

# Pilot-scale tests to optimize the treatment of net-alkaline mine drainage

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## Introduction

In South Korea, there are approximately 2,500 mines, including 906 metal mines, 379 coal mines, and 1,173 non-metal mines. Among these mines, approximately 150 abandoned surface and underground coal mines are responsible for acid drainage discharges into water streams, and are continuously contaminating surface and groundwater. An estimated 100,000 tons per day of mine drainage is being discharged from these mines into water streams (CIPB 1995; Jung 2003). Acid mine drainage (AMD) from abandoned metal mines not only pollutes the natural environment, for example surrounding soil, and surface and ground water, but also has toxic effects on crops and humans as a result of concentration of the contamination (Jung 1994).

In general, drainage from coal mines is not only of low pH but also contains high levels of  $\text{SO}_4^{2-}$  and heavy metals, including Fe, Al, and Mn (Sengupta 1993). These properties of mine drainage disrupts stream ecosystems and further aggravate the problem by creating yellow or white sediments (Chon and Hwang 2000). Thus, mine drainage treatment is necessary to prevent pollution of watercourses with iron/aluminum precipitates and acidity.

Basically, mine drainage treatment utilizes the chemical properties of the main contaminants, for example Fe, Al, and Mn. Two different conventional methods are mainly used to treat mine drainage—active or physicochemical treatment (which needs energy and chemical input) and passive or biological treatment (which does not need additional input of energy or chemicals) (Johnson and Hallberg 2005;

Akcil and Koldas 2006). Most active treatment involves pH adjustment, by adding an alkaline material, and removal by precipitation as a result of the formation of oxy/hydroxides. pH adjustment is helpful for treatment of large quantities of AMD. Although active treatment enhances treatment efficiency by use of chemicals, there is a large economic burden, because of the high cost of maintenance and chemicals, and this process requires continuous operation (Johnson and Hallberg 2005). Compared with active treatment, passive systems are economical but require longer retention times and greater space; they are, therefore, not appropriate for treatment of large-scale mine drainage. Although passive treatment has been implemented on full-scale sites in several countries, treatment efficiency can be uncertain, because of seasonal changes in flow rate and temperature, and the systems are apt to fail during long-term operation. As the primary mechanism of metal removal from acidic effluents, passive treatment uses the affinity properties of metal compounds with sulfur or carbonate ions; metals are also removed by adsorption or precipitation with organic compounds (Gazea et al. 1996). Not only biological treatment using microbial activity but also chemical treatment using the sensitivity of metal species to changes in pH is the main approach of the passive system. Metal species occur as ions under acidic conditions; however, they are converted to hydroxides when pH increases. In South Korea, sites with large-scale mine drainage flows occur in uneven and narrow terrain. Passive treatment of these contaminated sites has the setback of needing large treatment areas (Hedin 2008). Accordingly, considering the special status of Korea and two different treatment concepts with advantages and disadvantages, a complementary new approach should be developed to

minimize maintenance and chemical input and enhance treatment efficiency.

The objective of this study was to investigate the applicability of aeration and pH adjustment for treatment of mine drainage with net alkalinity on a large scale by conducting pilot-scale tests. A pilot-scale (30 m<sup>3</sup>/day) plant was designed and built to conduct experiments on the large-scale treatment of the mine drainage (about 6,000 m<sup>3</sup>/day). The main themes were to determine the effects of aeration, retention time, and pH change on the oxidation of ferrous, and the effect of ferrous oxidation on precipitation of the oxidized products. The results of pilot-scale tests could be expected to contribute to the design of a full-scale plant on the actual site by constructing the optimized process on the uneven ground of the site.

## Materials and methods

### Pilot-scale plant setup

With a scale of 30 m<sup>3</sup>/day, a pilot-scale treatment facility was constructed and set up to treat AMD which was continuously flowing from Jami (JM) adit of Hambach coal mine. As shown in Fig. 1, the pilot-scale plant mainly consisted of an oxidation basin (OB, 1 m<sup>3</sup>), a neutralization basin (NB, 0.4 m<sup>3</sup>), a reaction basin (RB, 0.4 m<sup>3</sup>), and a settling basin (SB, 1 m<sup>3</sup>). At the bottom of the OB, nine air diffusers (disk-type) were set up at equal intervals to produce air bubbles as homogeneously as possible. The rate of aeration from all the diffusers ranged from 0 to 450 L/min and was controlled by a mechanical flowmeter. The inlet flow rate was fixed by controlling the pumping pressure of a submersible pump and a valve in an equalization basin (0.15 m<sup>3</sup>). An agitational device (150–250 rpm) was set up in both

the NB and RB for homogeneous mixing. The roundshaped SB has a circular sludge collector, including scraper and sludge hopper, and a surface-loading rate of 21 m<sup>3</sup>/m<sup>2</sup> per day. The rotation speed of the scraper was 0.4 rpm. The sludge could be discharged by means of a sludge pump. To control the pH of mine drainage in the NB, a pH controller was set up with a pH probe and a metering pump. The target Ph

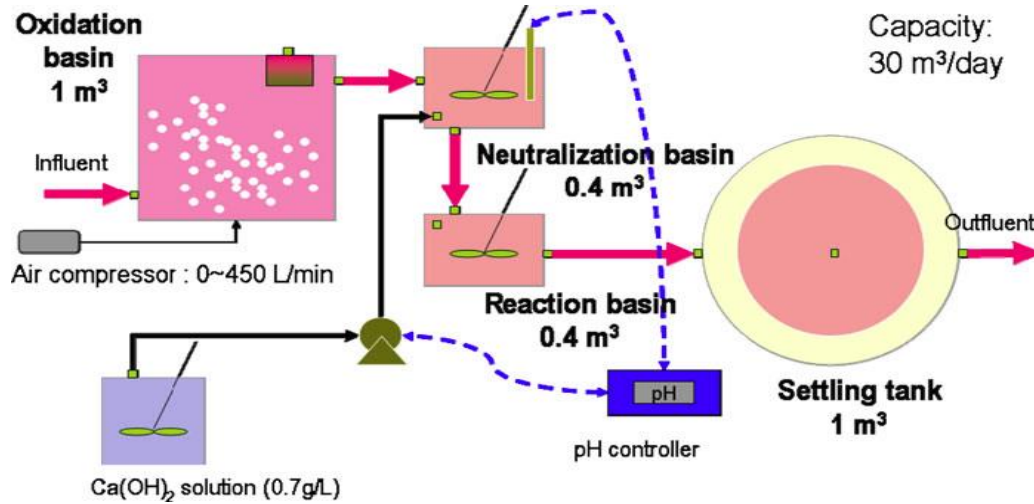


Fig. 1 Schematic diagram of pilot-scale mine drainage treatment process

of mine drainage was automatically adjusted with an error of  $\pm 0.1$ . Lime ( $\text{Ca(OH)}_2$ ) was used as neutralizing agent. Lime slurry was prepared with a lime concentration of 0.7 g/L and injected at different flow rates (max. 0.25 L/min) into the NB.

In this study, pilot-scale tests were conducted to estimate not only Fe(II) oxidation efficiency but also the efficiency of precipitation of oxidation products. As shown in Table 1, these tests were conducted under different operating conditions. In the treatment process, the main operating conditions were rate of aeration of the OB, retention time, and pH of the NB.

Analysis and physicochemical properties of mine drainage

Samples obtained from the inlet to the pilot plant and of the effluent from each basin were analyzed for physicochemical properties. The pH, ORP, TDS, and EC of mine drainage and the samples were measured with a portable pH/ORP and EC/TDS meter (Orion 3 star) and DO meter (Pocket calorimeter, HACH). To evaluate the effectiveness on the oxidation of Fe(II) and precipitation of oxidative products, and to measure total recoverable and dissolved metals of samples obtained before and after treatment, EPA method 3005A (acid digestion procedure) was used (EPA 1992). For analysis of total recoverable metals, 40 mL drainage sample was measured with a measuring cylinder and transferred to a conical tube, and 0.8 mL conc. HNO<sub>3</sub> and 2 mL conc. HCl were injected. The samples were then digested by use of a heating block at 90–95\_C until the sample volume reduced to 8–10 mL. The digested samples were cooled to room temperature, and the volume was measured and diluted to 40 mL with de-ionized water, followed by filtration through a 0.45-µm pore membrane filter. Concentrations of heavy metals in the filtrate were measured by ICP-AES (720-ES, Varian). The alkalinity of samples of pH[4.5, was measured as follows:

Full text is available at :

<http://www.ncbi.nlm.nih.gov/pubmed/21046432>

<http://link.springer.com/article/10.1007/s10653-010-9353-3>