

# Electrokinetic Properties of Perlite

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**Electrokinetic properties of expanded and unexpanded perlite samples have been investigated using the microelectrophoresis technique. Perlite samples yield practically no isoelectric point in the pH range of 3 to 11. Both of the perlite samples remain negatively charged in the pH range studied. The expanded perlite has a more negatively charged surface than unexpanded perlite. NaCl, KNO<sub>3</sub>, NaNO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, and Na<sub>2</sub>SO<sub>4</sub> are indifferent electrolytes for perlite whereas AlCl<sub>3</sub> and CaCl<sub>2</sub> change the interface charge from negative to positive. Acid-activation has no significant effect on the zeta potential of perlite.** © 1997 Academic Press

**Key Words:** electrokinetic properties; zeta potential; perlite; surface charge.

## 1. INTRODUCTION

Perlite is a glassy volcanic rock which will, upon rapid controlled heating, expand or “pop” into a frothy material of low bulk density, valued as a lightweight aggregate (1). Expanded perlite meets competition from various other industrial minerals. However, this versatile, lightweight material with its low bulk density continues to grow in popularity even though it is by no means the cheapest (2). Along the Aegean Coast, Turkey possesses about 70% ( $70 \times 10^9$  tons) of the world's known perlite reserves (3). The uses of expanded perlite are many and varied and are based primarily upon its physical and chemical properties. Early uses of perlite were related exclusively to the construction industry. The primary use of perlite now is as an aggregate in insulation boards. Because of its low thermal conductivity, high adsorption of sound, low bulk density, and fire resistance, perlite aggregate plasters hold many advantages over conventional plaster. As most perlites have a high silica content, usually greater than 70%, and are adsorptive, they are chemically inert in many environments and hence are excellent filter aids and fillers in various processes and materials. Miscellaneous uses of expanded perlite include fillers or extenders in paints, enamels, glazes, plastics, resins, and rubber;

as a catalyst in chemical reactions an abrasive; and as an agent in mixtures for oil well cementing (1).

However, no studies about the surface interactions that occur at the interface when perlite is incorporated into aqueous dispersions have been found. Therefore, the electrokinetic properties of both the unexpanded and expanded perlite have been investigated in this study.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The unexpanded and expanded perlite samples were obtained from Cumaovası Perlite Processing Plants of Etibank (İzmir, Turkey). The chemical composition of the perlite found in Turkey is given in Table 1 (3). The unexpanded and expanded perlite samples were treated before using in the experiments as follows: The suspension containing 10 g/L perlite was mechanically stirred for 24 h, and after waiting for a couple of minutes the supernatant suspension was filtered. The solid sample was dried at 110°C for 24 h, then sieved by 100-mesh sieve (4, 5).

In order to obtain the acid-activated perlite samples H<sub>2</sub>SO<sub>4</sub> solutions were used. The aqueous suspensions of both the unexpanded and expanded perlite samples in 0.2, 0.4, and 0.6 M H<sub>2</sub>SO<sub>4</sub> solutions (so that acid/solid ratios were 1/5, 2/5, and 3/5) were refluxed with a reflux apparatus and then filtered and dried at 110°C for 24 h (4–9).

The cation exchange capacity (CEC) of the samples obtained as explained above was determined by the ammonium acetate method (4, 6), and the density was determined by the pycnometer method (6). The specific surface area of the samples of Expanded (EP), Acid-activated expanded perlite (EHP(0.6)), Unexpanded (UP), and Acid-activated unexpanded perlite (UHP(0.6)) were measured by BET N<sub>2</sub> adsorption (4, 6).

The results are summarized in Table 2.

All chemicals were made by Merck.

### 2.2. Methods

Zeta potentials of perlite samples were measured at  $17 \pm 1^\circ\text{C}$  using a Zeta Meter 3.0 equipped with a microprocessor

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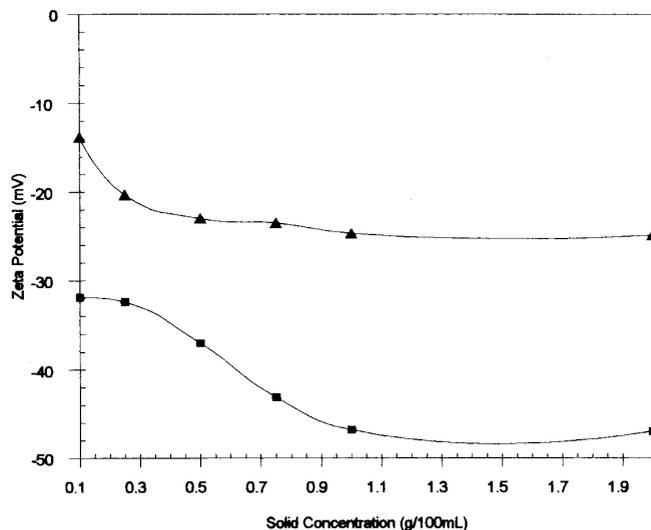
**TABLE 1**  
**Chemical Composition of Perlite**

Constituent	Percentage present (%)
SiO <sub>2</sub>	71–75
Al <sub>2</sub> O <sub>3</sub>	12.5–18
Na <sub>2</sub> O	2.9–4.0
K <sub>2</sub> O	4.0–5.0
CaO	0.5–2.0
Fe <sub>2</sub> O <sub>3</sub>	0.1–1.5
MgO	0.03–0.5
TiO <sub>2</sub>	0.03–0.2
MnO <sub>2</sub>	0.0–0.1
SO <sub>3</sub>	0.0–0.1
FeO	0.0–0.1
Ba	0.0–0.1
PbO	0.0–0.5
Cr	0.0–0.1

unit. The unit automatically calculates the electrophoretic mobility of the particles and converts it to the zeta potential in terms of Smoluchowski equation. A 1 g amount of perlite was conditioned in 100 cc of bidistilled water for 10 min. The suspension was kept still for 5 min to let the larger particles settle. Each data point is an average of approximately 10 measurements. All zeta potential measurements were carried out at natural pH of the suspension except those in which the effect of pH was investigated. The pH of the suspension was adjusted using dilute HCl and NaOH (10). All solutions were prepared using bidistilled water.

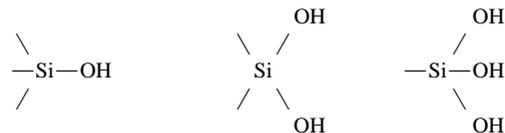
### 3. RESULTS AND DISCUSSION

The silicon atoms at the surface tend to maintain their tetrahedral coordination with oxygen. They complete their coordination at room temperature by attachment to monovalent hydroxyl groups, forming silanol groups. Theoretically, it is possible to use a pattern in which one silicone atom bears two or three hydroxyl groups, yielding silanediol and



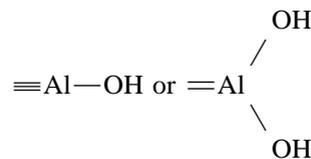
**FIG. 1.** The effect of solid concentration on the zeta potential of expanded (■) and unexpanded (▲) perlite samples.

silanetriol groups, respectively. It is stated as improbable that silanetriol groups exist at the silica surface. The type of silanol groups are shown below (11):



Hydroxyl or silanol groups    Silanediol groups    Silanetriol groups

The hydrous oxide surface groups in alumina are given as following (12):



**TABLE 2**  
**Some Physicochemical Properties of Perlite Samples Used in the Study**

Sample	Nomenclature	CEC (meq/100 g)	Density (g/mL)	Specific surface area (m <sup>2</sup> /g)
Expanded, purified in water	EP	33.30	2.2422	2.30
Expanded, 0.2 M acid-activated	EHP (0.2)	38.20	2.0976	
Expanded, 0.4 M acid-activated	EHP (0.4)	43.38	2.0397	
Expanded, 0.6 M acid-activated	EHP (0.6)	54.24	1.9290	2.33
Unexpanded, purified in water	UP	25.97	2.3047	1.22
Unexpanded, 0.2 M acid-activated	UHP (0.2)	32.79	2.3228	
Unexpanded, 0.4 M acid-activated	UHP (0.4)	35.00	2.3781	
Unexpanded, 0.6 M acid-activated	UHP (0.6)	36.56	2.4610	1.99

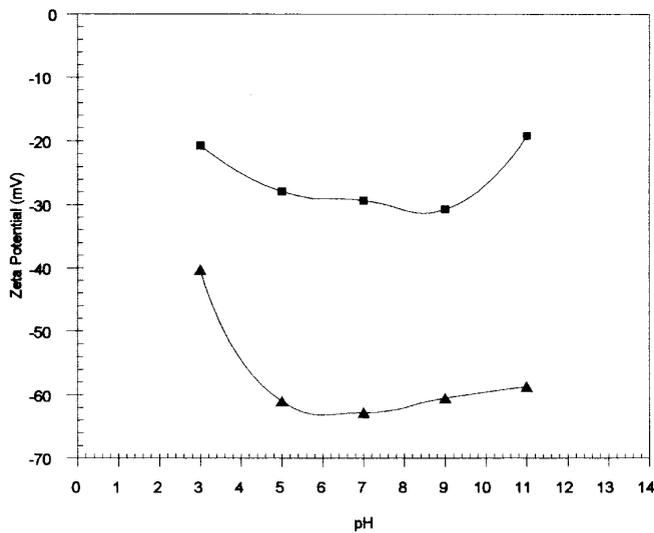
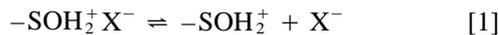
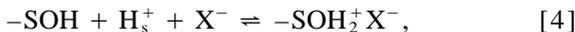


FIG. 2. The effect of pH on the zeta potential of expanded (▲) and unexpanded (■) perlite samples.

The specific adsorption of supporting electrolyte ions is assumed to occur and form surface ion pairs with charged surface groups. To account for specific adsorption of electrolyte ions, Yates *et al.* propose the formation of ‘ion pairs’ at charged surface sites. For an oxide in a simple electrolyte system (13, 14):



Davis *et al.* have proposed that it is more instructive to write the reactions as complex ionization reactions (14):



where the subscript *s* denotes the surface.

### 3.1. Effect of Solid Concentration

As shown in Fig. 1, the zeta potential change with the solid concentration in solution, indicating that solid concentration in solution is a major parameter governing the surface charge generation. This means that the ionic species produced at the solid–liquid interface increase with increase in solid concentration and that using inadequate solids concentration can lead to erroneous conclusions in the interpretation of zeta potential measurements. Therefore, in the subsequent zeta potentials measurements the solid-to-liquid ratio has been kept constant as 10 g/L.

### 3.2. Effect of pH

Figure 2 illustrates the effect of pH on the variation of zeta potential of perlite. Shown in this figure the perlite

samples have no point of zero charge and exhibits negative zeta potential value at all pH values. This result agrees with that obtained on electrokinetic measurements of clay minerals (10). Although the origin of this charge is still a controversial issue, it is known that it arises from isomorphic transactions, defects in the crystal lattice, broken particle edges, and structural hydroxyl groups (10).

The electrical charge at the oxide surface/aqueous phase to protonation/deprotonation of the surface hydroxyl can be ascribed as (15)

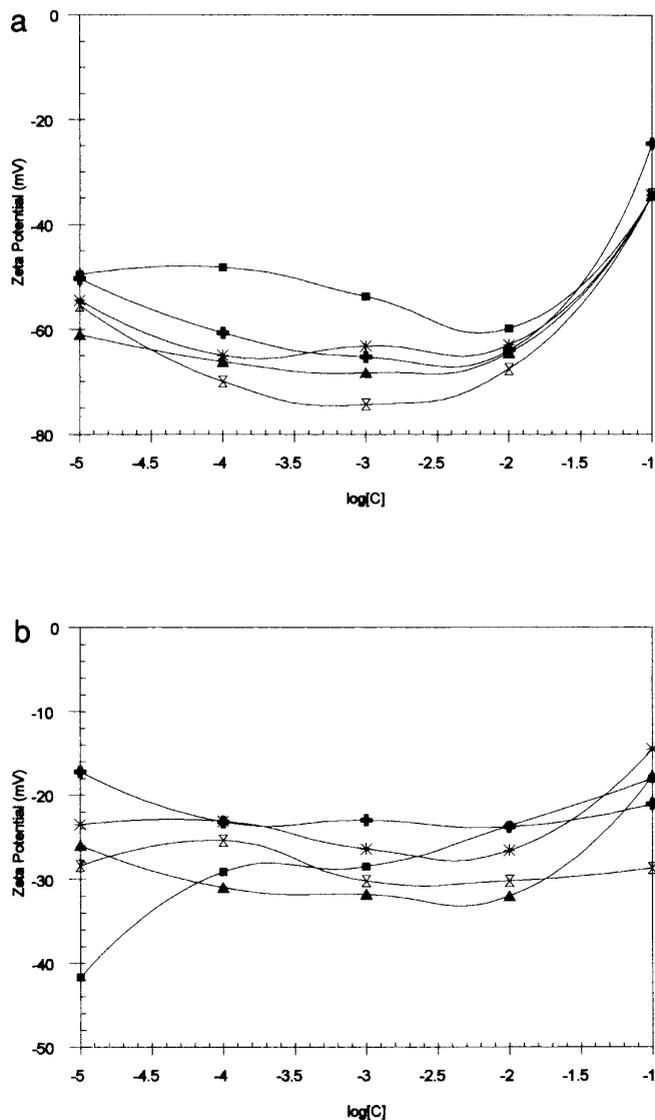


FIG. 3. The variation of the zeta potential of perlite with electrolyte concentration; (a) expanded and (b) unexpanded perlite. (■) NaCl; (+) KNO<sub>3</sub>; (▲) NaNO<sub>3</sub>; (\*) Na<sub>2</sub>SO<sub>4</sub>; (X) Na<sub>2</sub>CO<sub>3</sub>.

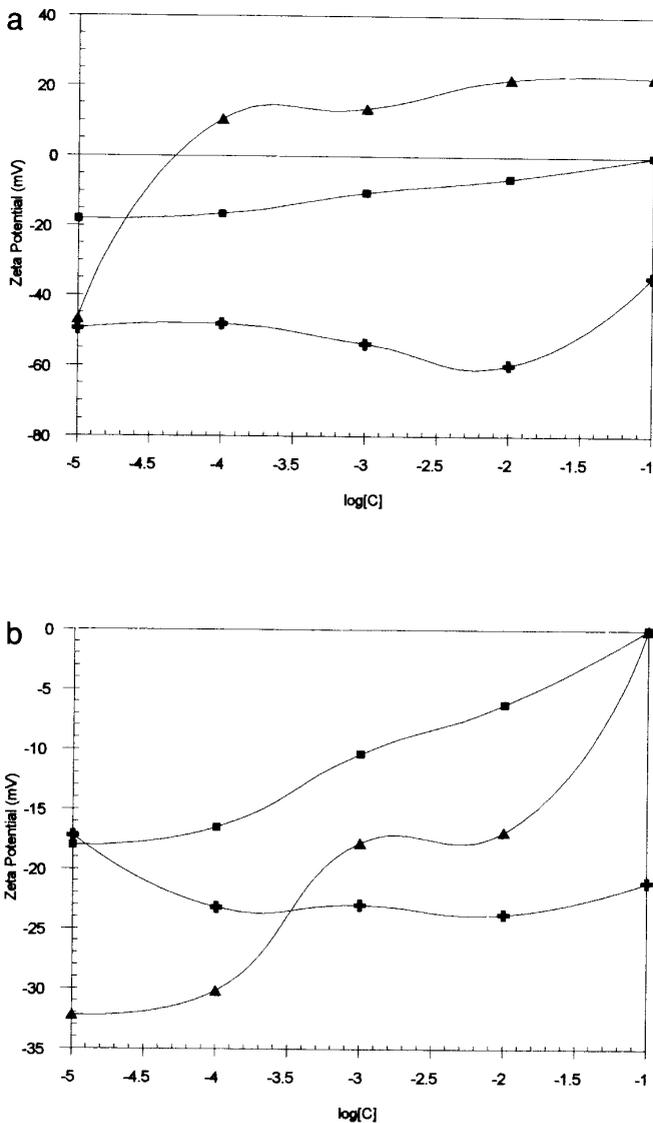


FIG. 4. The variation of zeta potential of perlite with electrolyte concentration; (a) expanded and (b) unexpanded perlite. (▲) AlCl<sub>3</sub>; (■) CaCl<sub>2</sub>; (+) NaCl.



and at IEP,



The fact that there was no IEP shows that the reaction responsible for the surface charge of the solid is mainly the reaction in Eq. [6].

Furthermore, the expanded perlite sample has higher negative zeta potential values compared to the unexpanded perlite

sample, presumably due to increasing the broken edges during the heating to produce the expanded perlite (10).

### 3.3. Effect of Electrolyte

The results obtained at the natural pH of the medium with the electrolytes NaCl, KNO<sub>3</sub>, NaNO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, and Na<sub>2</sub>SO<sub>4</sub> for both of the samples are shown in Fig. 3a and 3b, indicating that in the presence of an electrolyte the surface is, at first, more negatively charged, and then the negativity decreases as the concentration of electrolyte increases. By acting as indifferent electrolytes which are defined as counterions adsorbed by electrolytic attraction and thereby by compressing the double layer, they render the surface of the solid less negative (10, 16). This result is in a good agreement with the literature. In simple electrolyte systems, e.g., KNO<sub>3</sub> and NaNO<sub>3</sub>, no net specific adsorption occurs and  $\text{pH}_{\text{pzc}}$  equals  $\text{pH}_{\text{IEP}}$ . Other authors often refer to such systems as being “in the absence of specific adsorption” since  $\text{pH}_{\text{pzc}}$  equals  $\text{pH}_{\text{IEP}}$  (17). Negative ions were envisaged to adsorb on the positive sites on the surface make it more negative, so other anions such as NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, and CO<sub>3</sub><sup>2-</sup> were found to behave similarly. It can be seen that the curves for different electrolytes were similar for 0.1 M electrolyte concentration, and the zeta potential is found to be increasing because of adsorption of cations at the surface at higher electrolyte concentrations. This indicates that there is little specific interaction between oxide surface and monovalent cations, so selective differences are quite small, as is usually observed for oxides (18). Similar behaviors have been observed with montmorillonite type clay minerals and ulexite mineral (10).

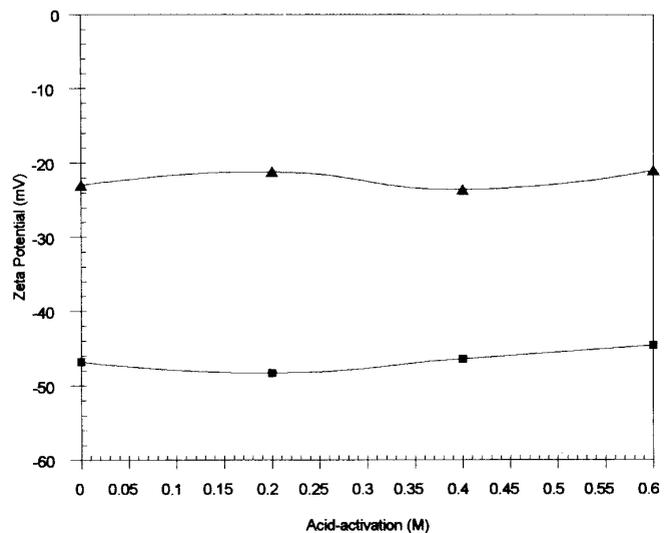
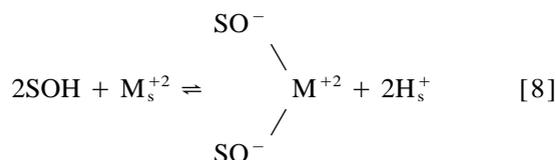


FIG. 5. The effect of acid-activation on the zeta potential of expanded (■) and unexpanded (▲) perlite samples.

The variation of zeta potential with concentration of the electrolytes NaCl, CaCl<sub>2</sub>, and AlCl<sub>3</sub> is shown in Fig. 4a and 4b for both of the perlite samples. While NaCl acts as an indifferent electrolyte, CaCl<sub>2</sub> and AlCl<sub>3</sub> change the electrokinetic properties of interface. According to the following reactions given by Davis *et al.* who suggested that surface charge may be a result of some combination of following reactions (17), in the case of M = Mg:



The result obtained in this study can be explained by considering the H<sup>+</sup>/M<sup>n+</sup> stoichiometry (18): since specific adsorption of multivalent cations almost always involves proton exchange as indicated by reactions [8] and [9], an important characteristic of this adsorption process is the number of protons released, or hydroxide ions adsorbed, for each cation adsorbed. The fact that the H<sup>+</sup>/M<sup>2+</sup> exchange stoichiometry is usually less than two for divalent cation adsorption means that the surface charge becomes increasingly positive, which is reflected in a change in the electrokinetic properties of the interface. A similar observation is also possible for trivalent cations. In this case, the specific adsorption reverses the sign of the effective charge of the surface as seen in these figures.

### 3.4. Effect of Acid-Activation

The effect of acid-activation on the zeta potential of both of perlite samples is shown in Fig. 5.

It can be said that the activation with acid has no significant effect on the zeta potential. In order to change the zeta potential the new charged sites should have been formed during the activation. The fact that the cation exchange capacities given in Table 2 are not so different supports this conclusion.

## 4. CONCLUSIONS

The following points are the results of this study.

- (i) The expanded perlite has a more negatively charged surface than unexpanded perlite.
- (ii) The zeta potential of perlite is affected by solid concentration; however, it remains negatively charged at all solid concentrations.
- (iii) NaCl, KNO<sub>3</sub>, NaNO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, and Na<sub>2</sub>SO<sub>4</sub> are indifferent electrolytes for perlite, whereas AlCl<sub>3</sub> and CaCl<sub>2</sub> change the interface charge from negative to positive.
- (iv) Acid-activation has no significant effect on the zeta potential of perlite.

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