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**INVESTIGATION OF SUSPENDED SEDIMENTS
IN THE WETLANDS OF THE NEMUNAS BASIN**

**Summary of Doctoral Dissertation
Technological Sciences, Environmental Engineering**

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VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2003–2008.

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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NEMUNO BASEINO ŠLAPŽEMIUOSE TYRIMAI**

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Introduction

Problem

It is important to assess impact of the Nemunas, the main river of Lithuania that falls into the Curonian Lagoon, on the sedimentation, siltation and eutrophication processes in the Lagoon, and to foresee possible suppressing and control of these processes.

Considering possibilities for holding back the sediments in the floodplains of the lower reaches of the Nemunas, the most attention shall be paid to fine suspended sediments washed away from the fields. The danger of such sediments is related to their fineness, which prevents them from settling in the river stream, they start settling only in the backwaters, or continue floating to the Lagoon. These fine particles have a very large comparative surface area, therefore they sorb and bind biogenic substances and heavy metals intensively, produce aggregates. Thus, these wash products are the main carriers of biogenic substances and heavy metals, and, respectively, the main agents causing contamination of the Curonian Lagoon.

One of the main possibilities to control dynamics of sediments is inducement of sedimentation processes in the floodplains of the lower reaches of the Nemunas. However, to perform such modifications of the sedimentation mode, we need to investigate and assess processes of the sediments dynamics in the inundated areas. Numerical modelling of suspended particles sedimentation in floodplains is rather complicated because of insufficient investigation of the influence of grassy vegetation on the sedimentation processes. That was the key problem of this work.

Topicality

The Curonian Lagoon is an important chain in distribution and sedimentation of flood sediments between the floodplains of the lower reaches of the Nemunas and the Baltic Sea. The major part of water and sediments runoffs to the Curonian Lagoon is carried by the Nemunas during the spring flood. If hydrological and sediment mode are changed in the floodplains of the lower reaches of the Nemunas, changes would occur in the Curonian Lagoon as well. If the dynamics of suspended sediment is controlled purposively, the conditions of water self-purification and reduction of eutrophication in the Curonian Lagoon could be improved.

The lower reaches of the Nemunas Delta due to its relief is of utmost importance for investigation and control of sediment dynamics in the floodplains of the lower reaches of the Nemunas. If sedimentation modes are investigated there and modified, floods in the lower reaches of the Nemunas

and water overflow into the floodplains could bring significant benefits. First of all, it should be said about depositing of fine clay and mud particles in the floodplains. These deposited sediments would not just improve the mechanical composition of the soil in the floodplains, they would also fertilise it. Furthermore, such increased sedimentation would cause purification and improvement of the Curonian Lagoon water, and, simultaneously, partial improvement of the water quality in the Baltic Sea: its eutrophication and contamination with heavy metals would be reduced.

Aim and tasks of the work – to investigate and establish regularities in sedimentation of fine suspended sediments in the grasslands in the lower reaches of the Nemunas valley and, with the help of numerical model, to calculate amounts of sediments deposited during the investigated period 1950–1991. The following tasks were solved in order to achieve the aim of the work:

1. To perform measurements of the flood sediments dynamics, establishing distribution of fine sediments concentration versus flow depth in field conditions in the lower reaches of the Nemunas valley during floods of different extent and with different areas of inundated grasslands.
2. To establish capability of grassy vegetation to trap the amounts of suspended sediments and their fractional composition.
3. To perform numerical modelling of the flood sediments dynamics in the upper and lower parts of the Nemunas delta for the period 1950–1991.

Scientific novelty

The novelty of the work is such that the sedimentation in the lower part of periodically inundated Nemunas delta has not been modelled and investigated yet. The numerical model “Delta”, was used for investigations in this work, after the adjustment of the model to the particular terrain conditions – the lower valley of the Nemunas delta.

Defended propositions

1. Transport of the finest silt particles with the highest biogenic load washed to the river Nemunas, and their sedimentation in the periodically inundated valley is very beneficial for protection of the Curonian Lagoon against eutrophication and for improvement of soil in the floodplains.
2. Inundated grassy vegetation has the greatest impact on trapping of fine sediments in the floodplains.
3. In numerical modelling of trapping of fine suspended sediments by inundated grasslands a multistratum hydraulic resistance model should be applied.

4. The lower part of the inundated Nemunas delta is more efficient in trapping transported, than the upper part of the delta.

Approbation of the results. The results of the work were published in 7 scientific publications: 2 articles in the reviewed Lithuanian scientific magazines, included in the list approved by the Department of Science and Studies; 1 – in the conference papers, in the referred information in the data base of the Institute of Scientific Information (Thomson ISI Proceedings); 1 scientific article in the reviewed foreign publication; 3 scientific articles in the Lithuanian publications.

The results of the scientific work were discussed in 2 international conferences and scientific meetings and 3 national scientific conferences. 5 scientific publications were issued in the conference papers.

The scope of the scientific work. The scientific work comprises the Introduction, 3 Sections, General Conclusions, Referred Literature, the list of the Author's publications and lecture papers, Annexes on the subject of the scientific work. The scope of the work is 125 pages of text without 3 annexes, includes 64 figures, 7 tables.

1. Interaction between the river flood sediments and the valley streams

1.1. The floodplains of the Nemunas River lower reaches

Our purpose was to evaluate the effect of the Nemunas, as the main river of Lithuania falling into the Curonian Lagoon, on the sedimentation in the closed estuary, the Curonian Lagoon, and the amounts of sediments deposited in the Nemunas delta.

The lower reaches of the Nemunas have the most favourable conditions for inundation of floodplains. The natural reserve – the Nemunas Delta Regional Park – has been established in the floodplains of the lower reaches of the Nemunas (Fig. 1). Inundation is conditioned not only by the naturally higher flow of this part of the river, but also by the plain terrain, abundance of branches connecting the river with the sea. Therefore there are many wetlands and periodically inundated natural grasslands. The area of the delta is about 930 km², about 605 km² of them may be periodically inundated during floods.



Fig. 1. The Nemunas Delta Regional Park

1.2. Types of sediments and their dynamics in the floodplains

Investigations of sediments are performed in almost all biggest rivers in the world. However, the main attention is paid to the establishment of the river bottom formation particularities. Fine wash products have not been investigated much. First of all, it shall be mentioned that fine particles are very difficult to investigate, as large scale measurements in field conditions are required to determine their dynamics, and application of hydraulic models is very complicated, as connecting equations are missing. Therefore, for their numerical description only separate observations of sedimentation processes in field conditions can be relied upon. Fine wash products were selected as a research subject for analysis of sediments trapping capacities in the lower reaches of the Nemunas.

1.3. The review of numerical modelling of sediments dynamics in the Nemunas floodplains

For the purpose of p modelling, we divided the Nemunas delta into the lower and the upper parts. It shall be mentioned that the upper part of delta is 4–5 m higher and has more dikes than the lower part. The lower part is plainer and, even at low flood, water flows out of the river bed into floodplains. In the lower part of the delta, flood water stays in the floodplains 2–2,5 times longer

than in the upper part of the delta. The length of the flood streams is sufficient to settle a significant part of the finest clay particles, therefore it was thought that the main part of the finest sediments carried to the Nemunas delta settle there. The floods in the lower part of the delta are determined not only by the natural course of flood in the Nemunas, but also by the situation in the Curonian Lagoon related to wind and ice. The possibility of flooding there is even 95–98 %. Therefore, modelling of the sediments dynamics in the lower part of the Nemunas delta constituted novelty of our work.

One of the tasks of this work was to investigate with the help of the numerical model, what amount of sediments is trapped in the upper and in the lower parts of the Nemunas delta, and what is the influence of grassy vegetation on the intensity of sedimentation.

1.4. Modelling peculiarities of sediments settling in the floodplains above grass

Sedimentation of fine particles on the grass in the floodplains is much more intense than in the riverbeds with the bottom covered with deposits. This is because the water velocity through the grass is low, therefore each particle that occurs in the grass is trapped and settles soon. In such way the capacity of the grass to trap suspended sediments, therefore they settle in the grass at relatively high water velocities and small concentration of sediments, and somewhat settling of sediments in the floodplains occurs all the time. This is the main distinction between the fine particles sedimentation processes in the clean water bed and in the delta overgrown with luxurious grassy vegetation. With consideration of the above, we decided to pay an appropriate attention to the methods of modelling the dynamics of fine suspended particles in our work.

Having reviewed the literature about similar investigations made in Lithuania, we found that investigations of similar character were performed 20 years ago in the upper part of the Nemunas delta, however, the processes of fine particles transport have not been investigated in the sufficient extent. Much attention so far has been paid to the investigation of distribution of water flows, streams and levels in the Nemunas delta, which is very important for further investigation of the dynamics of fine suspended sediments. Furthermore, the conditions of sediments deposition in the lower part of the Nemunas delta were not numerically modelled earlier.

Distribution of concentrations of suspended sediments throughout the depth of the flow in the river bed without grass, and above the grass stratum, established in hydraulic model by other authors and described in the literature, is shown in the Figure 2.

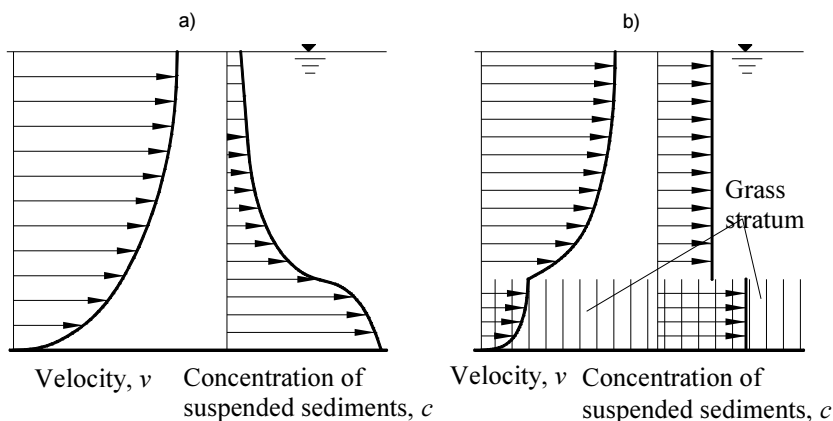


Fig. 2. Distribution of velocities and concentrations of suspended sediments throughout the depth of the flow: a) in the main river bed, b) in the inundated floodplain

The selected research subjects of this work: 1) the Nemunas Delta Regional Park, the floodplains of the upper and the lower parts of the Nemunas delta; 2) the floodplains of the Nevėžis River; 3) suspended wash products, transported by water flow.

The input of the author of this work into solving of the analysed problem is measurement of the distribution of suspended sediments concentration in field conditions in the inundated grasslands of the Nemunas delta and numerical modelling of the lower part of the Nemunas delta.

2. Methodology of research

Several methods were used for the investigation of sedimentation processes in the river valley: investigations in field conditions during inundation period – velocities of separate flows were measured, and vertical distribution of sediments in the respective measurement points; during ebb period – granulometric investigation of deposited sediments; numerical modelling.

Experimental measurements of sediments concentration in the lower reaches of the Nemunas River during the spring flood were performed, granulometric composition of sediments was investigated. Numerical modelling with application of the program “Delta” was used for modelling of hydraulic phenomena in the floodplains of the lower part of Nemunas delta. Experimental measurements in the floodplains of the Nevėžis River near Kėdainiai town were

performed in order to increase the reliability of field and numerical data, and to investigate effect of grassy vegetation on sedimentation processes.

3. The results of the research

3.1. The results of measurement of suspended sediments concentrations in the floodplains of the Nemunas in field conditions

Though the flood in 2004 was not the highest during the entire period, during which floods in the lower reaches of the Nemunas were measured, the selected measurement points represented the most characteristic locations very well, i.e. the places of the Nemunas river bed, the old river beds in the valley, the places where the flow was compressed by the road banks, places of slow flow, places of flow overflowing from the valley. It was decided to perform measurements of sediment concentrations near Rambynas Hill, at the overflow across the road to the farmstead near Girininkai Village, at the lower part of Užlenkė Bridge at 10, 50, 100, 150, 200, 250, 300 m distance from the bank, several measurement points were chosen near the flooded road Šilutė–Rusnė near the overflow to the Leitė valley. Several measurement points were also selected near Plaškiai Village, where purified valley flow returns back to the river bed.

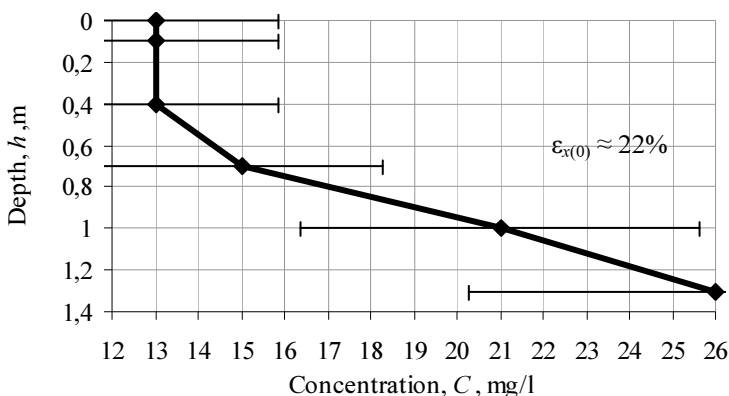


Fig. 3. Suspended sediments concentration at the measuring place in the old riverbed of the Nemunas valley near Užlenkė Bridge (10 m from the left bank, vertical No. 2–1)

As the data of sediment concentrations measurement in the Nemunas valley inundated by the spring flood and in the river bed showed, the

distribution obtained corresponded very well to the character of vertical distribution of sediments concentrations versus depth in the samples described in the literature and depicted in the Figures 3–7. The obtained distribution of concentrations showed that vertical changes of concentrations in the river bed and in the bridge spans differs from those in the floodplains.

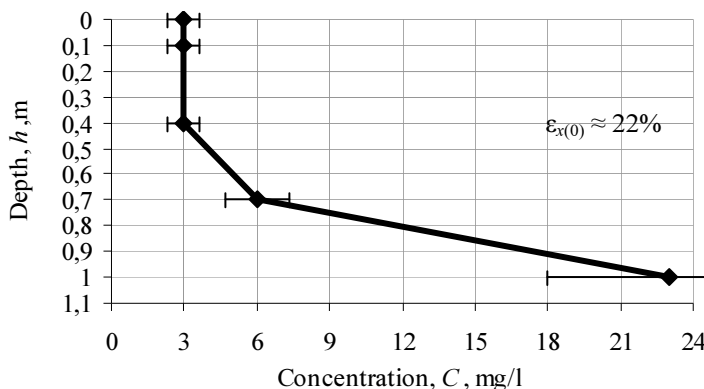


Fig. 4. Suspended sediments concentration at the measuring place in the old riverbed of the Nemunas valley near Užlenkė Bridge (250 m from the left bank, vertical No. 2–6)

The vertical distribution of sediment concentrations in the flow that we measured in the river bed near Užlenkė Bridge (Fig. 3–4) was close to parabolic (Fig. 2a).

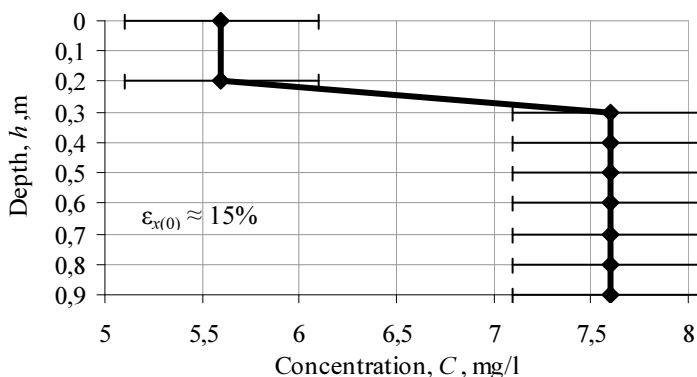


Fig. 5. Distribution of suspended sediment concentration versus depth, along the vertical line No. 5–3, near the outflow to Leitė valley

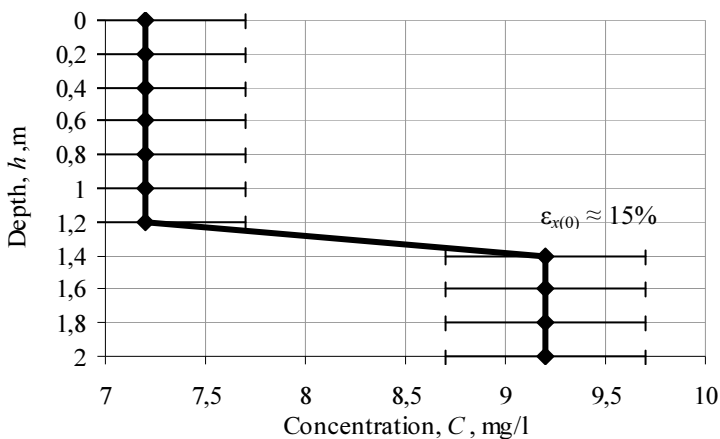


Fig. 6. Distribution of suspended sediment concentration versus depth, along the vertical line No. 3–1, near Plaškiai

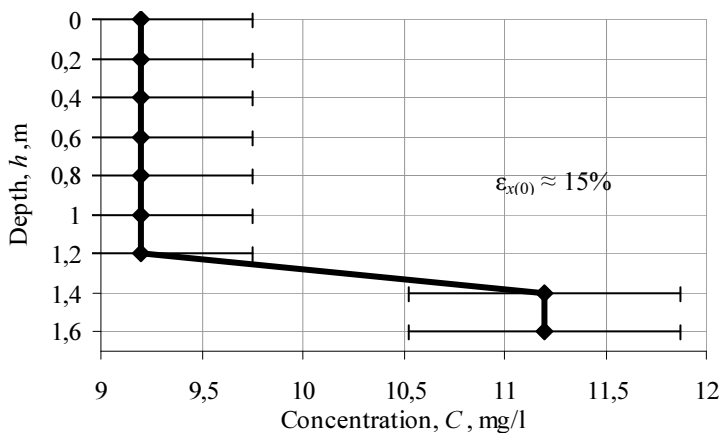


Fig. 7. Distribution of suspended sediment concentration versus depth, along the vertical line No. 3–2, near Plaškiai

Distribution of sediment concentrations in the inundated valleys of the Nemunas River complied with the distribution determined by other scientists during laboratory tests (Fig. 2b). We think that fine suspended sediments distribute into two clearly defined zones there – that is the part above the grass

stratum and the part in the grass stratum (Figures 5–7). Change of sediment concentrations in the both parts of flow is close to straight line.

Before the flood of 2004, we reviewed the location near ties Plaškiai, which possibly would be flooded. We found that the selected measurement locations were covered with luxurious grassy vegetation. (Fig. 8). That confirms the further measurements and the assumptions made at the beginning of the work that grass has a great influence on the velocities and distribution of sediments into two separate zones (Fig. 5–7).



Fig. 8. Luxuriant grassy vegetation near Plaškiai

Having performed investigation in the field conditions we see, that conclusions regarding the threshold change of sediments in the grass we true, therefore other formulas, that better reflect sediment sedimentation and adhesion in the grasslands of the Nemunas lower reaches, should be used for more accurate numerical model of sedimentation in floodplains.

Our data was confirmed by the results of investigations of regularities in distribution of sediment concentrations in the grass and water stratum, published by other researchers during the recent years. However, we shall not forget that the reliability of the all dependencies obtained so far are empiric. Therefore the reliability of existing numerical models developed so far is comparatively low. It is mainly related to complexity of detailed field investigations and shortage of field investigation data, it determines insufficient understanding of physical processes, happening in the floodplains.

3.2. The results of field measurements of sediments deposited and trapped in the grass in the floodplains of the Nevėžis River

The purpose of measurements in the Nevėžis River near Kėdainiai was to investigate the change of fractional composition of sediments in the floodplains during the spring flood, in order to find out the amount of sediments adhered to the vegetation of floodplains, their aggregate state and fractional composition.

Analysis of the collected data showed that the main difference in the total balance of sediments (between the turbidity concentration of the river bed and the valley) occurs between the fraction 0,005 mm and fraction 0,001 mm. Therefore we can state that grass stratum is the most efficient in settling finest clay and silt fractions of the size less than 0,005 mm.

The obtained results support our assumptions and hypotheses about significant effect of grass stratum on settling of the finest particles of suspended sediments, and confirm other authors' notes on different concentrations of suspended sediments in the river beds and floodplains.

3.3. Numerical modelling and analysis of suspended sediments

The obtained data showed that the particles of the coarsest fraction made the major part of suspended sediments settled in the upper and the lower parts of the delta. Such quantitative distribution of sediments by fractions can be explained so, that the stripe "river bed-floodplain" was modelled. As we know, the sediments of the coarsest fractions are transported and settled in the river bed more, than in the floodplains, where sediments of finer fractions are settle.

It was established by numerical model that a large amount of fine particles was settled in the lower part. As mentioned before, floods in the lower part of the Nemunas delta continue for a longer time period, they are more often even at a small flood flow. Therefore the amount of fine particles settled in the lower part of the delta is greater than in the upper part.

It was established that during the modelled period, 1950–1991, 336 thousand m³ of the coarsest 0,1 mm fraction sediments, 598 thousand m³ of 0,02 mm fraction sediments, 309 thousand m³ of 0,01 mm fraction sediments and 125 thousand m³ of the finest 0,005 mm fraction sediments was deposited in the upper part of the Nemunas delta (the river bed and the valley). The total amount of sediments in the upper part was 1369 thousand m³. In the lower part of the Nemunas delta (the river bed and the valley) the following amounts of sediments was deposited: 380 thousand m³ of the coarsest 0,1 mm fraction sediments, 688 thousand m³ of 0,02 mm fraction sediments, 501 thousand m³ of 0,01 mm fraction sediments and 457 thousand m³ of the finest 0,005 mm

fraction sediments. The total amount of sediments in the lower part was 2028 thousand m³.

The total amount of sediments deposited in the modelled sector of the Nemunas delta during 42 years period was approximately 3397 thousand m³. As our field measurements showed, the 9–30 mg/l concentration of sediments prevailed in the stratum next to the bottom in the Nemunas delta during the flood of 2004. Going closer to the mouth, this concentration gradually decreased. It means that the water was becoming cleaner. As mentioned above, since mainly coarse sand sediments (0,02 mm and 0,1 mm fractions) are transported and settled in the Nemunas river bed, the amount of such sediments deposited during the modelled years was the greatest – 59% of the total amount of sediments. It was also determined by the fact that the flood water does not inundate the floodplains of the upper part of the Nemunas delta every year, thereby fine particles can not settle there and are transported further.

3.4. Analysis of the numerical modelling of sediments dynamics in the upper and lower parts of the Nemunas delta and improvement of the model

As we saw, in order to model distribution of sediments carried over and deposited in the Nemunas delta, an accurate determination and analysis of physical processes occurring in the grass stratum during flood is essential.

The numerical model “Delta” evaluates the effect of grassy vegetation on the transport and settling process of suspended sediments with the help of mathematical formulas. Grass stratum is evaluated there as a roughness coefficient.

As mentioned above, there are different conditions in the floodplains of the Nemunas, starting with densely overgrown riverside areas, to the hayfields, still used for farming purposes. Thus, evaluation of grass by the sole roughness coefficient is neither very accurate, nor erroneous, particularly if the grass is not high (2–15 cm).

Low grass stratum. For improvement of the model “Delta”, efficiency of a low grass stratum in trapping of sediments may be expressed in mathematical formulas that are obtained by hydraulic modelling at the University of Aberdeen, the UK, with the low grass stratum.

It was established these, that particles carried through the grass stratum are usually fine (maximum size 20 µm). Usually an assumption is made that these particles are carried as suspension. In such case a classical one-dimensional convection-diffusion equation may be used, making an assumption that the

particles once settled are not raised back to the flow. This equation is written in the following way:

$$\frac{\partial \left(\frac{hq_{s,s}}{q} \right)}{\partial t} + \frac{\partial \left(\frac{\partial q_{s,s}}{q} \right)}{\partial x} = \varepsilon_x \frac{\partial^2 \left(\frac{hq_{s,s}}{q} \right)}{\partial x^2} - \lambda_s q_{s,s}. \quad (1)$$

This method for calculation of sediments trapping in the grass is suitable for such floodplains of the Nemunas, where grass is relatively small. That is because other processes, which occur when water flows over the stratum of high grass (i.e. capability of grass to trap sediments and to adhere them by surface tension) are not evaluated there.

A high grass stratum. As mentioned above, due to changes in farming conditions in the Nemunas Delta Regional Park, at present grasslands are almost not mowed down. Therefore high grassy vegetation starts prevailing there, which eventually becomes thicker. The mentioned factor shall be taken into consideration, when modelling trapping of sediments in the Nemunas floodplains. However, it is rather difficult to do that mathematically. The researchers Velasco et al. by the tests of the hydraulic model performed in 2007–2008 established that capability of high grass to trap sediments can be numerically expressed through shear stresses (tensile forces) (Fig. 9). That means that under the effect of different tangential stresses, velocity gradients in the flow are distributed in different ways, and, accordingly the concentration.

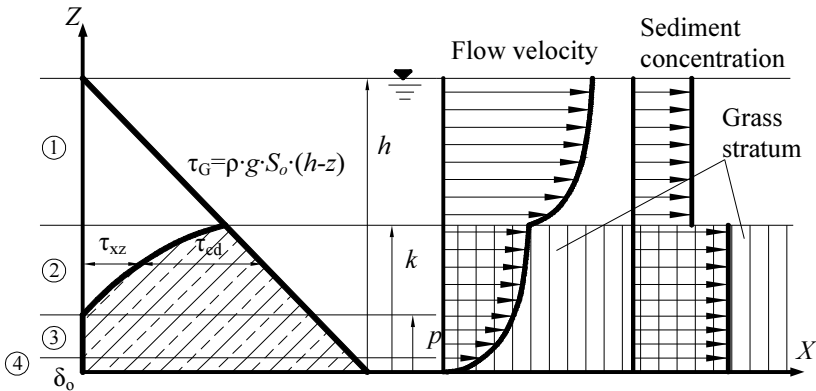


Fig. 9. Distribution of tensions, water flow velocities and sediment concentrations through the water flow with high grassy vegetation: h – total water depth, k – grass stratum height, p and δ_0 – relative depths depending on the tension values

According to this vertical distribution, the flood flow in the inundated grassy area can be divided into several zones. Sediments settle in each zone due to different factors. Such distribution of sediments concentration by zones was also noticed during field experimental tests carried out in the Nemunas delta in 2004 (Fig. 5–7). The laboratory tests performed by the researcher Velasco et al. confirm and clarify vertical character of sediments distribution noticed by us.

The motion quantity equation (Reynolds equation) makes the basis of the laboratory hydraulic model.

$$0 = \rho \cdot g \cdot S_0 + \rho \cdot v \cdot \frac{\partial^2 U(z)}{\partial z^2} + \left(\frac{\partial \tau_{xz}(z)}{\partial z} \right) - f_{cd}(z). \quad (2)$$

As mentioned above, four tension (particle) distribution zones were established during laboratory rests: zone 1 – external stratum, when $h > z > k$; zone 2 – internal stratum, when $k \geq z > p$; zone 3 – stratum without shear stresses, when $p \geq z > \delta_0$; zone 4 – viscosity stratum, when $\delta_0 \geq z$.

Thanks to this model, mathematical expressions were received, assessing distribution of tangential stresses in the vertical line of the water flow. Therefore, further improving the numerical model of the Nemunas delta, the sedimentation process could be numerically expressed by the above equations.

General Conclusions

1. Research performed in the field conditions of the Nemunas delta demonstrated that distribution of sediment concentrations along the vertical line of the Nemunas river bed and the old river bed near Užlenkės bridge was close to parabolic, and fine suspended sediments in the floodplains separate into two clearly defined zones: into the part carried above the grass stratum and the part that settles in the grass stratum. Change of sediments concentrations above the grassy vegetation on the vertical line of the flow is close to the straight line.

2. In the sediments collected during the research performed in the field conditions of the Nevėžis river, a significant fraction of sediments, attributable to dust category was found (~25%). We found that relative water turbidity is higher in the main Nevėžis river bed, than in the valley. Fine sediments, i.e. small (less than 0,001 mm) mud-dust particles make the major part of sediments carried to the valley.

3. Formerly created in the Water management Institute of Lithuanian University of agriculture the mathematical model “Delta” was supplemented in this work with new boundary conditions for lower reach of the Nemunas delta. The data for these boundary conditions was collected from topography, hydrometrical annual books and field investigations of roughness coefficient.

To evaluate roughness coefficient the investigations in field conditions during inundation period 2004 in Nemunas delta was made.

4. With the numerical modelling it was found that distribution of the sediments by fractions in the upper part of the Nemunas delta was as follows: 25% of the coarsest 0,1 mm fraction sediments, 43% – 0,02 mm fraction sediments, 23% – 0,01 mm fraction sediments and 9% – 0,005 mm of the finest fraction sediments. The total amount of sediments in the upper part was 1369 thousand m^3 . Distribution of the sediments in the lower part of the Nemunas delta was as follows: 19% of the coarsest 0,1 mm fraction sediments, 33% – 0,02 mm fraction sediments, 25% – 0,01 mm fraction sediments and 23% – 0,005 mm of the finest fraction sediments. The total amount – 2028 thousand m^3 .

5. The content of finest fraction of sediments (0,005 mm) amounted to 9% of all sediments deposited in the upper part of the Nemunas Delta (1369 thousand m^3), and to 23% of all sediments in the lower part of the Nemunas Delta (2028 thousand m^3). It means that the lower part of the delta was much more efficient if trapping fine suspended sediments.

6. The total amount of sediments deposited in the modelled area of the Nemunas delta (the upper and the lower parts) during the research period, 1950–1991, was approximately 3397 thousand m^3 . The major part of these sediments, deposited during the modelling years, were coarse sand sediments (0.02 mm and 0.1 mm fractions), they made 59% of the total amount of sediments.

Proposals

1. To increase the amount of settled suspended sediments in the Nemunas valley and clarify floodwater, that gets into Curonian Lagoon, i'm propose leave the not eclosed territory of the floodplain of the Nemunas and his tributarys for required fine particles sedimentation, increase the amount of overflowing floodwater in to the grassed valley and leave not moved territory such more as possible.

2. For evaluation of the optimal choises of the sedimentation in the Nemunas delta, calculation of the economical usefulness and hydraulic modeling in the separate typical places could be performed.

3. According the data of sediment concentration distribution that collected during this work in the field investigations in the floodplains ower grass, i'm propose to improve the numerical model of the Nemunas delta flows and sediments. Mathematically the sedimentation process could be evaluated using

multistratum hydraulic resistance in conditions over luxuriant grass stratum and low grass stratum.

**List of Published Works on the Topic of the Dissertation
In the reviewed scientific periodical publications**

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2. Rimkus A., Vaikasas S., Stankevičius M., 2006. The investigations of the impact of flood stream on the sediment dynamics in the Nemunas delta. *Water Management Engineering* 29(49) (Vandens ūkio inžinerija: mokslo darbai 29(49)): 18–26 (in Lithuanian). ISSN 1392–2335.
3. Stankevičius, M., 2005. Some problems of sedimentation modeling in the River floodplains, in *The 6th international conference “Environmental engineering”*: May 26–27: selected papers vol. 1. Vilnius Gediminas technical university, 484–489. ISBN 9986-05-850-3. (Thomson ISI Proceedings).

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4. Stankevičius, M. 2005. Principal scheme of numerical modeling of sedimentation processes in the river floodplains, in *ICID-CHD 21th European regional conference “Integrated land and water resources management: towards sustainable rural development”*. Frankfurt (Oder), Germany and Slubice, Poland, 15–19 May, [interaktyvus] [CD-ROM].
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SKENDINČIŲJŲ NEŠMENŲ SEDIMENTACIJOS NEMUNO BASEINO ŠLAPŽEMIUOSE TYRIMAI

Mokslo problemos aktualumas. Kuršių marios yra svarbi grandis, paskirstant ir nusodinant potvynio nešmenis tarp Nemuno žemupio ir Baltijos jūros. Kryptingai valdant skendinčiųjų nešmenų dinamiką, įmanoma gerinti vandens apsivalymo bei eutrofikacijos sumažinimo sąlygas Kuršių mariose.

Ištirus ir čia pakeitus sedimentacijos režimus Nemuno žemupio potvyniai ir vandens išsiliejimas į slėnį atneštų ir nemažą naudą. Pirmiausia tai pasakytina apie smulkių molio ir dumblo dalelių nusodinimą užlietose pievose. Šie nusėdę nešmenys ne tik pagerintų užliejamų pievų grunto mechaninę sudėtį, bet jas ir patreštų. Be to, dėl šios padidintos nešmenų sedimentacijos geriau apsivalytų ir pagerėtų Kuršių marių, o tuo pačiu ir dalinai Baltijos jūros vanduo: sumažėtų jo eutrofikacija ir teršimas sunkiaisiais metalais.

Skendinčiųjų nešmenų sedimentacijos užliejamose pievose matematinis modeliavimas yra gana sudėtingas dėl nepakankamai ištirto žolinės augalijos poveikio nešmenų nusodinimo procesams. Tai ir buvo pagrindinė šiame darbe nagrinėjama problema.

Darbo tikslas ir uždaviniai – ištirti ir nustatyti smulkiųjų skendinčiųjų nešmenų nusėdimo į žolinę augaliją dėsningumus Nemuno žemupio slėnyje ir matematinio modelio pagalba apskaičiuoti iškritusių nešmenų kiekius per tiriamą 1950–1991 m. laikotarpį. Užsibrėžtam darbo tikslui pasiekti buvo sprendžiami tokie uždaviniai:

1. Atlikti potvynio nešmenų dinamikos matavimus, nustatant smulkiųjų nešmenų koncentracijos pasiskirstymą vandens tėkmės vertikalėse natūrinėmis sąlygomis Nemuno žemupio slėnyje įvairaus dydžio potvynio metu bei esant įvairiems užliejamos žolinės augalijos plotams.

2. Nustatyti žolinės augalijos gebą sulaikant skirtingų frakcijų nusėdančių skendinčiųjų nešmenų kiekius Nevėžio užliejamose pievose.

3. Atlikti Nemuno deltos aukštutinės ir žemutinės dalių matematinį 1950–1991 m. laikotarpio potvynio nešmenų dinamikos modeliavimą.

Darbo naujumas ir jo reikšmė. Darbas yra naujas tuo, kad periodiškai užliejamos Nemuno deltos žemutinės dalies sedimentacija iki šiol nebuvo modeliuota bei tirta. Šiame darbe naudotas matematinis modelis „Delta“ buvo pritaikytas konkrečioms reljefo sąlygoms – žemutiniam Nemuno deltos slėniui. Modelis padėjo įvertinti nusėdinamų nešmenų kiekius Nemuno deltoje. Reikia pažymėti, kad pasaulyje upių slėniuose šiuo metu panašūs procesai yra per mažai tiriami. Kaip minėta, nuo laukų nuplautieji smulkūs nešmenys pasižymi specifinėmis judėjimo ir sėdimo tėkmėje savybėmis, todėl jų tyrimus atlikti natūrinėmis sąlygomis potvynio metu yra sunku ir sudėtinga.

Ginamieji teiginiai

1. Nuo laukų nuplautų ir į Nemuno upę patekusių smulkesnių didžiausią biogeninių krūvi turinčių dumblo dalelių išnešimas ir nusodinimas periodiškai užliejamame slėnyje labai naudingas saugant Kuršių marias nuo eutrofikacijos bei gerinant užliejamų pievų dirvožemį.

2. Apsemta žolinė augmenija turi didžiausią įtaką sulaikant smulkiuosius nešmenis slėnyje.

3. Matematiškai modeliuojant smulkių skendinčiųjų nešmenų sulaikymą esant apsemtai žolinei augalijai reikėtų taikyti daugiasluoksnio hidraulinio pasipriešinimo modelį.

4. Užliejama Nemuno deltos žemutinė dalis yra efektyvesnė už aukštutinę deltos dalį, sulaikant smulkiuosius nuo laukų nuplautus judančius skendinčioje būklėje nešmenis.

Darbo apimtis. Darbo apimtis yra 125 puslapių, neskaitant priedų, tekste panaudota 61 numeruota formulė, 64 paveikslai ir 7 lentelės. Rašant disertaciją buvo panaudota 119 literatūros šaltinių.

Įvardiniame skyriuje nagrinėjamas problemos aktualumas, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autoriaus pranešimai ir publikacijos, disertacijos struktūra.

Pirmasis skyrius skirtas literatūros apžvalgai. Apibendrinant literatūroje aprašytus eksperimentus nustatyta, kad pagrindiniai faktoriai, lemiantys didelį skendinčiųjų nešmenų nusodinimą apsemtose žolėtose pievose, yra mažas tėkmės greitis ir žolių savybė prilipdyti smulkiąsias nešmenų daleles ar jų agregatus.

Antrajame skyriuje aprašoma darbe naudotų tyrimų metodika. Nešmenų sėdimo procesų tyrimams upės slėnyje naudoti keli metodai: tai natūriniai tyrimai užliejimo laikotarpiu – matuojami atskirų tėkmių greičiai ir tų matavimo taškų vertikalūs nešmenų pasiskirstymai; nusėdusių nešmenų granulimetriniai tyrimai; matematinis modeliavimas.

Trečiajame ir rezultatų skyriuose pateikiami gauti rezultatai ir jų analizė. Atlikus natūrinius tyrimus nustateme, kad apie slenkstinį nešmenų pokytį žolėje iškelti teiginiai buvo teisingi. Šis darbas aplinkosaugos srityje yra labai svarbus tuo, kad padės labiau suprasti vykstančius smulkiųjų nešmenų judėjimo ekohidraulikos procesus. Tai yra svarbu gerinant Kuršių marių vandens kokybę, o tuo pačiu planuojant Nemuno deltos regioninio parko vystymą ir pritaikymą natūraliai vykstantiems paviršinių vandenų apsisvalymo procesams.

Bendrosios išvados

1. Natūrinių tyrimų Nevėžio upėje pavasario potvynio metu surinktose nuosėdose rasta didelė nešmenų dalis (~25 %), priskiriama dulkių kategorijai (mažesnės nei 0,001 mm). Nustatyta, kad vandens santykinis drumstumas yra didesnis pagrindinėje Nevėžio upės vagoje nei slėnyje. Tai rodo, kad „švari“ vaga be žolės pasluoksnio turi mažesnę skendinčiųjų nešmenų sulaikymo efektyvumą.

2. Nemuno deltoje atlikti natūriniai tyrimai parodė, kad nešmenų koncentracijų kitimai tėkmės gylyje upės vagoje skiriasi nuo pasiskirstymų upės salpoje: Nemuno vagoje ir senvagėje ties Užlenkės tiltu nešmenų koncentracijų pasiskirstymas tėkmių vertikalėse gautas artimas paraboliniams, o apsemtuose slėniuose smulkieji skendintys nešmenys pasiskirsto į dvi aiškiai išreikštas zonas: į virš žolės sluoksnio nešamą dalį ir į žolės sluoksnyje nusodinamą dalį. Nešmenų virš žolinės augalijos koncentracijų kitimas tėkmių vertikalėse yra artimas tiesei.

3. Lietuvos žemės ūkio universiteto vandens ūkio institute anksčiau sukurtas matematinis modelis „Delta“ šiame darbe buvo papildytas, jį pritaikant ir konkrečioms Nemuno deltos žemupio ruožo kraštinėms sąlygoms. Modelio kraštinių sąlygų keitimui duomenys gauti iš topografinių planų, hidrometrinių metraščių, natūrinių hidraulinio šiuurkštumo matavimų. Hidraulinio šiuurkštumo įvertinimui buvo atlikti ekspediciniai natūriniai matavimai užlietoje Nemuno deltoje 2004–ųjų metų potvynio metu.

4. Atlikus modeliavimą nustatyta, kad per tiriamą 1950–1991 m. laikotarpį Nemuno deltos aukštutinėje dalyje nusėdo 1369 tūkst. m³ nešmenų. Iš jų – 25 % stambiausios 0,1 mm frakcijos nešmenų, 43 % – 0,02 mm frakcijos nešmenų, 23 % – 0,01 mm frakcijos nešmenų ir 9 % – 0,005 mm smulkiausios frakcijos nešmenų. Nemuno deltos žemutinėje dalyje nusėdo 2028 tūkst. m³ nešmenų. Iš jų – 19 % stambiausios 0,1 mm frakcijos nešmenų, 33 % – 0,02 mm frakcijos

nešmenų, 25 % – 0,01 mm frakcijos nešmenų ir 23 % – 0,005 mm smulkiausios frakcijos nešmenų.

5. Nemuno deltos aukštutinėje dalyje smulkiausios frakcijos nešmenų (0,005 mm) nusėdo 9 % nuo viso nešmenų kiekio aukštutinėje dalyje (1369 tūkst. m³), o žemutinėje – 23 % nuo viso nešmenų kiekio žemutinėje dalyje (2028 tūkst. m³). Žemutinė dalis yra daugiau efektyvesnė sulaikant smulkiuosius skendinčiuosius nešmenis.

Pasiūlymai

1. Norint padidinti slėnyje nusodinamų nešmenų kiekį bei nuskaidrinti potvynio vandenį, kuris patenka į Kuršių marias, siūlau palikti sedimentacijai būtinus neatitvertus Nemuno upės ir jo intakų slėnių plotus, didinti besiliejančių į deltą potvynių vandens debitą bei palikti kuo daugiau nešienaujamų žaliųjų plotų.

2. Geresniems nešmenų nusėdinimo užliejamose Nemuno deltos pievose variantams parinkti, būtų tikslinga atlikti ekonominius naudingumo skaičiavimus ir nešmenų pasiskirstymo konkrečiose vietose hidrodinaminį modeliavimą. Detaliau išanalizuoti smulkiųjų dalelių sulaikymą žolėse geriausia sumažinto mastelio hidrodinaminiam modelyje.

3. Remiantis šiame darbe atliktais natūriniais skendinčiųjų nešmenų dinamikos virš žolių tyrimais siūlau tobulinti hidraulinį matematinį modelį „Delta“, t. y., didinant skaičiavimų tikslumą ir tyrinėjamų faktorių vertinimo galimybes, skaičiavimo algoritme turėtų būti numatytas atvejis, kai žolės apsemiamos nedideliu gyliu ir vanduo žymia dalimi teka tik pro žoles. Vykdam skaičiavimus tai pat reiktų įvertinti galimybę didinti nešmenų sėdimą užlietoje salpoje su vešlia augmenija.

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**INVESTIGATION OF SUSPENDED SEDIMENTS IN THE WETLANDS
OF THE NEMUNAS BASIN**

Summary of Doctoral Dissertation

Technological Sciences, Environmental Engineering (04T)

Mindaugas Stankevičius

**SKENDINČIŲJŲ NEŠMENŲ SEDIMENTACIJOS NEMUNO BASEINO
ŠLAPŽEMIUOSE TYRIMAI**

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