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Research Article

Electroosmotic Dewatering of Iron Ore Tailings: A Laboratory Study to Improve Geotechnical Properties

Salih Yüksek

Department of Civil Engineering, Sivas Cumhuriyet University, Sivas 58140, Turkey

Correspondence should be addressed to Salih Yüksek; syuksek@cumhuriyet.edu.tr

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Minerals are subjected to ore processing to turn them into usable and saleable raw materials. First of all, the ore is reduced to the smallest size with the crushing-grinding process, and after using water and chemical additives, according to the characteristics of the ore, useful minerals are taken, and unwanted minerals are stored in the tailings pools. Approximately, 26 million tons of mineral wastes were generated annually from ore processing facilities in Turkey. The construction of tailings pools, the stability of the tailing sludge, and the safety of dams are a burdensome issue faced by miners. In the ore plants, an average of 3 tons of water is used to enrich 1 ton of ore, and most of the wastewater cannot be removed by traditional methods, causing various economic, environmental, and stability problems. In this study, the dewatering of an iron ore tailing by applying different voltages by the electroosmosis method was investigated in the laboratory environment. By discharging the water of the iron ore tailings by the electroosmosis method, the solid content was increased from 43.01% to 87.63%. Thus, it has been observed that there will be a significant improvement in the geotechnical properties of the tailings' material. It has been estimated that electroosmotic dewatering rises with increasing the voltage gradient and the energy consumption varies in the range of 0.588–30.645 kWh/dry ton. The void ratio decreased from 5.58% to 0.23%. In the dewatering experiments, different parameters such as the amount of water discharged, density, void ratio, water content, and power consumed were measured or calculated and the relationships between them were discussed with graphics. In electroosmosis experiments, it has been observed that besides the voltage applied in the discharge of water, the mineralogy of the tailings has a significant effect. Since there are serious abrasions on the electrodes used in the experiments, alternative electrodes should be tried.

1. Introduction

While the mining industry is growing rapidly in the world, it also causes a wide variety of social and environmental effects [1]. Mineral processing facilities produce two types of products, categorised as either economic or noneconomic. The noneconomic product, usually known as tailings, consists of waste (by-product), small quantities of valuable minerals or metals, chemicals, organics, and process water [2]. It is emphasized that with the increase in the production of low grade ores in the future, it is inevitable to produce higher tonnage of tailings, and in 2010, approximately 14 billion tons of waste was produced globally by the mining industry [3]. In the mining industry, the growing demand for mineral products and the accumulation of large amounts of fine mineral tailings generated by mega-scale mining operations are still an ongoing problem [4]. Many tailings contain significant amounts of fines with clay minerals that slowly settle under self-weight consolidation. These tailings with high water content and low shear strength cause instability [5]. The construction of large tailing dams is required for the storage of wastes, and the mining investors are faced with the geotechnical and geo-environmental problems of these tailing storage facilities. In some tailing storage facilities, highly wet tailings with low solids have been deposited. Many years after placement of tailings, the water content remains relatively high, resulting in high risks of instability and extremely difficult rehabilitation [6]. In fact, collapses and landslides have caused great damage to many mine tailing dams in the world [7–9]. The role of water in mineral processing is important, and an average of 3 tons of water is used to enrich 1 tonne of ore, and sometimes, the used water can be fed back to the plant. Paste thickening equipment has been developed and used in the dewatering and thickening of tailings in coal preparation facilities. High frequency screens, thickeners, filters, centrifugal pumps, and geosynthetic pipes are widely used to remove water from tailings and reuse water in some tailings [10]. Sieves from these methods are used for solid-liquid mixtures with particle sizes larger than 0.3 mm, while other methods are used for mixtures with finer particle sizes. The water content of tailings, which are thickened with thickeners or filters and turned into pulp slam or paste, is reduced to 65–75% and even 35–45% [11, 12].

Before disposal, the mining tailings accumulated in the waste pool/dam are dewatered, concentrated, the water content is lowered, and the shear strength resistance is increased, reducing the cost of closing the dam, and these tailings should be easily transported to places that will not pollute the environment. Dewatered, thickened, or pasty tailings can be used as filling material in underground mines [13]. On the other hand, since the volume of dewatered tailings decreases and their shear strength increases, it is possible to store the tailings in suitable environments without the construction of a tailing dam [14].

Mineral processing tailings typically contain significant amounts of colloidal and ultrafine particles, mainly clay. Due to the layered structure of the clays, the adsorbed water cannot be dewatered by gravity methods. These clays often cause significant problems in the dewatering of tailings, with slow settling rates and poor consolidation [15]. Electroosmosis has been given the most attention in geotechnical engineering because of its practical value for transporting water in fine-grained soils. It has been used for dewatering, soft ground consolidation, grout injection, and the containment and extraction of chemicals in the ground [16].

The first studies on the use of the electroosmosis method for the dewatering of mine tailings were carried out by the United States Bureau of Mines (USBM) and led to further studies [17–19]. The electro-osmotic dewatering method, which is actually one of the electrokinetic processes, was first applied by Casagrande [20] in the 1930s. He determined that the water in the ground moves from the anode to the cathode when the direct current is transmitted to the ground, and he directed the flow towards the excavation surface towards the excavation thanks to this technique. This method, which was initially used for soil improvement and slope stability, has started trial applications in the laboratory and in the field for the dewatering of mine tailings in the following years. However, disadvantages such as corrosion of the electrodes used in this method and high electricity costs cause it to be not accepted by the mining entrepreneurs. However, Fourie et al. [6] demonstrated in their laboratory and field studies that this problem can be overcome by using geosynthetics developed to prevent corrosion of electrodes.

There are many successful studies in the literature on the dewatering of tailings. Lockhart [21] stated that sand washing plants, kimberlite, and tin recovery facility tailings can be dewatered in the laboratory by the electroosmosis method, but kimberlite tailings are not dewatered well due to their high alkaline content, and other tailings can be obtained in the form of cakes. Chen et al. [22] observed in the electroosmotic dewatering experiments of three different mine wastes that the water removal increased with the increase of the zeta potential, and the applied pressure had no effect on the velocity of the discharged water. Shang and Mohamedelhassan [23] investigated in the laboratory that a sand mine tailing can be dewatered and water recovered by electrokinetic dewatering. Very fine grained glass sand plant tailings, which are dewatered to some extent by high pressure filters, are dewatered by the electrokinetic method, and a hard cake is obtained [24]. In the dewatering of petroleum sand tailings, it was observed that the water content of the tailing samples decreased and there were significant overall increases in shear strength, along with significant changes in tailing plasticity [25]. Lee et al. [5] dewatered mine wastes with 83.4% water content using DSA electrodes by applying increasing and decreasing voltages in pressurized and nonpressurized electroosmosis experiments. In Chile, the electroosmotic method was found to be effective in the dewatering of copper plant tailings [26]. Valenzuela et al. [27] obtained lower moisture levels in their electroosmosis experiments for copper leaching than those obtained from gravity drainage tests. By using electrokinetic and electroosmosis techniques together, precious metals are obtained from mine wastes, while at the same time, the water in the tailings can be recovered and fed back to the plant [28].

Electro-osmosis is actually one of the electro-kinetic processes, and it is called the movement of very fine-grained tailings or water in the environment from the anode to the cathode with the help of direct current. When direct current (DC) is supplied to the system, electrophoresis and electromigration events occur together with electro-osmosis in the environment. Electrophoresis is the movement of charged suspended solids in a liquid due to an applied electrical potential gradient. Ionian migration is defined as the movement of charged soluble ions in the pore fluid caused by an applied electric potential. The conceptual model of electrokinetic processes is clearly shown in Figure 1. The theoretical explanation of electrokinetic and electroosmosis phenomena has been explained in detail in the literature [15, 30–33]. Researchers have shown that many factors such as soil content, pH and zeta potential, electrode type, applied electric field, and conductivity of the medium affect electrokinetic processes [34–38]. Shang [39] states that electroosmotic permeability depends on a number of factors including tailing mineralogy, void ratio, zeta potential, applied voltage, and current. In electroosmotic permeability, the zeta potential is a variable parameter that depends on the salinity and pH of the water. The tailings normally have a high negative zeta potential, which is ideal because it indicates a high potential for flow. Increasing pore water salinity reduces the zeta potential [40].

In this study, tailings from an iron ore mining process in Sivas, Türkiye, were characterized in terms of their physical, mineralogical, and chemical properties. Then, an experimental study of electroosmotic dewatering was carried out using steel and copper electrodes. The research focused on the effectiveness of the electroosmosis method of highly wet iron ore tailings.

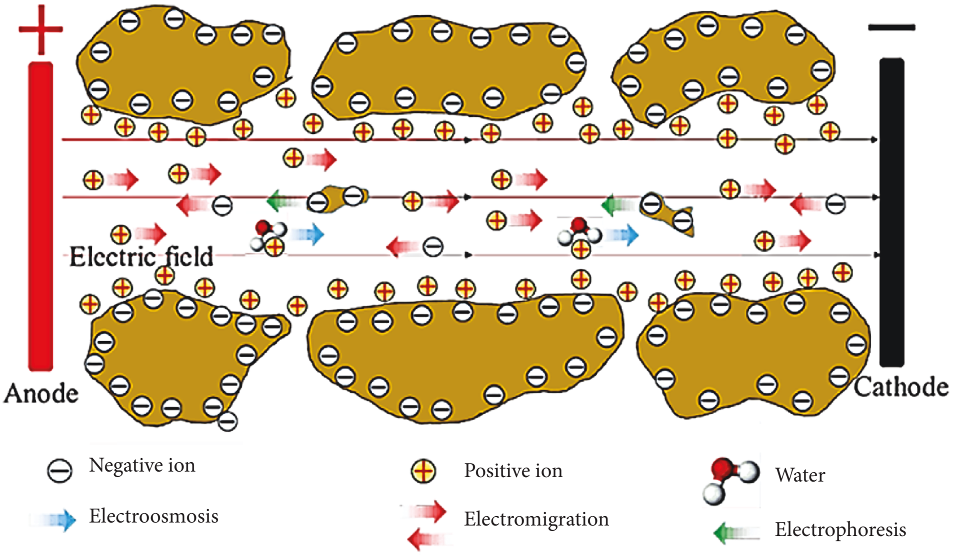


Figure 1: Electrokinetic processes [29].

2. Materials and Methods

2.1. Materials. The iron ore tailings to be used in the electroosmosis experiments were obtained from an ore processing waste dam near Sivas province. The iron ore with an average of 56% Fe grade brought from the mine is ground under 2 mm in rod mills and hydrated to 65% Fe concentrate grade and fed to magnetic separators. The remaining material is thrown out of the system with water. The tailings of the facility, which is approximately 300,000 tons per year, are stored in the existing waste dam, solids are precipitated, and free wastewater on the surface is removed [41]. Currently, the tailing facility is about to fill up and the Ministry of Environment has requested that studies be carried out for dewatering of the tailings, ensuring the safety of the tailing facility, and minimizing its risk. Despite the long-term settlement of highly wet iron ore tailings, the water content remains high and the volume is filled in a few years (Figure 2).

2.2. Characterization of the Tailing Material. The tailings material taken from the waste dam was brought to the laboratory, and the physical, mineralogical, and consistency limits of the waste were determined. SEM image, EDX, XRD analysis, master sizer, and Atterberg limit analysis of the iron ore waste sample were performed. The TESCAN MIRA3 XMU device was used for SEM and EDX analyses. In the scanning electron microscope (SEM), the image focuses on high-voltage accelerated electrons in the sample, collects the effects caused by various interferences between electrons and sample atoms during scanning of this electron beam on the sample surface, and transfers them to the screen of a cathode ray tube after passing through signal amplifiers. The samples used in the experiment were coated with Au. The Malvern Master Sizer 3000 brand device was used for particle size analysis. With this device, it offers the opportunity to determine particle sizes from nanometers to millimeters in both dry and wet samples. The Master Sizer Hydro 3000 device analysis process is based on the determination of particle size by taking into account the scattering angle and intensity of the light obtained as a result of the reflection and refraction of the laser light sent to the sample.

Figure 2: Discharge of iron ore processing waste into the waste pond.

The iron tailings sample was properly prepared, and dimensional analysis was performed. The RIGAKU Miniflex 600 device was used for X-ray diffraction (X-RD) analysis. In this method, each crystal is based on the principle of refracting X-rays in a characteristic sequence depending on the atomic sequences of the phase. For each crystal phase, these diffraction profiles are a defining feature for that crystal. The X-ray diffraction analysis method does not damage the sample during analysis and allows the analysis of even small amounts (liquids, powders, crystal, and thin films). With the X-ray diffraction device, qualitative and quantitative investigations of rocks, crystalline materials, thin films, and polymers can be made.

In fine-grained (cohesive) environments, the softness and hardness of the soil are specified by the consistency limits. The consistency limits the change in a wide range from very rigid to fluid consistency as the amount of water in the soil sample increases. Accordingly, great differences occur in engineering properties such as strength, strain, and compression. Some boundary water content values have been defined to experimentally determine changes in the consistency of water content in the consistency of fine-grained soils. The experiments developed by the Swedish scientist Atterberg are known as the consistency limits, and these are the liquid limit (LL), plastic limit (PL), and plasticity index (PI) values [42].

2.3. Experimental Setup and Electro-Osmosis Experiments. For electro-osmosis tests, a glass cabinet with dimensions of 36 cm × 20 cm × 6 cm (total 4320 cm^3 volume) was manufactured. The glass assembly is placed on a steel table to remove the water drain from the bottom (Figure 3). The perforated copper cathode (−) rod to be used as a drainage well is mounted in the middle of the experiment cabinet with silicone gaskets. A ball valve is also attached to the end of the cathode copper tube to ensure water drainage. A perforated steel plate is used as the anode (+) rod to allow the water and gases to pass through. During the experiment, a clean gravel zone was created in the area of 6 mm diameter outside the cathode (−) perforated copper pipe, which will be used as a drainage well, in order for the water to flow better into the well and to act as a filter.

Before starting the electro-osmosis experiment, the tailing material was placed in the experiment cabinet and the valve was opened and the water in the tailings was allowed to drain by gravity. This process was covered with nylon stretch to prevent evaporation until the water flow was completely finished and waited for 24 hours. After the water flow was completely finished, the initial properties of the soil were determined and recorded by taking samples to determine parameters such as the initial water content and density of the material. Then, electro-osmosis experiments were started, and initially, it was adjusted to have an electric field of 0.5 V/cm from the adjustable power source to the system. It has been observed that the water in the ground slowly moves towards the copper pipe with the electro-osmotic event. During the experiment, parameters such as the amount of water accumulated in the beaker under the valve, the water flow rate, and temperature of the environment were measured by keeping time with a timer. The durations of the experiments vary between 165 and 225 minutes depending on the applied voltage range. After the electro-osmotic water flow stopped, the experiment was terminated and the properties of the soil were determined after the sample was taken and written on the test form paper. In the same processes, DC electricity was supplied to the system from an adjustable power source to create an electric field of 1 V/cm, 1.5 V/cm, 2 V/cm, 2.5 V/cm, and 3 V/cm, and the water discharged from the system and other parameters were measured and recorded.

3. Results

In electro-osmosis dewatering, it is stated that the amount of fine grains of the tailings, the ratios and types of clay, and other minerals and elements are effective. For this purpose, such properties of iron ore tailing material were determined before electroosmosis experiments. The SEM image of the tailing material, EDS, XRD analysis, size analysis, density, water content and consistency limits, and electro-osmosis test results are summarized in the following paragraphs. The SEM image and the EDS analysis chart to determine the content and microstructure of the iron ore tailings are shown in Figures 4 and 5. It is generally understood that the tailing material consists of magnetite, quartz, zeolite (clay) minerals, and iron complex compound grains. The presence of zeolite in the sieve tissue of the waste suggests that water can also be adsorbed in these cells. The SEM image shows that the tailing material contains widespread voids. According to the EDS analysis, it was determined that the iron tailings contain the peaking components Ca, K, C, O, Fe, Mg, Al, and Si, respectively (Figure 5).

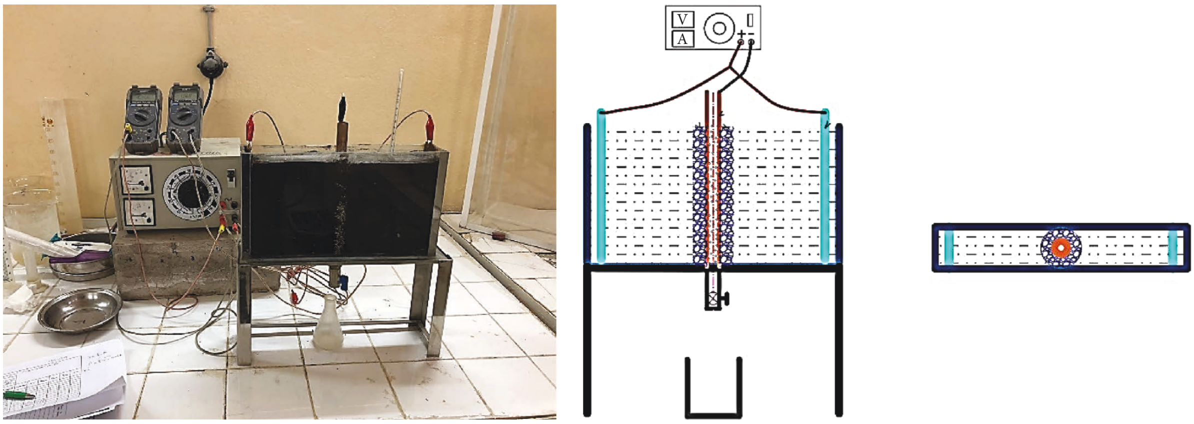
Dimensional analysis-master sizer results and the distribution chart of five iron ore tailing samples are shown in Figure 6. It was observed that 10% were greater than 9.81 μm and 90% less than 146 μm. According to the results of this analysis, the tailing material consists of very fine grains.

The results of the XRD analysis performed to determine the iron ore tailing components are given in Figure 7. Magnetite (Fe_3O_4), quartz (SiO_2), and zeolite (Na, Alumina Silicata) minerals were determined in the tailings, and XRD analysis was found to be compatible with chemical analysis and EDS analysis.

As can be seen from the XRD graph, it was determined that there were two or more different mineral overlaps in the peaks. It can be thought that the residual phases other than the main phases in the graph come from the solution body or from other sources.

As can be seen in Figure 6, the presence of Al and Si peaks in the analyses is due to the presence of zeolite and other clay minerals in the tailing material. Bentonite, olivine, and lime are used as binders in the pelleting process in the iron ore pelletizing and concentration facility. There is a possibility of discharge to the tailing facilities from the bentonite residue used in the pelletizing plant.

The fact that the tailing material contains clay minerals has led to the determination of consistency limits. It is important to determine the consistency limits of the strength properties of the tailing material. As a result of the Atterberg experiments, the liquid limit of the iron ore tailing was determined as 25%, the plastic limit as 18.75%, and the plasticity index as 6.25. According to the plasticity classification of soils by IAEG [43], it was seen that the iron ore tailing sample was in the “ML” class and the plasticity index was in the “low plasticity” class. The characteristics of the iron ore tailings, detailed in the above paragraphs, are summarized in Table 1.



(a) (b)

Figure 3: Photograph of the electro-osmosis experimental setup: (a) and cross section and plan diagram (b).

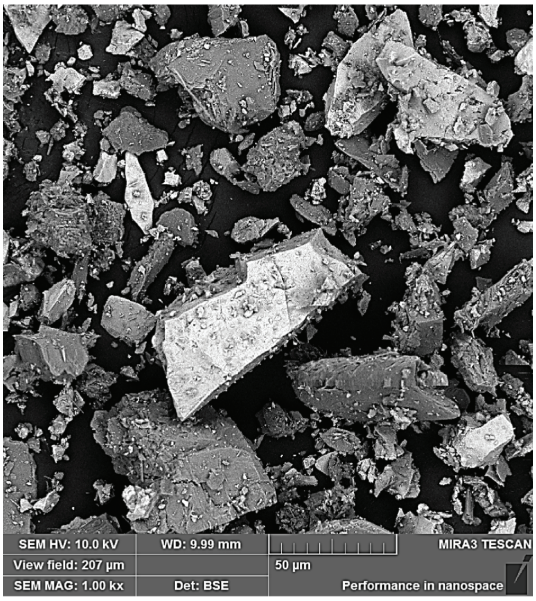


Figure 4: SEM images of the tailings. Magnetite, quartz, and zeolite minerals.

Individual tests were carried out for 15 V, 30 V, 45 V, 60 V, 75 V, and 90 V for electro-osmotic dewatering of iron ore tailings whose characterization was determined. In the electro-osmosis experiments, parameters such as the average temperature of the iron ore tailings, electric current, electrical resistance, electrical conductivity, consumed power, unit weight, void ratio and water content, water discharge amount, and discharge rate were measured and calculated for each voltage range. The test results are given in Table 2.

The solid content of iron tailings, which was 43.01% at the beginning, has been achieved with electro-osmosis experiments, varying between 48.66% and 87.63%, depending on the voltage range applied. The solid content of 87.63% indicates that a very good value has been reached with an increasing consolidation of the tailing material. For each voltage range, power or energy is calculated in watts multiplied by voltage and current according to Joule's law and is given in the last row of Table 2. The energy consumed for 1 ton of dry tailings was calculated in proportion to weight of the tailing material in the experiment cabin and is shown in Table 2. Here, the volume of tailings used in the experimental setup (34 cm × 15 cm × 6 cm) is taken into account as 3060 cm^3 in calculations. Naturally, with the increase in applied voltage, the energy consumed for dewatering each ton of wet tailings increased. As can be seen from Table 3, the estimated energy consumption varies between 0.588 and 30.645 kWh/dry ton for 1 ton of tailings that is relatively dried at the determined humidity.

4. Discussion

Results such as initial and final solid contents and energy consumption obtained from some studies on the dewatering of mine tailings are given in Table 3. As can be seen from

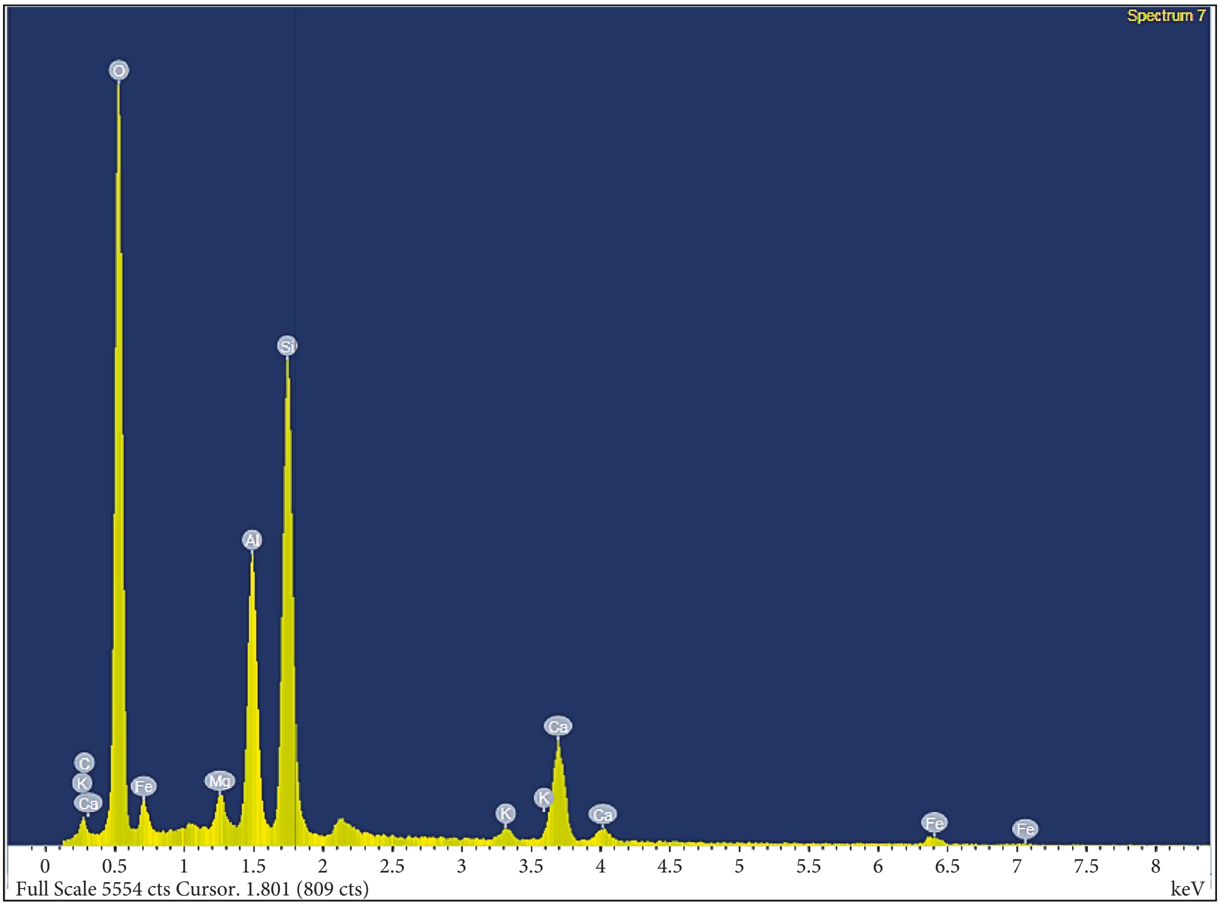


Figure 5: Structural analysis of the element presence in the tailings by EDS.

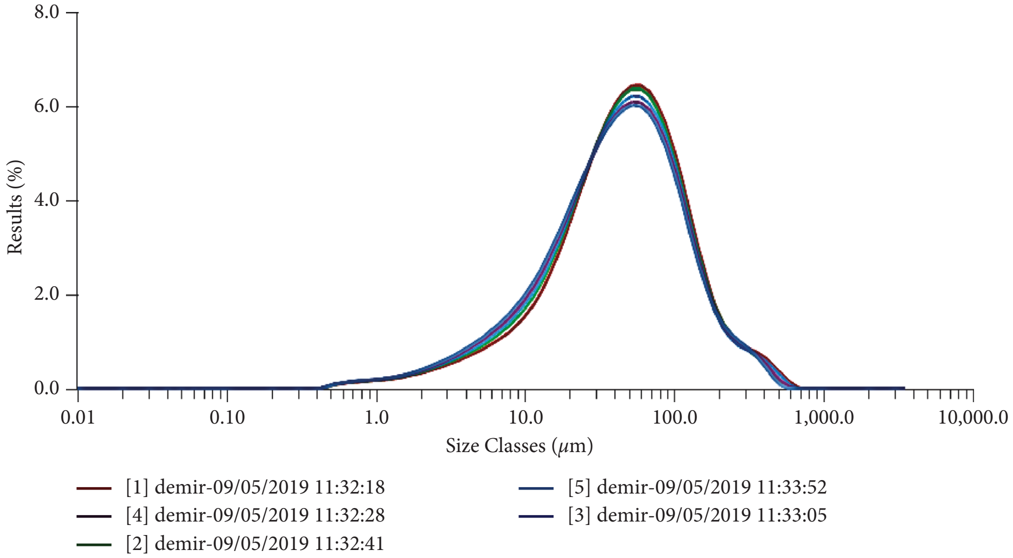


Figure 6: Master-sizer analysis results of tailing material.

Table 2, the energy consumed in the studies is different from each other. Many factors such as the mineralogy of the tailings used, the clay type and content, the ion concentration of the tailings fluid, the experimental setup and boundary conditions, the electrode used and the current gradient, and accurate and precise measurements are effective. For this reason, it is necessary to compare the studies carried out according to their common context.

Despite all this, as can be seen in Table 3, the solid content of iron tailings in this study was better than the

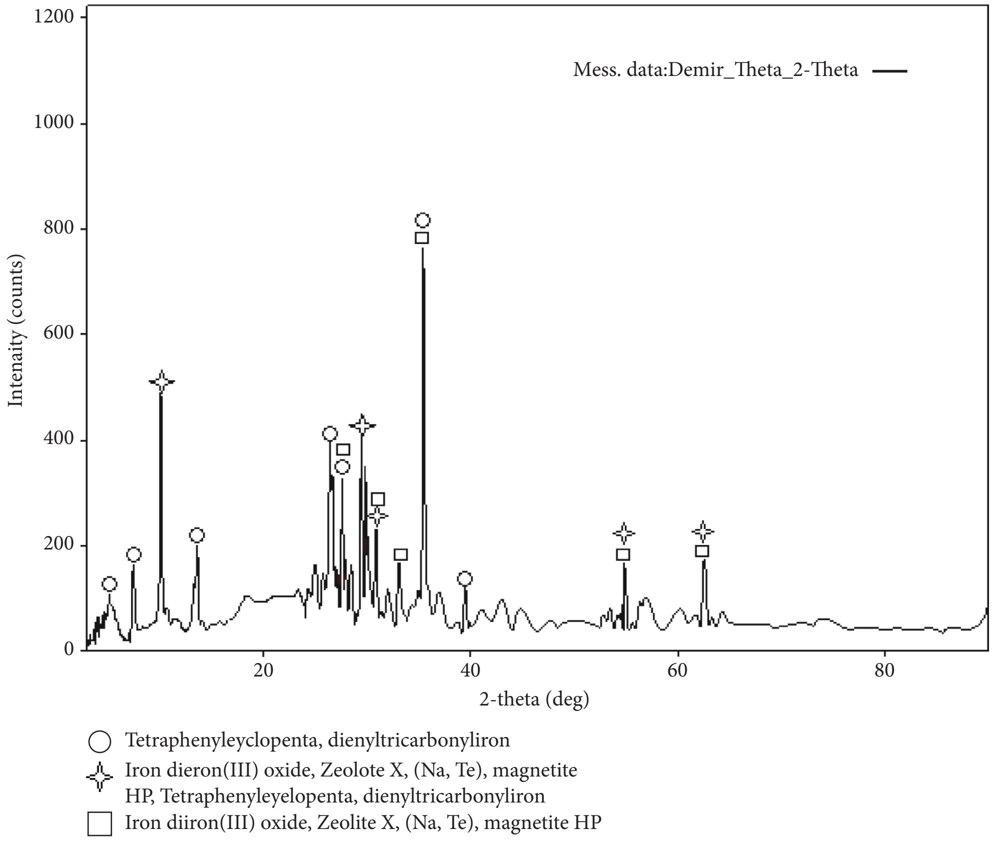


Figure 7: XRD cluster analysis results of the tailing material.

Table 1: Characteristics of analyzed iron ore tailings.

Property	Value
Dry density (g/cm^3)	1.49
Wet density (g/cm^3)	2.34
Mineralogical composition	Magnetite, quartz, zeolite, and iron complex compounds
Chemical composition	Ti % 0.72, Si % 1.46, Fe % 61.30, Mg 1.0%, % Al 0.87 and C % 4.21
Particle size (μm)	Dv10: 9.81; Dv50: 47.0, Dv90: 146
Specific surface area (m^2/kg)	341.9
Atterberg limits	The liquid limit is 25%, plastic limit is 18.75%, and the plasticity index is 6.25 low plastic material
pH	8.2
Water content (%)	56.99

results of other researchers. In addition, it is understood that the energy consumed in the dewatering of iron tailings in this study is dewatered with the lowest energy consumption on a relatively average basis compared to the results of other studies.

On the other hand, in addition to the energy consumption in the dewatering of mine tailings, another economic parameter or problem is the cost of the electrodes used. Different electrode materials have been tried to reduce the high corrosion and voltage losses in the traditional electrodes used in the research works, especially in the anode electrode [52]. Trials could not solve the corrosion problem. The newly developed electrokinetic geosynthetic electrodes (EKG) are used instead of traditional electrodes, and there are a few studies in the literature on longer use [6, 14, 40, 53]. It is planned to be used in field applications in our future studies due to its positive features such as the long life of EKG electrodes and the fact that the pH of the environment does not drop suddenly during electro-osmosis.

Relationships between the measured and calculated parameters were developed according to the results obtained from the electro-osmotic experiments. It was observed in the experiments that the electro-osmotic time increased with the applied voltage and the highest electro-osmotic time was 225 minutes for 90 volts. It was observed that the electro-osmotic discharge gradually decreased at all voltages over time, the cumulative discharge increased gradually, and the highest cumulative discharge occurred when 90 volts of electricity was applied (Figure 8). It was observed that as the voltage increased, the cumulative discharge and the discharge rate

Table 2: Electro-osmotic test results for iron ore tailings: measured and calculated parameters for different voltage ranges.

Parameters	Applied voltage (volt)						
	0	15	30	45	60	75	90
Saturated density (gr/cm^3)	2.336	2.250	2.048	2.004	1.932	1.780	1.670
Dry weight (gr)	37.2	37.2	37.2	37.2	37.2	37.2	37.2
Wet weight (gr)	58.4	56.3	51.2	50.1	48.3	44.6	41.8
Porosity (%)	84.8	76.4	56	51.6	44.4	29.6	18.4
Void ratio (%)	5.58	3.24	1.27	1.07	0.8	0.42	0.23
Water content (%)	56.99	51.34	37.63	34.68	29.84	19.89	12.37
Total discharge (cm^3)	0	31.6	35.2	38.8	40.6	51	77.4
Total discharge time (min)	0	180	165	180	180	195	225
Average discharge rate (cm^3/min)	0	0.1756	0.2133	0.2156	0.2256	0.2615	0.344
Average temperature (°C)	18	19.58	22.36	20.33	22.66	26.07	32.33
Average electric current (amp)	0	0.09	0.15	0.18	0.29	0.39	0.46
Average resistance (ohm)	0	166.67	196.08	255.68	204.78	191.33	193.97
Average conductivity (ohm^{-1})	0	0.006	0.0051	0.0039	0.0049	0.0052	0.0052
Average consumed power (watt)	0	1.35	4.59	7.92	17.58	29.4	41.76
Energy consumption (kWh/dry-ton)	0	0.588	2.014	3.875	8.921	17.542	30.645

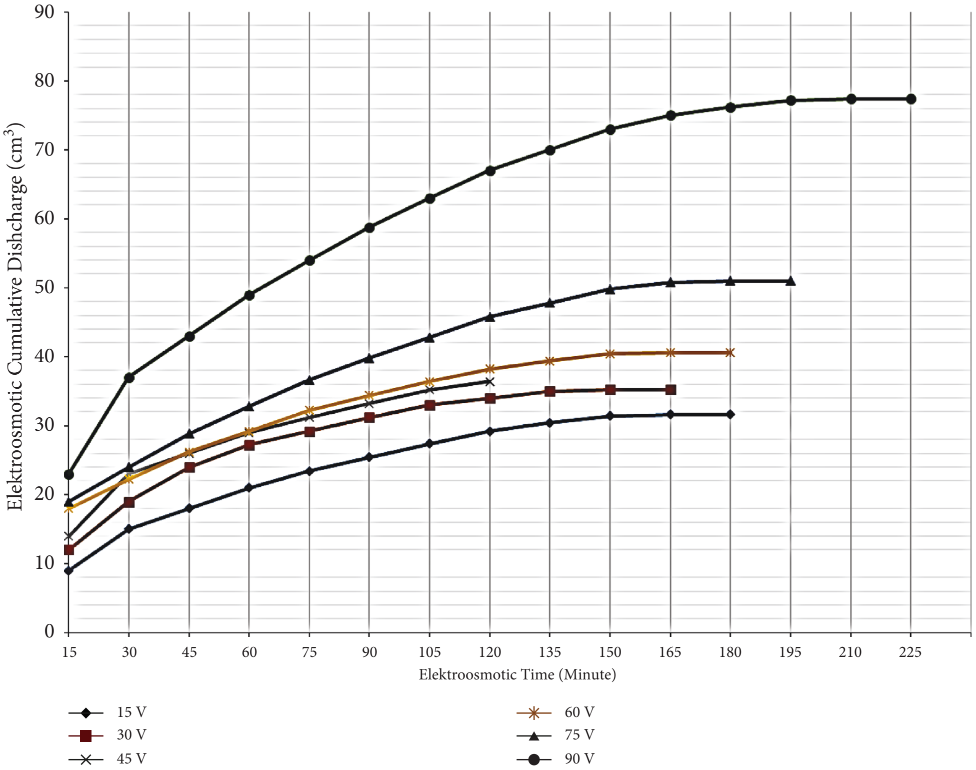


Figure 8: The relationship between electro-osmotic time and cumulative discharge for applied different voltages.

increased, and the discharge rate and discharge amount were the highest at 90 volts. In other words, electro-osmotic dewatering up to 90 volts has been found to be efficient.

As a result of electro-osmosis tests, the porosity and water content of iron tailings were calculated for each voltage range. According to the results obtained, as the applied potential gradient voltage increased, the porosity and water content of the medium decreased (Figures 9 and 10). It has been observed that there is a highly linear negative relationship between electrical potential gradient voltage, porosity, and water content. The filler will undergo particle rearrangement, resulting in a reduction in porosity. Thus, as the water is removed from the tailing material, consolidation is achieved. The amount of consolidation in the tailing material will be taken into account and determined in our next study.

There are studies on the application of in situ electro-osmotic technique in improving the geotechnical properties of soils [54–57]. However, there are very few trials on the in situ plot scale application of mine tailings with the electro-osmotic technique. This technique has been studied mostly on its use in the remediation of mine wastes [58–60].

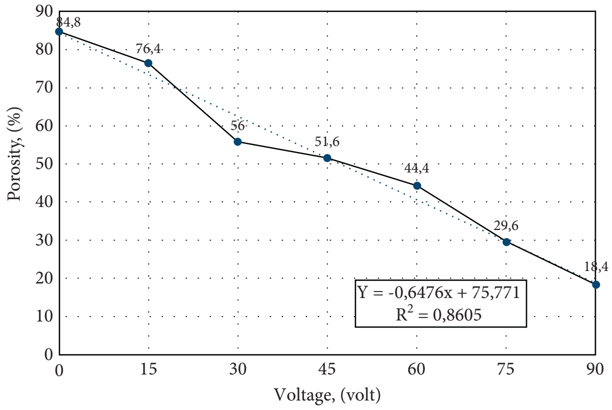


Figure 9: The relationship between applied voltage and porosity.

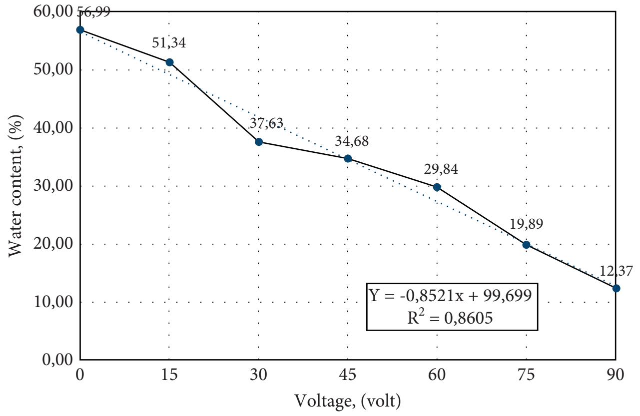


Figure 10: The relationship between applied voltage and water content.

Table 3: Electro-osmotic dewatering of some mine tailings and their solid content and energy consumption.

Tailings	Voltage (V)	Initial solid content (%)	Final solid content (%)	Consumed energy	Reference
Phosphate clay	13–15 V	14–17	25–39	21.3 kWh/dry-ton	[44]
Coal	2–46 V	17	31–35	64 kWh/dry-ton	[19]
Coal	33–40 V	45	75	20–30 kWh/dry-ton	[45]
Kimberlite and tin	16–46 V	8.1		144–880 kWh/dry-ton	[46]
Coal	30–60 V			20 kWh/dry-ton	[47]
Phosphate clay	3–20	13.2	25.7	96 kWh/dry-ton	[48]
Sand	22–50 V	45	67	33–94 kWh/dry-ton	[49]
Sand	10–30 V	% 233 (initial water content)	% 78 (final water content)	38.6 kWh/dry	[50]
Bauxite	5–15V	20–30	43–66	31.4 to 375.2 kWh/m^3	[51]
Iron	15–90 V	43.01	48.66–87.63	0.588–30.645 kWh/dry-ton	This study

he demand for metals is increasing in the world, and as a result, a lot of fine mineral waste is generated. Fine-grained wastes become more difficult to dewater. Trials of on-site application of the electrokinetic waste dewatering technique should be started. At the same time, studies should be started in this field in order to make valuable mineral recovery functional as well as removing water from wastes with this technology.

5. Conclusions

Iron ore tailings containing magnetite, quartz, zeolite, and iron complex compounds can be dewatered to a certain point with conventional methods. In an atmospheric environment, while the upper layer of the tailings dries in the form of a crust, the material with high water content in the form of mud in the lower part often remains, posing an environmental risk. To overcome this situation, it has been observed that the electro-osmosis method can be used efficiently in the laboratory environment in the dewatering of iron ore plant wastes. The following main results were obtained in this study:

(1) In electro-osmosis experiments, it has been observed that besides the voltage applied in the discharge of water, the mineralogy of the tailings has a significant effect.

(2) As in all other studies, as the voltage applied in the experiments increased, the total amount of water discharged from the system and its duration, the resistance of the tailings, and the temperature of the environment increased. In addition, with the increasing voltage range, the unit weight, porosity, and water content of the tailings decreased, and therefore, the tailings were consolidated. In our next study, parameters such as settlement amount, soil shear strength, and internal friction angle will be determined.

(3) Again, with electro-osmosis experiments, the void ratio decreased from 5.58% to 0.23%.

(4) One of the most important parameters is the water content, or in other words, the solid content. In this study, the initial solid content was increased from 43.01% to 48.66%–87.63% according to the applied voltage gradient.

(5) It has been observed in electro-osmosis experiments that as the applied voltage increases, more water is removed from the tailings and the energy consumption varies between 0.588 and 30,645 kWh/dry ton. This result was found to be better when compared to that of some other researchers.

Significant and encouraging data have been obtained for a metallic mine tailing through the experiments, and it is important for preliminary studies. It was observed that there was considerable wear on the electrodes used in the experiments. In our future work, experiments will be made with EKG electrodes in the laboratory and in the field, and the geotechnical properties of the tailing will be investigated.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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