# IMPROVEMENT OF A PASSIVE TREATMENT SYSTEM FOR ACID ROCK DRAINAGE GENERATED NEAR AN ABANDONED QUARRY, KOREA

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## Abstract
A passive treatment system was originally established in late spring 2006 for abatement of metal content and acidity in drainage from waste material of an abandoned quarry. The system consisted of a 1st settling pond, a SAPS (Successive Alkalinity Producing System), a 2nd settling pond, a neutralization pond with commercial neutralizing powder, and a 3rd settling pond. After two months of operation, the pH value of the final effluent did not increase, and the concentrations of some metals in the discharge remained high. In order to improve the passive treatment system, water analysis and tracer test were performed on site, and some batch tests for the evaluation of used substrates were also carried out.

The main reasons why the system failed to remove some metals and acidity were: insufficient retention time and unsuitable material in SAPS. A new system was proposed to enhance the removal of metal and the acidity of the original system by enlarging the SAPS and by supplementary installation of a new aerobic wetland. To enlarge the size of SAPS, the 1st settling pond and the original SAPS were proposed to be changed to a 1st SAPS. The 2nd and 3rd settling ponds and the neutralizing pond were proposed to be changed to a 2nd SAPS, and the last pond transformed into an aerobic wetland.

## Introduction
Exposure and oxidation of iron sulfide minerals in mining or non-mining activities results in acid rock drainage (ARD), causing serious water pollution problems over the world. Several low-cost passive treatment technologies utilizing natural and biological processes have been developed to clean ARD and reduce the associated hazards (Barton and Karathanasis, 1999; Brown et al., 2002; Younger et al., 2002). Public concern was raised about water pollution associated with ARD from abandoned mining areas in Korea; most of ARD actually involved moderate loads, and was treated by passive treatment technologies.

The objective of this project was to renovate an existing passive treatment system for acid rock drainage (ARD) occurring at the toe of a pile of excavated rock fragments near a quarry where slate, shale and limestone had been quarried for producing slate roofing materials during several years. The drainage was produced by rain infiltration, and caused contamination of an irrigation canal. The results of chemical analysis indicated that ARD was fairly acid ($pH \leq 4$), and contained high concentrations of Fe, Al and Mn, as well as of toxic heavy metals such as Cd (Table 2). The flow rate of ARD is proportional to rainfall, reaching a maximum of 300 $m^3$/day. A company in charge of road construction implemented in late spring 2006 a passive treatment system consisting of a 1st settling pond, a Successive Alkalinity Producing System (SAPS), a 2nd settling pond, a neutralization pond and a 3rd settling pond (Table 1 and Fig. 1). However, the system failed to remove metals and acidity (Table 2).

## Methods
Water analysis and tracer test were performed on site, and some batch tests for the evaluation of used substrates were also carried out. Influent and effluent samples for chemical analysis were collected at each unit of the existing facility. pH, Eh and conductivity were determined in the field as soon as the samples were collected. Samples for metal analysis were acidified with ultrapure $HNO_3$ immediately upon collection, after filtration through a 0.45-μm membrane filter. Metal concentrations were determined using ICP atomic emission spectrophotometry.

A tracer test was performed to determine the actual retention time of ARD in SAPS. Green food colors were injected at the inlet of SAPS, and the time of their appearance in the discharge of SAPS was recorded. In addition, mushroom compost, aggregates in the SAPS and commercial neutralizing powder in the neutralization pond were collected to find out their ability of pH adjustment, and to identify the mineral composition of each substrate.

## Results and Discussion
Chemical analyses show that, with the exception of Al, most of metals are not efficiently removed in the present treatment system (Table 2). pH measurement of the final effluent also indicates that there was no increase of pH

when water passed through the SAPS. Eh measurements revealed that reduction process did not occur in SAPS. The concentrations of Fe, Mn and Zn slightly increased.

According to the flow rates and the volume of ponds, nominal retention times of ARD in the facility were 20.5 days and 3.5 days in cases of flow rates 50 and 300 $m^3$/day, respectively. It was thought that such retention times were enough to remove a significant amount of metals and acidity, according to literature references and engineering guidelines (PIRAMID, 2003). However, the tracer test indicates that retention time in substrates of mushroom and aggregates in SAPS was only 11 hours. Apparently, the real retention time was not enough to complete reaction of ARD with the substrate. According to X-ray diffraction and chemical analysis, aggregates were dolomitic limestone with small amounts of pyrite, and had a low content of calcium carbonate; such a material presumably has a moderate buffering power, and slow reaction times. Hence, the main reasons why the system failed to remove metals and acidity of ARD were apparently the insufficient retention time and the unsuitable composition of aggregate in SAPS.

**Table 1. The layout of existing passive treatment system.**

| Order of system | | | | | | |
|---|---|---|---|---|---|---|
| Settling pond | SAPS | Regulator of outflow | 2nd settling pond | Neutralization pond | 3rd settling pond | Discharge |

**Table 2. Chemical analysis of influent and effluents.**

| | pH | Eh | Cond. | TDS | DO | Fe | Mn | Al | Zn | Pb | Cd | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mV | µS/cm | mg/L | | | | | | µg/L | | |
| 1st settling pond | 3.96 | 258 | 5170 | 2450 | 7.75 | 165 | 97.2 | 102.0 | 21.3 | 17 | 321 | 168 |
| SAPS | 4.04 | 255 | 5210 | 2460 | 2.43 | 197 | 99.3 | 100.9 | 24.9 | 20 | 338 | 191 |
| 2nd settling pond | 4.20 | 248 | 7260 | 3530 | 4.97 | 141 | 101.5 | 30.3 | 14.4 | 14 | 121 | 27 |
| Neutralization pond | 4.26 | 244 | 7600 | 3720 | 5.21 | 116 | 231.0 | 7.3 | 12.7 | 9 | 93 | 13 |
| 3rd settling pond | 4.11 | 251 | 7510 | 3680 | 5.67 | 113 | 92.1 | 6.3 | 13.2 | 10 | 107 | 18 |

**Table 3. The volume of each units and nominal retention time.**

| | Type and volume of substrates ($m^3$) | Nominal retention time (day) according to flow rates | |
|---|---|---|---|
| | | average, 50 ($m^3$/day) | max., 300 ($m^3$/day) |
| 1st settling pond | - | 4.0 | 0.7 |
| SAPS | limestone, mushroom compost (450) | 6.0 | 1.0 |
| 2nd settling pond | - | 4.0 | 0.7 |
| Neutralization pond | neutralizing powder (108) | 2.6 | 0.4 |
| 3rd settling pond | - | 4.0 | 0.7 |

A new system was then proposed to enhance the removal of metal and the acidity of the original system by enlarging the SAPS and by supplementary installation of a new aerobic wetland (Fig. 2). According to metal and acidity loads, the SAPS unit would be essential to increase the alkalinity, and the following aerobic wetland is required for the precipitation of metals as well. In order to enhance the treatment using the same land area, it was suggested that two separate SAPS and one aerobic wetland would be needed.

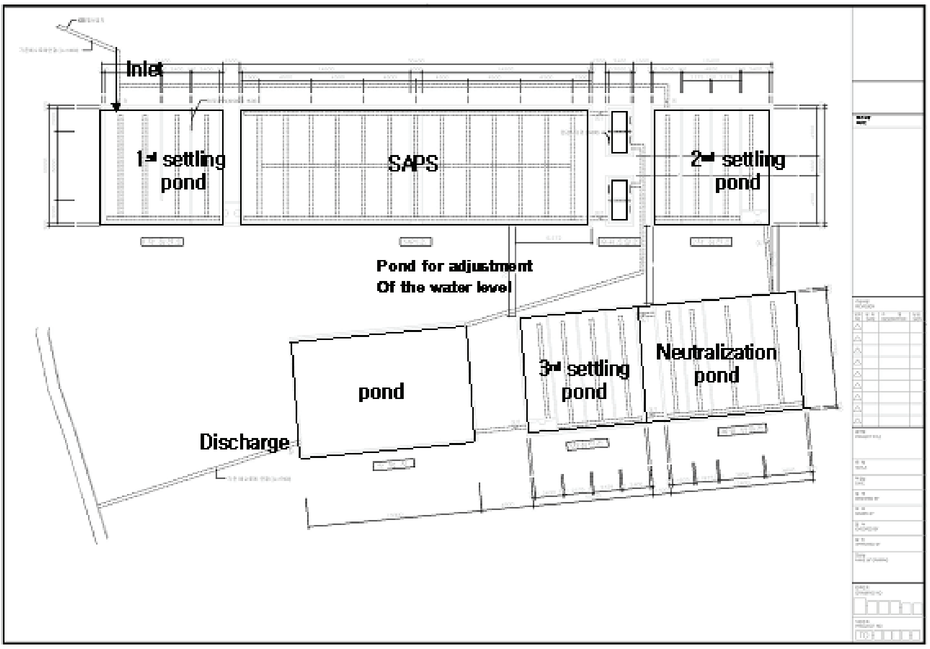


**Figure 1. Plan view of existing passive treatment system.**

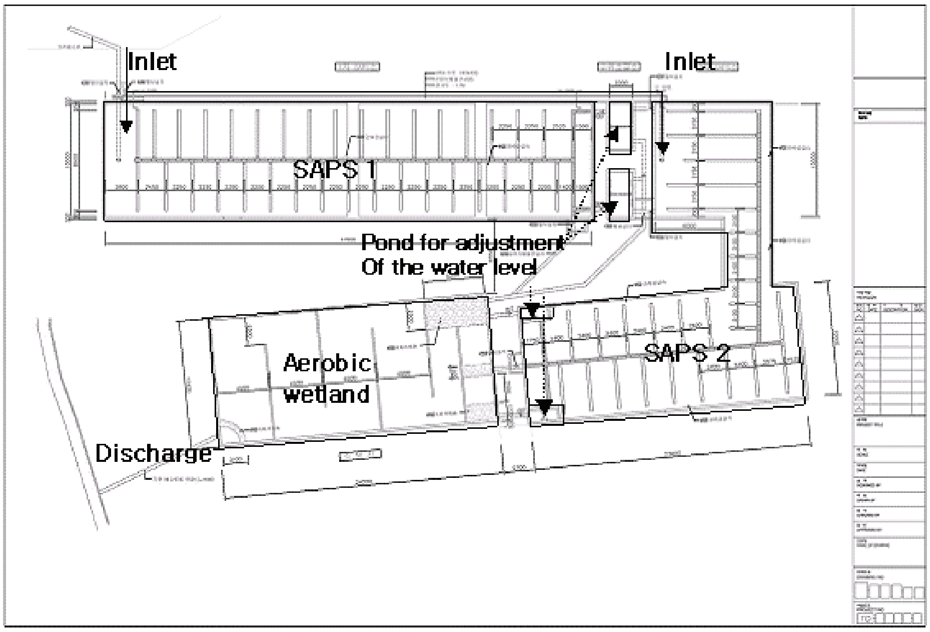


**Figure 2. Plan view of renovated passive treatment system.**

The two SAPS cannot be arranged in sequence due to the lack of topographic relief. To enlarge the size of SAPS, the 1st settling pond and the original SAPS are proposed to be changed to a 1st SAPS. The 2nd and 3rd settling ponds and the neutralizing pond should be changed to a 2nd SAPS, and the last pond reconstructed into an aerobic wetland (Fig. 2).

## Conclusions

Results of chemical analysis and tracer test revealed that malfunction of the original facility is probably caused by the sequence of treatment units, use of poor quality limestone, and insufficient retention time in SAPS. Therefore, it was recommended that the most important direction of renovation was enlargement of SAPS. Specifically, the first settling pond and existing SAPS should be changed into a new 1st SAPS; the second and third settling ponds and neutralization pond changed into SAPS 2; and the final pond changed into a new aerobic wetland to precipitate suspended solids.

After completion of renovated facility, it was not possible to perform chemical analyses, because during the dry season there was no inflow of ARD. However, it was observed that pH of stagnant effluent in discharge regulator installed in SAPS reached 6.5. This result is very encouraging for removal of metals and acidity of ARD. Indeed, it is expected that in case of neutral pH in effluents of SAPS, significant amounts of metals should be removed. Therefore, it is likely that the renovated facility will generate a considerable amount of alkalinity, and remove contaminant loading due to an increase in actual retention time, especially in SAPS, and use of good quality (high neutralizing power) limestone in the renovated SAPS.

## Acknowledgements

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