

ECOLOGICAL HEALTH OR ILLNESS OF URBAN STREAMS –CASE STUDY FROM PRAGUE

D. Komínková, J. Nábělková and J. Caletková

Czech Technical University in Prague, Faculty of Civil Engineering, Department of Sanitary and Ecological Engineering, Thákurova 7, Prague 6, 166 29, Czech Republic, email: kominkova@lermo.cz; nabelkova@lermo.cz; caletkova@lermo.cz

ABSTRACT

During the last few decades, rivers and streams have been impacted by anthropogenic activities at an increasing rate. The term “river health” has become widely used in freshwater ecology and it defines the ability of the aquatic ecosystem to support and maintain key ecological processes and a diversified biota comparable with biota of undisturbed habitats within the region. The river health was assessed for three urban creeks in Prague, affected by different anthropogenic impacts (combine sewer overflow, stormwater drain discharges, WWTP). The long term monitoring of chemical, biological and hydromorphological conditions was used as a background of the health assessment. The results shows that health of all the observed creeks is very poor, even they are closer to illness, than to health. The health is disturbed by alternation of morphological, hydrological and chemical conditions. The alternations of the environmental conditions cause in all study creeks changes in biota and result in ability of the ecosystem to support only low diversified biota with presence of a few tolerant species with moderate to low bioindication value. The assessment of river health shows that the alternation of the hydromorphological conditions is the primary causation of the poor health. The identification of the primary causation of poor health is necessary for proposal of efficient measures to improve present situation. In the case of all study creeks, measures in the watershed and restoration of the river channel are the primary steps to improve the recent conditions.

Key words: urban creek, river health, urban drainage, aspects of river health, monitoring

1. INTRODUCTION

During the last few decades, rivers and streams have been impacted by anthropogenic activities at an increasing rate. The impacts cause loss of natural channel character and function of water bodies. The pattern of changing natural systems is obvious especially in urban areas, where the pressure is increasing exponentially with population growth. On the one hand, there is increased community use of resources associated with growth in populations and their higher life style, and on the other hand, there is an increased expectation of maintaining good environmental conditions. In urban areas these requirements manifest especially in the field of urban drainage. The levels of wastewater and pollutants discharges have increased dramatically during the last few decades, often exceeding the capacity of the sewerage system. In the past, the sewerage system was constructed with respect to a technical grade of single sewer structure. Recognition of the sewerage as complex systems requires integrated design and management. The primary management goals comprise the minimization of pollution of the aquatic ecosystem and minimization of the costs of operation and maintenance. This new approach to urban drainage brings necessity to understand well the processes in river bodies which are crucial for driving response of the aquatic ecosystem to a disturbance and identification of the fate of pollutants in an aquatic environment.

Improvement in urban drainage design has to be done based on understanding of these natural processes, or it will not be long term sustainable. Drawing on three examples of Prague urban streams, the paper illustrates the process of gaining deeper understanding of these processes. Based on this knowledge, the paper recommends measures to improve the recent drainage system and consequently to lead to improvement of the river health (status).

'River health' is usually defined in terms of ecological integrity and is used to give a measure of the overall condition of a river ecosystem. The working definition of "river health" is: 'The ability of the aquatic ecosystem to support and maintain key ecological processes and a community of organisms

with a species composition, diversity, and functional organisation as comparable as possible to that of undisturbed habitats within the region' (Schofield and Davies 1996). Following the definition of river health it is possible to define river illness as conditions of the river ecosystem, which do not support and maintain key ecological processes and community of organisms is disturbed and far from community composition from undisturbed habitats.

2. OBJECTIVES

The objective of the paper is to identify ecological health or illness of urban creeks based on monitoring of chemical, biological and hydromorphological conditions of study creeks. The paper also compares impact of different urban drainage types on ecological health and proposes measures to improve the health of the creeks.

3. METHODS

The health of the creeks was assessed based on the long term monitoring of chemical, biological and morphological conditions of the streams.

3.1. Study creeks

Identification of river health (status) was done on three creeks in Prague. The study creeks are affected by different type of urban drainage. The Botic creek is affected by combine sewer system. The Zatiscky creek is impacted by stormwater drainage discharge from residential area and the last creek, the Uneticky creek is affected by discharge from waste water treatment plant. The WWTP treats waste water from the Prague airport.

The Botic creek (study sites are marked B) is studied in approximately 2.5 km long section impacted by two combine sewer overflows (CSO). The sewer drains residential and industrial areas and roads with heavy traffic. The river continuum of the Botic creek is disturbed by large and small reservoirs and by artificial steps in the river bottom.

The Zatiscky creek (study sites Z) was monitored in its whole length (3km). The creek is affected by seven stormwater drain discharges (SWD), which drain residential area with a high percentage of impermeable surfaces. The river continuum is disturbed by three retention reservoirs and a number of artificial steps. A restoration of the creek was done in the 70th of the 20th century. The amount of water entering body of the creek during rain events causes erosion and devastation of the creek and the restoration measures are devastated.

The Uneticky creek (study sites U) was studied in section 5 km long, from the spring to the confluence with other small creek. The creek is affected by the Prague airport waste water treatment plant (WWTP). The technology used in the WWTP is highly efficient. The WWTP discharges waste water to the creek approximately 1.5 km from the spring. The second creek drainages the second airport's WWTP. The river continuum of the Uneticky creek is disturbed by ponds, from the spring the stream is heavily canalized, lower part of the study section is less canalized and has more natural character.

3.2. Methods of stream health (status) assessment

The stream health is primarily determined by hydromorphological, chemical and biological status of the water body. The complex state of the water body is essential for function of the river body.

The hydromorphological status was assessed with Swiss methodology Level F (BUWAL, 1998) (morphological part) and the methodology IFIM and its tool PHABSIM were used for assessment of hydrological and hydraulic conditions (Bowie, 1995; Jirinec et al, 2001).

The chemical status was assessed by basic physical and chemical parameters (COD, BOD, NO_2^- , NO_3^- , NH_4^+ , PO_4^{3-} , TP, etc.) as well as by concentration of specific pollutants as heavy metals and PAH. The samples for evaluation of chemical status were collected periodically every 2 to 3 months, with respect to identified impact of different season activities on chemical quality.

Biological status was assessed by surviving benthic community; in the case of the Uneticky creek also attached algae were survived. The biological survive of benthic community was primary designed for collection of data for PHABSIM (Caletkova and Kominkova, 2005) later on the data were used to assess biological status of the study creeks. The biological status was evaluated by number of biotic indexes (diversity index, saprobic index, ASPT, etc.) (Kokes and Vojtiskova, 1999). The biological samples were collected three times per year in different seasons.

4. RESULTS AND DISCUSSION

4.1. Assessment of hydromorphological conditions

The assessment of hydromorphological status is summarized in **Error! Reference source not found.** As the table shows, the health of the creeks is disturbed in the morphological status by disturbance of river continuum and alternation of morphology features. The highest disturbance was identified for the Uneticky creek, which is in 70% of the study length artificial. The smallest disturbance of the morphological status was found on the Botic creek, with no artificial state in the study section. The Zatissky creek has moderately modified morphology.

Tab 1: Morphological assessment of creeks as a percentage belonging to each quality class (1-natural, 5-fully artificial)

Stream	Type of impact	1.	2.	3.	4.	5.	River continuum impaired
Botic Ck.	CSO	24	50	16	8	0	Yes
Zatissky Ck.	SWD	5	15	40	30	10	Yes
Uneticky Ck..	WWTP	0	20	0	10	70	Yes

The assessment of hydrological conditions shows that the optimal ecological flow identified for benthic community is not kept during most of the time and that during rain events the maximal ecological flow is exceeded. In the cases of the Botic creek and the Zatissky creek, every rain episode causes exceeding of maximal ecological flow and causes washing out of aquatic organisms, especially benthos. The frequently occurring disturbance of aquatic community by unsuitable flow causes deterioration of the ability to recover and causes worsening of the community status. In the case of the Uneticky creek the optimal ecological flow is exceeded due to high outflow from WWTP during extreme rain events, when retention capacity of retention basins on WWTP is exceeded, it means that the disturbance by an unsuitable flow does not occur so often than in the other two creeks. The range of optimal ecological flows (range of flows supporting the highest diversity of organisms and their life stages) is listed in Tab 2. Caletková (in preparation) shows that range of optimal ecological flow may vary with season.

Table 2: Range of ecological flows (m^3/s)

Stream	Type of impact	Ecological Flow		
		Minimal	Maximal	Optimum
Botic Ck.	CSO	0.11 – 0.12	0.80 – 0.83	0.20 – 0.22
Zatissky Ck.	SWD	0.02 - 0.03	0.62 – 0.64	0.04 – 0.05

The modified hydrological and hydraulic conditions in the studied creeks do not support ecological integrity of the creeks and cause disturbance of the aquatic community, due to the loss of ability to support development of diversified biota, the creeks health is affected.

4.1. Assessment of chemical conditions

Physico-chemical quality of water of all studied streams, because of their low flow rates, is very sensitive and easy influenceable. Most of monitored parameters do not exceed EQS (Czech regulation 61/2003) during common conditions. But several parameters (listed in **Error! Reference source not found.**) occasionally exceed limits during extreme conditions (rain events, overflows from combine sewer in the Botic creek). In the stream impacted by combine sewer, organic pollution in combination with higher temperatures in summer months significantly decreases concentrations of DO to levels below EQS. In all studied creeks eutrophication is evident according to nutrients' concentrations represented by total P that are increased even during common conditions (mean value).

Table 3: Basic physico-chemical parameters of water quality exceeding EQS

		EQS		Botic Ck.	Zatitsky Ck.	Uneticky Ck.
				CSO	SWD	WWTP
DO	mg/L	6	mean	8.3	9.1	8.7
			min	3.2	7.6	5.5
BOD	mg/L	6	mean	5.2	3.1	5.6
			max	12.5	6.1	69.0
COD	mg/L	35	mean	26.4	18.2	26.2
			max	80.7	54.8	165.0
Total P	mg/L	0.15	mean	0.2		0.2
			max	0.4		1.3
NH₄⁺-N	mg/L	0.5	mean	0.4	0.3	0.2
			max	1.6	0.9	1.4
NO₃⁻-N	mg/L	7	mean	4.4	3.2	6.3
			max	8.6	8.8	9.6

Specific pollutants as HM and PAH are typical of their binding into solid phase - sediment particularly. Therefore their concentration in water is mostly below EQS. Organic matter in sediment and fine particles in those sections of creeks, where the flow rate enables long term accumulation, play an important role in binding of HM and PAH. For the assessment of concentrations in sediment US EPA standards (TEC - Threshold Effect Concentration) as EQS were chosen because of absence of acceptable standards in the Czech legislation (ES/ER/TM-95/R4, 1997). Concerning heavy metals in sediment, the most significant, according to EQS, is Cu, Zn and Pb. Figure 1 shows mean concentrations of these metals in the profiles of the studied streams, which are not affected and which are directly affected by CSO, SWD and WWTP in the case of the Botic creek, the Zatitsky creek and the Uneticky creek respectively. The highest (potentially risky) concentrations of Cu and Pb are observed below CSO in the creek affected by combine sewer (the Botic creek). In the case of Zn, comparable concentrations exceeding EQS were found out in the Botic creek and the Uneticky creek in the profiles affected by CSO and WWTP respectively. However, Pb concentrations are significant not only in the Botic creek below CSO, but also below SWD in the sediment of the Zatitsky creek, where they exceed EQS as well. On the other hand, the negative impact of WWTP on Pb concentrations in sediment was not observed in the Uneticky creek. Pb concentrations in profiles above WWTP outlet were observed even higher, exceeding EQS. This fact can be explained by long term effect of old loads caused by heavy traffic roads in the surrounding.

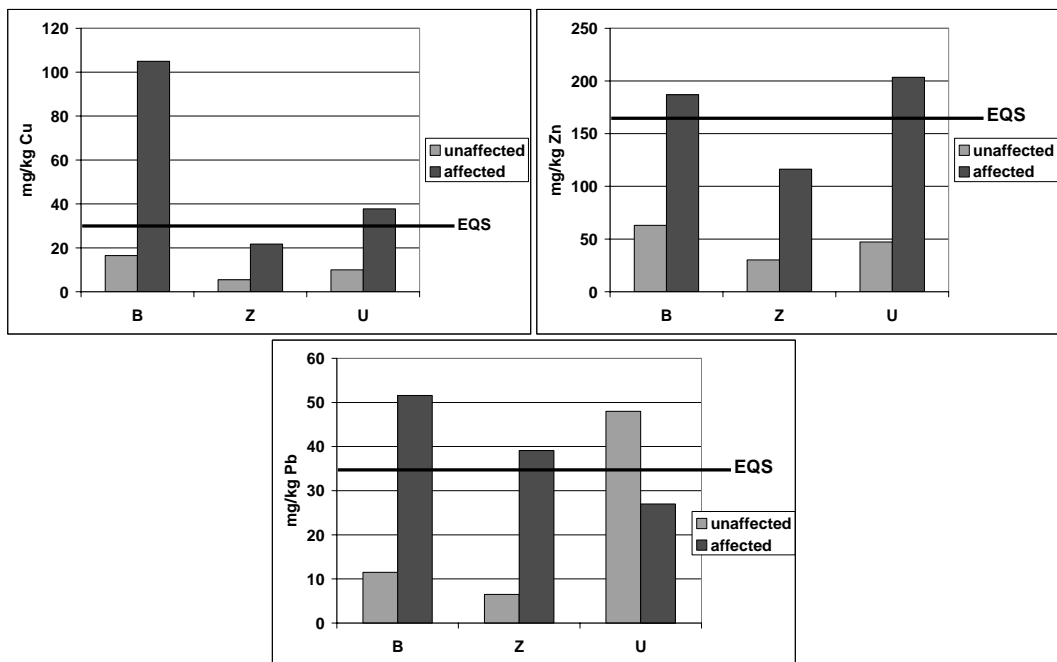


Figure 1: Concentrations of the most significant metals in sediment of the Botick creek, the Zatiscky creek and the Uneticky creek - mean concentrations from profiles above and below an effect (CSO, SWD and WWTP resp.)

Concerning of total PAH in sediment, the impact of WWTP is the strongest from the three compared impacts (Figure 2). In the Uneticky creek total PAH concentrations exceed EQS more than five times. Significant effect is observed also in profiles of the Botick creek affected by CSO. In the Zatiscky creek affected by SWD as well as in profiles in the Botick creek and the Uneticky creek which are not impacted by CSO and WWTP respectively, concentrations of total PAH in the sediment are not risky according to EQS.

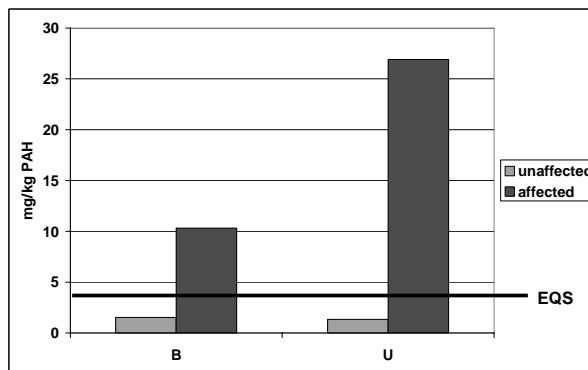


Figure 2: Concentrations of PAH in sediment of the Botick creek and the Uneticky creek - mean concentrations from profiles above and below an effect (CSO and WWTP resp.)

The assessment of chemical conditions of the studied creeks shows that the chemical aspect of the stream health is highly impaired. In the case of profiles directly affected by objects of urban drainage (especially CSO and WWTP) the chemical conditions show that the creeks are not healthy, they are ill. The accumulation of specific pollutants (heavy metals and PAH) in sediment and consequent exceeding of EQS and potential risk for aquatic organism are the chemical aspects significantly deteriorating creeks health. The other aspects deteriorating creeks health are nutrients and during rain events also other basic chemical parameters of water quality. The chemical conditions of studied creeks do not support and maintain diversified community of aquatic organisms.

4.1. Assessment of biological conditions

All the observed creeks are small and as a result, there is no permanent fish population. Therefore the identification of biological conditions was based on assessment of benthic community; in the case of the Uneticky creek also attached algae were assessed.

Table 4: Biological indexes for benthos community

		Botic Ck.	Zatissky Ck.	Uneticky Ck.
ASPT	mean	4.77	4	4.9
	max	5.34	4.9	5.4
BWMP	mean	39.5	29	50
	max	48	54	61
Si	mean	2.5	2.1	1.8
	max	2.84	2.5	2.5
Diversity	mean	1.65	1.49	1.4
	max	1.7	2.1	2.1

The attached algae on the Uneticky creek indicated slightly better biological condition than benthos community. The small differences in value of saprobic index can be explained by smaller requirements of attached algae on habitat quality compare to benthos and consequently presence of more species with higher saprobic value. The assessment of biological status based only on saprobic index, ASPT and BMWP can be quite misleading. In the case of study streams the indexes, saprobic index and ASPT, indicate clean to moderately polluted water in all streams. The BMWP index shows higher differences among the study creeks. Assessment based on diversity is in contradiction with above presented indexes assessment. Diversity shows low to very low values. It means presence of only few species with medium indication value. The differences among assessment of the benthic community by different indexes and approaches show, that it is necessary to assess the health of the benthic community by combination of different indexes to take in account different aspects of the health and to get complete information about the benthos community.

As it was mentioned above, the chemical, hydrological and morphological aspects of creek health do not support diversified biota, it means that the results of the biological monitoring are in agreement with the results obtained by monitoring of the environmental conditions of the studied creeks. The health of the creeks is impaired in all aspects. The creeks lost their ability to support and maintain diversified biota. The biota is composed by a few tolerant species and the recovery potential of the biota is very low, due to the disturbance of the river continuum and modification of the natural habitats.

5. CONCLUSION

In the case of all three creeks, the health was identified as a very poor. The creeks are closer to an illness than to a health. The conditions in none of the studied creeks support and maintain key ecological processes and a community of organisms with a species composition, diversity, and functional organisation as comparable as possible to that of undisturbed habitats within the region. In the term of European Water Framework Directive all creeks do not achieve a good ecological status and due to a partially change morphology of stream channel and disturbance of river continuum they may be identified as heavily modified water bodies. Though the type of anthropogenic impact varies among study creeks, the prime symptoms of poor health or poor status of all study creeks are physical alternation in the watershed causing hydraulic stress and excess of maximal ecological flows (flow allowing maximal diversity of organisms). The other crucial symptom is alternation of the stream

channel and missing suitable habitats for aquatic organisms. The highest variations are among chemical symptoms, but on all study creeks they are during most of the time less significant. The lowest significance of chemical aspects was monitored in the case of the Zatisický creek, where the chemical quality of water and sediment are the highest. In the case of the Botický creek and the Unetický creek the significance of disturbance of the chemical aspect of the river health is higher, especially because of high toxicological risk of specific pollutants as heavy metals and PAH. The alternation of water quality shows irregular fluctuation and usually it causes a short term acute risk for aquatic organisms. The alternation of sediment quality has a long term character and it presents a chronic risk for organisms.

The identification of crucial symptoms and understanding of their role in an aquatic environment is a good background for proposal of measures to improve health (status) of the streams. The rehabilitation of the creeks should therefore start with the application of measures in the watershed which would decrease the amount and rate of water directly entering the streams during rainfall periods from the drainage systems. While end of pipe measures, such as retention basins, decrease the peak discharges entering receiving waters, they do not solve the problem of increased volume of discharge. Other more sustainable approaches include the reduction in area of impervious surfaces, but these measures are only practicable in new development areas. Measures decreasing the amount of impervious surfaces or effective impervious surfaces (directly connected to water body) lead to improvement of hydrological conditions of streams by rehabilitating connection between surface and ground water, thereby reducing the number of non-acceptable discharges and potential for streambed erosion (Walsh et al 2005). The changes in watershed should be then followed by rehabilitation of river channel and banks to provide more suitable habitats for aquatic organisms. The elimination of chemical stress is one of the last tasks of the restoration, because it's low significance. The chemical stress is partly eliminated already by some of the measures mentioned above.

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