Project: **Sustainable Hydro Assessments and Groundwater Recharge Projects**
Project acronym: SHARP

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APPENDIX: Long version of good practices to be adapted report

GPA 1	Effects on groundwater by mining

Involved Project Partners:
Saxon State Office for the Environment, Agriculture and Geology (LfULG)
International Resources and Recycling Institute (IRRI)
Region of Western Macedonia (RWM)
Region of North Aegean (RNA)

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1. Concise description of the adapted good practice

1.1 Introduction

Effects on groundwater by mining occur in many of the Sharp Project countries and were focused within the project. The LfULG took the role as lead or responsible partner of this adaptation topic because of experience. Especially Saxony in the eastern part of Germany, beside the well-known Ruhr area, has a long mining and therefore a long contamination by mining history and now a nearly 20 years recultivation experience. Therefore the LfULG is the main donator, but also got a lot of information from the corresponding partners (Scotland, Greece and Poland). Within discussions the present approach was critically analyzed.

Opencast lignite mining goes along with groundwater quantity and quality problems during active mining and after mining. To ensure and enable active opencast mining usually the existing groundwater has to extract – for the whole period (decades!) of active mining. After the active mining the opencast will still exist and has to be fulfill even by soils or water. The groundwater rising will suddenly appear when the groundwater pumps will stopped. But with this come a lot of problems. The flooding has to be supported in the context of stability of the surrounding and to shorten the flooding period with additional water if needed, for example.

One of the main quality problems is acid mine drainage (AMD). Acid mine drainage forms metal-rich water from the chemical reaction between water and rocks containing sulphur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulphur-bearing mineral.

The principle of AMD in mining areas in an example for pyrite containing rocks shows Fig. 1 and can be described as following:

- The weathering of pyrite in lignite overburden dumps is caused by oxygen and water
- As a result of weathering of pyrite formed under oxic conditions mainly iron (III) hydroxide and sulfuric acid
- The result is a highly mineralized water with high sulfate and iron concentrations
- The pH value is in the range 2.5 to 6
- That is the reason why the water body is in an acidic status

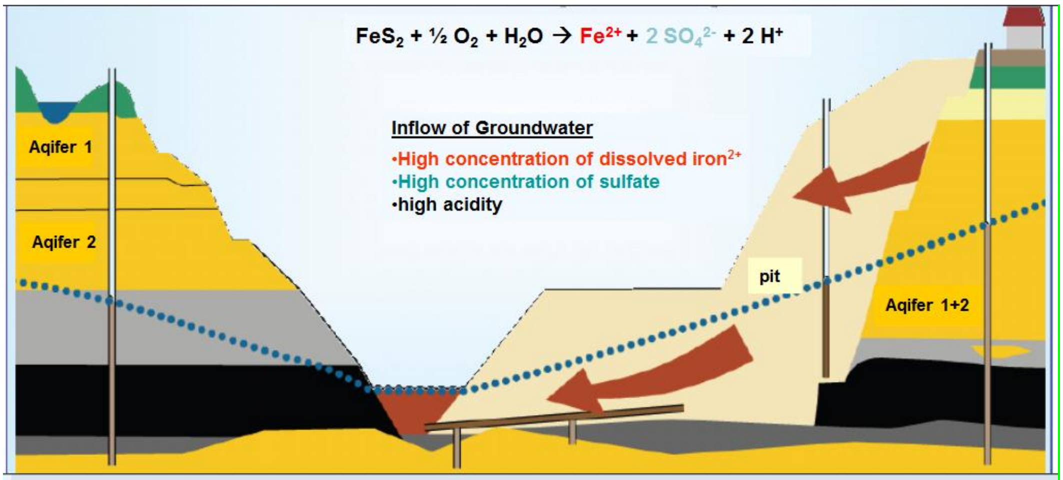


Fig. 1: Principle of Acid Mine Drainage (AMD) of pyrite in mining areas in the Lusatian area (Germany).

In Scotland, the most significant problem after the closure of a mine is also (AMD). For this reason, we decided to focus (see Chapter 2 "Description of Adaptation process") on methods to clean such acid mine water.

Unfortunately there is no universal remedy; it is much more a matter of finding a good solution for the present situation and circumstances. So we decided that our good practice is a collection of treatment methods that can be used or further researched.

But all these methods have the same goal: to neutralize the water and remove metals from the waters to prevent that other waters come in contact with the contaminated mine waters (fresh groundwater, surface water).

1.2 Important characteristics of the good practice

Tab. 1 shows the collection of treatment methods that can be used or further researched supported by project Vodamin.

Tab. 1: Collection of treatment methods that can be used or further researched supported by project Vodamin.

Nr.	Treatment of	Title	Treatment goal	Range of application	Experienced experts	Stage of development	Already known	Unknown	Need more info	No interest	because of * 1- does not occur, no need 2- stage of development or no practical application 3- other (please explain on an extra sheet)
1	Groundwater	Heterotrophic Sulphate-Reduction in the aquifer	remove metal, suphate and reduce acidity	Iron- and sulphourus, acidic groundwater	Brandenburg University of Technology Cottbus; BioPlanta GmbH	multiannual operation of a pilot plant in the field	☐	☐	☐	☐	
2		Autotrophic Sulphate-Reduction	remove metal, neutralisation, main sulphate removel , create alkalinity	Iron- and sulphourus, acidic groundwater	Groundwater Competence Center Dresden	4-year operation in a pilot reactor	☐	☐	☐	☐	
3	Surface water	Membrane process (Nanofiltration)	reduce salinity (sulphate- and calcium concentration) in (iron free) mining waters	neutralized oxic water, application past metal separation	Brandenburg University of Technology Cottbus	laboratory scale (plans for pilot scale)	☐	☐	☐	☐	
4		Inlake Reactors for reductive sulphate separation	reduce sulphate concentration in surface waters and increasing the alkalinity (reducing acid load)	lakes formed from open-cast mines	Center for Environmental Research UFZ	pilot scale	☐	☐	☐	☐	
5		Inlake method to neutralize the lake water	(Initial-) Neutralisation of surface water	lakes formed from open-cast mines	Lausatian and Central-German Mining Administration Company (LMBV), TU Bergakademie Freiberg	state of technology (ongoing field investigation concerning optimization of costs, input and neutralization agent)	☐	☐	☐	☐	
6		Conditioning of the lake system	developing a carbonate buffer in a already neutralized in non floating waters	lakes formed from open-cast mines	Groundwater Center Dresden, IWB Dr. Uhlmann	first pilot test in the field (pilot tests of further-reaching solid particle solution)	☐	☐	☐	☐	
7		Reaction carpets for inflow treatment	reduce sulphate- snd ironconcentration within the offstream of surface waters and increasing the alkalinity	embankment of lakes formed from open-cast mines (area of inflow)	BIUG GmbH Freiberg	Field application on pilot scale since 2004	☐	☐	☐	☐	
8		Oxidative mine water treatment	remove metal and neutralisation	iron- and aluminum-rich acidified surface waters and sump water flow	LMBV, Vattenfall Europe Mining, MIBRAG	state of technology, further development needed if additional to iron also other metals have to seperate	☐	☐	☐	☐	
9		Membrane electrolysis facility	remove metal, neutralisation and partial sulphate removal	iron- and sulphate-rich acidified surface waters	VKTA Rossendorf	poperation of a pilot plant in the field (actual procedure toughening with CO_2-input)	☐	☐	☐	☐	
10		Iron sulphate precipitation	remove sulphate and iron	iron- and sulphate-rich acidified surface waters and sump water flow	Vattenfall Europe Mining, GEOS Freiberg	test in pilot scale	☐	☐	☐	☐	
...	...	***to be amended***									

Substitutionally for all other methods or techniques of the given collection some of them are described and illustrated in more detail.

The principle of a mine water treatment plant (visit of the mine water treatment plant in Schleenhain, Germany (PP7 and PP8)) is now explained in more detail – see Fig. 2.

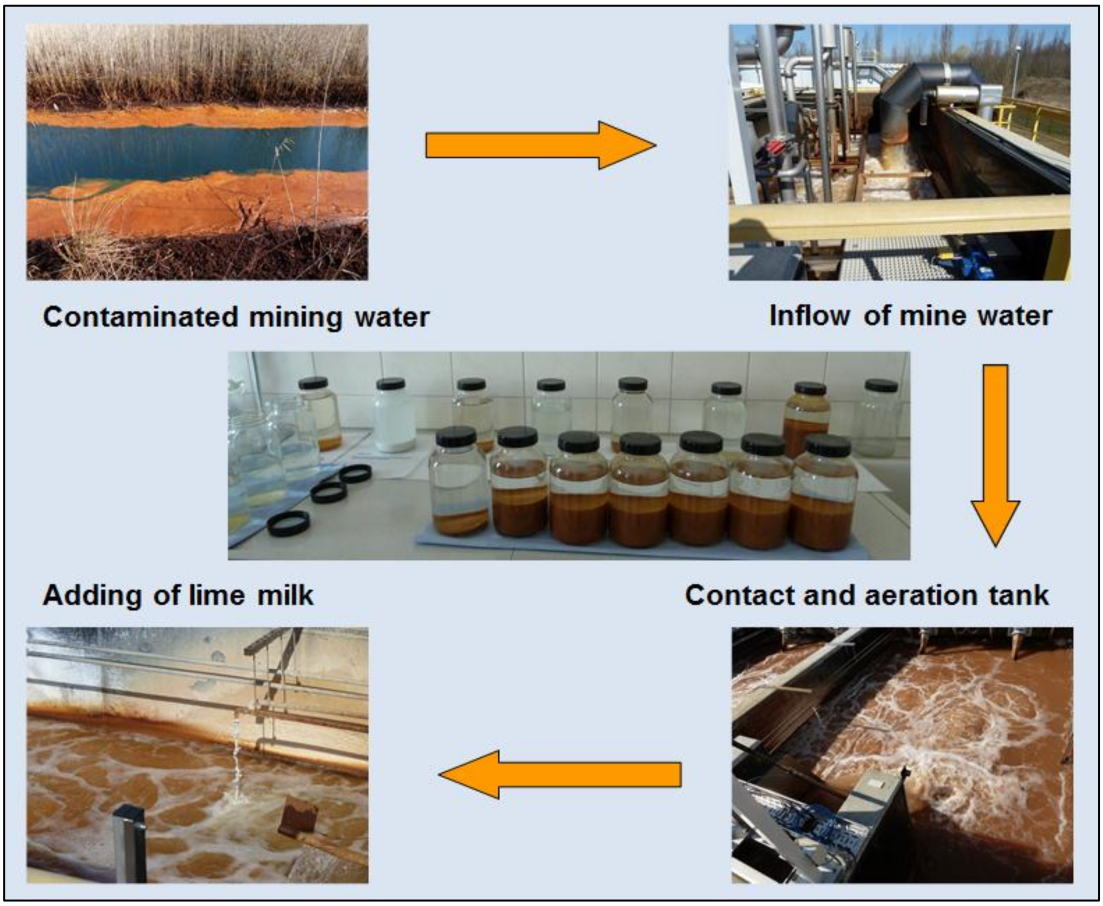


Fig. 2: schematic diagram of amine water treatment plant Schleenhain/Germany.

- Because the mine water is discharged into receiving waters, it is first necessary to clean the water concerning the pH value, iron content and suspended solids
- In this plant, the iron contained in the mine water is removed. In addition, the pH value is increased
- The mine water treatment plant consists of the following process stages or plant parts:
    - Liming plant with silos
    - Contact and aeration tank
    - Circular tanks of various sizes with a capacity of up to 5,000 m^3 of water
    - a machine house, a factory building and piping systems
- The supply of lime milk and oxygen causes a neutralization of the pH value of the mine water
- The iron content - according to regulatory requirements – to less than three milligrams per liter reduced
- About 60 cubic meters of water per minute can be treated in the plant

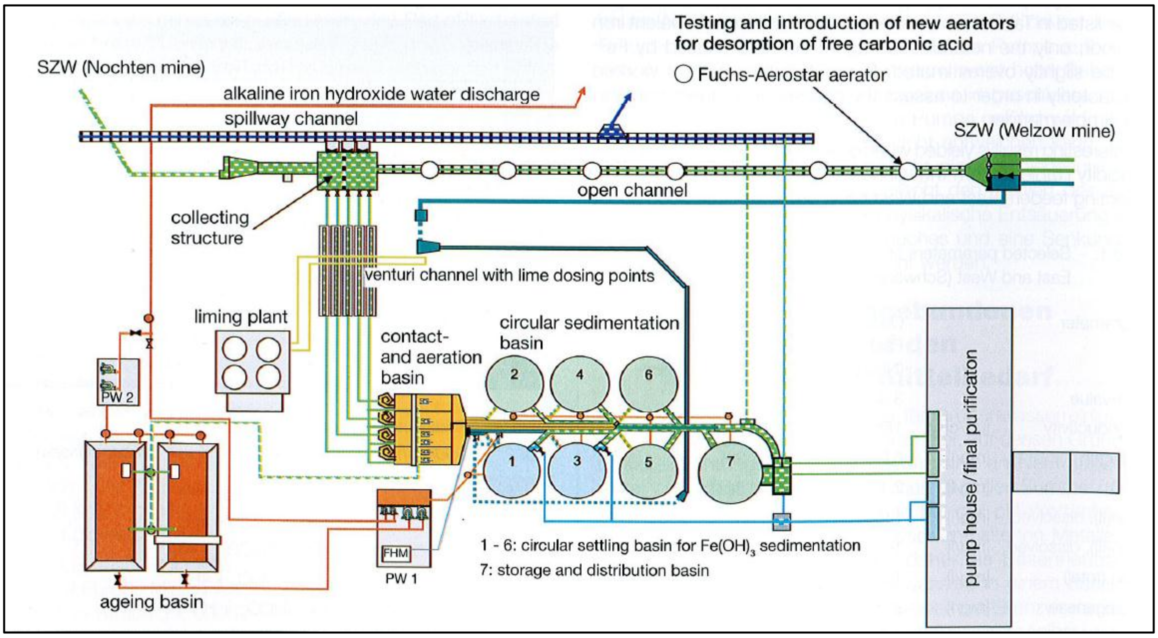
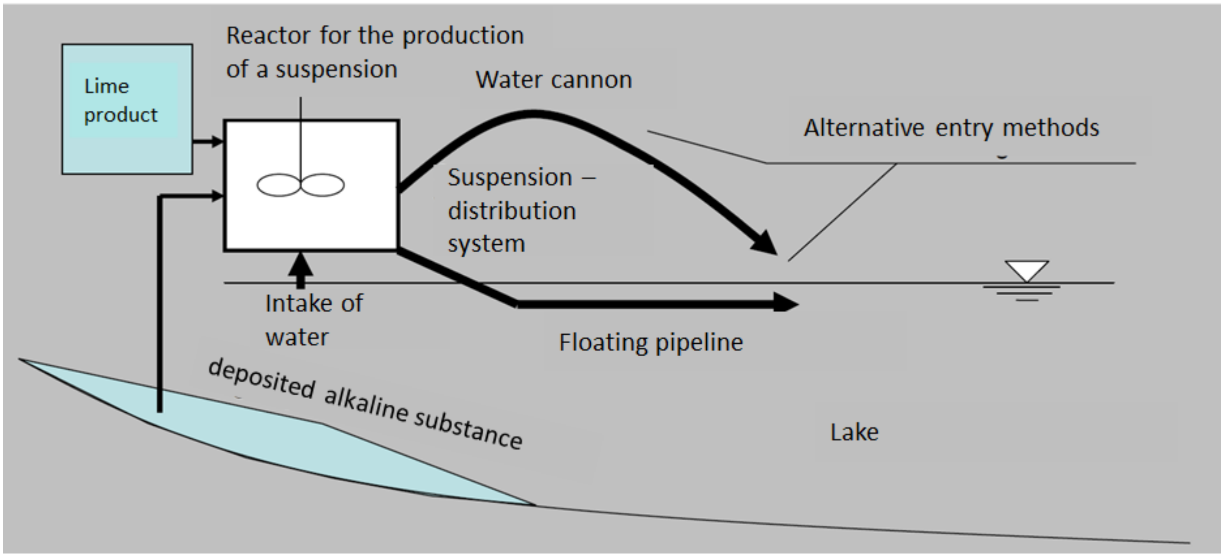


Fig. 3: Mine water treatment plant MIBRAG mbH.

Another method is the Inlake technique to neutralize the lake water. A neutralization of surface water is possible by inserting of lime products. This can be done in combination with metering stations on the banks/shores and with floating distribution systems on the water or by a kind of rehabilitation ships. Unfired ground or burnt limestone products such as CaCO3- or Ca (OH)2 suspensions were used. The abreaction is largely in seawater body. Wind-induced mixing of the lake water is an intentional and required part of the process.



1.3 Benefits of the good practices

The benefits of the collection of treatment methods that can be used or further researched are:

- Using these methods and techniques leads to better water quality
- Methods and techniques are transferable
- Gives a good overview about actual methods
- Gives a good overview about actual stage of science/research
- Information are easily available
- Further information and help can be provided by experienced experts
- Ideas behind the methods does not have to reinvent (with mining problems you are not isolated)
- Further benefits (for the presented examples):
  - Inlake method to neutralize the lake water are:
    - Fast and relatively well predictable effect of the process
    - Safe neutralization and (chemical) precipitation of dissolved metals
  - Oxidative mine water treatment are
    - High precipitated chemical substances
    - Adaptable to the removal of other pollutants

2. Description of adaption process

At the beginning of joint cooperation a questionnaire was sent to PP7 in order to define the current state of knowledge in the field of mining in Scotland. The following points were answered by IRRI.

- Historical overview and future development
- Which raw materials are mined
- Which methods are used (daylight mining, deep mining, …)
- Areal extent of mining operations
- Responsibility for mining and rehabilitation
- Which remediation measures are planned and how are these techniques selected
- What problems occur during mining
- What problems occur after mining

Because the Scottish partner is very interested in the cleaning of acidified mine water, we visited 2011 the mine water treatment plant in Schleenhain, Germany.

Additionally, internal experts of the LfULG were invited. These experts work on the Project VODAMIN. This is a project that searches solutions for the purification of contaminated mine water. The results of VODAMIN are also included in SHARP. So there is possibility to exchange experiences of current methods to clean mining waters. During the SHARP meetings the Greek partners (PP2 RWM) have expressed their interest in this topic and presented treatment methods and all project partners visited the mining area of Ptolomeida, Greece. Additional this topic is important for PP6 (IMGW); during the study visit all project partners also saw the mine Turow and the mine water treatment plant in Poland.

Within the cooperation it was figured out, that project partners are now in different situations or stages of active as well as after mining activities. Also political strategies make it difficult to bring the presented techniques into work in another project partner work within these three years of SHARP project duration. But in the scope of SHARP the main steps were taken, contacts were made and we provide a common basis for future work.

2.1 Steps for Adaptation

Easily transferable methods (without adaptation) are the mine water treatment facilities, the presented Inlake method to neutralize the lake water and oxidative water treatment.

All other presented methods (passive / active techniques; geotechnical, chemical, physical, biological, microbial processes) are actually not state of technology and are at different stages of research. Depending on the actual stages the following general steps has to be taken or fulfilled to successful adapt the methods for the use in rehabilitation:

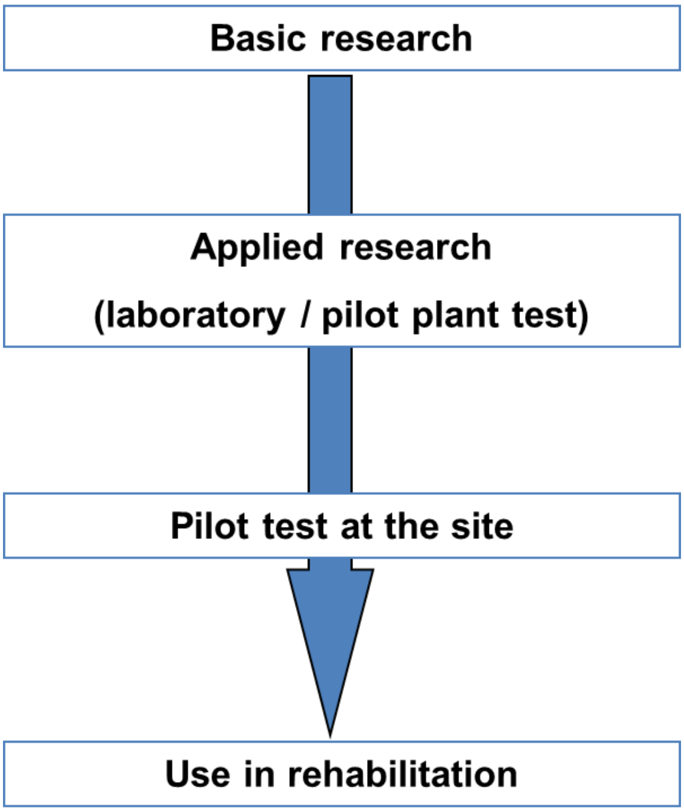


Fig. 4: Steps of adaption.

However, there is the possibility that the good practices are obsolete in the future. There is a great need for research. A lot of the methods and techniques presented in Tab. 1 are still in testing stages and not in state of technology, and the sulphate removal is still a very difficult task.

But for this reasons the SHARP project was a good possibility to exchange the knowledge (practical and theoretically) and to give less experience partners information and an idea of problems that occur after mining and how to face them if they will get in this situation. Then they will have the contacts or the access to the experience.

So this is also a benefit for all partners and will still benefits in the future.

List of Literature:

Reinigungsverfahren von Grundwasser und Oberflächengewässern, Endbericht Februar 2012, LfULG (Auftraggeber), DGFZ (Auftragnehmer).