Economical and environment-friendly adsorption of arsenic from mine drainage: Comparison between CMDS-bead and GFH

Ki-Rim Lee[1], Duk-Min Kim[1], Hye-Lim Kwon[1], Nam-Kyu Kim[1], Young-Min Kim[1], Dae-Gyu Im[2], Sin-Dong Kim[3], Oh-Hun Kwon[4] and Mi-Sun Park[4]

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

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

[3]*Environment Energy & Chemical Solution, Pocheon 11154, South Korea, catalite@hanmail.net*

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

Extended Abstract

The presence of arsenic in mine drainage poses substantial threats to both human health and crops through surface water and groundwater contamination. Ferric hydroxides exhibit a strong affinity for arsenic and are often characterized by a large surface area. Moreover, with a high point of zero charge (PZC), they act as adsorbents particularly for oxyanions. These chemical and electrostatic characteristics make them highly effective for arsenic adsorption.

In previous studies, adsorbents such as GFH (Granular Ferric Hydroxides) and polyurethane impregnated with CMDS (Coal Mine Drainage Sludge) have demonstrated excellent arsenic adsorption capabilities (Lee et al. 2018; Kumar et al. 2020). In particular, GFH has the drawback of being expensive. Therefore, in this study, we aim to assess the adsorption efficiency of CMDS shaped into bead and pellet forms to demonstrate a relatively economical and environment-friendly adsorption method.

In this experiment, CMDS-Bead and CMDS-Pellet, shaped into bead and pellet forms using sludge generated from mine drainage treatment facilities, were utilized. Additionally, CMDS-Bead and CMDS-Pellet were purchased at around \$6 per kg, while the commercially purchased adsorbent GFH was also used, purchased at around \$9 per kg (Fig. 1). These materials, primarily composed of ferric hydroxides, were employed as adsorbents in batch and column experiments. In the batch experiments, an artificial water was created by adding arsenic to deionized water. Adsorption isotherm and adsorption kinetic experiments were conducted in these batch experiments. In contrast, in the column experiments, two different mine drainage samples (GR and GJ) were utilized (Table 1). Hydraulic conductivities were measured to assess the hydraulic applicability of the adsorbents in adsorption reactors. Furthermore, XPS and FT-IR analyses were performed for the used adsorbents.

For GFH, the Freundlich model showed a higher R^2 value than the Langmuir model in the short-term (3 days) experiment, but the Langmuir model exhibited a higher R2 value in the long-term (30 days) experiment. This suggests that as the arsenic adsorption time increases, arsenic adsorption on GFH approaches a monolayer saturation state. Meanwhile, CMDS-Bead was evaluated as having similar R^2 values for the Langmuir and Freundlich models in both short-term and long-term experiments. CMDS-Pellet was closer to the Freundlich model but still showed high R^2 values in the Langmuir model. The maximum adsorption capacities (q_{max}) were 16.2 mg g^{-1} for CMDS-Bead and 16.7 mg g^{-1} for CMDS-Pellet, comparable to the 17.6 mg g^{-1} observed for GFH. Kinetics experiments conducted for 30 days revealed that both GFH and CMDS-Pellet were closer to the pseudo-second order (PSO) kinetic model than the pseudo-first order (PFO) kinetic model, suggesting the involvement of chemical processes such as

chemisorption, not just electrostatic adsorption. CMDS-Bead demonstrated a closer alignment with the PFO kinetic model. While GFH approached equilibrium adsorption after 15–30 days, CMDS-Bead and CMDS-Pellet exhibited continuously increasing adsorption capacities. Therefore, assessing adsorption performance through PFO and PSO may have limitations for CMDS-Bead and CMDS-Pellet.

In the column experiments, CMDS-Bead exhibited breakthrough at 10,145 BV (GR mine drainage) and 8,861 BV (GJ mine drainage), surpassing the arsenic discharge standard in the Republic of Korea (0.05 mg L^{-1}), while GFH did not exhibit breakthrough even after passing through 13,291 bed volumes (BV). Calculated hydraulic conductivities were 1.49×10^{-2} cm s^{-1}, 5.32×10^{-2} cm s^{-1}, and 9.51×10^{-2} cm s^{-1} for GFH, CMDS-Bead, and CMDS-Pellet, respectively. Thus, GFH and CMDS-Bead were classified as homogeneous sand, while CMDS-Pellet showed hydraulic conductivity similar to homogeneous gravel or sand. XPS and FT-IR analyses of collected adsorbents from the columns confirmed the presence of ferric hydroxides and the adsorption of arsenic.

In conclusion, CMDS-Bead with economic viability exhibited excellent adsorption capacity. This suggested its potential as an environment-friendly and alternative arsenic adsorbent.

Figure 1 Photos of (a) GFH, (b) CMDS-Bead, and (c) CMDS-Pellet as arsenic adsorbent.

***Chemical composition** of mine drainages (GR and GJ)*

	T(°C)		Cation (mg/L)											Action (mg/L)					
			As	Fe	Mn	Al	Cd	Ca	Cu	Pb	Zn	Ni	Na	SO_4^{2-}	F^-	Cl^-	Br^-	PO_4^{3-}
GR	19.3	8.05	0.220	0.026	0.014	–	–	46.920	0.070	–	0.214	–	7.951	111.2	0.2	7.8		–
GJ	20.0	8.67	0.460	–	0.003	–	–	60.696	–	–	–	–	6.527	114.5	0.1	1.7	–	–

Keywords: Arsenic, ferric hydroxides, adsorption, CMDS-bead

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