Mining and environment in the Western Balkans

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This study was initiated by the Environment and Security Initiative (ENVSEC), a partnership between UNDP, UNEP, OSCE, NATO, UNECE and REC.

"Mining and Environment in the Western Balkans" is also available as interactive map and information film for further insight in this subject. Both are available at **www.envsec.org**

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Preface

Over the last few years UNEP and its ENVSEC partners have been working to identify and reduce transboundary environmental risks from hazardous mining operations in South Eastern Europe, with the focus on Albania, Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia, Kosovo (Territory under Interim UN Administration), Montenegro and Serbia.

This has been achieved by collecting, analysing and distributing valuable environmental data, facilitating knowledge exchange, and creating partnerships within the region and beyond. Our team has prepared and supported pilot remediation projects in the region which reduce environmental risks at mining sites. In addition, these practical measures help build local capacity in technical, managerial and administrational approaches to tackle other mining sites of environmental concern.

This document seeks to provide an overview of the results and experience created over this period to facilitate related work in the future and ensure broad dissemination of the lessons learned to guarantee that the efforts made so far can be sustained.

Executive summary

Mining and Environment

Practically all human societies depend on the availability and use of mined products. But the expansion of mining operations into environmentally sensitive and fragile areas has increased the level of environmental destruction and the impact on basic ecosystem services and biodiversity.

The mining industry has been involved in some of the most widely publicized environmental disasters. Well-known examples of mining-related environmental accidents and long-term deterioration include Rio Tinto, a river in southern Spain, the colliery spoil heap failure at Aberfan, Wales, or the Baia Mare cyanide spill in Romania.

Mining and mineral processing has played a vital part in the history and economy of the Western Balkans. Richly endowed with mineral resources such as copper, chromite, lead and zinc, it boasts some of the largest deposits in Europe. Capitalizing on such mineral assets will be a priority for South Eastern Europe in order to boost local economies and attract foreign investment. To secure the environmental, economic and social sustainability of such new or restarted operations, the region will need to define and enforce a legal framework for sustainable mining practices.

Good practice, research and experience in policy making, enforcement and technical approaches are all available. Information exchange between South East European countries and international partners transferring relevant knowledge to assist local Governments in adopting suitable mechanisms and approaches has been shown to be highly valuable.

Policy requirements – the Mining for Closure principles

All around the world there are examples of mines that were not properly "closed". Some ran out of money before completing a cleanup and rehabilitating land, others had to struggle with ownership issues and consequently liability and so forth. Regardless of whether mine legacies were left by private or state-run operations, it is usually governments which must pay for responsible mine closure and rehabilitation where no clear regulations for such sites exist.

New practices have shown that these problems and the associated financial and human costs can be avoided by a process of intelligent planning prior to mining – or at least well in advance of cessation of mining activities. We call the avoidance of future mining legacies via good planning "mining for closure". Others call it "best environmental practice for mining", "integrated mine planning" or "sustainable mining practice".

Mining for closure involves addressing the following issues:

- defining a vision of the end result for mining land with concrete objectives for implementation;

- ensuring that the mine closure plan is an integral part of the project life cycle;
- preparing a mine-closure plan early in the process of mine development and in consultation with the regulatory authority and local communities;
- explicitly including environmental, social and economic issues when planning mining operations;
- allowing for review and change extending from the pre-mine planning phase, through construction, mining, and mine closure to post-mine stewardship.

Environmental problems at mine sites

- Waste,
- Air pollution,
- Adverse impact on land use and biodiversity,
- Water pollution and availability,
- Hazardous materials,
- Noise and vibration,
- Energy use,
- Visual impacts.

Transboundary impacts

It has been demonstrated that waterways (fluvial transport) are the dominant vector for exposure, at all levels of interest. Airborne toxic emissions from smelters transported in the atmosphere, which constitute a second vector, also have been a very significant issue in the past. However, in the Western Balkans numerous smelter operations have ceased operations. In general the regional and transboundary importance of airborne emissions seems to have decreased in importance. A third important vector appears to be toxic-particulate pollutant transport as dust, which has a largely local or sub-regional effect.

Tailings management facilities

Tailings are the fine-grained waste material remaining after the metals and minerals have been recovered (extracted) from mineral ores via various technical processes. Tailings management facilities (TMF), also often referred to more simply as tailings dams, tailings ponds or tailings impoundments, are waste storage sites for milling and extraction residues and some of the most common sites of concern in relation to mining activity at a site. TMFs are associated with two main areas of risk for the environment. The first is the potential for losing large volumes of water and/or tailings in a large-scale failure. The second relates to the eco-toxicity of the tailings themselves.

Common technical problems at tailings management facilities comprise:

- Water-diversion structure failures,
- Overtopping failures,
- Chronic leakage of pollution.

Contaminated mine water

The potential toxicity of mine water and its adverse affects on the environment can be ascribed to four characteristics common in such effluents: acidity, iron and its precipitates, trace metals (e.g. cadmium, zinc, copper, lead etc.) and turbidity.

Mine water prevention

The goal of mine water prevention is to minimize contaminant release. This can be achieved by excluding one or more of the factors relevant to mine water generation. The essential components for sulphide weathering are sulphide minerals, water and oxygen.

Passive prevention of pollutant release is achieved by the surface or subsurface installation of physical barriers which inhibit pollution-generating chemical reactions and/or prevent the migration of existing polluted water.

Re-mining may be another viable option at mining sites in South Eastern Europe as much mine waste has a relatively high concentration of marketable material due to the inefficient metal extraction processes applied at the time of ore beneficiation. In some instances the revenue from such operations could cover part of the expense of remediation measures for the site, thus facilitating further improvement.

Active and passive treatment

Water treatment prevents distribution of the contaminants into the environment. It is considered an "end-of-pipe" technology, so treatment applications are not a genuinely sustainable solution to the problem. But it is often the only solution where generation of contaminated effluents cannot be avoided.

Active treatment techniques rely on conventional, well-recognized technology and are regarded as "proven technology". They have been implemented for decades all over the world and the experience gained over time has led to reliable techniques.

Passive treatment schemes rely on naturally occurring processes to improve the quality of the influent waters with minimal operation and maintenance requirements. These processes are chemical, biological and physical in nature. The aim is to provide such conditions where the highest removal rate for a particular contaminant can be achieved.

Mining sites in the Western Balkans

The mineral extraction industries, which focus primarily on mining for base and precious metals and metallurgy, have had a long history in the Western Balkans. In the period up to the early 1990s, mining, minerals processing and downstream exploitation of the base metals introduced above, established the region as a major European source of copper, lead, and zinc. The region, and in particular Albania, was also a major world producer of chromate.

Though traces of very old mining exploitation and metallurgy are still visible in many places and likely to contribute to the environmental risk of mining sites in some ways, it is the more recent activities which have left the most serious mining legacy for the region.

Thousands of old "abandoned" or "orphaned" sites are scattered all over the region. On such sites, with no liable legal owner, the necessary measures to close the site (stabilization, water management, replanting of vegetation, etc.), minimize the risk of accidents and prevent environmental pollution have often not been taken. Taking them now is very expensive.

Coping with this situation is complicated, with a large number of sites with serious environmental impacts, high remediation costs and the liable owners missing. In most cases the government is held accountable. But the huge financial liability attached to any systematic rehabilitation programme represents a challenge that far exceeds the financial or organizational resources of any one regional actor. The situation is further aggravated by the lack of expertise required to take practical responsibility for dealing with abandoned sites and the associated issues.

Governments in South Eastern Europe are in the process of preparing and implementing mine privatization and closure. This seems to constitute a good opportunity to clean up a substantial number of mining sites as part of new and ongoing operations. As such, the reopening of sites with modern industrial practices, as stipulated by the European Union in its BREF documents, could make urgently required mitigation and rehabilitation much more feasible than was thought a few years ago.

Remediation exercise – Emergency risk reduction at tailing management facilities in Albania

Three priority sites in Albania – Fushe-Arrez, Reps and Rreshen – were chosen for more detailed investigation, with the definition of appropriate risk-reduction interventions as pilot activities for the region. All three mining sites comprise non-operational tailings management facilities (TMF) that display severe signs of instability, leakage and failure. The results are presented in the following section.

To reduce the risk of further destabilization and uncontrolled release of mining waste short to medium-term interventions were identified as the most feasible way of improving the situation at the sites. When developing feasible interventions it is also essential to make allowance for the limited availability of both technical and financial capacities.

Serious environmental and public health implications of the selected sites:

- widespread pollution of rivers due to chronic erosion and release of contaminated waters, and larger acute failure events;
- waterways significantly affected by pollution from the sites;
- all rivers flow through populated areas and are used for irrigation during the summer months;

Mining and environment

Mining and environment

Almost all societies depend on the availability and use of mined products such as minerals and metals. They are the basis of our wealth and ensure economic development all over the world. But the expansion of mining operations into environmentally sensitive and fragile areas has increased the level of environmental destruction and the impact on basic ecosystem services and biodiversity. Furthermore, inadequate provision for closure and post-closure is leaving a growing number of abandoned and/or orphan mining sites around the world.

As a result, mining and environment are often seen as antithetical and many consider 'sustainable mining' a contradiction in terms. After all mining entails the exploitation of non-renewable resources. Depending on its definition, sustainable mining may refer to the extraction of mineral resources from the earth in a manner that allows this activity to continue indefinitely. However in this work, sustainability in mining applies to policies and practices that preserve the environment, protect indigenous cultures, and promote the welfare of local communities.

There is nothing new about mining giving rise to environmental concerns. In 1550, in the first European textbook on mines and quarries, the scholar and miner Georgius Agricola wrote:

"The strongest argument of the detractors is that the fields are devastated by mining operations … And when the woods and groves are felled, then are exterminated the beasts and birds … Further, when the ores are washed, the water which has been used poisons the brooks and streams, and either destroys the fish or drives them away ... Thus it is said, it is clear to all that there is greater detriment from mining than the value of the metals which the mining produces."

The mining industry has been involved in some of the most widely publicized environmental disasters. One well-known example of a mining-related environmental accident and long-term deterioration is Rio Tinto, a river in southern Spain. Research suggests that ancient (and modern) mining activities around the Rio Tinto have caused highly acidic conditions in the entire river system creating hostile living conditions and high concentrations of heavy metals which have persisted for millennia. During the 20th century mining accidents caused death and injuries all over the world. In 1966 the collapse of a colliery spoil heap in Aberfan, Wales, killed 144 people, including 116 children. Numerous catastrophic releases of toxic materials have occurred in the Balkans, one of the most high-profile being the failure of the Baia Mare tailings dam in Romania. In January 2000 the facility overflowed, releasing 100,000 cubic metres of cyanide-contaminated effluent into the Tisza river. By the time the overflow was detected, the heavily contaminated waste water had reached the Danube and was on its way to Hungary and beyond. Large quantities of cyanide entered the drinking water of numerous towns in seven countries and water supplies serving thousands of people and agriculture. Traces of cyanide, albeit at a very low level, could still be detected in the river water when it reached the Black Sea two weeks later.

But exploitation of mineral resources can yield great benefits for the population, with scope for economic growth and regional development. When proper allowance is made for environmental and safety concerns, with appropriate environmental management and contingency planning measures, the benefits for population and environment can be maximized.

Such experience has not only raised environmental awareness but also expectations for the environmental performance of mining operations – and of the environmental quality of areas affected by mining in the past. Changing social demands have prompted significant improvements in regulatory requirements and mining practice in many countries worldwide. Many miners have introduced management policies, practices and technologies that markedly reduce the environmental damage done by mining. When taken alongside the growing will to preserve land as a repository for valuable biological assets, natural environmental services and aesthetic appeal, these developments appear likely to drive continuing improvement in mining practice.

In the past communities often thought the only choice was whether or not to mine a deposit, but now the way a mine is planned can substantially change for the better the scale and duration of impacts over the life of the development and following its closure. As part of this positive trend, mine planning, closure practices and conduct of operations to facilitate environmentally and socially acceptable closure have also changed significantly in recent years.

This is of particular relevance to the Western Balkan states, comprising Albania, Bosnia and Herzegovina, the Former Yugoslav Republic of Macedonia, Kosovo (Territory under Interim UN Administration), Montenegro and Serbia). Mining and mineral processing has played a vital role in the history and economy of the region. Richly endowed with mineral resources such as copper, chromite, lead and zinc, it boasts some of the largest deposits in Europe. In the 20th century the mining industry played a vital role in former Yugoslavia and Albania but with the disintegration of the Yugoslav common market, economic conditions in the region deteriorated and in the early 1990s the Balkan economy declined sharply. Industrial output dropped significantly, with a widespread shutdown of operations such as mining. In environmental terms this cuts both ways. With the dramatic drop in industrial output, pollution decreased. But at the same time plants were either abandoned or privatized under conditions that did not clearly establish environmental liability.

This left a vast legacy of orphaned[1] and abandoned[2] mines scattered across the region with significant environmental

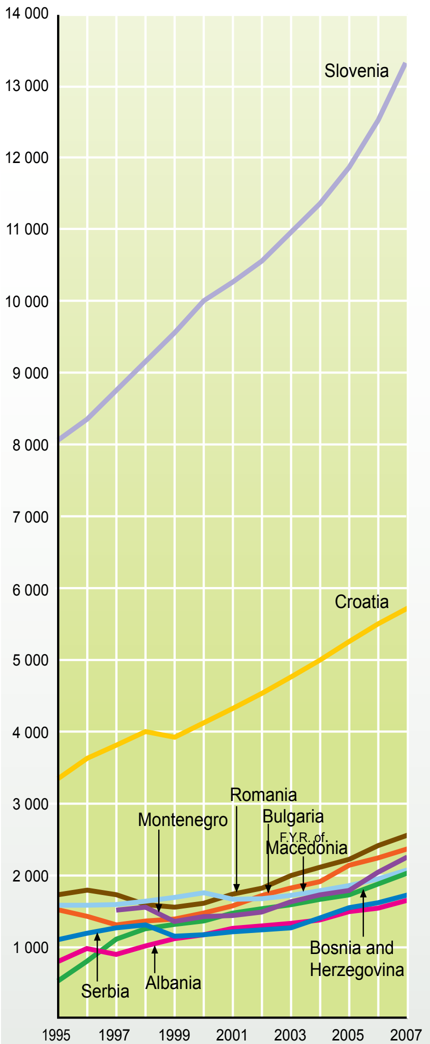
1. Mines for which the owner cannot be found.
2. Mines for which the owner is financially unable or unwilling to carry out clean-up.

risks requiring remediation. These environmental legacies are among the most widespread environmental concerns in the Western Balkans. A wide range of mining sites do not meet today's standards for sustainable mine management. Environmental problems, such as water and soil pollution from heavy metals, are the result of sub-standard operations and improper mine closure.

Today mining and quarrying accounts for only 1.2% of total GDP in the Western Balkans. But the potential remains with numerous reserves awaiting exploitation. Capitalizing on such mineral assets will be a priority for South Eastern Europe in order to boost local economies and attract foreign investment. To secure the environmental, economic and social sustainability of such new or restarted operations, the region will need to define and enforce a legal framework for sustainable mining practices. This will also include mine planning and mine closure requirements to avoid further environmental legacies in the future. For the legacies that already exist, solutions need to be found to address the technical, financial and administrative problems which inhibit appropriate risk reduction and monitoring at the sites.

Leading mining nations have built up a wide array of good practice, experience and research in policy making, enforcement and technical approaches. International partners can provide valuable sup-

Gross Domestic Product (GDP) per capita
In constant USD (2000)



Source: The World Bank, Washington DC.
Note: In 2006, Serbia and Montenegro split to form independent states

port to South East European countries by transferring related knowledge and assisting Governments to adopt suitable mechanisms and approaches. The international community will be needed to support this knowledge exchange, provide access to information and facilitate demonstrations of environmental remediation on the ground.

UNEP and its partners have established a targeted programme to reduce transboundary environmental and human safety risks posed by sub-standard mining and mineral processing operations – both active and abandoned – in South Eastern Europe. Related work has been assessed and a wide range of mining sites in the Western Balkans prioritized. Mining sites were visited and analyzed, accompanied by mining experts from Canada, Germany and Australia. This has resulted in detailed remediation planning for several mining sites which will serve as a pilot exercise for similar sites in the region. Mining sites have also been addressed as part of the industrial hotspots project carried out by the UNDP-led Western Balkans Environment Programme with the support of the Dutch Government and others.

The findings of this work in the region create unique possibilities for improved environmental management and environmental protection throughout the region built on past experience and new insights as well as regional partnerships. To capitalize on these outcomes and increase their benefits, this approach needs to continue, taking into consideration important developments such as the recent global economic slowdown and increased understanding of climate change impacts which may pose novel threats, hindering efforts to improve the situation.

Development of national boundaries in South Eastern Europe

1878
Congress of Berlin

1913
After the Balkan Wars

1923
Treaty of Lausanne

1945
After World War II

1995
Dayton Agreement

2010

Policy requirements

The Mining for Closure principles

Policy requirements

Economic growth is still the main criterion for social development so ecological principles are often neglected. It cannot be expected that mining operations will become completely environmentally neutral but with environmentally sound planning and increasing economic capacity, the chances are that mining as well as overall environmental standards will substantially increase in the Western Balkans.

Country-specific reviews of the environment show that mining-related problems, in particular mine water issues, are amongst the most severe and widespread. Short and long-term pollution from active and abandoned mines is one of the most serious threats to the water environment in South Eastern Europe.

With numerous ore deposits in South Eastern Europe still unexploited or unsustainably developed in both technical and environmental terms, considerable wealth with high added value may be derived from systematic exploitation of the deposits or restructuring of industrial activities. Exploitation of the ore could promote the development of this region, which has endured poverty, war and political instability in the past. Extraction industries are in this sense vital and despite their numerous environmental implications.

What is Mining for Closure?

All around the world one can find examples of mines that were not "closed" properly, or ran out of money before completion of cleanup and rehabilitation of land. Developed nations, as well as the developing and emerging economies, face decades, if not centuries of work with the clean-up of mines and mining debris. The Western Balkans is a prime example of a region facing such challenges.

Regardless of whether state-run operations or the private sector left mining legacies, it is usually governments that must pay for responsible mine closure and rehabilitation. Governments usually have to pay the social costs left behind by closing mines too.

However, new types of practice in leading mining nations have shown that these problems and the associated financial and human costs are often avoidable. This requires a process of intelligent planning prior to mining – or at least well in advance of cessation of mining activities. We call the avoidance of future mining legacies via good planning "mining for closure". Others call it "best environmental practice for mining", "integrated mine planning" or indeed "sustainable mining practice".

Regardless of the name, a growing number of countries have shown that such goals can be achieved through sound governance. In short, corporate practice, regulatory frameworks, governance guidelines, financial markets and insurance sectors can be developed to support a modern mining industry and protect the environment and society. Moreover, there is increasing evidence that win-win situations are possible – if done the right way, mining for closure can benefit the State, society and mining companies.

Successful mining for closure requires planning for the entire life cycle of a mine – and the environmental and social effects of the operation. In its simplest form, this means the mine closure plan should be an integral part of the project life cycle and be framed to ensure that:

- future public health and safety are not compromised;
- environmental and resources are not subject to physical and chemical deterioration;
- the after-use of the site is beneficial and sustainable in the long term;
- any adverse socio-economic impacts are minimized; and
- socio-economic benefits are maximized.

It also requires legislators to strictly apply the polluter-pays principle, with mine operators setting financial resources aside before and during mine operation to pay for the costs of closure.

The role of government is to ensure that the expectations of all stakeholders are met. Furthermore, it should be borne in mind that stakeholder expectations are inherently fluid and that in the Western Balkans the views and demands of social stakeholders are likely to become much more important in coming years than at present.

The Mining for Closure approach…

- defines the end result for mining land and sets forth concrete objectives for implementation;
- ensures that the mine closure plan is an integral part of the project life cycle;
- prepares the mine closure plan early in the process of mine development and in consultation with the regulating authority and local communities;
- explicitly includes environmental, social and economic aspects in planning for mining operations;
- allows for review and evolution stretching from the pre-mine planning phase, through construction, mining and mine closure to post-mine stewardship.

As more specific items, such processes should incorporate:

- the concerns and participation of other stakeholders in reclamation objectives;
- plans for action if ownership reverts to the state despite all efforts to ensure otherwise;
- the preservation of mine management and geological records;
- early delineation of project creditors' claims on the site;
- legal considerations for ownership, both now and in the past;.
- maintenance of control over tenure if leases expire and another party wants to obtain rights to the surface or sub-surface;
- adequate capacity among regulatory personnel;
- ongoing research and testing of remediation strategies and technologies and integration of results in mining for closure review processes;
- surveillance of the views and desires for the involvement of local communities (in particular where such parties wish to check the quality of information they are receiving – demanding a role in site-monitoring and access to information to ensure accountability of the operator and governments, for example);
- the maintenance of communication between private and public bodies to improve closure policy and regulations;
- ongoing searches for financing measures for clean-up; disaster response; spills management and so forth, particularly for orphaned sites.

Why governments benefit from Mining for Closure practices

A vibrant mining sector can yield many benefits to a country with mineral resources. For the Western Balkans the mining sector has long been an integral and vital part of its industrial infrastructure. Today, in the light of economic restructuring and industrial modernization, the mineral resources of the region may again become important contributors to economic development.

However the environmental and social costs associated with past mining activities have left intractable and expensive legacies in environmental and social terms. As the shutdown of mines has been relatively sudden and unplanned, the State has been left responsible for proper mine closure and rehabilitation of mines.

Despite the reality of such difficulties, work in leading mining countries around the world has clearly demonstrated that many of the legacy issues associated with mining can be prevented. It has also been shown that as long as a mine continues to operate, its subsequent legacy can be reduced. Indeed there is growing international expectation that mining companies will always dealt with such legacies while they are still mining. Future mining legacies can be prevented by mining for closure activities and principles. Prevention is feasible and desirable via sound governance. Governments should focus on preventive measures if society is to benefit from a country's mineral resources.

Some of the advantages for Governments yielded by mining for closure methods fall within the following broad categories:

- lower financial burden on the national purse for mine closure and rehabilitation;
- lower risks for significant post-closure liabilities;
- prevention of harmful environmental and social impacts and reduction of the significant associated costs;
- lower risk of non-compliances by operators;
- greater acceptance and/or lower resistance from key stakeholders (in particular local communities and land owners) to plans to open new mines, refurbish old mines, change land-use etc.;
- improved national access to project finance on reputable international finance markets.

In the context of developing and restructuring economies such preventive strategies are just as relevant as for leading mining nations – the jurisdictions that already benefit from such approaches. But if governments lack sufficient fiscal resources to deal with legacies, even greater invention and flexibility will obviously be needed to protect the public and the environment from the hazards left by mining legacies.

Why business benefits from Mining for Closure practices

The mining for closure approach places a number of demands on mining companies. It requires achievement of many planning items, many types of rehabilitation work, and consideration of a number of social parameters that have not traditionally been carried out by mine operators. On the contrary governments have had to pick up the costs after mines stopped working. Among other things, mining for closure requires concrete targets to be set for how sites will be closed – long before closure is anticipated; it requires ongoing site rehabilitation during mining operations; it demands explicit inclusion of environmental, social and economic issues in planning of mining operations. The polluter-pays principle means mining enterprises are responsible for the costs of damage their activities cause – this is the best incentive for such damage to be avoided in a cost-effective manner. Accountability for all or a significant part of the environmental and social impacts of mining is thus the new norm for mining organizations.

Initially mining companies may retort that such demands will make it difficult to run a competitive mining business. Fortunately, the costs and benefits are dynamic and if mines are operated intelligently they may still be competitive.

Leading mining companies worldwide have shown that it also makes good business sense to adopt best environmental practice in mining, and mine for closure. Among other things, this is a vital argument for governments to have in mind when engaging in the privatization process. Importantly for mining organizations, these benefits are apparent during mining operations and at the end of a mine's life.

The benefits for mining companies all the way through a mine service life include:

- steady reduction in liability by optimizing rehabilitation work during the productive phase of mining operations rather than deferring costs to the end of the project, with required rehabilitation achieved at a lower overall cost;
- increased efficiency in execution of work (reduction of double-handling for waste materials and topsoil, costs avoided in spoil-dump fire control, etc.);
- lower ongoing responsibilities for the site and easier timely relinquishment of tenements and bond recovery;
- lower risk of regulatory non-compliances and less exposure to contingent liabilities linked to public safety and environmental hazards and risks;
- greater acceptance and/or less resistance for mining operations from key stakeholders (in particular local communities and land owners) through lower environmental, social and economic impacts on local communities from mine operations;
- improved access to capital from reputable lending institutions and potential reduction in cost of capital and liability insurance.

Integrated mine closure planning

As mine decommissioning usually occurs at a stage in the life of an operation when the economically viable recovery of minerals has ceased, and cash flows are minimal or non-existent, it is no time to be undertaking the bulk of rehabilitation operations.

The mine decommissioning process should be integrated with the overall mine-operation planning process. The best actors to rehabilitate a mine site are commonly the operators. They can achieve the best result at the lowest cost. The best time for this to be planned is before the impacts occur, and the best time for rehabilitation activities to be carried out is during the mine's service life. Furthermore, if decommissioning and closure are not undertaken in a planned and effective manner, the results will very probably also be sub-standard.

While the benefits of such methods are maximized when planning for the start of a new mine, experience has shown that tangible benefits also exist for mines that have operated for many years. It is never too late to start.

Environmental problems at mine sites

Environmental problems at mine sites

Waste

Mines generate large volumes of waste, involving materials that must be removed to gain access to the mineral resource, such as topsoil, overburden and waste rock, as well as tailings remaining after minerals have been largely extracted from the ore. Some of this waste is inert and consequently unlikely to be a significant environmental hazard apart from smothering river beds and the risk of collapse if stored in large quantities. However other fractions, in particular those generated by the non-ferrous metal mining industry, may contain large quantities of dangerous substances, such as heavy metals.

Structures such as waste dumps, tailings impoundments and/or dams, and containment facilities should be planned, designed, and operated in such a way that geotechnical risks and environmental impacts are appropriately assessed and managed all the way through the mine cycle.

Water use and quality

Management of water use and quality in and around mine sites can be a significant issue. Potential contamination of water sources may occur early in the mine cycle during the exploration stage and many factors including indirect impacts (e.g. population migration) can result in negative impacts to water quality. Through the extraction and subsequent processing of minerals, metals and metal compounds tend to become chemically more available, which can result in acid or alkaline drainage. Reduction of surface and groundwater availability is also a concern at the local level and for communities in the vicinity of mining sites, particularly, in arid regions, or in regions of high agricultural potential.

Land use and biodiversity

Habitat alteration is one of the most significant potential threats to biodiversity associated with mining. It may occur at any stage in the mine cycle with the greatest potential for temporary or permanent alteration of terrestrial and aquatic habitats during construction and operation. Additionally, exploration often requires the construction of access routes, transportation corridors and temporary camps to house workers, all of which may result in land-clearing and population influx to a varying extent.

Air quality

Managing ambient air quality at mine sites is important at all stages of the mine cycle. Airborne emissions may occur during each stage of the mine cycle, but particularly during exploration, development, construction and operation. The main sources include dust escaping from blasting, exposed surfaces such as tailings facilities, stockpiles, waste dumps, haul roads and infrastructure, and to a lesser extent, gases from combustion of fuels in equipment and vehicles.

Hazardous materials

Hazardous materials may be used at various stages of mineral extraction, for example cyanide for gold leaching. Such materials should be handled, stored and transported in such a way as to avoid leaks, spills or other types of accidental release into soils, surface water and groundwater resources.

Other environmental concerns include noise and vibration, energy use and visual impacts created by mining operations.

Transboundary pollution

Mining and minerals processing operations share a number of pathways in which the surrounding environment and communities can be exposed to the harmful effects of pollutants which can be of transboundary nature. Once pollution travels across boundaries, it adds the potential for political conflict between the affected countries. Relevant transboundary pathways include:

- airborne transport of pollutants such as dust, smelter emissions, gases, vapours;
- mass movement of "solid" wastes (generally tailings containing heavy metals and toxic compounds);
- mass movement of liquid, or semi-liquid wastes (again, generally tailings containing heavy metals and toxic compounds);
- waterborne transport of wastes as suspended solids and as dissolved materials.

It has shown that the dominant pathway of exposure – at all levels of interest – is via waterways (fluvial transport). A second exposure pathway, airborne toxic emissions from smelters transported in the atmosphere, has been a very significant issue in the past. However, as a number of smelter operations have ceased operations, or are closed until such time that acceptable levels of emission can be achieved through upgrading of plant, the regional and transboundary importance of airborne emissions appear to have generally reduced in importance. A third important pathway appears to be toxic particulate pollutant transport as dust – this is a largely local and sub-regional effect.

The importance of river transport

Fluvial transport mechanisms for tailings wastes have a pivotal importance for both regional and transboundary pollution risk in the Western Balkans. This bears several implications with it. To name but a few – very large volumes of materials can be involved with catastrophic damage to downstream land, property and ecosystems associated with the physical impacts of such accidents; biochemical, and eco-toxicological effects of these pollutants can be catastrophic and can extend far beyond the zone physically affected by such materials; the physical and biochemical, and eco-toxicological effects can be long term.

Mine structures – tailings management facilities

Tailings management facilities, also often referred to more simply as tailings dams, are waste storage sites for milling and extraction residues and some of the most common sources of concern in relation to mining activity at a site.

Tailings are the fine-grained waste material remaining after the metals and minerals have been recovered (extracted) from mineral ores via various technical processes. The material is rejected at the "tail end" of the process with a particle size normally ranging from 10 μm to 1.0 mm.

A tailings management facility (TMF) includes all the structures which deal with tailings: the tailings dam, tailings impoundment, clarification ponds, stormwater diversion structures, delivery pipelines and so on. Many environmental problems in mining are related to tailings management and storage as their volume and contaminant content can be very high and securing the structure's reliability a major challenge.

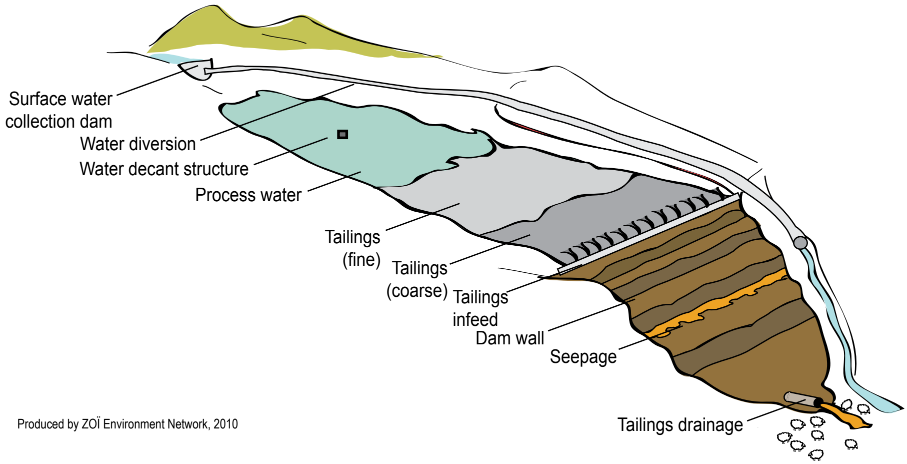
The TMF is used to contain tailings and generally includes a tailings dam (impoundment and pond), decant structures and spillways. The tailings dam comprises embankments, dam walls or other impounding structures designed to retain tailings and process water, and allow tailings to settle. A TMF should be carefully designed and built under close supervision.

As can be seen from the description above, a TMF is an important engineered structure. Indeed, it represents a large capital investment and an integral part of mining and mineral processing activities. Its proper operation is a key factor in the overall operation of a successful mining project and its industrial processes. But the difference between the TMF and mining activities as such is that the TMF and the associated risks remain after the mining project ends. As such, there are several reasons for concern with TMFs – particularly facilities which were not carefully designed and built, or have been left for any period of time without monitoring and maintenance.

TMFs entail two main areas of environmental risk: first its potential for losing large volumes of water and/or tailings in a large scale failure; secondly the ecotoxicity of the tailings themselves. They contain the remains of complex mineral or metal compounds which could not be removed, and often residual process chemicals that may be toxic in themselves. The effluents from tailings dams are often either markedly acidic or alkaline and generally carry dissolved metals or other contaminants.

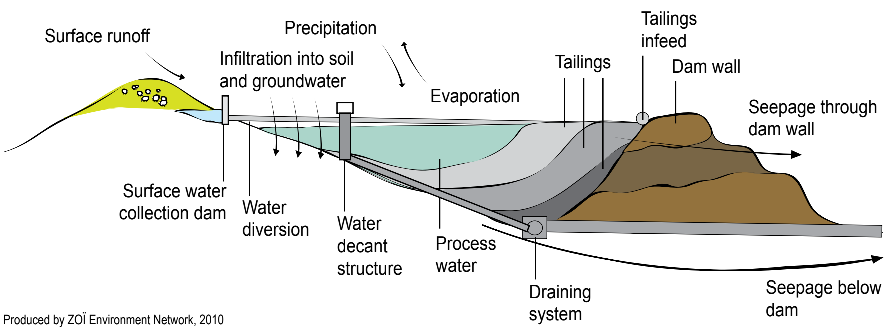
There is growing understanding that environmental degradation of national and transboundary watercourses, international lakes and seas can be caused by un-

Tailings management facility



Produced by ZOÏ Environment Network, 2010

Tailings management facility - cross section



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intended large scale movement of hazardous materials as a result of TMF failures; these can have far-reaching consequences for the environment and environmental services, for human health and the social acceptance of mining activities.

Furthermore there is growing awareness that all categories of TMF pose such risks: active, idle or inactive, neglected, temporarily or permanently closed, abandoned or orphaned. As has been mentioned, there is particular concern regarding the large number of neglected, abandoned or orphaned TMFs where active monitoring or maintenance is not being undertaken in the Western Balkans.

Frequent technical problems at tailings dams

Water diversion structure failures

To obtain a structure that will actually hold tailings, water inflows such as surface runoff and streams must be diverted to limit seepage and erosion. A dam may therefore be built upstream from the tailings, with a channel (tailrace) or pipe to carry inflow around, or in some cases under, the tailings impoundment. Problems generally arise with such diversion structures when they are not maintained or when flooding occurs that exceeds their design capacity. With time lack of maintenance leads to increasingly poor performance – as structures fill with sediment or leak and erode. This is followed by eventual failure. A flood event on the other hand can lead to immediate failure. When water is no longer diverted away from the TMF, new types of problems arise.

Decant structure problems

Defective decant systems affect the next line of defence in a TMF. Under normal operating conditions a TMF decant structure is supposed to prevent the level of liquid (generally contaminated water called "supernatant") from rising above a certain level, compromising structural stability of the dam (or overtopping of the dam crest). If the pipes or ductwork in the decant structure are blocked or not large enough to remove liquid flows into the dam, then the level continues to rise.

Overtopping failures

Overtopping failures occur when water builds up in a TMF to a level higher than

the dam crest. Several things can occur at this point. In some tailings dams, the crest may have a spillway allowing the water to cascade over the top without eroding the structure of the dam itself. In such cases, as long as the structural stability of the dam itself is not threatened by the high water levels (with potential saturation of the dam structure), a failure can be avoided. But in many cases the dam crest is not designed to cope with overtopping. The water flowing over the structure quickly erodes the material of the dam wall. Depending on the volume and speed of the flow tailings material is then carried downstream. In some cases, the whole dam may fail.

Chronic leakage of pollution

Chronic leakage refers to ongoing flows of effluents or transportation of waste in relatively small quantities. An ecosystem may be able to assimilate one such flow, but the net result of many such flows – in particular over a long period of time – may well exceed that capacity. Day after day the effluents from substandard TMFs carry acidic water containing dissolved metals. These flows enter river systems and eventually the sea, making water unsuitable for agricultural or public use.

Contaminated mine water

Contaminated mine water, often referred to Acid Mine Drainage (AMD), can be a consequence of mining coal or mineral deposits. A large amount of scientific research has been conducted to determine the chemical reactions that create acidity and lead to the precipitation of dissolved metals, but despite improvements in prediction and prevention methods, acid mine drainage problems persist. The acidity of mine drainage is caused primarily by the oxidation of pyrite, a mineral containing Iron and sulphide, commonly found in tailings, overburden and other mine waste piles. The rate of oxidation depends on the following: reactive surface area of the pyrite, the oxygen concentration and pH of the water, and the presence of Iron-oxidizing bacteria (e.g. Thiobacillus ferroxidans).

The potential toxicity of mine water and its adverse affects on the environment can be ascribed to its four main characteristics that are acidity, iron and its precipitates, trace metals (e.g. cadmium, zinc, copper, lead etc.) and turbidity. Sulphate is another regular component in mine water as it is formed during pyrite oxidation. Not all of these components have to be present in mine water in order to cause harm but in most cases they are found in combination with each other.

More distinct are the terms Acid Mine Drainage and Alkaline Mine Drainage. The former is acidic water (pH <5.0), laden with iron, sulphate and other metals, which forms under natural conditions when geologic strata containing pyrite are exposed to the atmosphere or oxidizing environments. AMD can form from mining, both in surface and in underground mines. Alkaline mine drainage is water that has a pH of 6.0 or above, but may still have dissolved metals that can create acid by oxidation and hydrolysis. The drainage quality (acid or alkaline) depends on the acid and alkaline minerals contained in the geologic material.

In the Western Balkans context we find contaminated mine water formation fuelled by:

- ore types and rock with significant acid mine drainage generating potential;
- absence of mine planning for AMD control, and or closure;
- large (historical) milling and concentration plants with significant tailings impoundments and mountainous terrain;
- periods of heavy rain and/or snowmelt;
- lack of ongoing physical and/or biochemical monitoring of operational and/or abandoned sites;
- lack of ongoing maintenance, both proactive and reactive.

Low pH/acidity

One of the characteristics considered most troublesome in mine water is low pH. The direct effects of low pH are considerable in themselves. They include loss of the aquifer or stream as a drink-

What to analyze in mine water?

Determinant	Type of study				Guideline values
	Reconnaisance study	Geological investigation	Routine data for design	Site-specific determinats	
pH	✗	✗	✗		6-9
Conductivity	✗	✗	✗		
Temperature	✗	✗	✗		< 3 degree differential
Alkalinity		✗	✗	✗	
Dissolved oxygen		✗			
Calcium		✗			
Magnesium		✗			
Sodium		✗			
Potassium		✗			
Manganese		✗	✗		
Aluminum		✗	✗		
Iron	✗	✗	✗		2 mg/l
Sulphate	✗	✗	✗		
Lead				✗	0.02 mg/l
Copper				✗	0.3 mg/l
Zinc		✗		✗	0.5 mg/l
Cadmium				✗	0.05 mg/l
Nickel				✗	0.5 mg/l
Chromium (VI)				✗	0.1 mg/l
Cobalt				✗	
Arsenic				✗	0.1 mg/l
Mercury		✗			0.002 mg/l
Cyanide				✗	1 mg/l
Nitrate				✗	50 mg/l*
Ammonina		✗		✗	
Uranium				✗	0.015 mg/l*
Radium				✗	
Radon				✗	
BOD_5				✗	50 mg/l
User identified	✗			✗	

Source:
Environmental, Health and Safety Guidelines for Mining, World Bank, 2007
*WHO Guidelines for drinking water quality, 2006

ing water supply and degradation of living conditions for most organisms in a natural waterway. But the indirect effects further aggravate the risk through metal solubility. This means that the lower the pH in water, the more likely it is that high concentrations of heavy metals will occur, because acidity dissolves metals.

Iron and iron precipitates

Iron is often the most abundant contaminant in mine water, particularly in coal mine drainage. Apart from its contribution to acidity, excess iron in watercourses can have several other environmental impacts.

Iron, much as many other metals, is a trace element needed by humans and other vertebrates. But when organisms take up large amounts of iron, acute and chronic toxic reactions occur, such as peroxidation of lipids followed by damage to protein structures. As a chronic toxin, iron can cause haemochromatosis, cirrhosis of the liver, vascular congestion and eventually death. Moreover, turbidity caused by iron precipitates (ochre) reduces the incidence of light in the water body, impeding photosynthesis in these areas and causing food chains to break down. The biodiversity of affected areas declines and may finally upset the balance of the ecosystem, a readily visible effect of mine water contamination.

Trace metals

Apart from iron, other ecotoxic elements (such as Cd, Zn, Cu, Pb, etc.) can cause health risks and serious ecosystem degradation.

When trace metals are released from their stable, isolated state in the geosphere, they are disseminated via waterways where they are available to the biosphere. Until they are transferred back into sediments and eventually rock, metals can persist through cycles and reactions where they may cause toxic effects. Small amounts of these elements are common in the environment but elevated amounts of any of them may cause acute or chronic toxicity. Possible effects occurring under exposure to such metals are, among others, damage to the human nervous system, blood composition, lungs, kidneys, liver and other vital organs. In streams where mine water is discharged with high levels of one or more ecotoxic metal present, significant loss of biodiversity has been observed in several cases.

Trace metals are mainly a problem where metal ores are mined. This is the case for many mining sites in the Western Balkans where copper, lead, zinc and other elements are frequent.

Sulphate

Sulphate is usually not a contaminant of major concern except under special conditions. The recommended limit for sulphate in drinking water is about 250 mg/l. This value has largely been chosen for aesthetic reasons (i.e. taste and odour) but at higher concentrations sulphate does have powerful, temporarily laxative effects.

Sulphate can also constitute a large proportion of the total amount of dissolved solids. In arid and semi-arid regions where watercourses may already display high salinity due to evaporation, further salinization by mine water can significantly decrease water quality, making it unsuitable for human uses such as irrigation and livestock watering.

With regard to the Western Balkans, several areas feature low atmospheric precipitation and high evapotranspiration. In such places, high sulphate concentrations are likely to have a negative impact on water usability and consequently on the quality of life in the region.

Environmental impacts from pollution

Parameter	Chemistry	Environmental impact
Low pH	H^+	Degradation and death of animals and plants, reduction in drinking water quality, mobilization of metal ions, corrosion of man made structures.
Iron precipitates	Fe3+, Fe2+, $Fe(OH)_3$	Discoloration and turbidity, clogging up of fish gills, encrustation of man made-structures.
Trace metals	Cu, Pb,Zn,Cd,Co,Ni,Hg,As,Sb	Degradation and death of animals and plants, bioaccumulation, reduction in drinking water quality, soil and sediment contamination
Total dissolved solids	Ca, Mg,K,Na, Fe, Al, Mn,Si, SO_3	Reduction in drinking water quality, soil and sediment contamination.

Source: Mine wastes: characterization, treatment, and environmental impacts by Bernd G. Lottermoser, 2007

Remediation approaches

As we all know, prevention is better than cure so avoiding or at least reducing the output of contaminated mine water in the first place is a goal in itself. Preventive measures should consequently seek to reduce the amount of contaminants being released into the water and the total amount of water leaving a mining site. Unfortunately prevention is not always possible due to technical restrictions and local conditions.

The goal of mine-water prevention is to minimize contaminant release. This can be achieved by eliminating one or more of the factors relevant to mine-water generation. The essential components for sulphide weathering are sulphide minerals, water and oxygen.

Passive prevention of pollutant release is achieved by the installation of physical barriers (requiring little or no long-term maintenance) on or below the surface to inhibit chemical reactions which produce pollution and prevent the migration of existing polluted waters.

Possible techniques for mine water prevention:

- dry covers,
- water covers,
- selective diversion of surface water,
- inundation,
- alkaline addition,
- alkaline injection,
- coating/encapsulation,
- biocides,
- separation of sulphides.

In the Western Balkans the prevention of mine-water generation in the first instance is of course of very high importance where feasible. At many high-risk sites the situation could be substantially improved by implementing preventive measures such as clay capping to reduce water ingress from atmospheric precipitation and water diversion channels to reduce ingress of surface run-off from the surrounding area.

Re-mining, i.e. the processing of mine waste for metal extraction, may be another viable option in the Western Balkans as much mine waste contains a relatively high concentration of marketable material due to the inefficient metal extraction processes applied at the time of ore beneficiation. In some instances, the revenue from such operations could cover a portion of the expenses generated by remediation measures for the site and thereby facilitate further improvement. At a number problematic of sites, the first consideration should be mine-water prevention because it is a very efficient measure to reduce tailings dam instability and pollution.

Active treatment

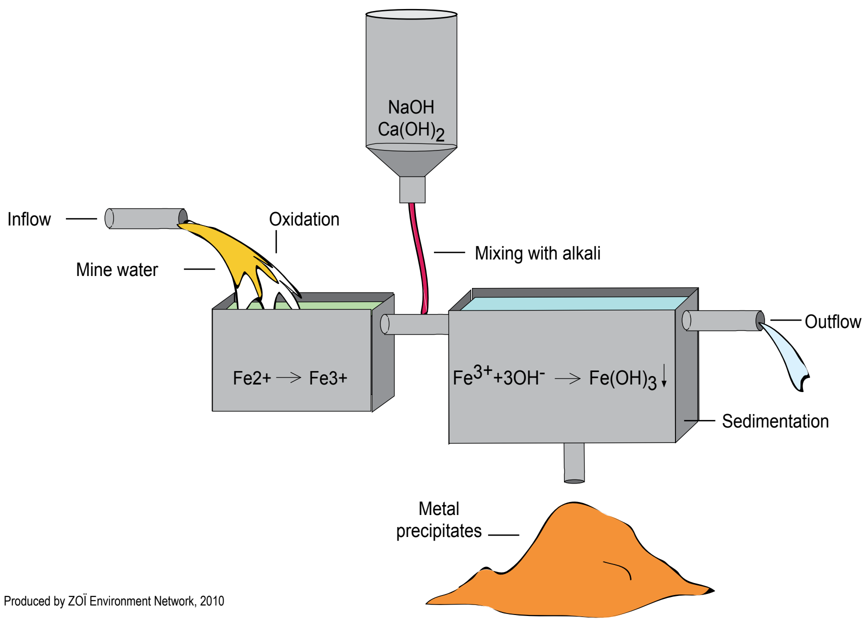
As water treatment is not tackling the contamination source, but “only” preventing the spread of contaminants into the environment, this counts as an end-of-pipe technology. So treatment is not a genuinely sustainable solution to the problem, but it is often the only one where negative effects cannot be avoided.

Active treatment techniques rely on conventional, well-recognized technology and are regarded as “proven technology”. They have been used for decades all over the world and the experience gained over time has lead to reliable techniques.

Apart from the current state-of-the-art of the two treatment approaches, they also differ in where they may be applied. The most striking advantage of active treatment plants is the high contaminant load they can handle and their reliability for compliance with regulations on effluent quality. This is possible because the variables are adjusted to suit changing mine water quality and quantity.

A major drawback of active systems is that they are very expensive. The main costs arise during the operational phase of the plant. Active treatment systems need constant energy and/or chemical input, and monitoring and maintenance that has to be undertaken permanently by staff on the spot. Moreover, a relevant cost factor in an active treatment system is the disposal of the resulting metal laden sludge – which can accumulate in very significant amounts over long periods of time. It is not uncommon for water treatment costs to exceed $200,000 per year at sites using active treatment. The costs associated with operating an active mine-water treatment plant are ongoing for the lifetime of the plant, or rather, for as long as mine-water output continues.

Active mine water treatment scheme



Produced by ZOÏ Environment Network, 2010

Currently, chemical precipitation is the most widely used technique for metal removal from mine waters. Although it is an attractive process, there are also several disadvantages, such as the production of large amounts of sludge, the need for further treatment of sludge to meet disposal criteria, and the loss of valuable metals.

In principle, the mine water issues that arise in the Western Balkans could be addressed with active mine water treatment plants but so far, they have not yet been widely used in the region.

Passive treatment

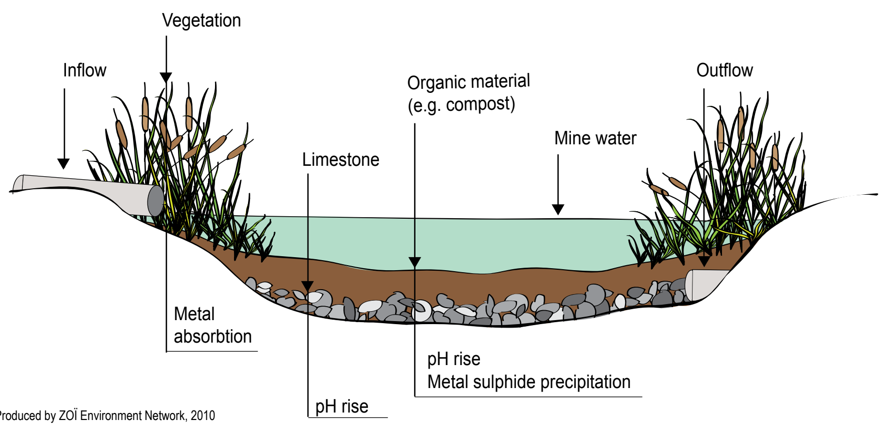
The principle of passive treatment involves using natural processes to improve the quality of incoming water with minimal operation and maintenance requirements. These processes are chemical, biological and physical in nature.

- Chemical removal processes: oxidation, reduction, coagulation, adsorption, absorption, hydrolysis, precipitation.
- Physical removal processes: gravity, aeration, dilution.
- Biological removal processes: biosorption, biomineralization, bioreduction, alkalinity generation.

Genuinely passive systems work without any regular input of cost-intensive resources, such as manpower, energy and chemicals. But in reality, a completely passive system is hard to achieve as many sites often require active components such as pumping or aeration. However, even when systems are not entirely passive according to the definition, overall operational life cost profile is lower than for adequate, fully active systems.

With active treatment, the costs are distributed over time, i.e. operating costs are high and exceed by far the cost of designing, building and commissioning a plant. These operating costs are caused by needs such as constant energy and/or chemical input, staff and high maintenance costs. Passive systems, on the other hand, re-

Example for passive mine water treatment installation



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quire the main financial input to be made when the system is being built.

Estimates suggest that the upfront installation costs for a passive system are, depending on the size of the application, similar or at times marginally higher than an active system. As the nature of passive systems is to be self sustaining, at least to a certain degree, the cost following successful commissioning of the plant will be low compared to an active solution.

Compared to conventional treatment, research suggests that passive systems entail about half the capital outlay and less than 1/20 of the maintenance costs of active systems. Other calculations are less positive but still indicate that the cost advantage is only small in the early years of operation but then starts to increase.

In general these systems are less cost-intensive in their life-cycle, require less technical assistance and have a cost structure which favours external funding. On the other hand they are not yet as reliable and predictable as conventional techniques. Passive systems have a background of less than 20 years, so there is a significant need for more experience.

A number of innovative mine-water management measures have been developed and have been shown to successfully address common contaminants in mine water. Track records and the frequency of application vary strongly within the available techniques. The applicability of the techniques varies with incoming water quality, surrounding conditions and managerial issues.

Mining in the Western Balkans

Mining in the Western Balkans

The mineral extractive industries, focussing primarily on mining for base and precious metals and metallurgy, have a long history in the Western Balkans, reaching back through historical records to at least the 5th century BC. In Serbia for example, copper mining at the Bor deposit is believed to have prehistoric beginnings,. It is also believed that the Crveni Breg lead and silver mine and the Šuplja Stena mercury mine on the Avala in the vicinity of Belgrade were in operation prior to recorded history. By the time of the Roman empire, there is evidence that many of the deposits mined today were already being exploited and almost all known lead and zinc deposits were being mined by the 13th and 14th century.

While traces of very old mining exploitation and metallurgy are still visible at many localities, and are likely to contribute to the environmental risk portfolio of mining sites in some ways, it is post-1945 activities which have generated the most serious mining legacies for the region. These areas will pose a task for both this and for coming generations.

By the early 1930s mineral deposits in the region were well-defined, with increasing levels of exploitation. The major base metals mined have included aluminium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, and zinc. Precious metals such as gold, silver, palladium and platinum are found mainly in association with base metals such as copper, lead and zinc. Industrial minerals, represented by a broad range of carbonate and silicate rocks, gravels, and sands as well as clays and volcanic materials have also been important. Mineral

fuels extracted in the region include coal (lignite), natural gas and petroleum.

In the period up until the early 1990s, mining, minerals processing and downstream exploitation of the base metals cited above established the region as a major European source of copper, lead and zinc. The region, in particular Albania, was also a major international source of chromate.

The use of low grades of coal and lignite in the region's industrial and electric power generation facilities had raised the emission of sulphur dioxide in some areas to levels that were reportedly twice those recorded in Western Europe. Concentrations of SO_x and NO_x consistently exceeded safety guidelines set by the World Health Organisation (WHO) and uncontained emissions from the nonferrous metals processing plants and smelters contributed to regional acid rain. Moreover, such sites often contributed to serious local and subregional heavy-metal contamination of the environment due to fallout.

Mining was one of the flagship industrial sectors, influencing the area more extensively than in simply economic terms. After the disintegration of the Yugoslav common market, economic conditions in the region aggravated and in the early 1990s the Balkan economy declined sharply. Industrial output dropped significantly, with a widespread shutdown of operations such as mining. In environmental terms this cut both ways. With a dramatic drop in industrial output, pollution decreased. But at the same time plants were either abandoned or privatized under conditions that did not clearly establish environmental liability.

Such long association with mineral extractive industries indicates that both a long-established culture of mining activity and a socio-economic dependency on mining and metallurgical activities can be expected in many parts of the region. Unfortunately, it is also indicative of a higher likelihood of multiple abandoned mining sites that may constitute point sources of pollution. Furthermore, broad acceptance of such industries and their pollution is likely at many levels within the societies in the region.

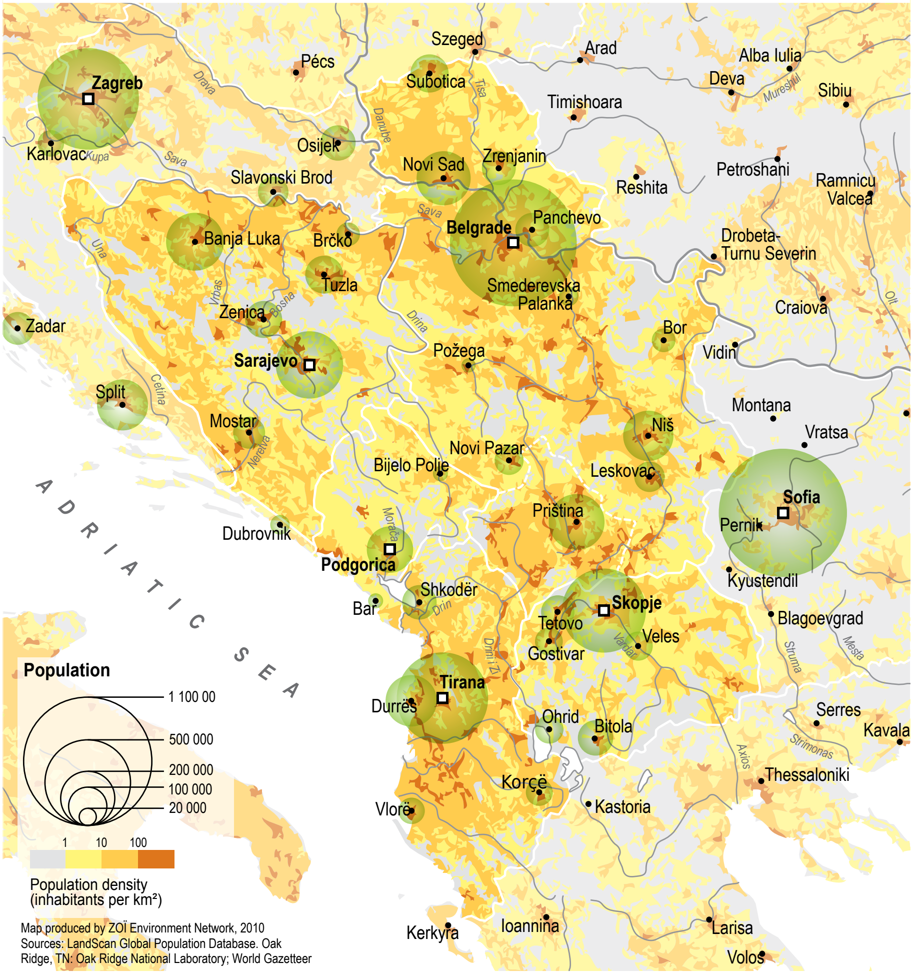
Situation today

The environmental legacy associated with extraction industries is all too familiar. Badly operated or abandoned mining sites have already caused severe pollution, some with impacts reaching across national boundaries: heavy metal spills from Baia Borsa tailings in Romania; the cyanide spill from Baia Mare in Romania; heavy metal spills from Sasa tailings in Macedonia; and various releases at Majdanpek and Veliki Majdan in Serbia, and Mojkovac in Montenegro. Watercourses are the main vector for transboundary pollution, whether it is ongoing and chronic, or infrequent, acute and accidental. Smelters also contribute to air pollution, with serious consequences for human health.

Thousands of old "abandoned" or "orphaned" sites, with no liable legal owner, are scattered all over the region. In Bosnia and Herzegovina, Montenegro, Serbia, Albania, Macedonia and Kosovo (Territory under Interim UN Administration) alone the ENVSEC initiative identified over 180 separate operations, some with many individual sites of activity. About a third of these appeared to be of significant environmental and security concern, and nearly a fifth was deemed to involve potential transboundary risks.

On many abandoned sites the necessary measures for proper closure (e.g. stabilization, water management, replanting of

Population density in the Western Balkans



vegetation, etc.), to minimize the risk of accidents and to prevent environmental pollution were never taken. Implementing them now is very expensive.

Coping with the present situation is complicated, with a large number of sites with serious environmental impacts, high remediation costs and the liable owners missing. In most cases the government is held accountable. But the huge financial liability attached to any systematic rehabilitation programme represents a challenge that far exceeds the financial or organizational resources of any one regional actor. The situation is further aggravated by the lack of expertise required to take practical respon-

Factors contributing to environmental risks at mine sites

The region has almost the full range of risks entailing large-scale environmental damage, in particular:

- ore types and rock with significant acid mine drainage (AMD) generating potential;
- absence of mine planning for AMD control, and/or closure;
- large (historical) milling and concentration plants with significant tailing impoundments mountainous terrain;
- periods of heavy rain and/or snowmelt;
- numerous rivers and catchment areas shared by several countries;
- significant seismicity (earthquakes);
- abandoned and orphaned sites with little or no closure or control;
- lack of ongoing physical and/or biochemical monitoring of operational and/or abandoned sites;
- lack of ongoing maintenance, both proactive and reactive;
- absence of institutionalized accident/disaster response procedures;
- apparent focus upon site jurisdictions rather than natural boundaries such as watersheds

sibility for dealing with abandoned sites and the associated issues.

Most modern mining operations consequently include a bonding system which ensures that sufficient financial resources are set aside during the active period of the mine. If appropriate such resources are released when mining stops and the measures mentioned above need to be taken.

In the Western Balkans, the situation is far away from that. Funds necessary for even routine maintenance of hazardous sites such as tailings ponds and hazardous waste dumps have been very limited. As an inevitable result, the likelihood of environmental accidents has increased markedly.

Governments in the Western Balkans are in the process of preparing and implementing the privatization and closure of mines. This appears to provide a sound basis for cleaning up a substantial number of mining sites as part of new and ongoing operations. As such, the reopening of sites under modern industrial practices, as stipulated by the European Union (BREF documents), could make urgently required mitigation and rehabilitation programmes much more feasible than was assumed a few years ago.


MONTENEGRO
Podgorica
Kotor
Cetinje
Bar
Ulcinj
Shkoder
Lake Skadar
Moraca
Zeta
Lim
Cem
Plav
Beli Drim
Pec
Kosovo
(UN administered Territory under UNSC 1244)
Pristina
Gnjilane
Dakovica
Orahovac
Urosevac
Presovo
Juzna Morava
Prizren
Drin
Kumanovo
Fushe Arrez
Giegan
Kalimash
Kukes
Tetovo
Skopje
Pcinja
Vardar
Bojana
Rreshen
Reps
Kurbnesh
Fan
Lezhe
Mat
Rubik
Gostivar
Treska
Peshkopi
Lac
Burrel
FORMER YUGOSLAV REPUBLIC OF MACEDONIA
Kruje
Debar
Kicevo
Bulqize
Shijak
Erzen
Tirana
Martanesh
Durres
Prilep
Struga
Kavaje
ALBANIA
Lake Ohrid
Ohrid
Elbasan
Shkumbin
Crna Reka
Bitola
Lake Prespa
Lushnje
Podgarec
Pogradec
Devoll
Florina
Seman
Kucove
Fier
Patos
Berat
Osum
Vijose
Korce
Rehove
Kastoria
Vlore
Corovode
Shushice
Haliacmon
Tepelene
Gravena
Gjirokaster
GREECE
Sarande
Mining site
Korfu
Thiamis
Trikala
0
25
50
75 km
Ioannina
Map produced by ZOÏ Environment Network, 2010
Igoumenitsa
Aratos

Albania

Albania is situated on the Adriatic and Ionian coast between Greece and the former Yugoslavia. It has rich biodiversity with a landscape of coastal plains and a largely forested mountainous interior. Albania faces serious anthropogenic threats to its environment. Erosion, illegal cutting and harvesting of forest and vegetation resources, urban waste, industrial pollution and rapid population growth have led to severe environmental degradation. The coastal plain continues to be used for extensive, unsustainable agricultural practices to support the population. Current agricultural and grazing practices have led to severe erosion, environmental destruction and pollution in Albania's watersheds.

In the period from 1945 to 1991 Albania's industry and general economy developed under a system of central economic planning with a large part of the economy based on mining and beneficiation of chromite, copper, nickeliferous iron ore and ferrochromium minerals.

Albania's industrial facilities were less efficient and caused more pollution than those in other Eastern European countries, but operations were conducted on a significantly smaller, less widespread scale. There are nevertheless serious point sources of pollution in the country, primarily related to industrial sites, such as mines, smelting and refining complexes (chromite, etc.), the Elbasan iron and steel plant, refineries, lignite-fired thermal electric power stations and chemical plants.

Fortunately, despite the considerable concerns in Albania listed above, relatively large areas of the country remain largely unaffected by industrial environmental pollution.

Albania's mineral sector

Before 1990, the mining sector accounted for a substantial share of export earnings, and Albania was the world's third largest producer of chrome ore. Following the economic collapse and social unrest, the mining industry's workforce was halved to around 10,000 by the late 1990's. The neglecting of mines that were already in poor conditions has resulted in severe environmental damages.

Chrome mining and semi processing is based in the Dibra and Mat districts, copper in Mirdite and Puke, iron-nickel in Pogradec, nickel - silicate and coal in Korce, and phosphorite in Tepelene. All Albania's copper mining operations were underground, reaching their peak in the late 1980s at about 1 million tonnes a year.

With the exception of the Rehove mine and beneficiation plant in south-eastern Albania, copper ore was mostly mined, processed, smelted and refined in the north. Fushe Arrez, the country's largest copper mining and beneficiation complex, produced and concentrated more than 320 000 t/yr of copper ore. Copper concentrates were smelted at the Gjegjan (Kukes), Lac and Rubic pyrometallurgy primary smelters in the far north-eastern

part of the country. Poor copper deposits have dictated the construction of 7 mineral processing plants, in order to produce copper concentrate grade over 18 % Cu and about 88% recovery. These plants are situated in Kurbnesh, Reps, Fush-Arrez, Rreshen, Rehove and Golaj. Today, many mineral processing plants in Albania are no longer in operation, some of them have been closed and others have been planned for conservation.

During the 1980s, production of nickeliferous iron ore in Albania ranged from 1 to 1.2 million t/yr, of which about a half was consumed at the Elbasan iron and steel works to produce pig iron, a small amount of steel, and salts of nickel and cobalt. Deposits of commercial-grade nickeliferous iron ore were exploited in ultramafic massifs near Pogradec in eastern and central Albania. The principal mines were at Prrenjas, Guri i Kuq and Bitinska. Until 1991 the largest mining operation was at Prrenjas, which produced about 600 000 t/yr of ore. The production of nickeliferous iron ore in Albania ceased in 1994 following the collapse of centrally planned economic systems in the countries of Central Europe and the Balkans.

Albania's bauxite deposits are mainly in the centre of the country, just east of Tirana, and in the north near the border with former Yugoslavia. Bauxite reserves are minor, an estimated 12 million t.

Albania also has reserves of lignite, natural gas and crude oil. The country's exploitable coal resources amount to about 158 million t of low-calorie lignite. Lig-

nite is mined for domestic consumption, mainly at thermal electric power stations. At present industrial production consisting of the mining and enrichment of copper and chromium ores, coal (lignite) mining, oil exploration and oil processing, and extraction of construction materials generates a large share of industrial waste in Albania. The main environmental problems at the decommissioned industrial facilities relate to waste accumulated from previous operations.

Like most of Albania's industry, the mining sector has been handicapped by obsolete equipment and technology and a lack of management expertise, as well as the disruption of production and supply lines caused by civil unrest. Production methods are labor intensive and often dangerous.

Assessed mineral mining and processing sites

In the environmental assessment, chromite-related sites were generally given a lower priority by national actors, higher priority being allocated to copper mining sites. It was explained that waste disposal practices associated with copper mining in the country have caused serious problems in several areas. Although it was confirmed that mining and mineral-related sites are among those of highest concern, it was stressed that there are also several other priority sites related to the oil and chemicals industry, and to hazardous waste disposal, which have severe implications for environmental health. These sites come very high – some even at the top – on the list of national priorities for risk amelioration and remediation work.

Elbasan complex

Elbasan represents one of the most serious metals industry related hotspot in the country leaving behind an accumulation of some 35 years of metallurgical wastes. Waste from smelting activities there, about 1.5-2.0 million t of ferronickel slag and ferrochromium waste, contaminates soil and groundwater with heavy metals (chromium, nickel and manganese) in the area. The water in the Shkumbini river is also contaminated by trace metals and phenolics from this dump.

Rreshen

Rreshen is a major centre for copper mining, with seven or more mining and copper ore concentrator operations located on both arms of the Mati-Fani river system and contributing to a succession of environmental problems, including tailings dumps partly located in the river. As a result of the nature of the ores (arsenopyrites) significant concentrations of arsenic are among the heavy metals in effluents polluting agricultural irrigation water. Tailings apparently contain around 0.8% copper and as such should represent an economic resource suitable for reprocessing and safe disposal.

Kurbnesh

Kurbnesh was described by Albanian representatives as a "very large disaster area", discharging into the Fani and Mati rivers. Here too the site involves tailings from copper concentrators that have been dumped just next to or in river beds.

Fushe Arrez area

The area boasts the largest copper mining and beneficiation complex in the country, which produced and concentrated more than 320 000 t/yr of copper ore when operating at full capacity. Again arsenic contamination of surface and ground waters is an issue due to Arsenopyrite deposits and the location of residue stockpile(s) near the bank of the Fani river. On the positive side for this site it was reported that very rich copper grades are (still) present here (about 4% Cu, 2% Zn, 4g/t Au and up to 40g/t Ag) suggesting that ongoing mining activity is likely in the medium to long term, with possible scope for remediation work.

Pogradec

Ferronickel crusher deposits (nickeliferous iron ore) have been dumped near Lake Ohrid. These materials are presumably from the mines near Pogradec (Prrenjas, Guri i Kuq and Bitinska). The preliminary samples that Albanian scientists have collected at the Guri i Kuq mine show concentrations of metals in the near shore lake water that are very high. It is likely that the muds and sands in these near shore locations are also contaminated, and this may pose a risk to the invertebrates, fish and birds living in this section of the lake. People who catch and eat fish in the area may also be at risk and it is possible that local drinking water sources have been contaminated.

Kalimash/Kukes/Gjejan

The area comprises copper mining operations including mines, concentrator(s) and a smelter. The ore contains Arsenopyrite and is generating significant As pollution to water in the middle Drini river.

CASE STUDY

Elbasan

Location: The town of Elbasan has a population of approximately 100 000 inhabitants. The industrial complex lies six kilometres to the south-west. Four to five villages, home to about 5 000 people in all, are located within a five-kilometre radius of the complex.

Type of operations: The complex was an iron and steel works covering about 250 ha. The owner of the complex is the Enterprise for the Production of Steel (a state company). Operations at the complex started in October 1976. Before the metallurgical activities started, the site was used as agricultural land. Most of the production facilities have not been used since the 1990s. But part of the plant is now in use by a private company, Kurum International. Of the original 12 000 pre-1990s workers, the site now employs 1 500 people.

Previous production: Pig iron from iron ore; cast iron; oxygen; calcium carbonate; nickel; ferrochrome; coke; carbon mass; fire bricks.

Environmental issues: Because of the intensity of the activities, the whole of the 250 ha site must be considered to be completely contaminated. There are reports that 1.5 to 2.0 million t of solid waste (slag, dust from chimneys, tailings and other wastes) has accumulated at the site.

Water pollution: Various dumpsites of slag, ashes, dust from the chimneys, tailings and other kinds of waste are situated on the banks of the river Shkumbin, along the southern perimeter of the complex. The dumpsites have been there since the complex opened. Leaching of heavy metals, cyanide and phenols, normally occurs under such circumstances and ends up by having a large scale impact on the water system.

Air pollution: The metallurgical complex of Elbasan was known for its air pollution, with enormous emissions of polluted dust and other components. In 1998 dust deposition in Elbasan was reported as 327 mg/m2/day. Because of the decline in industrial activity these emissions have been reduced in the last decade. There is no recent data available on air quality.

Soil pollution: A study of the environmental impact of the Elbasan metallurgical complex shows that extremely high concentrations of metals have been measured in samples taken around the complex. It is assumed that atmospheric deposition of contaminated dust particles has contributed to contamination of the top soil layers.

Soil analyis at Elbasan complex

		Nickel	Cobalt	Chromium
Concentration range most polluted samples	mg/kg	1 210 – 2 950	97 – 181	1358 – 4 130
Dutch intervention values for remediation in soil	mg/kg	69	125	Cr(III) 140 Cr(VI) 61

Source: UNDP Preliminary Site Investigation Report Metallurgical Complex of Elbasan, 2009

Remediation: The complex includes a biological wastewater treatment plant, built to process effluents containing phenols. The plant is currently out of order and the process that produced phenol wastewater has been shut down. Untreated wastewater continues to be discharged into the river Shkumbin. The private company operating the site has fitted electric filters to reduce the output of dust from its current activities. These filters have dust-capture efficiency of about 95%. However, the vast environmental legacy at the site remains to be addressed.

Bosnia and Herzegovina

Politically, Bosnia and Herzegovina (BiH) remains divided into three administrative zones: Federation of Bosnia and Herzegovina, Republic of Srpska and District Brcko based on the Dayton Peace Agreement signed in December 1995. The population of the country is currently approximately 3.5 million after a rapid decline in the number of people during the war that reached its lowest point in 1996.

Much of the territory of Bosnia and Herzegovina (BiH) is mountainous with nearly 60% above an altitude of 700 metres. Hilly or mountainous terrain covers nearly 84% of the country with some 80% of land in the country having slopes of 13% or more. The high barrier situated along the Mediterranean creates a range of specific microclimates and ecosystems characterized by high biodiversity. Bosnia and Herzegovina has a very short coastline roughly 25 km long.

Although the timber industry is not competitive on the world market, the country is rich in forests, which cover roughly half the land area. Illegal logging is also a significant problem. The country has roughly 2.6 million hectares of agricultural land and some 2.5 million hectares of forest.

Water is relatively abundant in Bosnia and Herzegovina and the total length of rivers is estimated at about 2 200 km. The main river is the Sava (331 km inside Bosnia and Herzegovina), which runs along the northern border. Bosnia lies in the Sava river valley and Herzegovina is situated in the Neretva basin and upper reaches of the Drina. Rainfall exceeds evapotranspiration by a ratio of more than two-to-one in most of the country, and areas above 900 metres and the Mediterranean zone of the country experience mainly moist climates with annual rainfalls of up to 2 000 mm. The climate varies from mild Mediterranean (10 to 15°C yearly average) to cool-to-cold temperate (2°C to 8°C) in mountainous areas.

Much of the territory exhibits limestone karst geology and as a result groundwater migration – and the migration of any sub-surface pollutants – is often rapid due to the existence of underground watercourses. Karst springs are common throughout the territory and surface watercourses are generally swiftly flowing.

Sewerage and water reticulation systems are generally in poor condition and waste and water-borne pollutants, often arising from areas of waste disposal, are a serious concern for the environment and public health in the country. Currently municipal waste is only collected in half the urban municipalities but rural municipalities are generally not included in waste collection. Large quantities of waste are reportedly being dumped illegally at roadsides, rivers, abandoned mines and so forth, posing a threat to public health and the environment. Among areas of significant pollution

from land-based activities, hotspots are listed as the sewerage system and waste-water treatment plant in the town of Mostar, red-mud disposal areas associated with the aluminium factory in Mostar and the Neum-Klek area on the coast.

Bosnia and Herzegovina's mining sector

Before the dissolution of the Federal Republic of Yugoslavia and the subsequent civil war, Bosnia and Herzegovina was a major centre for metallurgical industries in former Yugoslavia. The country's total steel output from the Rudarsko Metalurški Kombinat plant at Zenica (or Zeljezara Zenica) then amounted to more than 2 million t/yr. By the end of 1999 production had steadied at roughly half this amount.

The country was also a major source of bauxite, alumina and aluminium. Production was administered by Energoinvest with bauxite being mined in Vlasenica, Jajce, Bosanska Krupa and a range of other sites – located in the north-west part of the country. In the late 1990s Bosnia and Herzegovina's bauxite resources were estimated to be about 41 million t of marketable grade ore containing about 50% Al2O3 and about 5% SiO2. Alumina refineries were located at Birac-Zvornik and Mostar. Mostar was also the centre of aluminium manufacture and the aircraft industry. In 1999, following a period of post-conflict reconstruction, an operational capacity of about 97 000 t/yr of primary aluminium was achieved at Mostar.

The production of other non-ferrous metals included only relatively minor amounts of lead and zinc ore mined and milled at Srebrenica (Sase mine) in RS and at Olovo and Vares in the FBC. Reserves were estimated to be about 12 million t of ore grading 1.8% to 4% lead and 2.5% to 6% zinc. In addition manganese has been mined at Buzim (Buchim).

In the past Bosnia and Herzegovina was also a major source of asbestos, barite, gypsum and salt, as well as construction

aggregates, cement, clays, dimensioned stone, dolomite, kaolin, limestone, magnesite, sand and gravel and other industrial minerals. The latter were mainly produced for local use. Asbestos and asbestos cement are reportedly mined, milled and produced near the border crossing to Croatia.

Coal mining in Bosnia and Herzegovina is organized into two separate operations. In the FBC, the Middle Bosnia and the Tuzla coal mines supply the Kakanj and the Tuzla powerplants with more than 80% of their total coal production. The lignite surface mine at Gacko and the brown coal surface mine at Ugljevik were fully integrated with the Gacjo and Ugljevik powerplants respectively. Coal reserves for the entire country are estimated to be 3.8 billion metric tonnes.

Assessed mineral mining and processing sites

Vares

Vares is a historical centre of iron-ore mining and iron smelting, and lead/zinc mining and concentration, where a range of mining legacies with serious environmental implications exist. In particular, there is significant concern with tailings dam monitoring and stability. Due to the lack of funds and the conflict in BiH, mining activity ceased and mines have been left without rehabilitation or closure measures. When mining activities stopped, the Smreka mine pit filled with water and is now an artificial lake (about 3 Mm^3) used in summer for recreation by local people (over 10 000 inhabitants). Moreover, agricultural activities (stock-raising, fish farming, etc) are presently carried out.

Srebrenica

Lead and zinc mining and concentration at this site covers some 90% of the locality. It has reportedly been mined or affected by mining in the past, and according to local experts, there are currently some 120 locations where contaminated mine water reaches the surface and flows into local waterways. Pollution can be associated with lead and zinc ore and acid-mine drainage. Polluted water runs into the Krivaja river, which joins the Drina river at the nearby Serbian border. Previous acute accidents are associated with the area – a tailings dam reportedly failed in the 1970s causing transboundary pollution.

Jajce

This site comprises a ferro-alloy smelter with associated air, soil and water pollution problems. A high risk waste pond is also reported. Very limited data is available for this site although it has consistently been reported as an environmental and health risk concern.

Mostar

Both alumina refining and aluminium smelting take place in Mostar. Downstream processing industries made the city the country's centre for aluminium manufacture and the aircraft industry. Primary environmental concerns indicated by local experts relate to the toxicity of leachates (high pH of 12+ and contaminants) and a flooded mine pit.

Former Yugoslav Republic of Macedonia

The Former Yugoslav Republic of Macedonia is situated in the central southern part of the Balkan peninsula. Large, high mountain massifs characterize the country's topography. The average elevation is 850 metres above sea level and more than 30% of the land area is above 1 000 metres with 14 mountain peaks higher than 2 000 metres. The highest peak, Golem Korab (2753 m) stands on the Albanian border. In the midst of the mountains are flat valleys and plains interconnected by passes or deep ravines. The Vardar river runs across the whole country, with 301 km of its total length (388 km) inside the country. The Vardar passes through the capital Skopje before crossing into Greece and finally flowing into the Aegean near Thessalonica. The rivers of the country belong to three basins: the Aegean basin (covering 80% of the country), the Adriatic basin and the Black Sea basin. As a result of the country's diverse natural conditions – with eight distinct climate and vegetation soil areas – the country has rich and diverse flora and fauna. The country has three large tectonic lakes (Ohrid, Prespa and Doyran), over 30 glacial lakes, 15 mountain ecosystems, and 15 river basins with associated rivers.

Surface water runs in about 250 waterways (watersheds larger than 20 km^2), and the largest surface waterway is the Vardar river. Significant parts of watersheds and lakes lie within the territory of neighbouring countries. In general the summer and autumn is warm and dry, and winter is relatively cold with heavy snowfall. The maximum summer temperature in most agricultural areas reaches 40°C, and the coldest winter temperature can fall to as low as –30°C, while the average annual temperatures are above +10°C almost everywhere. The average temperature in July is 22°C and in January –3°C. The warmest region of the country is Demir Kapija, where temperatures in July and August exceed 40°C . Although water shortages do occur the quality of drinking water, when available, is generally high.

Water pollution is apparent in rivers and groundwater all over the country. The most seriously polluted waterways are reportedly the central and lower sections of the Vardar, Pcinja, Bregalnica and Crna rivers. Polluted groundwater is also an issue near Skopje, and especially in Veles. The most serious water pollution concerns are the discharge of untreated wastewater from mining and industry, as well as wastewater from urban centres and livestock breeding farms. Reportedly, only 6% of wastewater in Macedonia is treated prior to discharge into rivers.

The country is in a region of high seismic activity. In 1963, Skopje suffered a devastating earthquake which damaged or destroyed about 80% of its buildings and killed more than 1 000 people. Between 1970 and 1990, the Skopje Seismological

Observatory registered about 30 earthquakes with a magnitude exceeding 5 degrees on the Mercalli-Cancani-Sieberg (MCS) scale or roughly 4.8 on the Richter scale.

Former Yugoslav Republic of Macedonia's mining sector

The Former Yugoslav Republic of Macedonia has deposits containing economic grades of copper, iron, lead, precious metals such as silver and gold, and zinc. In the second half of the 20th century an extensive processing and fabricating infrastructure was also established allowing production not only of these metals and their alloys, but also o ferro-alloys such as ferrochromium, ferromanganese and ferronickel, and aluminium. In addition, industrial minerals such as bentonite, feldspar, gypsum, sand and gravel, stone (carbonate and silicate), cement and other quarry-based construction materials were produced, mainly for export.

Macedonia's aluminium industry centred on Alumina AD in Skopje, a company with the capacity to produce about 20 000 t/yr of billets (primary shapes) and 12 000 t/yr of semi finished aluminium products.

Bucim Radovis DM in Radovis was the country's only producer of copper ore with capacity to produce about 4 million t/yr of ore, 50 000 t/yr concentrates, 8 000 t/yr copper cathode and 3 000 t/yr copper alloys. The company also produced gold and silver bars and granules as by-products. MHK Zletovo-Veles operated the country's smelter and refinery for the production of lead, zinc and associated metals. About 45% of the feedstock came from domestic lead and zinc mines , the balance was imported concentrate. The zinc refinery had a production capacity of 14 000 t/yr and the lead refinery of 40 000 t/yr capacity.

Macedonia operated two ferro-alloy plants at Tetovo and Kavadarci. The Jugohrom HEK-Jegunovce ferro-alloy plant at Tetovo was established in 1952 to produce mainly such chromite-related products as ferrochromium, ferro-silicochromium and sodium dichromate. Power was supplied by nearby hydroelectric plants and used water from Lake Mavrovsko Ezero. Originally chromite was supplied by the nearby Radusa mine. Ferro-alloy capacity at the plant was about 70 000 t/yr. The FENI-Kavadarci (FENI) ferronickel plant at Kavadarci started operation in 1982 with an installed capacity of about 12 000 t/yr using nickel or feedstock from the Rzanovo Mine. Skopje also has a cold-rolling steel mill with 600 000 t/yr capacity and a 100 000 t/yr galvanizing line, now also under foreign ownership.

According to the Ministry of Environment at least 150 million t of mine waste (principally tailings containing Pb, Cd, Zn, Cu, and organic flotation reagents) are held on mine sites, of which smelters have produced at least 6 million t of metallurgical slag and cinder. The two largest mining-power generation complexes have so far produced about 330 million t of waste (mine spoil/tailings, cinder and ash).

The privatization process is of key importance to the status of sites and their potential for ongoing operation and rehabilitation, or closure.

Assessed mining and metal-processing sites

The Former Yugoslav Republic (FYR) of Macedonia hosts deposits containing economic grades of copper, iron, lead, precious metals such as silver and gold, and zinc. In the second half of the 20th century an extensive processing and fabricating infrastructure was also established allowing production not only of these metals and their alloys, but also ferro-alloys such as ferrochromium, ferromanganese and ferronickel, and aluminium. While not covering all the operations in the country, we include a brief summary of major operations.

Bucim

The Bucim mine is the country's only producer of copper ore with capacity to produce about 4 million t of ore, 50 000 t concentrates, 8 000 t copper cathode, and 3 000 t copper alloys every year. The site, located at Radovis in eastern Macedonia, is the country's only major copper mine. It is consistently listed as a major environmental problem for the country with pollution-related risks encompassing heavy-metal contamination of water and soil, particulate emissions to the air, and (possible) stability concerns in tailing impoundments.

Sasa

The Sasa lead and zinc mine is located roughly 10 km north of the small town of Makedonska Kamenica, in a relatively remote location some 5 km to the west of the Bulgarian border. The mine was opened in 1963 and during the 1990s ore production levels at Sasa were roughly 0.5 million t/yr. The site has a number of significant environmental issues including atmospheric dust emissions, mine and tailings dam discharges to surface waters, and a tailings landfill that has no environmental safeguards with respect to the lining of its base; the treatment of wastewater discharged from its base; or dust emission controls under windy conditions. A culvert under the dam failed in 2003 causing a large-scale release of tailings.

Veles

The country's smelter and refinery for the production of lead, zinc and associated metals is located at Veles (MHK Zletovo-Veles). The zinc refinery had a production capacity of 14 000 t/yr, with 40 000 t/yr for the lead refinery.

The smelter is located on the north-western outskirts of the town of Veles (population of about 60 000). The main smelter operations started in 1972-3. An ion-exchange cadmium plant followed in 1979 and other minor processing operations were added in the 1980s. In the 1990s production levels were roughly 65 000 t zinc, 35 000 t lead and 125 000 t sulphuric acid by-product. Emissions from the smelter are contributing to regional atmospheric pollution, but the precise extent of this is as yet uncertain. The river Vardar flows in a south-easterly direction some 0.75 km to the east of the smelter and the slag landfill and is affected by effluents from these sites. Extensive impacts on local soils and community health have also been recorded.

Tetovo and Kavadarci

Macedonia operated two ferro-alloy plants at Tetovo and Kavadarci. The Tetovo plant was established in 1952 mainly to produce chromite-related products such as ferrochromium, ferrosilicochromium and sodium dichromate. The Kavadarci plant started operation in 1982 with an installed capacity of about 12 000 t/yr using nickel or feedstock from the Rzanovo Mine.

Lojane

The Lojane chromium and antimony mine was active from 1923 to 1979, during which time antimony and chromium ores were extracted and processed. The mine site, including the remains of the beneficiation plant and the residual waste dump, is located north of Kumanovo, near the border with Serbia and Kosovo. Due to its position near the border, the mine was in the one of the crisis areas most affected by the 2001 ethnic conflict and is consistently listed as a major environmental problem for the country. The site is next to a school and some small villages. It is a very serious human health risk given high concentration arsenic wastes there.

Zletovo

Zletovo mine first opened in 1947, to provide lead and zinc concentrates for the Veles smelter. The current Zletovo lead and zinc mine is close to Dobrevo village, roughly 3 km north-east of the town of Probistip and 7 km north-west of Zletovo village. The sites associated with this mine give rise to various serious environmental concerns. Above all heavily contaminated mine water is being discharged onto agricultural land, with extensive cadmium, lead and zinc contamination of crops irrigated by river water below the Zletovo mine and other nearby facilities.

The ore is processed at the Probistip concentration plant where the tailing-storage facility is known to be prone to failure. In 1975 the tailing dam at Zletovo failed and the lagoon discharged, flooding villages and agricultural land downstream. The tailing impoundment has no environmental safeguards with respect to the lining of its base, the treatment of wastewater discharged from its base, and control of dust emissions under windy conditions. The tailings pond is another very significant hazard.

Toranica

The Toranica mine is located roughly 18 km south-east of the town of Kriva Palanka and 2 km west of the Bulgarian border. The mine started commercial production in 1987 and for Macedonia was considered to be a relatively new lead and zinc facility. At its peak it accounted for about 20% of Macedonia's total lead and zinc output. The site gives rise to several environmental concerns. There is extensive cadmium, lead and zinc contamination of river water downstream from the mine. The tailings impoundment lacks environmental safeguards for the lining of its base, the treatment of wastewater discharged from its base, and control of dust emissions under windy conditions.

Silmak

Uncontrolled disposal of waste material from the plant and improper handling of material containing chromium salts have caused severe chromium contamination of groundwater and soil, including in the vicinity of the river Vardar. In 1982 the plant began monitoring soil and groundwater and the data confirmed chromium-contamination of the water. To address this problem the plant designed, installed and financed a groundwater abstraction system, achieving a 200-800 mg/l reduction in Cr^{6+} concentrations to total contamination levels of 5-15 mg/l. The plant's target was reportedly 1 mg/l.

CASE STUDY

Bucim

Location: The Bucim mine is located in the municipality of Radovis, in south-eastern FYR of Macedonia. A total number of 50 000 inhabitants live in Radovis and the villages along the Topolnica, Lakavica and Bregalnica rivers.
Bucim, Topolnica and Damjan are the three communities in the direct vicinity of the mine. They comprise about 5 000 inhabitants.The region's main economic activity is agriculture and cattle breeding.

Type of operation: The copper mine has been operational since 1978, apart from a short period of closure following a first failed privatization bid in 2004. The mine was then closed for a short period, re-privatized and then re-opened under Russian ownership in April 2005. Concentrate production contains metals equivalent to approximately 7 to 8 000 t per tonne of copper concentrate and 300-400 kg of gold. About 120 million t of waste rock (still containing 0.11% Cu) is stored alongside the pit, and some 80 million t of flotation tailings are in a nearby valley. About 8 Mm^3/yr of water passes through the process loop and tailings dam and about 2 Mm^3/yr of additional process water is acquired from a near-by source. Pumped water volumes from the pit are generally in the range of 2.5 to 3 Mm^3/yr.

Environmental issues: Copper ore mining and beneficiation (the process of separation of an ore mineral from the waste mineral material) produces waste rock and tailings. The total area degraded by mining operations is estimated as 2 750 ha, of which 65 ha are covered by the open pit, 153 ha by the ore waste dump and 39 ha by the tailings dam.

Water pollution: This site has issues with contaminated effluents despite the relatively modest flow volumes. The major source of contaminated water (mostly Cd, Cu, Zn, Ni, and As) is the waste rock dump outside the mine pit. Other sources include the flotation plant and the sedimentation pond though these are mostly contained. These industrial streams merge and flow into agricultural land at an average rate of roughly 20 litres per second.

Surface water and sediment samples clearly show environmental contamination by heavy metals such as copper and cadmium, with concentrations in the acidic water (pH 3) in the 400-800 ppm range and 189 ppm respectively. At these concentrations copper and cadmium are up to 1 600 and 37 800 times higher than the EU standard for drinking water. A short distance downstream from the mine, the acidic heavy metal and copper-contaminated waters precipitate as a green-to-bluish deposit after merging with neutral or slightly alkaline tailings waters. The stream, which is still toxic, continues downstream to agricultural land and drains into the Topolnica, Lakavica and Bregalnica rivers, which are the main sources of irrigation in the central and eastern part of the country (i.e. between Stip, Radovis and Negotino).

Tailings: Copper tailings from the operation's concentrator plant are delivered by a tailrace and pumped system to an approximately 40 ha tailings dam in the nearby valley. The tailings dam contains over 80 Mt of solid residues from the flotation process containing Cu, As, Ni and other minerals. Although the dam itself is in good condition there is always a risk of dam failure, which would result in serious consequences for the inhabitants in the villages along the Topolnica and Lakavica river valleys and lead to long-term contamination of the environment. Measures to relocate the village and its inhabitants at a less vulnerable site in an adjacent valley are currently under discussion.

Air pollution: In addition to effluents from the dam which mix with acidic and copper rich effluents from other mine sources, dust from the tails surface can also blow onto the nearby village of Polnica (located directly below the tailings dam) and the surrounding land. According to a 2003 REC report, many of the mine-workers have rheumatic ailments and silicosis from inhaling dust. In an effort to reduce the dust, trees have been planted and a polymer has been applied to a 4-hectare area.

Remediation measures:

- Install a water recycling system for mine drainage from the open pit;
- Install a water collection and treatment facility for waste rock drainage;
- Install dust control measures;
- water diversion channels surrounding the dump;
- drainage well for shallow ground water;
- active mine water treatment system comprising absorption columns;
- passive mine water treatment system including settling ponds and an alkalinity-producing lake;
- pumping stations and pipeline to convey water to the tailing pond;
- plant trees on stabilized tailings beaches;
- spray water on exposed areas with no plant cover and new tailings beaches.

Implementation status: Long and short-term dust controls have now been introduced or expanded. The short-term controls primarily use sprinkler systems which have been extended to suppress dust production on the newly created or unvegetated tailings beaches. Long-term measures include revegetation of a further 30 hectares of the tailings dam surface.

Water diversion structures to separate clean and contaminated water, and reduce the volume of contaminated water have now been built. The diversions reconnect to the clean-water flows further downstream from the mine, thus acting as a clean recharge below the contaminated zone.

Work is currently underway to install a pumping station and conduits to collect all contaminated water from below the waste rock drainage (the major source of contaminants) and pump it into the tailings dam. This will close the loop on this source of contamination and all but eliminate the waste rock as a source of contamination to the surrounding surface and ground water.

A fully costed feasibility study has also been completed which will in the future allow the contaminated water captured below the waste rock dump to be treated, producing saleable copper and technical water which would subsidize operating and treatment costs. This study is based on a similar application in Bulgaria.

Lojane

Location: The Lojane mine and its associated ore processing facilities are located in the municipality of Lipkovo in the north-east of FYR of Macedonia. The municipality borders on Serbia to the north. The municipality of Lipkovo has almost 30 000 inhabitants and comprises 21 rural settlements. The village Matejce is the biggest settlement with 3 000 inhabitants.. The main economic activity in the municipality is agriculture which occupies 95% of the active population. The private sector employs a small number of people mostly in trade and small companies producing concrete blocks.

Type of operation: The Lojane mine was in operation between 1923 and 1979. For the mine's first 30 years chromium was extracted. In 1954 the mine began to extract antimony, and in 1965 an antimony smelter started operating at the site. An open dumpsite for flotation waste created by the mine contains more than 1 million t of tailings comprising arsenic, antimony and other hazardous substances. The infrastructure – production and beneficiation facilities, ore waste dumps and tailing ponds, etc. – was abandoned without carrying out any conservation measures.

Environmental issues: The site is a source of high concentrations of arsenic, heavy metals and other toxic compounds contaminating surface and underground water, soil and air. Arsenic is one of the most toxic elements that exist. Humans may be exposed to arsenic through food, water and air, as well as through skin contact. Exposure to the inorganic arsenic present in the Lojane mine can cause various health problems such as stomach irritation, decreased production of red and white blood cells, skin changes and lung irritation. It is suggested that uptake of a significant amount of inorganic arsenic can increase the likelihood of cancer developing, particularly skin, lung, liver and lymphatic cancer. The local school and a few residential and commercial premises are located next to a number of sources of highly concentrated mining and process waste, posing a significant threat to the health of children and adults living in adjacent areas.

Water pollution: The adjacent Suva river receives considerable drainage and runoff waters from the mine and the waste dumps. The arsenic content in the Suva river is up to 40 times higher than the threshold limit value (TLV) for effluent waters in FYR of Macedonia. This water is occasionally used for irrigation, thus impacting the irrigated soil and the crops produced. The concentration of contaminants in the Lojanska and Tabanovska rivers also exceeds national threshold values for certain contaminants but is significantly lower than in the Suva river due to favourable hydrology and hydrogeology conditions. However water from these rivers is more widely used for irrigation and drinking water (Lojanska river) which poses a threat to human health, especially in prolonged use or contact. Based on the samples taken, the ground water quality is satisfactory and only slightly increased concentrations of arsenic are observed.

Soil pollution: The soils in the immediate vicinity of the pollution sources are highly contaminated. For example, the arsenic concentration is 50 times higher than the NOA (Netherlands Standard for Soil). The most critical points are along the Suva river and near the tailing dump.

Another source of toxic-metal contamination is located near the international railway station in Tabanovce where 4 000 t of arsenic concentrate is stored at the open storage yard, left completely unprotected. In addition, there are some 2 500 barrels filled with As_2O_3 and on the verge of disintegrating at the same location.

Air pollution: Due to the very fine structure of the dumped material the tailings dumps are subject to wind erosion. Airborne particulate pollution is a direct hazard to human health in the villages especially to people living and working in the immediate vicinity of the arsenic ponds (e.g. the school in Lojane). The high concentration of arsenic is one of the most serious risks for the community. Swab samples of dust taken inside the school reveal arsenic levels close to chronic health impact levels from this source alone.

Waste: Roughly 90 000 t of waste rock containing low grade antimony and arsenic (1-2%) and a 5 000 t stockpile of ore containing high-grade antimony and arsenic (5-10%) are located in the upper reaches of the valley. These dumps are prone to mechanical disintegration, wind and water erosion thus presenting a significant source of contamination for the area between villages of Lojane and Vaksince. The tailings dump near the old flotation plant contains about 1 000 000 t of fine-grain material with an average concentration of arsenic and antimony of up to 1-2%. The concentrate storage pond contains about 15 000 t of high-grade arsenic-oxide concentrate (>50%). A soil sample taken at the edge of the dump contained 8 093 mg/kg of arsenic, more than 50 times higher than the German threshold for arsenic in industrial soil.

Remediation measures: The intervention currently implemented by UNDP aims to address the air pollution affecting a nearby school as resources are not available at this stage to carry out a more comprehensive remediation programme for the site. The limited intervention is urgently needed to reduce the health hazard for the children posed by air pollution. Remediation measures aim to reduce the amount of dust from the major sources of arsenic contamination from being carried into or around the school. This involves the mine concessionaire using barrier sprays on the concentrate storage ponds, or removing them altogether, and a capping and containment system for other arsenic waste on a further 2 ha. Although this only addresses part of the contamination problem it is should bring a significant and immediate reduction in air-borne arsenic and its corresponding health hazards for the children in the nearby school.

Work in general will involve the following:
- Construction of a diversion ditch;
- Blocking of the leaking abandoned well installed within the tailings dump, by injection of an impermeable solution and a concrete block plug;
- Reshaping the body of the tailings dump;
- Scraping waste rock and transporting it to the tailings;
- Capping construction, in the following order: waste rock, clay and clayey sand, bentonite clay, waste rock and top soil;
- Revegetation with indigenous plants and trees covering roughly 2 ha in all.

Implementation status: Work will be completed by mid-2010. Regarding the use of barrier sprays or the removal of the arsenic concentrate, negotiations continue with the mine concessionaire to prevent this material from remaining a potential source of contamination

Montenegro

Red bauxite, together with coal, represents the key strategic mineral raw material in Montenegro. The country's main bauxite mines, which were operated by Rudnici Boksita Niksic, are located in Montenegro's Niksic area. Primary aluminium was produced by DP Kombinat Aluminjuma, which had smelting facilities at Podgorica. This smelter has capacity to produce over 100 000 t/yr primary aluminium. Lignite deposits are also located at the Pljevlja region, while brown coal deposits are found in the Berane area. In addition, several peat deposits are located in the Skadarsko Lake basin.

Montenegro also has some lead and zinc deposits.

Although there has been oil drilling along the coast of Montenegro for the last 50 years, no economically viable deposits have so far been discovered. Prospecting for oil and gas nevertheless continues in promising areas such as Budva and Bar.

In addition gravel and sand deposits are abundant in the bed of the Moraca river, near Podgorica, in the Lim valley, and in the upper reaches of the Tara river.

Mining is concentrated at several sites in this small country, with bauxite exploitations mostly having a visual impact on the natural landscape but with lead and zinc mines leaving serious environmental legacies. Gravel and sand excavations are also major problems in the south of the country.

Assessed mining and metal-processing sites

Mojkovac

The lead and zinc tailing storage facility for material from the closed Brskovo mine is located directly on the Tara river and for the most part inside the town of Mojkovac. The Tara river and its gorges are on the Unesco World Heritage List. About 3.5 million t of toxic mining and processing waste has accumulated in a tailings pond near Mojkovac in the course of Pb-Zn mining operations. Its Tailings Mine Impoundment (TMI) occupies an area between the right bank of the Tara and the western perimeter of the town itself. The impoundment covers 19 ha, containing about 2 million m^3 of impounded tailings.

Podgorica

The red-mud storage facilities (bauxite residue from alumina production) from the alumina/aluminium plant are located 10 km from Podgorica in the Zeta Valley upstream from Lake Skutari. More than 7 million t of red mud have accumulated at two adjoining dumps, both of which are contaminating groundwater, with the effects apparent in the lake. Apart from the serious problems associated with leachate with a pH as high as 13 and a significant fluorine, phenolic, arsenic and cyanide content, about 10 tonnes of PCBs have also been dumped here, contaminating the groundwater.

Work to recover the PCBs was carried out in 1998. About 1.5 tonnes of broken barrels were recovered but 9 tonnes are still missing. A sarcophagus was built to contain the barrels and contaminated soil. Sediment samples taken in the lake reportedly indicated PCB levels as high as 0.1 ppm at the time, with fish samples as high as 3 mg/kg.

Supla Stijena

At present the mines and flotation facilities of the lead and zinc mill are closed and toxic tailings are dumped on the bank of the river Cehotina. Of particular interest for rehabilitation is the presence of trace metals in the tailings, reportedly of commercial interest (germanium, uranium). This suggests there may be several options for securing and/or remediating the tailing facility in the future.

CASE STUDY

Mojkovac-Brskovo

Location: The town of Mojkovac is located in northern Montenegro on the banks of the Tara river. The canyon downstream is on the UNESCO World Heritage List.

Type of operation: The Brskovo lead and zinc mine started operations in 1976 and went bankrupt in 1990, when work stopped. The mine complex consisted of underground mining and processing facilities, using a wet process to extract lead and zinc. Waste water from the flotation plant containing toxic substances was transported by pipeline to a final disposal pond, located in the town, along the right bank of the Tara river.

Environmental issues: About 3.5 million t of toxic mining and processing waste accumulated in a tailing pond during the 14 years of Pb-Zn mining and processing. The tailing deposit is estimated to contain about 140 000 t of lead and zinc ore. The tailing pond occupies 20 ha, with an average depth of 12 m and is located at an altitude of 807.5 m. Main concerns:

- Seepage from the tailings dam into the Tara river;
- Untreated sewage water discharged into the tailings dam (and subsequently into the Tara);
- Water inflow into the tailings facility increasing seepage and compromising stability;
- Wind erosion of tailings material and subsequent air pollution;
- Bioaccumulation of contaminants in macrophysics, fish, birds, etc.

Tailings: The tailing dam walls have failed twice in the past and could have caused more severe damages had they not been repaired in time. One of these events occurred in the autumn of 1992, when the northern region of Montenegro was struck by very heavy rainfall.

Heavy metals: Analysis of the air, bottom sediments, mud and waste water at the pond revealed relatively high concentrations of heavy metals, such as Pb, Zn, Cd, Hg and As, as well as pesticides, phenols and cyanides.

Air pollution: Air samples at the site indicate high concentrations of SO_2, NO_x and heavy metals, with cadmium, lead and mercury exceeding maximum permitted concentrations. The current situation at Mojkovac needs urgent remediation to ensure the safety of the dam in the event of flooding, erosion or an earthquake.

Remediation measures: Previous reclamation work at the site has included the reinforcement of the dam walls with gravel and concrete slabs, and the placing of a bottom liner to protect the Tara river from contamination. The deposit surface was covered with gravel, followed by a layer of humus, then vegetation was planted. Since mid-2005 the following activities have been implemented:

- Construction of a storm water collection pool;
- Recommissioning of the water decanting structure and existing sewer-discharge tube in the tailings dam;
- Installation of a discharge tube for draining surface waters at the TMI into Tara river;
- Technical design project for a wastewater treatment plant.

Other measures currently implemented by UNDP:

- Construction of a wastewater treatment plant;
- Reconstruction and completion of the sewerage system for wastewater in the tailings impoundment;
- Removal of surface water from the tailings Impoundment;
- Lime stabilization of 500 000 m^3 of tailings mud.

Implementation status: All work has now been completed. The wastewater treatment plant and infrastructure has been installed and is now fully operational. Water in the tailings dam has been pumped out at a rate at which it can be diluted in recipient water sufficiently to ensure environmental or drinking water standards are met. The liquid mine tailings mud has been stabilized through batch and in situ mixing with lime. This means the surface of the tailings now consists of solid material. The Montenegrin Government will now continue to fill the remaining void with inert materials, prepare a final capping layer and plan for productive use of the final level surface.

0
50
100
150
200 km
Map produced by ZOÏ Environment Network, 2010
Mining site
HUNGARY
ROMANIA
CROATIA
BOSNIA AND HERZEGOVINA
SERBIA
MONTENEGRO
ALBANIA
BULGARIA
FORMER YUGOSLAV REPUBLIC OF MACEDONIA
Vojvodina
Kosovo
(UN administered Territory under UNSC 1244)
Veliki Krivelj
Majdanpek
Cerovo
Bor
Zajaca
Krupanj
Veliki Majdan
Kolubara
Szekszard
Hodmezovasarhely
Szeged
Arad
Subotica
Mureshul
Sombor
Timishoara
Hunedoara
Lugoj
Osijek
Tisa
Petrosani
Zrenjanin
Dakovo
Vukovar
Danube
Novi Sad
Timish
Resita
Targu Jiu
Pancevo
Jiu
Brcko
Belgrade
Drobeta Turnu Severin
Bijeljina
Sava
Sabac
Smederevo
Tuzla
Morava
Valjevo
Drina
Vidin
Sarajevo
Uzice
Cacak
Kragujevac
Gorazde
Kraljevo
Timok
Krusevac
Lim
Nis
Pljevla
Juzna Morava
Tara
Novi Pazar
Bijelo Polje
Ibar
Leskovac
Berane
Mitrovica
Niksic
Pristina
Pec
Pernik
Vranje
Podgorica
Herceg-Novi
Kjustendil
Lake Skadar
Drin
Prizren
Kumanovo
Shkoder
Bar
Kukes
Tetovo
Skopje
Kocani
Struma
Vardar
Bojana
Lezhe
Gostivar
Veles
Burrel

Serbia

Serbia is in the central and northern part of the Balkan peninsula and shares boundaries with Bosnia and Herzegovina, and Croatia to the west, Montenegro, Former Yugoslav Republic of Macedonia, and Kosovo (Territory under UN Interim Administration) to the south, Romania and Bulgaria to the east, and Hungary to the north.

The capital, Belgrade, straddles the crossroads between eastern and western Europe in the Balkans, standing on the banks of the Sava and Danube. The two rivers run along three sides of the city. The Danube is the largest river in the country, flowing for 588 km inside Serbia, while forming the border with Romania. Other notable waterways include the Zapadna Morava (308 km), the Južna Morava, Ibar, Drina, Sava, Timok, Velika Morava, Tisa, Nišava, Tamiš and Begej rivers.

Water pollution is a major issue here. Small industrial operations are generally located in urban areas, discharging their wastewater into the public sewers. Larger industrial operations however, are generally located outside urban settlements, usually near riverbanks or in their immediate vicinity. The wastewater from these facilities is often discharged directly into waterways without treatment. Reportedly this is also the case for mining facilities.

According to the Ministry for the Protection of the Natural Resources and Environment, the largest proportion of industrial and mining wastewater is discharged into the Sava and its tributaries. However, the Timok basin is thought to be under the greatest pressure, due to the composition of the discharged industrial and mining wastewater, its high contamination, and the capacity of the basin to assimilate this influx. On the other hand, the Federal Ministry and Working Group for Environmental Protection reports that the most serious conditions are found on the watershed in the vicinity of the mines at Bor, Krivelj, Majdanpek, Mojkovac and associated operations. This pollution is mainly due to ore beneficiation. Among serious incidents in these areas the tailing impoundments were breached at Majdanpek, Veliki Majdan and Brskovo, causing direct pollution of the rivers Pek, Drina and Tara.

Serbia's mining sector

The mining industry in Serbia represents a vital component of the economy in general. Primary minerals extracted in Serbia include copper, coal, lead-zinc with associated gold, silver, copper, bismuth and cadmium, red bauxite and modest quantities of oil and gas. Prior to the conflicts of the 1990s, the country represented a significant proportion of European capacity for refined aluminium, copper lead, silver and zinc. Significant reserves of other mineral commodities, such as silica raw materials, quartz mineral sands, dolomite, zeolite, feldspars, clays, phosphorite, wollastonite, barite, bentonite, sea salt, and construction materials have also been identified in many different locations in Serbia. Copper ore deposits occur as porphyry copper and massive sulphide types, located predominantly in the East Serbian sector of the Carpatho-Balkanides (i.e. the Bor metallogenic zone). In addition to the significant concentrations of gold in the Bor metallogenic zone, other areas with gold potential have been found in Serbia, including the volcanic complex of Lece, where gold is associated with hydrothermal vein-type lead, zinc and copper deposits, and with several other prospective areas of volcanic-hosted gold mineralization.

Rudarsko Topionicki Bazen's (RTB) Bor mining, beneficiation, and smelting complex in Serbia accounts for all of Serbia's total mine output of copper from its Bor, Majdanpek and Veliki Krivelj open-pit mines. The Bor mining and metallurgical complex produces copper ore in quantities that are significant at a regional level. Secondary precious metal refining at the complex is also substantial. An important point in the context of this study is that continued operations are to be expected in the Bor zone. In 1994, a major deposit of 700 million t copper ore (4million t copper) was discovered in the Bor region.

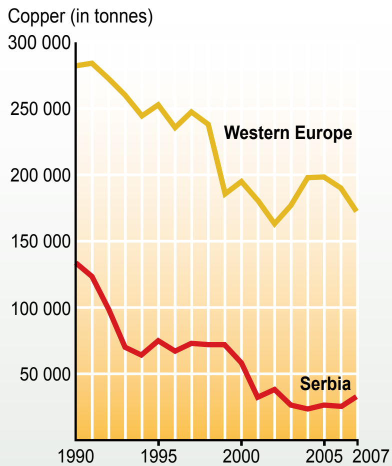
Small quantities of petroleum and natural gas are produced in Serbia's northern Vojvodina Province. Oil and gas reserves are minor compared to other regional producer countries. The most important oil field is Mokrin, in the Kikinda region, which accounts for 60% of all Serbian production.

Serbia is also a major source of coal in the region, with lignite making up more than 98% of output. It is mainly surface-mined in the Kostolac and Kolubara basins, which contain low-calorie coal (lignites).

Serbian production of industrial minerals includes such commodities as clays (bentonite, fire clay, and kaolin), feldspar, gypsum, magnesite and pumice. In addition, silica raw materials, with mineral potential quartz sands are located in the Sava, Danube, Morava and other riverbeds. The main producers of building material are the cement factories at Beocin, Kosjeric and Novi Popovac, and brick factories at Kikinda, Novi Becej, Novi Pazar, Ruma and Kanjiza.

With the wide range and extensive nature of Serbian mining operations, the existence of serious pollution sites is almost a given. Several of these deposits are situated in protected natural areas, even in national parks. While there are seri-

Copper mine production



Note: Western Europe includes Finland, Norway, Portugal, Spain, Sweden
Source: US Geological Survey

ous problems with unstable and eroding waste at the mines in Kolubara and Kostolac; the most seriously polluted areas are in the watershed in the vicinity of the Bor, Krivelj and Majdanpek mining areas. Pollution risks are first and foremost related to mineral-beneficiation sites (milling and flotation plants). The most serious incidents listed are the breaches of tailing dams at Majdanpek and Veliki Majdan causing direct, serious contamination of the river Pek by heavy metals.

Assessed mining and metal-processing sites

Bor copper mines and smelting complex
The smelting complex and series of copper mines appear in every list and is highlighted by all sources in the region. It arguably represents the region's most serious environmental legacy. Extreme pollution is released to the Borska, Timok and Kriveljska rivers with the Danube river as the final recipient. There is also a high risk of catastrophic failure in one or more engineered structures containing tailings. Extreme pollution is also released to the air, thus affecting human and animal health to a serious, even catastrophic extent.

Veliki Krivelj

This site is also part of the Bor complex and pollutes the Kriveljska and Timok rivers, then the Danube (final recipient). This site has an engineered structure with a high probability of failure. The Veliki Krivelj tailing dam is located in the Kriveljska river valley and was built by diverting the river (tunnel and collector) and damming it up and down-stream. This collector is damaged and may fail, releasing toxic substances to the river system.

Cerovo

This smaller copper mine and mill are also part of the Bor complex. Mine water is heavily contaminated with heavy metsls.

Veliki Majdan

The lead and zinc mine is in the vicinity of Ljubovija, close to the river Drina. Apart from the usual environmental problems associated with lead and zinc mines in Serbia, this site has been involved in at least one serious release of tailings. At the beginning of summer 2001 a flood significantly damaged a dam. Part of the dam, made of flotation waste, was swept into the Crnacka reka and then on into the Drina a few kilometres downstream. Tests carried out afterwards proved the presence of heavy metals in excess of acceptable limits in the water of the Drina.

Zajaca smelter

This operation, where antimony mining, beneficiation and smelting took place, is close to the Drina river. Mining operations were conducted underground and serious acid-mine drainage with a high concentration of heavy metals in effluents are reported.

Kolubara

The site is adjacent to the Kolubara river, a tributary of the lower Sava. The lignite pits there reportedly cause problems with particulates, phenols and other contaminants in waste water discharging from the coal drying facility. In addition, abandoned mine pits and land are still not replanted.

CASE STUDY

Bor complex

Location: A century ago the town of Bor was just a small village. All that changed with the discovery of copper ore and its exploitation since 1903. The village has turned into an industrial and urban centre in north-eastern Serbia.

Type of operation: The Rudarsko Topionicki Bazen's (RTB) Bor copper mining, beneficiation, and smelting complex comprises several mines and processing facilities. At peak output, around 1990, it employed 14 000 people. With the subsequent economic decline the state of infrastructures has deteriorated, and unemployment and poverty have rapidly increased.

Environmental issues: The copper ore treatment process produced large amounts of ore waste and flotation tailing heaps, located in the vicinity of the towns of Bor and Majdanpek. The waste and tailings heaps pollute the environment in various ways, sometimes verging on minor environmental disasters. A century of mining has reportedly have left over 11 000 t of waste per citizen of Bor. Air pollution, lifeless rivers, and damaged and destroyed agricultural soil are among the other problems people in the region must face. Mining related hazards at the Bor mining site involve:

- toxic/acidic effluents;
- uncontained waste rock;

- dust emissions and unsecured workings;
- toxic solid waste;
- airborne toxic substances and SO2;
- poorly contained and/or unstable tailings wastes;
- poorly contained smelter residues and chemicals.

Water pollution: Mine water from underground mining flows directly into the Bor river. It subsequently joins the Kriveljska river, which also drains water from the Veliki Krivelj and Cerovo mines. About 9 km to the east of the mines, long-term studies have identified the following water characteristics:

Water analysis at Bor complex

Parameter	Unit	
pH	-	3.7 - 6.5
Sulphate	mg/l	880 - 3235
Iron	mg/l	0.8 - 233
Copper	mg/l	0.5 - 315

Source: UNDP Feasibility study for the remediation of Bor mine surface- and groundwaters, 2006

In addition to mine drainage, copper smelting and electrolysis processes discharge process-effluents into the Borska river basin. The water course formed when the Borska and Kriveljska rivers join is known as the Crna reka (black river). It is part of the Danube basin. Crna reka is considered one of the most polluted rivers in Serbia.

Remediation: A basic design for remediation works was decided in 2007. The Government of Serbia intends to use the proceeds of part of a World Bank loan to pay for:
- site investigations;
- technical and organizational planning;
- carrying out an environmental impact assessment;
- preparing environmental management plans for the remediation of the tailings dump facilities (TDF) and mining waste dump sites at the Bor mining area.

Currently, the Government of Serbia is considering other possible options for privatization of RTB Bor. The tailing ponds, waste dumps and some other facilities that are not going to be the part of the future operations will return to the responsibility of the Government of Serbia. The Government will need to deal with these liabilities in terms of remediation and/or closure, and maintenance. The feasibility study carried out in 2007 identified various priorities: the urgent need for remediation of the tailings ponds, waste dumps, dam facilities, and the Veliki Krivelj collector; a river bypass through a tunnel underneath a tailing pond.
Rehabilitation of the Veliki Krivelj collector is already the subject of an ongoing remediation project.

Kosovo
(UN administered Territory under UNSC 1244)

The territory of Kosovo (Territory under UN interim Administration) is of particular interest in the trans-boundary context of the Balkans. It is both a centre of considerable mining activity and a source of water for each of the three distinct watersheds in the region. As such, all fluvial flows from Kosovo are trans-boundary.

Kosovo is landlocked in the centre of the Balkan peninsula and has a surface area of nearly 11 000 km^2. It is bordered by the FYR of Macedonia, Albania, Serbia and Montenegro and has varied terrain with high plains at around 500 metres above sea level, rolling hills and mountains that reach an altitude of over 2 000 metres. Its rivers flow into three different seas; the Adriatic, Aegean and Black Sea via the Danube. Except for the source of the Ibar which is 30 km upstream from the boundary, virtually no water flows into Kosovo.

Kosovo is home to a rich ecosystem and biodiversity. Some 46 000 ha or roughly 4.3% of its territory is under protection. Through forested areas it connects to the Curst mountains, Durmitor and the Dinarik forest. There are reportedly more than 2 000 endemic species in the Sharr forest area representing nearly 20% of European flora. The Curst mountain area is also an important part of European and Balkan biodiversity, home to about 750 types of endemic alpine flora.

Kosovo is separated in 30 municipalities with Prishtina/Pristina as its administrative capital and largest urban centre. Other large cities or towns are Prizren, Peja/Pec, Mitrovica, Gjilan, Ferizaj/Urosevac and Djakova/Djakovica. The population has grown steadily since the mid-20th century and is expected to continue to increase well into this century, with one of the highest population densities in Europe. The majority of the population consists of ethnic Albanians while the largest minority is Serbian. Other minority ethnic groups include Bosnians, Turks and Roma.

The major towns in Kosovo are supplied mainly by reservoirs; the Gazivoda reservoir for Mitrovica; the Batllava and Grancanka reservoirs for Prishtina/Pristina, and the Radoniq reservoir for Djakova/Dakovica. Other towns rely on surface water and/or groundwater. Around 44% of the total population, and only 8.4% of the rural population, has access to piped municipal water. The rural population relies on village water-supply systems, their own wells or on springs and surface water. Rural wells are generally in poor condition and subject to organic contamination.

In villages and other small settlements, waste water is disposed of in open channels contaminating surface and ground-waters. Industrial waste water is generally discharged directly into rivers without treatment. As a result, river

water quality in the lowland rivers is very poor, while the upstream rivers are mostly of good quality. Some of main rivers downstream (e.g. Sitnica river) from larger municipalities and industries are so heavily polluted that the water is unfit for human consumption. Groundwater quality is significantly affected by pollution.

Kosovo is located in a region of high seismic activity, namely the seismically active zone of the Alpine- Himalaya Orogenic Belt. Historical records show that the region has experienced some 82 earthquakes exceeding 5 degrees on the Mercalli-Cancani-Sieberg (MCS) scale or roughly 4.8 on the Richter scale. Of these, 25 have been of intensity 7 or greater.

Kosovo's mining sector

Before the period of hostilities during the 1990s, Rudarsko-Metalursko-Hemijski Kombinat za Olovo i Cink Trepca (Trepca) in the (then Serbian) province of Kosovo was the country's and the region's largest lead and zinc mining, beneficiation, smelting and refining complex. Trepca also produced associated metals such as antimony, bismuth, cadmium, gold and silver.

The other major metallurgical facility in Kosovo was Ferro-Nickel D.D. Glogovac, which was the only mine producing nickel ore and smelting ferronickel in Serbia at that time. Glogovac has reportedly been closed since 1998. Mining for bauxite was also conducted in Kosovo by AB Kosovo Klina.

Trepca Mines Ltd. was established by the Selection Trust in London in 1927 and regular production started at the Stan Terg mine in 1930. The nearby lead smelter at Zvecan was commissioned in 1940. After the Second World War Trepca became a major employer with widespread business units throughout Kosovo, Serbia and Montenegro. However from the early 1980s onwards Trepca began to suffer from inadequate investment, and insufficient repair and maintenance. The period of social instability, which starting in 1990 and continued until recently, led to further deterioration in Trepca's business and its operations.

The arrival of the Nato-led Kosovo Force (KFOR) in June 1999 also separated Trepca. In the north, the mines in the Leposavic area and the lead smelter at Zvecan continued to operate. South of Pristina, at Kizhnica and Artana (Novo Brdo), Albanian workers repossessed the mines, but were unable to restart any production due to lack of supplies, consumables and other materials. In August 2000, KFOR forced the closure of operations at the lead smelter in Zvecan for environmental reasons and all production at Trepca came to an end.

Kosovo has extensive deposits of pliocene brown coal (lignite) in the Prishtinë basin. Coal is currently produced from Bardh and Mirash open cut mines and used for power generation. At least 6 billion tonnes of coal resources are estimated to exist in Kosovo. Other coal resources previously controlled by the Trepca mining conglomerate are reportedly not in operation for technical as well as legal reasons linked to the ownership of Trepca. In general the lignite mined in Kosovo was valued throughout the region for its low-sulphur content.

Though several sources report that problems associated with air, soil, and water pollution by hazardous materials are widespread in Kosovo, there is a noticeable lack of data on the extent of problems.

Trepca – Artana/Novo Brdo

Location: Located 51 km south of Pristina, the lead and zinc mine remained operational until the 1999 conflict. The site comprises the mine itself and two tailings dumps adjacent to the former Artana concentrator along the Marec-Kriva riverbank.

Type of operation: The Novo Brdo ore field has two mines, Artana (Novo Brdo mine) and Farbani Potok. There has been mining here since the Roman era, with intensive production of lead, zinc and silver in medieval times. Modern mining started after 1945 at Artana and 1963 at Fabani Potok. So far about 1 million t have been mined from these deposits.

Environmental issues: The Trepca conglomerate has had a long history of environmental problems: toxic and/or acidic effluents, uncontained waste rock, dust emissions and unsecured workings, poorly contained and/or unstable tailings wastes.

Tailings: Two large tailings impoundments are located on the embankments of the Kriva river. Tailings pond no.1 (roughly 400 000 m^3) is situated just next to the old Marec concentrator (close to the Artana mine), whereas tailings pond no.2 (roughly 1.6 million m^3) is located further downstream. Zinc and lead are present, both at concentrations of up to 4%. Both represent a significant source of environmental pollution and a potential source of revenue for reprocessing. Both tailings ponds are severely eroded and result in large amounts of contaminated, toxic waste being carried into the river.

Water pollution: Acidic runoff, heavy metals such as cadmium, lead and zinc are carried into the river via surface runoff and leaching. Resulting water pollution presents an enormous threat to human and terrestrial species in the immediate vicinity and to aquatic species in the Kriva river. Contaminated water is also discharged from the mine workings and flows to a short drainage conduit, then straight into the Marec-Kriva river. The river downstream from the mine-water discharge is murky brown and the stream bed is grossly stained. This situation persists for many kilometres downstream. Mine discharge is highly acidic (pH around 2-3) and contains a significant metal load (mainly zinc and iron).

Remediation measures: The ongoing erosion and slope instability of both tailings heaps is of great concern. Complete removal of both tailings heaps (possibly for subsequent recovery of metals in the tailings) would be the optimal solution in environmental and geotechnical terms. However given the limited funds available, priority has been given to emergency measures to mitigate the environmental impact through river protection works which will reduce the movement of contaminated tailings into the river. Such work is envisaged as a temporary measure until the tailings can be removed for reprocessing in the future. The measures to be taken include the following;

- Site clean-up (approximately 30 000 m2 or 3 hectares for each site):
- Cleanup and collection of tailings from the smaller part of the dump, transport to the larger part and disposal (Tailings Dam #1 only);
- Excavation of contaminated soil from the vicinity of the nearest tailings dump;
- Backfilling of the excavations with inert material (waste rock, construction waste, fertile soil).
- Construction of diversion ditches – around the perimeter of the upper side to prevent runoff water from upstream from entering the containment, then flushing and spreading contamination via water erosion;
- Construction of a protective embankment to divert river flow and prevent water flushing the tailings material:
- Temporary capping construction to minimize wind erosion and water penetration inside the tailings body (Tailings Dam #1 only).
- Reshaping the tailings dump body to: i) optimize the total area to be covered; ii) optimize the slopes to achieve long-term stability (length, dip); iii) minimize wind and water erosion; iv) eliminate ponding; and v) maximize runoff.

Implementation status: Work to protect the river for Tailings Dam #2 has been completed. River protection works for Tailings Dam #1 has recently started and will be shortly completed.

CASE STUDY

Trepca – Stan Terg/Stari Trg mine

Location: The Stan Trg-Stari Trg mine is located roughly 8 km north-east of the town of Mitrovica. It is considered by some to be one of the richest lead, zinc and silver mines in Europe. Since 2000 rehabilitation work has been in progress with support from several international donors.

Type of operations: The tailings pond consists of a main dam; a western side dam and the pond area filled with tailings from the processing of lead and zinc ore at the Prvi Tunel concentrator. Gold processing residues have also been discharged into the tailings pond on a minor scale.

Environmental issues: The most serious environmental problems associated with this site are contaminated mine water, which is still polluting surrounding areas through contaminants leeching into the soil and ground water, and dust from waste material on uncovered tailings dumps. There is documentary evidence from a multitude of sources of the heavy impact of lead contamination on the population of the Mitrovica area, particularly regarding more seriously exposed minority groups.

Water pollution: Untreated mine water with elevated lead and zinc levels from the Stan Terg/Stari Trg mine, tailings and other process effluents from the process plant are discharged into the Zharkov Potok tailings pond. Dam seepage and decanted pond water are discharged without treatment into the Ibar river, adding to its pollution. It is estimated that an average of 6.5 tonnes of Zn and 30 kg of Cd are emitted annually in mine water into the Barska river (and subsequently into the Ibar river)..

Air pollution: No cover has been placed on the surface of the tailings and dam, making them a source for dust storms. The Zharkov Potok dam itself is located upstream the town of Mitrovica and contains up to 1% lead in its tailings. In addition to water pollution, the tailings pond is thus a significant source of airborne lead, a severe health hazard for nearby residents particularly during the hot, dry summer when strong winds blow across the dam and bare dry tailings beaches towards homes.

Remediation measures: Given the scale of contamination from mine and mine-related industries in the Mitrovica and Stari Trg area the planned intervention is quite limited. Remediation measures are focusing primarily on work to reduce the contaminant load entering the environment as much as possible. Studies have shown airborne dust to be the largest contribution to the burden of lead in human bodies. Work has therefore focused on dust prevention and tailings stabilization at Zharkov Potok to stop this source of lead pollution.

Proposed activities: Reinforcing, reshaping and levelling of the dam crest surface area, construction of a temporary surface cap and revegetation of the dam crest as a temporary emergency measure to improve air quality for residents living near the tailings pond.

Results to be achieved:
- Reduce generation of toxic tailings dust particularly for lead;
- Improve air quality for the residents living near the tailings pond.

Implementation status: Work has been completed.

Remediation exercise

Emergency risk reduction at tailings management facilities in Albania

Three priority sites in Albania – Fushe-Arrez, Reps and Rreshen – have been chosen for more detailed examination, with a view to developing appropriate risk reduction interventions as pilot activities for the region. All three mining sites comprise non-operational tailings dams that display severe signs of instability, leakage and failure. The results are presented in the following section.

Practical approach

To reduce the risk of further destabilization and uncontrolled release of mining waste short to medium- term interventions were identified as the most feasible approach to improve the situation at the sites. Both technical and financial capacities are limited which needs to be taken into account when developing feasible interventions. To provide realistic, replicable solutions that are sustainable and create local capacity for numerous similar sites in the region, it was recognized that these interventions needed to:

- apply locally sourced materials to reduce costs and involve the local community;
- employ locally available services (construction work, technical equipment, engineering techniques) to increase local capacity and promote replication of implemented measures;
- be robust and require low-maintenance to ensure proper functionality, lower cost, and longevity of the measures;
- be cost-efficient to achieve timely action, catalyze investment for follow-up activities and encourage applied measures at similar sites;
- be compatible with other risk-reduction and safeguard measures that need to be carried out to achieve long-term stabilization of the site.

The expert team developed three site-specific engineering solutions taking into account the guidelines described above. The designs and calculations provide a solid basis for technical intervention. Furthermore, the technical activities will be accompanied and harnessed for capacity-building activities such as training workshops and study tours to benefit from the unique opportunity to enhance local and regional know-how for environmental remediation, mining site management and risk reduction.

Rapid risk-reduction interventions

In practice, rapid risk-reduction measures involve several characteristic limitations. First, such measures must be achieved in a short period of time: the problem is sufficiently urgent for additional planning and execution time to be neither available nor advisable. This also often implies that significant trade-offs or limitations in performance of the interventions may have to be accepted. Secondly, budgets, design processes, technologies and construction techniques must be simple. Thirdly, in some cases it has to be accepted that the intervention will only last for a few years or perhaps a couple of decades, rapid risk interventions often being interim measures, rarely long-term solutions.

In the context of the Albanian sites, the following criteria apply to rapid risk interventions:

- simple robust engineering interventions to substantially reduce the risk of structural dam failures (which may suddenly release large volumes of tailings), which can be implemented at relatively low cost;
- engineered interventions to substantially reduce the volume of tailings lost through water erosion from each of the tailings impoundments;
- interventions designed and built without the need for detailed geotechnical investigations and with modest requirements for civil engineering design documentation;
- work to be carried out by local contractors with materials available in Albania;
- interventions to significantly reduce the generation of effluents contaminated with dissolved heavy metals (through more effective separation of water from contact with tailings);
- engineered works and practices established to ensure their operation will be sufficiently robust for them to be able to operate for many years.

It should however be noted that such interventions can reduce the release of effluents with elevated acidity and dissolved metallic pollutants, but they cannot completely stop them. Nor will risks of pollution or dam failure be completely removed, but the risks will be significantly reduced.

Why rapid intervention?

There are two important reasons for proposing rapid interventions: they can be achieved in a short time, and budgets, design processes, technologies and construction techniques must be simple. The limitations or trade-offs associated with such interventions have also been highlighted. In the context of the work in Albania, several additional reasons weigh heavily in favour of choosing such approaches, in particular the need to implement risk-based approaches to use scarce resources efficiently (and save money overall) and avoid wasting potentially valuable resources.

Tailings management facilities (TMF) in Albania – much as many others in the region – often contain relatively high concentrations of valuable residual metals. In many instances profitable reprocessing of the tailings at some time in the near or distant future will be both feasible and desirable. Full interventions to close and remediate such sites would often preclude such operations, wasting scarce resources. Rapid interventions on the other hand serve to reduce risks to an acceptable level in the interim period.

The land occupied by TMFs also has a value, sometimes a high and readily ascertained value (in urban areas where flat land for the siting of buildings or factories is in short supply), sometimes an intrinsic value (in areas where biospheres may be created) and so on. Full interventions require prior agreement among the relevant stakeholders as to what land use is desirable and appropriate for a TMF site after closure. This can be a complex and lengthy process. Resorting to rapid inter-

vention can be a good way of buying time to ensure a desirable long-term outcome.

In both the above instances, it should be noted that properly planned rapid interventions may indeed also be part of the long-term solution, the first important step. As such, approaches have been taken to ensure that money has not been mis-spent and resources have not been wasted.

In the context of the Albanian situation, the process of conducting, documenting and disseminating rapid risk-reduction work is also of great importance. It is required as both a capacity-building exercise for national actors, and as part of regional examples of cost effective and technically and/or environmentally effective solutions. Such capacity-building that does take place will also contribute to resources for future full-site remediation that will need to be carried out in future decades.

Long-term remediation-rehabilitation solutions for mine sites in Albania

There are very real differences between the approaches and goals for rapid risk-reduction activities addressed by this work, and those applicable to long-term solutions for mining sites. Genuine long-term remediation or rehabilitation solutions are only possible as part of mine-closure activities designed to ensure that:

- Future public health and safety are not compromised;
- Environmental and economic resources are not subject to physical and chemical damage;
- Subsequent use of the site is beneficial and sustainable in the long term;
- Any adverse socio-economic impacts are minimized; and
- All socio-economic benefits are maximized.

As we have said mine-site closure was not considered an integral part of the project life cycle for the mines in Albania and as a result significant legacies remain (such as those addressed by this report). However at some time in the future, proper closure will still be necessary. Achieving long-term solutions for mine sites (the closure process) must make allowance for community expectations and concerns, government requirements, and financial issues, while minimizing environmental impacts.

Having said that, one immediate difficulty for Albania is clearly that most mines and minerals-processing facilities have ceased operation. While still at the planning stage mines are entirely at liberty to address sustainable development goals during closure. Mines in the middle of their operating life have significant opportunities to do so too. But operations close to the end of their economic life have only limited options and those that have ceased operating have the least latitude. Bridging solutions such as rapid risk-reduction are required to reduce the unacceptable levels of risk which currently prevail until more sophisticated solutions become available.

Selection criteria

Technical issues, national priorities and capacity-building issues have contributed to the choice of sites for rapid risk-reduction work. Each of these sites meets the following important selection criteria:

Compliance with national priorities for environmental and health protection

- The types of pollution, the visibility of the sites, and the visibility of pollution are clearly relevant to key National Priorities expressed by the Albanian authorities (maintenance/restitution of public health and development of tourism);

Serious environmental and public health implications

- Each of the sites is contributing large amounts of pollution to rivers via both chronic erosion, chronic release of contaminated waters and larger acute failure events – heavy metals such as copper, zinc, cadmium, arsenic, lead and cobalt are carried by the rivers both in dissolved form and as suspended sediment (finely ground tailings);
- Receiving waterways appear to be significantly affected by the pollution entering them from the sites – anecdotal evidence suggests that pollution is seriously affect the health of the aquatic ecosystem;
- Rivers flow through populated areas and are used for irrigation during the summer months;
- Rivers are fast flowing and flow directly to the Adriatic Sea;
- The periods of highest tailings erosion correspond to high flow and flood periods indicating that suspended sediment containing heavy metals will be carried directly to the sea during such periods;
- The period when dissolved heavy metals will reach the highest relative concentration in waterways corresponds to low-flow periods when the rivers are used for irrigation. However it is still not clear how far the waterways carry dissolved metals before precipitation.

Capacity-building value

- Selected sites are suitable for extensive involvement of national actors in all stages of design, construction, operation and monitoring thus ensuring contribution to the capacity in conducting, documenting and disseminating rapid risk-reduction works in the Western Balkan region.

Applicability as examples for mining risk reduction activities in the Western Balkans

- Each of the sites represents related but distinctly different examples of mine legacy problems common to the Western Balkans (and other transition economies with mining histories):
  - Fushe-Arrez: A site with very serious tailings erosion problems where new operations and re-mining operations are apparently being allowed by the authorities, making the situation worse not better;

- Rreshen: A site with an underflow culvert water diversion where serious tailings loss (undermining) is currently occurring and may lead to full dam failure;
- Reps: A site where another dam overtopping event with resultant tailings erosion could cause a large dam failure.

- All the sites lack basic safety measures, are not maintained, and are releasing chronic pollution on an ongoing basis (in at least two cases involving large to very large cumulative volumes of material) – these being ubiquitious situations in the Western Balkans;
- all have very significant potential to release large amounts of pollutants into the environment (rivers and Adriatic Sea) through large scale failures;
- all sites are close to populated areas and main roads and are thus readily and easily accessible – facilitating both access for engineering interventions and for dissemination purposes;
- each site is well suited as an example of rapid risk-reduction work

Selected sites

Fushe Arrez

The Fushe Arrez site comprises two tailings facilities. One is quite new and is currently operational, processing copper ore at the site. The second facility remains Government-owned and is not operational. The older tailings dam is a source of serious ongoing pollution. The new facility is contributing to the pollution in the older impoundment and also constitutes a physical hazard in itself.

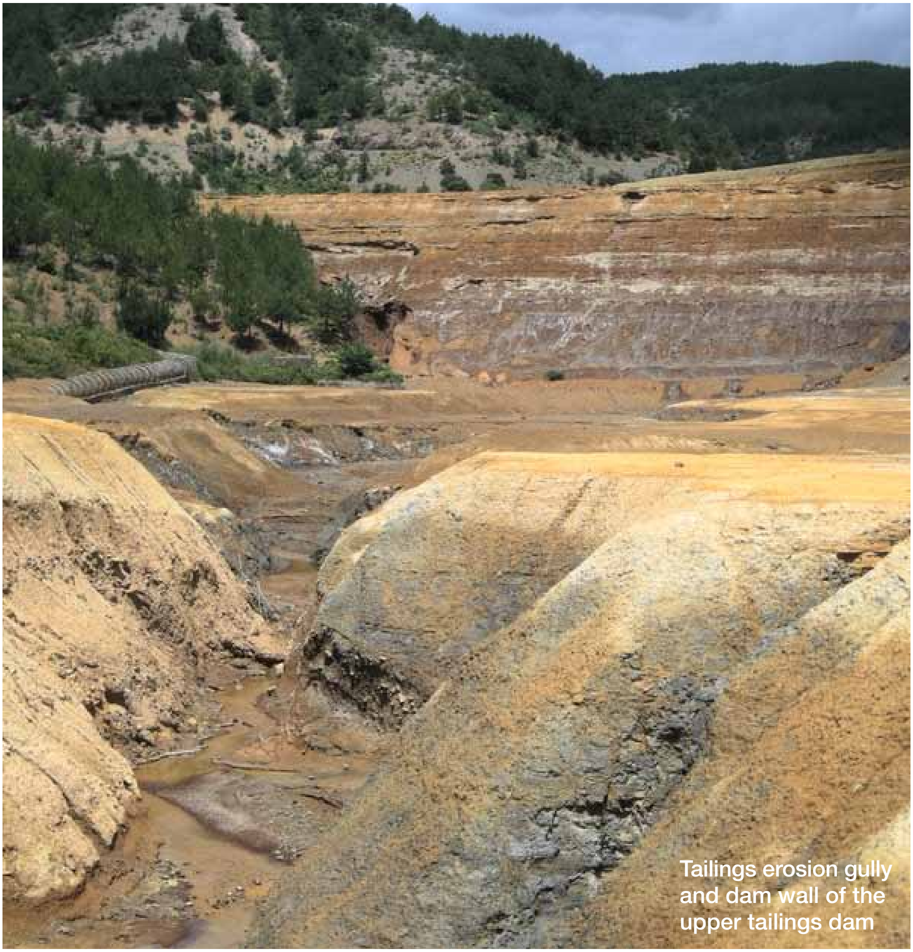
Due to overtopping of diversion structures causing a dam breach (at some time in the past decade) about 0.5 to 1 million t of tailings have already been eroded and washed into the Fani te Madh river. As a result of the failure of water diversion structures, large scale gully erosion of the tailings impoundments has occurred. Urgent measures are required to divert waters, halt further pollution and begin the process of planning for longer term solutions for the site. While the private company operating the metallurgy plant at the site has carried out work to "reinstate" water diversion channels, this has only been done as far as the boundary of their land. The water being released is still entering the downstream tailings impoundment and washing tailings into the river system at roughly the rate it has had over the past decade or so (about 50 000 t of tailings washed into the river every year. Estimates indicate that these materials contain about 100 to 150 tonnes of copper per year.

The new operators of the concentrator operation, who are depositing their tailings on top of tailings at the upper end of the site are increasing environmental risks by:

- creating a high risk site in the part of the site they control as a result of inadequate engineering, inappropriate seepage control, and inadequate management of tangible dam failure risks;
- delivering water that they divert from their part of the site directly to the State-owned part of the site where it is eroding tailings into the river;
- allowing leachate from their tailings impoundment to interact with the downstream tailings dumps on the State-owned part of the site, potentially exacerbating the tailings risk;

Dam wall between "new" tailings dam and "upper" tailings dam

View on the lower tailings dam with erosion channels



Tailings erosion gully and dam wall of the upper tailings dam

- discharging untreated (heavily contaminated) process water directly into the river without treatment;
- discharging tailings dam decant water directly into the river without treatment.

Proposed intervention

An engineered risk amelioration intervention has been defined for the Fushe Arrez site. In general terms, this focuses upon the following:

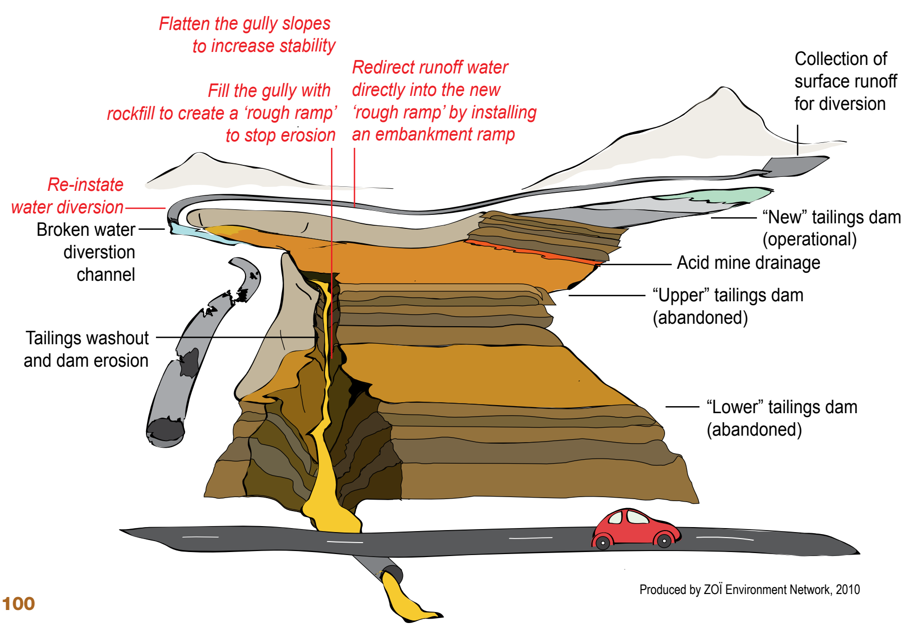
- erosion control works in the outflow channel (the channel formed by tailings erosion) to allow water from the site to pass through this channel without erosion or further damage to tailings structures;
- construction of a roughly two-metre high diversion dam below the top dam to ensure that any failure or overflow from the operational part of the site is diverted into controlled flow channels;
- seepage control and recycling from the operational part of the tailings dam.

Remediation design

The TMF downstream of the new dam contains old tailings that can be distinguished from the newer tailings by their color, as fresh tailings are greyish compared to the old tailings which turn yellowish over time because of iron oxidation.

There are three major impoundments in the valley (referred to here as "new", "upper" and "lower"). The lower tailings dam wall is located approximately 150

Tailings dam safety concerns and possible improvement measures at Fushe Arrez



m above the "Big" Fani river bed. These impoundments reportedly contain some 3 million tonnes of tailings with copper at low concentrations of 0.1 to 0.3% Cu plus other metals such as gold.

Reps

The Reps site has four tailings impoundments that all contribute to ongoing chronic pollution of the Fani te Vogel river. The concentration plant has been closed and the tailings dumps abandoned, though they remain the responsibility of the Albanian State. A large construction camp for the new motorway to Kosovo now stands on the tailings sites and the future motorway will pass just next to them.

Three of the tailings impoundments at Reps were built just beside the river bed – or in the riverbed below high water levels. This is a totally inappropriate method of disposing of tailings. The fourth impoundment is a valley-fill dam and its structural stability is significantly compromised – also due to the failure of water diversion structures. The proposed intervention will focus on the valley-fill dam, which is located upstream from a large flyover structure for the motorway.

All the damage to the dam – and all major risks at the site – are directly related to water flowing into the tailings dam, which in turn is caused by failed water diversion structures. In addition, there has been a very large loss of tailings from the face of the dam. This was reportedly caused by a dam overtopping event in 2004. The catchment in the valley above the dam is large and significant water diversion structures were built at the same time as the tailings dam and impoundment.

As indicated, due to at least one dam overtopping event in recent years, large concave washouts are present on the face of the dam where many hundreds of cubic metres of tailings have been washed away. The dam is in an unstable condition and is steadily losing tailings through erosion to the environment. Work on the dam must focus on safely diverting and managing such water flows.

View on Reps tailings dam

Failed water diversion channel

Proposed intervention

The engineered risk-amelioration work defined for the site focuses on the following:

- repair and reinstatement of a portion of the previous water-diversion structure on the left hand side of the catchment for the dam;
- increased bunding within the tailings dam to ensure that water does not approach the dam crest and that water is diverted;
- erosion control works in the outflow channel (the channel formed by tailings erosion) to allow water from the site to pass through this channel without erosion or further damage to tailings structures.

Remediation design

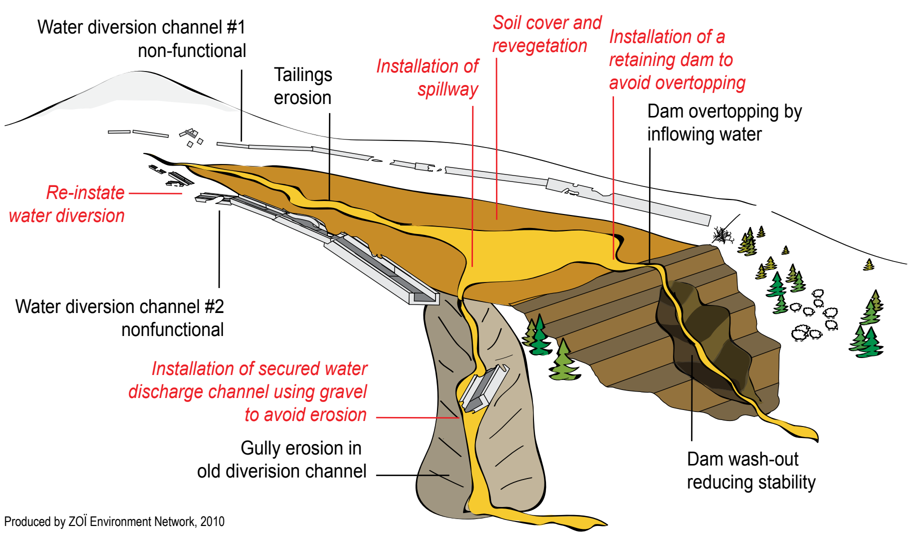
See figure below.

Rreshen

The site is located on the road from the Kurbnesh mining area to Tirana. The abandoned mining, milling and concentrator facilities at Rreshen are almost due north of Tirana (1 to 1.5 hours drive) on the Fani te Vogel river just above its junction with the Fani te Madh river, some 20 km upstream from the confluence of the Fani and Mati rivers.

The site consists of a metallurgical concentrator (copper) on a hillside overlooking the Fani river system with a tailings dam filling an adjacent narrow valley. The tailings dam is approximately 30 metres high and is of cross-valley construction. The dam is built entirely of tailings and no concrete or other engineered starter dam was observed.

Tailings dam safety concerns and possible improvement measures at Reps



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Top view on Rreshen tailings dam, second sinkhole outside the picture on the right

Sink hole

All the water flowing from the tailings dam, or seeping from below it, discharges straight into the river about 150 metres downstream.

The pH of the water in the drainage channels leaving the dam is close to 4.5 (acidic). Seepage water from the tailings area is initially clear but oxidizes downstream staining the rocks and drainage channels with iron. The tailings dam is just above the town's main road and adjacent to several shops, businesses and residential properties.

There are serious water concerns at this site that have very likely resulted in critical reduction of the structural integrity of the tailings dam. The underlying cause for this is the failure of a water diversion channel around the right hand side of the dam (when facing downstream).

The original water diversion pipe is located underneath the tailings material and the dam structure. Due to breakage of the channel system, tailings material is now entering the pipe and washing out tailings into the environment. For this reason two large sinkholes have formed on top of the tailings management facility.

In addition, due to the blocked diversion pipes, water has overflowed the dam and several large erosion channels have developed on the dam. This has lead to the discharge of large amounts of tailings material into the nearby river. The largest washout is located at the point of contact between the bedrock and the tailings.

Fine tailings on the upstream side of the dam are holding water on the top surface of the dam and roughly 40 to 50% of the tailings area is now covered with water. This indicates a high phreatic surface in the tailings impoundment.

Other issues observed at the site include:

- local residents dumping garbage on tailings and in drainage channels;
- residents reportedly picking herbs and other plants close to the tailings and metallurgy plant;
- wind blown tailings observed on the nearby hillside and in the valley below.

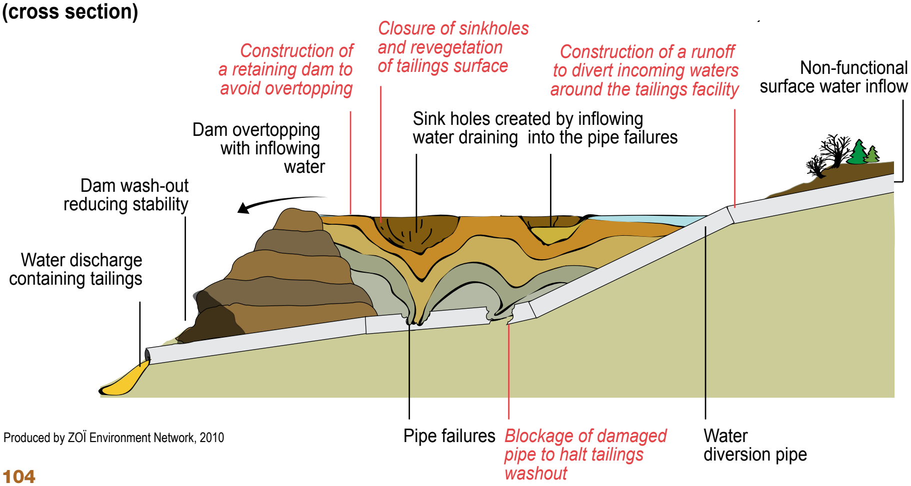
Proposed interventions

- Divert rainwater runoff from the watershed and secure the site, to prevent overtopping of the dam crest in the future;
- Build a retaining dam near the crest of the tailings dam;
- Close or block the buried pipe, originally laid to channel runoff from the watershed;
- Build a runoff duct to divert incoming waters round the tailings dam.

Remediation design

See figure below.

Tailings dam safety concerns and possible improvement measures at Rreshen (cross section)



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Mining and mineral processing has played a vital part in the history and economy of the Western Balkans. Richly endowed with mineral resources such as copper, chromite, lead and zinc, it boasts some of the largest deposits in Europe. Capitalizing on such mineral assets will be a priority for South Eastern Europe in order to boost local economies and attract foreign investment. To secure the environmental, economic and social sustainability of such new or restarted operations, the region will need to define and enforce a legal framework for sustainable mining practices.

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