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ASSESSMENT OF AGRICULTURAL UTILIZATION OF BOTTOM SEDIMENTS FROM THE BESKO RESERVOIR

OCENA ROLNICZEGO WYKORZYSTANIA OSADÓW DENNYCH ZBIORNIKA BESKO

Abstract

The research aimed at an assessment of physical and chemical properties of bottom sediments of the Besko reservoir located on the river Wisłok (Świętokrzyskie Voivodeship) for their agricultural applications. Studied bottom sediment revealed a considerable proportion of clay fractions in its composition, alkaline reaction, good sorption and buffering properties, therefore it may be used as a supplement to light acid soils to improve their productivity. While using the bottom sediment for plant cultivation, supplementary mineral fertilization should be applied because of its low content of nitrogen, phosphorus and potassium. Slightly elevated concentrations of some heavy metals do not prevent agricultural management of the sediment taken from strongly shallowed zones of the reservoir.

Keywords: bottom sediment, chemical composition, light soil

Streszczenie

Celem badań była ocena fizycznych i chemicznych właściwości osadów dennych zbiornika Besko zlokalizowanego na rzece Wisłok (województwo świętokrzyskie) pod względem ich rolniczego wykorzystania. Badany osad denny w swoim składzie wykazuje duży udział frakcji ilastych, zasadowy odczyn, dobre właściwości sorpcyjne i buforowe, zatem może być stosowany jako dodatek do gleb lekkich, kwaśnych w celu poprawy ich produkcyjności. Wykorzystując osad denny w uprawie roślin, należy zastosować uzupełniające nawożenie mineralne z powodu niskiej zawartości w nim azotu, fosforu i potasu. Nieznacznie podwyższone wartości niektórych metali ciężkich nie eliminują rolniczego zagospodarowania osadu wydobytego z silnie wypłyconych stref zbiornika.

Słowa kluczowe: osad denny, skład chemiczny, gleby lekkie

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1. Introduction

Chemical composition and properties of bottom deposits are shaped as a result of physical, chemical and biological processes occurring in a water reservoir and within its catchment, and are usually important indicators of anthropopressure. Therefore, the identification of bottom sediment chemical composition is important not only for an assessment of water reservoir degradation but also for determining potential applications of extracted deposit [12]. Bottom sediments are drawn in some countries from bottoms of rivers, retention reservoirs, channels, ports and ponds in order to maintain their navigability, increase their retention capacity and to improve recreational and aesthetic values. In pursuance of the ordinance of the Minister for the Natural Environment [13], bottom deposit (the output) is a waste marked with 1705 code, which requires appropriate management. If the material extracted from the bottom of silted water reservoir does not pose a hazard for the environment, the environmentally justified method of such sediment management is its use as a structure and soil forming material on soilless grounds and wastelands. Bottom sediments, particularly these revealing neutral or alkaline reaction and high contents of silt and clay fractions may be used for improving physicochemical properties of light and acid soils to improve their productivity [19]. On the other hand, Pelczar et al. [11] report that despite the high content of fertilizer substances, bottom deposits are unsuitable for agricultural application because of heavy metal contamination. These deposits should be used as a material for reclamation of mine waste landfills and fly ash disposal sites. Investigations on their potential environmental, including agricultural, applications were conducted among others by Fonseca et al. [3] and Baran et al. [2]. The research aimed at an assessment of physical and chemical properties of bottom sediments of the Besko reservoir located on the river Wisłok (Świętokrzyskie Voivodeship) for their agricultural applications.

2. Material and methods

The investigated material originated from the bottom of the Besko Reservoir situated on the Wisłok river in the Podkarpackie Voivodeship (Fig. 1). The reservoir was constructed in 1978 as a result of partitioning the river by means of a concrete dam located on a straight narrow stretch of the river in the shape of a deeply incised ravine. The Besko Reservoir is composed of two parts: the main one on the Wisłok river (capacity about 10M m^3) and the side part constructed on the inflowing Czernisławka stream (capacity ca. 3 M m^3). The main tasks of the reservoir comprise: water supply for the nearby water main, reduction of flood wave, power generation and levelling of low flows.

Field works comprised collecting samples of bottom sediments from the main part of the reservoir. The bottom sediment was sampled within the three zones of the reservoir: inlet, middle and outlet (close to the dam) (Fig. 1). The zones were selected according to intensive sedimentation in the widened parts of the reservoir. Properties of silts from the side part of the reservoir were described in the papers by Madeyski and Tarnawski [9, 10]. The samples were collected using Ekman's sampler. In order to average the material, 6 samples were taken from each of the above mentioned zones and mixed to form the final average sample. The sediment originated from the 0–15cm layer. In the air-dried

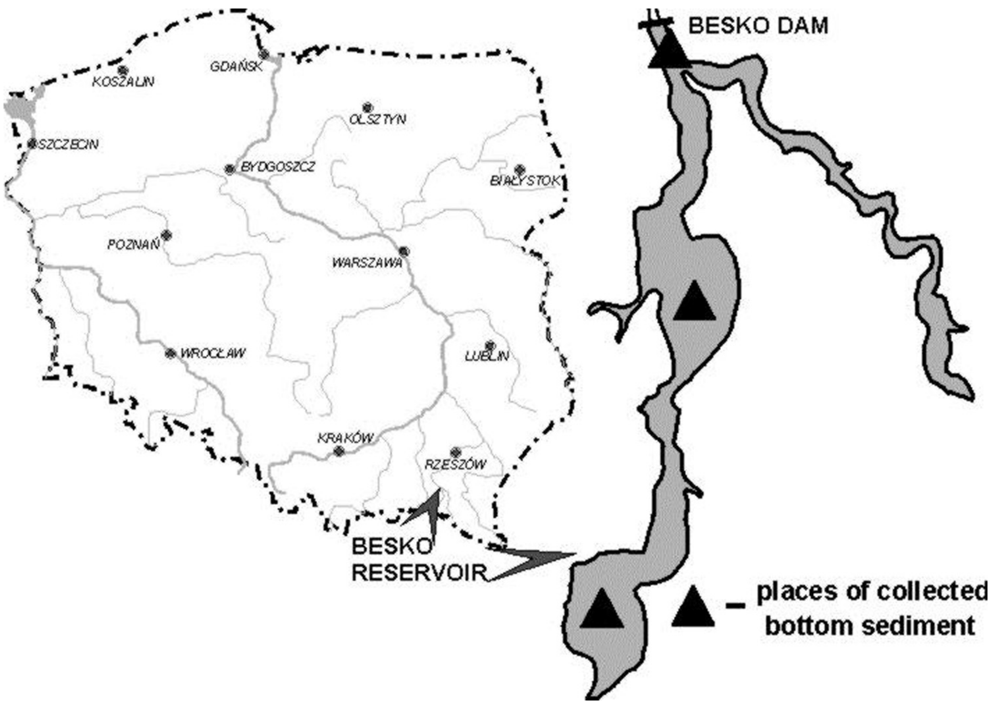

Fig. 1. Besko water reservoir with marked measuring cross sections and places of collected bottom sediment

Rys. 1. Lokalizacja zbiornika Besko i stref poboru prób osadów dennych

material granulometric composition was assessed using Casagrande's method modified by Prószyński and pH in 1 mol KCl · dm^{-3}. Subsequently the material was homogenized in an agate mortar and the following assessments were established: hydrolytic acidity and base exchange capacity (BEC) using Kapen's method, soil buffering, organic carbon content by Tiurin's method, total nitrogen by Kjeldahl's method, bioavailable phosphorus and potassium by Egner-Reihm's method. Total concentrations of trace elements (Zn, Cu, Ni, Cr, Pb, Cd, Fe and Mn) and their (Zn, Cu, Ni, Cr, Pb and Cd) forms soluble in 1 mol HCl· dm^{-3} were determined in the sediment samples. Total contents of the elements were assessed following their mineralization in the muffle furnace and subsequent mineralization in a mixture of HNO_3 and $HClO_4$ (3:2). Extraction of metal soluble forms from the sediments was conducted using static method by means of single shaking of the sediment samples with the solution at the sediment to solution ratio 1:10 and in the extraction time of one hour. Concentrations of the selected elements were determined in the obtained solutions by means of ISP-AES method on JY 238 ULTRACE Jobin Von Emission Apparatus. All laboratory analyses were conducted in 6 replications. Obtained results were elaborated statistically by computing arithmetic mean, standard deviation, minimum and maximum values and variability coefficients (V%).

3. Results

According to PN (Polish Standard) recommendations, the sediment collected from the Besko reservoir which contained a vast majority of floatable particles was classified to the group of clays (Table 1).

Table 1

Granulometric formation bottom sediment

Granulometric fractions and formation [%]				**Soil category [%] fractions < 0.02 mm**
1–0.1	0.1-0.02	<0.02	PN	
5	11	84	clay	Heavy > 35

Selected physicochemical properties were presented in Table 2. Generally a small diversification of the tested parameters was demonstrated, as evidenced by low values of variability coefficient. The studied bottom deposit revealed alkaline reaction, with pH ranging from 7.19 to 7.29 (Table 2). The investigations proved that the application of bottom deposits with alkaline or neutral pH may have a de-acidifying effect on the soil, it limits the toxic effect of heavy metals on plants and therefore may be a trap for heavy metals [2]. Cation exchange capacity (T) of the sediments was assessed on the basis of determined hydrolytic acidity Hh, base exchange capacity S and computed V%, i.e. base cation saturation (V = S/T ·100%) (Table 2). The value of hydrolytic acidity in the studied sediment ranged from 18.89 to 25.89 mmol (+) · kg^{-1}d.m.

The value S is an indicator of soil sorption capacity in relation to base cations and depends of granulation, organic matter content and hydrolytic acidity. The higher the acidity, the lower the share of base cations in soil sorption complex. In the bottom sediment from Besko the values of base exchange capacity (S) ranged from 201.78 to 235.78 mmol (+)· kg^{-1}d.m. (Tab. 2). Moreover, dominance of base cations (V% = 91%) was registered in the sorption complex. The high degree of base cation saturation of the examined sediment undoubtedly positively affects its buffering properties. In the light of the research conducted by Helios-Rybicka [4] buffer properties of sediments play a crucial role in heavy metal release. Buffering is the sediment ability to counteract changes of their pH under the influence of acids or bases. In the presented investigations the sediment buffering was assessed after adding to the sediment an appropriate amount of 0.1 mol · dm^{-3}HCl solution (2, 4, 6, 8 and 10 cm^3) and subsequent measurement of changes in pH value. Data presented in Fig. 2 show that the Besko bottom sediment has considerable buffering properties. A decrease in pH value in this sediment fell within the 2 to 10% range.

Table 2

Selected properties of bottom sediments

Parameters	pH	Hh[1]	S[2]	T[3]	V[4]	C	N	P_2O_5	K_2O
	KCl	[mmol · kg^{-1}]			[%]	[g · kg^{-1}]		[mg · kg^{-1}]	
Mean	7.25	21.28	227.61	248.89	91	18.2	1.40	8.85	106.77
SD	0.06	4.67	24.80	34.47	-	6.1	0.10	2.33	38.91
Minimum	7.19	18.89	201.78	218.67	-	11.40	1.30	7.24	62.30
Maximum	7.29	25.89	235.78	263.67	-	23.20	1.50	11.53	134.60
V%	1	22	11	14	-	34	7	26	36

[1]hydrolytic acidity, [2]base exchange capacity, [3] cation exchange capacity.

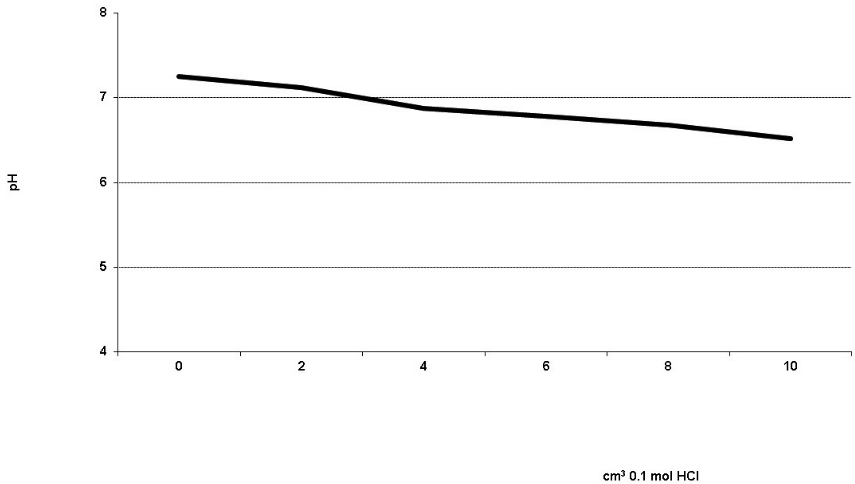

Fig. 2. Buffer properties of sediment

Rys. 2. Własciwości buforowe osadu

The content and quality of organic matter is an important characteristic of bottom sediments from the perspective of physicochemical conditions at the reservoir bottom. The main component of organic matter is organic carbon. Organic matter content in the studied sediment ranged from 11.40 to 23.20 g · kg^{-1}d.m. (Tab. 2). For comparison, sediments from the Chańcza reservoir contained on average 35.38 g C · kg^{-1}d.m. [17]. The tested sediments were characterized by a relatively low content of total nitrogen, which fell within a narrow range of 1.30 to 1.50 g N · kg^{-1}d.m. For comparison, in 2003 sediments from the Dobczyce reservoir (water intake for the city of Krakow) contained from 2.06 to 2.44 g · kg^{-1}d.m., from the Zesławice reservoir from 1.02 to 1.08 g; from the Chańcza reservoir 0.45–4.93 g, whereas from 1.5 to 19.5 g was assessed in the sediments from lakes in the Wielkopolski National Park, between 2.2 and 14.4 g in Długie Wielkie Lake and 12.4g · kg^{-1}d.m. in Gardno Lake [16-18]. C:N ratio describes the rate of organic matter mineralization. The lower the ratio, the higher the mineralization level. Moreover, as emphasized by Herczeg et al. [5] the value of C:N ratio in sediments may be an indicator of temporary changes in organic matter cycles in aquatic systems. Januszkiewicz [6], while investigating spatial composition of organic matter in bottom deposits, found that changes taking place there cause a much bigger loss of carbon than nitrogen. In the studied sediments the ratio of organic carbon content to total nitrogen C:N was 13. In the research conducted by other authors the C:N ratio fluctuated from 12.44 to 35.43 in the Krempna reservoir; from 12.85 to 15.34 in the Zesławice reservoir [7] and from 2 to 27.5 in the sediments from Długie Wielkie Lake [18]. The C:N ratio optimum for the microorganisms is 17, whereas its low values are the reason why in the process of microbiological decomposition of the sediment organic matter nitrogen is released into the depth of the water [15]. Very low concentrations of bioavailable phosphorus and potassium were registered in the tested sediment (Tab. 2).

Total concentrations of heavy metals in the studied bottom sediment ranged as follows: 69.20–180.30 mg Zn; 4.45–55.06 mg Cu; 9.80–88.05 mg Ni; 30.65–75.00 mg Cr; 0.05–1.55 mg Cd; 15.60–75.35 mg Pb; 1.68–47.95 g Fe; 0.02–1.10 g Mn $\cdot$ kg^{-1} d.m. (Tab. 3). With respect to their quantity heavy metals in the bottom sediment formed the following order Fe > Mn > Zn > Ni > Cr > Pb > Cu > Cd, whereas concerning the diversification, respectively Cd > Mn > Fe > Cu > Ni > Pb > Zn > Cr (Tab. 3).

Assessment of the quality of studied bottom sediments was based on the Decree of the Minister for the Natural Environment of 16 April 2002 on the kind and concentrations of substances which cause pollution of the output [13]. On the other hand, the way of studied sediment management was established on the basis of IUNG criterion [8] and the Decree of the Minister for the Natural Environment of 9 September 2002 on the standards of soil and earth standards [14]. In compliance with the above mentioned decrees heav y metal concentrations in the investigated sediments did not exceed their contents permissible for the output, for the soil or earth of group B. According to the IUNG classification distinguishing 6 degrees of soil classification regarding heavy metal content, considering the pH and granulometric composition, the studied sediment revealed an elevated content of Zn, Ni and Cr (1st degree).

Table 3

Total content of heavy metals in bottom sediment

Parameters	Zn	Cu	Ni	Cr	Cd	Pb	Fe	Mn
	[mg · kg^{-1}]						[g · kg^{-1}]	
Mean	116.20	30.64	49.67	55.23	0.80	41.65	25.97	0.60
SD	57.49	25.35	39.15	22.56	0.75	30.60	23.22	0.54
Minimum	69.20	4.45	9.80	30.65	0.05	15.60	1.68	0.02
Maximum	180.30	55.06	88.05	75.00	1.55	75.35	47.95	1.10
V%	49	83	79	41	94	73	89	91
IUNG	I	0	I	I	0	0	–	–
Norm[1]	<1000	<150	<75	<200	<7.5	<200	–	–
Norm[2]	300	150	100	150	4	100	–	–

[1]Dz. U. of 2002, no. 55, item 498, [2]Dz. U. of 2002, no. 165, item 1359.

Beside the general knowledge about the total heavy metal contents in the sediment it is also useful to know the contents of their readily soluble forms because of their potential mobilization from the solid phase and penetration into the aquatic environment. Moreover, the process of learning the element bioavailability is very important regarding a proper plant supply with these elements. Extraction of trace element bioavailable forms from the bottom sediment was conducted by means of the method using 1 mol HCl · dm^{-3}. Application of this test is a routine and commonly used method at agricultural chemistry stations and by IUNG for an assessment of soil concentrations of trace element available forms. Heavy metal solubility in 1 mol HCl · dm^{-3} reached the maximum value for Cd – 47% and the minimum for Cr which did not exceed 4% in relation to its total content (Fig. 3).

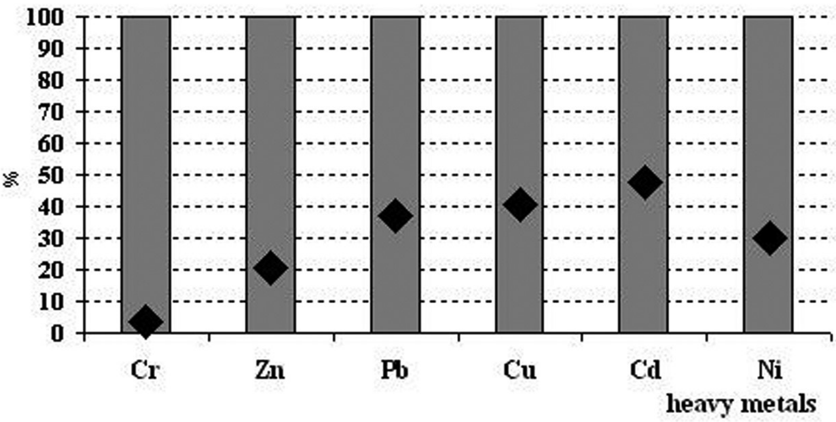

Fig. 3. Content of soluble forms in 1 mol HCl · dm^{-3} of heavy metals in bottom sediment

Rys. 3. Zawartość form rozpuszczalnych w 1 mol HCl metali ciężkich w osdzie dennym

Numerous investigations have shown that the sediment pH may affect heavy metal mobility in the environment [12]. The opinion prevails that metals may pass into less soluble forms at higher pH values [1]. In the presented research alkaline reaction of the sediments may affect a decrease in the solubility of most investigated elements.

4. Conclusions

1. Studied bottom sediment revealed a considerable proportion of clay fractions in its composition, alkaline reaction, good sorption and buffering properties, therefore it may be used as a supplement to light acid soils to improve their productivity.
2. While using the bottom sediment for plant cultivation, supplementary mineral fertilization should be applied because of its low content of nitrogen, phosphorus and potassium.
3. Slightly elevated concentrations of some heavy metals do not prevent agricultural management of the sediment taken from strongly shallowed zones of the reservoir.

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