Bleached Kraft Pulp Effluent Electrocoagulation: Energy consumption, sludge characterization & economic analysis

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INTRODUCTION

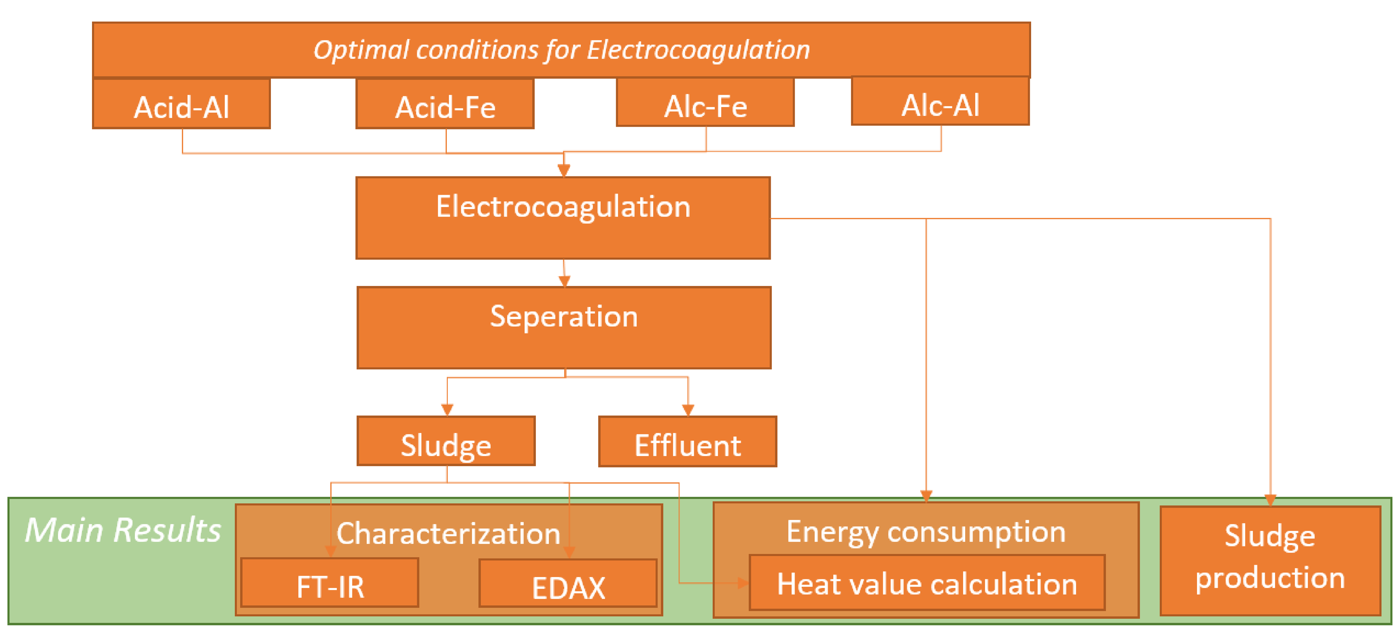
- The Kraft bleached pulp production industry is known for its high-water consumption. The intensive use of this resource is due to sequential manufacturing sectors, from wood chip preparation to bleached pulp production.
- The unit operation, bleaching, is mainly responsible for this high-water consumption and produces 2 types of (alkaline & Acid) wastewater that has to be treated before it can be discharged.
- This treatment can be done using electrocoagulation
- Electrocoagulation is done using 2 different electrode materials (Aluminium & Iron) and produces a form of sludge that might have interesting properties.
- The treatments of the 4 different conditions are done under optimal conditions that were validated by a previous study.

OBJECTIVES

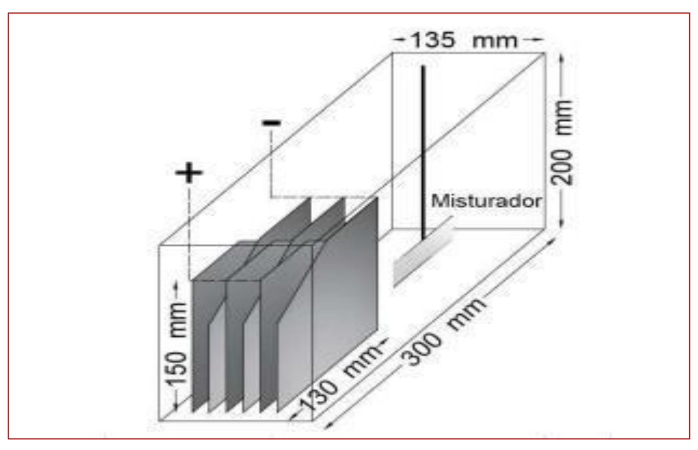
- the main objective of the study is to evaluate the energy consumption and the energy potential of the sludge generated in the treatment of two kraft pulp bleaching effluents, called acid and alkaline filtrates, by electrocoagulation, with aluminium and iron electrode under optimized conditions. For this, the energy consumption will be calculated in (kWh/kJ), this will be calculated using the heat values of the 4 different sludges. Sludges will be characterized by their physicochemical nature & settling behaviour. This study gives an insight into the possible use of a by-product in the processing of an effluent.

MATERIALS AND METHODS

General process of the project



Electrocoagulation & optimal conditions



Conditions	pH	CD	t
Condition 1 *Acid Treated & Aluminium electrode*	7.9	128	49
Condition 2 *Acid treated & Iron electrode*	4.6	104	40
Condition 3 *Alkaline treated & Aluminium electrode*	3.6	125	60
Condition 4 *Alkaline treated & Iron electrode*	6.3	101	42
Units	-	$A \cdot m^{-2}$	min

Energy consumption per kg sludge & Energy consumption / heat value ratio

$$E = \frac{(V_{EC} \cdot I_{EC})/1000) \cdot t_{EC}}{M_{f,sludge}}$$

$$E_{hv} = \frac{E}{H_v} = \left[\frac{kWh}{kg}\right] \cdot \left[\frac{kg}{kJ}\right] = \left[\frac{kWh}{kJ}\right]$$

Sludge characterization

- Sludge settling over 2.5 hours
- SEM-images
- SVI-value's[24h] → →
- EDAX
- FT-IR

$$MLSS = \frac{(Wt_{f+s} - Wt_f) \cdot 1000}{V_{mlss}}$$

$$SVI = \frac{SSV \cdot 1000}{MLSS}$$

Economic analysis

$$E_{m^3} = \frac{(V_{EC} \cdot I_{EC})/1000) \cdot t_{EC}}{V_{used\ eff.}}$$

$$EL_{m^3} = \frac{I_{EC} \cdot t_{EC} \cdot M_{w,material}}{Z_{material} \cdot F \cdot V_{used\ eff.}}$$

$$Operation\ costs = X \cdot E_{m^3} + Y \cdot EL_{m^3}$$

X = Electricity: 0,18 US $\$ \cdot kWh^{-1}$

Y = iron: 1.98 US $\$ \cdot kg^{-1}$

Aluminium: 7.24 US $\$ \cdot kg^{-1}$

ACKNOWLEDGMENTS

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RESULTS AND DISCUSSION

Acid filtrated effluents

Energy consumption per kg sludge & Energy consumption / heat value ratio

Conditions	Condition 1 Acid Treated & Aluminium electrode	Condition 2 Acid treated & Iron electrode	Units
Energy consumption / formed sludge	2.02	1.44	kW·h·kg-1
Formed sludge	0.00947	0.00659	kg
Heat value	1882	2344	kJ·kg-1
E/Hv Ratio	1.08	0.61	kW·h·kJ-1·1000-1
E/Hv Ratio (same sludge production)	1.08	0.43	kW·h·kJ-1·1000-1

- Comparison Condition 1 & 2
  - Condition 1: ~40% more sludge production
  - Condition 2: ~150% more energy efficient

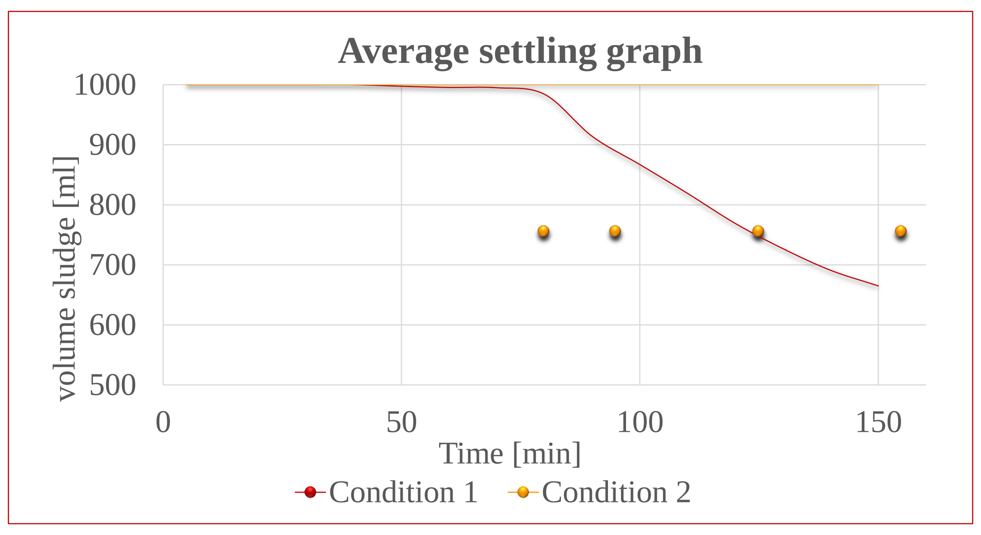
Alkaline filtrated effluents

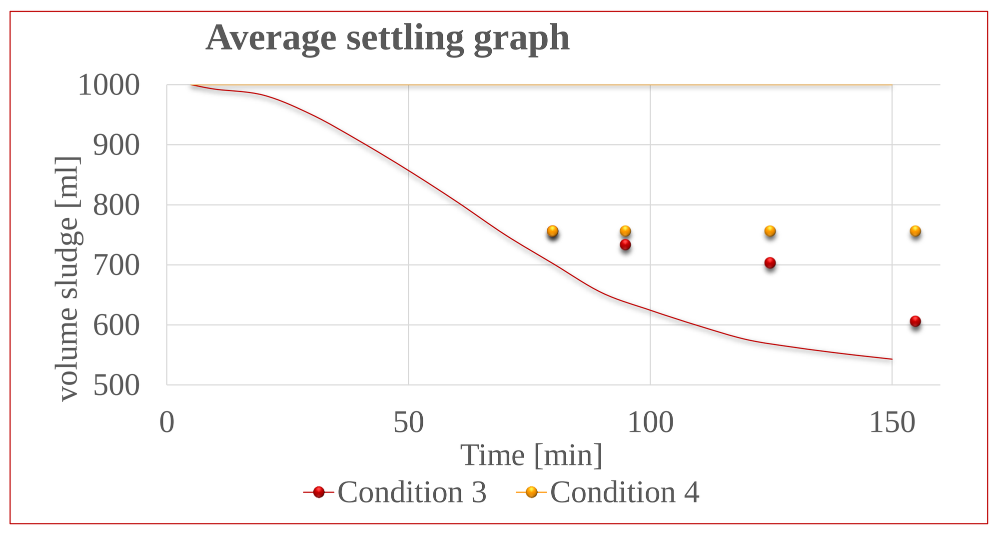
Energy consumption per kg sludge & Energy consumption / heat value ratio

Conditions	Condition 3 Acid Treated & Aluminium electrode	Condition 4 Acid treated & Iron electrode	Units
Energy consumption / formed sludge	3.34	2.62	kW·h·kg-1
Formed sludge	0.00967	0.00499	kg
Heat value	1138	2249	kJ·kg-1
E/Hv Ratio	3.19	1.25	kW·h·kJ-1·1000-1
E/Hv Ratio (same sludge production)	3.19	0.82	kW·h·kJ-1·1000-1

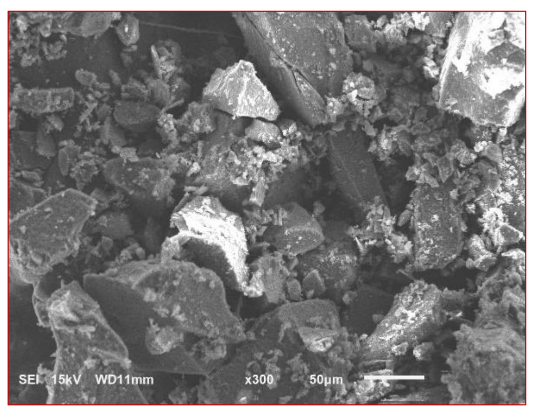
- Comparison Condition 3 & 4
  - Condition 1: ~90% more sludge production
  - Condition 2: ~290% more energy efficient

Settling over a period of 2.5 hours

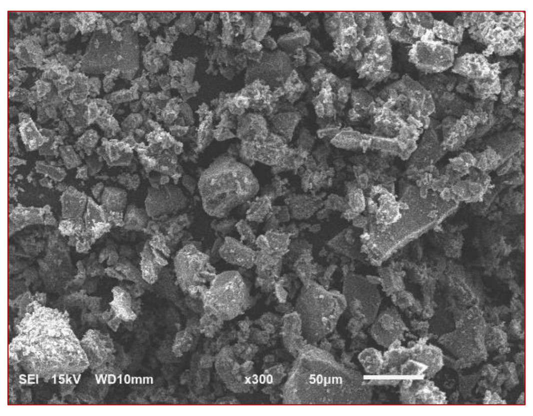




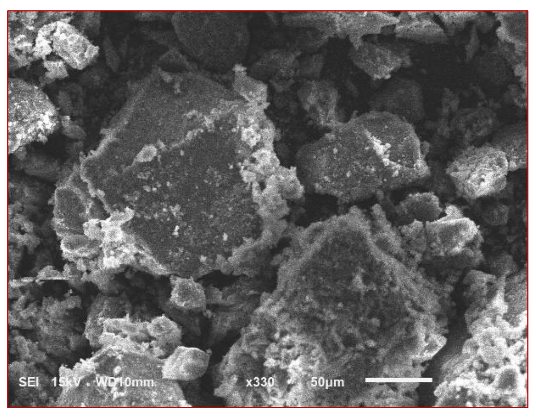
SEM-images & SVI-value's[24h]



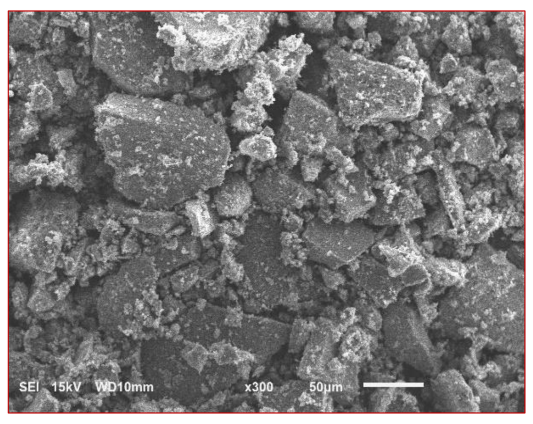
Sludge Condition 1



Sludge Condition 2



Sludge Condition 3



Sludge Condition 4

Conditions	SVI
Condition 1 *Acid Treated & Aluminium electrode*	78
Condition 2 *Acid treated & Iron electrode*	39
Unit	$ml \cdot g^{-1}$

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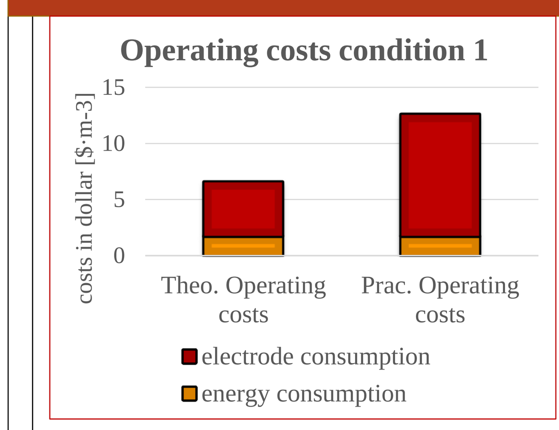
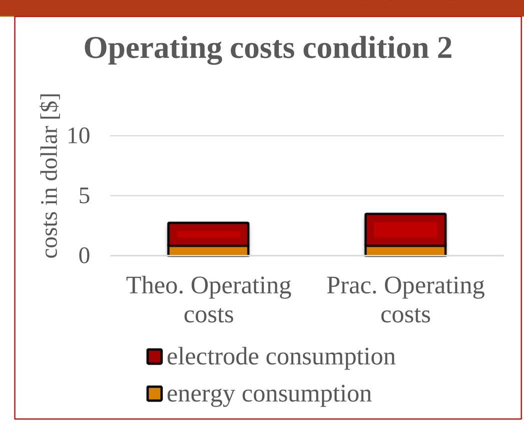
Condition 1 *Acid Treated & Aluminium electrode*	78
Condition 2 *Acid treated & Iron electrode*	39
Unit	$ml \cdot g^{-1}$

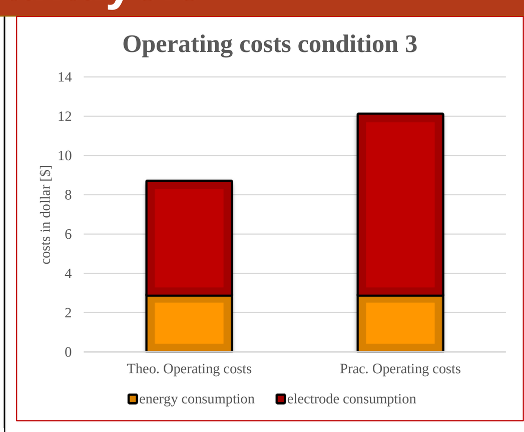
EDAX & FTIR

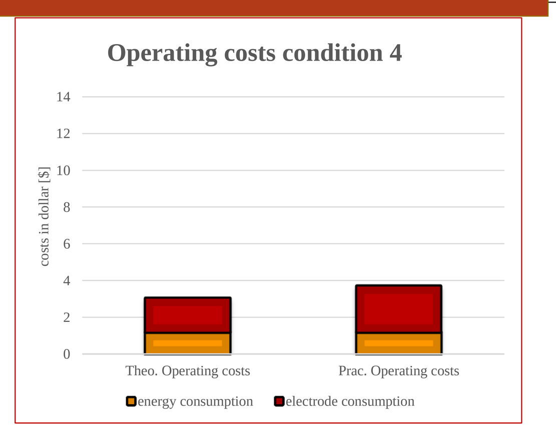
- FTIR
  - Showed no difference in Functional groups in the 4 different conditions
- ADEX
  - Showed that ¾ where contaminated with other electrode material

Economic analysis









- Comparison Condition 1 & 2
  - Condition 1: ~150% more expensive theoretically
  - Condition 1: ~270% more expensive practically
- Comparison Condition 3 & 4
  - Condition 3: ~190% more expensive theoretically
  - Condition 3: ~230% more expensive practically

CONCLUSIONS

Best Energy efficiency:	Condition 2
Best settling:	Condition 3
Lowest SVI-value:	Condition 2
EDAX:	Contamination ¾ conditions
FT-IR:	No difference in conditions
Lowest operating costs:	Condition 2