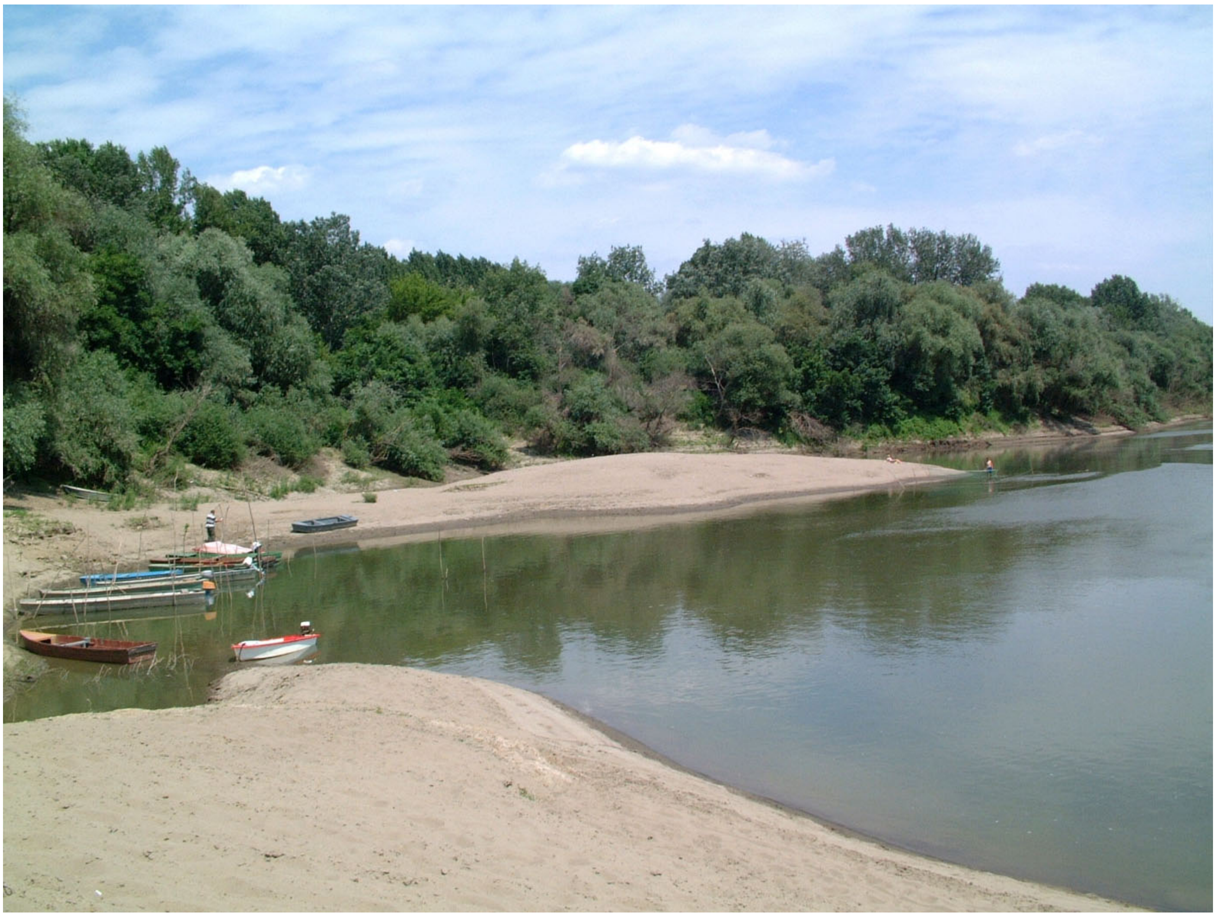
The Ecological Effects of Mining Spills in the Tisza River System in 2000



Vienna, April 2002

Acknowledgements

....

Important contributions to this study were made by:

- *WWF International Danube Carpathian Programme, Vienna, Austria* (Philip Weller, Jasmine Bachmann)
- *WWF Institute for Floodplains Ecology, Rastatt, Germany* (Erika Schneider, Detlef Günther-Diringer)

Other valuable comments came from *WWF Hungary* (Viktória Siposs), *WWF Sweden* (Lennart Henrikson), *WWF Spain* (Guido Schmidt), Robin Webster and Suzie Holt.

Contacts

WWF International Danube-Carpathian Programme, Vienna, Austria: http://www.panda.org/danube-carpathian
WWF Germany, Institute for Floodplains Ecology, Rastatt, Germany: http://www.wwf.de
WWF Hungary, Budapest, Hungary: http://www.wwf.hu

Cover page photo credit and Layout: U. Schwarz, *FLUVIUS*

Table of Contents

……………………………………………………………………………………………………..

1. Introduction

……………………………………………………………………………………………………..

At the beginning of 2000, the world's interest was focused on the River Tisza[1] in Central-Eastern Europe. Pictures of fishermen shovelling hundreds of dead fish went around the world and raised concern about the future of the river and the people living in its basin.

During the night of January 30 2000, a dam at a mine reprocessing facility, near the city of Baia Mare, had released approximately 100,000m³ of wastewater contaminated with heavy metal sludge and up to 120 tonnes of cyanide (BAIA MARE TASK FORCE 2000). After travelling down the Lapus and Szamos[2] rivers to the main channel of the Tisza, it became apparent that the spill was having major ecological consequences.

Only approximately one month after the cyanide spill (March 9 2000), a heavy metal spill occurred in another mining facility at Baia Borsa. 20,000 tonnes of solid waste and 100,000m³ of water containing high concentrates of heavy metals were released into the environment.

This report aims to make a synthesis of the studies of the ecological consequences of the cyanide/heavy metal spill from Baia Mare, and the subsequent heavy metal spill from Baia Borsa, which affected a further tributary to the Tisza as well as the Tisza itself.

It is apparent that two years after the spill a definitive assessment of the long-term consequences of the spill cannot be provided. However, information collected and synthesised here should shed light on the questions that have been raised worldwide about the ecological effects and consequences arising from the accident.

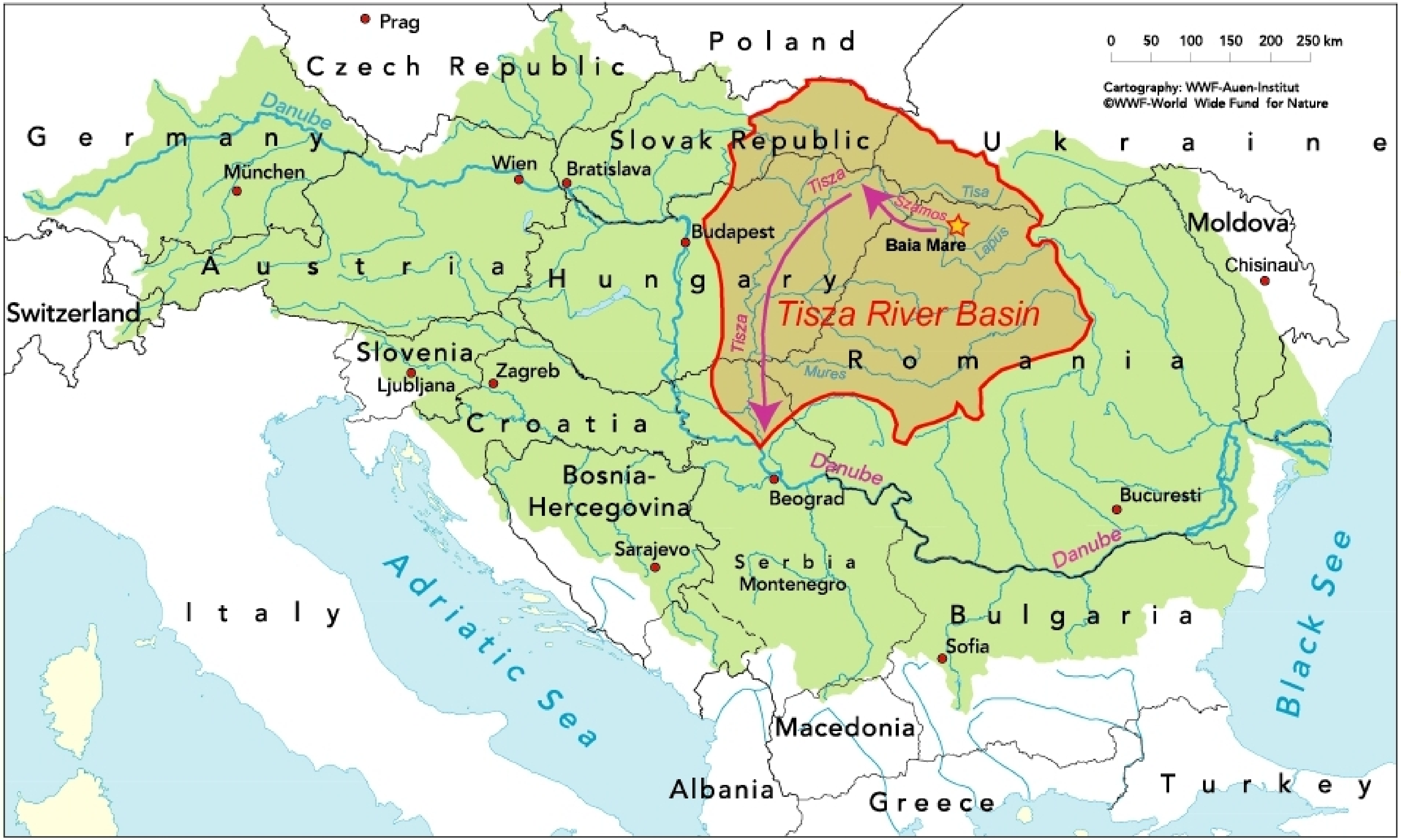
2. Ecological conditions in the Tisza catchment

....

The following map (Map 1) provides an overview of the Tisza basin, its size and location within the Danube river catchment:

[1] Tisza / Tisa
[2] Szamos / Somes

The Danube-River-Basin



2.1 The River Tisza and its basin

Five Eastern European countries share the Tisza basin: Ukraine, Romania, Hungary, Slovak Republic and the Federal Republic of Yugoslavia (Serbia and Montenegro). With a total length of 966km and a catchment area of approximately 157,220km², the Tisza is the largest tributary of the River Danube (see Map 1 and 2).

The river has two sources: the White Tisza (alt. 1,400m) and the Black Tisza (alt. 1,650m) in the forested Carpathian Mountains in Ukraine. From there until it joins the Danube, 40km upstream of Belgrade, the river's course is as follows: about 100km of the 966km lie in Ukraine, 60km form the border between Ukraine and Romania, 650km lie in Hungary and 150km in FR Yugoslavia (GASTESCU 1990, REGIONALE ZUSAMMENARBEIT DER DONAULÄNDER 1986).

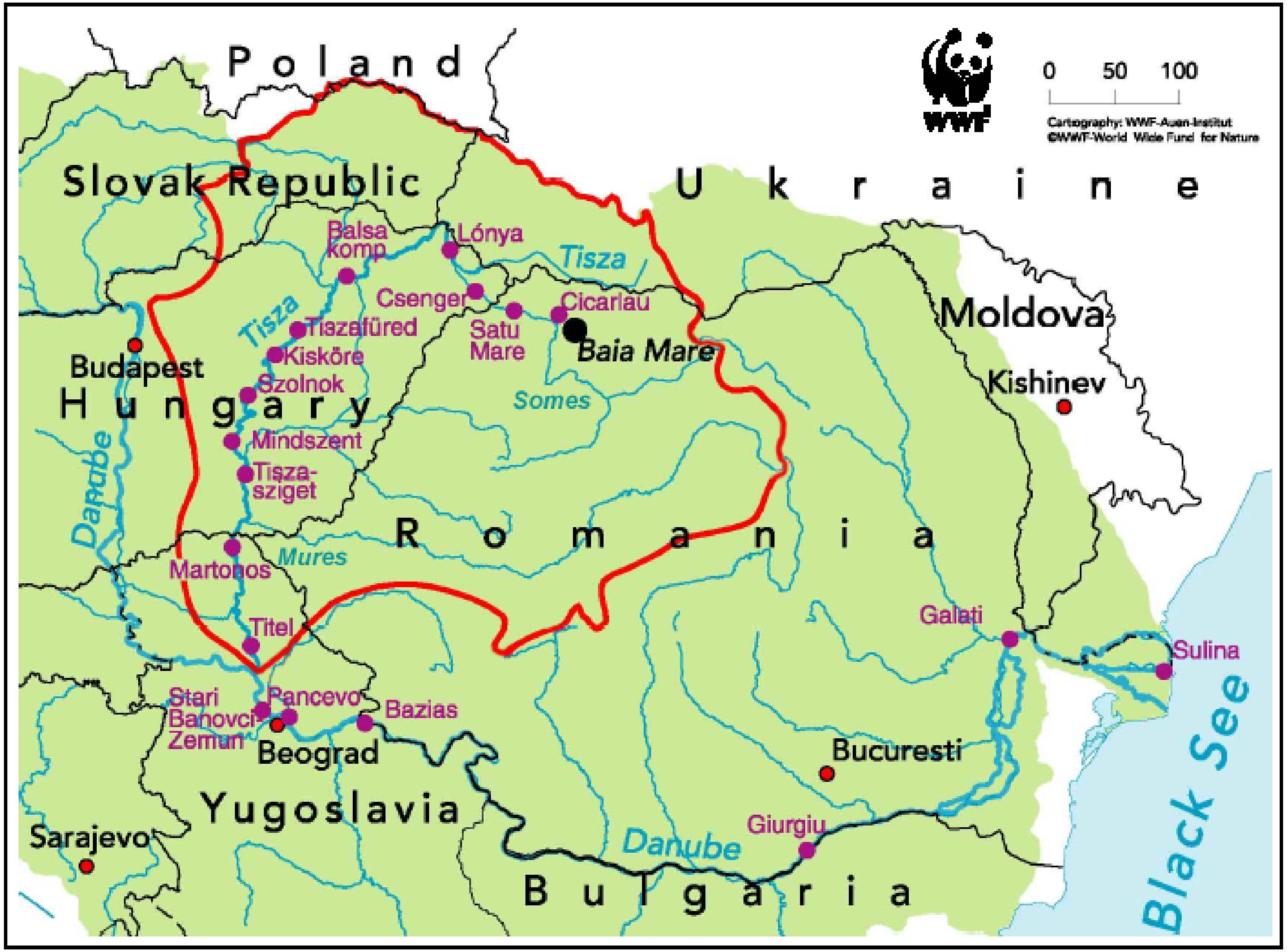
Table 1 indicates the catchment area of the Tisza in each country:

Country	Size of Tisza basin in country	Percentage of Tisza basin in country	Percentage of country area forming the Tisza catchment
Ukraine	12,735km^2	8.1%	2%
Romania	72,637km^2	46.2%	30%
Slovak Republic	15,250km^2	9.7%	32%
Hungary	46,223km^2	29.4%	52%
Federal Republic of Yugoslavia (FRY)	10,376km^2	6.6%	9%

About 14.5 million people live in the Tisza catchment area. The distribution of the population between the countries corresponds closely to their share of the catchment.

In the Ukrainian section, the Tisza has the character of a mountain water course, with a considerable slope (20-30‰). On crossing the Hungarian lowland, the slope is very low (0.02‰) and forces the river to form meanders. The floodplain and wetland area is locally very large in this area (more than 4km wide).

The following map (Map 2) provides an overview of the Tisza system and sampling sites:



Map 2: The Tisza river system and sampling sites

Following geomorphological and hydrological criteria, the River Tisza can be divided into three stretches:

- The Upper Tisza from its source in the Ukrainian Carpathians to Tokaj in northern Hungary. According to Hungarian authors (VARGA 1997), the Hungarian stretch of the Upper Tisza can be further subdivided into two stretches from Tiszabecs to Záhony and from Záhony to Tokaj.
- The Middle Tisza is made up of the river stretch from Tokaj to Csongrád, where the confluence with the Hármas-Körös is situated. It can also be divided into two subdivisions from Tokaj to Kisköre, where the Tisza Lake is located, and from Kisköre to Csongrád.
- The Lower Tisza consists of the stretch from Csongrád to the point where the Tisza joins the Danube near Slankamen in Yugoslavia. The Lower Tisza is further subdivided into two parts: from Csongrád, the confluence of the Tisza and Hármas-Körös rivers, to the point at which the Maros river joins[3], and from here to the Danube.

2.2 Hydrological regime

With the exception of the upper section, the Tisza can be considered a lowland river, with a discharge determined by middle-mountain tributaries. Its waters are fed from snowmelt and major rainfalls in the mountain areas and characterised by high discharge and water levels in spring (March-April, when large floods occur regularly) and low water levels in summer to late autumn (which are locally combined with remarkable dryness). In general, due to the continental climate, the rivers in the Tisza catchment area have an extremely fluctuating hydrological regime. The difference between water levels at low water mark and high level can even reach 13m. Water output during water level rises is 30-40 times higher than at the low water mark (HAMAR & SARKANY-KISS 2000).

The mean discharge of the Tisza at the point where it joins the Danube is 814m^3/s (GASTESCU 1990). The maximum discharge measured is 4,348m^3/s (Szeged) and the minimum 96m^3/s (REGIONALE ZUSAMMENARBEIT DER DONAULÄNDER 1986, GASTESCU 1990). The mean minimum annual discharge is 236m^3/s and the mean maximum annual discharge is 2298m^3/s (Szeged).

The large amount of sediments (10 - 11 Mio t/a) transported by the Tisza (GASTESCU 1990) is a determinant for the high amount of sediments in the river itself and also for the Lower Danube (see also LÁSZLÓFFY in LIEPOLT 1967).

As a result of rectification projects, the original length of the Tisza has been considerably shorted by about 40% (DOBROSI, HARASZTHY & SZABÓ 1993, VARGA 1997). This has led to an increased velocity of the running water and also increased riverbed erosion, with remarkable changes in the hydrological regime and consequences for the whole river system.

[3] Maros / Mures

The former floodplain of the Tisza, the so-called morphological floodplain[4], used to be 7,542km^2 in size, approximately 200km^2 of which were in Ukraine, 313km^2 in Romania, 4,637km^2 in Hungary and 2,391km^2 in the Federal Republic of Yugoslavia (FRY) (WWF 1999). Due to numerous drainage projects in the 18th and 19th centuries, the formerly large floodplain area has been reduced to a narrow one.[5] Regarding the recent floodplain, the area actually under the influence of flooding is 1,215km^2, of which 159km^2 are in Ukraine, 914km^2 in Hungary and 142km^2 in FRY. On the Romanian stretch of the Tisza, in the middle of the Carpathian Mountains, the floodplain area is very small.

The consequences of the loss of such a large floodplain along the Tisza can be evaluated by looking at the importance of the hydrological, biogeochemical and ecological functions of the floodplain and wetland areas (DISTER 1994, SCHNEIDER 2002). The functions can be summarised as follows:

Hydrological functions:
- Water storage basins/flood retention/moderating floods;
- Sediment transport;
- Groundwater supply and self-purification;
- Balancing factor for the hydrological regime/water cycle (improvement of the climate);

Biogeochemical functions:
- Carbon (C)/ Nitrogen (N)/ Phosphorus (P) cycling;
- Nutrient retention and recycling;
- Sediment and toxicant (pesticides, heavy metals) retention/filtering capacity;
- Transformations of organic and inorganic pollutants;

Ecological functions:
- Habitat for different species (spawning ground, feeding area, nesting area, etc.);
- Reservoir of biodiversity, store for genetic resources;
- Bio-corridors enabling genetic exchange;
- Bio-productivity/food webs.

Considering the importance of the afore-mentioned functions and looking specifically at the importance of the biogeochemical functions in the case of the Tisza toxic spill, the consequences and dimensions of the loss of such large floodplain areas becomes evident.

2.3 Nature and landscape

General description

On its journey of more than 960km, from the sources in the Carpathians to the Danube, the Tisza crosses various landscapes. It passes through the mountains,

---

[4] The morphological floodplain is the entire area of the floodplain that was formerly flooded without major anthropogenic influence, usually marked by a terrace. The period referred to dates from about 300 years ago.

[5] The recent floodplain is the area flooded during recent flood events. The maximum extension of this recent floodplain usually corresponds to the inundation area of the centennial flood event.

consisting of large areas of virgin beach, pine-beach and spruce forest and mountain-pine areas, along with alpine meadows, peat bogs, highland marshes, mountain streams with cascades, cave formations and mineral springs. Further downstream are lower hills with oak forest, as well as large lowlands with marshes, marshy meadows, floodplain forests, oxbows, backwaters and dry lands.

The Tisza floodplain has been considerably reduced in size, large areas having been cut from the water dynamics of the river. As a result of the ecological value of the floodplain areas along the Tisza, many areas have been put under protection, such as the Tiszatelek-Tiszabercel Floodplain Nature Conservation Area, Tokaj-Bodrogzug Protected Landscape Area and Hortobágy National Park (DOBROSI, HARASZTHY & SZABÓ 1993). At present, two years after the cyanide spill, no visible consequences in the afore-mentioned areas have been reported (according to information from the park authorities). However, in order to provide reliable data about the long-term effects, additional years of monitoring are necessary.

In the Tisza basin, the forest and water/wetland systems are great treasures. Nonetheless, the economic and social transformation that is characteristic of Central and Eastern European countries has caused serious damage.

This region's natural values are affected and threatened by human intervention and many may be destroyed or degraded.

<u>These impacts include:</u>
- Deforestation with no possibility of regeneration in the higher mountain areas;
- Soil degradation and moisture loss;
- Canalisation of the watercourses;
- Reduction and drainage of wetlands;
- Water pollution;
- Urbanisation;
- Intensive forestry and agriculture.

As a consequence of all of these human interventions, the natural functions of the river are affected or strongly reduced. The self-purification capacity is also severely decreased.

<u>Biodiversity</u>

The entire Tisza catchment area possesses a remarkable diversity of natural and semi-natural terrestrial and aquatic habitats, rich in species, many of which can only be found in this area (endemic species). The habitats and communities along the Tisza vary with slope and sediment size, which in turn are strongly related to river dynamics.

On certain central and lower stretches, the Tisza offers good conditions for natural regeneration of Black poplar (*Populus nigra*) and White willow (*Populus alba*), which is characteristic for new sites created by a dynamic river. In addition, the establishment of other pioneer species is also possible due to the creation of new river banks, supporting typical insect and bird species. Of the floodplain forests, some still show good structure and high diversity, offering habitats for many birds and mammals living and feeding on the river and its floodplains.

The different types of water bodies in the floodplains (e.g. old river branches, oxbow lakes, small streams) also include typical communities, in which water plants, benthos, phyto- and zooplankton play an important role. Studies undertaken in the area in 1992 on the Lower Szamos river demonstrated that anthropogenic effects, particularly domestic and industrial pollution, had a drastic impact on benthic communities (HAMAR & SÁRKÁNY-KISS 1999). However due to the self-purification of the Szamos and the decreased industrial pollution at the beginning of 1990, representatives of sensitive groups such as bryozoans, mussels (*Unionidae*), mayflies (*Ephemeroptera*) and caddis-flies (*Trichoptera*) were found in the river in 1996. Despite this evidence of the small improvement in the quality of the river, the zoobenthos were dominated by larvae of various species of worms (*Oligochaeta*) and midges (*Chironomidae*), which have a larger ecological amplitude and hence higher tolerance to pollution.

The Tisza is known for its rich fish fauna. During the past 20 years, a total of 68 fish species has been recorded, of which the 24 species shown below are protected under Hungarian nature protection legislation.[6]

Table 2: Protected fish species recorded in the Tisza (under Hungarian nature protection legislation).

Scientific Name	**English Name**	**Family**
Accipenser güldenstaedti colchicus	Black Sea sturgeon	*Acipenseridae*
Accipenser nudiventris	Sturgeon (or Ship sturgeon)	*Acipenseridae*
Barbatula barbatula	Stone loach	*Balitoridae*
Cobitis taenia	Spined loach	*Balitoridae*
Sabanejewia aurata	Golden spined loach	*Cobitidae*
Cottus gobio	Bullhead	*Cottidae*
Cottus poecilopus	Siberian or Alpine bullhead	*Cottidae*
Alburnoides bipunctatus	Rifle minnow	*Cyprinidae*
Barbus peloponnensius petényi	Southern barbel	*Cyprinidae*
Gobio albipinnatus	White-finned gudgeon	*Cyprinidae*
Gobio kessleri	Kessler's gudgeon	*Cyprinidae*
Gobio uranoscopus	Danubian gudgeon	*Cyprinidae*
Leucaspius delineatus	Owsianka	*Cyprinidae*
Leuciscus souffia agassizi	Soufle	*Cyprinidae*
Misgurnus fossilis	Weatherfish	*Cyprinidae*
Phoxinus phoxinus	Eurasian minnow	*Cyprinidae*
Gymnocephalus baloni	Balons ruffle or Danube ruffle	*Percidae*
Gymnocephalus schraetzer	Schraetzer	*Percidae*
Zingel zingel	Zingel	*Percidae*
Zingel streber	Streber	*Percidae*
Eudontomyzon danfordi	Carpathian lamprey	*Petromyzontidae*
Hucho hucho	Huchen or Danube salmon	*Salmonidae*
Thymallus thymallus	Grayling	*Salmonidae*
Umbra krameri	Mudminnow	Umbridae

[6] For detailed fish lists see study by WWF-Hungary 2000.

Most of these species occur in the Tisza upstream of the confluence with the Szamos. 46 fish species have been observed in this stretch of the river and only 58 species downstream from the confluence with the Szamos (WWF HUNGARY 2000). Some of the fish species were very rare even before the spills. This rarity was caused by the decrease in water quality over recent decades. The industrial and domestic sewage from towns at the foot of the Carpathian Mountains caused a drastic decrease in water quality, also heavily affecting the middle and lower branches of the River Tisza. The Szamos and Maros rivers can be seen as the most polluted tributaries of the Tisza.

However, pollution is not the only factor responsible for changes in species composition and structure of fish communities along the Tisza river. It has to be underlined that economically important alien species such as the Amur carp (*Ctenopharyngodon idella*) and Silver carp (*Hypophtalmichtys molitrix*) were first introduced to fishponds and then escaped into the rivers. Another alien species, originally from North-Asia, is the Goldfish (*Carassius auratus gibelio*). This species has become naturalised over time in the Tisza and Danube rivers and has replaced the native Crucian carp (*Carassius carassius*), which became rare over the last few decades. This species is found in standing water and also in sludgy parts of slow-flowing lowland rivers.

3. The Tisza mining spills and main pollutants

3.1 Cyanide spill at the Aurul tailing dam (January 30 2000)

The accidental pollution of cyanide and heavy metals occurred during the night of January 30 2000 at the S.C. AURUL S.A: Baia Mare plant, in the vicinity of Baia Mare (Nagybánya) in the northern part of Romania (Maramures county).

S.C. AURUL S.A. Baia Mare is an Australian - Romanian joint venture company established in 1992 in order to obtain gold and silver (see http://www.esmeralda.com.au). The operations began in May 1999 with the processing of an existing, 30 year-old, tailing dam located near the city of Baia Mare. The process consists of grinding soil-ore followed by extraction using cyan-dissolution. The source of raw materials is from mining solid wastes (containing gold, silver, copper, zinc, manganese, lead and other metals) that have been accumulated during the last decades. The technology used for the extraction involves a high concentration of free cyanide (~120mg/l). The dissolution technology demands considerable amounts of water and solid wastes are deposited into a new pond (the so-called Aurul tailing dam). This tailing dam has a surface area of 94ha and is located about 6km downstream of the city of Baia Mare near to the villages of Sasar and Bozanta Mare. The whole process operates in a closed circuit and the waters resulting from the flotation process are totally reused.

The 2000 pollution incident arose following a period of heavy rainfall (30l/m^2 of precipitation on 30 January 2000) and the melting of a 60cm thick snow layer. These resulted in a rise in the level of the sedimentation pond and led to a 25m breach in the dam embankment. Consequently, approximately 100,000m^3 of water containing suspended solids and a high cyanide concentration were released in 11 hours. The spill flooded land close to the pond (covering 14ha), where fine sediments with heavy metals were deposited and flowed through de-watering channels into the River Lapus, and from there into the Szamos, Tisza and Danube rivers.

Two days later, Aurul informed the local and national authorities. The embankment was partly closed by February 2, and the company used sodium hypochlorite to neutralise the concentrated cyanide solutions. The local Romanian authorities were alerted about a ban on using the river water for domestic needs, animal drinking and fishing. After being warned by the Romanian government, the Hungarian environmental and water management organisations prepared for the pollution wave and a defence action plan was developed to minimise its impact, including the closure of outflow sluices and the filling of the Kisköre reservoir (Tisza Lake) with clean water etc. In addition, the piped drinking water supply was terminated in the city of Szolnok (Hungary) during the pollution wave. These measures successfully contributed to reducing irreversible damage and probably enhanced the rehabilitation of the river ecosystem, although substantial damage did occur (VITUKI 2000, a).

Table 3: Characteristics of the cyanide wave in the control sections (see Map 2) on the Szamos, Tisza and Danube rivers (according to official data from Romania, Hungary and FRY).

River	Control Section	Data provider	Peak time		Peak concentration (mg/l)	Discharge (m^3/s)
			Date	Hour		
Szamos (R)	Cicarlau	Romanian Ministry	31.1.	11:00	13.26	111
Szamos (R)	Satu Mare	Romanian Ministry	01.2.	11:30	7.8	148
Szamos (H)	Csenger	Vituki, Hungary	01.2.	20:35	32.6	
Tisza (H)	Lónya	Vituki, Hungary	03.2.	12:00	13.5	
Tisza (H)	Balsa komp	Vituki, Hungary	05.2.	8:00	12.4	
Tisza (H)	Tiszafüred	Vituki Hungary	07.2.	16:00	4.9	
Tisza (H)	Kisköre	Vituki Hungary	08.2.	6:00	3.88	
Tisza (H)	Szolnok	Vituki, Hungary	09.2	4:00	2.85	805
Tisza (H)	Csongád	Vituki, Hungary	10.2	12:00	2.9	804
Tisza (H)	Mindszent	Vituki, Hungary	10.2.	20:00	2.0	1170
Tisza (H)	Tiszasziget	Vituki, Hungary	11.2	12:00	1.49	1800
Tisza (FRY)	Martonos	RHIS	11.2.	11:00	2.5	
Tisza (FRY)	Titel	RHIS	13.2.	17:00	2.28	
Danube (FRY)	Stari Banovci-Zemun	RHIS	14.2.	1:00	1.31	
Danube (FRY)	Pancevo	RHIS	14.2.	11:00	0.45	
Danube (RO)	Bazias	Romanian Ministry	15.2	14:00	0.342	8700
Danube (RO)	Giurgiu	Romanian Ministry	22.2.	22:00	0.095	8860
Danube (RO)	Galati	Romanian Ministry	26.2.	15:50	0.075	10000
Danube (RO)	Sulina	Romanian Ministry	28.2.	10:00	0.049	

3.2 Heavy metal spill at the Novat tailing dam (March 10 2000)

The accidental pollution with heavy metals occurred due to a break in the remote Novat tailing dam near Baia Borsa.

The Baia Borsa Mining Branch belongs to the National Company REMIN S.A. Baia Mare and its mining area covers about 14,000ha between the River Cisla and the

River Vaser, tributaries of the Upper Tisza. The main activity is non-ferrous mineral exploitation, processing complex ores of lead and zinc. The resulting waste is stored in the Novat settling pond, close to the processing factory. The Novat tailing dam is a “Valley type” pond, consisting of three individual dams: the main dam has a rock foundation, which becomes higher as the work in the flotation plant continues; the second dam is the hydro-technical construction of rocks that will support the main dam as it reaches its final dimensions; the third dam is also a hydro-technical construction of argyle and concrete and has the role of collecting resulting leaks from the dam for the re-pumping into the main dam. As with the Aurul dam, the Novat system is operated as a closed circuit.

Table 4 shows the average concentrations of solid waste deposited into the dam:

Copper (Cu)	0.05%
Lead (Pb)	0.1%
Zinc (Zn)	0.1%
Iron (Fe)	0.5%

The pollution incident occurred following heavy rainfall (37l/m² measured in Poiana Borsa) and the melting of the snow layer (70cm), causing the water level in the Novat tailing dam to rise quickly and the pumping stations stopped their activities. As a result, the embankment overflowed and the dam broke (length: 25m, height: 15m). About 40,000t of solid waste and 100,000m³ of water were discharged. Since about 20,000t of solid waste were retained, the remaining 20,000t entered the emissary. The company informed all the relevant authorities and prevented enlargement of the breach by creating a pre-embankment.

3.3 Description of the main pollutants

Cyanide

Cyanide is usually found in combination with other chemicals (in compounds). Examples of simple cyanide compounds are hydrogen cyanide (HCN), sodium cyanide (NaCN) and potassium cyanide (KCN). Cyanide can be produced by certain bacteria, fungi, and algae, and is found in a number of foods and plants. In the body, cyanide combines with a chemical to form Vitamin B_{12}.

Cyanide enters the environment from both natural processes and industrial activities. HCN is a colourless liquid with high volatility and an almond-like odour. In air, cyanide is mainly found as gaseous HCN. Solubility in water and volatility are characteristic for the high mobility of HCN in environmental structures and leads to a high toxicity in bio-systems.

NaCN and KCN are white solids which, in damp air, adopt an almond-like odour. HCN also occurs in the stones of various fruits, especially *Prunus* species (e.g. almond, apricot, cherry). Consequently, the excessive consumption of bitter-almond could result in lethal cyanide poisoning.

Most cyanide in surface water forms HCN and evaporates. However, at high concentrations, cyanide becomes toxic to soil micro-organisms and can pass through soil into groundwater. It is also apparent that HCN (rather than CN^-), is the major toxic agent and that toxicity varies markedly with pH and temperature. The percentage of HCN continues to increase as pH drops further, until at a pH of 7.0, about 99.5% of the cyanide exists as HCN. At a pH below 7.0, essentially all dissolved cyanide is present as HCN. Thus, most free cyanide in natural waters is present as HCN since the "natural" pH range is between about 6.0 and 8.5. HCN readily forms a gas, some of which is released into the air. Cyanide does not remain in the environment for long and does not accumulate in sediments or organisms (KOCH 1989). Cyanide compounds are seldom present in uncontaminated water in environmentally significant concentrations. Cyanide per se does not persist in the environment, but it must be emphasised that numerous other forms of toxic cyanide compounds do persist.

Essentially there are only three categories of cyanide that mine operators must normally be concerned with: free cyanide, weak-acid-dissociable cyanide and total cyanide. NaCN, CN- and HCN are often collectively referred to as 'free cyanides' and the relative amounts present are largely controlled by the water pH.

Reaction of various life forms to concentrations of cyanide

Free cyanides are known to be the most toxic forms of cyanide derivatives in mammals and aquatic life. Fish are approximately 1000 times more sensitive to cyanide than humans (see www.zpok.hu). Acute toxicity for various fish species ranges from about 20 to 640µg/l (MORAN 1998). Bird and mammal deaths generally result from cyanide concentrations in the milligram per litre range. The current US Environmental Protection Agency (EPA) water quality criterion for cyanide, set in 1986, is 5.2µg/l for freshwater aquatic life, and 1.0 µg/l for marine aquatic life and wildlife.

Sub-lethal levels of cyanide have physiological and pathological effects, which reduce the swimming ability of fish, interfere with reproductive capacity and can lead to seriously deformed offspring and fish more vulnerable to predators. According to KOCH (1989), NaCN is dangerous and highly toxic in the smallest concentrations, damaging the biocoenosis[7] of waters. Fish in general demonstrate exceptionally high sensitivity. The amplitude is between 0.02–0.03mg/l for highly sensitive species and 0.5mg/l for less sensitive species of fish. For other groups of aquatic organisms the values range from 0.2 to16.5mg/l.

While most forms of cyanide begin to degrade readily when exposed to air, water and sunlight, these same compounds may persist in the environment if released during winter when lakes or streams may have snow and ice cover and temperatures are reduced. Given the limitations of routine analytical techniques for measuring cyanide and the presence of breakdown forms of cyanide in mining wastewaters, there is considerable uncertainty regarding the actual toxicity of various forms of cyanide on living organisms (MORAN 1998).

[7] Biocoenosis: varied community of interacting organisms

Acute toxicity is described as those concentrations of cyanide that lead to the death of more than 50% of the test population within 96 hours. Chronic exposure may be described as exposure to less than lethal concentrations of cyanide. Chronic cyanide exposure may affect reproduction, physiology and levels of activity in many fish species (MORAN 1998).

The toxicity of cyanide in aquatic systems depends on various factors such as:

- Cyanide concentration;
- Oxygen concentration: toxicity increases with any reduction in dissolved oxygen below 100%;
- Temperature: toxicity increases three-fold with a 12°C decrease in temperature;
- pH: there is a slight decrease in toxicity at pH above about 8.5, due to conversion of cyanide to CN^-;
- Chloride: concentrations of more than 8.8 parts per thousand decreases survival time;
- Other dissolved constituents: the presence of zinc and ammonia result in a greater than additive increase in toxicity;
- Other factors: toxicity will also depend on the age and health of the fish, the amount of water ingested and the stress level experienced by the animal.

Table 5 indicates limit values of cyanide concentration for water organisms (according to different studies) for the following species or species categories:

Amphibians	0.01mg/l
Trout/*Salmonidae*	0.02-0.03mg/l
Perch/*Perca fluviatilis*	0.08mg/l
Zander Pikeperch/*Stizostedion lucioperca*	0.08mg/l
Roach/*Rutilus rutilus*	0.1-0.5mg/l
Ruff/*Acerina cernua*	0.1mg/l
Tench/*Tinca tinca*	0.1mg/l
Orfe/*Leuciscus idus*	0.3mg/l
Copepods/*Copepoda*	0.2mg/l
Waterflea/*Daphnia magna*	0.4mg/l
Snail/*Bythinia tentaculata*	10.0mg/l
Worm/*Tubifex*	25.0mg/l
Algae	40.0mg/l

Effects on humans

Chronic exposure to lower levels of cyanide by humans for a long period may result in breathing difficulties, heart pains, vomiting, changes in the blood, headaches and enlargement of the thyroid gland. According to local people, such effects have been observed in the area of the tailing lagoon near Baia Mare. Cyanides are able to enter the body very quickly through any entrance sites except intact skin.

In large amounts, cyanide is very harmful to human health. Cyanide inhibits the ingestion of oxygen by cells and causes the victim to effectively suffocate. Short-term exposure to high levels of cyanide in the air damages the brain and heart and, in the extreme, may cause coma and sudden death (i.e. within hours).

The lethal dose of cyan-hydrogen is 50-60mg for humans, while the body-weight specific dose is 1-2mg/kg (WHO 1984; KOCH 1989). The lethal dose of NaCN for humans is 5mg/kg weight (KOCH 1989) and approximately 2.9 mg/kg for potassium cyanide (KCN) (www.umweltbundesamt.de/gefahrenstoffe).

People who ingest large amounts of cyanide may suffer the following symptoms: deep breathing and shortness of breath, convulsions and loss of consciousness. High blood cyanide levels have also been associated with weakness of the fingers and toes, difficulty in walking, dimness of vision, deafness and decreased thyroid gland function; however, chemicals other than cyanide may contribute to these effects. Chronic effects of exposure to cyanide include weight loss, thyroid trouble and nerve damage.

The World Health Organisation (WHO) guidelines specify the amount of daily allowable cyanide intake as 8.4mg. According to the same guidelines, cyanides in cyanide-contaminated food decompose during cooking or frying; therefore their toxic effects are negligible. The EPA has set a maximum contaminated level of cyanide in drinking water of 0.2mg/l.

The Cyanide Intervention Level for drinking water is different in different European countries. In Germany for example it is set at 0.05mg/l, whilst in Switzerland the level for industrial water run-off is 0.1mg/l. In Romania, the standards allow 0.01mg/l for drinking water. In Hungary, the classification of the quality of surface waters is made in five classes: cyanide concentrations exceeding 0.1mg/l are considered heavily polluted (Class V). For drinking water, the Hungarian standards also state 0.1mg/l cyanide concentration as the maximum allowable limit for human consumption. In certain cases, European Union Directives specify stricter limits than the Hungarian ones. For example: Directive 75/440/EEC does not allow the use of surface waters for the production of drinking water at concentrations higher than 0.05mg/l; and Guideline 98/83/EEC specifies 0.05mg/l cyanide concentration as the maximum allowable value in drinking water.

Heavy Metals

Heavy metals do not break down and are "bio-accumulative" in plants, animals and the environment (VUJANOVIC, PLAMENAC, RAZIC & SIMONOVIC 2000). This means that toxins build up in an organism over time and its toxicity increases, posing a threat to local ecosystems. In general, fish accumulate heavy metals in greater concentrations than other species. Toxins may also be passed on to other species if a toxic organism is eaten. Therefore, living organisms face high risks from long-term and chronic exposure to heavy metals.

Among the heavy metals used by mining industries, arsenic, cadmium, lead, nickel, manganese and molybdenum are the most harmful to humans, even in small doses; while zinc, lead, aluminium, boron, chromium and iron are also all toxic to plant growth.

Copper (Cu)

Copper is found in the atmosphere, soil, groundwater, surface water and bottom sediments and is present as an essential trace element in animals and plants. The mean daily intake is 1mg. Copper is an essential element in nourishment and health. Exposure can occur through skin contact, inhaling, ingesting and consuming drinking water. The greatest potential exposure is drinking water consumption. In typical drinking water, copper concentration is 20-75µg/l. The mean dissolved copper concentration of natural waters is 5-10µg/l. Concentrations in groundwater are slightly higher. Acute and chronic effects to humans include stomach and intestinal distress, liver and kidney damage and anaemia. Copper, often found in river sediment, is also toxic to fish and most aquatic plants. The lethal concentration for freshwater fish is around 0.1mg/l, particularly where zinc and cadmium are present, but is also dependent on the water hardness (HÜTTER 1984). As copper easily dissolves in water, it is more available for uptake by living creatures along rivers. The EPA reports that the activation level for copper is 1.3mg/l.

Lead (Pb)

Lead is poisonous in all forms and can be found in all parts of the environment. In recent years, health concerns have forced a dramatic reduction in the use of lead in gasoline and paints. Lead is one of the most hazardous of the toxic metals because the poison is cumulative and the effects are many and severe. Lead oxide is more toxic than metallic lead or other less soluble compounds.

Lead can affect almost every organ and system in an organism. Relatively low levels of exposure can interfere with red blood cell chemistry. In humans it causes a delay in normal physical and mental development, produces deficits in attention span, hearing and learning abilities of children and slight increases in blood pressure in some adults. Studies show that some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neuro-behavioural development, may occur at blood lead levels so low as to be essentially without a threshold. Chronic exposure to lead has been linked to brain and kidney disease and cancer in humans. Lead causes a host of serious effects in mammals in general, including: blindness, haemorrhaging, depressed food intake and anorexia, reduced brain weight and cerebral pathology, convulsions, impaired motor skills, impaired visual discrimination and learning behaviour, abnormal social behaviour, increase in aggression, hyperactivity, disturbed sleep patterns and insomnia, reproductive impairment, increased foetal deaths and abortions and reduced survival and longevity. The acute toxicity of lead for fish is 0.2-3.1mg/l (HÜTTER 1984). According to the EPA, the activation level by content of lead in drinking water is 0.015mg/l.

Zinc (Zn)

Zinc is one of the most common elements in the earth's crust. It is found in air, soil and water and is present in all foods. While most zinc in soil stays bound to soil particles, zinc compounds can also move into groundwater, lakes, streams and rivers.

Zinc is an essential element in human diet - but only in moderate doses. The recommended dietary allowance is 15mg/day for men, 12mg/day for women, 10mg/day for older children and 5mg/day for infants. Exposure to higher levels, even briefly, can cause stomach cramps, nausea, and vomiting. Long-term over-use of zinc produces conditions such as anaemia, pancreas damage and lower levels of high-density lipoprotein cholesterol.

Relationship between cyanide and heavy metals

Except for the simple cyanide compounds consisting of a single metal ion in combination with CN^-, all readily soluble cyanide complexes are of different types, considering their solubility. The metal-cyanide complexes, which are commonly formed in mining effluents are:

- zinc and cadmium cyanides (weak complexes);
- copper, nickel and silver cyanides (moderately strong complexes);
- iron, cobalt and gold cyanides (strong complexes).

When metal-cyanide complexes are formed and released into the near surface environment, they begin to decompose at varying rates. This breakdown releases cyanide into the soil or water, generally at relatively low concentrations. Those complexes that most readily decompose are referred to as weak complexes; those most resistant to decomposition are called strong complexes. Some of the strong complexes do not break down in the presence of strong acids, but will decompose when exposed to various wavelengths of light, releasing cyanide ions. This is especially true of the iron cyanides, which are often the most common forms of these complexes found in mining wastes. The water temperature, pH, total dissolved solids and complex concentrations affect the decomposition rates of these complexes. Cyanide in mining solutions can undergo several types of reaction to form various toxic cyanide related compounds (MORAN 1998).

Metal-cyanide complexes are generally considered to be less toxic than free cyanide. The complexes break up and form HCN, which is the usual cause of toxicity. Some metal cyanide complexes including silver, copper and nickel cyanides may themselves be toxic. Iron cyanide complexes are not particularly toxic, but release free cyanide on exposure to sunlight (MORAN 1998). Heavy metals can have high concentrations in fish and enter the food cycle of fish-eating birds and mammals.

4. The chemical spill at the Sandoz factory, near Basel on the River Rhine

……………………………………………………………………………………………..

One of the most significant chemical accidents to date, the result of a major fire, occurred on 1 November 1986, in the Sandoz factory at Schweizerhalle near Basel (Switzerland), located on the Rhine. Despite the fact that the pollutants involved were different in this case to those at the Aurul spill, the consequences on the ecosystem can be compared (the death of an enormous quantity of fish and the extinction of / heavy damage to aquatic life in the polluted river stretch. Therefore a comparison with the Sandoz accident seems to be appropriate.

During the Sandoz accident around 30 tonnes of pesticides, in particular phosphoric acid ester-based insecticides (disulfoton, thiometon, etrimphos and propetamphos) as well as organic combinations of mercury, flowed into the Rhine, along with the water used for fire fighting. This produced an environmental disaster with considerable consequences for the biocoenosis in the river. A number of immediate (within a few hours) and short-term (after 10 days) consequences for the Rhine were evident including:

- Death of an enormous quantity of fish;
- Extermination or considerable damage to other aquatic life, in particular benthos species (the food basis for fish) right up to the mouth of the main river;
- Danger for drinking water;
- Threat to all possible uses of the water.

From the site of the accident (Rhine - km 159 counted from the spring) to km 560 in the river itself, as well as lateral flow in former arms, the entire stock of Eel (*Anguilla anguilla*) was exterminated. At km 640 extreme damage to fish was observed. On the Upper Rhine stretch of Switzerland and Baden-Württemberg, damage to the populations of Grayling (*Thymallus thymallus*), Pike (*Esox lucius*), Burbot (*Lota lota*), Brown trout (*Salmo trutta fario*), Zander/Pike-perch (*Stizostedion lucioperca*), White bream (*Blicca bjoerkna*) and Barbel (*Barbus barbus*) were registered (HEIL 1990, MÜLLER & MENG 1990). In the Swiss stretch of the Rhine, at the point at which the spill entered the river to upstream Basel, the river was practically devoid of all fish.

Concerning zoobenthos close to the accident location, from km 159 to km 174, the total extermination of flatworms, leeches, mussels, snails, freshwater shrimps (*Amphipoda*) and caddis-fly larvae (*Trichoptera*) was observed. Considerable damage to the benthos populations were recorded in the southern Upper Rhine stretch (km 174 to km 200) and the Alsacia side canal (km 174 to km 227) - from a total absence of some groups of organisms (freshwater shrimps (*Amphipod*a) and caddis-fly larvae (*Trichoptera*)) to much reduced populations of others (e.g. snails). Only in some places with a high inflow of groundwater were the damages reduced (DK 1986). In the middle and northern part of the Upper Rhine, as well as in the Middle Rhine, damage to macrozoobenthos was clear but different groups of organisms were affected to varying degrees. In the Rhine stretch from km 227 to 429 (the confluence with the River Neckar) the settling of flatworms, mussels and caddis-fly larvae (*Trichoptera*), and to a lesser degree freshwater shrimps, was very reduced (DK 1986). One year later, populations of most groups of the macrozoobenthos examined showed resettling had more or less taken place, with a small reduction in the number of specimens. The most affected group was caddis-fly larvae (*Trichoptera*), with a highly reduced amount of resettling in the first 50km from the point of the chemical spill and with further, smaller, reductions in specimen numbers up until km 360-400.

Regarding fish numbers, despite the fact that eels were killed and fish heavily affected downstream of the spill, it has been concluded that one year after the incident, the same fish species were present in the river as previously, although in reduced numbers. The results of 1987 surveys on the Swiss stretch of the Rhine (one year after the spill) indicate a gradual build-up of fish populations to approximately pre-accident levels, with the exception of Brown trout, Grayling and Burbot (MÜLLER & MENG 1990). Eels, which had been wiped out over several hundred kilometres, were found to be more or less as abundant (in the survey area near Basel) as they were before the accident, probably the result of downstream migration from unaffected areas. To assist the regeneration of eel stocks, a resettling programme has been established, with the aim of achieving pre-spill stocking levels in 7 – 8 years (HEIL 1990).

5. The ecological effects of the Tisza mining spills

The graphic pictures of dead and dying fish that were shown in newscasts in the days after the Baia Mare spill were evidence of the seriousness of the accident's ecological consequences. In contrast, the Baia Borsa spill in early March did not have such visible consequences; although more subtle and long-term consequences were feared by national and international experts as a result of the nature of the pollutants involved (heavy metals). While there was much speculation at the time of the incidents about the ecological impact of both accidents, it was very difficult to predict the long-term consequences.

Now, two years on from the time of the disasters (and with two vegetation periods completed), a clearer picture is emerging as to the consequences of the cyanide accident. Unfortunately there is much less data available on the effects of the heavy metal spill at Baia Borsa and, while it appears to have had a much more local effect, the long-term consequences for the ecosystem – bioaccumulation[8] – may be significant.

5.1 Species as indicators for ecological conditions

Since species react with varying sensitivities to the changing environmental factors of an ecosystem, they are good indicators for changes in the quality of a habitat. Species with larger ecological amplitudes are less sensitive than those specialised species with a smaller ecological amplitude. Ecological changes are not only caused by natural dynamics, but also by the chemical and biological quality of the water, which can lead to important changes in habitat and disturbance to the whole ecosystem. In combination with other species of benthos, mussels (*Unio sp.*) and snails which live on the bottom of the river are good indicators of water quality and living conditions. Species from different benthos groups are important for the evaluation of changes to a river system since they form the basis of the food chain.

The different toxicity of substances and the varying reactions of organisms to them have important impacts on ecosystems. Experience from the afore-mentioned toxic spills and river pollution incidents, such as the Sandoz poisoning on the Rhine near Basel, has shown that the highest sensitivity to toxics was observed among fish species with small ecological amplitudes: benthos and in particular caddies-fly larvae (*Trichoptera*), freshwater shrimps (*Amphipoda* - especially *Gammaridae*).

Some sensitive species observed during the Sandoz accident, including trout species (*Salmonidae*), Burbot (*Lota lota*) and Zander/Pike-perch (*Stizostedion lucioperca*), were also found on the Tisza.

[8] Bioaccumulation: accumulation of substances, such as toxic chemicals, in tissue which consequently build up in the food chain.

The monitoring and analysis of species and their reaction to pollution provide possibilities for evaluating the dimension of the poisoning incidents and allow a prediction of the time required for recovery, as well as an analysis of the needs of the system.

The following section summarises the data and information that is available on the consequences of the cyanide spill and suggests measures that are needed to continue to monitor the effects and to assist in revitalisation.

5.2 The impacts on the ecosystem

It is well established that an ecosystem is made up of a number of interacting parts, all of which are inter-dependent with one another. Fish such as pike, for example, cannot survive without smaller fish to feed on, and those smaller fish, in turn, are dependent upon zooplankton or aquatic insects as their food source. Further up the food chain, the White-tailed eagle (*Haliaeetus albicilla*) requires a steady supply of fish in order to survive and raise its young.

A large number of fish (an estimated 1,242t in Hungary) were visibly affected by the cyanide spill, but it is essential to look at the different elements of the ecosystem to gain an overall picture of what happened. Available information can be grouped according to four main categories: (1) Plankton, (2) Benthos, (3) Fish, (4) Birds and Mammals.

In addition, it is perhaps useful to state that the consequences of the solid cyanide incident differ significantly from the consequences of the Baia Borsa spill. It is also evident that not all parts of the River Tisza ecosystem were equally affected. Those stretches of the river closest to the pollution source likely suffered the greatest impact. The areas of the ecosystem affected by the spill can be grouped into five different sections:

1) River Szamos system: from Baia Mare (Romania) to the confluence of the Szamos and the Tisza (Hungary);
2) Upper Tisza system: from Baia Borsa (Romania) to the confluence with the Szamos and down to Tokaj (Hungary);
3) Middle Tisza: Tokaj (Hungary) to the confluence with the Crisuri/Körös near Csongrád (Hungary);
4) Lower Tisza: from Csongrád (Hungary) to the confluence of the Tisza and the Danube (FRY);
5) The Danube itself (FRY, Romania, Bulgaria, Moldova, Ukraine).

Plankton[9]

Plankton in the Szamos and upper Tisza in Hungary (the areas closest to the source of the cyanide pollution) were completely eliminated (100%) by the cyanide metal

[9] Plankton: microscopic animals (zooplankton) and plants (phytoplankton) which live and drift in water and are eaten by many aquatic animals.

pollution that resulted from the Baia Mare spill. This has been clearly demonstrated by samples taken near the pollution source on the Lapus and Szamos rivers by Romanian water authorities (see Table 6).

Table 6: Plankton measurements in the Lapus and Szamos rivers before and after the spills.

		before 17.11.99		during the spill 01.02.00		after the spill 16.02.00		22.02.00		20.04.00		19.07.00	
		Lapus/ Busag	Somes	Lapus/ Busag	Somes Satu Mare	Lapus/ Busag	Somes Cicarlau	Lapus/ Busag	Somes Cicarlau	Lapus	Somes	Lapus	Somes
Phytopl./l	Specimens	220 000	990 000	-	-	80 000	120 000	120 000	760 000	210 000	1 210 000	410 000	1 750 000
	Species	6	22	-	-	7	12	7	18	8	20	8	22
Zoopl./l	Specimens	4	9	-	-	6	10	3	7	1	25	5	12
	Species	2	5	-	-	3	6	2	2	1	5	2	4

In the middle and lower stretches of the Tisza, where there are both lateral river branches and tributaries bringing clean water into the Tisza, cyanide concentrations were lower. As a result, the immediate death rate of phyto- and zooplankton was also lower: 40-80% of the population during the plume passage. The Hungarian laboratories (Upper Tisza Regional Environmental Inspectorate Laboratory and the Lower Tisza Regional Inspectorate Laboratory) used biological tests (*Daphnia* test) to analyse the Tisza water during the cyanide plume . The water was found to be acutely toxic to *Daphnia magna* during the plume. The mortality was 100% during the maximum cyanide concentration. Previous routine tests from 1999 showed a mortality rate of 0-30% in the *Daphnia* test (UNEP/OCHRA 2000). These results also indicate that under "normal" conditions, the water of the Tisza is toxic to *Daphnia*.

By the time the pollution reached the Danube, it was so diluted that the death of phytoplankton and zooplankton was not observed.

In the days following the plume, the phytoplankton and zooplankton began to recover in both numbers and species composition throughout the entire river system. Samples taken on 16 February, 2000 at Busag on the Lapus river and at Cicarlau on the Szamos river (see Table 6) demonstrated the fast recovery process: the number of species of phytoplankton was recorded at 80,000 specimens/l (compare with a figure of 220,000 specimens/l at the same place before the spill). At Cicarlau the figure recorded was 120,000 in comparison with 990,000 specimens/l before the spill. One week later, the number of specimens measured had doubled at Busag and reached 50% of the pre-spill quantity. Downstream on the Szamos near Cicarlau, the number of specimens was measured at 760,000 specimens/l on February 22 - more than six times higher than one week previously, but still below the level recorded before the spill.

Current sampling indicates that the number and species composition of phytoplankton has now returned to normal on all river stretches. A major factor which appears to have assisted the recovery was the warm weather and flooding which occurred in March 2000 and presented ideal conditions for plankton growth. The fast recovery of the phytoplankton, which was supported by the high water levels, demonstrates the importance of active floodplain areas connected to the river. The floodplains served as a pool for unaffected species of phytoplankton, which then re-colonised the flowing river and sped up the recovery of the river system. This positive role of floodplains on biocoenosis was proved scientifically after the poisoning of the Rhine (OBRDLIK 1992).

Benthos[10]

Insects and other organisms (i.e. molluscs and crustaceans) which inhabit the bottom of a river are an essential component of the ecosystem and particularly vulnerable to chemical pollution.

Results of research in the area indicate that considerable mortality occurred among molluscs and other benthic organisms in the upper reaches of the Szamos. It appears likely, however, that some species may already have been reduced in numbers in this region through pollution that had occurred over many years (VITUKI 2000 a, b, HAMAR & SÁRKÁNY-KISS 1999). The fauna of the river has been further damaged as a result of the cyanide pollution. No species of molluscs were identified in samples collected in the Szamos, and numbers of leaches (*Hirudinea*) and crustacean fauna were found to be very poor during the investigation. The insect fauna was also found to be very low during investigations at the end of February 2000 (VITUKI 2000 a).

The findings of the UNEP report (UNEP 2000) stated "that the ecological state of the benthic organisms in the middle and lower Tisza region in Hungary and Serbia and Montenegro were not destroyed by the cyanide spill in a catastrophic manner." However, the situation in the upper Tisza is more complex, as described in this report.

In the middle and lower stretches of the river (Hungary and FRY), the benthic organisms appear to have survived the cyanide spill, although there is evidence that many organisms suffered reduced numbers as a result of the pollution.

In samples taken by the Hungarian Research Institute VITUKI (VITUKI 2000 b) "considerable influence on the macroinvertebrate fauna[11] of the rivers" (Tisza and Szamos) was found. The group with the most sensitive reaction was the crustaceans, where in some cases the death of over 50% of the existing populations was observed.

Of great relief, and of significance as an indicator of ecosystem conditions, was the survival of the endemic mayfly, the Tisza flower (*Palingenia longicauda*), which hatched in large numbers this summer throughout much of the Tisza river system. The conditions for hatching were apparently ideal following the spring floods and, as the cyanide appears to have been concentrated in the main channel of the river, the larvae survived and were able to hatch. Adult specimens of the Tisza flower and

[10] Benthic organism: organism living on the bottom of a river, lake or sea.
[11] Invertebrate: animal which has no backbone

other insects appeared in high numbers – probably due to the fact that numbers of fish had decreased and so predation was reduced.

However, in general it appears that the populations of macroinvertebrates were detrimentally affected by the spill, although not completely eliminated as originally feared. The recovery in the diversity of species and numbers progressed rapidly during the first growing season following the spill and continued in the second year.

Fish species

The visible death of fish provided a clear indication of the spill's consequences. Hungarian authorities report that a total of 1,242 tonnes of fish were killed as a result of the cyanide spill. Of this amount, 33.8% were predatory fish, 13.5% carp, 8.1% sturgeon, and 44.6% herbivorous and other fish. The dead fish collected included nearly all species known to be present in the river. It is clear, however, that not all fish were equally affected. The highest numbers of dead Bream (*Abramis brama*) and Ide (*Leuciscus idus*) were found at Csongrád (Hungary), where the numbers of Carp (*Carassius carassius*) were smaller (SALLAI 2000). Dead examples of species with high sensitivity to poisoning, such as the Zander/Pike-perch (*Stizostedion lucioperca*), were found in high numbers in all the samples along the river.

Many dead specimens of Zingel *(Zingel zingel*) have been found by Hungarian fishermen in the Kiskunság National Park and also on the stretch between Mindszent and Mártély (VITUKI 2000 c). In addition other sensitive species were found including Danube ruffe (*Gymnocephalus baloni*), Schraetzer (*Gymnocephalus schraetzer*), Burbot (*Lota lota*), Abramis species (*Abramis brama, A. sapa*), Perch (*Perca fluviatilis*) and Silver Carp (*Hypophthalichthys molitrix*).

Herbivorous fish, e.g. the non-native Silver carp (*Hypophthalichthys molitrix*), seemed to be particularly vulnerable to the cyanide due to the fact that they are active in winter, and consequently made up a large percentage of the fish that died. However, one should bear in mind that this fish has been artificially introduced to the Tisza fish communities. As is the case with many introduced alien species, the Silver carp interfered with the natural composition of the fish communities. Despite the economic loss, from an ecological point of view, this situation can be viewed as an opportunity for the restoration of more natural fish communities in the Tisza.

With reference to the poisoning effect of the cyanide and its immediate impact after the spill, it was feared that some endangered and threatened species could have been totally eliminated by the toxins. This category includes the Danube salmon (*Hucho hucho*) and the highly threatened sturgeon species (*Accipenser güldenstaedti* and *A. nudiventris)* which, even before the spill, occurred in very small numbers. Unfortunately no scientifically based analysis exists about the effects of the spills on these species.

One has to consider that the elimination of a certain fish species leaves an "empty niche" in the river ecosystem. This niche will be closed quickly by another fish species; therefore, the species ratio will be changed and some vulnerable species may be considerably damaged (by not being able to compete with more “aggressive” species) or may, in fact, be favoured.

The number of specimens of the sturgeon *Accipenser ruthenus* decreased. But according to HAMAR & SÁRKÁNY-KISS (2000) this decrease in populations in the Szamos is not only explained by the recent cyanide spill. Its decline is a result of a slow but constant deterioration of water quality in previous decades.

Another species of significance is the Zingel (*Zingel zingel),* a protected species in Hungary. On the Upper Tisza, along a stretch of only 3km, nearly 300 dead specimens were found immediately after the spill, but living specimens were also noted, giving hope for recovery (SALLAI 2000). The Danube salmon (*Hucho hucho*), a typical species of clear, fast flowing and oxygen-rich rivers, was also thought to have been strongly affected by heavy metal pollution (arising from the spill as well as earlier pollution incidents). The fish die either as a result of direct poisoning or from the fine sludge which blocks their gills and causes suffocation (personal communication with Mr. I. Beres).

Close to the tailing dam in the Lapus river at Bozanta Mare, fish numbers were found to be the poorest compared to all other sampled sections. Only six species (including Chub (*Leuciscus cephalus*), Bleak (*Alburnus alburnus*), Goldfish (*Carassius auratus gibelio*), Gudgeon (*Gobio gobio*, *Gobio albipinnatus)* and Bitterling (*Rhodeus sericeus*)) were identified, all with a reduced number of specimens (HAMAR & SÁRKÁNY-KISS 2000). Except for the last two, these fish are ordinary, ubiquitous species, with a large ecological variety. The Goldfish, despite being a non-native species in European freshwater ecosystems, has been naturalised for a long period. This species is replacing the Crucian carp (*Carassius carassius*) which has become very rare in recent years.

These species may have entered the main river stretch after the water quality improved, from the section which was unaffected by the contamination. The low percentage of juvenile specimens in the section surveyed indicates that these species have not multiplied successfully in recent times.

Downstream, at the confluence of the Lapus and Szamos, only 11 fish species were found, with 138 specimens in total. More than 50% of the species found are normally ubiquitous with a large ecological amplitude and high adaptability, with the Chub (*Leuciscus cephalus*) being dominant. This can be explained by the high adaptability of the species very early-on after the drastic contamination. Characteristic species for this river stretch, such as *Chondrostoma nasus,* Asp (*Aspius aspius*) and Barbel (*Barbus Barbus*) made up 26% of the samples. This is due to fact that these species are the most efficient at utilising food in this part of the river and they quickly occupied these river sections after the spill.

Two years after the incidents, it has been stated that none of the fish species recorded prior to the spill in the Rivers Tisza and Szamos have become extinct (WWF-Hungary 2000, a, b). But considerable damage has been done to populations of Burbot (*Lota lota*) and Pike-perch/Zander (*Stizostedion lucioperca*). Protected species, including the Zingel (*Zingel zingel),* survived the pollution.

One should bear in mind that artificial reintroduction of certain non-native, but economically important species, following the accidents might result in a negative impact on the already damaged populations of sensitive fish species. For the native species there is no need for artificial reintroduction - the young specimens of these species are a good basis for the regeneration the population. The 2000 and 2001 spring floods on the Tisza and the connectivity to floodplain waters also contributed to the regeneration of the species. However, the future species composition will be determined by the re-colonisation pattern and competition.

Investigations in the Federal Republic of Yugoslavia (FRY) indicate that fish populations do not seem to have been significantly affected by the spill (SIMONOVIC 2000). Some dead and dying fish were recovered in FRY. But three species of fish (the Common carp, *Cyprinus carpio*; Pike-perch/Zander, *Stizostedion lucioperca* and Silver carp or White bighead, *Hypophthalichthys molitrix),* that were examined in detail in a study prepared for WWF, showed no major population alterations (SIMONOVIC 2000). The study found that "only the stock of Zander, should be considered less that the previously reported, whereas both White bighead, and Carp, in fact, remained approximately the same or only slightly less." It also notes that "it is realistic to consider the recent decrease in Zander biomass is a consequence of cyanide pollution."

The strong effect of the cyanide on Pike-perch/Zander probably occurred due to both its strong sensitivity to cyanides and its high activity during the winter months. In contrast to Zander, fish of other species (excluding the Silver carp/White bighead) were less active at this time and would have retreated to over-wintering places with greater depth and calmer water current. They were therefore mainly out of reach of the cyanide toxic wave (SIMONOVIC 2000).

There exist no reports or any other evidence that fish in the Danube died as a result of the cyanide poisoning. The concentration of cyanides in the Danube was below the limit of tolerance for fish species. It is believed that the dead fish specimens found in the Danube were flushed downstream from the Tisza. In addition, further downstream on the Danube, on the Romanian and Bulgarian stretches, no specimens of dead fish were registered.

One of the important questions that emerged following the accident was why were there not more dead and dying fish observed near Baia Mare and on the Szamos river system in Romania. The explanation appears to lie in the fact that the ice-cover prevented dead and dying fish from being seen and that these were then washed downstream to Hungary where they were collected. In addition, it seems that on-going pollution of this section of the river had reduced the number and diversity of fish. It is also thought that the ice-cover presented ideal conditions for compounding the effects of cyanide[12] and that this deadly combination would have been most significant in the Tisza section of Hungary.

12 Due to the ice-covered stretches, the oxygen content of the river would have been reduced.

Birds and Mammals

Immediate observations of the effects of the pollution on birds and mammals were limited. Only a few dead birds such as the White tailed eagle (*Haliaeetus albicilla*) in Hungary and the Black-headed-Gull (*Larus ridibundus*) in the Federal Republic of Yugoslavia (FRY) were found. In addition, a few dead birds including two Cormorants (*Phalacrocorax carbo*), three Herons (*Ardea cinerea*) and three Black-headed-Gulls (*Larus ridibundus*) were found near the river bed at Becej in FRY in March, but the cause of death was not determined (PUZOVIC 2000).

The ability of mammals and birds to sense the presence of cyanide, the fast removal of the dead and dying fish and the presence of the ice-cover on parts of the river, probably prevented substantial contact with the pollution.

According to direct observations by Hungarian scientists and conservation groups, two specimens of White tailed eagles were poisoned by the cyanide. One died, but the other received care and survived.

The long-term effects on birds would probably be more significant in relation to reduced breeding success as a result of reduced food supply. The initial evidence from Romania, Hungary and the Federal Republic of Yugoslavia, however, is that no detectable signs of population loss can be determined among the species considered the most sensitive.

Studies of species presumed to be sensitive to the loss of their food-base through the spill in both Hungary and FRY found little evidence that major population loss has occurred. It seems these species, including Great cormorants (*Phalacrocorax carbo*), White storks (*Ciconia alba*), Black storks (*Ciconia nigra*), White tailed eagles (*Haliaeetus albicilla)*, Sand martins (*Riparia riparia*) and Kingfishers (*Alcedo atthis)*, have found sufficient food from the river or alternative sources, for instance fish ponds not affected by the spill. Greater insect numbers in the river even resulted in higher numbers of various insectivore birds.

At the top of the of the river system food chain are Otters (*Lutra lutra*). Studies and specimen counts of Otters on the Tisza indicate that the population relocated to other areas. Only two dead specimens were found immediately after the spill. Between February 2 and August 31, 2000, monitoring for the presence of Otters took place along the Szamos and Tisza rivers, with positive results on 97 and 259 occasions respectively.

As mentioned above, some of the active animals sensed the danger posed by the presence of the chemicals and migrated temporary from the region. This was clearly detected in the case of Otters, which moved from the Tisza to the nearby channels and creeks, where they had not previously been detected (in some cases they relocated as far as 30-40km away from their original habitat). Three to four weeks after the cyanide pollution, some Otters appeared to return to the main river and as of July and August 2000, it was estimated that the original density of Otters was re-established. The population was also monitored in 2001, the second year after the spill, and results showed that the population status was very good and that numbers have returned to the pre-spill figures.

Studies of Pond bats (*Myotis dasycneme*) also found that, despite the presumed reduction in numbers due to reduced food supply, the population may have increased during the past summer. One explanation seems to be that the reduced pressure from fish on insect populations may have made more food available for bats. One study has shown a significant increase in heavy metals concentrations in the excreta of bats compared with previous years, but more detailed analysis is needed (WWF 2000 a, b).

It is worth noting that during the timing of the pollution incident, many species would have been inactive (e.g. certain fish and amphibian species) or away from the region (e.g. bats).

6. Conclusion and final remarks

- The mining spills in the Tisza basin caused a drastic decrease in water quality, heavily affecting the upper stretch, but also the middle and lower stretches of the River Tisza. There is considerable evidence that some species of fish and benthos in this region may have been affected by previous pollution and were therefore very vulnerable to further stress.

- The two accidents resulted in high concentrations of cyanide and heavy metals in the water. Free cyanide is a poison whose effects are immediate for the organism, but not bio-accumulative or long-lasting. Heavy metals, on the other hand, are bio-accumulative with consequences that are often less immediate and direct for individual organisms.

- Different parts of the ecosystem were clearly affected in different ways by the cyanide spill. On the upper Tisza stretch the spill caused massive reductions in populations of fish, benthos (bottom fauna) and plankton. However, several species were inactive at this time (e.g. some fish species and amphibians) or had moved to other areas (e.g. Otter), which minimised the effects on these species.

- For some threatened or vulnerable species of fish, the pollution may have been very significant, e.g. for juvenile fish and species such as Pike-perch/Zander (*Stizostedion lucioperca*). However, no species are known to have been completely eradicated. None of the Protected Areas along the Tisza were affected in the long-term and the endemic mayfly (*Palingenia longicauda)* was also not severely affected.

- In the middle and lower sections of the Tisza, whilst there was clearly significant damage to some populations of fish and benthos, the ecosystem appears to be recovering well. In the lower stretch of the river, these impacts were considerably reduced and in the Danube itself, were not detectable.

- In general, it can be said that the entire system has shown a high degree of resilience. Favourable conditions following the pollution event and the recruitment from tributaries and side-arms unaffected by the cyanide have contributed to the re-colonisation of those areas where damage occurred. How complete the spectrum of species is for each group and the exact status of the populations can only be answered through long-term monitoring in the affected areas.

- It is likely that the resilience and recovery rate shown in the ecosystem were dependent on the condition of the floodplain (i.e. the existence of open water bodies, wetlands, lateral branches and old channels), its connectivity with the river and the cleaning and biological input from tributaries. Additional restoration of floodplains may therefore further enhance these.

- Of importance is the effect of the release of high quantities of heavy metals on the ecosystem. Their impact varies from substance to substance; the medium and long-term impact can only be analysed over a certain time period. On a long-term basis, the impact of heavy metals on the ecosystem might be larger than the direct impact caused by the cyanide, due to the fact that heavy metals build up in the food chain over time. Therefore it is crucial that a long-term monitoring programme, co-ordinated between the countries, is carried out.

7. Recommendations

....

In order to get a more comprehensive picture of the ecological effects of the accidents, long-term monitoring is needed. Particular attention should be given to the long-term effects of bio-accumulative heavy metals and hardly soluble cyanide-heavy metal complexes and also the stress experienced by species from long-term pollution. As has been stated (VUJANOVIC, PLAMENAC, RAZIC & SIMONOVIC 2000), fish mainly accumulate heavy metals in the liver, bones and muscles. An analysis which was carried out after the spills demonstrates clearly that the content of heavy metals found in species was the result of long-term accumulation caused by continuous exposure to pollution over the last decades.

<u>In order to gain a comprehensive picture of the long-term ecological effects of the spills, the following activities are necessary and recommended:</u>

- Permanent survey of the water quality of the rivers using chemical and biological methods;

- Analysis of river sediments;

- Long-term monitoring of various categories of macrozoobenthos;

- Long-term monitoring of fish species (including threatened species) and fish populations (including analysis of the structure of fish populations);

- Long-term monitoring and survey of insects (Tisza mayfly), fish eating birds (Kingfisher), insect eating birds (Sand martin) and mammals (Otter, bats);

- Long-term monitoring of the soil in the neighbourhood of the tailing dams including grassland, gardens and other grazing areas;

- Long-term monitoring and survey of the agricultural products of the region (including beef, diary etc.).

In order to gain a comprehensive picture of the general situation in the Tisza basin (to assist in the prevention of such accidents), the following activities are recommended:

- Development and adoption of a common methodology for hydrological and hydro-chemical observations (with chemical-analytical methods) as well as for data processing. This is the only way to develop the basis for a computer model of the river (computer useable data) and to elaborate a common GIS[13] for the entire Tisza river and its tributaries in the future.

- Further development of the warning and alarm system for accidents. This should be based on a common methodology on international criteria throughout the basin.

- Undertaking of additional security measures for factories processing hazardous material.

- Optimising the Tisza countries' monitoring network (covering Romania, Ukraine, Slovakia, Hungary and the Federal Republic of Yugoslavia) by enhancing the exchange of hydrological information and other data concerning the river.

- Optimising monitoring activities throughout the entire Danube river basin on the basis of basin-wide agreements.

- Ensuring that monitoring of bio-indicators (selected, sensible reacting organisms or groups of organisms) is included in the international trans-boundary monitoring programme, in addition to hydro-chemical factors.

- Increasing the capacity of pollution reduction and retention areas for flooding by ensuring protection of the valuable floodplain areas through a common, trans-boundary concept for protection and sustainable use.

- Ensuring that activities are undertaken to inform the public and raise general awareness. According to public opinion in Baia Mare, it is very important to enter into dialogue with responsible persons from the relevant companies in order to gain information about the current situation and possible dangers and also to create an 'environmental conscience'.

- Considering the role played by floodplains in the restoration of river biocoenosis (OBRDLIK 1992), a detailed analysis of the current status of floodplains along the Tisza and its tributaries (including the potential for restoration) is important. Following the results of the study concerning the evaluation of the ecological restoration potential of the Danube and its tributaries (UNDP/GEF 1999), the potential for restoration on the Tisza can also be demonstrated. (Such a study

[13] Geographic Information System

should be carried out in a more detailed way and be extended to include the main tributaries of the Tisza).

In the context of developing restoration concepts, it is important to analyse the possibilities for the improvement of the connectivity between the Tisza river itself and the floodplain area, as well as the connectivity between the main river and its tributaries. The restoration of floodplains can increase the regeneration potential for the Tisza river. The enlargement of floodplains has the same effect as improvement of river connectivity. In the long-term, this can be seen as one of the most important measures.

After the Sandoz chemical spill (Basel, Switzerland), the factory responsible created a foundation for financing recovery activities for the damaged river and research to ensure scientific guidance of the process and compensation. The Rhine has benefited greatly from these measures. These kinds of efforts are also highly recommended to Esmeralda, the Australian partner of the Aurul Mine, in assisting the recovery of the region. This activity should be pursued through national policy as well as through requests by the public.

8. References

8.1. Contacts for further information

WWF International
Danube-Carpathian Programme
Mariahilfer Str. 88 a/3/9
A – 1070 Vienna, Austria
Tel. +43 (0) 1 523 54 70
Fax. +43 (0) 1 523 54 70-70
office@wwfdcp.org
www.panda.org/danube-carpathian

WWF Germany
Institute for Floodplains Ecology
Josefstraße 1
D – 76437 Rastatt, Germany
Tel. +49 (0) 7222 3807-0
Fax. +49 (0) 7222 3807-99
auen@wwf.de
www.wwf.de

WWF Hungary
Németvölgyi út 78/b
H – 1124 Budapest, Hungary
Tel. +36 (0) 1 214 5554
Fax. +36 (0) 1 212 9353
panda@wwf.hu
www.wwf.hu

8.2. Literature

- Baia Mare Task Force Report (2000) Ed.: Report of the Baia Mare Task Force for Assessing the Baia Mare Accident, Brussels, Belgium.
- DISTER, E. (1994): The Function, Evaluation and Relicts of Near-Natural Floodplains. - Limnologie aktuell, Vol. 2, Kinzelbach (Hg.): Biologie der Donau, Gustav Fischer Verlag Stuttgart, Jena, New York.
- DK (Deutsche Kommission zur Reinhaltung des Rheins Ed.) (1986): Deutscher Bericht zum Sandoz-Unfall. December 1986, Deutschland.
- DOBROSI, D.L.; HARASZTHY, H.; SZABÓ, G. (1993): Magyarországi árterek természetvédelmi problémái (The Nature Conservation Problems of Hungarian Floodplains).- WWF-Füzetek, 3, Budapest, Hungary.
- GASTESCU, P. (1990): Fluviile Terrei (The Rivers of the Earth).- Editura Sport-Turism, Bucurest, Romania.
- HAMAR, J.; SARKANY-KISS, A. (1999) Ed.: The Upper Tisa Valley: Preparatory Proposal for Ramsar Site Designation and an Ecological Background Hungarian, Slovakian and Ukrainian Co-operation.- Tisza Club and Liga Pro Europe. TISCIA monograph series. Szeged, 502 pg., Hungary.
- HAMAR, J.; SARKANY-KISS, A. (2000): Biological Consequences of the Cyanide Spill in the Affected Rivers in Romania and Hungary with Respect to the Study of

Molluscs, Fish and the Tisza Mayfly.-Tisza Club and Liga Pro Europe. 24 pg., Hungary.

- HEIL, K.H. (1990): Die Auswirkungen des Sandoz-Unfalles auf die Biozönose des Rheins.- Limnologie Aktuell, Bd. 1 Biologie des Rheins: 11-26.- Gustav Fischer Verlag Stuttgart. New York.
- HÜTTER (1984). Wasser und Wasseruntersuchungen. -Verlag Sauerländer Salzburg.
- KNIJFF, L. M.; VERMIJ, P.H.M.; ZWOLSMAN, J.J.G. (2000): The Riza Mission on the Aurul Accident, Baia Mare, Romania, Directoraat-Generaal Rijkswaterstaat, 62 pg. Netherlands.
- KOCH, R. (1989): Umweltchemikalien. Physikalisch-chemische Daten, Toxizitäten, Grenz- und Richtwerte, Umweltverhalten.- VHC-Verlag Weinheim, New York, Cambridge, Basel, pp. 423.
- LIEPOLT, R. (1967) Hrsg.: Limnologie der Donau. Eine monographische Darstellung.- Schweitzerbartsche Verlagsbuchhandlung Stuttgart, Deutschland.
- MORAN, R.E. (1998): Cyanide Uncertainties – Observations on the Chemistry, Toxicity, and Analysis of Cyanide in Mining-Related Waters.- Mineral Policy Center Issue Paper No.1, Wash., D.C.
- MÜLLER, R.; MENG H. J. (1990): The Fate of the Fish Populations in the River Rhine After the Schweizerhalle Accident.- Limnologie Aktuell, Bd. 1, Biologie des Rheins: 405-421, Gustav Fischer Verlag Stuttgart.New York.
- OBRDLIK., P. (1992) Hrg.: Regenerierung der Rheinbiozönose durch Auengewässer (Schlußbericht).- Im Auftrag des „Rhein-Fonds“ der Firma Sandoz AG Basel, WWF-Auen-Institut Rastatt, pp. 100.
- PUZOVIC, S. (2000): Influence of Cyanide and Heavy Metal Pollution of Tisza in FR Yugoslavia on Bird Fauna.- The Institute for Protection of Nature of Serbia, 14 pg., FRY.
- REGIONALE ZUSAMMENARBEIT DER DONAULÄNDER (1986): Die Donau und ihr Einzugsgebiet. Eine hydrologische Monographie.- Deutsche Gewässerkundliche Mitteilungen Band 33- München, Deutschland.
- SALLAI, Z. (2000): Summary of the Impacts of the Cyanide Spill from the Nature Conservation Point of View,.-6 pg., Hortobágy National Park, Bükk National Park, Kiskunság National Park, Körös-Maros National Park, Hungary.
- SCHNEIDER, E. (2002): The Ecological Functions of the Danubian Floodplains and their Restoration with Special Regard to the Lower Danube.- Large Rivers, vol. 13, No 1-2, Arch. Hydrobiol. Suppl. 141/1-2: 129-149.
- SIMONOVIC, P. (2000): The Status of Stocks of Particular Fish Species in the Tisza River After the Cyanide Spill.- Ichthyologia, Vol. 32. No. 1, 83-91, Belgrade.
- UNDP/GEF Programme Coordination Unit (1999): Evaluation of the Danube Floodplain Areas in the Danube River Basin; in the framework of the "Danube Pollution Production Programme", carried out by the WWF International Danube-Carpathian Programme and WWF Auen-Institute (Germany).
- UNEP/OCHA (2000) Ed.: Spill of Liquid and Suspended Waste at the Aurel S.A. Re-treatment Plant in Baia Mare: Assessment Mission, Romania, Hungary, Federal Republic of Yugoslavia, 23 February-6 March 2000, 57 pg., Belgium.
- VARGA, Z. (1997): Fenntartható gazdálkodás, tájvédelem és természeti értékek megörzése a Tisza-völgyében (a Tisza-völgy ökológiai hálózata) (Sustainable-use, Landscape Protection and Protection of Natural Values in the Tisza Valley (The Tisza Valley Ecological Network). - manuscript, 13 pages, University of Debrecen, Hungary.

- VITUKI (2000, a) Ed.: Preliminary Assessments of the Environmental Consequences of the Romanian Cyanide Spill on the Hungarian Reaches of the Szamos and Tisza Rivers.- Budapest. 60 pg. + Annex, Hungary.
- VITUKI (2000, b) Ed.: Report on The Heavy Metal Pollution of The River Tisza, Originating from Romania, in March 2000.- Budapest, 10 pg. + Annex, Hungary.
- VITUKI (2000, c) Ed.: Preliminary Assessment of the Environmental Consequences of the Romanian Cyanide and Heavy Metal Spills on the Hungarian Reaches of the Szamos and Tisza Rivers.- Budapest, 116 pg. + Annexes, Hungary.
- VUJANOVIC, D.; PLAMENAC, Z.; RAZIC, S.; SIMONOVIC, P. (2000): Toxic Metals in River Tisa.- Department of Toxicology, Faculty of Pharmacy, University of Belgrade, FRY.
- WWF (2000 a) Ed.: Studies and Reports Written in Hungary Concerning the Cyanide and Heavy Metal Spill from Romania in February and March 2000.- Budapest, Hungary
- WWF (2000 b) Ed.: Tisza Report 2000.- Co-ordinated by WWF Hungary, research completed by Hungarian NGOs, 100 pg., English, Budapest, Hungary.
- WWF (2001) Ed.: The Doñana Mining Accident and its Consequences – a Background Document.- English, Barcelona, Spain.

- Foundation for Otters: http://cian.hu
- Tisza Platform: www.zpok.hu
- Mineral Mining Institute: www.mpi.org.au
- Mineral Policy: www.mineralpolicy.org
- www.esmeralda.com.au
- www.zpok.hu
- www.umweltbundesamt.de/gefahrenstoffe

WWF is one of the world's largest and most experienced independent conservation organisations, with almost 5 mio. supporters and a global network active in over 96 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction and wasteful consumption.