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UTILIZATION POSSIBILITIES OF SEDIMENT WASTE EXTRACTED FROM WATER RESERVOIR

MOŻLIWOŚCI UTYLIZACJI OSADÓW DENNYCH

A b s t r a c t

Sediments are a highly dynamic part of river systems and are not tied to a particular area but are transported through the river basin and cause silting of small water reservoirs, which is one of important problems in water management mainly due to the reduction of the basin accumulation capacity. Most reservoirs in the world, from small through medium to large capacity, are subject to siltation problems to some degree. For that reason it is necessary to control reservoir sedimentation rather than sediment removal. Otherwise, water management organizations must solve the problem with extracted sediment treatment, disposal or utilization. In this paper we present the results of monitoring the quality of bottom sediment that accumulates in the Klusov small water reservoir, where trapped sediments were removed from the drained reservoir for the reason of its silting. Also a possible use of extracted sediments is discussed here.

Keywords: sediment, utilization, water reservoir, sediment quality

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

Osady zaliczają się do wysoce dynamicznej części systemu rzecznego i są transportowane w strefie przydennej, a w konsekwencji powodują zamulanie małych zbiorników wodnych. Jest to jeden z ważnych problemów w gospodarowaniu zasobami wodnymi, a szczególnie w zmniejszaniu pojemności zbiorników. Problem zamulania dotyczy większości zbiorników wodnych na świecie, począwszy od małych poprzez średnie, aż do zbiorników o dużej pojemności. Z tego powodu ważniejsze jest kontrolowanie procesów sedymentacji niż usuwanie zalegających osadów. Ponadto podmioty zajmujące się gospodarką wodną muszą rozwiązać problemy związane z gospodarowaniem osadami dennymi, tzn. wydobyciem, składowaniem lub utylizacją. W artykule przedstawiono rezultaty monitoringu jakości osadów dennych gromadzących się w małym zbiorniku wodnym Klusov, z którego osady zostały usunięte po jego osuszeniu w celu jego odmulenia. Zamieszczono także dyskusję nad możliwością wykorzystania wydobytych osadów dennych.

Słowa kluczowe: osad, utylizacja, zbiornik wodny, jakość osadów

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1. Introduction

Siltation of water reservoirs with sediments is one of important problems in water management mainly due to the reduction of basin accumulation capacity, and also because of the utilization of sediment waste extracted from water reservoirs. Most reservoirs in the world, from small through medium to large capacity, are subject to siltation problems to some degree. It was evaluated that the storage capacity of the world's reservoirs is reduced annually by more than 1 % due to siltation [1]. One of the major factors affecting the proportion of sediment deposition in reservoirs is soil erosion in catchment areas. Enormous volumes of sediments have to be dredged worldwide for both maintenance and environmental reasons.

Sediment quality influences the ecological or chemical water quality status and nearly always complicates sediment management. However, the dredged material is increasingly regarded as a resource rather than aswaste. Dredged sediments have a wide range of uses. Considering their properties, biotic and abiotic utilization can be taken into account [2,3].

Abiotic utilization refers to construction materials used in concrete or raw materials for cements preparations instead of clayey components, construction of flood control structures such as dams, levees, dikes.

Biotic utilization is connected with the contaminant content in dredged sediments, which is the main factor in the assessment of a possible application on soil. Because reservoir bottom sediments also include a large part of the topsoil lost as a result of agricultural activities, i.e. generally a highly erosive process, they contain humic substances, carbonates and other salts of calcium and magnesium, compounds of nitrogen, phosphorus, potassium nutrients. Consequently, they are appropriate for the direct reuse on soils complying with the requirements given in Act No. 188/2003 of Code on application of sludge and river bed sediments on agricultural and forest soil [4]. Biotic utilization of bottom sediments is their direct application for purposes such as land reclamation at existing landfills, raising the elevation of low-lying areas and/or constructing new land areas, enhancement, e.g. landscaping, agriculture, forestry, horticulture, etc.

2. Material and methods

2.1. Watershed description

We are studying the sediments that accumulate in the small water reservoir Kľušov-Hervartov from the point of view of their possible removal and use. This reservoir is located in the Bardejov district in the east of Slovakia, and it belongs to the Tisovec river catchment. The area of this watershed is about 6.0 km^2 and it falls in the Topla river partial basin. An annual average discharge is 0.045 $m^3.s^{-1}$.The Kľušov-Hervartov reservoir is located at an altitude of 343 m, about 1.5 km eastward of Hervartov village. An average depth of the Kľušov-Hervartov reservoir is 3.5 m, the surface area is 2.2 ha, and its total capacity is about 72,000 m^3. It was built for fishing, irrigation, recreation and for retention of high water.

In general, planosols, cambisols and albic luvisols are the soil types of the watershed. Taking the soil texture into consideration, medium heavy soils (sandy loam) occur in this area. And according to the content of skeletons in the soil, slightly stony soils prevail.

The land use of the catchment was found to be of a mixed type. The upstream part and the middle part of the Tisovec catchment is an area mainly covered with forests (39.2%) and pastures (21.7%), while the lower part is an arable land (21.4%) mainly used for cereals (spring barley, winter wheat), corn silage and winter oilseed rape growing. The rest of the land area is designated for other uses.

2.2. Estimation of the reservoir sediment quantity

In 2004 the Slovak Water Management Enterprise (SWME) carried out the siltation measurements of this reservoir. The quantities of deposited eroded sediments in the reservoir are given in Tab. 1.

Table 1

Measurement results of Kľušov reservoir siltation

Year	Watershed area	Total reservoir capacity	Sediment quantity
	[km^2]	[m^3]	[m^3]
1986	6.0	72,188.00	0
2004	6.0	47,680.70	24,507.30

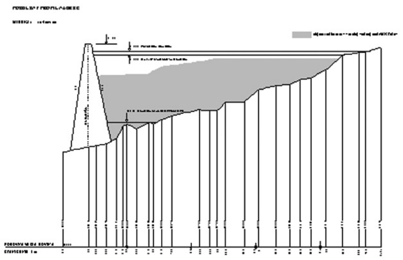

Fig. 1. Reservoir longitudinal profile

Rys. 1. Przekrój wzdłużny zbiornika

Fig. 2. Reservoir siltation

Rys. 2. Zamulenie zbiornika

Fig. 3. Reservoir siltation

Rys. 3. Zamulenie zbiornika

Fig. 4. Sediment removal by dredging

Rys. 4. Wydobycie osadu ze zbiornika

According to the measurements, for 19 years (1986–2004) the reservoir siltation processes resulted in the reduction in its useful capacity of about 33%. Therefore, water was discharged from this reservoir from 2005 to 2007, and the removal of reservoir sediment was done by dredging. The volume of sediments in the reservoir is illustrated in Fig. 1. Figures 2–4 show the drained reservoir, its siltation and sediments removal by dredging. The dredged sediments were temporarily stored in the vicinity of the reservoir.

2.3. Estimation of the reservoir sediment quality

Besides the estimation of the sediment quantity, also the sediment quality was monitored because of the sediment utilization. Sediment samples were collected from the reservoir in the period of 2005–2007. One composite sediment sample was taken from each selected locality – along the reservoir, by the dike due to the deposition of the finest particles (fractions below 63 μm) [5] and in various sampling depths from one locality. The previous research has shown that it was not necessary to collect samples more often, because the sediment quality in the reservoir from which the water is discharged is not evidently varying. The samples were collected to a plastic bucket. The weight of the collected composite samples amounted to about 3 kg. The samples were air dried at room temperature, any coarse lumps were crushed, and the samples were homogenized. The sediment samples were sieved through a 0.063 mm sieve. Bottom sediment samples were analyzed for total nitrogen, phosphorus and potassium in the accredited laboratory of State Geological Institute of Dionyz Stur, Spisska Nova Ves. The localities for sediment sampling are shown in Fig. 5. Fig. 6 shows the stratification of bottom sediment samples.

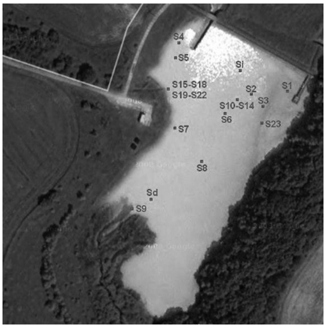

Fig. 5. Location of sediment sampling localities

Rys. 5. Rozmieszczenie punktów poboru próbek osadu

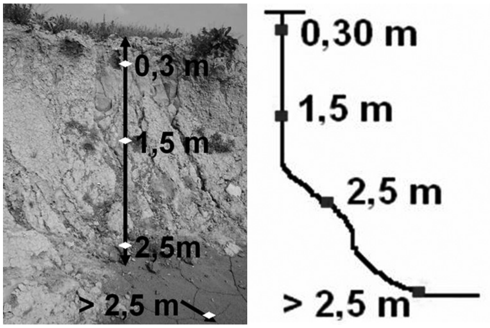

Fig. 6. Stratification of bottom sediment samples (samples S10-S14, S15-S18, S19-S22)

Rys. 6. Uwarstwienie osadów dennych (próby S10-S14, S15-S18, S19-S22)

3. Results and discussion

Samples taken from the reservoir inflow (Si) and near the reservoir dam (Sd) were analyzed according to Act No. 188/2003 of Code on application of sludge and river bed sediments on agricultural and forest soil (Tab. 2). Because this reservoir is situated in a submontane region mainly affected with non-point source pollution from agricultural production areas, the latter samples were analyzed only for total nitrogen (N), phosphorus (P) and potassium (K). The analyzed concentrations of total N, P, K in the bottom reservoir sediments are given in Tab. 3. The results of chemical analyses given in Tab. 2 showed that hazardous contaminants in sediments do not exceed the contaminant levels set by the Act No. 188/2003.

Table 2

Chemical analysis of bottom sediments according to Act No. 188/2003

Parameter	Unit	S_{dam}	S_{inflow}	Limit value (Act No. 188/2003)
Sediment pH	[-]	7.39	7.44	> 5
Dry matter (105°C)	[%]	97.75	98.12	–
Organic matter	[%]	3.01	3.18	–
N	[%]	0.20	0.14	–
P	[%]	0.09	0.07	–
K	[%]	2.05	1.71	–
Mg	[%]	0.77	0.62	–
As	[mg/kg]	9	8	20
Cd	[mg/kg]	< 0.3	< 0.3	10
Cr	[mg/kg]	100	98	1,000
Cu	[mg/kg]	25	19	1,000
Hg	[mg/kg]	0.09	0.07	10
Ni	[mg/kg]	39	30	300
Pb	[mg/kg]	26	21	750
Zn	[mg/kg]	136	105	2,500
AOX*	[mg/kg]	31.3	37.7	500
PCB*	[mg/kg]	< 0.01	< 0.01	0.8
PAU*	[mg/kg]	1.15	0.78	6

AOX* – adsorbable organic halogens, PCB* – polychlorinated bifenyls,
PAU* – polyaromatic hydrocarbons

Table 3

Results of bottom sediment chemical analysis in 2005–2007

Sample	N	P	K	sample	N	P	K
	[%]	[%]	[%]		[%]	[%]	[%]
S1	0.260	0.112	2.500	S13	0.250	0.103	2.400
S2	0.240	0.113	2.420	S14	0.250	0.108	2.420
S3	0.230	0.066	1.980	S15	0.150	0.049	1.880
S4	0.220	0.066	1.960	S16	0.160	0.049	1.940
S5	0.220	0.067	1.690	S17	0.160	0.052	1.990
S6	0.200	0.090	2.050	S18	0.180	0.061	2.020
S7	0.170	0.049	2.030	S19	0.170	0.048	2.020
S8	0.160	0.070	1.710	S20	0.160	0.055	2.000
S10	0.230	0.086	2.200	S21	0.170	0.059	2.040
S11	0.230	0.103	2.320	S22	0.190	0.077	2.330
S12	0.240	0.101	2.370				

Diverse concentrations of N, P, K in the following sediment samples (Table 3, samples S1-S9) confirm irregular sediment deposition in the reservoir. These concentrations increase in proportion with the finest particle fraction, and the concentrations by the dike are higher. In this case the precise information [5] about higher concentrations of the aforementioned elements (N, P, K) in the sediment samples in a fraction below 63 microns has been confirmed.

The N, P, K contents in sediment samples S10-S14, S15-S18, S19-S22 also increase with the sampling depth. This fact is related to a higher amount of fertilizers applied at the end of the 80s and in the beginning of the 90s. Since the year 2000 we can observe a repeated light increase in fertilizer consumption [6].

On the basis of chemical analyses results relating to the higher concentrations of the mentioned nutrients (N, P, K) in the sediment samples we can consider their application on the agricultural soil, but other requirements given in this act have to be complied with (the content of organic compounds in dry matter, content of skeletons in the sediment, soil pH, soil slope, depth of farmland, groundwater surface).

4. Conclusions

Soil erosion is a serious environmental problem due to the soil loss connected with decreasing stream capacity and silting of small water basins as well as with water quality concerns, because sediments play an important role by being the ultimate sink of pollutants, such as nutrients, heavy metals and pesticides.

The contaminant content in dredged sediments is the main factor referring to the sediment as waste or connected with its direct application on soil according to Act No. 188/2003. The study of the sediment quality in the water basin Kľušov shows that hazardous contaminants in sediments do not exceed the contaminant levels set by the Act No. 188/2003, and on the basis of the determined higher nutrient (N, P, K) concentrations in the sediment samples we can consider their application on the agricultural soil, but other requirements given in this act have to be complied with (the content of organic compounds in dry matter, content of skeletons in the sediment, soil pH, soil slope, depth of farmland, groundwater surface).

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