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Passive treatment of acid mine drainage with active geocomposites

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Abstract

Mining of finite resources inevitably leaves open pits and shafts after the mines are closed. Ideally, natural rehabilitation takes place, and the surrounding environment is re-established. However, the environment and the surface water still need to be protected. Rainfall corrodes rock and leaches metals and metalloids, such as aluminium, copper, iron, or nickel, into surface water. Interacting with high acidity, these substances pose an environmental risk to plants and animals. Vertical flow ponds or channels are a passive approach to mine water remediation. Surface drainage water is diverted to these retention ponds. In 'conventional' vertical flow ponds, metal-contaminated water percolates through a thick layer of limestone rock. This neutralises the pH and removes iron without the use of energy or costly technologies. Depending on the metal concentration and type, as well as pH, a variety of rock types are used to neutralise acid and precipitate metals. Such acid mine drainage retention ponds were built using 1 m thick limestone layers (Hedin 2020). Other ponds were built using thick layers of gravel plus amendments.

HUESKER along with an international consultancy to were engaged to create a vertical flow pond covered with an active geocomposite for an abandoned nickel mine in Finland. In the design, a thin layer of highly active cation adsorbent replaces the thick layer of limestone or gravel. The granular adsorbent is mechanically stabilised and fixed between two layers of geotextile and can therefore be installed with a constant layer thickness. Due to the large surface area of the adsorbent, the thin layer of the active geocomposite has higher efficiency for water treatment than a thick layer of stone. The simplified installation process of the geocomposite speeds up construction time for large-scale filter ponds. In August 2021, a pilot field was built in Finland to prove the application's long-term efficiency. Once a week, water samples are collected and analysed in the laboratory. The samples from the first three months show a reduction of nickel by an average of 65%, and copper as well as aluminium by an average of more than 90%. In addition, the reduction of other metals and the pH value are documented. This presentation introduces the concept of vertical flow ponds covered with active geocomposites and discusses all findings from the pilot plant in Finland.

Keywords: *active geocomposites, acid mine drainage, water treatment, innovative geosynthetic products*

1 Introduction

Acid mine drainage (AMD) is formed when pyrite (iron sulfide) reacts with air and water to form sulfuric acid and dissolved metals. This occurs when rain infiltrates through the heap where ores are stored, and then reacts with the pyrite forming the AMD. Waste rock piles must be built over with non-acid-generating waste rock to prevent/reduce AMD or be provided with a sealing system. Impermeabilities or structures where AMD is unavoidable pose a problem if drainage from the heap contaminates the surrounding area with metals. The runoff dissolves contaminants, such as copper, lead, and mercury, into groundwater or surface water, where it has a toxic effect on receptors such as plants and animals. Often, the groundwater is also no longer suitable as drinking water.

For treatment of AMD, active and passive treatment systems are available. In the case of very large quantities, active systems using energy, freshwater and wastewater are inevitable. Especially for small to medium quantities of AMD, the use of passive systems is often more financially economical. Limestone can be used as a mineral filtration material, as it is capable of neutralising acidity and reducing metal (especially iron) contamination. Vertical flow ponds or channels, as shown in Figure 1, can be designed for AMD treatment.

(a) (b)

Figure 1 (a) AMD of an abandoned mine in the USA (photo courtesy of R Williams); (b) Open carbonate channel with limestone during construction (photo: J Skouson)

This paper focuses on the introduction and description of active geocomposite for passive treatment of AMD. Active geocomposites are the main component for large-scale constructed, in situ or onsite filter systems. The filter mats consist of two layers of geotextiles sandwiching a highly effective sorbent. With the help of the geotextiles, the sorbents are mechanically stabilised and can be installed over large areas in the field. The approach of AMD treatment with active geocomposites is to substitute the thick layer of an inert material, such as limestone, with a thin layer of a highly active sorbent with the ability to remove metals and neutralise the pH value. In this way, large quantities of material can be saved, resulting in shorter installation times, fewer truckloads and consequently a better carbon footprint. The innovative purification components have been proven to be effective for the treatment of mine drainage.

2 Active geocomposites

2.1 Geotextiles

The term 'active geocomposite' describes the combination of at least two layers of geotextiles that sandwich a sorbent in between, as shown in Figure 2.

Figure 2 Illustration of an active geocomposite with different sorbents (Niewerth 2021)

The lower carrier layer and the upper cover layer of active geocomposites consist of either woven, nonwoven or a geocomposite. The use of mix sand capping or carbon/mix capping in subaqueous often results in an uneven surface. Hence, a thick layer of capping is required. These loose materials (not encapsulated in geotextile) are susceptible to erosion forces, unlike active geocomposite, which provides a constant layer of thickness across the entire area.

The layers are joined together by textile mechanical bonding techniques, such as needle punching or stitch bonding. The developed active geocomposite for heavy metals (HM) is manufactured with a length of 40.0 m and a width of 5.1 m under factory conditions. The product is done by needle punching, which leads to a higher peel strength of the cover and carrier geotextiles and avoids movement/erosion of the sandwiched granular adsorbent. Visually comparable to geosynthetic mats enclosing granulate bentonite in a uniform and mechanically stabilised manner have been used in landfill construction since the mid-1980s (Egloffstein 2014). These well-established geosynthetic clay liners (GBR-C) with swellable bentonite between the geotextiles can replace considerably thicker conventional compacted clay liners. In contrast to GBR-C, active geocomposites have high permeability, with a hydraulic conductivity of $k \geq 1.00E\text{-}5$ m/s. This is important to ensure that the contaminated water can flow unhindered through the mat.

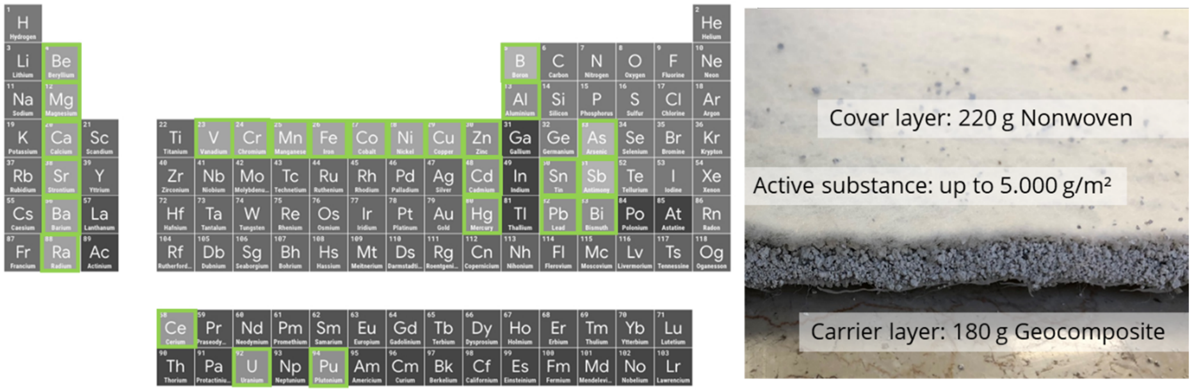
Furthermore, the durability of the components is important. Oxidation tests can be used to simulate the ageing of the geotextile components to make statements about their service life in situ. A life expectancy of 100 years can be considered normal for quality manufactured geotextiles that have been correctly installed and exposed to natural conditions with soil pH values of $4 \leq pH \leq 9$ and soil temperatures of ≤ 25°C.

2.2 Active substances

Active substances such as activated carbon, modified resins and activated iron are often used to filter pollutants. These substances remove contaminants from water with the help of different non-mutually exclusive binding mechanisms. There must be sufficient knowledge about the contaminant to enable the selection of the active substance. In environmental chemistry, a distinction is usually made between organic and inorganic pollutants. In AMD, inorganic pollutants, for example, metals and metalloids, such as iron, aluminium, arsenic, nickel, lead and others, are present. Even at low concentrations, some of these substances pose a risk to the environment and to human health. The substances accumulate over a long time in the tissues of living organisms – the receptors. For this reason, they are also known as cumulative toxins. To immobilise the contaminants, suitable active substances are used according to their properties. For the removal of metals, for example, active substances capable of cation exchange are suitable. Cationic adsorbers bind metals dissolved in water, such as arsenic, lead or chromium, by releasing a cation and exchanging it for the metal. An effective active sorbent for AMD treatment is adopted in the developed active geocomposite. The filter granulate has a high affinity to a wide range of metals present in AMD. The active granules consist exclusively of naturally occurring minerals. It can remove metals from leachates from contaminated soils, landfill waste, AMD, etc. Due to three exclusive binding mechanisms included in one material, the capacity for metals is high:

1. Adsorption: the large mesoporous structure offers space for a high amount of metals.
2. Cation exchange: In contact with leachate, harmless cations are released to make room for harmful metals.
3. Crystallisation: Metals are converted into poorly soluble compounds and incorporated into the structure of the sorbent.

The filter granulate was tested by HUESKER's laboratory to be effective for aluminium, arsenic, cadmium, chrome, copper, lead, mercury, nickel, radium, strontium, uranium, zinc. Moreover, it was used effectively in groundwater treatment measures with antimony, chloride, cobalt, iron, magnesium, tin, chromate, fluoride, phosphate, sulfate, arsenate, etc. A summary of the metals with a high affinity to the adopted active substance for AMD is given in Figure 3a, together with a cross-section of the active geocomposite HM in Figure 3b.



(a) (b)

Figure 3 (a) Metals with affinity to active substance; (b) Cross-section of active geocomposite HM

3 Performance analysis active geocomposites with AMD

3.1 Lab tests

3.1.1 Percolation tests with spikes leachate

In percolation tests according to German standard DIN 19528 the developed active geocomposite HM was tested for its retention capacity against metals in migrating waters. The test was done in an accredited third-party laboratory. The dissolved metals were present in the concentrations given in Table 1.

Table 1 Metal concentration for percolation tests

Element	Zinc (Zn)	Copper (Co)	Chromium (Cr)	Lead (Pb)	Cadmium (Cd)	Arsenic (As)	Mercury (Hg)	Nickel (Ni)
[µg/l]	4,800	4,700	4,300	4,500	5,000	3,900	4,400	4,800

The results in Figure 4 show a high affinity to all metals tested. The capacity limit was reached only after large amounts of leachate percolated through the filter. Initially, a breakthrough of nickel and cadmium was evident. Zinc and mercury followed. Arsenic, chromium, copper, and lead did not break through despite large amounts of water. This shows the great capacity of these metals.

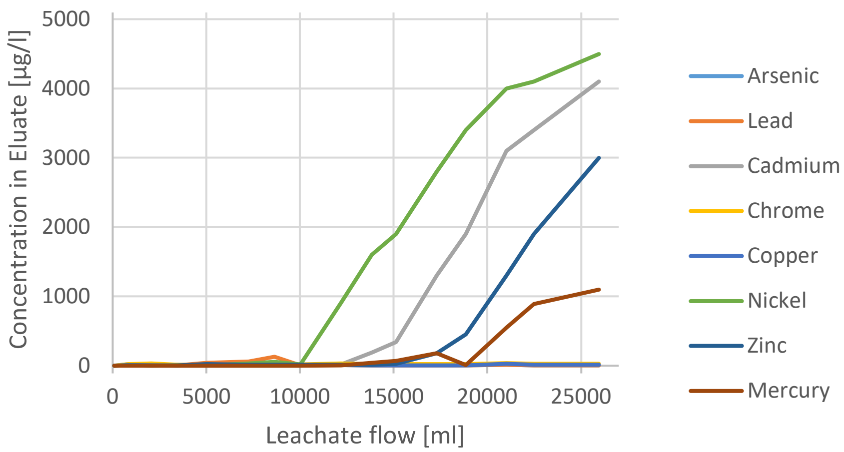


Figure 4 Test results with active geocomposite HM and spiked leachate

3.1.2 Radionuclides in synthetic leachate

In an authorised laboratory in Germany, synthetic leachate with several radionuclides was created. It was spiked with uranium (U-238, 234, 235), radium (Ra-226), lead (Pb-210), caesium (Cs-134) and strontium (Sr-85). The removal results of the filter granulate after 48 hours in the synthetic leachates are given in Table 2.

Table 2 Removal of radionuclides

Element	Effectiveness (%)
Uranium	99.1
Radium	98.4
Lead	99.8
Caesium	28.4
Strontium	89.6

The laboratory observed a high kd-value (partition coefficient) for lead and a strong sorption capacity of lead in comparison to other metals that were tested in column tests in 2020. In addition, an observation was made on the desorption performance of the sorbent.

3.2 Field trials

The developed active geocomposite HM was tested in field trials in an abandoned mine in Northern Europe. Two infiltration ponds are designed in a cascade to remove the dissolved metals from the drainage water from the waste rock dump. Figure 5 illustrates the two ponds, which are linked to each other.

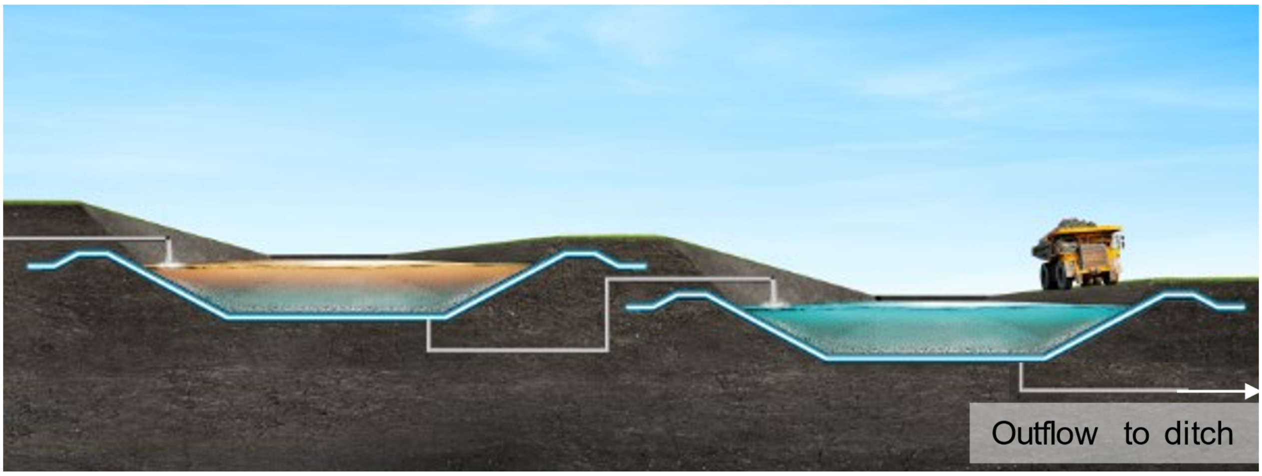


Figure 5 Illustration of vertical flow ponds lined with active geocomposite

To connect the ponds, the floor is lined with a geomembrane and bottom drains. On top of the sealing element, the active geocomposite is installed in the middle of a thin gravel layer. A cross-section is given in Figure 6. The size of the ponds is 7.5 m in length and width (Figure 7).

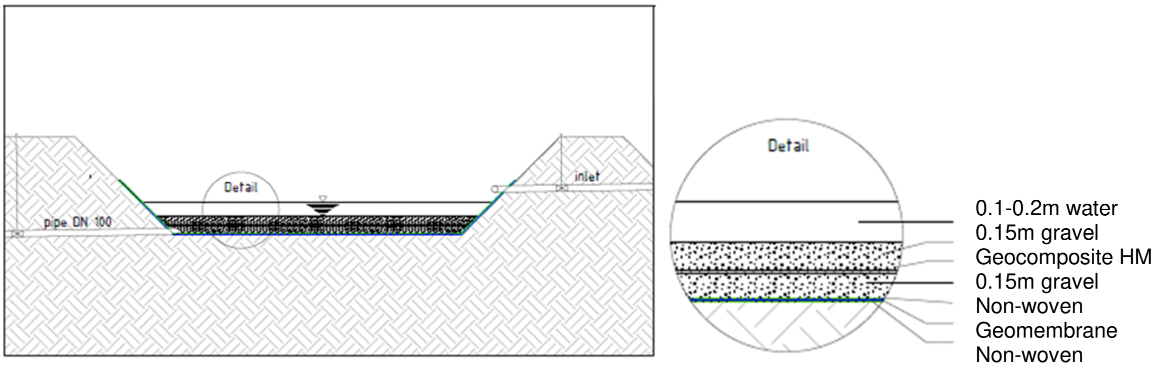


Figure 6 Cross-section of the filtration ponds

Figure 7 Photos of the test field (photo courtesy of S Niewerth)

To be highly effective in removing the metals, the water must be in contact with the active substance for a defined time – the so-called contact time. With a known thickness of the active layer of the filter mats, the maximum water flux can be calculated and set for an effective treatment.

The concentration of the metals in the drainage was measured in the inflow pipe as well as in the outflow pipe. The results are given in Figure 8. In this case, aluminium and nickel have the highest inflow concentration. Other metals, such as copper and zinc, were also present but with lower concentrations. It is observed that the removal of aluminium, copper, and zinc was highly effective. The affinity towards nickel was also measurable but with lower effectiveness. Due to the competitive behaviour of the ions, the effectiveness of different metals varies. Di- and trivalent metals in particular have a high affinity to the active substance used in active geocomposite HM. However, it was also shown that it is important to ensure frost-proof installation, as the performance of the active substance is reduced at low temperatures.

It is noted that after long shaking of the fully sorbent in DI water, no metals are released. Therefore, sorbent can be disposed in landfill without the threat of metal release.

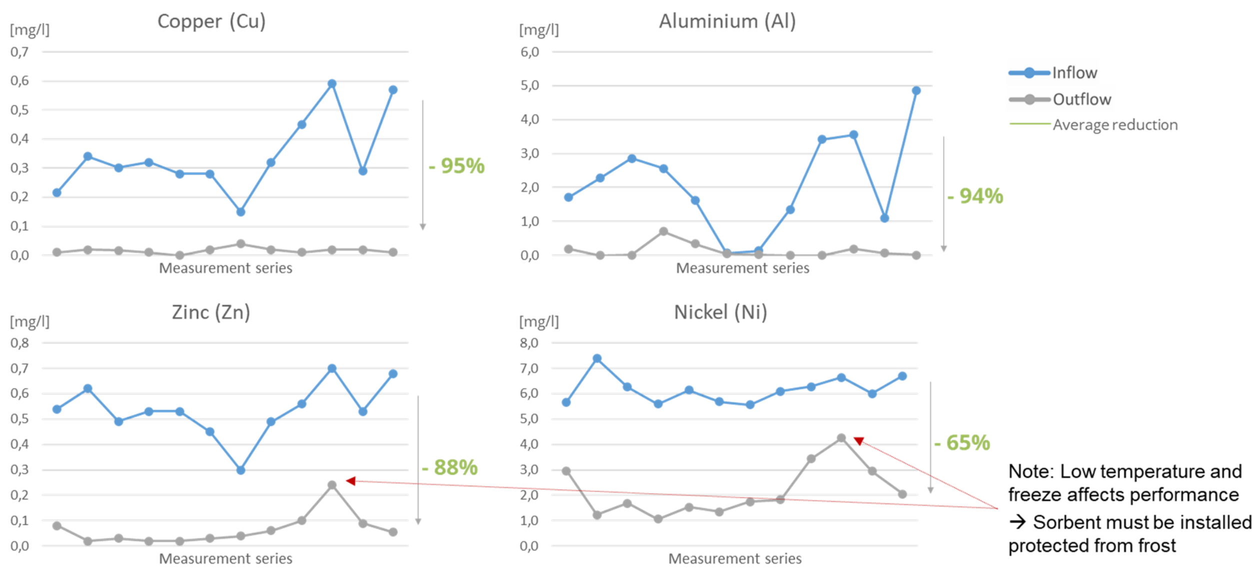
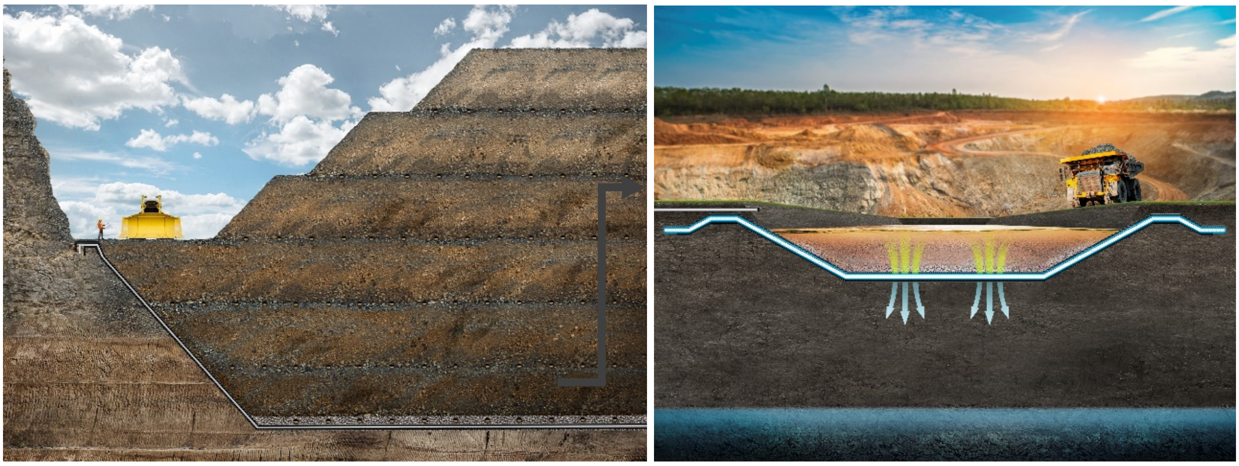


Figure 8 Test results of pond lined with active geocomposite heavy metals and mine drainage water

4 Installation scenario

Since heap leaching is a very common method to extract the minerals from ores, all these heaps have already been equipped with drainage pipes under the ores. The existing structure can be connected to ponds or channel systems lined with active geocomposites, as shown in Figure 9. One installation scenario is to cover the floor of a pond or trench with the active geocomposite to remove the metals from the AMD while it slowly seeps through without a sealing system underneath.

The results of the field trials in Northern Europe will help to further analyse the feasibility of this approach in general and understand its limitations. Based on the water analysis in the pilot study, the assumed capacity is well around 1.5×10^6 mg/m² of the active geocomposite. The larger the ponds are, the more water can be treated. Thus, the study here shows that a double- or multiple-layer system with active geocomposites doubles or multiplies the overall capacity of the system.



(a) (b)

Figure 9 (a) Illustration of a heap leach pad connected to (b) a treatment pond covered with active geocomposite (here as a single pond without a geomembrane underneath)

Another approach that is not addressed in this paper, but which has also already been tested by the manufacturer, is the combination of active geocomposites with geotextile dewatering tubes. In this way, two product components are combined to effectively remove metals from sludge with a very low energy input and without the addition of freshwater. The treatment process can thus be designed in an environmentally friendly way.

5 Conclusion

With the help of active geocomposites, small- to mid-scale quantities of AMD can be treated in onsite filter systems. The products contain a highly effective active substitute with a high affinity to a wide range of metals. The approach of using active geocomposite in soil remediation is similar to the use of geosynthetic clay liners to replace a thick compacted clay liner in a landfill application. Similarly, instead of using a thick layer of inert material, such as limestone, a thin layer of geocomposite encapsulating active substances can be adopted. Truck transport of inert limestone can be reduced drastically and the time for construction is decreased. The developer/manufacturer offers a proven, highly effective solution for the treatment of a wide range of metals in contaminated leachates. These active geocomposites can be easily installed in ponds, channels, or other designs of water filtration measures. In this way, the active layer interrupts exposure paths of contaminants. The high capacity and strong binding of the metals to the active substance allows for permanent protection against the spread of pollutants in the environment, as these metals are not released even under the circumstances of a fully saturated sorbent, thus protecting the environment from any harmful metals.

References

Egloffstein, T 2014, 'Entwicklung der geosynthetischen Tondichtungsbahn über die DIBt-Zulassung zum LAGA Eignungsnachweis' ('Development of geosynthetic clay liners with the help of DIBt-Approval for LAGA quality assurance'), *30. Fachtagung Die sichere Deponie – Geokunststoffe im Umweltschutz*, Arbeitskreis Grundwasserschutz e. V., Berlin, SKZ - ConSem GmbH, Würzburg.

Hedin, RS 2020, ‚Long-term performance and costs for the Anna S Mine passive treatment systems', *Mine Water and Environment*, vol. 39, pp. 345–355.

Niewerth, S 2021, 'Permeable Schadstoffbarrieren für Boden- und Gewässerschutz sowie Altlastsicherung' ('Permeable contaminant barrier for soil and groundwater protection as well as site remediation'), *Bauingenieur*, vol. 11, pp. 3–4.