9th International Conference on Sustainable Solid Waste Management

Comparative assessment of different Advance technologies for Treatment of Landfill Leachate

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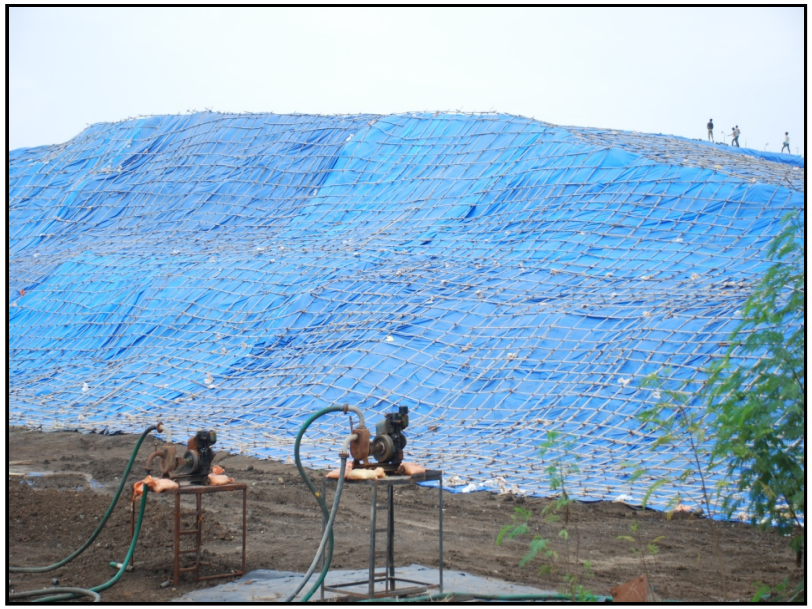
FRIDAY 17, JUNE 2022

Contents

Landfill operation leading to generation of toxic leachate

Sludge/Waste dumping

Sludge/Waste compaction



Leachate extraction

Background of the Study

TSDF at Ankleshwar

Leachate Generation and collection

Sent to Multiple effect Evaporator

Energy Intensive

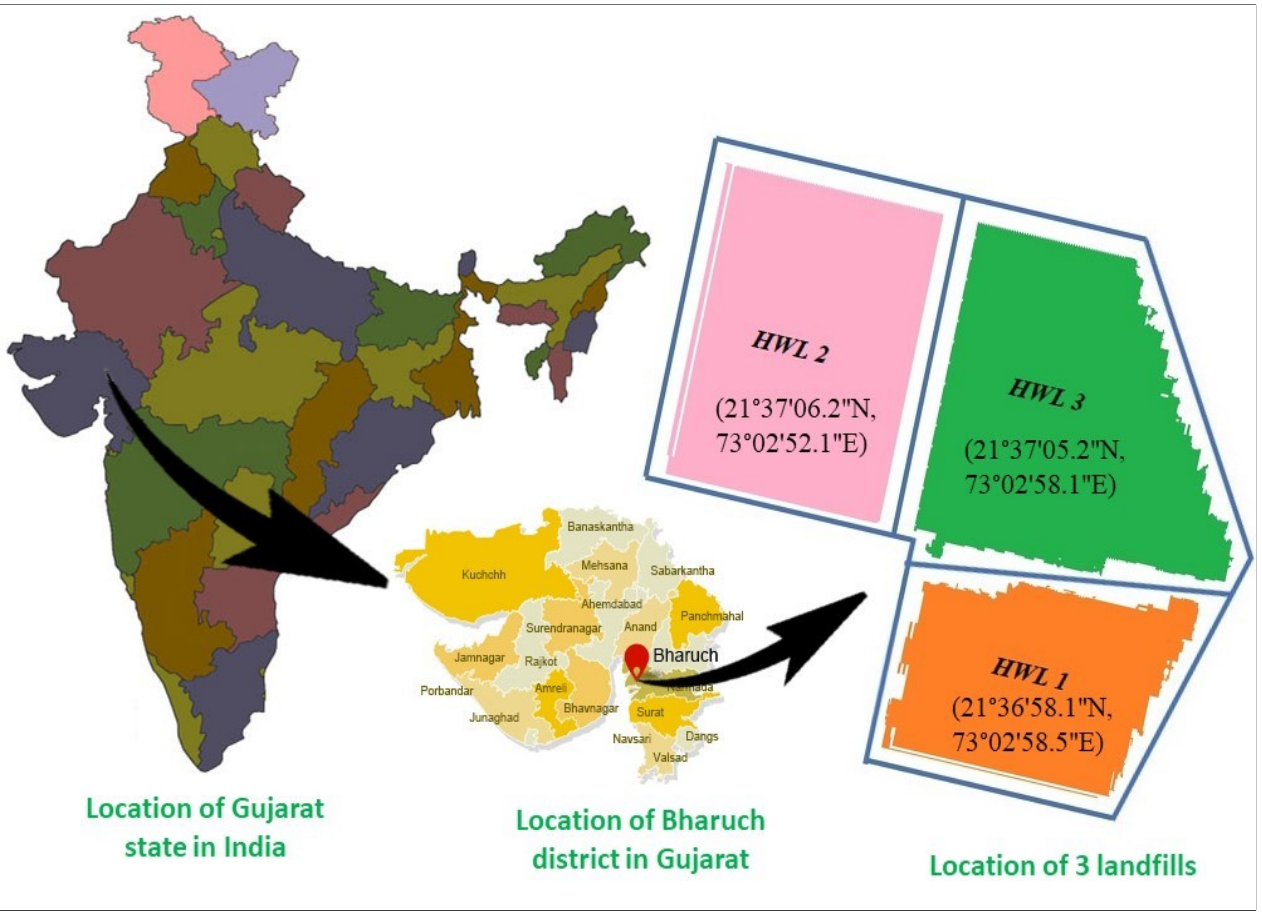
Expensive

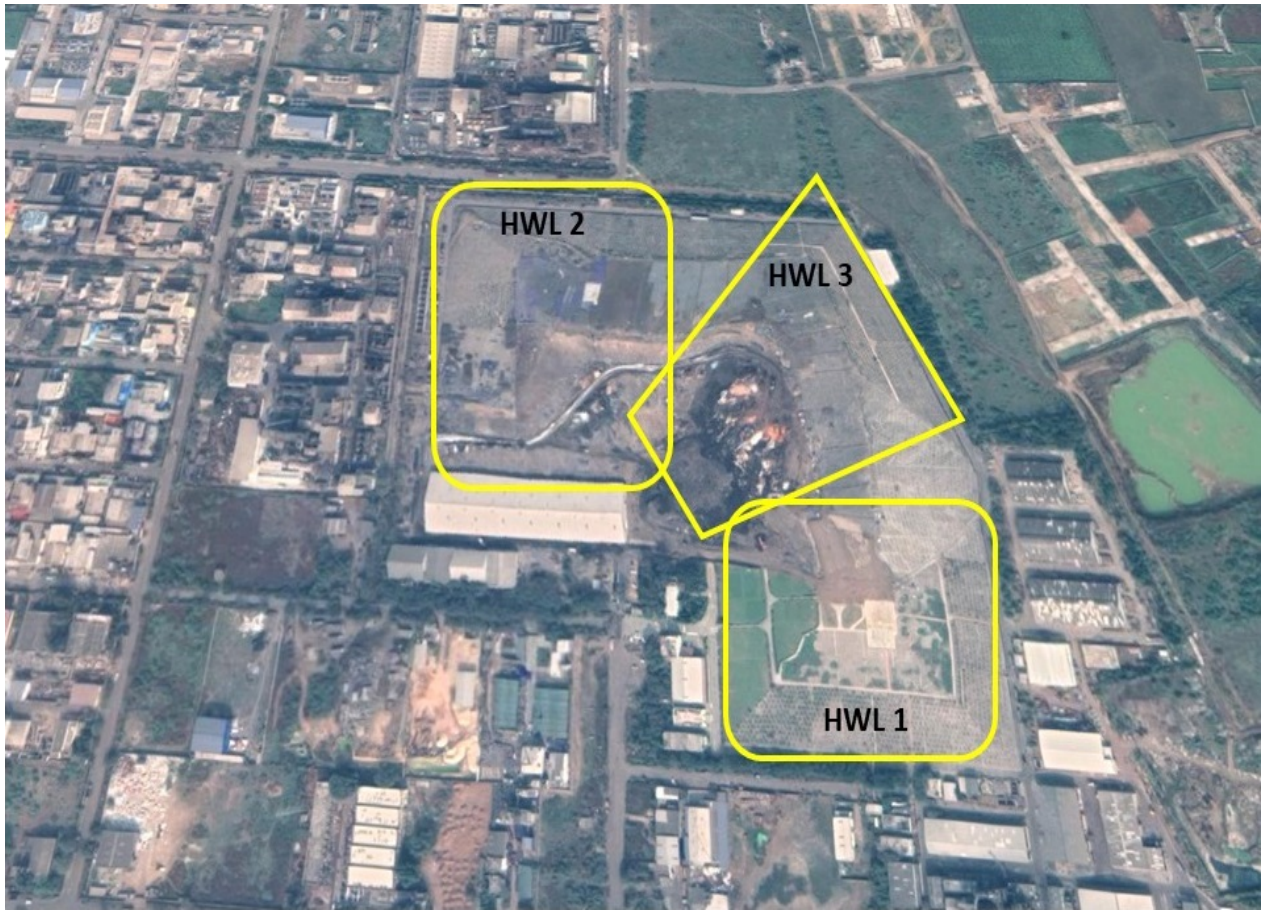
Finding Alternative of such energy intensive process which can be used at other sites

Condensate sent to CETP

Salts sent to landfill

Study Area


HWL 2
(21°37'06.2"N, 73°02'52.1"E)
HWL 3
(21°37'05.2"N, 73°02'58.1"E)
HWL 1
(21°36'58.1"N, 73°02'58.5"E)
Banaskantha
Kuchchh
Mehsana
Sabarkantha
Ahemdabad
Panchmahal
Surendranagar
Anand
Jamnagar
Rajkot
Bharuch
Porbandar
Amreli
Bhavnagar
Surat
Junaghad
Navsari
Dangs
Valsad
Location of Gujarat state in India
Location of Bharuch district in Gujarat
Location of 3 landfills


HWL 2
HWL 3
HWL 1

Landfill Details

Reference Code	Area Occupied	Capacity	Age (yrs)	Year of inception
HW-III	12000 m2	1.45 million tons	02	2016

WASTE TYPE

Industrial sludges, ETP sludges, Contaminated

Barrels, Contaminated/Discarded Products

LEACHATE

Soup generated (liquid extracted) from HW landfills contains elevated levels of dissolved solids, toxic elements, Chemical Oxygen Demand (COD) and Ammonical nitrogen etc.

Challenges

- High COD/BOD ratio
- High TDS
- Highly complex pollutant matrix
- Very less work on treatment of HWL leachate in comparison to MWL

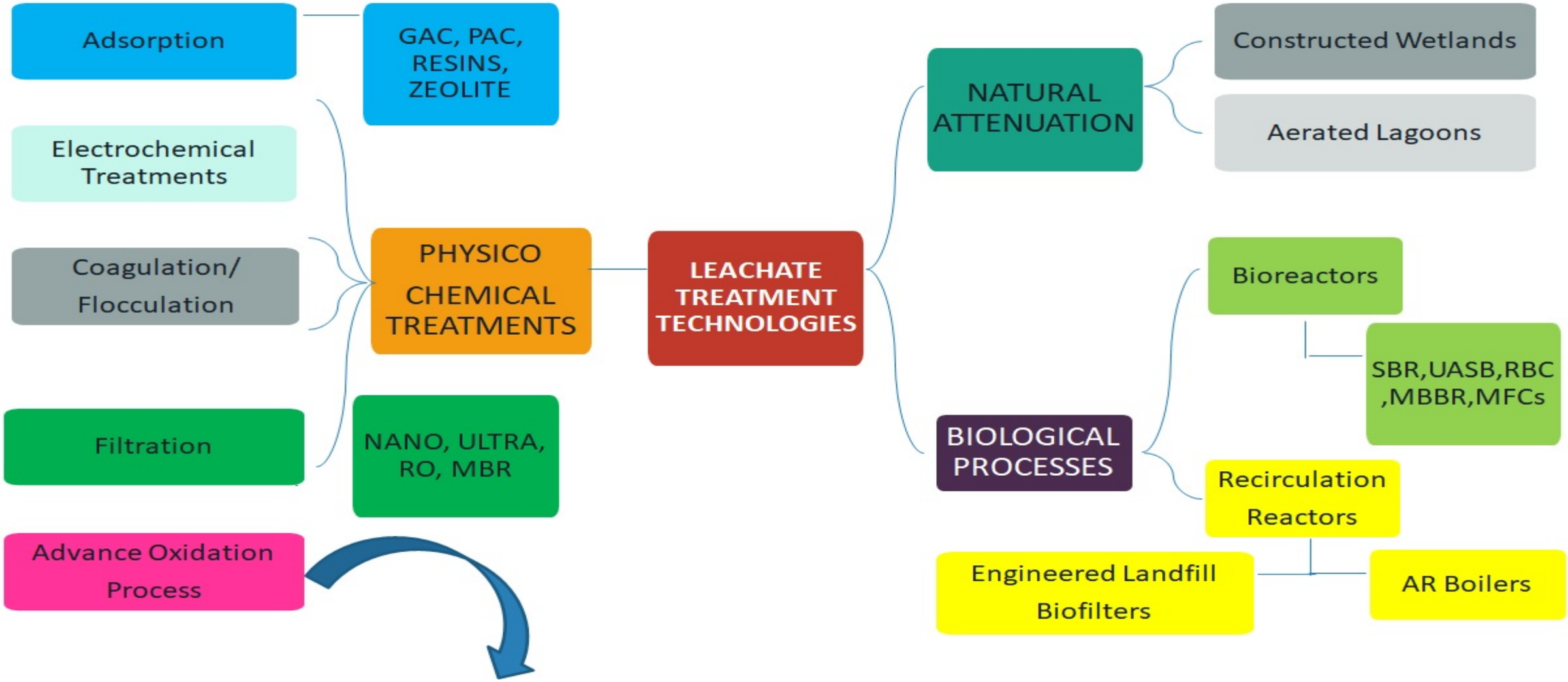
Leachate Characteristics (average of three HWL)

Parameters	Values (mg/l)	Parameters	Values (mg/l)
pH	7.38 units	Total hardness (TH)	10490.7
Color	8200.3 Hazen units	Total alkalinity (TA)	8350.1
Oil and grease	6.09	Total dissolved solid (TDS)	264569.8
COD	34030	Total suspended solid (TSS)	1519.6
BOD	11204.07	Chloride (Cl)	135156.5
TN	3162.5	SULFIDE	485.8
TKN	2482.5	Sulfate (SO42-)	26918.5
Ammonical Nitrogen	2037.1	TOTAL PHENOL	19.8
Total phosphorus (TP)	27.1	Total hardness (TH)	10490.7

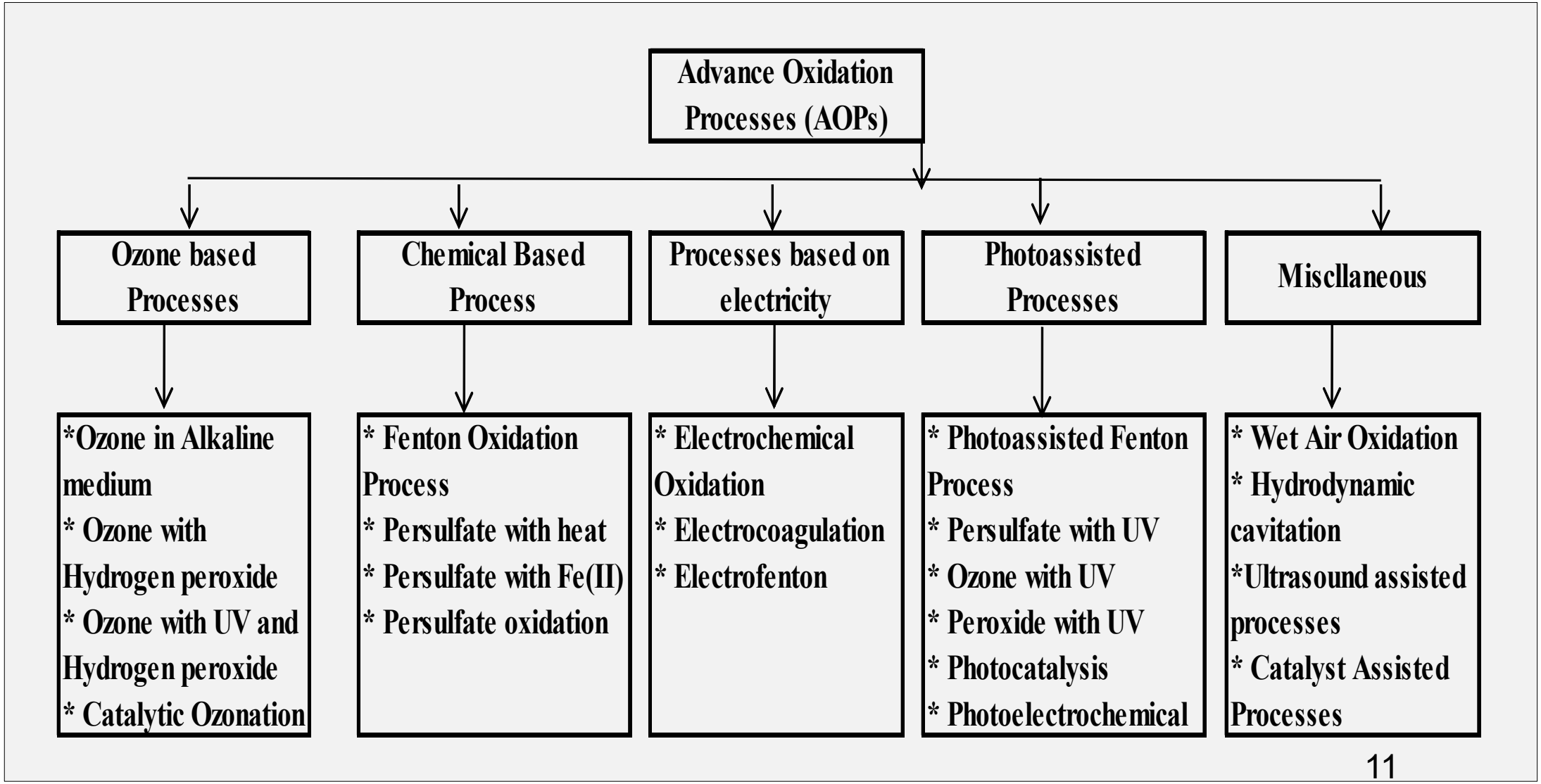
Leachate Characteristics (average of three HWL)

Parameters	Values (mg/l)	Parameters	Values (mg/l)
As	BDL	Hg	BDL
B	16.1	K	4571.9
Ba	BDL	Mg	2053.5
Ca	1351.1	Na	47007.8
Cd	0.3	Zn	1.1
Cr	0.7	Ni	2.7
Cu	0.9	Pb	3.1
Fe	4.4		
As	BDL		

Leachate Treatment Technologies

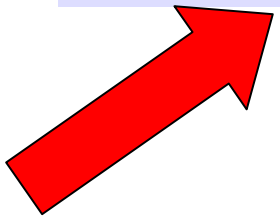


Advanced Oxidation Processes for Leachate Treatment



Experiments to assess the better technology for leachate treatment

Technology	% Reduction in Colour	% Reduction in COD	% Reduction in TOC	% Reduction in TDS
Coagulation using Polyaluminium chloride	45.2	22.1	6.9	4.8
Fenton Process	52.6	33.6	11.9	25.2
Electro fenton process using Iron Electrodes	70.9	46.9	28.7	28.9
Ozonation	45.9	59.2	36.2	11.5
Electrocoagulation using Iron electrodes	72.9	66.8	42.8	29.2



Electrocoagulation : A greener approach

- Easy operation
- Treated wastewater is palatable, clear, colorless and odorless
- Sludge is readily settleable and easy to de-water
- Flocs formed can be separated faster by filtration.
- Low TDS in treated waste water as compared to chemical treatment
- No use of chemicals solving neutralizing issues

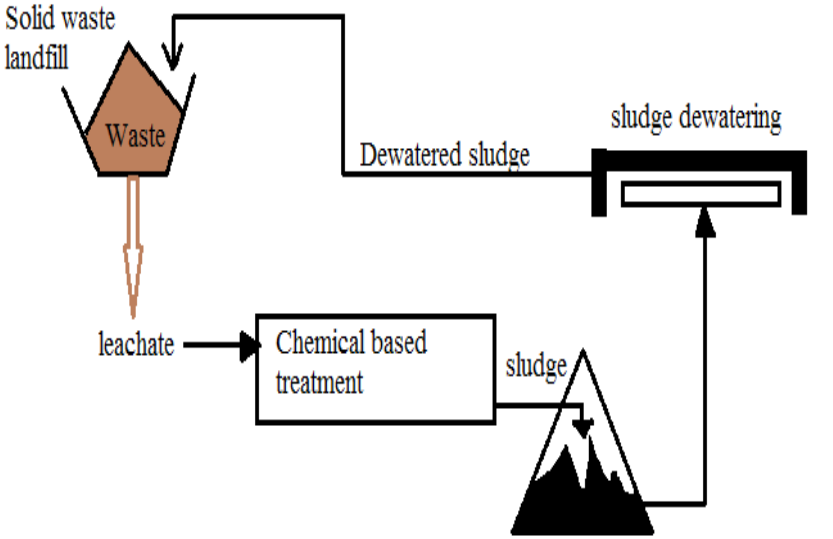
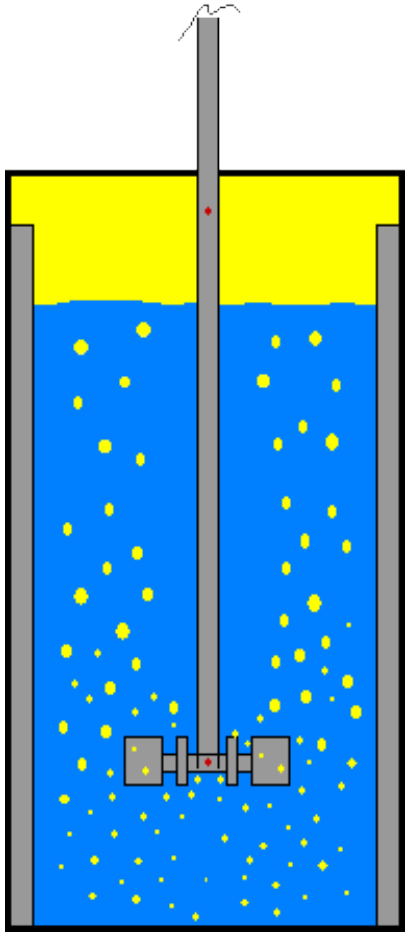
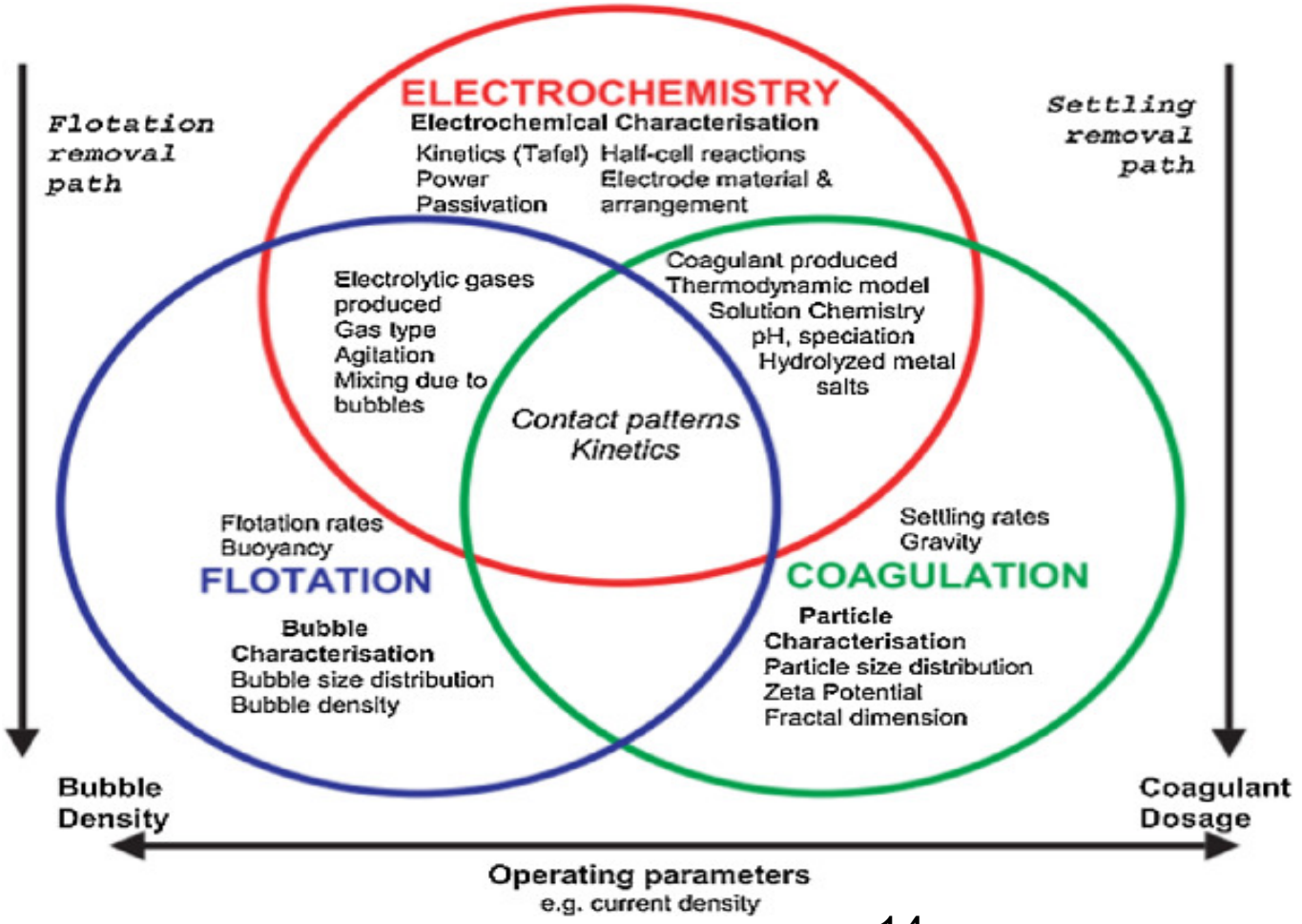


Figure 1: Cycle of waste dumping, leachate generation, treatment, sludge generation and again dumping in landfill.

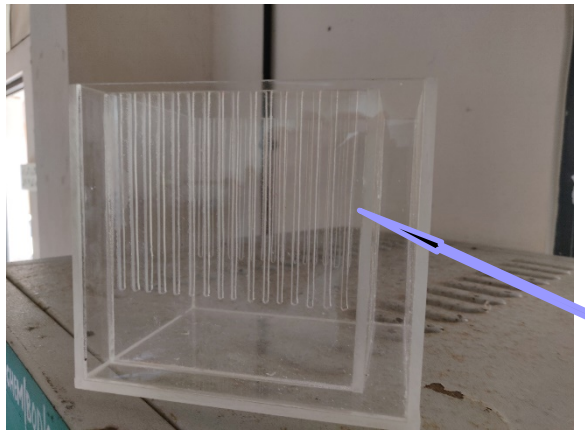
- The gas bubbles produced carry the pollutant to the top of the solution where it can be more easily concentrated, collected and removed.
- Controlled electrically with no moving parts, thus requiring less maintenance.

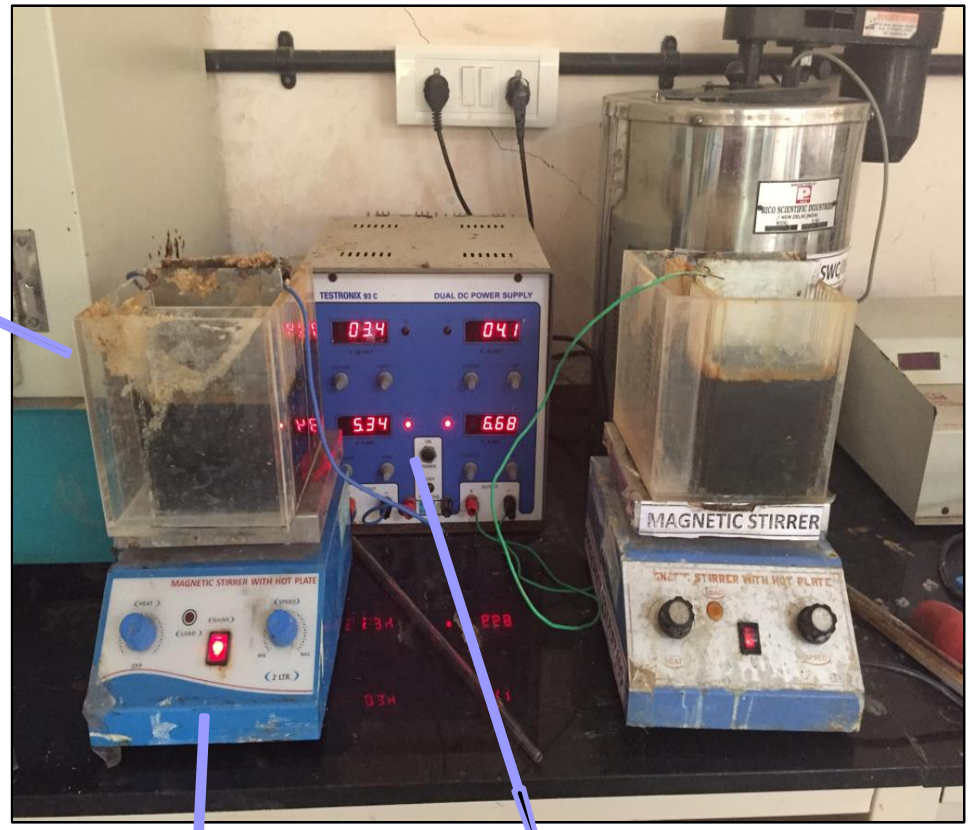
ELECTROCOAGULATION : TECHNOLOGY FOR TREATMENT





Experimental set up and Procedure





Magnetic Stirrer

Dual port Rectifier

REACTOR

MOC : Acrylic

Capacity : 1 ltr

Dimension : 12x10x14 cm

Slots : 16

- Checking initial pH and COD of leachate sample
- Taking 1 liter leachate in reactor
- Connecting proper electrodes at proper distance with rectifier
- Initializing the process and taking samples at regular intervals of 30 min
- Analyzing parameters like COD, heavy metals etc from the final treated leachate
- Repeating the experiment with changing electrode and other operating parameters

P Gautam, S Kumar

Selection of Electrode

Sample of leachate = 1liter

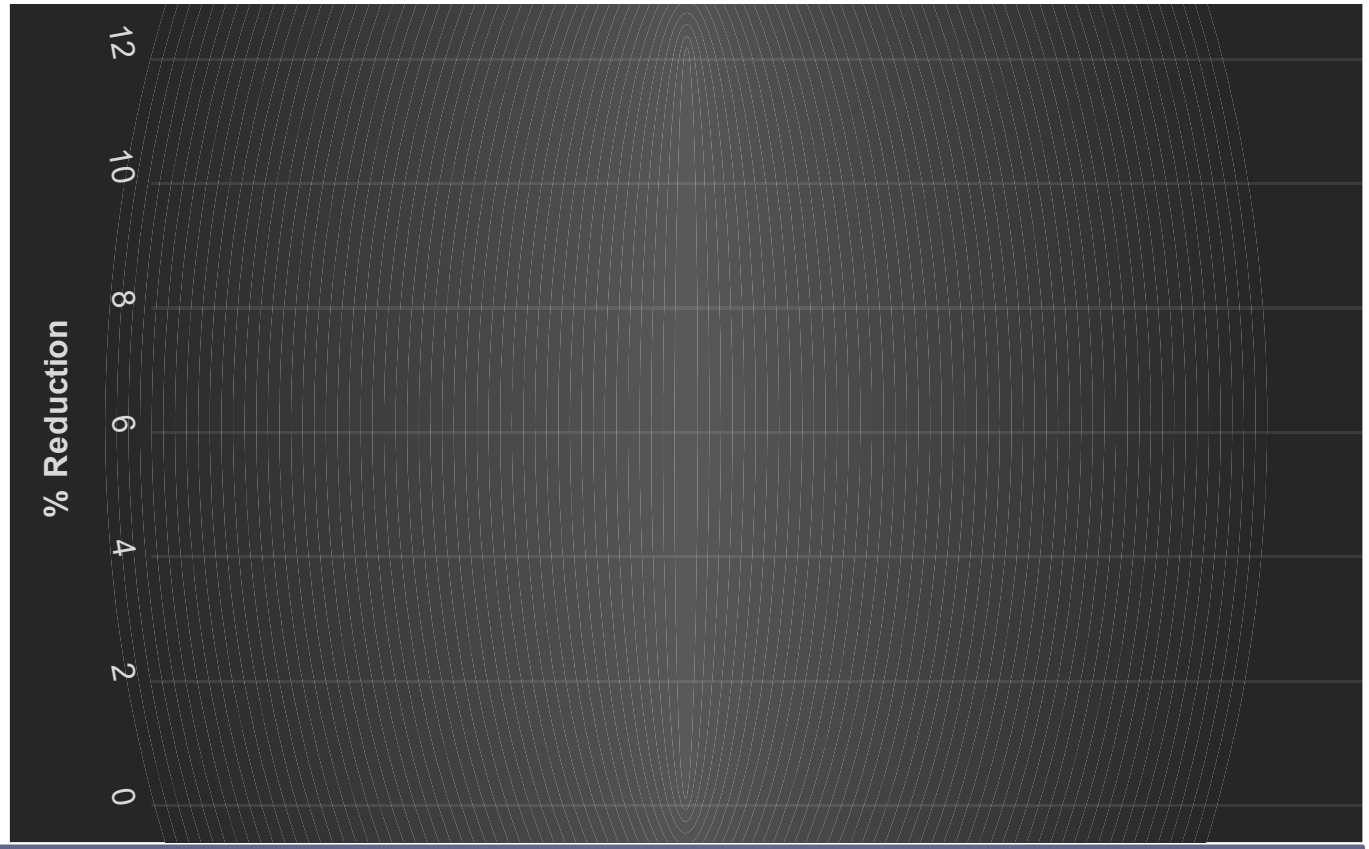
pH = 7.2

Electrolysis time – 180 min

Current density : 31.23 A/cm2

Distance between electrodes = 1.5 cm

Type of electrode	Initial COD	% Reduction in COD
GI	34300	64.21
MS	34000	45.16
SS	31000	55.74
Al	31000	34.45



GI & SS can be preferred electrode giving high COD reduction

SELECTION OF ELECTRODE

ANOVA

CODRED

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1500.623	3	500.208	44.112	.000
Within Groups	90.716	8	11.340		
Total	1591.339	11			

Post Hoc Test

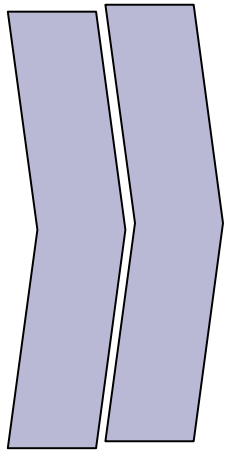
CODRED

Tukey HSD[a]

ELECTRODE	N	Subset for alpha = 0.05		
		1	2	3
AI	3	34.4500		
MS	3		45.1600	
SS	3			55.7533
GI	3			64.2100
Sig.		1.000	1.000	.060

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.



GI and SS as preferable electrode

Experiments with SS

Grades of SS

Content	SS-202	SS-304	SS-316
C	0.15	0.08	0.08
Si	1	1	1
Mn	7.5-10	2	2
P	0.06	0.045	0.045
S	0.03	0.03	0.03
Cr	17-19	18-20	16-18
Mo	-	-	2-3
Ni	4-6	8-10.5	10-14

Experiments with varying grades of SS

Sample of leachate = 1liter	pH = 7.4	Electrolysis time – 240 min	Voltage : 2.1 volts	Distance : 1.5 cm	No of electrodes : 02

Grade of SS used	Initial COD (ppm)	% Reduction in COD	% Reduction in Colour
202	**51000**	**43.14**	**73.8**
304	**45000**	**39.25**	**72.9**
316	**36000**	**61.11**	**74.6**

Experiments with varying distance using SS-316

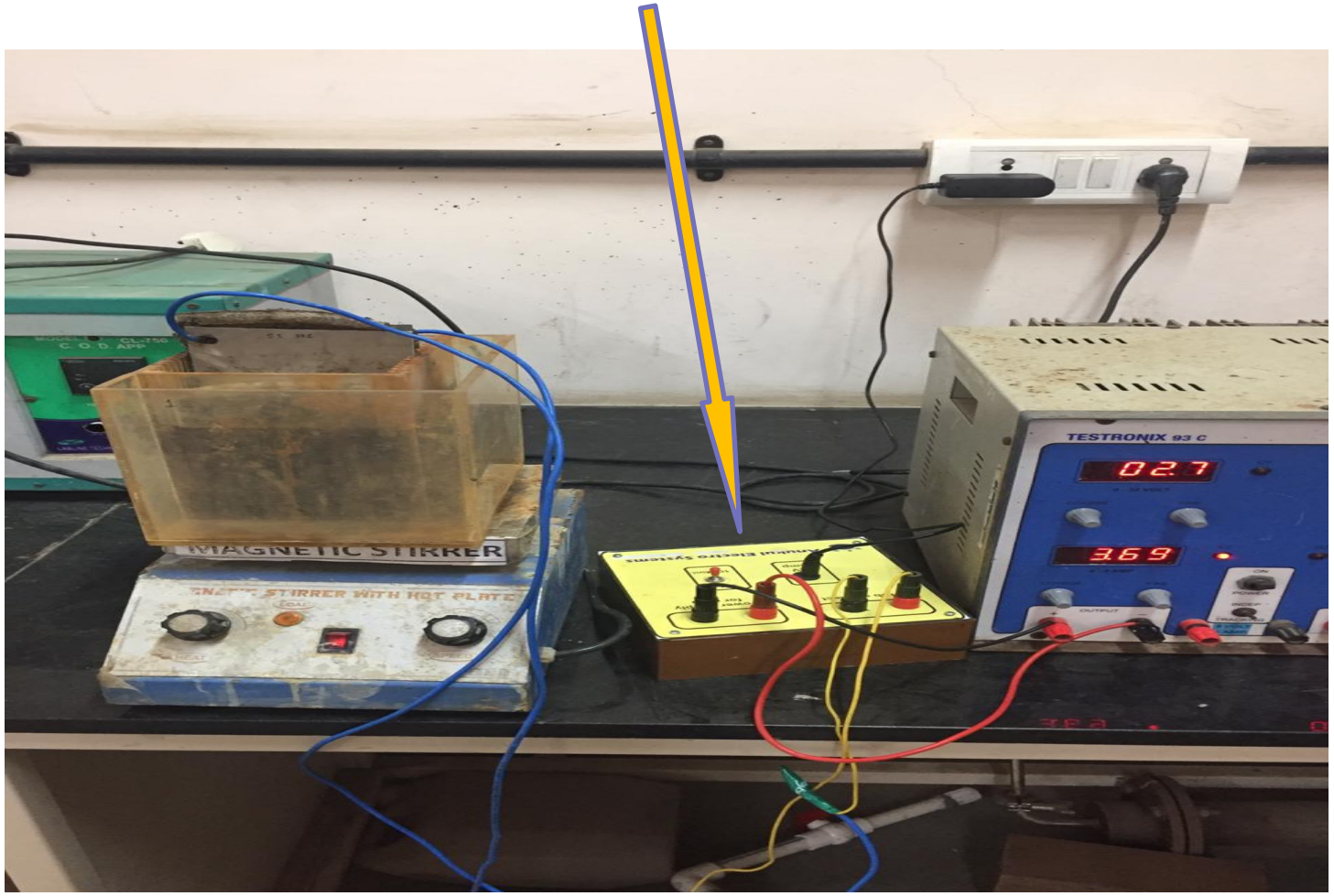
Sample of leachate = 1liter	pH = 7.4	Electrolysis time = 240m	Voltage : 2.1 volts	No of electrodes : 2

Distance between electrodes	Initial COD (ppm)	% reduction in COD	% reduction in colour	Total Chromium (Initial)	Total Chromium (Final)
1.5 cm	36000	61.11	74.6	0.3214	1.5703
3.0 cm	49500	43.25	70.7	0.43625	1.45157
4.5 cm	41000	36.58	56.3	0.5689	1.3298

CHROMIUM LEACHING

REVERSAL OF THE POLARITY

SOLUTION



Experiments with reversing polarity using SS-316

Sample of leachate = 1liter	pH = 7.4	Electrolysis time = 240m	Voltage : 2.1 volts	No of electrodes : 2

Time for reversing current (min)	Initial COD (ppm)	% reduction in COD	Max current density (mA/cm2)	% reduction in colour	Total Chromium (Initial)	Total Chromium (Final)
0	36000	61.11	34.13	74.6	0.3214	1.5703
5	45000	24.44	20.29	64.9	0.5371	0.9173
10	48000	45.83	20.61	70.8	0.4856	1.5663

CHROMIUM LEACHING

Reversing polarity using mix electrode system

Sample of leachate = 1liter	pH = 7.4	Electrolysis time – 240 min	Voltage : 2.1 volts	Distance : 1.5 cm	No of electrodes : 02

Time for reversing current (min)	Initial COD (ppm)	% reduction in COD	% weight reduction at Cathode (SS-316)	% weight reduction at Anode (GI)	Max current density (mA/cm2)	% reduction in colour	Total Chromium (Initial)	Total Chromium (Final)
0	52000	46.15	0.47	11.09	34.86	51.12	0.4992	0.465
10	52000	51.92	3.74	3.76	26.02	68.82	0.4992	0.7043

Conclusion for selection of electrode/s

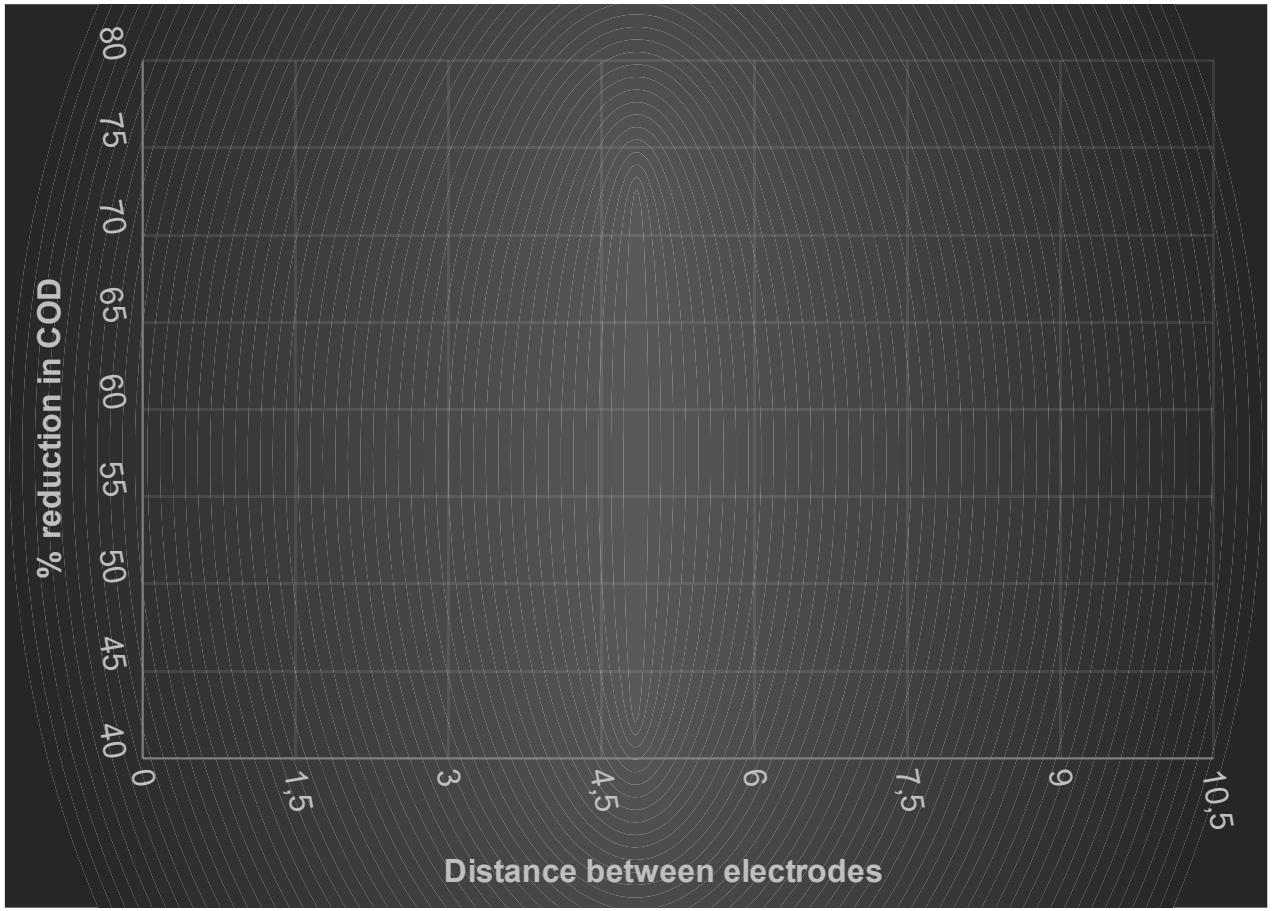
GI is the optimum electrode pertaining to the COD and colour reduction obtained in preliminary experiments

Experiments with GI plates (Varying distance)

Sample of leachate = 1liter	pH = 7.2
Electrolysis time – 240 min	Current density : 31.23 A/cm2

No of electrodes : 02

Distance between electrodes	% reduction in COD
1.5 cm	64.21
3 cm	52.96
4.5 cm	45.66
6.0 cm	49.06



1.5 cm distance looks optimum for EC using GI electrodes

EFFECT OF DISTANCE

ANOVA

CODRED

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	585.253	3	195.084	9.950	.004
Within Groups	156.857	8	19.607		
Total	742.110	11			

Post Hoc Test

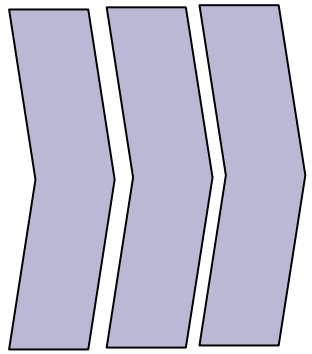
CODRED

Tukey HSD[a]

VAR.DIST	N	Subset for alpha = 0.05	
		1	2
4.5 cm	3	45.6567	
6 cm	3	49.0633	
3 cm	3	52.9767	52.9767
1.5 cm	3		64.2100
Sig.		.256	.057

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.



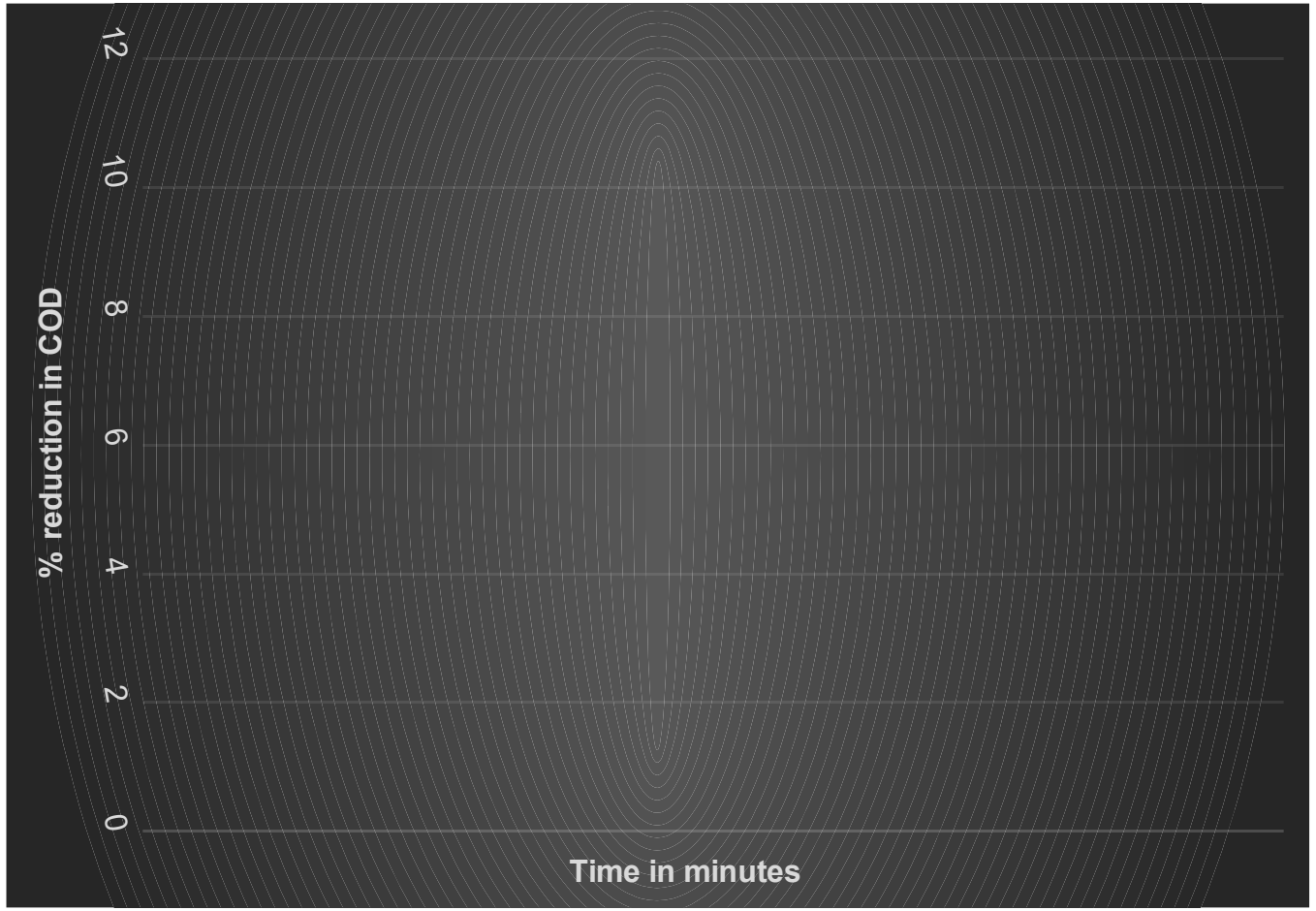
I.5 cm as preferable inter-electrode distance

Experiments with GI plates (Varying time)

Sample of leachate = 1liter	pH = 7.2
Distance = 1.5 cm	Current density : 31.23 A/cm2

No of electrodes : 02

Electrolysis time (min)	% reduction in COD
60	9.44
120	44.22
180	64.21
240	77.58



Electrolysis time is directly proportional to % reduction in COD

EFFECT OF ELECTROLYSIS TIME

ANOVA

CODRED

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7936.987	3	2645.663	257.433	.000
Within Groups	82.217	8	10.277		
Total	8019.204	11			

Post Hoc Test

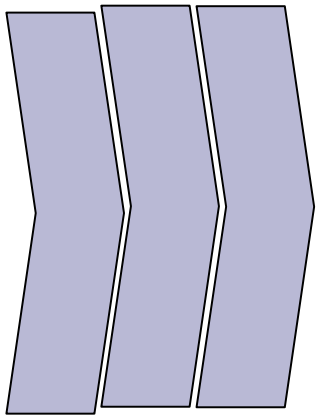
CODRED

Tukey HSD[a]

ET	N	Subset for alpha = 0.05			
		1	2	3	4
60 min	3	9.3167			
120 min	3		44.2200		
180 min	3			64.2100	
240 min	3				77.5800
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

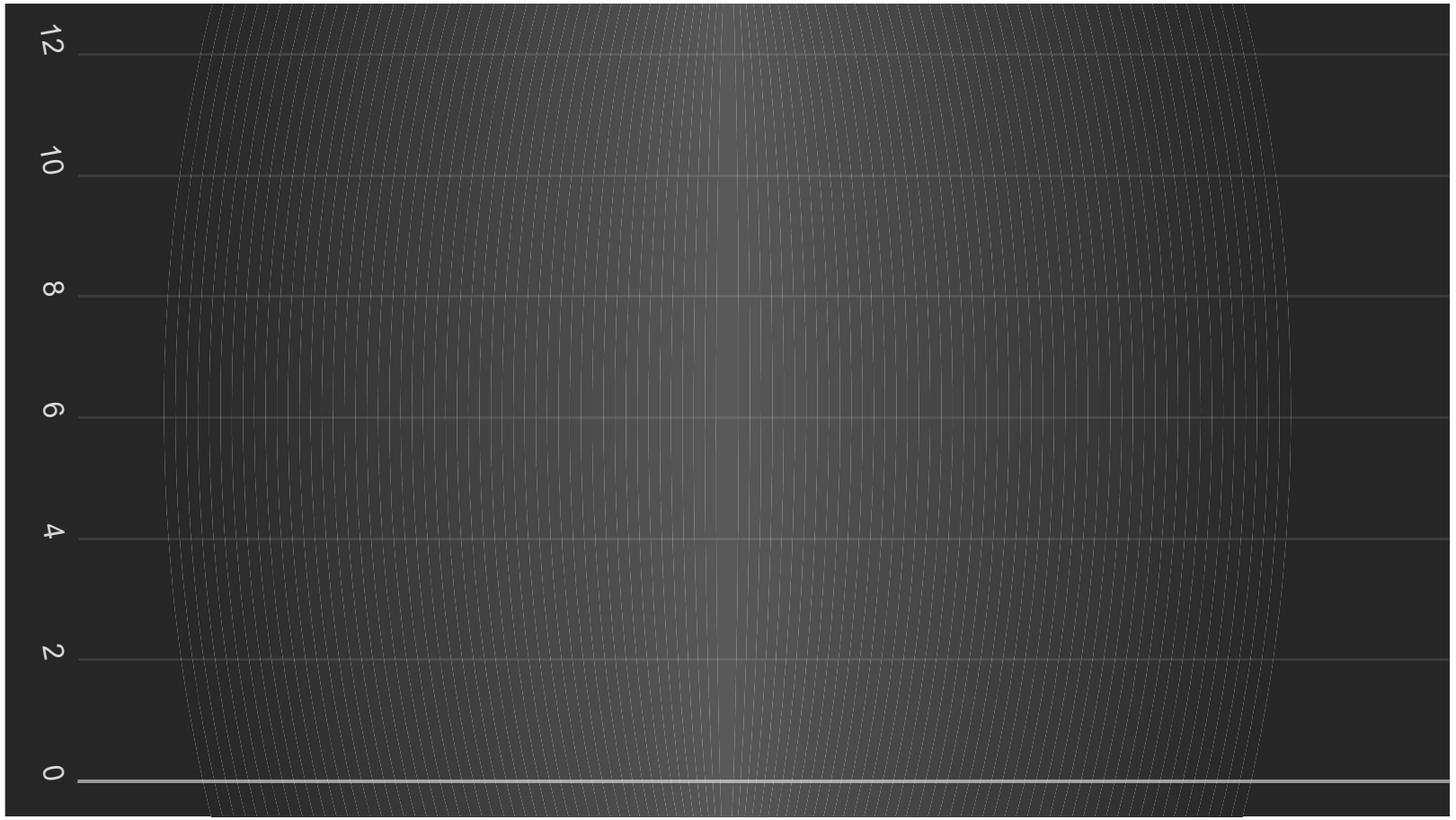


ET is directly proportional to COD reduction

Experiments with GI plates (varying current density)

Sample of leachate = 1liter	pH = 7.2	Distance = 1.5 cm	Electrolysis time = 240 min

Current density A/cm2	% reduction in COD
10.41	45.36
20.82	70.38
31.23	77.58
41.64	80.79



EFFECT OF CURRENT DENSITY

ANOVA

CODRED

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2316.699	3	772.233	165.753	.000
Within Groups	37.271	8	4.659		
Total	2353.970	11			

Post Hoc Test

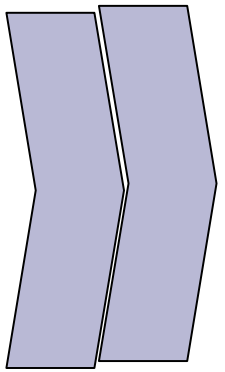
CODRED

Tukey B[a]

CD	N	Subset for alpha = 0.05		
		1	2	3
10.41	3	45.3633		
20.82	3		70.3767	
31.23	3			77.5800
41.64	3			80.7867

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.



CD is directly proportional to COD reduction

Experiments with GI plates (effect of pH)

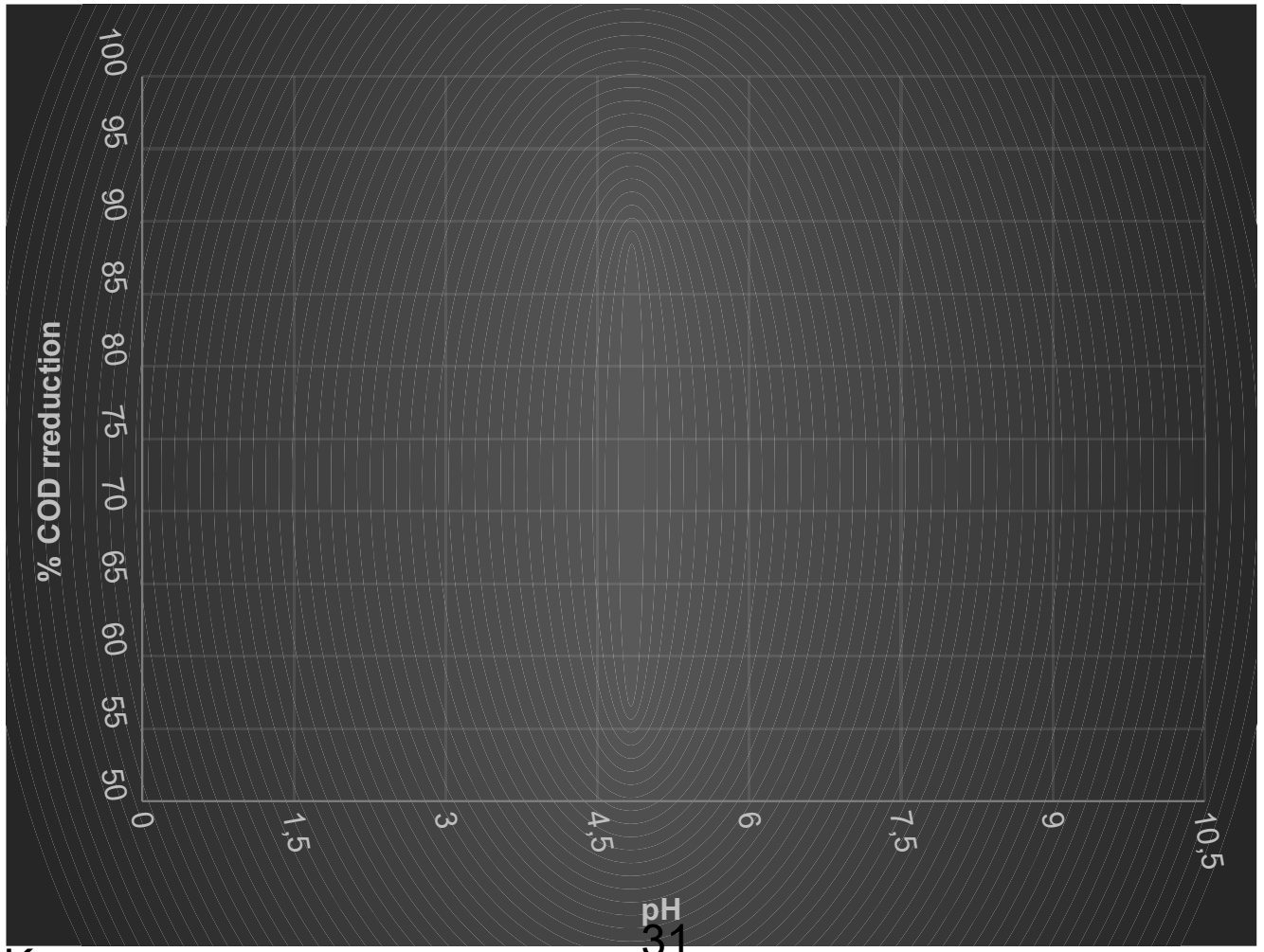
Sample of leachate = 1liter

Current density : 41.64 A/cm2

Distance = 1.5 cm

Electrolysis time = 240 min

Initial pH	Final pH	% reduction
3	5.3	62.03
4.6	6.1	70.3
7.2	7.5	80.79
9.2	10.5	74.25



EFFECT OF pH

ANOVA

CODRED

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	553.373	3	184.458	47.928	.000
Within Groups	30.789	8	3.849		
Total	584.162	11			

Post Hoc Test

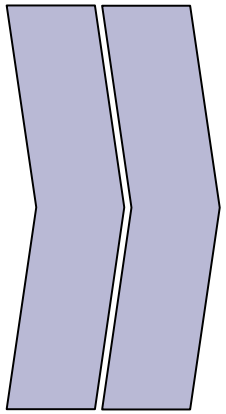
CODRED

Tukey HSD[a]

PH	N	Subset for alpha = 0.05		
		1	2	3
3	3	62.0333		
4.6	3		70.3000	
10	3		74.2633	
7.1	3			80.7867
Sig.		1.000	.139	1.000

Means for groups in homogeneous subsets are displayed.

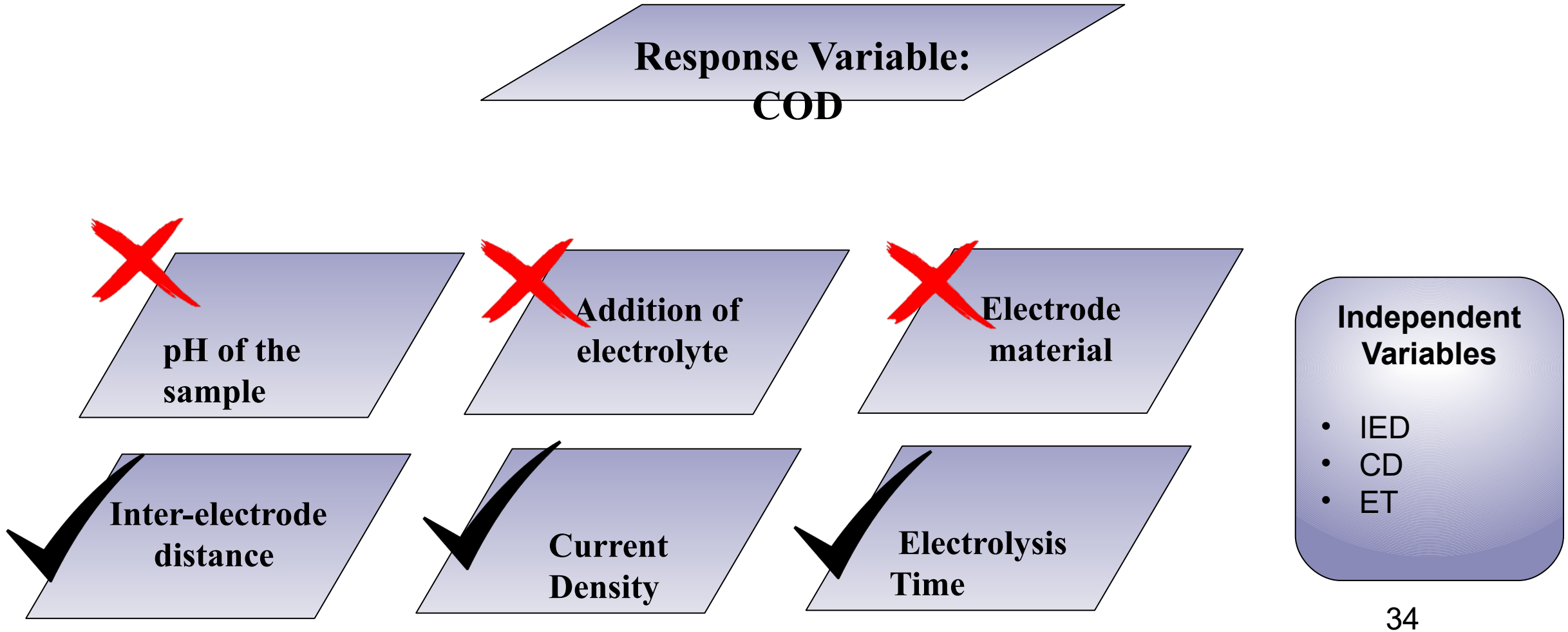
a. Uses Harmonic Mean Sample Size = 3.000.



Neutral pH is preferable

Optimization using RSM

Selection of variables



DOE for Optimization

Central Composite Design

Factors: 3 Replicates: 1
Base runs: 26 Total runs: 26
Base blocks: 1 Total blocks: 1

Two-level factorial: Full factorial

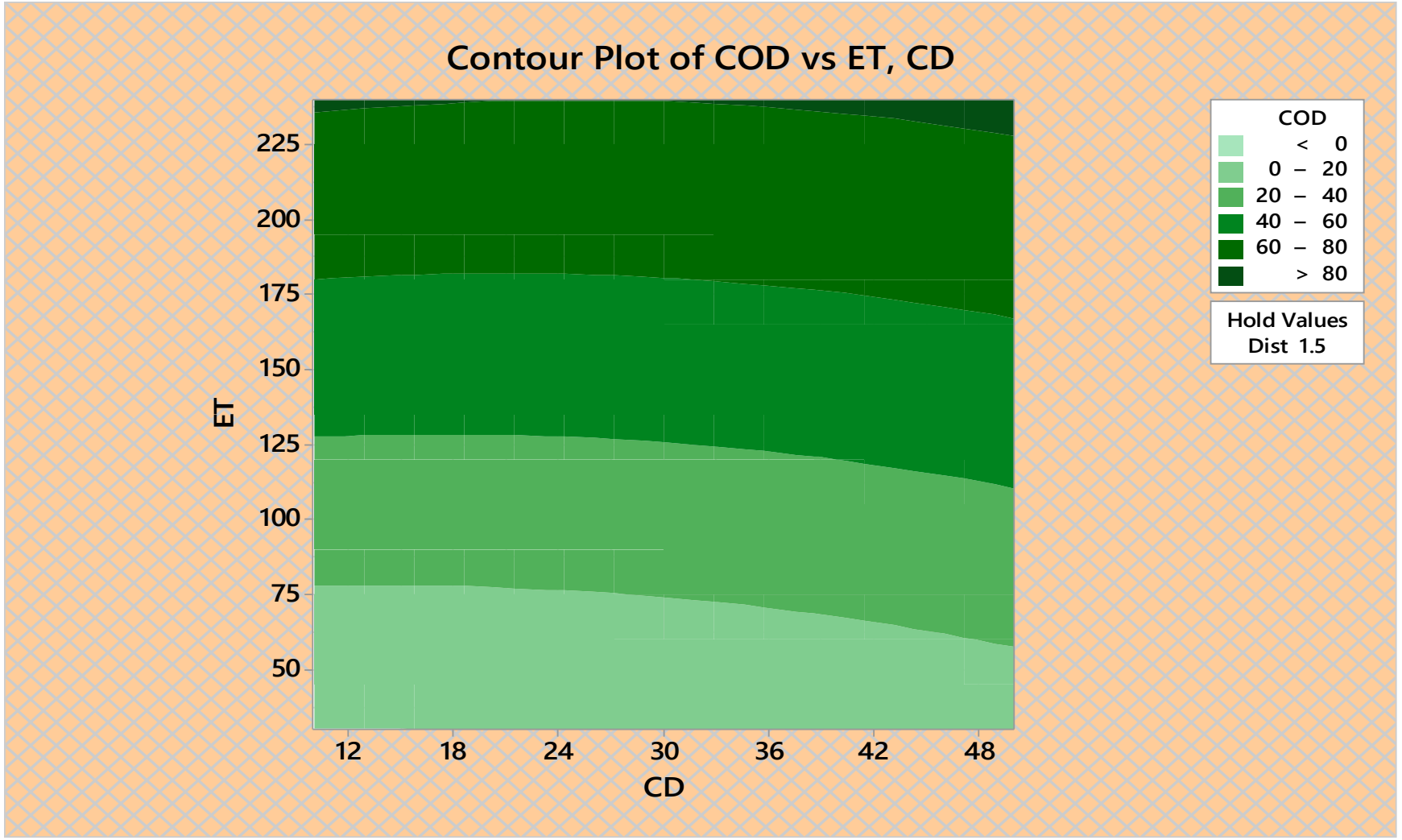
Cube points: 8
Center points in cube: 10
Axial points: 8
Center points in axial: 0

α: 1.41421

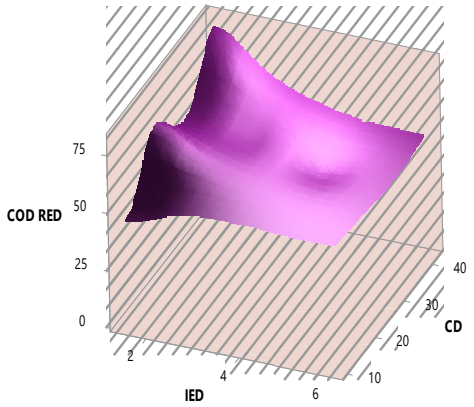
Personal comments: Factors>Axial Points
Design> Full with 13 runs

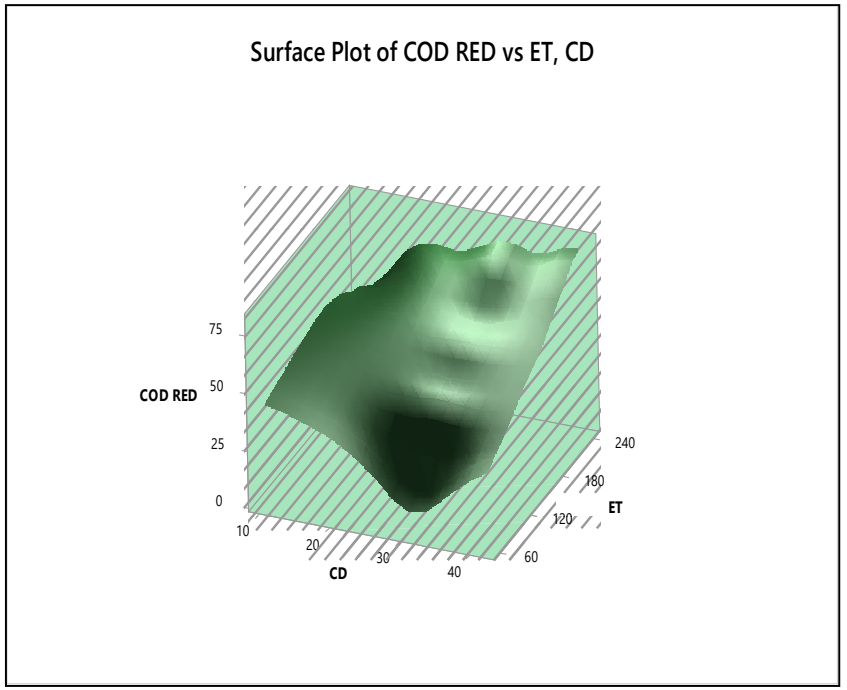
Std Order	RunOrder	PtType	Blocks	CD	ET	Dist	% COD Red
13	1	0	1	30	135	1.5	43.3
2	2	1	1	44.14214	60.75379	1.5	20.7
24	3	0	1	30	135	3	37.9
11	4	0	1	30	135	1.5	43.3
16	5	1	1	15.85786	209.2462	3	58.6
9	6	0	1	30	135	1.5	43.3
12	7	0	1	30	135	1.5	43.3
8	8	-1	1	30	240	1.5	76.7
1	9	1	1	15.85786	60.75379	1.5	10.3
23	10	0	1	30	135	3	37.9
19	11	-1	1	50	135	3	34.5
22	12	0	1	30	135	3	37.9
18	13	-1	1	10	135	3	41.4
5	14	-1	1	10	135	1.5	41.4
3	15	1	1	15.85786	209.2462	1.5	75.9
4	16	1	1	44.14214	209.2462	1.5	72.4
17	17	1	1	44.14214	209.2462	3	72.4
15	18	1	1	44.14214	60.75379	3	17.2
10	19	0	1	30	135	1.5	43.3
14	20	1	1	15.85786	60.75379	3	10.3
20	21	-1	1	30	30	3	1.2
26	22	0	1	30	135	3	37.9
25	23	0	1	30	135	3	37.9
21	24	-1	1	30	240	3	65.5
6	25	-1	1	50	135	1.5	48.3
7	26	-1	1	30	30	1.5	3.3

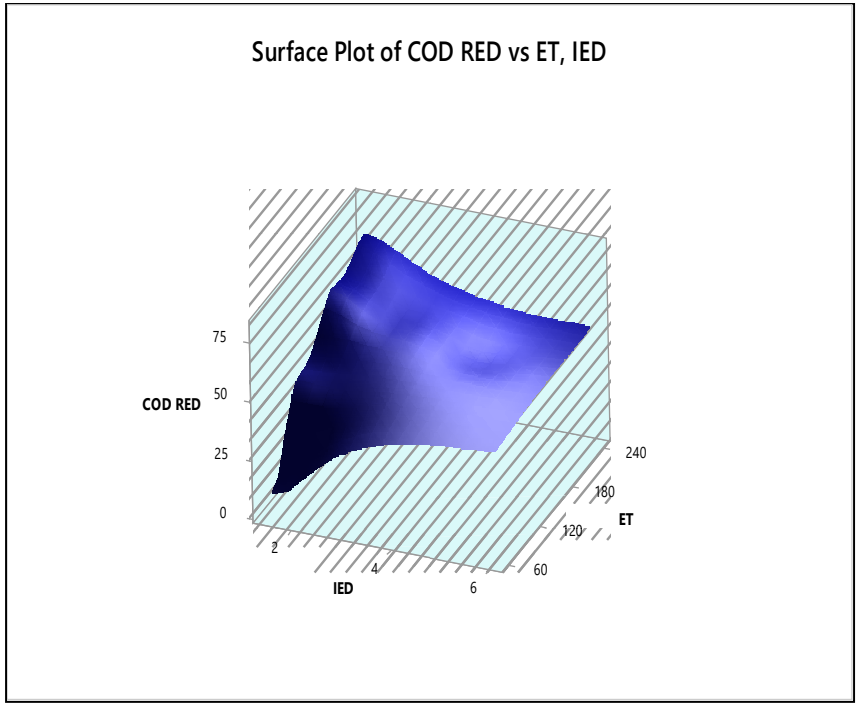
Response Surface Optimizer



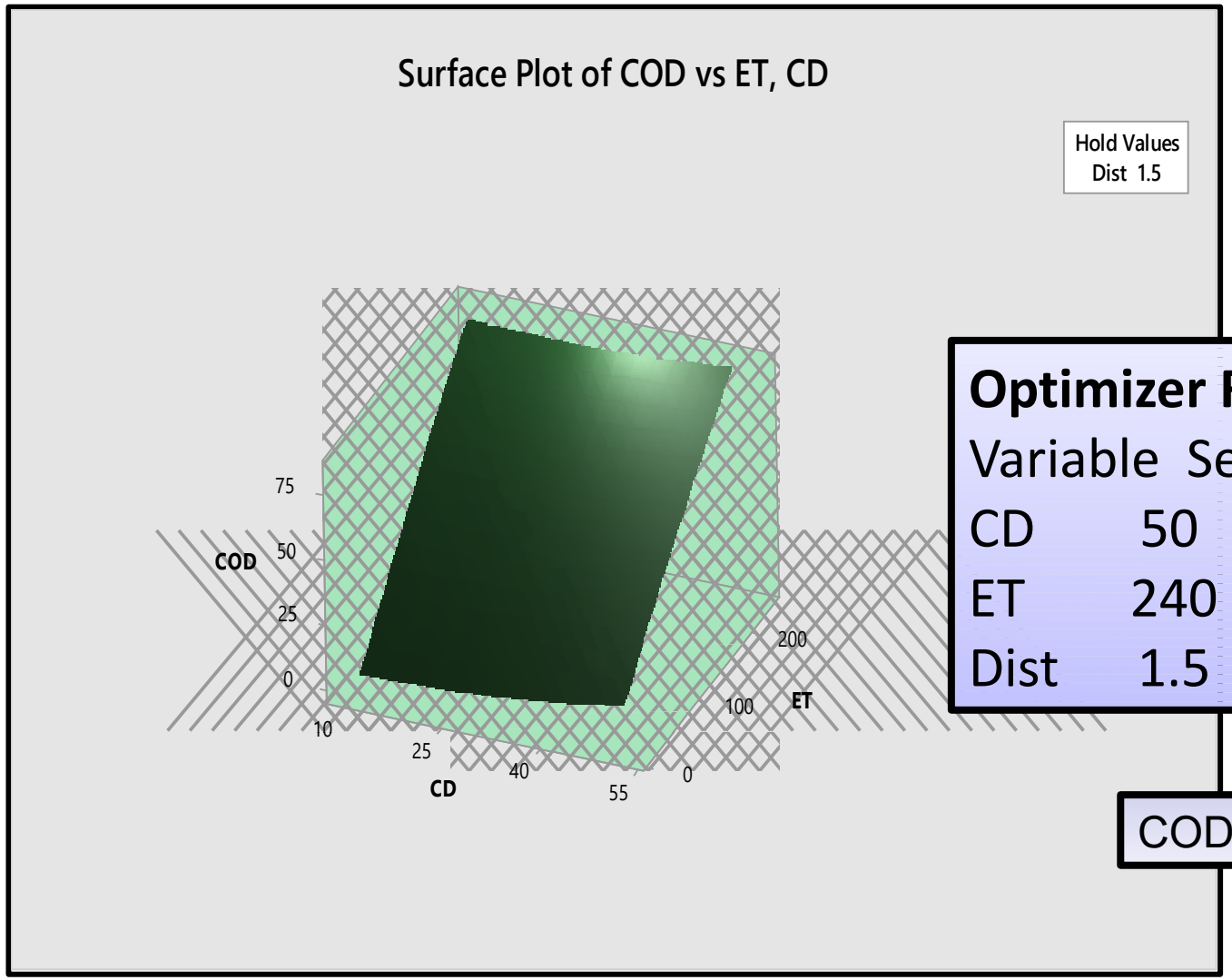
Surface plot diagrams







Response Surface Optimizer



Optimizer Result

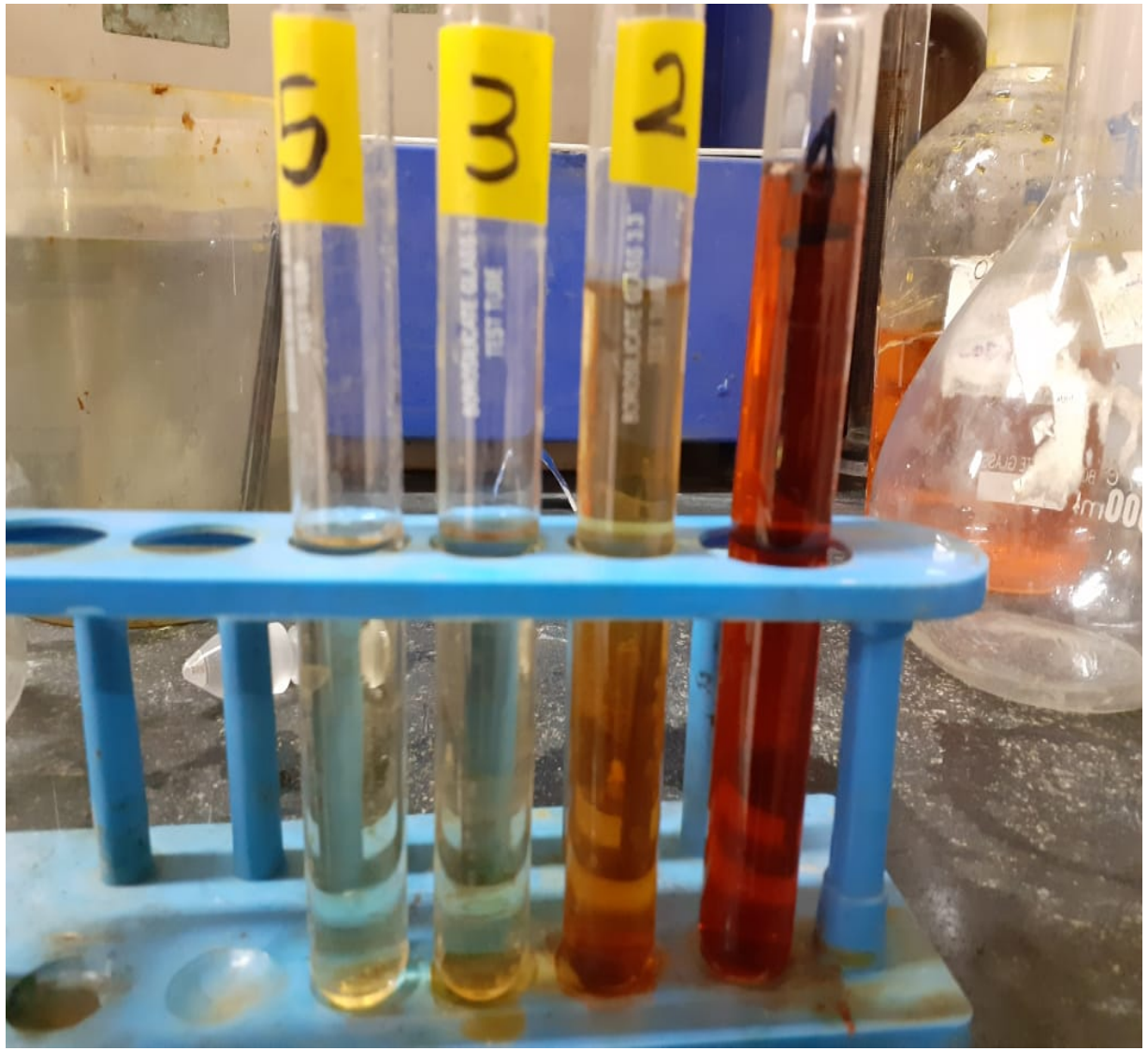
Variable	Setting
CD	50
ET	240
Dist	1.5

COD Reduction: 89.7%

CONCLUSION

OPTIMUM PARAMETERS FOR ELECTROCOAGULATION

% REDUCTION IN PARAMETERS FOR TREATED LEACHATE



TOC:
54.7%

ZINC:
63.6%

Cost incurred for the treatment of 1 KL of leachate of HWL

$$TC = (EP*EC) + (AP*ELC) + (STDC*SG) + (CP*CA) + MC + DP + LC - AM$$

Where, TC = Total Cost, EP = Electricity Price, EC = Energy consumption, AP= Anode Price, ELC = Electrodes consumption, STDC = Sludge transportation and disposal cost, SG = Sludge Generated, CP = Chemicals Price, CA = Chemicals Added, MC = Maintenance cost, DP = Depreciation, LC = Labor Cost, AM = Amortization

For our work, No external chemical was added, so CP = CA = 0. As the cost of treatment is being calculated at labscale, MC = DP = LC = AM =0.

$$TC = \underbrace{(EP*EC)}_{\text{Part 1}} + \underbrace{(AP*ELC)}_{\text{Part 2}} + \underbrace{(STDC*SG)}_{\text{Part 3}}$$

Cost incurred for the treatment of 1 KL of leachate of HWL

$$TC = (EP*EC) + (AP*ELC) + (STDC*SG)$$

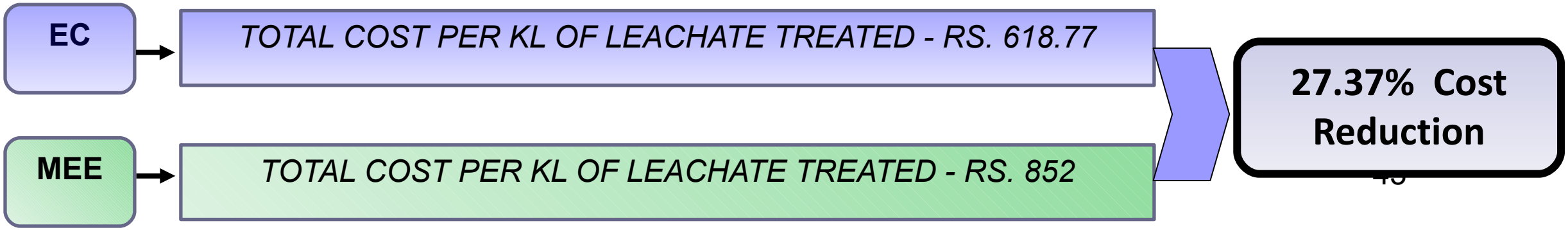
{ Part 1 } { Part 2 } { Part 3 }

TC =(7.5*44.8) + (40*6.144) +(0.94*35.45)

TC =(336)+(249.45)+(33.32)=618.77

The total cost of treatment for 1 m3 of leachate is Rs. 618.77

COST OF TREATMENT	
Cost of Electrode	249.45
Cost of Electricity	336
Cost of Sludge Disposal	33.32
Cost of overall treatment	618.77




Thank
You