WATER QUALITY ASSESSMENT OF RIVER HORNÁD, SLOVAKIA

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Abstract: *The article concentrates on the monitoring of surface water quality of River Hornád i.e. identification of the current state of the Hornád River Basin quality, identification and quantification of the main problems of pollution and use of the results of the analyses for further research activities. In order to evaluate the quality of surface water in the basin of River Hornád, three sampling points were selected – at the beginning of the flow in the village of Hranovnica, in the middle of the flow in the village of Malá Lodina and at the end the flow in the village of Hidasnémeti, at the point where the River leaves the territory of Slovakia. Based on the monitoring data parameters for assessing the quality of surface water were surveyed in these sampling points. Each indicator of water quality is classified separately. In general, the results of the assessment show that the values of the most of the evaluated parameters improved during the monitored period. The indicators show a positive trend of decrease and a steady state. Positive seems to be the fact that the limit values of four indicators are not exceeded.*

Key words: *water quality, River Hornád, BOD, COD, anthropogenic pollution*

1 INTRODUCTION

Nowadays focus on impurities in the surface water is not only at national but also at international level. Water is one of the basic components of the environment. It has an irreplaceable role in the functioning of the ecosystem as its quantity and quality directly affects our lives. Man and his activities (industry, agriculture, transport and so on) significantly contribute to the pollution of surface water in watercourses. Monitoring and evaluation of water quality has become a kind of instrument to determine the water source for different sectors of the economy and the household itself. Continuous monitoring of processes leads to the elimination of pollution of both surface and groundwater.

These days the approach to conventional exploitative use of water is remodelling due to comprehensive climate changes [1-3]. Climate change is affecting ecosystems by additional pressures because the water biogeochemical and physical-chemical parameters (e.g. salinity, pH) are changing so that the aquatic ecosystem is deteriorated [4]. Economic reflections are significant for interpretation of the outcomes from water handling, too. As these factors are uneasy to rank and prognosticate, a study [5] indicates the possibility of gaining a streamlined causal understanding of dominant water handling preferences.

The article concentrates on the monitoring of surface water quality of River Hornád i.e. identification of the current state of the Hornád River basin quality, identification and quantification of the main problems of pollution and use of the results of the analyses for further research activities.

2 HORNÁD RIVER CHARACTERISTICS

River Hornád raises about 4 km west of the village Vikartovce under the northern slope of the Kráľova hoľa hill in the hillside of Jedliská at an altitude of 1050 m above the sea level. It is the fifth longest Slovak river and is being created by numerous sources that are merging in a riverbed above the village of Vikartovce. Near the Kráľova hoľa hill the Bystrá creek flows into the River. After a short segment of a typical mountain terrain, River Hornád flows into the wider Hornád Basin with meadows and fields. The flow heads through melaphyre, Paleogene shales, sandstones, also flows in limestone bedrock of the Slovak Paradise National Park, Galmus, and the massif of Čierna hora where the River is flowing in quartzite bedrock. The River flows through Hornád Basin, the narrow valley of Čierna Hora and Košice Basin. The River leaves the territory of Slovakia at the state border at an altitude of 160 m above the sea level. The length of the River is 286 km while it leaves the territory of Slovakia after at the state border with Hungary after 193 km. The River forms the state border with Hungary in the length of 10.5 km (Fig. 1).

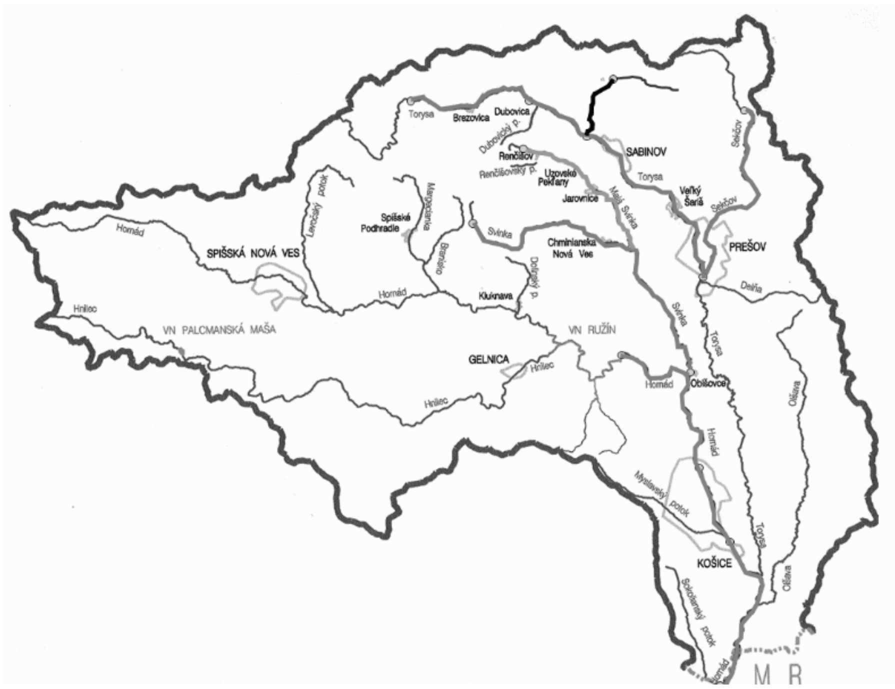

Fig. 1 Graphical representation of the Hornád River Basin

Prepared according to Svetoňová [8]

The basin of the River is bounded by the ridge starting from the valley of the Low Tatras continuing south-east direction through the Slovak Paradise National Park, by the ridges of Volovské vrchy hills and at Kojšova hoľa it turns to the Košice Basin, bordering through top of the hills of the valley to the state border with Hungary.

On the west the border of the River basin starts from Kráľova Hoľa hill, over Kozie chrbty ridge, heading north-east and routing between Popradská and Hornád Basins, and continues through the ridges of Levočské Vrchy Mountains eastward to Minčol in Čergov mountain range. The River continues further to the east to Šipotská hora hill in Ondavská vrchovina highlands. From this point it is taking direction to the south and over the Slanské vrchy ridge through the highest group of Šimonka, Makovica, Veľký Milič it gets to the state border. The River basin is bounded by the Basin of River Váh in the west, by the Basin of River Hron in the south-west, by the Basin of River Poprad in the north, by the basin of River Bodrog in the east, and by the Basin of River Bodva in the south [6, 7].

3 SOURCES OF ANTHROPOGENIC POLLUTION IN THE BASIN OF RIVER HORNÁD

The sources of pollution that negatively affect the water quality can be divided according to their nature and impact into two categories [9]:

1. point sources of pollution that significantly affect the quality of surface water and consequently the quality of groundwater in the alluvial sediments. In the case of these sources of contamination the source can be identified and its basic characteristics, e.g. the discharge mode, the quantity and quality of discharged water, and so on, can be determined.
2. diffuse sources of pollution - according to their origin continuous or intermittent sources can be distinguished, and their size and impact on water quality is conditioned by a number of factors. The sources of diffuse pollution are mainly agriculture, landfills and sludge beds, runoff from paved areas and polluted rainwater. Unlike the easily identifiable, locatable and measurable point sources of pollution of industrial and municipal origin, the diffuse sources are less targeted, more difficult to register, and problematic to measure, the summary effect is still only estimated.

The constant pollution of water resources heavily influences the development of industry, agriculture, progressive population growth, and unstable improvement of living standards which is conditioned by production growth. Quality of water sources thus come to the fore in the use of natural sources and pollution. The greatest threat to water of general nature is industry, mainly substances such as organic - oil, petroleum products, inorganic - lead, mercury, arsenic, radioactive substances, but also agriculture - industrial or fertilizers, pesticides, wastewater, and a major threat is the municipalities with huge production of liquid and solid waste as well as the transportation and air pollutants resulting from it.

The actual Hornád River Basin is mainly used in the industrial sector. According to the numbers the water taken from River Hornád is used for:

- industrial use - 71.8%,
- energy production - 14.1%,
- households - 13.5%,
- agriculture -only 0.6%.

In the Hornád River Basin there are significant mineral deposits of copper, uranium, molybdenum uranium, tin, and iron ores in the Slovak Rudohorie Mountain Range, especially in the area of Novoveská Huta - Rudňany - Poráč. From non-metallic raw materials there are significant deposits of gypsum, anhydrite, quartz, and talc in the Slovak Rudohorie Mountain Range and magnesite in the vicinity of Košice. Also building stone is mined [7].

Sludge beds are anthropogenic forms. Sludge beds are formed by accumulation of sludge that is most conveyed through sludge ducts. It is an area for permanent or temporary storage of mostly hydraulically deposited sludge. From an environmental point of view sludge beds are a very negative element in the country. The hazard of sludge beds is not only a question of the stability of their beds and the drainage system functionality but also contamination of percolating water from waste disposal and the environmental hazards in the territory under the water construction. These threats are closely linked and cannot be separated. Sludge beds are a subject to extensive monitoring for the stability of bed walls (by means of geodetic methods), to monitoring the amount of groundwater in wells and of chemical composition of leaking surface water. A serious problem is also blowing of fine dust particles containing heavy metals away the sludge bed surface during longer periods of drought in the summer months.

An industrial plant is located in the municipality of Krompachy, in the basin of River Hornád. The consequences of the activities of the industrial park are reflected in the increased levels of metals such as Cu, Pb, Zn, As, and Hg in surface water, soil, and in river sediments of surrounding watercourses. On the border of the areas of Krompachy and Slovinky there is a sludge bed posing a significant negative effect in the country and the environment. In the surroundings of the industrial plants there is the industrial sludge bed of Halňa, where there is, in addition to municipal waste landfill, solid industrial waste containing Pb, As, Cd, and liquids containing cyanide also stored in the amount of 760,000 m^3. Groundwater exceeds the limits for Cd, As, and Ni [10, 11].

Heaps, similarly to sludge beds, represent convex forms of anthropogenic relief. They are the most observable forms in the natural environment of mining areas. They take the largest area of all the anthropogenic forms of the landscape, and cause the most significant changes in the configuration of the terrain, underground and surface water. Even after centuries of existence they are best identifiable of all the montaneous forms of relief on the ground [10].

4 METHODS

The basic monitoring is carried out in a sufficient number of surface water bodies in order to assess the overall status of surface water basins. In order to evaluate the quality of surface water in the basin of River Hornád, three sampling points were selected – at the beginning of the flow in the village of Hranovnica, in the middle of the flow in the village of Malá Lodina and at the end the flow in the village of Hidasnémeti, at the point where the River leaves the territory of Slovakia. Based on the monitoring data parameters for assessing the quality of surface water were surveyed in these sampling points. Each indicator of water quality is classified separately.

The calculation procedure for measuring the values of variables for most of the parameters is set by the Slovak standard STN 75 7221. The characteristic value and its method of calculation depend on the frequency of monitoring. Frequency of the monitored sampling sites is usually 12 times a year, and, therefore, it is necessary to merge the results for two years in order to calculate the characteristic values; thus the classification refers to a biennium. If the frequency of monitoring is 11 to 23 samples, the characteristic value is determined as the average of the three most unfavourable values. If the frequency of monitoring is less than 11 samples, the characteristic value is the maximum value.

Surface water quality was evaluated according to the indicators set out in Annex 1 of the Government Regulation no. 269/2010 Coll. The measured values of 18 selected parameters were the basis for analysis to determine and monitor the quality of surface water of River Hornád.

5 RESULTS

Based on the detailed analysis of indicators for evaluation to determine the quality of surface water in the River, the following results according to the various indicators of surface water quality were recorded.

The general evaluation indicators of water quality were monitored as follows:

1. BOD – in the evaluation of the results of analyses of biochemical oxygen demand with suppression of nitrification the limit value was 7 mg/L during the monitored period. The limits were exceeded in the years 1993 - 1994 and 1997 - 1998. The maximum value exceeding the limit was a value of 9.16 mg/L in the biennium 1995 - 1996. The biochemical oxygen demand is declining. The limits were exceeded at the sampling sites Hranovnica and Hidasnémeti by 18.0 mg/L in 1995. As to the progress of the values of this indicator in the future steady to declining condition not exceeding the limit value can be expected.

2. COD – in the evaluation of the results of analyses of chemical oxygen demand the limit value was 35 mg/L during the monitored period. The limits were slightly exceeded in the years 1993 - 1994 and 2009 - 2010. A significant exceedance occurred in the years 2005-2006, and an exceedance with an extreme value of 47.45 mg/L occurred in the years 2007-2008. Maximum exceedance with an extreme value of 129.0 mg/L was reached in 1995. The exceedances most frequently occurred at the sampling site Hidasnémeti. As to the progress of the values of this indicator in the future steady state with no exceedance or slight exceeding of the limit value can be expected.

3. pH - in the evaluation of the results of analyses of chemical oxygen demand the limit value was from 6 to 8.5. The limits of this indicator were not exceeded in any biennium or sampling site. As to the progress of the values of this indicator in the future steady states of not exceeding the limit value range can be expected.

4. S_{105} - in the evaluation of the results of the analysis of the indicator solubles, dried at 105°C the limit value was 900 mg/L. The limits of this indicator were not exceeded in any biennium or sampling site. As to the progress of the values of this indicator in the future steady states of not exceeding the limit value range can be expected.

5. $N\text{-}NO_2^-$ - in the evaluation of the results of the analysis of the indicator nitrite nitrogen the limit value was 0.02 mg/L. The limits were slightly exceeded every year. Significant exceedances occurred in the years 1995-1996 and 1997-1998, and an exceedance with an extreme value of 0.24 mg/L was reached in the biennium 1993-1994. Maximum exceedance with an extreme value of 0.60 mg/L was reached in 1993. The limits were extremely exceeded at the sampling site Hidasnémeti. The limits were regularly exceeded at the sampling sites Hranovnica and Malá Lodina. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value and occasional significant exceedance can be expected.

6. $N\text{-}NO_3^-$ - in the evaluation of the results of the analysis of the indicator nitrate nitrogen the limit value was 5.0 mg/L. The limits of this indicator were not exceeded in any biennium or sampling site. As to the progress of the values of this indicator in the future steady states of not exceeding the limit value range can be expected.

7. P_{tot} - in the evaluation of the results of the analysis of the indicator total phosphorus the limit value was 0.4 mg/L. Slight exceedances of the limit occurred in the years 1995-1996 and 2001-2002 and significant exceedance occurred in the years 2003-2004, and an exceedance with an extreme value of 0.72 mg/L was reached in the biennium 1993-1994. Maximum exceedance with an extreme value of 0.97 mg/L was reached in 1993. The limits were only exceeded at the sampling site Hidasnémeti. In view of the development of the values of this indicator in the future steady state with of not exceeding the limit or slight and occasional exceeding of the limit value.

8. Al - in the evaluation of the results of the analysis of the indicator aluminum the limit value was 200 μg/L. The limits were exceeded in the years 2005 - 2006. An exceedance

with an extreme value of 2 340 μg/L occurred in the years 2007-2008. Maximum exceedance with an extreme value of 2 340 μg/L was reached in 2004. The limits were exceeded at the sampling site Hidasnémeti. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value can be expected.

9. NES - in the evaluation of the results of the analysis of the indicator non-polar extractable substances the limit value was 0.1 mg/L. The limits were slightly exceeded in the years 1993 - 1994 and 2009 - 2010. A significant exceedance occurred in the years 2005-2006, and an exceedance with an extreme value of 47.45 mg/L occurred in the years 2007-2008. Maximum exceedance with an extreme value of 129.0 mg/L was reached in the year 1995. The limits were extremely exceeded at the sampling site Hidasnémeti. The limits were regularly exceeded at the sampling sites Hranovnica and Malá Lodina. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value and single significant exceedance can be expected.

10. AOX - in the evaluation of the results of the analysis of the indicator adsorbable organic halides the limit value was 20 μg/L. The limits were slightly exceeded in the years 2003-2004, 2007-2008, 2009-2010 and 2013-2014. A significant exceedance occurred in the years 2005-2006, and an exceedance with an extreme value of 72 μg/L occurred in the years 2003-2004. Maximum exceedance with an extreme value of 75 μg/L was reached in the year 2005. The limits were extremely exceeded at the sampling site Hidasnémeti. The limits were regularly exceeded at the sampling sites Hranovnica and Hidasnémeti. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value.

11. As - in the evaluation of the results of the analysis of the indicator arsenic the limit value was 7.5 μg/L. The limits were slightly exceeded in the years 1993-1994, 1995-1996, 1997-1998, 1999-2000 and 2001-2002. A significant exceedance occurred in the years 1999-2000, and an exceedance with an extreme value of 77.7 μg/L occurred in the years 1999-2000. Maximum exceedance with an extreme value of 77.7 μg/L was reached in the year 1999. The limits were extremely exceeded at the sampling sites Hranovnica, Malá Lodina, and Hidasnémeti. In view of the development of the values of this indicator in the future steady state of not exceeding the limit value or slight exceeding of the limit value.

12. Zn - in the evaluation of the results of the analysis of the indicator zinc the limit value was 52 mg/L. The limits were slightly exceeded almost each year. A significant exceedance occurred in the years 1995-1996, and an exceedance with an extreme value of 285.45 mg/L occurred in the year 1995. Maximum exceedance with an extreme value of 470.1 mg/L was reached in the year 1996. The limits were extremely exceeded at the sampling sites Hranovnica, Malá Lodina, and Hidasnémeti. In view of the development of the values of this indicator in the future steady state of not exceeding the limit value or slight exceeding of the limit value.

13. PCB - in the evaluation of the results of the analysis of the indicator polychlorinated biphenyls the limit value was 10 ng/L. The limits were slightly exceeded in the years 1993-1994, 2001-2002, 2003-2004, 2005-2006 and 2009-2010. A significant exceedance occurred in the years 2003-2004. Maximum exceedance with an extreme value of 440 ng/L was reached in the year 1999. The limits were extremely exceeded at the sampling sites Hranovnica, Malá Lodina, and Hidasnémeti. In view of the development of the values of this indicator in the future steady state of not exceeding the limit value or slight exceeding of the limit value.

14. CB - in the evaluation of the results of the analysis of the indicator Coliform bacteria the limit value was 100 CFU/mL. The limits were slightly exceeded every year. A significant exceedance occurred in the years 1995-1996 and 1997-1998, and an exceedance with an extreme value of 32 266.7 CFU/mL was reached in 1997-1998. Maximum

exceedance with an extreme value of 50 000 CFU/mL was reached in the year 1998. The limits were extremely exceeded at the sampling sites Hranovnica, Malá Lodina, and Hidasnémeti. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value.

15. TCB - in the evaluation of the results of the analysis of the indicator thermotolerant Coliform bacteria the limit value was 20 CFU/mL. The limits were slightly or significantly exceeded every year. Maximum exceedance with an extreme value of 30 000 CFU/mL was reached in the year 2006. The limits were extremely exceeded at the sampling sites Hranovnica, Malá Lodina, and Hidasnémeti. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value.

16. EC - in the evaluation of the results of the analysis of the indicator intestinal enterococci the limit value was 10 CFU/mL. The limits were slightly exceeded every year. A significant exceedance occurred in the years 2003-2004 and 2013-2014, and an exceedance with an extreme value of 714 CFU/mL was reached in 2011-2012. Maximum exceedance with an extreme value of 2 050 CFU/mL was reached in 2011. The limits were extremely exceeded at the sampling site Hranovnica and Hidasnémeti. In view of the development of the values of this indicator in the future steady state with slight exceeding of the limit value.

6 CONCLUSION

In general it can be concluded that in the development of the values most of the evaluated parameters improved during the monitored period. The indicators show a positive trend of decrease and a steady state. Positive seems to be the fact that the limit values of four indicators are not exceeded.

Maximum values were mostly reached in the years 1993-1998 and 2003-2010 followed by a decline. Water quality parameters pertaining to the industrial activity recorded a downward trend in the years 1993 - 1998 and 2003 – 2010. It was most likely affected by the reduction of industrial production, particularly in Krompachy. In many cases, the improvement in these indicators involved an application of measures to reduce existing plants, or completely eliminate the cause for high indicators. Another benefit to the improvement of the state is the construction of industrial parks already incorporating measures to minimize the value of the indicators.

Water quality parameters related to the infrastructure of water treatment plants and sewage systems are recording a steady but negative character with exceedance of the limit values. According to the data from water companies working in the basin, the infrastructure of the wastewater treatment plants and sewer systems is built and functional at larger agglomerations (Spišská Nová Ves, Krompachy, Margecany, Kysak, Košice), and also at some smaller municipalities such as Hranovnica and Družstevná pri Hornáde. In other smaller agglomerations such infrastructure is underdeveloped, or in dysfunctional, malfunction state, that is, waste water is directly discharged into the river without prior treatment. The positive aspect is building and reconstruction of wastewater treatment plants and sewerage systems in smaller communities with high quality technologies for the use of EU structural funds.

Other indicators of water quality include indicators related to agricultural activity, which appear as the primary means for its intensification (fertilizers, agents for plant protection, etc.) and unsecured landfills, manures, etc. In order to improve this situation it is essential to respect the technology of proper storage, handling, and application of industrial and organic fertilizers, herbicides, and pesticides, etc., construction of wastewater treatment plants for agricultural senterprises. Some of these measures are gradually put into practice what appears to be positive.

REFERENCES

[1] MEDEMA, W. – MCINTOSH, B.S. – JEFFREY, P.J. 2008. From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector. Ecology and Society 13 (2), pp. 29.

[2] GIORGI, F. – LIONELLO, P. 2008. Climate change projections for the Mediterranean region. Global and Planetary Change 63 (2), pp. 90-104.

[3] VÖRÖSMARTY, C.J. – GREEN, P. – SALISBURY, J. – LAMMERS, R.B., 2000. Global water resources: vulnerability from climate change and population growth. Science 289 (5477), pp. 284.

[4] RIZZI, J. – TORRESAN, S. – CRITTO, A. – ZABEO, A. – BRIGOLIN, D. – CARNIEL, S. – PASTRES, R. – MARCOMINI A., 2015. Climate change impacts on marine water quality: The case study of the Northern Adriatic sea. Marine Pollution Bulletin 102 (2), pp. 271-282.

[5] CHEN, A. – ABRAMSON, A. – BECKER, N. – MEGDAL, S.B., 2015. A tale of two rivers: Pathways for improving water management in the Jordan and Colorado River basins. Journal of Arid Environments 112, pp. 109-123.

[6] SZABÓ, S., 2013. Rieka Hornád. Vucke.sk [16.08.2013]. Available on-line at http://abov.vucke.sk/trip/abov/abov/priroda/rieka-hornad.html.

[7] MŽP SR, 2009. Návrh plánov manažmentu povodí SR. Ministerstvo životného prostredia SR, Sekcia vôd a energetických zdrojov. [16.08.2013] Available on-line at http://old.vuvh.sk/rsv/docs/PMP/.

[8] SVETOŇOVÁ, M., 2011. Grafické zobrazenie časových zmien hodnôt vybraných fyzikálno-chemických ukazovateľov monitorovaných v povrchových vodách Slovenskej republiky (1995-2010). SHMÚ, Bratislava.

[9] LUMNITZER, E. – ROMÁNOVÁ, M. – BADIDA, M., 2007. Hodnotenie kvality prostredia. Strojnícka fakulta TU Košice, Košice, 2007. 245p.

[10] KROKUSOVÁ, J., 2013. Vplyv priemyselného odkaliska Halňa na štruktúru krajiny mesta Krompachy a možnosti jeho rekultivácie. Acta Facultatis Studiorum Humanitatis et Naturae Universitatis Prešoviensis, Prírodné vedy, Folia Geographica 21 (LV), pp. 48-66.

[11] MAZÚREK, J. 1998. Banská činnosť a jej vplyv na krajinu stredného Slovenska. Geografické štúdie 5, pp. 23-34.