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THE INFLUENCE OF SEWAGE SLUDGE PROCESSING IN WASTEWATER TREATMENT PLANT ON THE HEAVY METALS CONTENTS

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Abstract

This paper presents results of metals content analysis in sewage sludge from Kędzierzyn-Koźle wastewater treatment plant. The aim of this study was to determine metals contents in the following stages of sludge treatment process. Quantitative analysis of metals concentration in the sludge system is an important information for technologists about the preferable direction of sludge management. Sewage sludge samples were taken at five processing stages. The analysis was carried out by means of atomic absorption spectrometry technique (AAS). The average content of Na, K, Ca, Mg in each sampling points ranged from 24999.2 mg/kg$_{TS}$ to 41815.6 mg/kg$_{TS}$, whereas for heavy metals Cd, Pb, Ni, Zn, Cu total contents ranged from 894.5 mg/kg$_{TS}$ to 2191.2 mg/kg$_{TS}$. The highest concentration of metals was detected in primary settling tank and the lowest after dewatering process. Cr and Hg concentrations were below the detection limit. The concentration of trace elements in stabilized sludge did not exceed the limit values for heavy metals defined in the Regulation of the Minister of the Environment concerning municipal sewage sludge of 13th August 2010.

Streszczenie

W pracy przedstawiono wyniki badań zawartości metali w osadach ściekowych pochodzących z oczyszczalni ścieków w Kędzierzynie-Koźlu. Celem pracy było określenie zawartości metali na kolejnych punktach przeróbki osadów ściekowych. Analiza ilościowa stężeń metali w ciągu przeróbki osadów jest istotną informacją dla technologów w kontekście kierunku ich zagospodarowania. Osady pobierano z pięciu etapów procesu przeróbki. Oznaczenia wykonano techniką absorpcyjnej spektrometrii atomowej (AAS). Całkowita zawartość Na, K, Ca i Mg w poszczególnych punktach poboru osadów wahała się w zakresie 24999.2 mg/kg$_{sm}$ do 41815.6 mg/kg$_{sm}$, natomiast w przypadku metali ciężkich Cd, Pb, Ni, Zn, Cu wartości te były na poziomie 894.5 mg/kg$_{sm}$ do 2191.2 mg/kg$_{sm}$. Stężenia chromu i rtęci były poniżej granicy detekcji. Największe zawartości metali ciężkich odnotowano w osadniku wstępnym, natomiast najniższą po procesie odwadniania. Stężenie metali ciężkich w osadzie ustabilizowanym nie przekroczyło wartości dopuszczalnych określonych w Rozporządzeniu Ministra Środowiska w sprawie komunalnych osadów ściekowych z 13 sierpnia 2010 r.

Keywords: **Sewage sludge; Metals; Kędzierzyn-Koźle Treatment Plant.**

1. INTRODUCTION

Wastewater treatment is invariably connected with the formation of sewage sludge, which constitute both the primary sludge (originate from sedimentation of suspended solids in the primary settler tank) and excessive one (from biological processes) [5,14]. Together, they form raw organic sludge [5,8].

Heavy metals contents in sewage sludge constitute a significant problem in terms of its processing and management [8,3,10]. The occurrence of heavy metals in sludge is mainly due to the share of industrial wastewater in total wastewater load. Domestic sewage, surface run-off and sewer system corrosion could be also a source of metals [7]. Heavy metals are characterized by a long environmental persistence, mobility and

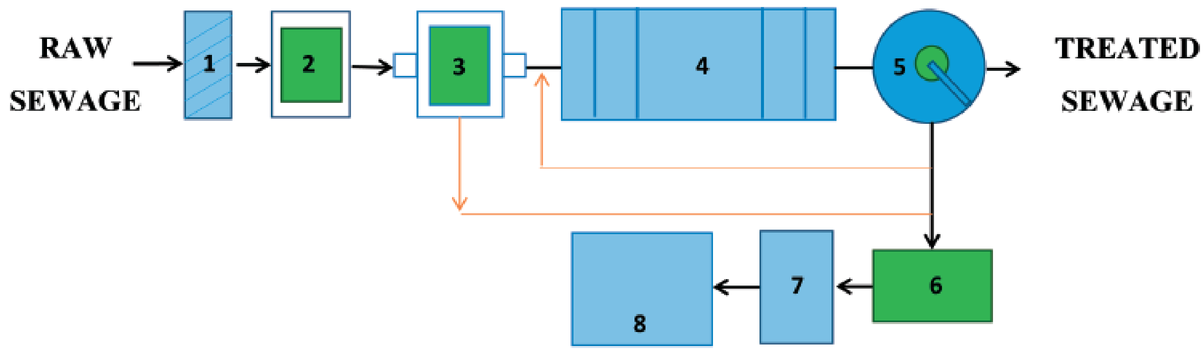

Figure 1.
Kędzierzyn-Koźle Wastewater Treatment Plant scheme

bioaccessibility for organisms [13]. In addition, there is a risk of metals migration from sludge into ground and surface water environment [10]. Sewage sludge contains heavy metals, which are not degraded during wastewater treatment. Metals which occur as a free ions in the sewage matrix, pass easily through the treatment devices and leave the line discharged with treated sewage (concentration similar to that in the influent), posing a threat to a surface waters. However, if heavy metals are strongly adsorbed onto sludge or complexed by suspended solids or forms soluble salts in the sewage, it will be removed with primary and secondary sludge. This phenomenon may contribute to the inhibition of the fermentation process, and thus eliminate the sewage sludge from agricultural disposal [4].

Acceptable content of heavy metals in sewage sludge is defined in the Regulation of the Minister of the Environment concerning municipal sewage sludge of 13th August 2010 [17]. In accordance with annex 4a to the Regulation of the Minister of Economy of 12th June 2007, from 1st January 2013 the storage of sewage sludge, which don't meet the criteria listed above, will be prohibited [16]. In 2004-2007, the amount of sludge produced in Kędzierzyn-Koźle city was approximately 2500 Mg_{TS}/year. It is estimated that within a year the amount of sludge will increase by 2.5%. The preferred management strategy for such large amount of sewage sludge in Kędzierzyn-Koźle community will be its natural disposal [15].

2. AIMS AND METHODS

2.1. Aims of the study

1. Estimating changes in selected heavy metal contents in sewage sludge from different processing stages.
2. Determining sewage sludge suitability for agricultural purposes.

2.2. Methods

For the analysis purposes Kędzierzyn-Koźle wastewater treatment plant (WWTP) based on Bardenpho system was selected. The average throughput in WWTP is Q = 16 000 m^3/d with population equivalent (PE) of 50250. Samples were collected from sludge sampled at five specified positions in the technological line: primary settling tank (3), secondary

Table 1.
Characteristics of raw sewage from Kędzierzyn-Koźle WWTP

parameter	raw sewage [mg/l]	treated sewage [mg/l]
COD	1023	32
BOD_5	640	5
Phosphates	-	0
$N\text{-}NH_4$	61.75	1.9
N_{TOT}	119	7
P_{TOT}	12	0.1
Suspended Solids	332	7

COD – Chemical Oxygen Demand,; BOD_5 – Biochemical Oxygen Demand,; $N\text{-}NH_4$ – Ammonium Nitrogen; N_{TOT} – Total Nitrogen; P_{TOT} – Total Phosphorus
(*) Data obtained from Kędzierzyn-Koźle WWTP

Table 2.
Characteristics of sewage sludge from Kędzierzyn-Koźle WWTP

parameter	unit	*WWTP mean value from 3 months	sampling place				
			primary settling tank	secondary settling tank	mechanical thickener	fermentation chamber	dewatering press
total solids (TS)	%	22.7	2.7	1.5	10.1	5.6	15.3
Na	mg/kg_{TS}	-	1392.2	2650.2	6987.4	5674.4	2341.1
K	mg/kg_{TS}	-	1392.2	2650.2	6987.4	5674.4	2341.1
Ca	mg/kg_{TS}	-	27531.0	11955.5	14171.9	19358.1	18475.5
Mg	mg/kg_{TS}	-	5955.8	8802.1	9085.1	2708.3	2879.6
Zn	mg/kg_{TS}	1516.0	1877.1	1191.8	1176.4	1019.2	751.6
Cu	mg/kg_{TS}	179.7	249.2	164.5	157.1	122.5	115.9
Cd	mg/kg_{TS}	1.5	2.7	2.0	1.8	1.4	1.4
Ni	mg/kg_{TS}	44.6	33.8	21.1	20.0	16.5	12.2
Pb	mg/kg_{TS}	27.3	28.4	18.5	15.8	15.4	13.3
Hg**	mg/kg_{TS}	0.6	-	-	-	-	-
Cr**	mg/kg_{TS}	65.3	-	-	-	-	-

(*) Data obtained from Kędzierzyn-Koźle WWTP
(**) under detection limit

settling tank (5), mechanical thickener (6), fermentation chamber (7) and dewatering press (8) (Fig. 1).

The content of selected elements: cadmium, copper, nickel, lead, zinc, chromium, mercury, magnesium, sodium, potassium and calcium, were determined in sludge samples.

Preparation of samples for analyses included drying to constant weight (105°C) and milling to obtain the analytical grain (RETSCH S1000 mill). Subsequently samples were subjected to mineralization. For this purpose 0.15 g of the sludge was weighted into PTFE vessels and 3 cm^3 of concentrated HNO_3 was added. After that acid was evaporated on a hotplate and samples were treated by 3 cm^3 of 65% HNO_3 addition. The sludge samples were mineralized in Milestone MLS 1200 MEGA microwave oven for 8 minutes with the power of 1000 W. In the mineralized samples metals content was measured by flame atomic absorption spectrometry (AAS) technique, using SpectrAA 880 apparatus (Varian). Cold vapor technique (CV-AAS) was used to determine the amount of mercury content. All analyses were performed in duplicate.

3. RESULTS AND DISCUTION

The study presents the results of metals contents analysis in sewage sludge from Kędzierzyn-Koźle WWTP. The characteristic of raw and treated sewage is presented in Table 1, and indicate its municipal origin. Treated sewage meets the criteria included in the Regulation of the Minister of the Environment of 28th January 2009 amending Regulation on the conditions to be met by the introduction of sewage into the water or soil, and on substances that are particularly harmful to the aquatic environment [18]. The concentration of metals in sludge samples from the subsequent stages of the processing line was calculated in relation to total solids (TS) content (Tab. 2). Obtained results revealed the considerable variation in the sludge solids contents, ranged from 1.5% to 15.3% with the highest concentration in the dewatered sludge.

The total amount of heavy metals in the analyzed sludge ranged from 2.6-4.3$\%_{TS}$, while usually this value varies between 0.5-4$\%_{TS}$ [2]. The concentrations of individual metals in the examined sludge was respectively: cadmium – 1.4-2.7; copper – 115.9-249.2; nickel – 12.2-33.8; lead – 13.3-28.5; zinc – 751.6-1877; magnesium – 2708.3-9085.1; sodium – 1392.2-6987.5; potassium – 11571.2-5412.0; calcium – 14171.9-27531.0 mg/kg_{TS}. Shirivastava and

Benerjee (2004) found that the hypothetical trend in the contents of individual metals in sewage sludge can be arranged as follows Zn>Cu>Cr>Ni>Pb>Cd. Similar trend was found in studied sludge: Zn>Cu>Ni>Pb>Cd. The content of heavy metals at different processing stages was: primary settling tank – Zn>Cu>Ni>Pb>Cd, secondary settling tank – Zn>Cu>Ni>Pb>Cd; mechanical thickener – Zn>Cu>Ni>Pb>Cd; fermentation chamber – Zn>Cu>Ni>Pb>Cd; dewatering press – Zn>Cu>Pb>Ni>Cd. There were a significant differences in heavy metals concentrations between different sampling points. The highest concentration of heavy metals occurred in sewage sludge from the primary settling tank, while the lowest was marked in dewatered sludge. However, in case of main components different tendency was observed, the highest content was detected in thickened sludge and the lowest after dewatering process. The difference in metals concentration between those points was for main components 49% and for trace elements 59%. Heavy metals reduction degree between the first and last sampling points amounted to: Zn – 40%; Cu – 47%; Cd – 53%; Ni – 36%; Pb – 47%. The obtained results are within the ranges reported for sewage sludge from activated sludge systems and show similar tendency in comparison to the WWTP Kędzierzyn-Koźle data (Tab. 2) [9].

The highest concentration of total solids was measured in mechanically thickened sludge and dehydrated one. Despite the increase of TS in thickened sludge, a decrease in heavy metals content was observed. Metals content in excess sludge was slightly higher compared to concentrated one. This pattern was probably due to the migration of metals to sludge liquid, which may contribute to biological processes inhibition (metals load recirculation with sludge liquid). A similar phenomenon was observed by Sorys et al. Zielewicz-Madej (2003) and Szymański et al. (2011).

Despite the increase in total solids amount after mechanical thickening the decrease in heavy metals content in relation to the excess sludge was observed. Probably it was connected with the low metals adsorption degree on sludge particles. Same decline in metals concentration in the following processing stages was observed. This situation may lead to the fermentation disruption due to increase in heavy metals load. Generally heavy metals load at single sampling positions didn't change much, although the total solids (TS) contents between primary settling tank and dewatering press increased by about 12%.

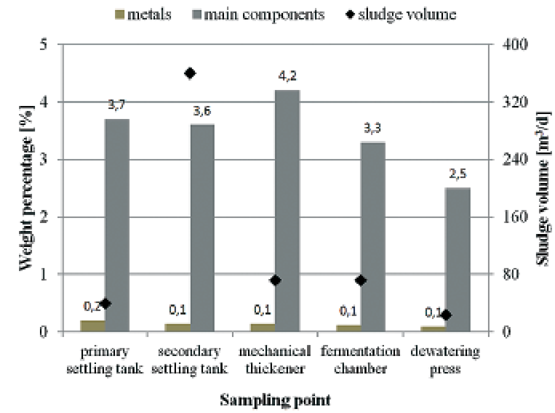

Figure 2.
Metal and main components mass percentage in sludge at single sampling positions

Figure 2 presents the percentage contents of metals and main components in the total mass of sludge at following sludge processing stages. The concentration of given components varied between single sampling points in low ranges. The highest content of metals was observed in thickened sludge. Considering the direction of agricultural sludge disposal, the knowledge about the presence of main components in sludge is extremely important, since those components are necessary for plant growth. However, the contents of those is not regulated by law.

The content of heavy metals in sewage sludge does not exceed the limit values defined in the Regulation of the Minister of the Environment considering municipal sewage sludge of 13th August 2010 [17]. Therefore, analyzed sludge could be used for environmental purposes i.e. in agriculture and land recultivation. Apart from quantitative metals contents in sewage sludge very important is to establish chemical and physical form of its occurrence in soil and water environment by speciation analysis [1,12,13]. Specifying chemical form of metals indirectly allows to examine their mobility from sludge to soil-water environment [7].

Based on the extensive investigations, it must be emphasized that in order to achieve a higher quality of stabilized sludge the systematic study of sewage sludge characteristic at different processing stages is necessary. Such proceedings allow to exclude mistakes made by the technologists. Moreover, proper monitoring and regular examination of sludge avoid exceeding the permissible levels of heavy metals contents. It minimalizes the risk of soil, surface and ground water secondary contamination.

5. CONCLUSIONS

Based on performed study, it was found that heavy metals content in sludge from the wastewater treatment plant in Kędzierzyn-Koźle don't exceed the limit values defined in the Regulation of the Minister of the Environment on municipal sewage sludge of 13th August 2010 and therefore it can be environmentally utilized [17]. The highest concentration of heavy metals was observed in sludge from the primary settling tank, which was related to the influent composition. In performed study it was found that due to migration of heavy metals to the liquid, its concentration in the sludge at different processing stages decreases. Generally Na, K, Ca and Mg concentration in analyzed sludge was high, which can be treated as positive phenomenon in terms of sewage sludge agricultural disposal.

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