# Maximising use of waters produced by mining

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## Abstract

Mining usually requires dewatering but water is also needed in mining for many purposes. Further more, water is a valuable resource. There are many examples for the utilisation of waters produced by mining. However, there are also limitations for utilising mine water like poor quality or limited demand. This paper gives an overview of the utilisation of mine water and discusses general limitation based on international literature. Although "Maximising use of waters produced by mining" does not make sense as an exclusive goal in itself mine water should be utilised where sustainably possible.

**Keywords**: agriculture, aquaculture, cooling, drinking water, geothermal heat, hydropower, integrated water resource management, metal recovery, nature conservation, pit lakes

## Introduction

Mining is faced with water issues from two opposite perspectives: On the one hand, mining requires usually dry conditions. The mined ground has to be dewatered and the mines have to get rid of the excess water. Due to environmental requirements, the water often has to be treated before discharged. All this causes costs. Beneficial utilisation of the water may limit those costs. On the other hand, many mining operations and related activities require water, e.g. for coal washing, ore processing and concentrate production, cooling in deep mine workings, dust mitigation at surface and underground. In regions of seasonal or permanent water scarcity, mining is competing with ecological needs and with other water users for water. This may have substantial impact on the economy of a particular mining operation and is a strong driver for utilising all available water produced by the mine. In addition, water is generally a very valuable resource resulting in an ethic requirement for carful handling and utilisation, irrespective if related to mining or not. Consequently, "Maximising use of waters produced by mining" appears as a reasonable goal.

The discussion of „Maximising the use of waters produced by mining" requires a definition of „waters produced by mining". In the sense of this paper, such waters include water resulting from dewatering operations, surface runoff from the mine area (including dumps, tailings and adjacent coal or ore processing facilities), water used for coal or ore processing and for tailings and overburden handling, water stored in tailings dams, clarification ponds or other storage facilities related to mines, pit lakes and water running or pumped out of abandoned mines.

The goal of this paper is to given an overview of possibilities to utilise mining produced waters and to discuss general limitations of the utilisation and, in this way, the sense of its maximising. This is done based on international literature and examples personally known to the author. Among the diverse literature, three sources have to be particularly mentioned: the IMWA journal Mine Water and the Environment, the proceedings of the IMWA meetings, and Wolkersdorfer (2008).

## Hydrological aspects

Mining causes temporary changes in local and regional hydrology. Dewatering turns groundwater into surface water. Direction and flow rates of the groundwater are changed, at least locally. Local evaporation and the flow rates in the receiving surface waters may be increased. After mine closure, there is a period of increased water consumption by the mined region due to re-filling of the dewatered underground and, in the case of many open cast mines, the filling of pit lakes. In the long term, many mining operations leave the mined area, and thus the respective catchments, with altered hydrological properties: pit lakes and wet covered tailings dams may increase water storage and evaporation, overburden dumps and backfilled mine voids form artificial aquifers which may provide storage space and increase base flow, abandoned underground workings act as draining and storing artificial karst, soil compacted during reclamation may cause higher flood frequency and intensity and remaining artificial, sealed riverbeds change the interaction between groundwater and rivers. The geochemical changes of the mining influenced parts of ground and surface result in water quality issues discussed below. All these aspects have consequences for the utilisation of waters produced by mining.

## General limitations

Although maximal utilisation of waters produced by mining appears basically desirable there are some general limitations. Firstly, the quality of mine water is often poor, in particular in the case of acidification. Concentrations of metals, including toxic ones, may reach several hundred milligrams per litre or even grams per litre. This requires treatment before release to the environment or any utilisation is possible, except recovery of metals. The concentration of dissolved solids is usually elevated also without acidification and after treatment in most cases (e.g. Geller and Schultze 2010, Nordstrom 2011, Younger et al. 2002).

Secondly, if water produced by mining shall be utilised for human purposes, like process water in mining, drinking water, agriculture, there has to be an excess of water in the respective catchment. Otherwise, the ecological needs of rivers, lakes, wetlands and the groundwater system require all the produced water for the mitigation of unacceptable adverse impacts on the hydrology in the catchments influenced by mining.

Thirdly, the utilisation of excess water produced by mining cannot exceed the local or regional demand. For example, mining operations in remote regions under humid or wet climate may produce an excess of water which is not needed because of the limited demand of the mine and the related miners community and the excellent availability of water due to the natural conditions.

Finally, water produced by active mining is usually a temporary source of water. This source becomes available when commissioning a mine and disappears basically with mine closure. As described above, it may be even replaced by a temporarily increased demand for filling dewatered ground and mine voids.

Leaving this important aspect out of consideration may result in serious problems after mine closure (see third example from Germany below).

## Reported utilisation of water produced by mining

The utilisation of mine water has been an issue already for centuries (Banks et al. 1996, Wolkersdorfer 2008). Table 1 gives a brief overview of the kinds of utilisation of waters produced by mining. The mentioned references are only a selection. There is a much larger body of valuable literature. Pit lakes are mentioned among the sources of water in the table. Often they are not only a source of water but also the location of diverse kinds of utilisation like nature conservation, recreation or flood protection.

In Table 1, the last kind of utilisation is the stabilisation of the regional water balance. This goal is involved also in almost all of the other kinds of use, intentionally or as a "by-product". For example, more recycling of water within mining results in smaller demand and allows for excess water which can be utilised for other purposes (e.g. Norgate and Lovel 2006, Wright and Vleggaar 2006). Nature conservation in wetlands requires the stabilization of the regional water balance (e.g. Arnold and Rolland 2005, Kulik and den Drijver 2006).

In recent years, many publications discuss the shortage of water availability for the mining industry due to (i) changes in environmental and water legislation (Salmon 2006), (ii) increasing demand caused by economic growth in mining impacted catchments and the respective competition for the limited water resource or because of declining ore grade and related increase in material to be mined and processed (Norgate and Lovel 2006) or (iii) expected water scarcity resulting from climate change (Koch et al. 2005, 2009). This puts the discussion on handling of water in the mining sector in a general context of water management in catchments, not only under environmental aspects. Integrated water resource management (IWRM) is an increasingly applied general concept for river basin management, including mining related water issues (e.g. Grünewald 2009, Loredo et al. 2010, Mey et al. 2006, Younger 2006). The South African hierarchy of mine water management as described by van Niekerk (2009) combines many aspects and puts utilisation of mine water into a more general context: (1) Pollution prevention at all potential sources on the mine → (2) Minimisation of potential impacts by mitigation measures → (3) Recovery and beneficial use of water on mine complex → (4) Treatment of mine water for beneficial use and discharge.

*Three examples from Germany*

In order to demonstrate the interaction of different kinds of utilisation of waters produced by mining, three examples from Germany are presented in the following. While the first two are exclusively stories of success the third one demonstrates the importance of the hydrological aspects and the resulting risks of inappropriate long-term planning for the utilisation of water produced by mining.

*Conservation of wetlands in the vicinity of surface mines*

A special case of stabilizing the water balance in a mining impacted region is the infiltration of mine water north to the open pit mine Garzweiler (Germany,

***Table 1*** *Summary of reported use of water produced by mining. OM – operating mines, AM – abandoned underground mines, PL - pit lakes.*

| Kind of utilisation | Water source | Examples for references |
|---|---|---|
| Water supply (drinking water, industrial purposes) | OM, AM, PL | Karakatasanis and Cogho (2010), McCullough et al. (2009, and references therein), Wolkersdorfer (2008, and references therein) |
| Recreation (including spas) | AM, PL | McCullough et al. (2009, and references therein), Schultze (2010, and references therein), Wolkersdorfer (2008, and references therein) |
| Aquaculture and fishery | AM, PL | Axler et al. (1998), McCullough et al. (2009, and references therein), Miller (2008), Otchere et al. (2004) Schultze (2010, and references therein) |
| Agriculture (irrigation, water for cattle) | OM, AM, PL | Annandale et al. (2009), du Plessis (1983), Harper et al. (1997), Idovu et al. (2008), Jovanovic et al. (2001), McCullough et al. (2009, and references therein) |
| Mining (including coal and ore processing and tailings) | OM | Bahrami et al. (2007), Barrett et al. (2010), Bender et al. (2010), Holten and Stephenson (1983), Loveday et al. 1984) |
| Recovery of metals | OM, AM, PL | Gammons and Tucci (2012), Rapantova et al. (2009), Wolkersdorfer (2008, and references therein) |
| Cooling (power plants, offices) | OM, AM | Watzlaf and Ackman (2006), Wolkersdorfer (2008, and references therein) |
| Geothermal heat | OM, AM | Digges La Touche and Preene (2011), Renz et al. (2009), Watzlaf and Ackman (2006), Whitebread-Abrutat and Coppin (2011), Wolkersdorfer (2008, and references therein) |
| Hydropower | OM, AM | Loredo et al. (2011), Whitebread-Abrutat and Coppin (2011), Wolkersdorfer (2008, and references therein) |
| Filling of pit lakes | OM | Schultze et al. (2011) |
| Nature conservation | OM, PL | Arnold and Rolland (2005), Kulik and den Drijver (2006), McCullough et al. (2009, and references therein), Schultze et al. (2012) |
| Stabilisation of regional water balance (including water storage and flood protection) | OM, AM, PL | Grünewald (2009), Kaden et al. (1985), Loredo et al. (2010), Norgate and Lovel (2006), Schultze et al. (2012), van Niekerk (2009), Wolkersdorfer (2008, and references therein) |

Rhineland lignite mining district; Trumpff 1990, Kulik and den Drijver 2006, RWE 2006). Infiltration wells, ditches and deep cutting infiltration trenches filled with gravel are employed for infiltration (Figure 1). About 64x10$^6$ m$^3$ of water from dewatering operations are treated and then infiltrated between the mine and sensitive wetlands annually in order to protect ecologically valuable wetlands, i.e. for nature conservation. For future, a maximal annual infiltration rate of 100x10$^6$ m$^3$ is expected equalising 2/3 of the dewatering water. In some cases, treated mine water is diverted directly into small streams (Kulik and den Drijver 2006). Similar measures were also reported for the lignite mine Jänschwalde (Lusatian lignite mining district, Germany) by Arnold and Rolland (2005).

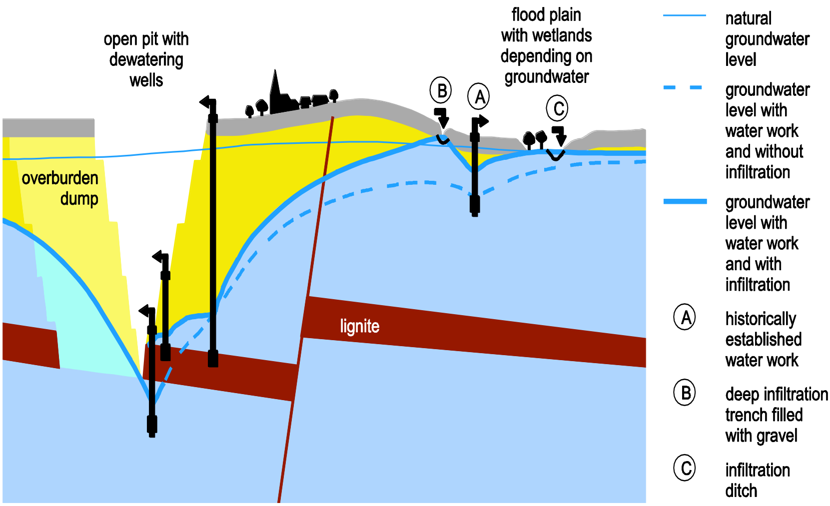


***Figure 1** Infiltration of mine water to maintain ecologically valuable wetlands north of the German lignite mine Garzweiler (from REW 2006, adapted).*

*Filling of pit lakes*

In the eastern part of Germany, mine water from dewatering operations of operating open pit lignite mines has been utilised to fill neighbouring pit lakes in already abandoned lignite mines. For the period 1990 to 2011, mine water contributed 20.9% to the pit lake volume to be filled. In addition, the filling of pit lakes with mine water is a successful strategy for the abatement of acidification (Jolas 1998, Schultze et al. 2011). Figure 2 shows the amount of mine water utilised for filling of pit lakes in the Lusatian and in the Central German lignite mining district. In the Central German lignite mining district, no treatment of the mine water has been necessary saving costs for the active mines.

*Water management in the Lusatian lignite mining district*

Water originating from the dewatering operations in the Lusatian lignite mining district (Germany) resulted in a substantial elevation of base flow in River Spree for many decades (by factor 5 to 10 for low flow periods; Grünewald 2009). Based on this temporarily elevated water availability, water utilisation was established downstream of the mining district which hardly can be sustained under the conditions after mine closure (Grünewald 2001, 2009). The demand of water for groundwater rebound and filling of pit lakes after mine closure made the situation even more complicated. Therefore, a model based, integrated water management system for River Spree and its neighbours, River Neiße and River Schwarze Elster was developed (Kaden et al. 1985, Grünewald 2001, Koch et al. 2005, Schlaeger et al. 2003). Water is transferred between the river systems and actual water management is done dynamically based on model simulations and weekly agreements between mining companies, regional authorities and other stakeholders within a framework of statutory rules, given water rights and long-term contracts (Gockel and Illing 2007, Grünewald 2009, Luckner 2006). All water produced and handled by the mines is involved in this management system. In order to manage expected future scarcity of water caused by climate change additional transfer of water from the River Elbe is being discussed (Koch et al. 2009).

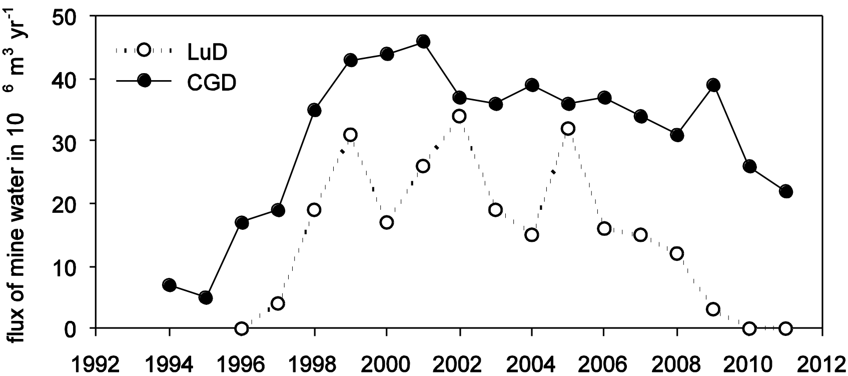


***Figure 2*** *Use of mine water for filling pit lakes in Germany. LuD-Lusatian lignite mining district, CGD-Central German lignite mining district. Data source: http:/www.LMBV.de.*

## Conclusions

There is a large body of literature describing examples and strategies of utilisation of waters produced by mining. This can be exploited as a source of ideas and knowledge by those who search for potential options of utilisation of mine water. The publications of IMWA comprise an exceptionally big portion of this literature.

South Africa and Australia are leading in publications on utilisation of water produced by mining. Obviously, the water scarcity produces high pressure. However, the basic value of water as a natural resource is reason enough to make "utilisation of waters produced by mining" a mandatory topic in mine planning, management and closure everywhere.

“Maximising use of waters produced by mining” does not make sense as an exclusive goal in itself. The utilisation of waters produced by mining has to be put into a broader context. IWRM is an appropriate tool for that purpose.

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