

Development of an Advanced Electrocoagulation System for Wastewater Treatment



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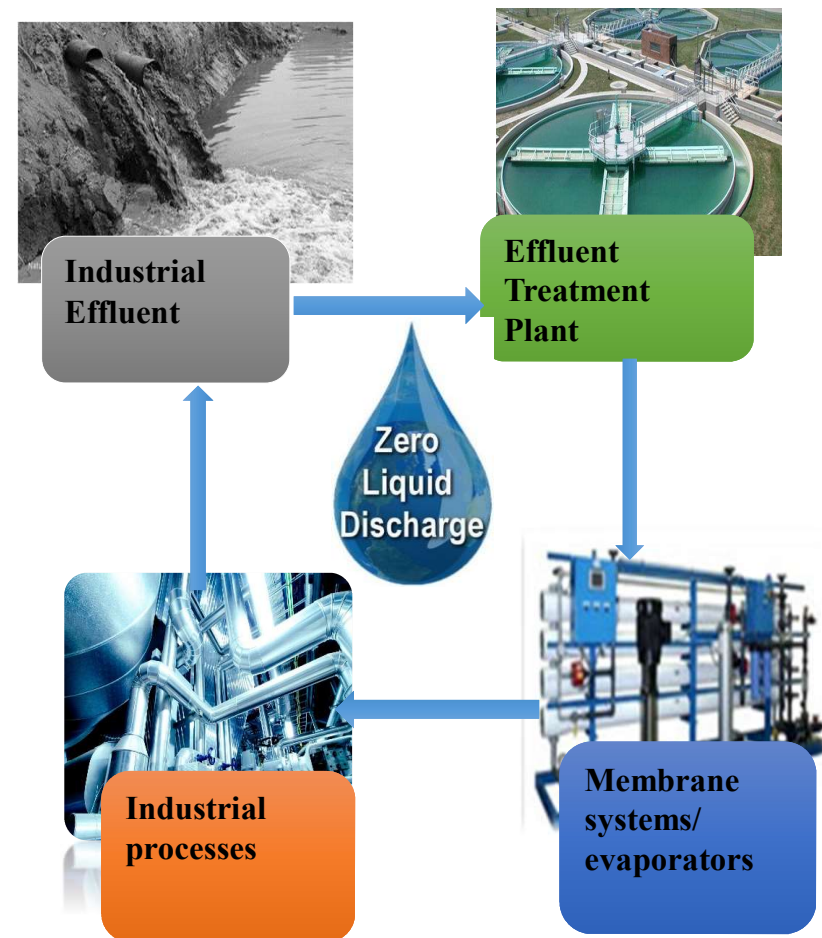
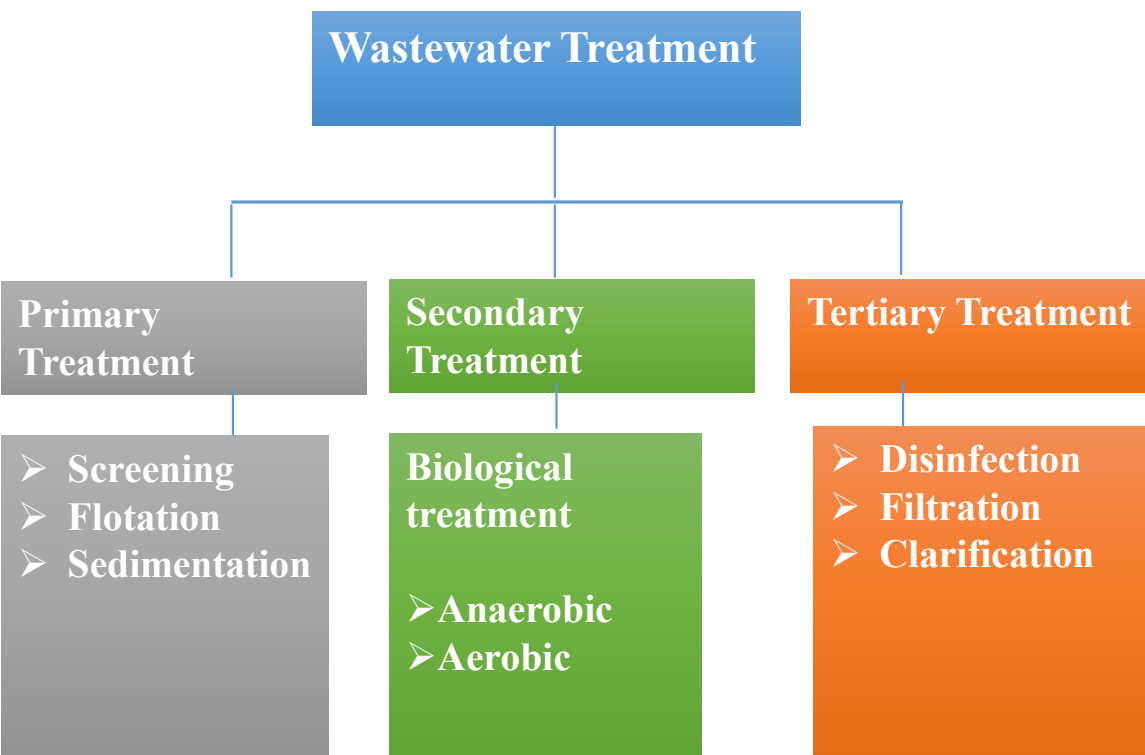
29-08-2026

Motivation

- Increase in water scarcity
- Sea, sewage and **industrial waste water**
- Considering that currently less than 30% of industrial waste water is treated before release into the environment



Agro based industries



Distillery Wastewater (DWW)

- Distilleries are most polluting
- 12-15 litres of spent wash per litre of alcohol
- Problematic color by Melanoidins (Recalcitrant)
- Non effective biological treatment
- High amount of carbon

➤ DWW:
KCP Sugars Ltd,
Vuyyur, Andhra Pradesh

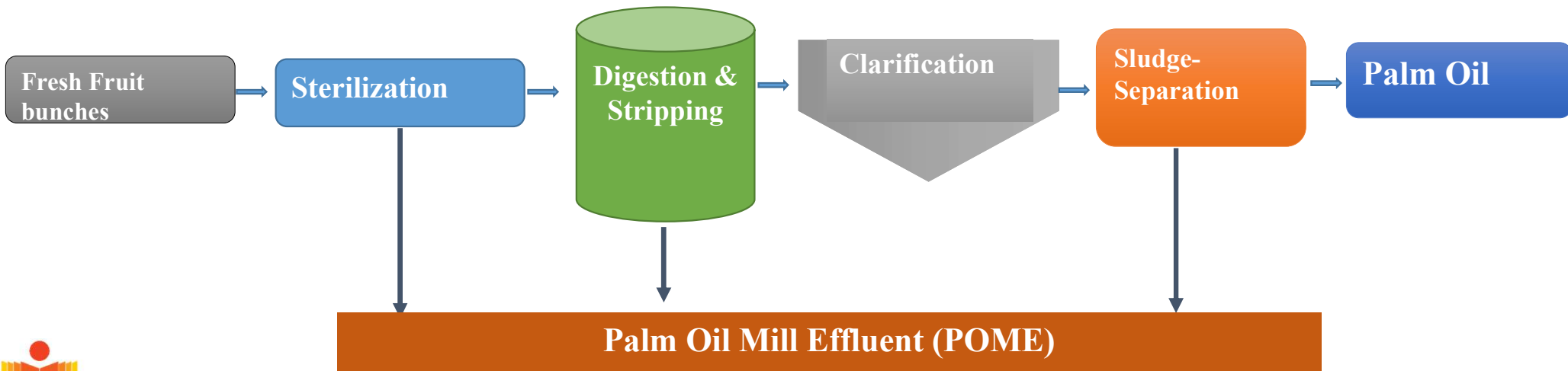
Palm Oil Mill Effluent (POME)

- India is the 4th largest edible oil economy in the world –Palm oil effluent
- 5- 7.5 ton of wastewater for 1 ton of palm oil
- High organic content
- High amounts of Nutrients

➤ POME:
Nav Bharat Agro industries Ltd,
Jangareddy gudem Andhra Pradesh

Initial Characterization

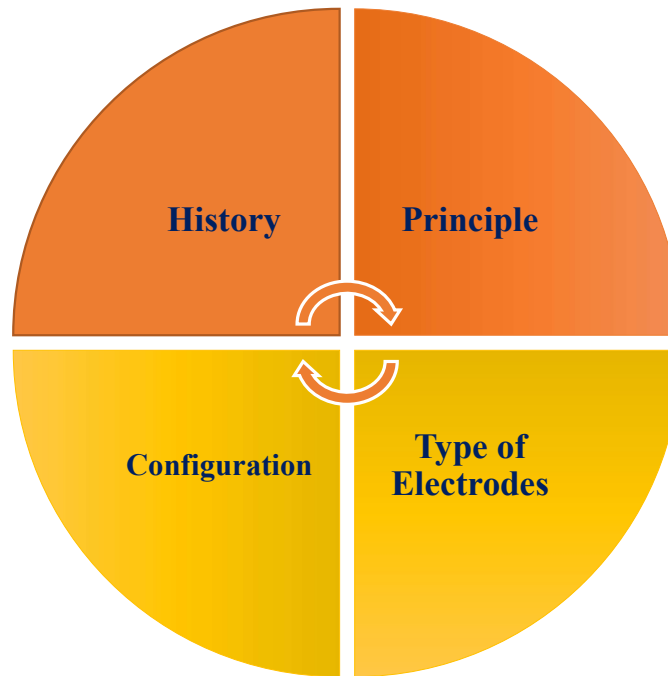
Parameters	Units	POME	DWW
pH		8.5	8.54
Electrical conductivity	mS/cm	16.91	14
Total Nitrogen	mg/l	76.37	1160.5
Total Organic Carbon	mg/l	2250	3775
COD	mg/l	5700	7600
TDS	mg/l	10000	25000
TSS	mg/l	300	600
TS	mg/l	10300	25600
Total Phosphorous	mg/l	389	180
Sulphate	mg/l	305.33	1507
Chloride	mg/l	2708	4323
Calcium	mg/l	39.3	39
Magnesium	mg/l	333.4	262
Sodium	mg/l	67	434
Pottassium	mg/l	1986	1222



Electrocoagulation

- Developed in 19th century
- Applied in 20th century
- Success is partial
- Widely accepted
- Ease of operation
- Zero chemical addition
- Lesser sludge production

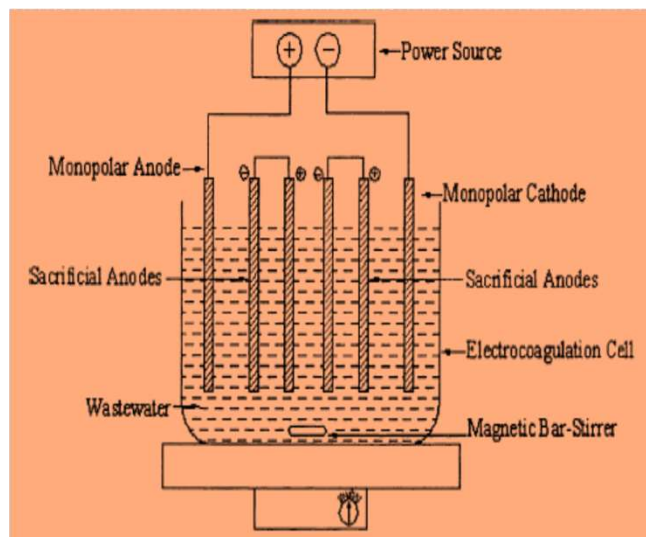
- Monopolar
- Bipolar



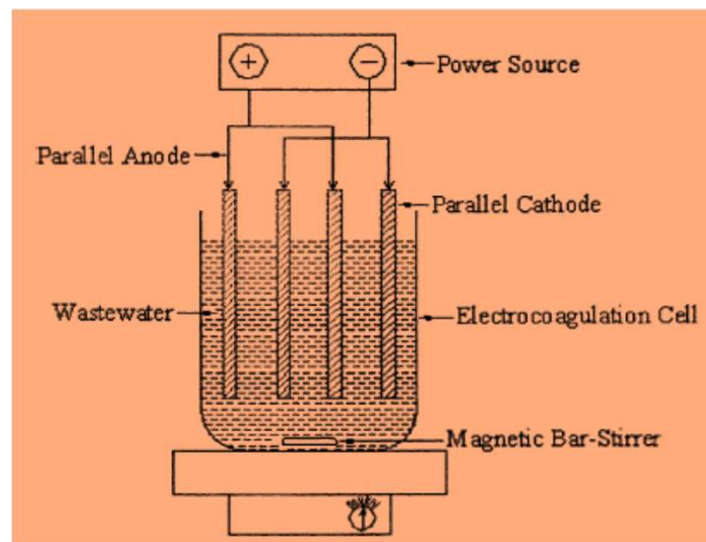
- Electrochemistry
- Coagulation
- Hydrodynamics

- Iron
- Aluminium

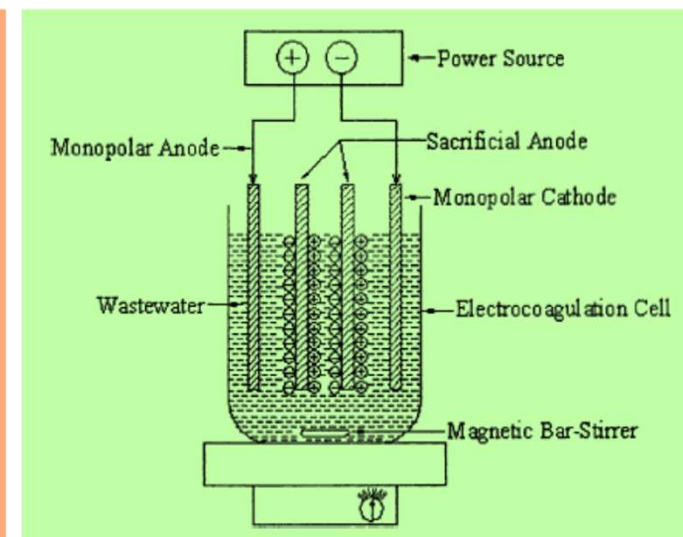
Configurations



Monopolar Mode (Series)

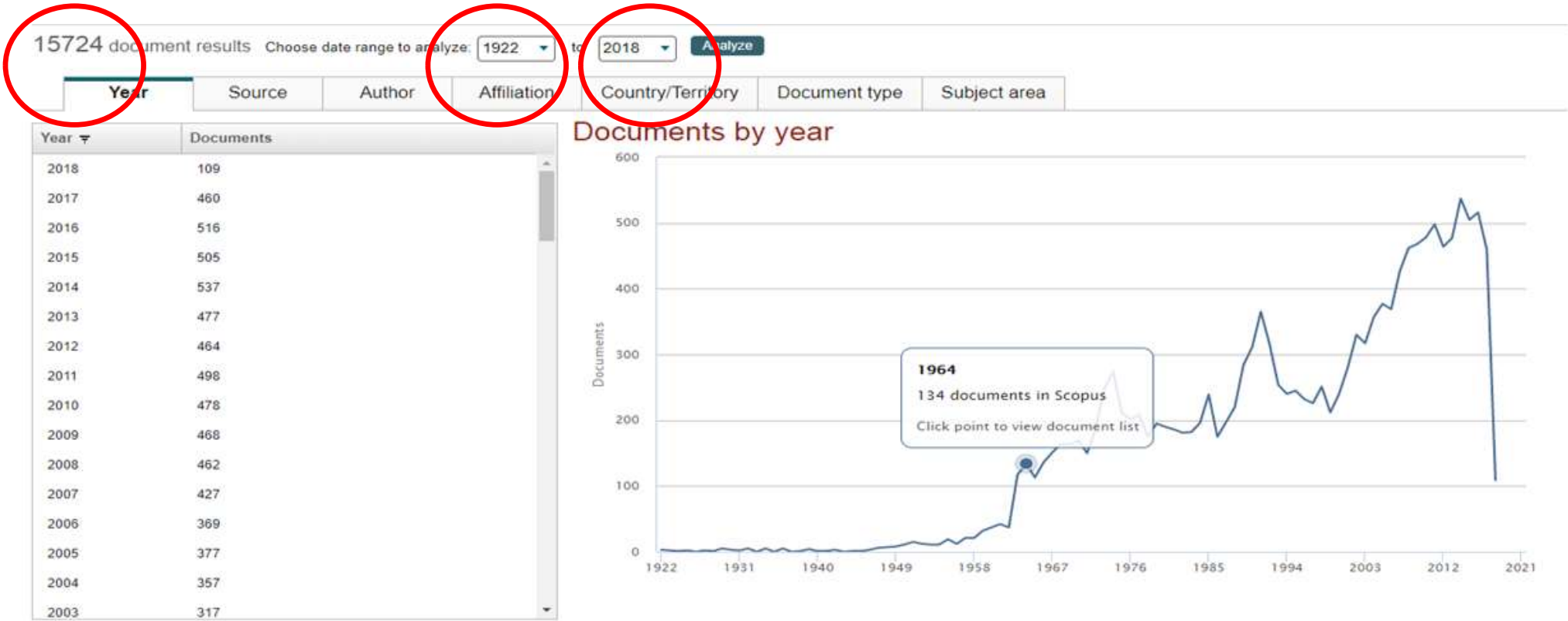


Monopolar Mode (Parallel)

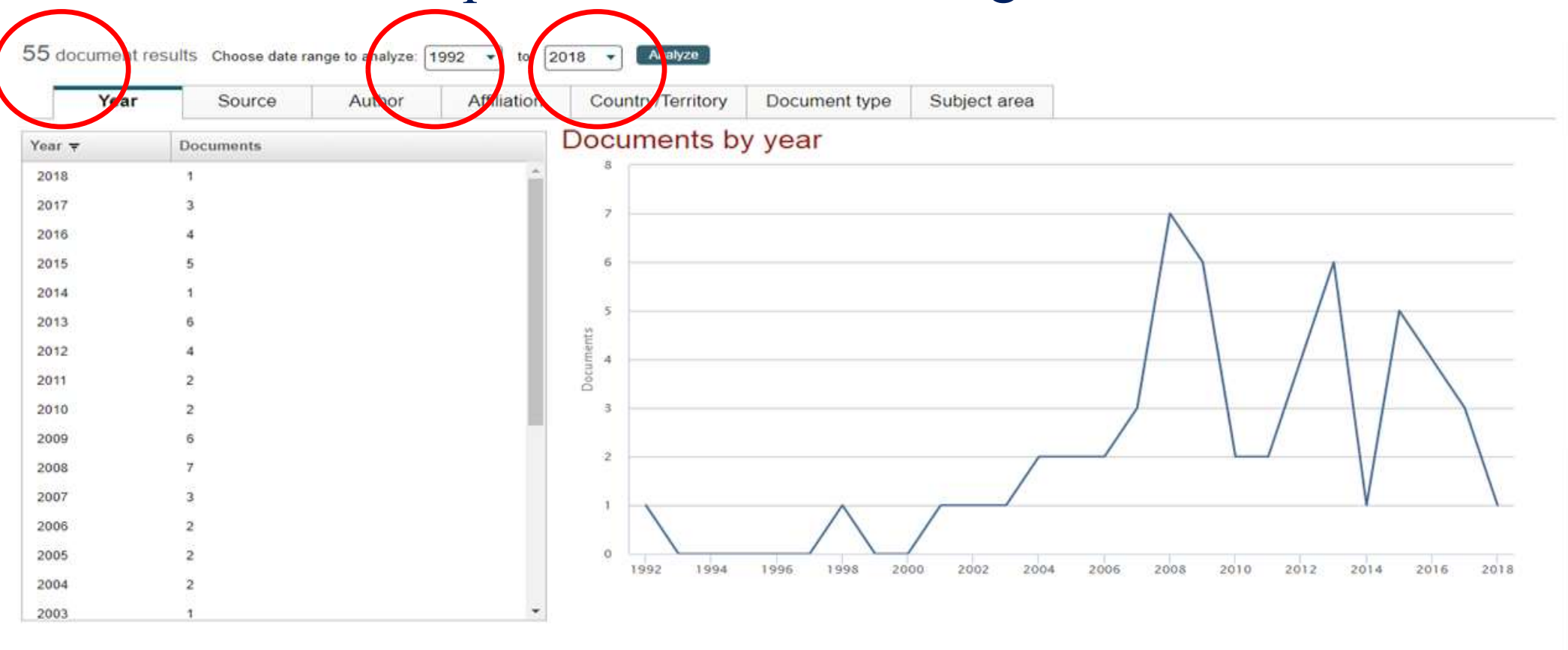


Bipolar Mode

Research Trend in Electrocoagulation



Research Trend- Bipolar-mode Electrocoagulation



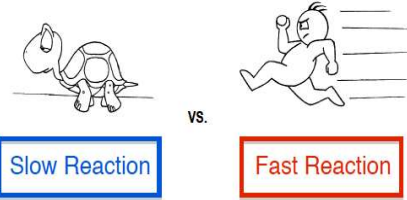
Objectives

1. **Develop** and **Optimize** a design for CBME system for treatment of recalcitrant carbon & Phosphorous
2. Develop a **Removal Mechanism** based on **kinetics**
3. Establish an **Enhancement procedure** for CBME
4. **Resource Recovery** from CBME sludge
5. Evaluation of **Field-scale** CBME system with **Lab-scale** design parameters

*CBME- (Continuous Bipolar-Mode Electrocoagulation system)

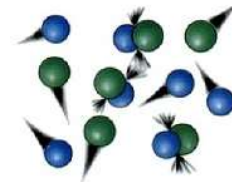


Feasibility Studies



Optimization Studies

Kinetics



Mechanism of Pollutant Removal



Enhancement Studies



Resource Recovery



Comparison of Lab-scale & Field-scale

Marigold processing wastewater

Palm oil mill effluent

Distillery wastewater

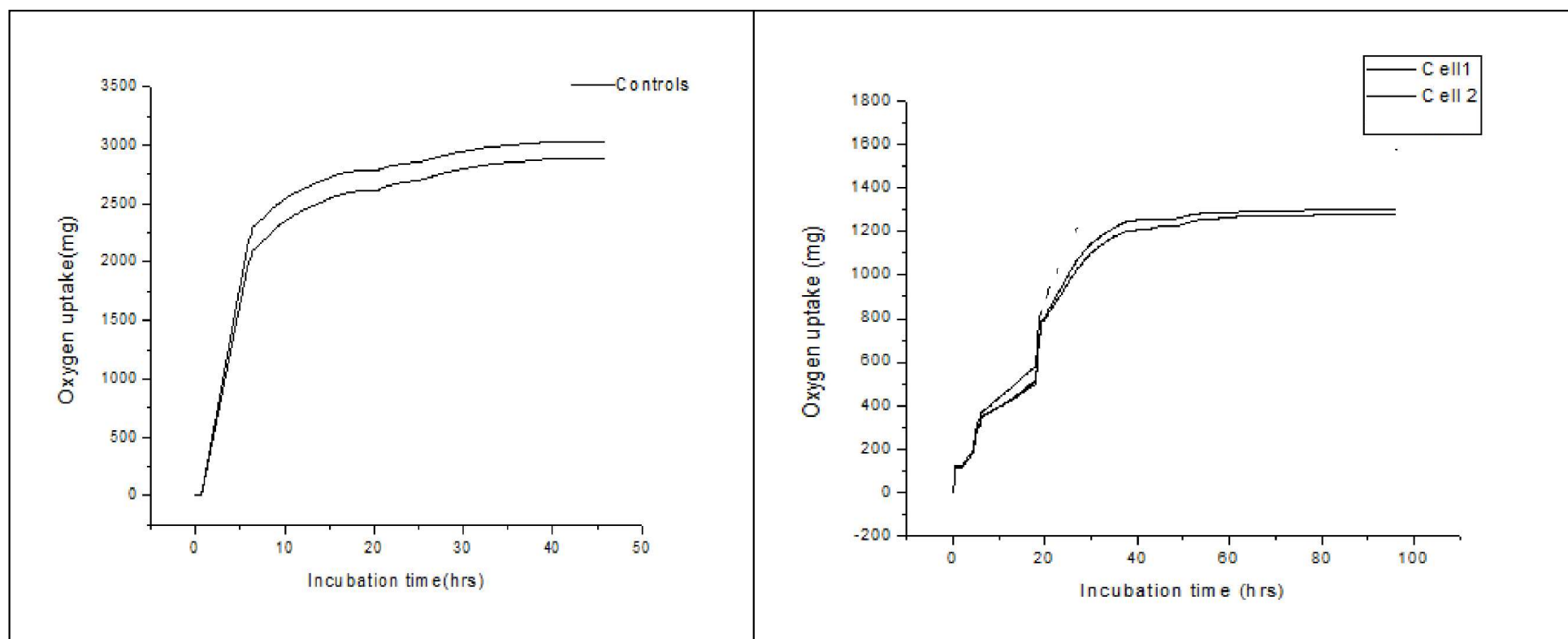
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Feasibility study

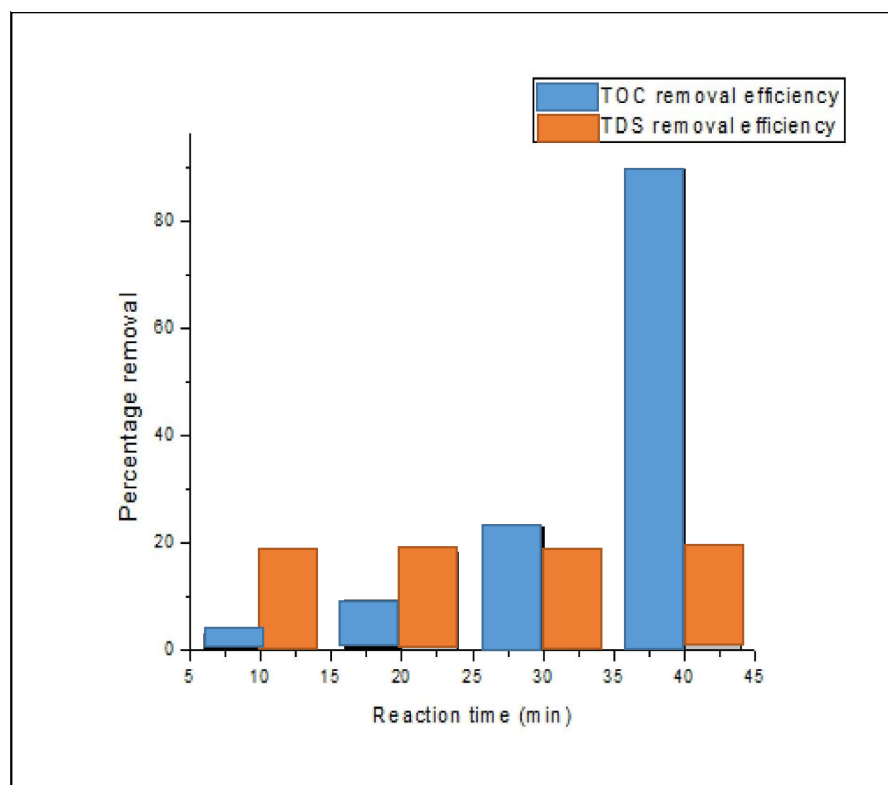
Parameter	Initial characterization	Respirometric study
pH	8	9
Color	Dark brown	Light yellow
COD (ppm)	4953 ± 50	800 ± 20
TOC (ppm)	1847 ± 4	177 ± 5



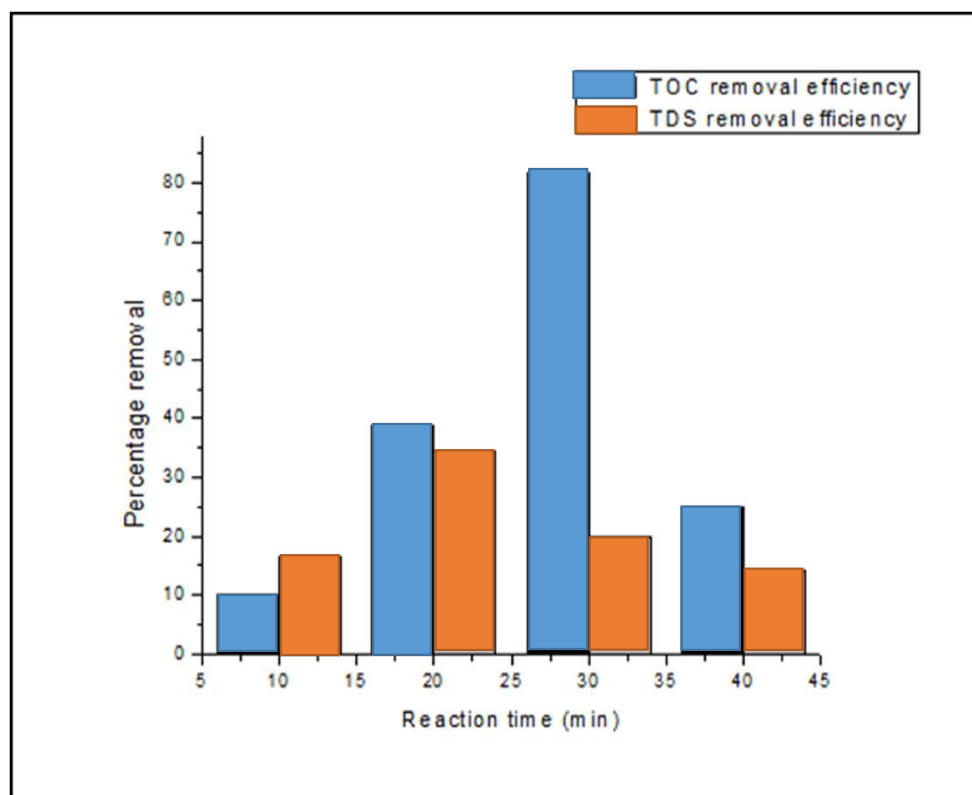
Respirometric study



Batch Electrocoagulation study

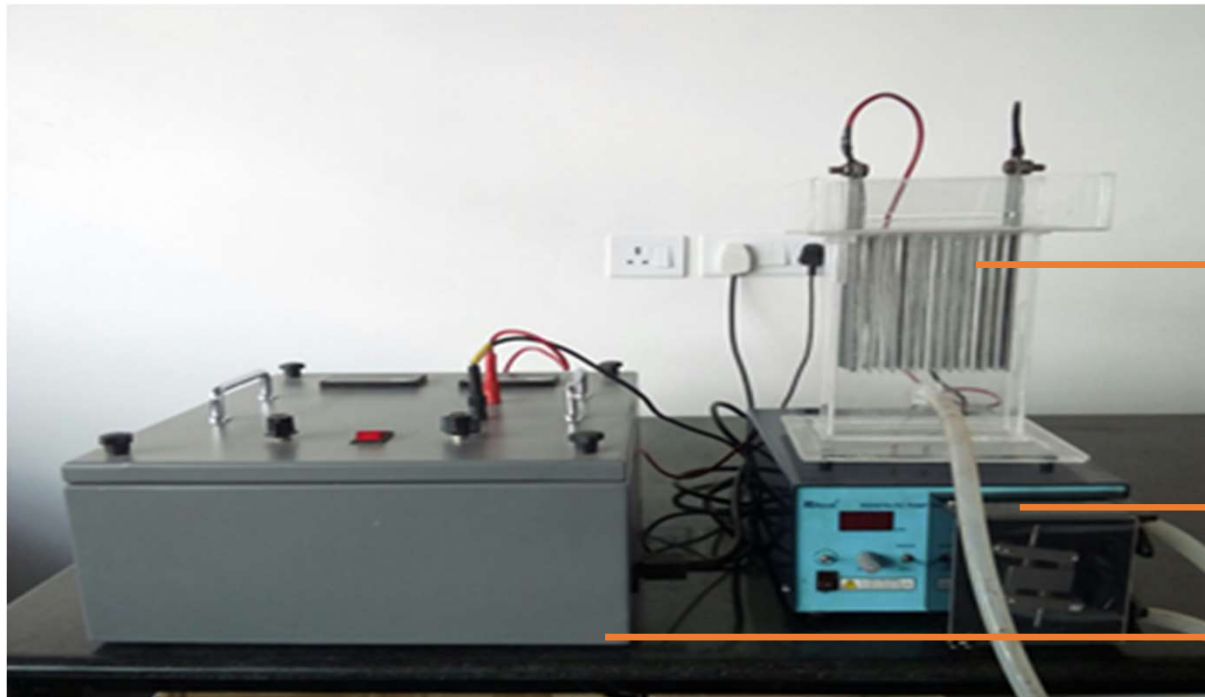


Aluminium



Iron

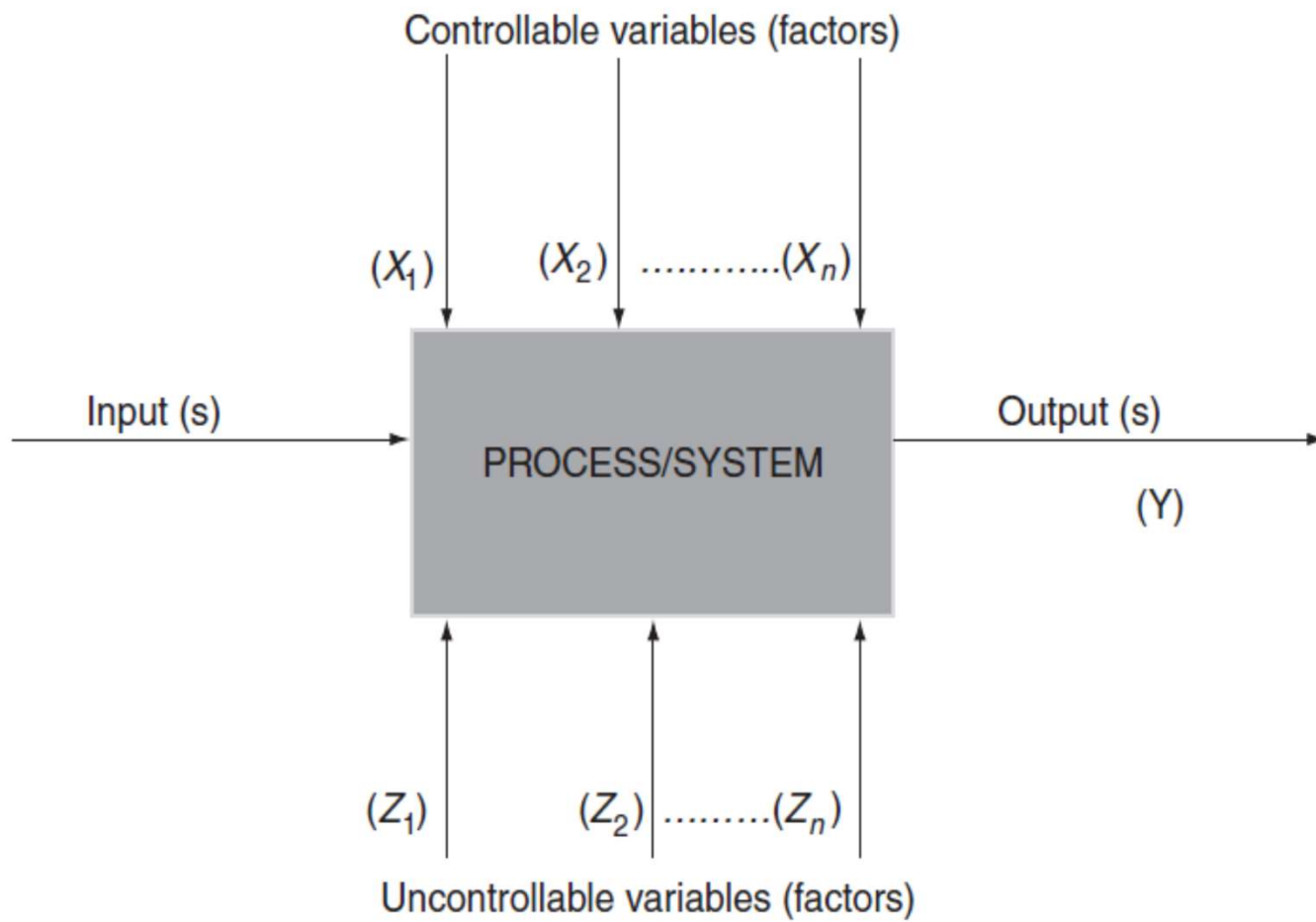
Continuous Bi-polar mode Electrocoagulation (CBME)



CBME
Chamber

Peristaltic
pump

DC-Power
supply



Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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POME

Variables	$-(\alpha)$	-1	0	+1	$+(\alpha)$
pH	3	4.7	6.5	8.2	10
Retention time (min)	0.5	2.8	5.2	7.6	10
Reaction area(sq.cm)	204	344	484	625	765
Current density(A/sqm)	40	58.7	77.5	96.2	115

DWW

Variables	$-(\alpha)$	-1	0	+1	$+(\alpha)$
pH	2	3.66	6	8.37	10
Retention time (min)	0.5	3.43	7.75	12.06	15
Current density(A/sqm)	13	18.3	26.14	33.9	40

Design of Experiments



Experimental runs



Model validation by ANOVA

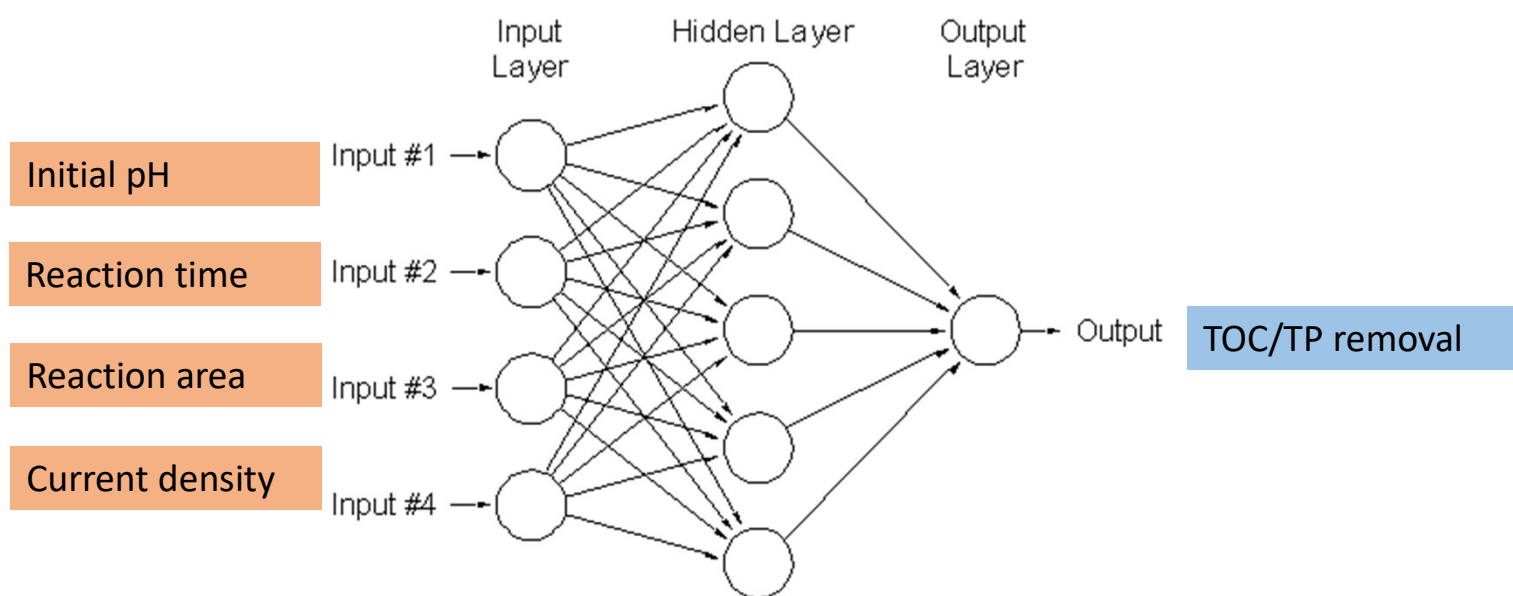


Model validation by ANN



Optimization by RSM

Artificial Neural Networks



Feed forward-Back
propagation algorithm

10 Hidden neurons

Sigmoid transfer function

Feasibility Study	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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POME

DWW

Design of Experiments

Experimental runs

Model validation by ANOVA

Model validation by ANN

Optimization by RSM

TOC					
Source	DF	Adj SS	Adj MS	F-value	P-Value
Model	14	206.82	14.77	49.9	0
Linear	4	130.9	32.74	110.59	0
Square	4	53.6	13.42	45.33	0
2-way interaction	6	22.196	3.6994	12.49	0

Total Phosphorous					
Source	DF	Adj SS	Adj MS	F-value	P-Value
Model	14	249.5	17.82	46.77	0
Linear	4	32.49	8.123	21.31	0
Square	4	194.77	48.69	127.76	0
2-way interaction	6	22.32	3.72	9.76	0

Model summary	TOC	Phosphorous
R-Square	0.93	0.93
R-Square(pred)	0.87	0.86

TOC					
Source	DF	Adj SS	Adj MS	F-value	P-Value
Model	9	6107.7	678.64	23.16	0
Linear	3	3995.7	1331.87	45.45	0
Square	3	1601.56	533.85	18.22	0
2-way interaction	3	510.63	170.21	5.81	0

Total Phosphorous					
Source	DF	Adj SS	Adj MS	F-value	P-Value
Model	9	9376.5	1041.8	470.22	0
Linear	3	1926.5	642	289.11	0
Square	3	7320.3	2440.24	1101.39	0
2-way interaction	3	129.5	43.17	19.49	0

Model summary	TOC	Phosphorous
R-Square	0.95	0.99
R-Square(pred)	0.84	0.98

Feasibility Study	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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POME

Total Organic Carbon

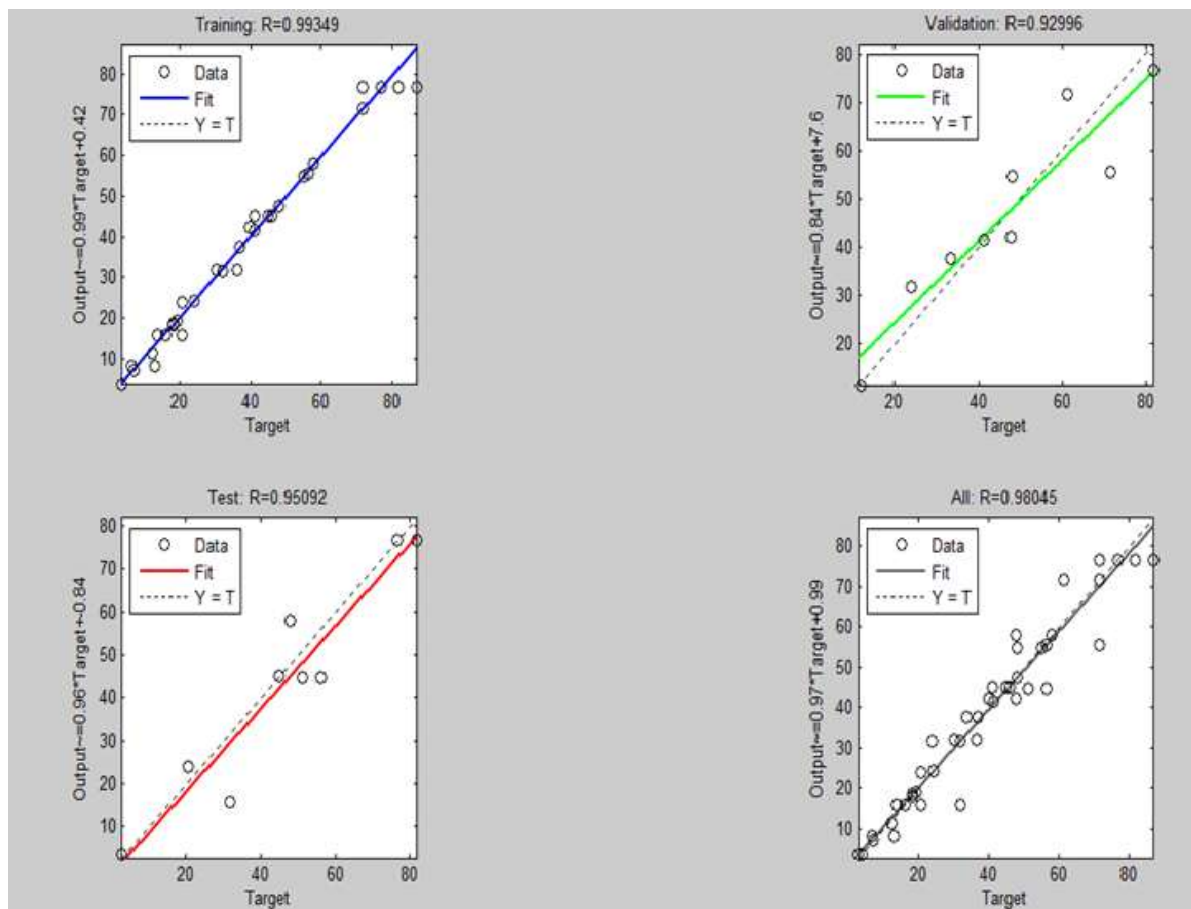
Design of Experiments

Experimental runs

Model validation by ANOVA

Model validation by ANN

Optimization by RSM



Feasibility Study

Optimization

Kinetics

Mechanism

Sludge studies

Comparison of Field
scale/lab scale CBME

Conclusion

POME

Total Phosphorous

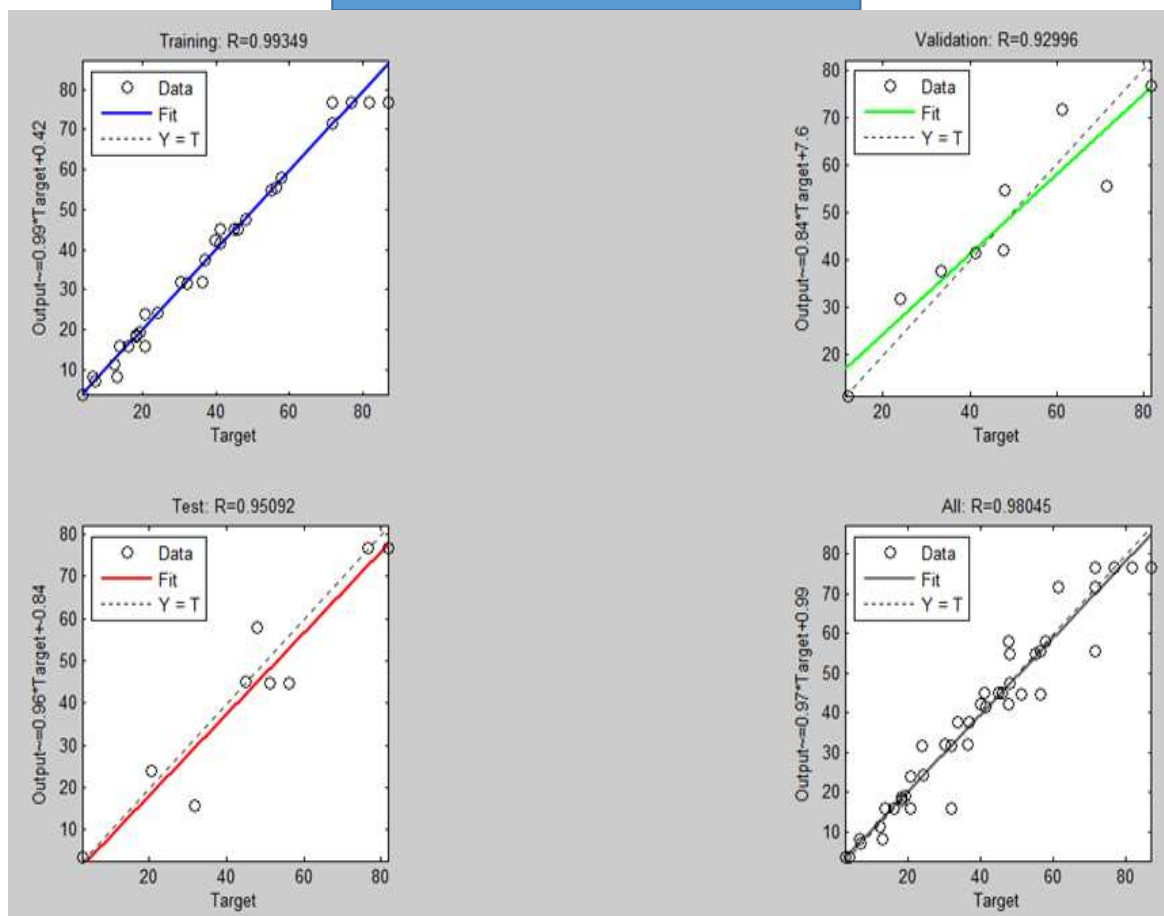
Design of
Experiments

Experimental
runs

Model validation
by ANOVA

Model validation
by ANN

Optimization by
RSM



POME

$$\begin{aligned} \text{TOC removal (\%)} = & -250.8 + 39.98 \text{ pH} + 28.81 \text{ RT} + 0.1575 \text{ RA} + 1.939 \text{ CD} \\ & - 2.045 \text{ pH}^* \text{pH} - 1.261 \text{ RT}^* \text{RT} + 0.000123 \text{ RA}^* \text{RA} + \\ & 0.00768 \text{ CD}^* \text{CD} - 0.2750 \text{ pH}^* \text{CD} - 0.0860 \text{ RT}^* \text{CD} - \\ & 0.002325 \text{ S/V}^* \text{CD} \end{aligned} \quad (1)$$

$$\begin{aligned} \text{TP removal (\%)} = & -303.6 + 82.36 \text{ pH} + 4.87 \text{ RT} + 0.0097 \text{ RA} + 1.694 \text{ CD} - \\ & 7.261 \text{ pH}^* \text{pH} - 1.980 \text{ RT}^* \text{RT} - 0.000149 \text{ RA}^* \text{RA} - \\ & 0.02105 \text{ CD}^* \text{CD} + 0.2080 \text{ pH}^* \text{CD} + 0.02451 \text{ RT}^* \text{RA} + \\ & 0.0923 \text{ RT}^* \text{CD} \end{aligned} \quad (2)$$

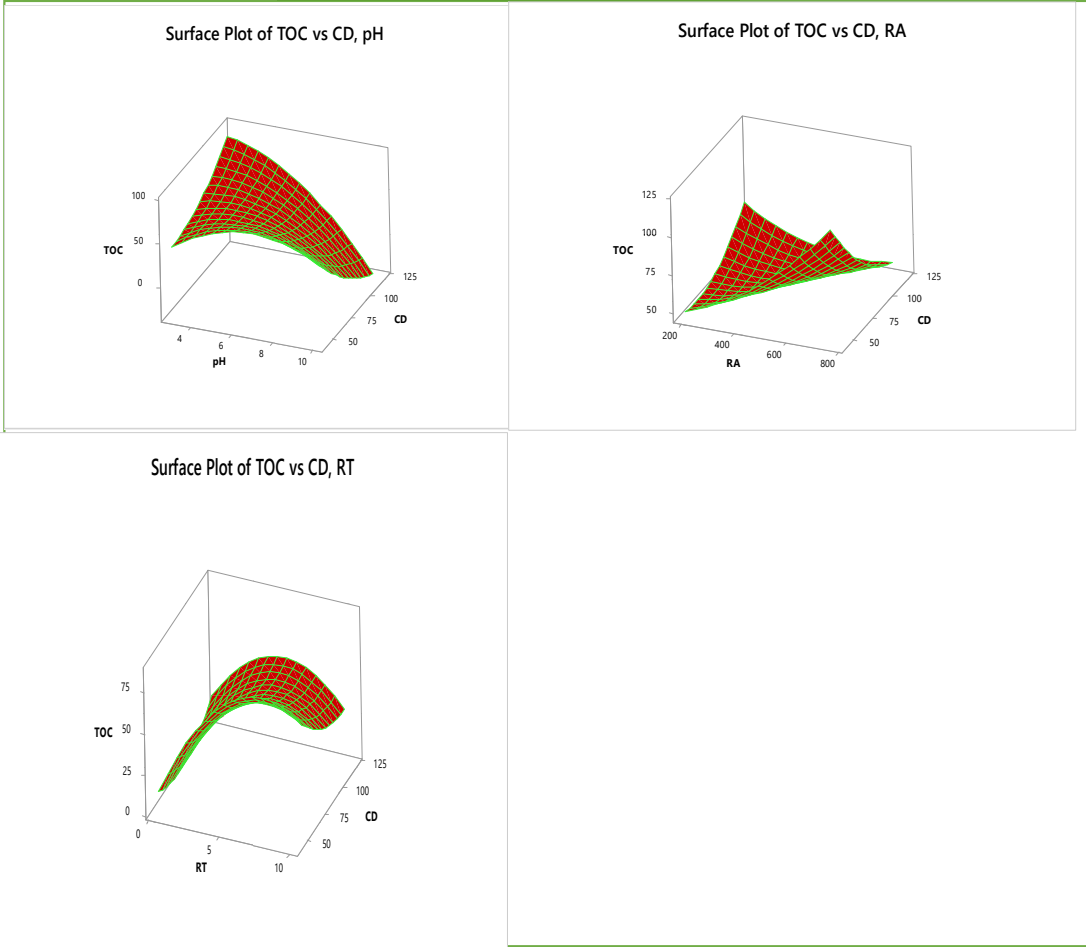
DWW

$$\begin{aligned} \text{TOC removal (\%)} = & 67.0 - 5.15 \text{ pH} + 3.42 \text{ RT} - 1.77 \text{ CD} - 1.100 \text{ pH}^* \text{pH} - 0.4800 \text{ RT}^* \text{RT} \\ & + 0.0048 \text{ CD}^* \text{CD} \\ & + 0.440 \text{ pH}^* \text{RT} + 0.270 \text{ pH}^* \text{CD} + 0.1286 \text{ RT}^* \text{CD} \end{aligned} \quad (3)$$

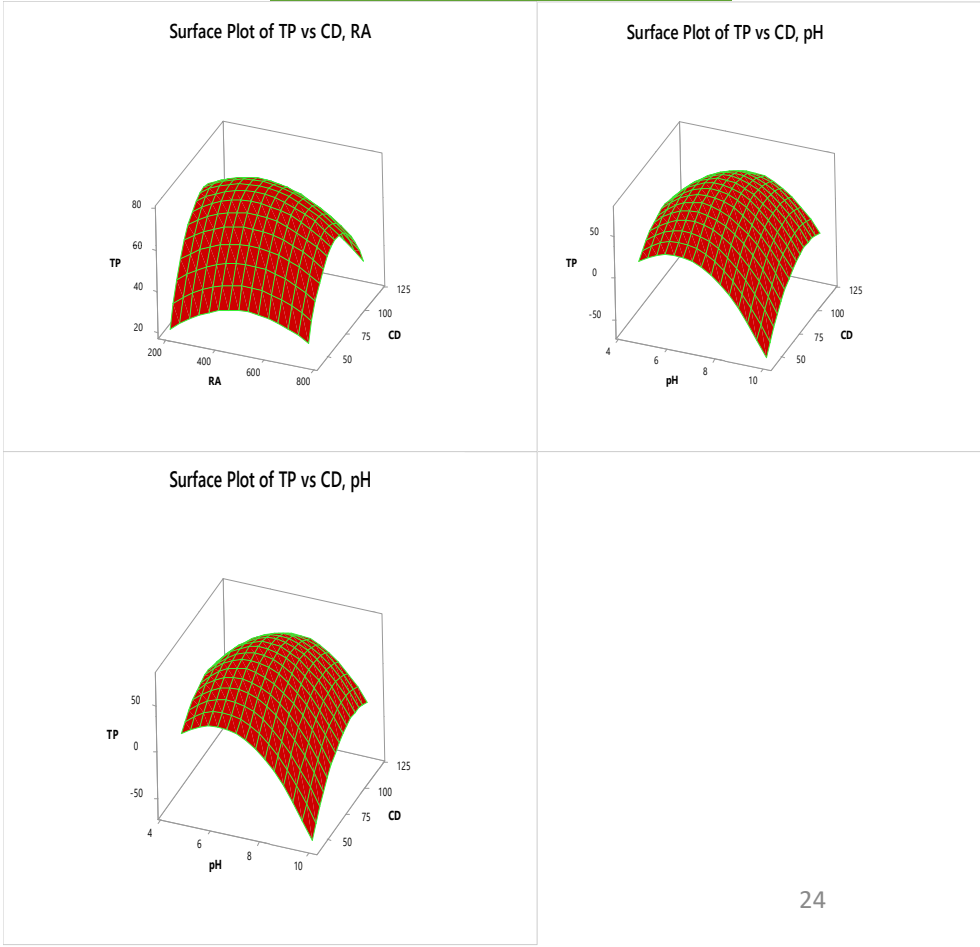
$$\begin{aligned} \text{TP removal (\%)} = & -123.20 + 37.53 \text{ pH} + 15.136 \text{ RT} + 0.704 \text{ CD} - 3.2813 \text{ pH}^* \text{pH} - \\ & 0.7401 \text{ RT}^* \text{RT} + 0.02537 \text{ CD}^* \text{CD} \\ & + 0.1610 \text{ pH}^* \text{RT} - 0.0647 \text{ pH}^* \text{CD} - 0.1035 \text{ RT}^* \text{CD} \end{aligned} \quad (4)$$

POME

Surface Plots for TOC

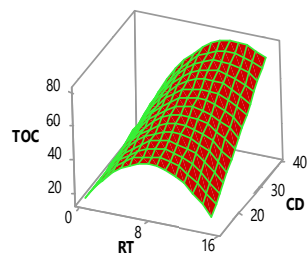
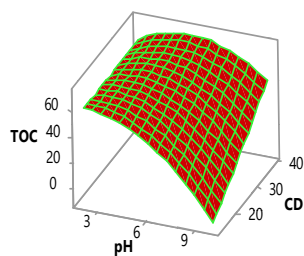
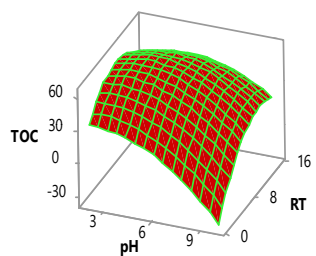


Surface Plots for TP

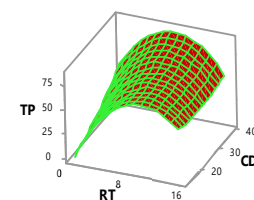
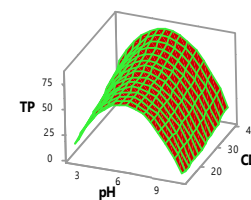
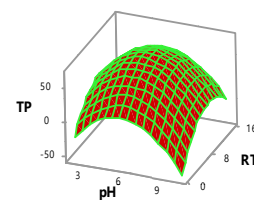


DWW

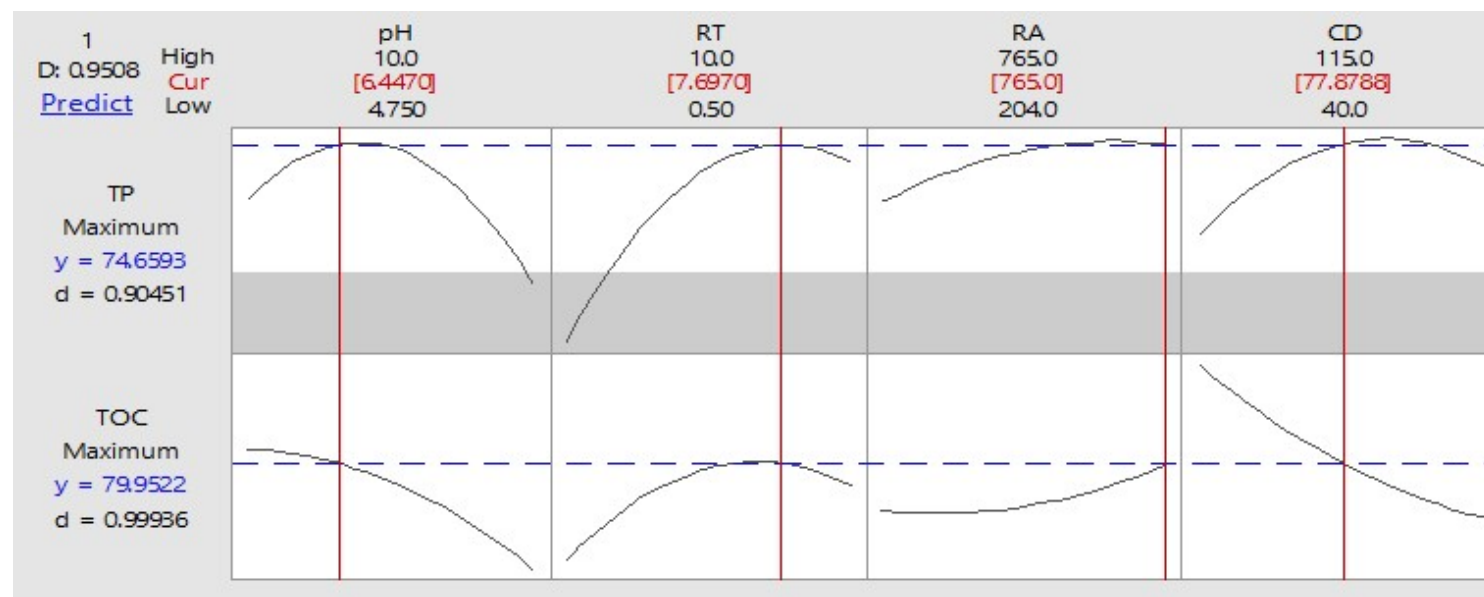
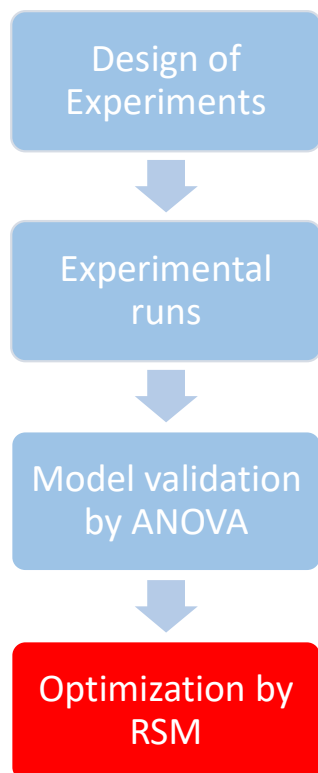
Surface Plots for TOC



Surface Plots for TP

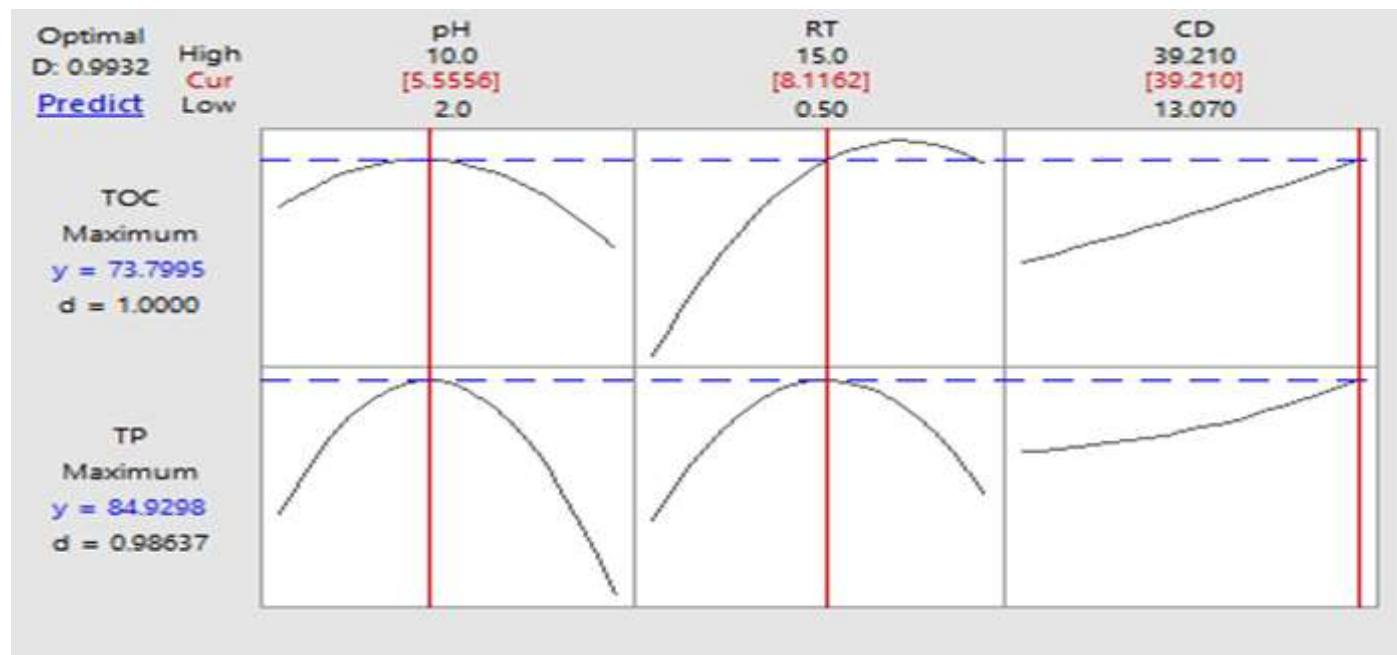
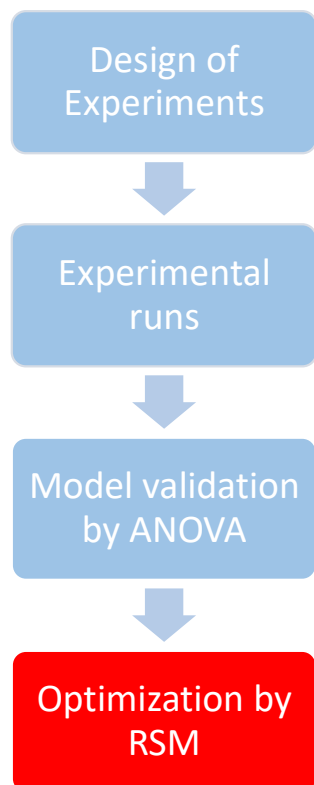


POME

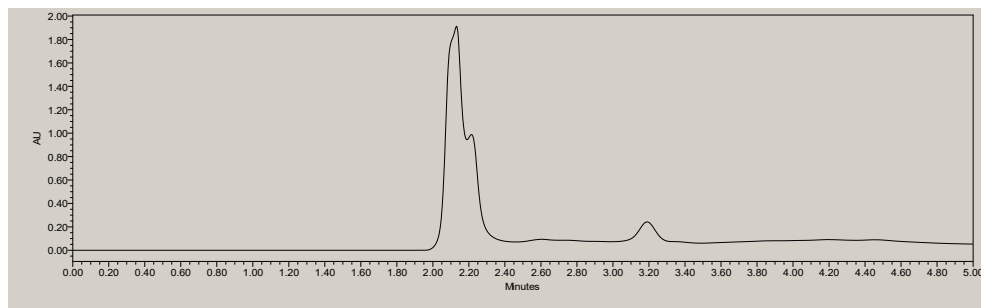


Parameter	Predicted	Experimental	Concurrence
TOC	79.9	77	94%
Phosphorous	74.5	73	90%

DWW



Parameter	Predicted	Experimental	Concurrence
TOC	73.79	71	97%
Phosphorous	84.29	85	100%

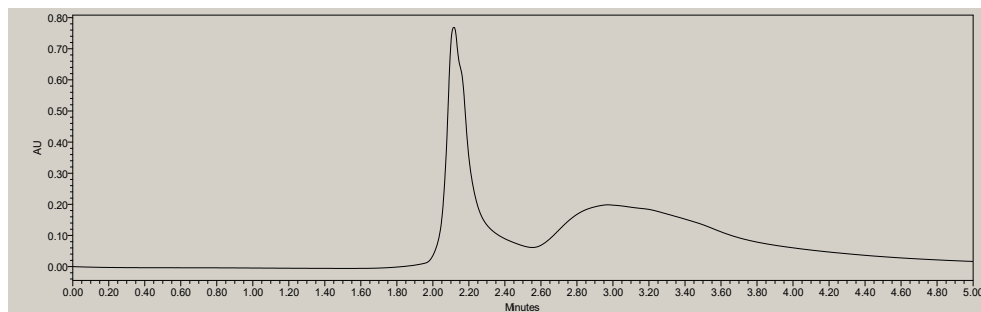


Synthetic Melanoidins

Time (min)	Area ($\mu\text{V}\cdot\text{sec}$)
2.131	11968014

Height (μV)
1909860

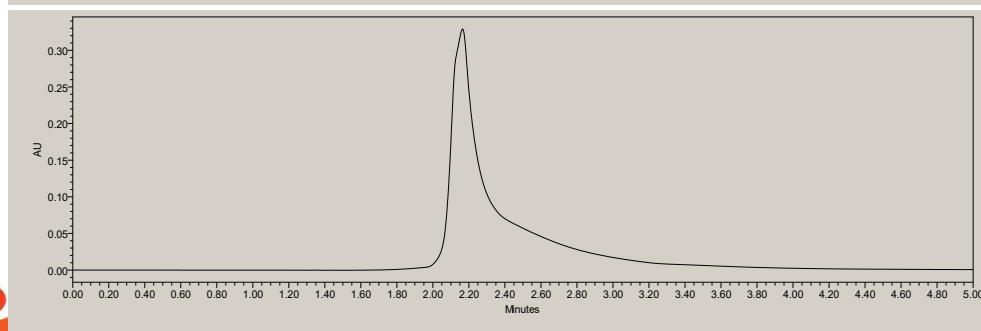
HPLC-Result



Raw sample

Time (min)	Area ($\mu\text{V}\cdot\text{sec}$)
2.117	7951912

Height (μV)
771591



Optimized run sample

Time (min)	Area ($\mu\text{V}\cdot\text{sec}$)
2.165	4699374

Height (μV)
326581

Optimization Results

Parameter	POME	DWW
pH	6.4	5.5
Reaction time	7.69	8.12
Reaction area	765	765
Current Density	77.8	39.2
Surface area/Volume ratio	76.5	76.5
Energy consumption(kwh/cu.m)	22.4	10.15
TOC removal efficiency	77%	71%
TP removal efficiency	73%	85%
Melanoidin removal	-	60%

Preliminary
Studies

Optimization

Kinetics

Mechanism

Sludge studies

Comparison of Field
scale/lab scale CBME

Conclusion

POME

Kinetic Studies

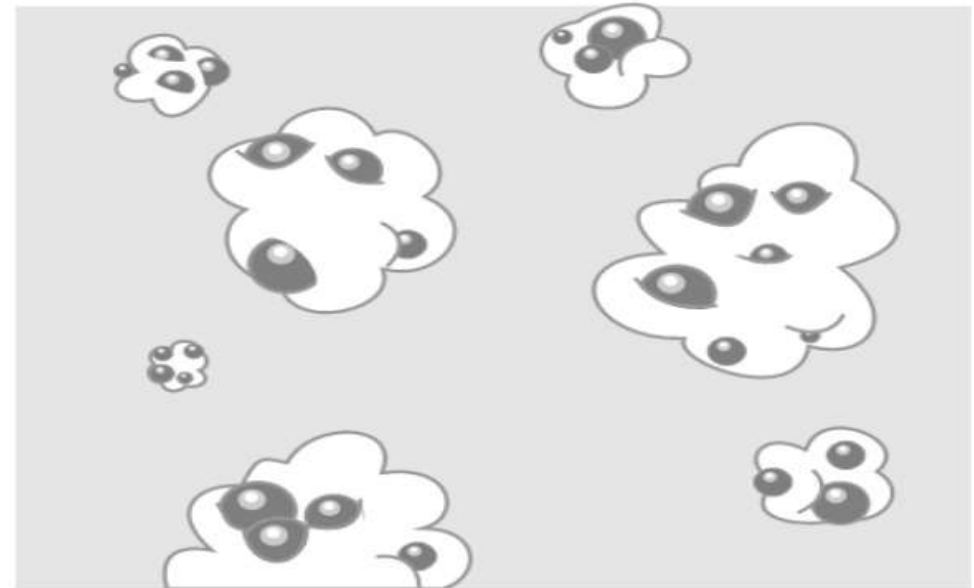
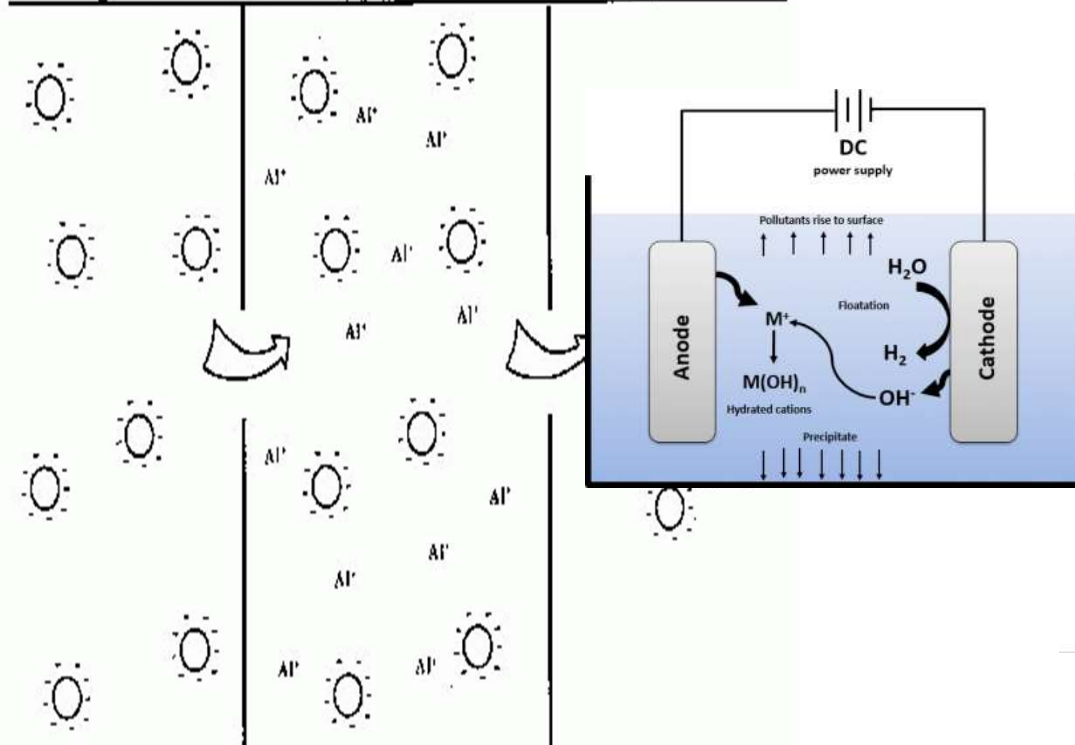
DWW

pH/C.D	40	58.5	77.5
3	✓	✓	✓
4.75	✓	✓	✓
6.5	✓	✓	✓
8.5	✓	✓	✓
10	✓	✓	✓

pH/C.D	13	26	40
2	✓	✓	✓
4	✓	✓	✓
6	✓	✓	✓
8	✓	✓	✓
10	✓	✓	✓

Mechanism

Charge Neutralization/Colloid Destabilization



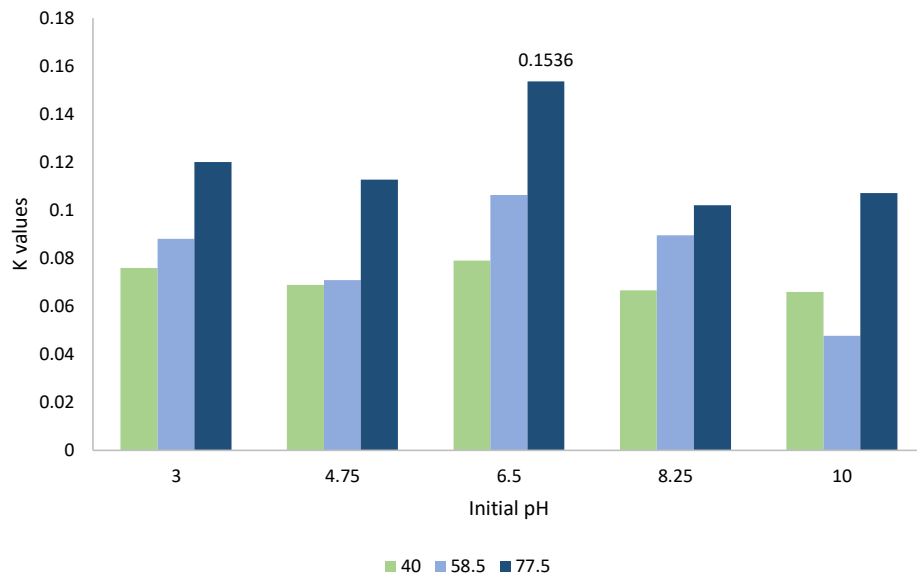
Sweep Flocc

Colloids become enmeshed in the growing precipitate.

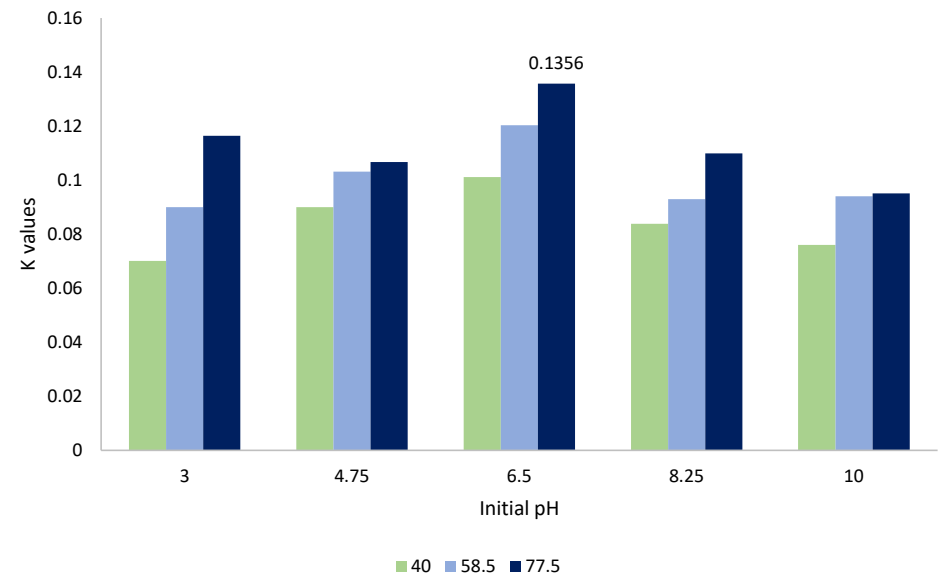
POME

Reaction Kinetics-k Values

Reaction kinetics-TOC



Reaction kinetics-TP



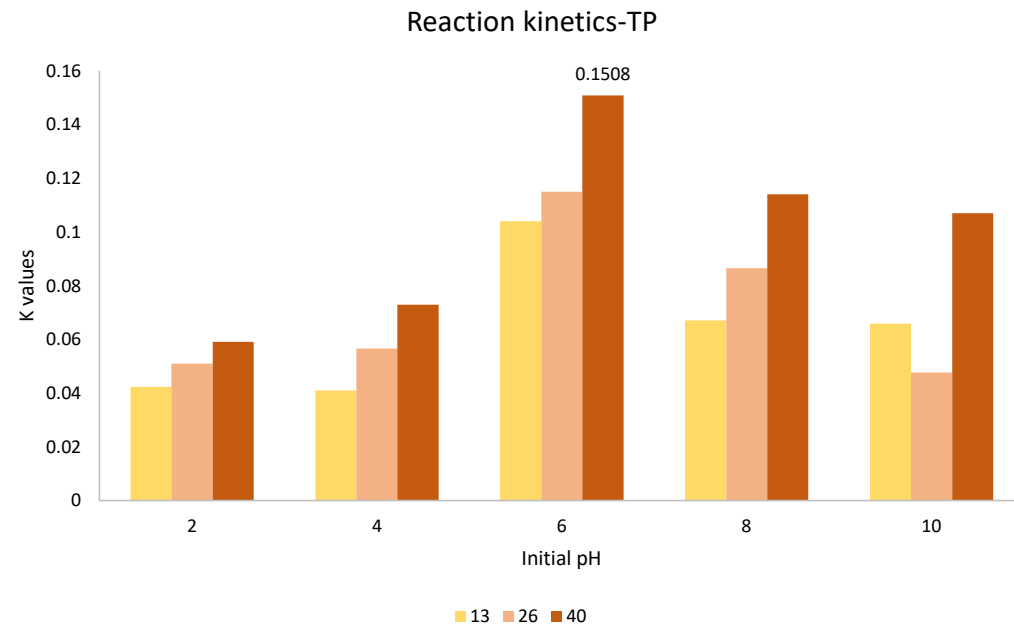
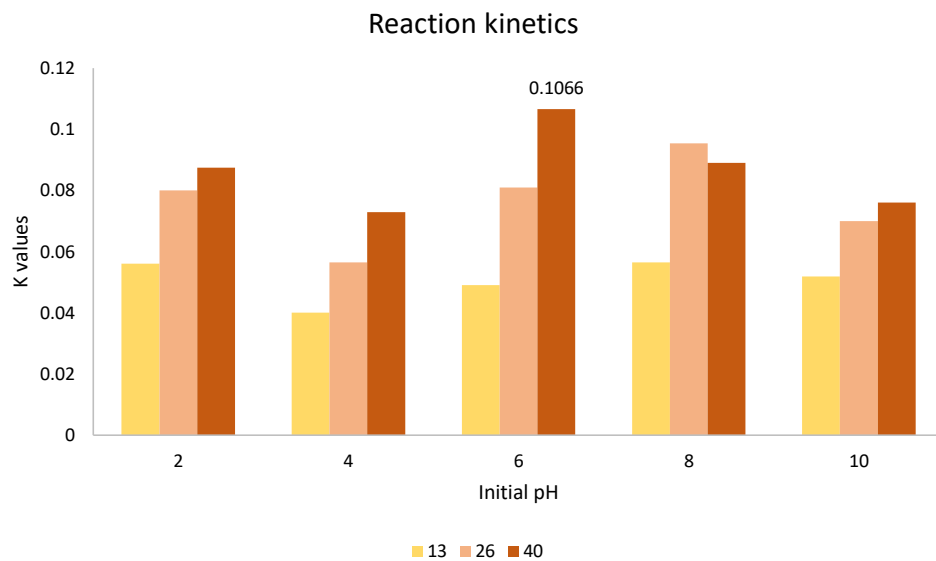
- Reaction Kinetics followed first order Kinetics
- Highest K –Values obtained at higher current densities and at pH-6.5

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DWW

Reaction Kinetics-k-values

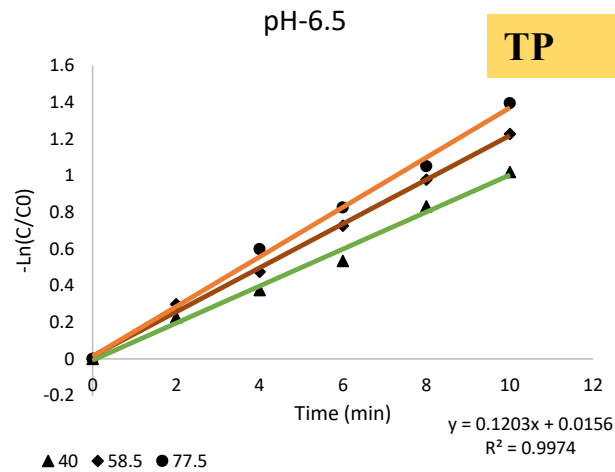
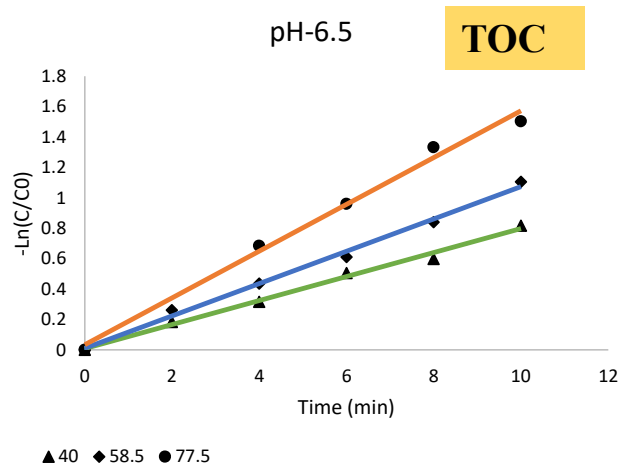


- Reaction Kinetics followed first order Kinetics
- Highest K –Values obtained at higher current densities and at pH-6

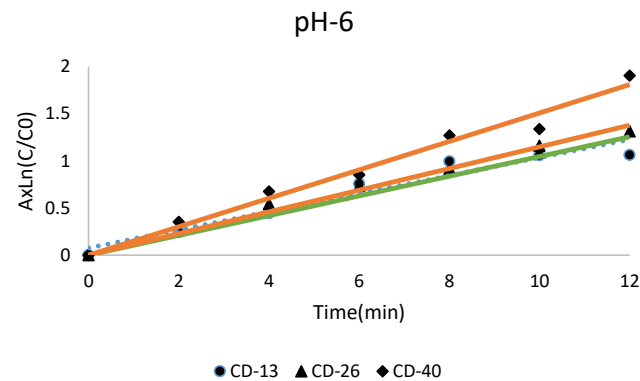
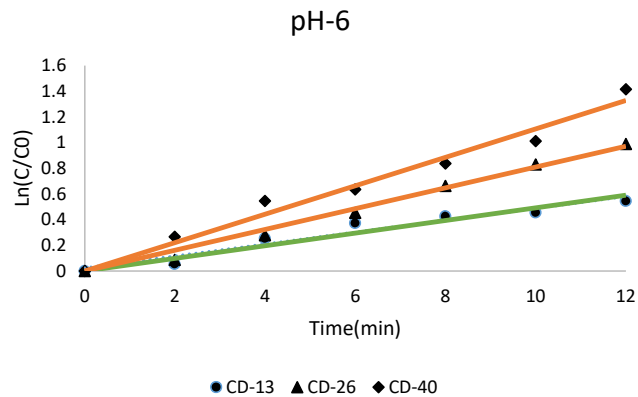
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Reaction Kinetics



POME

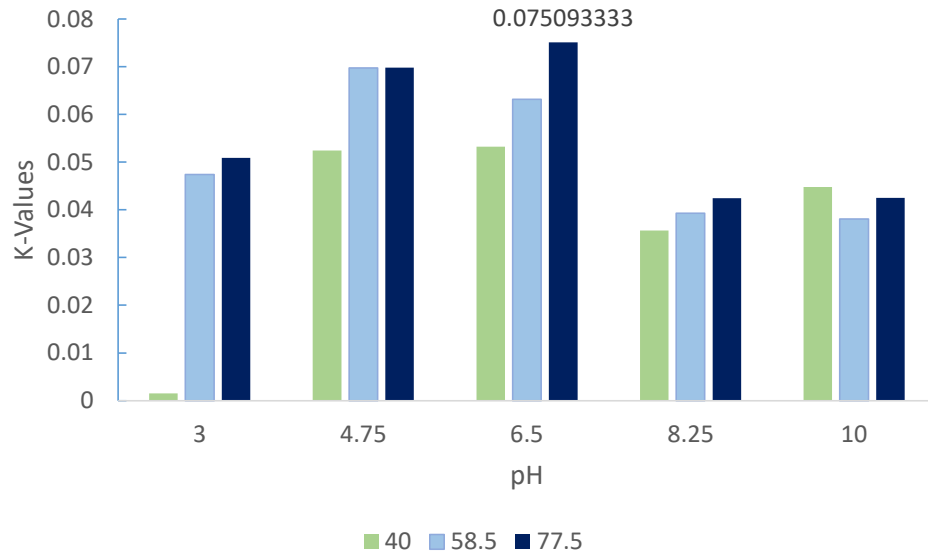


DWW

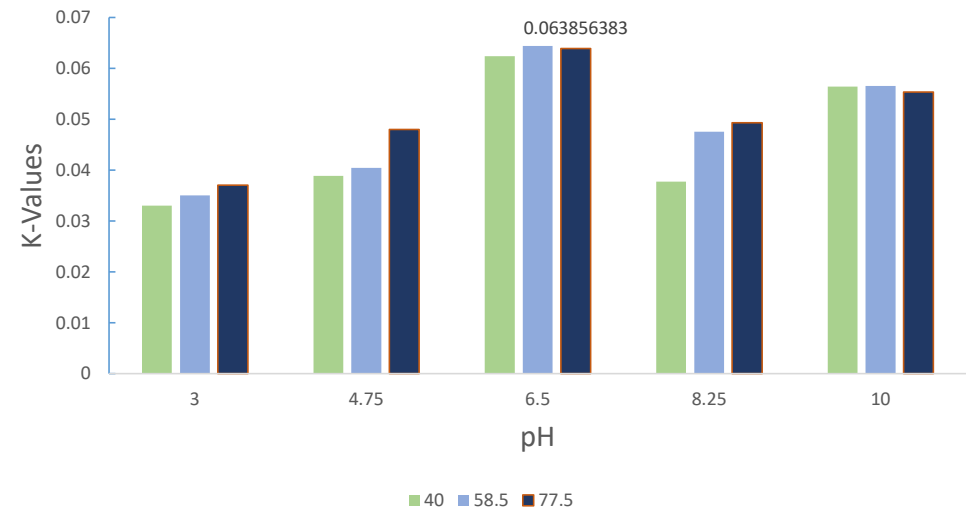
POME

Adsorption Kinetics- k Values

Adsorption Kinetics-TOC



Adsorption Kinetics-TP



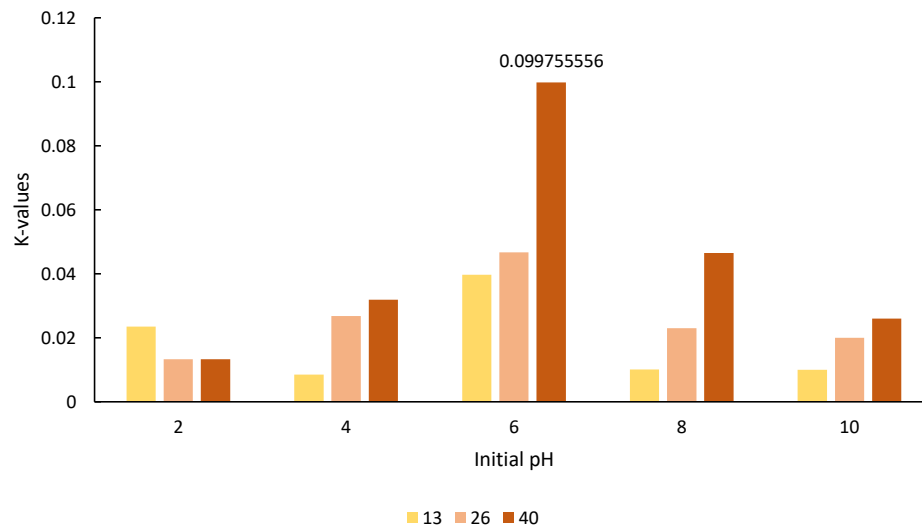
- Adsorption Kinetics followed Lagergran 2nd order Kinetics indicating Adsorption Equilibrium & chemical sorption
- Highest K –Values obtained at higher current densities and at pH-6.5

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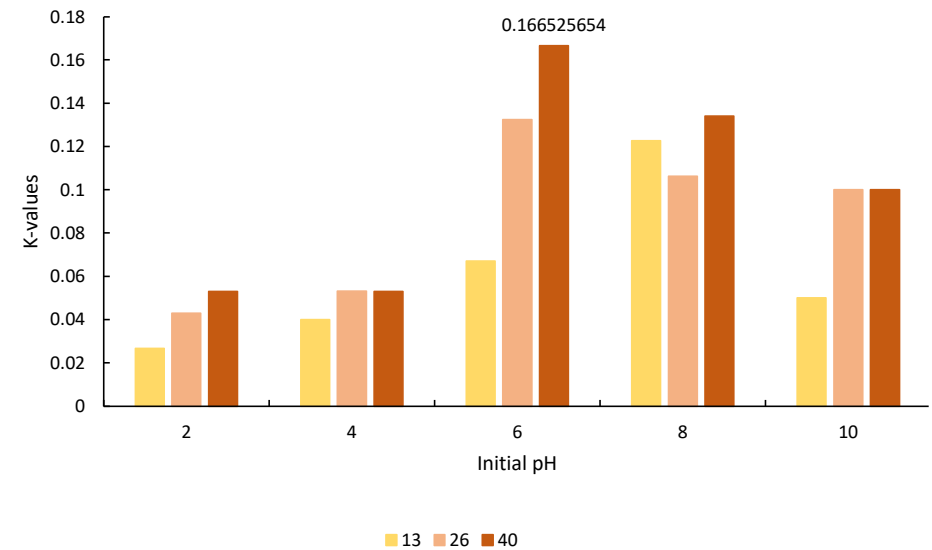
DWW

Adsorption Kinetics-k Values

Adsorption Kinetics-TOC



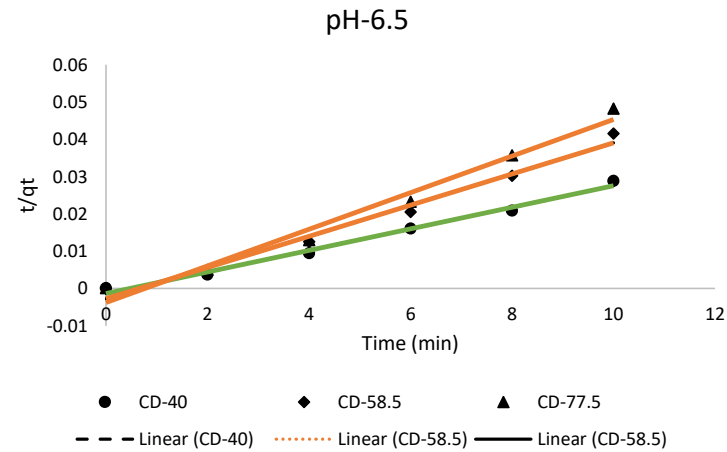
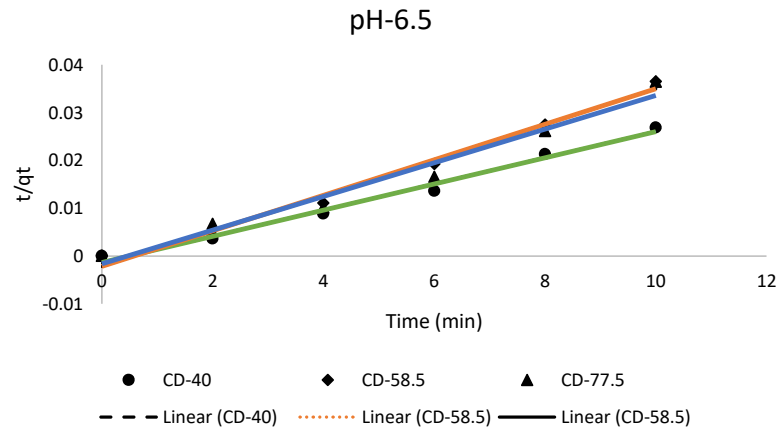
Adsorption Kinetics-TP



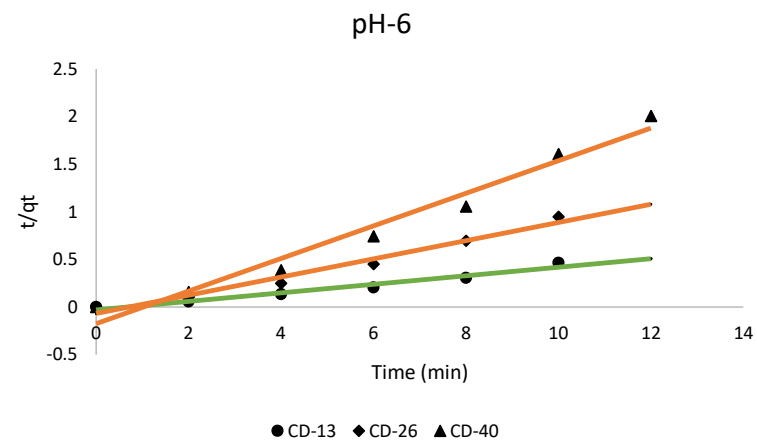
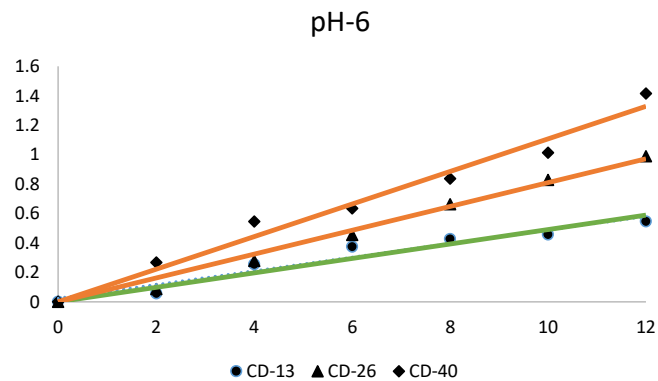
- Adsorption Kinetics followed Lagergran 2nd order Kinetics indicating Adsorption Equilibrium & chemical sorption
- Highest K –Values obtained at higher current densities and at pH-6

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Adsorption Kinetics



POME



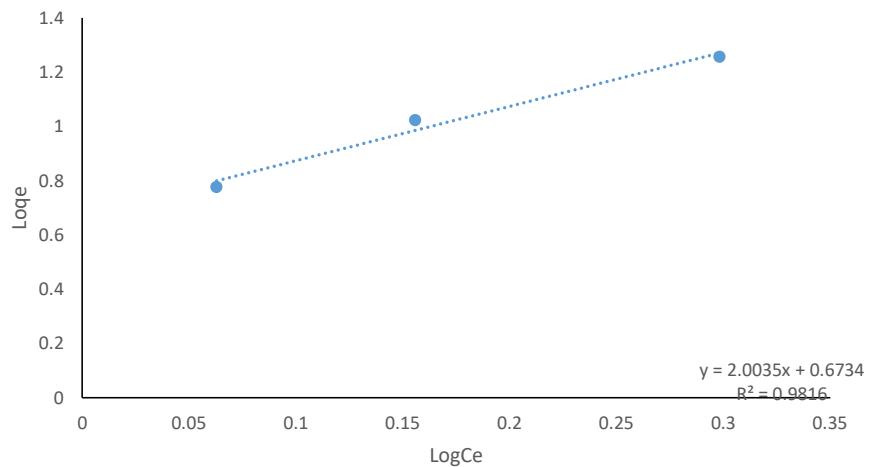
DWW

29-08-2026

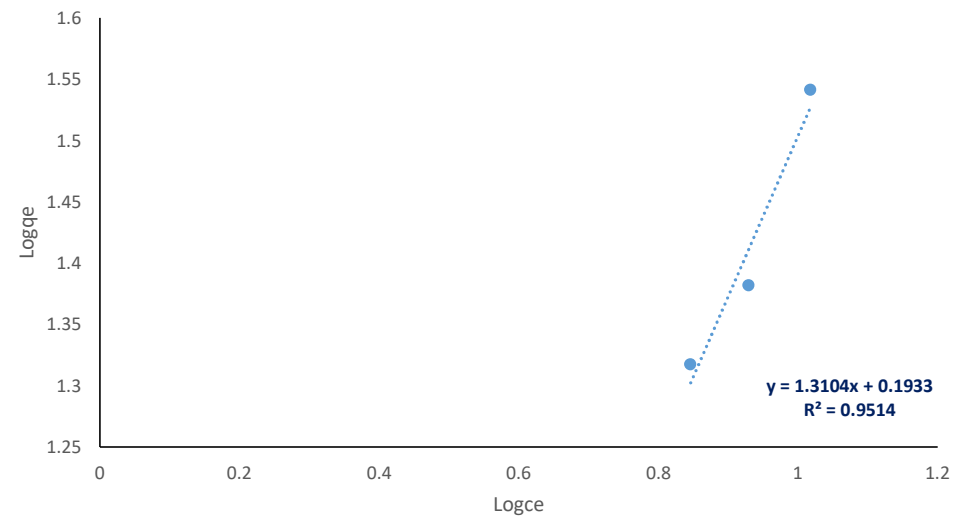
DWW

Adsorption Isotherms

Freundlich-TOC



Freundlich-TP



- Adsorption Isotherms best fit with Freundlich Isotherm
- Multilayer adsorption indicating reversible adsorption on heterogeneous surface

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Feasibility Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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Mechanism of Removal

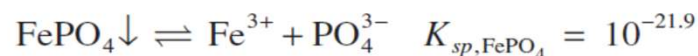
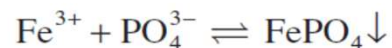
- **TOC removal Mechanism:**

pH<6; Indirect chemical oxidation; Oxidation of organic compounds

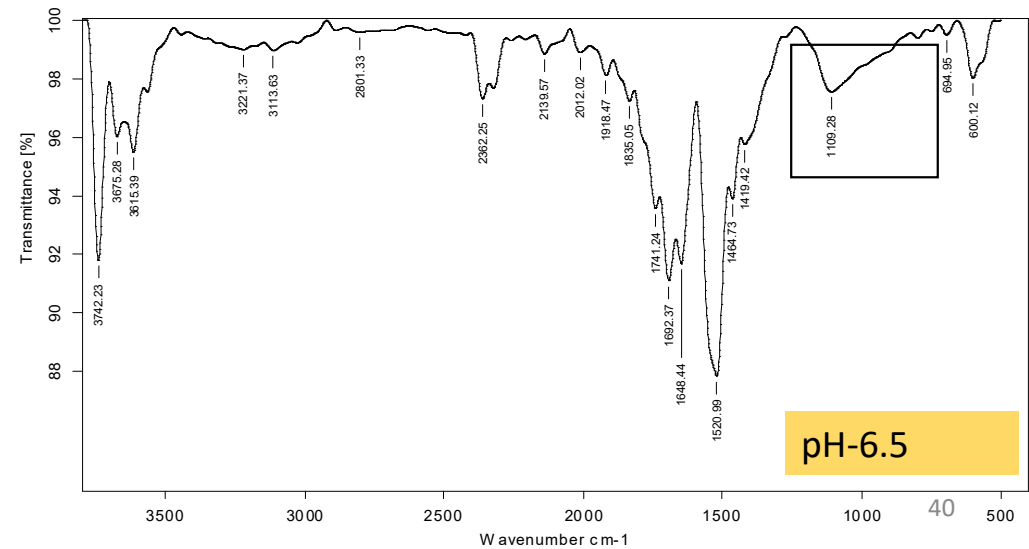
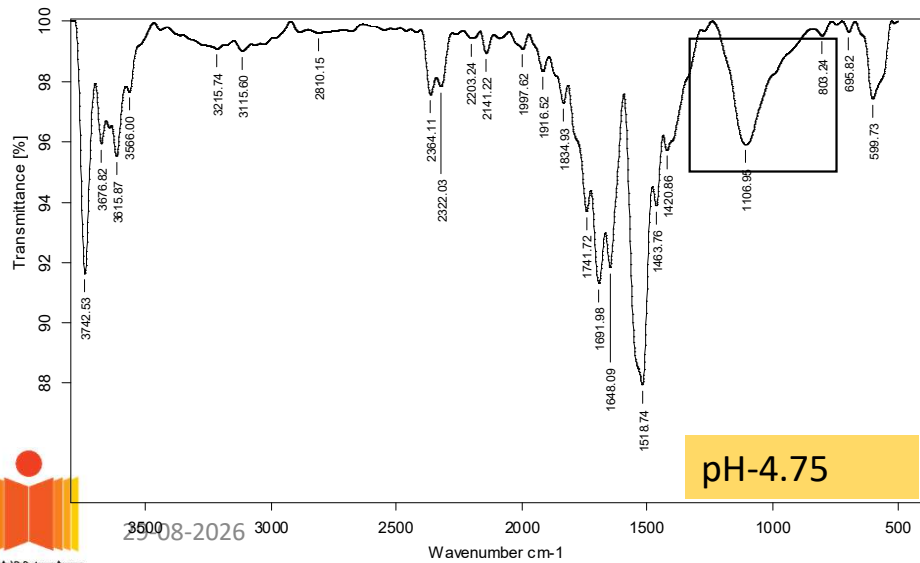
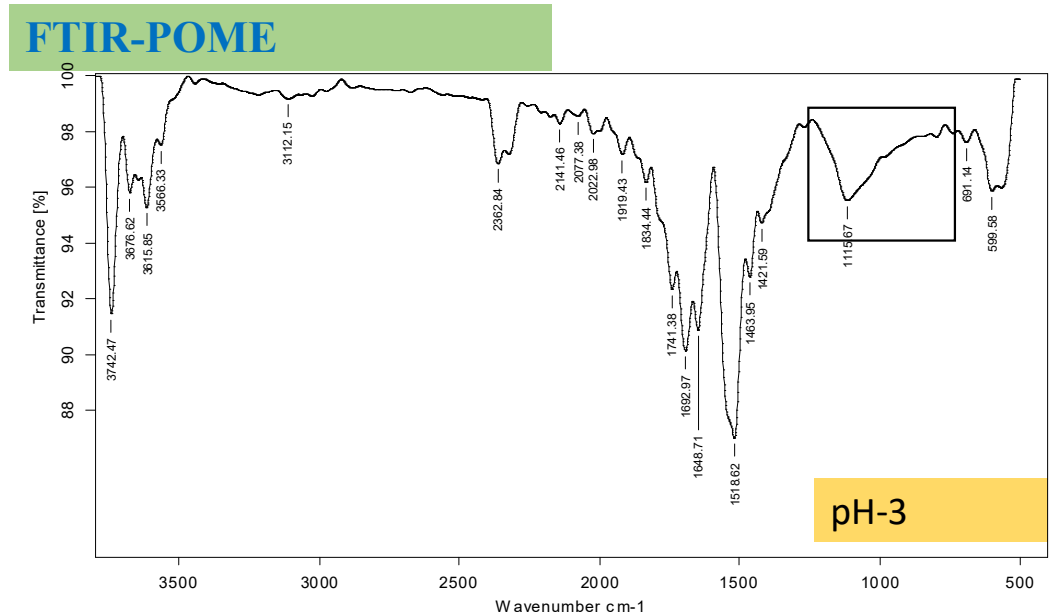
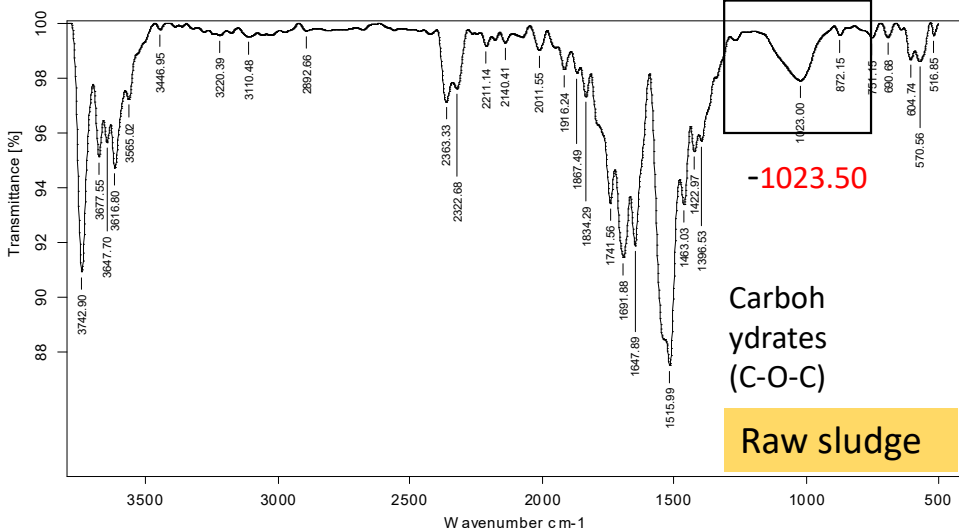
pH>6; Adsorption of organic particulates/ some extent of oxidation

- **TP removal Mechanism:**

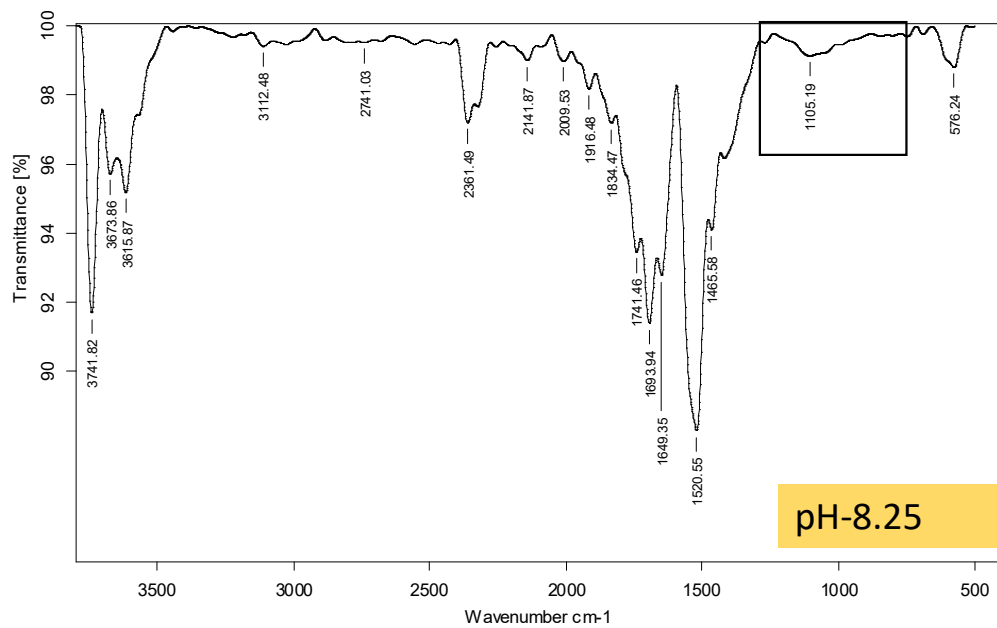
pH<6;



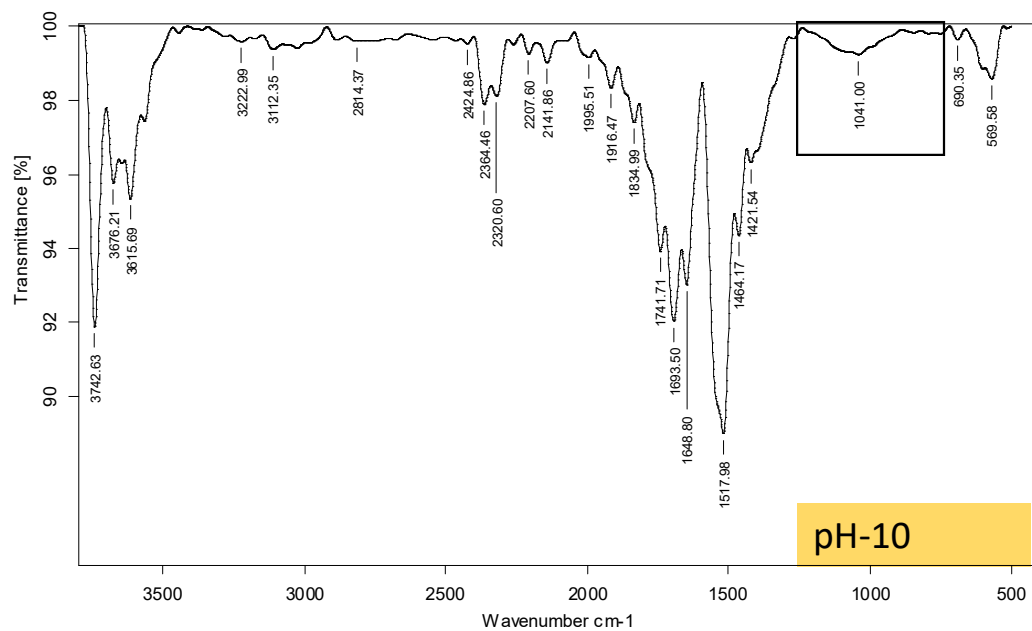
pH>6; OH⁻ ions dominate so FePO₄ formation retards and adsorption of orthophosphates happen on Fe(OH)₃



FTIR-POME



pH-8.25

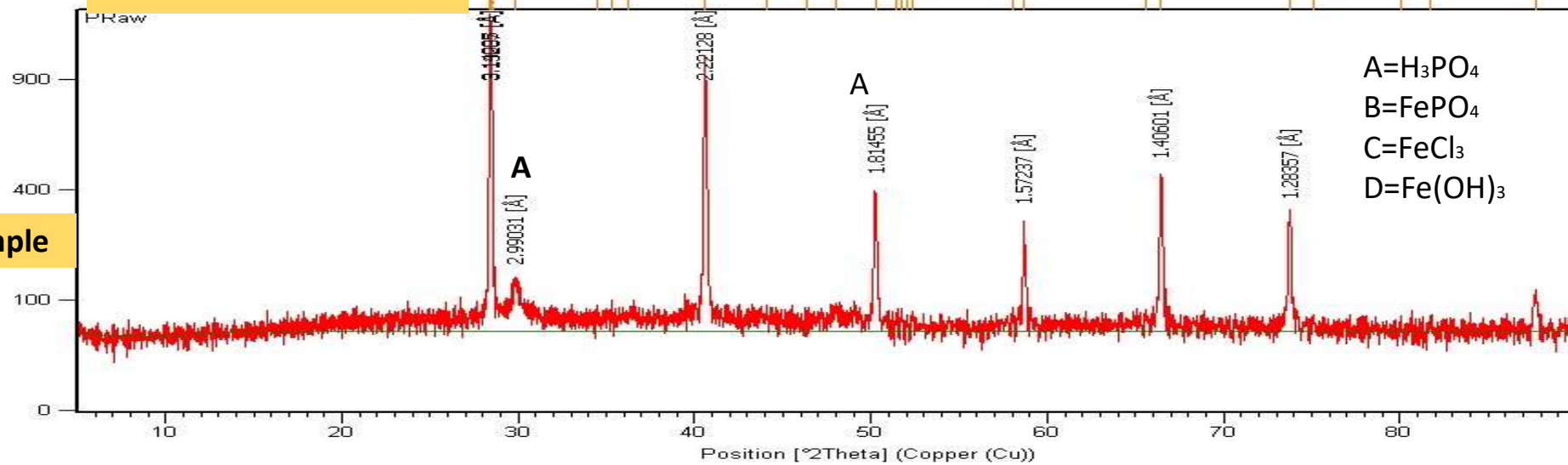


pH-10

XRD-POME

Counts

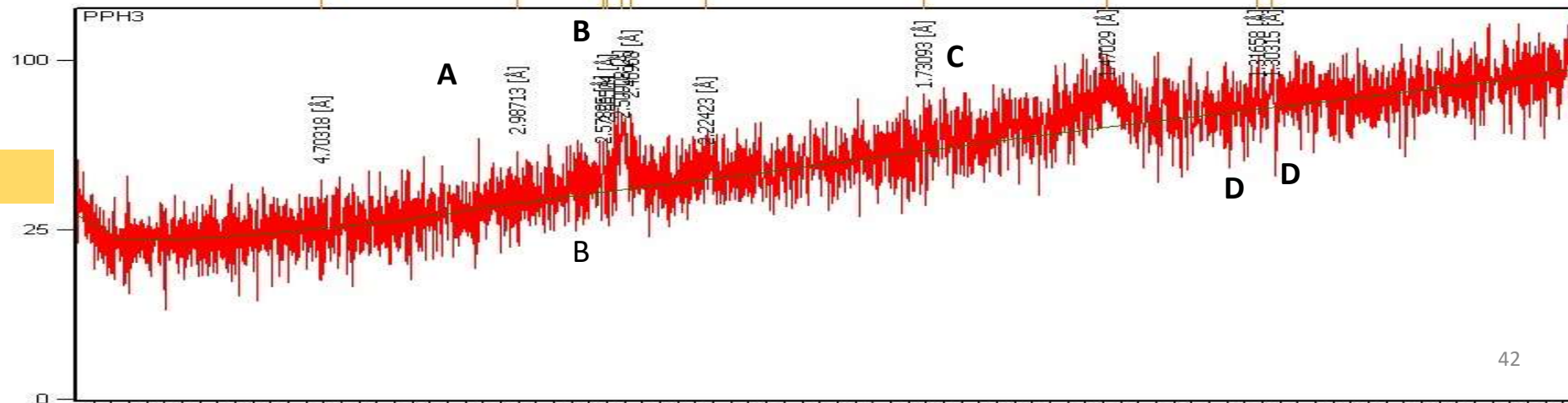
PRaw



Raw sample

Counts

PPH3

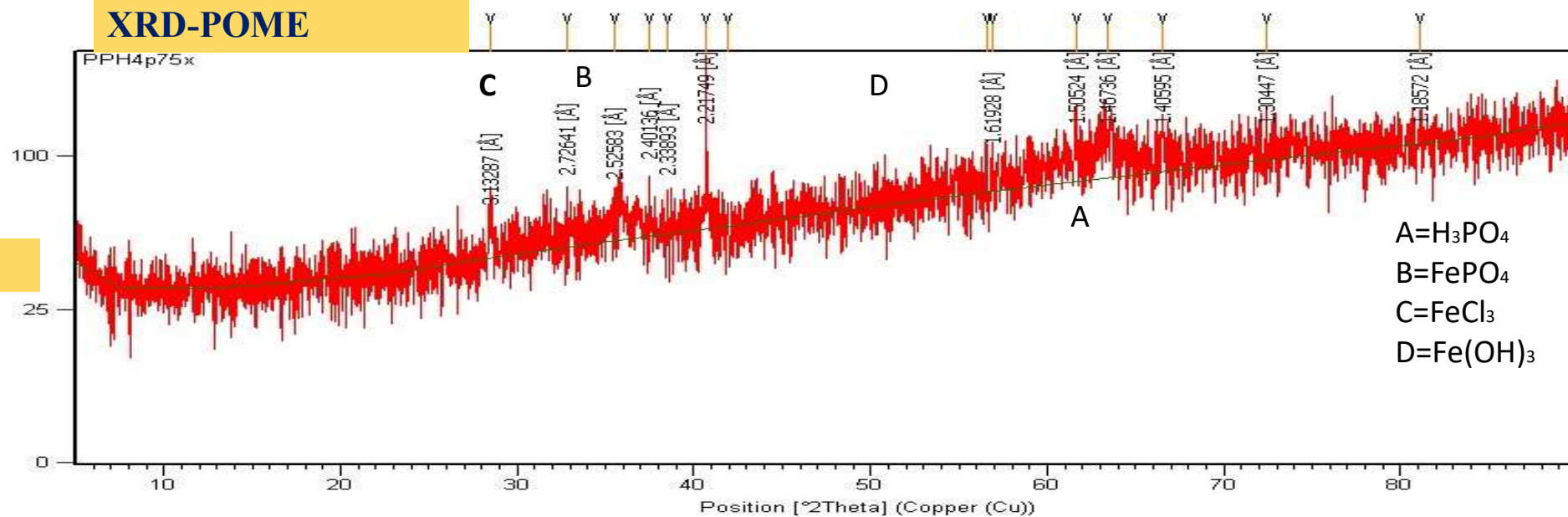


pH-3

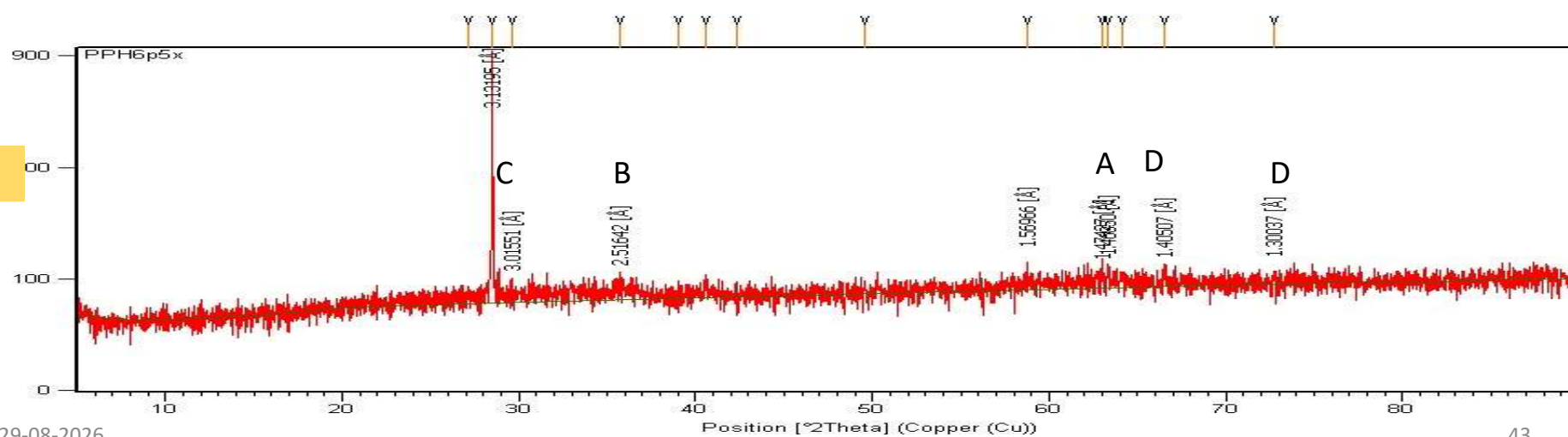
XRD-POME

Counts

pH-4.75



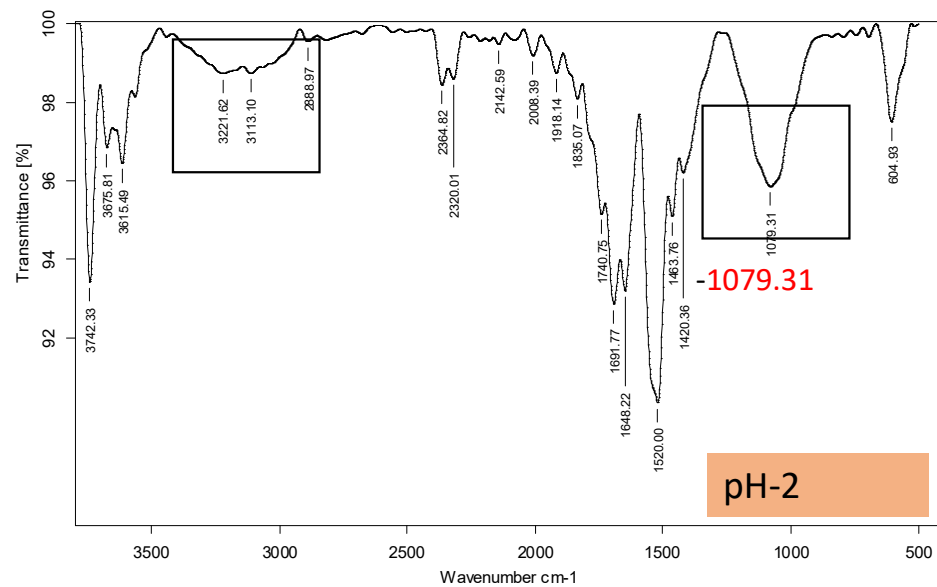
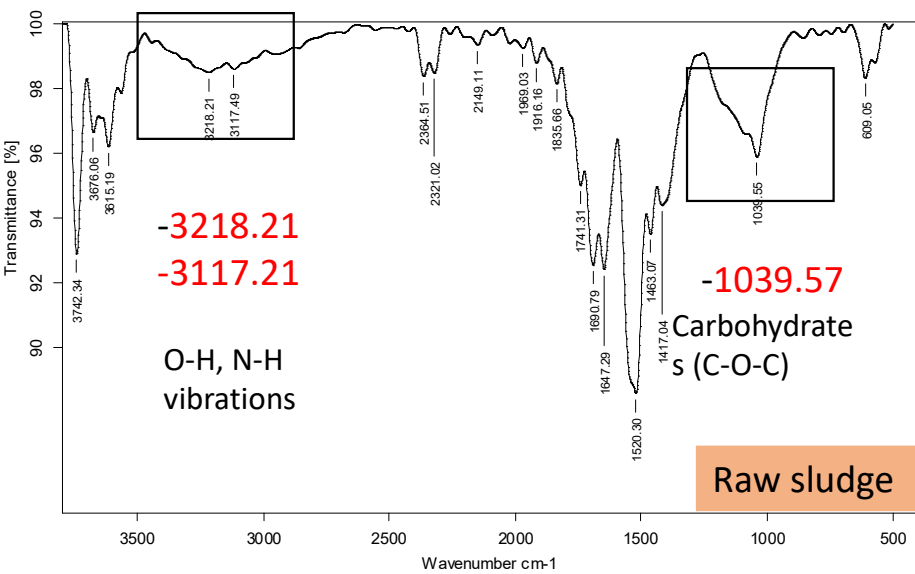
pH-6.5



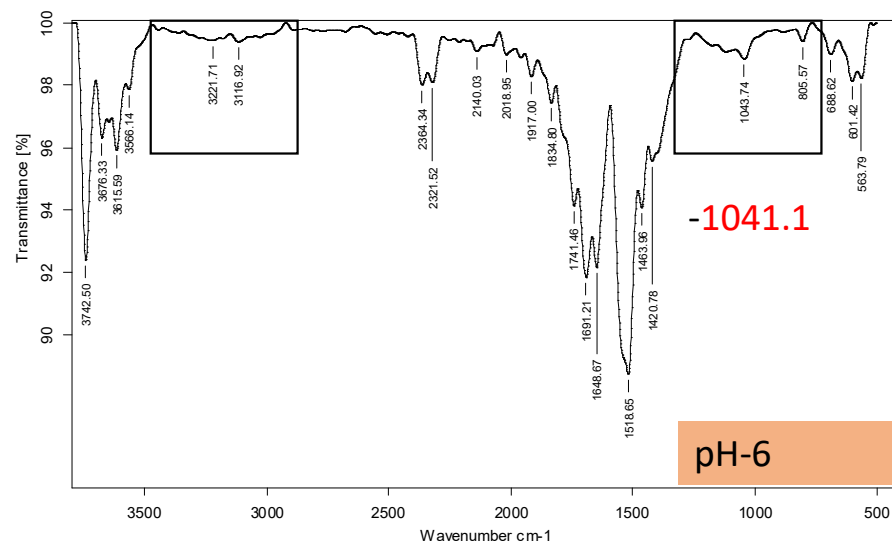
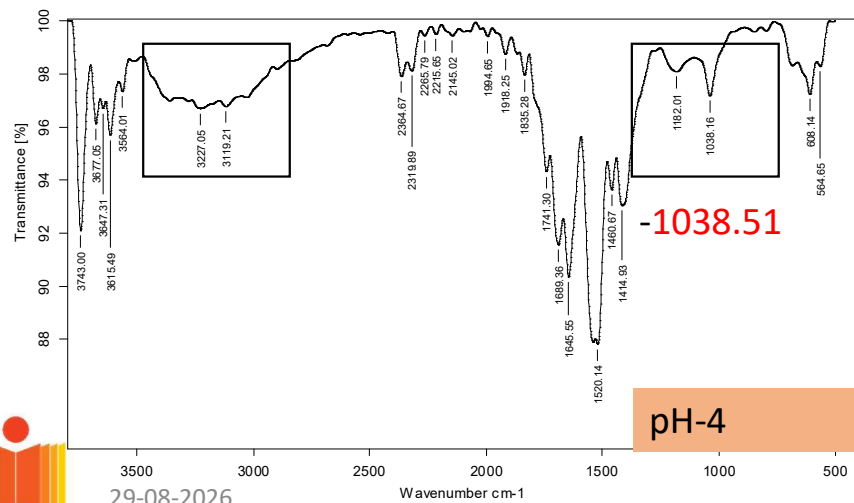
29-08-2026

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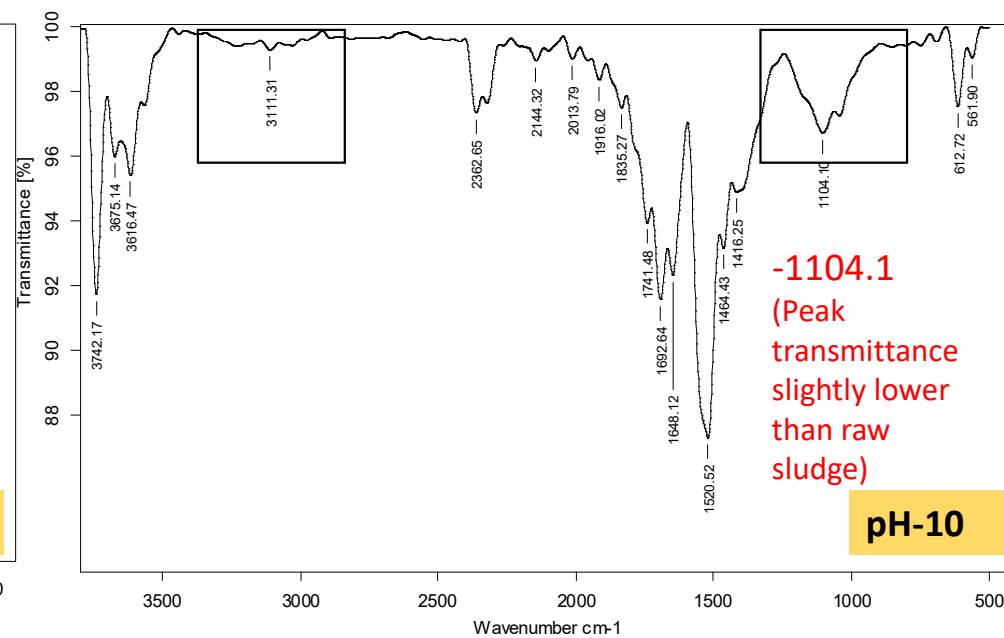
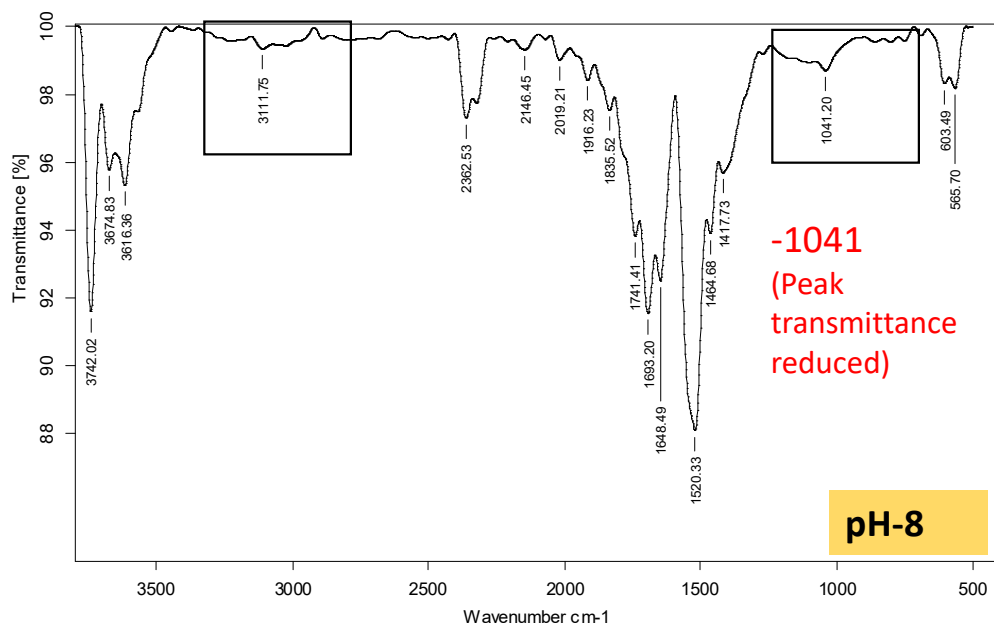
Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
POME pH change-POME Reaction Kinetics Adsorption Kinetics			Initial pH	TOC removal	TP removal	
			3	(Adsorption)	(Charge neutralization & adsorption/Chemical precipitation)	
			4.75	(Adsorption)	(Charge neutralization & adsorption/Chemical precipitation)	
			6.5	(Adsorption/oxidation)	(Charge neutralization & adsorption/Chemical precipitation)	
			8.25	(Oxidation/Adsorption)	(Charge neutralization & adsorption/Chemical precipitation)	
			10	(Oxidation/Adsorption)	(Charge neutralization & adsorption/Chemical precipitation)	

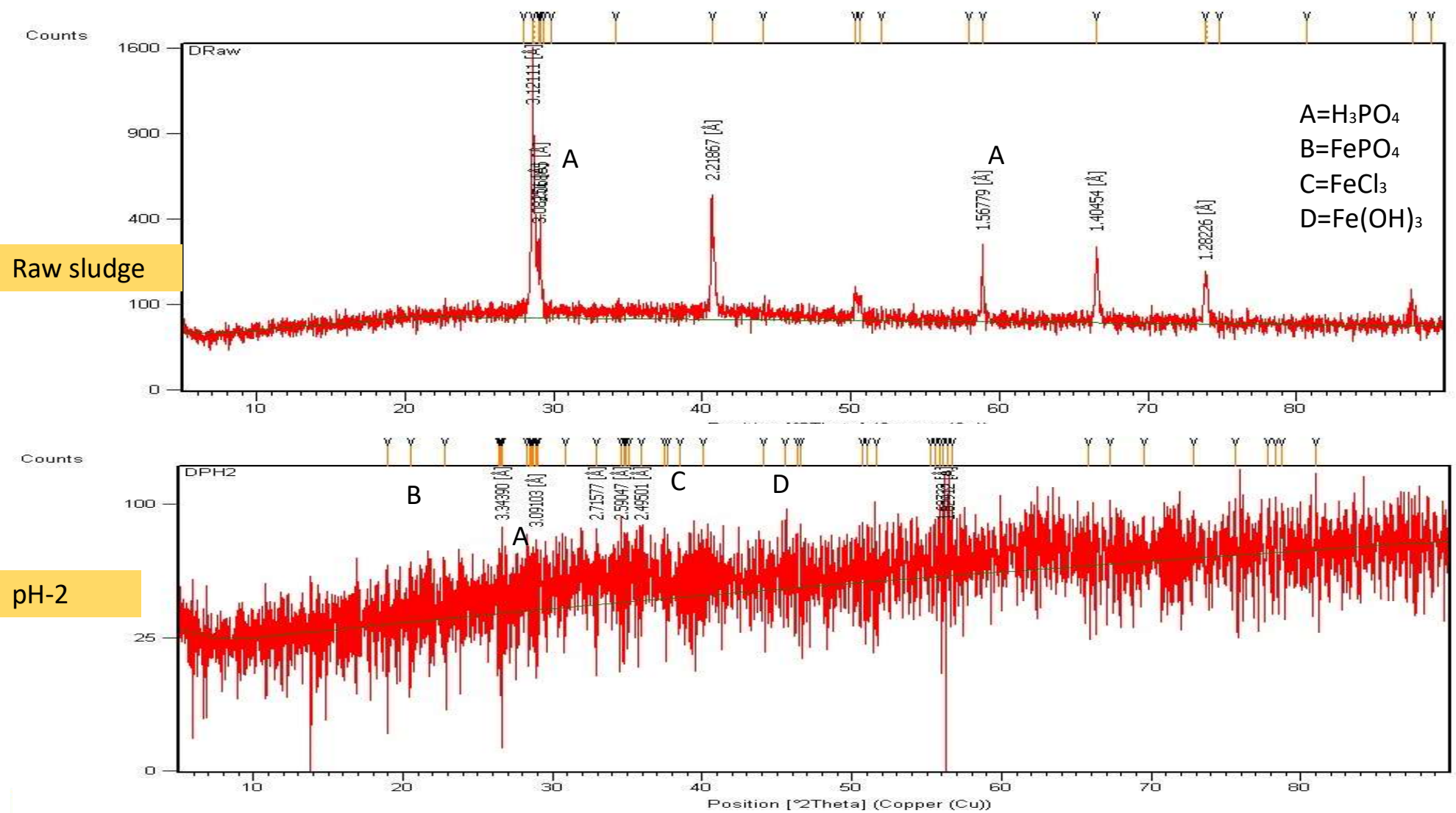


**DWW-
FTIR**



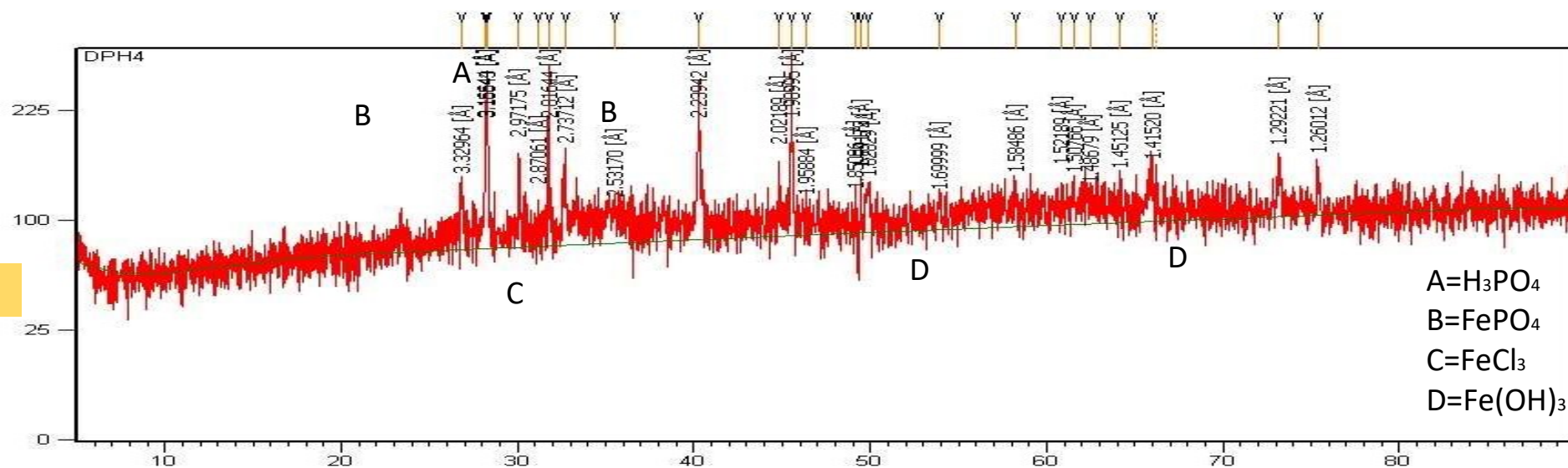
DWW-FTIR





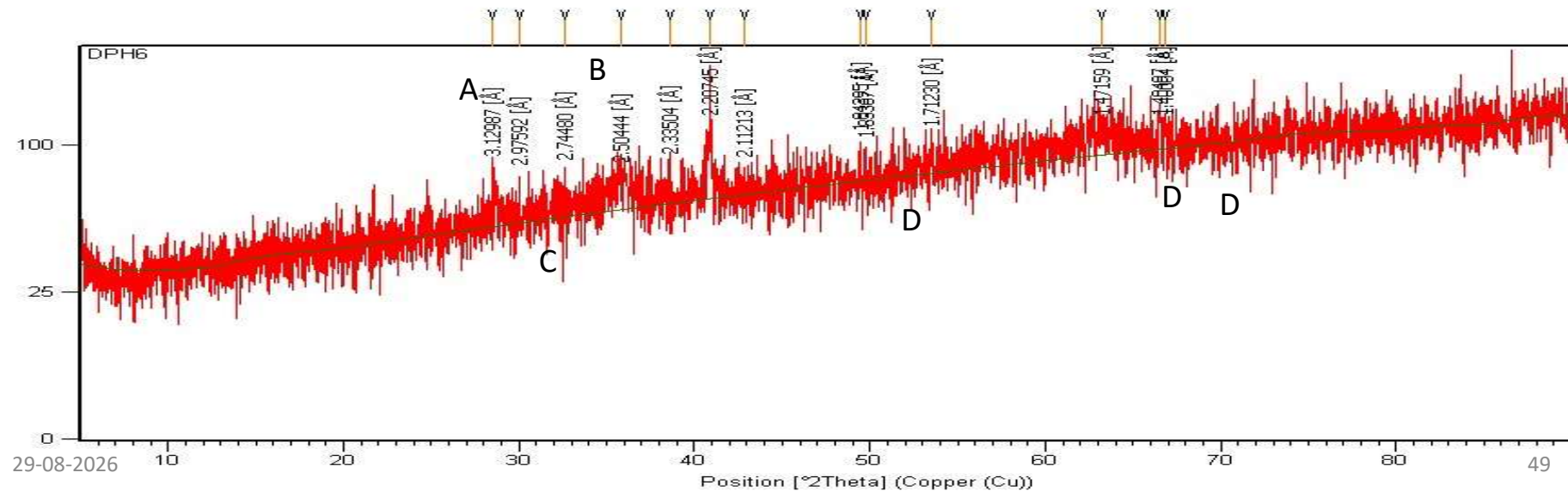
Counts

pH-4



Counts

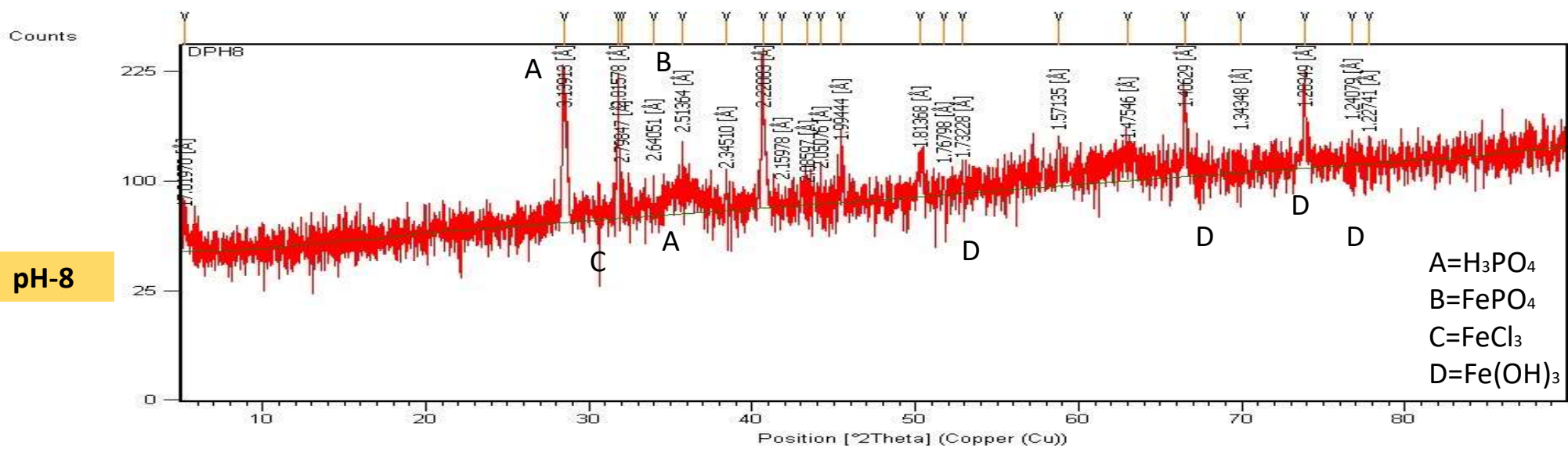
pH-6



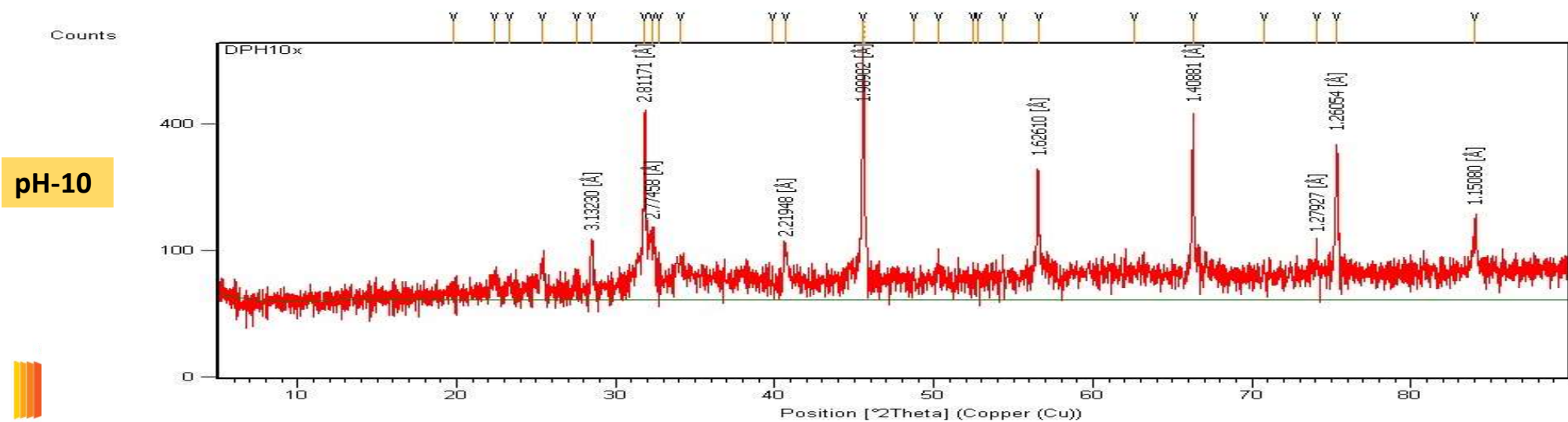
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pH-8



pH-10



Preliminary Studies

Optimization

Kinetics

Mechanism

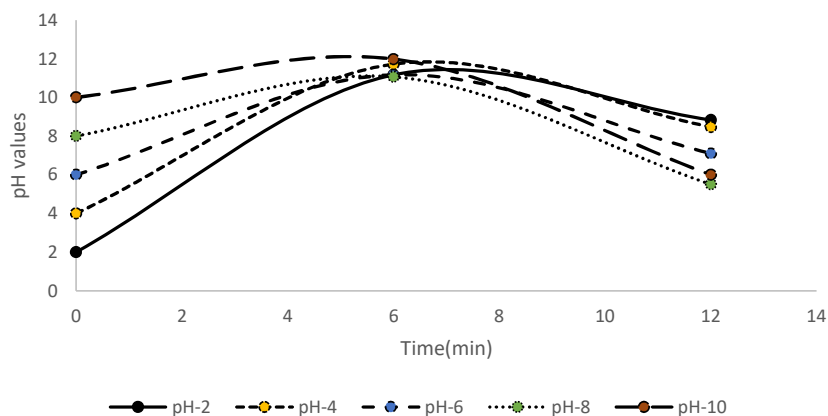
Sludge studies

Comparison of Field scale/lab scale CBME

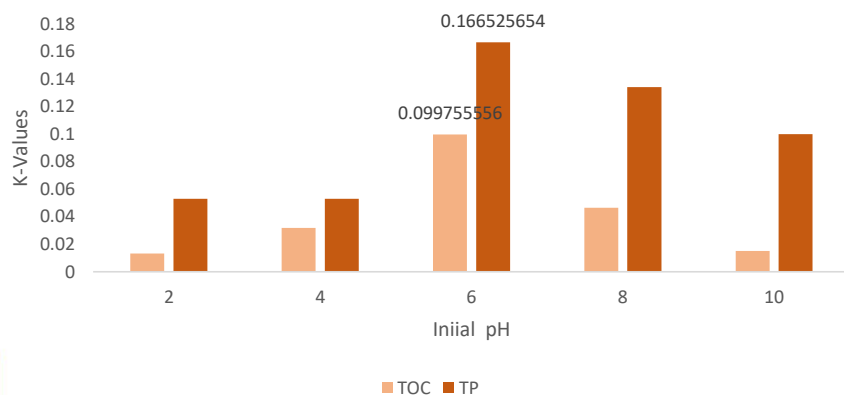
Conclusion

DWW

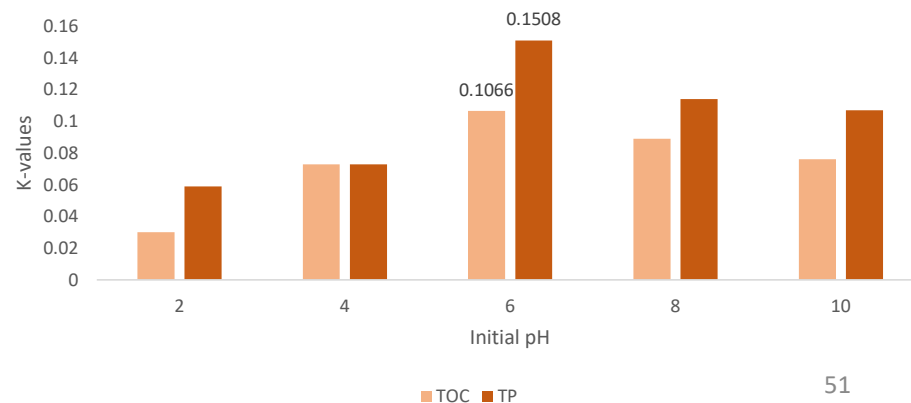
pH change-DWW



Adsorption -K values



Reaction Kinetics-K values



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Preliminary
Studies

Optimization

Kinetics

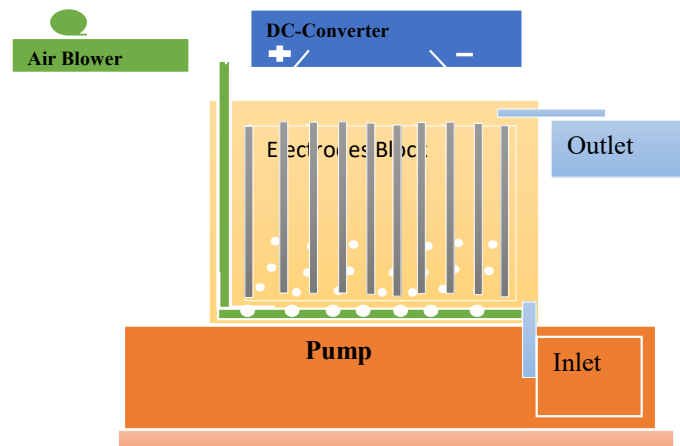
Mechanism

Enhancement

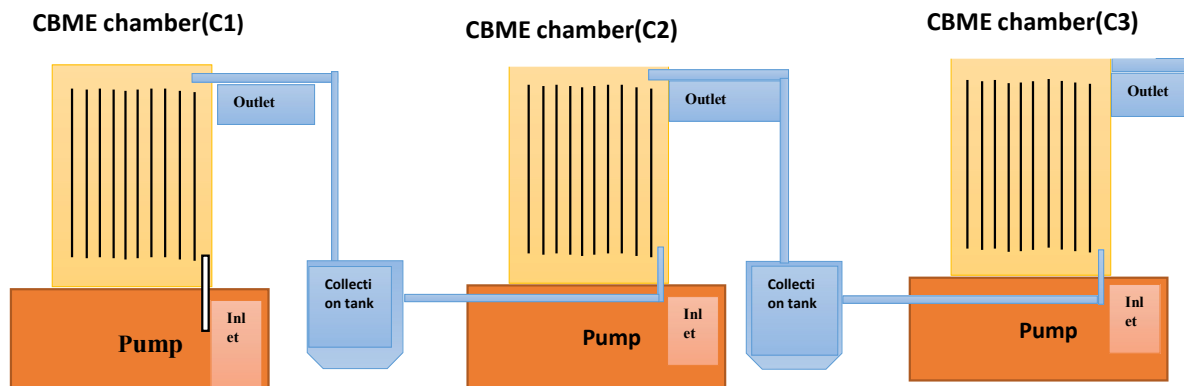
Comparison of Field
scale/lab scale CBME

Conclusion

- Change in Electrical conductivities
- Inclusion of aeration
- Microwave irradiation
- Ozonation
- CBME in series configuration

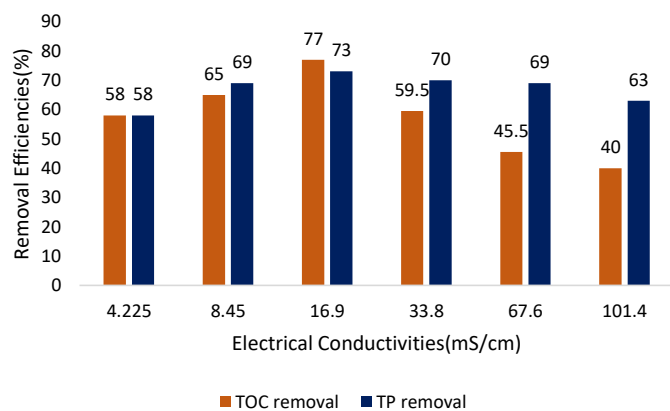


Aeration inside
CBME

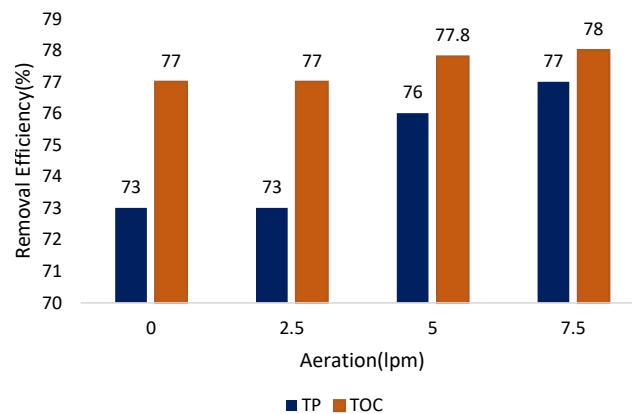


CBME in series configuration

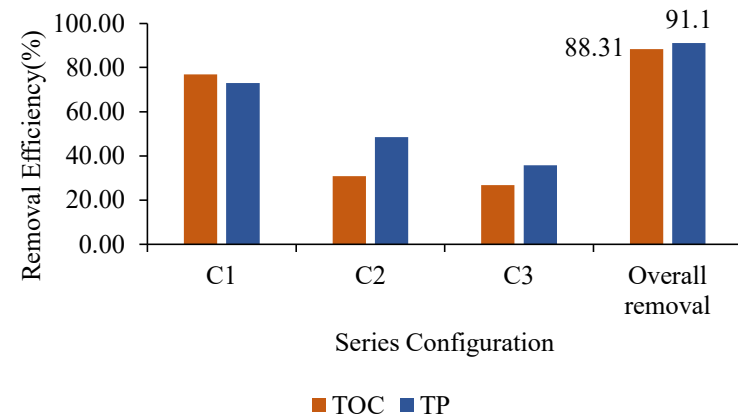
Electrical Conductivities



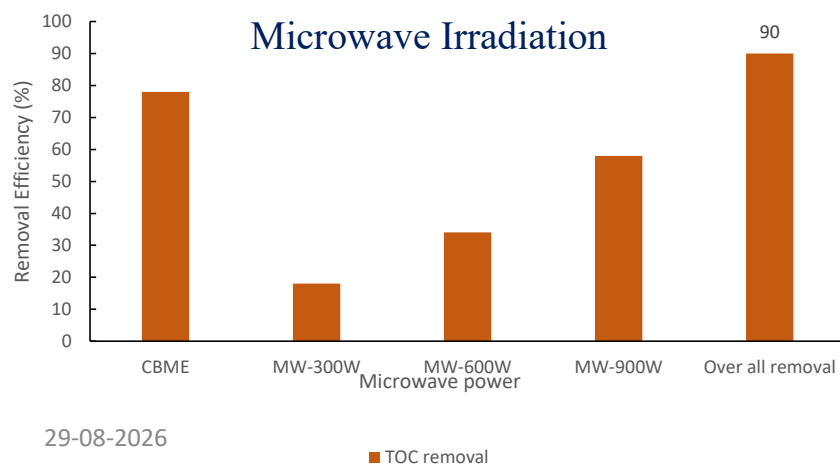
Aeration



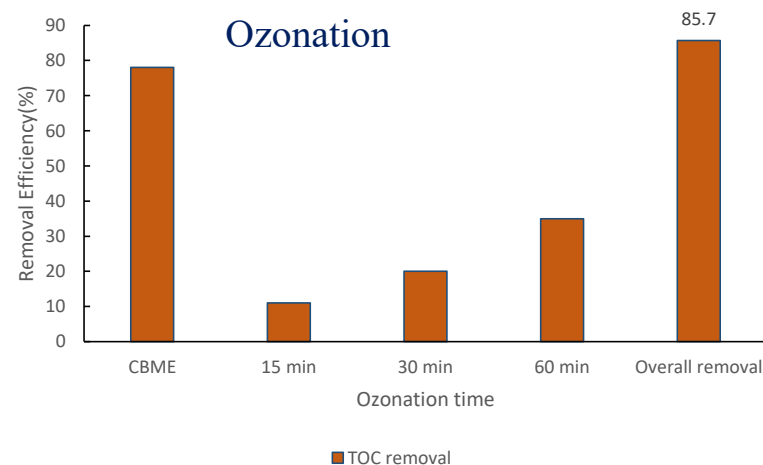
Series Configuration



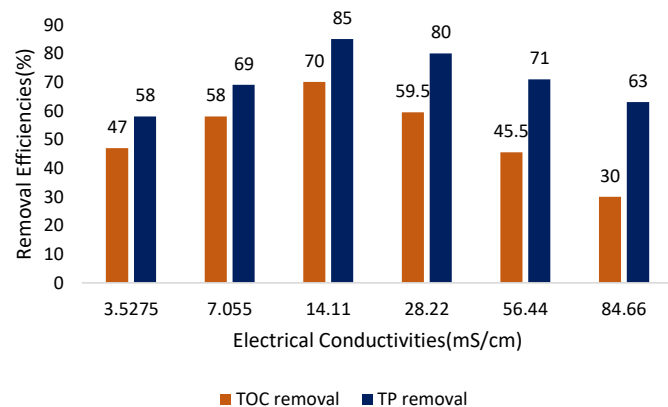
Microwave Irradiation



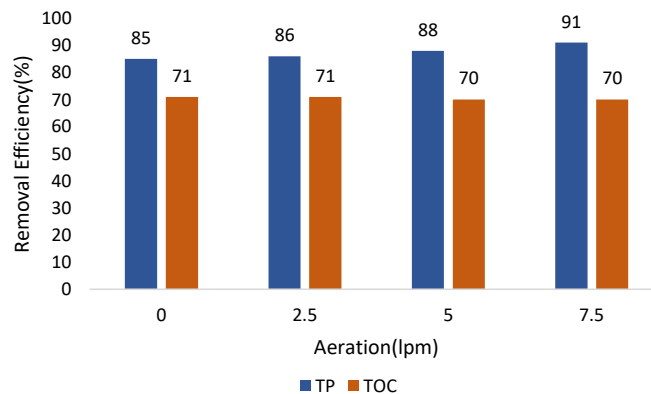
Ozonation



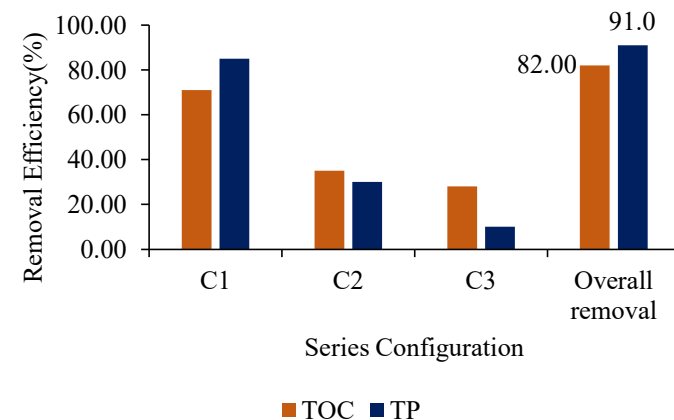
Electrical Conductivities



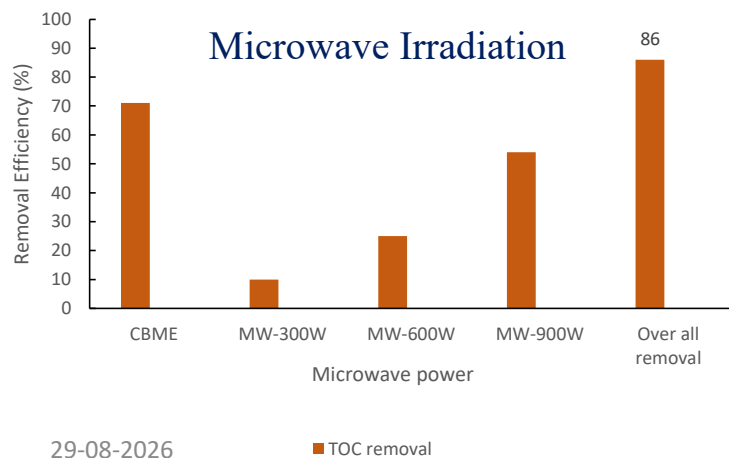
Aeration



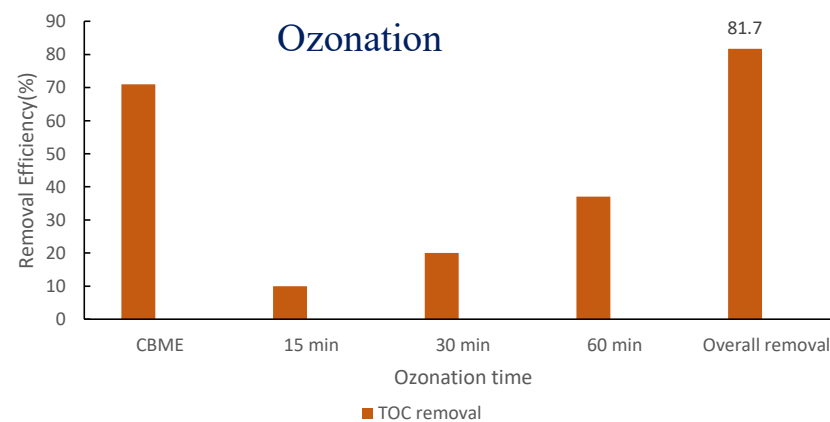
Series Configuration



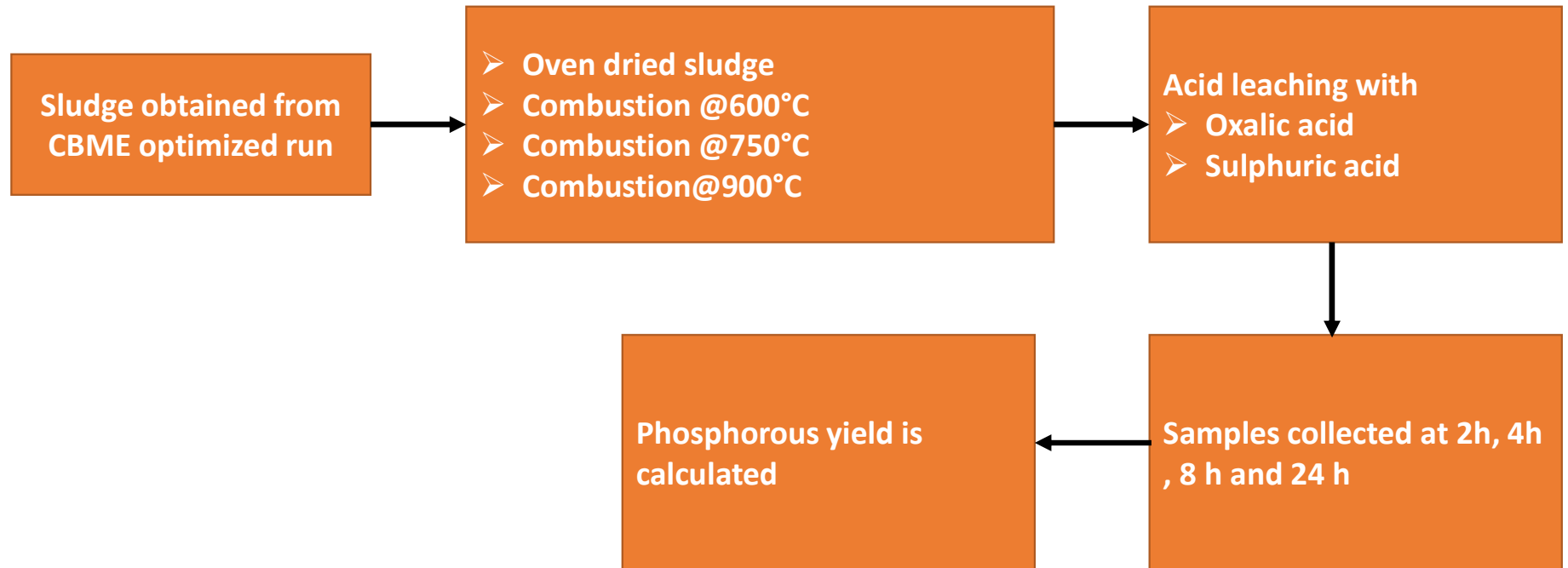
Microwave Irradiation

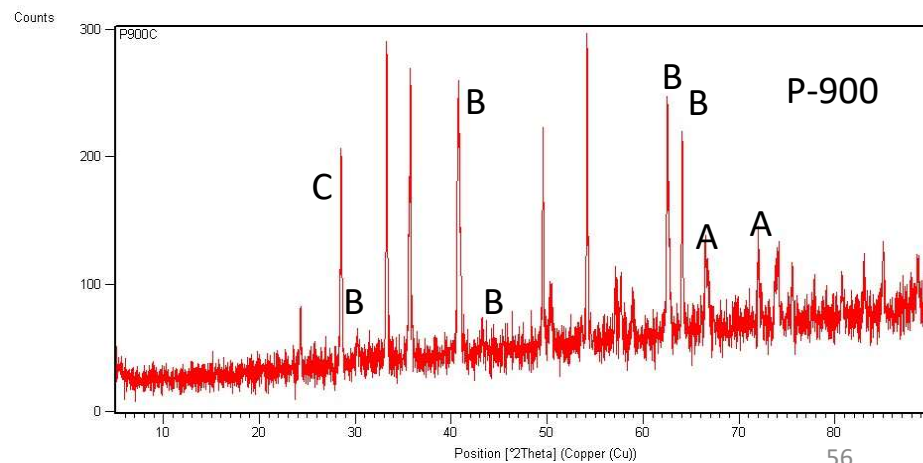
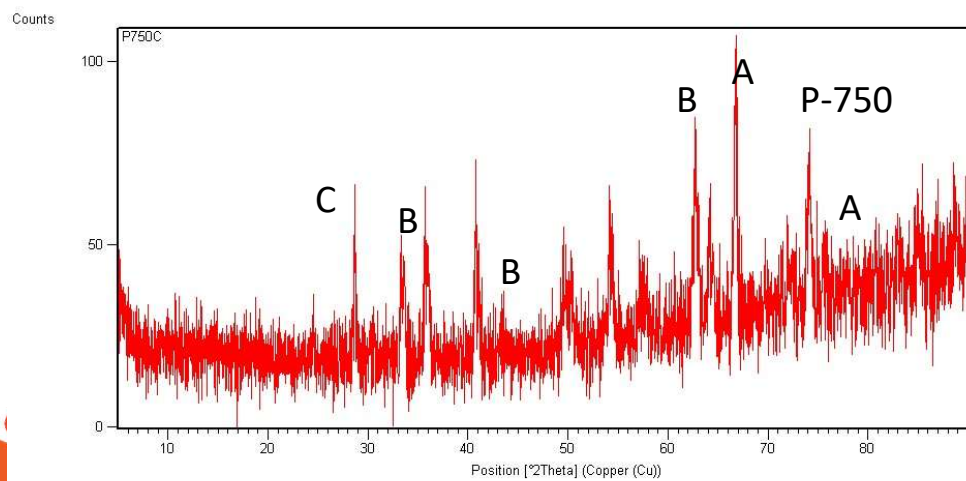
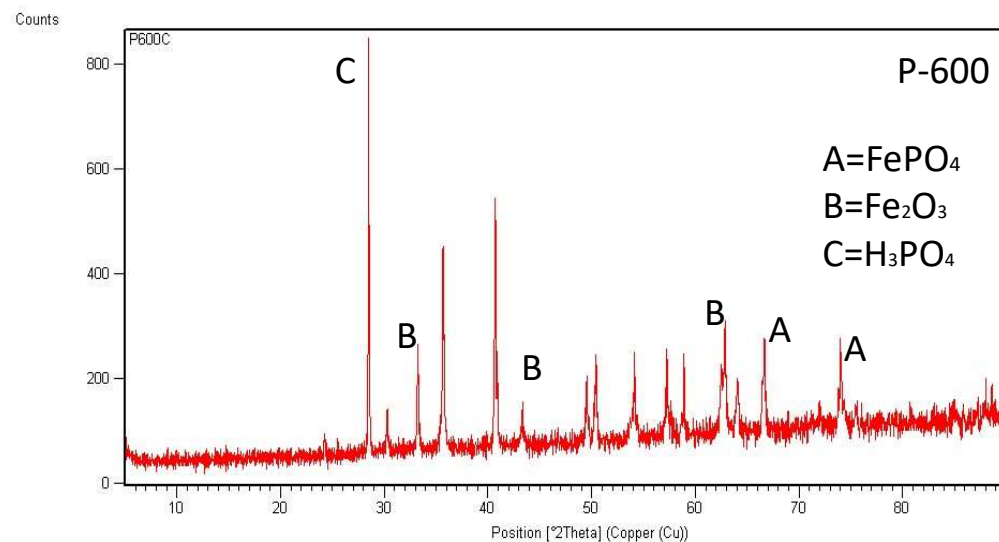
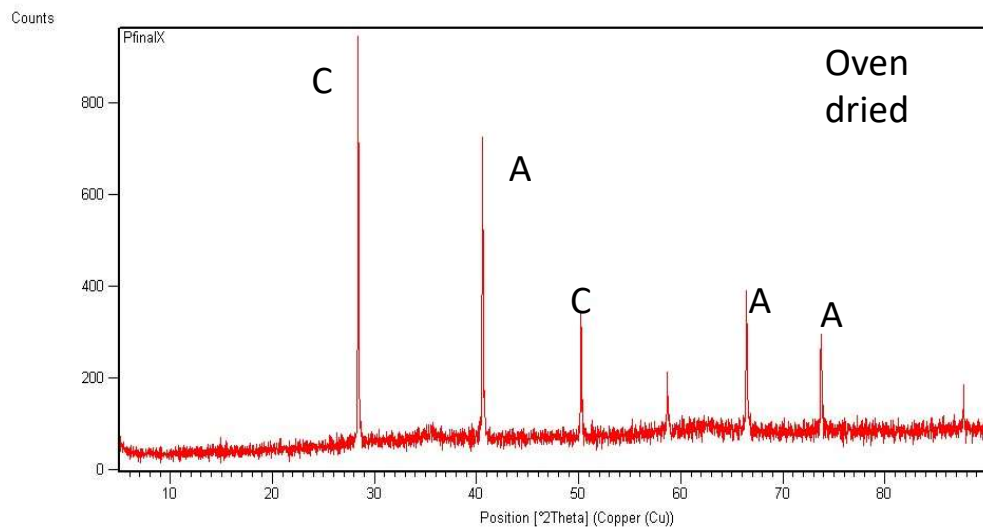


Ozonation



Recovery of Phosphates from POME Sludge



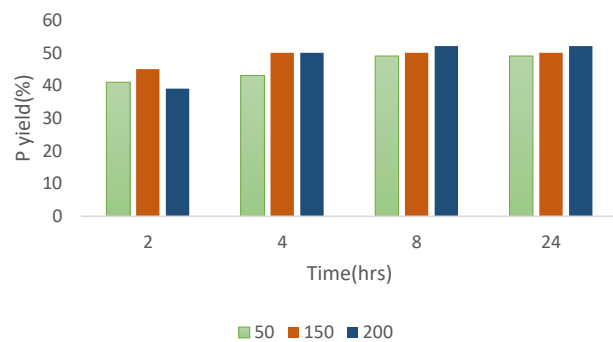


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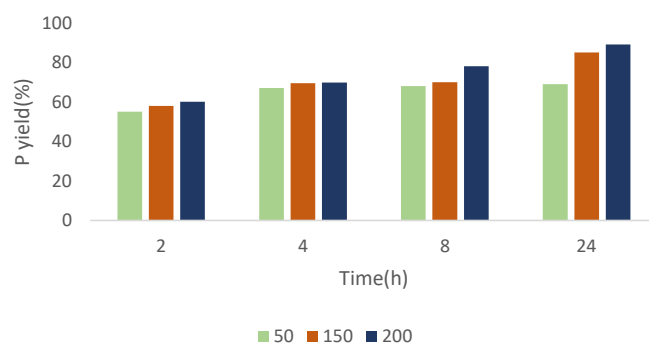
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Sulphuric Acid

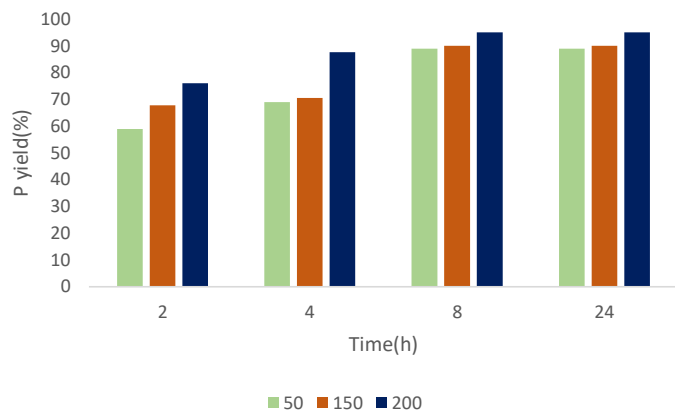
Oven dried



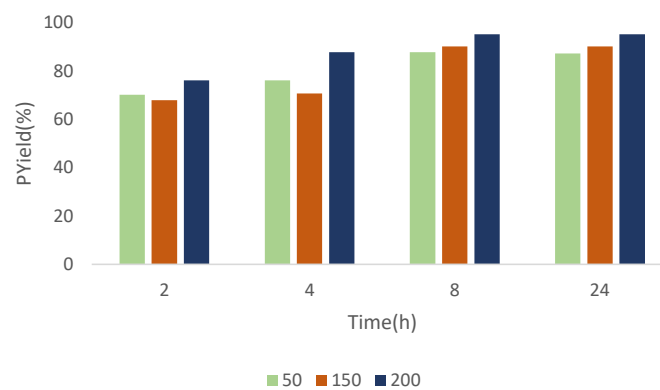
600°C



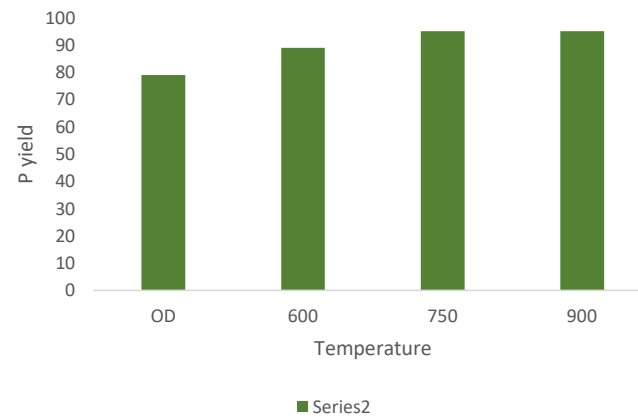
750° C

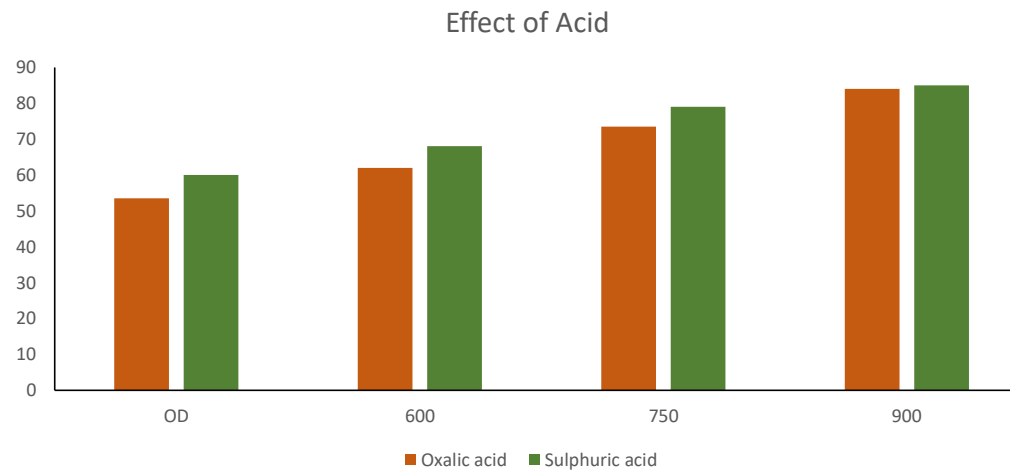


900° C



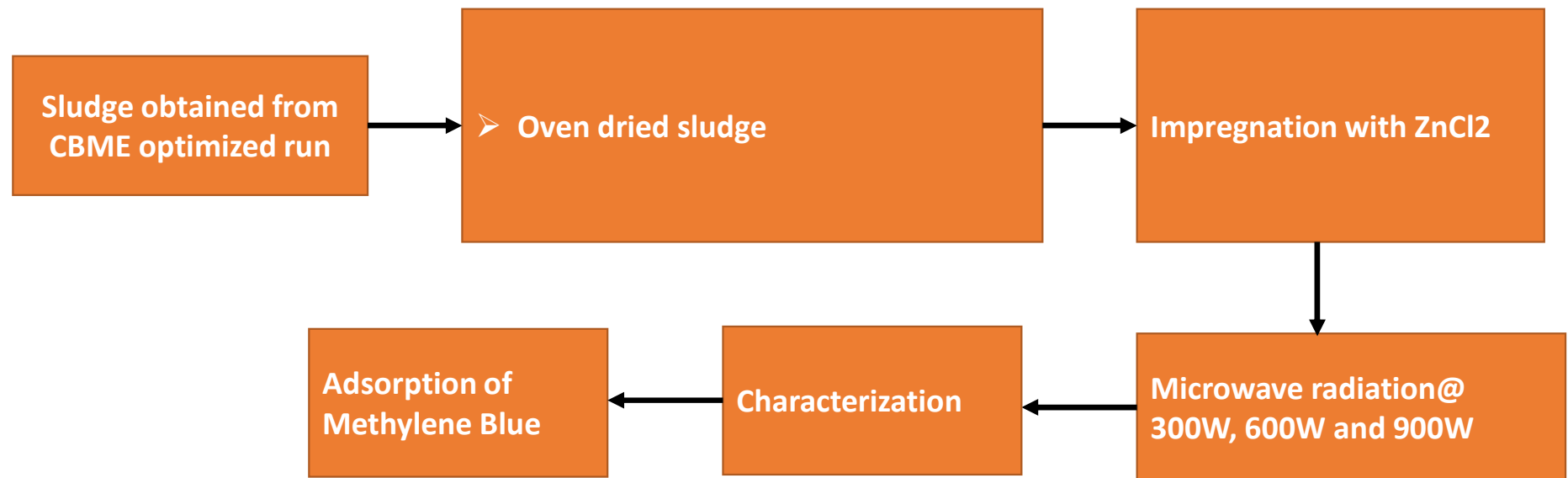
Effect of temperature



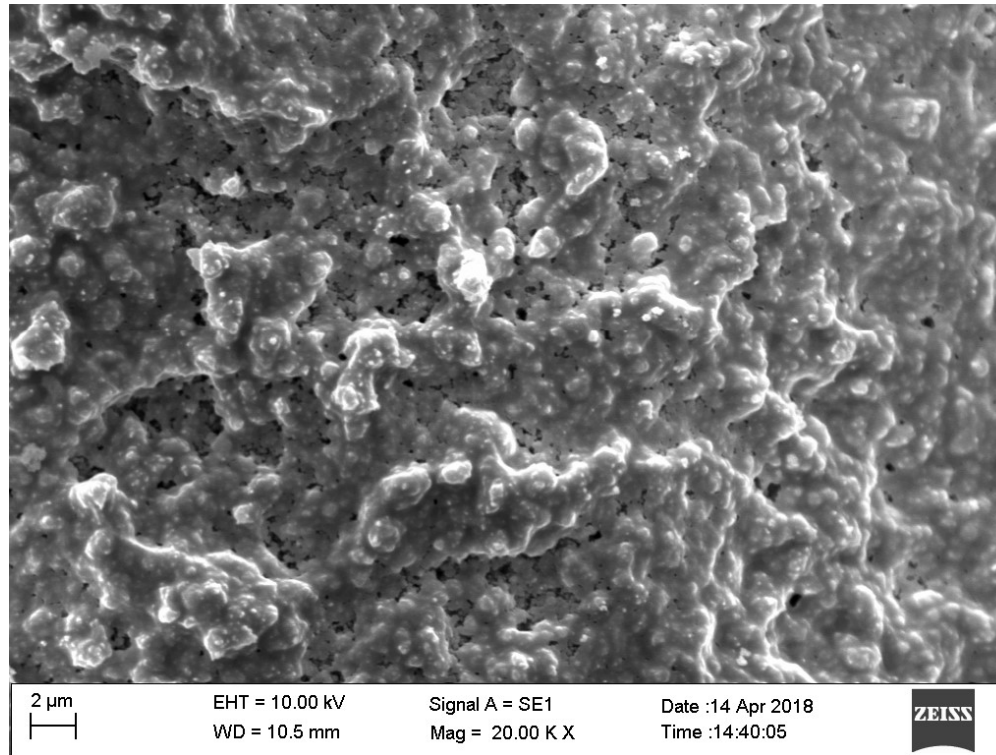


- Phosphorous recovery was found to be high at higher temperatures using both acids at 900°C
- Sulphuric acid has given highest recovery of phosphorous of 85%
- Liquid/Solid ratio of 150 and 200ml/g has shown higher recovery of phosphates

Preparation of Activated carbon from DWW sludge



Sludge characterization



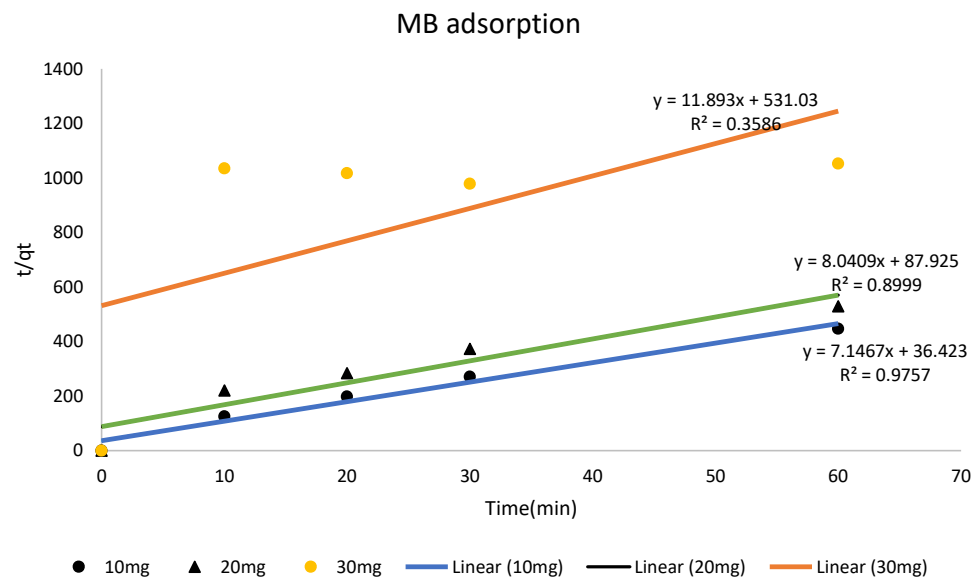
SEM image

Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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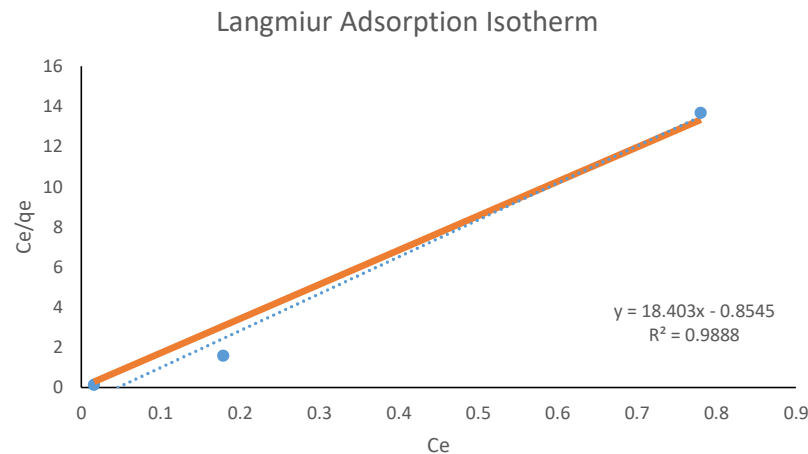
CHNS Analysis	Sludge	Activated carbon
Carbon	39.5%	59%
Hydrogen	3.33%	2.2%
Sulphur	2.22%	0.95%
Nitrogen	0%	0%
Oxygen	1%	0%

FTIR Analysis	Activated carbon
O-H	3437cm-1
-C=O	1037, 1026cm-1
-C=C	1630 cm-1, 1519cm-1, 1647cm-1

MB adsorption study



MB adsorption Isotherm



- Carbon Yield was found to be high at 40% $ZnCl_2$ at 600W Microwave power
- Adsorption Isotherm was studied with Methylene Blue .
- Langmiur Adsorption isotherm was found to be fit with Activated Carbon prepared indicating monolayer adsorption with irreversible adsorption

Preliminary
Studies

Optimization

Kinetics

Mechanism

Sludge studies

Comparison of Field
scale/lab scale CBME

Conclusion

Marigold flower processing Effluent Treatment Plant

Plant: Synthite Industries Ltd; Teligi, Davanagere District, Karnataka







29-08-2026





Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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Initial Characterization

Parameters	units	MWW
pH		8.7
Electrical conductivity	mS/cm	10.19mS/cm
Total Nitrogen	mg/l	569.5
Total Organic Carbon	mg/l	1180
COD	mg/l	2080
TDS	mg/l	5000
TSS	mg/l	100
TS	mg/l	5100
Total Phosphorous	mg/l	220.5
Sulphate	mg/l	359
Chloride	mg/l	1473
Calcium	mg/l	0
Magnesium	mg/l	47.6
Sodium	mg/l	543
Potassium	mg/l	743

Comparison of lab scale & Field scale

Parameters	Lab scale	Field scale
Volume of the reactor(cu.m)	0.001	0.2
Electrode area (m)	0.15X0.034X0.003	0.6X0.194
Number of electrodes	15	132
Total surface area(sq-m)	0.0765	15.2484
Surface area /Volume ratio(sq.m/cu.m)	76.5	76.5
Inter Electrode gap(mm)	6	5
Energy Consumption (kwh/Cu.m)	10.5	10.07
Maximum amperage(A)	20	100
Maximum voltage(V)	250	400
Practical voltage consumed by effluent	30-40	300-400
Optimization parameters	pH, RT, Current	RT and Current

Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Conclusion
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Lab scale

Field scale

Design of Experiments



Experimental runs



Model validation by ANOVA



Optimization by RSM

TOC						
Source	DF	Adj SS	Adj MS	F-value	P-Value	
Model	9	4314.2	479.50	70.87	0.000	
Linear	3	1246.16	415.6	61.41	0.000	
Square	3	2879.78	959.3	141.92	0.0004	
2-way interaction	3	188.63	62.88	9.30	0.0003	

Phosphorous						
Source	DF	Adj SS	Adj MS	F-value	P-Value	
Model	9	9609.55	1067.88	105.75	0.003	
Linear	3	1533.10	511.03	50.61	0.005	
Square	3	7779.56	2573.29	256.73	0.003	
2-way interaction	3	296.98	98.99	9.80	0.003	

Model summary	TOC	Phosphorous
R-Square	0.98	0.98
R-Square(pred)	0.91	0.96

TOC						
Source	DF	Adj SS	Adj MS	F-value	P-Value	
Model	5	2496.7	499.27	26.42	0.002	
Linear	2	1448.3	724.43	38.33	0.000	
Square	2	773.21	386.60	20.46	0.000	
2-way interaction	1	274.40	274.40	14.52	0.0002	

Phosphorous						
Source	DF	Adj SS	Adj MS	F-value	P-Value	
Model	5	3126.22	632.50	55.24	0.003	
Linear	2	774.47	387.24	33.82	0.000	
Square	2	2018.07	1009.03	88.12	0.000	
2-way interaction	1	369.97	369.97	32.31	0.000	

Model summary	TOC	Phosphorous
R-Square	0.94	0.97
R-Square(pred)	0.80	0.88

Preliminary
Studies

Optimization

Kinetics

Mechanism

Sludge studies

Comparison of Field
scale/lab scale CBME

Conclusion

Lab-scale

$$\text{TOC removal (\%)} = -152.1 + 44.87 \text{ pH} + 10.72 \text{ RT} + 25.64 \text{ Current} - 3.599 \text{ pH} \cdot \text{pH} - 0.733 \text{ RT} \cdot \text{RT} - 4.30 \text{ Current} \cdot \text{Current} - 0.287 \text{ pH} \cdot \text{RT} + 0.682 \text{ pH} \cdot \text{Current} + 0.336 \text{ RT} \cdot \text{Current} \quad (5)$$

$$\text{TP removal (\%)} = -160.1 + 55.78 \text{ pH} + 6.86 \text{ RT} + 26.86 \text{ Current} - 5.092 \text{ pH} \cdot \text{pH} - 1.081 \text{ RT} \cdot \text{RT} - 7.74 \text{ Current} \cdot \text{Current} + 0.742 \text{ pH} \cdot \text{RT} + 1.786 \text{ pH} \cdot \text{Current} + 1.058 \text{ RT} \cdot \text{Current} \quad (6)$$

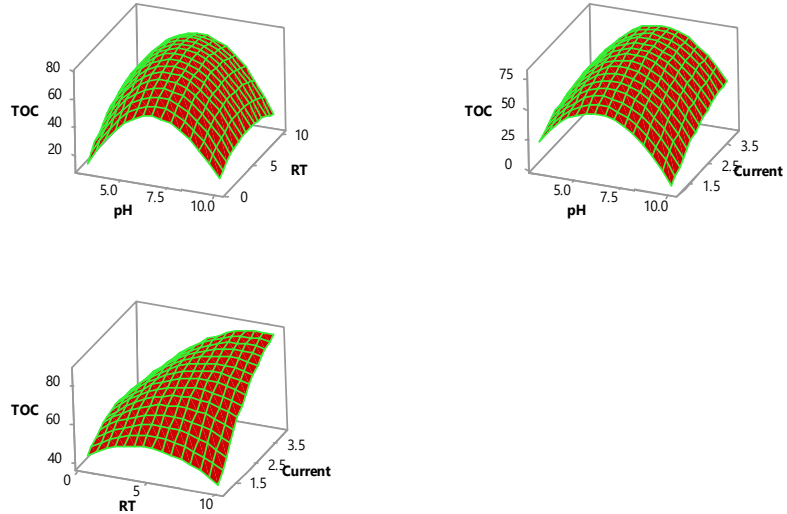
Field-scale

$$\text{TOC removal (\%)} = -39.74 + 12.67 \text{ RT} + 2.528 \text{ Current} - 0.539 \text{ RT} \cdot \text{RT} - 0.01767 \text{ Current} \cdot \text{Current} - 0.1073 \text{ RT} \cdot \text{Current} \quad (7)$$

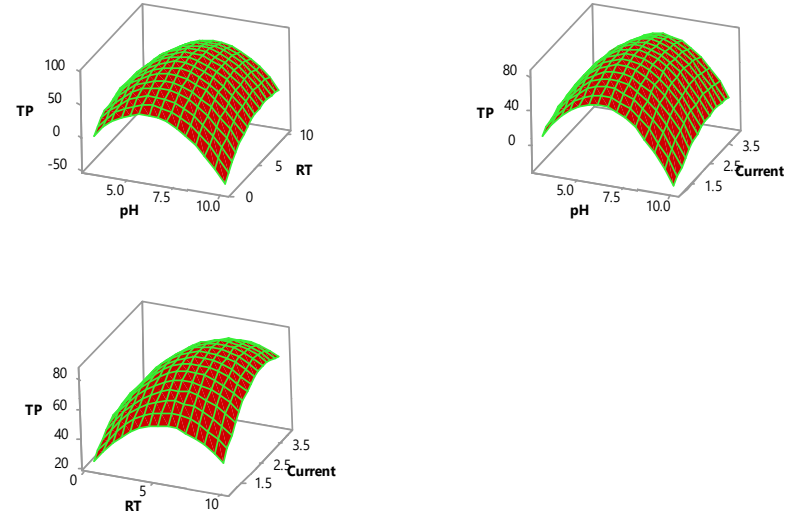
$$\text{TP removal (\%)} = 6.59 + 12.06 \text{ RT} + 0.850 \text{ Current} - 1.416 \text{ RT} \cdot \text{RT} - 0.01504 \text{ Current} \cdot \text{Current} + 0.1246 \text{ RT} \cdot \text{Current} \quad (8)$$

Lab scale

Surface Plot for TOC

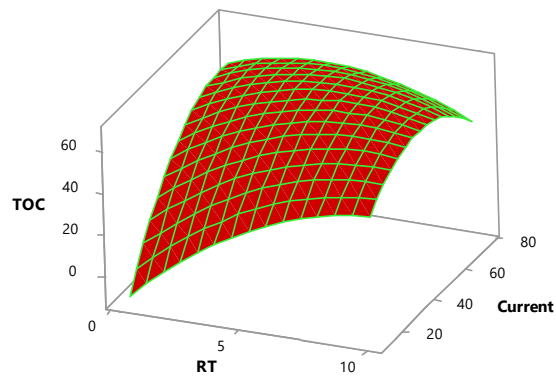


Surface Plot for TP

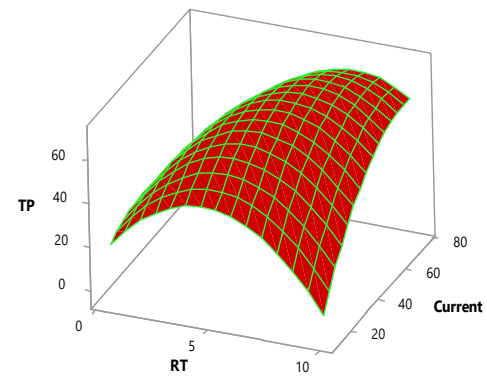


Field scale

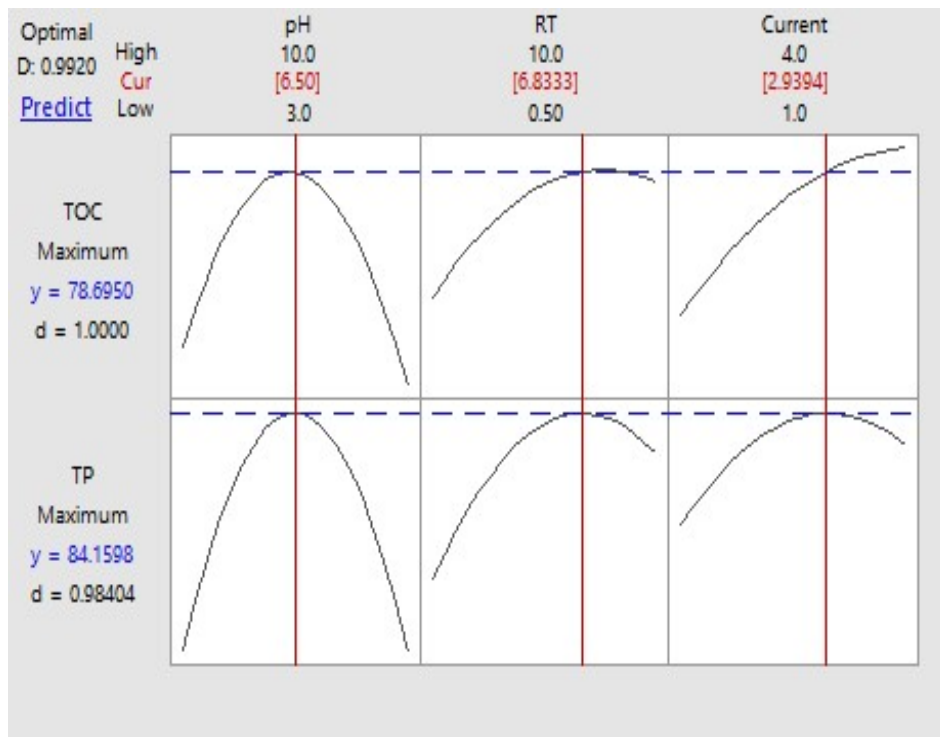
Surface Plot for TOC



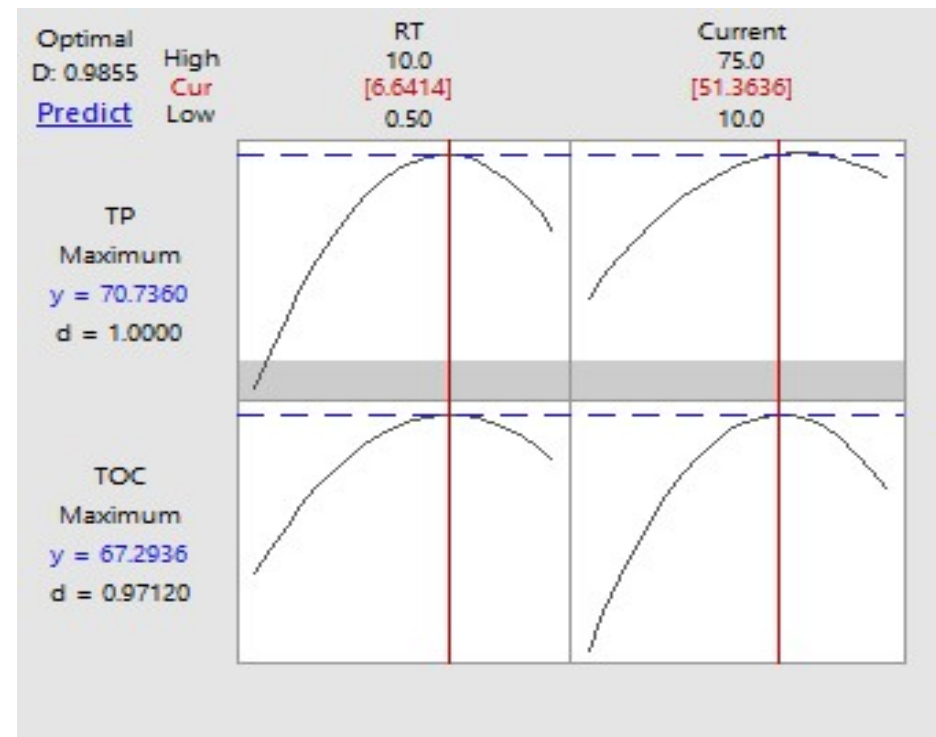
Surface Plot for TP



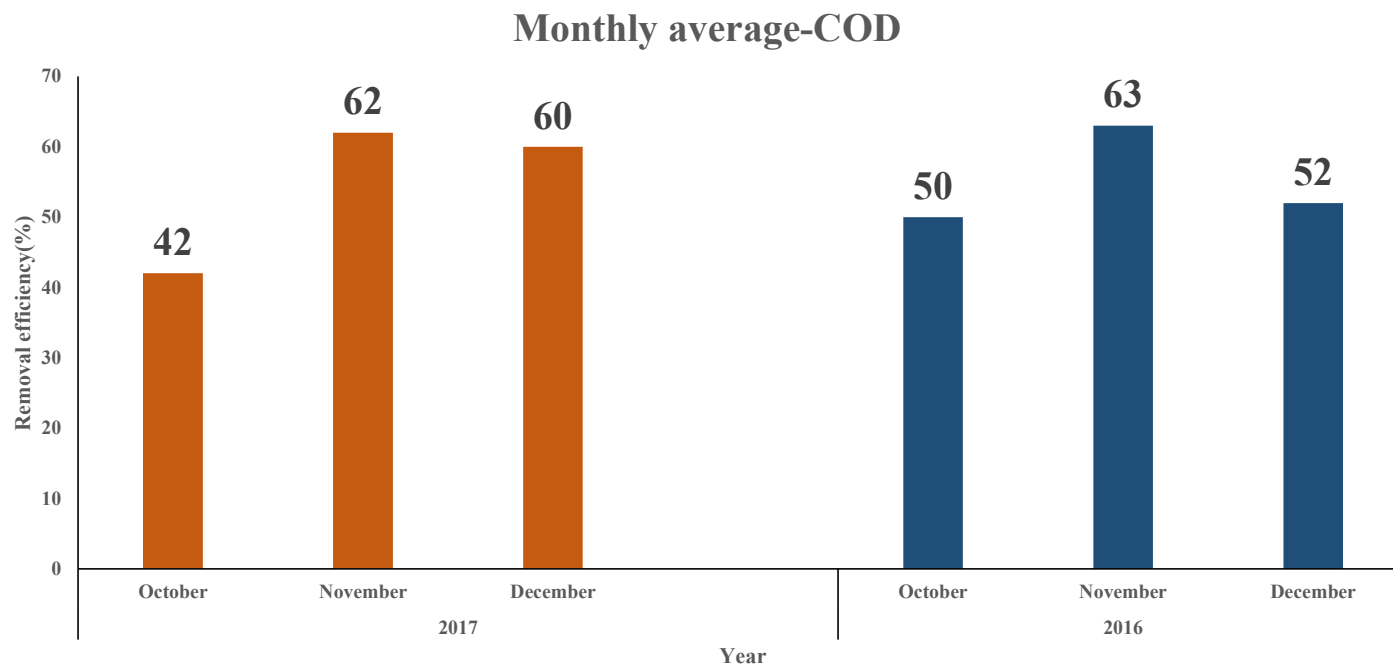
Lab scale Optimization



Field scale Optimization



Field scale plant performance before optimization



Comparison of Lab scale & Field scale optimization

Parameters	Lab scale	Field scale
pH	6.5	8.5 (Existing pH)
Reaction time(min)	6.8	6.6
Current(Amps)	2.9	51.3
Surface area /Volume ratio(m ² /m ³)	76.5	76.5
Energy Consumption (kwh/m ³)	10.5	10.07
TOC removal (Optimized)	78.57%	72%
TOC removal Verified	75%	69%
TP removal (Optimized)	84.5%	70%
TP removal Verified	80%	62%
COD removal efficiency	85%	80%

Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME		Conclusion	
Type	Number of Electrodes	Time in minutes	Electrical consumption (kwh/cu.m)	Electrode consumption(kg/ cu.m)	Electrical cost/cu.m(R s.6/kwh)	Electrode cost/cu.m (Rs.50/kg Iron)	Total operating cost/cu.m	References
Monopolar	2	30	39.7	0.82	238.2	41	279.2	Ilhan et al., 2008
Monopolar	10	90	16.2	1.17	97.2	58.5	155.7	Li et al., 2011
Monopolar	6	180	30	1.73	180	86.5	266.5	Yavuz; 2007
Monopolar	2	360	37.44	1.8	224.6	90	314.6	Susree et al., 2013
Monopolar	3	50	19.4	3.7	116.4	185	301.4	Zaieda et al.,2009
Monopolar	6	90	33.7	1.3	202.5	65	267.5	Mahesh.S et al., 2006
Monopolar	2	180	225	0.433	1350	21.65	1371.65	Farshi et al.,2006
Monopolar	2	120	400	3.4	2400	170	2570	Khandegar et al., 2012
Monopolar	2	90	202	1.8	1212	90	1302	Jadav et al., 2015
Bipolar	15	6.44	10.6	0.123	63.6	6.15	69.75	Lab scale prototype
Bipolar	132	6.4	10.07	1.58	60.20	79	139.2	Field scale Plant

Conclusion

- Continuous Bipolar Mode Electrocoagulation(CBME) system has been proved to be efficient in removal of Recalcitrant carbon and Nutrient Phosphorous from wastewater
- Optimization studies of POME and DWW revealed the removal efficiencies of TOC and TP were above 70% and 80% respectively.
- Sludge is characterized to form iron phosphates which actually can be directly used for organic farming, lithium battery making or manufacturing of paint coatings.
- Carboxylic acid groups found in sludge can be used in pharmaceutical and polymer industries
- Kinetic studies revealed higher rates of reactions of POME and DWW at higher current densities and at near neutral pH both TOC and TP.

Conclusion..

- Adsorption isotherm study emphasized on good fits with Freundlich isotherm, which indicates multilayer adsorption which is reversible for both the pollutants.
- Removal mechanism of phosphorous revealed that chemical precipitation and adsorption takes place at all the pH values simultaneously because of the shift in pH value with time.
- Removal mechanism of organic carbon was found to be possible oxidation at higher initial pH values in POME and at lower pH values in DWW. However, Adsorption was evident at all the pH values
- Enhancement of CBME can be done by series configuration for recalcitrant carbon and Phosphorous removal. Series configuration has shown 91% removal of TP and 82-88% removal of TOC

Conclusion..

- Microwave irradiation was effective for removal of TOC with 86-90% removal efficiency in both the effluents.
- Sludge obtained from POME was studied for Phosphorous recovery.
- Phosphate recovery was found to be maximum with sulphuric acid for sludge heated at 900°C.
- Sludge obtained from DWW was found to be potential for conversion into activated carbon, for methylene blue adsorption.
- Methylene blue adsorption studies indicated the Langmuir adsorption isotherm indicating the monolayer adsorption

Conclusion..

- Pilot scale and field scale CBME systems have found to be reacted in a similar fashion which indicates lab scale system parameters can be used for upscaling of the reactor.
- pH, Reaction time, Surface area/Volume ratio and Energy consumption was found to be potential design parameters for design of CBME system in Field scale.

Parameters	Range
Initial pH	5.5-6.6
Reaction time(min)	6-8
Surface Area/Volume ratio(m ² /m ³)	76.5
Energy Consumption(kwh/m ³)	10-22.4

Conclusion..

- Microwave irradiation incorporation inside the CBME system can be a future scope of study
- Operating cost was found to be low compared to monopolar mode Electrocoagulation systems even at field scale
- This research study helped in improvising the performance of the reactor at field scale.

Publications

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Preliminary
Studies

Optimization

Kinetics

Mechanism

Sludge studies

Comparison of Field
scale/lab scale CBME

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Preliminary Studies	Optimization	Kinetics	Mechanism	Sludge studies	Comparison of Field scale/lab scale CBME	Publications
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THANK YOU...



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