EVALUATION OF SUSTAINABLE DEVELOPMENT WITH RESPECT TO LAND USE AND WATER QUALITY IN THE POPRAD CATCHMENT

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Poprad catchment was chosen as an area of interest. The aim of a paper is a population and land use impact on the water quality in the Poprad, Kežmarok and Stará Ľubovňa district according to Statistical Office of the Slovak Republic and Slovak Hydrometeorology Institute data sets. The water quality was evaluated in the years 1972-2011 from the three stations – Poprad – pod Svitom, Poprad – Veľká Lomnica and Poprad – Čírč. During the observed period the population increased in all districts with the minimum land use change. Decreasing trend of BOD₅ as well as COD Mn in the station Poprad – pod Svitom was noticed, in the stations Poprad – Veľká Lomnica and Poprad – Čírč the decreasing trend was minimum. Progress of N-NO₃ and N-NH₄ values was unstable and there was no visible decreasing or increasing trend of values.

Introduction

In recent years, we follow major changes in many areas of our lives. Over the past decades we can monitor changes in the population of the municipalities in the districts of Slovakia, which cause impact on its development. Changes have also occurred in land use and agricultural landscape itself. Changes are related to the economical policy of the European Union and globalization, which we had to gradually adapt (Blažík, 2004). According to Žigrai (1995) land use means a specific impact of human activity in space and time represents the clash of the natural conditions of the territory, technology and knowledge of humans and at the same time it carries information on the historical, economical, social and cultural potential of the country. Rovný and Nagyová (2007) state that sustainable agriculture in appreciable way affects the agricultural production and land use. Landscape is thereby used on providing nutrition, and forms the countryside. Slovakia is basically agricultural country, although the traditional agriculture largely receded in many areas. Agriculture plays an irreplaceable role in the economical, social and environmental field. Water quality is the sum of its physical, chemical, microbiological, biological, radiation and toxic properties of the expressed values of water quality parameters. Assessment of water quality based on
individual indicators is the fastest indicator of the changes or temporary, eventually extraordinary deterioration of water. It is the best way to quantify the changes, which are the result of the executed changes. This assessment is also the indicator of the potential changes that may occur after the permission the discharge of wastewater containing pollutants into the aquatic environment (Valúchová, 2011). The surface water quality monitoring and processing reports on water management are involved in Slovak Hydrometeorological Institute (SHMI), Slovak Water Management Enterprise and Water Research Institute (VUVH, 2011). The monitoring results are stored in a central database managed by SHMI (VUVH, 2012).

In this paper we follow the development of the population and land use, and assess their potential impact on long-term change in water quality in the river Poprad through selected indicators of COD$_{Mn}$, BOD$_5$, N-NH$_4$, N-NO$_3$.

**Material and methods**

Area of interest is Poprad, Kežmarok and Stará Ľubovňa districts situated in Prešov region, Slovakia (figure 1). Within those districts our attention is focused on implementing some analysis as analysis of population, land use analysis and water quality analysis in the Poprad River. Data of individual municipalities processing was based mainly on documents of the Statistical Office of the Slovak Republic (SOSR). Demographic trends in the population of the municipalities we determined from the land-use plans and official web pages of communities. For analysis of changes in land use, we used the information from database of aggregate values of land that can be found in the Statistical Yearbook of the land fund – in Slovakia. The available data were for the period from 1970 till 2011, the land use data for the years 2008 – 2012, and the crop data sets 1997 – 2011.

Water quality datasets were received from SHMI in Bratislava. There were chosen 3 places - Svit, Veľká Lomnica (both in Poprad district) and Circ (in Stará Ľubovňa district) - on the river Poprad, which is main river in the area for water quality analysis. The Poprad River is a tributary river of the Dunajec River near Stary Sacz, Poland. Total length of the Poprad River is 170 km, 107 km of river are located within the territory of Slovakia and a basin area of 2,077 km$^2$ (1,594 km$^2$ of river basin is located in Slovakia). The water quality data sets were analysed for the years 1976 – 2011.

**Fig. 1.** Poprad catchment with the position of Poprad, Kežmarok and Stará Ľubovňa district in Slovakia.

**Obr. 1.** Povodie Popradu s lokalizáciou okresov Poprad, Kežmarok a Stará Ľubovňa.
Results and discussion

A human population and its potential is one of the basic potential for development of each region. Population is the basic demographic indicator and it may be terminated by the development of the municipalities, just by the number of people who live there. At the end of 2011 according to demographic statistics, there were 108,662 inhabitants in the cadastral district of Poprad. The population of the district has nearly constant upward trend, when it is compared with the population in 2010 (103,961). The first reference year – 1970, the population was 69,346, which means an increase of 57% in the last reporting year. District Stará Ľubovňa had in 2011 population of 53,034. From year to year we can observe the growth in population there. Compared with the year 2010 (52,335), we observed the growth of 699 people. In the comparison of population between years 1970 (39,010 inhabitants) and 2001 (50,805 inhabitants) the population increase was 36%. Population in the Poprad district on 31.12.2002 was for a first time over the compared period lower than previous state, reaching 104,526 people. The decline was recorded in 2003 when the population in the district of Poprad declined from the previous year by 170 people and represents value of 104,356 inhabitants, respectively in 2004, when the endpoint was the value of 104,326 inhabitants (decrease from the previous year by 36 people). In 2005, the population of the district increased slightly and the end of 2005 it was 104,326 inhabitants. Slight increase over the previous year was recorded in 2006 when in the district was 104,333 inhabitants. From 2006 to 2009, we observed an increase in the number of population and the change occurred in 2010, when there was a decrease of 866 residents. The highest number was recorded in 2011 – 108,662.

In the district of Stará Ľubovňa from the first reference year 1970 to 2011 we can observe the rising trend. The highest number we can see in the last reporting year, it is 53,034 people.

We can state that the population in the District Kežmarok was increasing in the period 1970 -2011 except the period 1980 - 1991 when the population decreased from 51,766 to 50,515. The population has been increasing in last decade. For example, the number of inhabitants was 70,845 in 2011 (according to demographic statistic data in District Kežmarok); respectively 63,496 in 2001 which makes increase 7,349 inhabitants. The number of inhabitants was 47,197 in 1970 (the first monitored year) and 70,845 in 2011 (the last monitored year), i.e. the total increase was 23,648 inhabitants. Generally, we can see a rising trend in population development in the districts, as we can see in Fig. 2.

In terms of environmental interest of society and a sustainable agriculture, agricultural systems must be well managed and in addition to targeted quantity and quality of production it must also provide:

- socio - economical and cultural benefits to farmers
- permanent preservation of the production capacity of the country
- sustainable use of natural resources
- increase the share of environmental technologies and renewable resources
- adaptation of the functioning of natural auto - regulatory mechanisms in the field of ecosystems
- conservation of biodiversity, including genetic resources
- protective functions of natural and semi-natural ecosystems in the country.

![Fig. 2. Population development in the district of Poprad and Stará Ľubovňa (SOSR).](image-url)
Sustainability in sustainable agriculture is reflected in soil protection, biodiversity of water, and landscape (DOLCETA, 2012).

Agricultural land in Slovakia contains almost 50% of the whole territory. The highest percentage of agricultural land of Slovakia represents arable land, nearly 60% of the total agricultural land. Sustainable development is generally subject to functionality and stability of four main pillars: economical, social, environmental and institutional. Its integrated balance is also a prerequisite condition of sustainable agriculture. Sustainable agriculture is usually defined as an integrated system of plant and animal production, while the goal is to produce healthy food and feeding stuffs provided by judicious use of natural resources and environmental protection.

In the Fig. 3 shows a comparison of land types in Poprad and Stará Ľubovňa district. These values are different for each district. It is obvious that district of Poprad has significantly bigger value of total area, higher values for this district represents gardens, permanent grasslands, agricultural land and other land. The remaining soil types reach higher values for Poprad district. The biggest difference can be seen in the forest land, which represents much higher value than in Stará Ľubovňa district (value is higher more than one time).

Total land area of the Poprad district is 1,105.092 square kilometres. Agricultural land forms 25.2% (278.784 km²). Within the agricultural land the arable land has significant representation (113.945 km²), which in this area (agricultural land) represents 40.9%. Smallest land area size have gardens, it is a 3.735 km² and for district Stará Ľubovňa is it a 4.762 km². Total area of the Stará Ľubovňa district is 1,507.867 km². Agricultural land is 301.496 km², which is 20% of the total area. Arable land has an area of 82.097 km², which is 27.2% of agricultural land. The total area of District Kežmarok is 629.997 km². As far as the land use in the district, the agricultural land with its area of 322.075 km² (51.12% of the total district area) is prevailing. The agricultural land includes arable land, gardens and perennial grassland (53.58%), forest land (40.46% = 254,899 km²). The gardens themselves occupy 4.554 km². The urban area (villages) occupies 10.3% of the total district area.

Generally, cereals per unit area have a lower cost and the most important role in sowing takes wheat, barley and corn. The most important crop in the production of cereals is wheat, which feeds more than half of population. In our agriculture, an important role also has the production of oilseeds because of edible vegetable fats and oils which are important components of food. Among oilseeds we include oilseed rape, whose production exceeds sunflower and among other types of oilseeds belongs seed, mustard, poppy, etc. Potatoes have also important place in the nutrition of our population. It is an important crop in terms of production and sales.

**Fig. 3. Structure of chosen land types in districts of interest (SOSR).**

**Obr. 3. Štruktúra využívania krajiny v riešených okresoch (ŠÚSR).**
As to the crops of economic plants, the highest value for the Poprad district we monitor in 2008. The weakest was year 2010, when grains, potatoes and cereals reached the lowest values for the entire period. In Stará Ľubovňa district in 2011 we can see the highest values of three types of crops, which we consider as a successful year. Values of crops for both districts are similar and it changed over the years, the highest yields per hectare we monitor for potatoes.

When we compared first reporting year with the last one, we observed the growth of grains, cereals and potatoes in both regions. For oilseeds and silage on arable land is it about decrease. For potatoes we observe the highest growth over the years.

Systematic monitoring of the quality water in Poprad River started in 1972. The number of monitored profiles and parameters has been gradually increasing. This paper deals with stations Poprad – pod Svitom (119.7 rkm), Poprad – Veľká Lomnica (107.6 rkm) and Poprad – Čiřč (39 rkm).

Organic substances can enter surface waters from 2 resources, i.e. directly from the catchment and from settlements near considered river section. Substances from a catchment cause natural pollution of a river. The organic substances from surrounding forests and area get into rivers via surface runoff. However, main factors causing decrease of quality of flowing water are urbanisation, industry, change of land use and alteration of rivers. The worsened water quality decreases the usability of water in lower river sections, threatens human health and functioning of ecosystem and availability of water. This increases the competing pressure on utilization of the ware resources (GWP, 2000).

This was also confirmed by our paper, since the quality of water in river Poprad is influenced by industry in towns at the river. There is chemical enterprise Chemosvit a.s. and textile enterprise Tatrasvit a.s. in the town Svit which influenced the water quality in river Poprad in the past but they also do at present.

There are companies Tatravagónka (production of cargo railway coaches), Tatramat (white goods) and Whirlpool Slovakia (from 1992). The company Tatraľan in Kežmarok, which especially in the past processed flax and produced linen. The quality of water in the town Stará Ľubovňa was especially in the past influenced by the company Skrutkárēň which was producing steel connection material (screws and bolts).

Several farms with intensive plant and agricultural production are situated along the whole river. Since 2006, the waste waters produced in the upper part of the river are discharged and treated in a water treatment plant in Poprad – Matejovce. The wastewaters from the village Veľká Lomnica are also treated in the wastewater treatment plant in Poprad - Matejovce. Up to 2006, the wastewaters from the Veľká Lomnica were treated in the village wastewater treatment plant. Part of the wastewaters from individual houses is accumulated in septic tanks.

Hydraulic impacts, pathogenic organisms and acute toxic substances influence the recipient for a relatively short time; however discharge of waste waters into rivers can cause considerably longer effects (Krejčí, 2002). Figures 4 and 5 show average annual $BOD_5$ in the period 1976-2011, resp. $COD_{th}$ in the period 1976-2005. There is obvious decrease of values $BOD_5$ and $COD_{th}$ in the location Poprad – Čiřč. The values of $COD_{th}$ several times exceeded 50 mg . $l^{-1}$ in the beginning of monitored period. The maximal measured value was over 70 mg . $l^{-1}$. The company Chemosvit exchanged the chemical character of production at break of 70-ties and 80-ies of the 20th century (Vitková, 2008). This considerably changed also the water quality in the Poprad River.

The parameters $BOD_5$ and $COD_{th}$ have similarly decreasing character in the monitored period, except the station Poprad – Čiřč, where the values of $COD_{th}$ increased, including minimal values.

The treatment of waste waters from Veľká Lomnica was poor before the year 2006, therefore the water quality in the river Poprad was very low (poor). Due to population growth the amount of produced waste waters also increased.

In spite of increase of water quality in upper part of the river, the water quality according to these indexes $BOD_5$ and $COD_{th}$ in the station Poprad – Veľká Lomnica was only a little bit better than in the beginning of monitored period. If we omit the extreme value from the year 1978, the average $BOD_5$ was 6.48 mg . $l^{-1}$ in the period 1972 – 1989 and 4.3 mg . $l^{-1}$ in the period 1990-2011. Since 2009, the average $BOD_5$ values in the station Poprad – Veľká Lomnica are below 2 mg . $l^{-1}$.

Other monitored parameters of water quality are nitrogen compounds. Their main influences on the water body include consumption of oxygen in water (nitrification), toxic impacts ($NH_4^-$, $NO_2^-$) and nutrients ($NO_3^-$) (Krejčí, 2002). The ammonia in water is created by disintegration of proteins. It is secreted in animal excrements. The amount of toxic ammonia in water, which is released from ammonium salts, depends on pH of water and fluctuates from several tenths up to several mg . $l^{-1}$ (Heteša and Šukop, 1994).

The highest average annual values of $NH_4^-$ during the whole monitored period were measured in the station Poprad – Veľká Lomnica. There is evident decrease of average annual values at the end of monitored period in the station Poprad – pod Svitom. However the situation is different in other stations. The average annual values in the station Poprad – Čiřč did not exceed 0.8 mg . $l^{-1}$ and they fluctuate, although they have decreased in last years.

The course of average annual values of $NO_3^-$ also fluctuate but in other periods and values. The highest values are in the station Poprad – Čiřč and the lowest in
the station Poprad – pod Svitom. While the values of N-NO₃ increase down by the river, this is not true in case of N-NH₄. The nitrates enter the water especially through agricultural activities, application of fertilizers and improper agricultural measures near surface waters. They depend on surface runoff from the area and follow the characteristics of runoff creation.

Renwick et al. (2008) present seasonal character of occurrence of ions NH₄⁺ and NO₃⁻ in water. The highest concentration was observed in time of winter and early spring. In summer, their occurrence was minimal. The situation in our river basin confirms this assertion. We also observed the highest values in winter. The decrease starts in spring and increase in autumn.

Fig. 4. Yearly average values of BOD₅ in the years 1976-2011 in mg. l⁻¹.
Obr. 4. Priemerné ročné hodnoty BSK₅ v rokoch 1976-2011 v mg. l⁻¹.

Fig. 5. Yearly average values of COD Mn in the years 1976-2005 in mg. l⁻¹.
Obr. 5. Priemerné ročné hodnoty ChSK Mn v rokoch 1976-2005 v mg. l⁻¹.
Conclusions

Sustainable agriculture - represents a system that is economically viable, environment friendly, is technologically possible and socially acceptable (Dlouhý, 2003).

It takes into account the social needs of farmers and promotes rural communities, as well as right of future generations to a healthy soil, healthy food.

The impact of population growth on development district of Stará Ľubovňa is not a negative, because there
is no sharp increase in urban areas, which is due to the fact that this district has marginal position. For sustainable regional development it is necessary to avoid the factors that burden the country. It is important to protect the air, prevent soil and water contamination, and avoid excessive socio-economic activities. These factors can influence the development of the country. If we look at the use of agricultural land and agricultural production in the examined region over the years, significant changes have occurred just in the transition period, when there was a loss of some agricultural crops; specifically in the district of Stará Lubovňa occurred a sharp decline in the cultivation of potatoes, for which this area was known. We can assess that there is a significant change in land use. The water pollution in a river basin cannot be eliminated completely. Some substances occur naturally in increased concentration. With the help of proper agricultural activity we can secure minimal surface cleaning of waste waters and proper industrial activities. Nowdays it is necessary to take into account the needs of future generations; therefore, much attention focuses on the environment and its sustainability. Only the ecological and sustainable agriculture and integrated water management are the possibilities of the sustainable development in the Slovak regions.

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References


Kvalita vody vo vodných tokoch je ovplyvňovaná prírodnými aj antropogénymi vplyvmi. Poznanie dlhodoboľeho priebehu ukazovateľov kvality vody, vývoja obyvateľstva a využívanie územia umožňuje sledovať vplyv človeka a jeho činnosti na kvalitu vody vo vodnom toku. Na základe toho je možné následne vyhodnotiť ďalší dopad ľudskej aktivity na vodný tok a kvalitu vody v ňom.


V priebehu sledovaného obdobia došlo k poklesu hodnôt BSK₅, ako aj ChSK₅ v stanici Poprad – pod Svitom, v staniciach Poprad – Veľká Lomnica a Poprad – Čirč bol pokles minimálny. Najmä na začiatku sledovaného obdobia boli hodnoty BSK₅ a ChSK₅ rozkolsané, ale po zmene úpravy priemyselnej tehnológie a začatí čistenia odpadových vôd z ďalších obcí došlo k zvýšeniu hodnôt v týchto ukazovateľoch v stanici Poprad – pod Svitom. Priebeh hodnôt N-NO₃ a N-NH₄ je počas celého obdobia rozkolsaný a nie je viditeľný jednoznačný trend poklesu alebo nárastu hodnôt. Bola zaznamenaná sezónna dynamika hodnôt, keď v jarných mesiacoch bol zaznamenaný pokles hodnôt a v jesenných mesiacoch ich nárast, pričom maximum bolo dosahované v zimných, resp. na prelome zimných a jarných mesiacov.

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