Geotourism and water quality of river Hornád (E. Slovakia)

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The paper deals with some issues concerning geotourism and the environmental problems of the Hornád river valley (E. Slovakia). The data given below were obtained within the „RECENT", „Caring after my river Hornád" projects as well as from the Watershed management company (PBaH) databank. The paper gives some basic data on the river valley, and of the main contaminating agents. Then their significance from the point of view of environmental quality of the studied region and its impact on geotourism is analysed. The impact of water quality on trekking, water sports and fishing are considered, together with the aesthetic problems posed by waste dumping.

Key words*: Geotourism, environmental quality, quality of water, contaminating agents.*

Introduction

From geotourism point of view, the Hornád river valley contains a number of thrilling sites. Thus the Slovenský Raj area with a canyon grafted by the river and a number of steep, romantic canyons eroded into limestone by tributary creeks (Kyseľ, Sokoľ etc.), then the area of the Ružín dam and the surrounding area (e.g. Ružinek valley with its caves, Sivec, etc.) form a great attractor to tourists.

The river as well as the dam enables water sports to be performed. If we consider that swimming, sailing, paddling, kayaking and fishing need surface water of quality class 1-3 (STN 75 7221), it is appropriate, that we investigate this aspect of the river.

In geotourism, the state of the environment is always very important. The quality of environment depends on the synergy of geographical, geological and anthropic factors. Apart from geological and industrial reasons, one of the reasons for a relatively low quality of environment in the Hornád river valley is the low environmental awareness of the local inhabitants. Their way of managing communal and other waste (like scrape-metals, plastics, building material, chemicals, etc,) consists often of discarding them on illegal dumping sites that are frequently adjacent to the river. The situation is difficult also due to a lack of a reliable monitoring system that would help keeping track of the mobility of contaminants. A number of illegal dumping sites were mapped along the river. Fig. 1 shows their localisation. Fig. 2 shows a typical view of a part of an illegal dumping site near the river.

The toxicity of water and water sediments are described in Bencko, Cikrt, Lener, (1995), Stevens, Hall, Farmer, DiPasquale, Chernoff, Durham, (1977); Taylor (1966) and others. The proper methods of waste dumping are given in World Bank/WHO/UNEP (1989).

The studied area and its characterisation

River Hornád starts in Slovakia and its lower part flows through Hungary. Hornád is a tributary of Tisa. The Hornád valley belongs to the Fatra-Tatra district of the Inner Western Carpathian subprovince. It flows through the Košice basin (which is a part of the East Slovakian basin) (Mazúr, Lukniš, 1978). The Hornád valley is asymmetrical; its bed is dipping towards south. The river reaches out from the Hornád valley between Smižany and Hrabušice. The tributary network is asymmetrical. The basins of the tributaries are simple, with the exception of the Margecanka stream in the eastern part of the basin. Along the Hornád, the profile of the hilly terrain is moderately undulated and smoothly shaped. In its middle part, which is formed by flysch sandstones, the morphology is more articulated. The Košice basin has a relatively flat, moderately undulated mountainous shape. Its edges are geomorphologically monotonous but there are extensive sedimentary fans of the tributaries that come mainly from Slanské vrchy, Čierna Hora and Slovenské Rudohorie mountains. The tributaries of river Hornád have a low yield. The most significant tributaries are Torysa and Veľká Svinka. There is an artificial water reservoir in the Ružín area, with 2 dams.

The temperature of the Hornád river water is influenced by the climatic properties of the area, which is warm, moderately dry to dry, with average yearly temperature around 9^{o}C. The average yearly rainfall is around 650 mm.

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(Review and revised version supplied 27. 10. 2009)

River sediments

The river sediments have good absorption properties, so they tend to cumulate heavy metals and also other substances from surface water. The chemical composition of the sediments usually reflects the chemistry of the bedrock, soil chemistry and the contaminants coming from anthropic activities.

The geochemistry of river sediments reflects significant anomalies due to anthropic activity. Thus e.g. in the area of Myslava and Barca anomalies of Pb, Zn, Ag, and Cu were detected; at the sedimentation basin of the Košice Heat production plant (the cooling water is taken from Hornád) anomalies of As, Se, Li and Mo were detected; in the area of the confluence of Hornád and Torysa anomalies of Ag, Zn, Cu, Cd, Sn, Bi were found (Volko, 1995). The water quality of Hornád is affected also by the waste deposits along the river (Fig. 2).

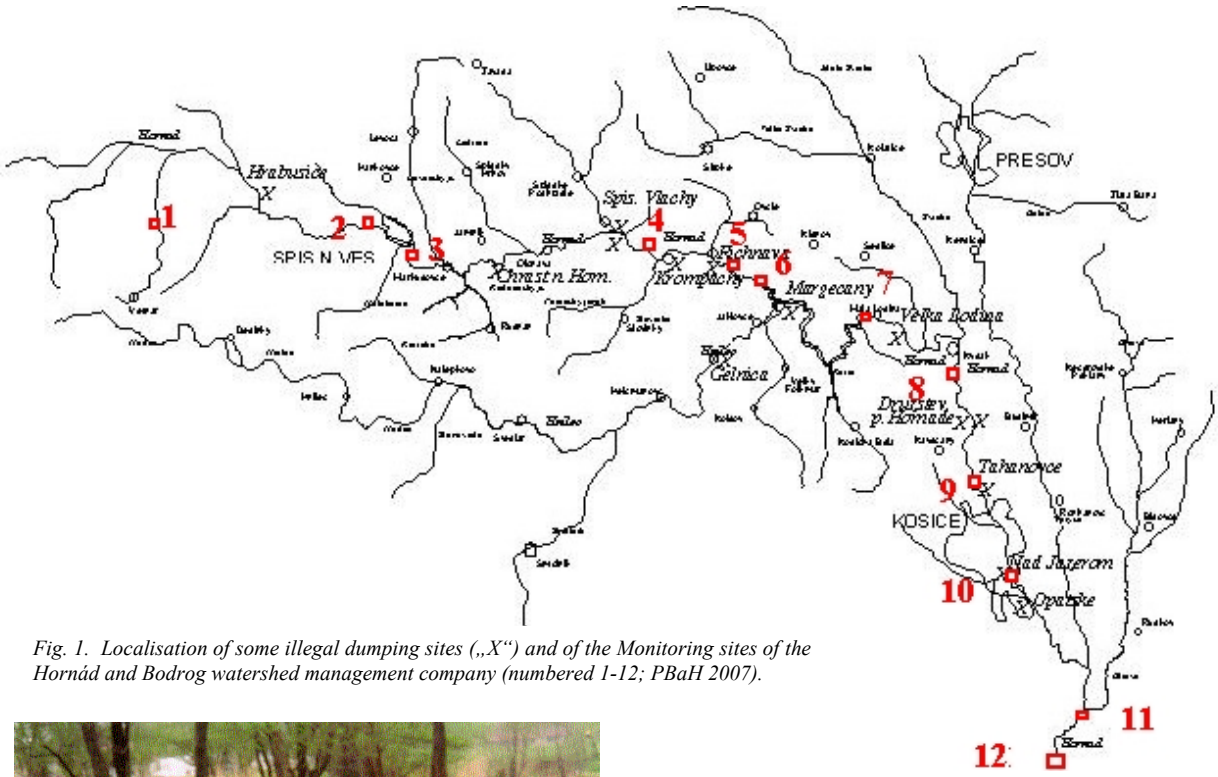

Fig. 1. Localisation of some illegal dumping sites („X") and of the Monitoring sites of the Hornád and Bodrog watershed management company (numbered 1-12; PBaH 2007).

The quality of surface water is assessed according to the Slovak Technical Standard STN 75 7221. Grade 1 is the best quality; grade 5 is the worst one. Grade 4 and 5 cannot be well used even for irrigation. Only water of grade 1 and 2 quality can be processed for drinking water production. To give some examples, at Kysak, the water quality of Hornád river tends to change from grade 3 to grade 5. The fact, that in Kysak there is an illegal dumping site and a panel manufacturing plant for the construction industry, contributes to that condition. The water quality of tributaries - Torysa, Hnilec, Olšavka, Belá, Svinka, Sopotnica and Sokoľ vary. In the area of the Sokoľ village, the Sokoľ stream tends to manifest the worst water quality of all the surface water resources in the Košice region.

Fig. 2 A view of a part of an illegal dumping site at the outskirt of Košice - part nad Jazerom.

Water contamination

From the point of view of utilisation of water by plants and animals it is necessary to maintain certain qualitative parameters. Various plants and animals have different level of tolerance towards inorganic and organic compounds and even though they may adopt, they may become poisonous. This is important in case of wild berries and mushrooms (often collected by tourists for consumption) as well as fish (their meat may be contaminated). For swimming, the water quality should be at least of grade 3.

The degree of contamination depends also on climatic factors, bedrock type, fracture systems in bedrocks etc. Parts of the contaminants come through melted snow, contaminated by imissions.

Waste dumps can thus be very dangerous pollution sources of surface- and underground water, soil and rock.

The transport of contaminants through rocks is affected by:

- degree of fractionation of rocks,
- resistance of rocks against metamorphosis and/ carstification,
- the rocks under and around Hornád river are well permeable and thus the risk of contamination is high.

Inorganic contaminants.

Inorganic contaminants may be geogenic and anthropogenic (Husár, 1995). Below are the data obtained by water and stream sediment analysis in the studied area. The heavy metal contents (Ag, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, V, and Zn) of river water and river sediments were monitored in 1995 within the RECENT project at 8 sites along the river (Tab. 1). A selection of the monitoring results is shown in Tab. 2. Later results, given by PBaH monitoring are shown in Tab. 3.

Tab. 1. Monitoring sites of the RECENT project.

1	Hornád above Rudňanský creek
2	Rudňanský creek below the RB plant
3	Hornád below the Rudnianský stream
4	Hornád at Richnava
5	Hnilec at the confluence with the Ružín dam
6	Ružín at the dam wall
7	Hornád at Ťahanovce
8	Hornád at Ždaňa

Tab. 2. Water quality along the river flow according to STN 75 7221 – by Hg content. Y axis: quality grade (5 – worst, 1 – best quality). X – axis: sampling sites. Shading – dates of sampling (Timčák et al., 1995).

Mercury (Hg) – water quality according to STN 75 7221								
Date/quality grade	1	2	3	4	5	6	7	8
14.5.95	4	4	5	1	1	1	1	1
24.6.95	5	5	5	4	4	5	4	4
23.9.95	5	5	5	5	5	5	5	5
7.10.95	5	5	4	4	5	5	5	4

For our purpose we have chosen Hg as an indicator of level of heavy element contamination. Tab. 2 and Fig. 3 shows the trend of contamination levels. For sampling sites see Fig. 1. The discontinuities stem from changes in the monitoring pattern.

Mercury – a geogenic contamination is abundant in the Spiš - Gemer Ore Mts. Anthropic contamination comes from mining and mineral processing in the Rudňany area, to a certain degree historically also from agricultural chemicals and to a lesser degree from illegal waste dumps.

The rest of the anomalies are also connected to the mineralization of the rocks along the river. The mineralisations are not evaluated in this paper.

Organic contaminants

The most frequent contaminants are: pesticides, polyaromatic hydrocarbons, chlorinated hydrocarbons, aromatic hydrocarbons and oil derivatives. Here we have also bacterial infestation possibility.

Some of the organic contaminants are toxic and some also carcinogenous. They can be found in greater Košice around car services, transfer stations and other workplaces, where they can escape into the environment and also to the river. Bacterial infectants come usually from improper sewage.

In the legal waste dumps materials unsuitable for dumping under the given conditions (like in Gelnica and Krompachy) could be found. Their placement in the vicinity of Hornád poses a risk especially if we consider the possibility of extremely high rainfall.

Tab. 3. Quality of Hornád river water (STN 75 7221) regarding Hg contents (PBaH 2007).

Sampling sites	**Water quality in terms of Hg contents**								
1	-	4	4	1	1	1	1	1	-
2	3	2	1	1	1	1	1	1	1
3	1	1	2	1	1	1	1	1	-
4	3	2	2	1	2	2	1	2	2
5	3	3	1	2	2	2	2	2	2
6	-	-	-	-	-	-	5	5	2
7	5	4	3	1	2	2	2	2	1
8	-	-	1	2	3	2	1	-	1
9	5	4	3	3	3	4	1	-	1
10	3	2	1	1	1	2	1	-	-
11	3	3	1	1	2	2	2	1	1
12	3	3	4	2	2	2	2	1	1
Years	1997	1998	1999	2000	2001	2002	2003	2004	2005

Within the „Caring after my river“ project of the SOSNA NGO, the pH, soluble O_2, NO_2, NO_3, NH_4 and PO_4 content was monitored in 1996-7 at 25 Slovakian and Hungarian localities. Figs. 3-4 show the 1997 results for the northernmost and southernmost point of the Slovakian part of the river that was monitored within the said project. Data on soluble O_2 and coliform bacteria contents in shown in Tab. 5a, 5b. It can be seen, how the surface water quality tends to vary and deteriorates along the river. The coliform bacterial content is higher then desirable. In Butkus (1999), the non-point source loading rates used for phosphorus and nitrogen species, biochemical oxygen demand, and total suspended solids in a model of Hornád river water quality improvement are shown (Tab. 4). The colour, taste and odour are affected by both organic and inorganic material. A spatial evaluation of all the factors was made by using GIS (Timčák, Orlitová, Dugáček, Jablonská, 1996).

Tab. 4. Non-point source (dump sites) loading rates used for phosphorus and nitrogen species, biochemical oxygen demand, and total suspended solids in a model of Hornád river water quality improvement (for further references, see: Butkus 1999).

Land Cover Type	Ammonia Loading		Nitrate Loading		Nitrite Loading		Organic Nitrogen Loading	
	[kg/ha/yr]	reference	[kg/ha/yr]	reference	[kg/ha/yr]	reference	[kg/ha/yr]	reference
Dump Sites	0.44	1	3.14	1	0.0628	10	9.20	1
Land Cover Type	Dissolved Phosphorus Loading		Organic Phosphorus Loading		BOD_5 Loading		TSS Loading	
	[kg/ha/yr]	reference	[kg/ha/yr]	reference	[kg/ha/yr]	reference	[kg/ha/yr]	reference
Dump Sites	0.87	1	9.20	1	19	12	210	12

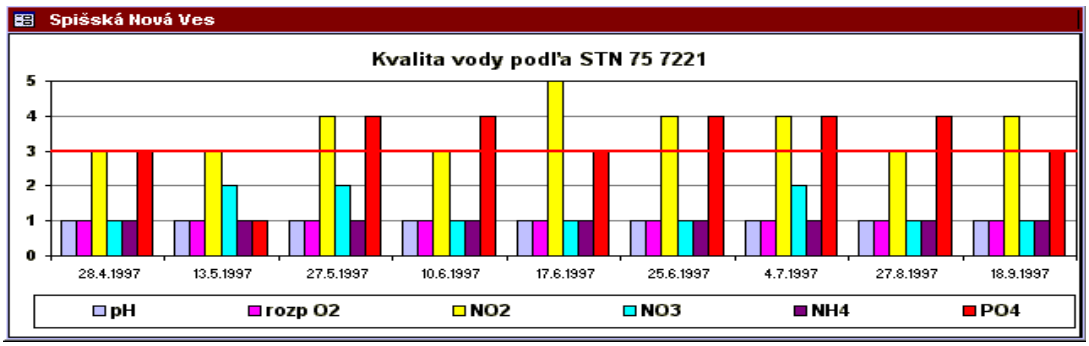

Fig. 3. Water quality by STN 75 7221 at Spišská N. Ves (Nothern part of the river)– characterized by pH, soluble O_2, NO_2, NO_3, NH_4 and PO_4 content. Y axis: quality grade (5 – worst, 1 – best quality). X – axis: sampling dates. Colours – data type. („Caring after my river Hornád“, 1997).

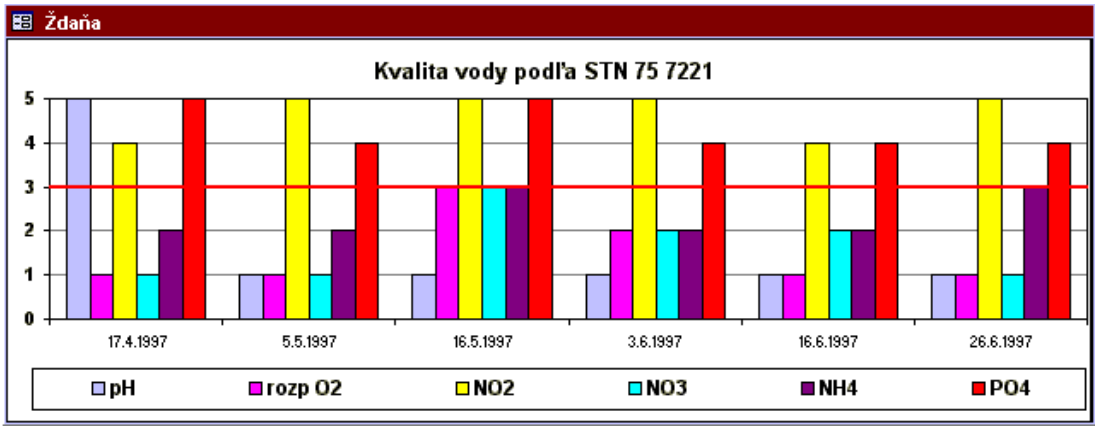

Fig. 4. Water quality by STN 75 7221 at Ždaňa (Southern part of the river) – by pH, soluble O_2, NO_2, NO_3, NH_4 and PO_4 content. Y axis: quality grade (5 – worst, 1 – best quality). X axis: sampling dates. Colours – data type. („Caring after my river Hornád", 1997).

Tab. 5a. Oxygen availability in the water of river Hornad and its effect on water quality. Water quality is given by soluble O_2 level according to STN 75 7221. Y axis: quality grade (5 – worst, 1 – best quality). X axis: years. (PBaH 2007). The discontinuities stem from changes in the monitoring pattern.

Sampling sites	Water quality in terms of soluble O_2								
1	2	4	4	3	3	3	3	2	3
2	2	3	3	3	3	3	3	4	4
3	2	2	2	3	4	3	3	4	4
4	2	2	2	3	4	3	3	3	3
5	3	3	3	4	5	4	3	5	4
6	-	-	-	-	-	-	4	5	5
7	2	2	4	3	3	3	3	3	4
8	2	1	1	2	2	2	2	2	2
9	2	2	2	2	2	3	4	3	2
10	2	2	2	2	4	4	4	4	4
11	3	2	3	3	4	5	5	4	3
12	3	3	3	3	3	3	4	5	5
Years	1997	1998	1999	2000	2001	2002	2003	2004	2005

Tab.5.b. Coliform bacteria content of the water of river Hornad and its reflection on water quality. Water quality by coliform bacterial content level is given according to STN 75 7221. Y axis: quality grade (5 – worst, 1 – best quality). X – axis: years. (PBaH 2007). The discontinuities stem from changes in the monitoring pattern

Sampling sites	Water quality in terms of coliform bacteriae contents									
1	5	5	5	5	5	4	4	4	4	4
2	5	5	5	5	5	4	4	4	4	4
3		5	5	5	5	5	4	4	4	4
4	5	5	5	5	5	5	4	4	4	4
5	5	5	5	5	5	5	4	4	4	4
6								4	4	4
7	5	5	5	5	5	4	4	4	4	3
8	5	5	5	5	5	4	4	4	4	3
9	5	5	5	5	5	4	4	4	4	3
10	5	5	5	5	5	5	4	4	4	4
11	5	5	5	5	5	5	4	4	4	4
12	5	5	5	5	5	5	4	4	4	4
Years	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005

Material composition of illegal dumping sites

The illegal dumping sites are of two types – concentrated and diffuse. The first one are those that are very well visible (especially during Summer), and pose an environmental risk as well as a deterioration of visual and olfactory aesthetic impression of the area. The second one is usually the waste left behind by tourists/trekkers. This waste can be found on the ground and also in the water. These are visible only at a close distance. Nevertheless, it spoils the feeling of comfort of all visitors that are not in the habit of leaving waste behind.

Illegal dumping sites are in woods, on the riverside as well as in the water reservoir. The composition of material deposited at the described illegal dumping sites along the Hornád river is given in Tab. 6. Their character is illustrated by Figs 2, 5, 6**.** The most frequently occurring materials found at the dumps are plastics and plastic or metal boxes with remnants of their original contents. The remnants of contents can get mobilised and transported to soil and surface water.

The total area of the described illegal dumps is 56 647 m^2 and the yearly atmospheric water throughput (at an assumed annual rainfall of 650 mm) is about 36 820 550 litres of water, which flows to the Hornád river, percolates to the bedrock and can reach underground water resources. The exact study of chemical composition of dump leachates could not be performed.

Fig. 5a, b. Dumping site in Sp. Vlachy, next to the railway station – near the field road. This dumping site was later simply covered by earth and re-vegetated.

Water quality and geotourism

It was shown that in spite of the high background values of the heavy metals in the surrounding rocks, after cessation of mining in Rudňany, the quality of water shows an improving trend. The river and water reservoir sediments accumulate heavy metals and to a certain degree get re-activated through organic mechanisms. This causes a contamination of water animals (e.g. fish), what may pose a problem for fishing. Thus fishing with catch return is recommended. The organic contamination, which is still a problem at a number of points along the river poses a potential problem for bathing and swimming.

Fig 5 shows the Spišské Vlachy illegal dumping site. It was later simply covered with earth (without remediation) and re-vegetated. The site will be thus forgotten and later only its adverse effect on the environment will be experienced, as the leaching of toxic material to the river (Fig. 6) will continue.

As it was mentioned, for geotourism, the main problem is the anthropic aesthetic harm done to the countryside (large scale wood-cutting, waste deposition, etc.). Next is the possible adverse effect of inorganic and organic contaminants on humans through water. Finally, we have the consequences of consuming biogenic products that accumulated toxic material.

From aesthetic point of view, the counter-aesthetic factors visible along the river are:

- quarries,
- mine tailings
- illegal dumping sites
- legal dumping sites
- waste left behind by tourists
- waste deposited in the creeks, river and in the water reservoir.

Tab. 6. Composition of the analysed dumping sites.

Locality	Area [m^2]	The water throughput of the dumping site [l] in case of average yearly precipitation equal to 650 mm	Distance from Hornád river [m]	Materials found at the dumping site
Hrabušice, beyond the village near the stream	12	7 800	1300	Rubber, textile, glass, metals, PVC, paints
Chrasť n. Hornádom, beyond the village, at the Gipsy campus	14	9 100	0	PVC, textile, rubber, glass
Spišské Vlachy, left bank	4000	2 600 000	100	plastics, glass, corroded metal paint containers, paper
Spišské Vlachy, railway station, a cut in the terrain	25000	16 250 000	10	Paint containers, bricks, metals, paints, thinners, PVC
Krompachy, before the regular dumping site next to the road	10	6 500	500	PVC, rubber, metals, paper
Richnava, right bank	21	13 650	0	PVC, rubber, metals, paper
Margecany, the Ružín dam, next to a railway station box	1000	650 000	0	Oil and paint containers, plastics, paper
Veľká Lodina, beyond the village, at the right bank, 2 dumps	15	9750	0	Metal containers, plastics, domestic waste, paper
Družstevná pri Hornáde, next to the railway bridge, both sides of the river	20000	13 000 000	1	Corroded metal waste, glass, plastics, rubber, textile, paints
Družstevná pri Hornáde, next to Chemika plant	5000	3 250 000	400	Domestic waste, barrels, metal containers, plastics, paints, textile,
Ťahanovce, at the garden area before the railway tunnel	1500	975 000	6	Corroded metallic waste, paint and oil containers, textile, footwear, polyethylene, glass, PVC, rubber
Košice - Nad Jazerom, Nižná Úvrať, dead branch of Hornád	60	39 000	0	Corroded metallic waste, paint and oil containers, textile, footwear, glass, PVC, rubber car batteries, paper
Opátske	15	9 750	0	Corroded metallic waste, paint containers, glass, PVC, paper

Fig. 6. View of the small distance between the river and the illegal dumping site in Sp. Vlachy shown in Fig. 5.

We have not discussed the environmental quality and aesthetics of settlements (especially of Roma settlements) along the river, as it is outside the scope of our paper, even though aesthetically these may not be pleasing. From sanitary point of view the problems are:

- surface water quality (bathing, swimming, paddling, kayaking, etc.),
- fish contamination by toxic trace elements,
- wild animal contamination by toxic trace elements,
- contamination of wild berries and mushrooms by trace elements.

As it was already mentioned, the quality of surface water regarding inorganic contaminants has improved in recent years, but the accumulation of trace elements in river and dam sediments, in fish and warm blooded animal meat as well as wild fruits and plants continues to pose a problem. The organic contaminants do not show such positive course of development.

Conclusions

The studied area is well suited for geotourism. If geotourism is to develop, the environmental problems indicated in the paper have to be tackled. The dumping sites continue to contribute to the pollution of the surface water and in some cases, underground water in the Hornád valley. The illegal waste dumps contribute to heavy element and organic pollution of water and soil. Their quantitative contribution is difficult to assess without doing detailed study of leachate chemistry next to the dumping site. The studied 13 illegal dumping sites are so close to the river that their effect on surface water contamination seems to be evident. In any case, dumping site remediation would be a very important task to do. The wastes spoil also the aesthetic values of the valley, so their proper remediation is imperative.

Local communities and tourists should be educated and motivated to minimise waste production and to improve waste management. The improvement of waste water treatment of settlements along the river is another priority (Butkus, 1999). Many of the smaller settlements do not have a central sewage system and thus communal waste is ill treated and poses an environmental threat in spite of the existing rigorous legislative measures. The water quality is improving if the inorganic contamination level is considered, but the organic contamination level is still higher than desirable. The high coliform bacteria content is also adversely affecting some water-related sports and leisure activities.

The amelioration of the aesthetics is an on-going task that has many players and should be coordinated on the Košice county level. Only under such conditions could geotourism in the Hornád river valley develop to its full potential.

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