The Assessment of Environmental Changes of Selected Water Bodies in the Area of Cracow over the Past Two Decades

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***Abstract*—Six water bodies or their complexes - four in Cracow and two in the Commune of Niepołomice, Southern Poland - were studied focusing the changes they have undergone and the present state from the point of view of their attractiveness to the visitors. The degree of threat to the water bodies was also assessed. The highest grades were given to the ponds of Niepołomice (Zamkowa), due its well management. The lowest grades were attributed the ponds of Płaszów (also the most threatened pond) and Staniątki (probably a temporary situation). The least threatened complex of water bodies is the one in Przylasek Rusiecki. Two of the described water bodies (Dąbie and Staniątki) diminished their area within the last 20 years and the pond of Płaszów diminished earlier.**

Keywords - water bodies; tourism; chemical analysis; sustainable development.

I. INTRODUCTION

Small and medium size water bodies are habitats often subdued to various changes, related both to weather/climate fluctuations as well as direct human influence [1]-[5]. They can be subdued to drainage as much as polluting factors much easier than bigger water bodies. The region of Cracow (in Polish Kraków) is rich in small water bodies [3]-[5]. Many of them are human made [5], [6]. Over their longer or shorter history they went through different changes in their functions and the function of the ecosystems surrounding them. One of the important function, apart from small retention and ecological function is recreational function. This function depends on the natural properties of the water body (size, shape of the shoreline) and the way of management (facilities, maintenance of the area, etc.) [5]-[8]. Another important function is maintaining biodiversity. Water bodies attract animals and plants, including rare species. This creates opportunities for nature-based tourism and increase tourist attractiveness.

There are two main objectives of this paper: (1) to present changes in selected water bodies of Cracow over the last two decades and, if possible, also earlier and (2) to quantify the assessment of the sites from the point of view of sustainable development. The assessed values were tourist attractiveness, understood as the amount of features that could be attractive to visitors from the point of view of leisure and/or sight-seeing (including observations of fauna and flora), as well the degree of threat, understood as quantified expression of various dangers to the water body. It does not necessarily have to be the threat of total disappearance of the water body, but also all the factors making the water body or its surroundings less attractive or diminishing the biodiversity of the area. Section II briefly describes the study area. Section III presents the methods of the studies. Section IV presents the results of long term observations and laboratory analyses. In Section V proposals of changes are discussed in the context of social responsibility.

II. THE STUDY AREA

The water bodies in two communes – the city of Cracow and the commune of Niepołomice (Wieliczka District) were studied. The selection included water bodies of anthropogenic origin. They were the following:

Ponds situated in the city of Cracow:

1. Staw Płaszowski (the Płaszów Pond) - a 9.0 ha borrow pit formed after the exploitation of sand and gravel in 1930s. The area of the pond was decreased. In 1975 and 1965 it had a surface of 9.98 ha and 11.95ha, respectively [6]. The diminishing of the surface was due to making an open market and then covered market.
2. Bagry – a borrow pit of 30.1 ha, also formed in 1930s. Used as bathing resort. Its surface did not change much. The infrastructure has been improving over the years.
3. Staw Dąbski (the Dąbie Pond, 2.1 ha – situated in Craców, east from the centre, formed in 1930s after the exploitation of clay. Originally, there were more ponds,

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but in 1960s they were filled in and only one remained. The original area of 2.6 ha has been diminished due to the building of the Market and Entertainment Centre (*Centrum Handlowo-Rozrywkowe*) "Plaza" [6]. In 2010 the pond was announced Environmentally Useful Area by the City Council of Cracow [9].

4. Przylasek Rusiecki – a complex of 10-11 gravel borrow pits (the number is changeable, because some water bodies can temporarily be joint or separated), of the total area of 82.19 ha, situated in the eastern part of Cracow, quarter Nowa Huta. One of the ponds makes bathing resort.

5. Niepołomice – Zamkowa street - 0.1 ha. The pond undergone restoration works in 2005. The shores were reinforced with wicker and an islet was formed in the middle. However, after a few years the islet submerged. Significant changes in the surroundings were also observed. The pond was originally an anti-fire reservoir and fishing pond. Nowadays fishing is forbidden and the pond has a decorative function, as a part of the local ethnographic museum [5]. Some changes were illustrated in the photographs in Figure 1.

6. Staniątki (the Commune of Niepołomice), Figure 6. – two ponds near the Benedictine Convent in Zagórska street , 0.12 and 0.05 ha. Originally, it was one pond, with a bigger surface. It served as a fishing pond. Later on it was abandoned, but in 1996 the project of management was accepted. In 2005 facilities such as a railing and teeters were built. They were destroyed due to the construction works regarding the neighbouring buildings [5]. Changes were illustrated in the photographs in Figure 1.

Information about locations is contained in [5]-[8].

III. METHODS

The following methods were applied:

A. Field Observations and Area Measurement

Study visits were carried out in every location. The observations of fauna and flora were made. The area of the water bodies was measured based on airborne images received from the Polish Central Geodetic and Cartographic Resource and calculated by the Quantum GIS program.

B. Laboratory Analyses

Laboratory analyses were carried out in October and November 2015, at AGH University of Science and Technology in Cracow, Faculty of Mining Surveying and Environmental Engineering, Laboratory of Department of Environmental Management and Protection, led by Ms. Marta Nowak-Bator, M.Sc., Eng. The instrument for the measurements was photometer PF-12, by AQUA Lab. If possible, the results were compared to the earlier results of analyses.

C. Semi-quantative Assessment

To assess the value (tourist attractiveness) of each water body and the way it is threatened, the Saaty method of hierarchic analysis [10] was applied to give weight to each characteristic (parameter). Namely, the authors had to decide, which feature is more and which less important. The weights were calculated in such a way that the characteristics were compared in pairs and for each pair the decision was made in terms of which characteristic was more important. The following intensities of importance, for each pair, were considered: 1 – equal importance, 3 – moderate importance, 5 – importance, 7 – very strong importance, 9 – extreme importance. Less important characteristics of the less important value of each pair took values: 1/3, 1/5, 1/7, 1/9, respectively. The calculations were made using the computer programme by K. D. Goepel [11]. The values of weights are shown in Tables I and II. For each characteristic, grade 1-4 was given (4 was the highest). All the characteristics contribute to the value of tourist attractiveness (leisure and sightseeing opportunities) or the degree of threat. Finally the following formula was applied:

$$S = \sum_{i=1}^{n} w_i x_i$$

where:
S – final assessment
x_i – assessment of subsequent parameters
w_i – weights of subsequent parameters
.

The parameters (characteristics) were the following:

1) Facilities: benches, sanitary facilities, restaurants, etc.

2) Flora and Fauna – species protected by law, especially included in the EU Directives

3) Sports and leisure – swimming, playgrounds etc.

4) Water – derived from laboratory analyses

5) Landmarks – points important from historical or cultural point of view

6) Landscape – the easthetic impression about landscape

7) Management – is the area clean an tidy?

The degree of threat to the water bodies was also assessed and computed as a sum the following characteristics:

1) Landscape degradation – visual degradation

2) Transport – the proximity to the road

3) Drainage or backfilling – to which extent it occurred

4) Industry – the proximity of industrial plants

5) Vandalism and littering – amount of litter and damage

6) Invasion of alien species – number of alien plant species, based on observation and previous studies [6]

The criteria were based on previous papers [3] and [8], but modified, according to the specifics of this study.

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TABLE I THE WAY OF CALCULATING WEIGHTS REFERRING TO VARIOUS ASPECTS OF TOURIST ATTRACTIVENESS

	F	FF	SL	W	LM	LS	M	Weight
Facilities	1							0.217
Flora and Fauna	1	1						0.132
Sports & Leisure	1	1	1					0.137
Water	1	1	3	1				0.190
Landmarks	1/3	1	1	1	1			0.139
Landscape	1/3	1	1/3	1/3	1	1		0.084
Management	1/3	1	1	1	1/3	1	1	0.100

TABLE II THE WAY OF CALCULATING THREAT REFERRING TO VARIOUS ASPECTS OF THREAT TO WATER BODIES

	L	T	D	I	V	A	Weight
Landscape degradation	1						0.077
Transport	3	1					0.238
Drainage or backfilling	1	1	1				0.185
Industry	3	1	3	1			0.294
Vandalism and littering	3	1/3	1/3	1/3	1		0.103
Alien species	3	1/3	1/3	1/3	1	1	0. 103

IV. RESULTS

The results of laboratory analyses are shown in tables III and IV. The values were compared to the Enactment of the Minister of Environment [12]. The Figures in bold mean the values exceeding the maximum accepted values for the first and second class of the water quality in the mentioned Enactment. For the conductivity this value is given in Enclosure II (values for lakes and reservoirs) and both for first and second class must not exceed μS/cm. For other values, which are not included in the Enclosure II, values in Enclosure I (for rivers and streams) were taken. In most cases there was no visible trend in time referring to the parameters. There were no bigger changes in pH, which ranged from 7.0 (Niepołomice) to 8.9 (Przylasek Rusiecki). Conductivity was the parameter which was exceeded in most of the locations. The highest value was in Dąbie in 2008. In 2015 the value was lower, nevertheless remained high. In all the locations conductivity values of 2015 were lower than in 2008. Chemical analyses showed that the values of nitrates were high only in Niepołomice and the highest values of phosphates were in Dąbie (in 2003 and 2008). The values of chlorides were low, except of Płaszów.

The analyses of the airborne images and personal observations show that over the last 20 years the area of the Dąbie Pond and the Staniątki Pond decreased in 1990s and the area of the Płaszów pond decreased in 1960s and 1970s.

Observation of animals focused on birds, because they have the greatest significance for amateur nature observations (bird watchers). The list of animals observed in the ponds is given in table V. Species included in the Bird Directive and Habitat Directive (Enclosure 1) are marked with letters P and D, respectively. The bird included into the Bird Directive was the common tern *Sterna hirundo*, seen on the Bagry pond.

The management of the area changed most in Dabie, Niepołomice and Staniątki (still undergoing changes).

Table VI shows the values and grades attributed to each site, according to the method described in Section III. The highest grade can be given to the pond of Niepołomice, especially due to very good management. The second grade is given to Bagry. The Pond of Dąbie received 3rd grade. The maximum assessment of the flora and fauna is not due to birds, but due to the presence of the Amur bitterling *Rhodeus sericeus* (Pallas) [13]. The lowest values were received by the ponds of Płaszów and Staniątki. In the latter case, the area was under construction.

The most threatened pond is the pond of Płaszów. The biggest problem there is littering and (to certain extent) vandalism. The area is being built up and the pond is not the object of interest of the public, so it is subdued to degradation. On the second place is the pond of Staniątki, nevertheless the present state seems to be temporary. The least endangered is the complex of ponds in Przylasek Rusiecki.

V. CONCLUSIONS

The study showed that the water bodies of Dąbie, Staniątki and Staniątki were undergoing big changes, especially in the state of management. Unfortunately one can fear that if the area is “too well managed” (reed regularly cut) the habitat for the birds nesting in the reed (e.g., moorhen) will be destroyed.

The water bodies of Dąbie and Staniątki diminished their area within the last 20 years and the pond of Płaszów diminished in 1960s and 1970s. Other ponds did not change much in surface, but there were changes in the management of the surrounding area.

In the commune of Niepołomice (ponds of Niepołomice and Staniątki), the biggest improvement in the aesthetics of the area was carried out in 2005. Some of these changes were not long lasting, though.

The highest differences in the assessment of water bodies were observed in the facilities provided and the management. The smallest differences were referring to landscape.

The water bodies can contribute to sustainable tourism as well as economic development of the area. Nevertheless, in some cases (Płaszów, Staniątki) their potential is not fully used. The improvement in the management is highly recommended. This should include cleaning as well as putting information tables about the flora and fauna.

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TABLE III. PHYSICAL AND CHEMICAL PARAMETERS OF WATERS IN THE WATER BODIES NEAR IN CRACOW AND VICINITY

Location	pH								Conductivity [µS/cm]						
	1996-1997	1998	1999	2001-2004	2005	2008	2015[6]	2015[7]	1996	1999	2002-2004	2005	2008	2015[6]	2015[7]
Płaszów	Not measured			8.1[1]		8.4	7.8	n.m.	n.m.		**1600**[1]	n.m.	**1417**	**1166**	n.m.
Bagry - west	Not measured			8.2[2]	8.6	7.8	8.4	n.m.	Not measured				**2250**	585.5	n.m.
Bagry - east	Not measured			n.m.	8.5	7.7	8.0	n.m.	Not measured			**717**	**1426**	**622.6**	n.m.
Dąbie	Not measured			7.6[3]		7.7	8.3	n.m.	Not measured		**1291**[3]	n.m.	**2336**	**1094.5**	n.m.
Przylasek - road	Not measured						7.7	7.6	n.m.					409.5	373.5
Przylasek - beach	8.7[3]	n.m.	8.2	7.8[4]	8.3	**8.9**	7.9	7.6	n.m.	**610**	422[4]	574	**958**	402.5	429.5
Niepołomice	7.0[5]	7.0	7.0	7.3[4]	8.1	n.m.	7.9	n.m.	**990**[5]	**680**	591[4]	**740**	n.m.	**733.5**	n.m.
Staniątki	7.5[5]	7.1	7.5	n.m.	7.3	n.m.	7.7	n.m.	**800**	133	**762**[4]	n.m.		544.5	n.m.

[1)]Measurements made on 25/07/2001; [2)]Measurements made on 1/05/2004; [3)]Mean of two measurements taken on 24/09/2003 by Szczęsny et al. [11], [3)]Measurements made on 19/08/1997, [4)]Measurements made in 2002, [5)] Measurements made in 1996, [6)]Mean of two measurements on 5/10/2015; [7)] Mean of two measurements on 21/10/2015

TABLE IV. PHYSICAL AND CHEMICAL PARAMETERS OF WATERS IN THE WATER BODIES IN CRACOW AND VICINITY

Location	NO_3^-		PO_4^{3-} [mg/dm^3]				Cl^-				
	2015[6]	2015[7]	2003	15/10/2008	2015[6]	2015[7]	1996	1997	1999	2015[6]	2015[7]
Płaszów Pond	0.7	n.m.	n.m.	**0.349**	0.20	n.m.	Not measured			**241.4**	n.m.
Bagry - Łanowa	0.0	n.m.	n.m.	n.m.	0.215	n.m.	Not measured			56.8	n.m.
Bagry - Bagrowa	0.0	n.m.	n.m.	**1.095**	0.155	n.m.	Not measured			56.8	n.m.
Dąbie	0.0	n.m.	**1.2665**	**1.095**	**0.38**	n.m.	Not measured			110.05	n.m.
Przylasek - road	0.25	<1.0	n.m.	n.m.	0.31	0.20	Not measured			56.8	60.35
Przylasek - beach	0.1	<1.0	n.m.	n.m.	**0.185**	**0.85**	Not measured			56.8	56.8
Niepołomice	**7.35**	n.m.	n.m.	n.m.	0.25	n.m.	82.4	50.00	54	127.8	n.m.
Staniątki	1.25	n.m.	n.m.	n.m.	<0.2	n.m.	40.7	n.m.	42	35.5	n.m.

TABLE V. BIRDS OBSERVED AT THE WATER BODIES IN CRACOW AND VICINITY

Location	Płaszów	Bagry	Dąbie	Przylasek	Niepołomice	Staniątki
Mute Swan *Cygnus olor* (Gmell.) [P]	+++	+++	+++	+		
Mallard *Anas platyrhynchos* L.	**+++**	+++	+++	+++	+++	++
Tufted Duck *Aythya fuligula* (L.)				+ (April 2003)		
Coot *Fulica atra* (L.)	**+++**	+++	++			
Moorhen *Gallinula chloropus* (L.) [P]						+ (April 1996)
Great Crested Grebe *Podiceps cristatus* [P]	**++**	++	+ (April 2007)	++		
Common Gull *Larus canus* L. [P]				++		
European Herring Gull *Larus argentatus* L. [P]				++		
Black Headed Gull *Larus ridibundus* L. [P]	**+++**	+++	+++	++		
Common Tern *Sterna hirundo* L. [D]		++				
Great Cormorant *Phalacrocorax carbo* (L.) [P]		++		+++		
Barn Swallow *Hirundo rustica* L. [P]		++		++		
House Martin *Delichon urbica* (L.) [P]					++	

[P] – species protected by the Polish Law, [D] – species included in the Enclosure 1 of Bird Directive
+++observations of October 2016
++ only observations before October 2016 (more than once)
+ only one observation

TABLE VI. ASSESSMENT OF WATER BODIES IN CRACOW AND VICINITY

Location	Facilities		Flora and Fauna		Sports and leisure		Water		Landmarks		Landscape		Management		Total Assessment and Rank	
	A	B 0.217	A	B 0.132	A	B 0.137	A	B 0.190	A	B 0.139	A	B 0.084	A	B 0.100	Without weight	With weight
Płaszów	3	0.651	3	0.396	2	0.274	2	0.380	2	0.278	2	0.168	1	0.100	15 (6)	2.247 (5)
Bagry	4	0.868	3	0.396	3	0.411	3	0.570	2	0.278	2	0.168	3	0.300	20 (2)	2.991 (2)
Dąbie	4	0.868	4	0.528	2	0.28	2	0.380	2	0.278	2	0.168	4	0.400	20 (2)	2.902 (3)
Przylasek	2	0.434	3	0.396	3	0.411	3	0.570	2	0.278	3	0.252	2	0.200	18 (4)	2.541 (4)
Niepołomice	4	0.868	2	0.264	2	0.274	2	0.380	4	0.556	3	0.252	4	0.400	21 (1)	2.994 (1)
Staniątki	1	0.217	2	0.264	1	0.137	3	0.570	4	0.556	2	0.168	3	0.300	16 (5)	2.212 (6)

A – the assessment in 1-4 scale, B – with weight; ranks given below

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TABLE VII. ASSESSMENT OF THE THREAT TO THE WATER BODIES IN CRACOW AND VICINITY (explanations like in table VI)

Location	Landscape degradation		Transport		Drainage or backfilling		Industry		Vandalism and littering		Invasion of alien species		Total Assessment and Rank	
	A	B 0.077	A	B 0.238	A	B 0.185	A	B 0.294	A	B 0.103	A	B 0.103	Without weight	With weight
Płaszów	2	0.154	3	0.714	1	0.185	3	0.882	4	0.412	3	0.309	16 (1)	2.656 (1)
Bagry	3	0.231	2	0.476	1	0.185	3	0.882	2	0.206	2	0.206	13 (4)	2.186 (5)
Dąbie	2	0.154	3	0.714	2	0.370	3	0.882	1	0.103	2	0.206	13 (4)	2.429 (3)
Przylasek	2	0.154	2	0.476	1	0.185	2	0.588	2	0.206	2	0.206	11 (6)	1.815 (6)
Niepołomice	3	0.231	3	0.714	3	0.555	1	0.294	2	0.206	2	0.206	14 (3)	2.206 (4)
Staniątki	2	0.154	3	0.714	4	0.740	2	0.588	2	0.206	2	0.206	15 (2)	2.608 (2)

Figure. 1. The pond in Niepołomice. Left: April 1996 – view from the eastern side (Zamkowa Street); centre: July 2005 – view from the western side (3Maja Street), the pond after the renovation works – the islet is visible; right: October 2015 – the islet isappeared, the note saying that fishing is forbidden was put. Previously the pond was used for fishing, photos: A. Wagner.

Figure 2. The fragment of the Staniątki Pond. Left: 2nd May 1996; centre: 1st August 2005 – the railing was built; right: 10th November 2015 – the white building on the left is the newly built nursing home, the railing was removed, photos: A. Wagner.

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