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# Study of Particle Granularity Impact on Nutrient Concentration

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Sediments, detached through water erosion, play an important role in elemental cycling in the aquatic environment. They are responsible for transporting a significant proportion of many hazardous contaminants that are preferentially attached to the high surface area of the finest particles (fractions below 63 microns). Contaminants also mediate their uptake, storage, release and transfer between environmental compartments. Especially nutrients binding to sediments are the important pollution source because they may cause eutrophication what results in a reduction in the dissolved oxygen content of the water, thus killing off much of the animal and plant life.
This contribution is presenting the results of the particle size distribution analysis of sediment samples from Klusov reservoir (Eastern Slovakia) and its effect on the total nutrient concentration in reservoir bottom sediments. Bottom sediment samples were analyzed for total nitrogen by elemental analysis (EA) and for total phosphorus using inductively coupled plasma-atomic emission spectrometry (ICP-AES) technique. The particle size distribution of the sediment samples was performed using a Malvern Mastersizer 2000 with a Hydro 2000S wet dispersion unit. The particle size distribution results indicate that the fine-grained sediments (< 63 μm in particle diameter) are transported and deposited toward the dam. The results of chemical analyses proved the dependence between the total nutrient concentrations in sediments and their particle size. The highest nutrient contents in bottom sediments have been determined in sediments sampled near the dam.

## 1. Introduction

Sediments originated through water erosion act as a potential sink for many hazardous contaminants. Mainly large amounts of nutrients adsorbed to soil particles can be transported via soil erosion to water bodies that result in water pollution problems. The increased concentration of nutrients (nitrogen and phosphorus) in water bodies accelerates the eutrophication process (the growth of algae and other aquatic plants) and it is connected with decreasing of dissolved oxygen levels.
Knowledge of the size gradient of particles that make up suspended load in river system is a prerequisite for understanding the source, transportation and, in some cases, environmental impact of sediment. Although particles of sizes ranging from fine clay to boulders may exist in a river, suspended load will rarely contain anything larger than coarse sand, and in many rivers and reservoirs 50 - 100 % of the suspended load will be composed only of silt + clay-sized particles (< 63 µm) (Ongley, 1996).
The sediment deposition process in reservoirs generally follows the basic pattern, with coarser sediments settling first in the upper reservoir area as the river inflow velocities decrease, forming a delta. Deposition continues from upstream to downstream, with the sediment gradation becoming finer as the deposition progresses towards the dam until the inflowing sediment is deposited throughout the length of the reservoir (Ferrari and Collins, 2006). Some of the inflowing fine sediments (silts and clays) typically stay in suspension and may discharge through the dam outlets or spillways. The size boundary between sand and silt + clay, i.e. 63 µm, is important if the nature of infilling of a reservoir is to be determined or if sediment quality is of interest, because the < 63 µm fraction of suspended sediment is mainly responsible for the transport of chemicals adsorbed on particles. Clay minerals show significant sorption capabilities for

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some anions such as phosphate while other anions, for example, nitrate, show essentially no sorption tendencies on clay minerals (Lee, 1970). Junakova and Balintova have presented in their works (Junakova and Balintova, 2012a) the model for predicting of total nitrogen and phosphorus concentrations adsorbed on reservoir bottom sediments that are detached and transported through water erosion.

For sediment characterization, particle size distribution (PSD) analysis is very important, because physical and chemical properties of contaminants are closely correlated to the PSD (Weiss et al., 2010). Fine grained sediments (silt + clay) are responsible for a significant proportion of the annual transport of metals, phosphorus, chlorinated pesticides and many industrial compounds (Ongley, 1996), since they have relatively high surface area, which facilitates contaminant adsorption.

## 2. Material and methods

Investigation of particle size effect on nutrient concentration in sediments was realized in the catchment of small water reservoir Klusov, situated in Eastern Slovakia, in Bardejov district (Figure 1). This catchment is affected particularly by non-point sources of pollution from agricultural production areas, and no significant point source of pollution is located there. The area of this catchment is about 6.0 km$^2$ with annual average discharge 0.045 m$^3$/s and it falls in the Topla partial river basin. The Klusov reservoir was built for fishing, irrigations, recreation and for retention of high water.  Its basic attributes are shown in Table 1.

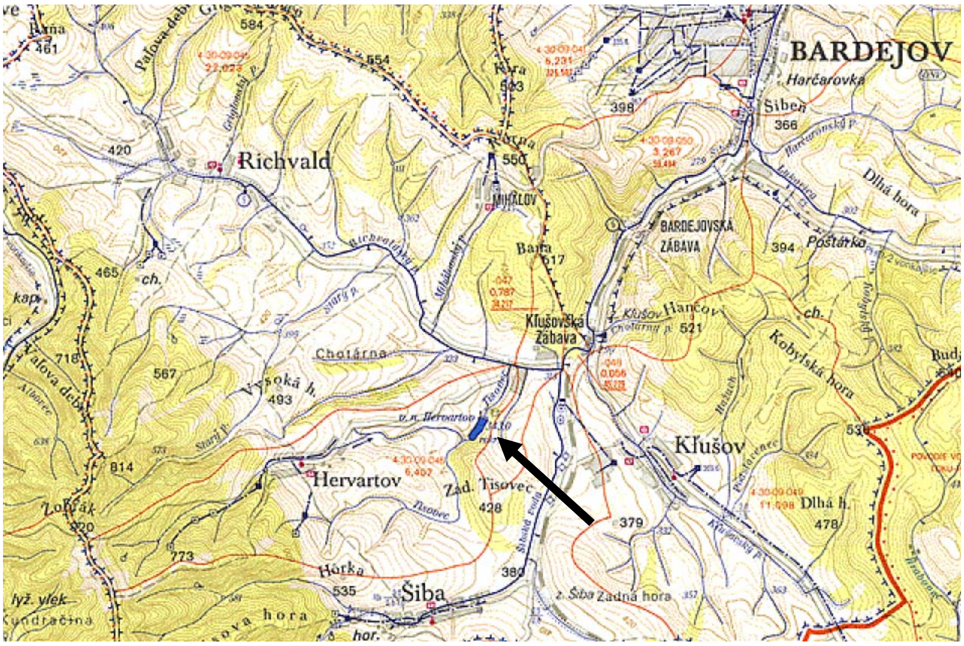


*Figure 1: Location of the Tisovec catchment and Klusov-Hervartov reservoir*

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

*Table 1: Basic attributes of the Klusov small water reservoir*

| Altitude [m above SL] | Average depth [m] | Surface area [ha] | Total capacity [m$^3$] |
|---|---|---|---|
| 343.0 | 3.5 | 2.2 | 72,128 |

Reservoir siltation processes during 19 y resulted in the reduction of its useful capacity about 33 %. Because of excessive silting of this water reservoir, it was drained completely (from 2005 to 2007) and thus it was more available to monitor bottom sediment quality. Since the catchment of water reservoir is affected predominantly by agricultural production, the main pollution elements in bottom sediment samples are nitrogen and phosphorus.

Sediment sampling localities were placed toward the dam due to deposition of the finest particles preferentially attaching the nutrients (fractions below 63 µm) - samples S1-S4. Other samples were collected along the reservoir - S1, S2, S3, S6-S9 (Figure 2).
From each sampling locality, one composite sediment sample was taken to plastic bucket. The weight of the composite samples represented about 3 kg. In laboratory conditions, the samples were air dried at room temperature, any coarse lumps were crushed and samples were homogenized.

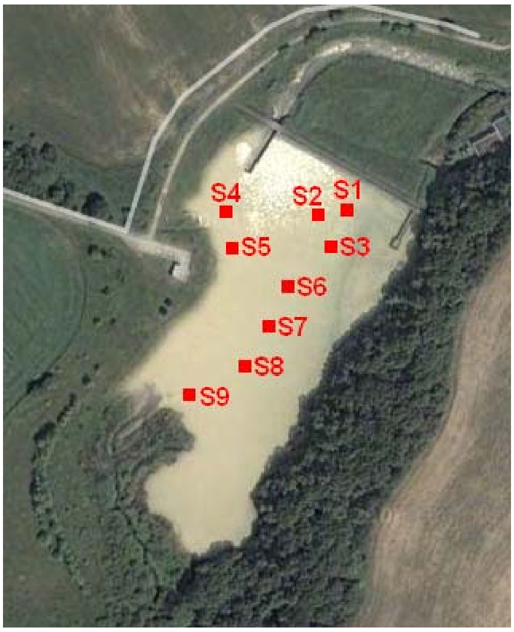


*Figure 2: Location of sediment sampling sites*

The particle size distribution (PSD) of the sediment samples was performed using a Malvern Mastersizer 2000 (Malvern Instruments, 2007) with a Hydro 2000S wet dispersion unit, capable of analyzing particles between 0.02 and 2,000 µm. The refractive index used for the sediment samples was 1.503 (clay minerals). Sediments were suspended in water with a refractive index of 1.330. The samples were run at 2,800 rpm on the sample stirrer and cell pump respectively. Agglomerates were broken up by the action of the ultrasonic, turned on for 5 min after sample addition.
Bottom sediment samples were analyzed for total nitrogen by elemental analysis (EA) and for total phosphorus using inductively coupled plasma-atomic emission spectrometry (ICP-AES) technique.

## 3. Results and discussion

### 3.1 Particle size distribution analysis

The results of the PSD analysis of sediment samples are given in Table 2. Figure 3 graphically presents the PSD undersize curve from selected localities in order from S1 to S9.

*Table 2: The theoretical laser diffraction results*

| Sampling site | d (0.1) µm | d (0.5) µm | d (0.9) µm |
|---|---|---|---|
| S1 | 3.397 | 9.560 | 26.813 |
| S2 | 3.811 | 11.166 | 30.742 |
| S3 | 4.601 | 17.685 | 48.937 |
| S4 | 4.548 | 16.997 | 46.577 |
| S5 | 5.022 | 18.262 | 49.420 |
| S6 | 5.219 | 20.133 | 55.936 |
| S7 | 5.046 | 19.361 | 62.125 |
| S8 | 5.567 | 24.889 | 91.583 |
| S9 | 14.260 | 45.979 | 108.270 |

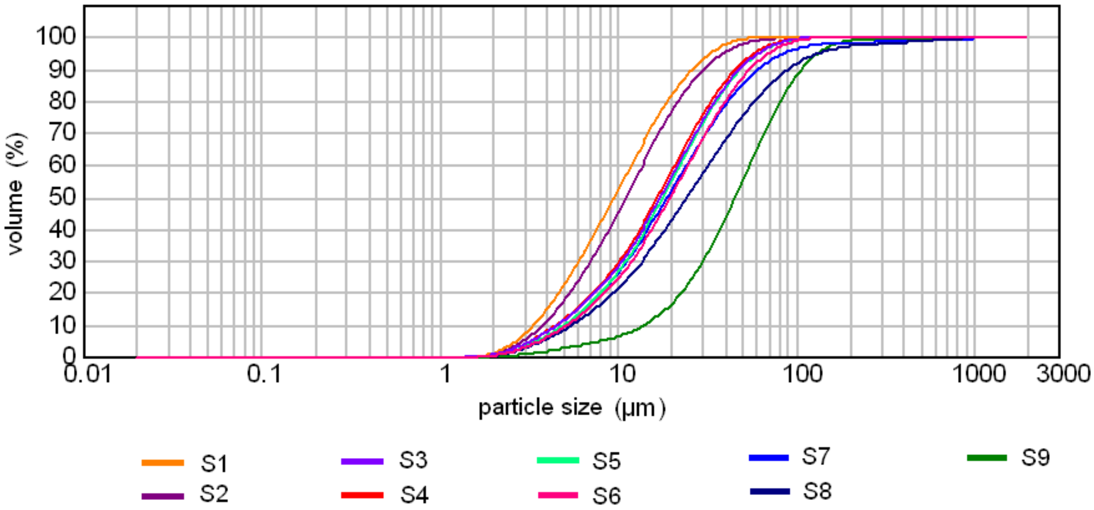


*Figure 3: Particle size distribution results of sediment samples (Malvern 2000, UK)*

The PSD results indicate that the fine-grained sediments (< 63 µm in particle diameter) are transported and deposited toward the dam (samples S1-S4). The sample S1 has 99,92 % and sample S2 99 % fraction of particles under 63 µm. Sediment granularity rises with the increasing distance from the dam, what declares samples S3 (with the 95 % proportion of particles < 63 µm) up to S9 (with the 67 % proportion of particles < 63 µm). The obtained results confirm literary information (Ferrari and Collins, 2006) about deposition process in reservoirs, where coarser sediments settling first in the upper reservoir area as the river inflow velocities decrease and forming a delta. Deposition continues from upstream to downstream, with the sediment gradation becoming finer as the deposition progresses towards the dam until the inflowing sediment is deposited throughout the length of the reservoir.

### 3.2 Chemical analysis

In sediment samples the effect of particle size distribution on the total nutrient concentration in reservoir bottom sediments was also studied, because of preferentially pollutants attaching to the finest particles (fractions < 63 µm). The chemical analysis results of the samples are given in Table 3 and graphically in Figure 4.

*Table 3: The chemical analysis results of the sediment samples*

| Sampling site | $N_{total}$ (%) | $P_{total}$ (%) |
|---|---|---|
| S1 | 0.260 | 0.112 |
| S2 | 0.240 | 0.113 |
| S3 | 0.230 | 0.066 |
| S4 | 0.220 | 0.066 |
| S5 | 0.220 | 0.067 |
| S6 | 0.200 | 0.090 |
| S7 | 0.170 | 0.049 |
| S8 | 0.160 | 0.070 |
| S9 | 0.110 | 0.031 |

From the results of chemical analyses (Table 3, Figure 4) follows that the total nutrient concentrations in collected sediment samples are diverse due to irregular sediment deposition in the reservoir and increase with the proportion of fine-grained particle fraction (Ministry of Environment of the Slovak Republic, 1998). The concentrations of followed chemical elements are the highest in samples collected near the dam (samples S1-S4). With the increasing of sediment sampling distance from the dam the proportion of fine-grained particles (< 63 µm) decreases and also the total nutrient concentrations in sediment samples are lower (Junakova and Balintova, 2012b).

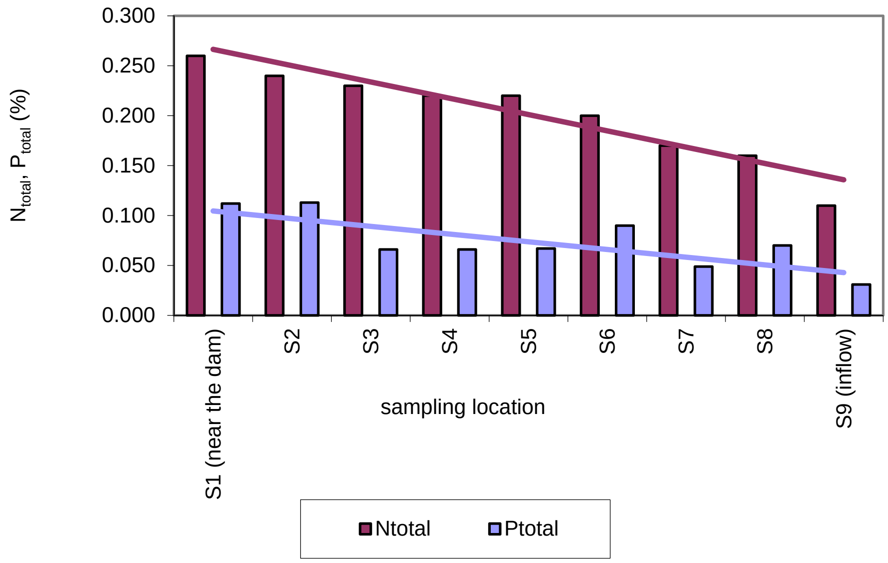


*Figure 4: Impact of sediment sampling distance from the dam and PSD on changes in nutrient concentration in sediments throughout the length of the reservoir*

## 4. Conclusion

The results obtained from particle size distribution analysis confirmed, that the fine-grained sediments (< 63 μm) sampled from Klusov reservoir are deposited near the dam. With the increasing of sediment sampling distance from the dam the proportion of fine-grained particles decreases.

The results of chemical analyses proved the dependence between the total nutrient concentrations in sediments and their particle size. The highest nutrient contents in bottom sediments have been determined in sediments sampled near the dam. It can be related to the high proportion of fine-grained eroded particles which have more surface area per unit of mass, and therefore contaminants adsorb preferentially to them.

The information about deposition of sediments in reservoirs, their size distribution and chemical composition can contribute to solve a problem with desilting and utilization of sediment dredged from water reservoirs (Junakova and Balintova, 2011).


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