles in ‘raw’ and ‘tap’ water, the better removal of finest suspensions of microorganisms from water resulted in a higher content (concentration) of the organic substances in sludge and worsened its susceptibility to conventional dewatering on plots, forcing new technologies such as mechanical dewatering on belt filter presses [1, 8, 9].

2. Sludge processing at the two reference water treatment plants

The methods of sludge treatment and final disposal at WTPs usually depend on the chemical and biological composition of treated water, the technical and technological potential of WTPs, as well as economic (e.g. capital and operating costs) and field (land area designated for the facility) conditions. In the case of the reference WTPs, both the water quality and the capacity of the plants were decisive factors. The Raba WTP is the larger of the two reference plants and its nominal capacity is 186,000 m^3/d. The plant collects water from the water reservoir – the Dobczyckie lake. There are two different types of sludge produced in two main treatment lines [1]; the slight differences between them are described in detail below.

Sludge from the older treatment train (in operation since the early 1970s, including basic physical and chemical processes such as coagulation, sedimentation + rapid anthracite/sand filters '+') was collected:

- periodically, from the bottom of the rectangular clarifiers (every few days),
- daily, after the rapid backwashing of filters.

Water treated in the second train (in operation from late 1980s, with coagulation/sedimentation in suspended sludge flocculators-clarifiers i.e. accelators, ozonation and filtration using dual media filters) has the sludge discharged [1, 12]:

- periodically (every few hours), from 'accelators',
- incidentally, after ozonation chambers,
- daily, after rapid dual media filters backwashing.

The sludge passes to one of six gravity thickeners and is then pumped to the sludge drying beds (covered). Sludge thickeners are oversized, as for the actual needs. This is a typical situation found at the many Polish water treatment plants built before 1990, planned and designed for the large water consumption expected in future. The thickeners, although designed as continuous flow reactors, are operated in sequence. The plant is specific since it draws water from the water reservoir, which results in a relative reduction in the mass of pollutants (due to sedimentation in the reservoir). On the other hand, the plant has to dose powdered activated carbon to maintain the required odour and water taste.

The other unit, the Rudawa WTP, with a capacity of 55,000 m^3/d) produces three types of sludge:

- solids after sand filter backwashing, discharged daily,
- solids after carbon filters backwashing, discharged once per fortnight,
- solids from rinsing clarifiers, rapid mixing chambers and flocculation chambers, discharged about twice per year.

All types of sludge are pretreated in sludge sedimentation tanks (thickeners) after being mixed with rainwater and then the supernatant is discharged directly into the Rudawa river (as specified in the water permit). The common issue for both WTPs is a very heavy traffic in the catchments above the water intakes, which, in spite of the safety devices, always poses a risk of water contamination by heavy metals. However, as was demonstrated in previous research, the concentrations of the metals in both raw and treated water did not exceed the limiting values [1, 8].

3. Changes in sludge quality at the Raba WTP

The Raba WTP produces water at a relatively constant rate; its monthly average flow rate is about 2.9 million (about 95,000 m^3/day), with the extreme monthly values ranging from 2.5 to 3.4 million m^3. The research focused on the sludge quality and the presence of heavy metals, which is the most important issue regarding its future handling and disposal. The results of these studies are shown in Tab. 1. The values exceeding the limits for the use of sludge for both agricultural and non-agricultural purposes, as specified in the Regulation of the Minister of the Environment of 1 August, 2002 on municipal sewage sludge, were bolded [13].

Table 1

Sludge produced at the Raba Water Treatment Plant from years 2010 to 2013

Metal	Unit	Agriculture	Non--agriculture	Results						
				20.08.2010	02.11.2010	11.04.2011	11.10.2011	12.04.2012	08.10.2012	04.03.2013
Chromium	mg/kg DS	500	100	90	**113**	**110**	58	**199**	**120**	20
Cadmium	mg/kg DS	10	25	4.0	< 3	< 3	< 2.2	< 2.4	6	2
Copper	mg/kg DS	800	1,200	65	85	82	89	128	75	161
Nickel	mg/kg DS	100	200	83	99	86	67	**212**	68	**151**
Lead	mg/kg DS	500	1,000	36	56	27	31	27	104	27
Mercure	mg/kg DS	5	10	< 0.5	< 0.5	0.5	< 0.4	< 0.5	4.2	< 0.4
Zinc	mg/kg DS	2,500	3,500	158	179	182	146	354	182	211

Table 2

Sludge from the Raba Water Treatment Plant and the possibility of its final disposal

Metal	Percentage of tests meeting the requirements to use		The ratio of the metal content in the most contaminated sample to the least contaminated sample
	Agriculture	Non--agriculture	
Chromium	100%	43%	10 : 1
Cadmium	100%	100%	3 : 1
Copper	100%	100%	2.5 : 1
Nickel	100%	71%	3.9 : 1
Lead	100%	100%	3.9 : 1
Mercure	100%	100%	10 : 1
Zinc	100%	100%	2.2 : 1

Table 2 shows results of tests on heavy metals content in sludge, as an important factor influencing potential sludge disposal methods. The last column of this table underlines the issue of relative variability of heavy metals in sludge; the lowest concentrations were compared with the highest values found in the samples. The authors also tried to determine whether, and to what extent, the sludge meets the requirements of the final natural application (by specifying the percentage of allowable metal content found in the worst sample). It should be noted that due to the high content of chromium and nickel, some samples did not meet the requirements of the regulations of the Minister of Environment of 1 August, 2002 on municipal sewage sludge [13].

4. Changes in sludge quality at the Rudawa WTP

The amount of sludge produced in the Rudawa WTP was clearly smaller than in the other treatment plant due to both the lower water production of the plant and because of its higher quality of raw water. The study on heavy metals in sludge collected in clarifiers was conducted once or twice a year. The results of these tests are included in Tab. 3. It was observed that all samples met the requirements for sludge applied to the land application and/or for agricultural purposes. The quality of the sludge was clearly better than at the Raba WTP.

Table 3

Sludge from the water clarifiers at the Rudawa Water Treatment Plant for the years 2008–2012

Metal	Unit	Year				
		2008	2009	2010	2011	2012
Chromium	mg/kg DS	17	7.4	10.4	23	21
Cadmium	mg/kg DS	4.5	3.7	3.7	68	6
Copper	mg/kg DS	28	40	22	32	27
Nickel	mg/kg DS	14	18	19	28	21
Lead	mg/kg DS	78	64	64	69	89
Mercure	mg/kg DS	0	0.11	0.13	0.5	0.5
Zinc	mg/kg DS	668	554	570	560	456

In Fig. 1, the average and the maximum values observed in the analyzed period in sludge from both plants were compared. One can find the clear impact of a type of activated carbon used on heavy metal content in sludge. The metals that are effectively adsorbed on activated carbon are captured within a sludge mass; in the case of granular carbon, they are retained in the carbon bed volume [4] and do not become a component of the process sludge reported in Fig. 1 and Tab. 3.

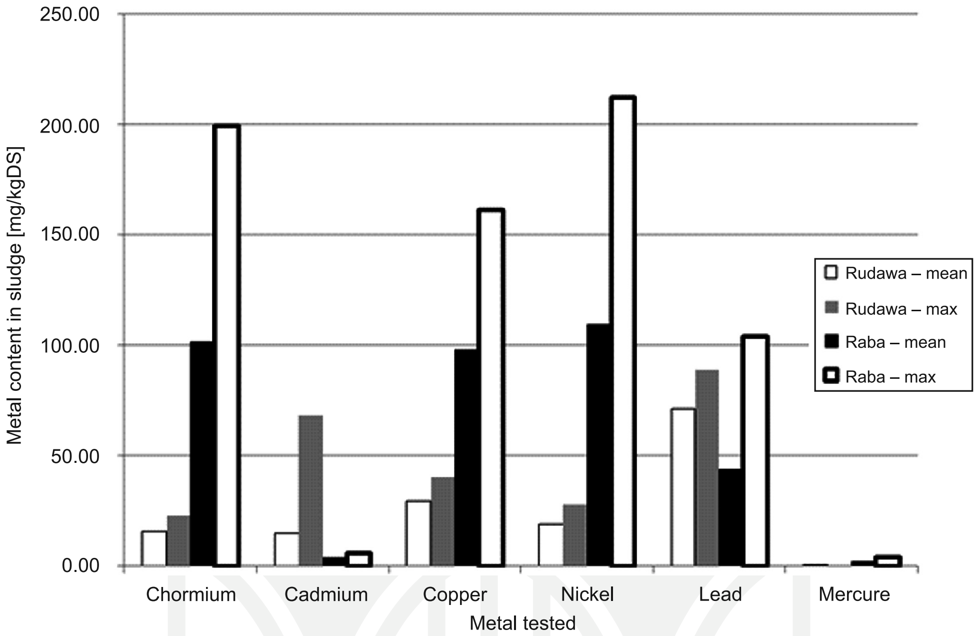

Fig. 1. Average and maximum concentrations of heavy metals in sludge from both water treatment plants during the study period

Metals with a low activated carbon removal efficiency (e.g., cadmium) are mainly removed by coagulation/sedimentation and thus, they are present in the post-coagulation sludge (the high content in the sludge from the Rudawa WTP). This phenomena requires further investigations.

5. Conclusions

- The paper analyzed sludge produced at two surface water treatment plants, treating water of similar quality but with different treatment technologies.
- In terms of heavy metals, none of the water samples tested in the years 2008–2013 exceeded the limiting values. Also, no increase in the concentration of these specific contaminants was observed in sludge during the treatment process, although in one WTP, the heavy metal content in sludge was too high to permit its use for land reclamation.
- The observed differences in the heavy metal content in sludge can be explained by the different forms of activated carbon applied; in the case of powdered activated carbon, heavy metals become components of the sludge, worsening its composition.

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