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LAND USE AND WATER QUALITY IN THE UPPER STROPNICE RIVER CATCHMENT

KATEŘINA HELLEBRANDOVÁ[1], LUBOMÍR BODLÁK[1], JANA ŠTÍCHOVÁ[1],
LIBOR PECHAR [1,2*]

[1] University of South Bohemia in České Budějovice, Faculty of Agriculture, Applied Ecology Laboratory, Studentská 13, 370 05 České Budějovice, The Czech Republic, e-mail: katerina.hellebrandova@seznam.cz
[2] Institute of System Biology and Ecology, Academy of Sciences of the Czech Republic, Department of Wetlands Ecology, Dukelská 145, 379 00 Třeboň, The Czech Republic

Abstract

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The purpose of our study is to characterize relationship between complex land use configuration and stream water chemistry. The study area (upper Stropnice river catchment) has a large scale of different landcover types and its mosaic patterns are characteristic at the selected region. It offers an opportunity to study impacts of different land use on surface water quality. This study compares hydrochemical data from outlets of twenty sampling sites and land use using several statistical methods: cluster analysis, factor analysis, multiple linear regression and on-way ANOVA.

Several types of pollution sources were identified, arable areas seemed to be the most important factor that influences surface water quality within the upper Stropnice river catchment. Portions of arable land were significantly correlated with average concentrations of the most monitored ions.

Key words: surface water chemistry, land use, agricultural pollution sources

Introduction

The dramatic changes in land use and especially enhancement of agriculture over the past 150 years have gradually resulted in large increases in nutrients and minerals being leached into the surface and ground waters. It is well known and documented that the expansion and intensification of agriculture has led also to an accelerated mineralisation of soil organic matter, followed by leaching of dissolved mineral ions and nutrients through soils to

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* corresponding author

the water courses (Ripl et al., 1994). The phenomenon of escalating matter losses can be observed in all major agricultural areas of Europe. Studies in Europe and USA show that average losses of nitrogen from agricultural land are around 20–30 kg ha^{-1} yr^{-1} (Ripl et al., 1994). However, losses of the base cations are even higher. For the Stör river catchment (a 1155 km^2 catchment area in NW Germany), Ripl et al. (1994) reported average losses of total mineral salts of 900 kg per hectare per year, calcium ions would be about 200–300 kg (i.e. 600–700 kg as $CaCO_3$). Similar losses of mineral salts were reported for the Elbe river catchment at the Czech/German border (Pokorný et al., 2003). Such patterns in landscape matter losses indicate distortion of lanscape sustainability. Sustainable ecological units are characterised by almost closed water and matter cycles – this means evenly-distributed water flows and minimum losses of matter from the ecosystems. According these observations, Ripl (1995) suggested in his Energy-Transport-Reaction concept to use catchment matter losses as a measure of landscape sustainability. Detailed quantitative evaluation of the matter losses based on budget studies is difficult task. Stream water quality is considerably affected by land use and related processes in the soils. The concentrations of major ions and their ratio in the discharged water could provide at least some qualitative information on the potential matter losses.

Objective of this paper is characterizing relationship between the land use type and stream water chemistry, in order to identify major sources of individual ions and their pathways.

Research sites and methods

Study area

The Stropnice river catchment is located in the southern part of Bohemia (Czech Republic) and represents a common type of submontane landscape in Central Europe. The Stropnice river originates in the Novohradské mountains on the Czech-Austrian border. Watercourse of the river is 54 km long, it discharging water from the 397 km^2 area and belongs to the Vltava river watershed. Area under study (133 km^2) comprises of an upper part of watershed above the watershed outlet on the river kilometre 32.2. The area around Horní Stropnice has a large scale of different landcover types and its mosaic patterns are characteristic at the selected region. It offers an opportunity to study impacts of different land use on surface water quality.

During the 1970s and 1980s, the study area experienced a rapid intensification of land use. During this period very extensive drainage and land consolidation were completed. The majority of field margins growing shrubs and trees were ploughed-up and large fields of the size of hundreds of hectares were created. More than 35% of agricultural land was drained using a sub-surface drainage system. For most of the drainage, concrete tubes of 30–60 cm diameter were placed to collect water from a system of smaller, clay pipes (8–18 cm in diameter), that were laid to a depth of 0.9 to 1.1 m and 9–16 metres apart. Water from the main drains was then discharged into open concrete canals. These changes had, and still continue to have, an adverse effect on the catchment‘s hydrology and functioning.

Since 1989, the socio-economical transformation in the Czech Republic initiated rapid changes in land ownership and also in agricultural practices. Important part of arable lands was converted into permanent grassland especially in “less-favoured areas” similar to the Stropnice catchment. In spite of this, study area still includes significant portion of arable land.

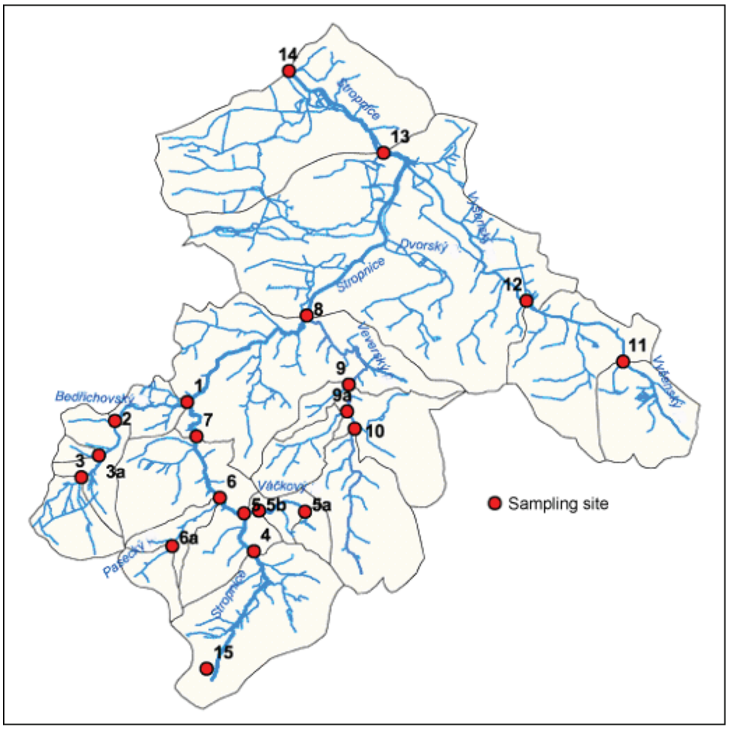

Fig. 1. Location of sampling sites and boundaries of sub-catchments.

The monitoring of water quality in upper Stropnice river catchment has started at the beginning of 2001. Altogether, fourteen sampling sites for hydrochemical analysis were chosen on the basis of collected data and knowledge of local conditions (Fig. 1, sampling sites 1–14). Later, in 2002, the total number of sampling sites was supplemented by six additional ones (3a, 5a, 5b, 6a, 9a, 15). Data for this study were collected from January 2001 to December 2004. Sampling sites represented outlets of sub-catchments which differ in the landuse and its management. The basic information about sub-catchments is presented in Table 1.

Samples collection and analysis

Water samples were taken for the period of every three weeks into 100 ml polyethylene bottles for major ions determination and into 1 l polyethylene bottles for determination of pH, conductivity, alkalinity and suspended solids. Samples were analysed in the laboratory for pH, conductivity and alkalinity. Alkalinity was determined by potentiometric titration with 0.1 M HCl.

Samples were also analysed for ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), chloride (Cl^-), sulphate (SO_4^{3-}), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}).

Anions ($N\text{-}NO_3^-$, $N\text{-}NO_2^-$, $P\text{-}PO_4^{3-}$, Cl^-, SO_4^{2-}) and $N\text{-}NH_4^+$ were determined by flow injection analyser (FIAstar 5010 duo, Tecator, AB, Sweden) using standard spectrophotometrical methods. Cations Ca^{2+}, Mg^{2+}, K^+, Na^+, and metals Fe, Zn, Mn, were analyzed on a Varian SpectrAA-640 atomic absorption spectrometer.

Table 1. Basic characteristics of the sub-catchments

Sampl. site	area [ha]	urban [%]	arable [%]	meadows and pastures [%]	forests [%]	water and wetlands [%]	other areas [%]
1	852	1.52	33.84	11.76	50.89	1.29	0.70
2	659	0.13	29.65	7.88	61.73	0.01	0.60
3	302	0.00	9.32	0.03	90.20	0.00	0.45
3a	46	0.00	88.17	0.63	11.20	0.00	0.00
4	1025	0.07	7.60	4.99	87.15	0.03	0.16
5	217	0.00	34.66	0.44	64.51	0.38	0.00
5a	94	0.00	0.00	0.00	100.00	0.00	0.00
5b	Boundaries not delineated						
6	312	1.77	6.51	24.98	66.70	0.00	0.05
6a	156	2.58	5.44	21.75	70.13	0.00	0.10
7	1518	1.13	32.50	22.37	43.29	0.33	0.37
8	5630	2.36	31.08	16.13	48.86	1.29	0.28
9	1656	0.18	20.12	5.98	73.09	0.63	0.00
9a	270	0.00	58.12	4.24	37.64	0.00	0.00
10	742	0.00	2.30	5.77	91.78	0.15	0.00
11	546	1.38	33.03	3.20	60.21	0.57	1.62
12	1409	1.35	35.10	4.36	57.60	0.52	1.08
13	9622	3.30	26.21	16.78	48.56	4.72	0.43
14	13250	Was not classified					
15	Boundaries not delineated						

Land use characterization and GIS analysis

Actual state of land cover and land use was mapped directly in the field in 2002 and 2003, using the methodology created for mapping of Natura 2000 network (Chytrý et al., 2001; Guth, 2002). These maps (basic maps in scale 1: 10 000) were scanned and georeferenced by using ArcGis 9.1. Orthophotos in scale 1: 5000 (taken in spring 2002) were used to particularize the resulting data layer.

Considering that classification system of CR biotopes for NATURA 2000 network is very detailed, attribute corresponding with terminology of database CORINE Land Cover (Bossard et al., 2000) was assigned to every polygon. Seven basic land use classes were created.

ArcGis 9.1. was used to determine composition of the land use in each sub-catchment.

Statistical analysis

All statistical procedures were conducted with STATISTICA software (Statsoft, 1999).

Cluster analysis

Cluster analysis was used to expose basic structure in the datasets, and to make a meaningful generalisation. The hierarchical method of cluster analysis was used for division of sampling sites into groups with similar characteristics.

Average values of hydrochemical data from the given period (2001–2004) were used as an input data. Unweighted Pair Group clustering procedure was chosen. The squared Euclidean distance was used as a distance measure.

Factor analysis

Factor analysis was applied to clusters created by way of cluster analysis to established internal connections and correlations among chemical indicators. Input data for analysis were concentrations from 2001–2004 periods.

Factor analysis was performed as follows:

1. The main component extraction method was used.
2. The eigenvalues was calculated to quantify the contribution of a factor to the total variance.
3. The factors that are significant (with eigenvalues more than one and explaining the higher percentage of the total variability of the data) were noted.
4. The factor loadings were calculated by a varimax rotation technique.
5. The number of factors for individual clusters was chosen on the basis of their eigenvalues. Cumulative variance was also taken into consideration.

Factor loadings > 0.75 were considered as high, factor loadings ranging between 0.5–0.75 were considered to be intermediate. This division should be booked upon as consensual; there is not unambiguous method for designation of significant factor loading. Evans et al. (1996) and Puckett a Bricker (1992) determined the same categories in their papers. Loadings < 0.5 were considered to be insignificant.

Multiple linear regression

Water quality – landscape interactions were explored by using multiple linear regression. It was used to determine the effects of the landscape factors influence on separate water quality variables, and to show how strong this interaction was.

The input datasets were average values of the individual water quality indicators as dependent variables, and percentage of individual landscape indicators as independent variables.

The Kolmogorov – Smirnov "goodness of fit test" was used to test normality of datasets distribution. Data were log-transformed to approximate normal distribution.

Results and discussion

Surface water quality in the upper Stropnice river catchment

The concentrations of dissolved solids (TDS) for the most widespread type of water in the Novohradské mountains and their foothills were ranging from 63 mg/l to 316 mg/l (Pavlíček, 2004). It corresponds to the range of conductivity approximately from 80 to 380 μS.cm^{-1}. Ripl et al. (1994) quoted, that conductivity of surface water without anthropogenic influences would be circa 50 μS/cm^{2}. This value corresponds to conductivity of rainwater, draining from surface of area with undisturbed system of humic acids capable of keeping soil moisture.

In our sampling sites the conductivity ranged from 66 μS/cm^2 (sampling site No. 6a, upper part of catchment of Pasecký stream) to 258 μS/cm^2 (sampling site No. 5b, outfall of subsoil drain in catchment of Váčkový stream). Simon et al. (2000) assessed relationship between conductivity on outlets of small watersheds and condition of landscape within the watersheds. Altogether 967 profiles (monitored by Agricultural Water Management Authority throughout the Czech Republic) were evaluated and five categories were defined in order to characterize the cultural landscape destabilization:

< 50 μS/cm^2 – extremely low
50 to 200 μS/cm^2 – stable landscape
200 to 500 μS/cm^2 – destabilized landscape
500 to1000 μS/cm^2 – soil destruction
> 1000 μS/cm^2 – intensive soil destruction

According to this assessment, 85% of our sampling profiles were in the category of a "stable landscape" and 15% in the category of "destabilized landscape" (sampling profiles 5, 5b, 3a), within upper Stropnice river basin. 8% of the sampling profiles (monitored by Agricultural Water Management Authority), occurred in the category of "stable landscape" and 52% in the category of "destabilized landscape", at the level of entire Czech Republic (Simon et al., 2000).

Cluster analysis

Sub-catchments were divided into the seven clusters. Two clusters were created by single sub-catchments. These single sub-catchment clusters were joined with the nearest sub-catchments for the use of following analysis and the number of clusters was reduced to five:

Cluster No.	Sampling sites
1	10, 15, 5a
2	3, 6, 6a, 4, 9
3	2, 7, 8, 9a, 11
4	5, 5b, 12
5	1, 13, 14, 3a

Differences in chemical composition of individual clusters were tested by One-Way ANOVA method. Individual chemical parameters of all clusters were then compared with each other. Results of this analysis are shown in Table 3.

The greatest similarity was found among catchments joined in clusters No. 1 and 2, where direct impact of man was minimum (differences at $P = 0.001$ were not significant for six parameters) and among catchments joined in clusters No. 3 and 4 (differences were not significant for five parameters).

Table 2. Average concentrations of major ions [mg/l] for individual sampling sites and individual clusters

Samp. site cluster	HCO_3^-	NO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
5a	4.77	1.10	1.31	18.15	4.29	1.30	4.16	0.91
10	8.78	2.55	1.95	22.63	6.15	1.52	4.75	1.25
15	10.35	3.75	1.45	26.59	9.94	1.59	4.51	1.84
AVR. cluster1	**7.97**	**2.47**	**1.57**	**22.46**	**6.79**	**1.47**	**4.48**	**1.33**
3	18.34	3.80	1.60	14.49	5.14	1.52	4.44	0.88
4	16.44	4.29	1.79	18.57	5.97	1.80	4.59	1.11
6	19.43	5.12	2.77	14.08	5.63	1.66	4.28	1.95
6a	14.60	6.45	2.22	10.61	3.89	1.29	3.66	1.92
9	19.71	6.60	4.25	25.84	9.19	2.66	5.76	2.08
AVR. cluster2	**17.70**	**5.25**	**2.53**	**16.72**	**5.96**	**1.79**	**4.55**	**1.59**
2	27.68	15.35	3.72	21.80	11.94	3.08	5.88	1.73
7	26.00	7.50	3.72	21.38	8.42	2.41	4.98	1.79
8	37.08	7.01	6.50	26.65	12.84	3.31	6.67	2.96
9a	35.27	15.02	7.31	27.05	13.77	3.76	7.28	3.02
11	28.75	7.40	6.19	30.40	12.81	3.64	4.88	3.34
AVR. cluster3	**30.96**	**10.45**	**5.49**	**25.46**	**11.96**	**3.24**	**5.94**	**2.57**
5	31.45	15.01	6.04	39.20	19.56	5.25	6.59	2.09
5b	42.05	18.81	7.87	58.27	25.46	6.90	6.39	2.30
12	18.79	12.24	7.52	42.02	14.80	4.72	5.55	3.03
AVR. cluster4	**30.76**	**15.35**	**7.14**	**46.50**	**19.94**	**5.63**	**6.18**	**2.47**
1	47.36	18.01	5.05	26.34	18.26	4.26	6.91	2.58
3a	37.93	29.57	4.71	36.22	19.99	4.91	7.00	2.05
13	54.78	6.30	7.12	27.90	16.21	4.02	6.94	3.86
14	56.09	5.64	6.62	27.38	16.29	4.06	6.90	3.84
AVR. cluster5	**49.04**	**14.88**	**5.87**	**29.46**	**17.69**	**4.31**	**6.94**	**3.08**

Sources of TDS in the upper Stropnice river catchment

Surface water quality in the upper Stropnice river catchment sampling profiles resembled natural patterns given by geological, geomorphologic and soil conditions, climate and vegetation. As for the chemistry of the groundwater in this area, spring and well water are mainly calcium-sulphate mixed water types (Pavlíček, 2004). These natural patterns of water chemistry in upper parts of the Stropnice river catchment were modified mainly by atmospheric deposition. Higher concentrations of sulphate anions were common in the sampling site No. 15 (spring area in Hojnovodský primaeval forest) and sub-catchments No. 10, 5a. Proportion of sulphates reached in average 35%. Average proportion of sul-

T a b l e 3. Results of One-way ANOVA (p values) – comparison of differences in chemistry among the clusters

Compared clusters		conductivity	pH	alkalinity	HCO_3^-	NO_3^-	NO_2^-	NH_4^+
1	2	0.438	< 0.001	< 0.001	< 0.001	< 0.001	0.010	0.428
1	3	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.015
1	4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004
1	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
2	3	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.001
2	4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.008
2	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
3	4	< 0.001	< 0.001	0.035	0.037	< 0.001	< 0.001	0.169
3	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
4	5	< 0.001	< 0.001	< 0.001	< 0.001	0.104	< 0.001	< 0.001
		PO_4^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
1	2	0.102	< 0.001	< 0.001	0.365	0.001	0.865	< 0.001
1	3	0.372	< 0.001	0.006	< 0.001	< 0.001	< 0.001	< 0.001
1	4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
1	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
2	3	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
2	4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
2	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
3	4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.615	0.730
3	5	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
4	5	< 0.001	< 0.001	< 0.001	0.040	< 0.001	< 0.001	< 0.001

phates in precipitations was 38 % in this area (Hellebrandová, Bodlák, unpublished data). Procházka (2004) mentioned a similar content of sulphates in the Šumava mountains, where sulphate long-term average in precipitation represented 39%. Atmospheric deposition was still an important source of sulphates, in spite of Hruška et al. (2000) reference on a decrease from 12 kg/ha/year in 1992 to 6.3 kg/ha/year SO_4^{2-} in 1999 for highlands of the Šumava mountains.

Sampling sites, mentioned above, were associated within the cluster No.1. – Forested areas formed between 90–100% of all.

Sub-catchments belonging to these sampling sites are represented by forested areas, which form 90–100%. Factor analysis produced five factors for this cluster (Table 4). Factors explain 74% of total variability in analyzed variables. Factor 1 explains 31% of the total variability. The high factor loadings are typical for Na^+, K^+, Mg^{2+} and medium for Ca^{2+} and sulphates. Direct human influence in these sub-catchments is minimal; factor 1 could be considered a result of natural mineralization.

Table 4. Factor loadings for cluster 1

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
HCO_3^-					
NO_3^-			**0.92**		
NO_2^-		**0.82**			
NH_4^+					**0.96**
PO_4^{3-}				**0.93**	
Cl^-		**0.84**			
SO_4^{2-}	0.58				
Ca^{2+}	0.72				
Mg^{2+}	**0.76**				
Na^+	**0.87**				
K^+	**0.78**				
Cumulativ. Var [%]	31.35	44.19	55.59	65.23	73.77

Table 5. Factor loadings for cluster 2

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
HCO_3^-			**0.84**		
NO_3^-				**0.93**	
NO_2^-		**0.81**			
NH_4^+		**0.89**			
PO_4^{3-}					**-0.97**
Cl^-			0.55		
SO_4^{2-}	**0.89**				
Ca^{2+}	0.67				
Mg^{2+}	0.63		0.53		
Na^+	0.54		0.69		
K^+			0.61		
Cumulativ. Var [%]	34.73	48.42	61.11	70.50	77.58

The sub-catchments with relative small human impact, containing higher portion of pastures and scattered settlement are associated in cluster 2 (sampling sites 3, 6, 6a, 4, 9). In the case of cluster 2, there are five factors explaining 77.5% of total variability in water chemistry (Table 5). Factor 1 (34% of total variability) has the closest correlation with SO_4^{2-}, Na^+, Ca^{2+} and Mg^{2+}. Na^+ has higher factor loading in factor 3. It is possible to interpret this factor in a similar way like a factor 1 in case of first cluster, hence like a factor of natural mineralization. Factor 2 is correlated with NO_2^- and NH_4^+, thus with ions, which are considered to be an indicators of organic pollution. As a result, this factor could be linked with pastures and small settlements.

Arable land, as a source of TDS, comes to be important in sub-catchments, associated in clusters 3 and 4. Factor analysis for both of these clusters brings similar results. In both cases first three factors explain more than 90% of total variability (Table 6 and 7). Factor 1 explains more than 70% of total variability of input data matrix in both cases. Factor 1 is probably corresponds to the decisive role of processes in the arable land on hydrochemical patterns of discharged water. Factors 2 a 3 explain variability of only one variable (HCO_3^- and SO_4^{2}).

Table 6. Factor loadings for cluster 3

	Factor 1	Factor 2	Factor 3
HCO_3^-		**0.95**	
NO_3^-	**0.75**		
NO_2^-	**0.96**		
NH_4^+	**0.96**		
PO_4^{3-}	**0.96**		
Cl^-	**0.87**		
SO_4^{2-}			**0.95**
Ca^{2+}	**0.75**		
Mg^{2+}	**0.94**		
Na^+	**0.91**		
K^+	**0.93**		
Cumulativ. Var [%]	77.36	85.76	93.14

Table 7. Factor loadings for cluster 4

	Factor 1	Factor 2	Factor 3
HCO_3^-		**0.95**	
NO_3^-	0.69		
NO_2^-	**0.98**		
NH_4^+	**0.98**		
PO_4^{3-}	**0.98**		
Cl^-	**0.92**		
SO_4^{2-}			**0.95**
Ca^{2+}	0.69		
Mg^{2+}	**0.95**		
Na^+	**0.95**		
K^+	**0.98**		
Cumulativ. Var [%]	74.07	83.76	92.84

Table 8. Factor loadings for cluster 5

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
HCO_3^-					0.61
NO_3^-					**-0.80**
NO_2^-			**0.90**		
NH_4^+	**0.88**				
PO_4^{3-}			**0.81**		
Cl^-	0.62				
SO_4^{2-}				**0.96**	
Ca^{2+}		**0.87**			
Mg^{2+}		**0.83**			
Na^+		**0.79**			
K^+					**0.81**
Cumulativ. Var [%]	32.43	48.81	60.84	68.49	75.30

The influence of point pollution sources is visible on outlets of greater sub-catchments. Those sampling sites are categorized in cluster No. 5. Sampling sites No. 13 and 14 are latest two sampling sites on the river Stropnice and their chemistry is very similar. The sampling site No. 1 is outlet of Bedřichovský stream in the village Horní Stropnice.

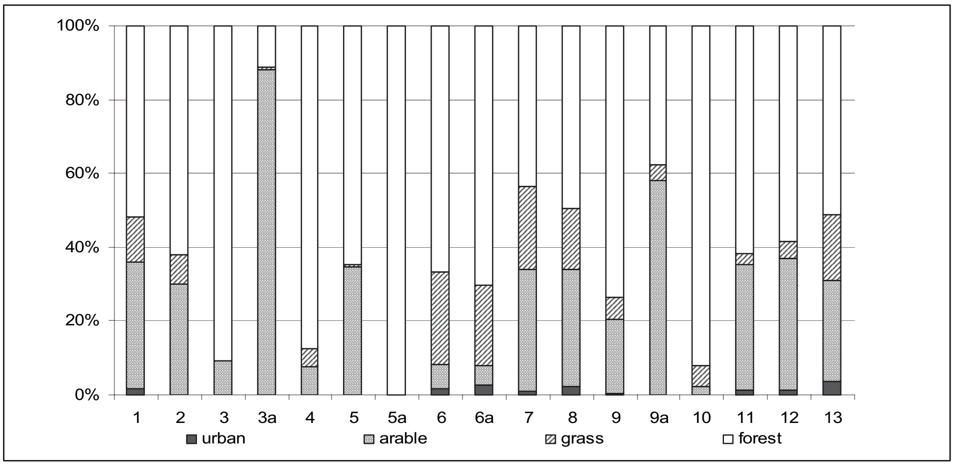

Fig. 2. Proportion of main land use types in individual sub catchments; urban – urbanized area; arable – arable land; grass – grassland; forest – forested area.

Results of factor analysis (Table 8) are difficult to interpret. Integration of non point and point sources influence and natural processes is very strong and inseparable in these sub-catchments.

Land use in the upper Stropnice river catchment is approximately 49% forested, 26% arable, 17% meadow and pastured, 5% wetland and water and 3% urban (Fig. 2). Concentrations of TDS were strongly related with land use in the upper Stropnice river catchment. The closeness of these relations was evaluated by using multiple linear regression.

Conductivity, concentration of chlorides, sulphates, nitrates, hydro carbonates and base cations showed significant correlation with the arable land in the catchment (Table 9). Similar results have been published by Williams et al. (2005). Relationship between concentration of phosphates, ammonium, nitrites and land use has not been established.

Relationship between arable land and concentration of nitrates was shown in number of studies (e.g. Osborne, Wiley, 1988). Relation of nitrates to arable land was confirmed as the closest in the study area ($R^2 = 0.85$). This close relation could be the consequence of the construction of draining systems during ´70s. These drainage systems participated in increasing nitrate leaching from the soil profile (Kvítek et al., 2002).

Faster mineralization of organic matter in drained soils could be responsible for the leaching of base cations from the soil. During the decomposition of organic matter, acids (NO_3^-, SO_4^-) and CO_2 are created, the CO_2 reacting with water and forming a proton H^+ and HCO_3^-. Base cations are displaced from soil sorption complex by H^+ ions and transported out with the outflow from the catchment (Thimonier et al., 2000). Similar results reported Procházka et al. (2001) in drained pastures in the Šumava mountain.

Potassium ion is significantly directly correlated with two types of land use – arable land and urbanized area. Williams et al. (2005) determined K^+ to be the best indicator of catchments disturbances caused by human (relative proportion of urban and agricultural

T a b l e 9. Results of linear regression between chemical parameters and land use types

	Urban	Arable land	Grassland	Forest	R^2	p
conductivity		+			**0.755**	**0.001**
pH					**0.609**	**0.016**
HCO_3^-		+			**0.840**	**0.000**
NO_3^-		+			**0.847**	**0.000**
NO_2^-					0.429	0.122
NH_4^+	+				0.448	0.104
PO_4^{3-}	+				0.377	0.189
Cl^-		+			**0.748**	**0.001**
SO_4^{2-}		+			**0.557**	**0.032**
Ca^{2+}		+			**0.754**	**0.001**
Mg^{2+}		+			**0.802**	**0.000**
Na^+		+			**0.637**	**0.010**
K^+	+	+			**0.715**	**0.002**
Fe	+				**0.591**	**0.021**
Zn	+		+		0.401	0.156
Mn					0.350	0.233

areas has the best correlation with K^+ concentration in their study). Potassium is mobile ion which is leached from soil easily and it is also presented in municipal waste waters.

In spite of correlation between land use and ammonium, phosphates and nitrates was not statistically shown, it seems that there is some connection between residential density and concentrations of these ions and potassium. Xie et al. (2005) classify these ions on the basis of factor analysis as anthropogenic ions and refer to their correlation with density of settlement. It is advised to calculate better with density of population than with urbanized area. For example Hejzlar et al. (2001) discovered positive correlation between concentrations of total P, PO_4^{3-}, NH_4^+ and percentage representation of villages, density of dwellers and municipal sources of phosphorus, and positive correlation between concentration of nitrate and meadows and pasture areas.

Conclusion

Despite of the generally positive assessment of the study area under in term of biodiversity, landscape and aesthetical functions (Papáček, 2004) the results show significant differences in concentrations of solutes in differently managed sub-catchments. Arable areas were identified as the most important factor that influences surface water quality within the upper Stropnice river catchment. Portions of arable land were significantly correlated with average concentrations of the most monitored solutes. Increase of TDS indicates less ability of landscape to avoid the matter losses and less degree of stability. In accordance with this assessment, 85% of our sampling profiles are in category “stable landscape” and 15% are in category “destabilized landscape” It is possible that sub-catchments with proportion of arable land less than 30% can be qualified as stabile within the current intensity of agricultural production.

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Hellebrandová K., Bodlák L., Štíchová J., Pechar L.: **Vztah mezi využíváním krajiny a kvalitou povrchových vod v povodí horní Stropnice.**

Vztah mezi způsobem využívání krajiny a kvalitou vody v drobných vodních tocích byl studován v povodí řeky Stropnice. Studované území představuje typickou podhorskou krajinu střední Evropy a nabízí širokou škálu různých typů krajinného pokryvu s rozdílným způsobem hospodaření. Povodí horní Stropnice tak představuje vhodnou oblast pro studium vlivu využívání krajiny na hydrochemické poměry. Vzorky byly odebírány v období 2001–2004 na 20 odběrových profilech. Výsledky statistických analýz, analýzy shluků, faktorové analýzy, analýzy rozptylu a vícenásobné lineární regrese ukázaly, že chemismus drobných povrchových vod je významně ovlivňován charakterem krajinného pokryvu a způsobem hospodaření. Nejvýznamnější vliv byl prokázán ve vztahu k orné půdě, která je zdrojem nejen dusičnanů, ale zejména hlavních kationtů (Ca, Mg, K a Na) v povrchových vodách.