Assessment of Feasibility and Scale Generation of Hydrothermal Energy in Abandoned Mine Area

Hye-Lim Kwon[1], Duk-Min Kim[2], Dae-Gyu Im[3], Bu-Sung Kang[4], Mi-Sun Park[5]

[1]*Department of New Energy and Mining Engineering, Sangji University, Wonju 26339, South Korea, ossgpfla@naver.com*

[2]*Department of New Energy and Mining Engineering, Sangji University, Wonju 26339, South Korea, kdukmin8@sangji.ac.kr, ORCID 0000-0002-1537-6866*

[3]*Department of Earth and Environmental Sciences, Korea University, Seoul 02841, South Korea, daegull1995@korea.ac.kr*

[4]*Korea Mine Rehabilitation and Mineral Resources Corporation (KOMIR), Wonju 26464, South Korea, civilebs@komir.or.kr*

[5]*Korea Mine Rehabilitation and Mineral Resources Corporation (KOMIR), Wonju 26464, South Korea, mspark@komir.or.kr*

Abstract

The feasibility of applying hydrothermal energy in abandoned mine areas was assessed, and experiments on scale generation and removal were conducted. In the effluent of active treatment facilities that applied a cylindrical settling tank, the annual water temperature variation was particularly low. However, in semi-active treatment facilities that used long rectangular sedimentation tanks, the retention time was excessive and showed temperature fluctuations similar to those of surrounding stream water. In a bench scale heat exchanger, iron concentration decreased at effluent, which indicated deposition of Fe oxides as scale. The accumulated iron was discharged by washing using a weak acid.

Keywords: Hydrothermal energy, mine water, socio-economic, heat exchanger

Introduction

Hydrothermal energy supplies cooling and heating to buildings by utilizing the high specific heat of water (Jeong *et al*., 2017). It has recently been in the spotlight as a new renewable energy for heating and cooling that reduces use of fossil fuel. To be used as a water source for hydrothermal energy, water temperature should not change much with time, which can be found in inclined or vertical shafts. Temperature of mine water in adits and shafts in South Korea is generally around 15°C throughout the year. Meanwhile, in the case that scales composed of Fe/Al/Mn (hydr)oxides and/or calcium carbonate are accumulated in the heat exchanger, heat conductivity is decreased, water passing cross-sectional area is decreased, and pressure loss is increased (Shin *et al*., 2001; Korea Energy Agency, 2003; Jiwon Tech, 2011; EcoScale, 2014). The disadvantage of using mine water is the high scaling potential. Some coal and limestone mining areas have mine water saturated with calcium carbonate, which usually contains dissolved iron, manganese, aluminum, or suspended solids (SS) of several to tens of mg/L or more. In this study, the annual water temperature variations of the influent and effluent of mine water treatment facilities, divided into active and semi-active treatment facilities, were assessed. Experiments on the deposition and washing of scale generated from mine water were also conducted.

Material and Methods

Continuous flow experiment method for bench-scale heat exchangers

A heat exchanger (CB14–4H, V: 120 mL, BHE Manufacturing, Ronneby, Sweden) was used on-site to pass the mine water. The residence time in the heat exchanger was one minute, referring to the heat exchangers at the High1 Resort that use the mine water as a hydrothermal energy source, as well as other experimental cases. After 20–25 minutes of continuous flow experiment, field measurements of the inflow and outflow of the heat exchanger were conducted at the studied mine, and samples were collected for the analysis of cations and anions. After the experiment was completed, the inside of the heat exchanger was washed with 1 L of 0.06 N HCl to dissolve any accumulated scale, and a sample for cation analysis was collected.

Analytical methods

The collected water samples during the experiments were filtered through 0.45 µm membrane filters and transferred into conical tubes. The samples for the cation analysis were preserved by adding a few drops of concentrated HNO_3 to keep the pH < 2. The cations were analyzed using inductively coupled plasma atomic emission spectroscopy (ICP-AES; ICP-730ES, VARIAN, Australia) at the National Instrumentation Center for Environmental Management (NICEM), Seoul National University, South Korea. The anions were analyzed by ion chromatography (Dionex ICS-3000, ThermoFisher Scientific, USA) at the National Instrumentation Center for Environmental Management (NICEM), Seoul National University, South Korea. For both analyses, the relative standard deviations (RSD) were less than 5% of the measured value.

Result and discussion

Assessment of annual water temperature variation for active and semi-active facilities

The water temperature variations in influent and effluent of the water treatment facilities for mine drainage at Hanbo mine were investigated in 2020. Although the air temperature varied between −15 to +32°C in 2020, the water temperature of the mine water and the effluent from the treatment facilities ranged from 11.9 to 19.4 °C and 10.3 to 20.5 °C, respectively, showing a similar range of variation with each other (Fig 1). This indicates that there is not a substantial change in water temperature depending on the air temperature while staying in the cylindrical settling tank, especially with a short residence time, in the water treatment facilities owing to the high specific heat of water. This indicates the feasibility of utilizing the effluent with low potential for scale formation, such as low concentration of suspended solids.

The water temperature variations in influent and effluent of the water treatment facilities for mine drainage at Yeongdong coal mine were assessed in 2020 (Fig 2). Although the air temperature varied between −8 to +28°C in 2020, the water temperature of the mine water ranged from 10.9 to 19.2°C. In contrast, the water temperature of the effluent ranged from 6.9 to 22.0°C, showing a large water temperature variation similar to that

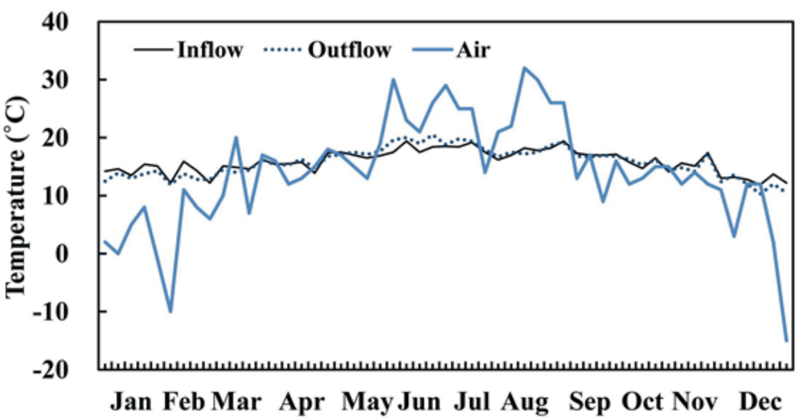

Figure 1 *Variation in air and water temperature of influent and effluent from Hanbo active treatment facilities in 2020*

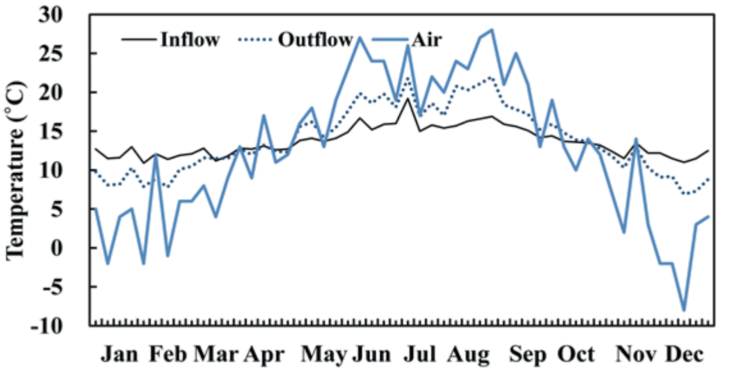

Figure 2 *Variation in air and water temperature of influent and effluent from Yeongdong semi-active treatment facilities in 2020*

of the stream water. The rectangular settling tank of the Yeongdong coal mine water treatment facilities had a long residence time of 48 h, which induced sufficient time for heat exchange with ambient air.

The scale deposition and washing experiments in mine water

The Fe concentration decreased from 13.88 mg/L in the influent to 12.61 mg/L in the effluent of the heat exchanger (Fig 3). This is possibly due to oxidation, precipitation or adsorption inside the heat exchanger. The composition of the effluent after washing the heat exchanger with 1 L of 0.06 N HCl exhibited an iron concentration of 10.61 mg/L. Additionally, copper, lead, zinc, and nickel concentrations were not low, which is thought to be due to the stainless steel and copper included in the heat exchanger material, and additional assessment of the effluent from washing, such as using a weak acid with higher pH, is needed in the future.

Conclusions

The assessment of annual water temperature variations in active and semi-active treatment facilities showed that the effluent from semi-active treatment facilities can exhibit temperature variations similar to those of surrounding stream water and active treatment systems or mine water were highly applicable to hydrothermal energy. The scale deposition and washing experiments conducted on mine water showed that the Fe concentration in the outflow of heat exchanger decreased, and the composition of the effluent after washing the heat exchanger with 1 L of 0.06 N HCl confirmed that iron was accumulated then washed. Hydrothermal energy from the effluent of treatment facilities and mine water can be used as energy needed in local communities surrounding abandoned mine area, which needs socio-economic revitalization due to the decrease of

Figure 3 *Results of continuous flow experiments and washing assessment of heat exchangers using mine water at Dongwon coal mine*

economic power. Additionally, carbon dioxide generated indirectly in the heating and cooling process using fossil fuels can be reduced by alternatively using hydrothermal energy. In the future, it will be necessary to conduct verification experiments on scale deposition and washing, assess the variations in the influent water temperature and the circulating water temperature of the heat exchanger-heat pump system, and assess the efficiency variations due to scale deposition.

Acknowledgements

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References

Shin, S., Kim, K., & Mo, J. (2001). Performance assessment of scale prevention devices for heat exchangers. Journal of the Korean Society of Mechanical Engineers, B, 25.9 (2001): 1149-1156.

Econonscale, 2014. "An Overview of Pipe Scale", November 7, 2014, http://blog.naver.com/econonscale/220174301051

Jeong, J.W., Nam, J.S., and Kim, H.S., 2017. "Utilization cases of thermal energy from domestic sewage and stream water in Korea." Journal of Korea Water Resources Association (Water and Future) 50.10: 50-58.

Jiwon Tech, 2011. "Optimization of heat exchangers for energy savings", September 22, 2011, http://www.jiwontech.com/index.html