DEWATERING OF SLUDGE BY ENHANCED ELECTRO-OSMOSIS

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ABSTRACT

Laboratory scale tests are being conducted to optimize enhanced electro-osmotic dewatering (EED) for fine suspensions, which are simulated as the sludge waste generated from nuclear power stations ; the mixture of powdered ion exchange resin and iron compound. The test shows that the EED increases the dewatering rate and decreases the final moisture content in the sludge, as compared to gravimetric dewatering. The EED method is a combination of conventional electro-osmotic dewatering and the action which hydrated Na^+ ions are forced to transfer in the electric field, that is, water molecules are moved in the sludge by the Na^+ ions. It has been proved that the marriage of the two dewatering mechanisms enhanced the dewatering rate and overall moisture reduction.

INTRODUCTION

A large amount of sludge, which is composed of powdered ion exchange resin and crud, has been generated in nuclear power plants. The authors have studied methods to dewater the sludge mentioned above and reduce its volume with a simple system.

As electro-osmosis is said to be particularly effective for hardly dewaterable sludge, the authors investigated the adaptability of this method to simulated sludge. Conventional electro-osmotic methods were capable of treating such sludge as contained iron compounds. However, powdered ion exchange resin was found to be unsuitable for electro-osmotic dewatering. So, an enhanced electro-osmotic dewatering method was researched. This method combines conventional electro-osmosis and the action which forces water molecule to move by Na^+ ion in the form of hydrated ion. In this work, the watering rate and the final moisture content in simulated sludge were measured and compared with those for the gravimetric method, to evaluate dewatering properties for this technique.

ENHANCED ELECTRO-OSMOSIS MECHANISMS

An electro-osmotic dewatering method has been often used for many kinds of materials and suspensions, which have the same charge signs (normally negative). Previous research by the authors has also shown that simulated crud, i.e. the mixture of amorphous iron hydroxide and iron oxide, could be dewatered with this method as was expected. However, a system, in which particles have opposite charge signs are mixed, for example, powdered ion exchange resin (the mixture of powdered cation exchange resin and anion exchange resin) couldn't be treated so effectively by this method. So, it was necessary to develop an enhanced electro-osmotic method to treat such sludge.

It is well known that water has a large dipole moment and is attracted to cations (mainly Na^+ ions) to form hydrated ions. This action would assist the dewatering from the sludge, if the separation between water molecules and Na^+ ions could be made possible by a membrane filter. Figure 1 shows the mechanisms for this method. While Na^+ ions, contained in electrolyte solution, transfer from the cathode to the anode passing through the cation exchange membranes, water molecules in the sludge are accompanied by Na^+ ions. These molecules (hydrated ions) can be passed through a filter cloth. However, these can't be done through a cation exchange membrane, locate adjacent to a filter cloth. So, only Na^+ ions pass through, the other water molecules are separated in the surface of this membrane and discharged. Also, if the sludge is subjected to an electrical field of appropriate strength, the charged particles migrate toward an oppositely charged electrode and the water in the sludge moves oppositely, due to electro-osmotic forces. This electric field will cause particles to move away from the permeable electrode (filter cloth), so more rapid dewatering can occur without clogging the filter medium. The marriage of the two dewatering mechanisms enhances the dewatering rate and overall moisture reduction.

EXPERIMENTAL APPARATUS AND PROCEDURE

The apparatus used in this work is shown in Fig. 2. It consists of an acrylic resin cell (100mm x 100mm) [8], filter cloth [7], cation exchange membrane [6], and electrodes [4]. Both electrodes are made of perforated platinum-plate titanium with 3mm hole diameter. Na^+ ions are supplied from the electrolyte solution (sodium sulfate solution) [3]. Powdered ion exchange resin, amorphous iron hydroxide and iron oxide were used as the simulated sludge in these

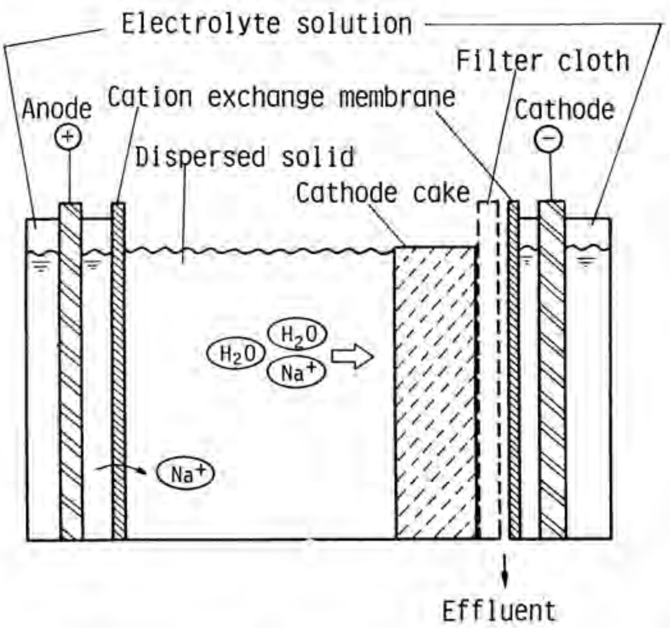

Fig. 1. Enhanced Electro-Osmotic Dewatering Mechanism.

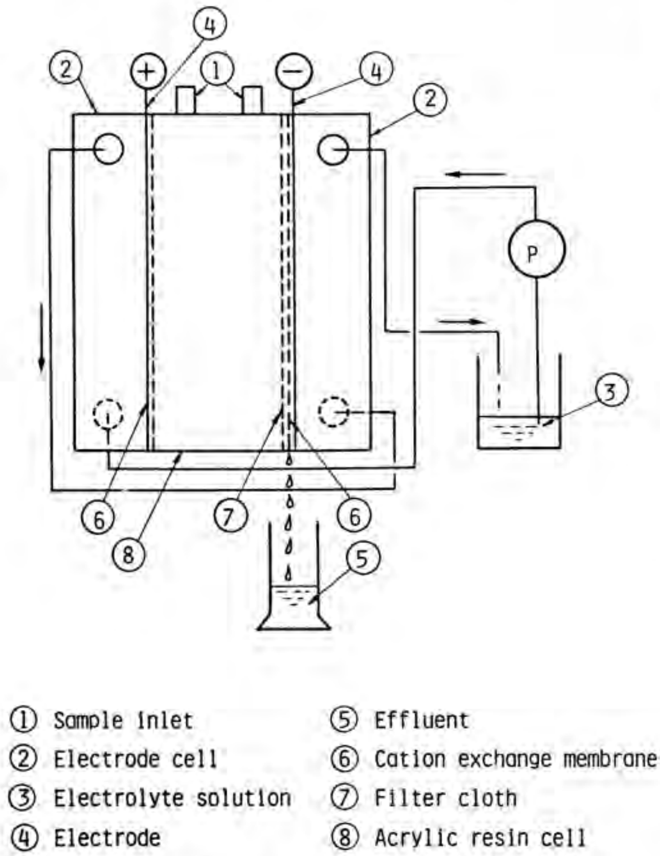

Fig. 2. Experimental Apparatus Diagram.

experiments. Their properties are listed in Table I. Also, the zeta-potential polarity for each solid particle is shown in Fig. 3.

The sludge is adequately mixed with deionized water and is poured into the cell from the sample inlet [2], as shown in Fig. 2. The electric fields, under constant voltage or constant electric current conditions are applied to the sludge bed by a regulated D.C. power supply and current or voltage is measured. The dewatering rate (Q) is determined by the amount of water which was discharged from the electric cell as effluent. Also, both moisture content and dewatered sludge volume were measured.

RESULTS AND DISCUSSION

Dewatering characteristics for powdered ion exchange resin

For powdered ion exchange resin sludge, dewatering rate Q and t are shown in Fig. 4. This figure shows that this, method is effective for dewatering such sludge. The arrows in Fig. 4 show that sludge feed stopped at this point. Before this, point sludge was fed continuously at the same flow rate as that for the dewatering rate. After the cell was filled with sludge, the sludge feed was stopped and only sludge contained in the cell was dewatered. C/A means the ratio of powdered cation exchange resin and anion exchange one by weight. The more the ratio of cation resin increases, the less the dewatering rate decreases. This phe-

TABLE I

Simulated Sludge Properties

Contents	Initial Solid Conc. (g/dm^3)	Average Particle Size ($x10^{-6}m$)	Zeta-Potential Polarity
Powdered ion exchange resin		Cation resin: 11	negative
		Anion resin: 8	positive
	8-92		
Iron compound mixture (A / B = 8/2)			
A. Amorphous iron hydroxide B. Ironoxide		2	Depends on pH (Refers to Fig. 3)

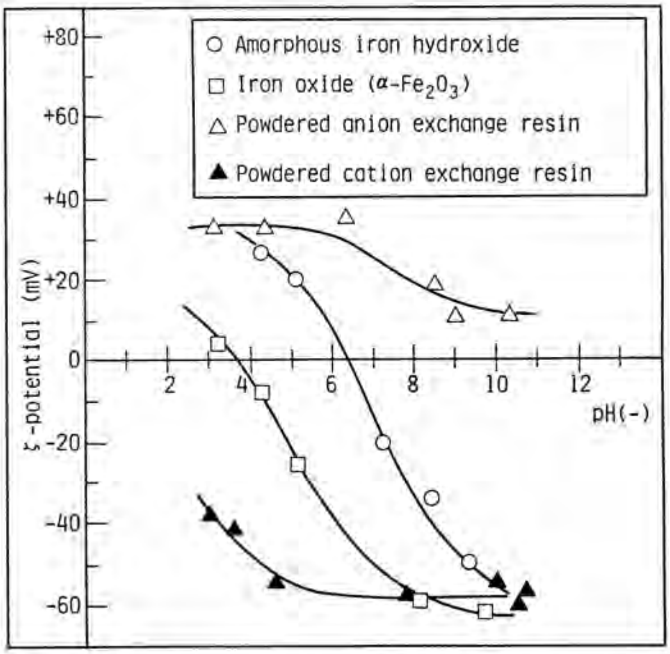

Fig. 3. ζ - Potential Polarity for Each Solid Particle.

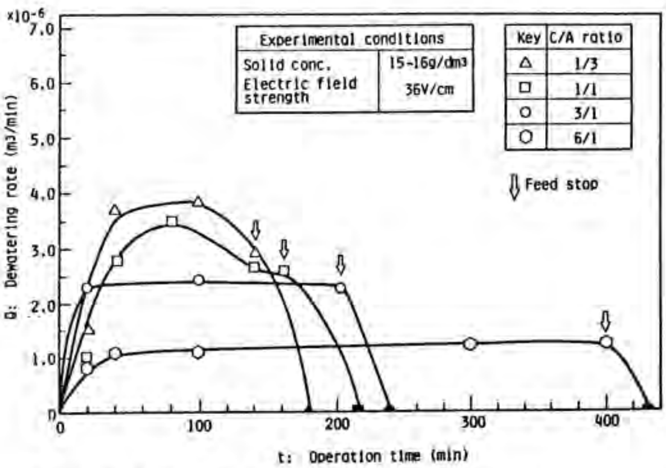

Fig. 4. Relations Between Q and t under Constant Voltage With Powdered ion Exchange Resin.

nomena was considered to be that the greater amount of cation resin catches Na^+ ions more easily during their transference from the cathode to the anode.

Dewatering characteristics for powdered ion exchange resin containing simulated crud

It is necessary to know the dewatering characteristics for the mixture of powdered ion exchange resin and simulated crud, because actual waste sludge, generated

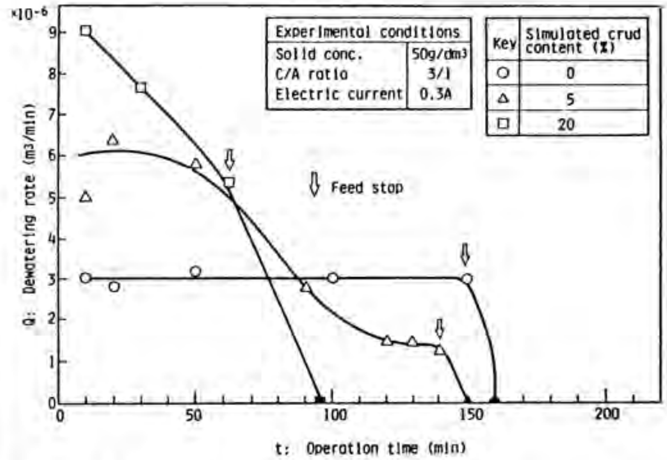

Fig. 5. Relations Between Q and t Under Constant Electric Current With Powdered Ion Exchange Resin and Simulated Crud Mixture.

from nuclear power stations, contains such materials. The result is shown in Fig. 5. It was found that dewatering characteristics vary with the amount of crud contained in powdered ion exchange resin. More crud makes the dewatering rate higher. Considering the polarity of zeta-potential for simulated crud particles, these have negative polarity at the pH region, where the work was done. Therefore, simulated crud was dewatered also by the electro- osmotic force on the surface of a filter cloth. This force accelerates the dewatering rate.

ELECTRO-OSMOTIC DEWATERING PROPERTIES

Table II summarizes the data, compared with dewatering by enhanced electro-osmosis and that by gravitation. It was found that this technique can be more effective than the force of gravity. Enhanced electro-osmotic dewatering rate is about 5 to 20 times that for gravitation. Product moisture is about 55 to 75 % and sludge volume could be reduced by approximately 1/10 to 1/20. The other filter medium sludge, for example, solka flock, were also dewatered effectively.

Scale-up test

A cylindrical dewatering vessel was made and some scale-up tests have been carried out. This vessel was simulated as a drum package container with about 3 liter volume. In this system, any other parts, except for an acrylic resin cylinder, which is the waste container, are capable of

TABLE II
Electro-osmotic Dewatering Properties

Method / Items Sludge	Enhanced Electro-Osmotic Dewatering PR	C	PR + C	Gravimetric Dewatering PR	C	PR + C
Relative dewatering rate (-)	1	5	1	5	50	20
Product moisture (%)	55	74	65	90	92	90
Volumetric reduction ratio	20	10	20	9	3	8

PR: Powdered ion exchange resin

C: Simulated crud

PR + C: Mixture of powdered ion exchange resin and crud

$$\text{Volumetric Reduction Ratio} = \frac{\textit{Feed sludge volume}}{\textit{Dewatered sludge volume}}$$

being taken out at one time including electrodes and reusing for another container. The test data is good and increasing the scale is not so difficult for the actual size drum package (200 liter scale). This system enables dewatering sludge contained in drum packages automatically and safely.