INFRASTRUKTURA I EKOLOGIA TERENÓW WIEJSKICH
INFRASTRUCTURE AND ECOLOGY OF RURAL AREAS

Nr IV/1/2016, POLSKA AKADEMIA NAUK, Oddział w Krakowie, s. 1217–1228
Komisja Technicznej Infrastruktury Wsi

DOI: http://dx.medra.org/10.14597/infraeco.2016.4.1.089

AGRICULTURAL USE OF SEDIMENTS FROM NAROŻNIKI RESERVOIR – YIELD AND CONCENTRATION OF MACRONUTRIENTS AND TRACE ELEMENTS IN THE PLANT

Agnieszka Baran, Marek Tarnawski, Tomasz Koniarz, Czesława Jasiewicz
University of Agriculture in Krakow

Abstract

The aim of study was to assess the effect of bottom sediments on the concentration of macronutrients (K, P, Na, Mg, Ca) and trace elements (Zn, Cd, Pb, Cr, Ni, Cu) in the plant test. The experimental design comprised 6 treatments: soil (control), soil + 5% of sediment, soil +10% of sediment, soil + 30% of sediment, soil + 50% of sediment and sediment (100%) in relation to the soil dry mass. The test plant – maize was harvested after 70 days of vegetation. Bottom sediment added to soil had a positive effect on maize biomass in the lowest dose, i.e. 5%. Higher doses of the sediment caused a reduction in maize yield. Bottom sediment positively affected concentration of nutrients: N, Mg, Na, K, Ca, Zn, Ni, Cu of maize shoots. However, the shoot biomass did not meet for fodder with respect to quality. Applied bottom sediment, has high content of sandy fractions, acid reaction and low concentration of organic carbon, nitrogen, phosphorus and potassium, can not be used as a fertilizer. Using bottom sediment from Narożniki reservoir in plant cultivation, one should take into consideration a necessity of application of supplementary NPK fertilization due to low concentration of these elements both in the bottom sediment and maize yield.

Keywords: bottom sediment, agriculture purpose, pot experiment, macronutrients, trace elements, maize

INTRODUCTION

The construction of dam reservoirs is connected with environmental risk. Loss of water storage due to sediment accumulation process within reservoir is the one of main factor the negative impact of reservoirs on the aquatic and terrestrial environment (Fonseca et al. 1998, Szalińska 2011, Walter et al. 2012). Some global researches highlight the significance of sediment accumulation process, quantifying the erosion load from reservoir watersheds (White 2001, Walter et al. 2012). Evaluation of sediments properties is important not only for assessment of water reservoir degradation but also for determining potential applications of dredged sediment (Baran et al. 2011, 2015, Baran, Tarnawski 2015, Mamindy-Pajany et al. 2011, Perrodin et al. 2006, Urbaniak et al. 2015). Dredging of the sediments accumulated in the bottom of the reservoir has been proposed to remediate the problem silting (Canet et al. 2003, Popenda et al. 2007, Szalińska 2011). If the dredged sediement from the reservoirs does not pose a risk for the environment, reasonable method of such sediment management is their use one agriculture purpose (Canet et al. 2003, Karanam et al. 2008, Baran et al. 2011, Terziyski et al. 2014). The reuse of sediment in soil restoration improving their physicochemical properties and therefore increases the productivity of soils (Walter et al. 2012). In the literature were found some examples utilization of dredged sediments as agricultural amendment (Wiśniowska-Kielian, Niemiec 2007ab, Jasiewicz et al. 2010, Baran et al. 2010, 2012, Tarnawski et al. 2015, Ebbs et al. 2006, Canet et al. 2003, Kaczmarski, Jasiewicz 2013, Fonseca et al. 2003, Wyrwicka et al. 2014). There are also indicated that sediments rich in nutrients (NPK), organic carbon and microbial activity can be use as a fertilizer substitutes for crop production (Karanam et al. 2008).

The aims of study were: 1) to determine properties of bottom sediments from Narożniki reservoir as soil amendment or fertilizer, 2) to assess the effect of bottom sediments on the concentration of macronutrients and trace elements in the plant test.

MATERIALS AND METHODS

Physico-chemical properties of bottom sediments

The water reservoir in Narożniki is situated on the Dęba stream (Małopolskie Voivodeship) (Figure 1).

The characterization of reservoir was detailed described in Michalec et al. (2006), Koniarz et al. (2015), Baran et al. (2015). The bottom sediments were sampled within the three zones (from the 0-15 cm layer) of the reservoir: inlet, middle and outlet using an Ekman 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. Selected physico-chemical properties of sediment were presented in Table 1. The dominant grain size fraction in sediment was sand – 86%. The sediment was characterized by acid reaction, low content of organic carbon and bioavailable phosphorus and potassium (Table 1). The trace elements concentration in bottom sediments was assessed on the basis of IUNG criterion and the Regulation of the Minister of the Natural Environment of 9 September 2002 on the soil and ground quality standards (Kabata-Pendias et al. 1995, Journal of Laws 2002, no 165, item 1359). Trace elements concentrations in the sediment did not exceed the permissible content for the soil from grounds B (Journal of Laws 2002, no 165, item 1359). According to IUNG assessment the analysed material revealed natural concentrations of trace elements.

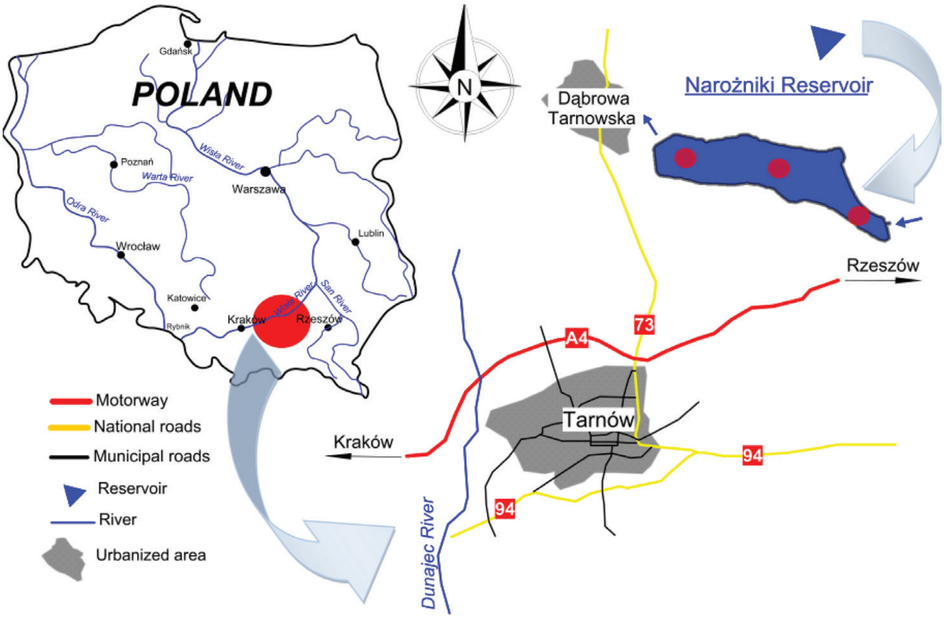

Figure 1. Localization of the reservoir and 3 station samples

Scheme of pot experiment

The pot experiment was conducted on soil with granulometric structure of loamy sand, neutral pH and organic matter content of 16.0g · kg^{-1} (Table 1). The experimental design comprised 6 treatments in three replicates (n = 18): soil (control), soil + 5% of sediment, soil +10% of sediment, soil + 30% of sediment, soil + 50% of sediment and sediment (100%) in relation to the soil dry mass. The same NPK fertilization, dosed respectively 1g N, 0.4g P and 1.1g K per pot (6 kg of soil d.m.) was used in all treatments. The test plant was maize, Bora c.v. The test plant was harvested after 70 days of vegetation. During the vegetation period the plants were watered with de-mineralized water and constant moisture of the substratum was maintained, initially on the level of up to 50% and then up to 60% of maximum water capacity. After the harvest the plant material was dried at 65°C in a dryer with forced air flow and the amount of dry mass yield was determined (the shoots and roots). Subsequently the plant material was crushed in a laboratory mill and subjected to chemical analysis. Concentrations of macroelements (K, P, Na, Mg, Ca) and trace elements (Zn, Cd, Pb, Cr, Ni, Cu) were assessed in the plant material using ICP-OAS method after dry mineralization and dissolving the ash in HNO_3 (1:3). Nitrogen content was determined using Kjeldahl distilling method. The obtained results were verified statistically using one factor ANOVA and Tukey test at significance level $\alpha < 0.05$ using Statistica 11 software.

Table 1. Properties of bottom sediment and soil

Materials	Granulometric composition	pH_{KCl}	C	N	P_2O_5	K_2O
			$g \cdot kg^{-1}$ d.m		$mg \cdot kg^{-1}$ d.m.	
Sediment	sand	5.0	4.80	0.44	7.68	29.6
Soil	loamy sand	6.2	16.0	0.30	180	199
Concentration of trace elements ($mg \cdot kg^{-1}$ d.m.)						
Materials	Zn	Cu	Ni	Cr	Pb	Cd
Sediment	38.3	4.70	5.55	14.1	7.54	0.28
Soil	62.0	18.8	4.15	10.6	29.7	0.68

RESULTS AND DISCUSSION

In the studies was shown a significant effect of sediment to the soil on the maize yield (Table 2). Significantly highest shoots and whole plant yield were demonstrated for the treatment with a 5% admixture of bottom sediment. The highest roots yield was found in the control treatment. The date revealed that the applied doses of bottom sediment over 5% decreased maize biomass. On treatments with a 100% bottom sediment was found the lowest yield of maize (Table 2). In the treatment with 100% of bottom sediment, the yield of shoots and roots decreased about 3-fold in compared to the treatment with a 5% bottom sediment supplement.

Maize yield considerably affected on the concentration of microelements and trace elements in tested plant. Table 3 shows the effect of the sediments on the macronutrient concentrations in maize shoots and roots. In all cases significant effects were found depending on the application dose used. Sediment supplements to soil caused a significant increase in K, Na, Mg, Ca and N, in maize shoot and root biomass in relation to the control. In both part of maize, a bottom sediment addition significantly decreased P concentration. In the shoots the highest concentration of K, Na and Mg was found in the treatment with a 30% supplement of bottom sediment, whereas Ca and N in the treatment with a 100% of bottom sediment (Table 3). The highest concentration of K, Na, Mg, Ca and N in root biomass was noted on the treatment with a 100% of bottom sediment. Assessment of the macroelements distribution in the parts of maize evidenced higher mean concentration of nitrogen, potassium, phosphorus in the shoot biomass in comparison with roots, whereas an opposite dependence was registered for calcium, magnesium, sodium.

Table 2. Yield of maize

Treatment	Shoots	Roots	Whole plant
	$g \cdot pot^{-1}$		
Soil (control)	84.1^{b*}	17.4^{c}	101.5^{c}
5% sediment	86.9^{b}	15.3^{bc}	102.2^{c}
10% sediment	78.8^{b}	14.0^{bc}	92.9^{b}
30% sediment	73.5^{b}	11.6^{ab}	85.2^{b}
50% sediment	66.2^{b}	12.8^{ab}	78.9^{b}
100% sediment	29.4^{a}	4.8^{a}	34.2^{a}

*homogenous groups according to Tukey test, $\alpha < 0.05$

Trace elements concentration in maize shoots and roots were presented in Table 4. Sediment supplements to soil caused a significant increase in Zn, Pb, Cu, and Ni concentrations in shoot biomass in relation to the control. However, bottom sediment addition significantly decreases of concentration of Cr, Pb, Cd and Ni in roots biomass in comparison with the treatment without sediment. The highest concentration of Zn, Pb, Cu, Ni in shoots was found in the treatment with 100% doses of sediment whereas Cr and Cd in the treatment with a 10% supplement of bottom sediment. In the root biomass the highest concentration of Cr, Pb, Cd and Ni was noted on the control treatment whereas Zn and Cd in the treatment with a 50% and 5% doses of bottom sediment respectively. The maize roots contained more metals from 1.5 (Zn) to 7.5 (Pb) – fold than that shoots.

The results from this study suggest that sediment from Narożniki reservoir can not be utilized for fertilizing purposes. Applied sediment revealed a high share of sandy fractions, acid reaction, low content of nutrients (C – organic, P, K) and also low concentration of trace element. However, a positive effect of bottom sediment on maize yield was found on the treatment with a lower – 5% supplement of bottom sediment. We suppose that higher doses of bottom sediment decreased of yield caused by the unfavourable air-water conditions and acidification in the formed substratum. In our previous study indicated that other bottom sediment from Besko and Zesławice reservoirs added to soil had a positive effect on plant biomass but also when applied in a low dose, i.e. 5% (Jasiewicz et al. 2011, Baran et al. 2012). A positive effect of bottom sediments from the Rożnów reservoirs was also noted by Wiśniowska-Kielian and Niemiec (2007ab). Authors found that increasing doses 0-10% of the sediment, maize yield significant increased. Additionally the same research shown that highest dose of sediment, between 14 and 16% caused decrease in yield of the plants. A positive effect of the substrata prepared from soil and bottom sediments on vegetables production was registered in the study of Fonseca et al.1998, 2003 (pepper), Canet et al. 2003 (lettuce) and Ebbs et al. 2006 (pepper, tomato and beans). The concentration of macronutrients and trace elements in plants growth in soil enriched with bottom sediments was subject of numerous studies (Canet et al. 2003, Ebbs et al. 2006, Niemiec, Wiśniowska-Kielian 2010ab, Jasiewicz et al. 2010, 2011, Baran et al. 2012, Wiśniowska-Kielian et al. 2012, Kaczmarski, Jasiewicz 2013, Tarnawski et al. 2015). In the study noted that increasing doses of bottom sediment supplement in soil affected an increase concentration of macronutrients: N, Mg, Na, K and Ca, trace elements: Zn, Ni, Cr, Pb, Cu and decrease concentrations P and Cd in shoot biomass. The increase of elements concentartion in the maize shoots, probably due to lower production of plant biomass in the treatment of bottom sediment over 5%. Similar results were presented by Baran et al. (2012) – increasing doses of bottom sediment from Besko reservoir in light soil influenced an increase in the concentration of K, Ca, N, Mg in maize shoot but a decrease in P and Na concentrations. Wiśniowska et al. (2013) observed similar results for concentration of micronutrients in plants after applying the bottom sediment from Rożnów reservoir. Study of Jasiewicz et al. (2011) found that increasing doses of bottom sediment supplement in soil affected a decrease of Mg, and P concentration however an increase concentration of K, Ca and N in maize shoots.

The experiment also assessed the effect of bottom sediment supplement to the soil on macronutrients and trace elements concentrations because their concentration in plants is the basic criterion of plant fodder destination. The optimal macronutrient concentrations in maize at 8 leaves stage have been assumed as: 30-50g N; 3.0 – 6.0g P; 30-45g K; 2.0-6.0g Mg and 3.0-10g Ca $\cdot kg^{-1}$ d.m. (Antonkiewicz 2007). The permissible concentration of trace elements in feeds are: Zn < 100 mg; Cu < 30 mg; Cr < 20 mg; Ni < 50 mg, Cd < 0.5 mg and Pb < 10 mg; Cd < 1 mg $\cdot$ kg^{-1}d.m. (Journal of Law 2015, no 20, item 1141, Kabata-Pendias et al. 1993). Maize shoot biomass in the treatments with bottom sediments revealed deficient concentrations of K, P and N, however the optimal concentration of magnesium (treatment with 5%, 10%, 30%, 50% doses of sediment) and calcium (treatment with 100% dose of sediment) (Table 3). The assessment of trace elements concentration in shoots found that the maize would be used for production of animal feeds.

Table 3. Concentration of macroelements in maize

Treatment	Shoots g · kg^{-1} d.m					
	K	Na	Mg	Ca	P	N
Soil (control)	14.9[a]	0.026[a]	1.94[b]	1.97[a]	2.02[d]	8.70[ab]
5% sediment	15.0[a]	0.026[a]	2.00[b]	1.89[a]	1.80[c]	8.53[a]
10% sediment	16.0[ab]	0.027[ab]	2.06[b]	2.43[ab]	1.72[c]	9.37[ab]
30% sediment	18.2[b]	0.030[b]	2.42[c]	2.83[bc]	1.26[b]	10.10[b]
50% sediment	17.3[ab]	0.024[a]	2.17[b]	2.63[b]	1.07[ab]	8.86[ab]
100% sediment	16.6[ab]	0.027[ab]	1.24[a]	3.24[c]	0.86[a]	13.20[c]
Treatment	Roots g · kg^{-1} d.m					
	K	Na	Mg	Ca	P	N
Soil (control)	3.41[a]	0.19[a]	2.63[a]	3.94[a]	1.71[c]	8.16[a]
5% sediment	5.20[a]	0.23[a]	3.43[a]	4.86[a]	1.40[b]	9.08[a]
10% sediment	4.26[a]	0.21[a]	2.99[a]	4.26[a]	1.40[b]	9.04[a]
30% sediment	4.59[a]	0.46[b]	5.42[a]	6.27[a]	0.96[a]	9.31[ab]
50% sediment	4.11[a]	0.48[b]	4.23[a]	4.80[a]	1.14[ab]	8.25[a]
100% sediment	16.3[b]	3.67[c]	17.8[b]	46.9[b]	0.95[a]	10.9[b]

*homogenous groups according to Tukey test, $\alpha < 0.05$

In summary, if the dredged bottom sediments not constitute environmental risks, inorganic and organic pollution concentration in the sediments are below toxic thresholds, reasonable method of such sediment management is their agriculture purpose. However bottom sediments can not replace fertilizer, but they can by used as soil improving agents (Jasiewicz et al. 2011, Baran et al. 2012, Tarnawski et al. 2015). We found that using bottom sediment form Narożniki reservoir for plant cultivation should apply supplementary mineral fertilization because of low concentration of nitrogen, phosphorus and potassium in the sediment and deficient nutrients in plant biomass.

Table 4. Concentration of trace elements in maize

Treatment	Shoots (mg · kg^{-1} d.m.)					
	Cr	Zn	Pb	Cu	Cd	Ni
Soil (control)	0.50	35.6^{a}	0.41^{ab}	1.51^{b}	0.32	0.27^{a}
5% sediment	0.75	41.7^{a}	0.53^{ab}	1.51^{b}	0.36	0.56^{b}
10% sediment	1.14	38.1^{a}	0.51^{ab}	1.46^{b}	0.39	0.37^{ab}
30% sediment	0.80	48.5^{a}	0.62^{b}	1.05^{a}	0.28	0.43^{ab}
50% sediment	0.73	37.7^{a}	0.37^{a}	1.08^{a}	0.25	0.33^{ab}
100% sediment	0.64	72.0^{b}	0.63^{b}	2.14^{c}	0.26	0.92^{c}
Treatment	Roots (mg · kg^{-1} d.m.)					
	Cr	Zn	Pb	Cu	Cd	Ni
Soil (control)	5.29^{c}	60.3	6.76^{c}	3.87	2.43^{b}	3.75^{b}
5% sediment	3.04^{ab}	68.5	5.05^{bc}	3.77	2.56^{b}	2.82^{a}
10% sediment	2.49^{ab}	58.5	3.56^{abc}	3.43	2.33^{b}	2.29^{a}
30% sediment	2.81^{ab}	80.9	2.87^{ab}	3.22	1.86^{b}	2.98^{a}
50% sediment	1.91^{a}	73.8	3.70^{abc}	3.62	2.47^{b}	1.79^{a}
100% sediment	1.42^{a}	67.0	1.06^{a}	3.09	0.37^{a}	2.23^{a}

*homogenous groups according to Tukey test, $\alpha < 0.05$

CONCLUSION

1. Bottom sediment added to soil had a positive effect on maize biomass but only when applied in the lowest dose, i.e. 5%. Higher doses of the sediment caused a reduction in maize yield.
2. Bottom sediment positively affected concentration of nutrients N, Mg, Na, K and Ca, Zn, Ni, Cu of maize shoots. However, the shoot biomass did not meet for fodder with respect to quality because of too low concentration of macronutrients.
3. Applied bottom sediment, due to high content of sandy fractions in its composition, acid reaction and low concentration of organic carbon, nitrogen, phosphorus and potassium, can not be used as a fertilizer. However, it can be used as soil improving agent. While utilizing bottom sediment from Narożniki reservoir in plant cultivation, one should take into consideration a necessity of application of supplementary NPK fertilization due to low concentration of these elements both in the bottom sediment and maize yield.

ACKNOWLEDGEMENTS

The work was financed by: grant no. N N305 295037 provided by the National Science Centre, and from the subsidy for science DS-3101/KChRiŚ and DS-3322/KIWiG granted by the Polish Ministry of Science and Higher Education.

REFERENCES

Antonkiewicz J. (2007). Ocena składu mineralnego pasz z runi łąkowej i pastwiskowej. Monografia pt. Ocena składu chemicznego roślin, pod redakcją B. Wiśniowskiej-Kielian i W. Lipińskiego. Wyd. Polskie Towarzystwo Inżynierii Ekologicznej, Krajowa Stacja Chemiczno-Rolnicza. Kraków-Warszawa-Wrocław, 23-30.

Baran A., Jasiewicz Cz., Tarnawski M. (2010). Effect of bottom deposit on trace element content in light soil. Ecol. Chem. and Eng. 17(12), s. 1553-1561

Baran A., Tarnawski M., Kaczmarski M. (2011). Assessment of agricultural utilization of bottom sediment from the Besko Reservoir. Czasopismo Techniczne. Chemia 1-Ch 8(108): 3-11.

Baran A., Jasiewicz Cz., Tarnawski M. (2012). Effect of bottom sediment supplement to light soil on the content and uptake of macroelements by maize. Ecol. Chem. and Eng. A, 19(8), 863-872.

Baran A., Tarnawski M., Michalec B. (2015). Assessment of metal leachability and toxicity from sediment potentially stored on land. Water SA, 41(5), s. 606-613

Baran A., Tarnawski M. (2015). Assessment of heavy metals mobility and toxicity in contaminated sediments by sequential extraction and a battery of bioassays. Ecotoxicology, 24(6), 1279-1293.

Canet R., Chaves C., Pomares R., Alibach R. (2003). Agricultural use of sediments from the Albufera Lake (eastern Spain). Agric Ecosyst Environ. 95, s. 29-36.

Ebbs S., Talbott J., Sankaran R. (2006). Cultivation of garden vegetables in Peoria Pool sediments from the Illions River: A case study in trace element accumulation and dietary exposure. Environ Int. 32, 766-744.

Fonseca R. M., Barriga F., Fyfe W. S., 1998. Reversing desertification by using same reservoir sediments as agriculture soils. Episodes, 21, 4, s. 218-224.

Fonseca R., Barriga F. J. A. S., Fyfe W. (2003). Dam Reservoir Sediments as Fertilizers and Artificial Soils. Case Studies from Portugal and Brazil. In: K. Tazaki (ed.) Proc. Water and Soil Environments, Biological and Geological Perspectives. Internat. Symp, Kanazawa University. pp. 55-62.

Jasiewicz Cz., Baran A., Tarnawski M. (2010). Effect of bottom sediment on content, bioaccumulation and translocation of heavy metals in maize biomass. J Element, 15(2), s. 281-291.

Jasiewicz Cz., Madeyski M., Tarnawski M., Baran A. (2011). The effect of bottom sediment supplement to soil on yield and chemical composition of maize. Ecol. Chem. and Eng. A 18(11), s. 1505 – 1514.

Kabata-Pendias A., Piotrowska M., Motowicka-Terelak T., Maliszewska-Kordybach T., Filipiak K., Krakowiak A., Pietruch Cz. (1995). Podstawy oceny chemicznego zanieczyszczenia gleb – metale ciężkie, siarka i WWA. Państwowa Inspekcja Ochrony Środowiska. Bibliot. Monit. Środ., W-wa, s 41.

Kaczmarski M., Jasiewicz Cz. (2013). Impact of bottom sediments on assimilability of copper and zinc in light soil., Ecol. Chem. and Eng. A, 2(10), s. 1185-1193.

Karanam P.V., Wani S.P, Sahrawat K.L., Jangawad L. S. (2008). Economic evaluation of sediment as a source of plant nutrients. Current Science, 95(25), s. 1042-1050

Koniarz T., Tarnawski M., Baran A., Florencka N. (2015). Mercury contamination of bottom sediments in water reservoirs of southern Poland. Geology, Geophysics & Environment, 41(2), 169-175.

Mamindy-Pajany Y. Hamer B., Roméo M., Géret F., Galgani F., Durmisi E., Hurel C. & Marmier N., (2011). The toxicity of composted sediments from Mediterranean ports evaluated by several bioassays. Chemosphere, 83(3), s. 362-369.

Michalec B., Tarnawski M., Kupiec A. (2006). The forecast of silting for small water reservoir. Infrastruct. Ecol. Rural Areas 2, s. 75–84.

Niemiec M., Wiśniowska-Kielian B. (2010a). Effect of dredged bottom sediment addition to the substratum on the fodder value of plant material. Part 2. Quantitative ratios between macroelements. Ecol. Chem. and Eng. A, 17(8), s. 991-1000.

Niemiec M., Wiśniowska-Kielian B.(2010b). Effect of dredged bottom sediment addition to the substratum on the fodder value of plant material. Part 1. Macroelements content. Ecol. Chem. and Eng. A, 17(4-5), 461-472.

Perrodin, Y., Babut, M., Bedell, J.-P., Bray, M., Clement, B., Delolme, C., Devaux, A., Durrieu, C., Garric, J., Montuelle, B. (2006). Assessment of ecotoxicological risks related to depositing dredged materials from canals in northern France on soil. Environ. Int. 32, s. 804-814.

Popenda A., Malina G., Siedlicka E. 2007. Składowanie jako metoda unieszkodliwiania osadów dennych zanieczyszczonych metalami ciężkimi. Ochrona Środowiska i Zasobów Naturalnych 32, s. 246-252.

Regulation of the Minister of Environment of 9 September 2002 on soil and earth quality standards. Journal of Laws of 2002, No. 165, item 1359

Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 23 stycznia 2007 w sprawie dopuszczalnych zawartości substancji niepożądanych w paszach. Journal of Law 2015, no 20, item 1141, Szalińska E. (2011). Rola osadów dennych w ocenie jakości środowiska wód kontynentalnych. Seria Inżynieria środowiska nr 396, Wydawnictwo Politechnika Krakowska, s. 123

Tarnawski M., Baran A., Koniarz T. (2015). The effect of bottom sediment supplement on changes of soil properties and on the chemical composition of plants. Geology, Geophysics & Environment, 41(3), s. 285-292.

Terziyski D. I., Hadjinikolova L.D., Ivanova A.S., Kalchev R. K., (2014). Some chemical characteristics of sediments from carp fishponds treated with different fertilizers. Ecologia Balkanica, 5, s 28-32.

Urbaniak,M., Zieliński,M. Wagner I. (2015). Seasonal Distribution of PCDDs/PCDFs in the Small urban Reservoirs. Int. J. Environ. Res., 9(2), s. 745-752.

Walter K., Gunkel G., Gamboa N. (2012). An assessment of sediment reuse for sediment management of Gallito Ciego Reservoir, Peru. Lakes and Reservoir: Research and Management, 17, s 301-314.

White W.R. (2001). Evacuation of sediments from Reservoirs. Thomas Telford Publ., London, s. 260

Wiśniowska-Kielian B, Lipiński W. (2007). Ocena składu chemicznego roślin. Odziała Krakowski Polskiego towarzystwa Inżynierii Ekologicznej, Krajowa Stacja chemiczno-Rolnicza, Kraków-Warszawa-Wrocław, ss 57.

Wiśniowska-Kielian B., Niemiec M. (2007a). Effect of bottom sediment addition to the substratum on the quality of produced maize biomass. Ecol. Chem. and Eng. A, 14(5-6), s. 581-589.

Wiśniowska-Kielian B., Niemiec M. (2007b) Effect of increasing share of bottom sediment in the substratum on cadmium and lead uptake by the plants. Ecol. Chem. and Eng. A, 14(5-6), 591-599.

Wiśniowska-Kielian B., Arasimowicz M., Niemiec M. (2012). Post-effect of bottom sediment addition to the substratum on chemical composition of white mustard (Sinapis alba l.) biomass part 2. Quantitative ratios between macroelements. Ecol. Chem. and Eng. A, 19(4-5), s. 387-393.

Wiśniowska-Kielian B., Niemiec M., Antonkiewicz J. (2013). Następczy wpływ dodatku bagrowanego osadu dennego do podłoża na pobieranie metali ciężkich przez kukurydzę. Mat. Konf. „Technologie bezodpadowe i zagospodarowanie odpadów w przemyśle i rolnictwie", Międzyzdroje, 11-14.06.2013 r., str. 261-264, ISBN 978-83-7518-556-0.

Wyrwicka A., Steffani S., Urbaniak M. (2014). The effect of PCB-contaminated sewage sludge and sediment on metabolism of cucumber plants (*Cucumis sativus* L.). Ecohydrology & Hydrobiology 14, s. 75–82.

Prof. dr hab. Czesława Jasiewicz, dr inż. Agnieszka Baran
Department of Agricultural and Environmental Chemistry
Al. Mickiewicza 21, 31-120 Kraków, Agnieszka.Baran@ur.krakow.pl
Ph. 48 12 662 43 52

Dr hab. inż. Marek Tarnawski, mgr inż. Tomasz Koniarz
Department of Hydraulic Engeenering and Geotechnics
Al. Mickiewicza 24/28, 30-059 Kraków, m.tarnawski@ur.krakow.pl
Ph. 48 12 633 40 52

University of Agriculture in Krakow

Received: 15.04.2016
Accepted: 22.09.2016