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# "A Study on effect of Coconut Shell Biochar Modified with Aluminium Chloride on sludge dewatering of secondary sludge in wastewater treatment plant".

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## Abstract

The effects of coconut shell biochar as a skeleton builders paired with aluminium chloride ($AlCl_3$) on secondary sludge conditioning were studied, and the sludge dewatering process was investigated. Al-rich biochar (Al-CSBC) was tested for its catalytic influence on sludge dewaterability. The sludge dewatering using Al-rich biochar conditioning greatly increased sludge dewaterability as compared to the conditioner alone, resulting in a 69 percent reduction in moisture content. Chemical reactions such as complexation processes and charge neutralisation increased sludge floc strength as extracellular polymeric substances (EPS) content decreased. Turbidity, nutrient and heavy metal removal concentration was also studied using Al-rich coconut shell biochar. Characterization studies like scanning electron microscope were investigated. As a result, the sludge cake produced by biochar and $AlCl_3$, along with its voids and incompressible structure, as well as the biochar's stiffness structure, increased sludge dewaterability.

**Keywords:** *Nutrient, Heavy metals, phosphate, conditioning, turbidity.*

## 1. Introduction

Wastewater treatment facilities generate a lot of sludge (WWTPs) as a result of rising industrialization and urbanization, and it often includes more than 98 percent moisture. Prior to sludge disposal, a dewatering step is frequently necessary to reduce volume by eliminating the substantial amount of water content in sludge, which will significantly increase the efficacy of sludge disposal methods including burning, composting, and landfilling (Liu et al., 2018).

Chemical conditioners, such as inorganic and organic coagulants, are commonly used before mechanical dewatering to increase sludge dewatering efficiency through inter particle bonding and surface charge neutralization process. It is hard to achieve a higher solid content as a sludge cake due to the higher compressibility of the sludge during the compression stage of sludge dewatering (Park et al., 2003).

Anaerobic sludge conditioning with polyelectrolytes increased the sludge cake's compressibility, making it easier to alter shape under pressure during the compression phase of mechanical dewatering, according to study on this topic. Sludge dewatering is made more challenging by the possibility of void closure as a result of this sludge cake deformation.

Physical conditioners, commonly referred to as skeleton builders or filter aids, are substances that help sludge establish a porous, lattic structure, which keeps the sludge cake permeable even under high compression pressure. They are used to make sludge less compressible. Cement, demolition debris, rice husk and bagasse, laterite soil, lignite, incinerator slag, gypsum, coal ash and industrial waste( Manjunath et al.,

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2019) have all been investigated as potential skeleton builders. Inert minerals and solid materials with high carbon content can also serve as skeleton builders. (Shi et al., 2015). Coconut shell (CS) is a agricultural leftovers produced in different countries, and it must be processed and disposed of appropriately to reduce environmental issues.

Physicochemical treatments such as chemical oxidation, thermal/hydrothermal treatment, alkaline hydrolysis, ultrasonication, and anaerobic digester approaches are used in full-scale WWTPs to reduce sludge generation. Sludge flocs were destroyed, microorganism cells were damaged, and intracellular chemicals were released using physicochemical procedures (Rashmi et al., 2020). Chemical oxidation with potassium ferrate, Fenton-like reagent, and calcium peroxide, for example have significantly increased in sludge settleability and moisture removal due to the coagulation effect of $Fe^{3+}$, whereas other process, such as ozonation, sulphate radical oxidation, alkaline hydrolysis, and ultrasonication, reveled during the investigation that theses process will reduce the sludge filterability and impose additional problems like subsequent treatment and disposal. The second most powerful neutralizing agent, ozone, is widely used in wastewater and sludge treatment.

Although the dewatering extent is determined by the moisture content of the dewatered cake particles, the dewatering rate tests are performed in the lab using a capillary suction time (CST) test or a filtration equipment that evaluates the specific resistance to filtration (SRF). However, since sludge dewatering efficiency cannot be determined by CST or SRF tests alone, compression dewatering, which is frequently utilised in WWTPs, also involves filtering and expression phases (VHR et al., 2016). Because no pressure is applied, the CST measurement is erroneous, whereas the sludge SRF merely shows how well the cake filters water during the filtration stage.

A more important test that can be used to determine both the filtration and compression stages is the filtration-compression cell test. Along with the SRF test and an assessment of the sludge's ability to absorb water, sludge compression dewatering was performed in the current investigation to comprehensively define the sludge dewatering process (Rashmi et al 2021).

The CS is a viable choice for physical conditioner for sludge dewatering because of its high porous structure, light in weight, large exterior surface area, and lattic structure. However, enhancing sludge dewatering under co-conditioning by chemical and Skelton conditioners remains a significant issue, because EPS's strong water affinity prevents water from draining through water passageways in the sludge cake.

The major objectives of this research were to i) examine into the possibilities of using CS-BC-Al for the first time to increase sludge dewaterability.; (ii) investigate sludge dewaterability after conditioning with CS- BC-Al as skeleton builder CS- BC-Al oxidation (iii) investigate the effect of CS-BC-Al oxidation on sludge physiochemical properties iv) analyze the behaviors of heavy metals (i.e., Cd, Zn, Cr, and Pb) in dewatered sludge filtrate

## 2. Materials and Methodology

Mixed primary and secondary aerated sludge was obtained from NITK wastewater treatment plant in Surathkal . The aerated sludge was collected in a polyethylene container and stored at 2°C. Before starting the experiment, the freeze sludge was inserted in a water bath at 25°C for 20 minutes. The whole approach of sludge dewatering utilising CS-BC-Al is depicted in Figure 1. The laboratory collected the raw coconut shells for examination, and they were ground into coconut shell powder using a mixer.

Then coconut shell powder were sieved, and obtained particles with a diameter of 240 micron meter were collected and burned for 30 min at 600°C in a muffle furnace (Rotex, India). biochar (20g) was drained in 1 liter of Hcl (1.5 mol/L) for a day. The biochar is then filtered, cleaned, and dried at 103°C in an oven (Rotex, India). At 1:15 ratio of CSB was immersed in $AlCl_3$ for 3 hours later it was sonicated (Skytron, India) at 30 °C, dried in the oven, and then used for further investigation.

The initial parameters of secondary aerated sludge, namely pH, temperature, CST, alkalinity and total solids, were tested using standard procedures in the laboratory. The conditioning of the sludge was done using jar test equipment. Six beakers were filled with 500 Ml of sludge, with the first beaker acting as a controller without the addition of the filter aid. Then, in all beakers except the control, quantity of coconut shell biochar with Aluminium chloride (CS- BC-Al) in varied amounts (15,30, 45, 60, 75 and 90% DS dry solids (DS) were applied. During additional study, CST and moisture content were determined for optimum rapid mixing (300 RPM) for 15 minutes, after 15 min the RPM was lowered to 60 for 20 minutes.

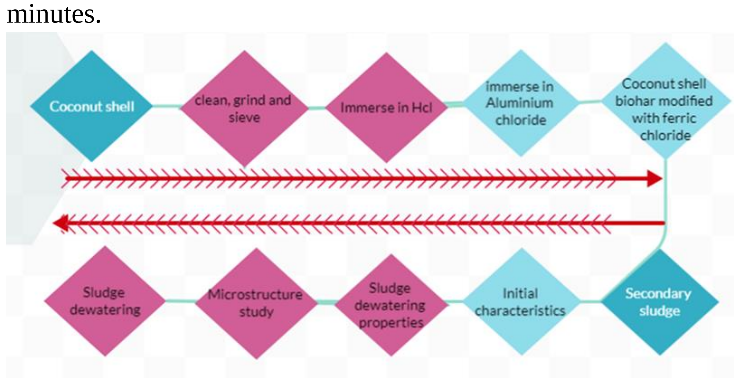


**Figure 1.** Overall flowchart of sludge dewatering using CS-BC-Al.

Vacuum filtration, drying of the sludge cake, and analysis of the sludge's microstructure were all performed on the conditioned sludge. The experiment was run through three times, with the average value used to calculate the effectiveness of sludge dewatering. Each sample was examined at least three times, and the results of all examinations were averaged.

## 3. Results and Discussion

### 3.1 Characteristics of secondary sludge

The characteristics of the secondary aerated sludge id dissipated in Table 1. The pH of the sludge was found to be in a neutral state. In addition, the electrokinetic potential of the raw aerated sludge sample was negative. The raw sludge was centrifuged and the filtrate was collected and found the initial characteristics of the sludge like alkalinity, turbidity, zeta potential and CST. Temperature, total solids, Total dissolved solids, total suspended solids, electrical conductivity, alkalinity were also determined using raw sludge. CST, total solids, and volatile solids values are shown in the table which clearly show that these values are higher. The requirement of conditioning dosage will be higher if the total solids and volatile solids presence is higher in the sludge. The moisture content of sludge is 95.4% that is sludge contains maximum water content and less solid fraction. Zeta potential (ZP) is a crucial surface property of sludge flocs in terms of flocculation and dewatering. A differentiating characteristic is the value of ZP, which demonstrates the strength of electrostatic attraction between adjacent, similarly charged scattered particles in the sludge. Colloids can flocculate when ZP is low because attractive forces can overpower repulsive ones. On the other hand, more stable colloids and a reduced risk of flocculation are produced by larger ZP values. In order to neutralise negative charges and reduce zeta potential magnitude, more cationic flocculant is needed. Sludge, with a value of -7.4 Mv, showed higher negative ZP values, as seen in Table 4. As a result, the sludge may require more polymers for conditioning.

**Table 1.** Overview of raw sludge

| Sl No | Variable | Denomination | Value |
|---|---|---|---|
| 1 | pH | - | 6.9 |
| 2 | Electrical Conductivity | Microsimens/cm | 216 |
| 3 | Temperature | Degree | 26 |
| 4 | Moisture content | % | 95.4 |
| 5 | Total solids (TS) | mg/L | 16424 |
| 6 | Total dissolved solids | mg/L | 4956 |
| 7 | Total suspended solids (TSS) | mg/L | 10956 |
| 8 | Alkalinity | mg/L | 2216 |
| 9 | Zeta potential | - | -7.4 |
| 10 | CST | Sec | 142 |
| 11 | Turbidity | NTU | 26 |

### 3.2 Effect of CS- BC-Al dosage on moisture content

Figure 2 illustrates the dewatering statistics for secondary sludge in terms of moisture content, using 60 percent DS CS-BC-AL conditioned sludge and a 5.0 bar applied pressure. The addition of CS-BC-AL increases the water release rate from 95.4 percent to 69 percent. These results indicate that the dewatering level can be drastically increased by introducing CS-BC-AL. The impact of sludge thickness on the dewatering procedure at 5.0 bar of pressure and 60% DS addition is shown in Figure 1. Sludge thickness apparently has a considerable effect on dewatering performance because it can cause a greater cake MC for a given applied pressure over longer times. According to the results, CTS conditioning reduced the sludge cake's water content, which also reduced its volume.

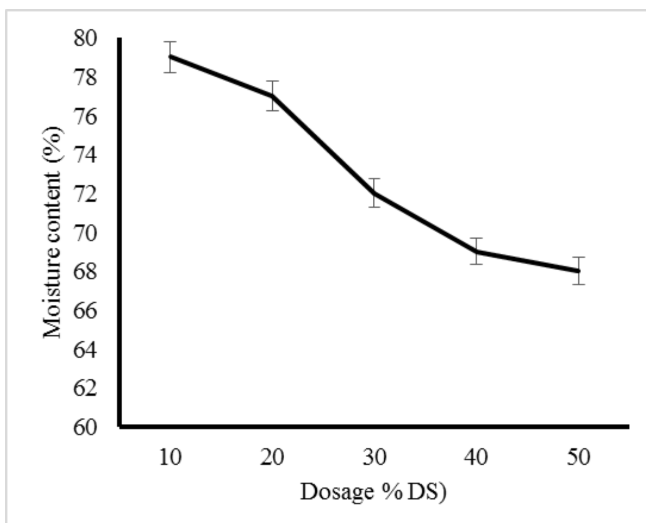


**Figure 2.** Illustrates the dewatering statistics for secondary sludge in terms of moisture content

## 3.3 Effect of CS- BC-Al dosage on CST

Figure 3 illustrates how the dosage of CTS was regulated in this region at 20–60%DS. The CTS's conditioning enhanced its ability to dehydrate sludge. The sludge cake's moisture content dropped when the CTS dosage was between 20 and 60%DS. The water content percentage of the sludge cake dropped amid 95.4% to 69.62% at a CTS dosage of 50%DS. Since CTS is a weak cationic polymer, it caused negatively charged sludge particles to lose their stability and changed the bound water in the sludge into free water, increasing the efficiency of sludge dehydration and deposition. However, the water content in the sludge cake increased again as the CTS dosage are increased to 60%DS, indicating that CTS had an optimal dosage; if the dosage was greater than the optimal value, it would not be helpful for sludge to flocculate.

This was due to the increased CTS making the sludge more viscous, reducing particle collisions, and affecting the effectiveness of the particles' sedimentation. Additionally, when CTS levels were exceeded, the sludge particles became negatively charged once more. As a result, the particles attracted one another and the system stabilized once more, finally resulting in ineffective dehydration. On the other hand, it was noted in the experiment that the sludge settled quickly and produced larger flocs following conditioning with CTS. The results of the cationic Fe experiment on sludge dewatering revealed a drop in water content in the solid cake amid 95.4% to 62.64%. This might be the result of the flocculation effect of CTS [Krishnamurthy et al, 2019) removing more interstitial water from the sludge. The mechanical dewatering efficiency of sludge was increased by better sedimentation performance. Above all, in our study, we were able to determine that 50%DS was the ideal CTS dosage for enhancing sludge settling and dewatering performance.

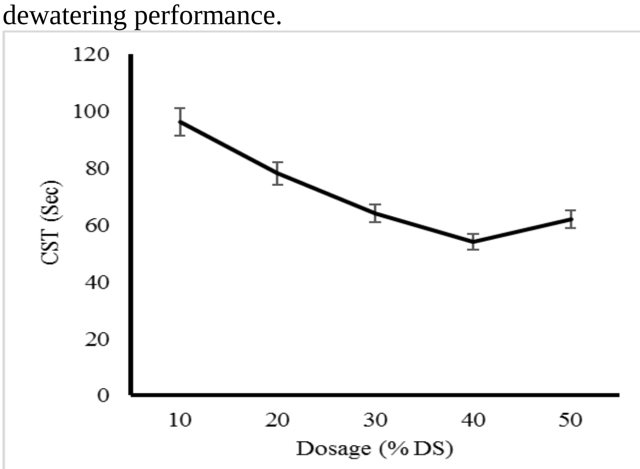


**Figure 3.** illustrates the dewatering statistics for secondary sludge in terms of CST

## 3.4 Effect of CS- BC-Al dosage on turbidity

Figure 4 illustrate the effect of Al-CSBC dosage on sludge dewatarability. The increase in dosage of Al-CSBC there is an decrease in the turbidity level. The optimum turbidity of 50% DS gives the maximum removal of turbidity. As the skeleton material Al-CSBC dosage increased more than 50% DS, the turbidity started increasing. As the dosage increased the solid content was also increased because the particle flocculation was carried out and further flocculation could not be developed by Al-CSBC there by acting as a skeleton material alone. When the dosage was 50%DS, the lowest turbidity of 8NTU was observed.

Low dosages resulted in sludge flocs that were too tiny and friable to effectively increase sludge dewatering performance because the flocculant was unable to neutralise negatively charged particles. As a result, DS was low and supernatant turbidity was high. The flocculant created the flocculation system positively charged when the dosage was too large, which increased the attraction between flocs and caused the flocs to stabilize (Vinod et al., 2020). The water in the sludge would become more viscous and challenging to filter if there was an excessive amount. The dry solid composition of the sludge cake was subsequently reduced. A 50%DS flocculant dosage was needed to successfully dewater the waste activated sludge.

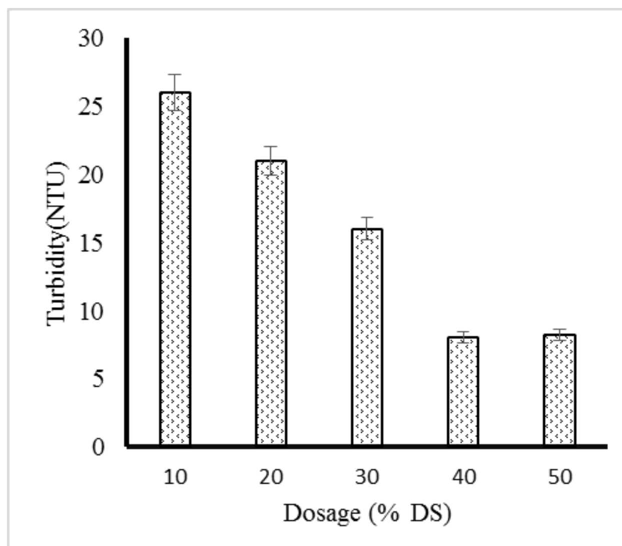


Figure 4. illustrates the dewatering statistics for secondary sludge in terms of turbidity

## 3.5 Response of CS- BC-Al dosage on Heavy metal removal

Numerous studies have looked into the use of oxidants in the treatment of sludge. There have been studies on heavy metal removal from sludge; instead, their studies have primarily concentrated on sludge dewatering, particularly using transition metal ions in dewatering. Additionally, there hasn't been much study on the application of Fe as a potent oxidant for treating sludge. Therefore, it's crucial to look into the best way to clean sludge so that it can be used as struvite by removing heavy metals from it. Heavy metal fractionation has an impact on how well they can be removed. The sludge's organic and sulphide fractions, as well as the carbonate-bound fraction, are where Pb, Zn, Cr, and Cd are often discovered because of their strong migratory ability. It is beneficial to get heavy metals out of sludge.

Variable CB-Al dosages in this investigation had minimal impact on the morphology of heavy metals. Researchers from several fields have studied how oxidants are used to cure sludge. Heavy metal removal from sludge has received little attention; instead, their study has mostly focused on sludge dewatering, particularly the use of transition metal ions in dewatering. The use of Fe as a potent oxidant in sludge treatment has also received little research. Therefore, learning how to remove heavy metals from sludge so that it can be used as struvite is crucial. The effectiveness of heavy metal removal is influenced by their concentration.

Commonly found in sludge's organic and sulphide fractions, as well as the carbonate-bound fraction, where they have a high migratory ability, are Pb, Zn, Cr, and Cd. Sludge can be processed to eliminate heavy metals, which is advantageous. Fig. 5 displays the removal effectiveness of several heavy metals (Pb, Zn, Cr, and Cd) from sludge after it was exposed to various CS-BC-AL dosages for two hours at pH 4 and 26°C. The highest metal removal rates were seen at the highest CS-BC-AL dosage. Removal rates for Pb, Zn, Cr, and Cd were 81.04%, 45.20%, 79.94%, and 592.41%, respectively. Pb percentage removal from sludge treatment rose with CS-BC-AL dosage, and among metals, oxidant concentration had the greatest impact on heavy metal removal rates (Manjunath et al., 2020).

Zn, Cr, and Cd removal rates were substantially higher after treatment with CS-BC-AL than after treated with Pb. After being treated with CaO2, the removal of heavy metals from sludge wasn't as effective as it could have been, and the percentage removal of Cd was poor for all CS-BC-AL doses.

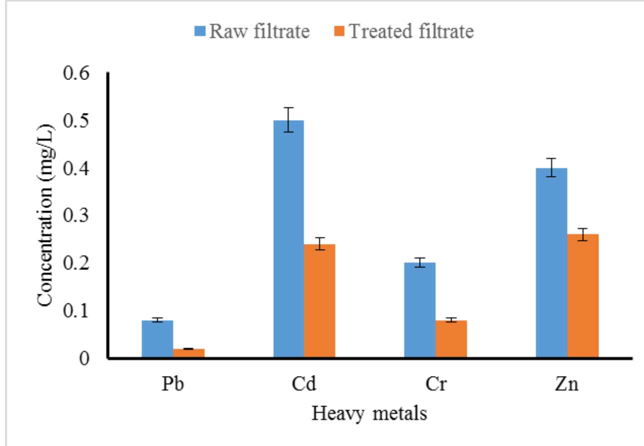


Figure 5. illustrates the heavy metal removal from the sludge filtrate

When the concentration of CS-BC-AL exceeded 40%DS, the clearance rates of heavy metals drastically decreased. The weight of dry matter in the sludge grew with the addition of a combination of solid materials created by different CS-BC-AL dosages, although the mud cake's heavy metal content was minimal and its clearance rate was rapid.

## 3.6 Effect of CS- BC-Al dosage on nutrient removal

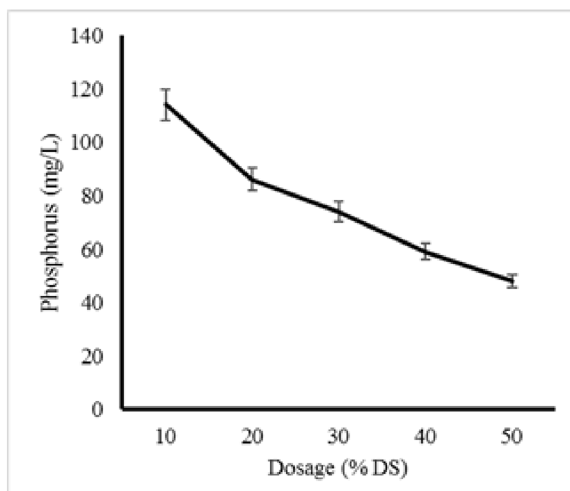


Figure 6. illustrates the nutrient removal from the sludge filtrate

The effect of dosage on nutrient removal is seen in Figure 6. The dosage was increased to 50% DS at pH 9 from 20% DS at pH 9. When the pH dropped below 9, the removal of phosphorus was significantly reduced. This was due to an increase in H+ concentration in the solution, which impeded phosphorus removal. When the pH rises above 10, the phosphorus is removed, resulting in the production of precipitate. The phosphorus in the filtrate was dramatically reduced as the pH increased.

The struvite fraction in the precipitate whose pH was maximised was determined by the initial molar ratio of ammonium, magnesium, and phosphate. At the ideal pH of 9, phosphorus was eliminated with a high rate. At the ideal pH of 9, phosphorus was eliminated with a high rate. In order to improve saturation, exogenous Mg must be dosed due to the low Mg/P molar ratio of 0.26 in the reject water, which indicated that Mg was the limiting element for the precipitation of struvite. The results were consistent, with phosphorus elimination increasing when the CS-BC-AL dosage was raised. Despite this, the CS-BC-AL had a minor impact on phosphorus removal via the adsorption process.

## 3.7 Characteristic study of raw and conditioned sludge

To confirm the presence of porous structure in the sludge cake, the sample was dried and examined the microscopic structure, as illustrated in the Fig. 7. The raw sludge has identical rough surface patterns, showing that both sludge has a flat surface with no channels or voids (Fig. 7a). This is due to the fact that high cake compressibility aids in the closure of voids in raw and flocculated sludge. The flocculated -sludge cake, generated a discontinuous surface with multiple channels or voids, as seen in Fig. 7b. CSB particles are highly incompressible, thus they can maintain channels or voids, preventing an impenetrable thin layer of sludge from forming on top of the filter medium during mechanical filtering ( Liu et al., 2018).

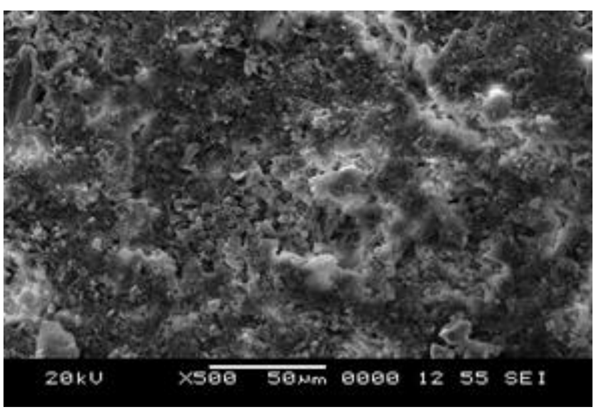


**Figure 7.** a) SEM image of raw sludge

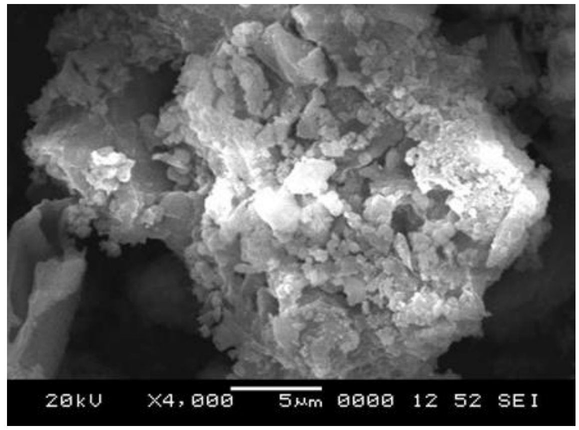


**Figure 7.** b) SEM image of treated sludge

## 4. Conclusion

The current work experimented to dewater sludge using coconut shell biochar modified with aluminium chloride. The experiment's objective was to investigate the CS- BC-Al characteristics (CST, moisture content, turbidity, phosphate content, zeta potential). The findings demonstrate that the filterability was improved by reducing compression and utilising a high porosity biochar structure, which affected the capacity for metal and nutrient adsorption. A SEM analysis indicates that the sludge particles' structural deformation had an impact on how many voids they provided for easy water flow. Another affordable heavy metal and nutrient adsorbent is CS- BC- Al. As a result, CS- BC- Al has shown to be an excellent skeleton builder and the most affordable and effective sludge dewatering option.

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