Application of biopolymer for enhancing the dewaterability of sludge

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Introduction

- Drinking and wastewater treatment produces containing about 90-99% of water.

Big Problem!!!
Handling &
Disposal

- Reduction of sludge volume by separation of water from the solids is the most important and costly step in sludge management.

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Introduction

- The water contained in the sludge is present as either FREE WATER or as BOUND WATER in the form of (Christensen *et al*., 2015):
  a) Interstitial water
  b) Vicinal water
  c) Water of hydration

- Extracellular polymeric substances (EPS) are the main reason behind the poor dewaterability of swage sludge (Skinner *et al*., 2015)

- Sludge conditioning to improve dewaterability: Coagulation and flocculation

- Common coagulants are:
  - Polyaluminium chloride (PAC)
  - Ferric salts

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APPLICATION OF BIOPOLYMERS FOR SLUDGE CONDITIONING

- Biopolymers are **complex molecular assemblies** that adopt precise and defined 3D shapes and structures which is the main reason of activity in vivo
- Some examples of widely available natural polymers that find extensive application as flocculants in different industrial processes are:
  - **Starch,**
  - **Amylopectin,**
  - **Guar gum,**
  - **Xanthum gum,**
  - **Kendu gum and**
  - **Chitosan**

APPLICATION OF BIOPOLYMERS FOR SLUDGE CONDITIONING

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- **Biopolymers** are **biodegradable** and **nontoxic**.
- Plant based materials are **inexpensive and widely available**.
- These materials can be **easily incorporated** into the existing treatment units without significant modifications.

Mechanism of coagulation-flocculation: Inorganic chemicals vs biopolymers

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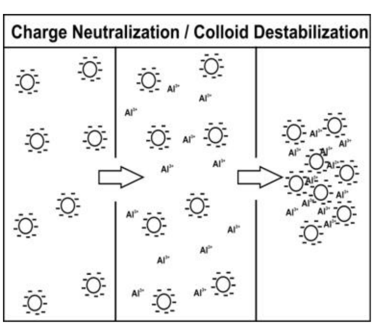
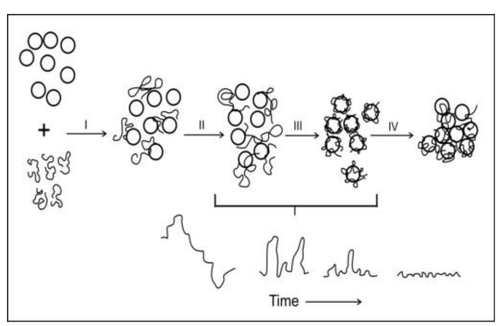


Coagulation-flocculation by inorganic chemicals



Flocculation by biopolymers

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APPLICATION OF BIOPOLYMERS FOR TREATMENT OF INDUSTRIAL EFFLUENT

Sludge volume index of Rubber mill effluent

Coagulant	Dose	pH	Volume of Sludge	SVI (ml gm^{-1})
Guar gum	1.75 mg L^{-1}	5	7	0.056
		9	10	0.08
		12	40	0.32
Alum	1 gm L^{-1}	5	60	0.48
		9	100	0.8
		12	85	0.68

Sludge volume index of Paper mill effluent

Coagulant	Dose	pH	Volume of Sludge	SVI
Guar gum	1.5 mg L^{-1}	5	5	0.063
		7	10	0.125
		12	35	0.438
Alum	1.5 gm L^{-1}	5	45	0.563
		7	105	1.313
		12	90	1.125

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COST OF WASTEWATER TREATMENT BY BIOPOLYMERS

Biopolymer	Price per kg (USD)	Quantity required per liter of wastewater (mg)	Cost for treating 1 million galon of wastewater (USD)
GG	3	1.7	1.35
XG	3.55	2	1.88
LBG	2.5	2	1.32
Alum	0.329	1000	86.91

- In case of guar gum, the quantity of biopolymer required was only 1/100th of alum.

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ADDITIONAL ADVANTAGES OF BIOPOLYMERS FOR WASTEWATER TREATMENT

- **Removal of Persistent organic pollutants by biopolymers**

Guar gum was found to efficiently remove approximately 99% of the identified POPs (phenol 2,4-bis(1,1-dimethylethyl) and DEHP) from farm effluent at an optimum dose of 4.0 mg L-1.

- **Removal of dissolved metals from water biopolymers: Lead and Iron** (Research is ongoing in this field)

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Enhancing the Dewaterability of Sludge using biopolymer

GUAR GUM

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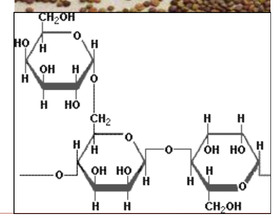
Properties of Guar gum

- Guar Gum also known as guaran is extracted from the seed of a leguminous shrub *Cyamopsis tetragonoloba*.
- The backbone is a linear chain of β 1,4-linked mannose residues to which galactose residues are 1,6-linked at every second mannose, forming short side-branches.
- The mannose: galactose ratio is approximately 2:1. The molecular weight range is 50,000-8,000,000
- In water Guar gum forms a non-ionic solution and is hydrocolloidal.



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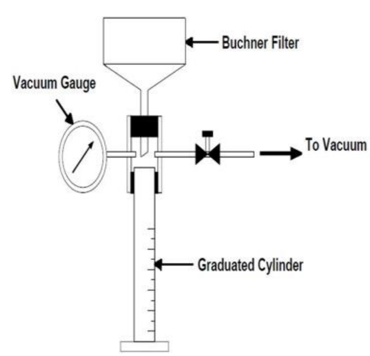
METHODOLOGY

- A 1000 mgL^{-1} guar gum solution was prepared
- 100 mL secondary sludge was used for the experiments
- pH of the sludge was adjusted to 4 and 10 with 0.1N H_2SO_4/NaOH prior to the addition of biopolymer solution.
- After dosing the sludge with the biopolymer it was mixed first at 250 rpm for 5 minutes and then at 40rpm for 10 minutes.
- The rate of filtration of the conditioned sludge was studied through standard Buchner funnel experiments



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SPECIFIC RESISTANCE TO FILTRATION (SRF)

The SRF was calculated by using the following formula:

$$r = \left(\frac{2A^2P}{\mu c*}\right).\mathrm{b}$$

r = specific resistance to filtration (m/kg)
A = the area of filter (m^2)
P = the pressure of filtration (N/ m^2)
μ = viscosity of the filtrate (Ns/m^2)
c* = weight of dry solids per volume of filtrate
b = slope of the line t/V vs V

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VARIATION OF SRF AT DIFFERENT BIOPOLYMER DOSE & pH

SRF value of raw sludge = 3.48 x 10^{13}			
	SRF values for treated sludge (x10^{13} m/kg)		
Dose (mgL^{-1})	pH		
	pH 6.8	pH 4	pH 10
1	2.898	2.93	5.857
5	3.103	1.559	8.179
8	2.403	1.941	9.187
10	2.76	2.102	10.23

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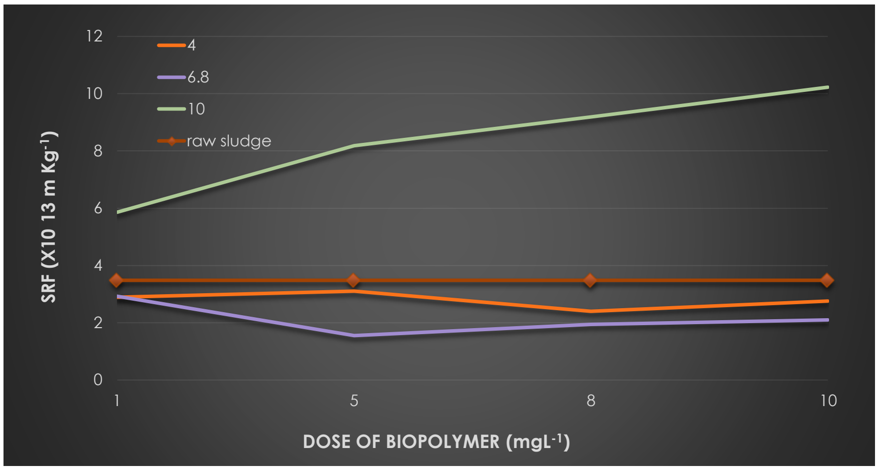
Variation of SRF at different biopolymer dose and pH



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TIME REQUIRED FOR FILTRATION

Volume	Time required for filtration at pH 4 (Sec)				
	Guar gum dose				
	1mg/L	5mg/L	8mg/L	10mg/L	12mg/L
20		7.6			
25	7.9	15.5			
30	10	20.9	8.9	7.5	9.3
35	16.1	37.3	18.2	10.7	15.1
40	22.6	46.8	25.4	16.9	22.7
45	31.1	58.2	35.1	23.7	30.1
50	42.7	71.1	44.2	33.4	40.8
55	56.4	83.1	55.9	44.2	52.1
60	90.3	97.8	69.3	56.4	65.6
65	109.5	114.1	83.8	68.9	79
70	130.6	134.4	99.8	87.4	96
75	156.9	140	120.9	105.4	113.6
80	192.9	147.1	140.7	124.7	134.3
85	222.3	154.1	182.1	147.2	166.8
90	244.1	163.1	197.2	180.1	181.3
91	297.3	175	219.9	190.5	195.9
92	368.8	188.4	260.7	204.5	235.5
93	923.6	217.3		225.6	261.4
94		344.3		262.9	290.1
Total Time (min)	**15. 39**	**5.7**	**4.3**	**4.38**	**4.83**

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CONCLUSION & FUTURE WORK

- Guar gum was able to reduce the SRF of the raw sludge to a certain extent.
- However, the reduction in SRF was not significant to be recommended as an effective alternative to present options.

Future Work

- Further research needs be conducted and other options explored.
  - Using Guar gum in conjunction with alum or other chemical coagulant.
  - Introduction of ionic charge on the biopolymer through grafting.

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THANK YOU

TIME REQUIRED FOR FILTRATION

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Volume of Filtrate (ml)		Time required for filtration (sec)			
		Guar gum dose			
	Fresh sludge	1mg/L	5mg/L	8 mg/L	10 mg/L
10				4.3	
20				8.1	5.2
30				20.2	11.1
35	6.9	9.5	7.8	26.8	15.7
40	22.5	16.7	24.7	39.8	24
45	32	25.6	33	47.6	34.6
50	42.6	34.9	44.2	60.6	43.4
55	53.9	49	57.8	74	57.2
60	68.6	62.9	73.6	87.7	70.5
65	86.8	79	91.8	111.3	88.3
70	112.3	99.4	116.6	133.2	109.8
75	134.4	123.7	137.7	161.9	134.5
80	159.9	152.6	169.2	197.5	161.1
85	210.9	190.5	210.5	266.6	198.2
90	284.2	250.8	291.8	301.1	243.9
91	369.7	285.9	372.3	354.5	333.9
92		341.9		559.6	378.8
93		542.9			618.8
Total time (min)	6.16	9.05	6.205	9.33	10.31

SPECIFIC RATE OF FILTRATION (SRF)

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SRF value of raw sludge = 3.48 x 10^{13}

SRF values for sludge treated with Guar gum without any pH change:
1mg/L = 2.898 x 10^{13} m/kg
5mg/L = 3.103 x 10^{13} m/kg
8mg/L= 2.403 x 10^{13} m/kg
10mg/L= 2.76 x 10^{13} m/kg

SRF values for sludge treated with Guar gum at pH 4:
1 mg/L = 2.93 x 10^{13} m/kg
5 mg/L = 1.559 x10^{13} m/kg
8 mg/L = 1.941 x 10^{13} m/kg
10 mg/L = 2.102 x 10^{13} m/kg
12 mg/L = 1.8918 x 10^{13} m/kg

SRF values for sludge treated with guar gum at pH 10:
1 mg/L = 5.857 x 10^{13} m/kg
5 mg/L = 8.179 x 10^{13} m/kg

Scanning Electron Micrograph

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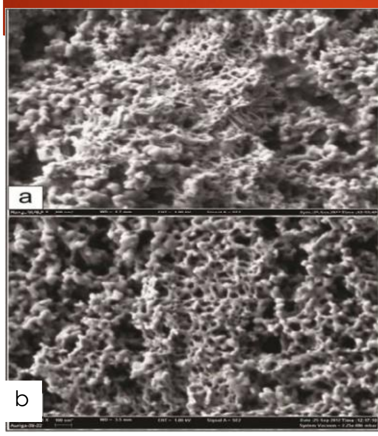
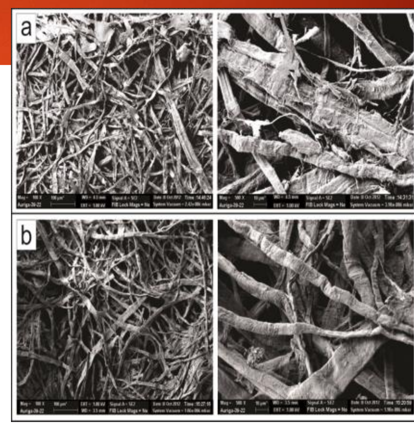


SEM images of (a)Alum flocs (b) Guar gum flocs of rubber mill effluent



SEM images of flocs produced by (a) Guar gum (b) Alum of paper mill effluent