

Development of a low-tech treatment for neutral mine water – a case study

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Abstract

Lovisagruvan is a Pb-Zn-Ag mine in mid-south Sweden, with a yearly production of some 40 000 tons. There are four main levels in the mine: 55, 105, 145 and 190 m below ground. Water is continuously pumped at a rate of 5 m³/h, passing sedimentation pools at each of the four main levels in the mine and finally one above ground. A modified backfill mining is used and in order to visually separate the ore from the waste rock limestone is used as a separating layer. Limestone addition in combination with non-acid producing mineralisation generates a pH-neutral mine water. For many years the mine has had problems with high levels of zinc and lead in the mine water released to recipient. The primary contaminants, lead and zinc, were mainly found as particles or associated to particles. With a combination of several measures including a sandfilter and FeSO₄ addition suspended matter was reduced 93 %, lead 91 % and zinc 71 %.

Key words: sand filter, sedimentation, iron hydroxides, lead, zinc

Introduction

Lovisagruvan is a mine located in mid Sweden where sulfide ore (Pb-Zn-Ag) has been mined since 2004. The ore consists almost only of galena (PbS) and sphalerite (ZnS). Every year around 40 000 tons of rock (containing 50 % ore) is mined. Ore is being crushed at the mine site prior to being transported for enrichment off site. There is thus no tailings produced at the mine site. No acid producing minerals are found in the mine and original mine water is therefore near neutral. During the mining operation crushed lime stone is used to separate ore and waste rock when loading the ore on mine trucks. This results in a near neutral or slightly alkaline mine water. Water is pumped up from the mine at a rate of 5 m³/h and is first collected in four sedimentation pools underground (at 190 m, 145 m, 105 m and 55 m below the surface) before it is pumped to a sedimentation pool above ground with a three days turnaround time. Before 2013, surface water from the sedimentation pool above ground was then released to the recipient. Mine water pumped from Lovisagruvan has a near neutral to slightly alkaline pH (7-8) and is mainly contaminated with lead (530 µg/L) and zinc (1.4 mg/L). Investigations prior to 2011 had shown that the water treatment facility at that time did not lower the heavy metal content enough and it was clear that the water needed further treatment. Filtration studies on the mine water had also shown that the major part of the contaminants in the water were associated to particles (mainly as sulphides). The particulate fraction was in early stages of water treatment development around 76 and 82 % for lead and zinc, respectively. Later, more lead and zinc have been found in the dissolved fraction.

Material and methods

Stepwise development

In order to improve the water quality a stepwise approach was used. Steps are summarized in tab. 1.

Step 1 and 2 – 2011

In spring 2011 a more extensive sampling program than what earlier had been present was initiated. This included thorough analysis of parameters, physical and chemical, with potential of having negative impact on the mine water quality. After some months of frequent sampling and measuring of water quality in the sedimentation pool above ground, a pattern of high metal concentrations was

found, clearly coinciding with week days when the primary crusher was active. Hence, the first action taken, in spring 2011, was to install a roof on the sedimentation pool above ground in order to keep metal containing dust from entering the pool. Lastly, the primary crusher was also moved from the proximity of the sedimentation pool in autumn 2011.

Table 1 Changes done to the dewatering and water treatment facility at the Lovisagruvan mine.

Step	Time	Performed change
1	2011 Spring	Installation of roof on the sedimentation pool
2	2011 Autumn	Moving of the primary crusher
3	2013 October	Sand filter installed
4	2014 March	Change of filter sand
5	2014 October	Pumping between underground pools changed in order to minimize resuspension
6	2014 October	Addition of FeSO ₄ started
7	2015 Spring	Addition of NaOH started

Step 3 – 2012 & 2013

With metal concentrations still exceeding recommended levels it was proposed to install a passive sand filter based on a nearby magnetite tailings material. Long term tests using the magnetite tailings were performed primarily to study removal of particulate contaminants from the mine water (Fahlqvist et al. 2012). Water from the mine was pumped from the sedimentation pool above ground into a 1 m³ container and transported to the laboratory. Water was pumped from the container to the columns at a rate of approximately 20 L/day. Total volumes through the columns were 1 300-1 600 L.

Initially the filtration increased the pH but as more water passed the values decreased to about the same as for the untreated mine water (pH 8.04).

Both zinc and lead concentrations decreased when passing through the columns, indicating that physical filtration was the dominating process. Lead concentrations were lowered with 97.5 % and zinc with 99.7 % (Fig. 1). Trace metal removal was higher in all columns compared to filtration through polycarbonate filters with an exact pore size. This indicated that also some adsorption occurred in the columns.

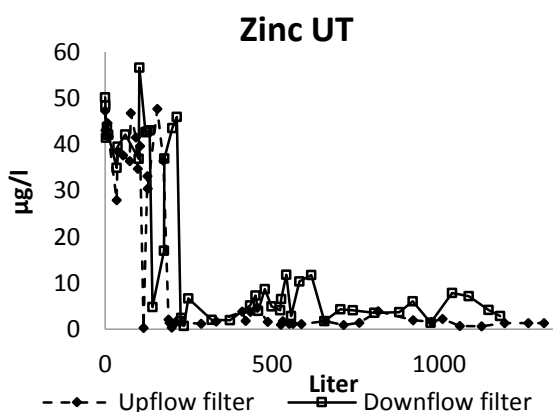


Figure 1a Zn in water filtered through the magnetite filter (Zn concentration in ingoing water: 690 µg/L).

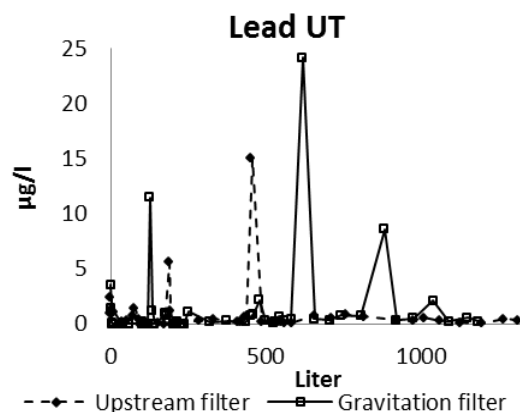


Figure 1b Pb in water filtered through the magnetite filter (Pb concentration in ingoing water: 370 µg/L).

In addition to column testing of the magnetite tailings from Stråssa, also 1 m³-filters were built on site at Lovisagruvan. These filters were in operation during one year and showed positive results, indicating the magnetite tailings would be a good choice for full-scale trials. Therefore, from the positive results from both the pilot scale test and the column test (Fahlqvist et al. 2012) it was decided

to construct a full scale filter to remove particulate metals from the mine water using the magnetite tailings.

In October 2013, a full-scale filter was ready to be taken in operation. The filter basin was divided into two subfilters in order to be able to run different filter materials and change the filter media without having to shut the filter down or by pass it. Volume for treatment in each subfilter was around 45 m³.

Step 4 – Spring 2014

In full scale it was, however, quickly noted that the grain size distribution of the magnetite tailings made the filters to clog due to the presence of small grain sizes. It was decided to change to a graded natural filter sand instead to improve the hydraulic properties of the filter.

Step 5 – Autumn 2014

As a result of water quality measurements in the underground sedimentation pools it became apparent that metal concentrations increased from the lowest to the highest underground level, as a result of resuspended contaminants in water entering the 145 level through gravity. Therefore, pumping between underground pools changed in order to minimize resuspension (Fig. 3).

Step 6 – October 2014

In order to increase the amount of adsorption surfaces in the sand filter (Benjamin et al. 1996) it was decided to start adding FeSO₄ solution to the pool 55 m below the surface. A very simple dosing system was designed based on an intermediate bulk container (IBC) and a small dosing pump. FeSO₄ solution in the IBC is prepared 1-2 times each month.

Addition of FeSO₄, however, made the pH to drop from around 8.1 to around 7.8, thus increasing the zinc concentrations.

Step 7 – Spring 2015

In order to increase pH to around original levels it was decided to start adding NaOH to the pool 55 m below surface. Experiments in the laboratory were therefore set up, with the purpose of optimizing the amount of FeSO₄ and NaOH to be added to the mine water in order to lower concentrations of primarily zinc (Fig. 2).

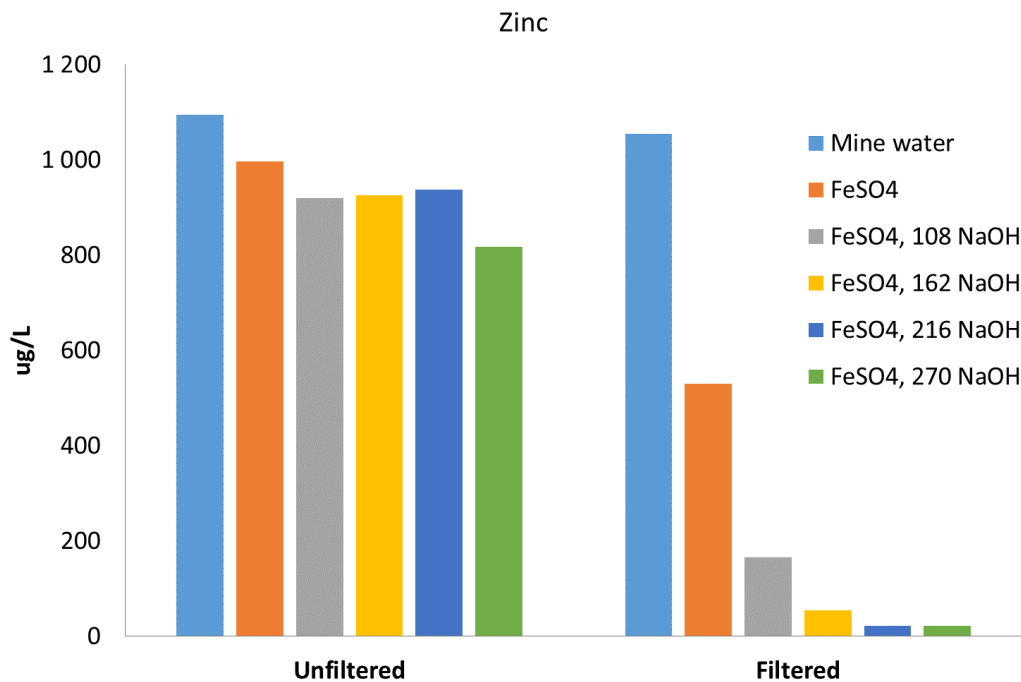


Figure 2 Optimization of FeSO₄ and NaOH addition to mine water at the pool 55 m below surface.

An outline of the mine water treatment presently working at Lovisagruvan is presented in Fig. 3. Water is pumped through four sedimentation pools below ground, and water that may contain resuspended contaminants at level 145 is re-circulated down to level 190. Addition of FeSO_4 and NaOH is performed at level 55 meters below ground. The sedimentation pool above ground is followed by a passive sand filter. Contaminated sand from the filter as well as iron(oxy)hydroxide sludge are backfilled in the mine.

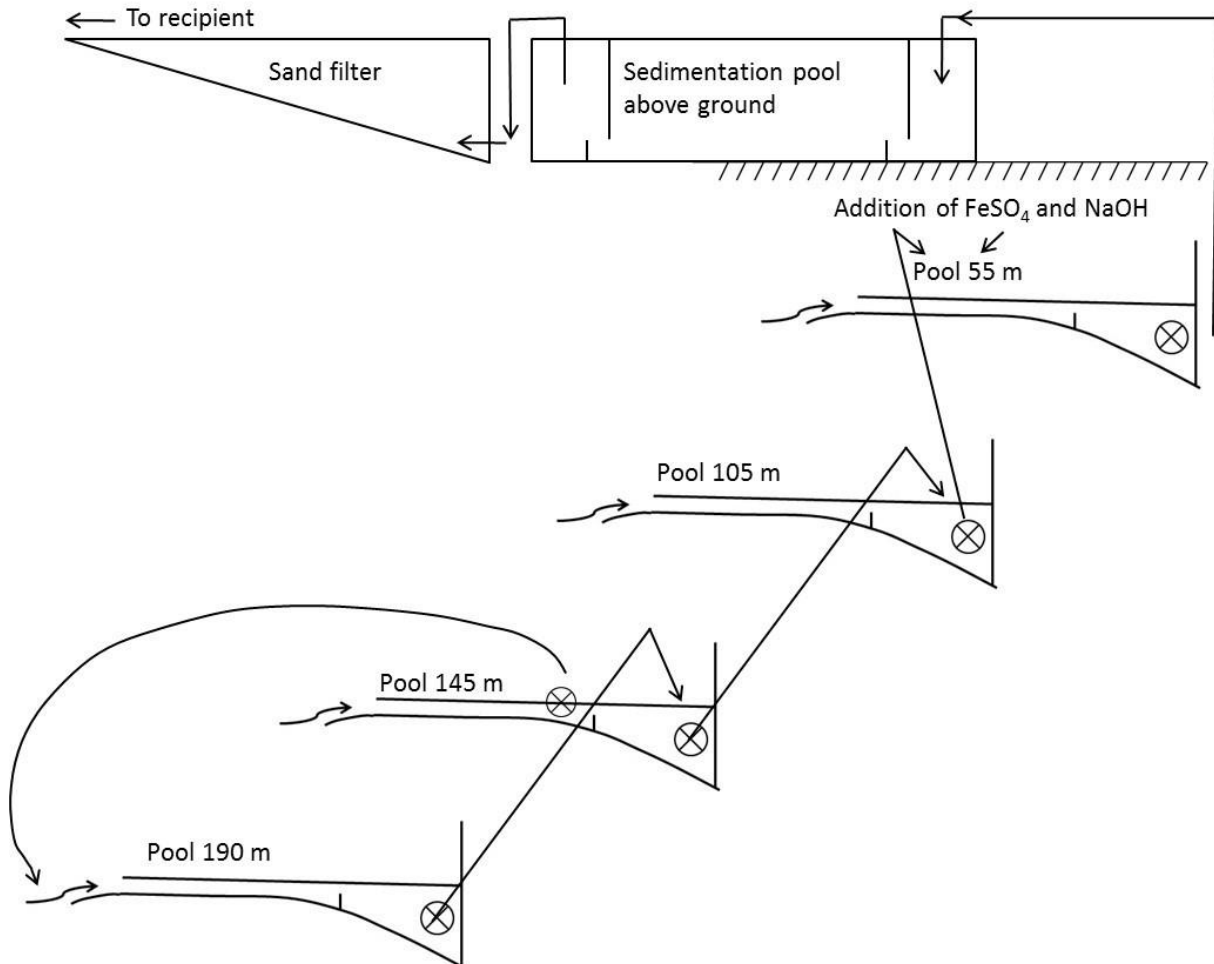


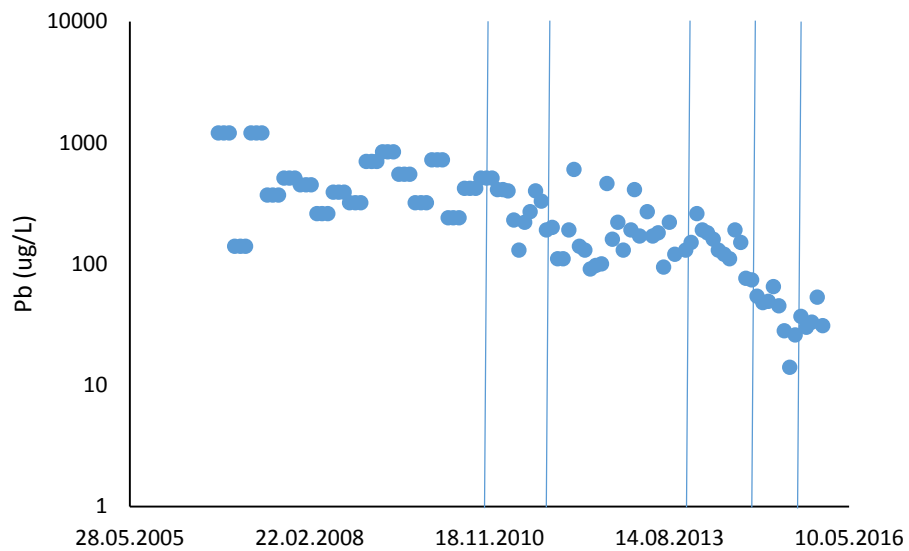
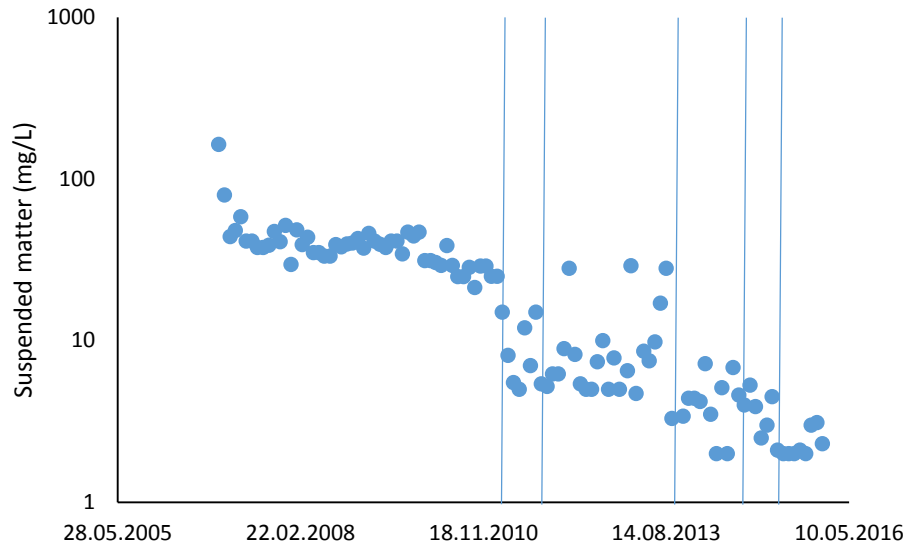
Figure 3 Principal layout of the dewatering and water treatment systems at Lovisagruvan, Sweden.

Results and discussion

Concentrations of suspended matter, lead and zinc from the mine are shown in Fig. 4. It is obvious that shielding the above ground sedimentation pool from the primary crusher (Step 1 and Step 2) reduced the concentrations of primarily suspended matter, but also reduced the concentrations of lead and zinc. Prior to shielding the sedimentation pool the average concentration of suspended matter was 40 mg/L compared to on average below 9 mg/L after (tab. 2). Lead and zinc concentrations also decreased significantly as would be expected if the deposition of ore particles to the sedimentation pool is reduced.

Passive treatment in Step 3, intended to use gravity to separate particles with lead and zinc followed by a sand filter for further removal. This step reduced the suspended matter with around 50 %, while the metal concentrations only decreased with around 25 % (tab. 2). At the end of October 2014 (Step 6) iron sulfate (FeSO_4) started to be added in the upper most sedimentation pool below ground (55 m). The goal was to achieve iron(oxy)hydroxide surfaces for sorption of metals. As precipitation of iron hydroxide is an acid producing reaction, pH decreased slightly during Step 6 (from around 8.2 to around 7.8). Concentrations of lead decreased significantly due to increased sorption onto formed iron

hydroxides, but for zinc, being more pH-sensitive, concentrations increased slightly during this step. This phenomena has been observed earlier for zinc in mining water at around pH 7 (Bäckström and Sartz 2011). In order to increase sorption of especially zinc, sodium hydroxide was added together with the iron sulfate in the spring of 2015 (Step 7) – bringing concentrations of lead and zinc to acceptable levels.



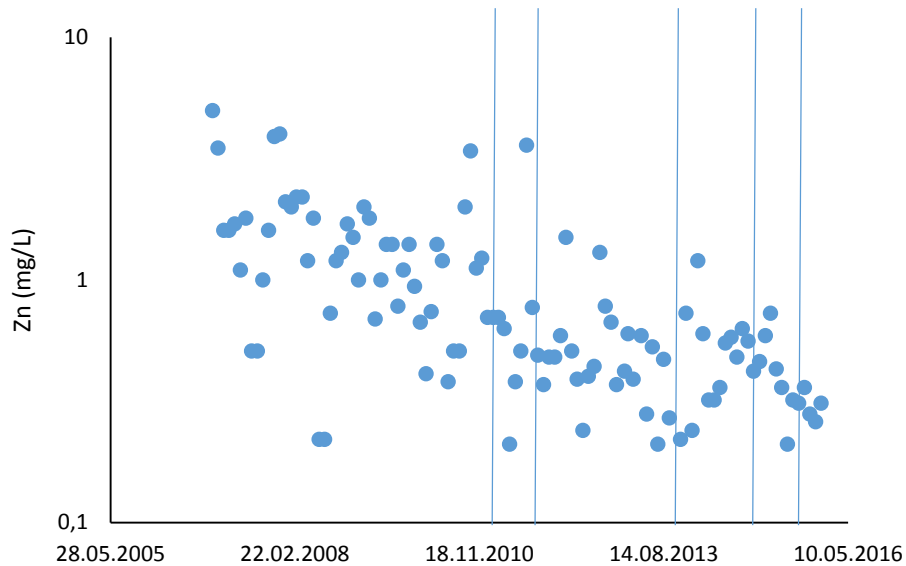


Figure 4 Suspended matter (mg/L), lead (µg/L) and zinc (mg/L) concentrations during development of the water treatment (2006-2015) at Lovisagruvan, Sweden. Blue lines indicate Step 1, Step 2, Step 3, Step 5/6 and Step 7.

Table 2 Average suspended matter, lead and zinc concentrations during different periods of the water treatment development.

Period		Suspended matter (mg/L)	Pb (µg/L)	Zn (mg/L)
Prior to Step 1	n 52	40	530	1.4
Between Step 1-Step 3	n 30	9.5	210	0.63
Between Step 3-Step 6	n 10	4.3	160	0.51
After Step 6	n 17	3.0	50	0.42

Conclusions

A stepwise approach towards mining water contamination using simple techniques reduced the concentrations of suspended matter 93 %, lead 91 % and zinc 71 %. This low-tech system has proven to be a good solution for Lovisagruvan. It is easy to handle and can without difficulty be managed by one of the mine workers. It is very robust and it is easy to find and fix any problems that may occur.

Acknowledgements

Thanks to Lovisagruvan AB for giving us the opportunity to present the case.

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