

Comparative Evaluation of Chemicals and Botanicals based Dehydration of Biogas Slurry

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Spent slurry from cattle dung based biogas plant was characterized and dehydrated by coagulation methods. Various chemical and botanical coagulants were tested at their different concentration levels. Alum at 3.6 % (w/v) produced maximum dehydration (40 %) and its dose was further reduced to 2% (w/v) by adding polyelectrolyte dimethylamine ultimately causing 44 % dehydration of fresh biogas slurry. Regarding botanicals, *Moringa* seed powder showed 30 % dehydration, better results than cactus mucilage (with only 5 % water removal). In case of *Moringa*, although the water separation was less than alum, the quality of separated water (in terms of EC, pH, N, P, K, TOC) was found better. The Zeta potential values of water separated out by *Moringa* seed powder and alum were found to be -18.1 and -17.3 mV respectively. Our results suggest that although the dehydration capacity of alum was superior than botanicals tested but quality of water removed was better in case of *Moringa*.

Keywords: Biogas slurry, alum, dehydration, coagulation, *Moringa*, Zeta potential

Introduction

India possesses the second largest numbers of biogas plants in the world producing 45 million tonnes of spent slurry every year which leads to its management problem¹. Although, the slurry is potential organic manure, its transportation to the fields is difficult due to its high water content (>90%) and unpleasant odour. Dewatering of biogas slurry (BGS) is therefore, a critical step in its utilization and disposal. Presently, there are several physical, chemical and biological methods being used for industrial sludge dewatering and treatment^{2,3}. These treatments include drying, filtration (belt press, screw press, vacuum filtration, pressure filtration, etc.) centrifugation, use of flocculants and chemical and botanical coagulants^{4, 5}. The use of physical methods such as filtration and centrifugation could be useful in removing water up to 60% from BGS but further cleaning of water separated is not possible due to highly colloidal nature of impurities in it. The proper BGS dehydration could be achieved by coagulation⁶ which has long been widely employed for waste water/sludge treatment. However, the dewatered sludge and effluent after the chemical treatment would be having low pH and high conductivity values, which further leading to the problem in discharge of these into the agricultural land for irrigation purpose or to be used as organic manure. The use of biological coagulants can be an

alternative but their efficiency has to be tested in this regard. The present research investigates the application of alum, cationic polyelectrolytes and *Moringa oleifera* seeds as primary coagulants for dewatering the BGS.

Materials and Methods

Procurement and characterization of biogas slurry (BGS)

BGS used for experiments was procured from Sri Krishana Gaushala, Ghaziabad, Uttar Pradesh, India. The ultimate and proximate analysis of oven dried BGS was done using standard methods and BGS was found to have 90 % moisture content, pH 8.2, EC 9.18 mS/cm, total nitrogen 0.88 %, total organic carbon 37.25 %, Potassium 0.87 % and phosphorus 0.58 %.

Dehydration by coagulants

Chemical coagulants were obtained commercially from Merck, India. *Moringa* seeds were purchased from local market and grinded to form powder. Cactus pads were procured from Micromodel, IIT Delhi. The mucilage extracted from cactus pads was dried and crushed into fine powder for coagulation⁷. Initial dose optimization of coagulants for the dehydration of BGS were conducted using standard jar test equipment with 250 ml slurry volume at optimum pH 6⁸. Stirring of BGS was done using homogenizer at 250 rpm for 30 min. Further dehydration of BGS through best performing coagulants was carried out using optimized flash mixing (120 rpm for 10 min) followed by slow stirring (30 rpm for 30 min).

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The sludge was allowed to settle for 2 h and the supernatant was collected and used for EC and pH analysis. The summary of the various methods used for BGS dehydration is shown below in flowchart divided into two phases (Phase I and Phase II).

Phase I: Selection of best chemical and botanical coagulant on the basis of EC, pH and % dehydration

Phase II: Chemical coagulant dose reduction and testing the properties of water and sludge separated by chemical and botanical coagulants.

Results and Discussion

BGS dehydration

Various chemical coagulants were tested for BGS dewatering. The doses of the coagulants were optimized previously. Urea, KCl, SSP and Gypsum were found ineffective even at very high doses. Optimized doses of Acrylamide, Gelatin and Alum were 1.2 %, 2.0 % and 3.6 % respectively. The gelatin removed 26 % water while Acrylamide only 20% (Table 1). In addition, the water separated was highly

turbid. EC of slurry after addition of Urea, KCl, SSP increased to a great extent (90 mS/cm, 50 mS/cm and 30 mS/cm respectively) (Fig. 1). The pH of slurry with all treatments except alum was found to be alkaline. Nonetheless, the water separated with these chemicals was also very turbid (> 900 NTU). Among all the chemical coagulants used, alum (3.6 %) produced best results removing 40 % water from the slurry with lowest turbidity (298 NTU). Alum is the coagulant of choice for many industrial wastewater treatment applications, due to its high efficiency, effectiveness in clarification, and utility as a sludge dewatering agent. The effectiveness of aluminum coagulants arises principally from their ability to form multi-charged polynuclear complexes with enhanced adsorption characteristics. The nature of the complexes formed may be controlled by the pH of the system^{9, 10}. In spite of short detention times, there are many drawbacks of coagulants reported, such as high cost of chemicals for precipitation as well as for pH adjustment and voluminous sludge production due to heavy dosages of chemicals^{10, 11} (Stephenson and Duff, 1996; Srivastava et al., 1984). From the foregoing discussion, it is clear that all treatment methods in use have some drawbacks, and there is a need to look for other alternative methods. Therefore, the further experiments were conducted in order to

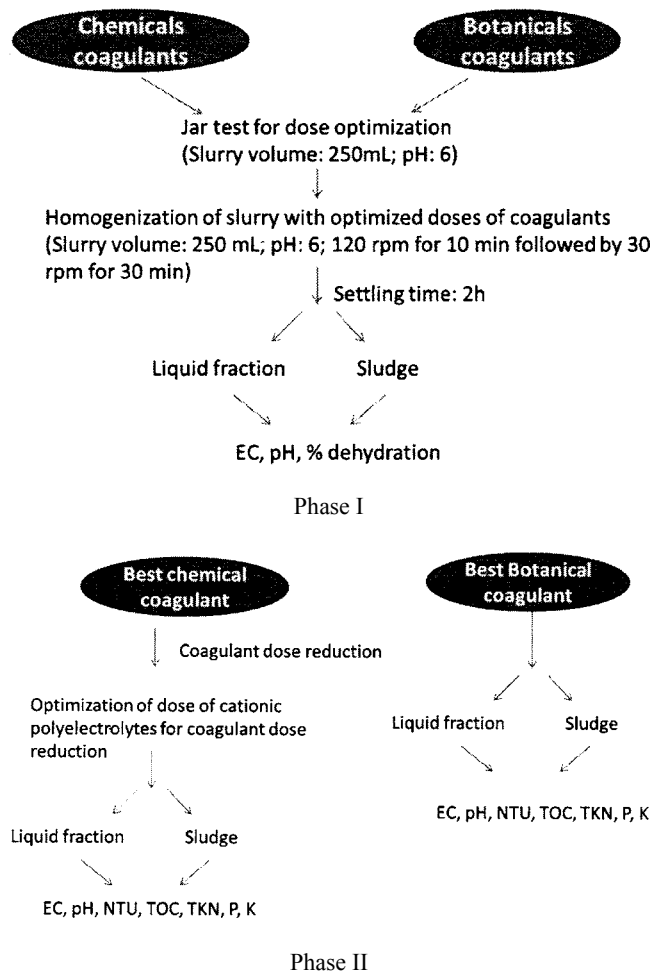


Table1 — BGS dewatering using chemicals/coagulants

S.No	Coagulant	Optimized dose of coagulant (g/l)	Dehydration (%)
1	Urea	80	< 5%
2	KCl	70	< 5%
3	SSP	70	< 5%
4	Gypsum	15	< 5%
5	Acrylamide	12	20
6	Gelatin	20	26
7	Alum	36	40

Initial water content of BGS: 92%

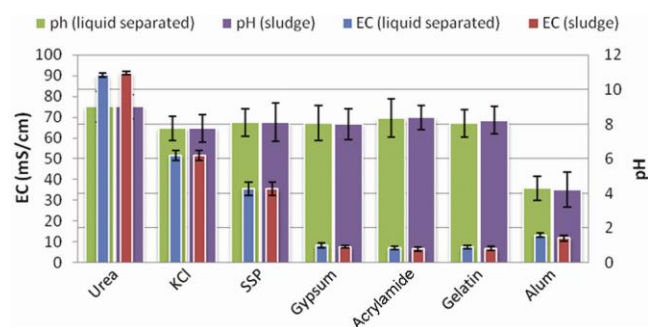


Fig.1 — Effect of various chemicals used on EC and pH of dewatered sludge and water separated

reduce the alum dose with the use of cationic polyelectrolytes. Likewise, the botanicals (Cactus and *Moringa*) were also tested for BGS dehydration.

Combination of cationic polyelectrolytes (PE) with alum

PE are currently used for the separation of suspended particles that are difficult to sediment³. In present study, various cationic PE viz., polyacrylamide, chitosan, epichlorohydrin and dimethylamine were combined with alum to further minimize alum dose and increase the dehydration efficiency. Best results pertaining to the BGS dewatering were obtained with dimethylamine (44 % removal of water with turbidity 242 NTU, Fig. 2; Table 2) followed by Epichlorohydrin (42 % dehydration with turbidity 456 NTU) with 2 % (w/v) alum dose. The PE might have acted as a bridge between the polar molecules and the surface of the aluminum hydroxide, leading to easy precipitation^{12,13}. The results pertaining to the properties of BGS fractions (water extracted and

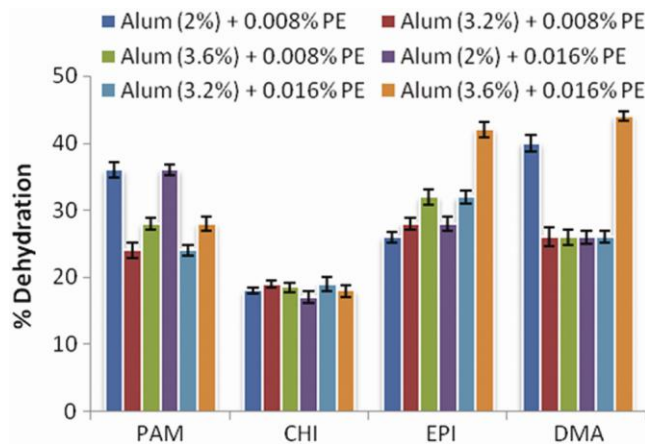


Fig. 2 — Reduction of alum dose by cationic polyelectrolytes PE: Polyelectrolytes (PAM: Poly Acrylamide; CHI: Chitosan; EPI: Epichlorohydrin; DMA: DiMethylAmine)

sludge) are depicted in Table 2. Increase in TOC % and TKN % in sludge showed the separation efficiencies of these polyelectrolytes. These polyelectrolytes can also act as a source of carbon and nitrogen to enhance the level of nutrients in biogas sludge¹⁴. Our results are in corroboration with Lee and Westerhoff¹³ (2006) who used cationic polymer and alum for wastewater treatment. Cationic polymers added during jar tests help neutralize the negative charge on more polar natural organic matter (NOM)^{12, 15}. More polar NOM fractions are nitrogen enriched^{13, 16}. At the same specific charge dose, however, aluminum sulfate combined with cationic polymer exhibited a synergic effect on carbon and nitrogen removals. There is also an increase in the P removal from water with the use of polyelectrolytes. The P removal from the BGS was up to 80 % and the amount is transferred to the remaining sludge. This might be due to the direct adsorption of phosphate ions in the hydrolysis products formed by the metal ion used as a coagulant and due to the formation of phosphate precipitates with the metal salts used as coagulants. Similar kind of trend was observed with potassium. The pH of both water and sludge was found to be acidic with high conductivity.

Use of Botanicals as coagulants in BGS Dehydration

Moringa seed powder (20 g/L) was found to remove the turbidity significantly similar to that of alum and removing 30 % water from slurry (Fig. 3). Cactus was found to be ineffective for both dehydration and turbidity removal. The results showed that although the water removal was 30 % with *Moringa*, the quality of both separated water and sludge was better as compared to chemical coagulants. The pH of water separated was almost neutral (7.54) while NTU was 350. EC of water

Table 2 — Characteristics of water and sludge separated by alum and cationic polyelectrolytes from BGS

Coagulant used	Characteristics of water separated (ml / l BGS)							Characteristics of Sludge separated (ml / l BGS)						
	NTU	TOC (%)	TKN (%)	EC mmho/cm	pH	P (%)	K (%)	Moisture content (%)	TOC (%)	TKN (%)	EC mmho/cm	pH	P (%)	K (%)
Alum (3.6%)	298±5.6	10.25±1.1	0.23±0.1	18.50±1.2	4.08±0.9	0.25±0.01	0.75±0.02	85±2.1	28.1±1.21	0.65±0.02	11.25±0.5	3.9±0.09	0.41±0.03	0.85±0.05
Alum (2%)	248±3.4	8.54±0.5	0.15±0.07	14.58±1.1	3.74±0.5	0.12±0.01	0.45±0.03	81±3.2	29.46±1.0	0.73±0.01	13.6±0.2	4.15±0.05	0.49±0.01	0.51±0.02
+PAM (0.008%)	227±4.6	8.23±0.8	0.11±0.06	12.55±1.0	5.89±0.2	0.1±0.02	0.42±0.01	80±2.1	29.77±1.1	0.77±0.01	8.53±0.2	4.86±0.04	0.47±0.02	0.56±0.01
Alum (2%) + CHI (0.008%)	456±4.6	11.21±0.8	0.25±0.06	15.62±1.0	4.88±0.2	0.13±0.02	0.76±0.01	87±2.1	26.99±1.1	0.63±0.01	7.26±0.2	4.76±0.04	0.47±0.02	0.90±0.01
Alum (3.6%) + EPI (0.016%)	6.5	1.0	0.9	1.35	0.2	0.02	0.01	1.1	1.0	0.02	0.2	0.04	0.02	0.1
Alum (2%) + DMA (0.008%)	242±3.8	8.35±0.8	0.12±0.05	13.90±1.21	4.97±0.1	0.15±0.01	0.42±0.02	76±3.0	29.85±1.2	0.76±0.02	6.74±0.1	4.66±0.02	0.44±0.03	0.53±0.01

PAM: Polyelectrolyte; CHI: Chitosan; EPI: Epichlorohydrin; DMA: DiMethylamin

separated was also very low (2.79 mmho/cm) as compared to alum (18.50 mmho/cm) and alum combined with DMA (13.90 mmho/cm). The findings of our study are in corroboration with Mumuni et al.¹⁷. The use of *Moringa* would lead to cost reduction in the conventional dehydration system using alum and no threat to environment in case of overdose as stated in the findings of Kaggwa¹⁸. *M. oleifera* has also been shown to produce significantly less sludge than alum, which is an advantage especially if the sludge is to be dewatered or treated in some other way before disposal¹⁹. Fig. 4 demonstrates the zeta potential value of various treatments for biogas slurry dehydration. Zeta potential for BGS was found to be -29.8 mV, which confers the stability of colloidal particles in the BGS and resists aggregation^{20, 21}. The Zeta potential values of water separated out by *Moringa* seed powder and alum were found to be -18.1 and -17.3 mV respectively. Zeta potential value was significantly affected by various treatments as its value shifted towards less negative value. The lower values of the potential might be due to the

binding of the coagulants to the slurry particles, mainly driven by hydrogen bonding and Vander walls force²². Also, the low value of the potential (irrespective of negative or positive), shows that attraction exceeds repulsion leads to breaking of dispersion and ultimately flocculation²¹.

Conclusion

Biogas Slurry, rich in colloidal particles is difficult to be dewatered. Chemical coagulants (alum combined with dimethylamine) found to be effective in biogas slurry dewatering but low pH and high conductivity values for both remaining sludge and water dehydrated is a matter of concern. On the other hand, *Moringa* seed powder yielded better quality of water but the quantity of water removed was less than chemicals. Our study is the stepping-stone in relation to the water removal from biogas slurry through coagulants. These encouraging results indicate that coagulation through chemicals and botanicals may be the first treatment application that can move to large scale adoption. However, to increase quantity of water separated from BGS, combination of *Moringa* and alum coupled with other techniques such as centrifugation, could be an appropriate option for continued success in this field.

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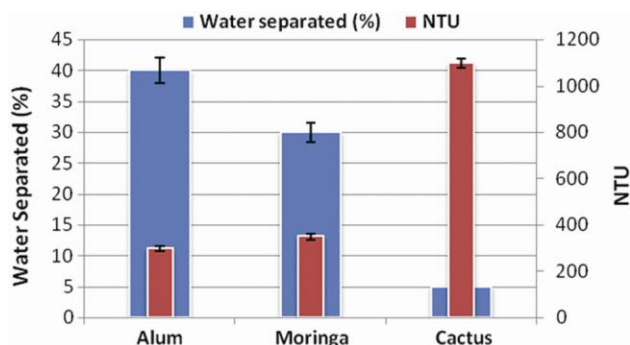


Fig.3 — Use of Botanicals (*Moringa* and cactus) for BGS dehydration

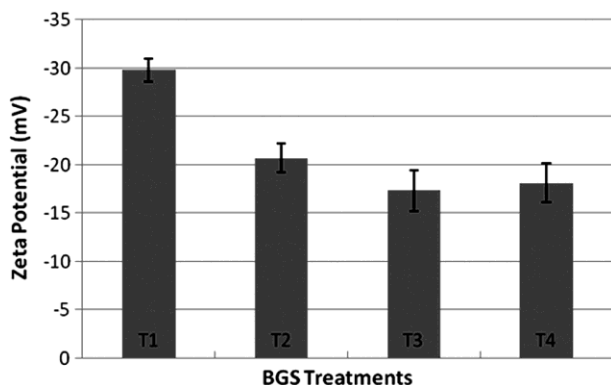


Fig. 4 — Effect of various BGS dehydration methods on Zeta potential values T1: BGS; T2: BGS + Alum (3.6%); T3: BGS + Alum (2.0%) + DMA (0.008%); T4: BGS + *Moringa* (10g/L)

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