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ON THE CONTRIBUTION OF TOURISM TO WATER POLUTION IN THE AREA OF TATRA NATIONAL PARK

The vast numbers of tourists who visit Tatra National Park raise serious sanitary problems. In this study, physico-chemical and bacteriological analyses of water from creeks and torrents are presented. Despite a considerable degradation of water quality at sites of sewage discharges, the water courses are capable of recovering within a short time due to a high degree of dilution rather than to biological purification. Bacteriological analysis showed disturbances in the quantitative composition of natural microflora. Conditional pathogens were found along the entire lengths of the creeks investigated. Most of them are resistant to antibiotics.

1. INTRODUCTION

The Tatra National Park covers on area of 215 km^2 and is situated in the highest mountain ridge of Poland. The Tatra is built of basalt and granite rocks in eastern part, and of sedimentary calcareous rocks in its western portion. The climate of this region resembles that of the Alps. Torrent water enters three major streams: Białka in the eastern part as well as Kościeliski and Chochołowski in the western part of the Tatra. The valleys through which the creeks flow are very attractive. It is estimated that the total number of visitors to the Tatra region is between 2.5 and 3.5 million. Such a number of people raise serious sanitary problems. High-purity creeks and torrents of this area are polluted by sewage from the nearby shelters, hotels, farms and restaurants, all of which are overcrowded. Thus, the beauty spot shelter "Morskie Oko", which has been designed to receive no more than 4000 visitors a day, has a daily number of tourists approaching 22 000. The majority of the shelters and farms situated in the Tatra National Park are examples of timber structures in old local style, but they are not equipped with sewage treatment fa-

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cilities. The continuing degradation of the Tatra environment due to tourism has become a problem of serious concern to the representatives of Nature Conservation. The objective of the study was to determine the contribution of the ever increasing tourist trade to the water quality in creeks and torrents.

2. METHODS

The data sets presented in this paper were collected in 1988 and 1989. Samples were taken along the following creeks: Białka, Kościeliski and Chochołowski. Samples for physico-chemical analysis were taken every two hours in two-day intervals. They were analyzed as daily samples. Microbiological examinations as well as standard bacteriological analysis were carried out according to Polish standard methods. To isolate bacteria from the *Enterobacteriaceae* family, samples of the volume of 2 dm^3 were passed through a membrane filter of *Coli* 5type. The filter was then placed in a Muller–Kauffman medium or in brilliant green lactose bile broth. After 24 hours of incubation, the material was isolated on Mac Conkey medium on SS agar and Sołtys medium [1]. Identification was made taking into account the biochemical and serological features of the isolated strains according to EDWARDS and EWING [5]. Some of the strains were selected to determine their resistance to antibiotics which are widely used in medicine. The resistance determinations involved the standard methods and the Muller–Hinton medium.

3. WATER QUALITY

The Białka creek originates in the Morskie Oko Lake and carries waters of very low salinity, very low hardness and very low concentration of organics. Within the first kilometer from the source, the creek receives a pollution load discharged by an overcrowded shelter. The average daily load of sewage entering the creek amounts to 0.75 m^3/h and shows enormous irregularity of flow. The sewage discharged to the stream undergoes a considerable dilution within the distance of hundred meters. This phenomenon is a result of turbulence. Physico-chemical analysis of the water samples collected at the distance of 1.5 km showed no pollutants. At a distance of 2.5 km from the source, the creek receives a second pollution load from nearby restaurant with a large parking space, which considerably deteriorates the water quality. Again, after several dozen meters, the water samples taken for analysis showed no increased concentration of pollutants under study.

In its lower part, the Białka creek becomes a river. At that sampling site, the river receives the sewage arising from numerous buildings inhabited by approximately 500 residents and a considerable number of tourists. The aforementioned method (table 1) proved that the composition of water varied.

The headwaters of the Kościeliski creek are slightly more mineralized than those of the Białka. Their composition is evidently influenced by the dolomitic limestone subsoil. Within the first 2 kilometers, the creek flows across boggy meadows and a forest and the water is enriched with humic substances. At a distance of 2 km from the source, it is polluted by the sewage discharged from a nearby shelter. Within the distance of several dozen meters, the

Table 1

Physico-chemical composition of the Białka creek water

Place and distance (km)		Conductivity (μS/cm)	COD_p[1] (g O_2/m^3)	BOD_5 (g O_2/m^3)	$N_{NH_4}^+$ (g/m^3)	TOC (g/m^3)	CL^- (g/m^3)	TH[2] (deg)
Morskie Oko	0	17	1.1	1.0	0.0	0.8	2.6	1.1
	0.5	573	74.5	178	19.5	39.3	71.4	2.8
	0.6	29	4.6	6.8	1.5	1.0	2.9	0.8
Żabie Oczko	1.5	20	1.0	1.6	0.0	1.3	3.0	0.9
Włosiennica	2.4	20	1.3	1.0	0.0	–	2.1	0.9
	2.5	210	51.9	78.5	23.3	10.8	30.8	2.3
	2.6	31	1.3	1.1	0.0	1.4	2.0	0.8
Roztoka	6.0	56	1.1	1.0	0.0	1.1	3.0	2.4
Łysa Polana	10.1	88	1.0	1.8	0.0	1.7	1.8	4.5
	10.2	167	103	234	6.5	42.3	9.7	5.6
	10.3	143	2.8	4.2	1.2	1.7	3.7	5.5

[1] permanganate COD, [2] (deg)·17.1=g $CaCO_3/m^3$.

Table 2

Physico-chemical composition of the Kościeliski creek water

Place and distance (km)		Conductivity (μS/cm)	COD_p (g O_2/m^3)	BOD_5 (g O_2/m^3)	$N_{NH_4}^+$ (g/m^3)	TOC (g/m^3)	Cl^- (g/m^3)	TH (deg)
Shelter	1.9	55	1.3	0.9	0.0	0.8	2.3	2.6
	2.0	736	221	442	70.5	70.6	231	39
	2.1	75	2.4	5.2	3.0	4.2	4.1	2.7
Hala Pisana	5.0	90	0.9	1.0	0.0	0.8	2.5	4.9
	8.0	108	1.6	1.1	0.0	1.6	2.6	5.0
Kiry	9.9	169	1.4	1.5	0.0	1.4	3.0	5.3
	10.0	525	146	360	36	115	70.2	10.1
	10.1	115	4.1	6.9	0.3	4.5	2.2	6.2

high pollution load is considerably diluted. Thus, physico-chemical analysis of the water samples collected at the distance of more than two hundred meters or so shows no increase in concentration of the pollutants in question. Owing to the high degree of dilution in the immediate vicinity of the sewage outfall, neither oxygen sag nor characteristic slime

growth is observed. In the lower part of the valley, the Kościeliski creek carries clean water until it reaches the farm and the tourist buildings of the village of Kiry. The sewage discharged from the number of hotels and farms noticeably deteriorates the quality of the creek water. There is a slight decrease in the available amount of oxygen. On the creek bed an overgrowth of characteristic brownish slimes is observed (table 2).

The Chochołowski creek, which carries unpolluted headwaters, receives a secondary effluent at a distance of 2 km from the source. As the biological treatment plant is overloaded, the treatment efficiency ranges from 50 to 60%. Sewage is discharged to a small stream, a tributary of the Chochołowski creek. At a distance of about 80 m from the point of sewage discharge, chemical pollution manifested itself as ammonium content and higher conductivity. In its further course, the Chochołowski creek carries chemically pure water at a distance of 11 kilometers (table 3) from its source.

Table 3

Physico-chemical composition of the Chochołowski creek water

Place and distance (km)		Conductivity (μS/cm)	COD_p (g O_2/m^3)	BOD_5 (g O_2/m^3)	$N_{NH_4}^+$ (g/m^3)	TOC (g/m^3)	Cl^- (g/m^3)	TH (deg)
Shelter	2.0	3	1.4	1.1	0.0	–	2.6	2.5
		348	51.3	104	32.5	43.6	37.3	5.4
	2.7	51	1.8	1.7	1.2	–	3.3	2.4
	7.0	42	0.9	1.2	0.0	–	2.2	2.4
Siwa Polana	11.0	130	1.6	1.3	0.0	1.3	1.6	4.4

4. BACTERIOLOGICAL STATE OF STREAM WATER

Only the headwater of each creek under study displays bacterial counts typical of unpolluted streams (table 4). Seasonal variations in the number of bacteria (especially psychrophilic organisms) depend on the rate of surface runoff. Bacteriological analysis of the Białka water samples has shown that the counts of psychrophilic and mesophilic bacteria, as well as *Coli* titre, increase rapidly as a result of sewage discharge. At a distance from the sewage outfall longer than 2.5 km, total bacterial number decreases approaching the values measured in an unpolluted water. Although the MPN of coliforms continues to decrease, it is still higher than that of the headwater. From the point of the first sewage discharge, and further along the whole length of the Białka creek, there is a persistent occurrence of some species belonging to the *Enterobacteriaceae* family.

The headwater of the Kościeliski creek exhibits a high number of psychrophilic bacteria, which should be attributed to its passage through a swampy area. The pollution load received by the creek at a distance of 2 km from the source accounts for the rapid increase

in the number of coliforms. In the middle part of the stream, the counts of psychrophilic and mesophilic bacteria were found to decrease and reach the values lower than those of the headwater. The MPN of coliforms remained at an enhanced level. If we follow the creek downstream, at the point where the Kościeliski creek receives sewage from the village of Kiry, bacteriological contamination again becomes a serious problem. The Kościeliski creek, like the Białka creek, is characterized by the presence of bacteria from the *Enterobacteriaceae* family which appear at the point of the first sewage discharge and persist along the whole length of the watercourse. Similar variations in the counts of the bacteria under study are observed in the Chochołowski creek, despite the fact that the pollution load entering the stream is the effluent from the biological treatment plant.

Table 4

Bacteriological state of the water of the Tatra creeks

Place and distance (km)		Number of bacteria per cm^3				MPN coliform per 100 cm^3
		Psychrophilic		Mesophilic		
		Mean	Max	Mean	Max	
Białka creek	0	177	330	27	76	7
	0.6	3431	155 000	3982	40 000	31857
	1.5	533	1200	518	1050	8160
	2.4	509	910	30	81	168
	2.6	1521	16 000	196	1300	2763
	6.0	252	450	37	108	517
	7.2	276	550	7	10	120
	10.1	267	432	22	38	36
	10.3	1276	4100	712	3300	8079
Kościeliski creek	1.9	9607	22 321	65	173	11
	2.1	595 762	2 440 000	95 380	253 000	11 025 000
	5.0	720	1280	34	36	122
	9.9	24 933	51 040	3399	5296	816 000
	10.0	227 666	340 000	75 500	240 000	982 557
Chochołowski creek	2.0	902	1096	125	243	361
	2.7	21 252	50 000	9463	49 200	288 060
	7.0	710	1910	796	1510	13 200
	11.0	2120	8700	697	2000	1148

It is worth noting that in each of the three creeks investigated, the number of bacteria, as well as the MPN of coliforms, were found to increase in the immediate vicinity of the building, even if there was no sewage discharge and the building itself was inhabited only seasonally.

5. DISCUSSION

The main watercourses in the Tatra National Park are exposed to intensive touristic trade. Both physico-chemical and bacteriological analyses have shown that only the headwaters are pure. Discharge of highly polluted sewage accounts for a considerable deterioration of water quality. Owing to a high degree of dilution, turbulence and oxygenation, the watercourse returns to good condition at the distance of 200–500 m from the point of discharge. Physico-chemical analysis shows that concentration of the pollutants investigated does not increase.

Table 5

Bacteria strains isolated from the Tatra creeks

Place and distance		Bacteria genus from *Enterobacteriaceae* family
Białka creek	0.6	*Morganella, Proteus, Escherichia, Klebsiella, Shigella*
	2.6	*Proteus, Escherichia, Shigella*
	6.0	*Escherichia, Klebsiella, Pseudomonas**
	7.2	*Proteus, Salmonella, Escherichia*
	10.3	*Proteus, Klebsiella, Escherichia*
Kościeliski creek	2.1	*Escherichia, Proteus*
	5.0	*Escherichia, Proteus*
	10.0	*Escherichia, Proteus, Morganella, Salmonella*
Chochołowski creek	2.7	*Proteus, Shigella, Escherichia, Klebsiella*

**Pseudomonadaceae* family

Bacteriological contamination follows a different pattern. The headwater of the creeks can be identified as katharobic. Successive sewage discharge brings about a rapid increase both in the number of psychrophilic and mesophilic bacteria and in the counts of coliforms.

Despite of low water temperature and high degree of dilution, bacterial contamination persists over a longer distance than physico-chemical pollution. Higher values of MPN and presence of bacterial species belonging to the *Enterobacteriaceae* family are found along the entire length of the creeks (table 5). The degree of bacteriological contamination depends upon the distance of the touring routes and facilities from a recipient stream.

The sanitary condition of the creek water should be considered from the two major view points. The creeks are the part of an area of special preservation. The pollution load

entering the streams disturbs the natural ecological equilibrium of the environment and is likely to cause irreversible changes in the entire biotope. The creek water is also used for household and hygienic needs, therefore its pollution is a serious and potential epidemiological hazard. Bacteriological analysis has shown that bacteria belonging to the *Enterobacteriaceae* family occur along the entire lengths of the creeks, from the first point of sewage discharge. The following pathogens or conditional pathogens are present in the water: *Salmonella, Shigella, Proteus, Klebsiella* and *Morganella.* The epidemiological hazard is substantially increased by the noticeable resistance of the isolated bacterial strains to antibiotics which are widely used in therapy (table 6). This fact is of ecological importance, because the immunity features may spread via interspecies and intergenus transfer even in aquatic environment, thus contributing to potential changes in the physiological features of the microbiocenosis [2], [3], [4], [7]. Taking this into account, we should be aware of the fact that even minor infection caused by the said bacteria can be very difficult to treat. Only sulfonamides showed the wide antibiotic properties.

Table 6

Resistance to antibiotics in bacterial strains from the Tatra creeks (%)

Bacteria genus	Antibiotic													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Proteus	43	10	90	100	71	62	10	33	81	76	100	86	100	9
Shigella	33	33	100	100	–	–	0	–	33	100	100	100	100	–
Morganella	25	0	50	100	100	75	25	0	50	100	100	100	100	0
Salmonella	0	0	0	100	100	0	0	100	0	100	100	100	0	0
Escherichia	17	0	33	100	83	17	0	33	17	50	100	67	83	0
Klebsiella	100	100	100	100	100	0	0	100	0	100	100	100	100	0

A – chloramphenicol, B – neomycin, C – nitrofurantoin, D – erythromycin, E – rifampicin, F – doxycycllin, G – gentamycin, H – carbenicyllin, I – oxytetracyclin, J – ampicylyn, K – cloxacillin, L – trimetoprim, M – sulfometaksazol, N – biseptol

The data sets obtained in this study show that estimates of water quality established in terms of physico-chemical parameters are inconsistent with those achieved by bacteriological analysis. Thus, despite the noticeably high level of clarity, the main creeks in the Tatra National Park may create serious epidemiological hazards.

Intensive tourist traffic, which owes its origin to the human desire of getting in touch with the nature, disturbs the ecological equilibrium in the natural environment.

REFERENCES

[1] BURBIANKA M., PLISZKA A., *Mikrobiologia żywności*, PZWL, 1977.

[2] COOK M., *Antibiotic resistance among coliform and fecal coliform bacteria isolated from sewage, sea water and marine shellfish,* Antimicrobial Agents and Chemotherapy J., 9 (1976), pp. 878–884.

[3] COOK M., *Antibiotic resistance among coliform and fecal coliform bacteria isolated from freshwater mussel Hydridella menziestii,* Antimicrobial Agents and Chemotherapy J., 9 (1976), pp. 885–888.
[4] COOK M., *Antibiotic resistance among coliform and fecal coliform bacteria from natural water and effluents,* New Zealand Journal of Marine and Freshwater Research, 3 (1976), pp. 391–397.
[5] EDWARDS P. R., EWING W. H., *Identification of Enterobacteriaceae*, Burges Minneapolis, Minnesota 1972.
[6] HUGHES C., *Nalidixide acid as a selective agent for isolation of Enterobacteriaceae from river water*, J. Hyg. Camb., 77 (1976), pp. 23–30.
[7] RICHMOND M. N., *Some environmental consequences of use of antibiotics: "What goes up must come down"*, J. Applied Bact., 35 (1972), pp. 155–176.

WPŁYW RUCHU TURYSTYCZNEGO NA ZANIECZYSZCZENIE WÓD TATRZAŃSKIEGO PARKU NARODOWEGO

Na podstawie fizykochemicznych i bakteriologicznych badań wód potoków tatrzańskich stwierdzono znaczne ich zanieczyszczenie poniżej odprowadzania ścieków ze schronisk. Poprawa jakości wód w dalszym biegu strumieni była spowodowana większym rozcieńczeniem zanieczyszczeń, nie zaś oczyszczeniem biologicznym. Na podstawie analiz bakteriologicznych wykazano zachwianie naturalnego składu mikroflory oraz stwierdzono obecność patogenów i względnych patogenów wzdłuż całej długości potoków, począwszy od miejsca odprowadzenia ścieków. Większość z nich wykazywała dużą odporność na antybiotyki.

ВЛИЯНИЕ ТУРИСТИЧЕСКОГО ДВИЖЕНИЯ НА ЗАГРЯЗНЕНИЕ ВОД ТАТРИНСКОГО ЗАПОВЕДНИКА

На основе физико-химических и бактериологических исследований вод татринских прудов было установлено их значительное загрязнение ниже отвода сточных вод из туристских баз. Улучшение качества вод в дальнейшем течении прудов было вызвано большим разбавлением загрязнений, а не биологической очисткой. На основе бактериологических анализов было обнаружено нарушение натурального состава микрофлоры и установлено наличие патогенов и относительных патогенов вдоль всей длины прудов, начиная с места отвода сточных вод. Большинство из них обнаруживало значительную устойчивость к антибиотикам.