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ASSESSMENT OF SURFACE WATER EUTROPHICATION AT ŽITNÝ OSTROV REGION

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The purpose of this report is to review the role of nitrogen (N) and phosphorus (P) in the eutrophication of surface water. The work was required by Water Framework Directive 2000/60/ES as part of investigating excessive nutrient enrichment. This report reviews nutrient inputs to surface water; the role of nutrients in the eutrophication of surface water; the response of biota to nutrient enrichment; monitoring of changes due to eutrophication and the management of eutrophication. Monitoring of surface water bodies has been provided in terms of requirements of the Water Framework Directive. With regards of international and national legislative for the ecological status assessment ecological potential, chemical status, biological quality elements, supporting physical-chemical and hydro-morphological quality elements as well as the specific substances have been investigated. The aim of this contribution was to analyse eutrophication problem, factors affecting this process, its consequences and possibilities of prevention. The partial aim was to evaluate eutrophication state of surface water in Žitný ostrov channel network following the assessment physical-chemical and microbiological indicators in monitored period.

KEY WORDS: surface water, eutrophication, nutrients, nitrogen, phosphorus

Introduction

Eutrophication is the term applied to the observable effects of increased nutrients on an aquatic system. The nutrients of primary concern are nitrogen (N) compounds and phosphorus (P) compounds. Eutrophication is a process not a state, requiring factors external to a system to act in order to bring about change within the system. This is especially so in rivers where plant communities respond to flow, sediment type, and underlying geology more than any transient changes in dissolved nutrient status derived from external inputs. Flushing in flowing systems tends to reduce exposure times to enhanced nutrient loads, thereby reducing the scale of any change. Increases in both N and P cause changes in plant communities (Jickells, 2005).
The majority of observable effects of eutrophication are due to enrichment of running waters by P, or a combination of N and P. Enrichment by N tends to be associated with dissolved nutrients in the water column, whereas enrichment by P is associated with both sediment-bound and water column nutrients. It is therefore theoretically possible to reduce the effects of N-enrichment relatively easily over a relatively short timeframe if inputs are controlled, while the effects of P will be less easily resolved over short timescales. Assuming that the major observable effects are P-driven, and exacerbated by N enrichment, then the observable effects of a reduction in N may not be detectable until P is also reduced (Nedwell et al., 2001; Newman et al., 2005; Pärn et al., 2012; 2018).
Eutrophication of rivers is best managed by reducing inputs to the river system, rather than any in situ remedial action. Point source pollutants are easily managed, but diffuse pollution from agriculture, industry, urbanisation and others is less easily controlled. Diffuse pollution may be caused by leaching of nutrients from soil over a long period. Significant reductions in nutrients are those that have the capacity to change plant community, population structure and to improve the water quality (Devlin et al., 2011; Harper, 1992).
The effects of an eutrophication process on submerged macrophyte species will be more easily characterised in large, slow-flowing, sediment-retaining rivers, rather than in fast flowing smaller river systems. The speed of change due to eutrophication will be more rapid in large, slow-flowing rivers because plant communities are able to adapt within the timeframe of exposure to increased nutrients. Monitoring of eutrophication rates and effects needs to be adapted to the type of river system under investigation. Groundwater nutrient concentrations and their variability by region and over time are less well documented and this needs further work. There are clear ecological effects of raised nutrient concentrations in both lakes and rivers, including (Dzuro and Králiková, 2016; Pavlidou et al., 2015).

The external supplies of N and P to aquatic ecosystems are derived from a wide variety of sources, including groundwater, fluvial, and atmospheric inputs. The sum of these three sources can be termed the external load. The external supplies of nutrients to a water body can originate both as point sources, which are localized and more easily monitored and controlled, and as nonpoint sources, which are diffuse and much more difficult to monitor and regulate. The relative contributions of these two types of sources can differ substantially from watershed to watershed, depending upon local human population densities and land use (Fiala, 2016).

N and P exports from point and nonpoint sources can have profound effects upon the quality of receiving waters. The most common effects of increased N and P supplies on aquatic ecosystems are perceived as increases in the abundance of algae and aquatic plants. However, the environmental consequences of excessive nutrient enrichment are more serious and far-reaching than nuisance increases in plant growth alone. The degradation of water resources by eutrophication can result in worsening of water quality (Hessen, 1999; Smith et al., 1999; Wang et al., 2001).

Eutrophication in freshwaters is primarily driven by increases in N and P compounds. In terms of N, nitrate concentrations in rivers (and groundwaters) have increased substantially during the last decades and have been linked to changing agricultural practices (increased levels of fertilisation and the move to growing crops with higher N demand). There has also been an increasing input from atmospheric N-deposition, but this is probably a relatively insignificant contribution apart from in upland catchments with little agricultural influence. For phosphorus the main period for the transport of diffuse, agricultural sources of P is during the winter and particularly the autumn rains and the P concentration from these sources will be at its highest during the low summer flows.

Changes in freshwater biological communities as a response to pollution have long been recognised. Mostly research has focused on impairment to water quality resulting from pollution of either a physical, chemical or organic nature. Gradually there has been recognition of the role of both point – and non-point (or diffuse) sources of nutrient enrichment of surface waters. Studies of this eutrophication have historically concentrated on lentic and transitional waters of estuaries and coasts, but since the 1960's interest has also turned to the importance of nutrient enrichment from increasing levels of nitrogen and phosphorus in lotic systems or flowing waters.

The impact of nutrient enrichment on rivers is complicated by their dynamic nature, but symptoms such as excessive phytoplankton and filamentous algae development, weed growth and changes in macrophyte communities have clearly impacted water supply, fisheries and conservation value.

The eutrophication of several water bodies leads to significant changes in the structure and function of the aquatic ecosystem. Some profiles in this region have recently been found to be highly eutrophic. Most of the surface water bodies are surrounded with densely populated human settlement areas and agricultural fields. The size of smaller water bodies in human settlement areas is on the decrease with rise in population. After treatment, some quantity of sewage from the households is regularly discharged into the water bodies. The runoff brings down fertilizers and other chemicals from agricultural fields. The nitrogen and phosphorus containned in these effluents is known to promote excessive growth of plants (Khan et al., 2005; Harper, 1992).

Continuous point sources of phosphorus, dominated by sewage treatment works, have a highly important influence on levels of bioavailable phosphorus in the water column through the growing season. It is important to tackle point sources comprehensively so that reductions in phosphorus concentrations are maximised during this critical time of year. Diffuse sources of phosphorus, particularly from agriculture, are a major contributor to phosphorus levels in riverine sediments, where it can be utilised by benthic algae and rooted plants. This phosphorus can also be released into the water column by a variety of processes. As point sources are brought under control, the relative contribution from diffuse sources becomes increasingly important (Mainstone et al., 2002). It is generally recognised that an increase in nutrient loading is a prerequisite of increased eutrophication in rivers (Schneider and Melzer, 2003). However, it has still not been unequivocally established which of the main nutrients, if any, is generally limiting in rivers. There is some evidence suggesting that phosphorus has a significant effect on macrophyte community structure. Although raised concentrations of nutrients in the water column (and pore water) are required to induce hyper-eutrophic conditions. Schneider and Melzer (2004) noted that all requirements for plant growth, such as light levels, trace nutrient concentrations, etc., must be in excess for plants to achieve their full growth potential, i.e. the maximum amount of growth which could be achieved at a given temperature if a specific nutrient were limiting and all other factors were in excess. Hence, if the river flows through a shaded area, such as a forest, then that growth potential will not be achieved due to light limitation and the river may not show any apparent signs of hyper-eutrophication. At low to medium productivity, nutrients probably limit macrophyte biomass but at high concentrations they are probably not limiting.

Impact of vegetation on flow in a lowland stream during the growing season investigated Velísková et al. (2017), Dulovičová et al. (2016), Schügerl et al. (2018). Vegetation growing in the water along watercourses has been the subject of several studies since it was recognized that it could have a significant impact on the water flow. It may increase resistance to flow and cause higher water levels. Also, it has an effect on the velocity profiles. Previous investigations on the flow of water through emergent vegetation have shown different results. The purpose of these studies was determine how aquatic vegetation influences flow resistance, water depth and discharge in the Chotárny channel at the Žitný Ostrov area. The Chotarny channel is one of three main channels of this network. Measurements performed during six years at this channel were used for an evaluation of vegetation impact on flow conditions. The roughness coefficient was used as one way of quantifying this impact. The results show variation of this parameter during the growing season. Vegetation causes resistance to flow; it reduces flow velocities, discharge and increases water depth. How the sprouting of stream bed vegetation influences channel`s flow conditions and its capacity was demonstrate.

The present state of surface water eutrophication in Slovakia indicate, that there was a change of water quality in 90`s in accordance with as consequence of social changes. Many practices result in point and non-point source of surface water pollution, include fertilizers and manure applications, dissolved nitrogen and phosphorus in precipitation, irrigation flows, and dry atmospheric deposition were reduced Phosphorus and nitrogen fertilizers were reduced very significantly, phosphorus fertilizers for 80% lower and nitrogen fertilizers for 51% lower than before 1989 (Kobza et al., 2008).

Mechanisms and assessment of water eutrophication investigated Yang et al. (2008). Water eutrophication has become a worldwide environmental problem in recent years, and understanding the mechanisms of water eutrophication will help for prevention and remediation of water eutrophication. Recent advances in current status and major mechanisms of water eutrophication, assessment and evaluation criteria, and the influencing factors were reviewed. Water eutrophication in lakes, reservoirs, estuaries and rivers is widespread all over the world and the severity is increasing, especially in the developing countries. The assessment of water eutrophication has been advanced from simple individual parameters like total phosphorus, total nitrogen, etc., to comprehensive indexes like total nutrient status index. The major influencing factors on water eutrophication include nutrient enrichment, hydrodynamics, environmental factors such as temperature, salinity, carbon dioxide, element balance, etc., and microbial and biodiversity. The occurrence of water eutrophication is actually a complex function of all the possible influencing factors. The mechanisms of algal blooming are not fully understood and need to be further investigated. The mechanisms of water eutrophication are not fully understood, but excessive nutrient loading into surface water system is considered to be one of the major factors. The nutrient level of many rivers and lakes has increased over the past several years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Mainstone and Parr, 2002; Cheng et al., 2006).

Eutrophication can be defined as the sum of the effects of the excessive growth of phytoplanktons leading to imbalanced primary and secondary productivity and a faster rate of succession from existence to higher serial stage, as caused by nutrient enrichment through runoffs that carry down overused fertilizers from agroecosystems and/or discharged human waste from settlements (Khan and Ansari, 2005). Water eutrophication can be greatly accelerated by human activities that increase the rate of nutrient input in a water body, due to rapid urbanization, industrialization and intensifying agricultural production. Because the influence of the human activities, excessive nitrogen, phosphorus and other nutrients are loaded into water bodies, which could cause negative ecological consequences on aquatic ecosystem structures, processes and functions, result in the fast growth of algae and other plankton, and deteriorate water quality (Western, 2001).

Material and methods

Factors influencing water eutrophication

Water eutrophication is mainly caused by excessive loading of nutrients into water bodies like N and P. Excessive nutrients come from both point pollution such as waste water from industry and municipal sewage, and non-point pollution like irrigation water, surface run water containing fertilizer from farmland, etc. Increased nutrient load to water body is now recognized as a major threat of water quality degradation.

At present, excessive total nitrogen (TN) and total phosphorus (TP) in water are considered as the only factors inducing water eutrophication, but nutrient enrichment is only the necessary but not the sufficient condition for algal boom. Eutrophication is not likely to occur if both TN and TP in water are low, but eutrophication may not occur in water high in TN and TP if other conditions such as temperature and current speed are not favorable. The influencing factors of water eutrophication include: (1) excessive TN and TP, (2) slow current velocity, (3) adequate temperature and favorable other environmental factors, and (4) microbial activity and biodiversity.

(1) Nutrient enrichment
(2) Hydrodynamics
(3) Environmental factors
(4) Microbial and biodiversity

(1) The relationship of nutrient enrichment to water eutrophication and algal bloom: (a) When P concentration in water is low, it may be the limiting factor for inducing water eutrophication and algal bloom; (b) When P concentration in water increases rapidly, other may become a new limiting factor, such as pH, water depth, temperature, light, wave, wind or other biological factors; N and P input and enrichment in water are the most primary factors to induce water eutrophication.

(2) Hydrodynamics is not related to disturbing water itself but is influenced indirectly by changing light and nutrient status. In shallow water, increased frequency of disturbance could increased the P release from the sediment, especially at high temperature.

(3) Temperature and salinity are the two important factors to induce algal bloom. Algal bloom always occurs at temperature between 23°C and 28°C, salinity between 23% and 28%. The variation of temperature and salinity also affect algal bloom, and an important condition for algal bloom is that temperature increases and salinity decreases faster than ever in short time. Statistical analysis shows that the influence of temperature on algal growth rate is the largest, followed by salinity and their interaction. Change of salinity is also influenced by the concentration of nutrition. Research shows that salinity is negatively related with $N\text{-}NO_3^-$ and $P\text{-}PO_4^{3-}$, but positively related with $N\text{-}NH_4^+$ and however, it is not very related with $N\text{-}NO_2^-$. Light plays an important role in the growth, diversity and density of aquatic flora.

Algal growth has been reported to increase with light intensity, and luminescence of 4000 lux was found most favorable. There are other factors like pH and dissolved oxygen affecting water eutrophication. The direct relationship between phytoplankton and dissolved oxygen content has been observed by a number of researchers. The change in pH is directly related to the availability and absorption of nutrients from solution. Ionization of electrolytes or the valence numbers of different ion species are influenced by changes in pH. High pH values promote the growth of phytoplankton and result in bloom.
It must be pointed out that many factors influencing eutrophication are relative and affect each other.

Methods of monitoring and assessment of surface water

Historically are important year 1991, when was passed Directive 91/271/EHS regard cleaning urban waste-water and Directive 91/676 EHS regard nitrate agricultural source pollution and year 2000, when was passed Water Framework Directive (WFD) 2000/60/ES. The ecological status, ecological potential and chemical status assessment the biological quality elements (phytoplankton, phytobenthos and water macrophytes, benthic invertebrates), supporting physical-chemical and hydromorphological quality elements as well as the specific substances have been investigated. Ecological status/ potential assessment has been type specific, it has reflected reference conditions, the species diversity, quantity (abundance or biomass) and sensitive species have been included as well. The classification schemes have been already harmonized in the process of European intercalibration.
With regards of international legislative was in national legislative proposed assessment of the trophic state of water bodies according to following metodics (Makovinská et al., 2015; Hucko et al., 2013; Tlučáková et al., 2016):

a) Assessment of the trophic state of surface water with regards of the Supplement No.1 Directive of Government SR No. 269/2010 – monitored indicators are: total nitrogen, total phosphorus, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen concentrations and phytoplankton biomass (chlorophyll-a) (Table 1).
b) Assessment of the trophic state of surface water with „France metodic“ – for the assessment is necessary to use average summer concentrations of nitrates, phosphates and total phosphorus and maximum summer concentration for chlorophyll-a (summer period means months april–september) (Table 2).
c) Assessment of the trophic state of backwaters with regards of OECD metodic (annual average of total phosphorus concentrations, chlorophyll-a concentrations a Secchi depth).

Monitoring of surface water in Žitný ostrov channel network (Danube Lowland, Slovakia) has been provided in terms of requirements Supplement No.1 Directive of Government SR No. 269/2010, Part A (general indicators) and Part E (hydrogeological and microbiological indicators) in the period of 1987–2019. For assessment of sensitive localities and identification of eutrophication endangered places the Supplement No. 12 and No. 13 are used.
Monitoring and assessment of following indicators were performed – total nitrogen (N_{TOT}), nitrate nitrogen (N- NO_3^-), nitrite nitrogen (N-NO_2^-), ammonia nitrogen (N- NH_4^+), total phosphorus (P_{TOT}), phosphate phosphorus (P-PO_4^{3-}) according the Supplement No.1 Directive of Government SR No. 269/2010, Part A and biomas of phytoplankton (CHL_a) according Part E.

Results and discussion

The Žitný ostrov is one of the most productive agricultural areas of Slovakia, situated on the Danube Lowland. Under its surface is the richest water reservoir of Slovakia. For this reason, it is very important to deal

Table 1. Evaluation of trophic state of surface water according to Supplement No.1 Directive of Government SR No. 269/2010

Indicator	Symbol	Unit	Value
Ammonia nitrogen	N-NH_4^+	mg l^{-1}	1
Nitrite nitrogen	N-NO_2^-	mg l^{-1}	0.02
Nitrate nitrogen	N-NO_3^-	mg l^{-1}	5
Nitrogen total	N_{TOT}	mg l^{-1}	9
Phosphorus total	P_{TOT}	mg l^{-1}	0.4
Phytoplankton biomass (chlorophyll-a)	CHL_a	μg l^{-1}	50

Table 2. Evaluation of trophic state – Directive 91/676/CEE – Surface water – rivers (France metodic)

Indicator	Unit	State				
		I Ultraoligotrophic	II Oligotrophic	III Mezotrophic	IV Eutrophic	V Hypereutrophic
Nitrates (average summer concentration)	mg l^{-1}	< 2	< 10	< 25	< 50	> 50
Phosphates (average summer concentration)	mg l^{-1}	< 0.1	< 0.5	< 1	< 2	> 2
Phosphorus tot. (average summer concentration)	mg l^{-1}	< 0.05	< 0.2	< 0.5	< 1	> 1
Chlorophyll-a (max. summer concentration)	μg l^{-1}	< 2.5	< 8	< 25	< 75	> 75

with quantity and quality of water resources in this region. The channel network at the Žitný Ostrov area was built up for drainage and also to provide irrigation water. There are three main channels of this network: Chotárny channel, Gabčíkovo-Topoľníky channel and Komárňanský channel. Chotárny channel – is the P1M water body type (partial river-basin Váh, code SKW0029), Gabčíkovo-Topoľníky channel – is the P1M water body type (partial river-basin Váh, code SKW0023), Komárňanský channel – is the P1M water body type (partial river-basin Váh, code SKV0226). For the evaluation the water quality we went out from the data obtained on Institute of Hydrology SAS during the 1987–2019. Monitored localities was chosen so that they be the most representative area-covering.

The main purpose of this paper is to provide a brief review on recent state of eutrophication in Žitný ostrov channel network and understanding the mechanisms of water eutrophication and progresses in identifying the influence factors inducing water eutrophication.

The nutrient level in surface water has decreased after 1990th in response to decreased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Fig. 1–4). However we observe slight increasing in Komárňanský kanál (Fig. 5, 6, 7) during last few years. Excessive nutrient inputs (have been gone over the limit values not only in some months, but average annual values for nitrates and phosphates, too) and other conditions, such as high temperature, decreased dissolved oxygen content, higher pH and increased light intensity in summer period induced enhanced water eutrophication.

Conclusion

The present review deals with the studies conducted on the impact of nitrogen and phosphorus amount on eutrophication in surface water on the Žitný ostrov channel network. The review covers the definition and concept of eutrophication and the adverse effects on quality and ecosystem functioning. The eutrophication of several water bodies leads to significant changes in the structure and function of the aquatic ecosystem. Some profiles in this region have recently been found to be highly eutrophic. Most of the surface water bodies are surrounded with densely populated human settlement areas and agricultural fields. The size of smaller water bodies in human settlement areas is on the decrease with rise in population. After treatment, a some quantity of sewage from the households is regularly discharged into the water bodies. The runoff brings down fertilizers and other chemicals from agricultural fields. The nitrogen and phosphorus contained in these effluents is known to promote excessive growth of plants.

The detergents that are the major source of phosphorus inputs into water bodies (through sewage and drainage systems) have been thoroughly discussed. The major part of detergents comprises builders containing polyphosphate salts. An environment-friendly and effective synthetic builder is yet to be developed to replace existing phosphorus containing builders of detergents. The utility of the alternative builders available has been reviewed. Nitrogen has also been reported to affect the phytoplankton production in eutrophic waters in temperate regions. This review is an account of the role, sources, and monitoring of nitrogen and phosphorus, as well as its influence on surface water eutrophication. Several environmental factors have also been found to add to the problem of eutrophication in addition to nutrients. The limiting factors - namely temperature, pH, light, dissolved oxygen and CO_2 level are known to affect eutrophic water bodies. The results of nitrogen and phosphorus amounts reported in this study are the best indicators of the level of eutrophication.

Continuous point sources of nitrogen and phosphorus, dominated by sewage treatment works, have a highly important influence on its level in the water column through the growing season. It is important to tackle point sources comprehensively so that reductions in nutrients concentrations are maximised during this critical time of year. Diffuse sources, particularly from agriculture, are a major contributor to nutrient levels in riverine sedi-

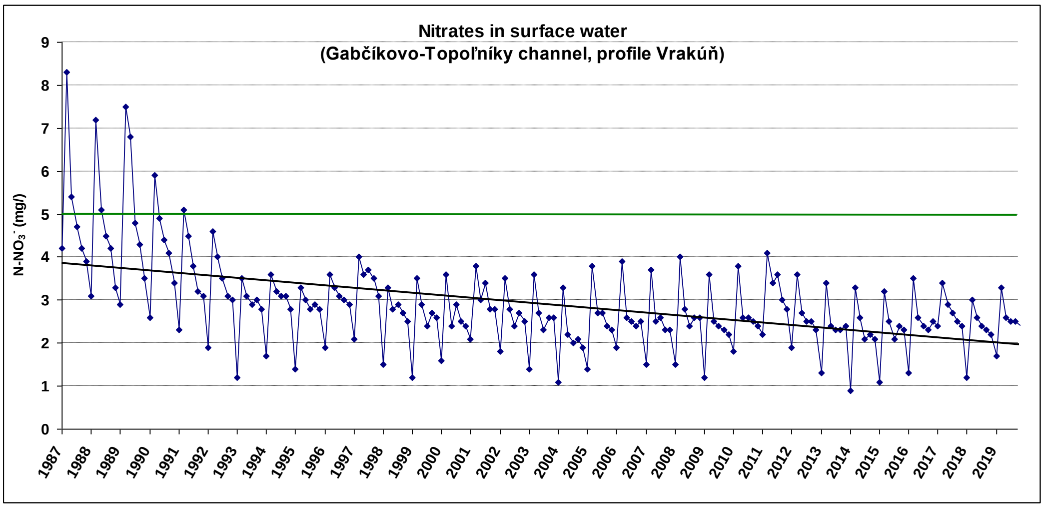

Fig. 1. *Nitrates in surface water – Gabčíkovo-Topoľníky channel.*

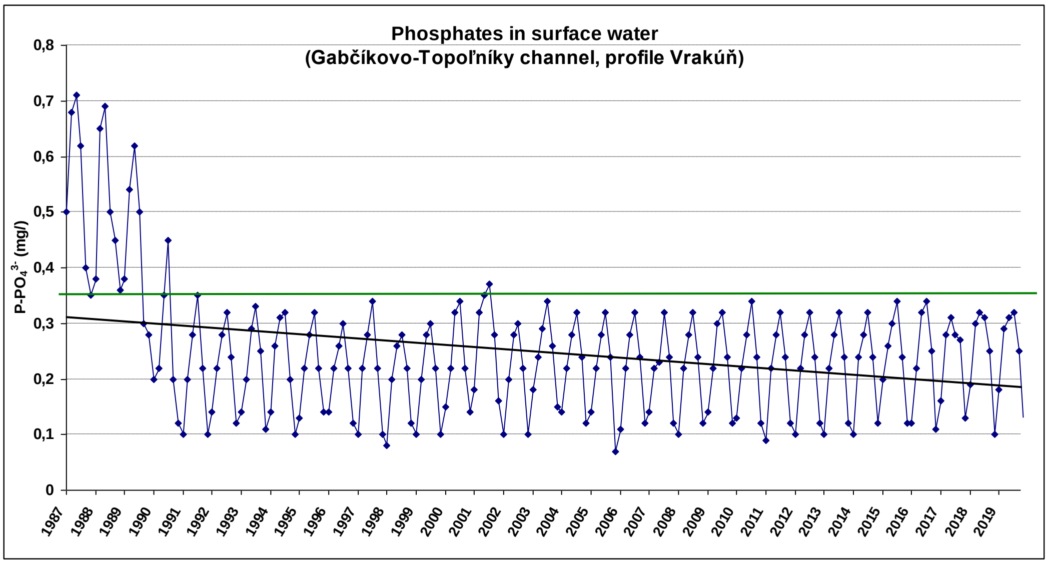

Fig. 2. *Phosphates in surface water – Gabčíkovo-Topoľníky channel.*

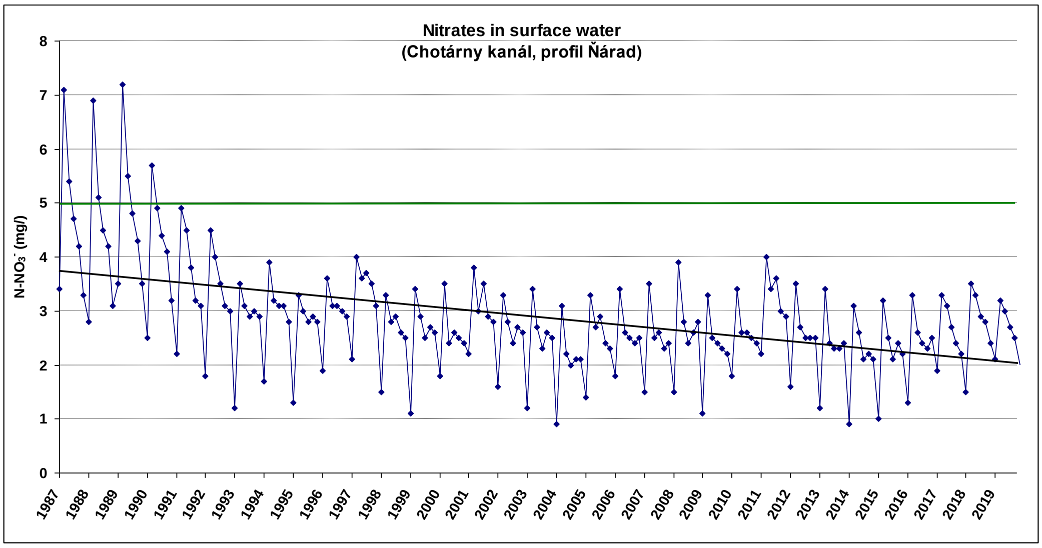

Fig. 3. *Nitrates in surface water – Chotárny channel.*

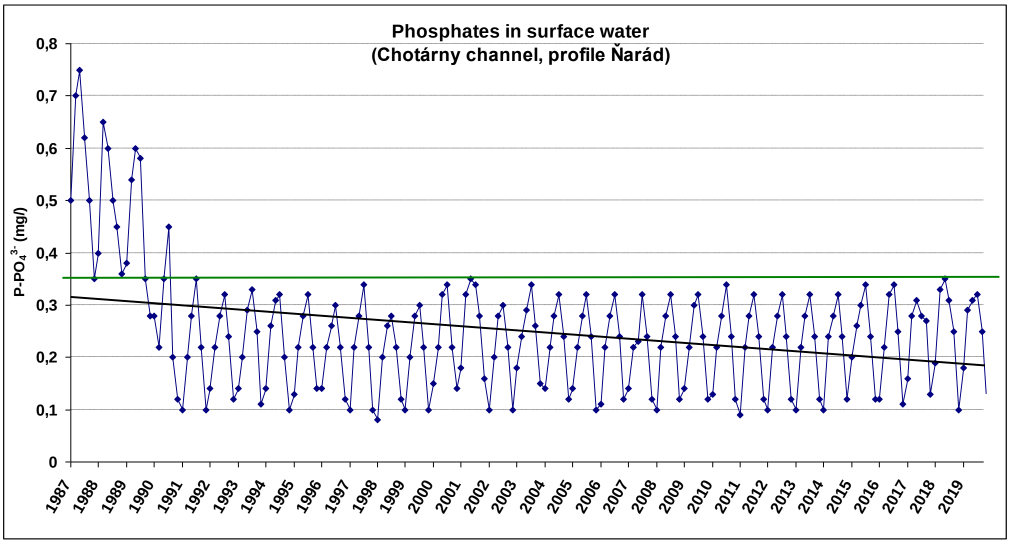

Fig. 4. Phosphates in surface water – Chotárny channel.

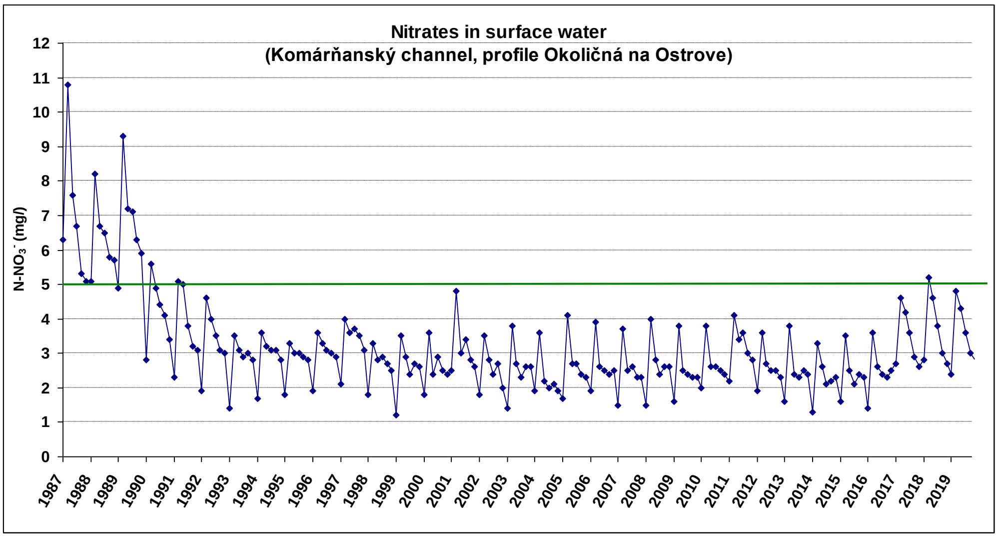

Fig. 5. Nitrates in surface water – Komárňanský channel.

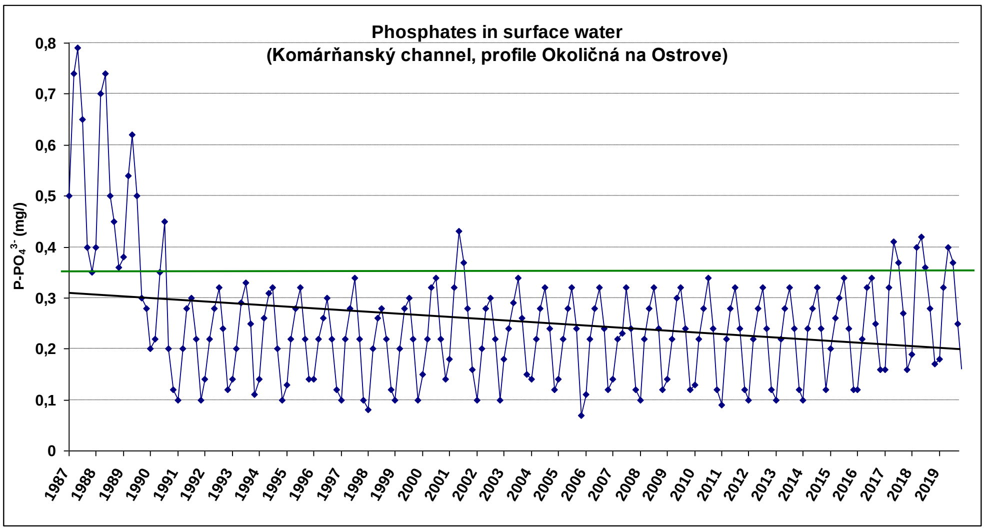

Fig. 6. Phosphates in surface water – Komárňanský channel.

Fig. 7. State of surface water eutrophication – Komárňanský channel (2019).

ments, where it can be utilised by benthic algae and rooted plants. This nutrients can also be released into the water column by a variety of processes. As point sources are brought under control, the relative contribution from diffuse sources becomes increasingly important.

The study is focused on identification of the long-term trends in the surface water quality in channel network at Žitný ostrov region. The paper shows changes in measured values of nitrates and phosphates in particular channels in years 1987–2019. It was shown the channel water quality has been changed significantly during the period 1987–1990, after 1990 is slightly decreased. However we observe slight increasing in some profiles of Komárňanský kanál with major agricultural activities during last few years.

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References

Devlin, M., Bricker, S., Painting, S. (2011): Comparison of five methods for assessing impacts of nutrient enrichment using estuarine case studies. Biogeochemistry 106, 177–205.

Directive of Government SR No. 269/2010 for accomplish suitable state of water.

Directive 91/271/EHS regard cleaning urban waste-water.

Directive 91/676 EHS regard nitrate agricultural source pollution (preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices).

Directive (WFD) 2000/60/ES Water Framework Directive

Dulovičová, R., Velísková, Y., Schügerl, R. (2016): Modification of Silts Hydraulic Conductivity along the Lowland Channel Gabčíkovo-Topoľníky (Slovakia). In 16th International Multidisciplinary Scientific GeoConference SGEM 2016: Conference proceedings. Book 3, vol. 1. Hydrology and Water Resources. – Sofia, 521–528. ISBN 978-619-7105-61-2.

Dzuro, T., Králiková, R. (2016): Effective patented method in the process of eutrophication of surface waters. Environmental Policy tools. Conference proceeding VI. Internat. Scientific Conference, Bratislava, 36–42.

Fiala, D. (2016): Boj o fosfor, aneb pracují všichni vodohospodáři na plný výkon? Vodní hospodářství, 5, 2016.

Harper, D. (1992): Eutrophication of Freshwaters : Principles, problems and restoration. Chapman & Hall 1992, ISBN 978-94-011-3082-0, https://doi.org/10.1007/978-94-011-3082-0

Hessen, D. O. (1999): Catchment properties and the transport of major elements. In: Nedwell, D. B., Raffaelli, D. G. (Eds.), Estuaries. Adv. Ecol. Res. vol. 29, 1–41.

Hucko, P., Štetina, M., Luther, S. (2013): Národný prístup hodnotenia povrchových vôd v SR. Vodárenská biologie, Praha, 1–21.

Cheng, X. Y., Li, S. J. (2006): An analysis on the evolvement processes of lake eutrophication and their characteristics of the typical lakes in the middle and lower reaches of Yangtze River. Chinese Science Bulletin, 51(13): 1603–1613. doi:10.1007/s11434-006-2005-4.

Jickells, T. (2005): External inputs as a contributor to eutrophication problems. J. Sea Res. 54, 58–69.

Khan, F. A., Ansari, A. A., (2005): Eutrophication: An ecological vision. The Botanical Review, 71(4): 449–482.

Kobza, J., Gáborík, Š. (2008): Súčasný stav a vývoj obsahu makro a mikroelementov v poľnohospodárskych pôdach Slovenska. VÚPOP Bratislava, 57 s.

Mainstone, C. P., Parr, W., (2002): Phosphorus in rivers-ecology and management. The Science of the Total Environment, 282–283.

Makovinská, J. a kol. (2015): Metodika monitorovania a hodnotenia vodných útvarov povrchových vôd Slovenska. VÚVH, 179 s., ISBN 978–80-89740–02–4.

Nedwell, D. B., Dong, L. F., Sage, A., Underwood, G. J. C. (2001): Variations of the nutrient loads to the mainland UK estuaries: correlations with catchment areas, urbanisation and coastal eutrophication. Est. Coast. Shelf Sci. 56, 951–970.

Newman, J. R., Anderson, N. J., Bennion, H., Bowes, M. J., Luckes, S., Winder, J., (2005): Eutrophication in rivers : an ecological perspective. Centre for Ecology and Hydrology, 37 pp., DOI: 10.13140/2.1.3711.5208

Pavlidou, A., Simboura, N., Rousselaki, E., Tsapakis, M., Pagou, K., Drakopoulou, P., Assimakopoulou, G., Kontoyiannis, H., Panayotidis, P. (2015): Methods of eutrophication assessment in the context of the water framework directive: Examples from the Eastern Mediterranean coastal areas. Continental Shelf Research, 108, 156–168.

Pärn, J., Pinay, G., Mander, Ű. (2012): Indicators of nutrients transport from agricultural catchments under temperature climate: A review. Ecological Indicators, 22, 2012, 4–15.

Pärn, J., Henided, H., Kasaka, K., Kauere, K., Sohara, K., Tournebozed, J., Uema, E., Välik, K., Mander, U. (2018): Nitrogen and phosphorus discharge from small agricultural catchments predicted from land use and hydroclimate. Land Use Policy, 75, 260–268.

Schneider, S., Melzer, A. (2003): The Trophic Index of Macrophytes (TIM) – a new tool for indicating the trophic state of running waters. Hydrobiology, vol. 88, 1, 49–67, doi.org/10.1002/iroh.200390005.

Schneider, S., Melzer, A. (2004): Sediment and Water Nutrient Characteristics in Patches of Submerged Macrophytes in Running Waters, Hydrobiologia, 527, 195–207.

Schügerl, R., Velísková, Y., Dulovičová, R. (2018): Identifikácia zmien prietokových pomerov a rýchlostného profilu pri prúdení s voľnou hladinou. Hydrologkcký výskum v podmienkach prebiehajúcej klimatickej zmeny. Monografia ÚH SAV. Veda, Bratislava, 391 s.

Smith, V. H., Tilman, G. D., Nekola, J. C. (1999): Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, 100, 179–196.

Tlučáková, A., Cibulka, R. (2016): Sledovanie časového vývoja priestorového rozšírenia dusičnanov v povrchových vodách Slovenska. Vodní hospod. 3, 2016.

Velísková, Y., Dulovičová R., Schügerl, R. (2017): Impact of vegetation on flow in a lowland stream during the growing season. Biologia 72/8, 840–846, DOI: 10.1515/biolog-2017-0095

Wang, J., Fu, B., Qiu, Y., Chen, L., (2001): Soil nutrients in relation to land use and landscape position in the semi-arid small catchment on the loess plateau in China. Journal of Arid Environments, 48, 537–550.

Western, D., 2001. Human-modified ecosystems and future evolution. Proceedings of the National Academy of Sciences of the United States of America, 98(10):5458–5465. [doi:10.1073/pnas.101093598]

Yang, X., Wu, X., Hao, H., He, Z. (2008): Mechanisms and assessment of water eutrophication. J. of Zhejjang Univ. Sci., 9 (3), 197–209.

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