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SEDIMENT AND NUTRIENT RETENTION IN RESERVOIRS OF SMALL HYDRPOWER PLANTS

Saulius Vaikasas[1], Romanas Lamsodis[2]

[1]*Vilnius Gediminas technical university, Saulėtekio ave. 11, LT-10223 Vilnius, Lithuania. E-mail: s.vaikasas@delfi.lt*
[2] *Water Research Institute of Lithuanian University of Agriculture, Parko 6, Vilainiai Lt-58102 Kėdainiai, Lithuania.*
E-mail: lammor@delfi.lt

Abstract. Dams segment river channels into dammed and undammed reaches causing both changes in the integrity of free-flow conditions and disturbance of the hydrological regime including downstream transport of both suspended sediments and nutrients. To learn more about the impact of small dams on these phenomena, the investigations were carried out in Lithuania and involved 17 small hydropower plant dams with heights from 2.25 to 14.50 m in four rivers of the 3rd to 4th order. Two beaver-built dam cascades in open drains of the 2nd order were used for comparison. The concentrations of suspended solids, total nitrogen, and total phosphorus there were studied both in each reservoir and river upstream from the reservoir and downstream from the dam. It was revealed that all dams and reservoirs changed the natural regimes of suspended solids trapping them and the finest particles therein. As a result, the percentage of the particles < 0.01 mm and amount of total nitrogen and total phosphorus in the reservoir bed substrates increased several times in comparison to that in the river bed upstream from reservoir. In the rivers below the dams, due to increased velocity and turbulence of flow as water drained off via turbines, the finer particles were scoured out from bed substrates resulting in both the progress of armouring of river channel beds and some increase in concentrations of suspended solids and total phosphorus. Certain consideration concerning environmental aspects related with the subject of the study is presented.

Keywords: dams, suspended sediments, nutrients, transport and retention.

1. Introduction

Water is the main agent for the transport of nutrients in both dissolved and solid (i.e. absorbed or incorporated into inorganic or organic particles) form. Once nutrient have entered the surface water, they are prone to a variety of transformation processes, including biological uptake and transformation, settling of particulates on to the streambed, lake bed, or floodplain, and resuspension (Jansson *et al*. 1994; Mourad and van der Perk 2004; Ren and Packman 2002; Vaikasas 2002; Vaikasas *et al*. 2004). Storm runoff from agricultural fields can contribute nutrients of a stream in dissolved forms as well as in particulate form. Increased export of the nutrients (nitrogen and phosphorus) from catchments has become problematic during the second half of the 20th century, because of eutrophication effects in downstream rivers, lakes, bays and shallow seas (EEA 2003; Eiseltová 1995). In cases where retention, uptake and sedimentation processes are not capable of lowering nutrient concentrations substantially, the elevated concentrations lead to eutrophication of surface waters. (Eutrophication has been defined as the enrichment of surface waters with nutrients, characterized by a rapid growth of algae, diatoms and macrophytes followed by anoxia, fish kills, and a rapid deterioration of overall water quality (Smith *et al.* 1999; Mander *et al.* 2000; Hilton *et al.* 2006)). It may have severe impact on the aquatic ecosystem: it decreases biodiversity and may damage the fishing and tourist economics and drinking water extraction possibilities. In general, policy for the prevention of excess nutrient loads in rivers is based on tackling sources, by the restriction of nutrient surpluses in agriculture, the improvement of sewage water treatment plants, and the prevention of transfer, which is achieved, for instance, conserving or developing buffer zones, contour plough, and increasing hydraulic residence times to enhance retention. The last one can be implemented by hydropower plant dams segmenting river channels into banks and pools (Water Framework Directive & Hydropower 2007).

The construction of small hydropower plants (HPP) as a useful source of renewable energy of electricity is based on modification of stream hydraulics (Jablonskis *et al.* 2008). Ranging from small temporally structures to huge multipurpose ones, dams can have profound and varying impacts on stream corridors. The extent and impact largely depend on the purpose of the dam and its size in relation to stream flow. As the potential energy of river is transformed to power of mechanical energy of turbine P that depends on hydrostatic head H and flow rate Q, the wish for increase height of dam is evident:

$$P = \rho g H Q \tag{1}$$

where: ρ = water density; g = gravity acceleration.

But dams segment river channels into dammed and undammed reaches, which causes changes in the integrity of free-flow conditions and greatly disturbs the hydrological regime of the river. Herewith the equilibrium of the ecological features of rivers and their riparian zones, coherent with both transport and retention of suspended sediments and nutrients, are also disturbed. In dammed segments, silt is not washed from the gravel beds on which many fish species rely on spawning. Every dam impedes or actually stops fish migration downstream, but even small dams are able to block the migration upstream (Graf 1993).

Dams also disrupt the flow of sediment and organic material. Thus, dams can affect sediment and nutrient loads and water quality as well. As stream flow slackens, the load of suspended sediment decreases and sediment drops out from the stream onto the reservoir bottom. But low dams with typically shallow reservoirs modify both the progress of natural flood events and wash product transport cycles only slightly. Notwithstanding, even such small structures still manage to affect the scouring processes and settling of wash products followed by deposition of adsorbed nutrients (Lopardo and Seoane 2004; Bustamante *et al.* 2004).

In 2007, 83 small HPP with the capacity of 27.0 MW, producing up to 66.1 ×10^6 kWh/yr of electricity, operated in Lithuania (Jablonskis *et al.* 2008; Gailiušis *et al.* 2001).

The aim of our research was to test this version and to learn more about small dam and reservoir impact on sediment and nutrient regime in plane relief conditions.

2. Materials and methods

The investigations were carried out in Lithuania and involved 17 dams built on four rivers of the 3rd to 4th order (Fig 1). The height of the dams and the capacities of their reservoirs ranged from 2.25 to 14.50 m and from 0.04 ×10^6 to 15.50 ×10^6 m^3, respectively (Table 1). Depending on the height, the dams and their reservoirs were considered to be small if the height ranged from 2.25 to 5.50 m and average if the height ranged from 7.40 to 14.50 m. All dams were completed with HPP. To bring water to the HPP turbines, the power-channels there were equipped to all dams lower than 5.5 m; whilst the higher ones were completed with the power-conduits, which submerged intakes were installed about three metres below the water levels in the reservoir.

To determine the concentrations of total suspended solids (TSS, by filtration and followed drying at 105° C: LAND 46-2007), total nitrogen (TN, by ISO 11905-1:1997 / LAND 59-2003), and total phosphorus (TP, by molybdenum with stannous chloride: LAND 58-2003), water samples were taken in the following spots: in a river channel upstream from a reservoir (spot I); in a reservoir about 50 m upstream from a dam and in the case of average reservoir in additional two or three spots scattered lengthwise the reservoir (spot II), and in a river channel about 50 m downstream from a dam (spot III). The sampling was conducted when the turbines of the HPP were opening, from February to April in 2009 and 2010; in either year, the reservoirs were covered by ice.

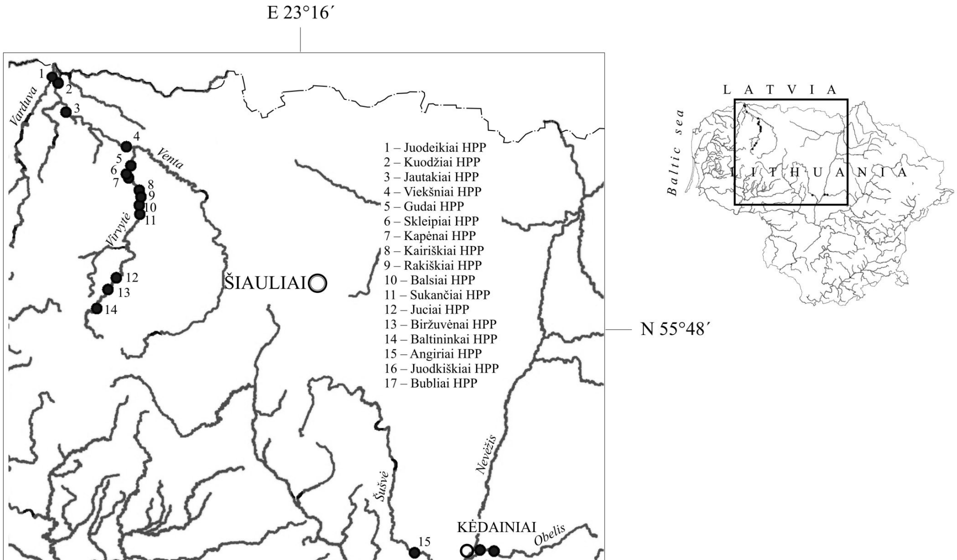

Fig 1. Location map of studied dams

Table 1. Characteristics of dams and reservoirs

River	HPP name	A, $\times 10^6 m^2$	H, m	V, $\times 10^6 m^3$
Virvytė	Gudai	1129	2.75	0.15
	Skleipiai	1069	3.50	0.05
	Kapėnai	1045	5.50	0.23
	Kairiškiai	980	4.80	0.07
	Rakiškiai	975	3.70	0.05
	Balsiai	972	2.95	0.11
	Sukančiai	971	3.25	0.13
	Juciai	435	3.30	0.04
	Biržuvėnai	420	3.50	0.04
	Baltininkai	392	4.30	0.06
Venta	Kuodžiai	4020	4.45	0.48
	Jautakiai	3392	2.92	0.49
	Viekšniai	3021	3.00	0.28
Obelis	Juodkiškis	660	9.80	4.40
	Bubliai	604	7.40	6.44
Šušvė	Angiriai	1050	14.50	15.50
Varduva	Juodeikiai	580	12.50	10.52

Notation: A, river catchment area at dam;
H, height of dam weir;
V, capacity of reservoir.

The sampling depth was about 0.3–0.5 m below the water surface in either side of the dams. Moreover, there were the bed substances both of the reservoirs and rivers (up- and downstream from the dams) sampled to determine their grain-size compositions.

When analyzing, the data were collated into two separate groups considering the heights of the dams at which the data were collected (either less or more than 5.50 m the dams were).

For comparison, there were two beaver-created cascades of 5 and 15 dams in open drains of the 2nd order selected. The catchment areas of the open drains covered 16.1 $\times 10^6$ and 6.8 $\times 10^6$ m^2. The dam heights in the cascades ranged from 0.90 to 1.65 m and from 0.85 to 2.50 m respectively; the capacities of all ponds of each cascade totalled 0.005 $\times 10^6$ and 0.021$\times 10^6$ m^3. Water samples for determining TN and TP concentrations were taken in these spots: in the open drain channels upstream from the beaver-pond cascades as close to the first pond as it was possible by eye to detect the beginning of the water lift (spot I); in the cascade ponds about 10–20 m from the dams (spot II); and in the open drain channels about 10-20 m downstream from the pond cascades (spot III). In all the spots, sampling depths ranged about 10–20 cm below water surfaces. The sampling was conducted from January to May in 2007; there stood no ice cover in the beaver ponds and open drains when sampling in this year.

3. Results

3.1. Suspended solids

It was established that: (1) concentrations of TSS varied widely despite the spots in which they were measured, and (2) natural regime of suspended solids was changed by all the dams when water was flowing via the reservoirs and downstream through the HPP turbines (Table 2). However, the regimes of suspended solids were running differently subject to both the dam height and reservoir capacity. In the case of the small dams and reservoirs, the mean concentrations of TSS exhibited some tendency to decline due to water delay in the reservoirs and then followed the more noticeable increase (by about 30 %) as water drained off into the river channel through the HPP turbines and even somewhat exceeded the values of TSS concentrations that were measured in river channel upstream from the reservoir. Versus to small dams, in cases of average dam reservoirs, it was measured these concentrations being much higher (by about 80 %) in the reservoirs than in the river channels upstream; and there was not measured any increase in the TSS concentrations in water downstream from the dams; the differences between the concentrations in the reservoirs and river below the dams were not significant here.

The increased TSS concentrations in the case of average dams suggest about the possible lateral pollution occurred due to the increase of length of shoreline of the larger reservoirs that enhances their potential to contact with the more number of likely sources of the suspended solids.

Table 2. Concentrations of TSS (mg/l) as water flowed via reservoirs of small and average dams

Group of dams/res.	Index	Sampling spot		
		I	II	III
Small	C_{min}	5.2	2.2	3.0
	C_{max}	17.0	22.4	24.0
	$\bar{C}\pm SE$	10.1±1.4	8.2±1.2	10.8±1.4
Average	C_{min}	3.6	1.0	2.0
	C_{max}	8.8	16.0	7.4
	$\bar{C}\pm SE$	6.0±0.8	6.7±1.2	5,1±1.6

Notation: C_{min} and C_{max},, minimal and maximal concentration values respectively;
$\bar{C}$, mean concentration value;
SE, standard error.

3.2. Fine particles

The available data revealed that all the reservoirs were trapping certain amount of suspended sediments including the finest of them. As a result, the percentage of the particles with diameters < 0.01 mm (hereafter fine particles) in the reservoir bed substrates increased about two- and fourfold in proportion to the percentage of the analogous particles in river bed substrate upstream from the reservoirs (Table 3). In the rivers below the dams, by reason of increased velocity and turbulence of flow when water drained off through turbines, the finer particles were scoured out from bed substrates resulting in both some increase in TSS concentrations (*v.* Table 2) and the progress of armouring of river channel beds downstream from the dams without reference to their heights. Such were the dams Gudai, Balsiai, Sukančiai, Juciai, Baltininkai, Kuodžiai, and Juodeikiai with heights ranging from

2.75 to 9.80 m, (*v.* Table 1). Actually, the mean percentages of fine particles were three- and fivefold less here in river below the dams as compared to the bed substrates in the reservoirs (Table 3).

Table 3. Percentage of fine particles (%) in reservoir and river bed substrates

Group of dams/res.	Index	Sampling spot I	II	III
Small	P_{min}	1.9	7.0	0.0
	P_{max}	17.2	39.5	11.9
	$\bar{P}\pm SE$	9.5±7.7	19.9±2.3	3.60±0.8
Average	P_{min}	3.7	4.8	0.0
	P_{max}	4.0	24.4	6.8
	$\bar{P}\pm SE$	3.9±0.2	13.2±1.7	4.7±1.6

Notation: P_{min} and P_{max}, minimal and maximal percentage of fine particles;
$\bar{P}$, mean percentage of fine particles;
Other notations as in Table 2.

The linear correlation with the coefficient r = 0.71 was found between the percentage of fine particles deposited in the small dam reservoirs and their capacities. On the contrary, there was linear inverse correlation with the coefficient r = -0.49 between such the reservoir capacities and percentage of fine particles in the river bed substrates below the dams (Fig 2).

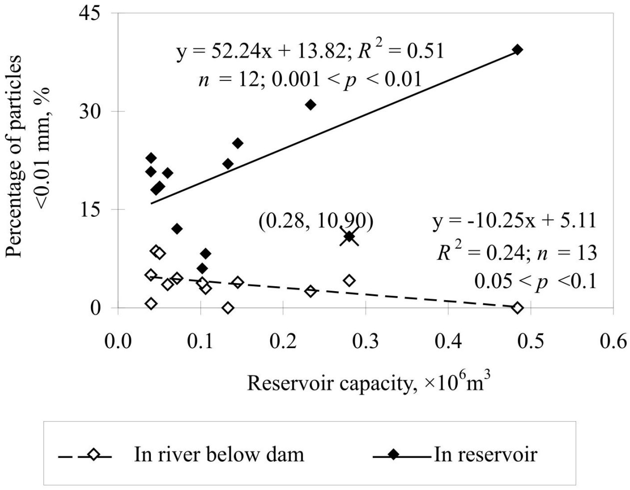

Fig 2. Dependence of percentage of fine particles in bed substrates both of small reservoirs and rivers below dams upon reservoir capacity. Crossed off outlier was not accepted; if it was accepted, coefficient of correlation (r) would equal 0.55 with level of significance $0.05 < p < 0.1$

In the case of average reservoirs, the dependence between reservoir capacity and percentage of fine particles in bed substrates of reservoir revealed, somewhat suddenly, the inverse trend (Fig 3), herewith suggesting that perhaps the threshold reservoir capacity could exist, if both the trendlines which concerned the fine particles in reservoir bed substrate were correct (*cf.* the trendlines in Fig 2 and Fig 3). The percentage of fine particles below the average dams demonstrated no dependence upon their reservoir capacity; even though the data from both groups of reservoirs were collated into one set (Fig 3).

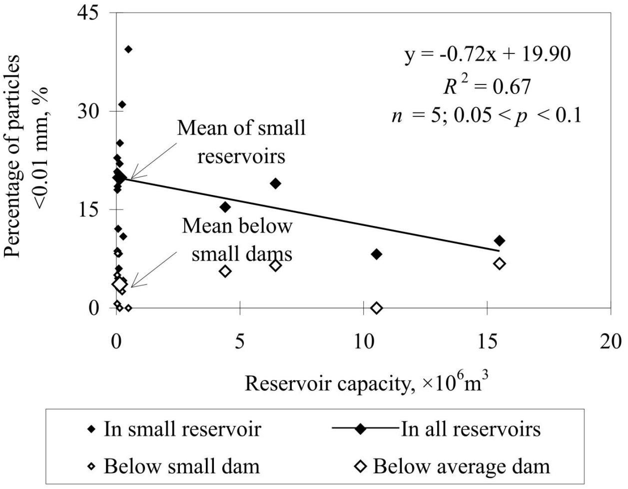

Fig 3. Dependence of percentage of fine particles in bed substrates of small and average reservoirs upon reservoir capacity in all rivers studied (mean values)

Although there were detected certain (1) alterations in both the mean TSS concentrations and percentage of fine particles, and (2) relationships of those variables with the magnitude of the reservoirs, the available data did not demonstrate any interdependent behaviour of TSS concentrations and percentage of fine particles neither in the reservoirs nor in the river channels below the dams.

3.3. TN and TP

The concentrations of TN and TP in small reservoirs mostly demonstrated some positive correlation to their capacities (the coefficients equalled 0.30 and 0.35 respectively). At that, the concentrations of both species of nutrients in water drained off into the river channels via the HPP turbines showed the same but more significant correlation with reservoir capacities (for TN: r = 0.48; for TP: r = 0.62) (Fig 4). Such dependency of the TN and the TP concentration upon the reservoir capacities could be related with the TSS concentrations which did an impact on the concentrations of nutrients (TP particularly) (Fig 5). As compared with reservoirs, the increased TSS concentrations in river channel below the small dams were the result of the scouring of the native rock of river bed, usually poor in nitrogen but some richer in phosphorus.

It was found that the dependencies of TN and TP concentrations in reservoirs upon their capacities were inverse (for TN: r = -0.28; for TP: r = -0.90) in the case of the average dams. Though, it will be observed that pollution of the reservoirs with phosphorus contrasted sharply in the Šušvė and the Obelis Rivers causing about the threefold higher TP concentrations in the Obelis than in the Šušvė River reservoirs (Table 4). By that, the reservoir in the Šušvė River was three–four times larger as those in the Obelis River (*v.* Table 1). These circumstances are to be understood before the above-presented coefficient of correlation, r = -0.90, is considered.

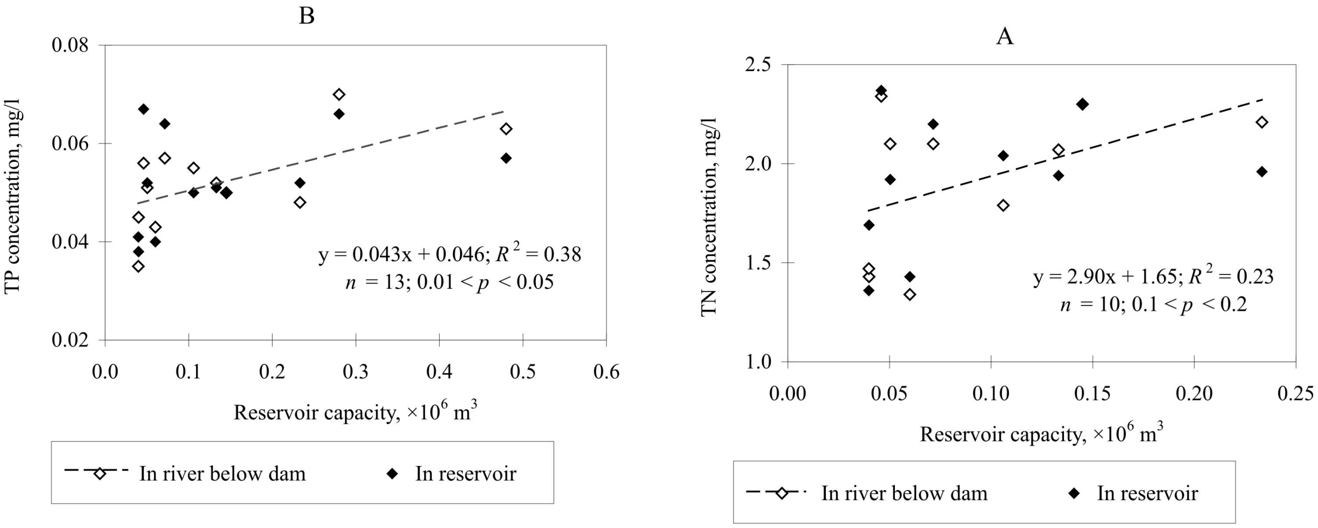

Fig 4. Dependences of TN (A) and TP (B) concentrations upon reservoir capacities in case of small dams and reservoirs

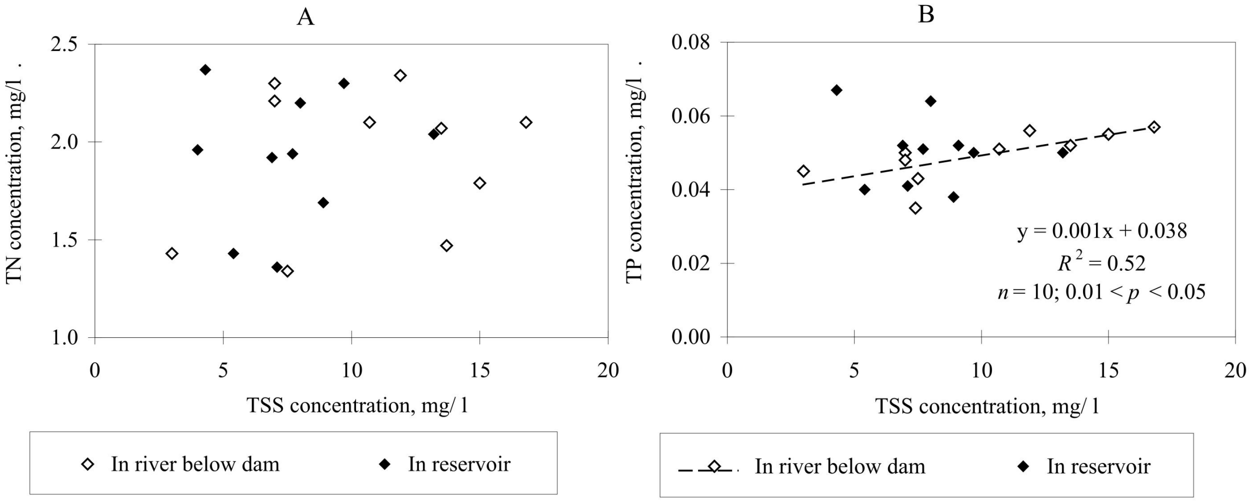

Fig 5. Dependencies of TN (A) and TP (B) concentrations upon TSS concentration in case of small dams and reservoirs

The concentrations of both nutrient species ranged widely in all the studied rivers and most sampling spots (coefficients of variation CV = 0.1–1.04). Consequently, the differences between the means of the concentrations were not highly significant even if their values were considerable. This notwithstanding, the available data showed some tendencies of alterations of the concentrations when water was being delayed in the reservoirs and then drained off downstream (Table 4). (1) All reservoirs demonstrated some reducing effect onto the TN concentrations, but the opposite was observed with the TP concentrations. (2) The mean concentrations were less downstream from all the dams: for TN, by about 3–18 %, for TP, by about 28–29 % in comparison to the reservoirs, except the mean TP concentration in the Obelis River. (3) The TN concentrations decreased to such degree that their mean value in the river channel below the dam got less than that in the river channel upstream from the reservoir; whereas the same cannot be said about the mean value of the TP concentrations.

Delay of water in the reservoirs, alterations of the concentrations, permanent accumulation of the suspended sediment into the bed substrates, their partial transport downstream via HPP turbines and further mixture with those that were re-suspended due to scouring of a river bed below the dams, all these phenomena reflected in the amounts of TN and TP in bed substrates as generalising effects. As a result, the mean amounts of TN and TP augmented considerably (by about 70 %) in the bed substrate of the reservoirs in proportion to the river channels upstream (Table 5). The opposite to the above-mentioned but even more significant alterations making about 63–77 % for TN, and about 45 % for TP there were found as the mean amounts of either nutrient in bed substrates of reservoirs were compared to that computed for river channels below the dams.

Table 4. Concentrations of TN and TP (mg/l) as water flowed via reservoirs of small and average dams, and downstream through HPP turbines

Group of dams/reservoirs	Index	TN			TP		
		Sampling spot			Sampling spot		
		I	II	III	I	II	III
Small:	*Cmin*	1.34	1.32	1.29	0.04	0.04	0.03
all dams	*Cmax*	2.60	2.77	2.72	0.06	0.08	0.06
	$\bar{C} \pm SE$	1.96±0.16	1.98*±0.11	1.92*±0.11	0.05±0.00	0.07±0.02	0.05±0.00
Average:	*Cmin*	2.58	3.55	2.58	0.05	0.05	0.05
TN: all dams	*Cmax*	11.60	9.20	5.97	0.05	0.10	0.05
TP: Angiriai	$\bar{C} \pm SE$	5.75±1.30	5.44±0.37	4.48±0.50	0.05**±0.00	0.07**±0.01	0.05±0.00
Average:	*Cmin*				0.07	0.13	0.20
Bubliai and	*Cmax*				0.23	0.24	0.23
Judokiškis	$\bar{C} \pm SE$				0.17±0.05	0.21±0.03	0.22±0.02

Notation: * differences between means marked by one asterisk significant at $0.1 < p < 0.2$;
** differences between means marked by two asterisks significant at $0.05 < p < 0.1$.
Other notations as in Table 2.

Table 5. Mean amounts of TN and TP (mg/kg) retained in river and reservoir bed substrates

Group of dams/ reservoirs	Index	TN			TP		
		Sampling spot			Sampling spot		
		I	II	III	I	II	III
Small:	*Xmin*	228	423	375	217	224	147
all dams	*Xmax*	3558	5023	1577	376	1063	367
	$\bar{X} \pm SE$	1457±759	2452****±438	559****±166	280***±35	487***±83	254***±30
Average:	*Xmin*	n/a	610	320	n/a	226	171
all dams	*Xmax*	n/a	1780	540	n/a	524	234
	$\bar{X} \pm SE$	n/a	1163**±339	430**±110	n/a	371**±86	202**±32

Notation: *Xmin* and *Xmax*, minimal and maximal amounts of TN or TP in bed substrate;
$\bar{X}$, mean amount of TN or TP in bed substrate;
*** differences between means marked by three asterisks significant at $0.01 < p < 0.05$;
**** differences between means marked by four asterisks significant at $0.001 < p < 0.01$.
(Other notations as in Table 2 and Table 4)

3.4. Beaver pond cascades

The concentrations of both species of nutrients varied quite widely in both open drains and most spots of sampling ($CV = 0.18–0.84$). The mean TN concentrations decreased about equally (by 13–14 %) when water was delayed in the beaver pond cascades despite both their size and the differences in the pollution extent of the open drains (Table 6). Moreover, the mean TN concentrations demonstrated the further drop by 0–6 %, when water drained off from the cascades; thereby, they kept less than that in the open drain channels upstream from the cascades. The mean TP concentrations, in contrast to the TN, showed the increase by 4–14 % as water drained off from cascades; but demonstrated the analogous to TN alteration due to delay of water in the ponds. (The increase of the mean TP concentration in the ponds of smaller cascade should be put aside as side-specific: the water discharged into this cascade contained no inorganic forms of phosphorus.)

Table 6. Concentrations of TN and TP (mg/l) as water flowed via beaver dam cascades created in open drains

Size of beaver dam cascade	Index	TN			TP		
		Sampling spot			Sampling spot		
		I	II	III	I	II	III
$N = 5$	*Cmin*	14.3	13.2	13.5	0.015	0.013	0.015
	Cmax	31.0	31.0	31.0	0.023	0.032	0.033
	$\bar{C} \pm SE$	23.7*±3.7	20.6*±3.6	20.6*±3.6	0.018**±0.001	0.021±0.004	0.022**±0.001
$N = 15$	*Cmin*	9.9	5.4	5.4	0.007	0.006	0.011
	Cmax	19.7	25.8	20.0	0.093	0.100	0.105
	$\bar{C} \pm SE$	14.8*±1.5	12.7*±1.0	12.0*±2.0	0.043±0.014	0.035±0.006	0.040±0.014

Notation: N, number of dams/ponds in cascade.
Other notations as in Table 2 and Table 4.

4. Discussion

The data available involved a short period of winters and springs of two years. So they were both not abundant and season-specific. Nonetheless, they showed the HPP dams and reservoirs in small rivers of lowland environment tended to retain suspended solids (Table 2 and 3). However, as Zdankus *et al*. (2008) has reported, the increased water depths and decreased flow velocities in the reservoirs resulted in the deposition of suspended particles in the special order: the coarse sand particles accumulated at the beginning of the reservoir, smaller ones travelled along the reservoir and settled below, silt particles reached the dam, and only the clay particles managed to be transferred downstream via the dam. But, if the reservoir is large enough, the settling of clay particles is possible here as well. Incidentally, Shteinman *et al*. (2004) has reported that along with the deposition of the suspended particles, various pollutants associated with them were deposited as well.

The positive dependence of the percentage of fine particles in bed substrates of small reservoirs upon their capacities (Fig 2) and the negative one in the case of average reservoirs (Fig 3) check out with the results of the above-mentioned authors quite properly. In the light of these either findings, the existence of the threshold reservoir capacity, at which the accumulation of fine particles starts to decline, gets more reliable.

There was just alone variable, the TSS concentration, which mean value increased in water below the dams (Table 2). As there was found no relationship between the TSS concentrations and both the TN and TP concentrations in the reservoirs (Fig 5) but the analogous relationships existed in river channels below the dams, it was very likely that some of suspended solids below the dams were of the new origin and not transferred from the reservoirs, i.e. scoured out from the river bed rock.

The HPP reservoirs in small rivers are capable to retain suspended solids and nutrients in bed sediment and somewhat to reduce the TN and the TP concentrations below the dams. In this aspect, the HPP reservoirs demonstrated a certain similarity to the beaver ponds where the decrease in mean TN and TP concentrations in ponds and downstream was measured (except the TP mean concentration which increase below the dams might be explained by the scouring effect of the bed rock by the falling down water) (Table 6). The more detailed studies conducted by Lamsodis (2003) have revealed the decrease in mean yearly concentrations of both the dissolved inorganic nitrogen and the phosphorus by about 14 and 40 % respectively. The positive linear correlation detected by Maret *et al*. (1987) between the concentrations of both suspended solids and the various species of compounds of nitrogen and phosphorus showed the very mechanism why water quality got better in the beaver dammed stretches of streams.

Although the HPP dams in small rivers possessed some positive effects in retention of suspended sediments and nutrients, they did not escape some environmentally negative effects. (1) These dams not always protect the downstream river channel from the enhanced supply of the fine suspended sediments when HPP are operating (Table 2). (2) Within reservoirs further downstream located sections, as it was mentioned by Jungwirth *et al*. (2005), "are heavily degraded due to the loss of fluvial dynamics and intensive sedimentation of suspended materials". (3) Shields (2009) indicated the inability of orthodox stream management structures to reduce the fine sediment yield from a watershed. (4) Loss of in-stream natural sand/gravel bars due to the bed silting, and raised water level both radically altered habitat quality for various original species. Lithuanian Fish Indices (LFI) measured in the dammed sections of the Virvytė River showed negative impact on fish habitats (LŽŪU 2010). González *et al*. (2004) have indicated that fish abundance and phytoplankton compositions were influenced by the changed variability observed into the reservoirs. (5) In-stream structures for river regulation resulting in the areas of permanent inundation within the main channel negate the normal hydraulic functioning of very flood event (WMO/GWP 2006; Mayer *et al*. 2010). All these consequences suggest that the project makers have to be careful when (1) selecting rivers for damming on purpose to install HPP, (2) choosing the constructive elements for the particular HPP; the pros and cons related to the generated electric power and loss of farmlands, and natural woods and meadows with often rare or endemic flora species after inundation of valleys are to be objectively weighed.

5. Conclusions

Under the conditions of low water periods in winter and early spring the HPP dams in small rivers of lowland environment impact on natural flow regime, sediment and nutrient retention

In proportion to river bed substrate upstream, the reservoirs, depending on their capacity, are capable to accumulate several times larger amounts of both fine particles and TN and TP in their bed substrates.

Below the dams, water discharged through HPP turbines scours out river bed substrate resulting in the increase in TSS concentrations and encouragement of the progress of armouring. The increase in TSS concentrations in water below the dams by 10 mg/l enhances the increase in TN and TP concentrations by 0.20 and 0.01 mg/l respectively.

Loss of both river continuum and fluvial dynamics due to erection of dams and elevation of water level, and natural gravel bars due to bed silting in reservoirs negatively impact on fish living habitats and the aquatic life in general.

References

Bustamante, M. A.; Morillo, S.; Freyer, Z. I.; Ruiz, M.; Angelaccio, C.; Rodríquez, M. I. 2004. The water quality modelling and environmental impact of an Azud (little dam) construction in Cuarto River (Argentina). In *Aquatic Habitats: Analysis & Restoration*. Fifth International Symposium on Ecohydraulics, 2004, Madrid, Spain. Madrid: IAHR, 1189–1193.

Eiseltová, M. 1995. Overview. In M. Eiseltová; J. Biggs. *Restoration of Stream Ecosystems: An Integrated Catchment* Approach. IWRB Publication 37, 1–4.

EEA (European Environment Agency) 2003. Europe's environment: the third assessment. Available on the Internet:http://reports.eea.europa.eu/ environmental assessment report 2003 10/ en.

Graf, W. L. 1993. Landscapes, commodities, and ecosystems: The relationship between policy and science for American rivers. In WSTB; NRC. *‚Sustaining Our Water Recourses*. National Academy Press, Washington, D.C.; 11–42.

Gailiušis, B.; Jablonskis, J.; Kovalenkovienė, M. 2001. *Lietuvos upės. Hidrografija ir nuotėkis* [Lithuanian Rivers. Hydrography and Runoff]. Kaunas: Lietuvos energetikos institutes. 792 p. ISBN 9986–492–64–5 (In Lithuanian).

González, M. A.; Servia, M. J.; Vieira-Lanero, R.; Cobo, F. 2004 Fluctuations in the distribution of biomass and abundance of benthic macroinvertebrates as a tool for detecting levels of hydraulic stress. In *Aquatic Habitats: Analysis & Restoration*. Fifth International Symposium on Ecohydraulics, 2004, Madrid, Spain. Madrid: IAHR, 1092–1096.

Hilton, J.; Hare, O.; Bowes, M. J.; Jones, J. I. 2006. How green is my river?A new paradigm of eutrophicationin privers. *The science of the Total Environment*, 365: 66–83.

Jablonskis, J.; Jurgelenaite, A.; Tomkevičienė, A. 2008. Lithuanian hydropower and environment protection. In *The 7th International Conference "Environmental Engineering"*: Selected papers, vol. 2. May 22–23, 2008, Vilnius, Lithuania. Vilnius: Technika, 557–562.

Jansson, M.; Andersson, R.; Berggren, H.; Leonardon, L.1994. Wetlands and Lakes as Nitrogen traps. *Ambio*, 23: 320–325.

Jungwirth, M.; Haidvogl, G.; Hohensinner, S.; Muhar, S.; Schmutz, S.; Waidbacher, H. 2005. Leiobild-specific measures for the rehabilitation of the heavily modified Austrian Danube River. *Artchiv Für Hydrobiologie* suppl. 155, *Large Rivers*, 15: 17–36.

Lamsodis, R. 2004. Upinio bebro (*Castor fiber* L.) veiklos melioracijos grioviuose padarinių, jų poveikio sausinimo sistemoms ir aplinkai tyrimai [Summary of Final Report "Effects of European beaver (*Castor fiber* L.) activities in open drains on drainage systems and environment"]. *Vandens ūkio inžinerija* [Water Management Engineering], 25(45):124–125 (in Lithuanuan).

Lopardo, R. A.; Seoane, R. 2004. Environmental impact of large and small hydraulic structures. In *Aquatic Habitats: Analysis & Restoration*. Fifth International Symposium on Ecohydraulics, 2004, Madrid, Spain. Madrid: IAHR, 867–872.

LŽŪU 2010. *Aplinkosauginių rekomendacijų hidroelektrinių (HE) neigiamam poveikiui aplinkai sumažinti parengimas* [Environmental Recommendations how to Reduce Negative Impact of Hydropower Plants, Final Report of Lithuanian University of Agriculture]. Kaunas-Akademija: Lietuvos žemės ūkio universitetas (in Lithuanian).

Mander, Ü.; Kull, A.; Kuusemets, V.; Tamm, T. 2000. Nutrient runoff dynamics in a rural catchment: Influence of land-use changes, climatic fluctuation and ecotechnological measures. *Ecological Engineering*, 14: 405–427.

Maret, T. J.; Parker, M.; Fannin, T. E. 1987. The effect of beaver ponds on the nonpoint source water quality of a stream in Southwestern Wyoming. *Water Research*, 21: 263–268.

Mayer, P. M.; Todtt, A. H.; Okay, J. A.; Dwire, A. K. 2010. Introduction to the featured collection on riparian ecosystems & buffers. *JAWRA*, 46: 207–210.

Mourad, D.; van der Perk, M. 2004. Modelling nutrient fluxes from diffuse and point emissions to river loads: the transboundary Lake Peipsi/Chudskoe basin (Russia/Estonia/ Latvia). *Water source and Technology*, 49(3): 21–28.

Ren, J.; Packman, A. I. 2002. Effects of particle size and background water composition on stream-subsurface exchange of colloids. *Journal of Environmental Engineering*, 128: 624–634.

Shields, F. D. Jr. 2009. Do we know enough about controlling sediment to mitigate damage to stream ecosystems? *Ecological Engineering*, 35: 1727–1733.

Shteinman, B.; Khanbilvardi, R.; Khazin, V.; Ozkurt, O. 2004. Some characteristic features of ecosystems functioning in the river mouths. In: *Aquatic Habitats: Analysis & Restoration*. Fifth International Symposium on Ecohydraulics, 2004, Madrid, Spain. Madrid: IAHR, 1238–1241.

Smith, V. A.; Tilman, G. D.; Nekola, J. C. 1999. Eutrophication: impacts of excess nutrient imputs on freshwater, marine, and terrestrial ecosystems. *Ennvironmental pollution*, 100: 179–196.

Vaikasas, S. 2002. Sedimentation and self purification in the Nemunas floodplain. In *Research for Rural Development 2002*. International scientific conference proceedings, Jelgava, Latvia, 2002. Jelgava, 121–125.

Vaikasas, S.; Lukianas, A.; Rimkus, A. 2004. Suspended sediment deposition in floodplain meadows. In *Aquatic Habitats: Analysis & Restoration*. Fifth International Symposium on Ecohydraulics, 2004, Madrid, Spain. Madrid: IAHR, 1423–1427.

Water Framework Directive & Hydropower, 2007. Common Implementation Strategy Workshop. Issues Paper. Berlin, 4-5 June 2007. 20 p.

WMO/GWP (World Meteorological Organization / Global Water Partnership), 2006. *Environmental Aspects of Integrated Flood Management*. WMO-No.1009. Geneva, Switzerland.

Zdankus, N.; Vaikasas, S.; Sabas, G. 2008. Impact of a hydropower plant on the downstream reach of a river. *Journal of Environmental Engineering and Landscape Management*, 16: 128–134.