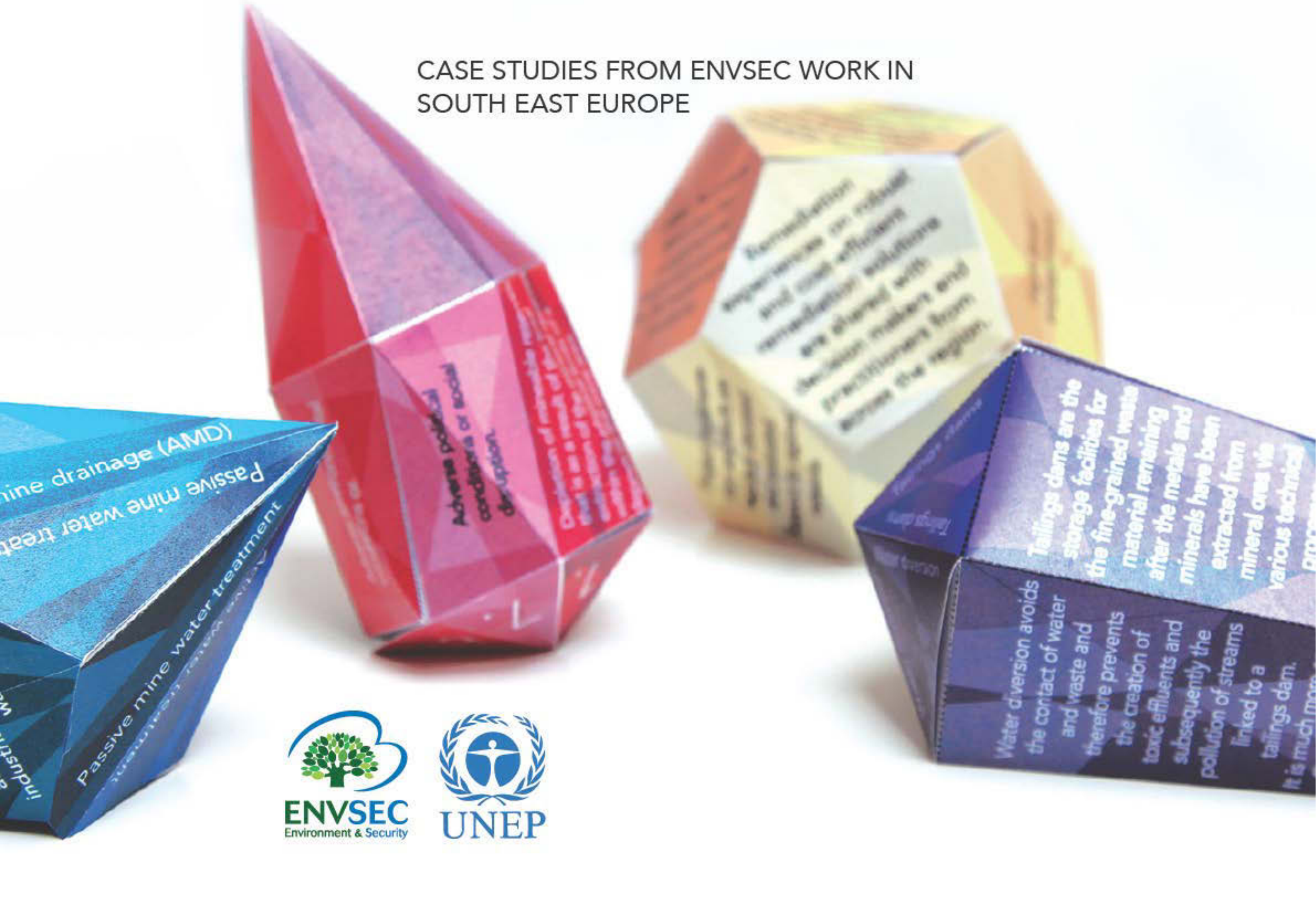
A SHORT INTRODUCTION TO ENVIRONMENTAL REMEDIATION FOR

MINING LEGACIES

CASE STUDIES FROM ENVSEC WORK IN SOUTH EAST EUROPE



ENVSEC Environment & Security

UNEP

The Environment and Security Initiative (ENVSEC) transforms environment and security risks into regional cooperation. The Initiative provides multistakeholder environment and security assessments and facilitates joint action to reduce tensions and increase cooperation between groups and countries. ENVSEC comprises the Organization for Security and Co-operation in Europe (OSCE), Regional Environmental Centre for Central and Eastern Europe (REC), United Nations Development Programme (UNDP), United Nations Economic Commission for Europe (UNECE), United Nations Environment Programme (UNEP), and the North Atlantic Treaty Organization (NATO) as an associated partner. The ENVSEC partners address environment and security risks in four regions: Eastern Europe, South Eastern Europe, Southern Caucasus and Central Asia.

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This publication has been prepared by Zoï Environment Network on behalf of UNEP in the framework of ENVSEC. Numerous organizations and experts from Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Montenegro and Serbia contributed to the publication. The financial support for the preparation has been provided by the governments of Austria and Finland.

ISBN: 978-2-940490-13-4

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BACKGROUND

Past conflicts and difficult transitions have left South East Europe (SEE) with a legacy of inadequate growth, high environmental stress and declining living standards evidenced by higher poverty, inequality, unemployment and limited prospects for economic growth. Today, while still fragile, the SEE region has improved its security situation. To advance this development the Environment and Security Initiative (ENVSEC) fosters cooperation among neighbouring countries on environmental issues to pave the way towards the dialogue and understanding that can lay the foundations for agreements on transboundary environmental management and create the possibility of long-lasting political stability.

Environmental concerns arise from industrial pollution, intensive agriculture and deficient water technology and infrastructure. In addition, use and management of shared natural resources such as transboundary lakes and rivers, mountain forest complexes and biodiversity pose both a challenge and an opportunity for cooperation.

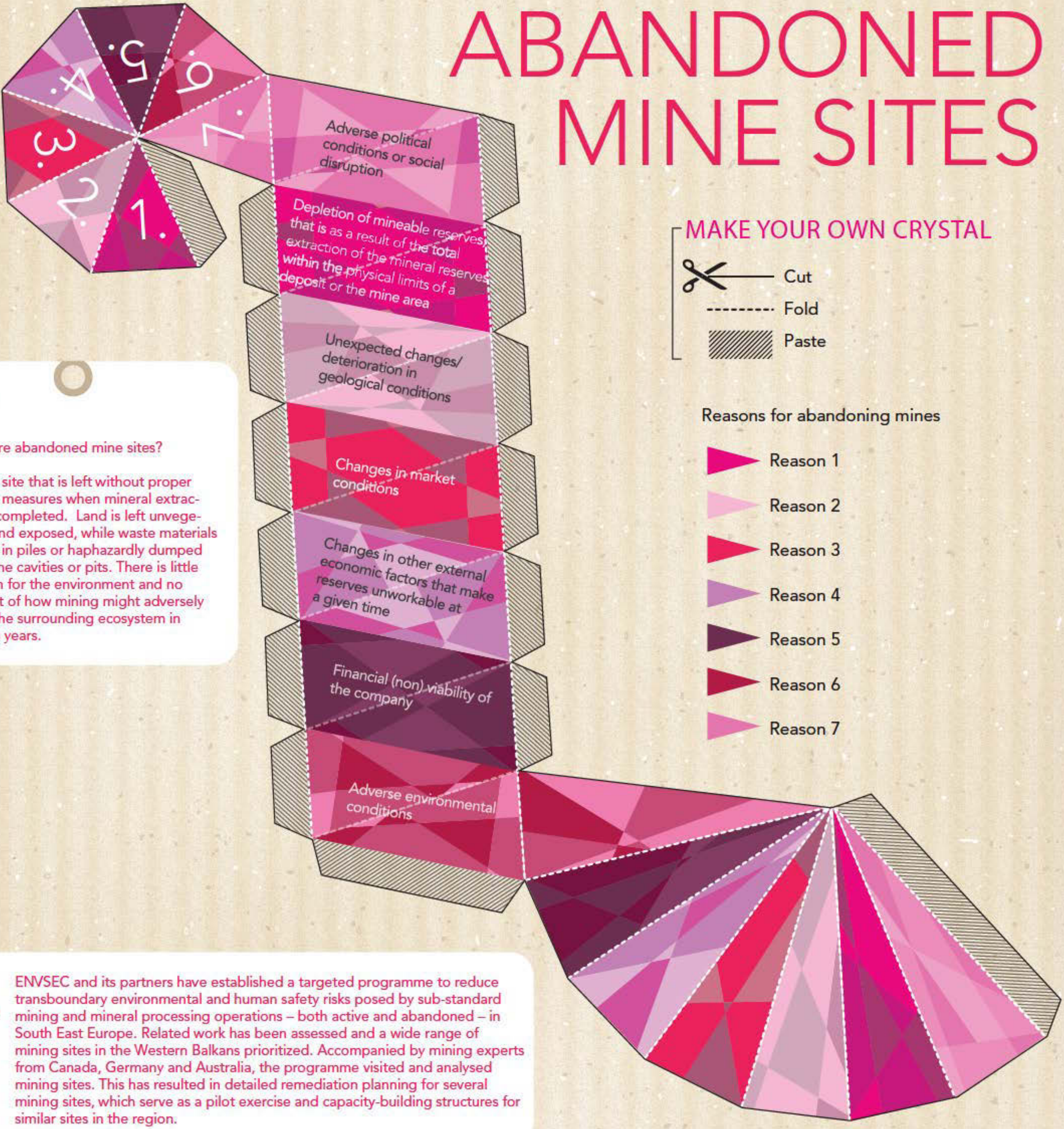
Between 2009 and 2012 the Environment and Security Initiative and in particular the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP) had the opportunity to continue their engagement in the mining legacies in the SEE region. The overall goal of the project was to contribute to the reduction of environment and security risks and to increased cooperation both between and within countries in SEE. In general terms the activities to achieve that goal include policy integration, capacity-building of government institutions (including local government), hotspot risk mitigation, the strengthening of civil society and the promotion of good environmental governance. The project contributes to improved knowledge, understanding and management of environmental and security risks.

The specific objectives of the project were: (a) prevention and mitigation of transboundary environmental risks arising from hazardous pollution hotspots, in particular from abandoned mines, tailing dams and chemical sites; and (b) capacity-building to support countries to ratify and implement the United Nations Economic Commission for Europe Industrial Accidents, Espoo and Water Conventions and its Strategic Environmental Assessment Protocol.

In regard to the first objective, the project brought to light that a significant reduction of environmental risks can be achieved with limited-cost interventions as is evident in such civil works as acid mine drainage treatment plants and the capping and re-vegetating of tailings. The project also conducted feasibility studies that support the plausibility of this approach. With the implementation of these remediation measures, the project hopes to have established that these practices are viable and achievable in the local contexts, which has been the goal of the extensive capacity-building efforts that surrounded the ground works. A range of publications, maps and graphics and training workshops were organized, involving a wide range of stakeholders from SEE.

Understanding the health and environmental risks arising from mining legacies is crucial for future decision-making, but simply knowing that the risks exist is not sufficient: providing solutions on how to reduce risks and enhance cooperation is also important. Therefore, ENVSEC wanted to create regional examples that provide realistic options on how these risks can be minimized with cost-efficient interventions that can be replicated across the region. These example sites are now being used as educational tools where experts, students and others can get in touch and acquire an understanding of what has been done, and can then apply their knowledge in similar projects in other locations.

ABANDONED MINE SITES



MAKE YOUR OWN CRYSTAL

Cut

Fold

Paste

Reasons for abandoning mines

Reason 1

Reason 2

Reason 3

Reason 4

Reason 5

Reason 6

Reason 7

a.

What are abandoned mine sites?

A mine site that is left without proper closure measures when mineral extraction is completed. Land is left unvegetated and exposed, while waste materials are left in piles or haphazardly dumped into mine cavities or pits. There is little concern for the environment and no thought of how mining might adversely affect the surrounding ecosystem in coming years.

b.

ENVSEC 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 East Europe. Related work has been assessed and a wide range of mining sites in the Western Balkans prioritized. Accompanied by mining experts from Canada, Germany and Australia, the programme visited and analysed mining sites. This has resulted in detailed remediation planning for several mining sites, which serve as a pilot exercise and capacity-building structures for similar sites in the region.

2.1 What is an abandoned mine site?

New ore bodies and mineral resources are constantly being discovered through exploration but the reserves contained in any particular deposit on which a project is based are finite, and all mining activities at a certain mine site must come to a close at some stage. Historically, the common practice was to abandon a mine site when mineral extraction was completed. The land was left exposed and without vegetation, while waste materials were left in piles or haphazardly dumped into mine cavities or pits. There was little concern for the environment and no thought of how mining might adversely affect the surrounding ecosystem in the coming years. These environmental problems associated with abandoned mine sites have not received the attention of other environmental issues.

Mining activity can cease for many reasons and almost at any time. Many mining legacies are much more than the result of mine abandonment in the absence of legal and regulatory frameworks to ensure adequate decommissioning works. In many instances they have been a part of larger economic or social situations that are in themselves stressful for communities dependent upon mining – and may in themselves have contributed to the cessation of mining activity.

Factors contributing to cessation of mining activities include, inter alia:

- Depletion of mineable reserves – the result of the total extraction of mineral reserves within the physical limits of a deposit or mine area
- Unexpected changes or deterioration in geological conditions
- Changes in market conditions
- Changes in other external economic factors that make reserves unworkable at a given time (including changes in liability conditions)
- Financial viability of the company
- Adverse environmental conditions
- Adverse political conditions or social disruption

In some cases mining may only be suspended for a period of time and the project placed under care and maintenance. In circumstances where it is clear that economic or other limits of the operations have been reached, however, decommissioning and final closure are required as well. In some instances, the delineation between a mine officially categorized as being on care and maintenance and one that is abandoned may be difficult to make.

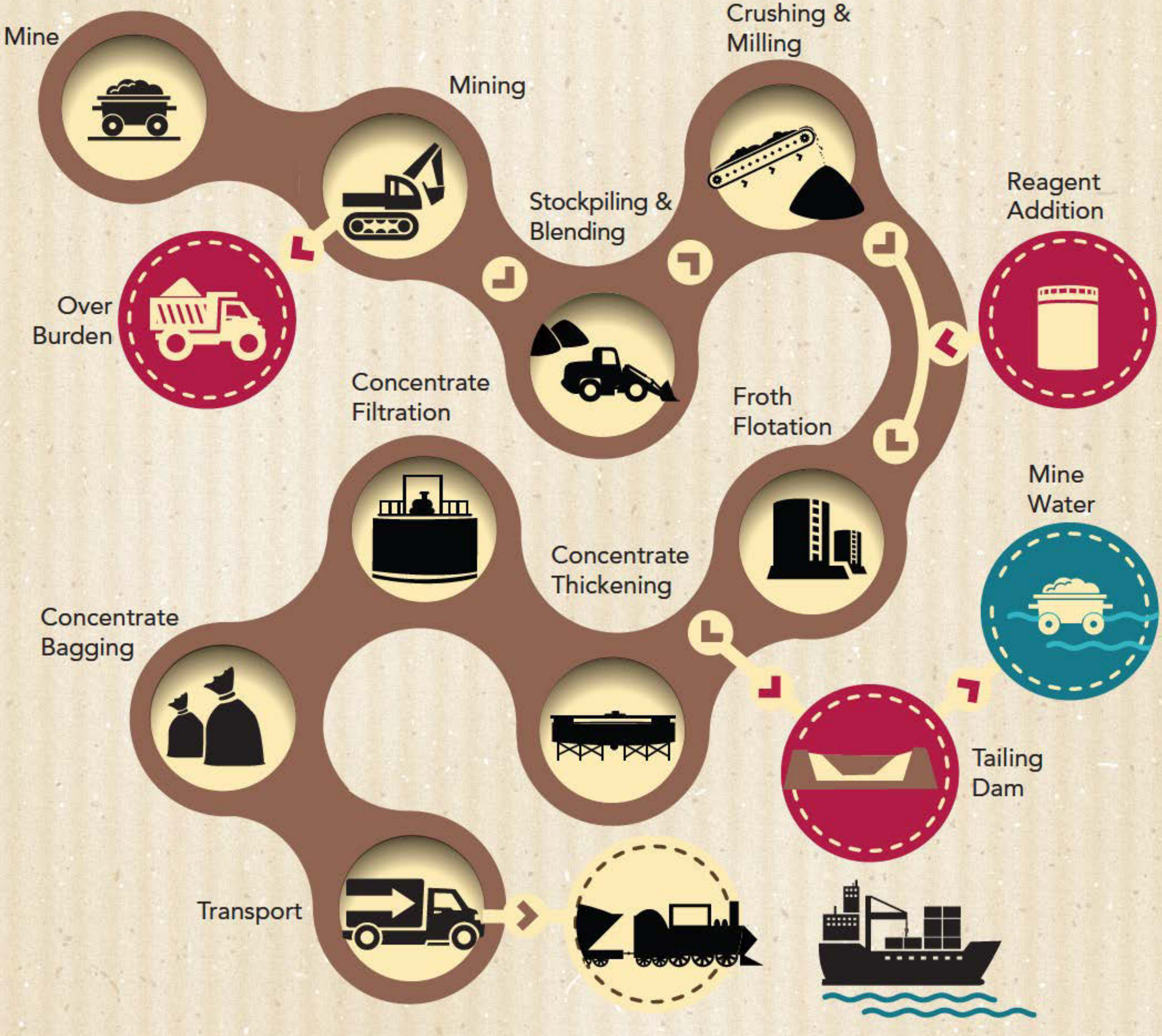
Discussions of environmentally and socially responsible mining are often focused on present or future mines. In recent years, however, ENVSEC has applied the concept of environmentally and socially responsible mining to legacies – the abandoned and orphaned sites of mineral-related activity. Here the problem is highly intractable, and calls for innovation and new action frameworks.

Many abandoned mine sites have no clearly responsible party, and the legal, financial and technical instruments being used – as well as the approaches to social issues – are inappropriate for the sites and their neighbouring communities. Further, factors such as the potential costs of wide-scale rehabilitation and the absence of criteria and standards for rehabilitation have delayed action by both the industry and public authorities. In the absence of appropriate criteria and standards, the closure and rehabilitation costs must be directly or indirectly borne by the state. Thus, the abandoned mines represent not only a major liability for the government but for the affected communities, adjacent areas and society at large: the latter must ultimately bear the financial burden of ensuring appropriate closure.

While there have been calls of varying intensity for action from international actors, between the beginning of the ENVSEC engagement and the present, there were few attempts by international bodies to examine the issue and provide concrete guidance to national institutions, and none addressing this issue specifically for the SEE region.

Figure 1 →

Mining scheme



Produced by Zoï Environment Network

Triggers for abandoned mines

- The general absence of mine reclamation policies and regulations until the latter part of the twentieth century
- Ineffective enforcement of mine reclamation policies and regulations, if and where in existence
- The absence of financial security mechanisms to ensure funds for parties to conduct remediation in the event of mining company bankruptcy, and the inability to cover the costs of rehabilitation
- Inadequate financial security to address remediation, if and where such funds were set aside
- Unforeseen economic events that caused early cessation of activities or left companies bankrupt, such as a sudden drop in metal prices, insurmountable difficulties with mining/milling, and/or infrastructure problems
- Past technical practices undertaken such as the sinking of numerous exploration shafts and mineral deposit test pits that were not backfilled prior to the introduction of drilling equipment for mineral deposit evaluation
- National security issues such as the supply cut-off for strategic metals in times of conflict leading to rapid mining activity with scant consideration of closure requirements or operational longevity
- Loss of mine data including records of underground workings and surface openings due to natural disaster, regulatory flux, unscheduled cessation of activities, political disruption and conflict
- Political unrest, conflict and political instability leading to unscheduled cessation of activities of mines
- Small-scale mining conducted by artisanal or illegal miners, including the uncontrolled occupation of mine sites

2.2 Abandoned mining sites in South East Europe

Up until the early 1990s, mining, minerals processing and downstream exploitation of base metals established South East Europe as a major European source of copper, lead and zinc. The region, and in particular Albania, was also a major global 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 that have left the most serious mining legacies for the region.

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

The large number of sites with serious environmental impacts, high remediation costs and missing liable owners complicates the situation. 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.

In response, ENVSEC and its partners have established a targeted programme to reduce the transboundary environmental and human safety risks posed by substandard mining and mineral processing operations – both active and abandoned – in South East Europe. The programme has assessed related work and has prioritized a wide range of mining sites in the Western Balkans. Accompanied by mining experts from Canada, Germany and Australia, the programme visited and analysed mining sites. This work has resulted in detailed remediation planning for several mining sites, and stands as a pilot exercise to guide capacity-building and remediation for similar sites in the region.

The findings of the ENVSEC work in the region create unique possibilities for improved environmental management and environmental protection built on past experience, new insights and regional partnerships.

Mining sites in the West Balkans

Map produced by ZOÏ Environment Network, March 2012.

* This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence

Sources: Zinke Environment Consulting (→ www.zinke.at) and Fluvius Floodplain Ecology and River Basin Management (→ http://fluvius.com);
Site assessment conducted by ENVSEC in 2006.

← Figure 2

TAILINGS DAMS SAFETY

MAKE YOUR OWN CRYSTAL

- Cut
- Fold
- Paste

- Tailings dams
- Water diversion
- Overtopping failures
- Chronic leakage of pollution

a. **Reps, Albania – abandoned copper mine**

- Water diversion in open channels
- Reshaping dam slope and base to create a erosion protection layer and implementing long-term water diversion structures
- Recultivation

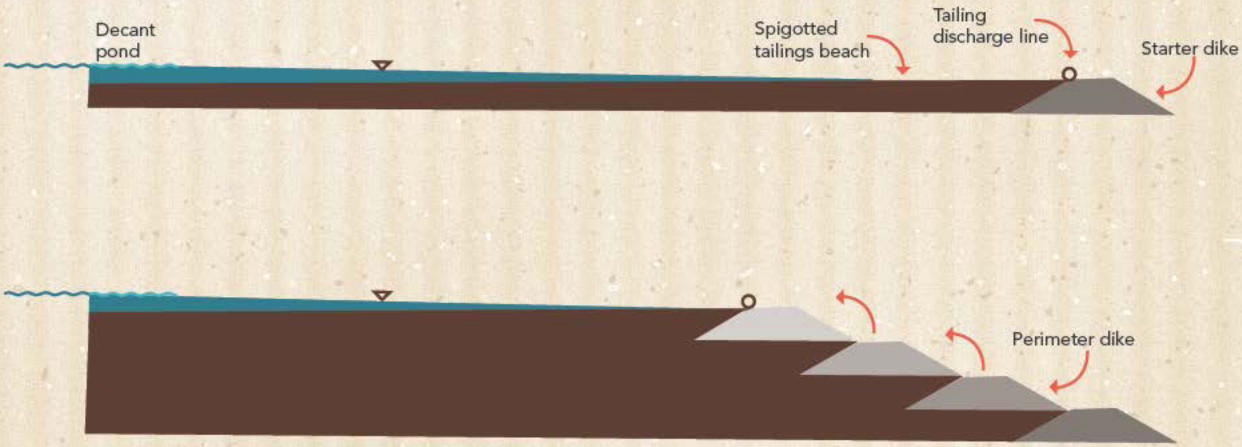
b. **Rreshen, Albania – abandoned copper mine**

- Construction of two diversion channels on each side of the dam to lead the water around the tailings. These channels are build as cascades and lined with gravel to reduce the velocity of the water flow to reduce erosion capacity.
- Improving structural stability of the tailings dam
- Recultivation

At mining and mineral processing sites the various structures that can cause environmental concern include the mine pit or galleries (depending on whether the mining is open cast or underground), the technical installations and the mine waste installations such as overburden dumps and tailings storage.

Tailings dam elements

Tailings dam construction



Produced by Zoï Environment Network

Tailings are the fine-grained waste material remaining after the metals and minerals have been extracted from mineral ores via various technical processes. Tailings management facilities – tailings dams, tailings ponds or tailings impoundments, depending on the type of structure – store tailings and other extraction residues after the extraction process. The sound management of tailings is one of the most important tasks at a mining site as their mass as well as chemical and physical properties can pose great risks to the environment over a long period of time. Tailings management facilities are associated with two main areas of risk. The first is that a catastrophic failure can release large volumes of liquid and tailings, the physical impact of which can cause destruction in downstream areas. The second is that tailings can be toxic depending on the composition of the ore mined (arsenic present in the ore, for example) and on the chemicals added in the extraction process. Another source of toxicity can arise from acid mine drainage (AMD) formation. (For a detailed description of AMD and related environmental impacts, see chapter on Mine water.) Structures containing tailings must therefore be stable and built to avoid any uncontrolled release of liquids. Since physical risks and toxicity of a tailings management facility remain far beyond the lifetime of a mine, safety measures and monitoring schemes need to address these issues in a similar manner.

← Figure 3

3.1 Water diversion structure failures

Water can be considered the enemy of any dam structure. Once water enters a tailings dam, it can cause erosion, destabilization and chemical reactions that increase the toxicity of the waste material. Therefore, the goal is to avoid contact with water as much as possible. This is particularly relevant for cross-valley dams (see figure 4), which are common in the Western Balkans. By nature, a valley collects all surface water (such as run-off) and directs it toward the dam. In extreme cases, rivers running at the valley bottom need to be redirected to avoid entering a tailings dam. This is the case for the tailings dam in Srebrenica where ENVSEC assisted in the reconstruction of water diversion measures to allow a small river to flow over a tailings dam without causing more erosion.

ENVSEC project experience: Srebrenica

→ Location and history

The SASE lead and zinc mine is located in the north-eastern part of the Republic of Srpska, in Srebrenica, about 7 km from the Drina River. This lead and zinc sulphide ore mine, was operative from 1965 until 1992. In 2004 a Russian company restarted the operations only to retreat shortly thereafter. The current company received a concession for exploration, exploitation and processing of ore deposits in 2007 and currently employs 512 workers. It expects to produce 244 000 tonnes of ore in 2012. Final products are lead and zinc concentrates, which are then transported to international smelters for treatment.

→ Situation at the site

Dimnicki stream flowed into the lake formed by recycled water from the production process. The amount of water required for processing was equal to 3.3 m^3/t of ore, and was supplemented as necessary with fresh spring water. The concrete pipeline that transported this water to the main collector in the tailings pond was burrowed approximately 12 m deep in the tailings material. A pipeline breakdown – an obvious threat – would cause a mixing of water and tailings material that would jointly flow through the main collector to the receiving waters, causing massive pollution.

The ENVSEC involvement focused on an evaluation of environmental data and the development of a monitoring programme to compile the additional data necessary to make assessments of the environmental status of surface waters, with special regard to AMD. The mine operator planned and executed the remainder of the works.

→ Technical solution

The company has invested €1.86 million in the design and construction of a water diversion channel to carry the clean upstream surface water past the tailings pond, and discharge it downstream with no contact with the tailings material in between. The tailings pond facility occupies 11 ha of a 23 ha site. A durable, high-quality diversion channel accommodates Dimnicki stream and all other water sources from the basin, and leads them to the receiving waters without any contamination. The difficult construction of the channel is considered one of the highest technical achievements in the region over the last 20 years. It is 1 350 m long with one part going through the tailings and another through the lake. The designed flow is 105 m^3/s, based on 1 000-year flow estimates. The first layer is 15 cm thick and made of reinforced concrete. A layer of geotextile is followed by a 2 mm geomembrane covered by another layer of geotextile. The final layer is a Reno mattress filled with locally available waste rocks. Both upper sides are stabilized with planted grass, and the surrounding area has been remediated and covered with greenery.

→ Next steps

Due to power losses that often occur in the area, the flotation slurry consisting of an active AMD source is occasionally discharged at the downstream side of the tailings pond. Acid mine drainage formation was observed at several locations, mainly close to inappropriately disposed old waste rock piles or exits from old mine adits.

The proposed surface water monitoring programme envisages measurements of physical-chemical and chemical parameters, as well as flow measurements of individual creek and adit drainages in order to assess the relative significance of specific streams in the overall surface water contaminant load. Old waste rock piles will also be located and recorded. The new analytical laboratory at the site has the qualified staff and all the necessary equipment for water analyses, and will conduct most of the measurements. Monitoring data will provide the basis for a feasibility study for the treatment of water contamination resulting from AMD and historical activities.

Because of the continuous destructive power water can have on a tailings dam, water management structures that minimize the contact between water and waste and dam are key installations at any waste storage site. In properly functioning water management structures, water from the catchment area of the valley is collected upstream of the dam and then led by pipes or channels around the dam to a discharge point where it cannot cause harm.

One of the more complicated examples of water management can be found at the Reps site in Albania where ENVSEC supported the installation of a new water diversion structure between 2008 and 2012. Here the original water diversion pipe was laid under the waste and the dam. In such a set-up, when the pipe breaks, it is difficult to notice the damage and even more difficult to access and repair the pipe. The damage becomes apparent when a crater-like sinkhole forms on the top of the tailings dam. In such cases, water flows through the tailings and washes tailings into the pipe causing the crater formation. Figures 4, 5 and 6 show what pipe failure craters in Reps looked like before the intervention. All the missing tailings material was washed out into the Fani River. If there had not been any intervention, the crater would have grown steadily until it reached the dam itself. This would have caused a massive destabilization of the dam, and could have led to a complete dam failure.

ENVSEC project experience: Reps

→ Location and history

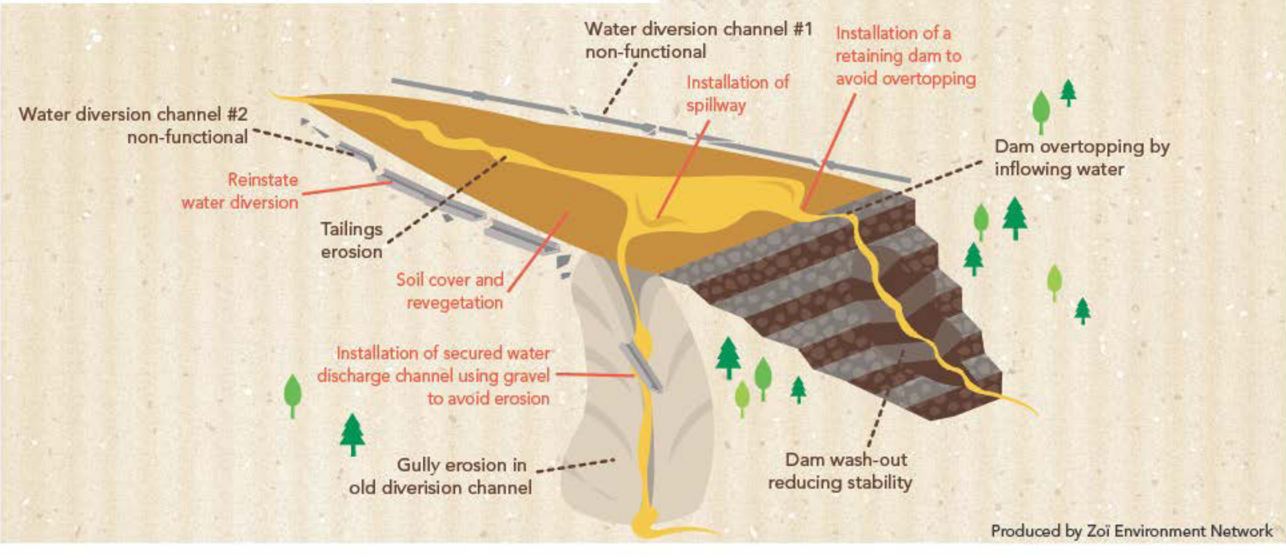
The abandoned milling and concentrator facilities at Reps are located in the central northern part of Albania, Lezhe Region, 100 km north of Tirana. Mining and milling operations reportedly started in the area in 1971 and were shut down in 1994. Two million tonnes of ore were processed in this period, according to Geological Survey of Albania. The tailings impoundments are in close proximity of the new highway linking Kosovo* and Albania.

→ Situation at the site

Of the four abandoned tailings facilities continuously polluting the local river, three have inappropriate disposal methods. The fourth and most dangerous facility (site 3) is a valley fill dam with compromised structural stability as a result of a failure of water diversion structures. All waters flowing from the tailings area are discharged directly to the Small Fani River. The former dewatering system consisted of buried pipes and open concrete channels. When both failed, the entire dewatering of the watershed started running on the tailings beach and sometimes reached the dam crown leading to overtopping. Hundreds of cubic metres of tailings were washed away. As a consequence, gully erosions on the right side of the embankment were frequent occurrences. Furthermore, there were partial dam failures on the left bank. Increasingly weak slopes led to further mass failures of the tailings dam, destabilizing the dam as whole.

↓ Figure 4

Tailings dam safety concerns and possible improvement measures at Reps



* This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

Reps before remediation

Reps after remediation

Figure 5 → Stabilized dam face

Figure 6 → Reconstructed water diversion channel

→ Remediation

Remediation work in Reps was divided into two phases. The first phase included final design and implementation of a sustainable solution to lead the surface water from the watershed area down to the river, and crown rehabilitation measures to protect it against overflows and erosion. After all necessary analysis, calculations and site visits, the creation of open channels was selected as the most effective solution to control the surface waters, a case of a water management solution inspired by nature's way to solve the problem. The second phase entailed forming and stabilizing the shape of the dam base and slopes to provide an erosion protection layer, and installing long-term ditches to carry water.

ENVSEC project experience: Rreshen

→ Location

The Rreshen tailings site is located near the municipality of Rreshen, situated in the Northern Mirdita District, Lezhe Region, 76 km north of Tirana, Albania. The site is in the vicinity of the new highway linking Kosovo* and Albania and close to the Fani River. The dressing plant and dam operation started in 1984, and were closed in 1996. Of the 300 000 tonnes of tailings deposited, 250 000 tonnes remained on the site.

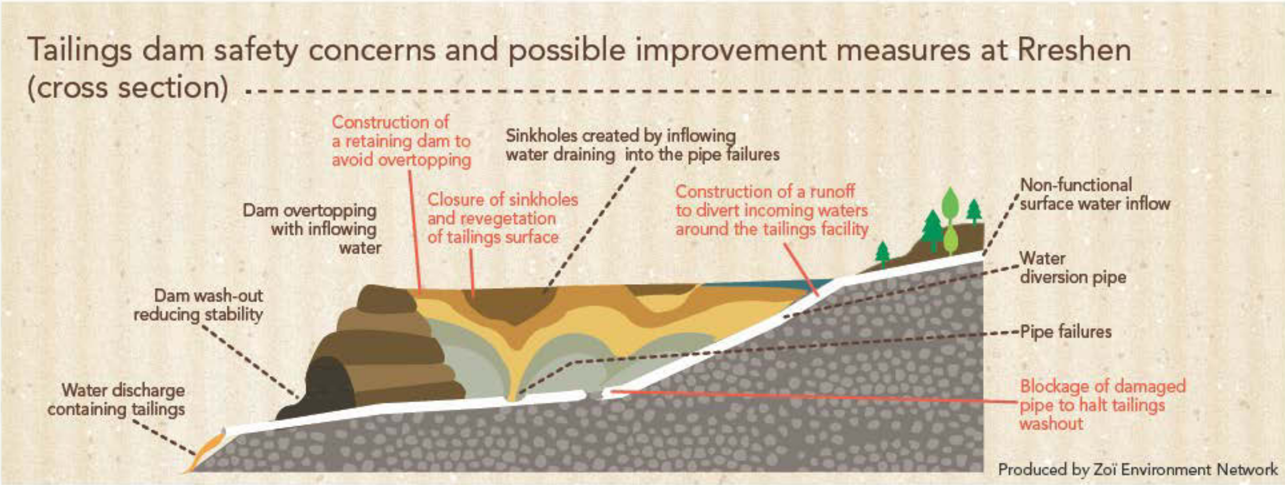
→ Situation at the site

The stability of the tailings dam in Rreshen was endangered by the presence of surface water and non-functioning water diversion channels running under the mine waste. Regular maintenance of the facility was lacking as well. Two sinkholes were visible on the surface where tailings were lost through holes in the water pipes underneath. The contaminated water from tailings was discharged into the Small Fani River, due to erosion caused by rainwater.

→ Remediation

The pipe running underneath the tailings was permanently sealed to prevent any further loss of tailings through the sinkholes. Without this procedure, the sinkhole would have continued to grow until it eventually reached the dam crest. The project built a small, upstream retention dam to collect surface water that would otherwise enter the dam area. From there, diversion channels were constructed on each side of the dam to lead the water around the tailings. These channels are built as cascades and lined with gravel to reduce the velocity of the water flow and thereby to reduce its erosion capacity.

↓ Figure 7



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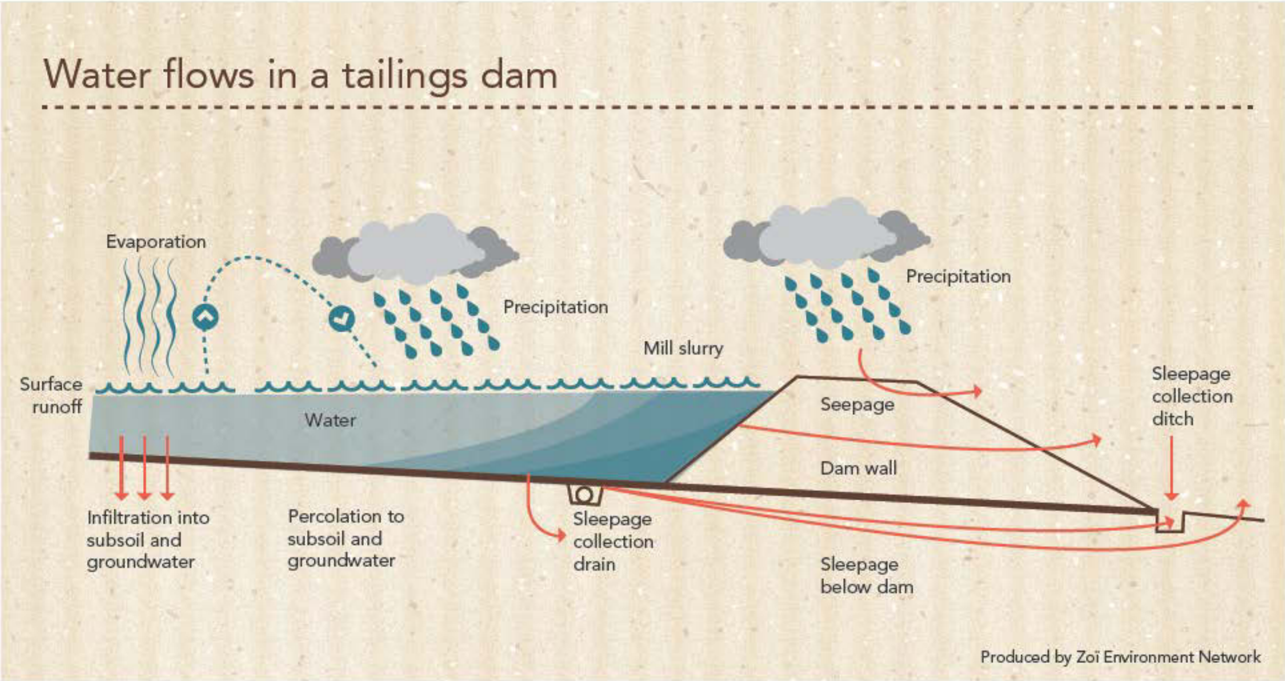
Rreshen before remediation

Rreshen after remediation

Figure 8 → Sinkhole removed and dam surface covered

Figure 9 → Reshaped dam from and water diversion channels installed left and right of the dam wall

Another intervention supported by ENVSEC focused on water diversion structures at Rreshen. Here surface water flowed in pipes around the tailings dam. Unfortunately, all pipe structures were destroyed and therefore non-functional. Instead of flowing around the dam, water entered the tailings dam and seeped through the dam wall causing severe erosion. Figure 9 shows the structural damage in the dam wall caused by the water.

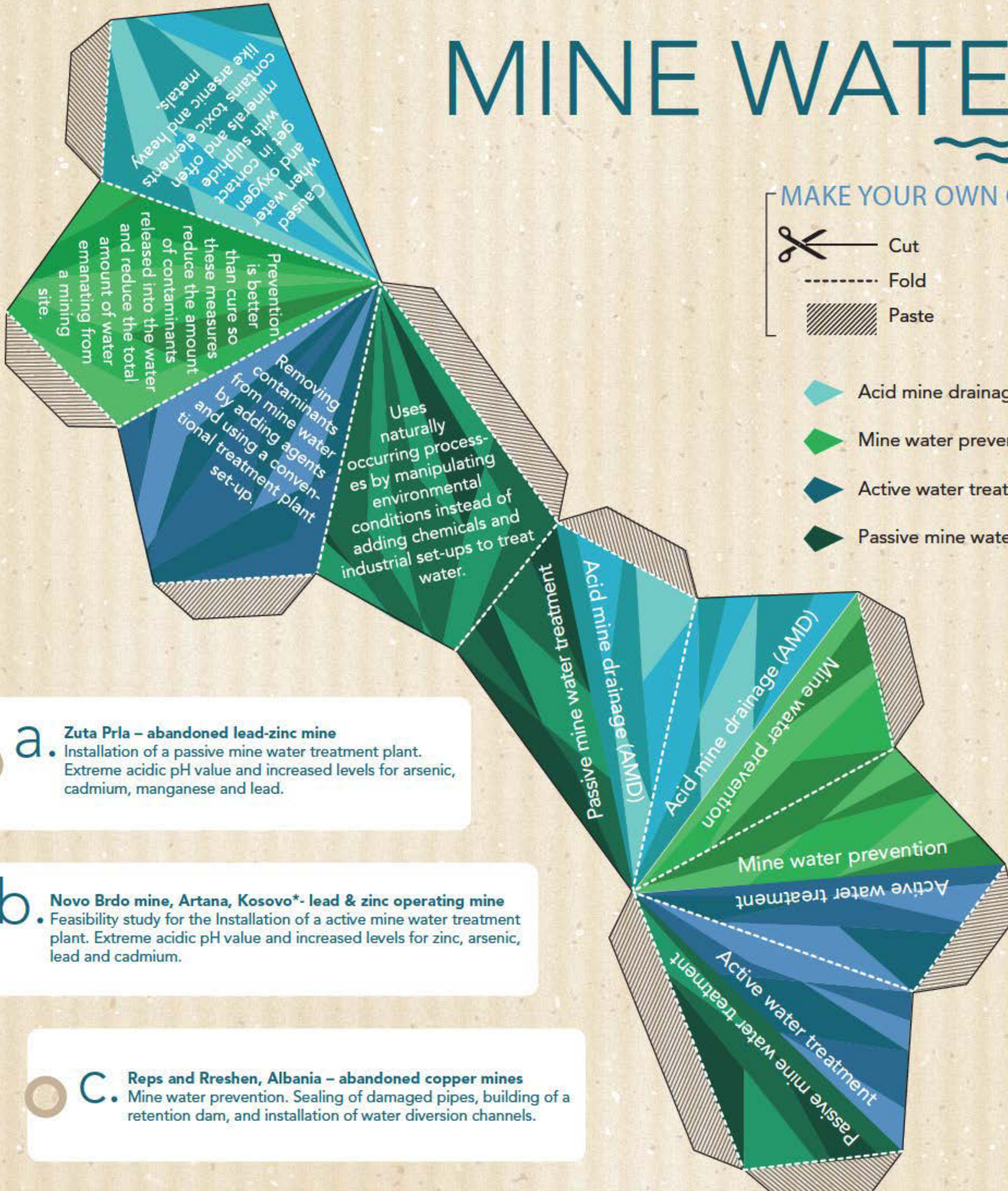


↑ Figure 10

3.2 Overtopping failures

Water that enters the tailings dam either seeps through the dam to find its way out or overflows the dam once it reaches a certain level. Overflowing – also called overtopping – of a dam is a highly undesirable condition as it causes severe erosion in the dam itself and therefore destabilizes the dam. To address this problem ENVSEC activities at the two Albanian sites also included an increase and reshaping of the dam surface structure that leads any water that enters the dam despite the renewed diversion structures (in case of extreme rainfall, for example) away from the dam crest. This reduces the risk of water flowing over the dam even if the water diversion fails.

MINE WATER



MAKE YOUR OWN CRYSTAL

- Cut
- Fold
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- Acid mine drainage (AMD)
- Mine water prevention
- Active water treatment
- Passive mine water treatment

a. Zuta Prla – abandoned lead-zinc mine
Installation of a passive mine water treatment plant. Extreme acidic pH value and increased levels for arsenic, cadmium, manganese and lead.

b. Novo Brdo mine, Artana, Kosovo*- lead & zinc operating mine
Feasibility study for the Installation of a active mine water treatment plant. Extreme acidic pH value and increased levels for zinc, arsenic, lead and cadmium.

c. Reps and Rreshen, Albania – abandoned copper mines
Mine water prevention. Sealing of damaged pipes, building of a retention dam, and installation of water diversion channels.

* This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

Chemical processes in the mine waste cause pollution apart from the destructive power water can have on tailings dams. Acid mine drainage occurs from the weathering of sulphide minerals in an entirely natural process. This natural process turns into an environmental problem when it is accelerated as minerals become intensively exposed to oxygen, as, for example, when they are mined. Under natural conditions, minerals are covered by soil and located below the water table. These natural barriers isolate sulphide minerals from the atmosphere and preclude the ingress of weathering agents. Mining, however, liberates them from their oxygen-free environment and exposes them to oxygen and water. Crushing, grinding and flushing minerals with oxygenated surface water creates a paradise for the bacteria responsible for this process, which releases acid by consuming sulphide minerals. The most common sulphide mineral present at mining sites is pyrite and it contributes significantly to the generation of acid mine water. Pyrite contains iron and what happens to it is the same as when iron rusts on a car or elsewhere - upon contact with water and oxygen, the iron oxidizes. In this process, acid is released. The strong red colouring of streams with AMD is caused by the “rust” created during AMD formation. (See figure 11 and 12.)

The direct effect of acid water may be the loss of a well or stream as a drinking water supply. A decreased pH value also correlates with the degradation of living conditions for most organisms, so that an AMD-affected stream will suffer a loss of biodiversity. Like many other metals, iron is a trace element necessary for humans and other vertebrates. But when organisms take up highly elevated amounts of iron, acute and chronic toxic reactions – such as peroxidation of lipids followed by damage of protein structures – can occur. As a chronic toxin, iron can cause haemochromatosis, cirrhosis of the liver, vascular congestion and eventually death.

The presence of toxic elements is another problem related to mine water. Metals such as copper and zinc become more mobile with increasing acidity. This means the more acid, the more other potentially damaging elements are discharged into the environment. Even though tailings have undergone mineral extraction, enough minerals remain to cause a damaging effect when released. In addition, because of the high mineralization of rocks in mining areas, there is often a vast array of elements – arsenic, for example – that are not extracted but get mobilized through processing and end up in the tailings.

Mine water can also be contaminated without being acid, in which case the term acid mine drainage does not describe the situation correctly. But in the absence of acidity, mine water might still require suitable prevention and treatment measures as its environmental impact can be just as severe.

Figure 11 →
Mine water with aluminium hydroxide precipitation

Figure 12 →
Mine water with iron hydroxide precipitation

4.1 Prevention

The most desirable situation is to not have any acid mine drainage at all. This saves a lot of work and cost and provides the safest conditions for the environment.

Prevention measures seek to reduce the amount of contaminants released into the water and to reduce the total amount of water emanating from a mining site. Unfortunately, prevention is not always possible due to technical restrictions and local conditions. The aim of mine water prevention, where possible, is to minimize contaminant release, which can be achieved by excluding one or more of the factors that are relevant to the generation of acid mine water. The essential components for sulphide weathering are sulphide minerals, water and oxygen. Other factors that influence the process are bacterial activity, temperature, pH and iron content.

At many high-risk sites the situation could be substantially improved by the implementation of such prevention measures as clay capping to reduce water ingress from precipitation, and water diversion channels to reduce ingress of surface run-off from the surrounding area. Works like this have been concluded by ENVSEC in Reps and Rreshen in Albania. (See case studies above.)

Re-mining of waste is another viable option at mining sites in the SEE region as many mine wastes have relatively high concentrations of marketable material due to the inefficient metal extraction processes that were 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. Based on ENVSEC recommendations, UNDP supported the installation of a copper re-mining facility operated by a private owner in Bucim, Macedonia, to recover copper from the waste heap and use the revenues of the operation for financing the mine water treatment system.

At a number of problematic sites, the first consideration should be mine water prevention because it is highly efficient and significantly reduces other risks – such as tailings dam instability – associated with mining sites.

4.2 Mine water treatment

In many cases where contaminated mine water occurs, subsequent water treatment cannot be avoided. As water treatment is not tackling the contamination source, but rather preventing the distribution of the contaminants into the environment, it is considered an “end-of-pipe” technology and, like other treatment applications, not a truly sustainable solution to the problem. On the other hand, it is often the only alternative at sites where mine water has significant adverse impacts on the surroundings.

In a sustainable approach, the goal must be that mine water abatement becomes an integral part of mine planning. Postponing the examination of the issue until the end of the mine life is likely to result in long-lasting mine water pollution that requires constant treatment. The high costs of treatment and the absence of revenues after mining activities have ceased make the implementation of the required treatment measures difficult to achieve, as referenced in the UNEP Mining for Closure publication.

The two main approaches to mine water treatment – active and passive – both aim to meet the existing regulations for discharge of liquid effluents. The ENVSEC project employed both strategies to create a broader knowledge base on mine water treatment in the region.

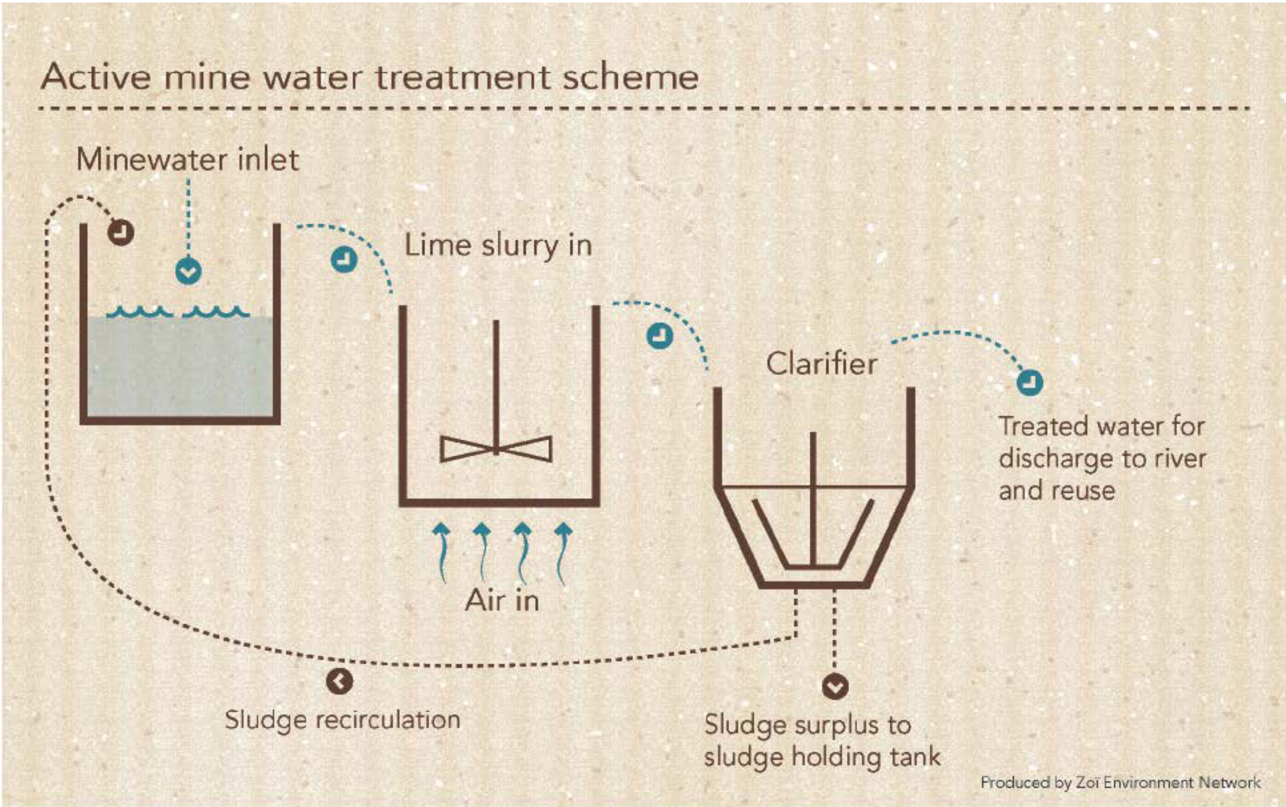
4.3 Active treatment

Active treatment systems have been used around the world for decades, and are more common than passive systems, which have only a 20-year history. Active treatment techniques rely on conventional, well-recognized and proven technology, and have a track record that includes long-term performance.

The most striking advantages of active treatment plants are the high contaminant load they can handle and their reliability in complying with effluent regulations. Unlike in passive systems, operators can adjust active treatment plants to changing mine water quality and quantity. Since passive systems cannot respond to changing treatment requirements, excess flow and contaminant load are discharged untreated into the receiving watercourse.

The crucial drawback of an active system is the high cost, particularly the high operating costs. Active treatment systems need constant energy and/or chemical inputs, and monitoring and maintenance that require permanent staff at the facility. The cost of disposal of the resulting metal-laden sludge, the amounts of which can accumulate to very significant volumes over long periods of time, is also significant. It is not uncommon for active water treatment costs to exceed $200 000 per year at AMD sites. These annual operating costs continue as long as water generation continues – potentially a long, long time.

Most applied conventional mine drainage treatment systems achieve neutralization by the addition of alkaline substances such as limestone, lime, sodium hydroxide, sodium carbonate or magnesia. These chemicals cause a rise in pH and the subsequent precipitation of metals. Active systems based on the addition of alkalinity generally require the installation of agitated reactors, precipitators, clarifiers and thickeners. Compared to other active treatment systems, the system of Oxidation, Dosing with Alkali and accelerated Sedimentation (ODAS) is a relatively uncomplicated and low-tech operational scheme with high efficiency.



↑ Figure 13

ENVSEC project experience: Artana

Novo Brdo mine, Artana, Kosovo*

→ Location and history

The Trepca Mining and Metallurgical Complex represents both Kosovo's* greatest potential for economic recovery and, simultaneously, its greatest environmental challenges. The Novo Brdo lead and zinc mine at Artana is remote from any sizeable villages or towns and lies in the drainage area of the Marevc River. Mining activity in the area has taken place since Roman times, with intensive production of lead and silver in the Middle Ages. Modern mining started after 1945.

→ Environmental impact

Mining activities at the Artana mines adversely affected the quality of the aquatic environment in the areas adjacent to and downstream from the mining activities. Although the upstream quality of the river meets the highest water standards, acidic discharges affect drinking and irrigation water of towns located downstream. Transboundary impacts can be considerable, since the Marevc River flows into the Morava e Bisnecës, which continues further into Serbia and finally via the Danube River into the Black Sea.

→ Research

Measurements at seven sampling points provided water quality and flow rate data between November 2011 and May 2012. Although the main source of AMD comes from Adit VI, the combined acidic V+VI stream presents the final mine discharge to the downstream natural receiving waters – the Marevc River. Acidity of the mine effluents was calculated at 1 024 mg $CaCO_3$/L while the average flow rate from combined adits was 50 m^3/h. The quality of this stream, as determined by average values of the three sampling campaigns, is characterized by low pH (3.3), high levels of sulphate ions (493.3 mg/L), iron (165.0 mg/L), zinc (59.7 mg/L), manganese (39.6 mg/L) and aluminum (19.4 mg/L). Heavy metals and toxic elements such as Pb, Cd, As, Cu, and Cr also appear in solution at levels and release loads significantly exceeding the prevailing national and international environmental limits.

→ Proposed treatment

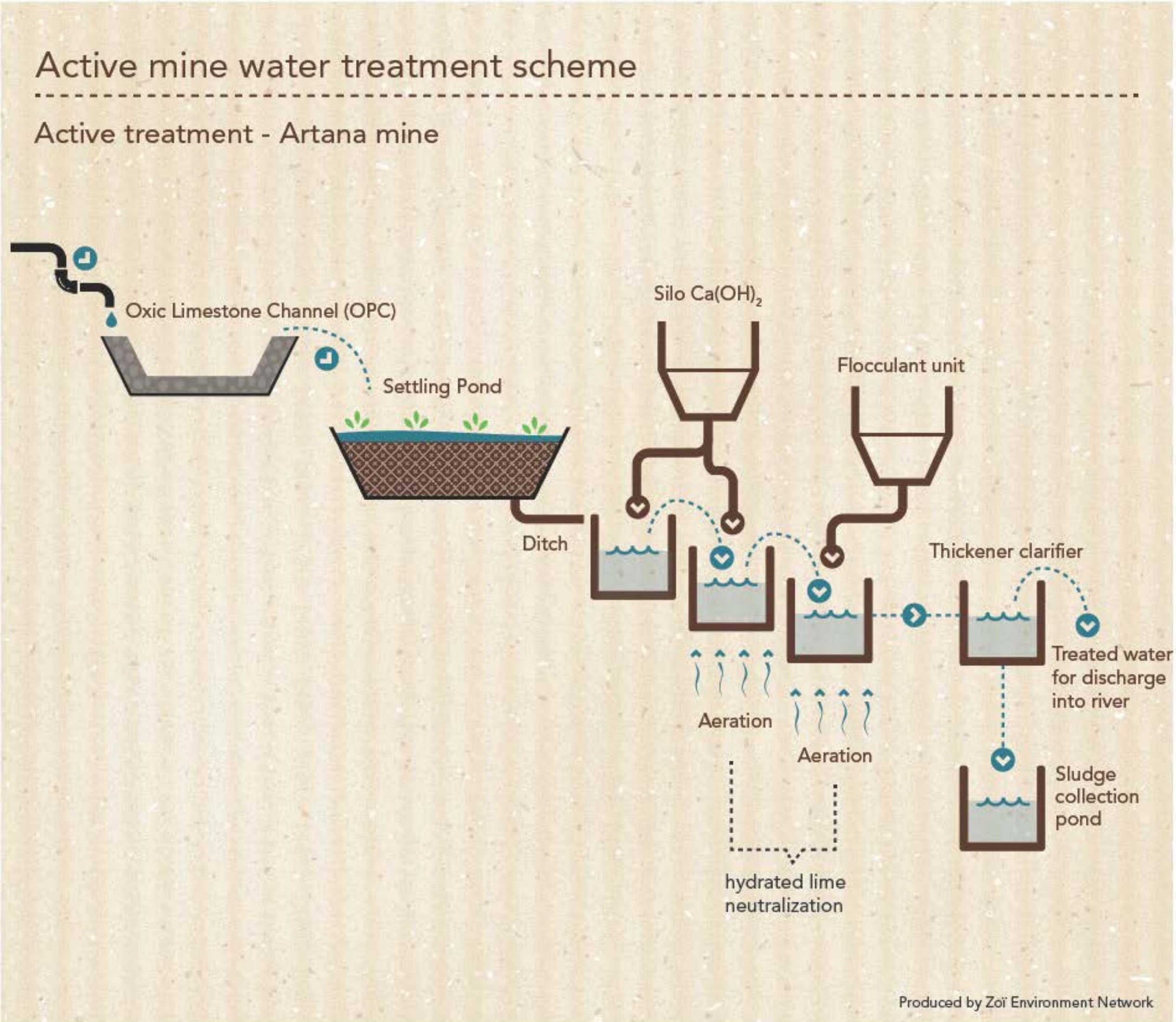
The feasibility study examined both active and passive systems for the treatment of AMD. Mine water quality, flow rates, land availability and contaminant removal provided the key evaluation parameters for the initial selection of the treatment scheme.

A passive treatment option comprising an oxic limestone channel, two settling ponds, a vertical flow pond and a manganese removal bed was dismissed on several grounds – average acidity does not fall within the scope of passive treatment; capital and operating (sampling for monitoring and sludge removal) costs are high; the necessary land area was significant; and most important, the option achieved only partial compliance with environmental limits.

The active treatment system option included an oxic limestone channel to add alkalinity to the system and to enhance ferric iron precipitation; the use of hydrated lime as a neutralization agent in three aeration tanks; and a thickener, settling pond and sludge collection pond for storage and consolidation of the neutralized sludge.

Active treatment provides controlled performance, consistent compliance with regulation, reduced capital costs (though operating costs are increased) and is easy to install and operate. The main technical problem with an active system is residual sludge (estimated at 1.8 kg/m^3 of AMD) that needs to be neutralized and properly disposed or utilized, if feasible. Sulphate removal must also be considered if the sulphate discharge limits are set below the values measured in gypsum-saturated neutralized effluents.

* This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.



Active mine water treatment scheme
Active treatment - Artana mine
Oxic Limestone Channel (OPC)
Settling Pond
Ditch
Silo $Ca(OH)_2$
Flocculant unit
Thickener clarifier
Aeration
Aeration
hydrated lime
neutralization
Treated water
for discharge
into river
Sludge
collection
pond
Produced by Zoï Environment Network

↑ Figure 14

→ **Next steps**

Given that the presently available flow and water quality data do not cover a complete hydrological year, the analysis estimated the potential for the reduction of mine discharge flows if an appropriate water management system were applied, and proposed a smaller-scale treatment system with a capacity of 25 m3/h for the next stage. Technical issues regarding sludge management at the site remain unresolved. Systematic monitoring of the flow and water quality are recommended prior to the full-scale application of a treatment scheme. A proposed water and river sediments monitoring programme comprises four locations on which physical-chemical and chemical parameters would be monitored monthly or quarterly, depending on the parameter. Additionally, mine personnel need to establish standard procedures, and conduct structured consultations with stakeholders from the early stages of project development.

4.4 Passive treatment

Passive treatment is an example of enhanced natural attenuation where naturally occurring processes are accelerated by the manipulation of environmental conditions in a treatment system. The aim is to provide conditions where the highest removal rate for a particular contaminant can be achieved. Truly passive systems function without any regular input of cost-intensive resources, such as manpower, energy and chemicals. Since many sites require active components such as pumping or aeration, a completely passive system is hard to achieve.

The costs of active treatment are distributed over time, and the high operating costs far exceed the costs of designing, building and commissioning a plant. In passive systems the major costs occur during the construction of the facility, and operating costs are minimal.

→ **Release of pollutants to natural receiving water after passive and active treatment (comparison), 80% average contaminants removal**

Emissions from Artana mine (V+VI), at average flow rate 50m^3/h	Zn	Cu	Ni	As	Cd	Pb	Cr
Passive treatment load, kg/y	5234.1	30.2	20.3	31.5	11.7	17.5	0.9
Active treatment load, kg/y	13.1	8.3	<2.2	4.4	0.2	3.9	<2.2
Limit set by EC Regulation 2006/166, kg/y	100.0	50.0	20.0	5.0	5.0	20.0	50.0

Figure 15 →

Passive mine water treatment systems

a

Aerobic Wetlands

2-8 cm Water
<30 cm Organic Matter

b

Anaerobic Wetlands

2-8 cm Water
30-60 cm Organic Matter
15-30 cm Limestone

c

Alkalinity Producing Systems (APS)

90-180 cm Water
5-15 cm Organic Matter
30-60 cm Limestone
Drainage System

d

Anoxic Limestone Drains (ALD)

60-120 cm Soil
30-65 mm Plastic Liner surrounding or covering LS Trench or bed of Limestone

e

Limestone Pond

90-180 cm Water
30-90 cm Limestone

f

Open Limestone Channel (OPC)

Small or large sized Limestone placed along sides and in bottom of culverts, diversions, ditches, or steam channels.

Produced by Zoï Environment Network

ENVSEC project experience: Zuta Prla

→ Location and history

The Zuta Prla mine is located in the north-east part of Montenegro, 4 km from the city of Mojkovac. This polymetallic sulphide mine most recently operated from 1976 through 1991, but mining occurred here for centuries: there are records from about 1270. More than 1.5 million tonnes of ore were excavated with underground methods from the Zuta Prla deposit.

→ Environmental impact

The former mining activity had an adverse impact on the aquatic environment at the site and downstream, mostly due to irresponsible management of the environmental pollution the extraction caused. The mine was declared an environmental hotspot. The main contamination was coming from easily accessible open shafts and adits discharging acid mine drainage contaminated with heavy metals. Sulphidic mine waste with AMD potential – from treated and untreated ore – contaminated the groundwater, and contaminants were leaching to Rudnica and the Tara River, the latter protected as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

→ Research

An expert from the National Technical University of Athens finalized the feasibility study in October 2010. Monitoring performed in the period May-August 2009 and in July and August 2010 resulted in analytical data showing great exceedances from environmental limits set in regulation. This stream was selected as a primary target for the application of mitigation measures because of its high acidic value, the increased level of contaminants and the contribution of the stream emanating from Adit Potkop I (located in the eastern mining area of Zuta Prla) to the contaminant loads released in the area. This stage of the project produced recommendations on preliminary design based on the available data, site measurements and a literature review, and included the approximate costs. The proposed passive treatment scheme included a relief chamber, an oxic limestone channel, a settling pond, a vertical flow pond and a manganese removal bed. Another design with an anaerobic wetland instead of a vertical flow pond was dismissed due to the requirement for a larger treatment area and to higher capital costs and total costs for 20 years of operation.

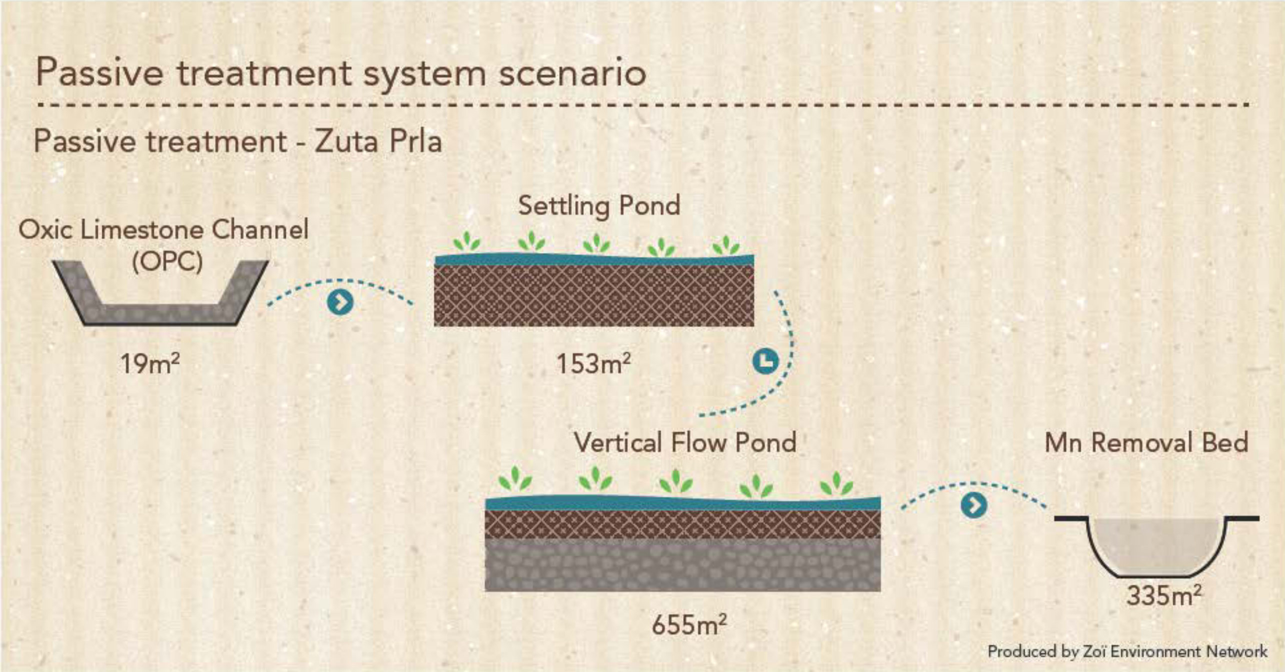
→ Treatment

The AMD flows through a concrete channel (100 mm in diameter) into a relief chamber to regulate the flow (designed for maximum flow of 0.6 l/s) and to provide a continuous flow rate to the treatment installation. The small (approximately 1 m^3) pond has a PVC outflow pipe installed under the water table. An open channel with stone reinforcement (in situ resources) was designed to prevent flooding in extreme situations.

→ Results of sampling campaign, 27.08.10, Ref.point 3.4 – Adit Potkop I

	pH	Al	As	Cd	Co	Cr	Cu	Fe	Mn	NI	Pb	Zn	SO_4
AMD, Zuta Prla	2.6	28.1	1.02	0.46	0.1	0.06	4.48	403	10.3	0.6	0.2	181	850
EU standards (Dir. 98/83/EC)	NA	NA	0.1	0.1	NA	0.05	2.0	0.2	0.05	0.02	0.1	NA	NA

↓ Figure 16



→ **Comparison between active and passive treatment**

Passive system	Active system
Much lower overall treatment costs with comparable treatment efficiency	Capable of treating higher flow rates and higher contamination levels
Very robust and hard to destroy physically	Reliable technology and experience in long-term application
Easy maintenance and no professional personnel required	Precise adjustment to change of influent quality and flow rates possible
Economic structure conducive to external funding	Removal ability not restricted to certain elements
Capable of adding ecological/biodiversity value by providing wildlife habitat	Little surface area required

CAPACITY-BUILDING

a.

Communication
- Synopsis on Mining & Environment related work in the Western Balkans
- Promotional video on selected hotspots
- Interactive mining map for the Western Balkan

b.

CSD learning centre
UNEP presented its Mining & Environment experiences to representatives of Western Balkan countries and others at the UN Commission on Sustainable Development (CSD)

- Instruction on principles, experiences and sources for best practice in mining, mine planning and mine closure
- Instruction addressing weaknesses and strengths in hazard assessment, monitoring and management and pathways to best practice
- Interactive discussion forum where specific scenarios are addressed and then contextualized by participants
- Summarizing and experience sharing where key outcomes from the training session and future needs for participants are discussed and documented
- Around 40 people trained and awareness raised

Its emphasis on capacity-building leads ENVSEC to seek improved cooperation, coordination and synergies among technical experts, policymakers, the private sector and academia in the region, and to facilitate the transfer of good practice in environmental management at mining sites from around the world. Key activities in ENVSEC projects are workshops and other forums where representatives of each country can share their experiences and their mining legacy challenges and where international experts in the field can lend their expertise. Although the characteristics, and therefore the environmental problems of each location are specific, such a joint platform increases the visibility of mining-related environmental problems and helps develop a region-wide network on responsible mining.

Further, ENVSEC seeks to raise awareness of the challenges as well as of the results achieved in the region at the international level with other United Nations organizations, international financial institutions, regional development banks, multilateral environmental agreement secretariats, civil society and other stakeholders. This awareness-raising is necessary to create synergies among the different work areas, to ensure the sustainable use of limited financial and human resources, to strengthen regional and national activities in the area and to provide a platform for multilateral approaches and for consistency in technology transfer.

ENVSEC project experience: Workshops

Technical workshop on emergency risk reduction at tailings management facilities

The remediation activities at Reps and Rreshen in Albania formed the basis for an emergency risk reduction workshop that presented robust and cost-efficient remediation solutions that can be applied at mining sites throughout the region and that can assist governments and private companies in meeting the environmental challenges with realistic solutions. Although emergency measures generally do not provide long-term protection, risk reduction activities may lead to more durable solutions once financial means and technical measures become available.

The workshop (6-8 October 2010) gathered 35 experts, practitioners, and decision makers from all six Western Balkan countries to share the experiences and knowledge gathered during the planning and implementation of the risk reduction measures at Reps and Rreshen. The workshop:

- Trained 35 people in emergency risk reduction at mining sites
- Raised awareness and stimulated the replication of remediation activities in the Western Balkans
- Fostered cooperation and expert networks for the region
- Secured institutional support for UNEP-led activities in the Western Balkans through a participatory approach and extensive consultations with regional representatives

Commission on Sustainable Development learning centre

The United Nations Commission on Sustainable Development (CSD) identified mining as one of the priority areas for its eighteenth session in May 2010, and UNEP presented its mining and environment experiences and approaches at this occasion to representatives of Western Balkan countries and others. The official programme of CSD-18 included a learning centre, which consisted of three-hour instructional courses focused on the specific themes of the session, including mining. The learning centre provided information on various facets of sustainable development at a practical level, enabling CSD participants to implement Agenda 21, the Johannesburg Plan of Implementation and other action frameworks in their countries.

The session had multiple objectives: to foster awareness of responsible mining practices, social and economic best practice and legacy management; to introduce guiding principles of financial, technical and capacity-building efforts that have been successful in establishing best practice mining; to stimulate experience sharing among session participants as a basis for ongoing work; and to deliver knowledge of where best practice information exists and how it can be made available to countries in need. The learning centre session provided:

- Instruction on principles, experiences and sources for best practice in mining, mine planning and mine closure

- Instruction addressing weaknesses and strengths in hazard assessment, monitoring and management, and pathways to best practice
- An interactive discussion forum where specific scenarios were addressed and then contextualized by participants
- Summarizing and experience sharing where key outcomes from the training session and future needs for participants were discussed and documented
- Training and awareness-raising for about 40 people

A UNEP side event presented the main goals and achievements of UNEP in South East Europe and within the ENVSEC initiative with regard to mining and environment.

The participants' warm reception of both the side event and the learning centre confirmed the relevance of abandoned mine site remediation far beyond the SEE region.

Kolasin workshop

In November 2012, ENVSEC organized a regional workshop held in Kolasin, Montenegro, to present and discuss the results of the ongoing project with representatives from Albania, Bosnia and Herzegovina, Montenegro, Macedonia and Kosovo.* As part of the programme they visited the Zuta Prla passive mine water treatment plant that was designed and built as part of the ENVSEC mining project. For the participants this created the opportunity to examine the passive mine water treatment plant and to review opportunities for further applications in the region.

The workshop participants evaluated the project implementation and results, and discussed the next steps for the continuation of the project. The workshop concluded that in addition to abandoned mining sites, future actions should target active mining operations to further advance responsible mining and to prevent the creation of new sites that might be abandoned in the long run.

* This designation is without prejudice to positions on status, and is in line with UNSC 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

ENVSEC project experience: Fundraising

The Trepca complex in Kosovo* is one of the most prominent mining conglomerates in the SEE region and still bears a wealth of minerals in its deposits. Despite its mineral riches, the site requires serious investment to capitalize on its assets and to tackle the numerous environmental legacies that pose serious risks to their surroundings.

The Environment and Security Initiative has long stressed the need for action at Trepca, and participates in the efforts to obtain support for environmental remediation. To support remediation activities at Trepca, ENVSEC provided an environmental feasibility study for an active mine water treatment plant at Artana (see Figure 14), and engaged in two donor conferences in Mitrovica organized by Trepca.

For other sites where ENVSEC was engaged through assessment and analysis, the project produced a series of leaflets that summarize the environmental concerns at each site and indicate a range of activities to mitigate the environmental impacts, including budget estimates and expected impacts. These leaflets were used as tools in communication with other donors and potential partners for cooperation at these sites.

ENVSEC project experience: High-level engagement

In recognition that the highest level of visibility and organizational support for environmental management is necessary for the achievement of long-term goals, ENVSEC invites high-level representatives of various organizations to take part in field activities. As a result of their participation in activities normally outside their agendas, these high-level representatives become familiar with the more technical issues.

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ENVSEC project experience: Cross-fertilization

Armenian study tour of remediation sites

In a situation similar to the SEE experience, Armenia had numerous mining operations undergo structural change, including privatization, after the dissolution of the common marketplace following the collapse of the Soviet Union. Among these operations, many sites had to be abandoned without appropriate environmental protection measures – stabilization, land reclamation and monitoring. In the context of its long-standing engagement in Armenia, ENVSEC recently started to promote mining and environment activities based on the SEE example. Stakeholders have appreciated these activities and have acknowledged the potential for replication in Armenia.

Building on this experience, Armenian representatives requested a study tour of ENVSEC remediation sites. The study tour introduced participants to the principles of mine site remediation applied in the region, demonstrated successful installations and provided exchange of experience with South East Europe experts on how to integrate environmental safeguards into ongoing and planned mining operations.

Expert excursions to Zuta Prla

Because of its highly innovative design and novel status in the region, the passive mine water treatment plant in Zuta Prla has attracted a number of visitors and groups interested to learn about the design and technology of the facility. The project framework provides for these highly welcomed visits from groups within the region, such as a recent visit by a delegation from Kosovo,* and from student groups both from the region and beyond, such as the visit by students from Switzerland.

ENVSEC project experience: Education

Project sites implemented by ENVSEC promote the education of students and actively cooperate with universities who want to utilize the sites for research and education. Similarly, the projects benefit from their engagement and results, which are used for medium-term monitoring. The passive mine water treatment site in Zuta Prla, Montenegro, for example, forms part of a master's thesis on passive mine water treatment by a student from Mojkovac.

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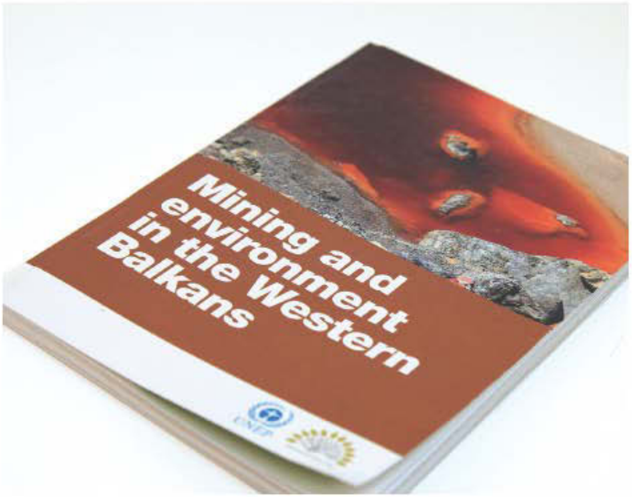
ENVSEC project experience: Communication

Despite all the efforts made with regard to fieldwork, site visits and workshops, a vast number of potential beneficiaries cannot be involved personally in these experiences. In order make the knowledge available and to involve others in the project, ENVSEC has created a range of communication materials that can be accessed in various ways to ensure a broad audience for these materials.

Mining and environment in the Western Balkans

This publication – Mining and environment in the Western Balkans – provides an overview of the activities carried out by UNEP within the ENVSEC initiative in the Western Balkans, and summarizes the environmental problems and possible approaches identified by this work. It also presents the most recent illustrations and designs of emergency risk reduction interventions produced in particular for this publication, and contains original graphics and photography. The report is currently available at http://www.unep.org/pdf/MiningBalkans_screen.pdf.



Promotional video on selected hotspots

In order to communicate mining and environment issues and opportunities to a wider audience, ENVSEC produced a promotional film illustrating the topic and showing examples of successful remediation actions in the Western Balkans. The five-minute video includes the use of animation, maps and copyrighted footage in addition to original photography provided by UNDP. The video was shown at several occasions to audiences at the Commission on Sustainable Development in New York, and is currently available at

http://www.envsec.org/index.php?option=com_content&view=article&id=86&Itemid=268&lang=en

Interactive mining map for the Western Balkans

An Internet-based interactive map produced by ENVSEC provides detailed information and photos of the mining hotspots identified by the UNEP regional inventory. The map includes original cartography, photos and text on each of the prioritized mining sites, and is available at:

http://www.envsec.org/maps/zoi-2010-11-08/index.htm.

FUTURE MINING OPERATIONS AND NEXT STEPS

The market for mineral resources is constantly evolving and as prices increase, new technologies enable economic exploitation of previously unprofitable mines or even mine waste. These prospective developments require a framework for sound environmental management that enables sustainable economic development in the region. These developments also need to involve governments, the private sector and civil society to ensure proper implementation and community support for any project. Local buy-in for mining projects has become increasingly difficult to obtain as the awareness of environmental impacts has grown and economic structures have evolved.

This situation is a challenge as well as an opportunity for the mining sector to establish or re-establish its relationship with local communities and to strive towards the environmental excellence that will satisfy the needs of their shareholders. Understanding the need for private sector initiatives via corporate social responsibility, industry leaders have become proactive and have raised the bar for their competitors. Governments are asked to provide a reliable legal framework and regulations, and are in the unique position to provide good incentives and to facilitate cooperation among the different stakeholders.

The relevance of abandoned mine sites has not diminished, as there are numerous sites that remain environmental hotspots throughout the region. But the time to prevent the creation of new hotspots in the future and to lay the foundation for responsible mining in the region is now.

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