

Magnetic Nano mineral and acid mine drainage interaction: An experimental study

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Abstract

In the environment, two main sources of heavy metals are natural backgrounds derived from parent rocks and anthropogenic contamination including mineral industrial wastes, tailing dumps of sulfide mines, agrochemicals, and other outputs of industrial activities and factories. In this work, the physico-chemical aspects of the magnetic Nano- mineral surfaces are studied in contrast to acid mine drainage using the multi-analytical techniques XRF, XRD, BET, SEM, TEM, FT-IR, and AFM before and after adsorption of toxic elements. According to the results obtained, the FT-IR analysis presents a suitable curve, showing that the adsorption site of the sorption is filled with Ni(II) and Cd(II) ions. The results obtained show that the adsorption reaction is due to the high removal of the toxic elements from acid mine drainages.

Keywords: *Wastewater Treatment, Magnetic Nano Minerals, Acid Mine Drainage, Adsorption.*

1. Introduction

Heavy metals, even at very low concentrations, pose threats to the human and environmental health for their hazardous effects, persistency, and accumulation tendency. Different technologies including precipitation, ion exchange, membrane filtration, electroplating, and adsorption have been developed to remove heavy metals from wastewater. Adsorption is a cost-effective, easy-to-operate, and environmentally friendly method. Natural adsorbents having adsorptive sites have proved to be the most effective ones in treating wastewaters containing heavy metals with concentrations below 100 mg L^{-1} [1]. The increase in the industrialization and technological developments during the last century has resulted in a severe metal pollution of the environment. Heavy metals such as copper [2-4], manganese [5-8], chromium [9, 10], cadmium [11], lead [12, 13], nickel [14], and mercury [15, 16] are nowadays among the most important pollutants in the aquatic environments. The mesoporous mass, as an adsorbent, has emerged as a potentially low-cost and environmentally friendly alternative technique to the existing methods for metal

removal. Many studies have demonstrated a desirable and reliable performance of adsorption, and separation and removal of organic and inorganic pollutants [17-19]. In this work, the physico-chemical aspects of the nano-mineral surfaces were studied in contrast to the acid mine drainage (AMD). Thus to express the changes in the surface of porous magnetic nano-minerals, the multi-analysis techniques XRF, XRD, BET, SEM, TEM, FT-IR, and AFM were considered before and after adsorption of the toxic elements. For this purpose, the removal of Ni(II) and Cd(II) ions in real binary AMD systems were carried out. Thus in a batch system, the interaction between magnetic nano-minerals and AMD was investigated. Without any extra explanation, in this paper, the potential use of magnetic nano- minerals as a novel nano-adsorbent and acid mine drainage interaction for the removal of the two toxic Ni(II) and Cd(II) ions was considered.

2. Materials and method

2.1. Preparation of magnetic nanoparticles

Minerals consisting of perlite were produced in a local area, and were then thoroughly washed using hydrochloric acid (3 M) to remove the impure and volatile components. After wet mill, the nanoparticles were filtered using a spray dryer (B-290 model). In the final stage, in order to prepare the magnetic perlite nanoparticles (MPNs), the Fe(III) and Fe(II) ions were coated on the natural mineral nanoparticles.

2.2. Physical characterization of MPDCN

The BET (Quantachrome 2200e model) specific surface area analysis was carried out for the MPNs and raw perlite nanoparticles (RPNs). The specific surface areas of MPN and RPN are given in Table 1.

Table 1. BET specific surface area of MPN and RPN adsorbents.

Adsorbent	Specific surface area (m ² /g)
MPN	11.2
RPN	3.5

According to the research work carried out by Muller in 2010, an increase in the surface area of nanoparticles by decreasing the perlite particle size results in a higher uptake of heavy metal ions

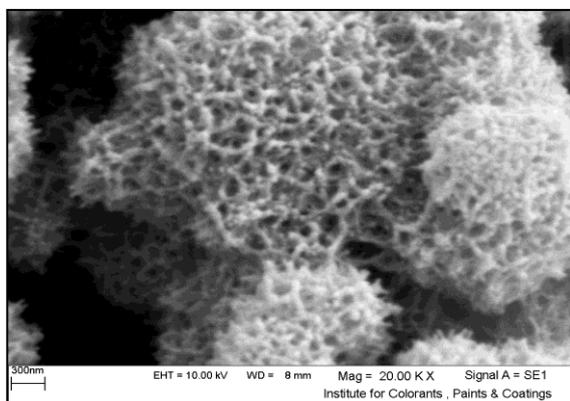
by the smaller particles rather than the larger ones [20].

A scanning electron microscope, model LEO-1455VP, was used to investigate the morphology and homogeneity of the MPN and RPN adsorbents. Figure 1 shows the SEM images for the original MPN and RPN adsorbents.

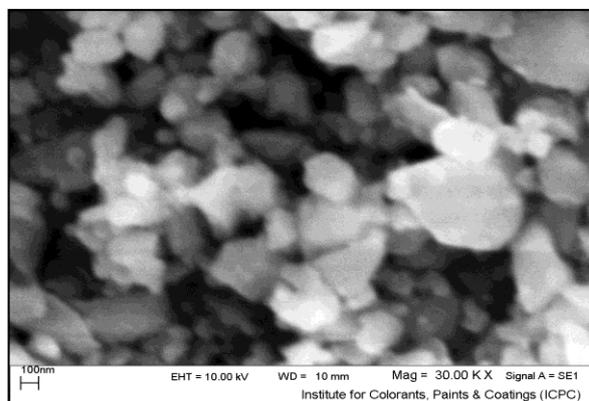
Figure 1 shows that pure MPNs are spherical in shape, arranged closely, with an average diameter of <100 nm and massive prose wholly, while the RPN samples have a massive and amorphous-granular morphology with an average diameter of 150–200 nm. A transmission electron microscope (TEM), model PHILIPS CM120, was used to study the morphology and homogeneity of the MPN and RPN adsorbents (Figure 2).

In Figure 2, MPNs have a tiny and opaque fine granular texture, and RPNs have a massive joined structure.

The FT-IR technique is one of the most important characterization techniques used to elucidate the changes in chemical structures. The FT-IR spectra for MPNs for 1 min are shown in Figure 3.

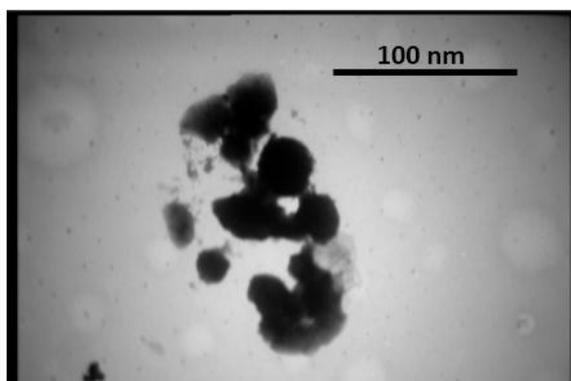


A

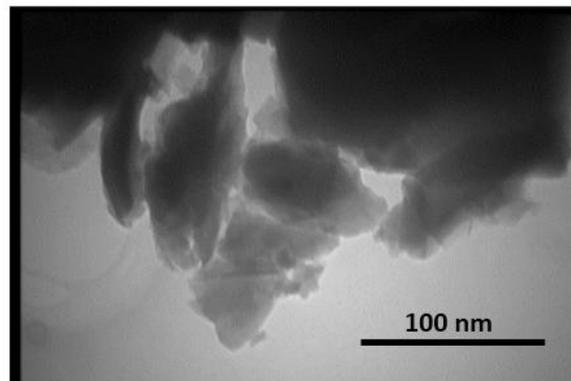


B

Figure 1. SEM images for MPN (A) and RPN (B) adsorbents.



A



B

Figure 2. TEM images for MPN (A) and RPN (B) adsorbents.

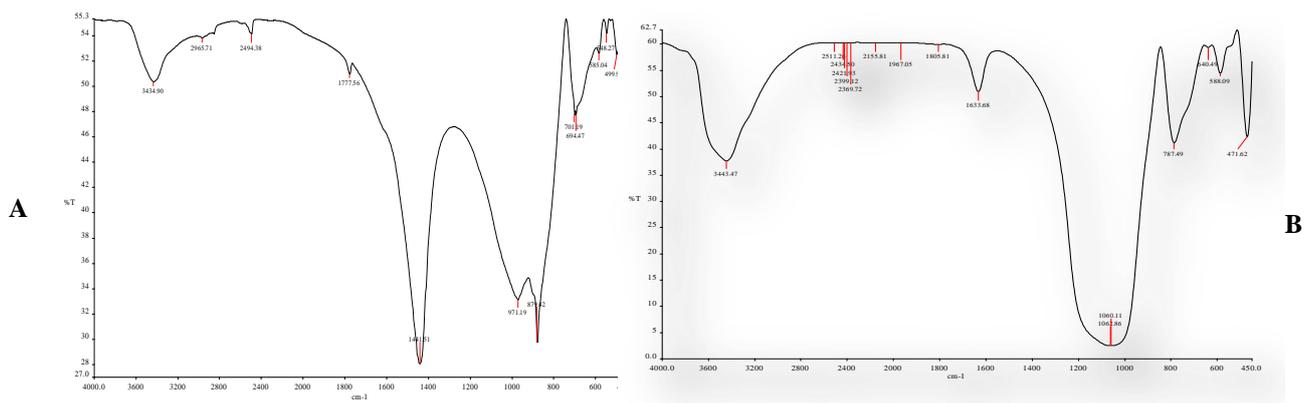


Figure 3. FT-IR spectra for MPN (A) and RPN (B) adsorbents for 1 min.

For MPNs, five main common absorption bands were observed at 474–482 cm^{-1} (B1), 922–936.1 cm^{-1} (B2), 1275–1331 cm^{-1} (B3), 2095–2106 cm^{-1} (B4), and 3595–3615 cm^{-1} (B5). Bands B1 and B2 are attributed to the Si–O stretching vibrations of Si–O–Si and Si–O–Al, respectively [21]. Band B3 is the deformation band of molecular water [22, 23]. Band B4 is attributed to adsorbed water molecules [21]. Band B5 is attributed to a combination of OH stretching arising from hydrogen bonding and free Si–OH [21, 24]. The intensity of the B3, B4, and B5 bands is closely related to the water content, similar to the other silicate materials and minerals such as volcanic tuffs and zeolites.

2.3. Chemical characterization of MPDCN

The chemical composition of MPNs and RPNs, determined by an XRF (XRF-1800 model), is given in Table 2.

According to Table 2, MPNs and RPNs are mainly composed of silica, as SiO_2 , and iron, as $\text{FeCl}_2 + \text{FeCl}_3$. The hydroxyl species and acid sites on the MPN surfaces and hydroxyl species were identified as a function of the adsorption process. X-ray diffraction (XRD) patterns for the MPN and RPN adsorbents were obtained using an

XMD300-Unisantia X-ray diffractometer (Figure 4).

In Figure 4, the coating of Fe ions in MPNs and RPNs is shown clearly. The AFM image was prepared for consideration of the surface morphology and dimension of the MPN and RPN particles. The AFM analysis of MPNs and RPNs is shown in Figure 5.

Table 2. Chemical analysis of MPNs and RPNs.

Constituent	MPN (wt. %)	RPN (wt. %)
SiO_2	27.98	56.87
K_2O	10.39	17.70
Al_2O_3	15.54	18.36
Na_2O	1.37	2.61
Fe_2O_3	40.74	2.53
CaO	1.88	0.96
ZrO_2	0.09	0.19
MgO	0.29	0.20
SO_3	0.37	0.27
TiO_2	1.28	0.17
MnO_2	0.07	0.13
Total	100	100

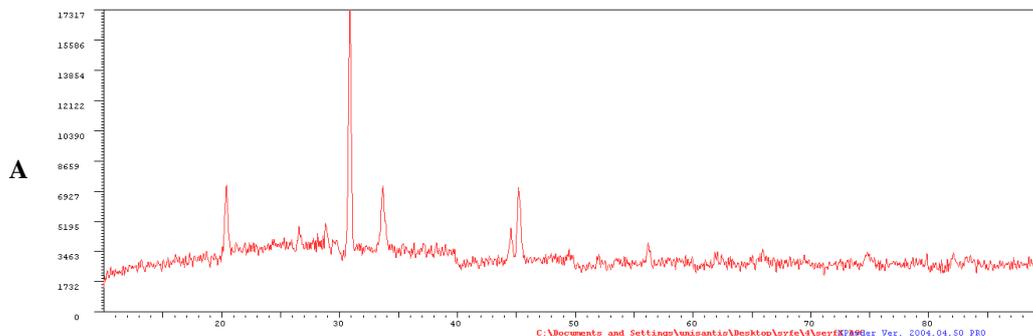


Figure 4. XRD patterns for MPN (A) and RPN (B) adsorbents.

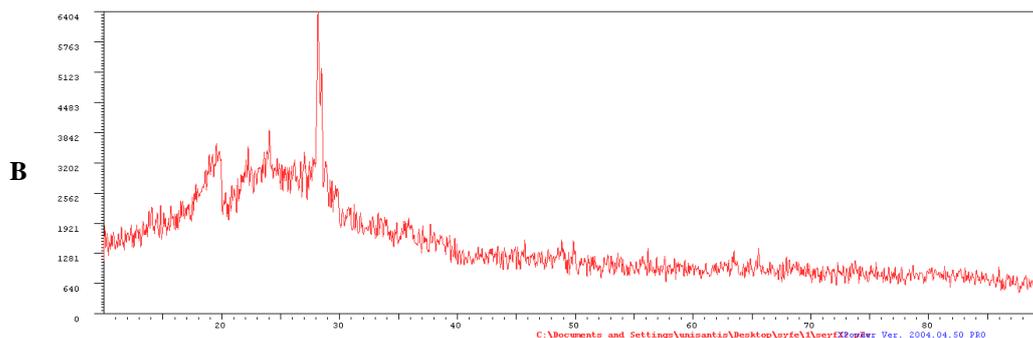


Figure 4. Continued.

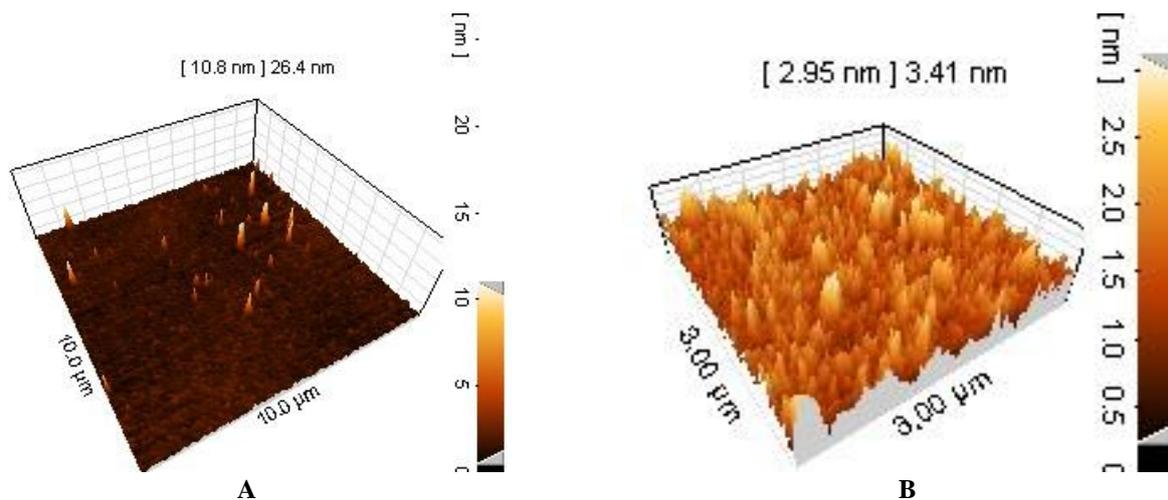


Figure 5. AFM analysis of MPN and RPN adsorbents.

2.4. Magnetic Nano mineral and acid mine drainage interaction

Figure 6 shows the FT-IR spectra for MPNs and RPNs after Ni(II) and Cd(II) ion adsorptions.

As shown, band B5 has a weaker OH band after the Ni(II) and Cd(II) ion adsorptions than before adsorption due to OH function saturating the Ni(II) and Cd(II) ions.

Also Figure 7 shows the SEM images for MPNs and RPNs after Ni(II) and Cd(II) ion adsorptions.

As it is obvious, the MPN and RPN reformations after the Ni(II) and Cd(II) ion adsorption processes than before, which is due to the Ni(II) and Cd(II) ion adsorptions.

3. Conclusions

The surface properties and potential use of MPNs and RPNs as sorbents for Ni(II) and Cd(II) ions were studied. The MPNs and RPNs were first

modified and then characterized by the XRD, XRF, SEM, TEM, FT-IR, AFM, and BET analytic techniques. The XRD and XRF spectra obtained showed that the main components were SiO₂ and Fe₂O₃. FT-IR showed the positive effect of the OH function in SiO₂. Also according to the FT-IR spectra for MPNs and RPNs before and after Ni(II) and Cd(II) ion adsorptions, one may conclude that band B5 has an OH band weakened after Ni(II) and Cd(II) ion adsorptions. This ability can be explored in the treatment technologies since perlite is a cheap, abundant, and locally available resource.

Acknowledgments

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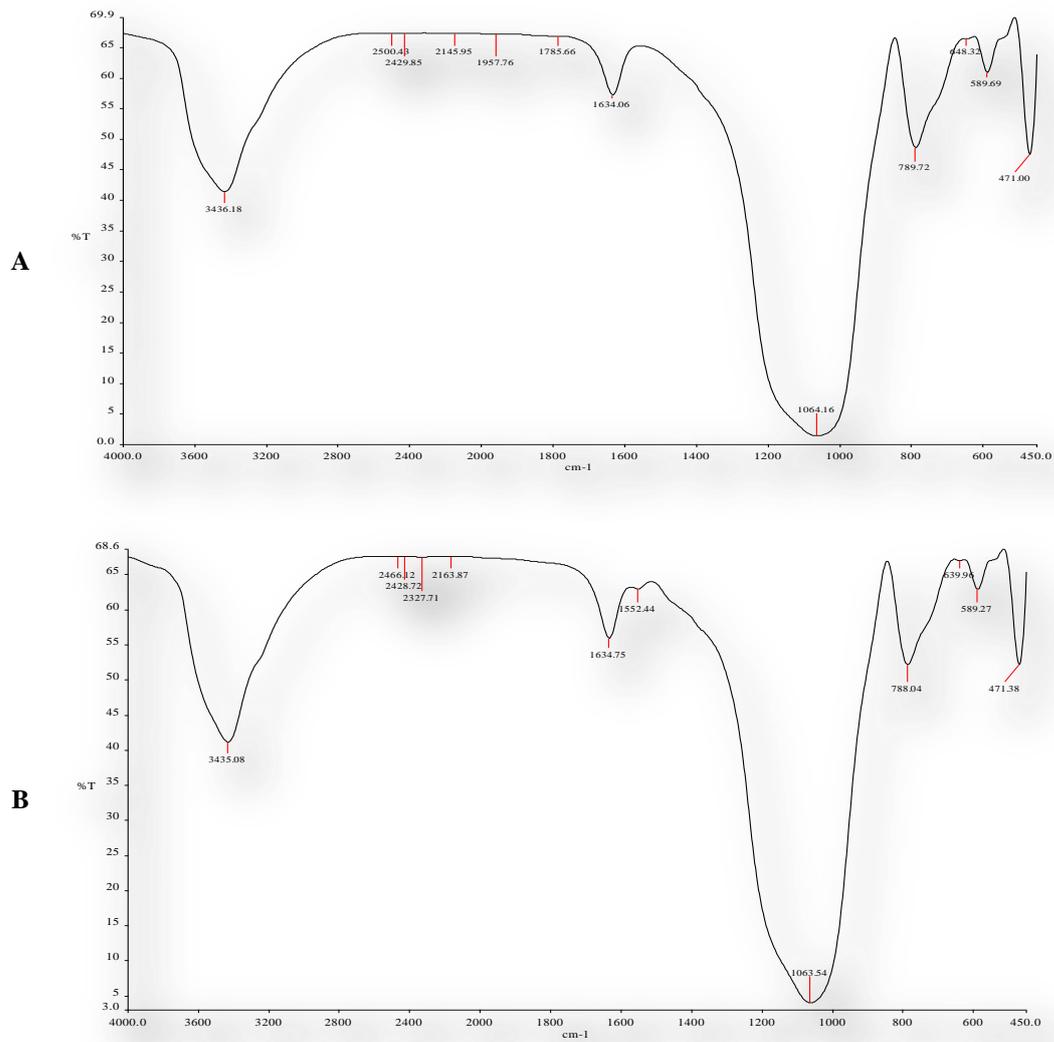


Figure 6. FT-IR spectra for MPNs and RPNs after A: Ni(II) and B: Cd(II) ion adsorptions.

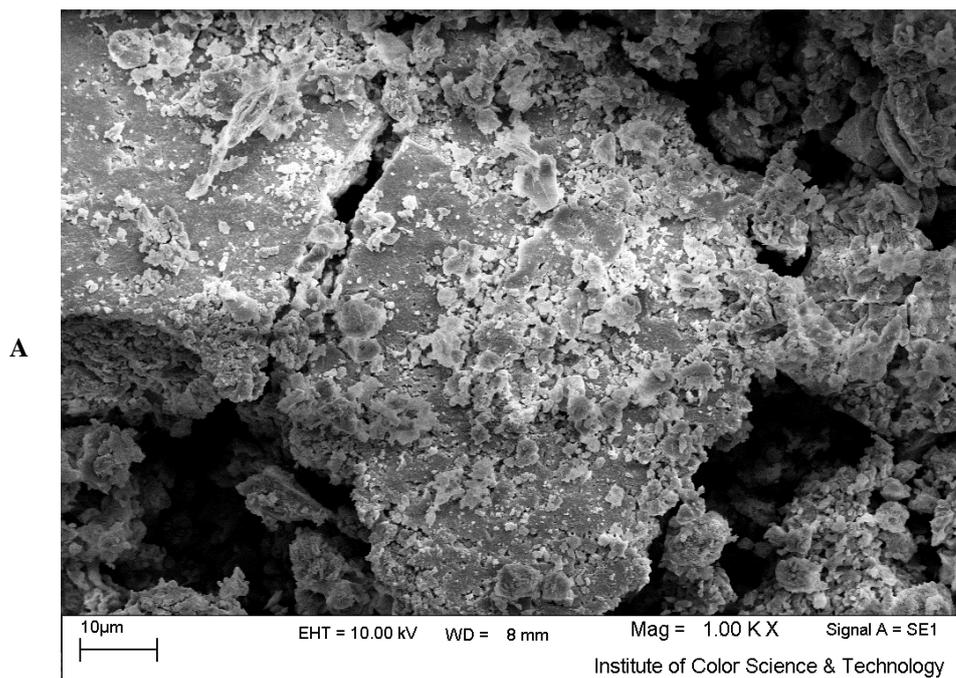


Figure 7. SEM images for MPNs and RPNs after A: Ni(II) and B: Cd(II) ion adsorptions.

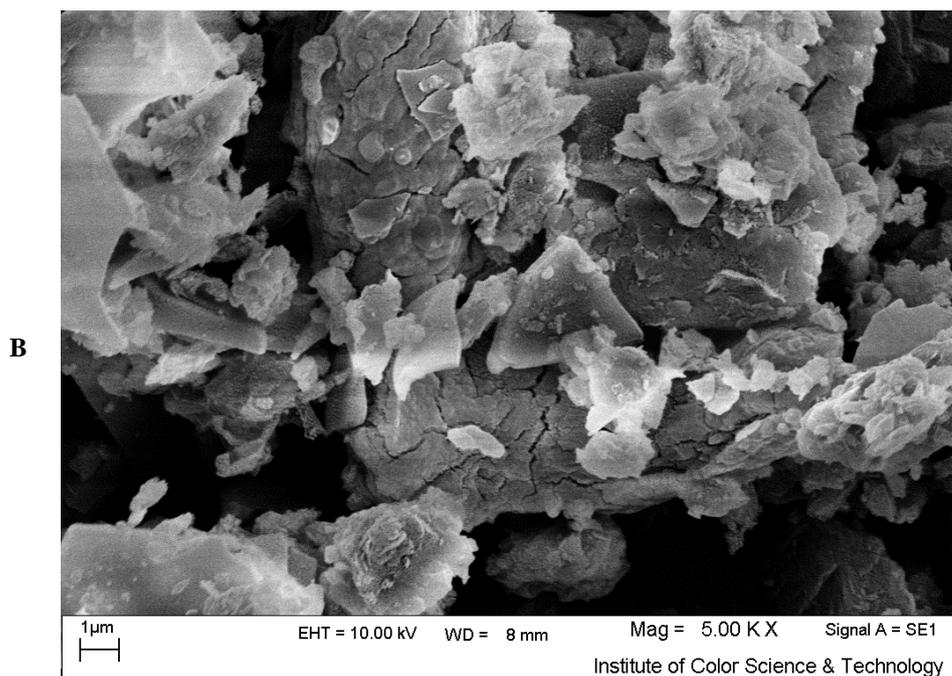


Figure 7. Continued.

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بررسی تأثیر متقابل زهاب اسیدی معدن و نانومینرال مغناطیسی در مقیاس آزمایشگاهی

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چکیده:

دو منبع عمده فلزات سنگین در محیط‌زیست عبارت است از: مقدار طبیعی موجود در سنگ‌ها و مقادیر نشأت گرفته از فعالیت‌های بشری مانند باطله‌های صنایع معدنی، دُم‌های باطله معادن سولفیدی، کارخانه‌های مواد شیمیایی و سایر فعالیت‌های صنعتی. در این تحقیق، جنبه‌های فیزیکوشیمیایی سطوح کانی مغناطیسی شده در مقیاس نانو در تقابل با زهاب اسیدی معدن با استفاده از آنالیزهای دستگاهی FT-IR, SEM, TEM, XRF, XRD BET و AFM قبل و بعد از فرآیند جذب فلزات سنگین موجود در زهاب بررسی شده است. با توجه به نتایج به دست آمده، آنالیز FT-IR منحنی مناسبی است که نشان می‌دهد سایت‌های جذب بعد از جذب یون‌های نیکل و کادمیم دو ظرفیتی اشباع شده‌اند. همچنین نتایج به دست آمده نشان می‌دهد که در اثر واکنش جذب آلاینده‌های فلزی از پساب با راندمان بالایی از زهاب اسیدی معدن حذف شده‌اند.

کلمات کلیدی: تصفیه پساب، کانی مغناطیسی شده در مقیاس نانو، زهاب اسیدی معدن، جذب سطحی.