27 SCOPING STUDY: APPLICABILITY OF PIR SYSTEMS TO MINE WATERS IN EASTERN AND SOUTHERN EUROPE

27.1 Project: PIRAMID

C. Wolkersdorfer[1], A. Hasche[1], J. Tschapek[1], M. Veselič[2], M. Leblanc[3]

[1]University Freiberg, Germany

[2]Institute for Mining, Geotechnology and Environment, Slovenia

[3]Université Montpellier, France

27.2 Executive Summary

Mining in Europe has great influence of the environment. A significant problem in many EU Member States and EU candidate countries is the long-term water pollution from abandoned mines and associated industrial sites. Sources of water pollution are e.g. pyrite oxidation, metal leaching by surface water or rain and leaching of residual process chemicals in the tailings.

In order to reach today's ecological standards polluted mine water needs to be treated in technical water treatment systems (conventional method). Water treatment will be necessary for a long time, consequently conventional methods will not be economically efficient.

Key objectives of PIRAMID are to draw developments of passive, ecologically-friendly in-situ remedial methods for mining waters together and to support the development of new techniques and innovations in order to apply such technologies to a variety of of polluted mine waters.

This report gives an overview of mine water problems in selected EU Member States and Accession States in Eastern and Southern Europe and assesses the potential applicability of passive treatment methods and where such methods are already applied.

For most existing mining sites in the reviewed countries the applicability of passive treatment methods is possible. Furthermore, in France, Germany, Poland and the Czech Republic experiences with different passive treatment methods e.g. aerobic/anaerobic wetlands, carbonate drain were already gained. The key condition for the application of such passive treatment systems is the existance of an acid drainage potential.

Often data about mine water chemistry, geological background and influence of mining on the environment are insufficient or not available. In order to assess the situation for several mining sites and the applicability of passive treatment methods it is important to collect more geological and chemical data of these mines in the future.

27.2.1 Austria

Raw Materials. In Austria are and were produced among other things brown coal, uranium, non-ferrous metals, iron and manganese ore, lead and zinc, and industrial minerals. Raw materials of minor importance are molybdenum, graphite and barite. Details on quantities from census in 1993 are in Table 27-1.

Major Mining Areas. Austria is number one world magnesium producer (WOLKERSDORFER et al., 2001). Lead and zinc production stopped after 1993. In 1993 102 mines were active in Austria. But a decline in mining led to closing some mines in the past years (WOLKERSDORFER et al., 2001).

Table 27-1: Production of mineral commodities in Austria (WOLKERSDORFER et al. 2001)

Commodities	1993 (10^6 tons)
brown coal	1.7
Uranium, non-ferrous metals iron and manganese	1.4
lead, zinc	0.279
copper, gold silver, salt rock	0.522
Kaolin	0.346
clay, sand, carbonate, gypsum	0.874
Magnesite	1
Graphite	0.004

Main brown coal areas are located e.g. Wiener basin. The most important iron mining field is also located in the Erzberg area where the iron ore is mined in open pit. Furthermore, Austria possesses a wolfram mine of importance (Mittersill). Salt mines Hallein, Hallstatt and Altausee belong to most important in Austria.

Historical Mining. Mining was important in Austria since Hallstadt era and through Roman times, middle and new age. A waste palette of metalliferous and energy resources was produced. Examples for historical mine sites are Trimmelkam, Wolfsegg (brown coal), Bleiberg/Kreuth (lead-zinc) and Lassing (talc; WOLKERSDORFER et al., 2001).

Applicability to PIR Systems. For some of the sulphide mines and for the most of lead and zinc mines PIR systems could be applied.

27.2.2 Bosnia and Herzegovina

Raw materials. Beside brown coal production mostly lignite the mining activities in Bosnia and Herzegovina are related to metal minerals e.g. iron, manganese, aluminium, lead and zinc, and to industrial minerals, including barite and kaolin.

Major Mining Areas. Important regions of coal mining are Tuzla coal basin, Central Bosnian coal basin and Mostar coal basin. After the war the coal exploitation reach to 25 % (1998: $3.5*10^6$ tons) of pre-war level (1991: $14.1*10^6$ tons; MIDZIC, 2001).

Historical Mining. Historical records of mining from medieval time can be found at Srebrenica, Kamenica, Olovo, Busovača, Fojnica, Kreševo, Vareš, Dusina, Deževica, Zvornik (WOLKERSDORFER et al., 2001).

Applicability to PIR Systems. At the most of complex sulphide and lead and zinc mines, where a potential of acid mine drainage occurs, PIR systems can be applied.

27.2.3 Bulgaria

Raw materials. In Bulgaria are mined brown coal, hard coal, anthracite, metal minerals and non-metals minerals. Further are exploited industrial minerals. Details on quantities of some commodities from census in 1998 are in table 27-2.

Historical Mining. No special data on past mining history are available to the author (WOLKERSDORFER et al., 2001).

Applicability to PIR Systems. PIR systems can certainly be applied at lead-zinc and copper mines because there are a high potential on acid mine drainage cause of sulphide oxidation processes. Furthermore, at bituminous coal and anthracite mines occurs water pollution (WOLKERSDORFER et al., 2001).

Table 27-2: Production of mineral commodities in Bulgaria (BGR 1999; WOLKERSDORFER et al., 2001)

Commodities	1998 (10^6 tons)	Mineral deposits
brown coal	31.1	e.g. Black sea coal basin
bituminous coal	0.121	Balkan basin
iron ore	0.895	Kremikovzi
manganese ore	0.055	Obrotschishte
copper	0.037	e.g. Burgas
lead/ zinc	0.04	e.g. Madan area
salt rock	1.5	Mirovo
silver	24 tons	Surnak
gold	1.7 tons	Tschelopetsch

27.3 Czech Republic

Raw Material. In the Czech Republic important mineral resources are hard coal, brown coal uranium, oil and gas.

Major Mining Areas. The country is divided in eight major mining areas with more or less importance. In **Central Bohemia** are deposits of several minerals, primarily coal in the Kladno-Rakovník basin. **South Bohemia** is not particularly rich in mineral raw materials. In the area of **West Bohemia** mineral and natural resources concentrate on extensive reserves of brown coal and substantial deposits of kaolin and ceramic clay in the basins of Sokolov and Cheb (EUROPEAN COMMISSION, 2000a). **North Bohemia** has an economic significance cause of extensive brown coal deposits in the districts of Chomutov, Most, Teplice and Ústí nad Labem. There are large deposits of uranium ore in the district of Česka Lípa (EUROPEAN COMMISSION, 2000a). The region of **South Moravia** is rich on deposits of non-ore raw materials. Of great significance is kaolin (Znojmo) and limestone (Brno). The region of **North Moravia** the black coal deposits in the Ostrava basin are of great economic importance (EUROPEAN COMMISSION, 2000a).

Historical Mining. All (or most of) the ore bearing deposits in the Czech Republic are closed (WOLKERSDORFER et al., 2001). So the mining of low grad iron ore has ceased in the Beroun and Příbram areas of Barrandien and the mining of gold at Jilové u Prahy and at Roudná u Vlašimi is no longer viable (EUROPEAN COMMISSION, 2000a). Kutna Hora, which was renowned for it's copper and silver, still has deposits of poly-metal ores (lead, zinc, copper and silver). Lead-zinc ores are still mined around the town Příbram (EUROPEAN COMMISSION, 2000a).

Applicability to PIR Systems. It is to assume, that most of the sites are flooded and have drainage water. Normally, conventional remediation methods are applied. In most cases, the water is then drained into public streams. Till now, chemical data of the mine waters were not available respectively do not exist (WOLKERSDORFER et al., 2001). Research of water chemistry was conducted in the Kutna Hora region (lead-zinc). The water is of strong acidity and rich in colloidal iron. Drainage waters from fluorite, barite, tin and wolfram bearing deposits near Nejdek are discharged into a natural wetland. The waters are running out from dumps (WOLKERSDORFER et al., 2001).

27.3.1 Baltic provinces

Raw Materials. Mining activities in Baltic provinces are not related to ore bearing deposits but they are concentrated on peat and industrial minerals, including clays, sand and gravels (EUROPEAN COMMISSION, 2000b). Besides the mining industry of Estonia is extracted oil shale (BRG, 1999), in the western part of Lithuania is extracted oil and the mineral industry of Latvia is engaged in the brick production (BRG, 1999). Except for the oil shale production in the Baltic provinces the mining activities are confined to quarries and open pits.

Major Mining Areas. During the 1980's was the major time of the industrial mineral production (LEVINE, 1997a, 19997b, 1998). In table 27-3 is given an overview of mineral resources and production.

Since then, no reports or current information of the development of new mines or enterprises producing industrial minerals are available, and there is a greater likelihood that some mining companies have stopped the production (LEVINE, 1998).

Historical Mining. All requests to ministries, geological survey, universities, and other authorities remained without response (WOLKERSDORFER et al., 2001). Information regarding ore bearing deposits and historical mine sites were not available. Only the report by LEVINE (1997a) contains information of uranium mining in Estonia. But the uranium was mined for only 8-year period (LEVINE, 1997a).

Applicability to PIR Systems. The results regarding that no problems with acid mine drainage water do exist in the Baltic provinces. The acid water from the underground oil shale mines, cause of shale oxidation, is buffered by high values of calcite occurring in the bedrock. A worst environmental problem were the tailings from the uranium-ore-processing in the past. Heavily contaminated water was seeping through the bottom layers of the tailings pond into the Baltic Sea, and the gravel dam that separated the pond from the Sea was slowly shifting towards the Sea and was damaged by storms (LEVINE, 1997a). But at the moment current information of this case are not available.

Table 27-3: Production of mineral commodities in Baltic provinces (BGR 1999)

	Raw material	**unit**	**1994**	**1995**	**1996**	**1997**
Estonia	oil shale	1,000 tons	14,530	13,310	14,735	14,383
	peat	1,000 tons	1,274	1,052	950	1,100
	clay	1,000 m^3	NA	160	NA	NA
	sand and gravel	1,000 m^3	14	14	NA	NA
Latvia	peat	1,000 tons	647	522	552	555
	limestone	1,000 tons	393	324	357	373
	sand and gravel	1,000 m^3	578	535	775	NA
Lithuania	oil	1,000 tons	51	159	161	213
	peat	1,000 tons	411	218	233	246
	sand and gravel	1,000 m^3	351	32	100	NA
	limestone	1,000 tons	NA	3,000	NA	NA
	clay	1,000 m^3	NA	700	NA	NA

NA: not available

27.3.2 France

Raw Materials. In decreasing order of importance, France has produced coal, iron ore, salt rock and metalliferous ores. Among these the more important exploited metals were aluminium, lead-zinc (silver), uranium, antimony and gold. The exploitation of fluorite, barite, and talc was also of importance.

Major Mining Areas. The main coal fields are located in the northern and eastern part of the country (Lorraine); smaller coal fields are distributed along the borders of the Massif Central. The most important iron mining field is also located in Lorraine whereas most of the other metalliferous mines (Pb-Zn, U, Sb, Au) are scattered in or along the borders of the Variscan massifs (Massif Central, Britany; WOLKERSDORFER et al., 2001).

Historical Mining. After the mining of the Roman times and middle age with the mainly exploitation of lead, zinc and gold the modern mining began during the first part of the 19th century. Today, and often after more than one century of active mining, most of the mining sites are closed, leaving more or less intensively contaminated areas (WOLKERSDORFER et al., 2001). The hard coal mines Messeix and Blangy mine, the lead and zinc mine Carnoulès and the gold and arsenopyrite mine Loperec are belong to the historical mine sites.

Applicability to PIR Systems. Potential areas for the application of PIR technology are the coal fields. The iron mining area of Lorraine and most of the other metalliferous mining sites are hosted in carbonate rocks (Jurassic terranes) which quickly neutralize the acidic mine drainage waters (WOLKERSDORFER et al., 2001). Thus, only a few metalliferous mining sites display serious drainage problems, often dealing with arsenic pollution (Carnoulès mine). In table 27-4 is given an overview of different passive water treatment methods and which are applied in France.

Table 27-4: Overview of applied PIR Systems in France

Location	PIR System	pH	Fe (mg/L)	As (mg/L)	SO42- (mg/L)
Alés mine	aerobic system	4.5 - 6	40 - 200	0.05 - 0.8	
Carnoulès mine	experimental bio-oxidizing system	3	1000 - 3000	100 - 300	2000 - 7000
Loperec mine	carbonate drain	5		10 - 15	

27.3.3 Germany

Raw Materials. Hard coal, brown coal, salt, iron ore, pyrite, uranium, tin, lead-zinc, terra alba, gypsum, barite, feldspar, carbonate, and shale are and were produced in Germany.

Major Mining Areas. About 77% of hard coal production is from the Ruhr coalfield where is mined from seams at depths exceeding 900 metres. The Saar Coalfield is also important, with substantial deposits of bituminous coal (NEWMANN, 1998). Brown coal mining is mainly in the Rheinish area to the west of Cologne and the Lausitz area near Dresden. On a much smaller scale, lignite is mined near Helmstedt (Mitteldeutsches Revier; NEWMANN 1998). Barite is mined in the Black Forest and Harz Mountain (mine sites: Clara, Wolkenhügel), iron ore is produced in mine sites in northern Germany (Wohlverwahrt-Nammen) and shale is mined in Thuringia (Lehesten mine) and in northern Bavaria (WOLKERSDORFER et al., 2001).

Historical Mining. In Germany all ore mining activities are finished. All fluorite mine sites in eastern Germany were closed in time period 1990 to 1991 and also all uranium mines were closed with the reunification. In table 27-5 is given an overview of historical mine sites in Germany.

Table 27-5: Overview of the historical mine sites in Germany (WOLKERSDORFER et al., 2001)

Mineral commodities	Mine sites
fluorite	Käfersteig, Clara
pyrite	Meggen(Siegerland)
uranium	Aue, Pöhla, Königstein, Ronneburg
barite	Thuringia, Saxonian Vogtland
lead, zinc	Erzgebirge, Harz Mountains, Meckernich, Siegerland

Applicability to PIR Systems. In Germany, in most cases, water treatment is necessary. Mostly conventional methods are applied for water treatment by addition of lime stone milk, drainage of the water (with pH > 7 or 8) into settling ponds (plants) and then into streams. Some cases exist, where passive methods (constructed wetlands) are applied (table 27-6). Potential areas, where PIR Systems are already used or could be used are the eastern German Brown coal fields, old mining areas in the Erzgebirge Region, Harz Mountains and in the Eifel Region, and bequeathment of former Soviet Union's uranium mining operations in the former GDR.

Table 27-6: Overview of applied PIR Systems in Germany (WOLKERSDORFER et al., 2001)

Location	Minerals commodities	PIR System	experiences
Lehesten	shale	anoxic limestone drain + aerobic wetland	pilot project (1997 to1999)
Pöhla	Uranium	aerobic/anaerobic wetland	pilot project
Peitzdorf	Uranium	aerobic/anaerobic wetland	under construction
Strassberg	fluorite	aerobic/anaerobic wetland	under construction

27.3.4 Poland

Raw Materials. Raw materials of importance produced in Poland are general: hard coal, brown coal, lead (silver), zinc (silver as a by-product) and copper. Furthermore, Poland has exploited nickel, gold, barite, salt rock and sulphur. All mine sites used to produce iron ore are closed. Under exploration are oil, gas, and peat (WOLKERSDORFER et al., 2001).

Major Mining Areas. The main hard coal fields are located in the Upper and Lower Silesian basins and in the Basin of Lublin in the eastern part of Poland. The brown coal production is from the Turow and Sienawa mines on the border to Germany and from the Belchatow mine to the south of Lodz (BRG, 1999). Copper is mined in the North Sudetic basin and lead-zinc mines are located in the north-eastern part of the Upper Silesian basin in the synclines of Bytom and Chrzanów, Olkusz and Zawiercie, (mine sites: Olkusz, Pomorzany, Boleslaw, Trebionka; WOLKERSDORFER et al., 2001).

Historical Mining. All of the iron ore bearing deposits in Poland are closed. Concerning iron ore deposits no detailed information about environmental problems are available (WOLKERSDORFER et al., 2001).

Applicability to PIR Systems. Application of PIR systems in Poland are only in a minor degree developed. Experiences exist in coal mining areas in the Upper Silesian basin where mostly represents saline, no acid water. Passive treatment of drainage water is not applied to water of coal mining sites. Saline water is treated in desalination plants e.g. in Debiensko. Saline water of the mining sites in the Upper Silesian basin contains CL- ~ 40 g/cm³, Na+ ~ 20 g/cm³, SO42- ~ 100 mg/cm³ (WOLKERSDORFER et al., 2001).

The only PIR system related to ore mining is applied in the Boleslaw mine (Olkusz region). The lead-zinc deposits are situated in Triassic carbonates. Since 400 years, lead and zinc contaminated waters discharged from the mine into the Biala River Wetland. It contains an area of ~7400 m² (WOLKERSDORFER et al., 2001). This wetland is naturally formed and currently under reconstruction. The wetland is characterized by an aerobic system. The main chemical data to characterize the mine water are shown in table 27-7 For further investigations, it is important to collect geological and chemical data of the named mine sites in Poland to recognize the real applicability to PIR systems.

Table 27-7: Chemical Data of the Biala River Wetland drainage water (WOLKERSDORFER et al., 2001)

elements	input	output
Fe (mg/L)	4 - 6	3 - 4
Zn (mg/L)	1 - 7	1 - 2
Pb (mg/L)	0.5 – 2.5	0.2 – 1.0
pH	7.2 – 8.8	

27.3.5 Romania

Raw Materials. In Romania are produced above all hard coal, brown coal and bituminous coal, and mineral commodities e.g. uranium, copper, lead, zinc, silver and iron ore. Besides are produced barite, gypsum, salt rock and talc (BRG, 1999).

Major Mining Areas. Romania has had in 1995 a total of 111 underground mines and 57 open pits. The non-ferrous ores are of poor quality, however, their potential for gold and silver exploitation is heating up the mining industry (WOLKERSDORFER et al., 2001).

Main hard coal fields are located in Petrosani district and Banat district; brown coal are mined e.g. in Brasov area, Bacau area and Cluj area; bituminous coal are produced in Schela/Oltenien. In the North carpatian are mined uranium (Crucea mine), copper, lead and zinc (Baia Mare, Baia Sprie, Cavnic etc) and in West Romania are mined iron ore (e.g. Bocsa, Tebea) and lead, zinc and gold (e.g. Rosia Montana, Baia Mare, Balan, Borsa, Certej and Rodna areas; BRG 1999).

Historical Mining. Historical mining records from Roman and medieval times exist in lead-zinc and copper mines.

Applicability to PIR Systems. PIR Systems can certainly be applied to lead-zinc and copper sulphide mines, and to bituminous coal producing mines, but no special data for the application of passive treatment systems are available to the author (WOLKERSDORFER et al., 2001).

Major regional ecological problems were provoked by the Baia Mare gold mines mine cyanide water spills (WOLKERSDORFER et al., 2001).

27.3.6 Slovenia

Raw Materials. Slovenia has produced brown coal and gypsum.

Major Mining Areas. Among the fully active brown coal producing mine Velenje Colliery in Slovenia were closed down Senowo, Zagorje, Kanižarica mines in 1996. Further, the production of lead-zinc (Mežica), uranium (Žirovski vrh), mercury (Idrija, Sv Ana) and copper (Cerkno) was shut down (BGR, 1999).

Historical Mining. In Slovenia Idrija (Hg) mine was active more than 500 years and Mežica (Pb-Zn) mine was active more than 300 years. Among these small iron ore and manganese alpine mines were active through 16th , 17th and 18th century; Vače (complex sulphide) mine was a short term important Austrian mine (WOLKERSDORFER et al., 2001).

Applicability to PIR Systems. There are exist mine water cases with low acid waters and industrial effluents with highly acid waters. Closing down Žirovski vrh uranium mine has a mine water outflow draining mostly an underlying carbonate aquifer. Its uranium content exceeds the pre-mining period, but conforms to standards. Tailings and waste rock dumps are radium containing and releasing (WOLKERSDORFER et al. 2001). It could be rewarding, if uranium and radium could be retained by some PIR System.

27.4 Conclusions

The focus of this report was to give an overview of mine water problems in selected EU Member States and Accession States in eastern and southern Europe and to give an assessment for the applicability to passive treatment methods and where such passive methods are already applied.

The overview of historical and current mining has shown, which in most of cases applicability to passive treatment methods are possible. In some countries gains experiences in recent years with different passive treatment methods e.g. in France, Germany, Poland and Czech Republic.

For the most of lead, zinc and copper mine sites in Romania, Bulgaria, Bosnia and Herzegovina, and Austria, both for historical and current mining, PIR Systems could be applied.

Furthermore, mine waters from the coal fields in France, Germany, Czech Republic, Romania and Bulgaria with brown coal, hard coal, bituminous coal and anthracite coal, have an more or less acidic e.g. as a result of pyrite oxidation. In these areas are suited for the application of passive treatment technologies.

Also uranium mine sites in Slovenia and Germany mainly tailings pond and waste rock dumps are potential areas, where passive treatment methods could be applied. Because of enormous volume of residue in such tailing ponds a PIR System for retaining uranium and radium could be reward.

For all named mine sites and mining areas where an applicability to PIR Systems are possible, it is important to collect more geological and chemical data of these for further investigations.

Great Problems exist at obtaining information about ore bearing deposits and historical mine sites in some EU candidate countries in particular Baltic Provinces. All requests to ministries, geological survey, universities, and other authorities remained without response.

27.5 References

BUNDESANSTALT FÜR GEOWISSENSCHAFTEN UND ROHSTOFFE (BGR 1999): Rohstoffwirtschaftliche Länderstudie XIV - Die Osterweiterung der Europäischen Union; Hannover/Berlin.

EUROPEAN COMMISSION (2000a): Portrait of the Regions - Volume 6: Czech Republic, Poland; Belgium.

EUROPEAN COMMISSION (2000b): Portrait of the Regions - Volume 8: Estonia, Latvia, Lithuania; Belgium.

NEWMAN, H.R. (1998): The Mineral Industry of Germany. - 8 pg., 2 tab.

LEVINE, R.M. (1997a): The Mineral Industry of Estonia. - 4 pg., 1 tab.

LEVINE, R.M. (1997b): The Mineral Industry of Latvia. - 3 pg., 1 tab.

LEVINE, R.M. (1998): The Mineral Industry of Lithuania. - 2 pg., 2 tab.

MIDZIC, S. (2001): WP1 BIH – Results of Steps Analysis in Bosnia and Herzegovina, Sarajevo.

WOLKERSDORFER, C.; LEBLANC, M.; VESELIČ, M. & TSCHAPEK, J. (2001): PIR applicability in European states. - 26 pg., 1 tab., Freiberg, unveröff. Bericht.