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EFFECT OF LANDSCAPE USE ON WATER QUALITY OF THE ŽITAVA RIVER

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Abstract

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Intensification of landscape use brings along the negative effects on environmental components. These include surface water pollution. The aim was to determine the effect of landscape use on the water quality of the Žitava river. It was assumed that an area with the high proportion of anthropogenic activity would negatively affect water quality. At the same time, we assumed that an area with the lower proportion of anthropogenic use and with the higher proportion of natural and semi-natural elements contributes to self-cleaning ability of the watercourse. At the four observed sites, ammoniacal nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), phosphate-phosphorus (PO_4-P) and water conductivity were monitored. Landscape use was analysed using the database of land cover based on the CORINE Land Cover methodology. Subsequently, it was observed how the landscape use affects the water quality. It was found that the very good state, represented by the Class I water quality, is according to the measured indicators mostly present in the areas predominantly covered by forests along with extensive use of elements of the agricultural land. The area with predominance of agricultural and urbanised sites where the anthropogenic influence prevails is characterised by average water quality. As the overall water quality of the Žitava river reaches the average, it is necessary to eliminate the pollution by constructing the sewer systems in the villages through which the watercourse is passing and, in agriculture, to ensure the adherence to the legislation concerning the protection of surface water against pollution from agricultural sources.

Key words: land cover classes, water quality indicator, ammoniacal nitrogen, nitrate-nitrogen, phosphate, watershed.

Introduction

Water quality of the watercourses is influenced by numerous factors. Anthropogenic pollution as a result of landscape use is significant amongst them. Important findings were published already in 1970s (Rimer et al., 1978). The relationship between the landscape use and pollution is observed in the works of Basnyat et al. (1999), Buck at al. (2004), Ahearn et al. (2005), Chang (2008), Wan et al. (2014), Ding et al. (2016), Peng et al. (2017) and others. Akasaka et al. (2010), Lu et al. (2015) and Muchová and Tárníková (2018) point out that ensuring good surface water quality plays an important role in the protection of biotopes, ecological stability, agriculture, food processing industry, and protection of public health. In Slovakia, the relationship between the landscape use and water quality was studied in the past, for example, by Mendel et al. (1994) and Pekárová, Pekár (1996). The works that are coming to the foreground in the recent years are mainly the ones that evaluate the water quality depending on the effects of natural factors (Babošová et al., 2017; Vanková, Petluš, 2014; Pratt et al., 2012) or only on selected pollution indicators (Jurík et al., 2013; Húska et al., 2013; Šulvová et al., 2009). An important part of knowing the relationship between landscape use and water quality is the simulation of pollution processes using IT systems (Maillard, Santos, 2008; Sahu et al., 2009; Li et al., 2015; Oliveira et al., 2016 etc.).

According to the data published at the website of Enviroportal (2017), the surface waters in Slovakia have long been of poor quality or of bad state. At present, they are gradually improving; however, a major effort is needed to meet the main environmental objective that arises from Directive 2000/60/EC on the good state of all water bodies. One of the steps to take remedial action is to analyse the landscape use in individual river basins, to identify and, subsequently, to eliminate sources of water pollution.

As part of the evaluation, we work with the hypothesis that the area with high proportion of eco-stabilising landscape elements positively affects the water quality of the watercourse.

The aim is to determine the effect of landscape use on water quality of the Žitava river based on the level of selected indicators of water pollution. The basis for the evaluation is the analysis of the landscape use within the individual watersheds of the Žitava river and the analysis of pollution indicators in water sampling sites.

As part of the evaluation, we assume that the territory with a high proportion of landscape elements in the landscape will positively affect the water quality of the watercourse.

The objective is to determine the impact of land use on water quality of the Žitava river based on the values of selected indicators of water pollution. The basis for the evaluation is the analysis of the use of the landscape within the individual watersheds of the Žitava river and the analysis of the pollutants at the site sampling locations.

Material and methods

The Žitava river and its basin

Total length of the watercourse is 69 km. The area of the Žitava river basin is 907 km^2, of which the assessed area represents 53.5% (485.21 km^2). It is a river basin area that flows into the lowest placed site sampling location, approximately 4 km north of the town Vráble (Fig. 1). According to the typology of bodies of surface water elaborated for the implementation of the Water Framework Directive, the lower course of Žitava river is classified as the medium-sized river of the Pannonian Basin; the remaining part belongs to small rivers in the Carpathians.

In the assessed part of the basin, the total length of the watercourses with a catchment area bigger than 10 km^2 is 211.3 km. Geomorphologically, the area belongs to the parts of Tribeč, Pohronský Inovec and the Danubian Hills. The geological base is predominantly the core mountains of Tribeč and volcanic rocks of Pohronský Inovec. The clastic rocks are predominant in the Danubian Hills.

The Žitava river flows through several types of landscape. In its upper course, the forest landscape, an extensive agricultural landscape and the settlements predominate. In the middle and lower course of the river prevails the intensive agricultural landscape with rural and two urban settlements. For the purpose of comparing the effect of landscape use on level of water pollution, the area was divided into four watersheds. The site sampling locations of the surface water were at the mouth of the watersheds.

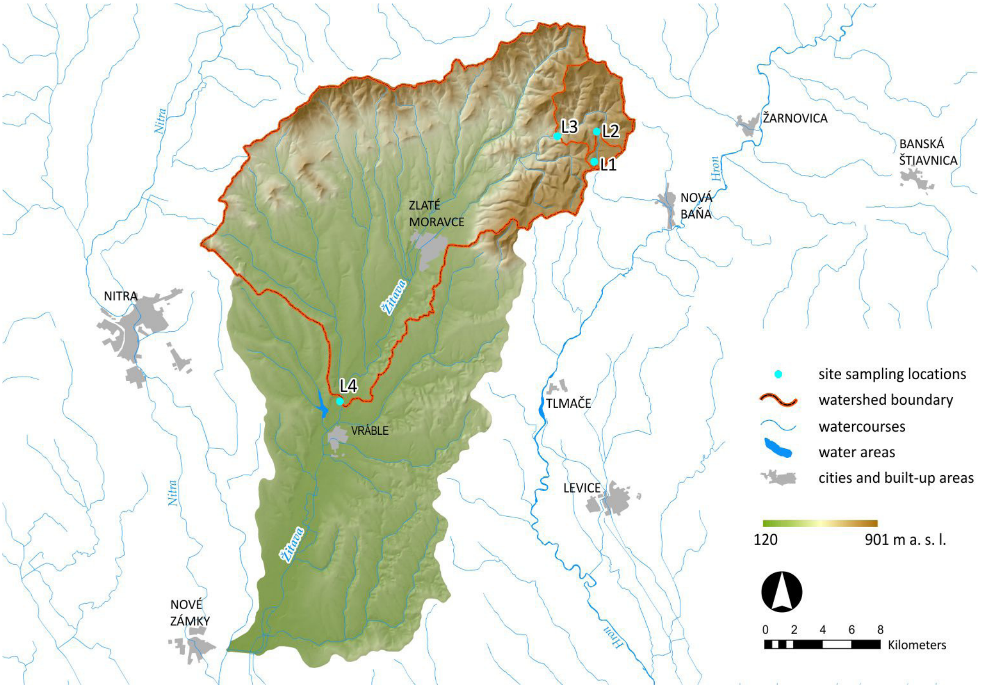


Fig. 1. Delimitation of watersheds and site sampling locations within the Žitava river basin (source of underlying layers: Digital Layers of Landscape Atlas of the Slovak Republic Landscape Atlas, 2002).

Location 1 (48,4498386N; 18,5612372E; 635 m above sea level, 69 rkm) – it has the character of spring area located on the border of cadastral area of the village Veľká Lehota (district Žarnovica), about 650 m north-east of spot height Kamennývrch (720 m above sea level). The site is located on the border of built-up area of the village, on a slope with large-scale arable land (currently grassed) and gardens of family houses. Botanically, the habitat can be characterised as highly herbaceous community on wet meadows (hygrophilous tall-herb fringe communities of plains and of the mountain to alpine belts).

Location 2 (48,4705192N; 18,5609244E; 535 m above sea level, 66.37 rkm) – located approximately 150 m north of the built-up area of the village Veľká Lehota (part Dolina). The width of the water flow at the sampling point is about 1.5 m. The site is located on the border of a built-up area near inoperative wastewater treatment plant built on the watercourse. Nowadays, it has the character of successively growing wet meadow accompanied with developed vegetation of woody plants with *Alnus glutinosa and Salix caprea*.

Location 3 (48,4652222N; 18,5193611E; 360 m above sea level, 59.65 rkm) – the cadastral territory of the village Jedľové Kostoľany outside the built-up part of the village 80 m north-east of the ruins of Živánska tower on the verge of the road II/1622. It has the character of mountain stream. Stony stream bed is about 3.5 m wide. It flows mostly through forested part of the landscape with well-developed vegetation of woody plants with *Alnus glutinosa*. There are mowed mesophilic meadows nearby.

Location 4 (48,2759625N; 18,3124114E; 150 m above sea level, 27.99 rkm) – the cadastral area of the town Vráble, part Horný Oháj, approximately 230 m south-west of water reservoir Nová Vesnad Žitavou. It has the character of slowly flowing river deeply cut below the level of the surrounding flat relief. The width of the stream bed is around 5 m at the site sampling location. It flows through intensively used agricultural landscape with prevailing large-scale arable land from which the watercourse is separated by a strip of woody bank vegetation with *A. glutinosa, Salix viminalis* and *Negundo aceroides.*

Methods

Landscape use analysis

Landscape use was analysed using the database of land cover based on the CORINE Land Cover methodology (CLC, 2012). The area was evaluated in terms of the CORINE Land Cover legend, identifying 18 classes of landscape cover (Table 1).

T a b l e 1. The landscape covers identified according to CORINE Land Cover (2012).

Level 1	**Level 2**	**Level 3**
Artificial surfaces	1.1 Urban fabric	1.1.2 Discontinuous urban fabric
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units 1.2.2 Road and rail networks and associated land
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites 1.3.3 Construction sites
	1.4 Artificial, non-agricultural vegetated areas	1.4.1 Green urban areas 1.4.2 Sport and leisure facilities
Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land
	2.2 Permanent crops	2.2.1 Vineyards 2.2.2 Fruit trees and berry plantations
	2.3 Pastures	2.3.1 Pastures
	2.4 Heterogeneous agricultural areas	2.4.2 Complex cultivation patterns 2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation
Forest and semi natural areas	3.1 Forests	3.1.1 Broad-leaved forest 3.1.2 Coniferous forest 3.1.3 Mixed forest
	3.2 Scrub and/or herbaceous vegetation associations	3.2.4 Transitional woodland-shrub
Water bodies	5.1 Inland waters	5.1.2 Water bodies

Landscape use was analysed in individual watersheds. The watershed is the basic (hydrologically) contributing area belonging to the site sampling location. When defining the watersheds, the digital relief model DMR 10 was used with a raster size of 10 m, generated from the Basic contour maps of Slovakia 1:10000.

Determination of selected water quality indicators

In water samples at the four monitored locations, ammoniacal nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N) and phosphate-phosphorus (PO_4-P) were determined using the spectrophotometer Spectroquant Move 100. Selected indicators of surface water indicate the inorganic anthropogenic pollution of surface water, for example, by agriculture. Subsequently, the device Hana II 991301 determined the conductivity (EC) that indicates the concentration of mineral substances in water. High values refer to possible presence of pollution. The temperature and pH of the water had to be measured for the optimal determination of the indicators and their interpretation. At the same time, the amount of oxygen dissolved in water was determined using Oximetra WTW Oxi 3310. Oxygen ration affects significantly the processes in water environment. The water analysis was carried out at monthly intervals from July 2016 to June 2017. The values were used in research of relationship between water quality and landscape use. At the same time, based on the Government Regulation No. 269/2010Coll., water quality class and state of the Žitava river were determined.

The data obtained from the analysis of landscape use in individual watersheds and values of indicators measured at site sampling locations were used as an input for research of the effects of landscape use on water quality. On the basis of the input data, the changes in concentrations of measured values of the NH_4-N, NO_3-N and PO_4-P; the changes in conductivity over the monitored period; and the seasonal changes in the concentration of indicators were observed in individual locations. The findings were confronted with the analysis of landscape use in individual watersheds.

The significance of the differences between locations and seasons was tested with factorial analysis of variance. Where the main factors were significant, the Tukey test was used. A significance level of 0.05 was used for both the analyses. All calculations were made in R software (R Core Team, 2017) using packages ggplot2 (Wickham, 2009), lsr (Navarro, 2015) and heplots (Fox et al., 2017).

Results

Landscape use in the evaluated part of the Žitava *river basin*

For the analysis of landscape use, the four watersheds were determined. The landscape use in the individual watersheds is given in Table 2.

The representation of land cover classes was influenced significantly by the size of watersheds. In watershed of location 4 that had the largest area, all land cover classes were identified. On the other hand, in watershed of location 1, only 2 classes were found (Fig. 2).

The grasslands that were created by grassing of arable land used mainly for the growing of cereals prevails in watershed of location 1. Nowadays, they are used as pastures. Urban fabric consists of residential houses, roads and gardens. The representation of land cover classes in watershed of location 2 is similar. However, here are prevailing lands occupied by agriculture that are currently used as pastures, with significant areas of natural vegetation, that is represented by successive linear or group-scattered woody vegetation. In this watershed, throughout the watercourse, the urban fabric is in contact with the river. In the watershed of location 3, there are mainly forest and semi-natural areas. The class of broad-leaved forests with woody areas prevails. There are oak-hornbeam forests represented, and in the higher altitudes, there are beech-oak forests. The vegetation with *Alnus glutinosa* was found in the bank along the watercourse. Texture of forests is complemented by pastures, transitional woodland-shrubs and scattered settlement. In watershed of location 4, the agricultural land slightly prevails over the forests (609.94 ha, 1.27%). Site sampling location is situated in the southern part of watershed where only the agricultural land is represented, which include intensively used arable land. In this part of watershed, right tributaries flow into the river collecting the surface water from the part of Tribeč. During the period of research, maize (*Zea mays* L.), rapeseed (*Brasica napus* L. *var. napus*) and common wheat (*Triticum aestivum* L.) were cultivated on both the riverbanks in the immediate proximity of the site sampling location. Vineyards, scattered, mainly linear vegetation, meadows, baulks, individual agricultural buildings and farms are all parts of the agricultural land.

T a b l e 2. Landscape use in the evaluated part of the Žitava river basin.

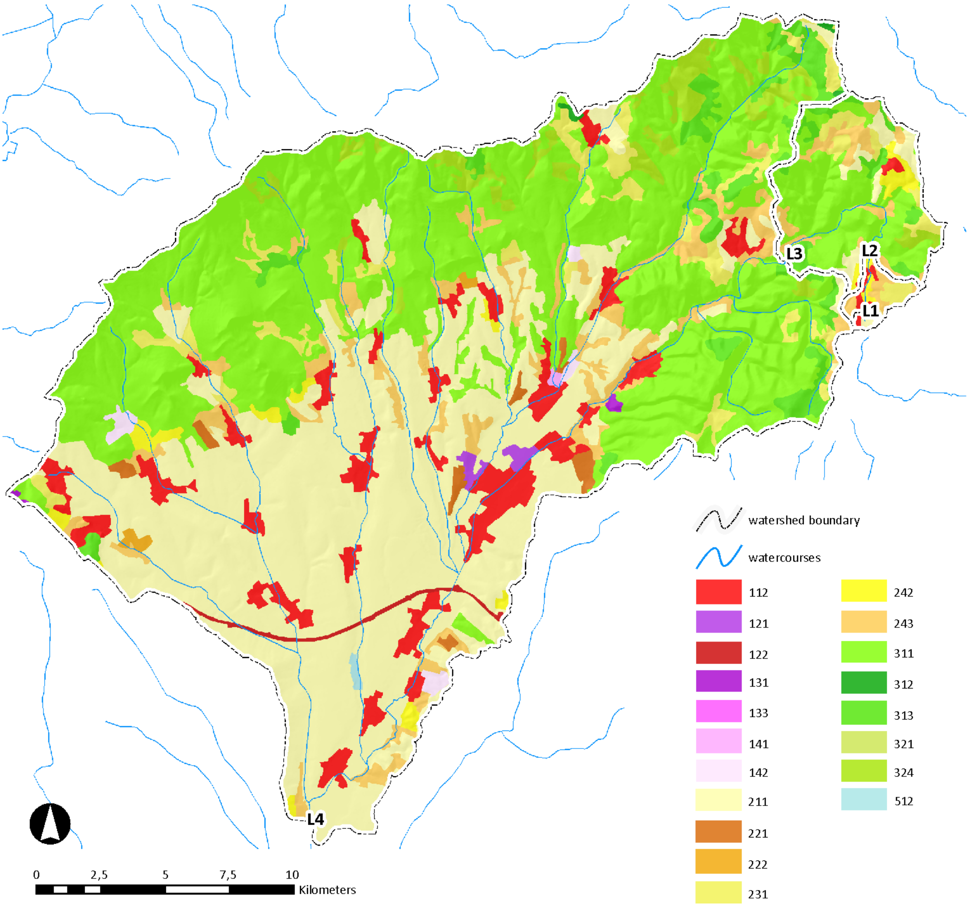
	Location 1		Location 2		Location 3		Location 4	
Class	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
1.1.2	10.54	21.19	68.45	17.53	110.88	3.15	2,781.76	5.73
1.2.1	-	-	-	-	-	-	135.46	0.28
1.2.2	-	-	-	-	-	-	131.15	0.27
1.3.1	-	-	-	-	-	-	47.76	0.10
1.3.3	-	-	-	-	-	-	43.02	0.09
1.4.1	-	-	-	-	-	-	25.08	0.05
1.4.2	-	-	-	-	-	-	214.38	0.44
Total	**10.54**	**21.19**	**68.45**	**17.53**	**110.88**	**3.15**	**3,378.61**	**6.96**
2.1.1	-	-	51.89	13.29	337.96	9.60	17,101.55	35.25
2.2.1	-	-	-	-	-	-	313.29	0.65
2.2.2	-	-	-	-	-	-	83.54	0.17
2.3.1	31.72	63.78	84.97	21.76	333.04	9.46	1,843.99	3.80
2.4.2	-	-	39.95	10.23	185.86	5.28	566.54	1.17
2.4.3	7.47	15.02	145.25	37.19	548.30	15.57	2,947.63	6.07
Total	**39.19**	**78.80**	**322.06**	**82.47**	**1,405.16**	**39.91**	**22,856.54**	**47.11**
3.1.1	-	-	-	-	1,588.43	45.11	19,074.87	39.31
3.1.2	-	-	-	-	4.95	0.14	62.26	0.13
3.1.3	-	-	-	-	332.09	9.43	1796.91	3.70
3.2.1	-	-	-	-	-	-	0.30	0.00
3.2.4	-	-	-	-	80.06	2.27	1312.26	2.70
Total	**-**	**-**	**-**	**-**	**2,005.53**	**56.95**	**22,246.6**	**45.84**
5.1.2	-	-	-	-	-	-	38.91	0.08
Total	**-**	**-**	**-**	**-**	**-**	**-**	**38.91**	**0.08**
In total	**49.73**	**100.00**	**390.51**	**100.00**	**3,521.57**	**100.00**	**48,520.66**	**100.00**

Notes: 1.1.2 – discontinuous urban fabric; 1.2.1 – industrial and commercial units; 1.2.2 – road and rail networks and associated land; 1.3.1 – mineral extraction sites; 1.3.3 – construction sites; 1.4.1 – green urban areas; 1.4.2 – sport and leisure facilities; 2.1.1 – non-irrigated arable land; 2.2.1 – vineyards; 2.2.2 – fruit trees and berry plantations; 2.3.1 – pastures; 2.4.2 – complex cultivation patterns; 2.4.3 – land principally occupied by agriculture, with significant areas of natural vegetation; 3.1.1 – broad-leaved forests; 3.1.2 – coniferous forest; 3.1.3 – mixed forest; 3.2.4 – transitional woodland-shrub; 5.1.2 – water bodies; - – the class is not present in the location.

Water quality of the Žitava river

The state and development of selected indicators was observed during the year based on the measured values. Significant monthly or seasonal differences were not observed, which was reflected as well in the classes of water quality in the individual indicators at all locations. The water temperature that influence the changes in the water quality varied in individual locations between 2.6 and 15.5 °C (location 1), 2.3 and 21 °C (location 2), 1.8 and 20.3 °C (location 3) and 3.6 and 23.3 °C (location 4). The average pH was 7.72 at all locations. The lowest value was 7.19, and the highest was 8.7. The measured values of water pollution indicators, dissolved oxygen and water quality classes according to the Government Regulation

Fig. 2. Land cover classes in the watersheds of monitored locations.



Notes: 1.4.2 – sport and leisure facilities; 2.1.1 – non-irrigated arable land; 2.2.1 – vineyards; 2.2.2 – fruit trees and berry plantations; 2.3.1 – pastures; 2.4.2 – complex cultivation patterns; 2.4.3 – land principally occupied by agriculture, with significant areas of natural vegetation; 3.1.1 – broad-leaved forest; 3.1.2 – coniferous forest; 3.1.3 – mixed forest; 3.2.4 – transitional woodland-shrub; 5.1.2 – water bodies; - – the class is not present in the location.

No. 269/2010 Coll. are given in Table 3. The amount of oxygen dissolved in water can be estimated as an average at all locations (Class III). It met the requirements for surface water quality only during the spring, which is related to the greater discharge of water in watercourse. It was caused by melting of snow and more precipitation during the spring. The lowest measured values were those of NH4-N, which reached optimal values during the whole observing period. Only in one case (February 2017, location 4), it exceeded the limit value of 1 mg/l, so the requirement for the surface water quality was not met. Locations showed predominantly

T a b l e 3. Values of water pollution indicators and water quality classes of the Žitava river.

	Jul 2016	Aug 2016	Sep 2016	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	May 2017	Jun 2017
	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC	MV/ WQC
	Location 1											
NH_4-N (mg/l)	0.19/I	0.19/I	0.24/I	0.26/I	0.19/I	0.01/I	0.04/I	0.12/I	0.04/I	0.01/I	0.03/I	0.01/I
NO_3-N (mg/l)	1.2/I	4.5/III	0.7/I	1.3/I	0.8/I	0.4/I	1.8/II	1.2/I	0.7/I	0.5/I	1.2/I	0.5/I
PO_4-P (mg/l)	0.09/II	0.44/III	0.06/II	0.04/I	0.02/I	0.01/I	0.25/III	0.27/III	0.19/II	0.02/I	0.02/I	0.02/I
O_2 (mg/l)	0.3/III	0.34/III	0.06/III	0.06/III	0.13/III	0.53/III	0.81/III	1.56/III	4.1/III	2.3/III	8.66/I	3.5/III
EC (mS/m)	170/III	690/III	150/III	120/III	170/III	150/III	210/III	290/III	180/III	160/III	170/III	30/I
	Location 2											
NH_4-N (mg/l)	0.19/I	0.19/I	0.24/I	0.63/II	0.18/I	0.21/I	0.14/I	0.4/I	0.26/I	0.32/I	0.22/I	0.01/I
NO_3-N (mg/l)	1.1/I	4.5/III	0.7/I	4.5/III	1.6/II	1.5/II	1.6/II	1.2/I	1.7/II	1.5/II	2.0/II	1.5/II
PO_4-P (mg/l)	0.42/III	0.44/III	0.06/II	0.54/III	0.34/III	0.18/II	0.16/II	0.17/II	0.15/II	0.33/III	0.29/III	0.02/I
O_2 (mg/l)	0.34/III	0.34/III	0.06/III	0.06/III	0.17/III	0.43/III	0.23/III	3.2/III	25.7/I	9.51/I	9.42/I	8.5/I
EC (mS/m)	250/III	690/III	150/III	290/III	230/III	190/III	160/III	16/III	160/III	210/III	220/III	150/III
	Location 3											
NH_4-N (mg/l)	0.18/I	0.19/I	0.24/I	0.27/I	0.16/I	0.02/I	0.05/I	0.12/I	0.07/I	0.01/I	0.07/I	0.09/I
NO_3-N (mg/l)	0.7/I	4.5/III	0.7/I	1.6/II	0.5/I	1.1/I	1.8/II	1.3/II	0.7/I	0.4/I	0.9/I	0.9/I
PO_4-P (mg/l)	0.08/II	0.44/III	0.06/II	0.17/II	0.03/I	0.05/II	0.06/II	0.04/I	0.04/I	0.03/I	0.05/II	0.02/I
O_2 (mg/l)	0.46/III	0.34/III	0.06/III	0.07/III	0.19/III	0.45/III	1.3/III	1.5/III	3.41/III	10.33/I	10.48/I	8.5/I
EC (mS/m)	310/III	690/III	150/III	240/III	280/III	230/III	170/III	180/III	20/I	220/III	20/I	150/III
	Location 4											
NH_4-N (mg/l)	0.19/I	0.19/I	0.24/I	0.82/II	0.27/I	0.53/II	0.13/I	1.02/III	0.36/I	0.05/I	0.14/I	0.09/I
NO_3-N (mg/l)	4.5/III	4.5/III	0.7/I	4.5/III	1.2/I	3.1/II	3.5/II	2.2/II	2.5/II	2.3/II	2.2/II	0.9/I
PO_4-P (mg/l)	0.44/III	0.44/III	0.06/II	0.26/II	0.22/II	0.19/I	0.13/I	0.18/I	0.13/I	0.15/I	0.23/II	0.02/I
O_2 (mg/l)	0.34/III	0.34/III	0.06/III	0.08/III	0.16/III	0.4/III	2.91/III	1.94/III	5.22/III	8.82/I	7.9/I	8.5/I
EC (mS/m)	690/III	690/III	150/III	690/III	70/I	630/III	520/III	40/I	640/III	570/III	530/III	150/III

Notes: MV – measured value; WQC – water quality class according the Government Regulation SR No. 269/2010Coll.

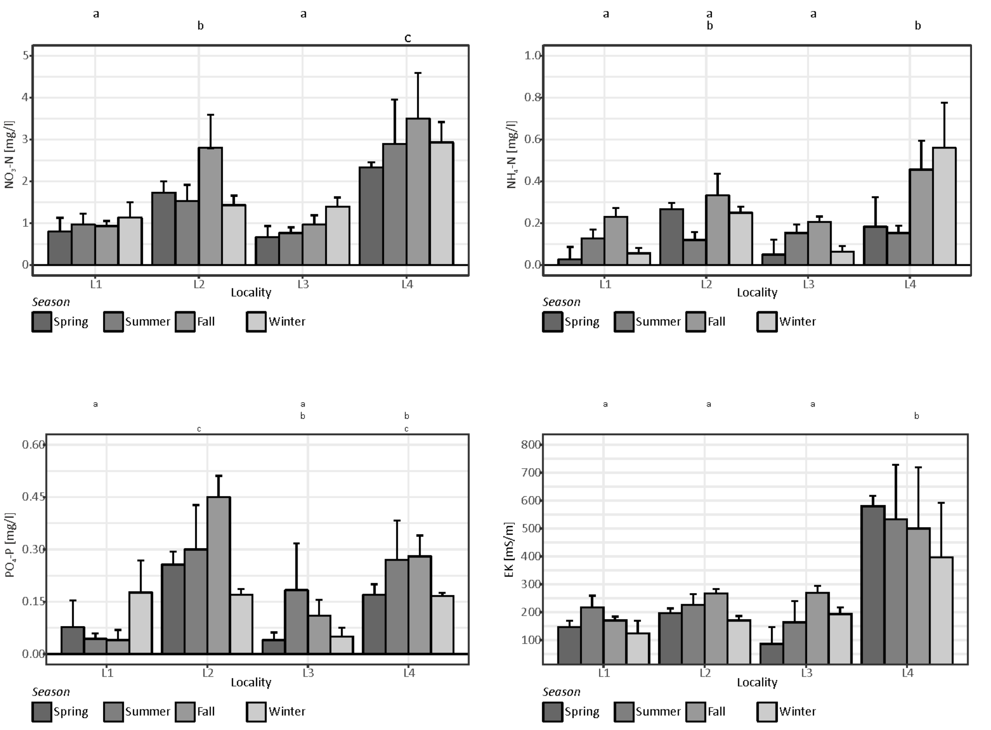
high EC values that exceeded the permitted values of 110 mS/m, which confirmed the presence of a high number of dissolved pollutants in water. On the basis of the measured values obtained from locations during the whole research period, water quality of the Žitava river reached Class III, which represents the average water quality state of the watercourse.

Effect of landscape use on water quality of the Žitava *river*

The values of water pollution indicators in individual locations show the differences in water quality. This is related to the concentration of individual pollutants and the placement of site sampling locations that are affected by the landscape use in the watersheds. Pollution in watercourses is affected by the current use of the area as well, for example, agricultural use. Therefore, the seasonal concentrations of pollutants at site sampling location were also monitored (Fig. 3).

A factorial analysis of Variance (ANOVA) was separately conducted to compare the main effects of season and location and the effect of the interaction between season and location on the NH_4-N, NO_3-N, PO_4-P and EC. Location included four levels (L1, L2, L3 and L4), and season consisted of four levels (Spring, Summer, Fall and Winter) (Table 4).

Fig. 3. Seasonal concentrations of pollutants at site sampling locations.



T a b l e 4. Analysis of variance of the effect of season and location on NH_4-N, NO_3-N, PO_4-P and EC.

		NH_4-N [mg/l]			**NO_3-N [mg/l]**			**PO_4-P [mg/l]**			**EC [mS/m]**		
Source of variation	df	MS	F		MS	F		MS	F		MS	F	
Season	3	0.08	2.99	*	0.98	1.33		0.02	1.49		15,406	0.61	
Location	3	0.14	5.11	**	10.48	14.17	***	0.12	8.65	***	306,339	12.07	***
Season x Location	9	0.03	1.22		0.42	0.57		0.02	1.32		9,981	0.39	
Error	32	0.03			0.74			0.01			25,392		

Notes: MS – mean square. Significance: *** – ≤0.001; ** – ≤0.01; * – ≤0.05.

Statistical analysis shows that the locations significantly affect the concentration of water quality indicators (NH_4-N: F (3.32) = 5.11, p = 0.005, NO_3-N: F (3.32) = 14.17, 0.001, PO_4-P: F (3.32) = 8.65, p <0.001, EC: F (3.32) = 12.07, p <0.001). On the basis of the Tukey post hoc test, it is clear that location 4 was notably different at all evaluated indicators. Concerning the indicators NO_3-N and NH_4-N, the difference was observed in location 4 compared to location 1 (NO_3-N: p = 0.011, NH_4-N: ps<0.001) and location 3 (NO_3-N: p = 0.015; NH_4-N: ps<0.001). Concerning the EC, the differences were observed compared to locations 1, 2 and 3 (all ps< 0.001). Concerning PO_4-P, the test showed that location 4 was different from location 1 (p = 0.039) and location 2 was different from location 3 (p = 0.002). Influence of the seasonality proved as significant only concerning NH4-N (p = 0.045). In the tests, the relationship between the locations and seasonality proved to be insignificant (NH_4-N: p = 0.313; NO_3-N: p = 0.814; PO_4-P: p = 0.265; EC: p = 0.929), indicating that the locations were not polluted differently during the seasons.

The results stated so far show that the highest concentrations are those of NO_3-N. They are particularly elevated during autumn in locations 2 and 4 (not statistically proven). Locations are characterised by increased anthropogenic use that affects the presence of NO_3-N in water. A similar pattern is evident in the concentrations of the NH_4-N indicator (statistically proven). Their development is related because the nitrogen forms undergo biochemical transformation, which decomposes NH_4-N to NO_3-N or to nitrites (NO_2-N). Municipal pollution from sewage water is the source of pollution in location 2, where NH_4-N is a part of physiological waste. The autumn fertilisation of winter cereal – wheat and rape – that were cultivated nearby is the source of pollution in location 4. This type of pollution was shown also concerning PO_4-P. Locations 2 and 4 are also characterised by high concentrations of PO_4-P during whole monitored period (mainly during the autumn). This is related to the faecal waste that is being released into the watercourse along with sewage water with the addition of washing powders and various detergents because the village Veľká Lehota does not have a sewer system. On the basis of the presence of anthropogenic pollution, which is expressed by conductivity, it is evident that location 4 is the mostly used watershed where the biggest pollution during the whole monitored period was observed. The water quality indicators monitored detect mainly anthropogenic pollution that is related to the landscape use. Comparing the landscape use in the individual watersheds belonging to site sampling locations, the watershed of location 4 is the most intensively used. There are represented all identified classes of land cover, mainly artificial surfaces and agricultural areas with arable land, which represent 54.07% of total area of watershed. Intensive landscape use affects water quality in the watercourse. Intensive human activity was also reflected in the watershed of location 2, where only artificial surfaces and agricultural areas are represented. In terms of landscape use, the evaluated locations are similar. The low water quality at site sampling locations in the watercourse was also similar. In the watershed of location 1, there are mainly agricultural areas with extensive pastures with significant areas of natural vegetation (78.80%) that do represent the risk of anthropogenic pollution. It was reflected in the average water quality at site sampling location. Location 3 is represented mainly by forests (56.95%) and agricultural areas used as meadows, pastures and complex cultivation patterns with significant areas of natural vegetation (30.31%). These classes of land cover do not require intensive human intervention, thereby reducing the potential water pollution. This affected significantly the water quality that was several times at all evaluated indicators of Class I water quality, such as Location 1. Locations 1 and 3 are similar in terms of landscape use. In locations 1 and 3 (compared to locations 2 and 4) were the measured values of NH_4-N, NO_3-N and also PO_4-P were lower, which is connected with the higher proportion of natural elements and low proportion of anthropogenic activity.

Discussion

The results of the work point out the effect of landscape use on water quality of the Žitava river. The results of measurements show that the very good state represented by Class I water quality is most represented in the area where the forests prevail along with extensively used elements of agricultural lands (they account for almost 88% of total area of the corresponding watershed). On the contrary, the watersheds with prevailing agricultural areas and urban fabric where the anthropogenic effect is dominating are characterised by the average water state. On the basis of the results, it can be stated that the forests and extensively used agricultural land have the positive effect on water quality and contributes to the self-cleaning ability of the watercourse. It is clear that the forest (location 3), which fulfils the water protection function, has the positive effect on water quality as the site sampling location situated below the village (location 2) showed only the average water quality state. The municipality has no sewer system, and sewage water and faecal waste from the households are being released into the watercourse. The results of this study are in compliance with the researches (Li et al., 2009; Tu, 2011; Jurík et al., 2013; Wan et al., 2014) that point out the correlation between the presence of nitrogen and phosphorus compounds and an intensive human activity. Thong and Chen (2002) stated that nitrogen compound pollution is related to the commercial use of land for agricultural and residential purposes. The impact of human activity was the lowest on location 1, which was situated at the river spring. There was almost no presence of NH_4-N and NO_3-N, and only a slight increase in PO_4-P. PO_4-P pollution might be caused by livestock breeding nearby the spring that can be washed to the spring after precipitation and concentrated in slowly flowing water. The location is characterised by an inappropriate oxygen regimen. It is related with the slow waterflow that was caught in the tank from where it flow only slowly. Low values of NH_4-N and NO_3-N indicate the extensive landscape use around the site sampling location. The opposite effect of pollution was observed in location 4 situated in lower course of the river where the agricultural areas and urban fabric are represented. In this area, the presence of intensive agricultural activity significantly affects the concentration of nutrients that soak to the soil by excessive fertilisation. They reach the watercourse by washing off, erosion and seepage, proven as well by the works of Ongley et al. (2010), Johnson at al. (2013), Húska et al. (2013) and Zhang et al. (2014). During the monitored period, the grain maize and common wheat were cultivated in the proximity of watercourse. Both crops require high nutrient intake in the form of inorganic fertilisers as well as pesticide use. These contribute to the increase in the local production of corps; however, they have negative effect on soil and water, many times also at regional level.

Conclusion

Water quality of the Žitava river is significantly affected by the landscape use. It has been confirmed that an area with a high proportion of anthropogenic activity negatively affects the water quality. It is possible to assume the high degree of water self-cleaning ability in the watercourse because in location 3, where the forests prevail, the water had a good quality. On contrary, in location 4 and in its immediate proximity, there is a high proportion of land cover with intensive effect of human activities and the water quality was not at appropriate level. Substantial water pollutant of the Žitava watercourse is the pollution by sewage water from households. Many municipalities do not have public sewer system; households release the sewage water directly to the watercourse. The current situation should change after 2021. By this time, the municipalities have a duty to allow the households to connect to a public sewer system. Another major polluter is an intensive agricultural activity focused on plant production. To eliminate the pollution in this area, it is necessary to respect the requirements and regulations in force that are part of the cross-compliance in agriculture and to ensure the protection of water from pollution from the agricultural sources, for example, by creating the buffer zones along the watercourses where industrial or organic fertilisers that can be considered as potential source of surface water pollution will not be used.

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