QUALITY OF BOTTOM SEDIMENTS IN SOME SMALL WATER RESERVOIRS AND FISH PONDS

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Abstract**:** Physical, chemical and rheological characteristics of bottom sediment is required to determine the appropriate method for sediment removal. Hydraulic removal of sediments by use of pumping and removal of sediments from water-soil mixture is possible when the reservoir is full or during initial consolidation period. The objective of this paper is to examine the physical, chemical and rheological characteristics of bottom sediment in some small water reservoir, located in the south part of Poland, in which the capacity is no more than 300 thousands cubic metres, and five fish ponds (located in central and south of Poland) to determine the appropriate method to sediment removal. According to sediments quality, later they can be used in agriculture as a fertilizer rich with mineral components.
Keywords: reservoirs, fish ponds, sediments quality.

SOHELEABLAGERUNGENQUALITÄT DER KLEINER WASSESPEICHERS UND FISCHTEICHE

Zusammenfassung**:** In der Arbeit sind die physikalische, chemische und rheologishe Eigenschaften der Sohlenablagerungen der kleinen Wasserspeichers und Fischteiche vorgestellt worden. Diese Wasserspeichers und Fischteiche liegen in Südpolen. Die Kenntnis dieser Eigenschaften hilft wie diese Sohlenablagerungen herauszuholen und für landwirtschaftliche Zweke zu benutzen.
Schluesselworte: Wasserspeicher, Fischteich, Sohlenablagerung

1. Introduction

Reservoirs are important for deposition of rivers sediment. Although sedimentation processes have been examined in large reservoirs, less information is available on the rates and magnitudes of these processes in small agricultural reservoirs. Fish ponds are a special type of small reservoirs characterised by their ecological significance, their relatively small volume capacity, depth and source of water supply to the pond.

The quality of sediments as well as the geometry flow conditions of a reservoir governs the rates and magnitudes of sedimentation in reservoirs and fishponds. Given differences in sediment supply and variable sediment chemistry from various land-use types, there is concern about sediment infilling and potential effects on the water quality of reservoirs.

2. Characteristics of bottom sediments

Physical, chemical and rheological characteristics of bottom sediment are required to determine the appropriate method for sediment removal. Hydraulic removal of sediments by use of pumping and removal of sediments from water-soil mixture is possible when the reservoir is full or during initial consolidation period. The objective of this paper is to examine the physical, chemical and rheological characteristics of bottom sediment in two typical agricultural small water reservoirs (one of them, Zeslawice which capacity is 225 thousand cubic meters, and second one Krempna which capacity is 115 thousand cubic meters), located in the south part of Poland, and four fish ponds to determine the appropriate method to sediment removal. According to sediments quality, later they can be used in agriculture as a fertilizer rich with mineral components.

The surface area of this fish ponds (called “Dwojka”, “Nierodek”, “Bez nazwy”, and “Topolowy”) ranges from 0,5 – 4.0 ha, within average of depth 1 – 1,5 m. These ponds contain carps and are supplied with water from various rivers. Differences in the quantity and physical, chemical and rheological properties of sediment result from catchment properties in

different physiographic regions. Samples of bottom sediments were taken from three sections, one for each: nearest to the pond (closest to the weir), middle section and the pond inlet. Bottom sediments were analyzed for wet and dry density, d_{50}, % of sediment particles less than 50 and 20 μm and number of organic particles in percent. The results were shown in Table 1.

Table 1. Physical features of examined bottom sediments

Name of pond And reservoir	Area [ha]	Density of solid particles ρ_s [kg * m^{-3}]	Humid sediment density ρ_m [kg * m^{-3}]	Number of organic particles [%]	Sediment grain size d		
					d_{50} [μm]	< 50 μm. [%]	< 20 μm [%]
Ponds:							
Dwojka	3.75	2490	1467	12.2	14	69	37
Nierodek	2.10	2420	1612	13.2	18	63	44
Bez nazwy	2.15	2480	1581	22.9	12	67	50
Topolowy	0.60	2390	1570	13.4	41	50	30
Reservoirs:							
Zeslawice Krempna	3.50	2610	1160	6.5	57	39	23

Chemical properties (micro and macro elements and content of heavy metals) were shown in Table 2.

Table 2. Chemical features of examined bottom sediments

Name of pond and reservoir	Level	Mean amount in inlet, middle and outlet section							
		Macroelements [mg · kg^{-1}]			Heavy metals [ppm]				
		NO_3	Ca	Mg	Cu	Zn	Pb	Cd	Ni
Dwojka	upper	9	2950	170	8	22	4,95	0,26	9
	lower	10	2190	180	8	23	5,10	0,28	10
Nierodek	upper	6	1370	87	7	20	4,40	0,30	11
	lower	6	1240	93	7	18	4,50	0,30	13
Bez nazwy	upper	7	1520	100	8	19	4,55	0,32	15
	lower	8	1330	100	7	21	5,00	0,33	15
Topolowy	upper	14	5420	153	18	60	8,45	0,45	24
	lower	16	3820	178	17	50	8,60	0,48	26
Zeslawice	upper	19	2940	268	12	80	19,5	0,60	16
	lower	26	4240	370	14	90	21,0	0,60	20
Krempna	upper	24	7930	230	21	80	13,0	0,30	40
	lower	25	6720	250	18	70	19,0	0,45	51

Rheological particles of the reservoir and pond sediments were determined using a rotative viscometer with two coaxial cylinders (Rheotest - 2 type). Measurements were carried out for a number of volumes each time for 4 -5 different sediment concentrations (C_V). This mixture was placed between two cylinders of radii, R_W (inner, rotating) and RZ (outer, stabile) and measured using a pseudo-flow curve. All the pseudo-curves were approximated with a two-parameter Bingham's model (Kemblowski 1973, Parzonka et *al* 1997). For each curve rheological parameters (plastic viscosity η_p and yield stress τ_o) were determined. Knowledge of these parameters permits determination of this change with sediment concentration (CV). The functional relation $\tau_o = f(C_V)$ was determined for the fish ponds and reservoir. In logarithmic scale this relation was approximated by use of straights (applying the method of minimal squares).

Concentration values (C_{VE}) corresponding to τ_o = 1,5 Pa were adopted by Migniot (1968) as the border between easy erosion regime and difficult erosion regime. According to this criterion, removal of sediment by flowing water (hydraulic erosion) is possible if the value τ_0 in bottom sediments does not exceed 1,5 Pa. Easy erosion (according to Migniot) does not require any heavy equipment for the removal of sediment.

Rheological features of the investigated sediments are shown in Table 3

Table 3. Rheological coefficients of the examined pond and reservoir sediments

No.	Name of pond and reservoir	Sediment concentration C_V	Yield stress τ_0 [Pa]	Plastic viscosity η_p
1	Dwojka	0.20	0.9	0.093
		0.24	3.0	0.201
		0.26	5.0	0.410
		0.30	12.0	0.463
		0.32	22.0	0.501
		0.36	50.0	0.551
2	Nierodek	0.24	6.0	0.345
		0.28	15.0	0.394
		0.32	30.0	0.483
		0.36	50.0	0.689
		0.40	100.0	0.903
3	Bez nazwy	0.14	1.4	0.040
		0.16	2.5	0.100
		0.17	3.8	0.374
		0.25	22.0	0.508
		0.34	85.0	1.780
4	Topolowy	0.22	3.0	0.203
		0.24	10.0	0.324
		0.37	80.0	0.574
		0.40	106.0	0.856
5	Krempna	0.22	15	0.071
		0.25	47	0.085
		0.29	149	0.196
		0.31	352	0.639
		0.33	698	1.423
		0.39	1127	2.345

Results

Physical properties of bottom sediments from the ponds and reservoir are presented in Table 1. The data show that reservoir sediments are much coarser than pond sediments. The “Topolowy” pond is an exception, with d_{50} = 41 μm. This pond is supplied directly by the river. Water is supplied to the other ponds through conduits and the sedimentation of coarse deposits occurs in the conduits. The organic content of particles in the reservoir sediment is considerably less than in a pond which is in agreement reported by Parzonka (1966).

The bottom sediments of fish ponds have a 10% higher organic content Madeyski (1998) found that the content of organic particles in upper sediment layers of fish pond is higher at the sediment surface than by depth. This pattern was observed in the agricultural reservoir.

Chemical properties of the deposits, both of the reservoir and ponds, were different depending on the depth of the sediment samples taken – upper layer of deposits contains bigger amounts of calcium whereas the bottom layer is characterised by a bigger amount of mineral compounds and iron. The amount of macro- and micro-elements in sediments is bigger in the reservoir and pond “Topolowy” which are supplied directly from the river, than in

ponds were the water is supplied by conduits. Chemical properties of sediments evidence also low content of heavy metals what – according to Polish regulations qualify them to zero class of solid pollution level. The sediments contain harmless natural content of heavy metals and can be used in agriculture (vegetable and field cultivation).

Rheological properties of reservoir and pond deposits are similar to properties from fine grained soils reported by Parzonka (1966). Based on the results of rheological analysis using a two-parameter Bingham's model, higher order models such as the Herschel-Bulkley, Vocadli models (Parzonka 1994) are not necessary.

The $\tau_0 = f(C_V)$ relationship from the pond and reservoir sediment is similar, but the slope from reservoir is much steeper. The transition from the newtotian and nonewtonian behaviour of ground and water mixture (order 17%) is highest for reservoir deposits whereas pond deposits are of the order 8-14%.

Deposition of sediments, formation of a more or less easily removable deposit layer at a bottom, consolidation of deposit is influenced both by the soil and shape of grains as well as presence of solved soil and concentration of solid particles. Small particles of dusts and clays (whose particles as less than 40 μm) are additionally subjected to flocculation and harder to be removed from the bottom of the reservoir and ponds. Under the influence of sedimentation and consolidation a quick densification, change of concentration and increase in soil water mixture viscosity take place. Fresh deposits immediately after entering the reservoir or pond have liquid newtonian properties but already several minutes following sedimentation nonnewtonian properties of the liquid occur in such mixtures. Further increases in concentration makes deposits are not easily removable by use of hydraulic methods i.e. application of a pump-water installation. It can, thus, be seen that hydraulic removal of pond sediments is not possible whereas sediments from the water reservoir could be removed by means of this method during a few hours to several days following the sediments entrance into the reservoir (Madeyski, Parzonka 1999)

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