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Improving the dewatering performance of red sludge with alternative methods in Eti Aluminum Plant in Seydisehir, Konya province, Turkey

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Abstract
Recently, alumina demand has increased significantly due to the increment of usage area of aluminum in the world. One ton of red sludge on dry bases has come out as a bauxite residue in the course of 1 ton of alumina and 0.5 tons of aluminum production respectively. Especially the high liquid ratio significantly reduces the life of the red sludge dam used as a disposal area. In this study, alternative techniques have been investigated to improve the dewatering performance of red sludge in ETI Aluminum Inc. For this purpose, the vacuum rotary drum filter, decanter centrifuge, and filter press methods have been searched, and the effects on ETI red sludge dewatering properties have been obtained. The dewatering studies have been performed not only at the laboratory scale but also at the pilot scale to determine the optimum technique and to achieve the most efficient performance. As a result of dewatering the 30% solids red sludge with vacuum rotary drum filter, decanter centrifuge, and press filter methods, solids ratios of 48%, 65%, and 70% were obtained, respectively. While the amount of caustic in the red sludge produced by the present method was between 1.5 and 3%, the amount of caustic remaining in the cake was reduced to 0.22%, 0.15%, and 0.95%, respectively, by vacuum filtration, decanter centrifuge, and press filter methods. Thus, reducing the amount of caustic in the red sludge has reduced its negative impact on the environment, and a significant amount of caustic has been recovered.

Keywords
Bauxite, Red Sludge, Dewatering, Vacuum Filter, Decanter Centrifuge, Pres Filter.

Introduction

While various industrial products are obtained in the world, many waste materials are released as by-products apart from the production purpose. While a significant part is removed from the environment in various ways, some of these materials can be recycled. These materials, which are obtained as by-products or waste and reach large amounts, cause significant environmental problems due to the harmful substances they contain, negatively affecting both human health and the ecological balance of nature.

The increasing use of aluminum in the world has led to increasing demand for alumina. Bauxite, the most important ore of aluminum, contains only 30–60% aluminum oxide (Al_2O_3), the rest being a mixture of silica, various iron oxides, and titanium dioxide (Harris et al., 1998). The aluminum oxide must be purified before it can be refined to aluminum metal. The principal industrial means of refining bauxite to produce alumina is the Bayer process. In the Bayer process, bauxite ore is heated in a pressure vessel along with a sodium hydroxide solution at a temperature of 150 to 200 °C. At these temperatures, the aluminum is dissolved as sodium aluminate. The aluminum compounds in the bauxite may be present as gibbsite ($Al(OH)_3$), boehmite (γ-$AlO(OH)$) and diaspore (α-$AlO(OH)$); the different forms of the aluminum component will dictate the extraction conditions. After the separation of the residue by filtering, gibbsite (aluminum hydroxide) is precipitated when the liquid is cooled and then seeded with fine-grained aluminum hydroxide. This converts the aluminum oxide in the ore to soluble sodium aluminate ($2NaAlO_2$).

According to the United States Geological Survey (2018), the world's bauxite resources are estimated to be approximately 55 to 75 billion tonnes. In addition, alumina production has considerably increased worldwide. China, Oceania, and South America accounted for 54.37%, 15.49%, and 8.27% of the global production of alumina in 2017, respectively, with the rest of the world accounting for approximately 20% (Liu et al., 2015).

Red sludge is a residue that is separated from the sodium aluminate solution as a result of the Bayer process and contains insoluble sodium aluminum silicates, iron, calcium, sodium and titanium oxides. It is usually red due to iron oxides and therefore it is called red sludge. For 1 ton of alumina or 0.5 ton of aluminum metal produced, approximately 1 ton of red sludge waste is occurred (Evans, 2015). According to these values, over 120 million tons of red sludge process waste is generated annually. Red sludge waste also contains rare earth elements such as V, P, Ce, Se, Sc, Ga, Cr, Pb, Cu, Cd, Ni, Mn, Zn, Zr, Nb, U, Th, K, Ba, Sr (Agatzini-Leonardou et al., 2008). These elements are recovered by various methods such as leaching, hydrolytic precipitation, chlorination, crystallization and liquid–liquid extraction, and the remaining residue is used in making cement, etc. (Borra et al., 2015). A maximum of 3% of this waste is recycled. Until today, 3 billion tons of red sludge has been produced as waste from the bauxite ores that have been processed, and a large amount is kept in the dams as stock (Power et al., 2011). These red sludge wastes which are stored in stock by various methods, can mix with groundwater. Preventing caustic mixing in underground waters or cleaning up contaminated waters is a very difficult and very expensive method. Plants that produce alumina solve this problem in two ways. One of them is to stock up on a reliable local area, and the second is to make the whole or part of it available. However, the increasing red sludge over the years and the inability to obtain the liquid contained in this sludge are causing the dam capacity to fill up rapidly. The area covered by the liquid volume in the dams is seriously reducing the life of the dam. Construction of waste dams is very difficult and expensive for a plant.

The harmful effects of red sludge on the environment can be effectively reduced by transforming red sludge into absorbent and other useful products (Narayanan et al., 2018). In recent years, scholars have studied various means, such as the use of microwave, hydrothermal, and chemical conditioning, to achieve the deep dewatering of sludge (Jomaa et al., 2003; Xin et al., 2016; Tao et al., 2019). For example, in practical application, the coagulation process has attracted public attention due to its high efficiency and low cost, and it has been expressed that coagulation efficiencies depend largely on the selected coagulant (Wei et al., 2018; Liu et al., 2020). On the other hand, scientists and researchers are doing much work to remove the environmental and harmful effects of red sludge available. Around 1200 patents and hundreds of technically successful tests have been found to reuse the red sludge (Evans et al., 2012). These studies have been mainly concerned with the recovery of one or all of the compounds containing red sludge, red sludge metallurgy, exploration of its utility in the construction and chemical industries, red sludge dewatering, and reducing environmental impacts. Red sludge can be used as a coloring additive in the production of bricks, tiles and concrete. With the evaluation of this industrial waste, besides preventing of the damage caused by this waste to the environment, economic benefits such as transportation, storage, and prevention of the loss of efficiency will be provided (Kilic, 2013).

The red sludge in the waste of ETİ Aluminum Inc. contains 20% Al_2O_3, 16% SiO_2, 36% Fe_2O_3, 10% Na_2O, 5% TiO_2 etc. in the solid phase, and a maximum of 3 g/L Na_2O and Al_2O_3 in the liquid phase. Approximately 45-48% of the bauxite entering the production process is red sludge. Only 1.6% of the resulting waste is recoverable in various processes and sectors (Arslan, 2016). The remaining amount is kept in the waste dam. This waste is a highly corrosive/alkaline chemical with high ionic strength around pH 12-14 because it contains caustic (NaOH). Therefore, there is a high possibility of harming the environment and all living things. On the other hand, the red sludge in the ETİ Aluminum Inc. facility is subjected to a washing process with a 6-stage thickener system operating with a counter-current principle and then sent to the barrage. The solid ratio of the red sludge received from the final washer is about 25-30%. This rate is very low in today's conditions. Low solids ratio causes to rise in the dam occupancy rate rapidly and also to rise in caustic and alumina losses in the liquid phase. These losses affect the plant negatively from an economic point of view.

Many plants use equipment such as Amphirols to aid in dewatering the sludge in order to compact and consolidate the residue (Evans, 2016). Studies show that there are structural differences between the behavior of the product obtained from conventional thickeners and the product obtained from high-pressure filters (Bánvölgyi and Huan, 2010). Filtration using drum filters and plate and frame filter presses to recover caustic soda produces lower moisture and more handleable bauxite residue have been employed for some 80 years and is now growing in usage. Alunorte (Brazil), Distomon (Greece), Gardanne, Kwinana, and many plants in China have already adopted or planned to adopt plate and frame filter presses (Evans, 2016). The vacuum drum filter method is based on the separation of the liquid and solid phase of the pulp from each other by operating a continuously rotating drum under vacuum. Continuous operation is an advantage of this system. The decanter centrifuge consists of a drum rotating at high speed a helix rotating at different speeds on the same axis with the drum, and the body carrying the elements that adjust the speed difference and rotate with the drive group. Decanters work with higher efficiency compared to old separation systems, saving product, time, and energy (Flottweg, 2009).

Nowadays, universities and industrial establishments attach great importance to the use and recovery of red sludge on a sectoral basis. Dewatering and storing at a high solid ratio of this red sludge will provide a great convenience for subsequent use stages. There have been studies to evaluate red sludge, but there has not been any study on the dewatering of red sludge, especially on an industrial scale. Dewatering units of the industrial scale of the decanter centrifuge method are rapidly becoming widespread (Flottweg, 2009). However, no conclusion has been reached regarding such an application in dewatering red sludge. In line with the results to be obtained, it plans to use the press filter method in Seydisehir (Turkey). As an alternative to existing conventional type thickeners, rotary vacuum drum filter, decanter centrifuge, and press filter methods were investigated, and studies were carried out to determine the most suitable method. On the other hand, this study aims to achieve significant gains, such as preventing caustic loss and reducing natural resource consumption by using less water. Also, dewatering is of great importance when considering the dam occupancy rate. In this study, it has been tried to increase the performance of the existing red sludge in the Eti Aluminum Inc. dewatering plant will be investigated by experimental and pilot experiments.

Materials and Methods

Materials

Eti Aluminum Inc. red sludge was used in the dewatering experiments of red sludge. All studies were carried out with the 6th washer thickener downstream sludge in the last stage of the red sludge washing cycle. XRF (X-ray fluorescence) analysis of the red sludge formed in the Bayer process was obtained using the ARL Advant'x 2098 Quantas device, and the results are presented in Table 1. As seen in the Table 1, the chemical composition of red sludge mostly consists of 36.03 % Fe_2O_3, 18.65 % Al_2O_3, 16.24% SiO_2, 8.92% Na_2O, and 5.05% TiO_2. For XRD (X-ray diffraction) analysis of red sludge, D 5000 Siemens XRD diffractometer was used. The obtained red sludge mineralogical XRD analysis results are shown in Table 2. According to Table 2, mostly hematite and silica minerals are found in red sludge. For the specific surface analysis determination (Brunauer-Emmett-Teller, BET), the Quantachrome Nova 2000e device was used, and the surface area of the red sludge was determined as 28.378 m^2/g. In addition, Malvern Mastersizer 2000 S Particle Size Analyzer was used to determine the particle size distribution of red sludge, and it was determined that the d_{50} value of the red sludge used was 12.8 μm and the d_{99} value was 28.7 μm. Chemical analyses of the solution and filtrate were made with an automatic titration device (Metrohm 809 Titrondo–Potansiometric Titration System). In the analysis performed on the 6th washer downstream sludge, it was determined that the amount of Al_2O_3 in the sludge was 1.5-2.5 g/l, and the amount of Na_2O in the sludge was 1.5-3.0 g/l. Flour + water + sodium aluminate mixture was used as a coagulant, and Nalco 9779, as a synthetic flocculant, was used in vacuum drum filtration experiments. In decanter centrifuge experiments, an anionic polyelectrolyte (Zetag 4120) was added. In addition, the solid ratio of the red sludge sample to be used in the experiments is 28.5%.

Tab. 1. XRF analysis of red sludge sample.

Element	(w/w) %	Component	(w/w) %
Fe	25.22	Fe_2O_3	36.03
Al	9.87	Al_2O_3	18.65
Si	7.58	SiO_2	16.24
Na	6.62	Na_2O	8.92
Ti	3.03	TiO_2	5.05
Ca	2.71	CaO	3.80
Cr	0.06	Cr_2O_3	0.09
Ni	0.04	NiO	0.05

Tab. 2. XRD analysis of red sludge sample.

Red sludge mineral phases	*w/w %*	*Red sludge mineral phases*	*w/w %*
Hematite, Fe_2O_3	40.5	Goethite, FeO(OH)	1.1
Sodium Aluminosilicate hydrate, $Na_6(AlSiO_4)_6.4H_2O$	30.5	Tridimite, SiO_2	1.1
Cancrinite, $3NaAlSiO_4.NaOH$	9.2	Perovskite	0.9
Sodalite, $Na_4Al_3SiO_3O_{12}Cl$	4.3	Rutile, TiO_2	0.7
Diaspore, AlO(OH)	4.1	Boehmite, AlO(OH)	0.6
Calcite, $CaCO_3$	3.4	Anatas, TiO_2	0.3
Gibbsite, $Al(OH)_3$	2.3	Sodium Titanate, $Na_2Ti_6O_{13}$	0.1

Methods

Vacuum filtration test, dewatering test with pilot scale decanter centrifuge method, and press filter tests were carried out to compress the red sludge and remove the liquid phase in it. All these tests were carried out with laboratory and pilot-scale test equipment.

Vacuum drum filtration experiments

Vacuum filtration studies were carried out in two different ways using coagulant and flocculant. Firstly, 8 different tests were carried out by adding a coagulant to the sludge. Before starting the experiment, a coagulant (flour + water + sodium aluminate mixture) was added to the pulp in a way to make 700 gr/ton sludge to assist filtration. In the experiments, a vacuum pump with a vacuum of about 0.65 bar, a special cap, and a filter cloth were used to ensure filtration. In order to measure and evaluate the performance of the experiments, filter cloth type, cake formation time (seconds), cake crack formation time (seconds), drying time (seconds), filtration vacuum (bar), drying vacuum (bar), filtrate amount (ml), filtrate solid amount (mg/l)), washing time (seconds), amount of washing water (ml), type of washing water, the temperature of washing water (°C), amount of washable caustic in the cake (%), cake thickness (mm), cake moisture (%), amount of solid (%), filtration area (cm^2), technical time (seconds), cycle time (seconds), filter capacity ($kg/m^2/h$) and immersion rate of the drum in the chamber (%) were investigated.

In the vacuum test, besides the low humidity, the amount of caustic to be removed from the cake should be at the lowest level. For this reason, condensate (80ºC hot process water) water used in the process was added after the drying phase while testing. After the addition of washing water, the test was continued until the cake became dry again, taking into account the washing time. As a result, filtration tests with filtration cycle times of 30, 40, and 50 seconds were carried out.

Decanter centrifuge experiments

In order to measure and evaluate the performance of the decanter centrifuge (Figure 1) experiments, the results of the amount of the solids in centrate (%) and the number of solids in cake (%) were examined. In the experiments, 2% anionic polyelectrolyte (Zetag 4120) was used as a flocculant. In order to see the flocculant effect on the pulp, the decanter centrifuge experiment was performed in two stages. No flocculant was used in the first stage, and 2% anionic polyelectrolyte was used in the second stage. Centrifugation was applied to both prepared samples with the centrifuge device in the laboratory for 5 minutes with the effect of 3000 G (Gravity) centrifugal force. Similar experimental studies were carried out with a pilot-sized decanter centrifuge installed in the facility. Figure 2 shows the installed decanter centrifuge. The working conditions of the decanter centrifuge are given in Table 3.

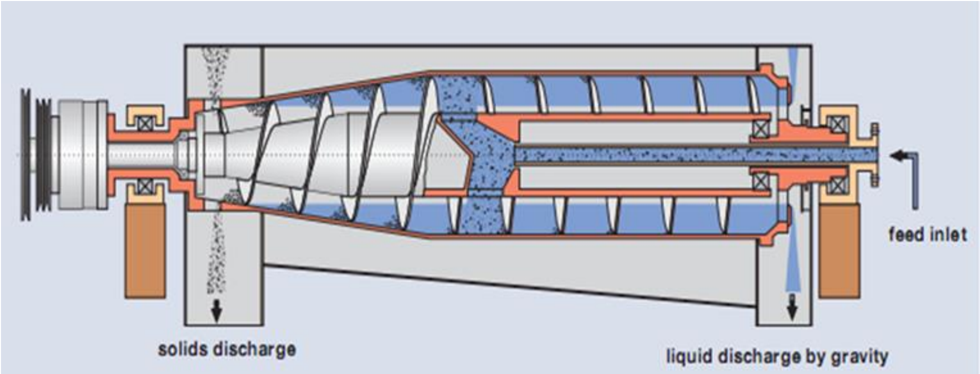

Fig. 1. Decanter centrifuge (Flottweg, 2009).

Fig. 2. Pilot-sized decanter centrifuge unit.

Tab. 3. The working conditions of the pilot-sized decanter centrifuge.

Equipment	Features	Work conditions	
Decanter	20/50 m^3/hour, 3400 rpm, 3-phase	Energy	150 kW
Flocculant tank	3000 litters with agitator	Water	4 Bar
Feed pump	22 kW, mono pump	Feed line	4 Bar
Power cord	3x50 + 25 Copper cable	Flocculant	25 Kg

Press filter experiments

Press filter works are divided into two. In the first stage, a press filter belonging to a domestic company was used, and in the second stage, a press filter belonging to a foreign company was used. Both pilot units have differences such as feeding pressure, feeding capacity, compression pressures, cake washing systems, and filtration surface areas. First-stage filter tests were performed with a manual press filter at the pilot scale shown in Figure 3. The press filter consists of 5 flat plates (chamber type). There is a diaphragm pump with a filtration volume of 3 dm^3 and a feeding capacity of 7 bar. It also has a manual hydraulic unit with a press pressure of 14 bar. Afterward, a pilot scale press filter design was made for the plant (Figure 4). The pilot press filter consists of 5 plates with dimensions of 1000x1000 mm and has a total filtration surface area of 6 m^2. The press filter plates are designed as mixed-pack flat type (chamber) and membrane type. Plates made of polypropylene material can withstand temperatures of 90 °C. The press filter also has air cake drying and cake washing features. In the tests, filter cloths with a monofilament woven structure and an air permeability of 12 l/dm^2/min were used. In order to measure and evaluate the performance of the experiments, the results of the filtration area (m^2), cake washing time (seconds), cake drying time (seconds), membrane compression time, membrane pressure (bar), total filtration cycle time (minutes), cake thickness (mm), moist cake weight (kg), cake moisture (%), cake separation, filtrate suspended solids (mg/l), washable caustic content (%), cake washing water amount (m3/ton) and specific filtration rate (kg/m^2/h) results were examined.

Fig. 3. Laboratory sized press filter.

Fig. 4. Pilot sized press filter installed in the red sludge washing circuit.

Results

Vacuum Drum Filter Method

<u>Vacuum filtration experiments using only coagulant</u>

The % solid amounts of the cakes obtained from the tests are given in Figure 5. When Figure 5 is examined, it is seen that the solid ratio, which is about 30%, has increased to 45-48%. In addition, the results were more successful in the tests performed with the cake wash. In Figure 6, the filtration capacity values obtained according to different filtration conditions are shown. It is seen that the cycle time of the filter increases as the cake washing system is switched to and the cake washing time increases, while the filtration capacity decreases in return. As can be seen from the Figure 6, a filtration rate or capacity of approximately 317 to 405 kg/m^2/h is obtained. Figure 7 shows the remaining amount of washable caustic in the cakes obtained. While the amount of washable caustic was around 0.5% in the tests without washing, this amount decreased to 0.18% according to the washing water ratio in the tests with washing. It is understood from here that the washing process must be done in the filters to have caustic recovery in the vacuum filtration method.

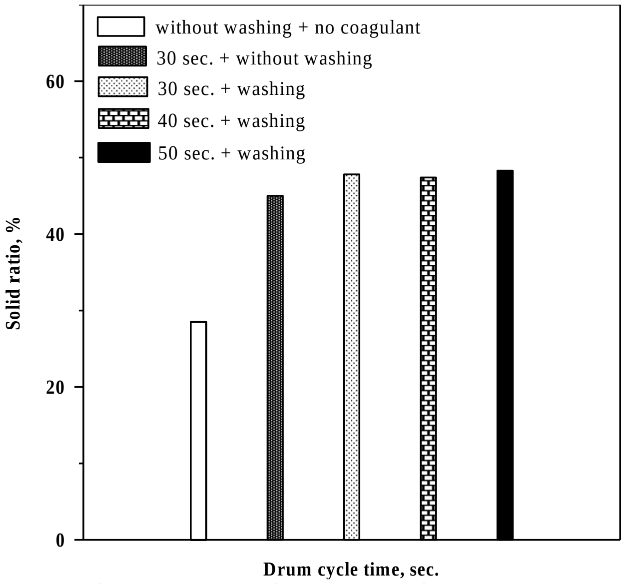

Fig. 5. The % solid amounts of the cakes obtained from the vacuum filtration experiments using only coagulant.

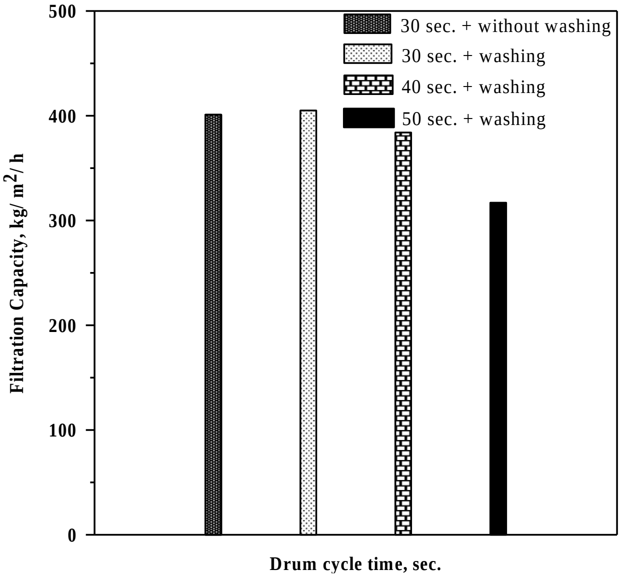

Fig. 6. The filtration capacity according to different filtration conditions from the vacuum filtration experiments using only coagulant.

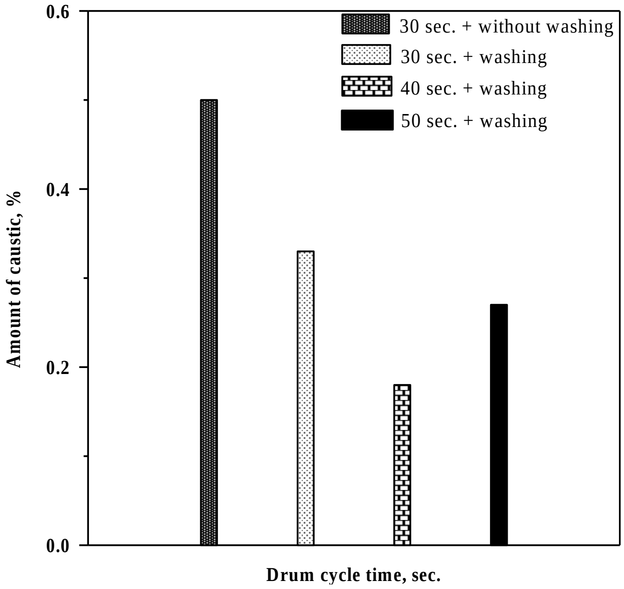

Fig. 7. The remaining amount of washable caustic in the cakes from the vacuum filtration experiments using only coagulant.

Experiments using coagulant and flocculant together

200 g/ton sludge Nalco 9779 synthetic flocculant and coagulant were added to the sixth washer red sludge. In Figure 8, % solid amounts are shown depending on the cycle time. It is seen that the results of the vacuum filtration test by adding coagulant + flocculant are better than the test results using only coagulant. According to Figure 8, solid values between 47.7% and 50.3% could be obtained. The filtration capacities obtained according to different cycle times are given in Figure 9. As can be seen in Figure 9, the cycle time of the filter increases as the cake washing system is switched to and the cake washing time increases, and in turn, the filtration capacity decreases. A filtration rate or capacity in the range of 295 to 470 kg/m^2/h was obtained. The amount of caustic values remaining in the cake is also shown in Figure 10, and the effect of the cake-washing process is also clearly seen here. According to this, the amount of caustic is around 0.22% when washed.

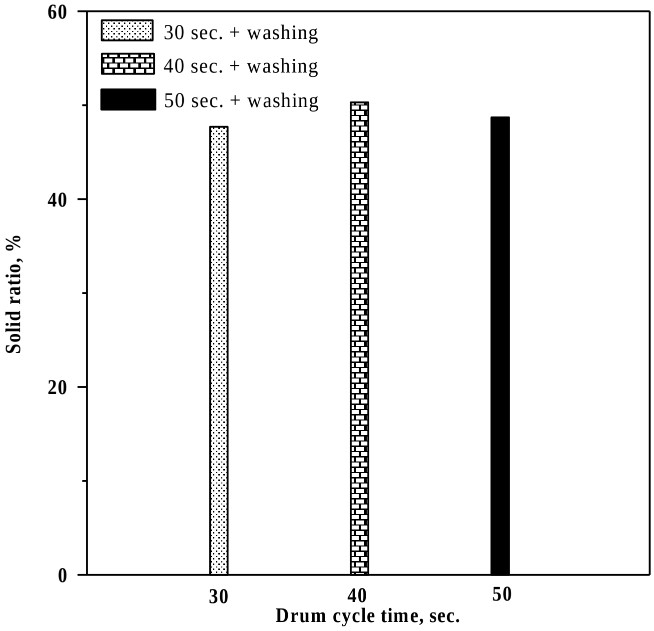

Fig. 8. The % solid amounts of the cakes obtained from the vacuum filtration experiments using coagulant and flocculant together.

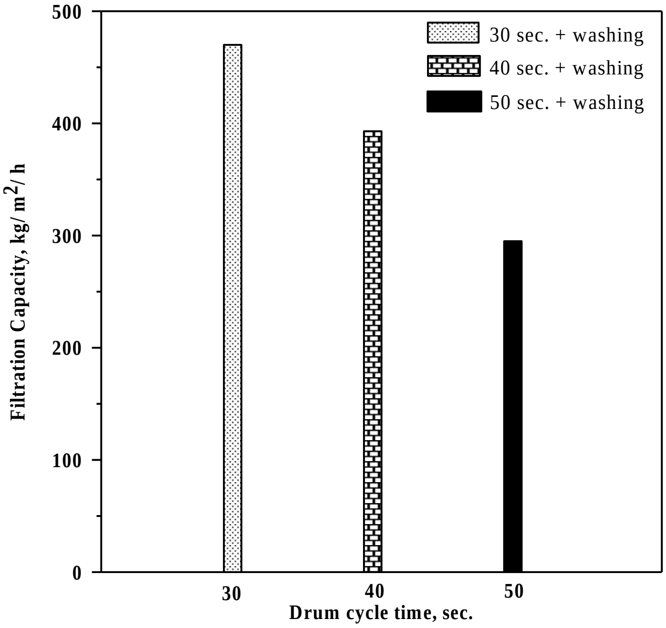

Fig. 9. The filtration capacity according to different filtration conditions from the vacuum filtration experiments using coagulant and flocculant together.

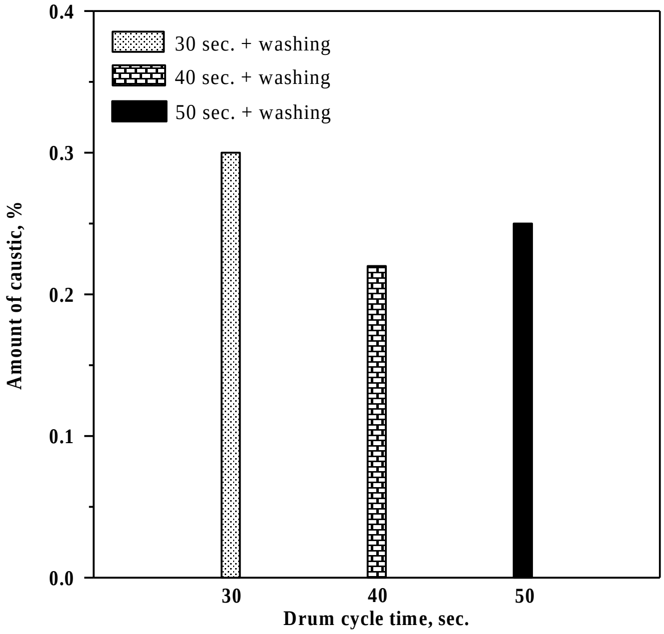

Fig. 10. The remaining amount of washable caustic in the cakes from the vacuum filtration experiments using coagulant and flocculant together.

Decanter Centrifuge Method

Centrate and cake images of the studies performed with and without flocculant by centrifugation method are shown in Figures 11 and 12, respectively. As seen in Figure 11 and Figure 12, the solid ratio in the centrate liquid and cake obtained when flocculant is not used is 1.18% and 48.19%, respectively, while when flocculant (Zetag 4120) is used, the solid ratio in the centrate liquid and cake is 0.72% and 48.42%, respectively. The results obtained from the experiments carried out with the pilot diameter decanter centrifuge installed in the facility are given in Table 4. As can be seen from the results, the solid ratio reached up to 65%. Also, the amount of caustic that remains in the cake is 0.15% with centrifuge technology.

Fig. 11. Centrate and cake image of the anionic flocculant added sample after centrifugation.

Fig. 12. Centrate and cake image of the sample without flocculant after centrifugation.

Tab. 4. Parameters and obtained results in dewatering of red sludge with decanter centrifuge.

Experiment no	Differential speed, rpm	Drum speed, rpm	Torque, %	Sludge feed rate, m^3/h	Polymer concentration, %	Polymer feed rate, m^3/h	Solid ratio, %
1	7	1613	18	10	0.3	1.1	51.17
2	8	1830	23	15	-	-	49.05
3	7.5	1936	21	15	0.3	2	53.47
4	9	1385	22.3	16.1	0.3	1.7	64.74
5	9	1380	22.6	20.3	0.3	2	56.36

Press Filter Method

First-stage press filter tests

Firstly, experiments were carried out with the 6th washer sludge with the pilot scale press filter test unit. During the filtration, pressing experiments were carried out as normal pressing, membrane pressing, membrane cake drying and membrane cake washing. The results from the experiments are shown in Table 5. Table 5 shows that the results of the pressing tests with the cake washing are better than the others. Accordingly, an average of 68.2% solid cake was obtained. The specific filtration rate was calculated as 20.1 $kg/m^2/h$. The amount of caustic that remains in the cake is 0.095%.

Tab. 5. The results were obtained from dewatering the 6th washer sludge with the pilot scale press filter method.

	Normal pressing method	Membrane pressing method	Pressing method with membrane and cake dryer	Pressing method with membrane and cake wash
Total filtration cycle time, min.	20 – 25	18 – 29	30	35 – 41
Cake thickness, mm	30 – 35	25 – 30	25 – 32	22 – 26
Moist cake weight, kg	132	106	108	111
Solid cake, %	62.5	67.7	67.8	68.2
Amount of caustic that remains in the cake, %	0.10 – 0.15	0.11	0.10	0.095
Amount of cake washing water, m^3/ton	-	-	-	2 – 3.2
Specific filtration rate, $kg/m^2/h$	36.9	31.1	23.9	20.1

Second-stage press filter tests

The 6th washer sludge tests were carried out with the pilot test unit installed in a suitable area in the red sludge washing circuit. The tests were performed with normal pressing, membrane pressing and cake washing, and the results are given in Table 6. Accordingly, an average of 70% solid cake was obtained. Filtration rates of approximately 27 kg/m^2/h without cake washing and 25 kg/m^2/h with cake washing were obtained. While the amount of caustic that remained in the cake was 0.15% in the pressing without washing the cake, the amount of caustic could be reduced to 0.03% in the pressing using 2 m^3/ton water.

Tab. 6. The results were obtained from dewatering the 6th washer sludge with the pilot test unit installed in a suitable area in the red sludge washing circuit.

	Normal pressing method
Total filtration cycle time, min.	
Cake wash	20
Cake without washing	30
Cake thickness, mm	19 – 30
Moist cake weight, kg	38
Solid cake, %	70
Amount of caustic that remains in the cake, %	
Cake wash	0.15
Cake without washing	0.03 – 0.12
Specific filtration rate, kg/m^2/h	25

Comparison of red sludge dewatering methods

The results obtained from the Vacuum Drum Filter, Decanter Centrifuge, and Second-Stage Press Filter Tests, which were carried out to further dewatering the red sludge and to reduce the caustic and alumina losses in the liquid phase, are shown in Figure 13 and Figure 14, respectively. Accordingly, it is understood that the best results are obtained with the press filter method.

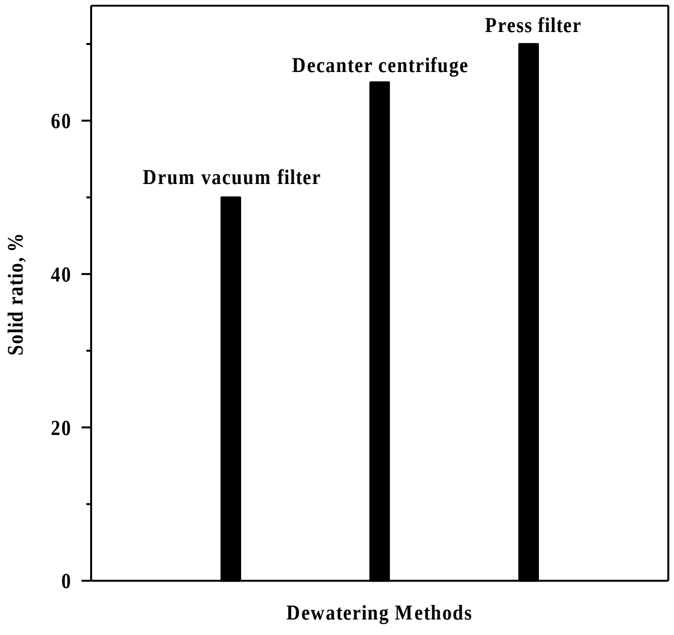

Fig. 13. Comparison of the % solid amounts of the cakes of the vacuum drum filter, decanter centrifuge, and second-stage press filter tests.

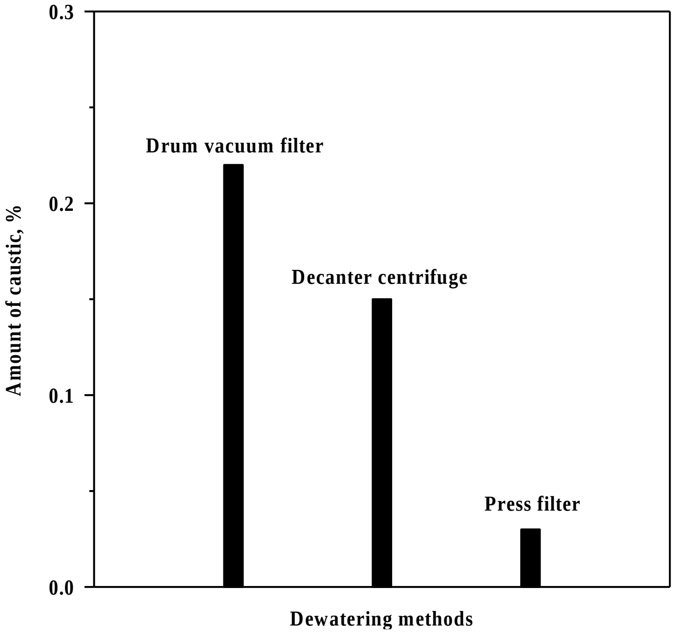

Fig. 14. Comparison of the remaining amount of washable caustic in the cakes of the vacuum drum filter, decanter centrifuge, and second-stage press filter tests.

Conclusions

In this study, first of all, the physical and chemical properties of the sludge were investigated in order to increase the dewatering performance of red sludge, which is the waste of the Bayer Process. Afterward, dewatering tests of red sludge were carried out with the vacuum drum filter method, decanter centrifuge method, and press filter method. The results obtained from this study led to the following conclusions:

- If coagulant is added to the sludge fed in the vacuum drum filter method, a solid ratio of 45-48% of the cake is obtained. Furthermore, the results were more successful in the tests performed with the cake wash. When the cake washing system was switched, the drum cycle time and cake washing time of the filter increased, while the filtration capacity decreased. A filtration capacity of approximately 317 to 405 kg/m^2/h is obtained. On the other hand, while the amount of caustic remaining in the cake was around 0.5% in the tests without washing, this amount decreased to 0.18% in the tests with washing depending on the ratio of washing water. Secondly, dewatering experiments were carried out in the vacuum drum filter method by adding flocculant and coagulant to the red sludge pulp. Vacuum filtration test results with the addition of coagulant + flocculant were better than the results of the test using only coagulant, and the solid cake was obtained between 47.7% and 50.3%. A filtration rate or capacity in the range of 295 to 470 kg/m^2/h was obtained and the amount of caustic remaining in the cake was found to be around 0.22%. In addition, the addition of coagulant/flocculant is very effective in preventing cracks on the cake surface.
- In the decanter centrifuge method, which has not been applied before, for the dewatering of red sludge, the decanter was observed to work efficiently and continuously, and 65% solid cake can be obtained. In addition, the amount of caustic remaining in the cake decreased to 0.15% with the decanter centrifuge method.
- In the press filter tests for the dewatering of red sludge, it was concluded that the red sludge could be dewatered more with the press filter than the existing system, and thus caustic and alumina losses can be reduced. In the current situation, the solid ratio of the red sludge sent to the dam or the next thickener with an average of 30% solids can be increased up to 70% by press filter application. Thus, the life of the red sludge dam will be extended. In addition, the specific filtration rate was determined as 20.1 kg/m^2/h, and the amount of caustic remaining in the cake was determined to be 0.095%.
- Thus, it is understood that the best results in increasing the dewatering performance of red sludge are obtained with the press filter method. As a result, the life of the dam used for solid storage is increased, and the volume of the dam can be used more efficiently. In addition, it will be easier to use dry-stocked red sludge as a raw material in other sectors. On the other hand, by reducing the amount of caustic in red sludge, its negative impact on the environment will be reduced, and caustic will be recovered.

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