



# A novel approach for improvement of purity and porosity in diatomite (diatomaceous earth) by applying an electric field



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## ABSTRACT

In this study, a novel and a facile purification approach using an electric field was developed to improve the porous structure of raw diatomite by removal of impurities from its surface and clogged pores. Voltages of 50 and 100 V were applied for 30 min, and the feasibility and efficiency of this approach were determined by comparison of the properties of the product with those of raw diatomite. The chemical, physical, and microstructural results confirmed that the electric field successfully improved the porosity, specific surface area, and enhanced absorptive efficiency of diatomite. The results suggest that application of an electric field has reasonable potential as an alternative method for improving diatomite quality. This is the first report documenting the successful improvement of diatomite using an electric field.

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## 1. Introduction

Diatomite, also known as diatomaceous earth, is a naturally formed non-metallic siliceous sedimentary material formed by the accumulation of the skeletal remains of single-celled algae. This material is mostly diatom shells of a wide variety of shapes and sizes, typically 10–200  $\mu\text{m}$  (Koruniv et al., 1998; Wang et al., 2013; Zhang et al., 2013). Diatomite offers a number of advantages with properties such as highly porous structure (80–90%), low density, high absorption capacity and relatively low price due to its abundance. It has been widely employed in filtration media, adsorbents, and as support for conventional catalysts (Sun et al., 2013a,b). Although diatomite has unique properties; its weakness is that the pores of raw diatomite commonly contain several types of impurities. These block some pores thereby reducing its microporosity, filtration efficiency, and commercial applicability (Franca et al., 2003). Therefore, research on treatment processes aimed at improving the properties of raw diatomite have occupied a considerable portion of the research on this material. Previously, a variety of approaches have been employed to improve the pore-size distribution by reduction of impurities. These have included acid leaching, calcination, a scrubbing method, high-speed shear, and ultrasonication (Ediz et al., 2010; Şan et al., 2009; Sun et al., 2013a,b; Zhang et al., 2013). However, with these methods, acid wastewater generation (acid leaching), inefficiency (scrubbing method), high operational cost (calcination and ultrasonication), and destruction of the diatomite structure (high-speed shear) could compromise the results (Sun et al., 2013b).

Normally, if a uniform electric field is formed between electrodes in a fluid, electrophoresis causes movement of charged particles suspended in the fluid. Organic impurities tend to be positively charged, while diatomite is neutral; so that charged impurities are pulled along the field lines towards an electrode with a charge opposite that of the particles (Shim et al., 2007). Accordingly, based on the difference in motion of the diatomite and impurities in the electric field, impurities may be removed from the pores. In light of the above findings, the objective of the present study was to develop a novel and facile system applying an electric field for removal of impurities embedded in the porous structure of raw diatomite. The physical, chemical, and microstructural properties of raw and purified diatomite were determined. Through the application of an electric field to a mixture of raw diatomite and water, the concentration of organic matter in supernatant was significantly increased, resulting in the improvement of pore size distribution and specific surface area of the purified diatomite. Compared to previous approaches, this method was simpler and more cost effective in terms of improving the pore size distribution by removal of existing impurities; organic matter in particular. This seems to be the first report documenting the successful improvement of raw diatomite properties using an electric field for purification.

## 2. Materials and methods

### 2.1. Diatomite

Natural diatomite powders with an average particle size of 50  $\mu\text{m}$  were supplied by Celite Korea Ltd. (Branch of World Minerals Co., USA).

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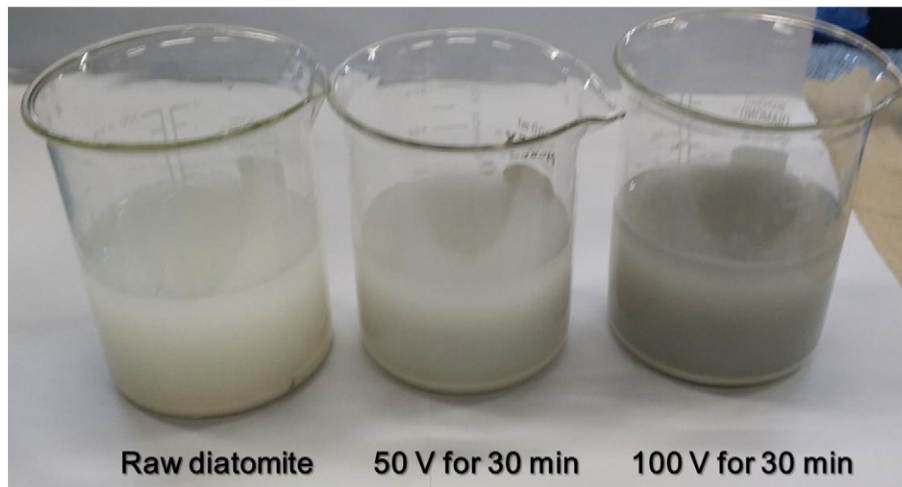


Fig. 1. The photograph of raw and purified diatomite mixture.

## 2.2. Purification method by electric field

The diatomite and water (D/W) ratio was fixed at 1:20 and was treated with applied voltages of 50 and 100 V using a power supply (Programmable DC Power Supply, ODA) and graphite electrodes ( $\Phi 10 \times 400$ , anode and cathode). The distance between the electrodes was fixed at 10 cm. After a reaction time of 30 min, the mixture was settled for 20 min to obtain a supernatant. Subsequently, the purified diatomite was dried in an oven (105 °C). To reduce errors (drying process effect) between raw and purified diatomite during the drying process, raw diatomite was also mixed with water for 30 min at a D/W ratio of 1:20, and then dried.

## 2.3. Analytical method

Chemical analysis of raw and purified diatomite, and each supernatant, was done using ZSX Primus-II X-ray fluorescence (XRF – Rigaku Co., Japan). The mineral content of the raw and purified diatomite was analyzed using Dmax 2500/PC X-ray diffraction (XRD – Rigaku Co., Japan). The morphology and microstructure of raw and purified diatomite were investigated by scanning electron microscopy (SEM), and surface element analysis was also conducted simultaneously with the SEM, at the same surface locations, using energy dispersive X-ray spectroscopy (EDS) (S-4200, Hitachi Co., Japan). Physical properties (i.e., BET specific surface area, total pore volume, and average pore diameter) of the samples were determined using BEL-mini II model (BEL Japan brand); using nitrogen gas as adsorbate. In order to check

the concentration of organic content in the supernatant, chemical oxygen demand (COD) was measured according to Standard Methods (APHA, 1998).

## 3. Results and discussion

### 3.1. Chemical and mineralogical analysis

In order to confirm the feasibility of using an electric field for purification of raw diatomite, voltages of 50 and 100 V were applied for 30 min. As clearly shown in Fig. 1, the supernatant color was darker than raw diatomite after application of the electric field, and it gradually darkened when the voltage applied to the mixture of water and diatomite was increased. In order to confirm the effect of the electric field on purification of raw diatomite, XRF was carried out to investigate the chemical properties of powder and supernatant of both raw and purified diatomite. These results are summarized in Tables 1 and 2. The chemical analysis (Table 1) shows that the raw diatomite has high silica content of 90.8% but considerably lower iron, calcium, potassium and sodium content. These results indicate that this raw diatomite is of good quality for commercial use (Ediz et al., 2010; Breese, 1994). After application of the electric field, the silica dioxide portion of the diatomite increased to 92.3%, when the applied voltage was 100 V, indicating a more chemically stable material with higher silica content. In addition, as shown in Table 2, even though the silicon concentration

**Table 1**  
Chemical analysis (XRF) of the powder in both raw and purified diatomite.

Components	Raw diatomite (%)	Purified diatomite (%)	
		50 V	100 V
SiO <sub>2</sub>	90.80	91.72	92.30
Al <sub>2</sub> O <sub>3</sub>	1.33	1.26	1.27
Fe <sub>2</sub> O <sub>3</sub>	4.12	4.08	4.03
Na <sub>2</sub> O	2.10	1.62	1.3
CaO	0.74	0.56	0.43
MgO	0.55	0.45	0.39
TiO <sub>2</sub>	0.16	0.12	0.12
K <sub>2</sub> O	0.09	0.08	0.08
V <sub>2</sub> O <sub>5</sub>	0.05	0.05	0.03
MnO	0.03	0.03	0.03
P <sub>2</sub> O <sub>5</sub>	0.02	0.02	0.01
Cl	0.01	0.01	0.01

**Table 2**  
Chemical analysis (XRF) of the supernatant in both raw and purified diatomite.

Components	Raw diatomite ( $\mu\text{g}/\text{cm}^2$ )	Purified diatomite ( $\mu\text{g}/\text{cm}^2$ )	
		50 V	100 V
Si	72.4	253	324
Na	3.71	25.70	34.1
Al	0.98	9.03	12.6
Fe	0.63	4.12	6.2
Mg	0.38	3.66	5.28
Ca	0.06	0.84	1.18
Ti	N.D.	0.38	0.53
K	N.D.	0.18	0.28
P	N.D.	0.01	0.05
Cr	N.D.	N.D.	4.06
Ni	N.D.	N.D.	0.02
Mn	N.D.	N.D.	N.D.
Organic matters <sup>a</sup> (mg/L)	N.D.	16.62	36.41

<sup>a</sup> Based on COD<sub>Cr</sub> concentration.

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