Remediation of contaminated sediments by mineral additives and thermal processing

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The aims of the study

Nowadays several possible directions in bottom sediment management include agricultural or horticulture utilization, landfill regeneration, applications in civil engineering (aggregate manufacture, construction). One of the major problems associated with land-based management of bottom sediment is its contamination with heavy metals. A promising ways to the utilization of sediment contaminated by heavy metals employs a two approaches: thermal processing and using mineral additives. Both technique can be suitable for the management of metal contaminated sediments because they immobilize them in the solid phase and reduce the mobility of heavy metals.

The aims of study were: 1) to evaluate the effect of three incineration temperatures on the content of heavy metals and properties of bottom sediment 2) to use of mineral additives (cellulose waste CW, biomass ash BA) to immobilization of heavy metals.

Materials and methods

1. The bottom sediment was sourced from the Chechło reservoir situated in the southern part of Poland, between Kraków and Katowice cities (Fig. 1). The Chechło reservoir is located in an area with a zinc and lead ore mining industry. High contents of heavy metals, especially Zn (39.37-4772 mg/kg), Cd (0.37-56.3 mg/kg) Pb (4,5-434 mg/kg) was found in bottom sediments.
2. In the first experiment, a 4 months scale experiment under controlled laboratory conditions was conducted. The experimental design covered 3 treatments with a combination of 50% bottom sediment BS and 50% of each additives (CW, BA), and a control sample which was only bottom sediment.
3. In the second experiment, samples of contaminated bottom sediment were incinerated in a muffle furnace at three temperatures (500°C, 800°C and 950°C).

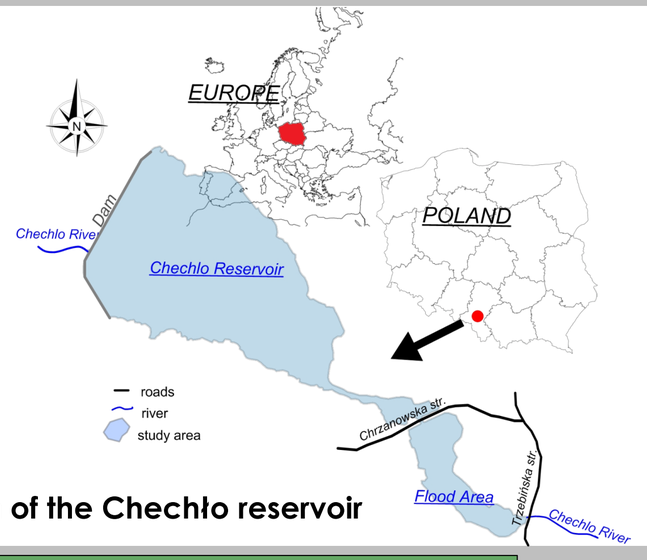

Fig 1. Localization of the Chechło reservoir

Results

Mineral additives

Table 1. Chemical properties of bottom sediment and mixtures

Treatment	pH	TOC g/kg dm	Zn*** mg/kg dm	Cd mg/kg dm	Pb mg/kg dm
100% BS*	5.67a**	91.8 b	3796 b	52.2 b	300 b
50% BS + 50% CW	12.3b	56.1 a	1702 a	26.3 a	133 a
50%BS + 50% BA	5.83 a	62.6 a	2125 a	27.5 a	154 a

*BS – bottom sediment, CW - cellulose waste, BA - biomass ash, **Means followed by the different letters indicate significant differences at a ≤ 0.05 according to the t-Tukey test, *** total content

Table 2. Content of soluble forms Zn, Cd, Pb in the sediment and mixtures

Treatment	Zn	Cd	Pb
Water extraction (mg/kg dm)			
100% BS	933 c	30 c	0.48 c
50% BS + 50% CW	0.55 a	0.01 a	0.01 a
50%BS + 50% BA	10.6 b	1.13 b	0.05 b
Extraction of 1 M HCl (mg/kg dm)			
100% BS	2673 b	43.6 b	175 b
50% BS + 50% CW	1100 a	17.0 a	53.6 a
50%BS + 50% BA	1447 a	18.0 a	80.0 ab

*BS – bottom sediment, CW - cellulose waste, BA - biomass ash,**Means followed by the different letters indicate significant differences at a ≤ 0.05 according to the t-Tukey test

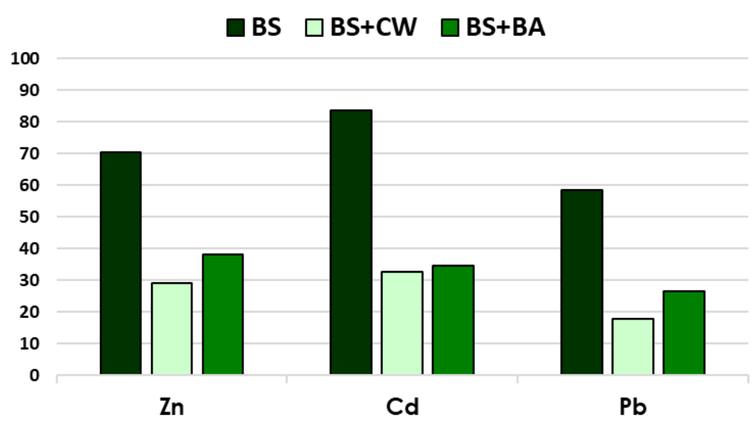

Fig. 1. Percentage of metal forms soluble in 1 M HCl in bottom sediments and mixtures

Thermal processing

Table 3. Total content of heavy metals and pH of bottom sediments after thermal processing

Treatment	pH	Zn mg/kg dm	Cd mg/kg dm	Pb mg/kg dm
T_1 500° C	5.39a*	5393 c	85.6 c	354 c
T_2 800° C	6.83b	2869 b	52.9 b	156 b
T_3 950° C	9.56c	355 a	11.3 a	99.2 a

*Means followed by the different letters indicate significant differences at a ≤ 0.05 according to the t-Tukey test

Table 4. Ecotoxicity of bottom sediments after thermal processing

Treatment	*Heterocypris incongruens*		*Alivibrio fischeri*
	Mortality %	Growth inhibition %	Luminescence inhibition %
T_1 500° C	100	100	100
T_2 800° C	100	100	93
T_3 950° C	71	82	49

Table 5. Total washing of metals from bottom sediments after thermal processing

Treatment	Zn	Cd	Pb
Water extraction (mg/kg dm)			
T_1 500° C	1630 b*	43.9 c	0.33 b
T_2 800° C	11.2 a	0.53 b	0.17 a
T_3 950° C	8.46 a	0.19 a	0.13 b

*Means followed by the different letters indicate significant differences at a ≤ 0.05 according to the t-Tukey test,

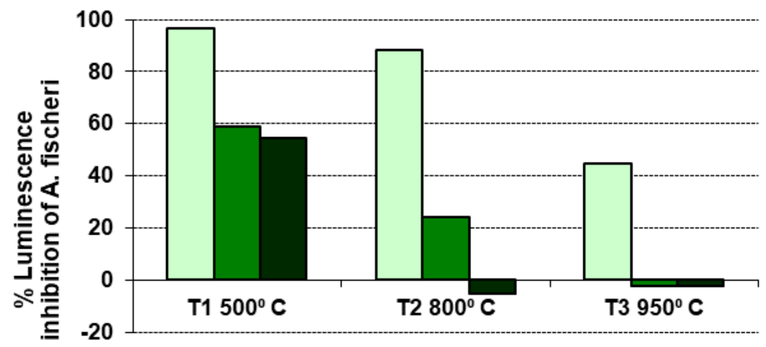

Fig. 2. Ecotoxicity of extracts prepared from sediments after thermal processing depending on the washout cycle (I, II, III) and temperature

Conclusions

1) The mixtures were slightly acidic (100% BS, 50% BS and 50% BA) and strongly alkaline (50% BS and 50% CW).
2) The highest total content and mobility (solubility) of heavy metals was demonstrated in the treatment with 100% BS. Significantly the lowest content of trace elements as well as their mobility was found in the mixture of 50% BS and 50% CW.
3) It was found that the reaction of the mixture based on BS and CW had a significant effect on the reduction of the mobility of the tested elements.

1) The thermal processing significantly influenced the chemical properties and ecotoxicity of bottom sediments.
2) The lowest total content of metals and their solubility were found in bottom sediments after the thermal transformation temperature of 950°C. Moreover the sediments were alkaline.
3) The thermal processing reduced the ecotoxicity of the sediments for *H. incongruens* and *A. fischeri*. The ecotoxicity of water extracts also decreased with increasing temperature. The sediment after T_3 was low toxic to *A. fischeri* and toxic to *H. incongruens*.

The obtained results suggest that the use of mineral additives and thermally treated are a good ways to immobilize the heavy metals present in bottom sediments, and the good way to transform the sediments from waste material to a valuable resource.