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EFFECT OF CLAY SLIMES ON FLOTATION IN CASE OF DADO COAL DEPOSIT, JIMMA, SOUTH WESTERN ETHIOPIA

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This is to certify that the project prepared by Abraham Feyisa entitled: "Effect of Clay Slimes On Flotation in case Of Dado Coal deposit, Jimma, Southwestern Ethiopia" and submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Mineral Engineering compiles with the regulations of the university and meets the accepted standards.

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Declaration

I hereby declare that this project is my original work and has not been presented for a degree in any other university, and that all sources of material used for the project have been duly acknowledged.

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Abstract

In Ethiopia, coal mining is a significant economic activity. The existence of clay slimes, which have an impact on the quality and amount of coal, is just one of many difficulties that coal mining activities must overcome. These problems regarding the impact of clay slime on coal flotation were the focus of this study project. Using flotation mixtures containing slime particles and coal particles in the 0.5-0.25 mm, 0.25-0.125 mm, and 0.125-0.063 mm size ranges, batch flotation and flotation rate tests were conducted with the primary goal of examining the impact of slimes on the recovery of coal particles by flotation. The findings of this study suggest that the content of slime particles and coal particle size had a bearing on the influence of sludge particles on the coal flotation recovery. Recovery of coal ash by flotation in all size fractions in the mixed flotation was larger than that of coal granules in each flotation cell when the mass proportion of the slime particles was below 20%. However, when the particle mass ratio of the slime exceeded 20%, the former was lower than the latter. Additionally, as the percentage of slime particles increased, coal particle recovery using flotation across all size fractions dropped. Additionally, it was easier to see how slime particles affected the Recovery via flotation of coarse coal particles.

Key words: Coal flotation, clay slimes, coal recovery, particle size

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CHAPTER 1: INTRODUCTION

1.1 Back ground

One of the most significant fossil fuels has always been coal (Glushkov et al., 2018). The majority of coal is often used as fuel, but it is also occasionally employed as a raw material for coking and the synthesis of organic chemicals (Glushkov and Strizhak, 2017; Nyashina et al., 2018). Despite the importance of coal, there are still many challenges in the beneficiation of coal, because coal is usually found mixed with impurities, such as sulfur, ash, and clay minerals. To achieve economic value, beneficiate coal using procedures like washing, gravity separation, and flotation to avoid impurities. Gravity separation and washing are both popular techniques for processing minerals based on their characteristics of the physical and chemistry, these techniques are used to sort minerals. In washing, contaminants are removed from the ore using water; in gravity separation, the ore is separated depending on density. The benefit of washing is that it is an easy, affordable procedure that can be applied to a variety of minerals. This approach, though, has drawbacks. Similar density minerals cannot be separated with this method, and it cannot get rid of all contaminants. 2009's (Mukherjee) On the other hand, gravity separation works well for sorting minerals with various densities. In the mining business, this technique is frequently used to separate heavy minerals like gold, tin, and tungsten. Gravity separation has the advantage of being able to eliminate a significant portion of contaminants. One of the key methods for coal preparation, froth flotation, is having trouble because of the slimes. These sludge mud may be categorized into three groups based on their composition: tiny coal particles, coal and gangue particles bound together, and gangue particles However, the clay's presence in minerals coal seams is important elements influencing the flotation process. The clay's presence minerals in coal beds typically results in low-quality coal because these being one of the most prevalent contaminants in coal. Clay minerals create clay slimes, ultra-fine particles that can reduce the size of air bubbles and have a detrimental impact on flotation recovery by coating and agglomerating coal surfaces. According to Zhang et al. (2016), the size of these slimes typically ranges from a few tens of microns to a few microns. These in one sense, they are typically suspended in the slurry and can flow freely with the water because of their small particle size and light weight. Because of this, the slimes simply enter the concentrate with the water flow (a process known as entrainment), disrupting the flotation process and lowering the concentrate's grade (Wang et al., 2015). These This study's objective was to explore the impact of slimy clay on the recovery of coal via flotation by performing coal flotation at a laboratory scale with various size fractions of coal particles under a mixed flotation condition of coal and slimes.

1.2 Statement of problem

Research has been done on the difficulties the coal business has while flotation of coal in silmy clay. In the current literature, there are both proponents and opponents of the finding that the impact of slimy clay is positively connected with coal flotation. The majority of researchers (Sun, 1943; Jowett, 1956; Fuerstenau, 1989) hold that slime coatings are the true cause of loss in recovery values in mineral flotation and that they are most significant when the slime is uncharged or oppositely charged to the material being floated. Similar findings were found in the study by Arnold and Aplan (1986b), which demonstrated the existence of clay had little to no impact on coal flotation and had no discernible impact on coal recovery. Consequently, more investigation is required. The goal of the study was to conduct research on the influence of slimy clay on floatability of coal in the case of the Dedo coal deposit in order to better understand this impact and develop effective strategies to optimize the process and increase the recovery and quality of coal, which can aid in the production of sustainable energy and the economic development of a nation.

1.3. Objective

1.3.1. General objective

This study's main goal was to assess how clay slimes affected coal flotation in the case of the Dado coal resource in Jimma, South Western Ethiopia.

1.3.2. Specific objectives were;-

- Determining how clay particles affect concentrate of the coal that is present in the study area.
- Coming to a theoretical conclusion or forecast regarding future flotation cell scaling up under the same circumstances.
- Perform these flotation of coal in the clay's presence at various slime proportions to assess the impact of slimy clay on the recovery of coal flotation.
- Perform flotation of coal in the absence of clay and analyze recovery and ash content.

1.4. Significance of the study

This research project has valuable insights into the challenges posed by clay slimes during coal flotation and their impact on the quality and recovery of coal. What this study's results showed provide important guidelines for improving the coal flotation process, raising coal recovery and quality, and lowering the level of contaminants in the coal concentrate, among other things. Of particular significance are:

- ➢ Beneficial to the community, as it contributes to the growth of the coal industry sustainably in Ethiopia, which is an important source of energy for the country
- ➢ Serve as a valuable addition to the existing data on coal flotation and clay slimes, which will be useful for future researchers in this field.
- ➢ Provide valuable information that can be used to improve the economic viability of coal mining operations in Ethiopia.
- ➢ To increase the efficiency of coal mining operations, reduce costs, and increase revenue for the country.

1.5. The study's scope

The objective of this project was to determine how clay slimes affect the coal via flotation of from the Dado coal resource in Jimma, southwest Ethiopia. This study's goal is to to discover the ideal conditions for coal flotation when clay slimes are present as well as the impact of different clay slime concentrations on flotation efficiency. This research also explores the properties of the clay slimes and their interaction with these during the flotation process, coal particles. The study were conducted through laboratory experiments using coal and clay slime samples collected from the Dedo deposit.

CHAPTER 2: LITERATURE REVIEW

2.1 Coal flotation

The world's power is largely produced by coal, which is the most accessible and widely used fossil fuel (Demirbas, 2007; Sivrikaya, 2014; Xia et al., 2020). Coal has various benefits, particularly low-rank coals, like easy accessibility and affordable mining (Yu et al., 2013). However, because to their high ash content and low calorific value, cleaning procedures are needed before using them in industry. (Sivrikaya, 2014; Xia et al., 2020). There are several other methods that can be used to clean coal, including dense medium separation, gravity separation, and froth flotation. Separation of dense medium (DMS) is a method that involves the use of a dense medium, typically a suspension of magnetite or ferrosilicon, to separate coal from impurities. The coal is fed into a bath of the dense medium, and the heavy impurities sink to the bottom while the lighter coal floats on top. The separated coal is then removed from the bath and sent for further processing. One advantage of DMS is its ability to remove organic impurities, such as sulfur and ash, which can be harmful to the environment and human health. However, it is less effective at removing inorganic impurities, such as mineral matter, which can reduce the concentrate of the coal. Gravity separation is another method that involves the use of gravity to separate coal from impurities. This method is typically used for coarse coal particles and involves feeding the coal onto a shaking table or other device that separates the heavier impurities from the lighter coal. The separated coal is then collected and sent for further processing. One advantage of gravity separation is its simplicity and low cost compared to other methods. However, it is less effective at removing impurities compared to DMS and coal flotation, and it may not be suitable for all types of coal. These coal flotation is a popular and effective process used to clean and enrich coal all over the world. The hydrophobic coal particles are selectively attracted to air bubbles, which causes them to be hoisted to on the face of the flotation cell and create foam. The coal flakes are then separated from the impurities and recovered from the froth. According to Honaker et al. (1996), the coal industry uses the technique of coal flotation to separate and concentrate the coal particles from the mineral materials. Due to its capacity to remove a variety of contaminants, coal flotation is frequently regarded as the most effective method and produce high-quality, low-ash coal. One advantage of coal flotation over dense

Medium separation is that it can effectively remove both organic and inorganic impurities, whereas dense medium separation is typically only effective for removing organic impurities. Additionally, coal flotation can produce a higher result clean coal concentrate compared to gravity separation, which tends to produce a lower yield. Another advantage of these coal flotation is that it the ability to treat a variety of coal types and, particle making it a versatile method for coal cleaning. In contrast, some these other approaches might be more limited in their ability to treat certain types or sizes of coal. Overall, while there are other techniques that are possible to clean coal, coal flotation is often preferred due to its effectiveness, versatility, and ability to produce high-quality clean coal. The process involves mixing the finely ground coal with water and various reagents to create a froth, which will allow the allowing coal flakes to float to the top and accumulate while Mineralized material sinks to the bottom. The importance of coal flotation in the coal industry cannot be overemphasized because it enables the production of high-quality coal and increased coal recovery. Also, because coal is a valuable resource, efficient and effective methods of processing it is crucial. According to (Arnold and Aplan (1986) the advantages of flotation for coal include increased coal yield, improved coal quality, and decrease in the amount of waste produced. Additionally, the process can reduce the sulfur content of coal, making it environmentally friendly (Table 1). Generally, the coal business relies heavily on the process of coal flotation. and it has many benefits, including increased yields and improved quality and reduced waste. Therefore, the technology is a valuable tool in the industry's efforts to meet global energy demands while minimizing its impact on the environment.

Technique	Principle	Feed size	Advantages	Disadvantages	References
Gravity separation	Based on the difference in specific gravity of matters	Good at a high size (coarse size)	Most efficient for removing undesirable minerals from coal and for treatment of middling. Large range of particle size	Sulphur minerals are usually finely disseminated in coal matrix and can be liberated only by grinding to a finer size. Not applied commercially. Relatively low separation accuracy. Not suitable for fine coal particles	(Chen & Peng, 2018)
Froth floatation	Based on surface properties (wettability) that hydrophobicity of coal and hydrophobicity of minerals matter is the driving force to separate coal from ash	The size less than < 0.5 mm	Relatively low capital. Low space requirements for the plant. Relatively high recovery was achievable under a wide range of operating conditions. Suitable for fine particles. Well-adapted and high efficiency	Using a large quantity of water. The coarse sample cannot clean unless it the crushed into powder form.	(Zhang et al., 2012)
Magnetic separation	The difference in naturalmagnetic properties of coal and associated mineral matters.	mostly for <177μm (dry magnetic separation)	Insensitivity to coal chemistry makes it useful for oxidized coals and magnetic separation can remove locked coal and pyrite	Magnetic susceptibility very small for coal separations and needs a strong magnetic field	(Xu et al., 2011)
Chemical leaching	Demineralization and desulfurization by leaching with effective alkali and acid reagent	size ranges at only in fine and ultrafine	Uses simple equipment and materials. An acid is solubilized the most minerals matter like phosphates, carbonates and sulfate that based upon the types of reagent used for leaching	Needs more chemical reagent. Treatment of water is more costly and causes environmental pollution. Select the removing minerals andneeds more temperature. Not all the minerals are washed with just one reagent.	(Wang et al., 2018)

2.2. The influence floatation of coal with clay

Clay slimes detrimentally impact coal flotation due to their negative impact on the coal's hydrophobicity and hindered bubble attachment. The existence of slimy clay in the coal slurry can lead to reduced flotation efficiency, lower recovery rates, and decreased product quality. Clay particles tend to coat the coal surface, making it less hydrophobic and inhibiting the attachment of air bubbles. This results in reduced bubble-particle collision and decreased coal recovery. Additionally, clay slimes can also contribute to froth stability issues and increased water entrainment in the frother stages, further affecting the flotation process negatively. Therefore, effective clay slimes removal or mitigation strategies are necessary to enhance coal flotation performance (Fig. 1 (Chen and Peng,2018).

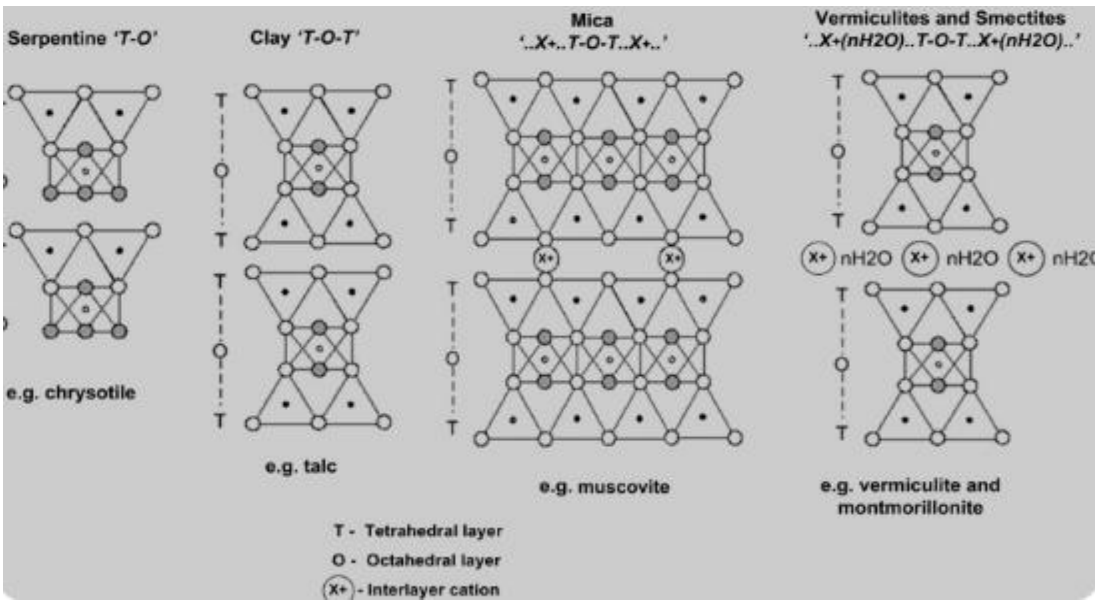


Figure 1: The classification of minerals in the phyllosilicate group

2. 2.1. Surface coating effect

Coal flotation plays a crucial role in the coal preparation process by separating valuable coal from unwanted mineral matter. However, the presence of clay slime poses a significant challenge to achieving efficient flotation separation. Clay slime particles have a high affinity for coal surfaces, resulting in coal loss and reduced product quality. To address this issue, surface coating techniques have been explored to modify clay slime particles and improve flotation performance. This paper thoroughly examines the effects of surface coating on clay slime during coal flotation, highlighting its potential benefits and challenges.

During coal flotation, clay slimes can these the coal's surface with a coating, leading to several negative effects on the Flotation technique. The existence of slimy clay particles at the coal surface reduces its hydrophobicity, which is crucial for effective flotation. Hydrophobicity refers to the coal's ability to repel water and attract air bubbles, which is necessary for identify coal from impurities.When clay slimes coat the coal surface, they create a physical barrier that hinders the attachment of air bubbles. The attachment of air bubbles to coal particles is essential for their separation from the slurry. The clay coating prevents the direct contact between the coal and air bubbles, resulting in reduced bubble-particle collision and decreased coal recovery.The clay coating also affects the stability of the froth phase, which is where the separated coal particles accumulate. Froth stability is crucial for efficient separation and recovery of coal. The existence of slimy clay can lead to froth destabilization, causing it to collapse or break down easily. This instability results in lower recovery rates and decreased product quality.Furthermore, clay slimes can contribute to increased water entrainment at the frother stage. Water entrainment refers to the trapping of water within the froth, which dilutes the concentrate and reduces its quality. The presence of excessive water in the frother stage can also lead to increased reagents consumption and operational challenges. Various surface coating techniques have been explored to modify the clay slime particles, including chemical modification, physical treatments, and the use of additives. Chemical modification involves the attachment of specific reagents or polymers to the clay slime surfaces, altering their hydrophobicity and interaction with coal particles. Physical treatments such as heat treatment or microwave irradiation can also modify the surface properties of clay slime particles. Additionally, the use of additives, such as surfactants or dispersants, can enhance the dispersion and separation of clay slime particles during flotation. Surface coating of clay slime particles has shown significant improvements in coal flotation performance. The modified clay slime particles exhibit reduced affinity for coal surfaces, leading to enhanced selectivity and increased recovery of valuable coal. The surface coating also promotes better dispersion of clay slime particles in the flotation pulp, reducing their agglomeration and improving the overall flotation efficiency. Furthermore, surface coating techniques can enhance the stability of froth, allowing for better recovery of coal fines and minimizing the loss of valuable coal. While surface coating techniques offer potential benefits for clay slime control during coal flotation, several challenges must be addressed. The selection of appropriate coating agents and conditions requires careful consideration, as the effectiveness of the coating may vary depending on the coal and clay properties. The stability and durability of the coating under flotation conditions also need to be evaluated to ensure long-term effectiveness. Moreover, the economic feasibility and scalability of surface coating techniques should be assessed to determine their practical applicability in the coal preparation industry. Coal flotation is a complex process involving the interaction of various components, including coal, water, and mineral matter. Clay minerals, commonly present in coal deposits, can negatively impact flotation performance due to their hydrophobic nature and affinity for coal surfaces. The addition of $Ca2+$ ions has been explored as a potential solution to mitigate the detrimental effects of clay minerals during coal flotation. Interactions between $Ca2+$ Ion, Clay Minerals, and Coal Surfaces$Ca2+$ ions can interact with clay minerals and coal surfaces through several mechanisms. Firstly, Ca^{2+} ions can form complexes with clay minerals, altering their surface properties and reducing their affinity for coal surfaces. This modification leads to improved selectivity during flotation. Secondly, Ca^{2+} ions can compete with clay minerals for adsorption sites on coal surfaces, preventing the unwanted attachment of clay particles. Additionally, Ca^{2+} ions can enhance the stability of coal froth, aiding in the separation of coal particles from clay minerals. Effect of Ca^{2+} Ion on Flotation Performance in the Presence of Clay Minerals The presence of Ca^{2+} ions during coal flotation in the presence of clay minerals has shown positive effects on flotation performance. Ca^{2+} ions can improve the selectivity of the flotation process by suppressing the unwanted attachment of clay particles to coal surfaces. This leads to increased recovery of valuable coal and improved product quality. Furthermore, the addition of Ca^{2+} ions can enhance froth stability, allowing for better separation of coal particles from clay minerals.

2.2.3. Increasing the pulp viscosity

Increasing the pulp viscosity in coal flotation can have significant effects on the flotation process. Pulp viscosity refers to the thickness or resistance to flow of the flotation slurry, which is a mixture of water, coal particles, and other components. The pulp's viscosity can be influenced by various factors, including the concentration of solids, particle size distribution, and existence of clay slimes.the effects of increasing the pulp viscosity is the reduction in the mobility and coal sludge particle movement and air bubbles within the flotation cell. These an increase in viscosity the movement of particles and bubbles becomes slower and more restricted. This reduced mobility hinders the efficient collision and attachment of air bubbles to coal particles, leading to decreased flotation efficiency and lower recovery rates. The attachment of air bubbles to coal particles is crucial for the isolation of coal from impurities. The bubbles adhere to the hydrophobic coal surface, lifting it to the frother stages while leaving behind the hydrophilic impurities. However, in high viscosity conditions, the attachment of bubbles becomes harder due to the hindered motion and reduced contact between particles and bubbles. This results in lower flotation recovery and decreased product quality. Furthermore, increased pulp viscosity can also reduce in the stability of the froth phase. Froth stability is essential for efficient separation and recuperation of coal ash. A stable froth allows for the accumulation and removal of separated coal particles from the flotation cell. However, in high viscosity conditions, the froth becomes less stable, leading to its collapse or break down easily. This instability further hampers the flotation process and reduces recovery rates. Another effect of increasing pulp viscosity is the increased water entrainment in the frother stages. Water entrainment refers to the trapping of water within the froth, which dilutes the concentrate and reduces its quality. In high viscosity conditions, the entrainment of water becomes more pronounced as it becomes more difficult for the water to drain out of the froth. This excessive water in the froth phase not only decreases product quality but also leads to increased reagents consumption and operational challenges.

To mitigate the adverse consequences of of increasing pulp viscosity, various strategies can be employed. One approach is to optimize the range of particle sizes of the coal feed. By regulating the viscosity and the particle size of the pulp can be reduced, allowing for better mobility and contact between particles and bubbles. Additionally, the use of dispersants or flocculants can help in reducing the viscosity and improving flotation performance. These chemicals can alter the surface chemistry of particles and reduce their tendency to aggregate. Furthermore, mechanical methods such as high-shear agitation or ultrasonic treatment can also be employed to break up aggregates and reduce pulp viscosity. These methods promote better dispersion of particles and enhance the interaction among bubbles and particles.

2.2.4. Clay mineral entrainment

The entrainment of clay's minerals in coal flotation can have significant effects on the flotation techniques. Clay minerals are commonly present in coal deposits and can be detrimental to the quality and efficiency of coal flotation. Entrainment refers to the unintentional trapping or inclusion of mud minerals in the frother stage when the flotation techniques, which can lead to reduced product quality, increased reagent consumption, and operational challenges (Akdemir & Sonmez, 2003). This hydrophilic nature makes them more prone to being entrained in the frother stage during flotation. The entrainment of clay's minerals when these particles are carried along with the froth, despite not being attached to air bubbles (Zheng et al., 2006).One of the consequence of clay mineral entrainment is the dilution of the coal concentrate. The entrained clay minerals increase the water content in the frother stages, leading to less in the concentration of valuable coal particles. This dilution reduces the overall quality of the coal concentrate, making it less desirable for commercial use. Additionally, the existence clay's minerals in the concentrate can lead to processing challenges downstream, such as difficulties in dewatering and handling(Akdemir & Sonmez, 2003).Moreover, the entrainment of clay's minerals can also result in increased reagent consumption. Frothers and collectors are commonly used in coal flotation to enhance the attachment of air bubbles to coal particles and improve separation

2.2. Location, physiography and drainage of the study area

2.2.1. Location and accessibility

The Dado coal deposit, situated in the Jimma Zone of the Oromia Regional State in the southwestern part of Ethiopia, holds significant importance as one of the country's crucial coal reserves. Geographically, the deposit is positioned within the latitude range of 7° 21'49"–7° 24' 31" N and the longitude range of 36° 48' 21"–36° 52' 54" E (Figures 2). A small village named Delbi is located approximately 50 kilometers south of Jimma town and around 390 kilometers southwest of Addis Ababa. The journey from Addis Ababa to Jimma can be conveniently made via an asphalt road, and from Jimma to Delbi, the subsequent 50 kilometers can be traversed on an all-weather gravel road. The Delbi-Moye Basin, situated at an elevation of 1660–2240 meters above sea level, is nestled within Ethiopia's Southwest Plateau.

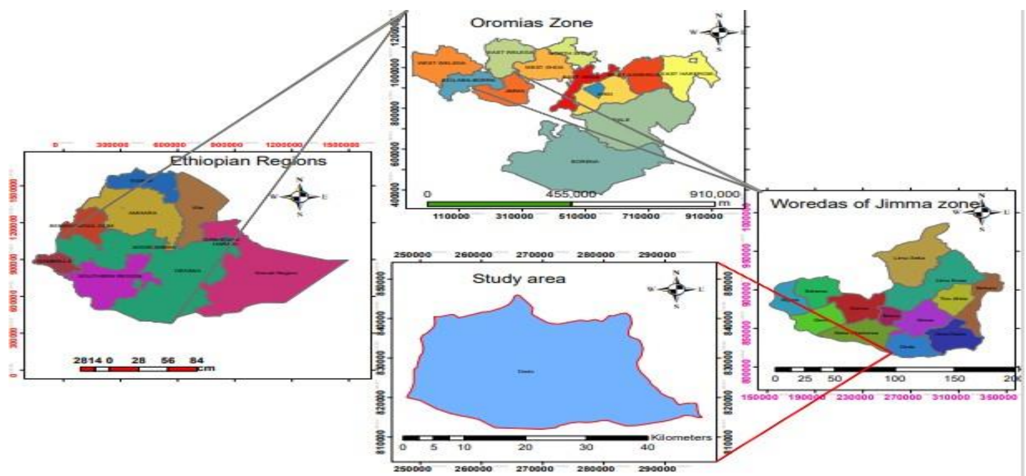


Figure 2: Study area location map

2.3.2. Physiography

The physiography of the study area exhibits a rugged topography with parallel ridges and varying elevations ranging from 2650 meters to 1500 meters above sea level. The low-lying regions within the basin are comprised of basaltic ridges, while trachytic hills aligned in a north-south direction can be observed. These hills are deeply dissected by basalt floored stream channels. In the eastern part of the area, hills and mountain ridges dominate the landscape.

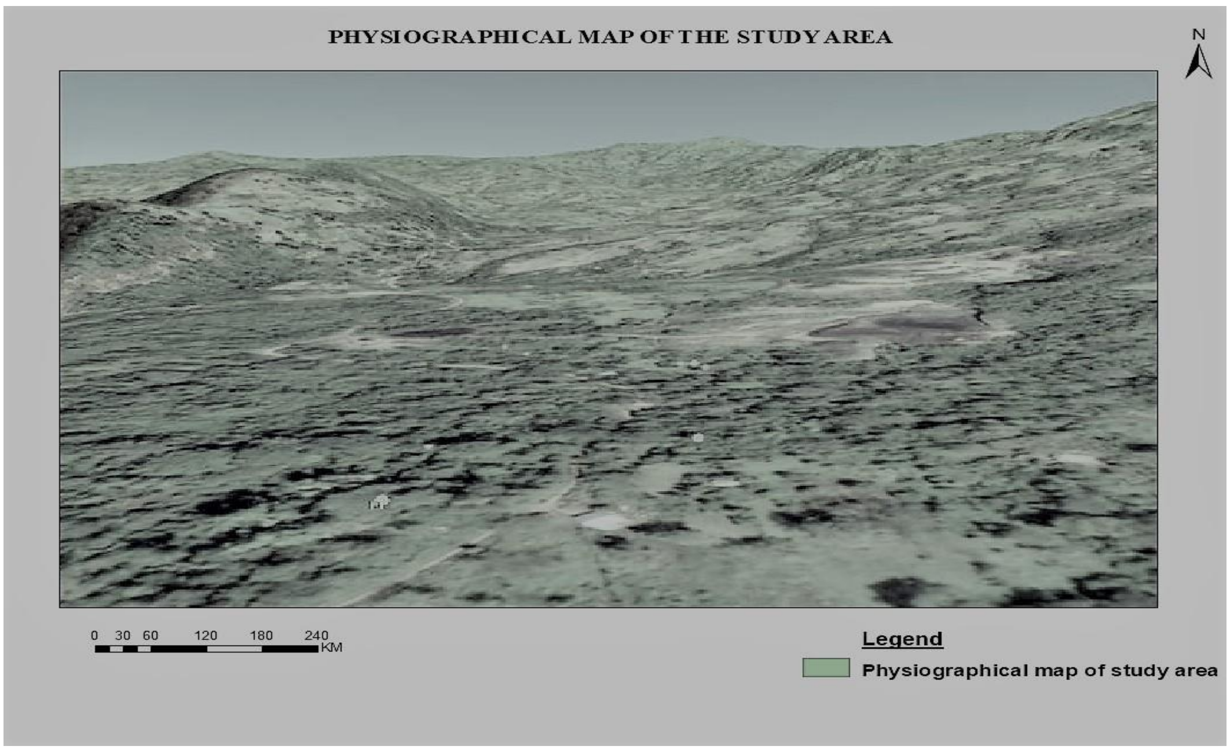


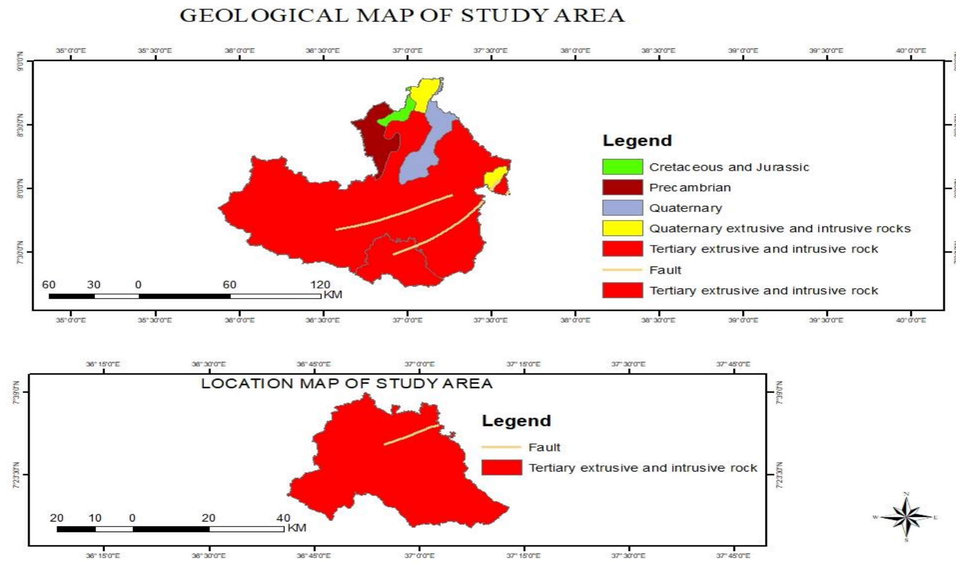
Figure 3; study area physiography

2.3.3 .Drainage

Most of the streams flow westwards and intermittent streams entering into the Gojeb River (Diddibo, Gonfa, Ramate, Bilacha, Laga Missie, Yebba and Okoshe). The stream that flows, approximately N-S direction. The drainage pattern is mainly of parallel dendritic type and rarely trellises (Bae et al., 1989; Getahun et al., 1993).

2.4. Geology of the study area

Geological studies have estimated that the Dado coal deposit holds around 219 million tons of coal, with a calorific value ranging between 3,700 to 5,000 Kcal/kg. The deposit is known for its high-quality coal, which makes it economically attractive for mining operations. However, a detailed understanding of the lithology surrounding the coal is essential for efficient extraction and mining planning. The lithology surrounding the Dedo coal deposit consists of various rock types that provide insights into the depositional environment and potential challenges in coal extraction. The lithological units identified include: Sandstone: Sandstone is a dominant lithology in the surrounding area. It is primarily made of quartz grains cemented together by silica or other minerals. The sandstone beds exhibit variable thicknesses and are often interbeded with other lithology's shale is another significant lithology found in close proximity to the coal deposit. Shale is a fine-grained sedimentary rock composed mainly of clay minerals. Its presence suggests periods of low energy deposition and organic matter preservation siltstone is occasionally encountered within the lithological sequence. It is composed of fine-grained particles, smaller than sand but larger than clay. Siltstone beds often exhibit good stratification and can act as barriers to fluid flow. Limestone: Limestone units are sporadically present in the lithological sequence surrounding the coal deposit. Its presence suggests periods of carbonate deposition in a marine or lacustrine environment. Mudstone: Mudstone is occasionally encountered within the lithological sequence. It is similar to shale but lacks the facility and laminations characteristic of shale. Mudstone is often associated with low energy environments and can act as a seal or barrier to fluid flow.



CHAPTER 3

MATERIALS AND METHODS

3.1. Apparatus and instruments

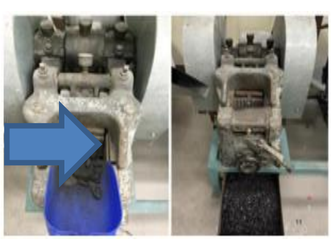
The apparatus and instruments used in this study are; a pick axe to extract the coal, a sac to hold the extracted coal, a universal hot, a jaw crusher to break up large particles into smaller ones, Centrifugal mill (used for to obtain the fine powders product approximately less than 500 µm), Sieve Shaker, Wedag flotation cell (used for attach hydrophobic particles to air bubbles), Adiabatic Bomb calorimeter. The flotation parameters, such as kerosene, Nocturnal, and flotation time, were optimized through preliminary experiments. These parameters were kept constant throughout the main experiments to ensure consistency.

3.2. Sample Collection

Coal samples was obtained from from the Dedo coal deposit, specifically targeting areas with known clay slime content. The samples were obtained from different coal seams to ensure representativeness.

3.2.1. Sample Preparation

The collected coal samples were crushed and ground to 500,250, 125, and 63 µm. Care was taken to minimize any potential contamination during the crushing and grinding process. Clay slime samples was also obtained from the same locations as the coal samples. The clay slime was separated from the coal using both physical and chemical methods. The separated clay slime was then washed and dried to remove any impurities.



a

b

c

Figure 6: a) the as-received run of mine coal was first crushed in Laboratory a jaw crusher b) Laboratory centrifugal mills was used to grind the coal samples further as secondary crusher c) Laboratory ball mill was then used to grind the coal samples to a finer size

3.3.1. Experimental procedure

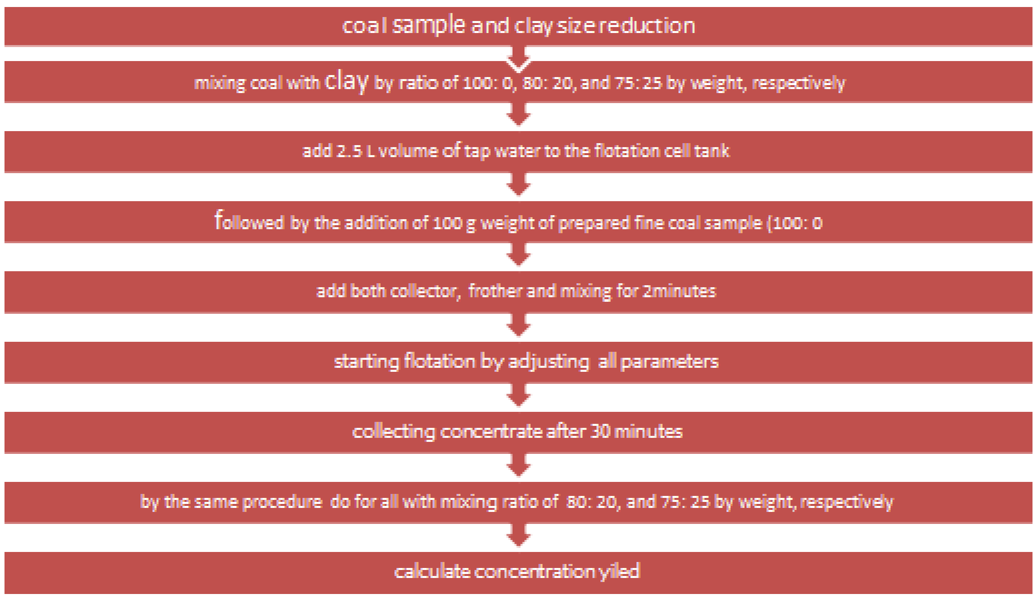


Table 5: The flotation results of coal: slime at different coal size fraction

Test	Feed coal sample (g)	Added clay %	Coal size fraction (µm,)	Recovery (%)
1	100	0	-500+250	39.4
2	100	0	-250+125	56.1
3	100	0	-125+63	62.5

4	80	20	-500+250	38.7
5	80	20	-250+125	43.6
6	80	20	-125+63	49.7
7	75	25	-500+250	29.1
8	75	25	-250+125	36.3
9	75	25	-125+63	38.8

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Effect of surface coating on the flotation recovery

The hydrophobicity Surface and floatability of valuable minerals are reduced after the mineral surface is coated with clay mineral particles by means of electrostatic attraction due to the anisotropic charges on the basal surfaces and edges of clay minerals. High reagent consumption and poor flotation selectivity occur with the increasing contents of clay minerals because of its large surface area and surface energy. Due to that, large quantities of clay's minerals were entrained into the frother products. In addition, slimy minerals coated on the face of valuable mineral particles form hydrophilic "armor", preventing the flotation reagent from adsorbing onto the face of the valuable minerals. Furthermore, clay minerals would be hold to the face of coarse valuable minerals to form an “aggregate” by means of strong mechanical agitation, which decreases the floatability of the coarse particles. From the table 5 tests no 9 indicate that the existence slimy minerals in frother foam directly affects frother to stable and decreases from 62.5 to 38.8 for the same particle size when 25% of kaolin added due to the large amount of flotation reagents adsorbed on the face of clay’s minerals.

Table 6: Coal cumulative recovery under different size fraction

Parameter	Coal size fraction (µm,)		
	-500+250	-250+125	-125+63
Recovery (%)	39.4	56.1	62.5

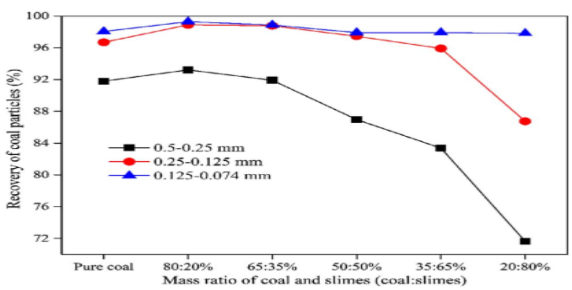


Figure 8: Relationship between the flotation recovery of coal particles within different size fractions and the mass ratio of coal particles and slime particles.

4.4. Kaolin particles' impact on coal flotation

The clay types known to be associated with Dado coal deposit were kaolin and Chemical analysis of a pure kaolin sample for mineralogy are shown in the Table 7. ken (1981) found that the kaolin sample was contain ~ 65% kaolin and less amount of illite , calcite, dolomite and magnesium.

Table 7. Chemical analysis of a pure kaolin sample (wt. %)

Component	SiO2	Al2O3	Fe2O3	Mg	K2O	CaO	TiO2
Content	74.57	19.65	0.516	0.47	0.67	3.56	0.369

Figure 9 shows that the recoveries (R) of coal presented an initial increasing and then a decreasing tendency as the mass ratios of kaolin increased in the mixed samples. These showed that the floatability of particle size fraction. (–500 + 250 mm) contained a small amount (20%) of kaolin of coal can have small or no effect on coal recovery rather it enhancing the consistency of the froth. Nevertheless, despite the stabilizing effects of the hydrophilic components, poorer coal recovery was observed at greater levels (>20%) of kaolin particles. According to these findings, moderately stiff froths would be formed by a low mix of course, very hydrophobic coal particles and ultra-fine, hydrophilic kaolin particles for the coarse size (–500 + 250μm) coal particles. to enhance coal recycling, when a high proportion of kaolin particles were present in the pulp, more kaolin particles attached to the coal face, forming "aggregates" and increasing its hydrophobicity. The bubble surfaces, were covered in ultra-fine kaolin particles that created a hydrophilic "armor" that stopped coal particles from being engulfed by the bubbles. Table 8: the -500 + 250μm coal under various C/K mass ratios

parameter	Coal/k ratios		
	100:0	80:20	75:25
Recovery	39.4	38.7	29.1

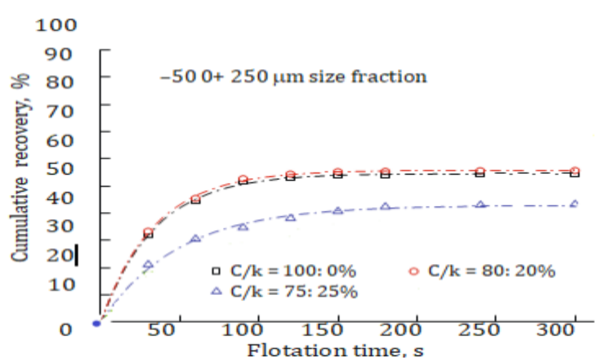


Figure 9: profiles of -500 +250 μm coal of different coal/kaolin mass ratios.

From Figure 10. It seen that the R∞ values of –250 + 125 µm coal showed a distinct trend than the coarse particles , showing a progressively declining tendency with an higher in C/K of ratio .kaolin in the mixed samples (–500 + 250 µm). Regardless of the proportion of kaolin in the samples, the existence of kaolin showed having a negative impact on coal recovery and the inhibition was more pronounced with higher in the proportion of kaolin in the mixed samples. In addition to inhibiting coal recovery by flotation, the existence of kaolin in the pulp significantly decreases the coal's flotation rate. The time value decreased gradually as the mass ratio of kaolin increased in the mixed samples. These results indicated that, for the medium-size (–250 + 125 µm) coal the kaolin particles may have covered on the bubbles and decreasing the collision probability between the bubbles and coal particles.

Table 9: + 250-125µm coal under various C/K mass ratios

parameter	Coal/k ratios		
	100:0	80:20	75:25
Recovery%	56.1	43.6	36.3

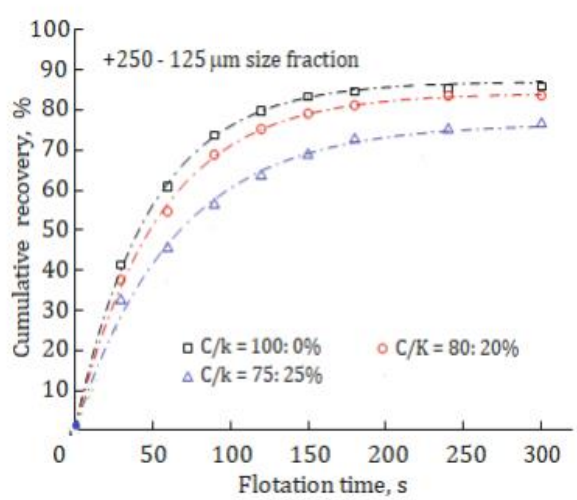


Figure 10: profiles of + 250-125 µm coal of different coal/kaolin mass ratios.

The impact of the C/K mass ratio on -125 +63 µm) coal is indicated in Fig. 11 .Consistent with the medium-size coal, the presence of the hydrophilic ultra-fine kaolin showed had effect on the floatation of the -125 +63 µm coal. The R of coal for fine-size c decreased gradually as the mass ratio of kaolin particles become higher in the mixed samples., the existence of ultra-fine hydrophilic kaolin particles can control the particle/bubble collision efficiency which showed that ultra-fine particles can boost froth stability and decrease bubble bursting likelihood without enhancing the adherence of coal to the bubbles.Table 10: The – 125+63 µm coal under various C/K mass ratios

parameter	Coal/k ratios		
	100:0	80:20	75:25
Recovery%	62.5	49.7	38.8

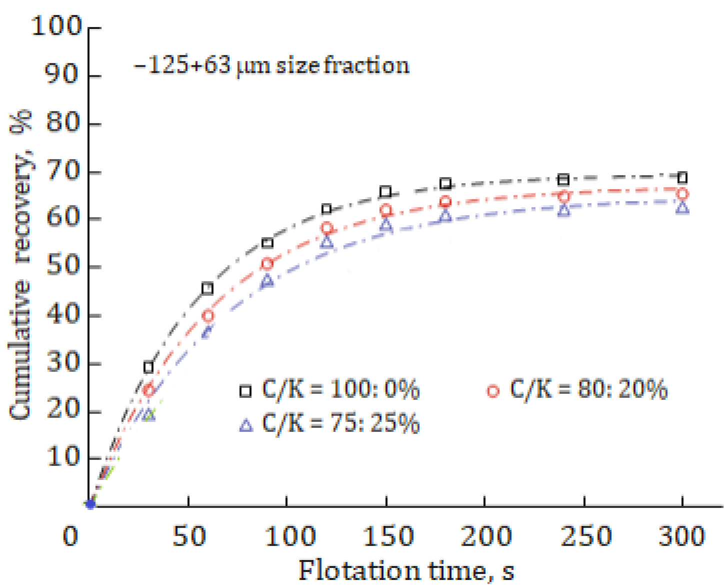


Figure 11: profiles of -125 +63 µm coal of different coal/kaolin mass ratio

CHAPETER 5.

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The findings of this study demonstrated that the size of the coal and kaolin particles both significantly affect the flotation process' foam stability and performance. With a size fraction of -63 + 125 m, the maximum coal recoveries in the sieved-size flotation and full-size flotation were 62.5 and 56.1%, respectively. The classical first-order kinetic model's k value rose as particle size rose, and vice versa. The recovery and flotation rate of the coarse size fraction of coal (-125 + 63 m) were increased by the presence of a small amount (20%) of kaolin, but for the other size fractions of coal (-125 + 63 m and -63 m), the presence of kaolin was harmful. Additionally, kaolin's impact on healing was. A more stable bubble did not boost the coal's adherence to the bubbles for the fine size fraction (-63 m) coal. The minimal value for the froth decay process was obtained from the coarse particle size (-125 + 63 m). The main reason why the the efficiency of coal flotation with a coarse size fraction was insufficient was due to poor froth stability. As coal particle size decreased, the water-solid ratio increased, indicating increased entrainment. With regards to the flotation of small particles, possibilities exist. The existence of kaolin boosted froth stability for all coal size fractions throughout both the froth production and froth decay processes. Additionally, kaolin had the greatest effect on the coal's ability to sustain its froth throughout froth degradation. Last but not least, kaolin may increase the quantity of hydrophilic kaolin particles entrained in concentrate products. This study evaluated the impact of slimes on coal particle flotation recovery in various size fractions. Various coal and slime particle mixing ratios were used in a series of laboratory batch flotation tests. From this research, the following conclusions are drawn:

(1) The effect of slime particles on coal flotation recovery depended on the size and coal with a concentration of the slime particles. The recovery of coal flakes in all size fractions by flotation in the mixed flotation was larger than that when the mass proportion of coal particles in the particular flotation the slime particles were below 20%. However, when the mass proportion of the slime particles exceeded 20%, the former was lower than the latter. Additionally, the flotation recovery of coal particles in all size fractions decreased as the concentration of slime particles rose. Additionally, it was easier to see how slime particles affected Flotation-based recovery of coarse coal particles.

(2) The coal's the quantity of and the size of slime particles both had the kinetics of flotation is affected of the coal. The floating occurrence of coal ash in all size categories reduced as the amount of slime Particles grew in size in the mixed flotation. However, compared to coal particle flotation rate in individual flotation, coal particle flotation rate in mixed flotation in the size range of 0.25-0.125 mm increased, while that of coal sludge in the assortment of sizes between 0.125 and 0.063 mm declined. As the concentration of slime particles rose, the rate of coal flakes flotation in the 0.5-0.25 mm size range initially increased and then declined.

(3) The inclusion of kaolin improved froth stability for all coal size fractions, whether during the froth generation or decay process. Additionally, stability of the foam in the coarse size fraction coal was most affected by kaolin during froth.decay. And more hydrophilic kaolin may be produced when kaolin is present.entrainment of particles into concentrate products.

5.2. Recommendations

Findings obtained from this study show that the clay slimes' existence that had an impact on coal floatability. To learn more about how clay slime affects the coal flotation process, more research will be required. It is suggested that the following studies be done in the future:

- Investigate the flotation behavior at various mixture ratios and adjust other parameter adjustments accordingly.
- Examine the flotation performance for various types of clay and adjust other parameters as necessary.
- The outcomes of the laboratory batch tests ought to be used to guide the pilot scale testing. Other types of coal with various ash concentrations should be examined for floatation when clay slime is exist.
- .Other flotation devices, such as column flotation cells, ought to be used to test flotation floatation when clay slime is exist.

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REFERENCES

Akdemir, U., & Sonmez, I. (2003). Investigation of coal and ash recovery and entrainment in flotation. *Fuel Processing Technology,* , 82(1), 1-9. doi:10.1016/s0378-3820(02)00248-5.

Arnold, B. J., & Aplan, F. F. . (1986a). The effect of clay slimes on coal flotation, Part I: The nature of the clay. *International Journal of Mineral Processing,* , 17, 225-242.

Arnold, B. J., & Aplan, F. F. . (1986b). The effect of clay slimeson coal flotation, Part II: The role of water quality . *International Journal of Mineral Processing,* , 17, 243-260. .

Bakker, C. W., Meyer, C. J., & Deglon, D. A. . (2010). The development of a cavern model for mechanical flotation cells. . *Minerals Engineering,* , 23(11-13), 968-972. doi:10.1016/j.mineng.2010.03.016.

Boshoff, E. T., Morkel, J., Vermaak, M. K. G., & Pistorius, P. C. . (2007). Kimberlite degradation: The role of cation type. . *Minerals Engineering,* , 20(15), 1351-1359. doi:10.1016/j.mineng.2007.08.008.

Chen, X., & Peng, Y. . (2018). Managing clay minerals in froth flotation—A critical review. . *Mineral Processing and Extractive Metallurgy Review,* , 39(5), 289-307. doi:10.1080/08827508.2018.1433175.

Cruz, N., Peng, Y., Wightman, E., & Xu, N. . (2015). The interaction of pH modifiers with kaolinite in copper–gold flotation. *Minerals Engineering,* , 84, 27-33. doi:10.1016/j.mineng.2015.09.019.

Dube, R., & Honaker, R. . (2019). Improving the flotation performance of an oxidized bituminous coal source. . *Minerals Engineering,* , 142, 105937. doi:10.1016/j.mineng.2019.105937.

Farrokhpay, S., Ndlovu, B., & Bradshaw, D. . (2016). Behaviour of swelling clays versus non-swelling clays in flotation. . *Minerals Engineering,* , 96-97, 59-66. doi:10.1016/j.mineng.2016.04.011.

Farrow, J. B., Johnson, R. R. M., Simic, K., & Swift, J. D. . (2000). Consolidation and aggregate densification during gravity thickening. *Chemical Engineering Journal,* , 80, 141-148. .

Greet, C. J., & Smart, R. S. C. . (1997). The effect of size separation by cyclosizing and sedimentation/decantation on mineral surfaces. *Mineral Engineering,*, 10(9), 995-1011. .

Gungoren, C., Guven, O., Cinar, M., & Ozdemir, O. . (2019). An investigation of the effect of clay type on coal flotation along with DLVO theoretical analyses. . *International Journal of Coal Preparation and Utilization,* , 1-13. doi:10.1080/19392699.2019.1603146.

Honaker, R. Q., Yoon, R. H., & Luttrell, G. H. . (2005). Ultrafine coal cleaning using selective hydrophobic coagulation. . *Coal Preparation,* , 25(2), 81-97. doi:10.1080/07349340590927413.

Hussain, S. A., Demirci, S., & Ozbayoglu, G. . (1996). Zeta potential measurements on three clays from Turkey and effects of clays on coal flotation. . *Journal of Colloid and Interface Science,* , 184, 535-541. .

Kelebek, S., Demir, U., Sahbaz, O., Ucar, A., Cinar, M., Karaguzel, C., & Oteyaka, B. . (2008). The effects of dodecylamine, kerosene and pH on batch flotation of Turkey's Tuncbilek coal..*International Journal of Mineral Processing,* , 88(3-4), 65-71. doi:10.1016/j.minpro.2008.06.004.

Konan, K. L., Peyratout, C., Carbelaud, M., Smith, A., Bonnet, J. P., & Alain, J. . (2008). Influence of two dispersants on the rheological behavior of kaolin and illite in concentrated calcium hydroxide dispersions. . *Applied Clay Science,* , 42, 252-257. doi:10.1016/j.clay.2008.01.001.

Li, C., Xu, M., & Zhang, H. . (2020). Efficient separation of high-ash fine coal by the collaboration of nanobubbles and polyaluminum chloride. . *Fuel,* , 260, 116325. doi:10.1016/j.fuel.2019.116325.

Liu, D., & Peng, Y. . (2014). Reducing the entrainment of clay minerals in flotation using tap and saline water. . *Powder Technology,* , 253, 216-222. doi:10.1016/j.powtec.2013.11.019.

Liu, D., & Peng, Y. . (2015). Understanding different roles of lignosulfonate in dispersing clay minerals in coal flotation using deionised water and saline water. . *Fuel,* , 142, 235-242. doi:10.1016/j.fuel.2014.10.082.

Mao, Y., Xia, W., Peng, Y., & Xie, G. . (2019a). Ultrasonic assisted flotation of fine coal: A review. . *Fuel* , 195, 106150. doi:10.1016/j.fuproc.2019.106150.

Mao, Y., Xie, G., Liang, L., Xia, W., & Peng, Y. . (2019b). Effects of ultrasonic treatment on the particle size, shape and ash content of fine coal. . *Physicochemical Problems of Mineral Processing,*, 55(3), 679-688. doi:10.5277/ppmp18182.

Mpofu, P., Addai-Mensah, J., & Ralston, J. . (2004). Flocculation and dewatering behaviour of smectite dispersions: effect of polymer structure type. . *Minerals Engineering,* , 17(3), 411-423. doi:10.1016/j.mineng.2003.11.010.

Ndlovu, B., Farrokhpay, S., & Bradshaw, D. . (2013). The effect of phyllosilicate minerals on mineral processing industry. *International Journal of Mineral Processing,* , 125, 149-156. doi:10.1016/j.minpro.2013.09.011.

Ndlovu, B., Forbes, E., Farrokhpay, S., Becker, M., Bradshaw,D., & Deglon, D. . (2014). A preliminary rheological classification of phyllosilicate group minerals. . *Minerals Engineering,*, 55, 190-200. doi:10.1016/j.mineng.2013.06.004.

Oats, W. J., Ozdemir, O., & Nguyen, A. V. . (2010). Effect of mechanical and chemical clay removals by hydrocyclone and dispersants on coal flotation. . *Minerals Engineering,* , 23(5), 413-419. doi:10.1016/j.mineng.2009.12.002.

Ozkan, S. G., & Kuyumcu, H. Z. . (2006). Investigation of mechanism of ultrasound on coal flotation. . *International Journal of Mineral Processing,* , 81(3), 201-203. doi:10.1016/j.minpro.2006.07.011.

Ozkan, S. G., & Kuyumcu, H. Z. (2007). Design of a flotation cell equipped with ultrasound transducers to enhancecoal flotation. . *Ultrason Sonochem,* , 14(5), 639-645. doi:10.1016/j.ultsonch.2006.10.001.

Papo, A., Piani, L., & Ricceri, R. (2002). Sodium tripolyphosphate and polyphosphate as dispersing agents for kaolin suspensions: rheological characterization. Colloids and Surfaces A:. *Physicochemical and Engineering Aspects,*, 201, 219-230. .

Peng, Y., Mao, Y., Xia, W., & Li, Y. . (2018). Ultrasonic flotation cleaning of high-ash lignite and its mechanism. *Fuel,*, 220, 558-566. doi:10.1016/j.fuel.2018.02.049.

Shabalala, N. Z. P., Harris, M., Leal Filho, L. S., & Deglon, D. A. . (2011). Effect of slurry rheology on gas dispersion in a pilot-scale mechanical flotation cell. . *Minerals Engineering,* , 24(13), 1448-1453. doi:10.1016/j.mineng.2011.07.004.

Tao, D., Zhou, X. H., Zhao, C., Fan, M. M., Chen, G. L.,Aron, A., & Wright, J. . (2007). Coal and potash flotation enhancement using a clay binder. . *Canadian Metallurgical Quarterly,* , 46(3), 243-250. doi:10.1179/cmq.2007.46.3.243.

uast, K., Ding, L., Fornasiero, D., & Ralston, J. (2008, 28September - 1 October). Effect of slime clay particles on coal flotation. . *Paper presented at the Chemeca 2008Conference, Newcastle City Hall, New South Wales, Australia.*

Wang, B., & Peng, Y. . (2014). The interaction of clay minerals and saline water in coarse coal flotation. *Fuel,*, 134, 326-332. doi:10.1016/j.fuel.2014.05.085.

Wang, B., Peng, Y., & Vink, S. . (2014). Effect of saline water on the flotation of fine and coarse coal particles in thepresence of clay minerals. *Minerals Engineering,* , 66-68, 145-151. doi:10.1016/j.mineng.2014.03.016.

Wang, H., Zhu, H., Zhu, J., Xu, W., Li, M., & Fei, Z. . (2018). Flotation of coal in the presence of quartz and clayminerals. *International Journal of Coal Preparation andUtilization,* , 1-11. doi:10.1080/19392699.2018.1487408.

Wang, L., Peng, Y., Runge, K., & Bradshaw, D. . (2015a). A review of entrainment: Mechanisms, contributing factors and modelling in flotation. *Minerals Engineering,* , 77-91. doi:10.1016/j.mineng.2014.09.003.

Wang, Y., Peng, Y., Nicholson, T., & Lauten, R. A. . (2015b). The different effects of bentonite and kaolin on copper flotation. *Applied Clay Science,* , 114, 48-52.doi:10.1016/j.clay.2015.05.008.

Wei, R., Peng, Y., & Seaman, D. . (2013). The interaction of lignosulfonate dispersants and grinding media in copper–gold flotation from a high clay ore. *Minerals Engineering,* , 50-51, 93-98. doi:10.1016/j.mineng.2013.06.012.

Xia, Y., Zhang, R., Cao, Y., Xing, Y., & Gui, X. . (2020). Role of molecular simulation in understanding the mechanism of low-rank coal flotation: A review. *Fuel,* , 262, 116535.doi:10.1016/j.fuel.2019.116535.

Xing, Y., Gui, X., & Cao, Y. . (2016). Effect of calcium ion on coal flotation in the presence of kaolinite clay. . *Energy & Fuels.*, doi:10.1021/acs.energyfuels.5b02474.

Xu, D., Ametov, I., & Grano, S. R. . (2011). Detachment of coarse particles from oscillating bubbles—The effect of particle contact angle, shape and medium viscosity. *International Journal of Mineral Processing,* , 101(1-4), 50-57. doi:10.1016/j.minpro.2011.07.003.

Xu, Z., Liu, J., Choung, J. W., & Zho, Z. . (2003). Electrokinetic study of clay interactions with coal in flotation. . *International Journal of Mineral Processing,* , 68, 183-196. .

Yu, Y., Ma, L., Cao, M., & Liu, Q. . (2017a). Slime coatings infroth flotation: A review. *Minerals Engineering,* , 114, 26-36. doi:10.1016/j.mineng.2017.09.002.

Yu, Y., Ma, L., Wu, L., Ye, G., & Sun, X. . (2017b). The roleof surface cleaning in high intensity conditioning. . *Powder Technology,* , 319, 26-33. doi:10.1016/j.powtec.2017.06.048.

Zhang, L. Z., Lu, Q., Xu, Z., Liu, Q., & Zeng, H. . (2012). Effect of polycarboxylate ether comb-type polymer on viscosity and interfacial properties of kaolinite clay suspensions. . *Journal of Colloid and Interface Science,*, 378, 222-231. doi:10.1016/j.jcis.2012.04.029.

Zhang, M., & Peng, Y. . (2015). Effect of clay minerals on pulp rheology and the flotation of copper and gold minerals. *Minerals Engineering,*, 70, 8-13. doi:10.1016/j.mineng.2014.08.014.

Zhang, M., Xu, N., & Peng, Y. (2015). The entrainment of kaolinite particles in copper and gold flotation using fresh water and sea water. . *Powder Technology,*, 431-437. doi:10.1016/j.powtec.2015.08.042.

Zheng, X., Johnson, N. W., & Franzidis, J. P. (2006). Modelling of entrainment in industrial flotation cells: Water recovery and degree of entrainment. *Minerals Engineering,* , 1191–1203. doi:10.1016/j.mineng.2005.11.005.

Zhu, Z., Yin, W., Yang, B., Fu, Y., & Xue, J. (2019). Reduction of the slime contamination on fine coking coal by using the reverse-and-direct flotation process. Colloids and Surfaces A:*Physicochemical and Engineering Aspects,*, 579, 123681. doi:10.1016/j.colsurfa.2019.123681.

Zou, W., Gong, L., Huang, J., Zhang, Z., Sun, C., & Zeng, H. (2019). Adsorption of hydrophobically modified polyacrylamide P(AM-NaAA-C16DMAAC) on model coal and clay surfaces and the effect on selective flocculation of fine coal. *Minerals Engineering,* , 142,105887. doi:10.1016/j.mineng.2019.105887.