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EFFECT OF LAND USE ON TOTAL PHOSPHORUS LOSS IN SELECTED LOCATIONS

Jiří Ciml, Jiří Pečenka, Jana Moravcová, Petr Lechner, Jan Kalíšek
University of South Bohemia in České Budějovice

Abstract. The study focuses on how land use in the selected location affects the amount of phosphorus in the watershed. Defines the basic concepts of this and related issues. The monitored value is total phosphorus and description of the measuring apparatus. The resulting data are arranged in tables and graphs and results are compared with standards of Czech norms (CSN) and other similar studies.

Key words: phosphorus, trophy, runoff, land use

INTRODUCTION

Water is an integral part of our landscape. Water quality monitoring is important activity for human life, which is dependent on water. This study monitors amount of total phosphorus in water. Measurements were made out on selected subcatchments with different landuse. For the purpose of the flows monitoring, there are placed measuring apparatus. The study will evaluate the role of land use management e.g. agriculture, development and planting and cultivating of certain crops [Šlezinger 2010]. Phosphorus and its variants of occurring in water are monitored for water eutrophication and human health purposes.

Objective

The main objective of the study was to evaluate what the phosphorus runoff is in selected locations, if we know the use of the catchment and its landscape character. The study will include an evaluation elements of data monitoring, and then comparison of the

Corresponding authors – Adres do korespondencji: ing. Jiří Ciml, ing. Jiří Pečenka, ing. Jana Moravcová Ph. D., ing. Petr Lechner, ing. Jan Kalíšek, Department of Landscape management, Faculty of Agriculture, University of South Bohemia in České Budějovice, Branišovská 1160/31, 370 05 České Budějovice, Czech republic; e.mail: moravcova.janca@seznam.cz.

data about phosphorus with Czech standard norms (CSN), based on this results the water quality in the observed profiles will be determined. After that there will be evaluated the total phosphorus in extreme rainfall-runoff situations.

The review

Local and global phosphorus cycle

Local cycle includes only the phosphorus circulation in the water. Aquatic organisms and plants absorb phosphorus in dissolved orthophsphate form and built it into their biomass. Phosphorus compounds in the biomass become part of the cycle in aquatic ecosystems, they run up in food chains until the organisms die [Novotná 2010]. Global cycle includes all movement of phosphorus in nature. In Šafarčiková [2006], Pitter [2009] and Orolinová [2009], this cycle is described as follows, the ecosystem phosphorus obtains in forms of dissolved orthophosphate or their conversion to ferric phosphate. The form of dissolved phosphate enters into other segments of the food chain.

Sedimentation and stratification of phosphorus

Massive transport of phosphorus is made during water erosion, when the phosphorus bound to soil particles. Much of phosphates gets into the water, and ends at the bottom of water reservoirs, rivers and oceans. With the fishing, activities of birds and human activities is phosphorus partially "recycled" and returns back. The inorganic phosphorus finally leaves the mainland and goes into the oceans, where phosphorus is integrated into the sediments. Phosphorus comes into the ecosystems in the form of dissolved phosphates. This phosphates are released from rocks [Šafarčíková 2006]. In comparison with other biogenic elements phosphorus have importance as an element, which is often limiting production processes in aquatic ecosystems [Lellák and Kubiček 1991]. Other researches has shown that when the sediment gets back into suspension, it increases in shallow waters, vulnerable to eutrophication, release of phosphorus [Hamilton and Mitchell 1997]. The concept of stratification can be explained as a layering. This is a periodic change during the year [Moldán et al. 1979].

Trophy

Trophy characterize a hydrochemical regime (mode) and related biology in aquatic ecosystems. It is determined by the amount of basic nutrients, that are carried in a cycle named composition of the biota. Oligotrophy and eutrophy after a certain period can even rotate [Hartman et al. 1998]. Basic trophic series are: oligotrophic (poor), mesotrophic (medium rich), nitrophilous (nitrogen rich), alcaline (nutrient rich, on alcalic rocks, limestones) [Sklenička 2003].

Eutrophication

Eutrophication is an increase in the production of algae in ponds and water reservoirs by supplying with nutrients, especially nitrogen and phosphorus. Subsequently it leads to increase and develop of photosynthetic organisms in the water, especially algae and cyanobacteriums, which then die and quality of water is decreased [Petráčková 2001, Kaufnerová 2007, Pitter 2009].

Sources of water pollution

Runoff is the main transport way for eroded material and other chemical or biological elements and compounds that cause pollution of streams and reservoirs [Kvítek 2005] and [Sklenička 2003]. In the Czech Republic there are two basic sources of phosphorus pollution: point and diffuse. Point sources of phosphorus are made by a communal wastewater from the wastewater treatment plant and by industrial buildings [Maršálek and Müller 2009]. Because in each catchment we have a lot of sources of this point pollution and it is very difficult to make a right evaluation. About population pollutions in Zitava river write a detail study [Húska et al. 2013]. Often we have only partial data, so the overall data must be totally recalculated, or sometimes even estimated. Surface contamination has one main source – agriculture. This is how the crop and livestock production make a pollution, the predominant is crop production. In livestock production these are mainly the production of waste – manure, liquid manure. There are many ways to determine the extent of diffuse sources of pollution. The basic methods are – balance method, additive method, mathematical modeling or specific substance loads [Langhammer 2002].

Legality

The legal protection of all water sources and water courses is necessary for these days and also for future. In the conditions of the European Union we protect the water resources according act 2000/60/ES of European parliament and council from 2000. The rule defines in detail the overall policy and means of water resources protection. It coordinates the administrative apparatus and determines the way of monitoring. Further it designates the rule and control organizations and characterized the protection for particular water types (surface, subsurface, ground water). Each country solves the problematic individually in more detail based on its own legalism. Nevertheless the rule serves for particular EU member countries as basic document, be half on which theirs internal legality is further developed (2000/60/ES).

The example of internal legality which applies the points of rule is the act 61/2011. In this rule there are in detail described and stated the maximal limits of pollution by individual inputs into different water types. The values are set in $g \cdot t^{-1}$ or $mg \cdot l^{-1}$. These legal rules can also serve for amending this problem besides the applied norms as Czech standard norm.

Water quality in EU and Czech republic

The Czech standards are more strict than EU norms. In EU are two possibilities how measured the values in the water streams. First is control each chemical substances in water. This method is use by Czech republic, Slovakia, Italy, France and another. Second choice is control whole water. This method is use by Germany, Austria, Luxembourg. Each method had their pluses and minuses. Each country must follow the primary standard of EU about emissions and immission. Water quality is generally very good in all Europe and still rise up. Some states have problem with deficit of water, but quality is not bad e.g. Spain. In last years, many states in EU spend a lot of money on water streams reconstructions. Because if we can work with water sources well, we of course must work with all country around. Because it is alpha and omega of all water problems.

MATERIALS AND METHODS

Catchment characteristies

The work was carried out on Jenin, Kopanina and Budsky stream catchments (see Tab. 1).

Jenin stream catchment – Jenin stream catchment is situated in South Bohemia near the village Jenin opposit*e Dolní Dvořiště.* We classify it into a climatic region MT3 – by Quitt [1971] (middle warm region). Monitored area is divided into two subcathments J1 and J2 with an area of 46.81 hectares and 55.21 hectares. Respectively matrix artificially consists of pastures and meadows, corridors consist of road network. These areas were drained (see Tab. 2). Agricultural activities in the area of interest is limited to extensive livestock. The entire catchment is an area of pastures with around 380 cows and 200 calves of meat type – of Aberdeen Angus, Simmental (meat type) and Charolais. The herds are kept in housing through the winter and on pasture they are from May to November. Herd is on one pasture throughout the all season [Moravcová 2011]. Grassing was carried out by the farmers themselves in the late 90's of the 20th century.

Kopanina stream catchment – Experimental catchment Kopanina stream is located in the center of the Czech Republic near Pelhrimov. From a geomorphological aspect catchment area is located in the Czech-Moravian highlands [Demek 1987]. Catchment is located in the climatic region MT4 – by Quitt [1971] (middle warm region), moderately warm and humid. Studied area is mark as P6 and has an area of 15.73 hectares. Agricultural areas subtype is potato-rye. Landscape matrix, consist of arable land, enclaves are represented by pastures and other areas and corridors are characterized by road network (see Tab. 2).

Budsky stream catchment – Budsky steam catchment is located in south bohemia near Malce and Sobenov village, East of Czech Krumlov. Catchment is in sanitary protection zone of Rimov dam. It is located in the southeastern part of the Sumava Moldanubicum, which occupies an area of Sumava and Novohradske mountains and their foothills. Climate region MT2 – by Quitt [1971] (middle warm region). The matrix is made by arable land with grown crops as rade seed and cereals. On grassland areas there is not intensive breeding of cattle (see Tab. 2).

Table 1. Basic catchments characteristics of the Jenin, Kopanina and Budsky basin

Name of stream (letters – subcatchments)	Kopanina (P6)	Jenin (J1)	Jenin (J2)	Budsky (B)
Ø altitude	525 m.n.m. Bpv	523 m.n.m. Bpv	520 m.n.m. Bpv	628 m.n.m. Bpv
Klimatic region	MT4	MT3	MT3	MT2
Area [ha]	15,73	46,81	55,21	713,1

Table 2. Landuse in subcatchments Jenin, Kopanina and Budsky basin (J1, J2, P6, B)

Land use	Jenin J1	Jenin J2	Kopanina P6	Budsky B
Arable land	0,0 %	0,0 %	92,2 %	52,8 %
Meadows and pastures	87,2 %	78,2 %	7,6 %	8,6 %
Forest	10,0 %	14,7 %	0,0 %	31,5 %
Urban areas	0,1 %	0,0 %	0,0 %	0,2 %
Other	2,7 %	7,1 %	0,2 %	6,9 %

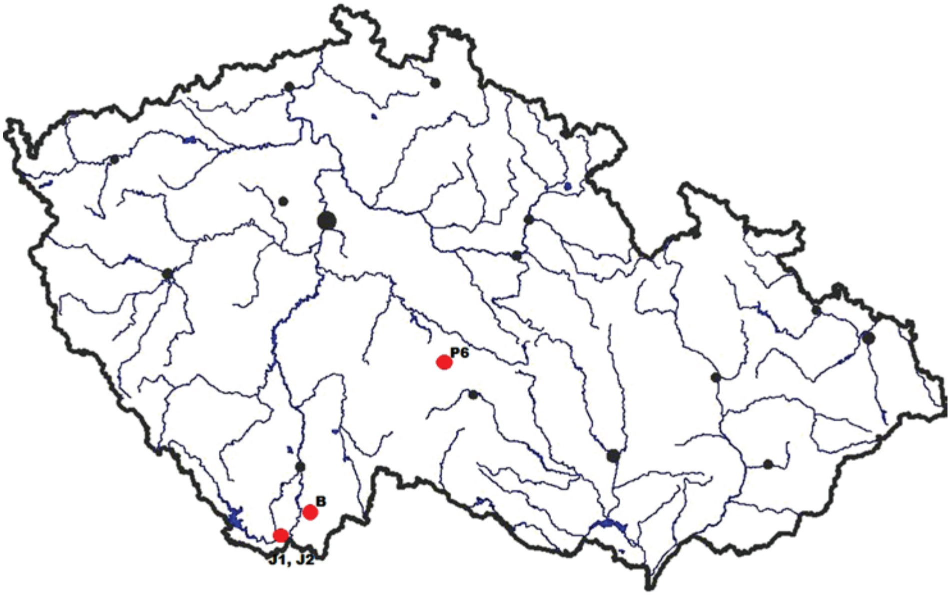

Fig. 1. Location of subcatchments in Czech republic

Methods

GIS data used in the study

Geographic Information System (GIS) is an organized collection of computer hardware, software, and geographic data designed for effective obtain, storing, editing, analyzing and displaying all forms of geographic information [http://gis.izscr.cz]. Used GIS layers:

- Catchment boundary – polygon layer, polygon defining the catchment is designed like an area from which all water flows through one closing profile.
- Subcatchments – polygon layer, polygons in this layer divided the catchment into subcatchments.
- Land use – polygon layer that separates subcatchments to polygons (multi-polygons and units) with the same land usage (arable lands, pastures and meadows, forests, urban areas...); other areas in data tables (properties) is a text description of the polygon.
- BPEJ – bonited soil ecological unit (characterized by climatic region, stoniness, depth, slope and exposition of the soil profile) layer, which divides subcatchent to polygons according to their characteristics.
- Contours – line layer (curves), containing data about altitudes.

Measuring equipments

All subcatchments have their own measuring equipment. At each location there is normalized rectangular vier. For the rainfall record there are in one-shuttle gauge measuring equipments. The equipment is heated only in J1. Heated version prevents freezing of the ensures device and the measurement of solid precipitation (snow, hail). Flow rates were measured in all of the profiles by ultrasonic process of water level (US1200) supplemented by recording units (M4016) constructed by Fiedler-Magr. Flow rates and water levels are recorded in a datalogger (device for collection and storage of analog and/or digital information) for normal runoff conditions in a ten-minute interval, during extreme rainfall-runoff events with minute time step. Values are stored by software in tables, which can be evaluated. For evaluation of the measured data MOST software was used, also developed by Fiedler-Magr, which mainly served to revise data from errors caused by dirt clogging of the profile, such as branches, leaves, vegetation or power outages sensors or recording unit adverse climatic conditions etc.

Monitoring

Surface runoff, and the kinetic energy of rainfall, leach soil and put away the elements and their compounds. These elements are monitored and their concentration is measured for each profile. During the year on the individual profiles there is carried out discrete monitoring of water quality at monthly intervals. Samples are complemented by continuous monitoring of water quality during extreme rainfall-runoff events (storm) when the sampling time step varies depending on the duration of the event in hours. This sampling is now on all profiles ensured through continuous auto sampler ISCO 6712 with the possibility of taking up to 24 water samples per cycle of the program. Automatic sampler by the variable settings can flexibly react to the beginning of the rainfall-runoff event. By this ensures an even distribution of individual samples, both the ascending and the descending branch of hydrograph describing the rainfall-runoff event [Moravcová 2011].

The samples are sent to an accredited laboratory, where these are analysed. Individual analyses are performed according to standard analytical methods and the finished results are sent back to the owner of measuring apparatus in printed or digital form. From the result data we have know only values of total phosphorus. Ideal statement would be to have all types and parts of phosphorus e.g. dissolved phosphorus forms. But analyse was made in the external laboratory and this information is not available.

RESULTS AND DISCUSSION

Data from the measuring apparatus includes a tables, that contains the basic characteristics of runoff and rainfalls. The chemistry of samples is evaluated by a certified laboratory. For the purpose of this article, were there used results about phosphorus and these were expressed in tables and charts. The data were statistically analysed – minimum, maximum, median, average, standard deviation, coefficient of variance and percentile C90 (see Tab. 3).

The predominant type of landuse in both Jenin stream subcatchments are pastures. Subcatchment J1 is composed mainly of pastures. Livestock production in that area is limited to cattle without milk production. Artificial drainage is from the 70s years of the 20^{th} century, but it is still largely able to provide its function. The forest, which covers 10% of the area is the second largest type of land use in subcatchment. This area does not belong to agricultural land and consists mainly of coniferous forests, sometimes even spruce monocultures. These forest complexes are used mainly for horticulture, and therefore there rarely can be found different tree species such as pine, oak, beech, larch, poplar and alder. The edges of the forest areas have very short shrub and herbaceous borders, so cannot act as a complete or accompanying element in the landscape. This accompanying role is played by clusters of small hedgerows, groups of trees (enclaves) which are directly in pastures. These units are composed of diverse tree composition, mainly deciduous trees, which are represented in even fruit trees (apple, pear, cherry). Most of these enclaves are also useful shrub layer and provides shelter to rear beasts and cattle. Urban areas represent here only a tiny percentage and these form marginal part of subcatchment J1.

Table 3. Basic values and parameters of total phosphorus in the catchment J1, J2, P6, B

	J1	J2	P6	B
	P	P	P	P
Maximum, mg · l^{-1}	0,400	0,440	0,818	0,144
Minimum mg · l^{-1}	0,024	0,019	0,020	0,020
Avarage mg · l^{-1}	0,095	0,119	0,063	0,047
Median mg · l^{-1}	0,075	0,100	0,055	0,042
Percentile C90	0,167	0,219	0,082	0,080
Standard deviation	0,070	0,078	0,036	0,021
Coeficient of variance	0,734	0,650	0,566	0,451

Subcatchment J2 is also largely made up of pastures. The livestock is the same as in subcatchment J1. In addition, however, there are feeding and water points in these pastures. Also there are places where cattle concentrated and often lying down, which is proved bare and compacted part of the pasture, which in case of rain becomes muddy and there is a standing water. This places, are obviously a source of high concentrations of manure. By higher rainfall amount, there may be a large load to surface, subsurface water and groundwater, by monitored elements – especially nitrogen. A similar problem occurs also with urban area – in subcatchment J2. The building, which is located in this area, clearly has not a well established septic. It seeps and runoff from it may again affect the measured data. The problem is indicated by vegetation that is characteristic for the site with high concentration of nitrogen and phosphorus, e.g. nettles. Forest areas are slightly larger than in subcatchment J1. These occupy 14.7% and with 7% of shrubs they form an important part of the landscape.

The Fig. 2 illustrate the value of total phosphorus in both subcatchmets from 2004 to 2013. The vertical axis is the concentration of phosphorus in mg · l^{-1}. We compare with the standard CSN (Czech standard norm). So we need to know what are the maximal allowed value for II. Water quality class. Standard CSN 75 7221 – Water quality – Classification of surface water quality. Allowed values are listed in the table below (see Tab. 4). The average value of total phosphorus is 0.095 mg · l^{-1} at J1 and 0.119 mg · l^{-1} at J2. Both subcatchments fall under the II. class, and that means that the water is usually suitable for most uses, especially for waterworks supplying and use, water sports, fishing and industry. Water has high value for landscape.

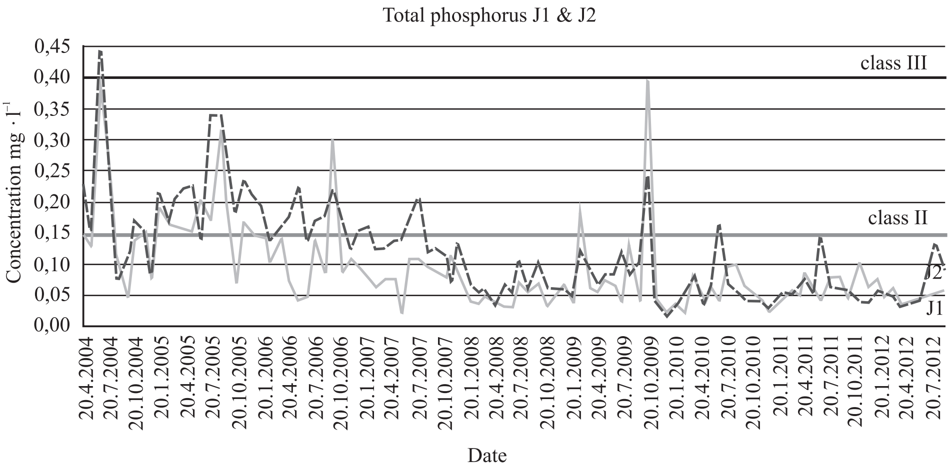

Fig. 2. Total phosphorus in both subcatchments of Jenin stream

Kopanina stream subcatchment P6 is composed only by arable land. The usual crops grown in the catchment are potatoes and cereals. Root crops such as potatoes, cause higher loss of the organic material during rainfalls (rain events) and these form higher wash out of chemicals from soils. Anti-erosion measures are only agrotechnics. In the eastern part of the area there is pasture. Distance and location of this pasture is not useful for changing of runoff values in this subcatchment. Other areas (0.3% of the area), are roads. The neighboring subcatchments are covered by forests and grasslands. However, there will also dominate agricultural production on arable land.

The Fig. 3 shows the values obtained for the subcatchment P6 between 2008 and 2011. Although the data are not complete and the time serie are not as long as in the

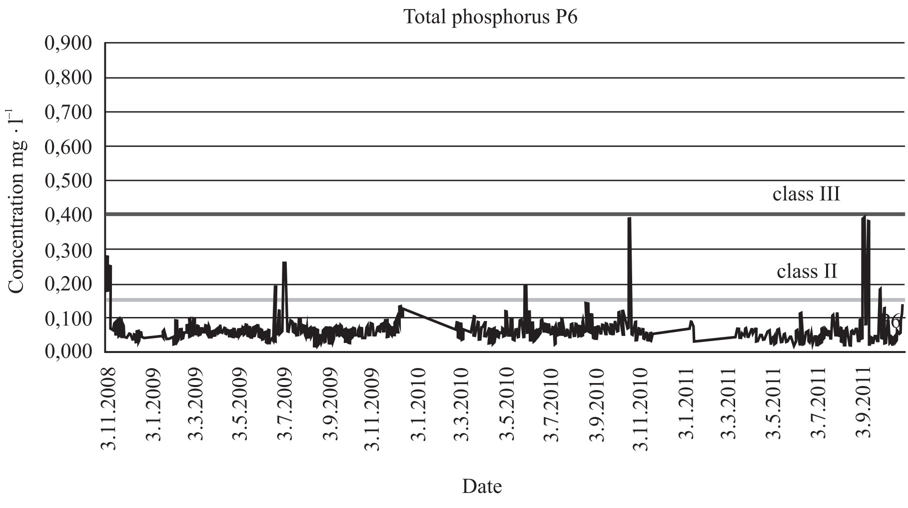

Fig. 3. Total phosphorus subcatchment Kopanina stream

Jenin stream subcatchment. We can deduce interesting information, namely that the average value of 0.063 mg · l^{-1} is not so high. According to CSN (Czech standard norm) 75 7221 – Water quality – Classification of surface water quality. The subcatchment P6 is in II. class, and this means that the water is usually suitable for most uses, especially for water supplying, water sports, fishing and industry. The values at high runoffs are strange as visible on the chart by high peaks. In November 2010, the value was even was 0.390 mg · l^{-1} and another was in September 2011 more than 0,8 mg · l^{-1}. This value would indicate IV. class – Heavily polluted water. Surface water quality was affected by human activity. The water quality indicators reach values that allowed the existence of only unbalanced ecosystem.

Budsky stream represents variable subcathment. Budsky stream represents a greater mixture of landuse types. The predominant arable land and forest complexes are supplemented by shrub sections. Other elements of landuse have more than 2% representation. Among the grown crops there are included cereals and rapeseed. Meadows are not used for intensive livestock farming.

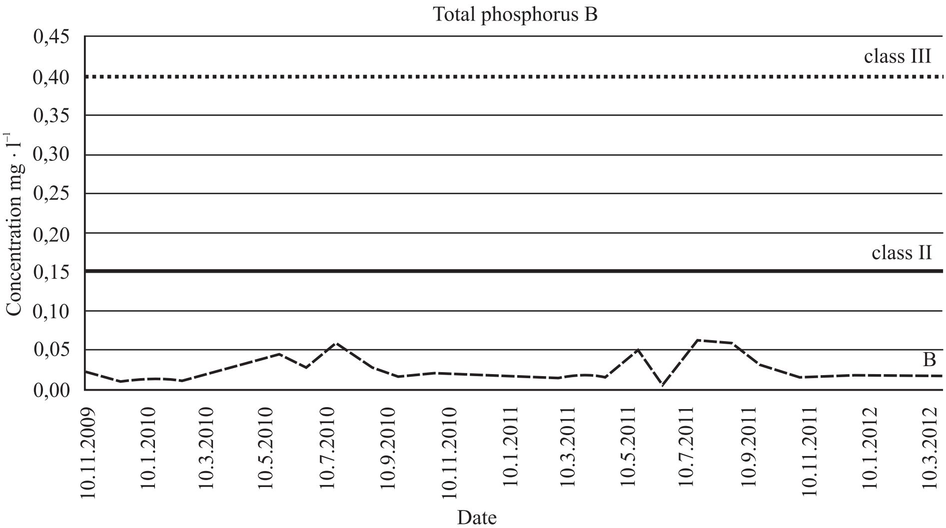

Fig. 4. Total phosphorus catchment Budsky stream

The Fig. 4 shows the values obtained for the subcatchment B in Budsky stream between 2009 and 2013. The measured average value of phosphorus is 0.047 mg · l^{-1}. It is the lowest of all the monitored catchment. According to CSN (Czech standard norm) 75 7221 – Water quality – Classification of surface water quality. The water is under normal condition characterized as I. class – Unpolluted water. This is surface water, which was not significantly affected by human activity, in which water quality indicators do not exceed the value corresponding to the current natural background. In extreme cases, the value of total phosphorus can overcome the limit of 0.15 mg · l^{-1}, and then it falls into II. class, and this means that the water is usually suitable for most above mentioned purposes.

Table 4. Allowed values according to CSN 75 7221 – Water quality – Qualification surface water quality. General, physical and chemical indicators

General physical and chemical indicators						
Indicator	Value (unit)	Class				
		I	II	III	IV	V
Conductivity	mS · l^{-1}	< 40	**< 70**	< 110	< 160	> 160
Soluble substance	mg · l^{-1}	< 300	**< 500**	< 800	< 1200	> 1200
Insoluble substance	mg · l^{-1}	< 20	**< 40**	< 60	< 100	> 100
Dissolved oxygen	mg · l^{-1}	> 7.5	**> 6.5**	> 5	> 3	< 3
BOD_5	mg · l^{-1}	< 2	**< 4**	< 8	< 15	> 15
COD_{Mn}	mg · l^{-1}	< 6	**< 9**	< 14	< 20	> 20
"Nitrites"	mg · l^{-1}	< 3	**< 6**	< 10	< 13	> 13
Total phosphorus	mg · l^{-1}	< 0.05	**< 0.15**	< 0.4	< 1	> 1

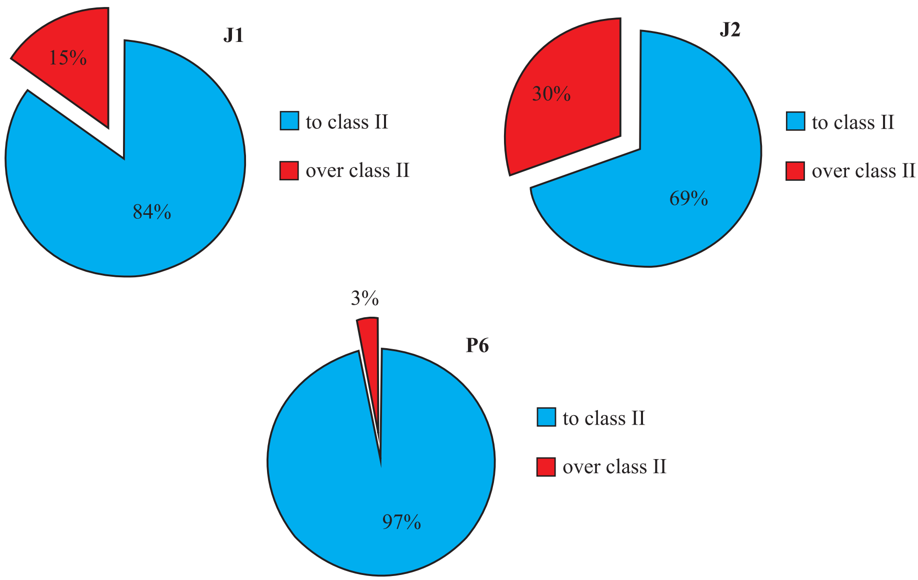

Fig. 5. Value for pass/failure a limit class II on subcatchments J1, J2 and P6 during timelines. Subcatchment B is not made because it pass on 100% (see Fig. 4).

CONCLUSION

The results point to the fact that a land use, crop rotation, mechanization, use of chemical substances and the location of the site. Play significant role in phosphorus runoff away from the catchment. The study also shows that the current trend of grassing the areas leads to a reduction of erosion. It prevents the leaching of certain substances and thus also prevents eutrophication of streams, this is therefore a step in the right direction. The concentrations of substances in grassland subcatchments reached by extreme rainfall--runoff events higher, but not critical values. In arable lands the variability of the concentrations is more critical and alarming. When extreme event occurs the concentration of phosphorus in the flow and increases significantly exceeds and VI. class water quality of the measurements in the longer time period, proves that it is possible to appropriately manage arable land, and the average value of the phosphorus concentration reaches II. class of water quality. Budsky stream catchment represents an agricultural area with a substantial part of the forest. In addition, the catchment is in II. sanitary protection zone of Rimov dam, resulting in the restriction of chemicals use in farming. Also, there is no grazing cattle. It is a water with the smallest variance of concentrations values catchments in the study. The results implies that if we are going to look at phosphorus in the water, on amount the average value, in any of the cases the measured value is critical. It is therefore important to monitor the content of phosphorus in the runoff in extreme rainfall-runoff evens. These values are meaningful and characterize well the possible water quality and water pollution in catchments. As other control parameters it can serve the monitoring of nitrogen, suspended solids, etc. Another studies on that issue (water chemistry) made for example Siwek et al. [2012] in Poland on river Stora Rzeka – subcatchments Lesný Potok and Kubale. In United Kingdom it was Muscutt and Whithers [1996].

REFERENCES

Demek, J. (1987). Geographic lexicon ČSR: Mountains and lowlands. Academia, Praha.

Hartman, P., Přikryl, I., Štědronský, E. (1998). Hydrobiology. Informatorium, Praha.

Hamilton, D., Mitchell, S. (1997). Wawe-induced shear stresses, plant nutrients and chlorophyll in seven shallow lakes. Freshwater Biol., 38(1), 159–168.

Húska, D., Krupová, K., Halaj, P., Mandalová, K. (2013). Evaluation of surface water in Žitava catchment under the aspect of anthropogenic impact. Acta Sci. Pol., Formatio Circumiectus, 12(3), 41–51.

Kaufnerová, V. (2007). Cyanobacteria and algae in flooded downs. ZČU, Plzeň.

Kvítek, T. (2005). Use and protection of water resources. University of South Bohemia, České Budějovice.

Langhammer, J. (2002). Surface water quality and water protection. Charles University, Praha.

Lellák, J., Kubíček, F. (1991). Hydrobiology. Charles University, Praha.

Maršálek, B., Müller, B. (2009). Pollution of surface water by nutrients: Possible solutions of eutrophication. Masaryk University, Brno.

Moldán, B., Zýka, J., Jeník, J. (1979). Environment eyed by naturalist. Academia, Praha.

Moravcová, J. (2011). The influence of landscape on selected indicators of water quality at higher flow rates as a basis for designing KPÚ. University of South Bohemia, České Budějovice.

Muscutt, A.D., Whithers, J.A. (1996). The phosphorus content of rivers in England and Wales. Water Research, 30, 1258–1268.

Novotná, M. (2010). Computer modeling of pollution in nature using Maple. Universitas masarykiana brunensis. Masaryk University, Brno.

Orolinová, M. (2009). Chemistry and the Environment. Trnava University, Trnava.

Petráčková, V. (2001). Academic dictionary of foreign words. Academia, Praha.

Pitter, P. (2009). Hydrochemic. VŠCHT, Praha.

Quitt, E. (1971). Climatic areas of Czechoslovakia. Studia Geographica, 16, 1–74.
Siwek, J.P., Żelazny, M. (2012). Determinants of seasonal changes in stream water chemistry in small catchments with different land use. Polish J. Environ. Stud., 22(3), 159–165.
Sklenička, P. (2003). Basics of landscape planning. Naděžda Skleničková Publishery, Říčany.
Šafarčíková, S. (2006). Nutrients in landscape. Daphne ČR Institute of Applied Ecology, Třeboň.
Šlezinger, M. (2010). Water restorations. Vutium.
GIS PORTÁL HZS ČR (2014). Czech Republic: HZS ČR, hrrp:// http://gis.izscr.cz/wpgis/ (2.01.2014).

WPŁYW UŻYTKOWANIA TERENU NA ODPŁYW FOSFORU CAŁKOWITEGO W WYBRANYCH ZLEWNIACH

Streszczenie. Przedmiotem pracy było zbadanie, jak wykorzystanie terenu w wybranej lokalizacji wpływa na ilość fosforu w dziale wodnym. Praca definiuje podstawowe pojęcia w tym i pokrewnych tematach. Opisuje monitorowaną ilość fosforu całkowitego oraz aparaturę pomiarową. Uzyskane wyniki są podane w formie tabel i wykresów w odniesieniu do standardów podawanych przez czeskie normy (CSN), a także przez inne podobne badania.

Słowa kluczowe: fosfor, trofizm, spływ, wykorzystanie terenu.

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