Water pollution from a cyanide spill in Eastern Europe

January 30, 2000

Baia Mare

Romania

Toxic releases
Sedimentation basin
Mining waste
Cyanide
Inclement weather
Design (flawed)
Organization
Cross-border effects
Animal mortality

Subsequent to the failure of a storage basin dyke on January 30, 2000, 300,000 m³ of cyanide-laced effluent destroyed all of the flora and fauna over more than 600 km of river habitat.

Photos courtesy of: D.R

Fishermen recover dead fish by the hundreds of tons

BACKGROUND AND FACILITIES INVOLVED

➢ **Baia Mare,** a Romanian metropolitan area with a population of 140,000, is crossed by the **SASAR**, which itself is a tributary of the **LAPUS**, flowing into the **SOMES** (in Hungary) and then the **TISZA,** the **DANUBE** River's main tributary. The **DANUBE** crosses Serbia[1], skirts Bulgaria and finally empties into the **BLACK SEA**.

➢ Baia Mare's extensive mining history has left large quantities of tailings stored in the middle of the city in the form of spoil heaps. Since these dumps had already given rise to repeated surface and groundwater pollution incidents as well as the release of large amounts of dust, local authorities launched an international call for tender to treat these tailings by a specialist.

➢ A plant was set up in Baia Mare in **May 1999** to process some 2.5 million tons of waste a year, through taking advantage of latest technologies that enable recovering, and in a profitable way, small quantities of gold and silver still present in the waste.

➢ According to this industrial process, tailings are mixed with water. The sludge obtained is then separated in a ball mill, before undergoing 2 successive steps of cyanide leaching (known as cyanidation) and carbon leaching. The residue (water plus leachates) is then pumped, transported by a 7-km long pipe and stored in a 96-ha capacity sedimentation basin fitted with a plastic membrane to prevent leakage. The basin was surrounded by an interior dyke as well as a lower exterior dyke. The interior structure was

The cyanide ion

- *The cyanide ion bonds with certain metal ions, in particular the ferric ion in mitochondrial cytochrome oxidase, thereby blocking cellular respiration.*
- *It is highly soluble in water and extremely toxic for aquatic life. A cyanide concentration of 1 mg/l for just a few hours proves fatal to trout; a dose of 0.05 mg/l induces mortality within 5 days (invertebrates: 0.08 mg/l, algae: 0.03 mg/l).*
- *According to European standards for drinking water, cyanide content must remain less than 0.05 mg/l.*

[1] In January 2000, the provinces of Serbia and Montenegro composed the Federal Republic of Yugoslavia.

regularly raised using the largest chunks of tailings, for the purpose of expanding storage capacity. A canal between the two dykes served to collect settled effluent, which still laden with cyanide was recycled as part of the cyanidation process. The canal however had not been designed to adequately handle a major leak in the internal basin.

THE ACCIDENT, ITS CHRONOLOGY AND CONSEQUENCES

The accident

During the weeks leading up to the accident, 70 cm of snow fell on Baia Mare, giving rise to a water accumulation estimated at 36 l/m².

➢ On **January 30, 2000**, the combined effect of heavy rains and snowmelt caused a rise in the level of effluents contained within the sedimentation basin. The site operator however did not undertake any measures to transfer this effluent to other basins.

- At **10:00 pm**, due to water pressure buildup, a piece of dyke 25 m long by 2.5 m wide broke away from the interior dyke structure. A large quantity of effluent then poured out between the two dykes and flowed over the exterior dyke.
- A total of **287,500 m³ of effluent** containing cyanide (115 tons) and heavy metals (Cu: 54.7 mg/l, Zn: 2.1 mg/l) contaminated a 14 ha area and polluted the SASAR River. A "wave" 30 to 40 km long with cyanide-laced effluent propagated over the ensuing days and weeks into the LAPUS, SZAMOS, TISZA and finally the DANUBE River.

Photo courtesy of: D.R.

- At **11:00 pm**, the operator shut down site activities and notified local and governmental authorities.

➢ On **January 31 at 1:30 am**, the operator was able to partially plug the opening by using sediments from a neighboring dumpsite. The cyanide effluent, which nonetheless continued to spill at a rate of 40 to 50 l/sec, was gradually "neutralized" through adding sodium hypochlorite over a 48-hour period, until the leak had been totally obstructed. In conjunction with this effort, the southwest side of the dam was being consolidated out of precaution, and authorities in countries located downstream of the spill (Hungary, Serbia, Bulgaria and the Ukraine) were informed of the pollution event.

➢ On **February 1**, experts from the National Dam Safety Commission visited the site to offer technical support.

➢ The leak was entirely stopped on **February 2 at 1:30 am**, yet the dyke would continue to undergo further consolidation work for another 6 days. Moreover, during this time, the operator initiated works to decontaminate the polluted soils.

➢ According to Romanian authorities, the cyanide concentration reached 19.2 mg/l in the LAPUS and 7.8 mg/l in the SZAMOS (as opposed to over 33 mg/l as reported by Hungarian authorities[2]).

➢ On **February 4**, the cyanide tailing reached the TISZA, one of Hungary's main watercourses crossing into Serbia. Upon entering Serbia on **February 11**, the cyanide content of TISZA's polluted water was still measured at 2 mg/l.

Source: EXPRESS

[2] According to experts, Romanian authorities could only have taken measurements after the peak pollution level, whereas the Hungarians, who were quickly notified, would have been able to track pollution evolution.

➢ By **February 14**, the pollution had extended over some 800 km of waterway and reached the DANUBE (CN^- concentration: 0.2 mg/l), whose system comprises the TISZA as major tributary.

➢ On **February 18**, the cyanide tailing was still perceptible (CN^-: 0.05 mg/l) in the river delta, **2,000 km downstream of the accident site.**

➢ As the cyanide wave rolled through, Romanian, Hungarian, Yugoslavian and Bulgarian authorities successively poured sodium hypochlorite in order to neutralize the cyanide. Hungarian authorities however have denied this account by maintaining that the frozen waters of the TISZA River would have prevented such a procedure.

Consequences

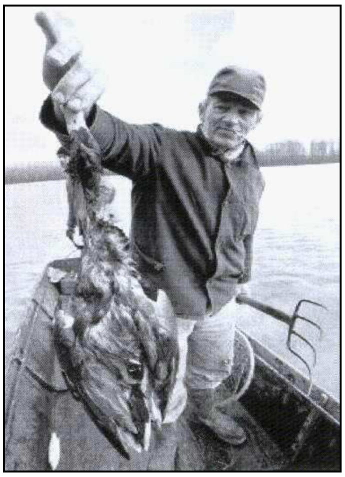
➢ In outlying areas from the site, private wells revealed the presence of cyanide. Several individuals who had ingested the contaminated water reported headaches, vomiting and dizziness.

➢ Pollution from this source affected **5 countries**: Romania, Hungary, Serbia, Bulgaria and the Ukraine.
All fishing and water consumption (irrigation, drinking water pumping) were temporarily prohibited.
Hungarian authorities proceeded with the distribution of bottled water in anticipation of an eventual water supply interruption.

Photo courtesy of: D.R.

Aquatic mortality

➢ **Ecotoxicological consequences**



Sources: AFP/ SASA STANKOVIC

Bird fatalities

According to Romanian authorities, only a small number of fish would have died in their country, as the introduction of an appropriate quantity of bleach had served to neutralize the cyanide and thereby limit its impact on the environment. On the other hand, the excessive addition of sodium hypochlorite by Hungarian authorities would have caused the death of most of the **1,241 tons of fish** extracted from this country's waters (sheatfish, perch, Danube salmon, sturgeon, etc.). A very high rate of fish mortality was also observed downstream over the Serbian portion of the TISZA.

While the exact causes of fish mortality could not be clearly established (cyanide or bleach?), the statement can nonetheless be made that pollutants were responsible for destroying just about all TISZA River flora and fauna over nearly 600 km, altering the entire food chain. Thousands of animals were found dead after having consumed contaminated water or other products (plants, mollusks, fish, etc.), including swans, cormorants, gulls, pheasants, pigeons, foxes, rabbits, horses, river otters, deer, hawks, ospreys and wild ducks.

Between **February 23 and March 6**, at the behest of the governments affected by the disaster, a group of 18 European experts in chemistry, ecotoxicology, biology, process engineering and dam design, accompanied by representatives from the World Health Organization, carried out an *in situ* scientific analysis of the environmental consequences associated with the accident. Surface water and sediment samples were extracted upstream of Baia Mare and along the pollution path in Romania, Hungary and Serbia.

These analyses revealed that 3 weeks after the accident, cyanide traces were more prevalent in the surface water of small rivers (SASAR, LAPUS and SZAMOS) than in either the TISZA or DANUBE, whose higher flow rates served to dilute pollution intensity. Findings also underscored the difficulty involved in identifying a significant impact from heavy metals released at the time of the accident, as the sediments had already been contaminated on a chronic basis through onsite extraction and metallurgical activities.

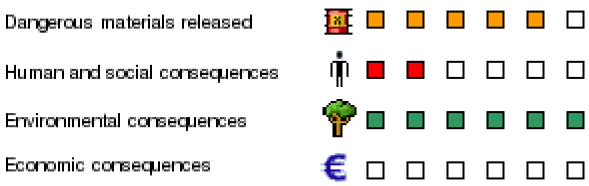
➢ Other expert missions (e.g. French, American) completed the series of evaluations focusing on the long-term ecotoxicological consequences.

➢ The accident also generated **indirect consequences**; restaurants stopped serving fish, agricultural cooperatives refused to buy produce from vegetable growers located along the TISZA, hotels reported a sizable jump in cancelled stays…

On the European scale of industrial accidents

By using rating rules applicable to the 18 parameters of the scale adopted in February 1994 by the Member States' Competent Authority Committee for implementation of the '*SEVESO*' directive on handling hazardous substances, each accident can be characterized by means of the four following indices, given the amount of information available:

The Baia Mare accident is characterized by the following indices:



The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.ecologie.gouv.fr.

Level 5 of the index relative to discharged hazardous substance quantities reflects the overflow of 115 tons of cyanide salts, i.e. products classified as highly toxic according to Directive 96/82/EC (so-called "SEVESO 2"), within the 300,000 m³ of accidentally-released aqueous effluent (parameter Q1).

The discomforts suffered by several neighbors after drinking the contaminated water explain the level 2 assigned, by default, to the 'human and social consequences' index (parameter H5).

The 1,241 tons of dead fish recovered or the 2,000 km of polluted waterway justify the level 6 assigned to the 'environmental consequences' index (parameter Env10).

Lastly, the 'economic consequences' index has not been rated due to a lack of information on the various financial costs associated with the damage caused by this incident.

THE ORIGIN, CAUSES AND CIRCUMSTANCES OF THE ACCIDENT

The opening in the dam was due to a combination of two factors:

➢ Design flaws

The dam had been built using mining waste that was supposed to contain coarse blocks and fine materials according to a very specific composition pattern. During the expert evaluation, it was observed that the proportion of blocks was considerably below the values indicated in the initial set of specifications. As a result, the dam could not offer the required level of strength.

➢ Poor weather conditions

While the more immediate meteorological conditions were responsible for a sizable rise in sedimentation basin water level, the heavy rainfalls and snowmelt served to soak the tailings composing the dyke and diminished their strength.

FOLLOW-UP STEPS

➢ The mine was reopened in May 2000. A new management team, appointed in September 2001, installed a cyanide effluent treatment plant along with a 250,000-m³ stormwater basin designed to handle overflow from the sedimentation basin prior to treatment and discharge into the natural environment.

➢ Upon completing their mission, the experts submitted the following proposal:

- To the site operator:
  - Implementation of precious metal extraction and treatment processes using less toxic products, especially cyanide-free products;
  - Introduction of default solutions that enable influencing occurrence probabilities and accident severity (i.e. risk analysis);
  - Planning, as of the dam design step, on measures to limit the impact of toxic effluent leaks (retention in basins, emergency storage basins, etc.);
  - Revision of emergency safety plans to define the roles and responsibilities of each party in the case of dam failure and environmental pollution.
- To the authorities:
  - Identification and evaluation of extraction industry risks in and around the Maramures Region in order to improve accident prevention and better prepare for emergency situations;
  - Adoption of a water quality monitoring program at the periphery of industrial sites and along rivers within the DANUBE catchment basin. Such a monitoring scheme, which relies on a set of indicators common to all countries affected, yields a baseline for pollutant concentrations already present in order to streamline identification of any new pollution;
  - Installation of a rapid information dissemination mechanism to warn local populations in the event of acute or chronic pollution. Moreover, an efficient communication network set up between the respective governments, regional and local authorities proves vital.

➢ The **"Baia Mare Working Group"**, presided by the European Commission

Composed of six senior staff members of the European Commission and international, national and regional environmental protection organizations, this group has been assigned to:

- elucidate the circumstances and causes surrounding the accident;
- assess damage and propose actions to remedy the associated negative impacts, which entailed creating a set of measures to reestablish the ecological equilibrium of all regions affected;
- determine the weaknesses inherent in Europe's mining and extraction industries, derive measures aimed at mitigating risks and, if necessary, offer changes in the existing regulatory framework;
- identify potential sensitive points within the DANUBE River Basin and propose measures intended to reduce risks when confronted with similar accidents.

➢ Six weeks after the Baia Mare disaster, a similar accident did occur, also in Romania (Borsa), and once again caused serious pollution to the TISZA. Spain had previously been subjected to a comparable extent at **Aznalcollar** in 1998.

➢ The severity and repetition of this type of accident led to **strengthening European legislation**, based on conclusions drawn by both the mission of experts and the Baia Mare Working Group, giving rise to:

- **modification of the "SEVESO 2" Directive on December 16, 2003** for the purpose of explicitly including the treatment of ores (in particular sedimentation basins for mining waste) or dykes constructed for this specific treatment. Operators performing this kind of activity must thus implement safety management systems that contain a detailed risk evaluation based on potential accident scenarios;
- publication of the **Directive relative to extraction industry waste management** (Directive No. 2006/21/EC promulgated by the European Parliament and Council on March 15, 2006), with emphasis on preventing or minimizing accident occurrence (through guaranteeing the long-term stability of dykes and storage basins, defining intervention mechanisms in case of accidents), mandating specific measures for installations with potential cross-border risks (information from the targeted countries, etc.);
- publication of the **Directive on environmental responsibility** in the aim of preventing and repairing environmental damage (Directive No. 2004/35/EC promulgated by the European Parliament and Council on April 21, 2004);

- drafting, within the scope of the IPPC[3] Directive(*), of a writ on **Best Available Techniques (BAT)** that serves to reduce ordinary pollution and prevent accidents in the nonferrous metals mining sector or at least mitigating their impacts.

THE LESSONS LEARNT

The most obvious preventive and protective measure, for avoiding accidents caused by an overflow of residual discharge basins, is to ensure that the dyke is well designed and built using materials capable of withstanding the forecasted loads. As such, **ongoing management and expansion of the sedimentation basin necessitates special attention**, notably as regards the equilibrium between solids and water within the dykes and the way in which this equilibrium is jeopardized, e.g. from heavy downpours. This accident highlights that the design and management of a basin of mining tailings must account for exceptional climatic conditions, such as heavy rainfall or snowfall, along with the impact of negative temperatures on facility operations.

The adoption of this measure is especially justified when basin contents might prove hazardous for human health or the environment, which is the case if cyanide cannot be neutralized.

➢ In Baia Mare, the emergency plan and means employed to combat pollution at the site were inadequate in light of the large quantities of hazardous substances in use. More specifically, no solution had been developed to cope with a rise in the sedimentation basin water level, even though in **September and December 1999**, major leaks had been detected in the dyke; 5 cows died after drinking from a watercourse contaminated by cyanide-laced effluent. Yet the operator's actions did comply with Romanian regulatory prescriptions: no emergency plan implementation had been required by the country's authorities.

The **initial warning system** made it possible to notify the neighboring countries (see insert opposite). The information exchange and measurements conducted by authorities in Romania, Hungary and Serbia undoubtedly enabled attenuating and mitigating impacts from the spill:

- the Hungarian Water Agency took advantage of the topography surrounding the Kisköre Dam, whose retention zone on both sides of the TISZA offered vast land expanses capable of storing diverted floodwaters. The dam was temporarily closed before the arrival of the cyanide wave in order to fill this zone; its reopening allowed increasing the TISZA flow rate, thereby diluting its pollution level;
- in Hungary, the early warning of water treatment plant operators provided the opportunity for them to test complementary treatments in the aim of temporarily accepting a 2 mg/l load while ensuring water supply distribution under conditions compliant with standards for human consumption (i.e. 0.1 mg/l). Though water sampling had been stopped for a few hours during the peak pollution occurrence, at no point did it prove necessary to halt the distribution of drinking water.

Initial warning system

In 1992, an agreement on the protection and use of cross-border watercourses and international lakes was adopted. According to its terms, all parties neighboring these lakes, rivers and streams are to be informed without delay of any critical situation capable of creating a cross-border impact.

Along these lines, the countries situated around the DANUBE River Basin set up Primary International Warning Centers, which receive notification in case of any increase in hazardous substance concentration within the DANUBE itself or water circulating in its catchment basin.

[3] Directive No. 96/61/EC adopted by Council session on September 24, 1996 relative to integrated pollution prevention and mitigation measures.

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OTHER ACCIDENTS LEADING TO SERIOUS RIVER POLLUTION

ARIA 4999 - 10/07/1976 - 69 - PIERRE-BENITE

24.1G - Production of other basic organic chemical compounds

20 tons of acroleine were discharged into the Rhone River. The production unit had been shut down for its annual closing and the neutralization basins (2 x 250 m³) were being repaired. For a period of 4 months, the washing water from cisterns had been poured into a 15 m³ neutralization channel and discharged without any preliminary control into the RHONE. During a rinsing operation, an operator accidentally drained a full tanker car (illegible reference number). The employee noted the anomaly an hour later, attempted without success to reach his superior by phone and, unaware of the intervention guidelines and potential consequences, continued the draining operation. Plant management was only informed 36 hours later. During an 8-day period, 367 tons of dead fish had to be collected over a 90-km section of the river (extending into 5 French departments). A safety system was implemented in order to prohibit recreational use of the river, monitor water intake and the wells fed by RHONE River flow, in addition to controlling potable water distribution. Outside of the fines issued (totaling 7,000 French francs), the operator paid out 4 million francs in 1976 currency (equivalent to 1.8 million Euros in 1993) in compensation to several fishing companies, and the plant director received a sentence. This pollution event along with other accidents prompted the first safety studies to be conducted in France (1.5 million francs spent on studies and 12.4 million francs on remedial works).

ARIA 7202 - 19/08/1995 - GUYANA - OMAI

13.2Z - Extraction of nonferrous metal ores

In an open cut gold mine where extraction proceeds by means of cyanidation, a major leak occurred on the dam built to settle out particles and decompose the cyanide by the effect of sunshine. For 100 hours, 3.2 million m³ of effluent laden with 25-30 mg/l of CN overflowed in the OMAI creek and the spill continued into the ESSEQUIBO River. In order to stop flow, a trench was dug and a dyke erected. Mine output was also curtailed. Cisterns full of potable water were quickly dispatched. 300 fish were recovered in the creek but none in the river. Dilution occurred and between 0.15 and 0.07 mg/l of CN were measured in both creek and river. The creek underwent cleanup operations and the mine remained closed for 3 to 6 months, the time required to build a new dam. When the dam failed, the quantity of fluid stored exceeded by eight times the maximum authorized according to the mine operating plan. A dyke investigation committee also noted a leak in one of the corrugated steel bypass pipes crossing the dyke, which would have caused the pipe to weaken.

ARIA 12831 - 25/04/1998 - SPAIN - AZNALCOLLAR

14.5Z - Extraction activities

A landslide caused a 50-m break in the dyke of a waste storage basin for a pyrite mine; as a result, 4 million tons of acidic water and 3 million tons of sludge laden with Zn, Fe, Cu, Pb and As (0.3 g/l) reached the RIO AGRIO and then the GUADIAMAR River, which overflowed by 200 to 300 m over a 20-km section. This toxic flow threatened the Donana National Park, around the boundary of which emergency workers built earthen embankments. In conjunction with this effort, authorities set up dams to confine the bulk of the pollution to the Entremuros Canal (despite which overflows still flooded the neighboring agricultural areas); a portion of the pollutants did reach the GUADALQUIVIR Delta, some 80 km downstream of the mine and polluted Gulf of Cadiz beaches. The effluent infiltrated into the groundwater, which constitutes the primary water supply resource for the Park and the city of Seville. The waste contaminated 7,000 ha of pastureland and marshland as well as 3,500 ha of farmland. The accident killed 30 tons of fish, in the tens of thousands of birds (geese, storks), 220 kg of shellfish, frogs, horses, goats, etc. Several individuals were slightly burned by the acidic water while trying to save cattle. Hunting, fishing and water consumption (irrigation, potable water pumping, etc.) were prohibited for a number of weeks. The decontamination operation lasted 8 months, and a total of 5 million m³ of sludge and 2 million m³ of excavated farmland were collected and stored in an old mine. 4.5 million m³ of water retained in the Entremuros Canal were treated according to the "STEP" process and discharged into the GUADALQUIVIR. Authorities implemented a water and soil quality monitoring and restoration plan and, in 2004, undertook a program to replant vegetation on the contaminated banks. The total cost attributed to the disaster was estimated at 240 million Euros, including all drainage and sanitation work, agricultural losses and authority repurchase of contaminated land. The mine was closed for a full 12 months, forcing layoffs of 500 employees; the mine would be shut down definitively in September 2001. The accident was caused by a 1-m landslide of a 600-m^2 marl plate 14 m thick on top of which the dyke had been positioned. Several expert reports had previously indicated in 1996 the vulnerability of this clayey subsoil and the dyke instability. The accidents at Aznalcollar and Baia Mare (No. 17265) led to strengthening European legislation on how mining waste is to be managed.

ARIA 17425 - 10/03/2000 - ROMANIA - BUCHAREST

10.1Z - Extraction and agglomeration of coal

Due to heavy rains and snowmelt, an opening (25 m wide, 10 m high) in the dyke of a sedimentation basin for a lead and zinc mine allowed 20,000 tons of sediments laden with heavy metals (Pb, Zn, etc.) to spill into the VISO River, which feeds into the TISZA and DANUBE Rivers. The pollution reached the parts of the Ukraine and Hungary crossed by these rivers, then Yugoslavia and ultimately Bulgaria, bordered by the DANUBE. A 50-km slick of pollution could be observed 4 days after and 200 km from the mine. Another opening (50 l/sec) appeared 16 days later due to the poor quality of repair work performed. As luck would have it, an exceptional flood (of 500-year proportions) occurred around the middle of April on the TISZA, through its Hungarian course, thereby mitigating the effects of this pollution.