Network for Research and Development in Africa
International Journal of Pure and Applied Science Research
ISSN: 2384-5918, Volume 12, Issue 1
PP 73-84 (February, 2025)
OTL: 45727711-11207-1
arcnjournals@gmail.com
https://arcnjournals.org

MECHANISM OF COAGULATION USING MORINGA OLEIFERA AND SOYA BEANS PODS EXTRACTS

Habiba Abdullah[1] and M. H. Bichi[2]
[1]Department of Sciences, Federal Government College Maiduguri, Borno State, Nigeria
[2]Department of Civil Engineering, Bayero University, Kano, Nigeria

***Abstract**: Natural coagulants have been in the limelight for over a decade owing to the problems encountered when chemical coagulants are used. The use of these chemicals has side effects on man, the environment, and unease in terms of affordability and accessibility. These effects have made researchers seek alternative means of providing clean water for man's usage. Moreover, natural coagulant was characterized using SEM, FTIR, and EDXRF. SEM of the Moringa pod gave a heterogeneous and porosity which gave room for the adsorption ability. Soya beans SEM shows dense jelly-like and closely packed in adsorption and charge neutralization. The EDX of both plant pods showed the presence of anions and cations indicating chemical adsorption via ion exchange. The presence of amines, amides, carboxyl, and carbonyl groups from the FTIR spectroscopy agree with the contribution from both particle bridging and charge neutralization mechanisms. The SEM and FTIR test results and EDXRF revealed that charge neutralization and adsorption sweeping mechanism induced by pods of moringa oleifera and soya beans combined with bridging mechanism led to the turbidity removal.*

***Keywords**: Accessibility, Affordability, Chemical, Environment.*

1.0 Introduction

Water is one of the most significant natural resources for survival. Rural communities with low in come especially in African and Nigeria in particular may depend on water which is not treated for their domestic usage. The use of this untreated water could result in about 1.7 million cases of diarrhea while about 760,000 child deaths is been registered annually. This have led to the need for an improve and safe water for drinking. Global water consumption has been on the increase annually by one per cent for over a few decades (UN, 2019). These increases are five folds and occur as a result of population growth and an increase in global water pollution (Nadiah et al., 2021). Factors such as social economic development and lifestyle also contributed to the increase in demand. This demand for water usage may continue to increase and may result to high water stress or scarcity (UN, 2019). The non-accessibility of portable water may have been as a result of decreasing water table, improper waste disposal and management in to rivers, rapid population growth and increasing salt content, which might had led to poor quality of surface water thereby making it expensive in terms of treatment for drinking and other human activities (De Graaf et al., 2017).

The unalloyed nature of pure water renders it to be not easily accessible. The diffuse particles such as minerals, organic compounds and gases causes change in its physical parameters which includes turbidity, colour, temperature and electrical conductivity. The chemical parameter which includes; (chemical and biological demand for oxygen, pH, alkalinity, total organic carbon) and also the biological parameters whose effect is as result of its makeup, amount and the nature of reaction in terms of the chemicals that occurs between the pollutants. (Richter 2009; Theodoro et al. 2013). Clean and palatable drinking water is a vital component for healthy wellbeing of the populace as such various water sources needs to be purify before being consumed.

Different purification methods are being used in order to improve the aesthetic quality of water so as to render it safe for drinking. The widely used methods is conventional, which involves the use of chemicals. Seasonal variation in turbidity is an issue in the purification processes of surface water (Aziz et al 2019). The use of chemicals in the conventional method has been used to reduce or remove turbidity. these chemicals include; alum, ferric chloride, and polyelectrolyte (Hussain and Haydar, 2020) and the process involves coagulation-flocculation, sedimentation, filtration and disinfection (Wei et al., 2018) The process highlights a water treatment mechanism that stimulates the aggregation of suspended particles which possess negative charge in water. Ironically, the suspended particle that causes turbidity and other issues in water varies but have the same surface charge, they tend to stabilize and repel one another when in a closer range to each other.

The coagulation-flocculation process aid in destabilization of the charged particles of suspended solids. Factors influencing the process include the source of the charge, composition of the charge, particle size, shape, and density of the suspended particles The coagulants possess a positive charge, which aimed at destabilizing the particles and neutralizes the negative charge of suspended particles. As the particles neutralizes, the suspended particles stick together to form slightly larger particles called flocs. Efficient coagulation is attained by rapid mixing which helps in dispersing the coagulant to enhance particle collision. The process is followed by gentle mixing and the particles clogs together to form larger flocs. These process is known as flocculation. Application of coagulation and flocculation processes and selection of the coagulants depend upon the Knowledge of interaction between these factors.

Although the conventional chemicals are efficient in removing turbidity, but have disadvantages which include; high cost of purchase, huge sludge production, and alteration in pH of treated water (Yin 2010). Furthermore, research has linked residual aluminum to Alzheimer’s disease and chlorine could be carcinogenic (Bichi et al., 2012). Over the years, there has been a lot of interest in investigating natural plant- based coagulants as alternative to inorganic chemical coagulants. Plant-based coagulants are cheap, can be produced abundantly, and are mostly non-toxic (Brathy 2006). More so, the plant-based coagulants do not affect the pH of treated water and produce lesser sludge (Ndabigengesere et al. 1995), which make them more cost effective. Therefore, this work tends to investigate the mechanism responsible for the coagulation of plant via characterization which is lacking in many research. The removal of turbidity and inorganic or organic pollutants from surface or wastewater by natural coagulant via coagulation process depends on its chemical composition and structural morphology, as well as its chemical properties. Therefore, the characterization of this type of coagulant is essential to understand its action towards turbidity removal. The coagulant of interest is the pods of moringa and soya beans.

2.0 Materials and Method

2.1 Synthetic raw Water

Turbid water was prepared using the method of Qannaf, Zaid, and Ghazali (2019). Ten gram of finely ground Kaolin clay was prepared by addition into 1 L of tap water. The suspended solution was stirred for 30 min using magnetic stirrer at 200 rev per min and the solution was allowed to settle for 24 h to enhance complete hydration of the clay particles and the supernatant was collected and transferred into another container. This clay suspension was diluted with tap water to obtain uniform turbidity of

300 NTU.

2.2 Preparation of pod powder from moringa oleifera pod and soya beans pods

Moringa oleifera and Soya Beans pods was obtained at Abattoir in Maiduguri, Borno state, Nigeria for the purpose of this work. Mature pod was selected, washed with tap water followed by distilled water, dried and grounded using MasterChef domestic blender. The ground powder was sieved using laboratory sieve 250 µm so as to obtain fine particle size of the powdered pod and was stored in an air tight container at room temperature to be use for preparation of the extract (AOAC, 1995).

2.3 Characterization of Moringa oleifera pod and soya beans pod

2.3.1 Energy dispersive X-ray fluorescence (EDXRF) analysis

The ash compositions of the samples were carried out using EDXRF. The sample was placed in a sample holder contained in the EDXRF equipment and oriented to an angle of 45^{O}. The X-ray machine was closed and the window of the X-ray tube was opened via the shutter. The filament voltage was set progressively to 40 kV and the current to 20 mA. A silicon drift detector was used to detect the secondary X-rays (X-ray detector) and to record the spectrum (acquisition and processing system). Then each element was displayed in their oxide forms (Silas, 2018).

2.3.2 Scanning Electron Microscopy (SEM) analysis

The mineralogical, morphological and microstructural characterization of the coal samples were done by Scanning Electron Microscopy (SEM) analysis. The tests were performed on the JEOL-JSM IT 300 LV (Germany) Scanning Electron Microscope (SEM). For each test, microscopic amounts of the samples were sprinkled on the SEM carbon stubs. Next, the samples were sputtered coated with platinum using the Quorum Q150R S Sputter coater for 10 minutes before SEM/EDX analysis. The analysis was performed at 20 kV and 5 mm working distance to obtain micrographs at magnifications of ×1000. The AZTEC EDX software from Oxford Instruments, UK was used to analyses the captured SEM images (Silas, 2018).

2.3.3 Fourier Transform Infrared Spectroscopy (FTIR) analysis

The Fourier Transform Infrared Spectroscopy (FTIR) analysis technique detects various characteristic functional groups that are present on the surface of the adsorbent. When the surface adsorbent interacts with infrared light, the chemical bond stretches contracts, or bends. As a result, each functional group tends to absorb infrared radiation in a specific wavelength range. The FTIR imaging was carried out using Perkin Elmer RX. The FTIR spectra was collected in the range of 4000-400 cm^{-1}. Potassium bromide (KBr) pellet was first prepared by mixing about 0.01 g of powdered catalyzed adsorbent with about 0.3 g of KBr (Merck; for spectroscopy) in an agate mortar. The mixture was compressed under certain pressure in a special die to form a small disk (Silas, 2018).

3.0 RESULT AND DISCUSSION

3.1 Turbidity Removal by Coagulants

Experimental result of turbidity removal using Moringa pod and Soya beans pod was found to are varies from 70.33 to 84.47 with average removal of 78.85% for Moringa. This is as depicted by Musa and Mohammed (2021) obtained 80 to 70%, 81 to 60% and 79 to 58% for low, medium and high turbid water samples. However, Soya beans achieved a better removal with values varying between 84.00 % to 91.00 % and average of 87.49%. From the foregoing it can be deduced that Soya beans pod gave a good result when compare to Moringa oleifera pod. The result corresponds to the findings of Hussain and Haydar (2020), for defatted Soya beans in his work yielded 72%, 98% and 86.7% as minimum, maximum and average values of turbidity removal for defatted Soya beans. More so, the finding in this work in respect to moringa was also in conformity with results obtained by Abubakar and Kasim (2018) and Muhammad (2017) indicated high removal efficiencies for both medium and high turbid water for moringa pod and pea pod respectively. The high turbidity removal was associated to the structure and constituents of the pods which were identified via different test.

3.2 Surface Morphology Analysis

The SEM images of Moringa pod and soya beans are presented in plate 4.1 an and b. The image illustrates high dispersion and incorporation of a smooth fiber surface with variable sizes structure of the Moringa pod biomass. Figure 4.1(b) shows the formation aggregated, and rough surface morphology of the soya beans sample. The morphology of moringa pod powered shows the the surface charateristic of the powder via SEM. The plate 4.1a depicts the heterogeneous and porosity of the pod powder and was found to be similar to the findings of as workineh, et al., (2020), and the structure aid in adsorption as a result of the interstices and also the protein content available in the pods. These charateristics help to conclude that moringa pod consist of sufficient morphological profile which can withhold the particulate causing turbidity.

The morphology and charateristic of soya beans pod shows dense jelly like and closely packed, as shown in the SEM analysis obtained in Plate 4.1(b) indicating formation of aggregated, and a rough surface morphology of the soya beans sample. Similar morphology was reported by Salmi et al., (2017) indicating the ability to adsorption and neutralize charges.

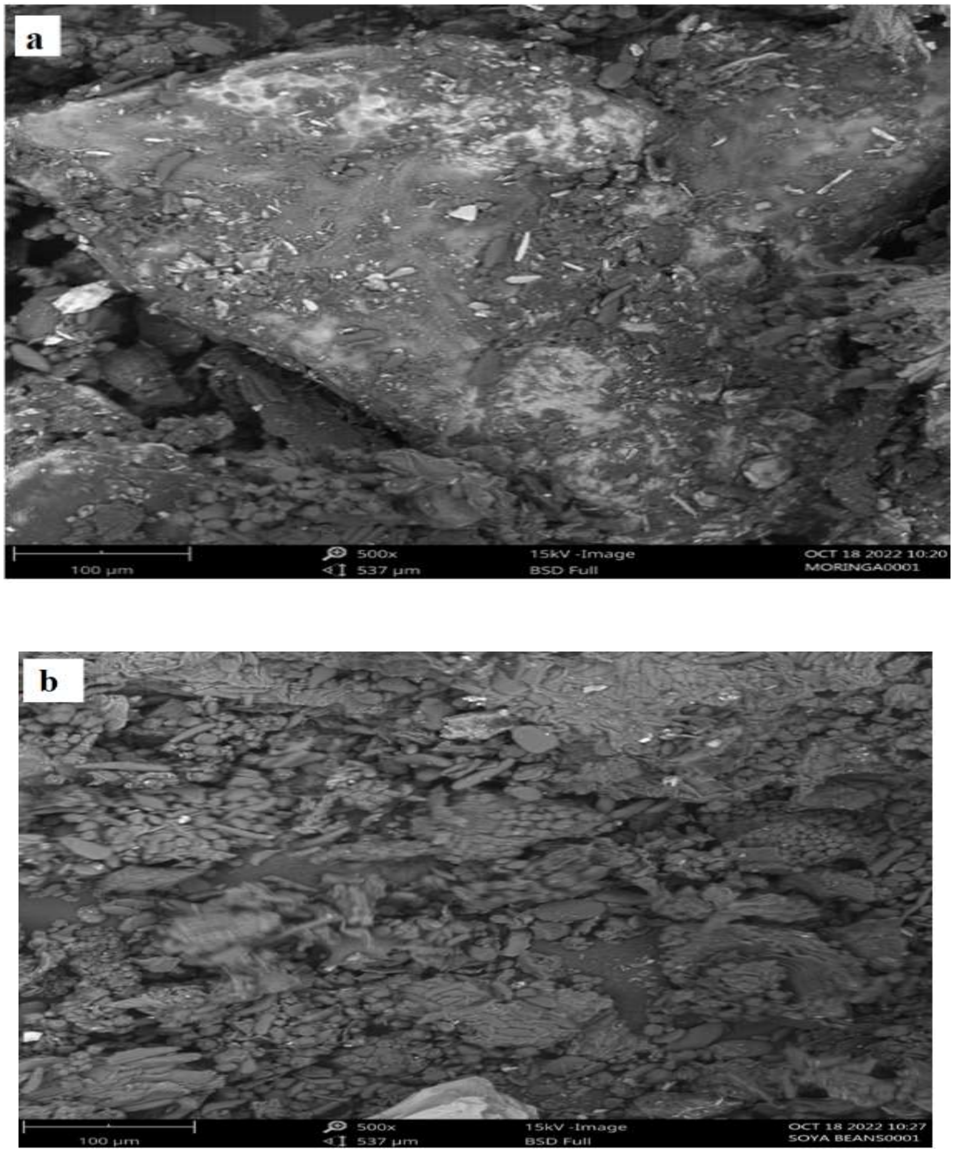


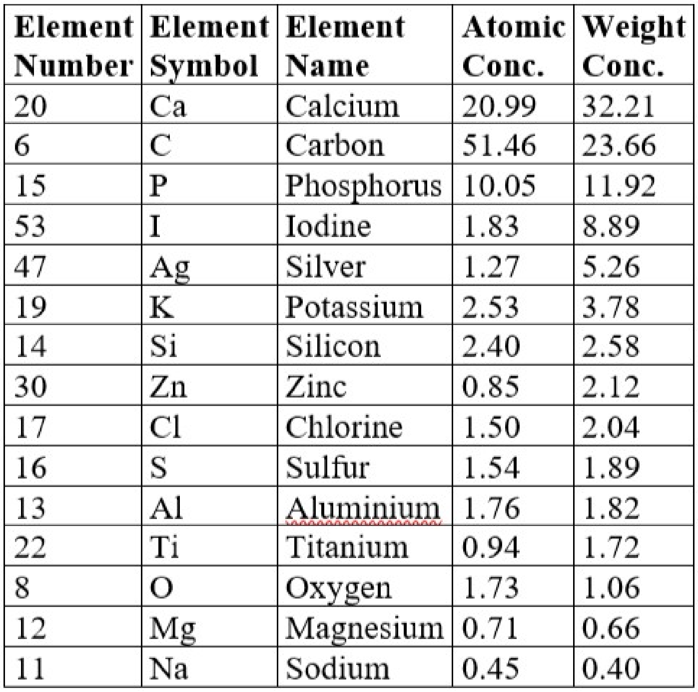
Plate 3: (a) The SEM of Moringa pod, (b) SEM of Soya beans pod

3.3 Energy-dispersive X-ray (EDX) technique

Moringa oleifera pod powder elemental component was investigated using the Energy – Dispersive X – ray (EDX) method. Elemental composition present in the pod from this work indicated the presence of carbon. But adsorption capacity is a function of active carbon, it is therefore a means in which adsorption process occur in turbidity removal. This is also as opined by Oladoja et al., (2017) with a value of 54% and 53% for before and after biossorption and Dada et al., (2012). The EDX data of the elemental component is shown below in Table 4.6 and 4.7 for moringa and Soya beans pods respectively. Concomitantly, Moringa oleifera pod and soya beans pod contain less carbon when compare with other parts of the plant as shown in this work, the amount is similar to what is obtained by Kawo et al., (2013).

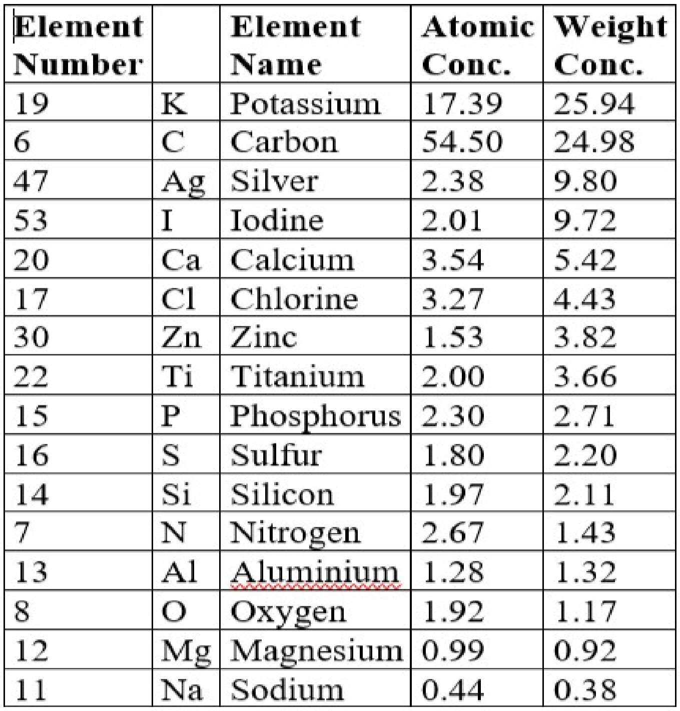
Consequently, in this work trace elements were identified via EDX characterization as shown in Table 4.6, and 4.7 for Moringa and soya beans pods respectively, which is by the studies of Kawo et al., (2009) and Fernanda et al., (2017) which also showed the presence of elements such as Na, Al, K, Si, Mn, Ca, Mg, Zn, Cu in his work. These trace elements verified the presence of anions and cations indicating chemical adsorption via ion exchange and was also depicted by Goldberg et al., (1996). The presence of functional groups in their compound form such as; lignin, protein, carbohydrates, and phenolic, contains carboxyl, hydroxyl, phosphate, and amino groups is significant for the adsorption mechanism as indicated in Table 4.6 and 4.7 and is in conformity with the findings of Meneghel et al., (2013).

Table 4.6 EDX spectra of Moringa



Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
20	Ca	Calcium	20.99	32.21
6	C	Carbon	51.46	23.66
15	P	Phosphorus	10.05	11.92
53	I	Iodine	1.83	8.89
47	Ag	Silver	1.27	5.26
19	K	Potassium	2.53	3.78
14	Si	Silicon	2.40	2.58
30	Zn	Zinc	0.85	2.12
17	Cl	Chlorine	1.50	2.04
16	S	Sulfur	1.54	1.89
13	Al	Aluminium	1.76	1.82
22	Ti	Titanium	0.94	1.72
8	O	Oxygen	1.73	1.06
12	Mg	Magnesium	0.71	0.66
11	Na	Sodium	0.45	0.40

Table 4.7 EDX spectra of soya Beans



Element Number		Element Name	Atomic Conc.	Weight Conc.
19	K	Potassium	17.39	25.94
6	C	Carbon	54.50	24.98
47	Ag	Silver	2.38	9.80
53	I	Iodine	2.01	9.72
20	Ca	Calcium	3.54	5.42
17	Cl	Chlorine	3.27	4.43
30	Zn	Zinc	1.53	3.82
22	Ti	Titanium	2.00	3.66
15	P	Phosphorus	2.30	2.71
16	S	Sulfur	1.80	2.20
14	Si	Silicon	1.97	2.11
7	N	Nitrogen	2.67	1.43
13	Al	Aluminium	1.28	1.32
8	O	Oxygen	1.92	1.17
12	Mg	Magnesium	0.99	0.92
11	Na	Sodium	0.44	0.38

3.4 Functional Groups Analysis using FTIR

The functional groups of the coagulant are studied using FTIR figure 4.2. Interestingly, the main functional groups present in Moringa oleifera pod extract have depicted a high similarity index with the pod of soya beans. The broadband of moringa oleifera pod centered at 3,862 cm–^{1}, 3761 cm–^{1}, 3665 cm–^{1}, 3541 cm–^{1}, 3435 cm–^{1}, 3251 cm–^{1}, 2920 cm–^{1}, 2884 cm–^{1}, 2630, cm–^{1} 2510 cm–^{1}, 1581 cm–^{1}, 1483 cm–^{1}and 1280 cm–^{1} attributed to O-H and –NH hydroxyl protein, carbohydrate, fatty acids and lignin, o-H alcohol, phenol, N-H amines, C-H aliphatic O-H carboxylic acid, C=C alkenes aromatic. The FTIR fields of soya beans pod clearly indicated several peaks with –OH alcohol and phenol, 3251 amines, 2920 aliphatic, O-H carboxylic acids, C=C alkenes and 1283 aromatic. These functional groups in both moringa oleifera pods and Soya beans pods are responsible for turbidity removal.

The emulsion particles' adherence onto the surface of Moringa pods and Soya beans pods is as a result of the interaction of charges by the hydrogen bonds of carboxylic and alkali groups, this was also opined by Saritha *et al*. (2019); Araújo *et al*. (2010); Espíndola-Cortés *et al*. (2017).

It can therefore be concluded that the functional groups vital for the high turbidity removal efficiency of Soya beans pod could be associated with the intermolecular attraction of the coagulant with hydrophobic colloidal particles and high fatty ester oil present in the Soya beans pods, leading to coagulation – flocculation steps. Adsorption occurs as a result of hydrogen bonding, it can therefore be concluded that adsorption played a significant role in plant based coagulation process. Thus the mechanism for the Soya beans pod is attributed to adsorption and charge neutralization. This concur with the findings of Hussain and Haydar (2020). More details on the mechanism was deduced from the morphology analysis which was distinct by adsorption and charge neutralization mechanism, which also concur with the work of Hussain and Haydar (2020).

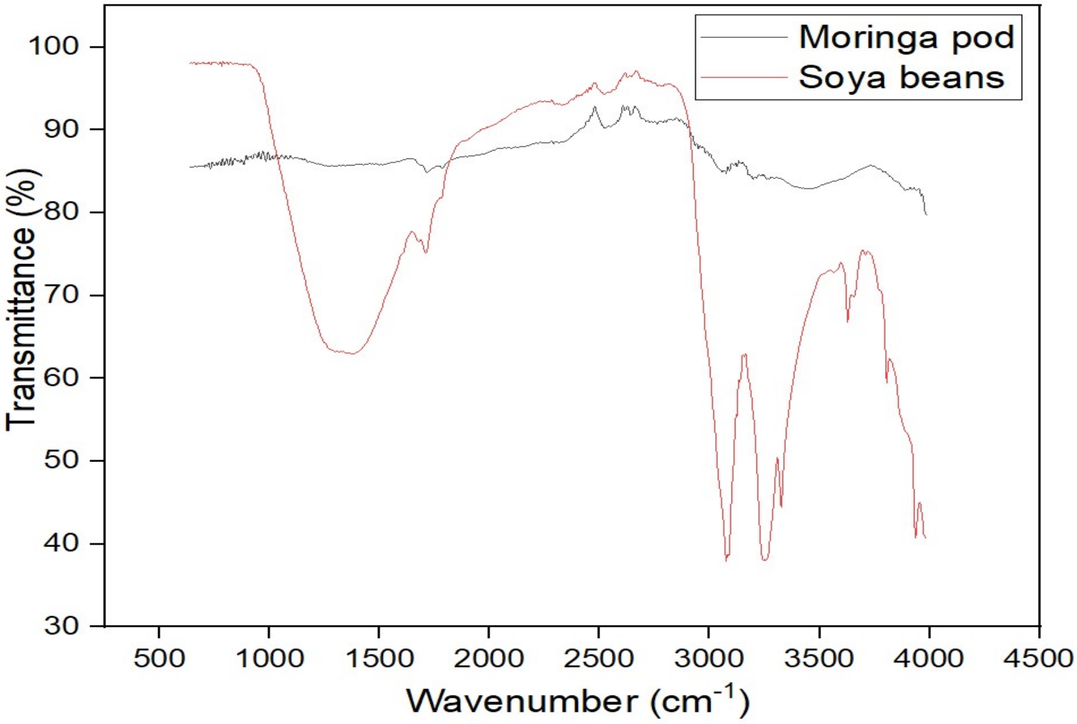


Figure 4.2 FTIR spectra od Moringa and Soya beans

3.5 Mechanism of Coagulation on Turbid water using moringa oleifera and soya beans pods.

Generally, mechanism of coagulation in the conventional approach involved the use of chemicals - aluminum (alum) and iron salts which are rapidly dissolved in water to produce cationic species which can be absorbed by negatively charged particles and neutralize their charge. In these mechanism, particles are destabilized, so as to attain flocculation. At this flocs formation stage, overdosing can interfere with the phenomenon, therefore, fairly precise control of coagulant dosage should be considered in water treatment plants. Results indicated that turbidity removal efficiency was varied by pH, alum dose and initial turbidity of water. The obtained results are in accordance with those obtained by Volk et al. (2000). When alum is added to water it dissociate to release aluminum hydroxide it enmeshes the particles and the process is known as coagulation. In the process alum ions introduces positive charges into the water. the positive charges help to neutralize the negative charges on the suspended particles thereby facilitating the particles aggregation. Gentle mixing is introduced so that the particles can form bigger flocs, the process is termed flocculation and the particle can be easily separated from the water

The mechanism responsible for coagulation from this work is the presence of alcohol, phenol and carbohydrate acids which is assign to lignin and tannin as evident from the FTIR results. This is similar to the finding Abderrezzaq et al., (2021), in their work acknowledge the presence of different functional groups such as alcohol, phenol and carbohydrate acids are responsible for coagulation thereby reducing turbidity to 5NTU from 13 NTU (Abderrezzaq et al., 2021).

Coagulation mechanism process in this work involved the principle of interaction of polymer with large number of functional groups which include; -OH, -NH and –COOH. This is as opined by Rajendran et al., (2013). The agglomeration of these functional groups with turbid water lead to adsorption process.

Moringa oleifera pod contain protein which led to its coagulation ability and this concur with the opined by Abderrezzaq et al., (2021). Both surface of Moringa pod and Soya beans pods has some negative charges, this aid in neutralization of charges and adsorption, this corroborate with the findings of Omar et al., (2018). The presence of cationic compounds was found in the Moringa and soya beans pods and was similar to the findings of Meng and Mohammed, (2021). Moringa pod and Soya beans pod also have protein content as shown in Table 4.5 and similar finding was depicted in the work of okiki et al., (2015). The protein is bridge up with the multi-functional groups of –OH, -NH_2 and -COOH and destabilize the particles to clog and form larger flocs, this is in agreement with the findings of Sivakumar, et al., (2020). The protein serves as synthetic which is positively charge, this is also in conformity with the findings of Folkard et al., (2001). It can also be concluded that the high protein content, tannin and mineral content as found in the result of the FTIR of this work is the reason for its coagulation ability.

4.0 Conclusion

The study evaluated the mechanism responsible for turbidity removal from surface water of high turbidity (300 NTU). The pods of moringa oleifera and Soya beans were found to remove the turbidity by adsorption and charge neutralization. Averagely, the turbidity removal efficiency for moringa oleifera pod is 78.8% while Soya beans is 87.49%. According to the results of this study, the FTIR, SEM and EDX gave an insight on the structure and composition of the pods of Moringa oleifera and Soya beans pods responsible for turbidity removal. The presence of protein, carbohydrates, tannin phenol and alcohol is established in this work. FTIR is an effective tool in determining the surface chemical composition of rigid foams. The major bands and their significance are shown. More so, EDXRF is a convenient technology to screen all kinds of materials for quick identification and quantification of elements.

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