Advanced Wastewater Treatment Technologies

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Introduction

- Industrial wastewater- variety of pollutants with varying concentrations and properties
- No single technology available to treat all industrial wastewaters
- Technology selection- based on type of pollutants, concentration of pollutants and treated water quality requirement
- Treatments: A combination of Physical, physico-chemical and biological processes

Physical Processes

- Sedimentation
- Filtration
  - Surface filtration
    - Sieves, cloth filters, membrane filters
  - Deep filtration
    - Sand filter
    - Other media filters
- Evaporation
  - Natural evaporators
  - Vacuum Evaporators
  - Mechanical evaporators
- Gas Transfer

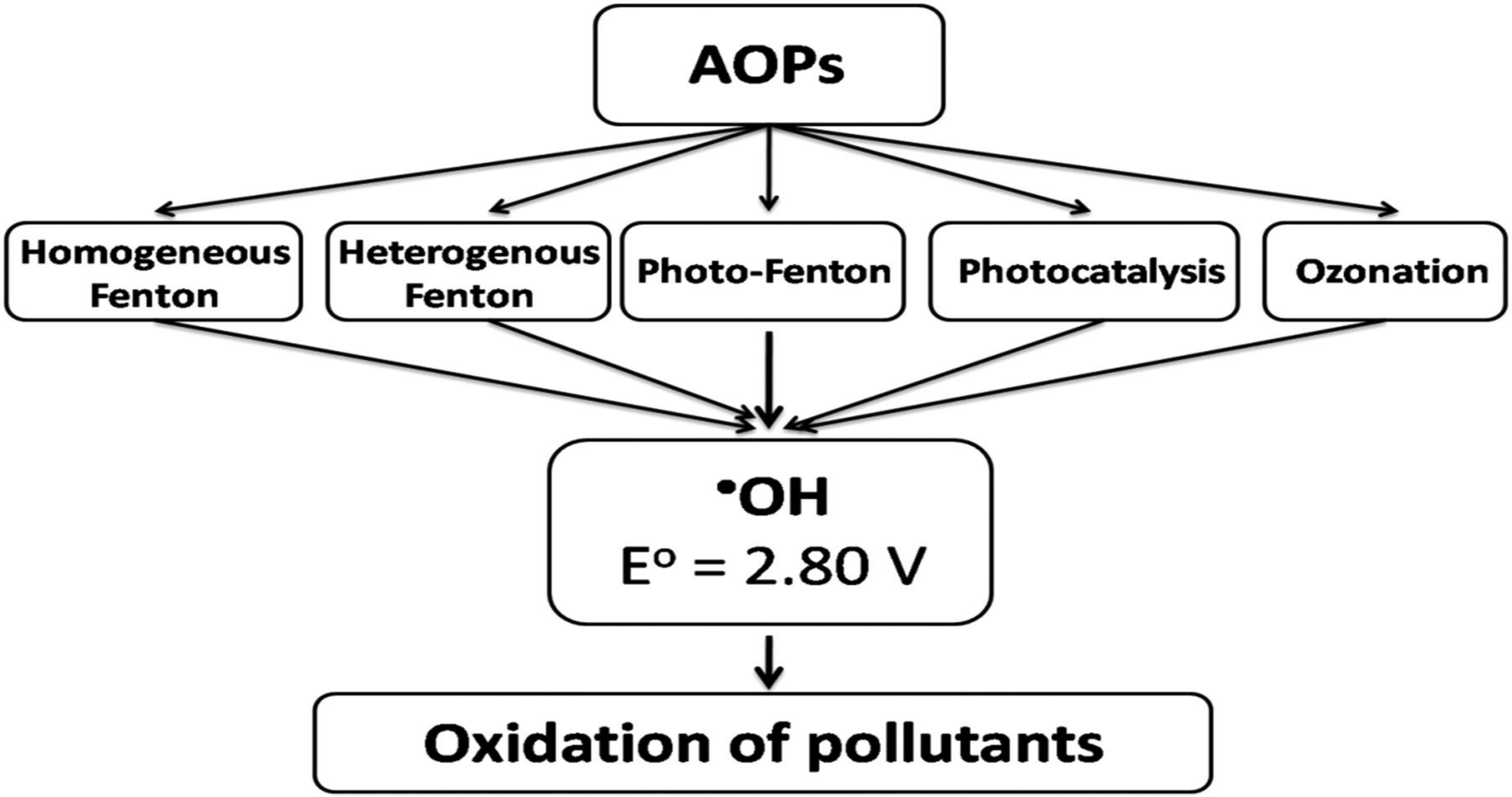
Physico-Chemical Processes

- Coagulation and flocculation, electro coagulation
- Adsorption- New and tailor made adsorbents
- Ion Exchange -
- Precipitation
- Membranes –RO, CDI, electro dialysis
- Oxidation Reduction
  - Advanced Oxidation

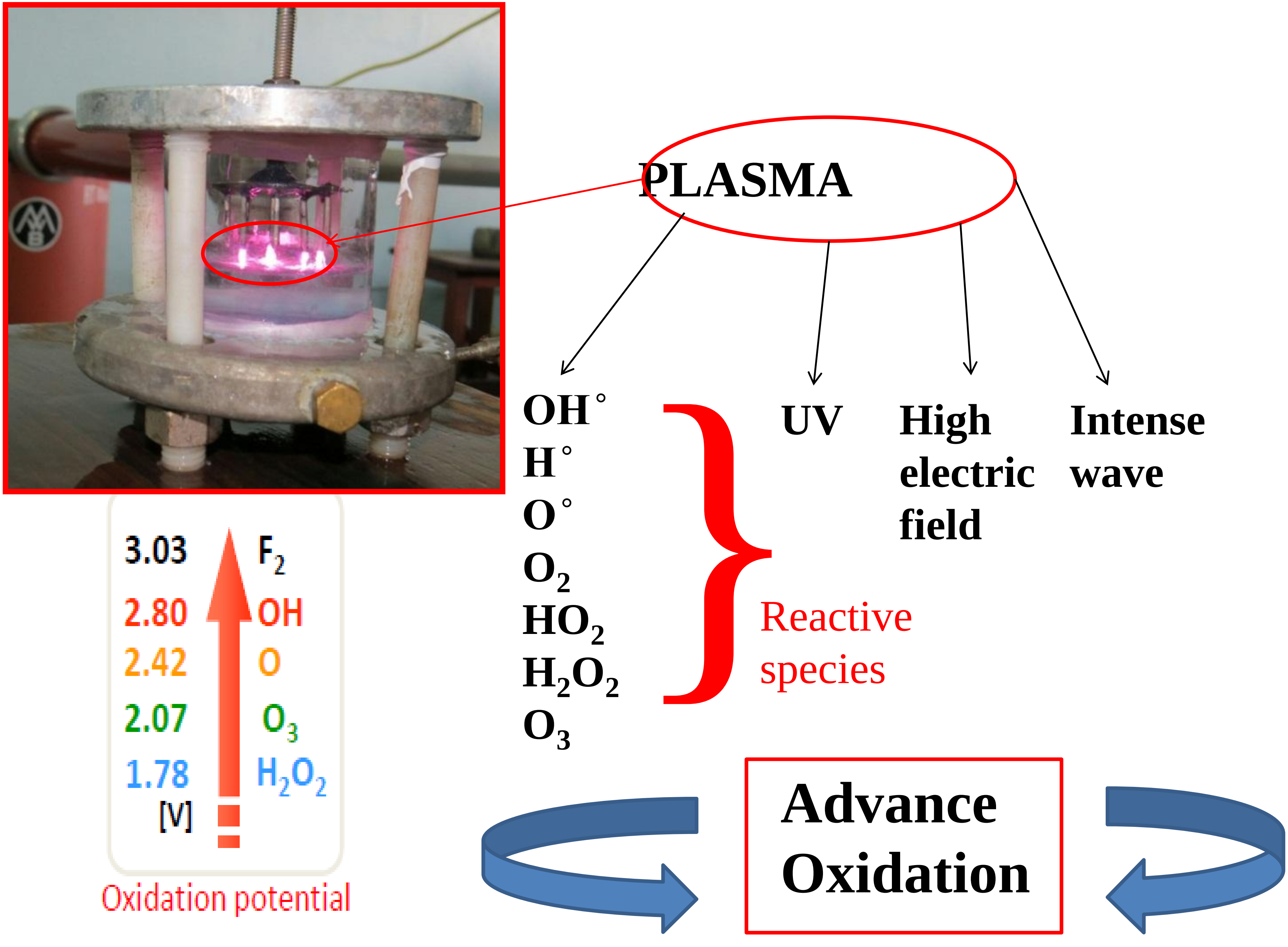
Biological Processes

- Aerobic
- Anaerobic
- Biological processes can be modified by using enriched microbes for selective complex organic wastes.

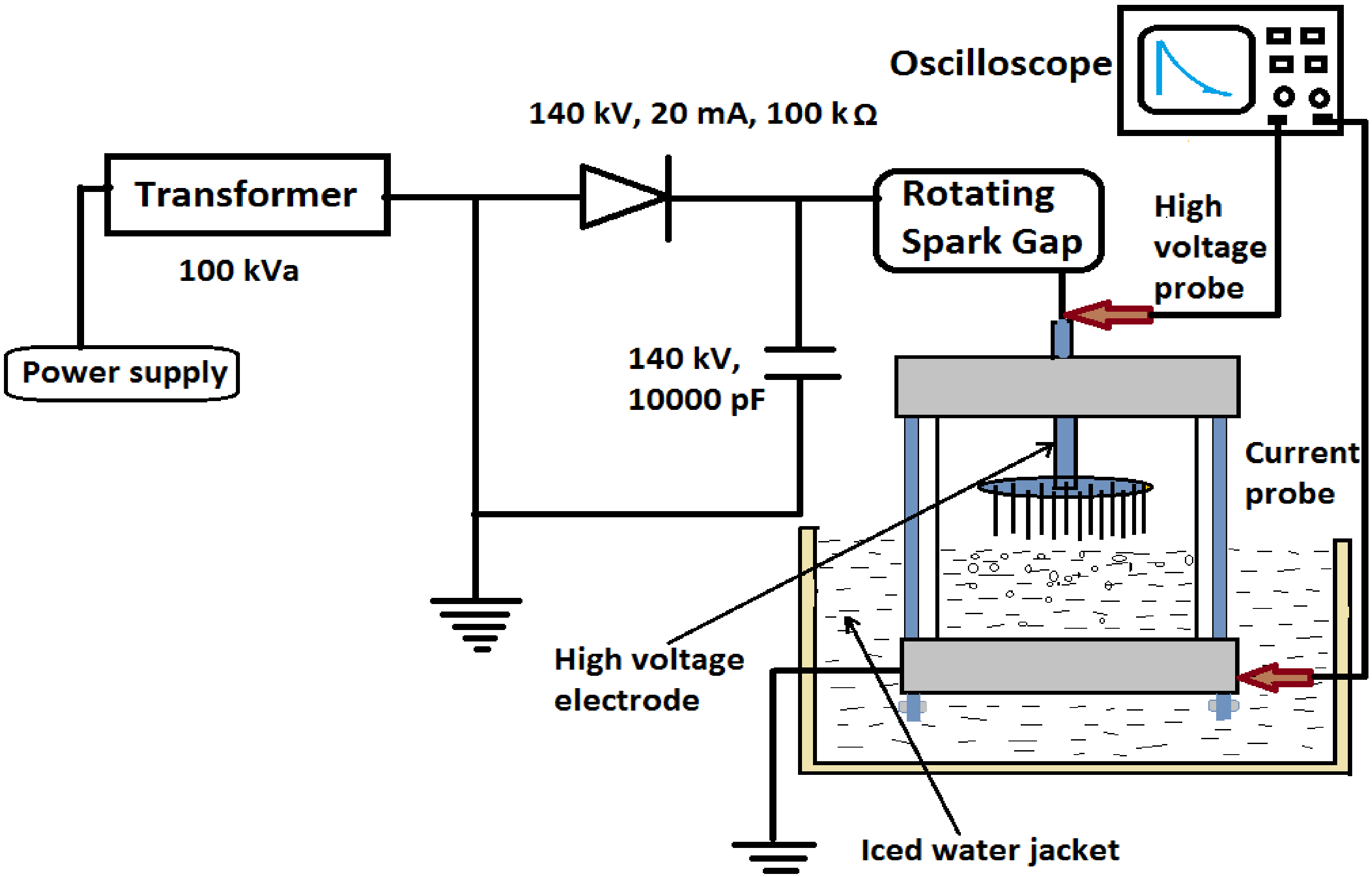
Advance oxidation processes(AOPs)



- Volume and treatment time is considerably reduced.

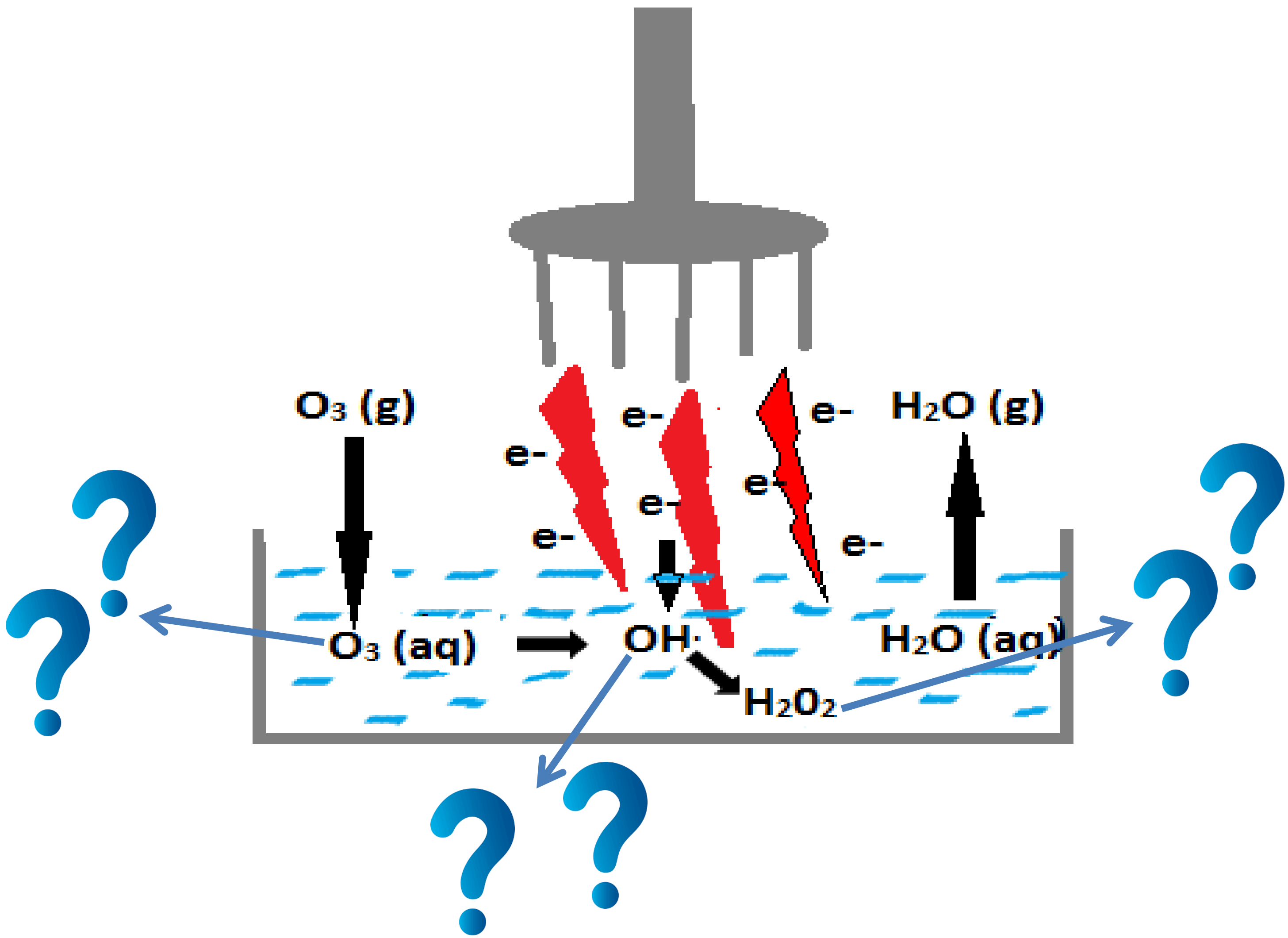

PLASMA
OH°
H°
O°
O2
HO2
H2O2
O3
Reactive
species
UV
High
electric
field
Intense
wave
Advance
Oxidation
3.03 F2
2.80 OH
2.42 O
2.07 O3
1.78 H2O2
[V]
Oxidation potential

Circuit Diagram for the Reactor set-up

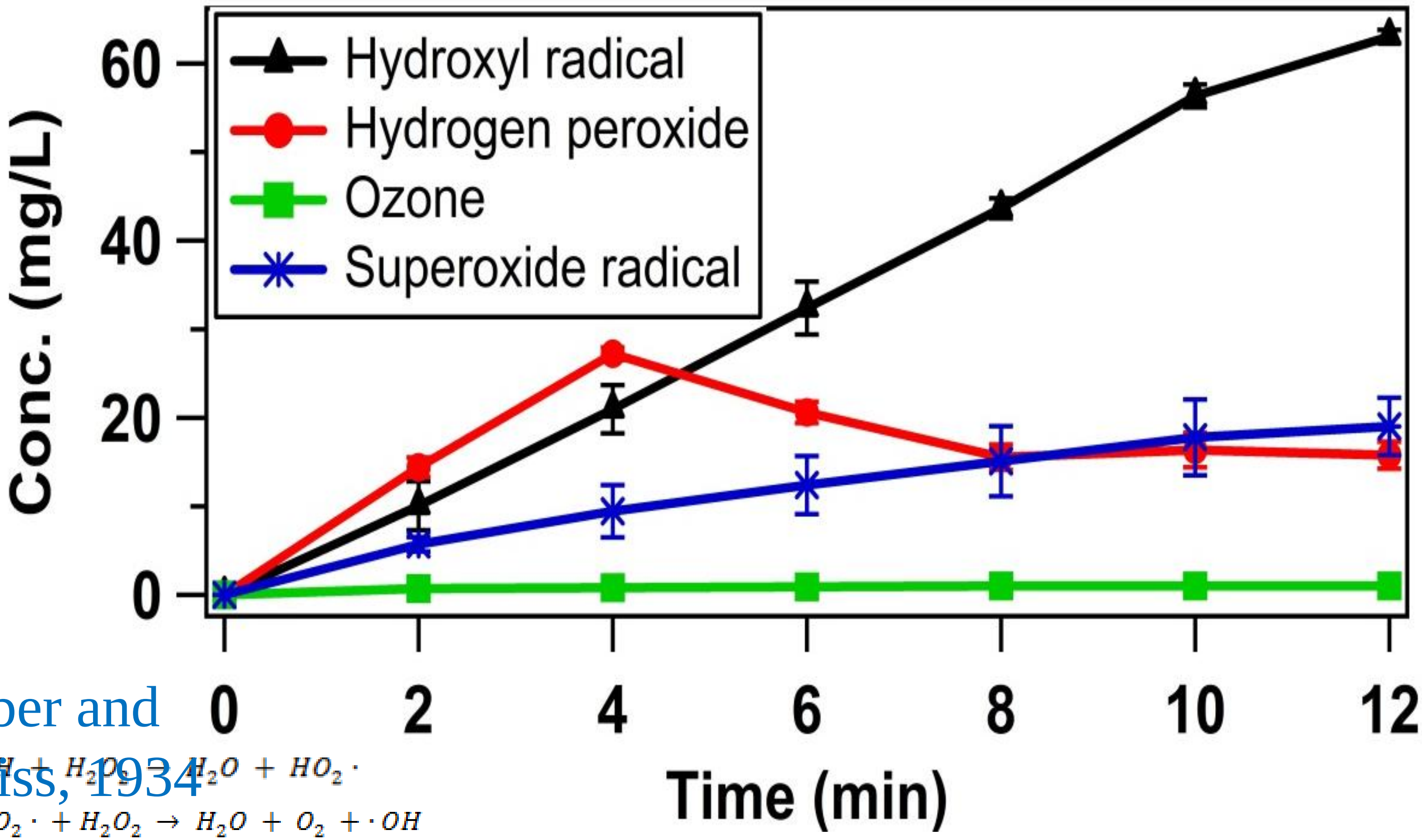


Singh Raj Kamal, Babu V., **Philip Ligy**, Sarathi R., (2016), Disinfection of Water Using Pulse Power Technique: A Mechanistic Perspective, RSC Advances, 6, 11980 – 11990.

Quantification of ROS



Trend of ROS formation



Haber and Weiss, 1934

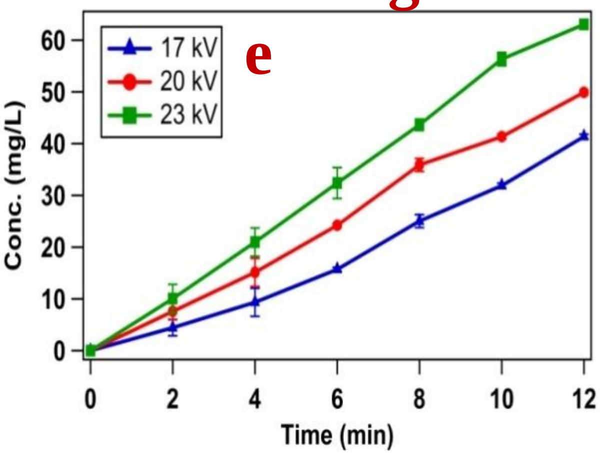
$$\cdot OH + H_2O_2 \rightarrow H_2O + HO_2\cdot$$

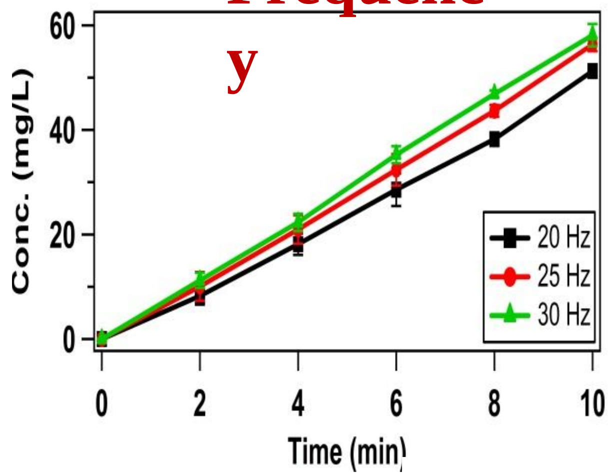
$$HO_2\cdot + H_2O_2 \rightarrow H_2O + O_2 + \cdot OH$$

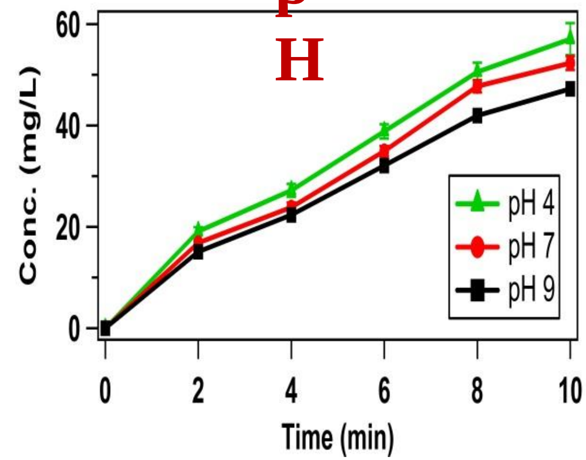
$$\cdot OH + \cdot OH \rightarrow H_2O_2$$

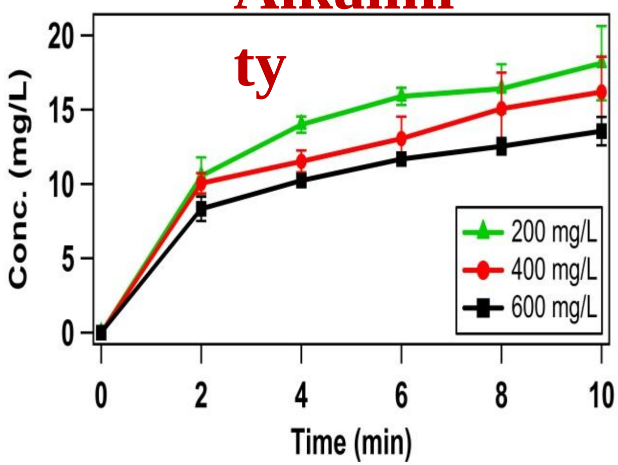
Singh et al., 2016c

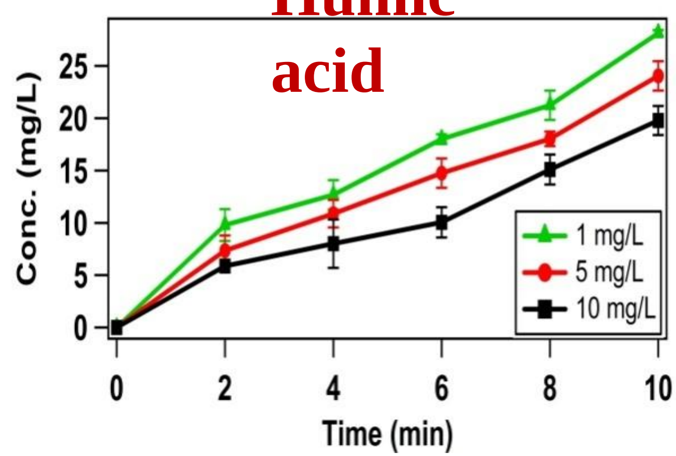
Effects of system parameters on $^{\cdot}OH$ formation



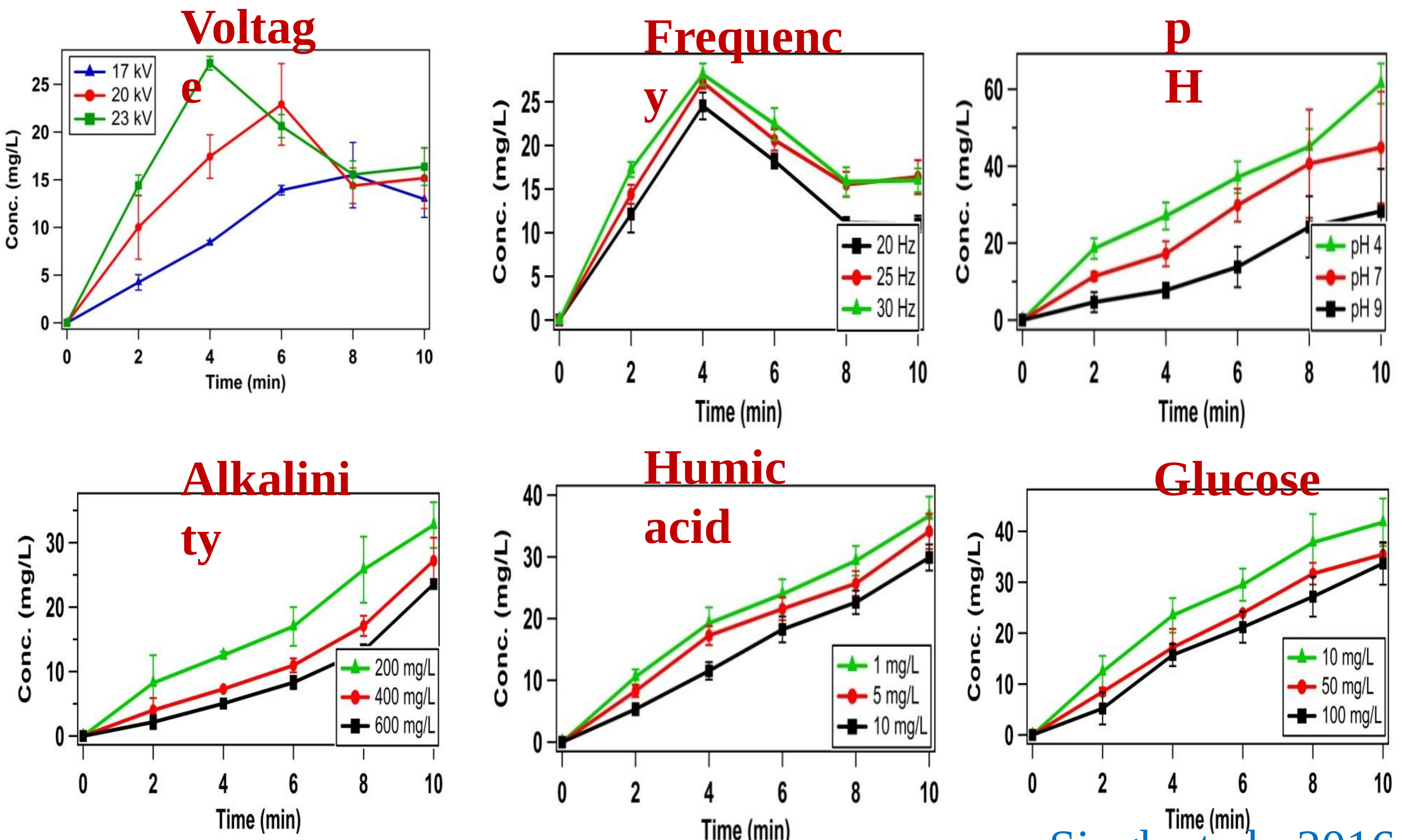








Effects of system parameters on H_2O_2 formation



Singh et al., 2016c

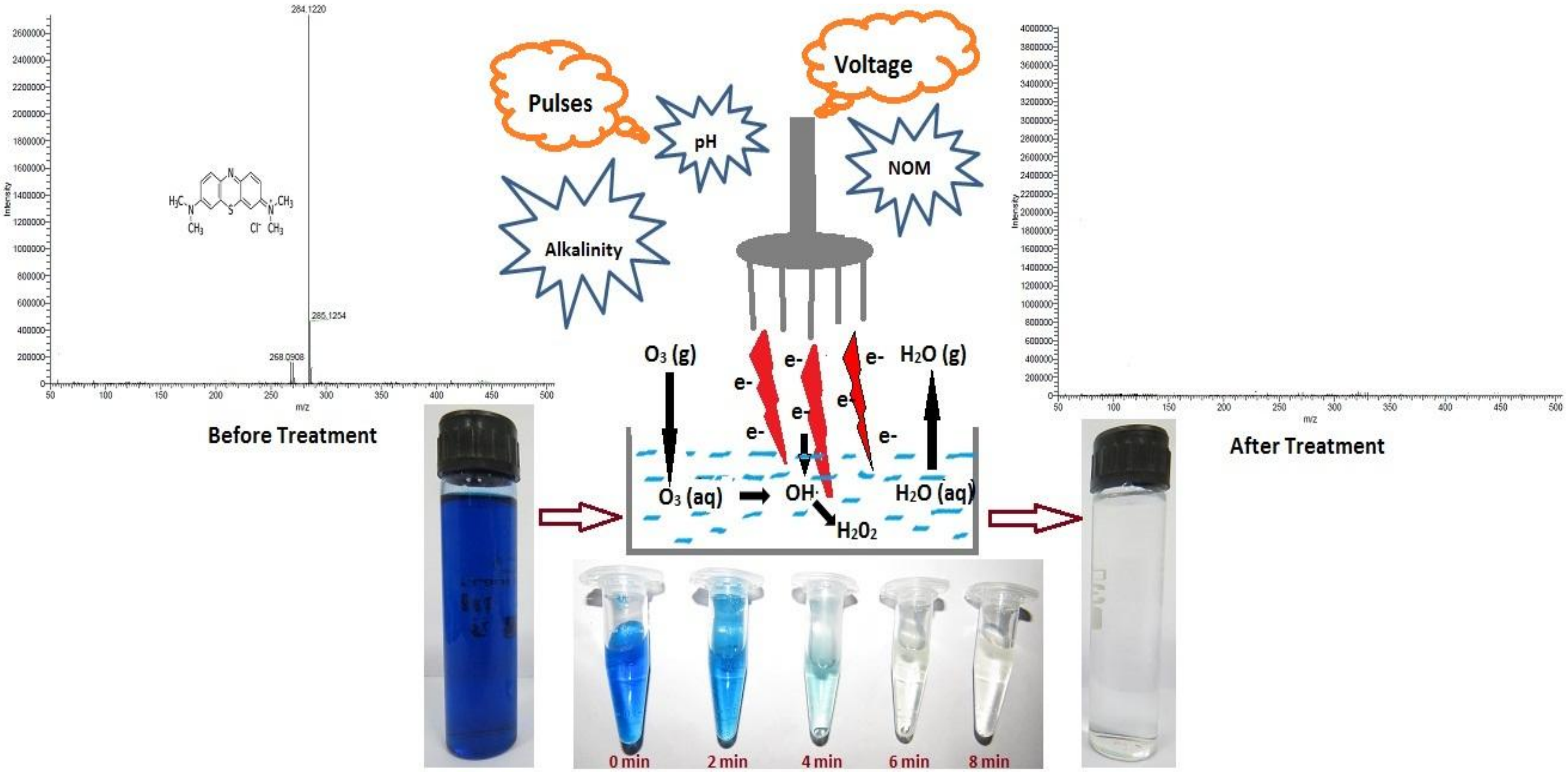
Kinetics study of ROS formation

Voltage (kV)	Rate of Reaction for OH radical (mol L−1 s−1)	Rate of Reaction for H_2O_2 (mol L−1 s−1)	Rate of Reaction for O_2^{2-} (mol L−1 s−1)	Rate of Reaction for O_3 (s^{-1})
17	3.1	1.0	0.4	0.195
20	4.0	2.0	0.6	0.225
23	5.3	3.4	1.0	0.28

***Note*: The unit for r_{OH}, r_{H2O2} and r_{O3} is 10^{-6} mol L^{-1} s^{-1}, 10^{-6} mol L^{-1} s^{-1} and 10^{-6} mol L^{-1} s^{-1}.**

Singh et al., 2016c

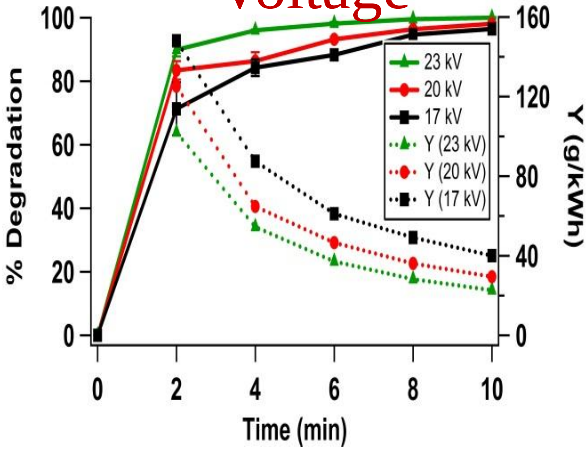
3.Methylene Blue Degradation Study



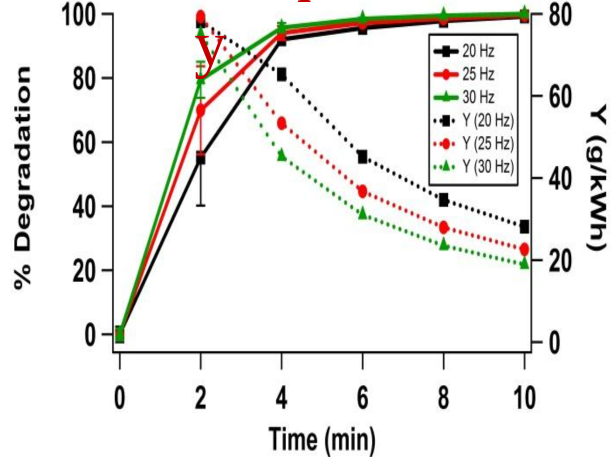
Singh Raj Kamal, Babu. V., **Philip Ligy**, Sarathi R., (2016), Applicability of Pulsed Power Technique for the Degradation of Methylene Blue, Journal of Water Process Engineering, 11, 118 – 129.

Effects of system parameters

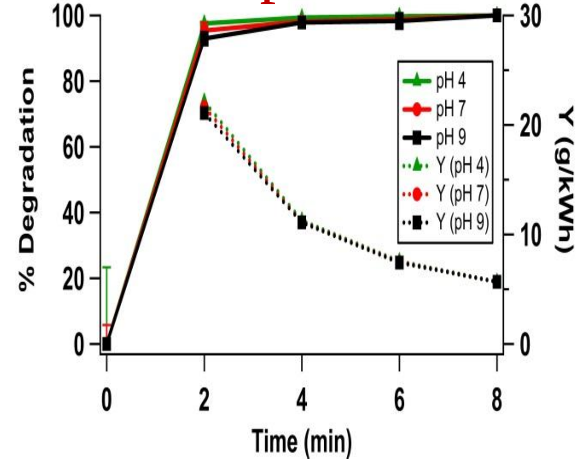
Voltage



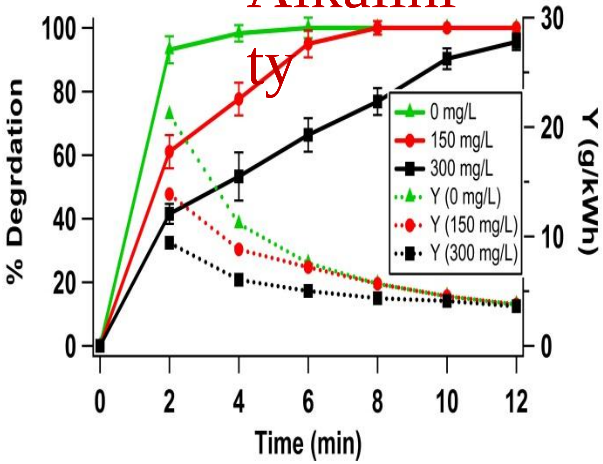
Frequency



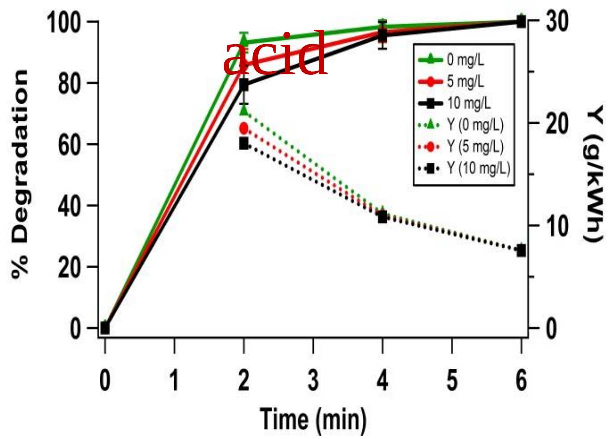
pH



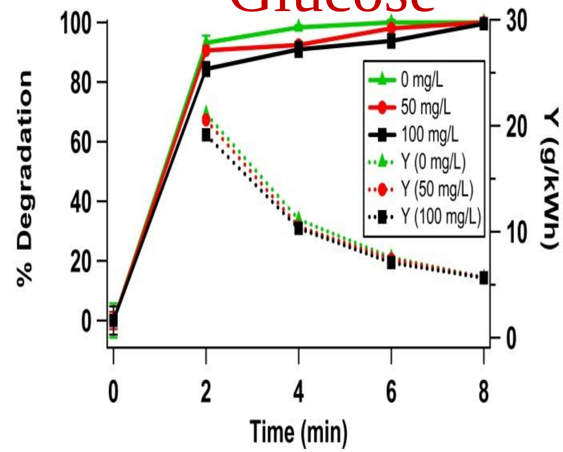
Alkalinity



Humic acid

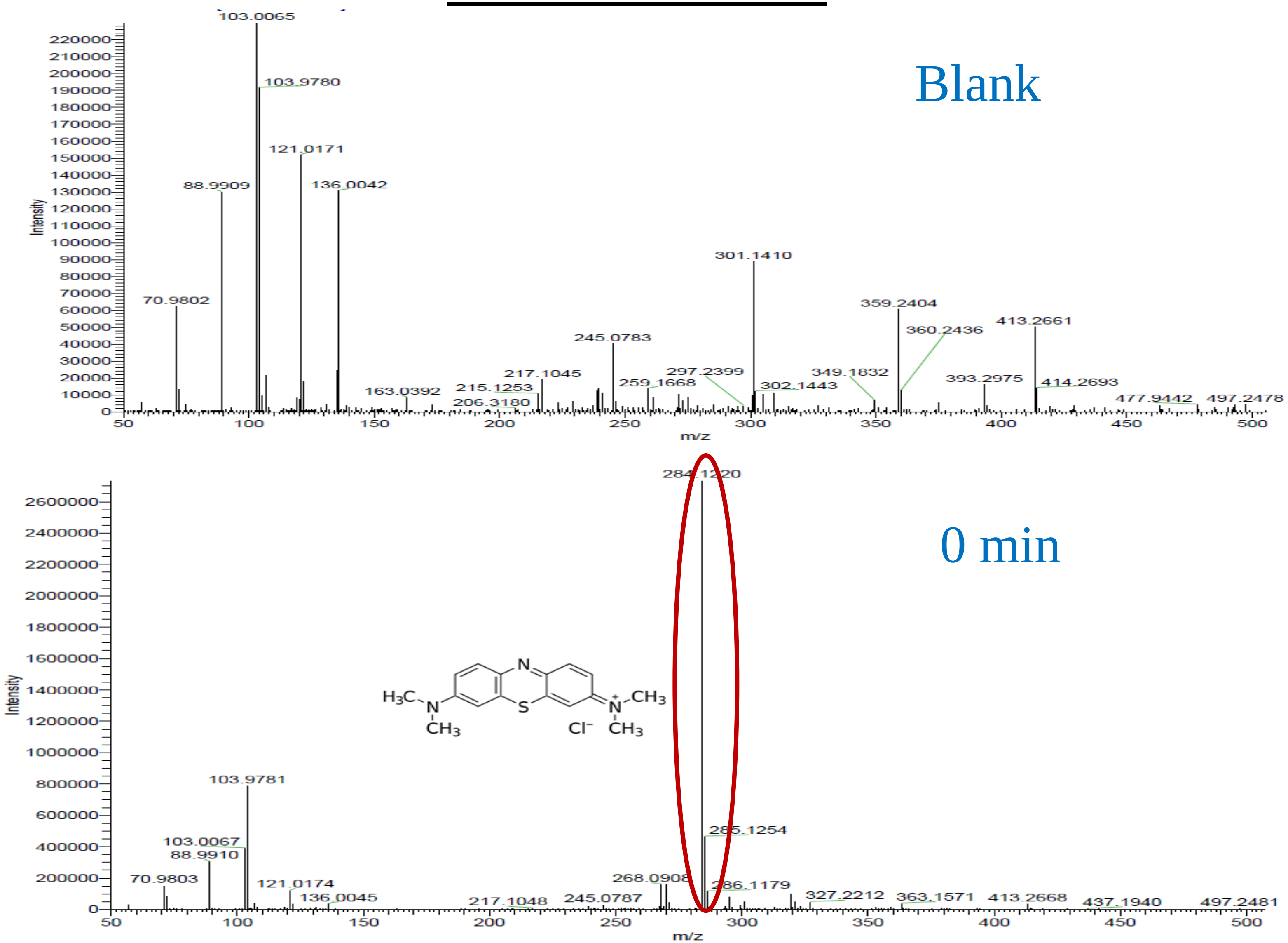


Glucose



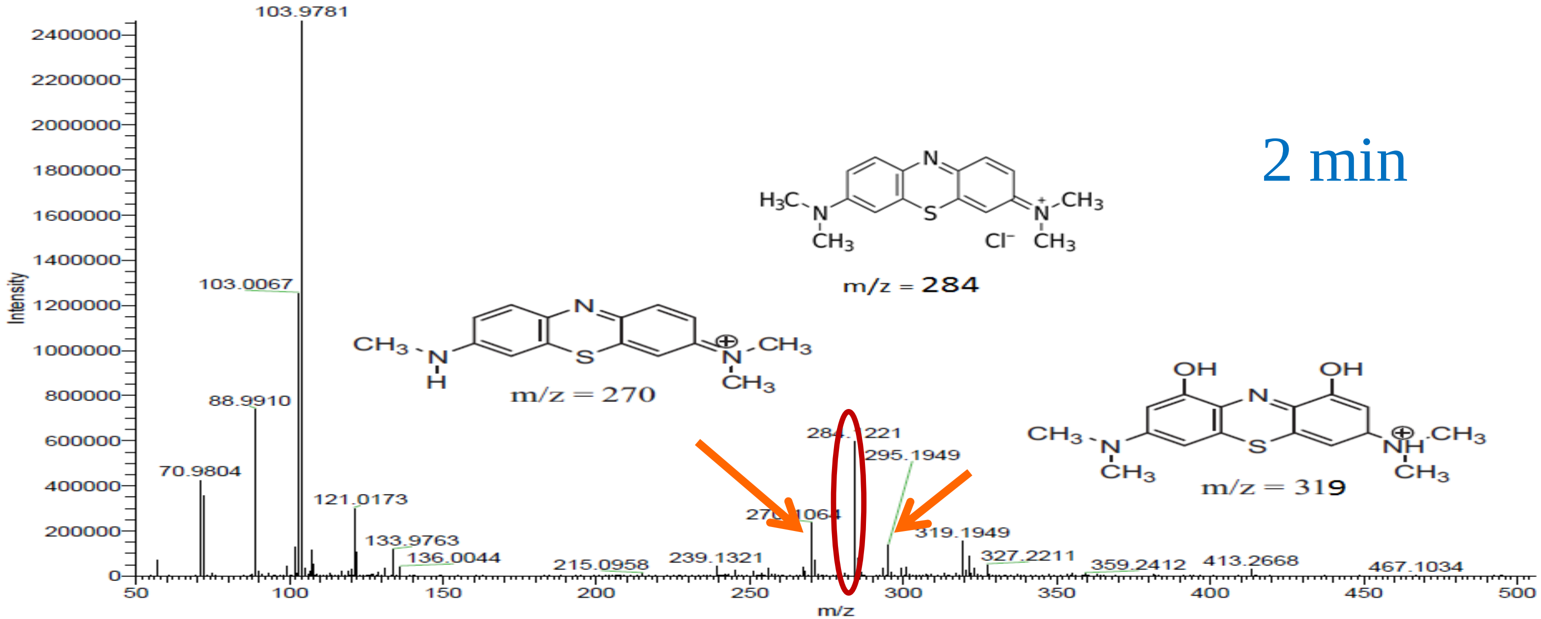
Singh et al., 2016c

Mass Spectra for Methylene blue and its intermediates

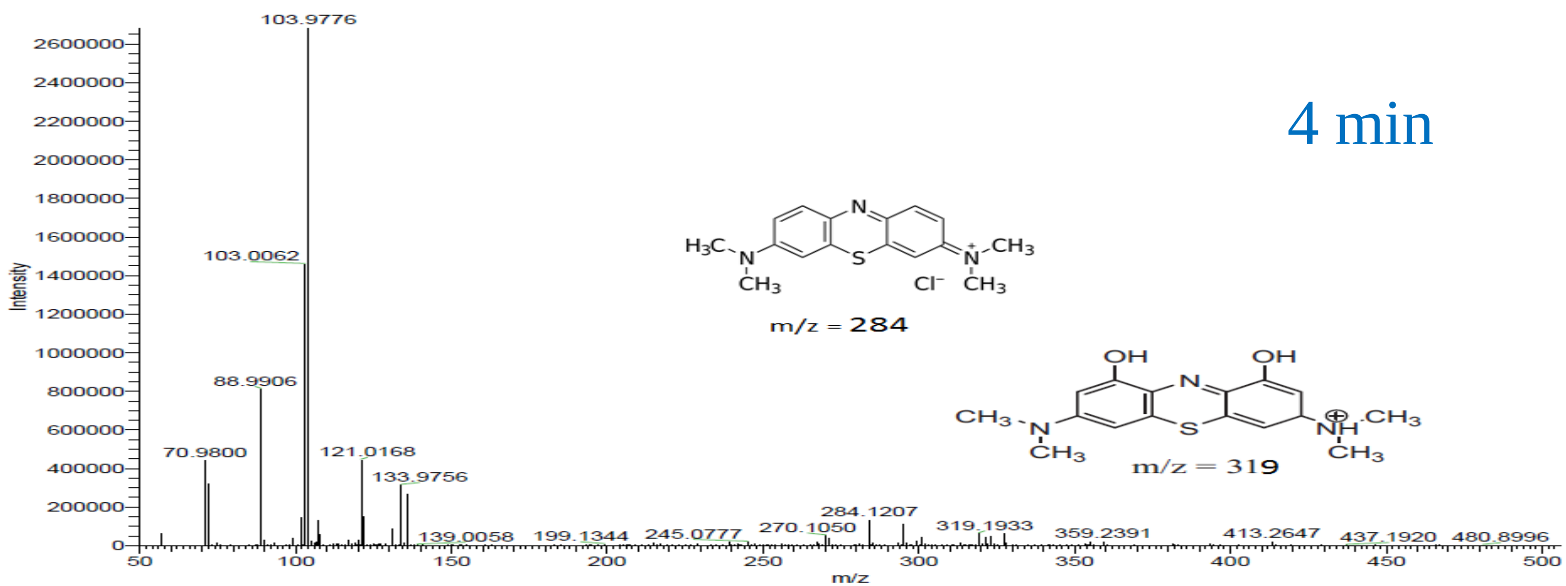


Singh et al., 2016c

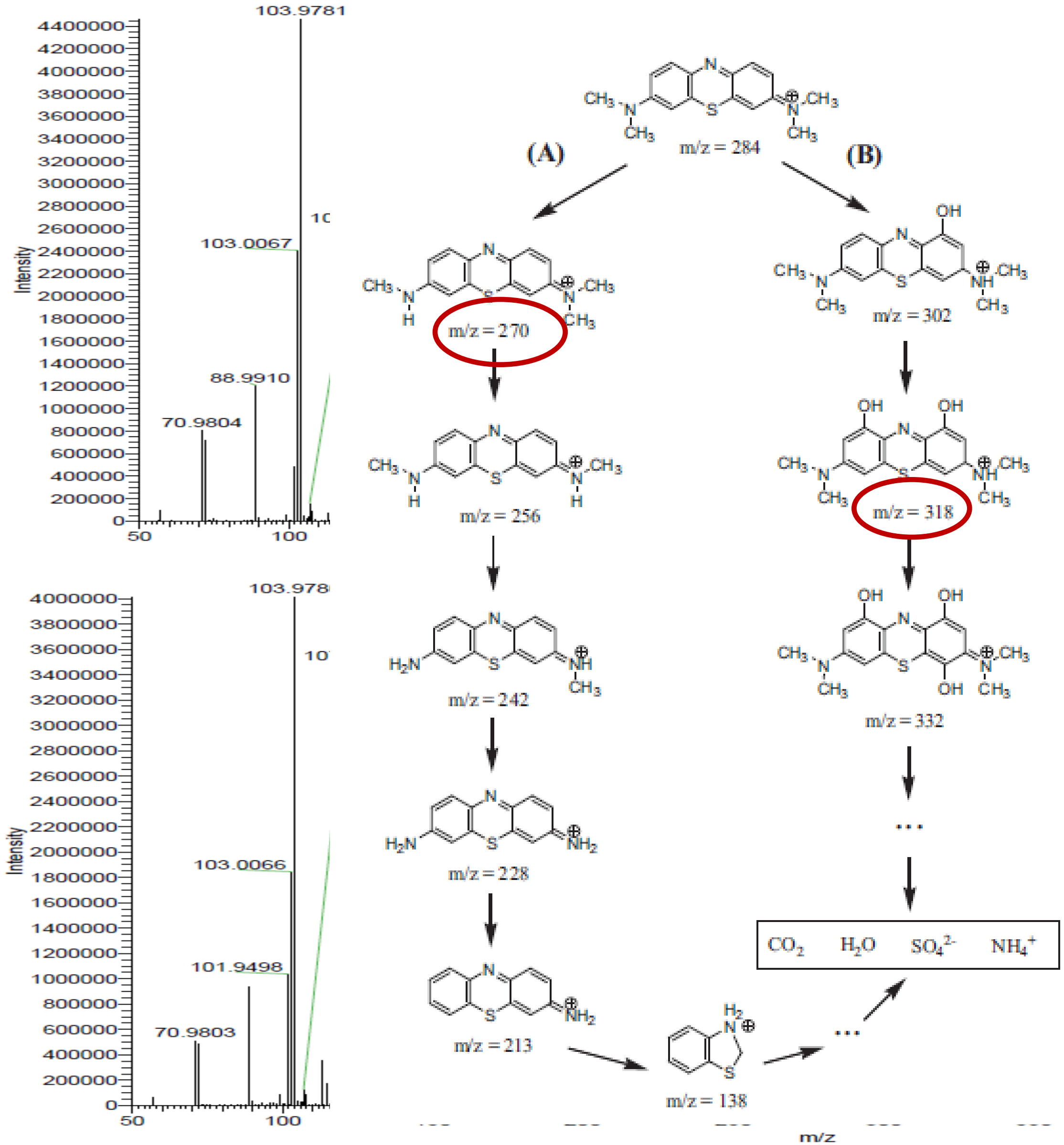
2 min



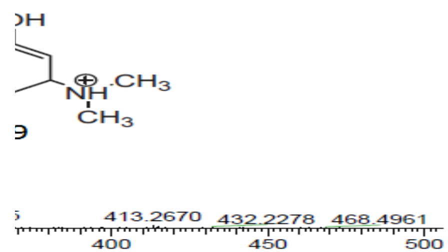
4 min



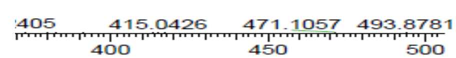
Singh et al., 2016c



6 min



10 min



Benetoli et al., 2012

Singh et al., 2016c

Technical Achievements

Rapid degradation and mineralization of Methylene blue (dye)

- **Description:**

  Investigation of PPT efficiency for the degradation of dye.

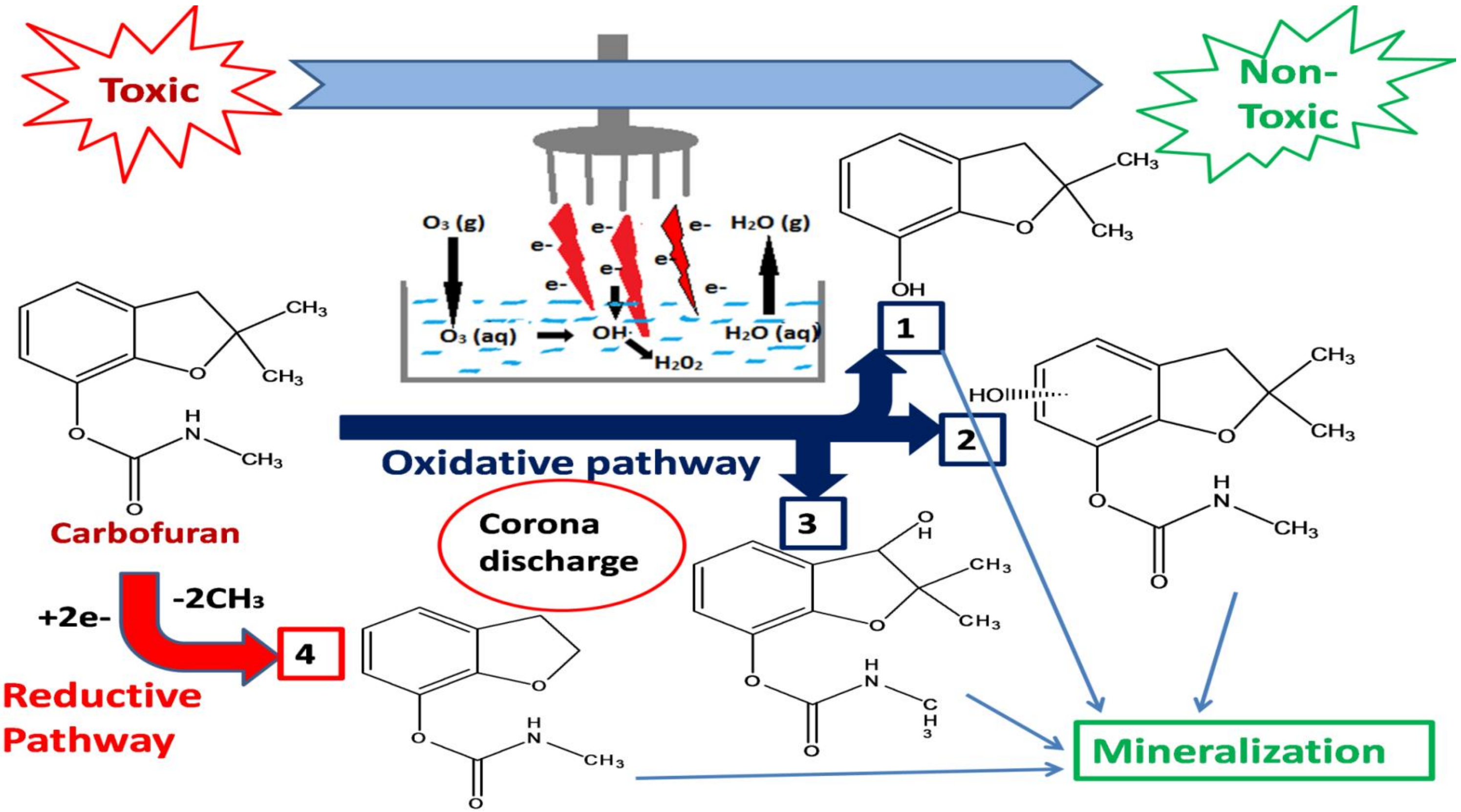
- **Novelty:**

➢ Different ROS such as $^{\cdot}OH$, H_2O_2, O_3 and $O_2^{\cdot -}$ quantification in different environmental conditions.

➢ Effect of different system parameters on treatment efficiency.

➢ Under PPT, methylene blue degradation pathway was proposed.

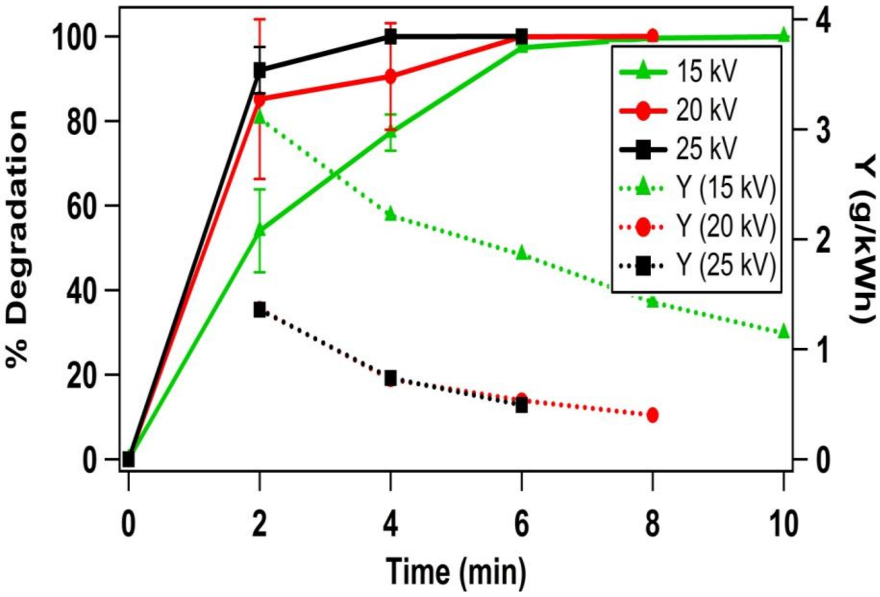
4.ECs degradation study



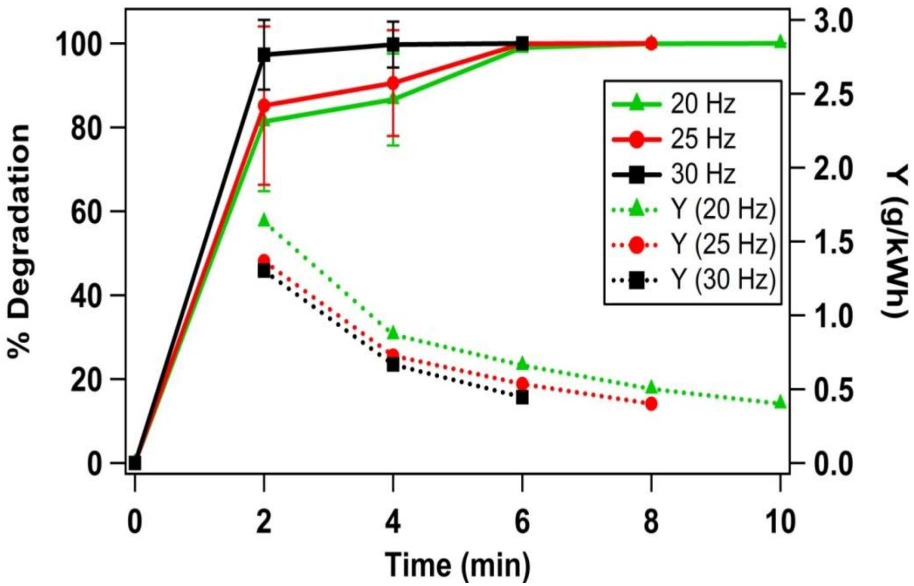
Singh Raj Kamal, **Philip Ligy**, Sarathi R., (2016), Rapid removal of carbofuran from aqueous solution by pulsed corona discharge treatment: Kinetic study, oxidative, reductive degradation pathway and toxicity assay, Ind. Engg. Chem. Res., Accepted manuscript.

Pesticide - Carbofuran

Initial Concentration – 1ppm



Voltage effect



Frequency effect

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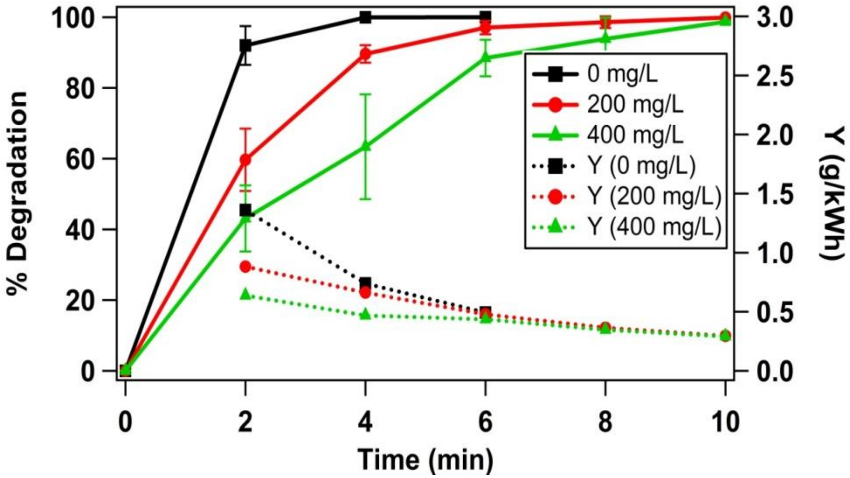
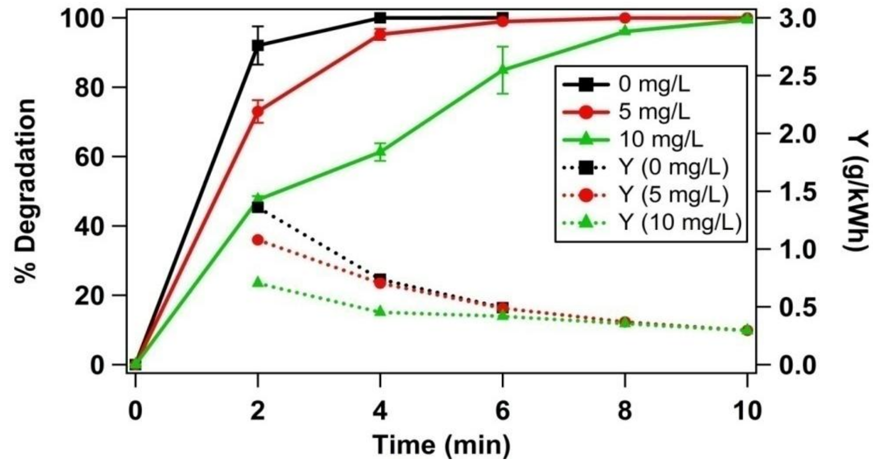
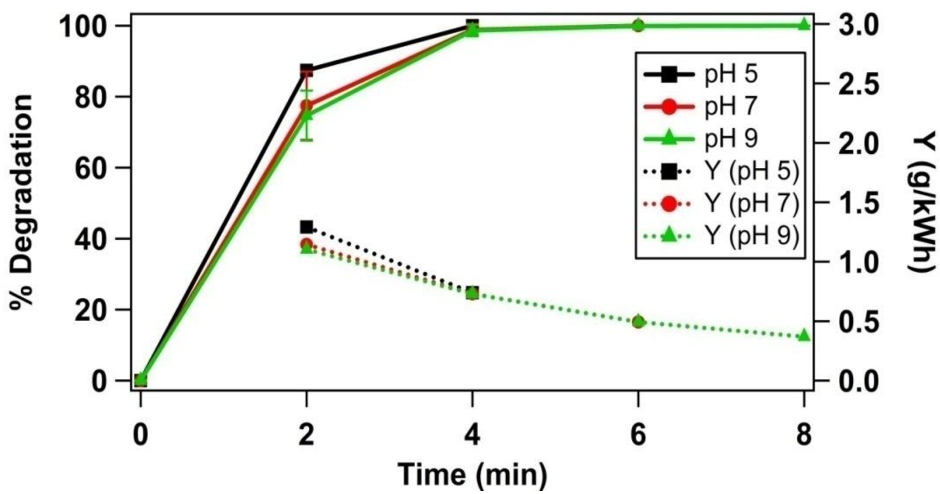
Effects of Environmental Parameters



Alkalinity



Humic acid



pH

Effect of Initial Carbofuran Concentration

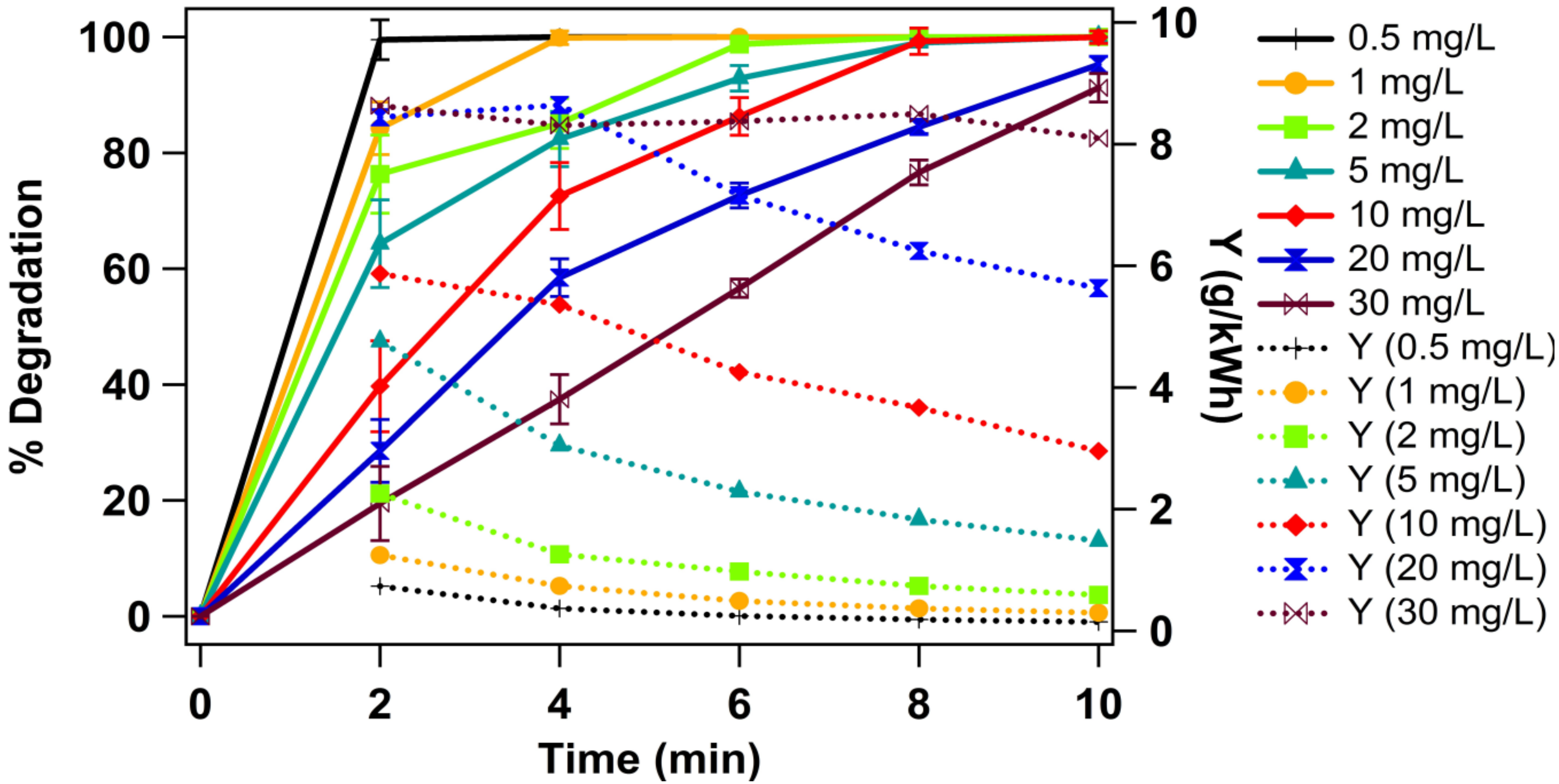


Table – Degradation kinetics of carbofuran degradation

Initial concentration (mg/L)	First order rate constant (min^{-1})	R^2	$t_{1/2}$ (min)
0.5	2.68	1.00	1.0
1	1.71	0.93	1.2
2	0.82	0.97	1.3
5	0.57	0.97	1.6
10	0.61	0.92	2.5
20	0.23	0.91	3.5
30	0.32	0.95	5.6

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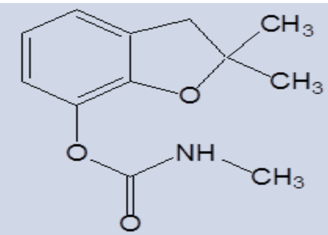
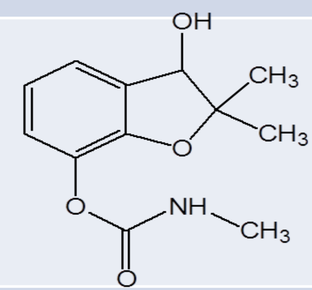
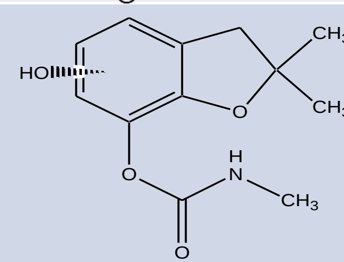
Main Carbofuran Intermediates – LC/MS analysis

Compound	Molecular mass (m/z) with Na^+ adduct	Actual molecular mass (m/z)	Chemical structure
Carbofuran	244	221	
A	260	237	
B	232	209	

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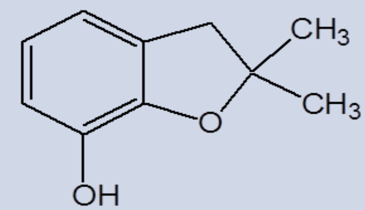
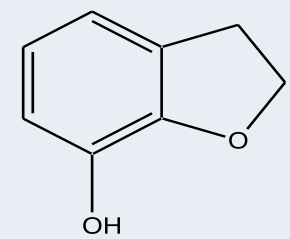
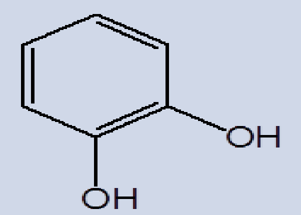
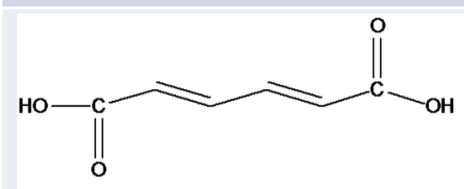
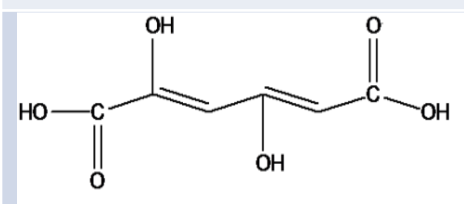
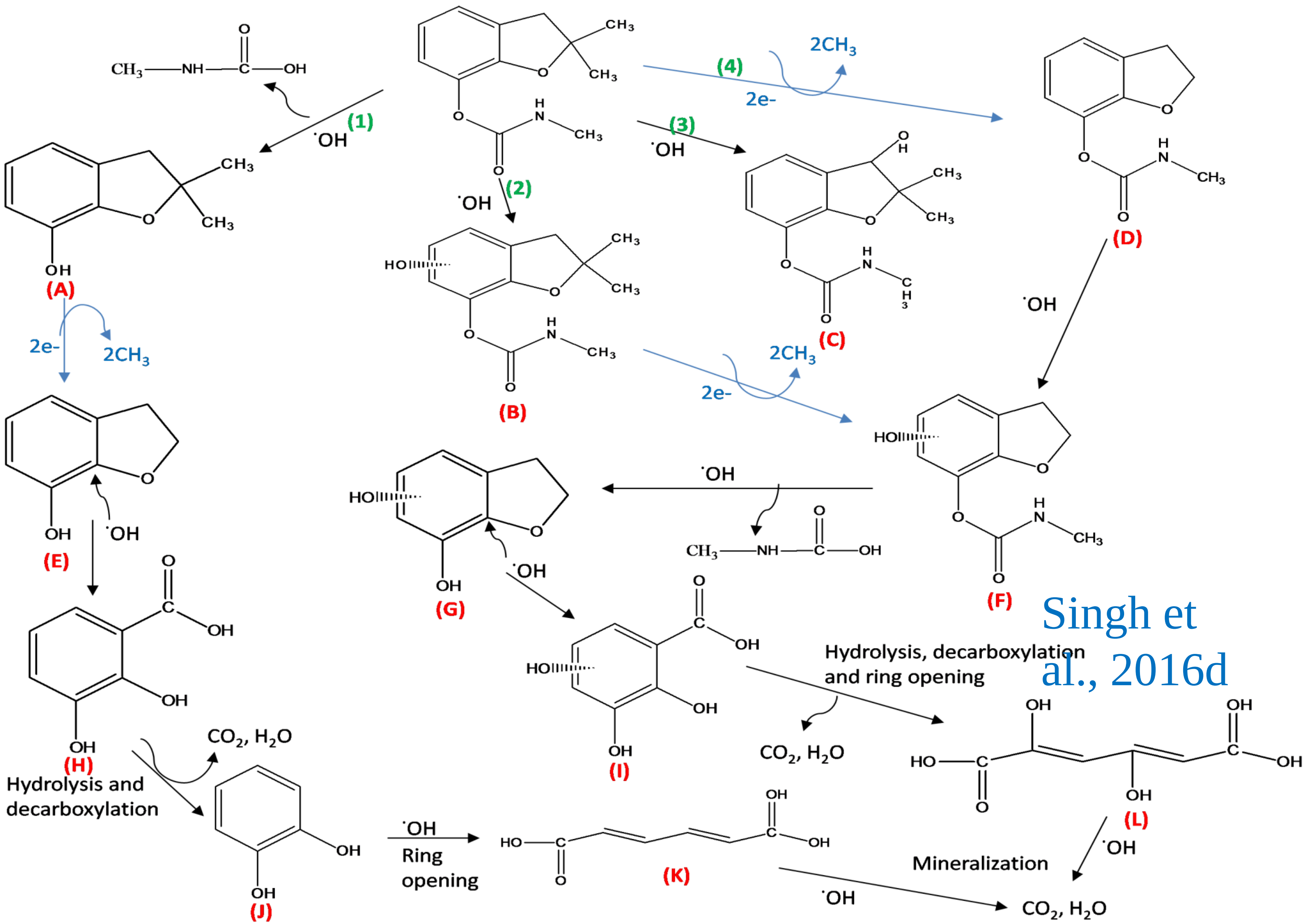
Compound	Molecular mass (m/z) with Na^+ adduct	Actual molecular mass (m/z)	Chemical structure
C	187	164	
D	159	136	
E	232	209	
F	133	110	
G	166	143	

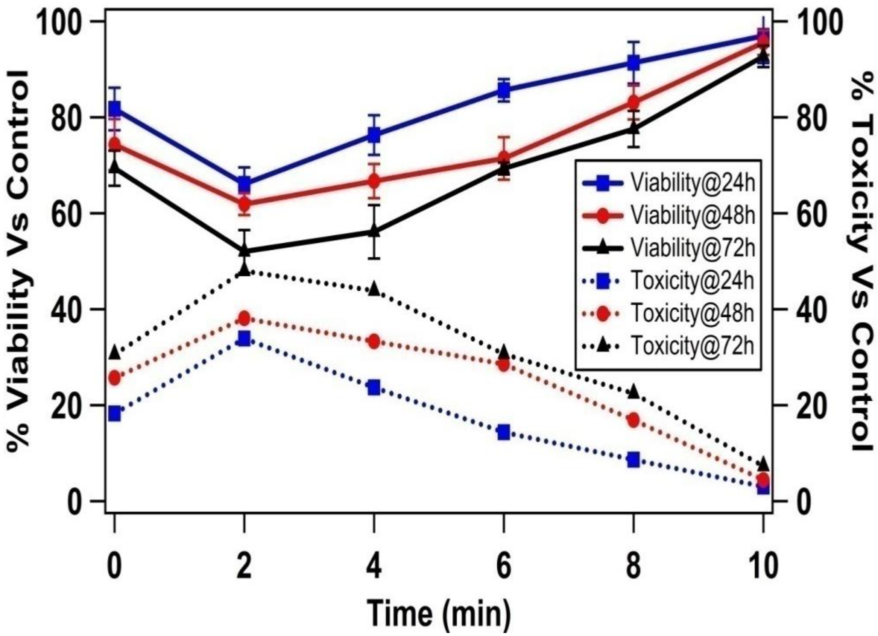
Proposed pathway for Carbofuran degradation

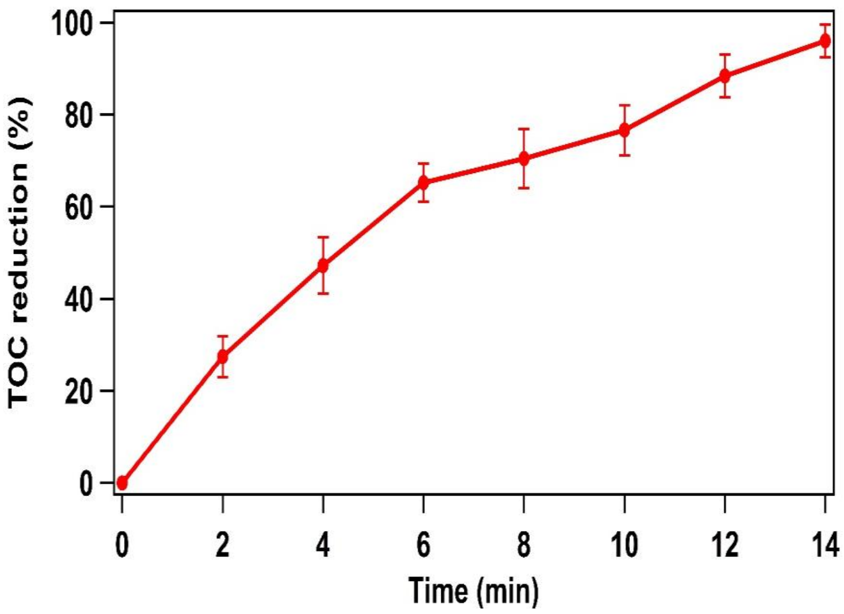


Singh et al., 2016d

Eco-toxicity assay for Carbofuran degradation

- Model Micro-alga – *Chlorella Vulgaris*





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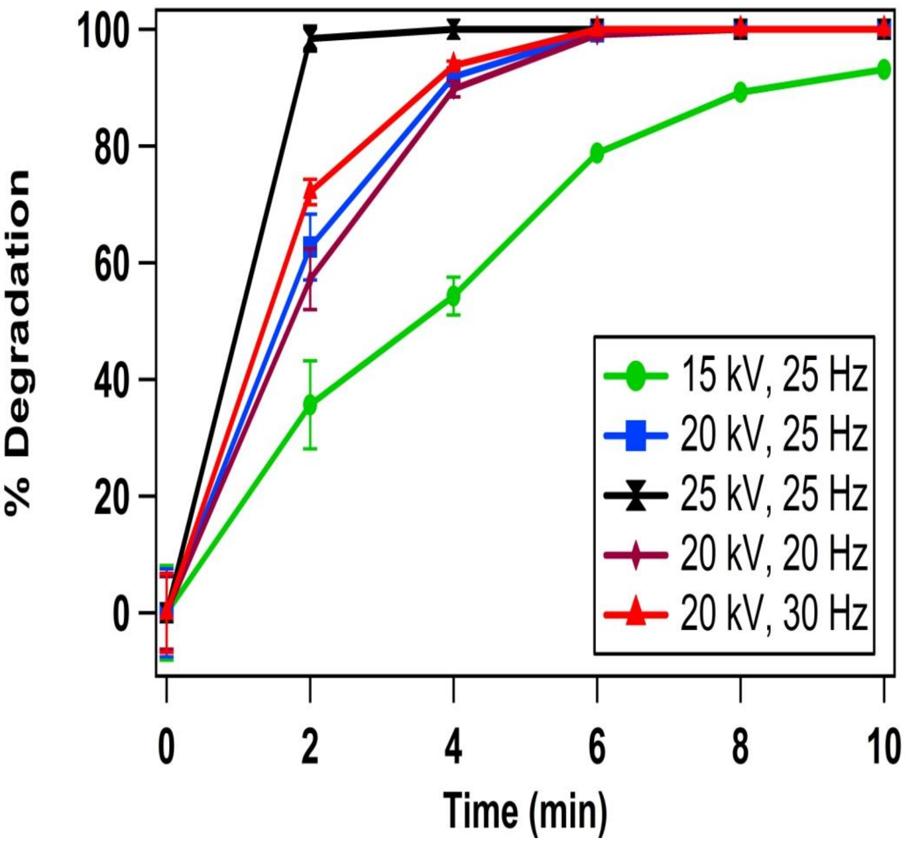
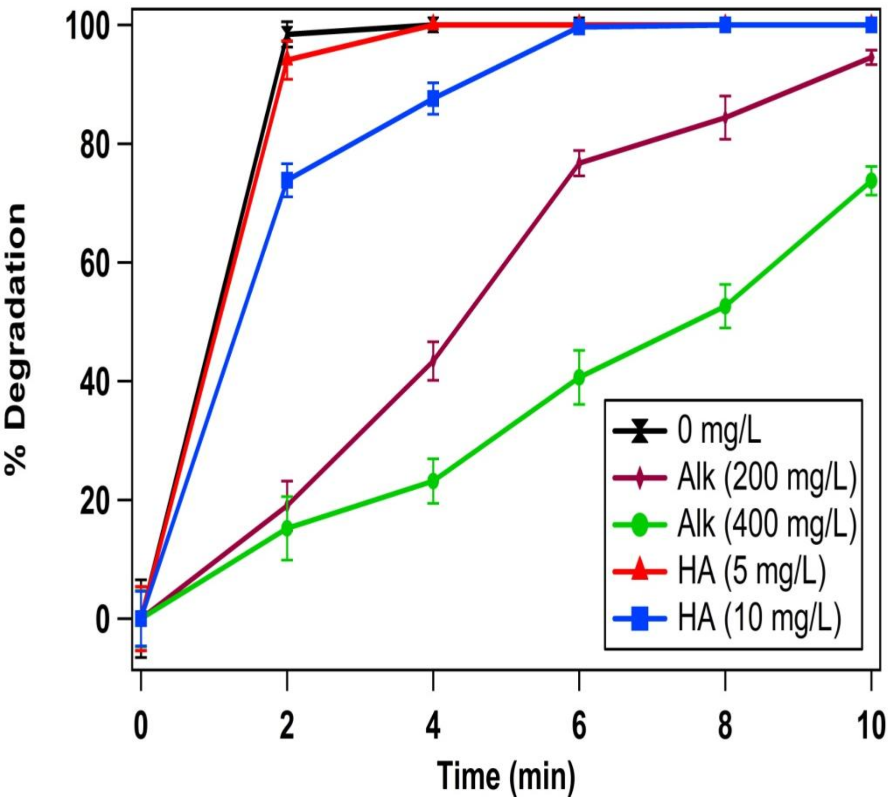
Pesticide: 2-4-D



Voltage and Frequency effect

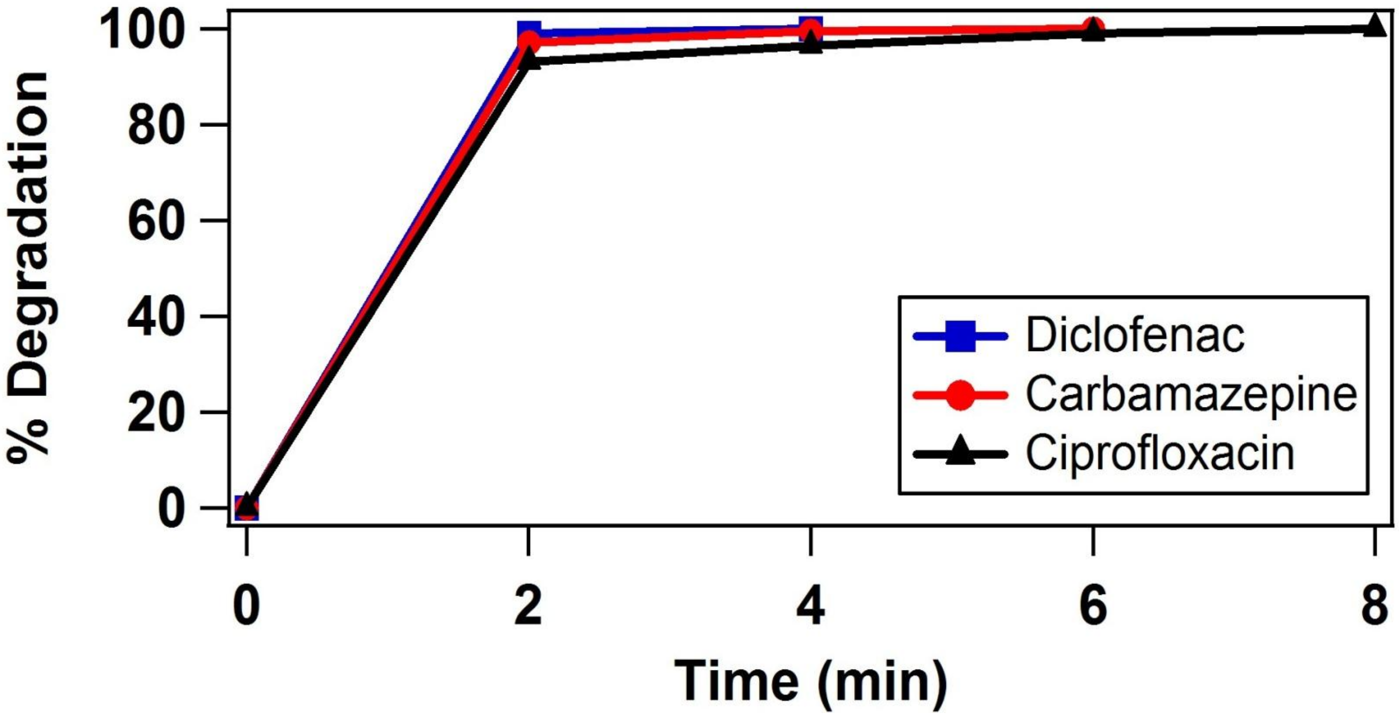


Effect of radicals quencher

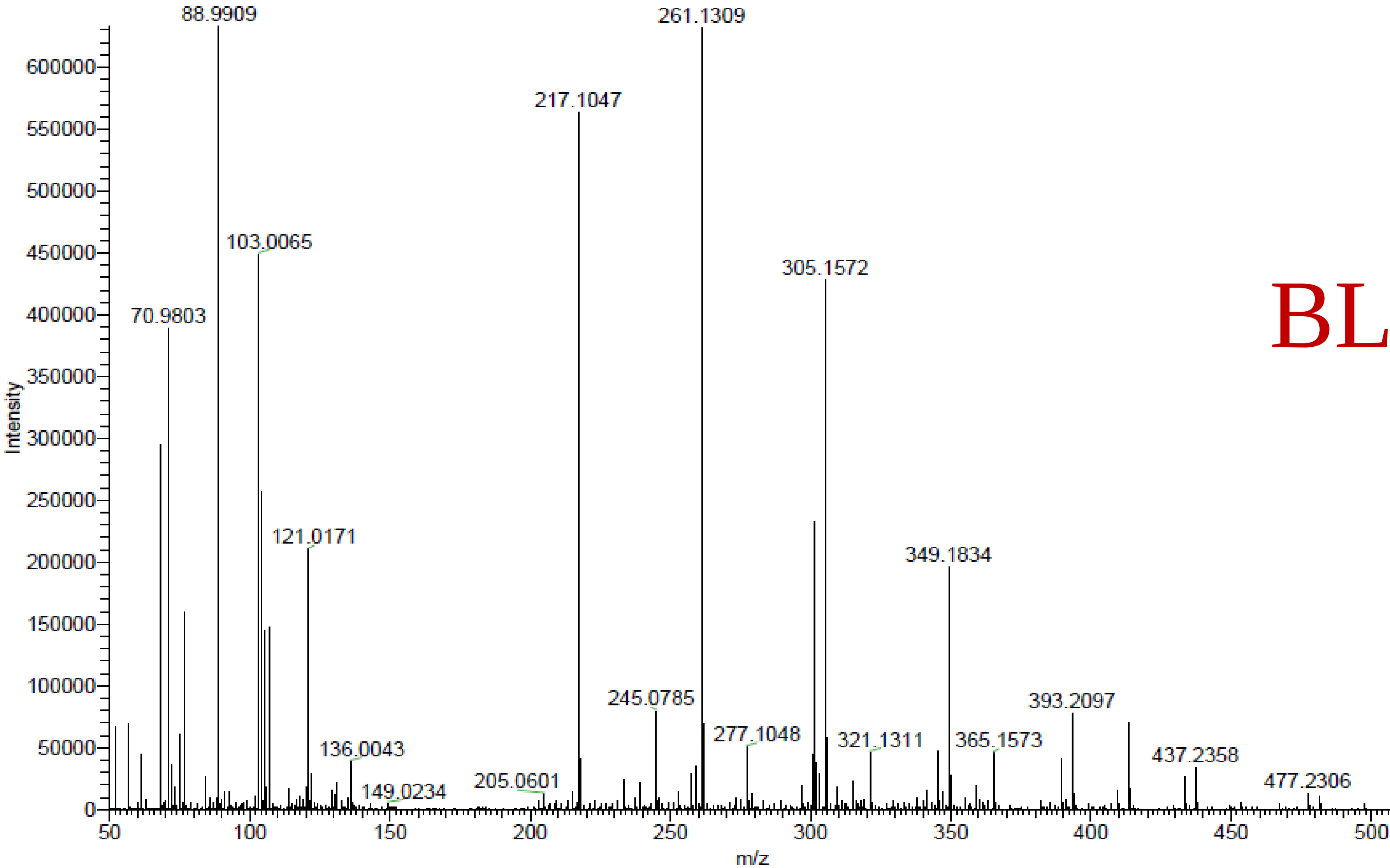
Pharmaceuticals Active Compounds (PACs)

PACs – Diclofenac, Carbamazepine and Ciprofloxacin – 1ppm

Voltage – 25 kV and Frequency – 25 Hz



LC-MS Analysis



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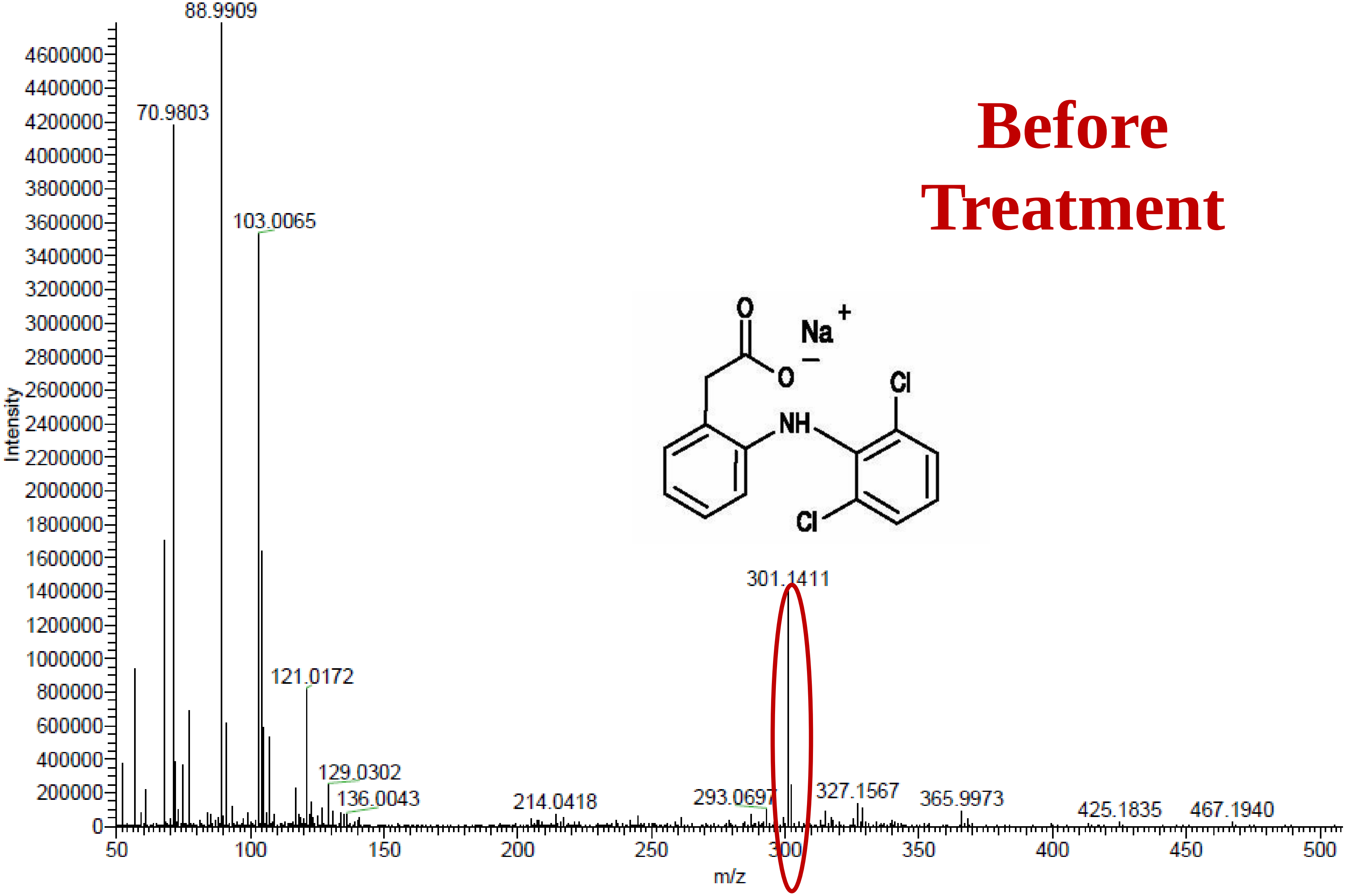
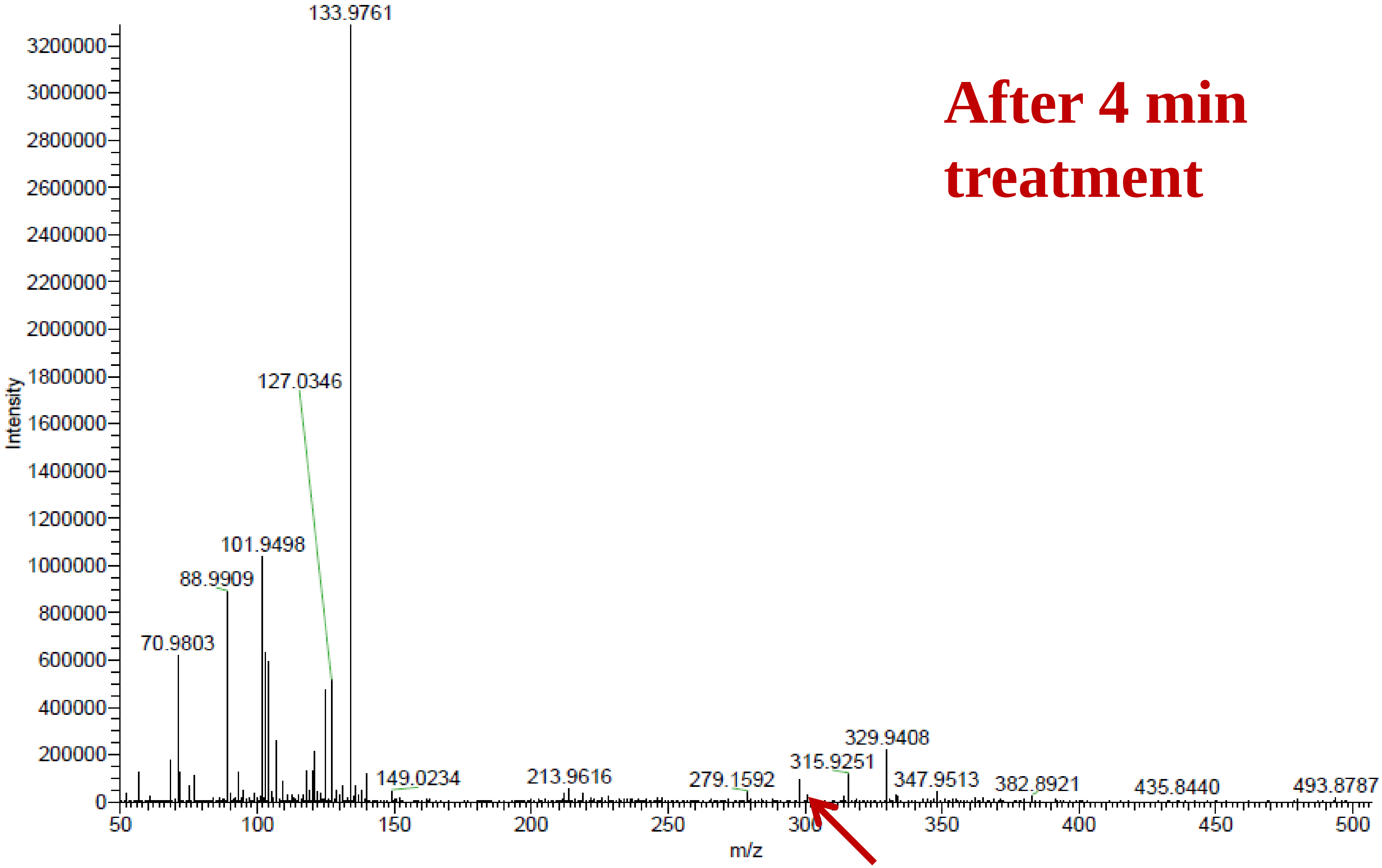
Diclofenac (DCF)

Before Treatment

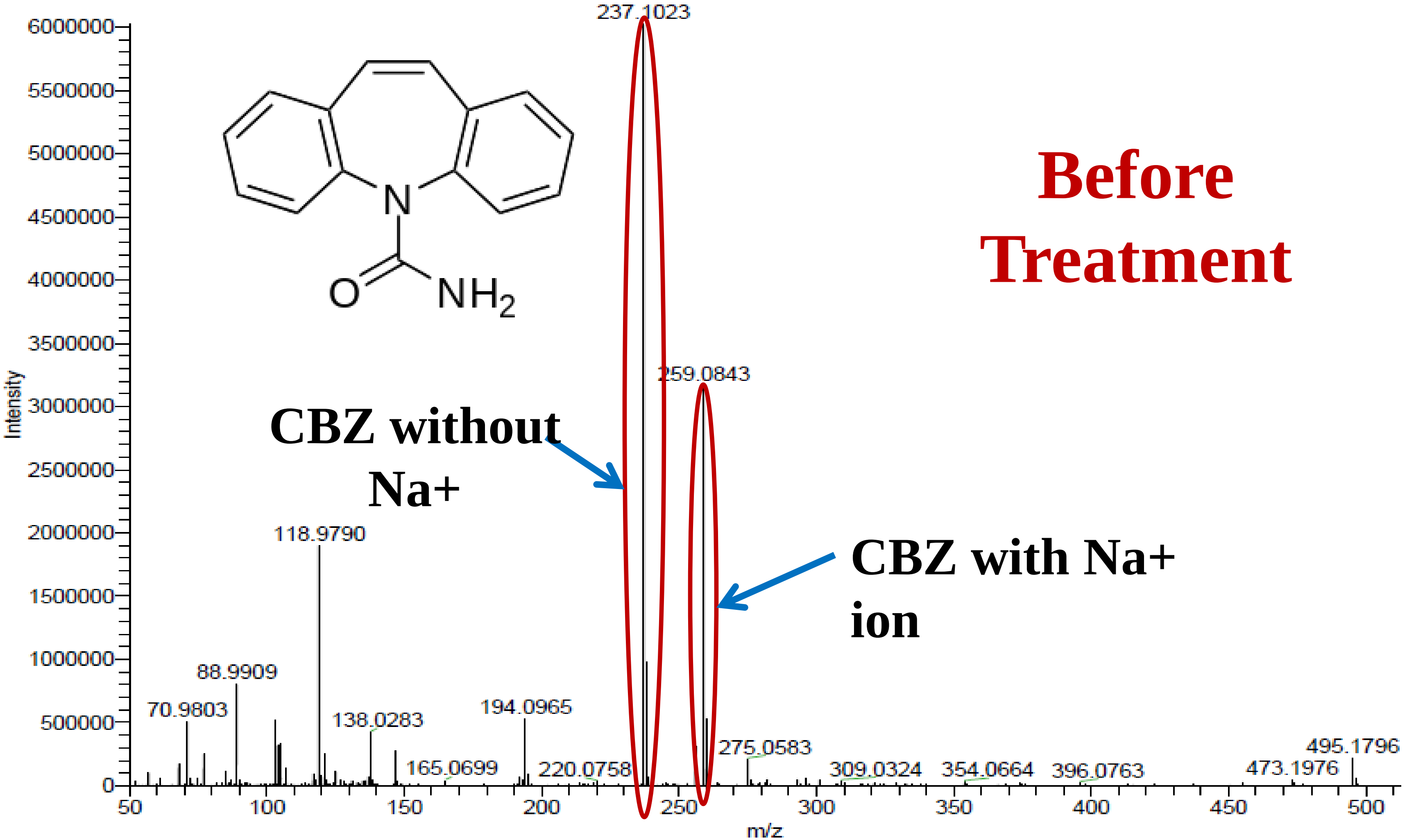


Diclofenec

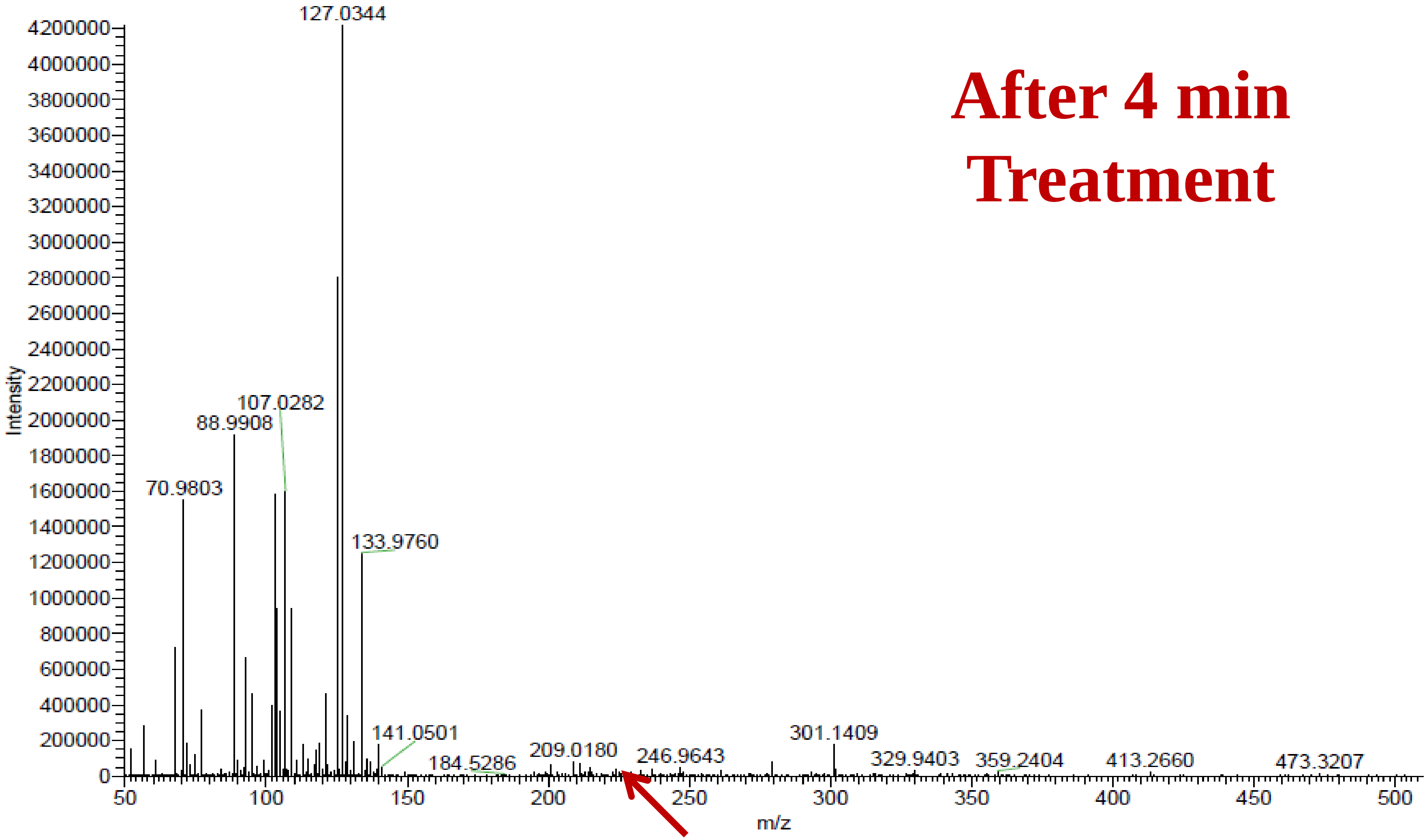


After 4 min treatment

Carbamazepine (CBZ)

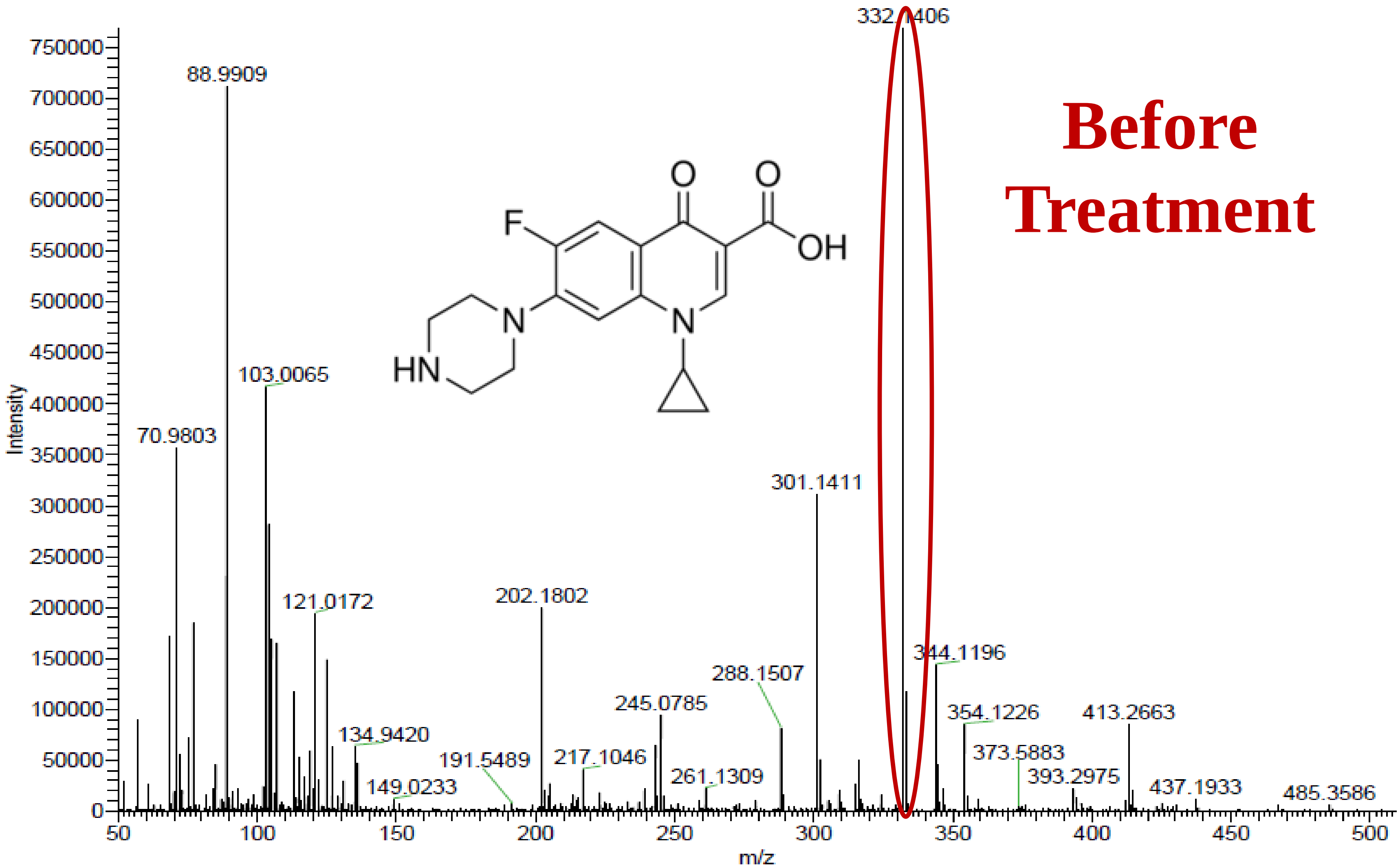


Carbamazepine

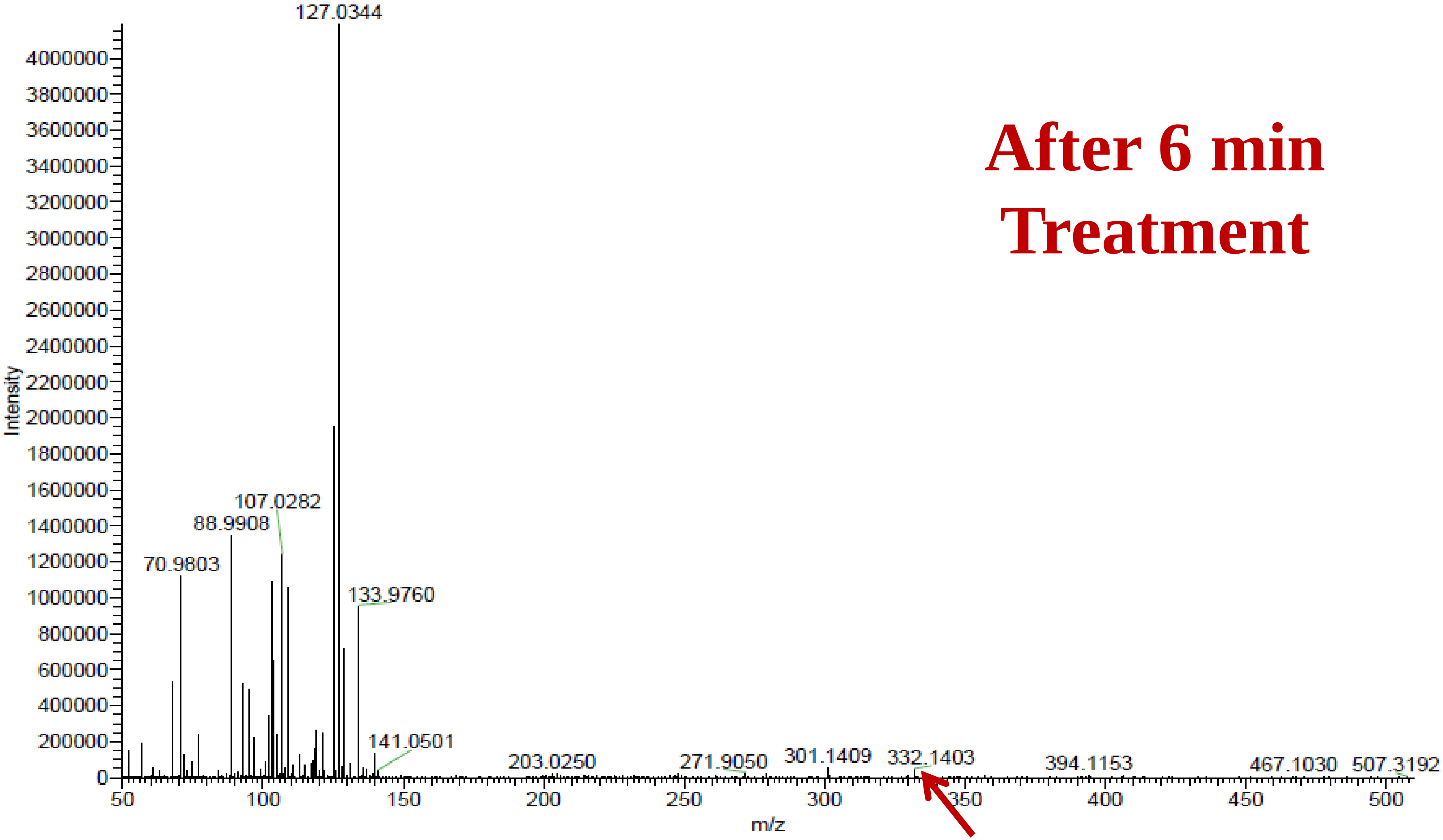


After 4 min Treatment

Ciprofloxacin (CPF)

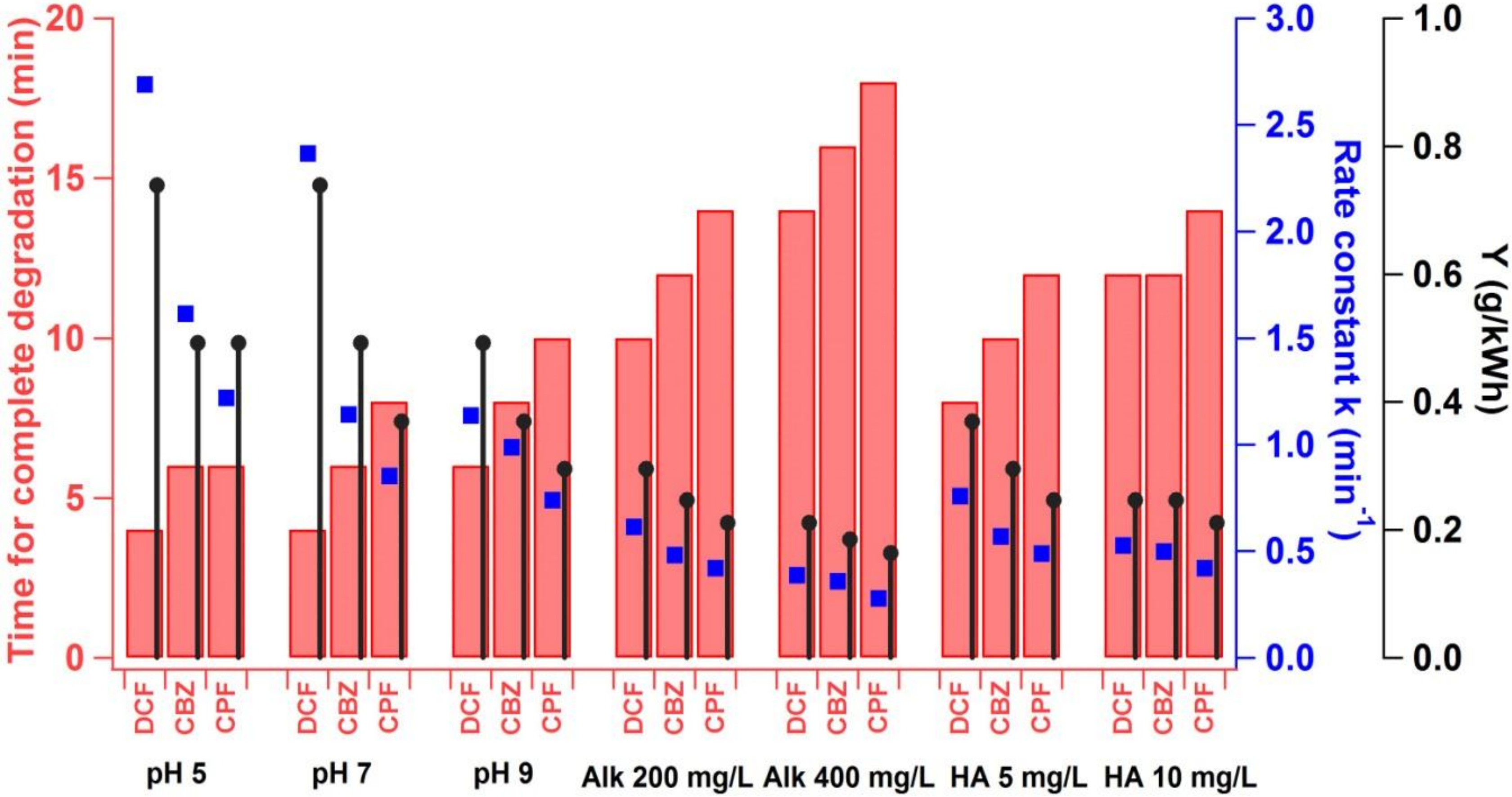


Ciprofloxacin

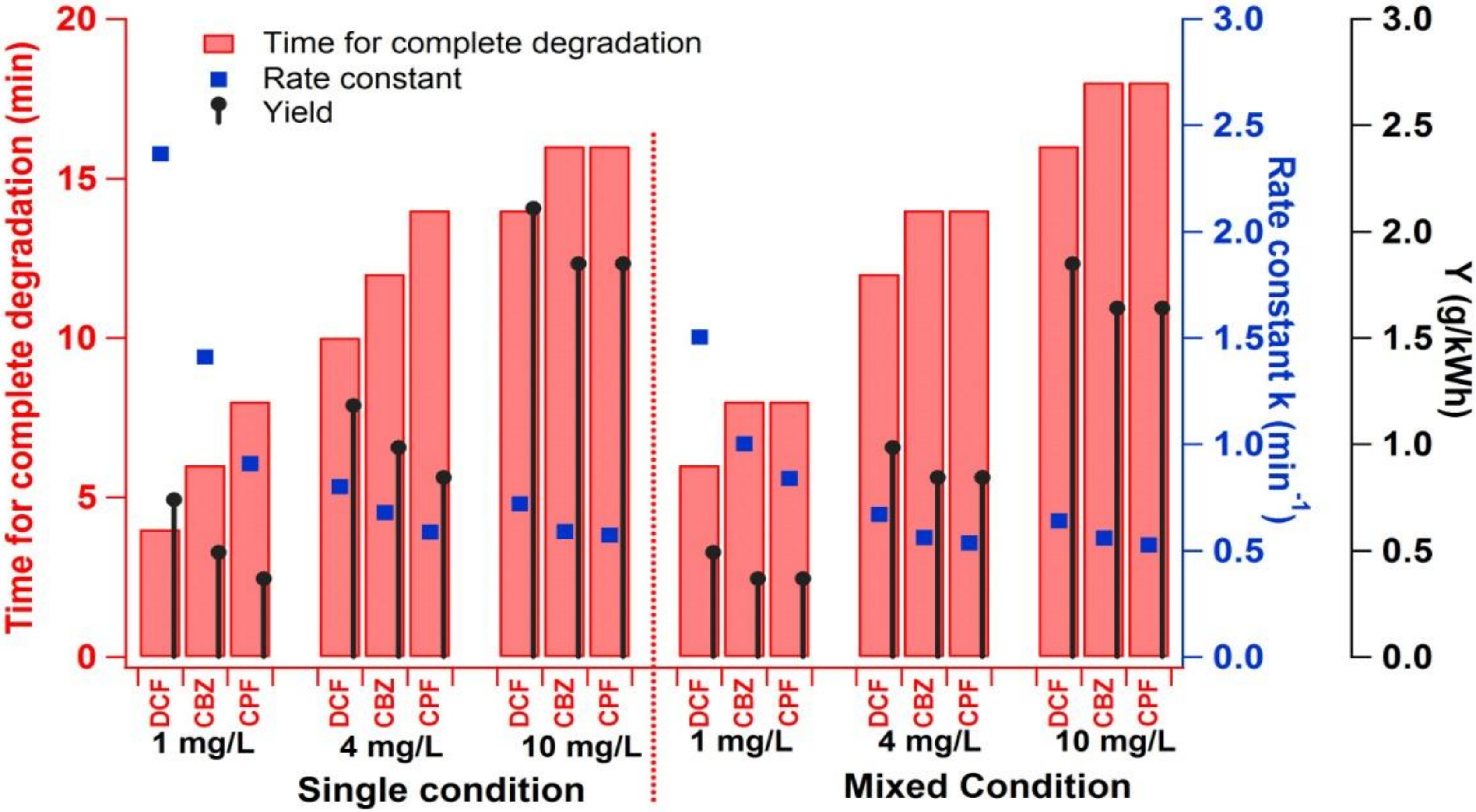


After 6 min Treatment

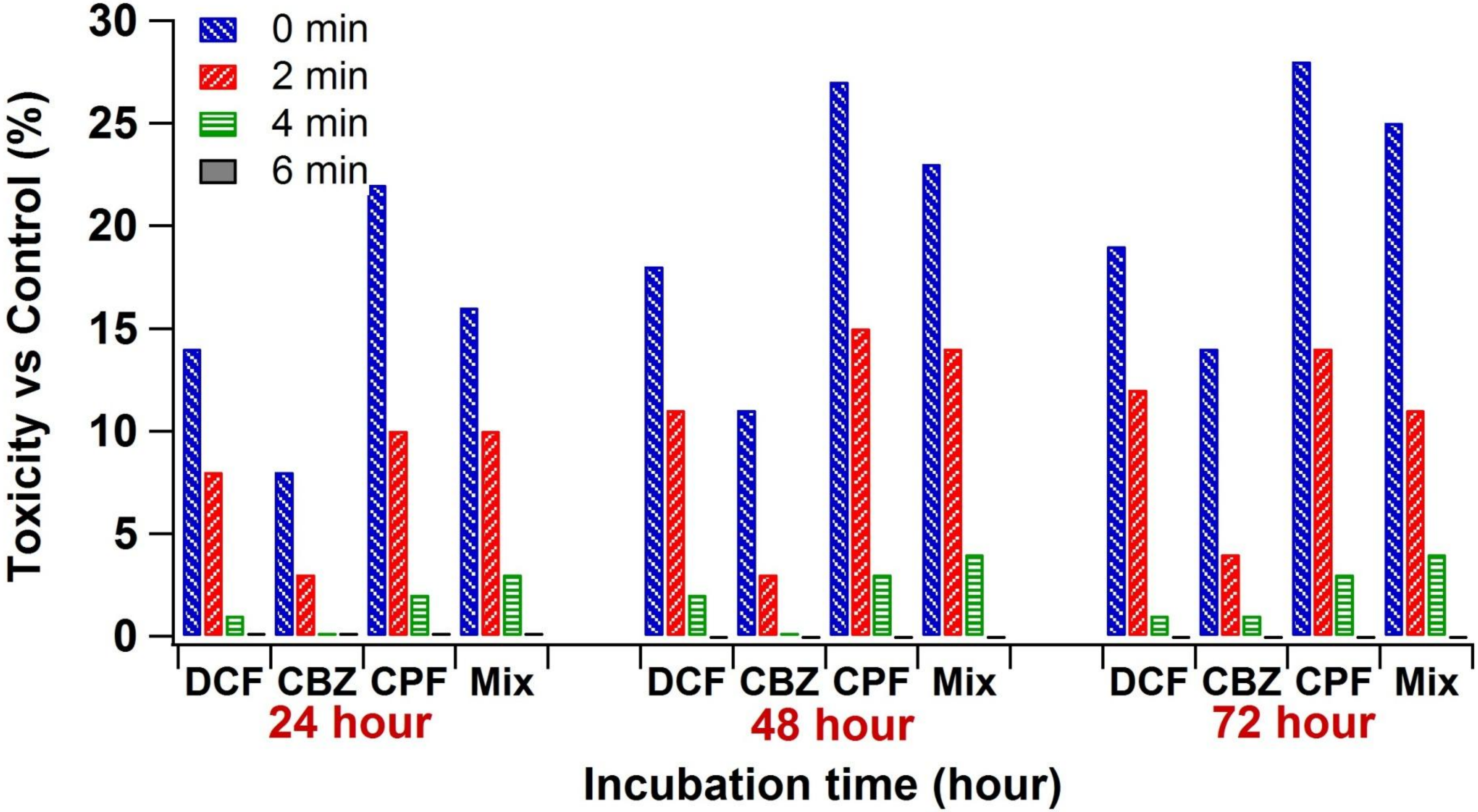
Effect of pH and radical scavengers



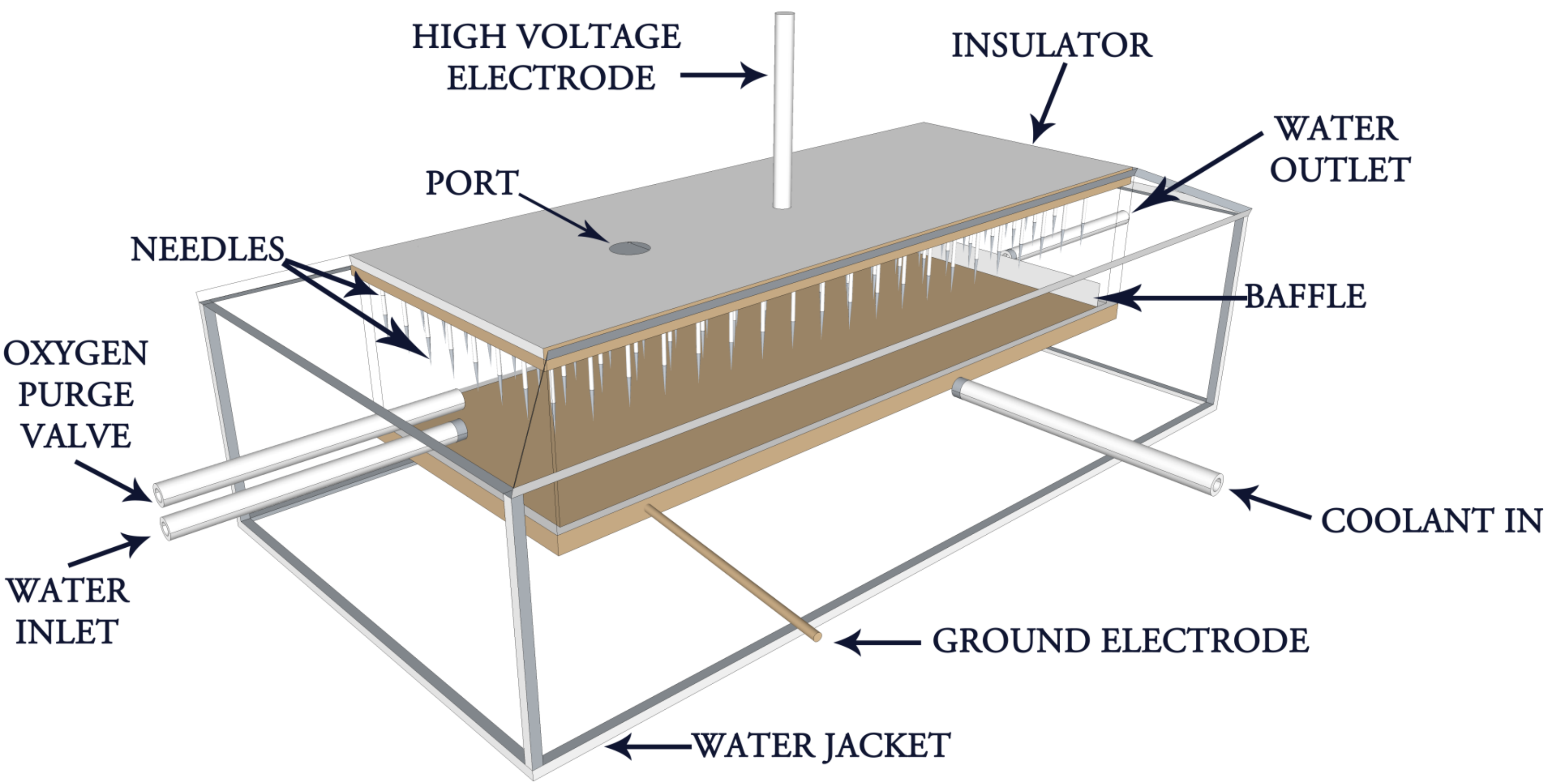
Single and mixed pollutant degradation



Toxicity assay



5. Continuous Reactor study

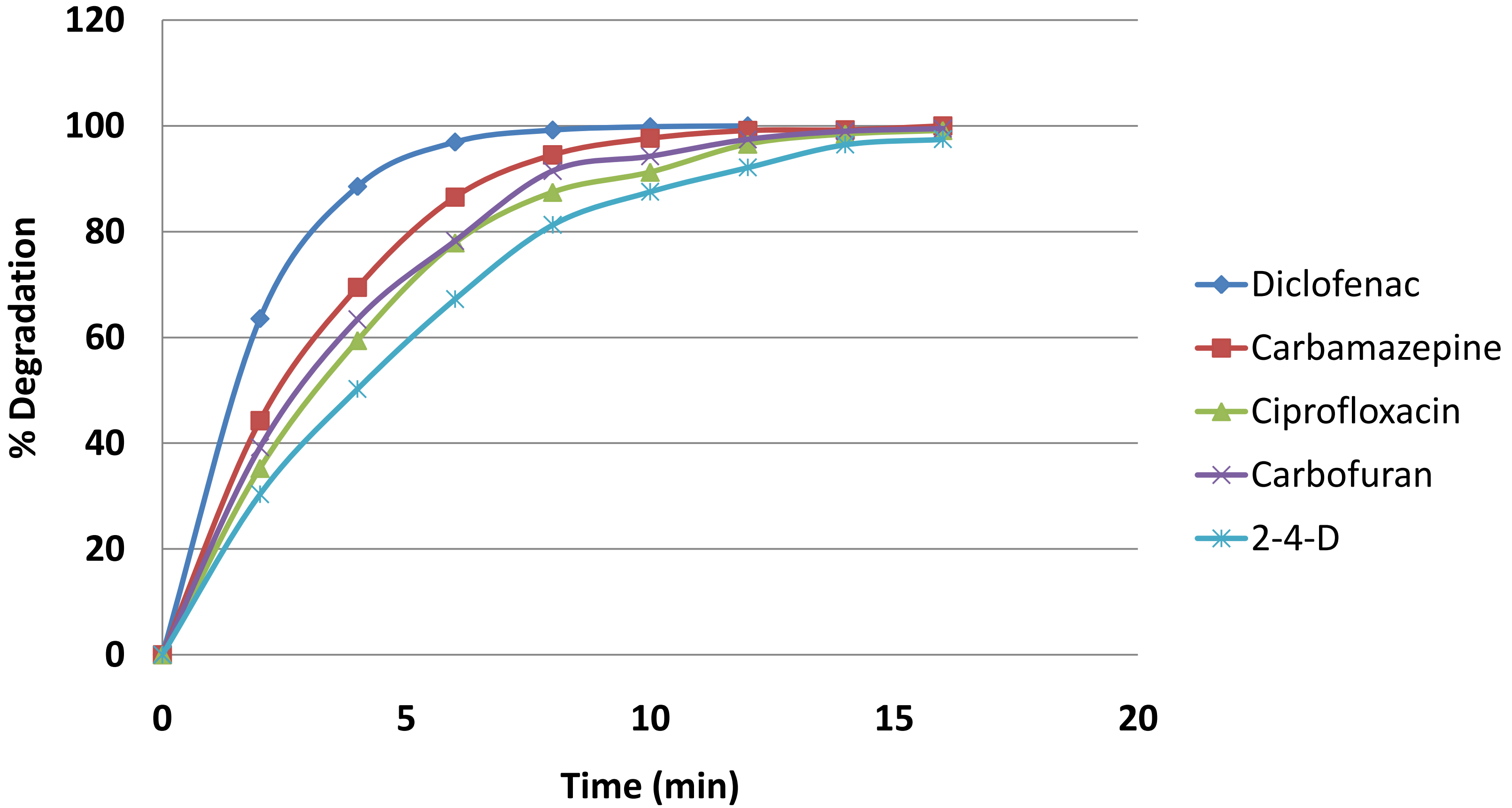


Continuous Reactor

- Reaction volume – 29 cm x 19 cm x 0.5 cm
- Spacing between the needles = 2 cm (optimized in batch reactor)
- Optimized flow rate = 10 mL/min

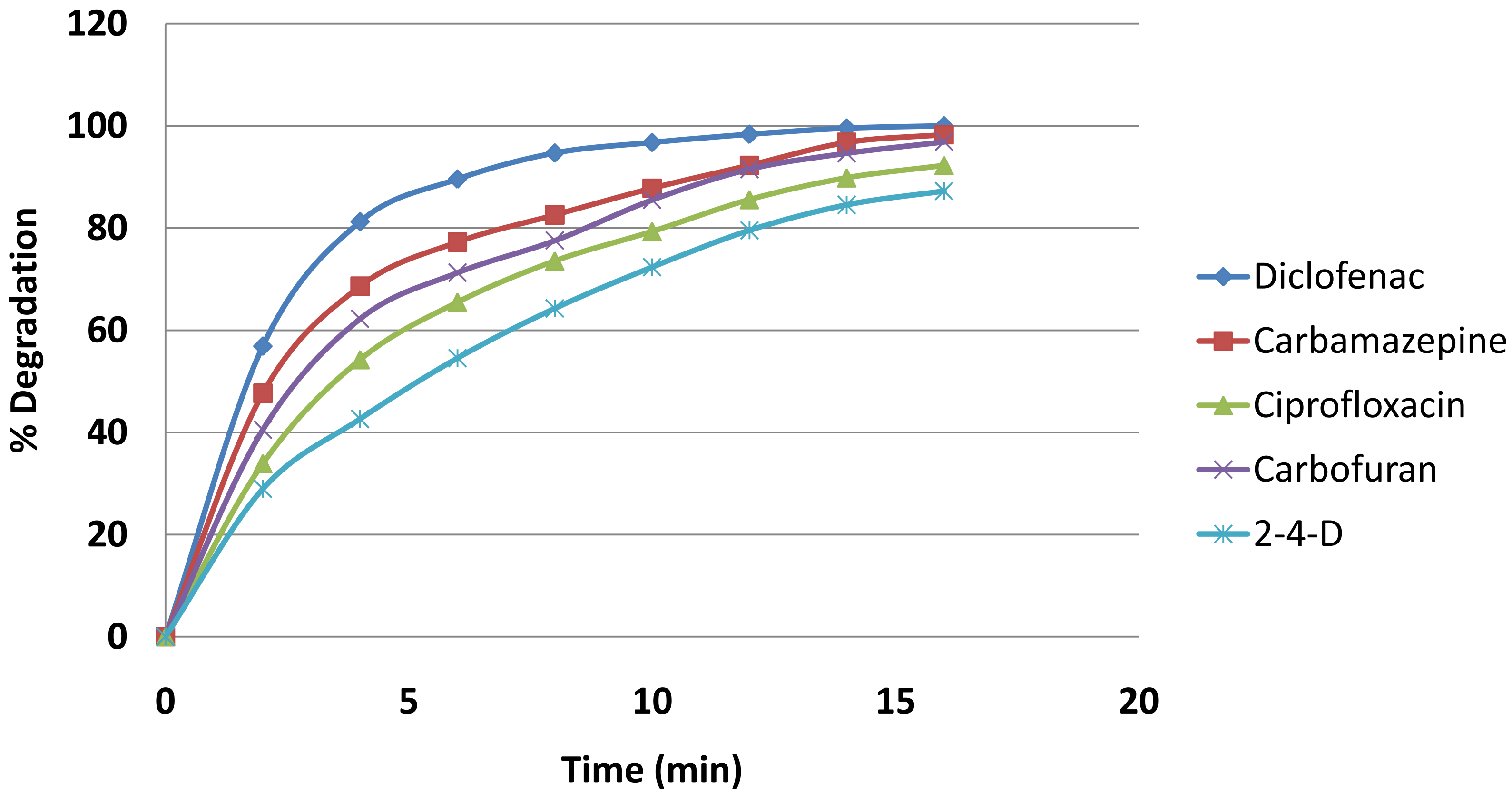
ECs degradation study

- Initial concentration – 1ppm



ECs degradation study

- Initial conc. – 10 ppm



Summary/Conclusion

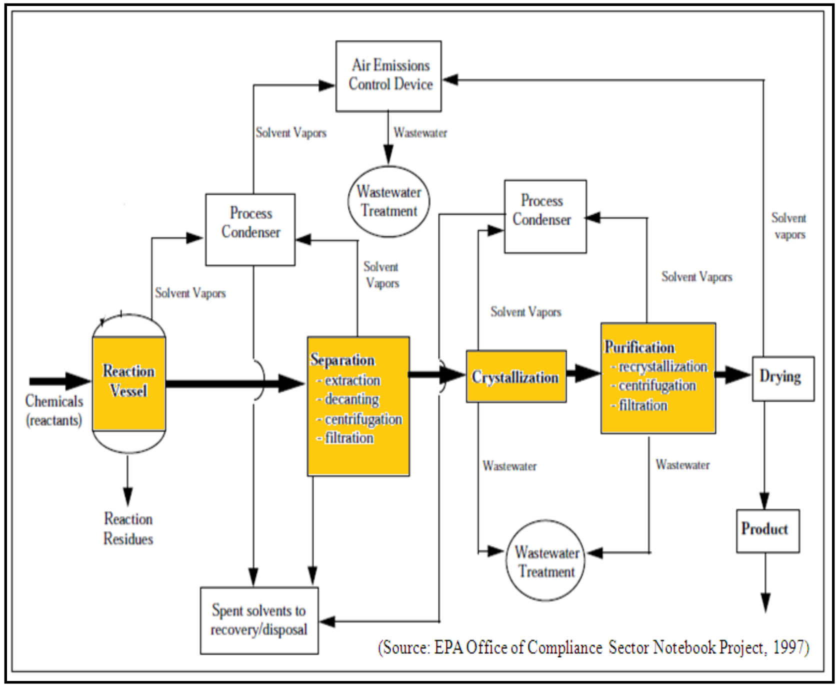
- Different ROS such as $^{\cdot}OH$, H_2O_2, O_3 and $O_2^{\cdot -}$ quantification in different environmental conditions.
- Effect of different time mode on disinfection efficiency.
- Combined effect of system parameters on disinfection efficiency and empirical model development.
- Understanding the bacterial disinfection mechanism in PPT.
- Study on dye degradation and its fate in PPT process.

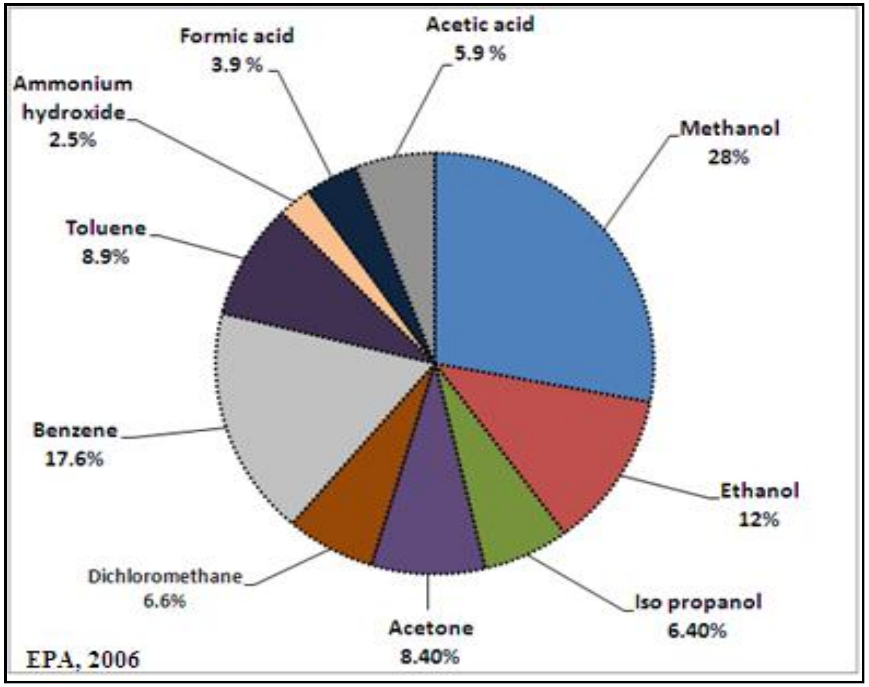
Summary/Conclusion

- Complete degradation of ECs (Carbofuran, 2-4-D, DCF, CBZ and CPF) was achieved within 4 to 6 min treatment time in batch study.
- Environmental parameters significantly affect the degradation efficiency.
- Possibility of Reductive pathway in plasma technology – not only oxidative pathway.
- Complete mineralization and detoxification of ECs was achieved.
- Continuous reactor – design and efficiency was evaluated.

Development and Performance Evaluation of a Hybrid Treatment System for the Complete Treatment of Pharmaceutical Wastewater

INTRODUCTION





PROCESS IN PHARMACEUTICAL INDUSTRY

DISTRIBUTION OF VOLATILE SOLVENTS IN WASTEWATER

MAJOR PROBLEM : VOC emissions during the treatment of pharmaceutical wastewater.

LIMITATION OF EXISTING TREATMENT SYSTEMS

❑ **Only focus on removal of organic pollutants** ❑ **Emission of VOC is not accounted**	Saravanane et al., 2001; Ince et al., 2002 Raj and Anjaneyulu, 2005

MOTIVATION

"Reduction of VOC emission from the treatment units"

LIMITATIONS IN EXISITING TREATMENT SYSTEM FOR REMOVAL OF VOC

- Individual pollutant study
- Degradation of VOC at low concentration
- No focus on the reduction of VOC emission from bioreactors

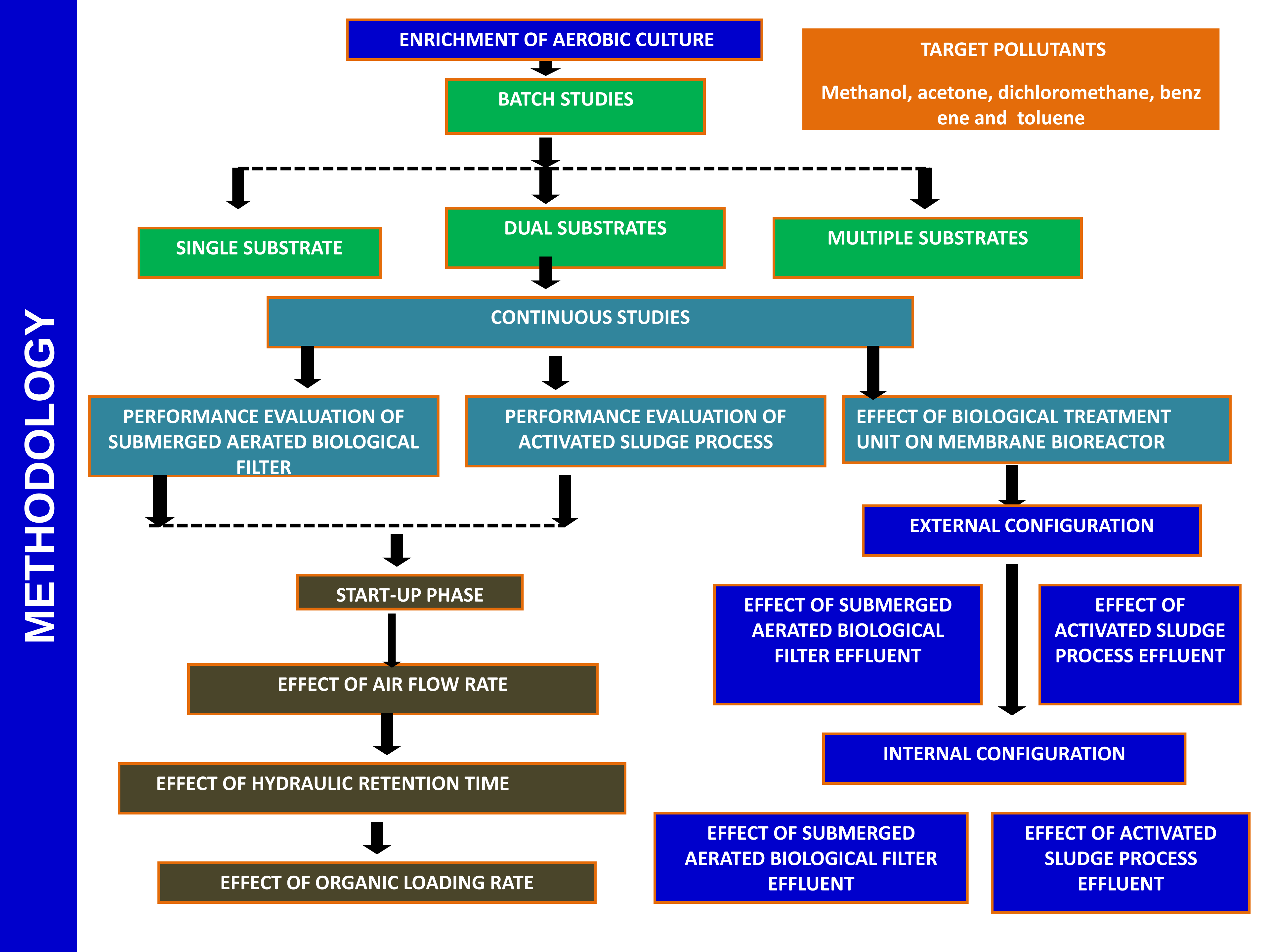
Cattony et al., 2005
Quesnel and Nakhla, 2005
Ozdemir et al., 2010
Dawery, 2013

Presence of high biomass is reported to reduce VOC emissions

- **Submerged aerated biological filter (SABF) and Membrane bioreactor (MBR)**

  (Cheng , 2009; Min and Ergas, 2006)

- Need to evaluate the performance **SABF** to treat mixture of VOC
- Effect of operational parameters like air flow rate, hydraulic retention time (HRT) and organic loading rate (OLR) on VOC emission is an area to be explored
- Feasibility of **Membrane bioreactor** as a post treatment unit and its potential to reduce VOC emission is an area to be explored


METHODOLOGY
ENRICHMENT OF AEROBIC CULTURE
TARGET POLLUTANTS
Methanol, acetone, dichloromethane, benz ene and toluene
BATCH STUDIES
SINGLE SUBSTRATE
DUAL SUBSTRATES
MULTIPLE SUBSTRATES
CONTINUOUS STUDIES
PERFORMANCE EVALUATION OF SUBMERGED AERATED BIOLOGICAL FILTER
PERFORMANCE EVALUATION OF ACTIVATED SLUDGE PROCESS
EFFECT OF BIOLOGICAL TREATMENT UNIT ON MEMBRANE BIOREACTOR
EXTERNAL CONFIGURATION
EFFECT OF SUBMERGED AERATED BIOLOGICAL FILTER EFFLUENT
EFFECT OF ACTIVATED SLUDGE PROCESS EFFLUENT
INTERNAL CONFIGURATION
EFFECT OF SUBMERGED AERATED BIOLOGICAL FILTER EFFLUENT
EFFECT OF ACTIVATED SLUDGE PROCESS EFFLUENT
START-UP PHASE
EFFECT OF AIR FLOW RATE
EFFECT OF HYDRAULIC RETENTION TIME
EFFECT OF ORGANIC LOADING RATE

BATCH STUDY

POLLUTANTS IN UNTREATED PHARMACEUTICAL WASTEWATER IN INDIA

Methanol (2500–3000 mg/L) , Acetone (500 mg/L – 1000 mg/L), Benzene and toluene (400–700 mg/L), Dichloromethane (120 - 380 mg/L)

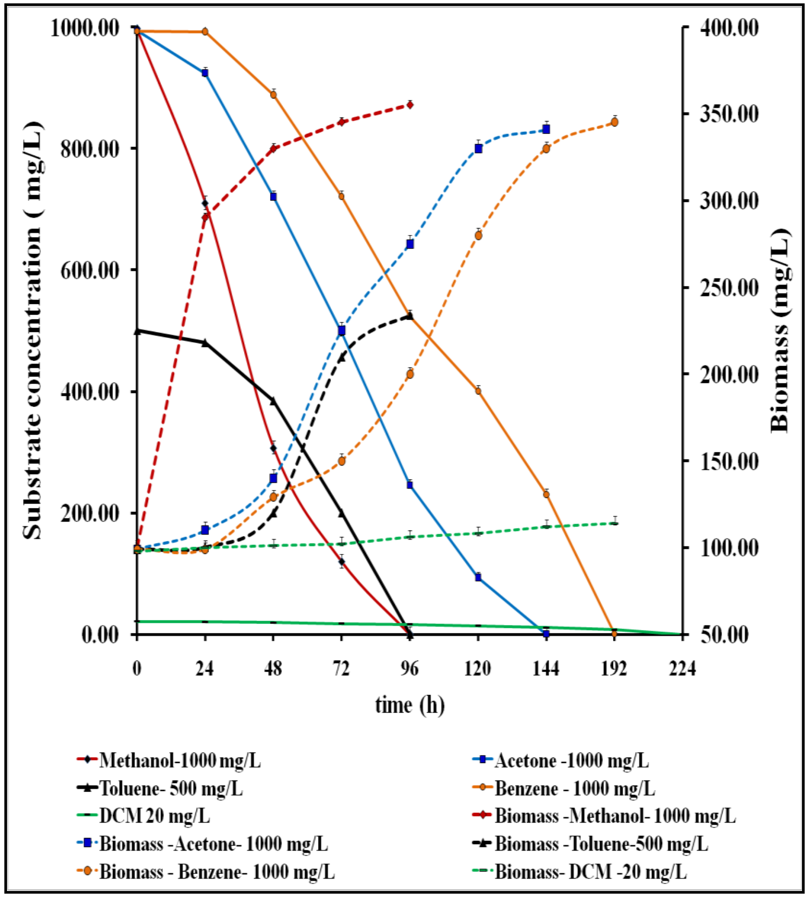
(Gupta et al., 2005, Virnig et al., 2003)

Studies with single substrate biodegradation		
Methanol, acetone , benzene	Toluene	Dichloromethane (DCM)
100, 300, 500, 700 and 1000 mg/L	100, 300 and 500 mg/L	10 and 20 mg/L
Dual substrate interaction studies with dichloromethane		
Low concentration studies	**High concentration studies**	
Methanol- DCM / Acetone- DCM Benzene- DCM/ Toluene- DCM Non chlorinated solvent ~ 100 mg/L , DCM ~ 50mg/L	Methanol- DCM / Acetone- DCM Benzene- DCM/ Toluene- DCM Non chlorinated solvent ~ 1000 mg/L, DCM ~ 50mg/L	
Multiple Substrate Interaction studies		
In the absence and presence of Dichloromethane	Mixture of methanol, acetone, benzene dichloromethane and toluene at equal concentration (50, 100, 200 mg/L)	

RESULTS

BATCH BIODEGRADATION RESULTS

SINGLE SUBSTRATE DEGRADATION



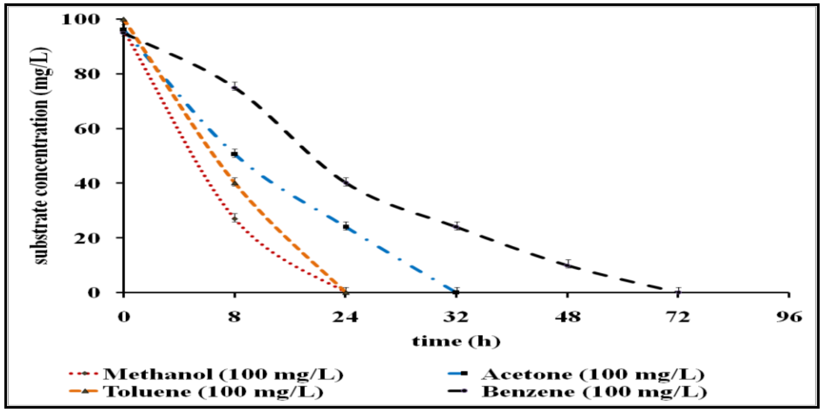
- Degradation of Non chlorinated pollutants were faster
- Dichloromethane was observed to recalcitrant to biodegradation
- *Burkholderia kururiensis* and *Bacillus cereus* were predominant species.
- Monod inhibition model predicted single pollutant biodegradation

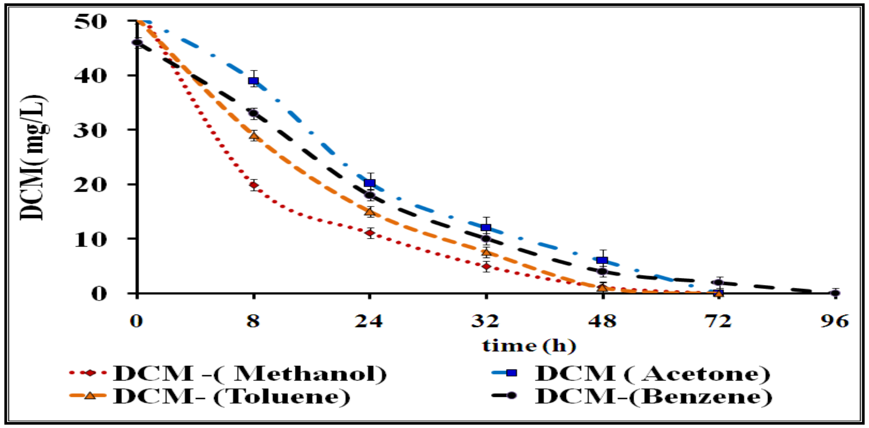
Priya, V.S., Philip, L. (2013). Biodegradation of Dichloromethane along with other VOCs from Pharmaceutical wastewater. *Applied Biochemistry and Biotechnology.* 169, 1197–1218.

RESULTS

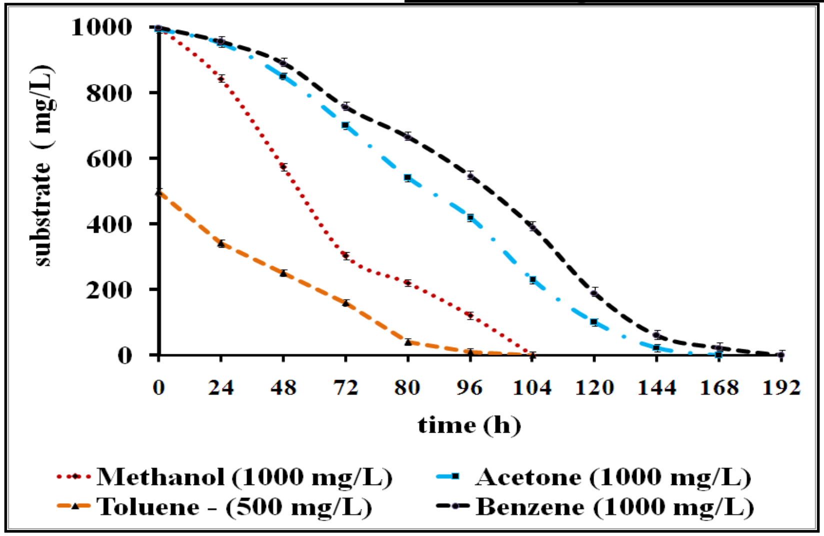
DUAL SUBSTRATE INTERACTION STUDIES

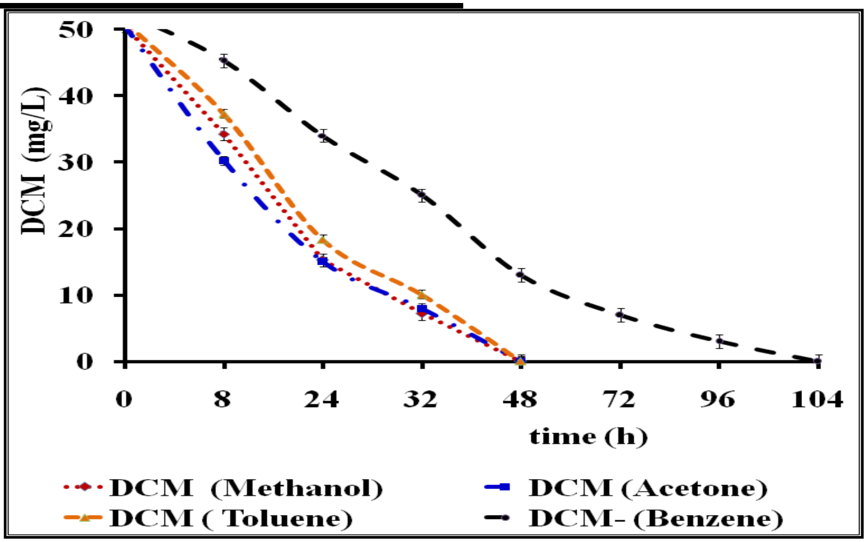
Degradation of 50 mg/L of dichloromethane in the presence of 100 mg/L of non chlorinated solvents





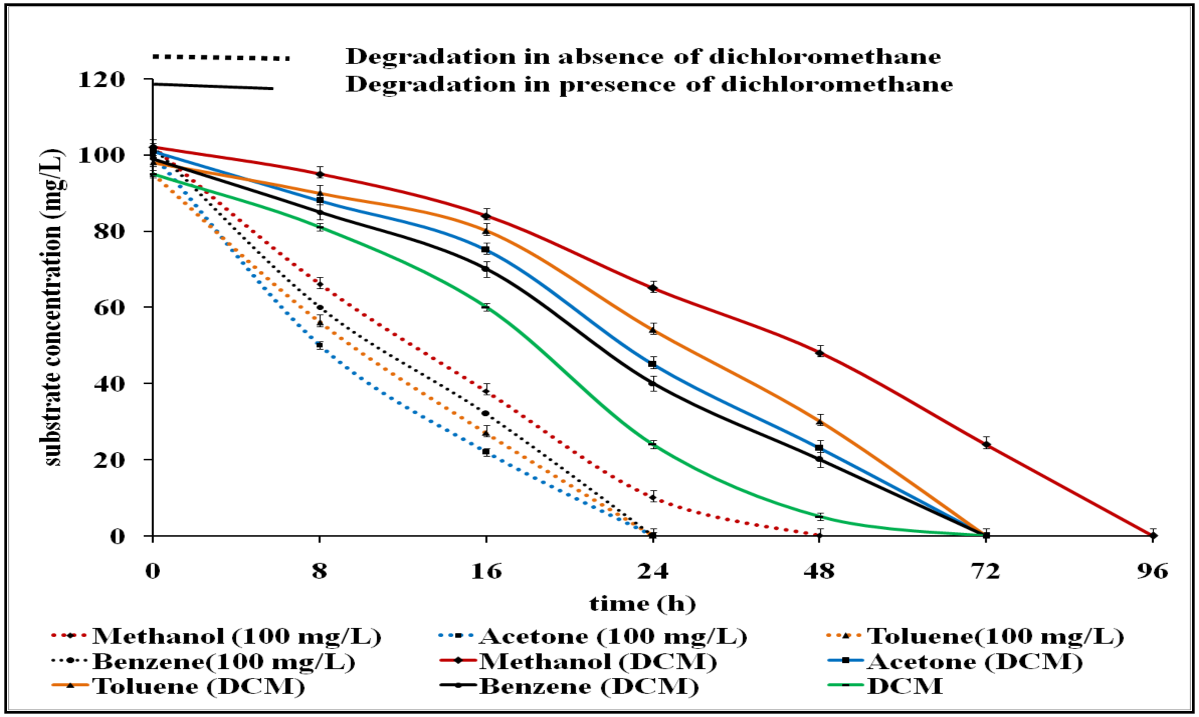
Degradation of 50 mg/L of dichloromethane in the presence of 1000 mg/L of non chlorinated solvents





RESULTS

MULTIPLE SUBSTRATE INTERACTION STUDIES



- **Absence of DCM :** All the non chlorinated solvents were degraded much faster compared to their degradation in a **single pollutant system.**
- **Presence of DCM** : Presence of DCM prolonged the degradation of all the non chlorinated solvents
- **Enhanced degradation of dichloromethane in the presence of other solvents**

RESULTS

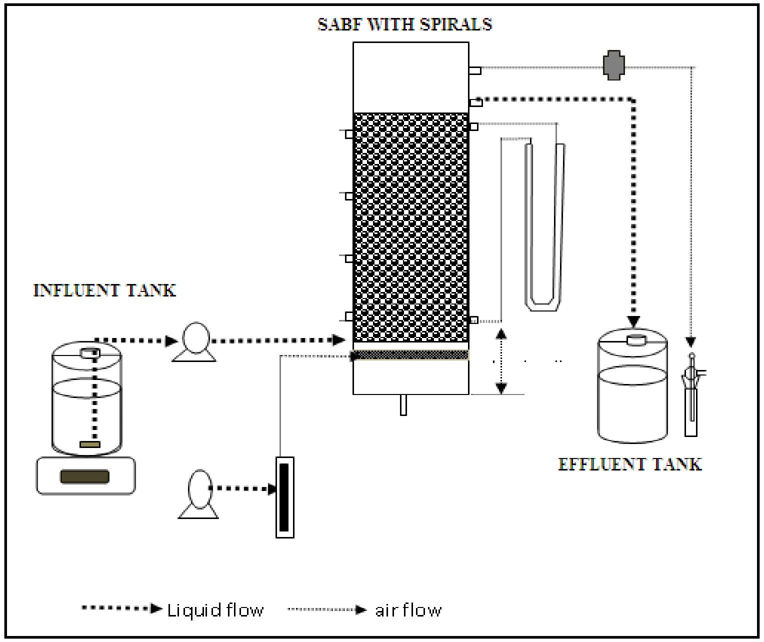
CONCLUSION FROM BATCH STUDIES

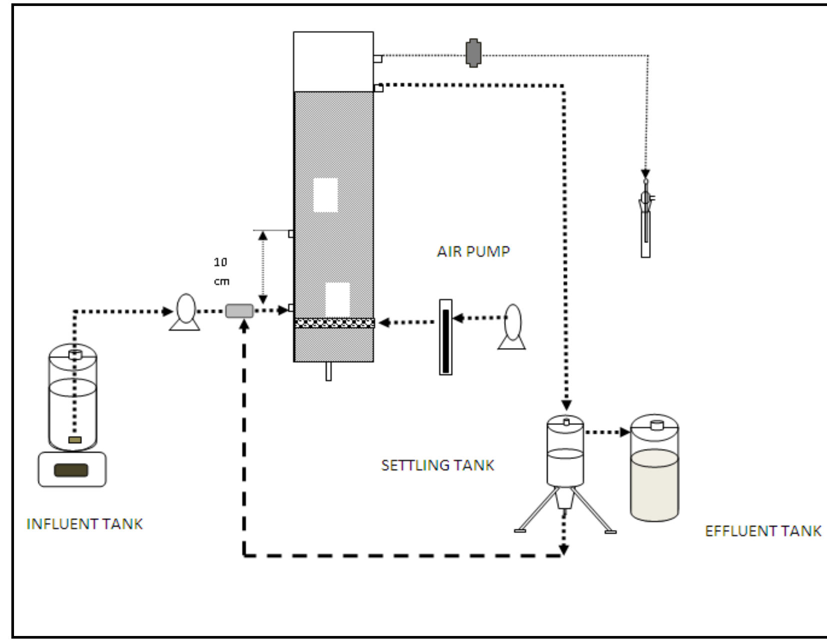
- All the target pollutants were degraded in the aerobic conditions
- **First report on the enhanced degradation of dichloromethane in the presence of other non chlorinated pollutants**
- Low concentrations (100 mg/L) of non chlorinated solvents did not interfere with the DCM degradation
- High concentrations of non chlorinated solvents (1000 mg/L) enhanced the DCM degradation and a severe competition between the chlorinated and the non chlorinated solvents was observed.
- In multiple substrate system also, presence of DCM prolonged the degradation of the other non chlorinated solvents.

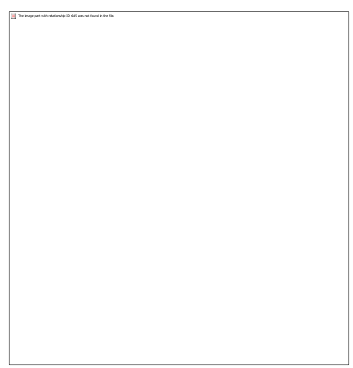
Priya, V.S., Philip, L. (2013). Biodegradation of Dichloromethane along with other VOCs from Pharmaceutical wastewater. *Applied Biochemistry and Biotechnology.* 169, 1197–1218.

ODEGRADATION STUDIES IN CONTINUOUS BIOREACTORS

CONTINUOUS BIOREACTORS



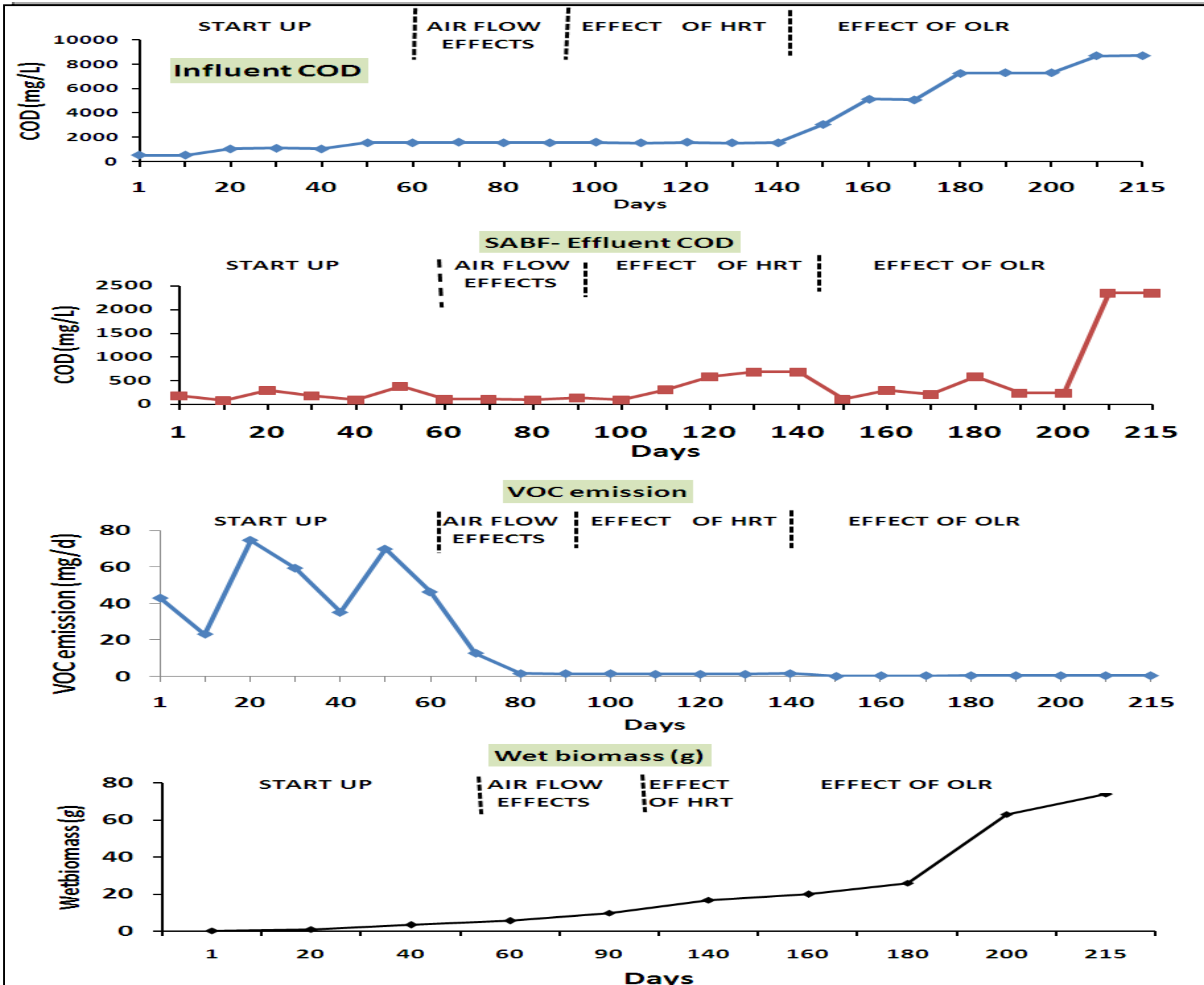




SUBMERGED AERATED BIOLOGICAL FILTER

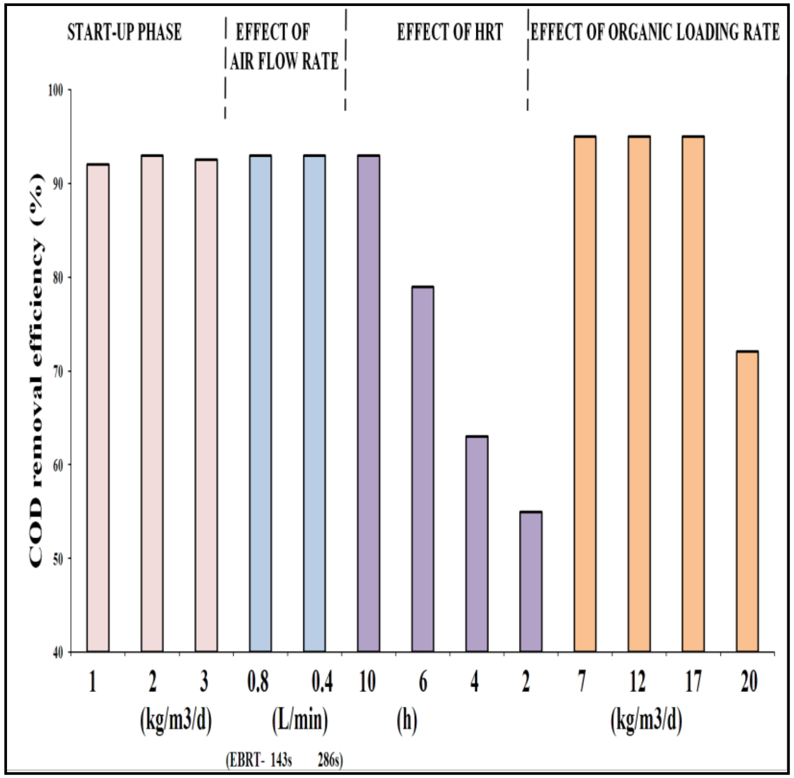
ACTIVATED SLUDGE PROCESS

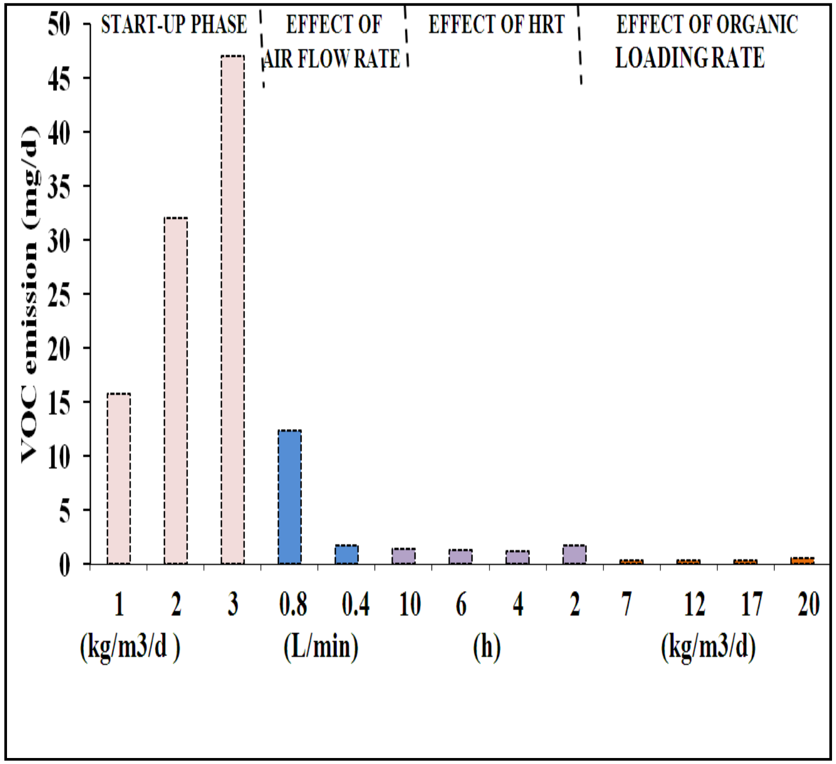
CONTINUOUS BIOREACTORS



PERFORMANCE OF SUBMERGED AERATED BIOLOGICAL FILTER (SABF) UNDER DIFFERENT OPERATING CONDITIONS

RESULTS



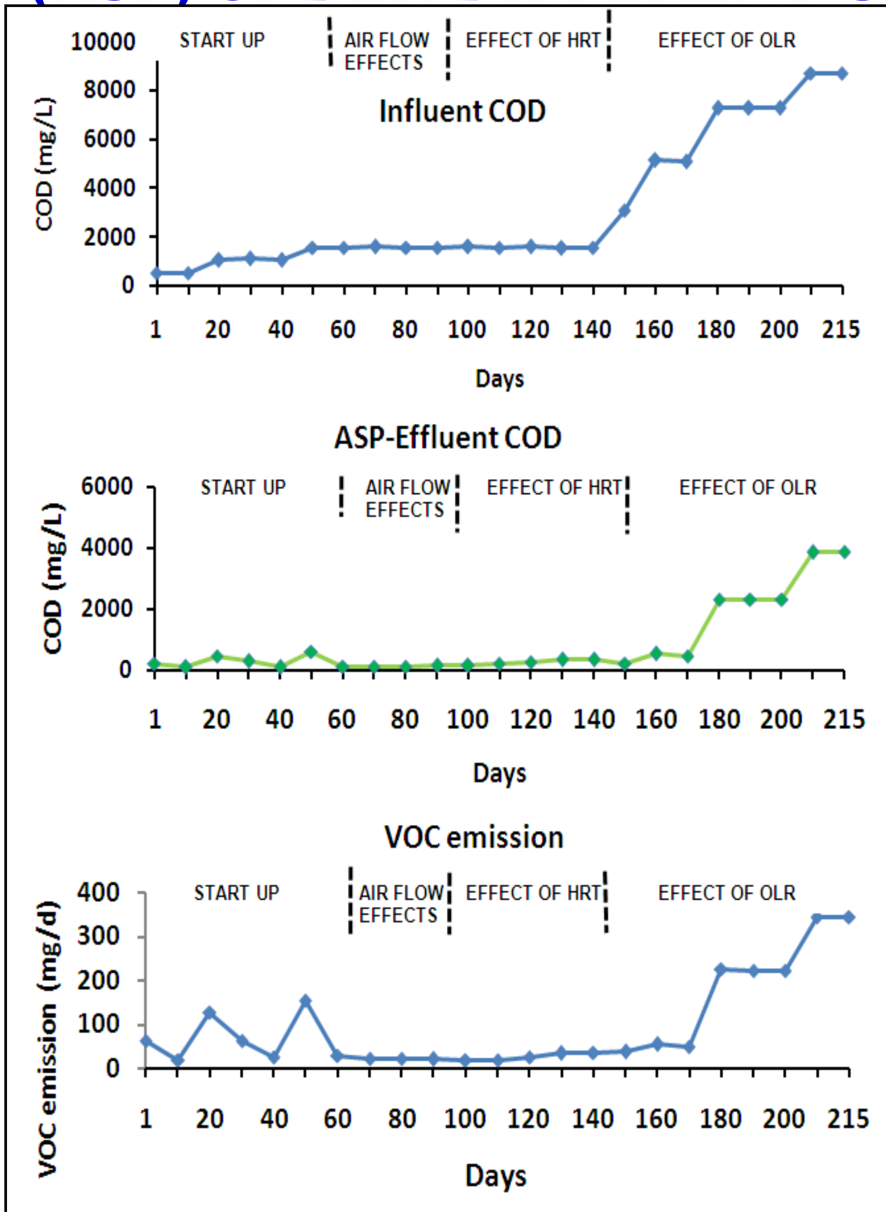


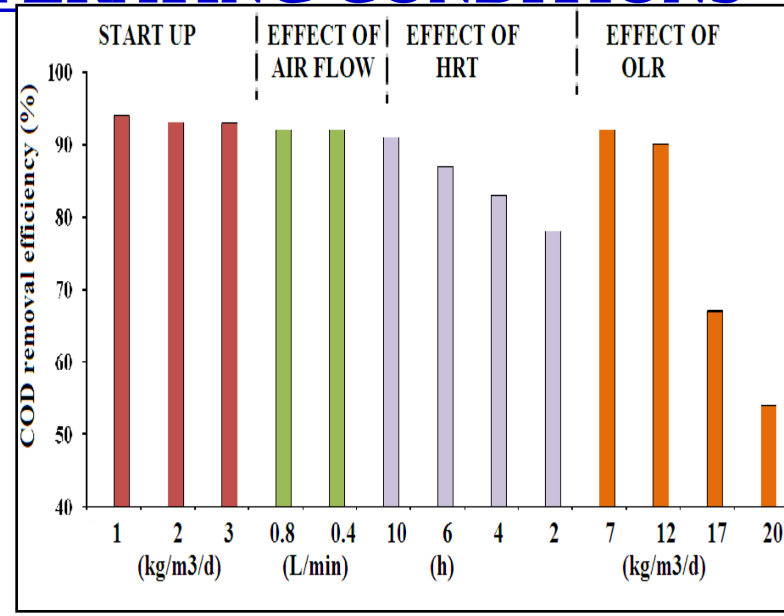
COD REMOVAL FROM SABF **VOC EMISSION FROM SABF**

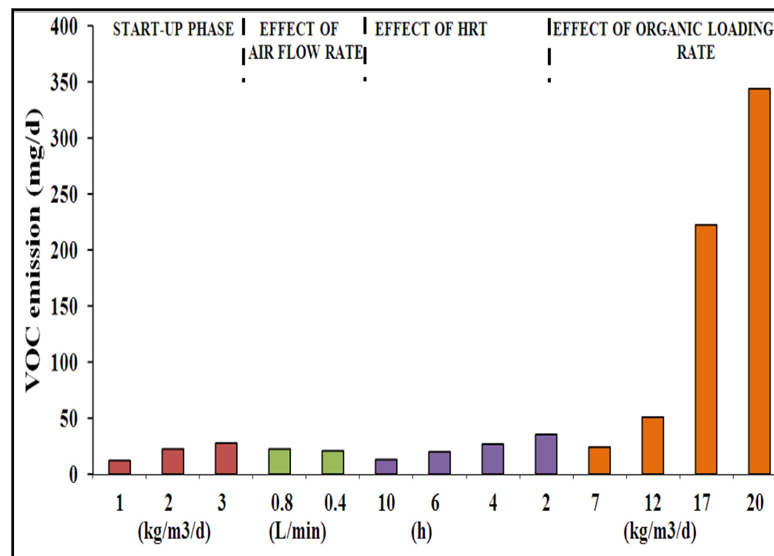
Priya.V.S., Philip,L. Treatment of Volatile Organic Compounds in Pharmaceutical Wastewater using Submerged Aerated Biological Filter (Accepted in Chemical Engineering journal)

RESULTS

PERFORMANCE OF ACTIVATED SLUDGE PROCESS (ASP) UNDER DIFFERENT OPERATING CONDITIONS



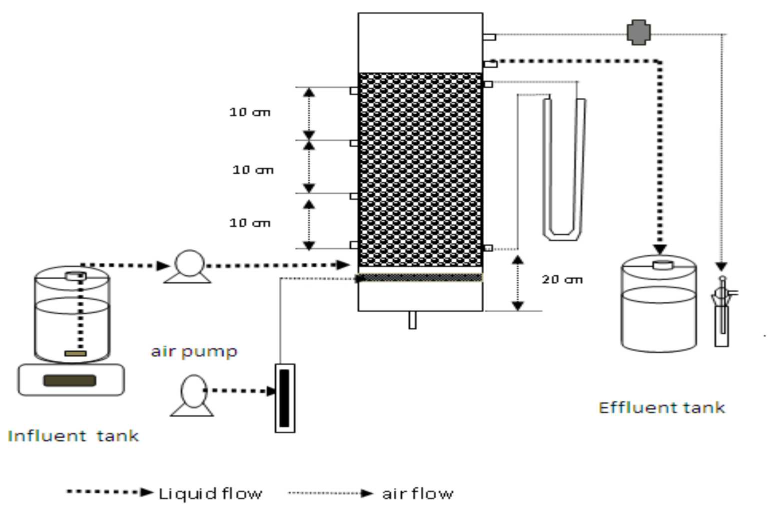




CONTINUOUS BIOREACTORS

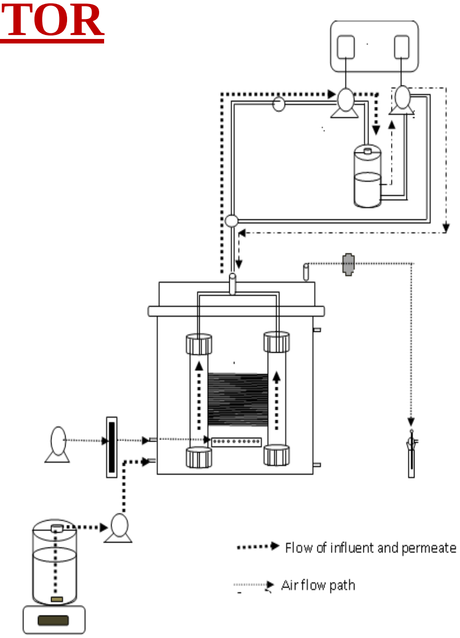
PERFORMANCE EVALUATION OF MEMBRANE BIOREACTOR

SABF COMBINED WITH MEMBRANE BIOREACTOR

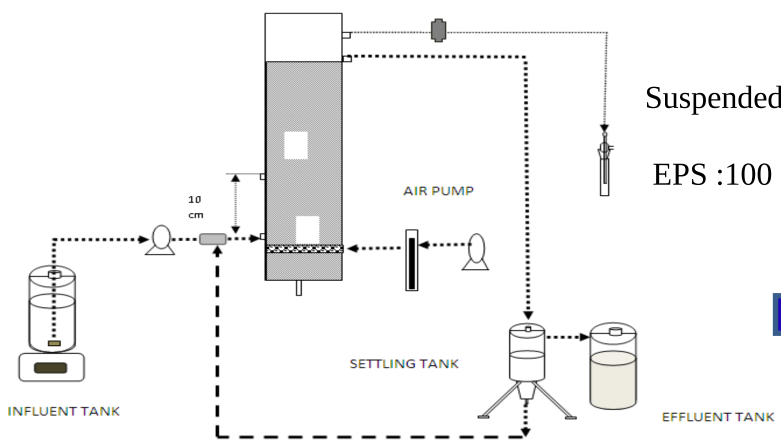


Suspended solids :60mg/L

EPS :12mg/g



ASP COMBINED WITH MEMBRANE BIOREACTOR



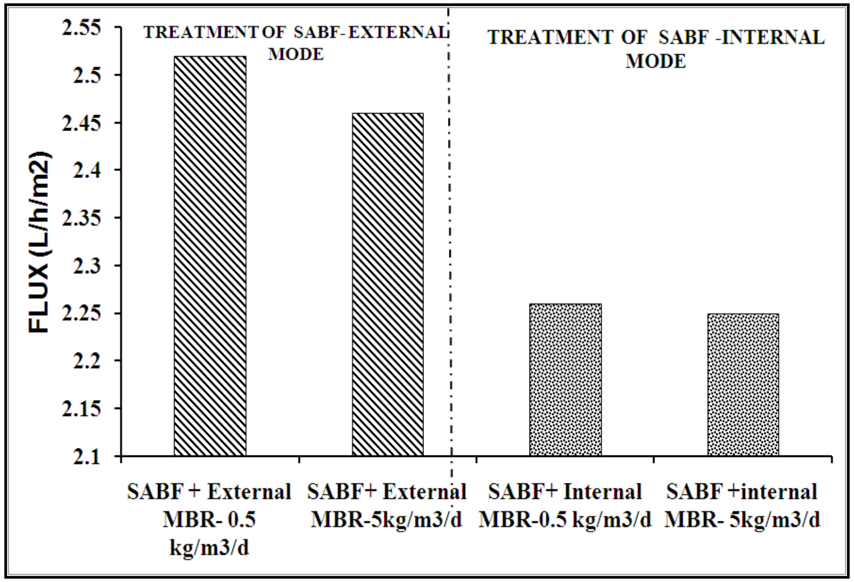
Suspended solids :2000mg/L

EPS :100 mg/g

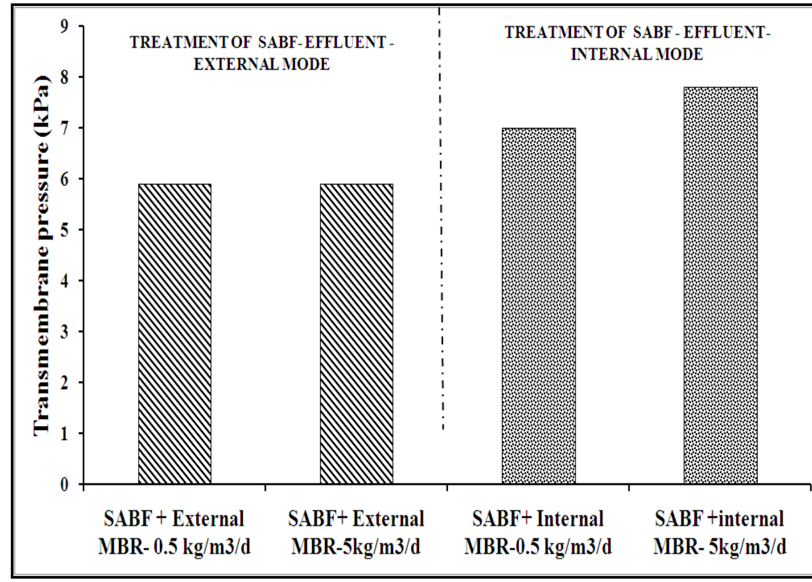
MEMBRANE BIOREACTOR

RESULTS

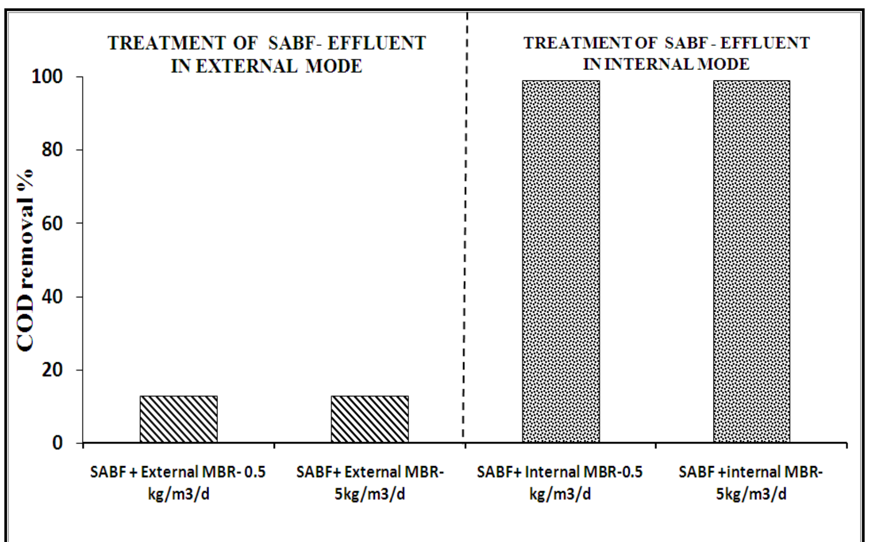
TREATMENT OF EFFLUENT FROM SUBMERGED AERATED BIOLOGICAL FILTER USING MEMBRANE BIOREACTOR



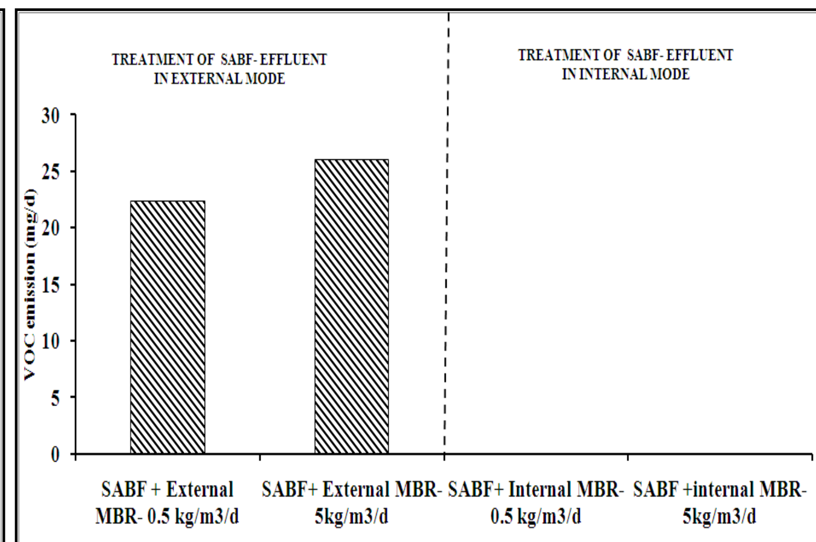
VARIATION IN FLUX



VARIATION IN TRANSMEMBRANE PRESSURE



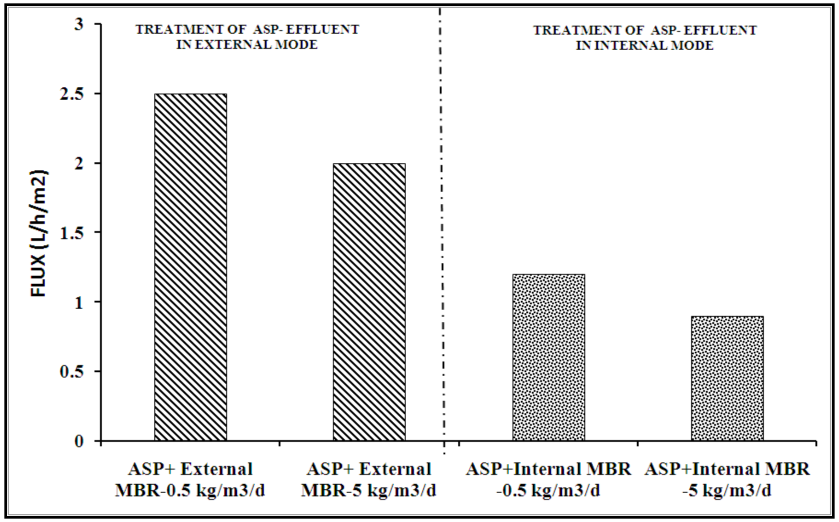
VARIATION IN COD REMOVAL



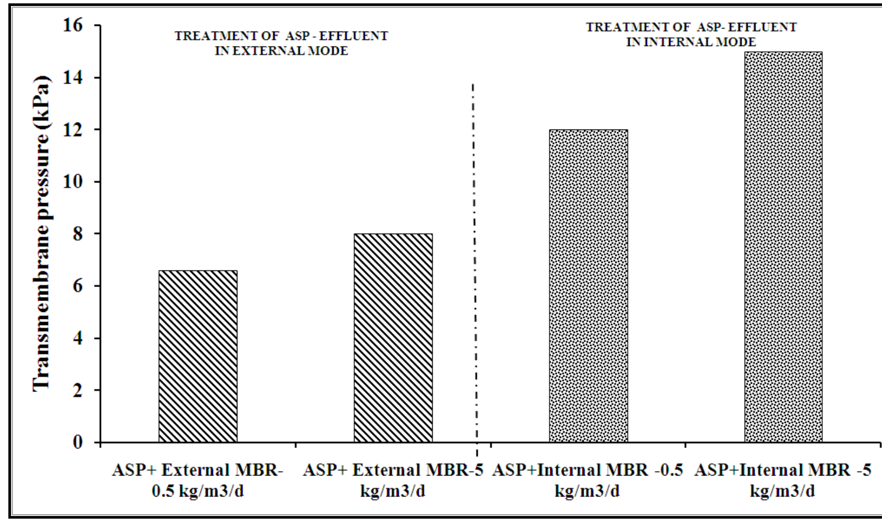
VARIATION IN VOC EMISSION

RESULTS

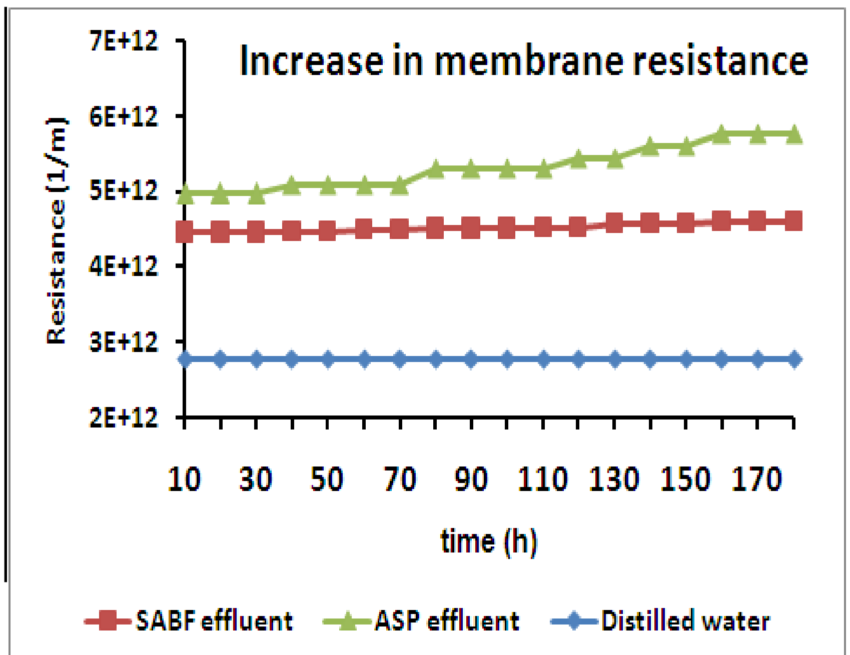
TREATMENT OF EFFLUENT FROM AERATION TANK OF ACTIVATED SLUDGE PROCESS USING MEMBRANE BIOREACTOR



VARIATION IN FLUX



VARIATION IN TRANSMEMBRANE PRESSURE



Performance of Hybrid treatment system

Condition	Permeate COD (mg/L)	% COD reduction	VOC emission (mg/d)
SABF+ External MBR	622	13	25
SABF + Internal MBR	0.04	99	nil

CONCLUSIONS

- Submerged aerated biological filter were more resistant to higher organic loading rate than compared to activated sludge process.
- Limited mass transfer of VOC to the gas phase at low air flow rate reduced VOC emission from submerged aerated biological filter
- Optimization of operating conditions such as air flow rate, hydraulic retention time and organic loading rate reduced the VOC emissions from submerged aerated biological filter
- Effluent from SABF were effectively treated using membrane bioreactor.
- Complete removal of VOC from SABF effluent was achieved while adopting internal MBR configuration.
- Flux reduction and TMP rise were more significant during the treatment of ASP effluent
- SABF can be coupled along with the MBR operated under internal configuration for the complete removal of VOC from the pharmaceutical wastewater.

BIOREMEDIATION OF Cr(VI) CONTAMINATED SOIL AND GROUND WATER SYSTEMS

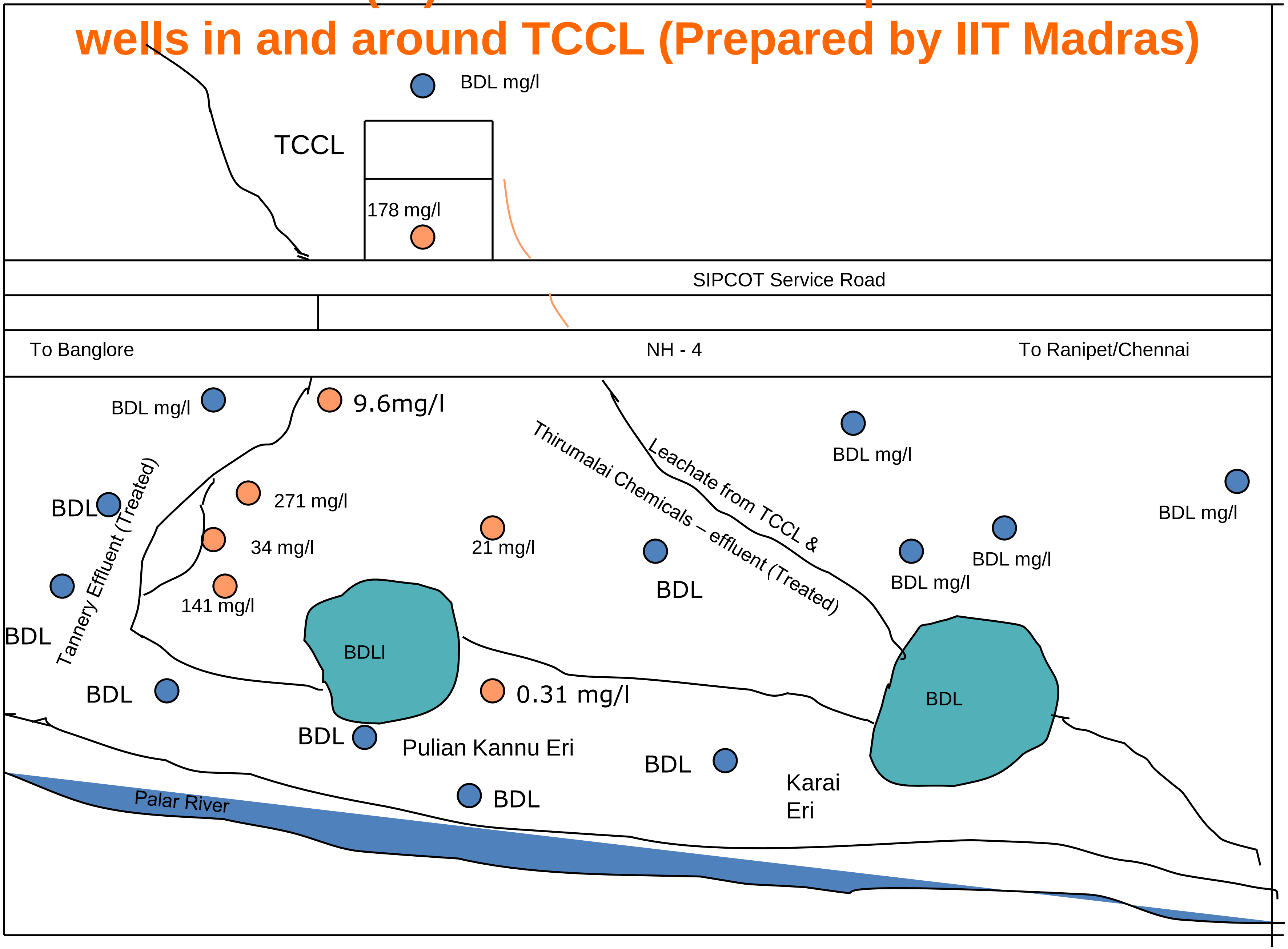
MOTIVATION

TamilNadu Chromate Chemicals Limited,
Ranipet, Vellore District , Tamilnadu.

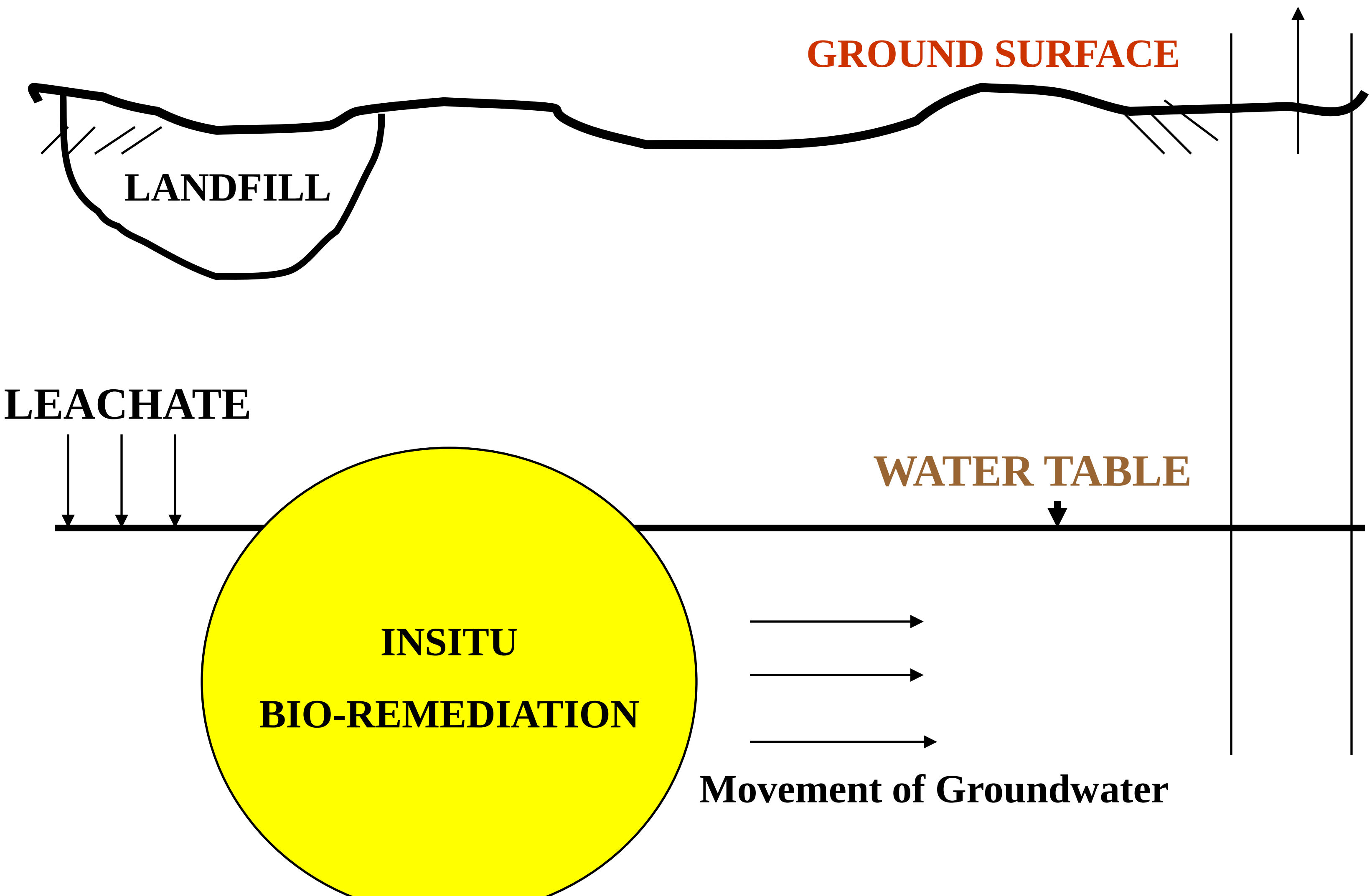

Chromium waste
Disposal area: 5 acres (2 hectares)
2 x10^5 Tones of waste)

Chromium Leachate in Ground Water

Cr(VI) Concentration in open wells/bore wells in and around TCCL (Prepared by IIT Madras)

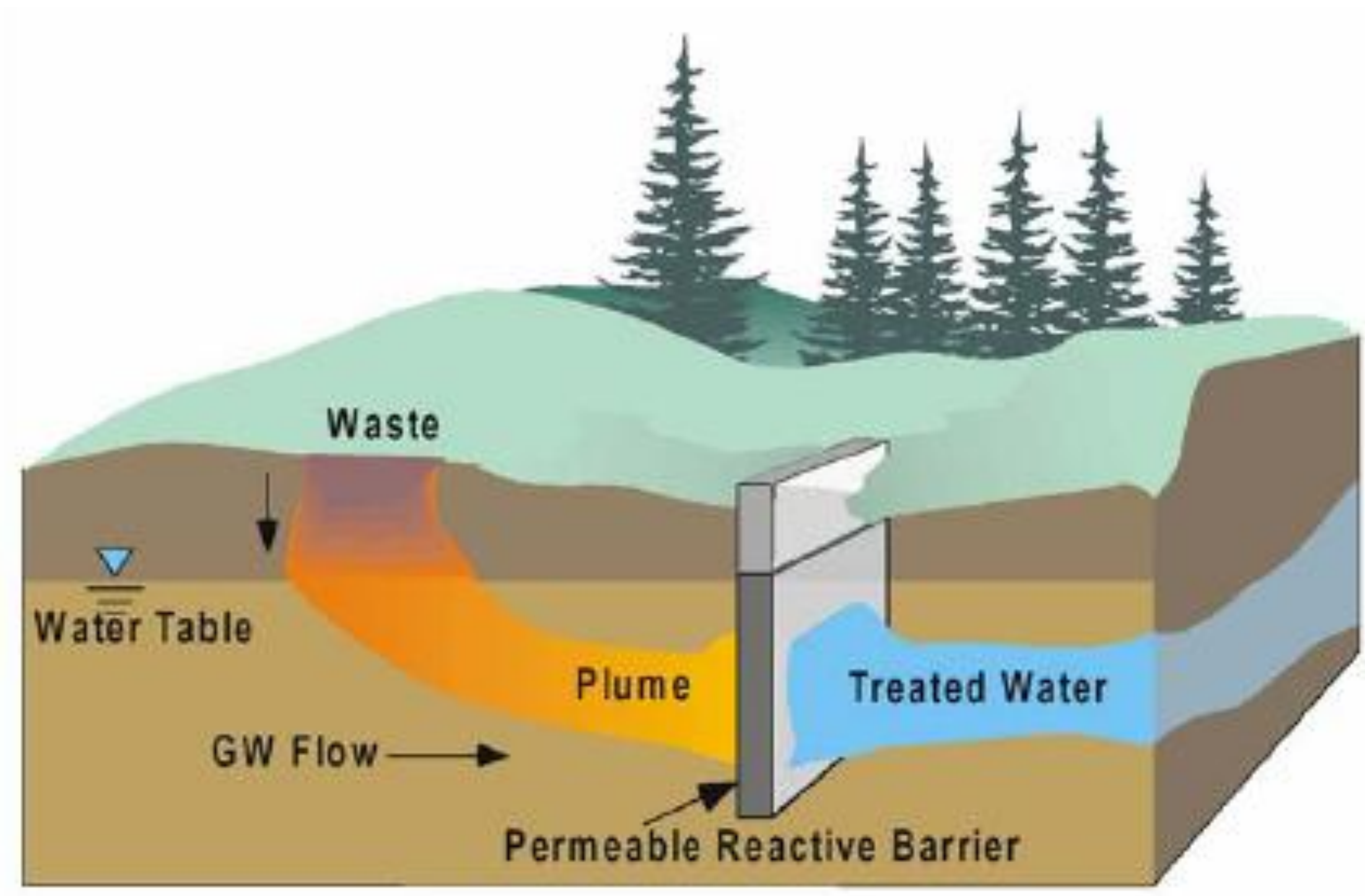


CLEANUP METHODS FOR FIELD CONDITIONS



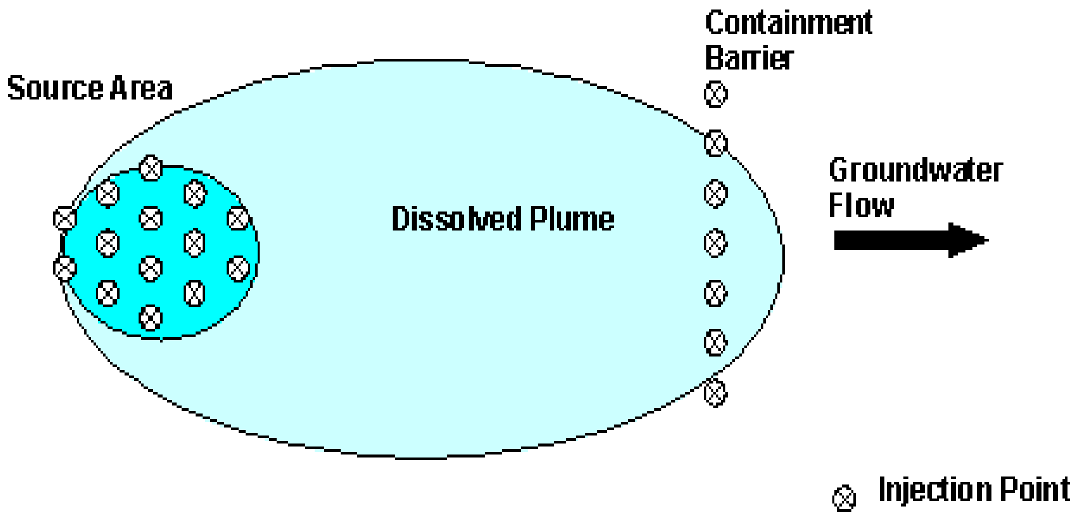
Methods for Remediation of Cr(VI) Contaminated Aquifers

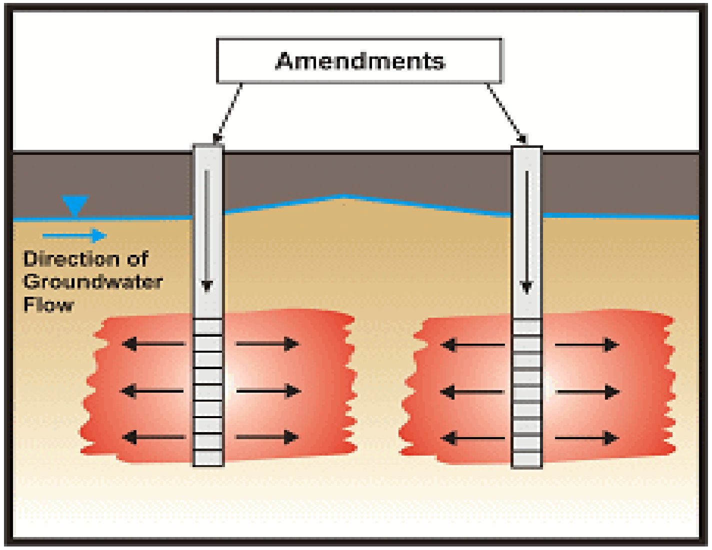
- Pump and Treat systems
- Geochemical fixation
- Permeable Reactive Barriers
- Reactive Zones
- Natural attenuation
- Phyto-remediation



Schematic Representation of a Permeable Reactive Bio-barrier

REACTIVE ZONES





2

BATCH STUDIES

- **Bio-kinetic parameters**

- **Adsorption Parameters**

Cr(VI) Reduction Studies with CRB, SRB and IRB, in Combinations

1. CRB –Aerobic
2. CRB -Anaerobic
2. SRB-Anaerobic
3. IRB- anaerobic
4. CRB+SRB
5. CRB+IRB
6. CRB+SRB+IRB

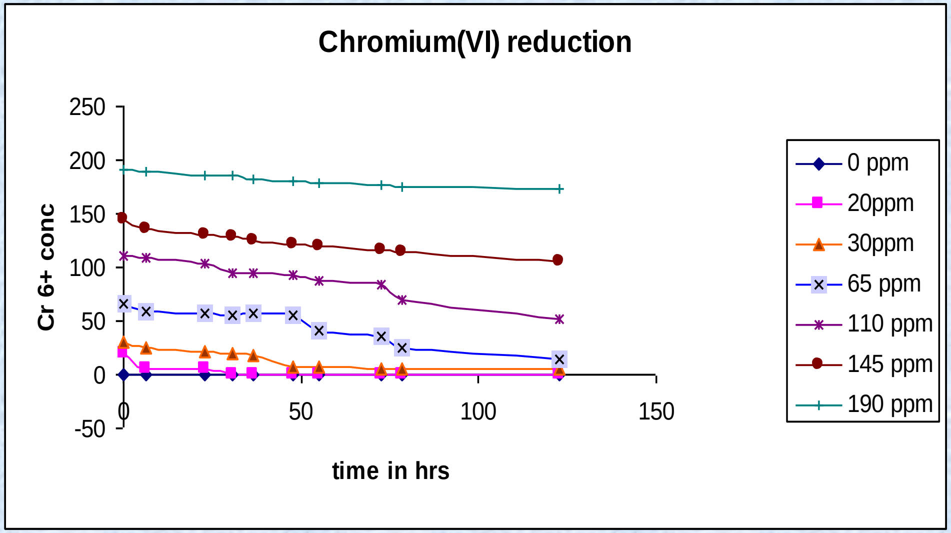
Adsorption Studies

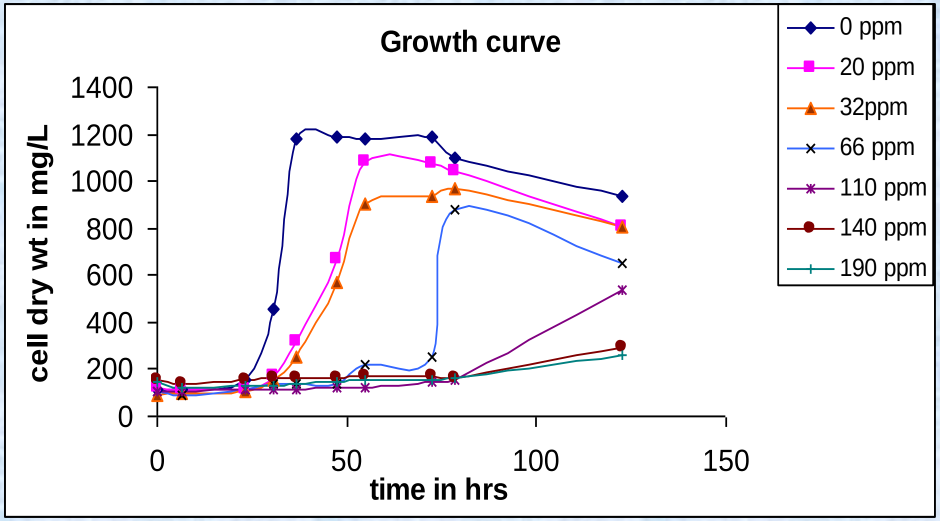
Adsorbents– Soil , Sand

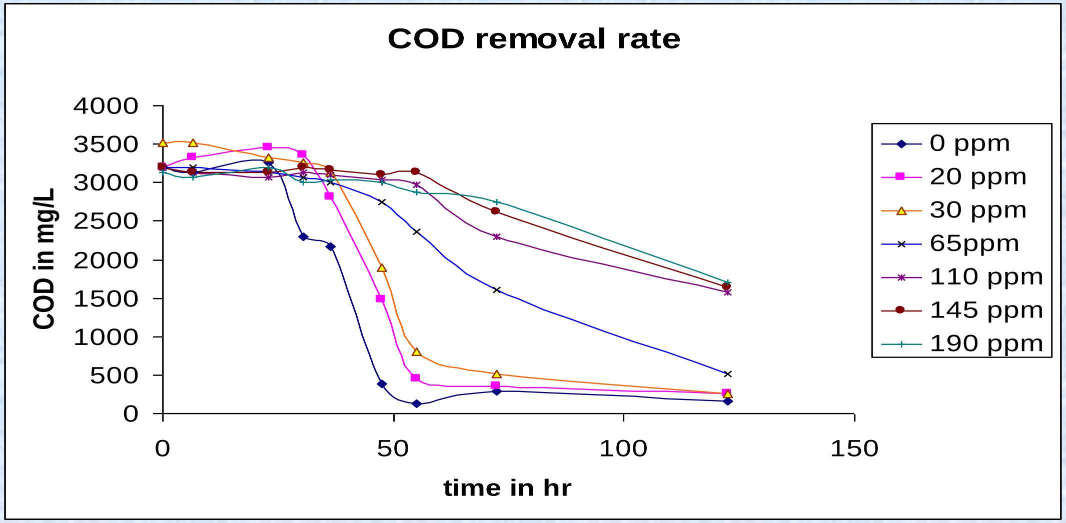
Adsorbates:

1. Cr(VI)
2. Molasses/Sugar
3. Lithium
4. Cr(III)

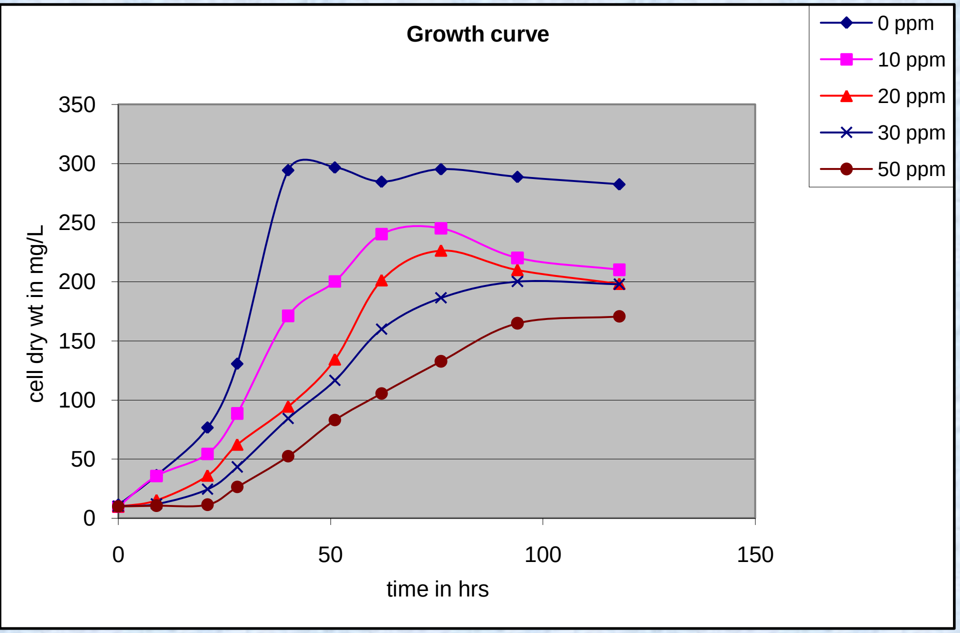
Cr(VI) Reduction in Aerobic Conditions

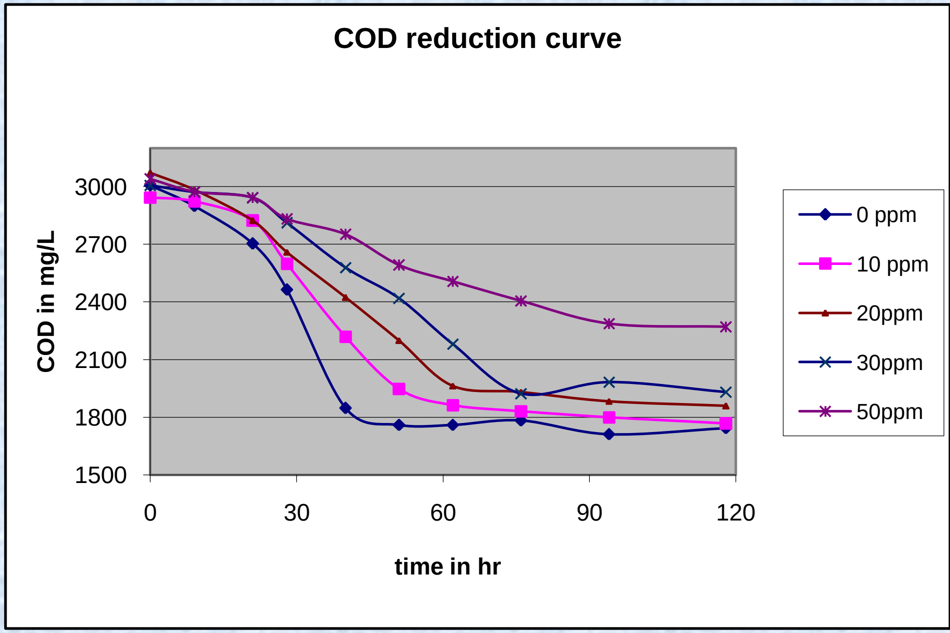


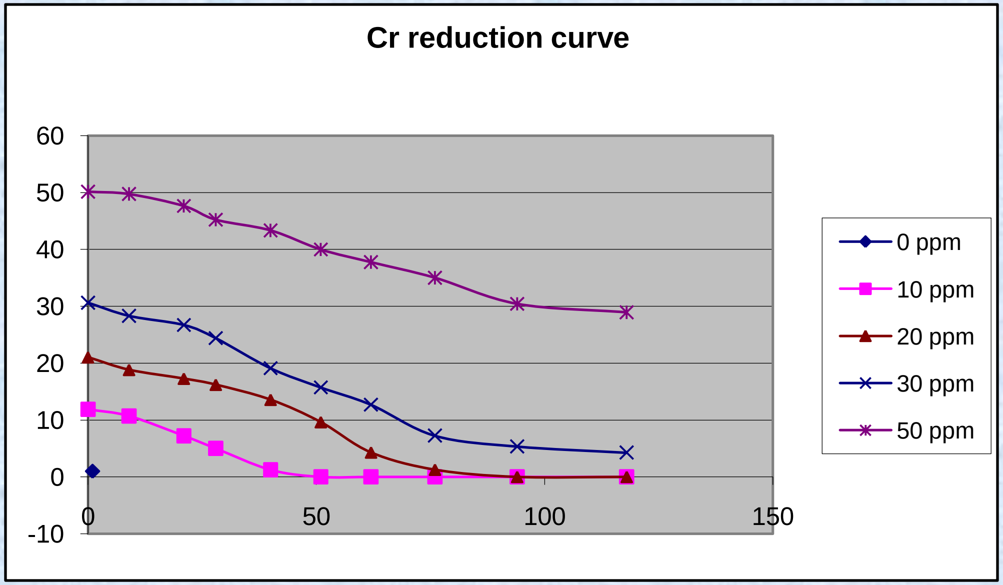




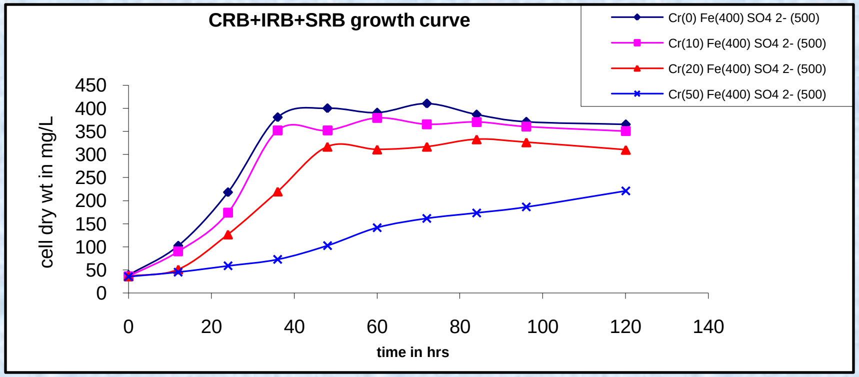
Cr (VI) Reduction by CRB under Anaerobic Condition

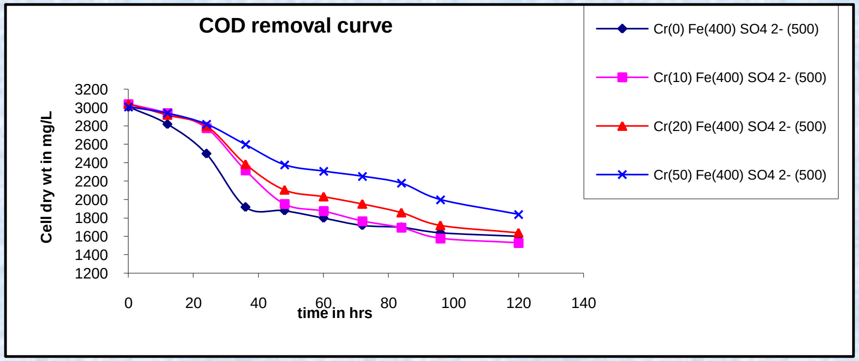


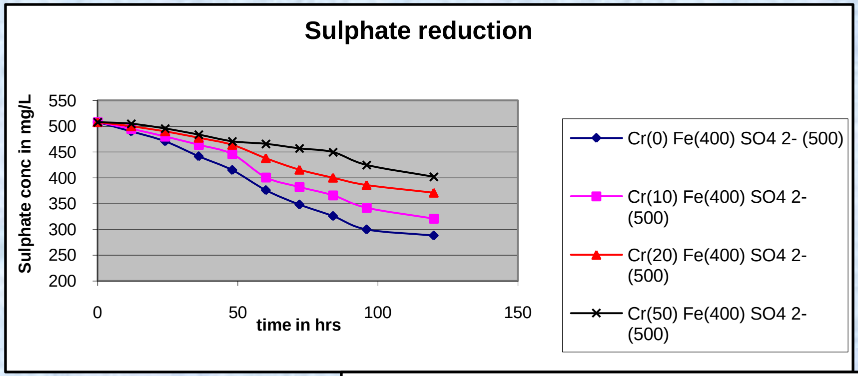


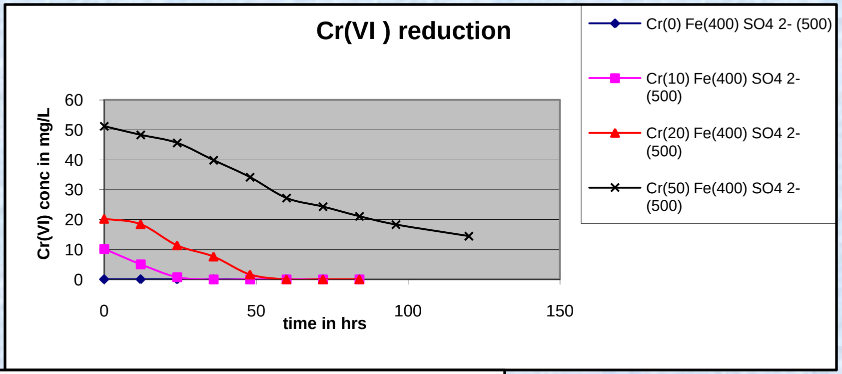


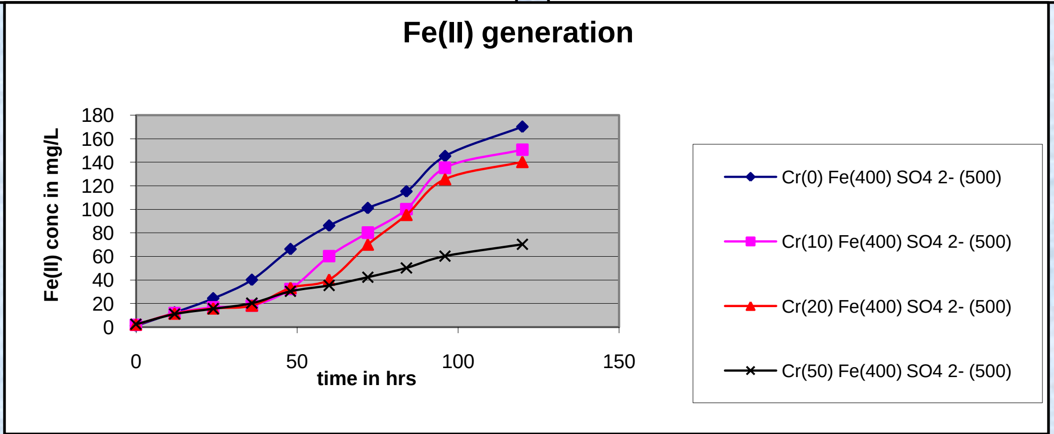
Growth of CRB+IRB+SRB under Anaerobic Condition Fe(400ppm,Sulphate(500ppm)











Model

Suffix 1,2,3 represents CRB,SRB,IRB respectively

$$M = \sum_{i=1}^{3} M_i$$

$$S = \sum_{i=1}^{3} S_i$$

$$Cr_6 = \sum_{i=1}^{3} Cr_{6i}$$

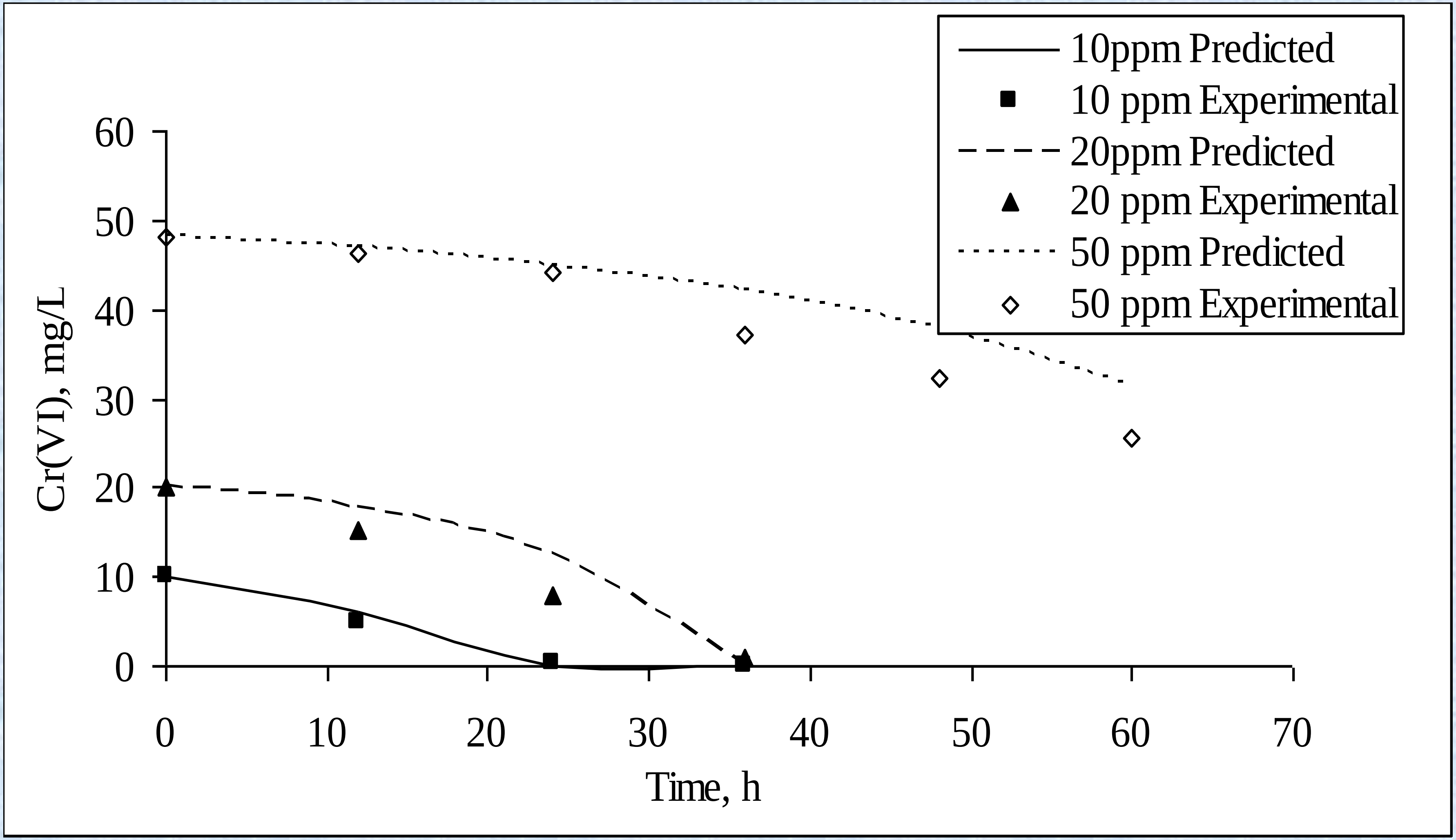
$$S_i = S\left(\frac{M_i}{M}\right)$$

$$Cr_{6,i} = Cr_6\left(\frac{M_i}{M}\right)$$

$$\frac{dM_{CRB}}{dt} = \frac{M_{CRB}.\mu_{\max,CRB}.S\left(\frac{M_i}{M}\right)}{K_{s,CRB} + S\left(\frac{M_i}{M}\right)}\left(\frac{K_{i,CRB}}{K_{i,CRB} + Cr_6\left(\frac{M_i}{M}\right)}\right)$$

$$\frac{dM_{SRB}}{dt} = \frac{M_{SRB}.\mu_{\max,SRB}.S\left(\frac{M_i}{M}\right)}{K_{s,SRB} + S\left(\frac{M_i}{M}\right)}\left(\frac{K_{i,SRB}}{K_{i,SRB} + Cr_6\left(\frac{M_i}{M}\right)}\right)$$

$$\frac{dM_{IRB}}{dt} = \frac{M_{IRB}.\mu_{\max,IRB}.S\left(\frac{M_i}{M}\right)}{K_{s,IRB} + S\left(\frac{M_i}{M}\right)}\left(\frac{K_{i,IRB}}{K_{i,IRB} + Cr_6\left(\frac{M_i}{M}\right)}\right)$$

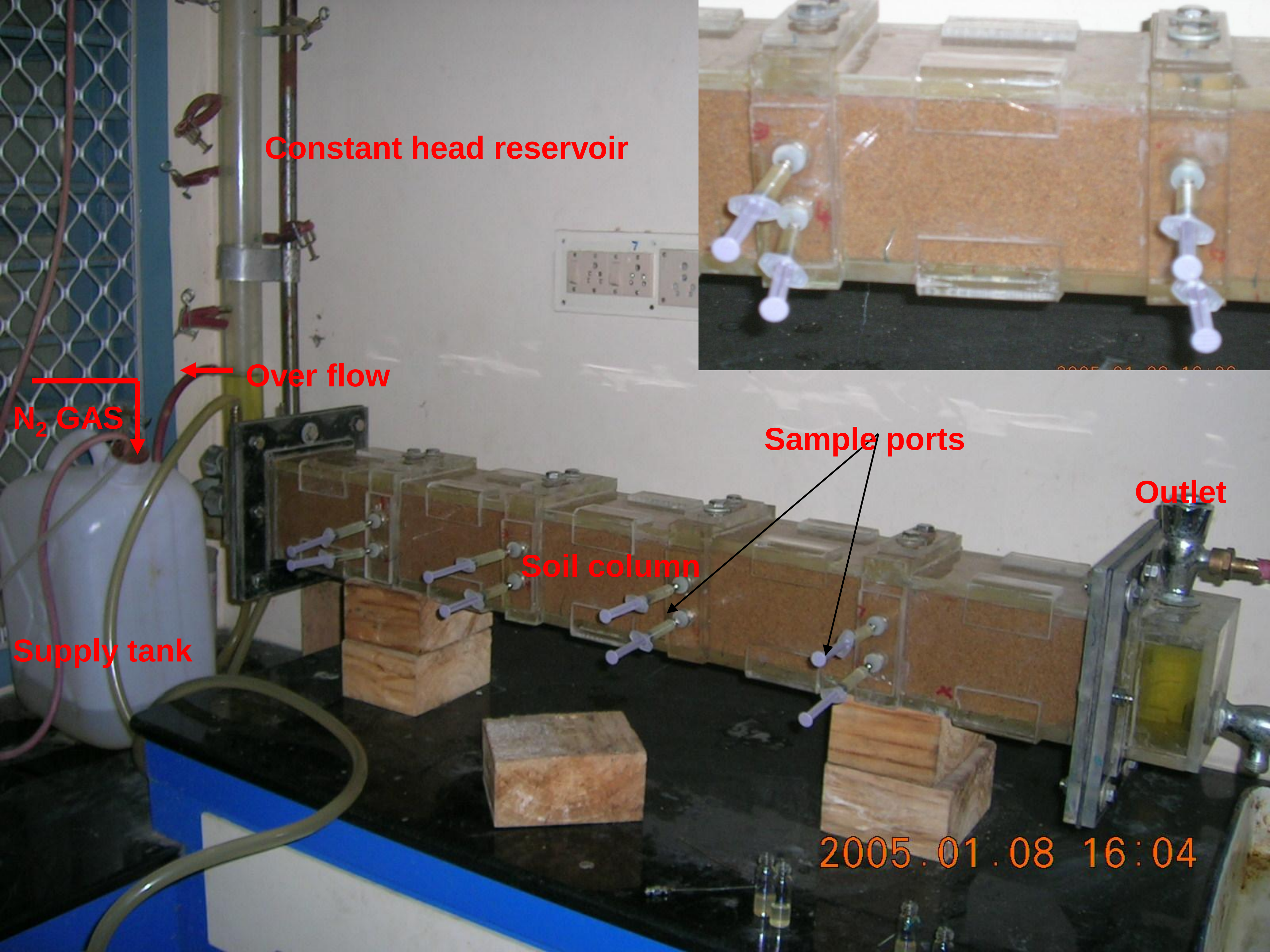


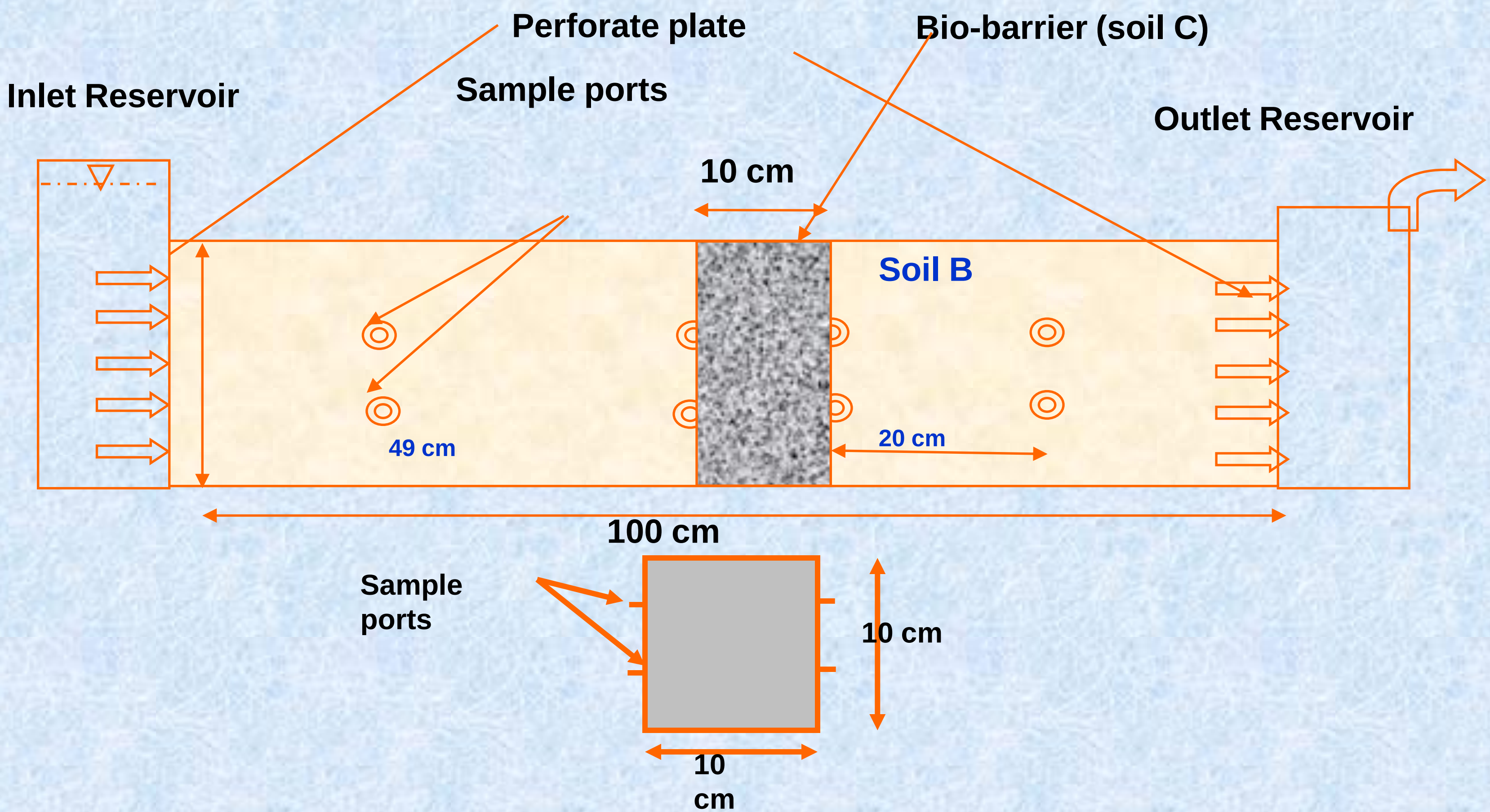
Cr(VI) reduction by CRB, SRB and IRB under anaerobic conditions for different initial Cr(VI) concentrations

Somasundaram et al., Jl. of Hazard. Mater., 2009

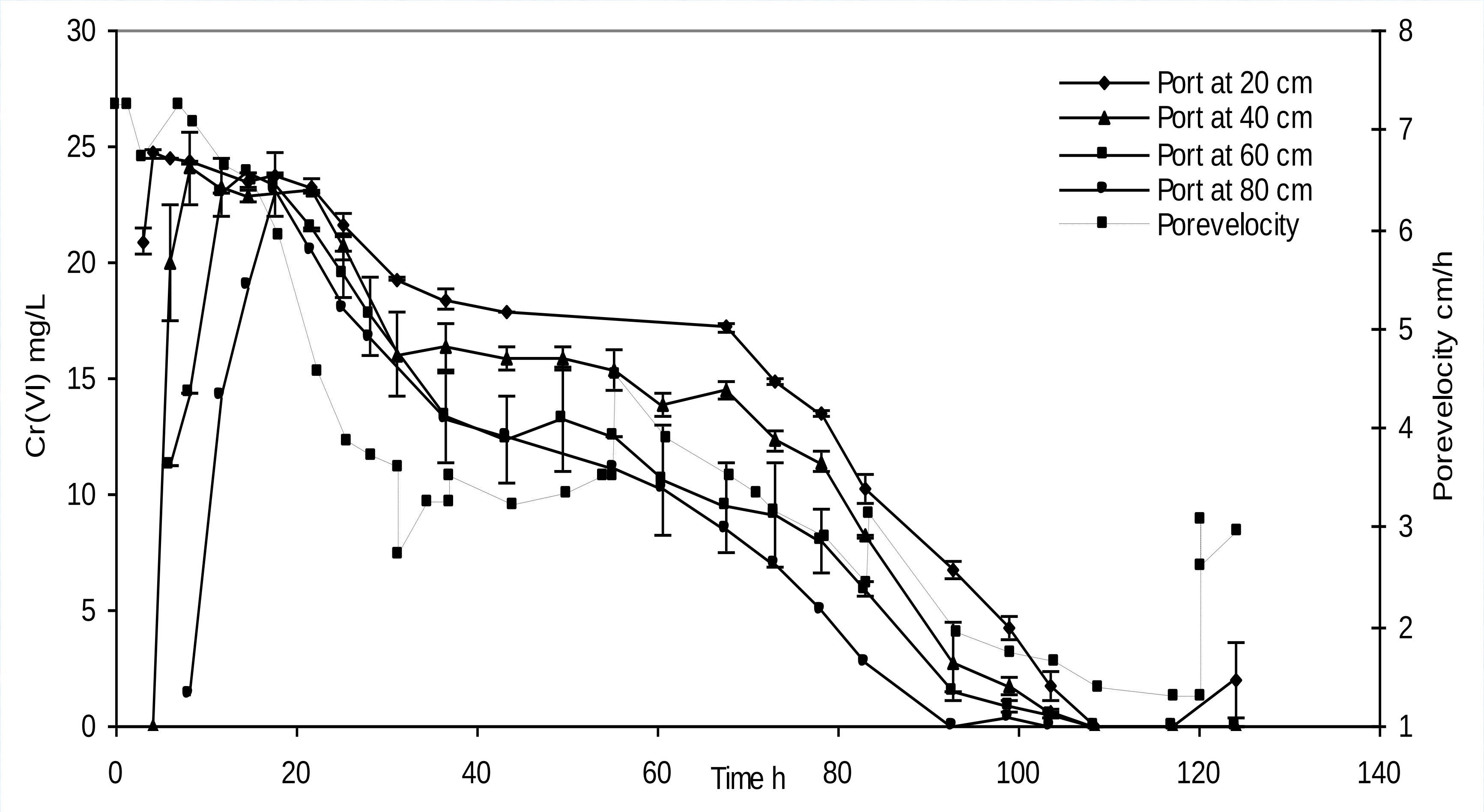
3

BENCH SCALE STUDIES


Constant head reservoir
Over flow
N2 GAS
Sample ports
Outlet
Soil column
Supply tank
2005.01.08 16:04

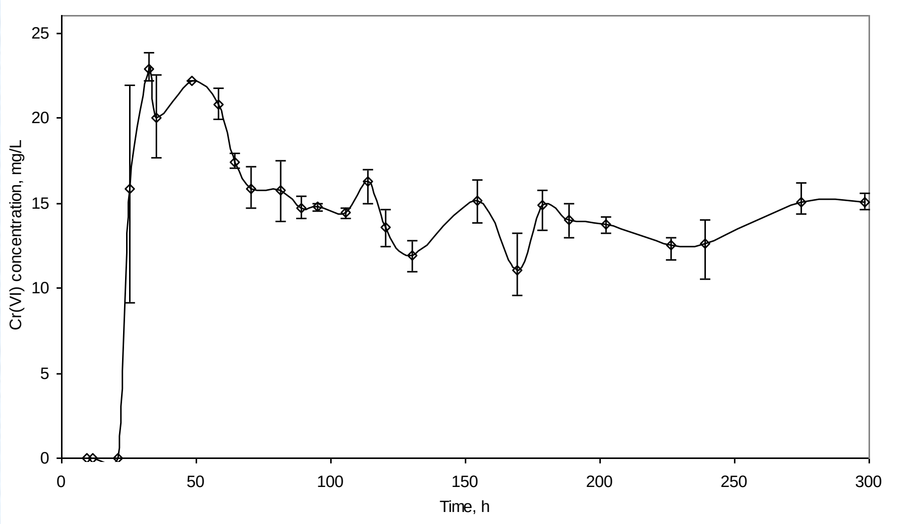


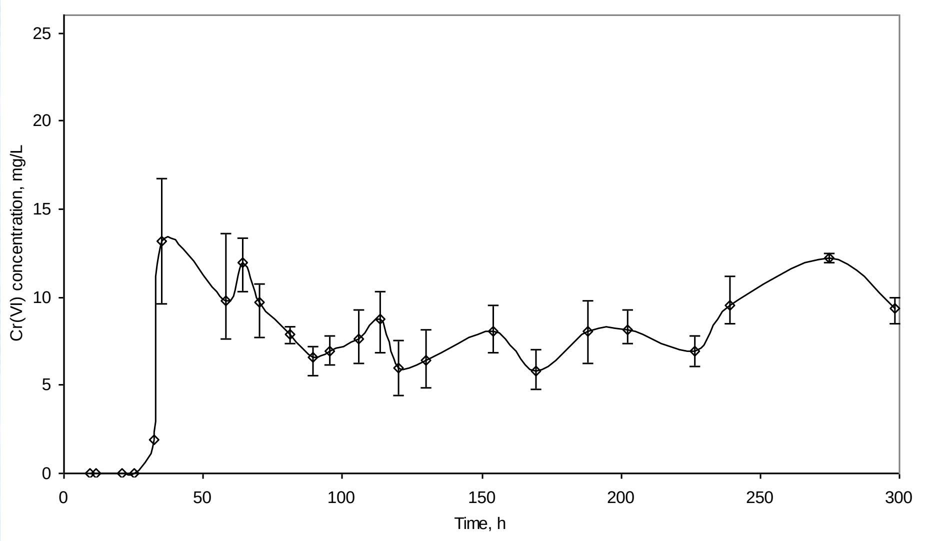
Schematic of experimental setup



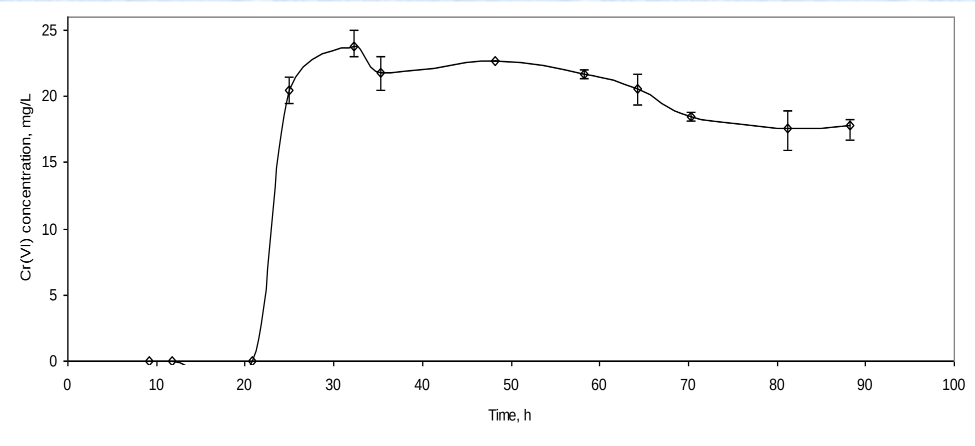
Cr(VI) break-through curve with biotransformation, Soil A

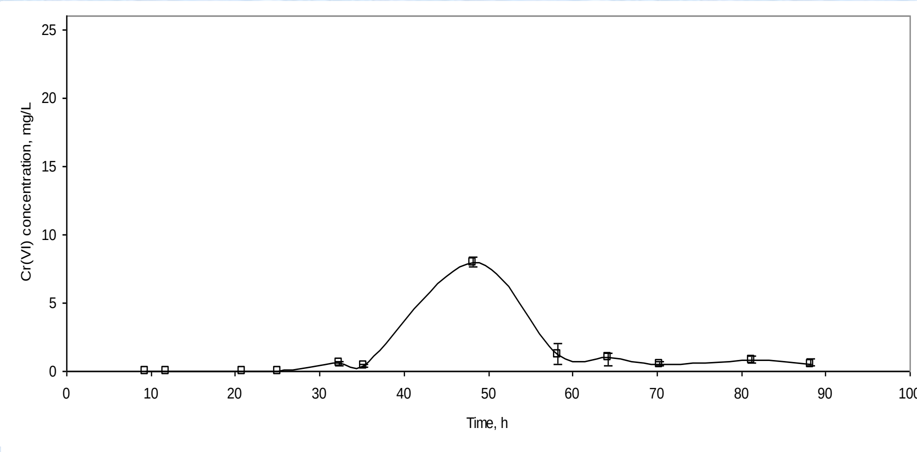
Shashidhar et al., Jl. of Hazard. Mater., 2006



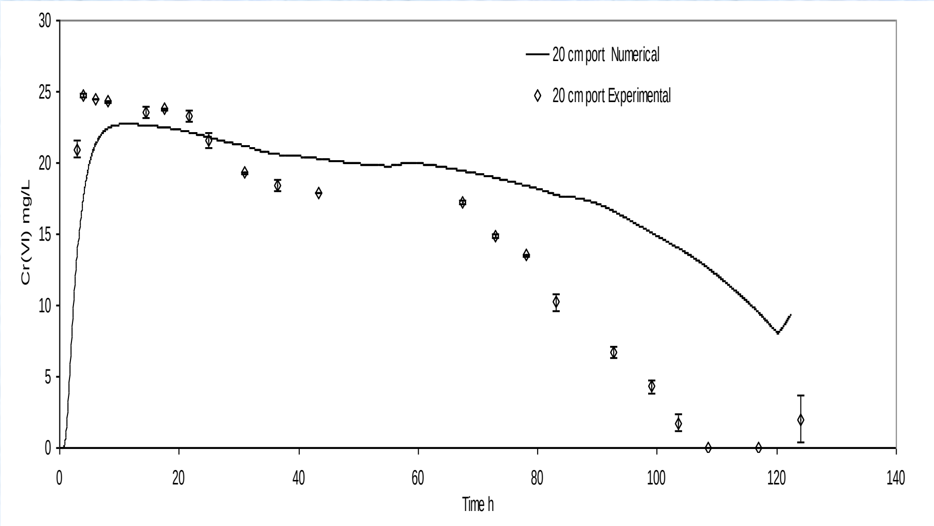


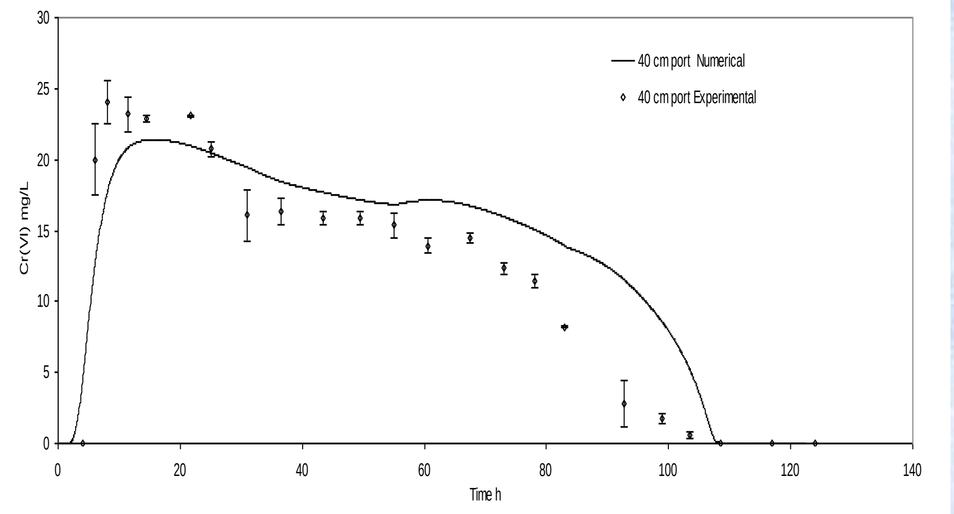
Cr(VI) breakthrough just before and after Biobarrier BB1
(Bact conc= 0.0205 mg/g of soil)





Cr(VI) breakthrough just before and after Biobarrier (BB2)
(Bact conc= 0.205 mg/g of soil)

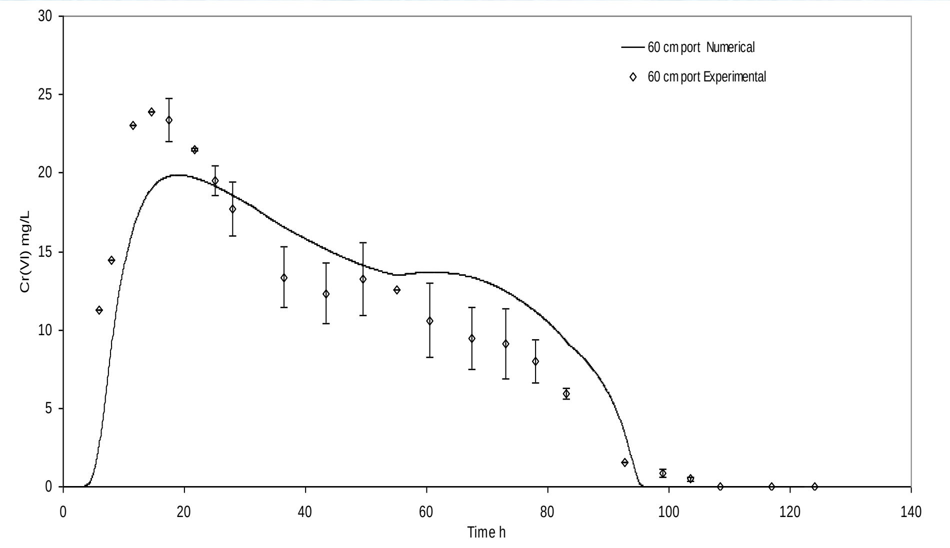


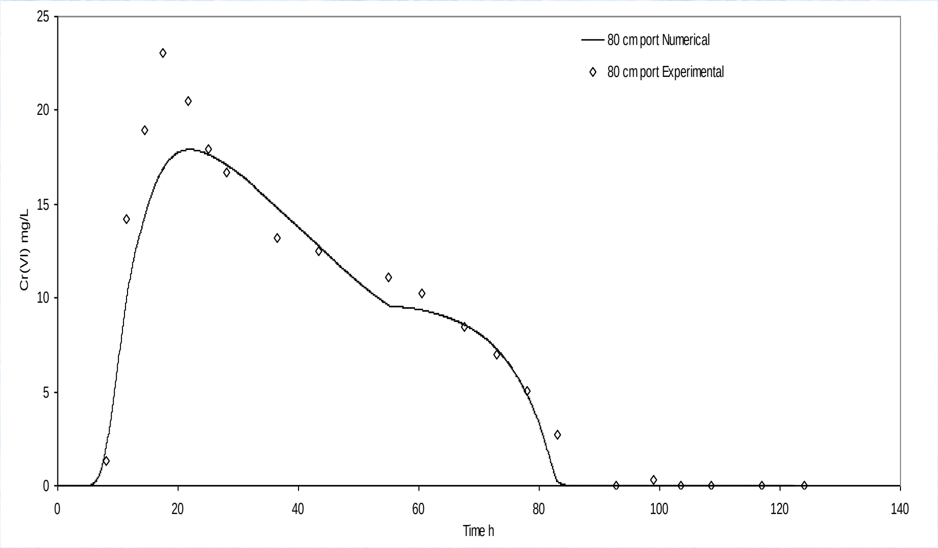


20 cm Port

40 cm Port

Initial pore velocity 7.3 cm/h





80 cm Port

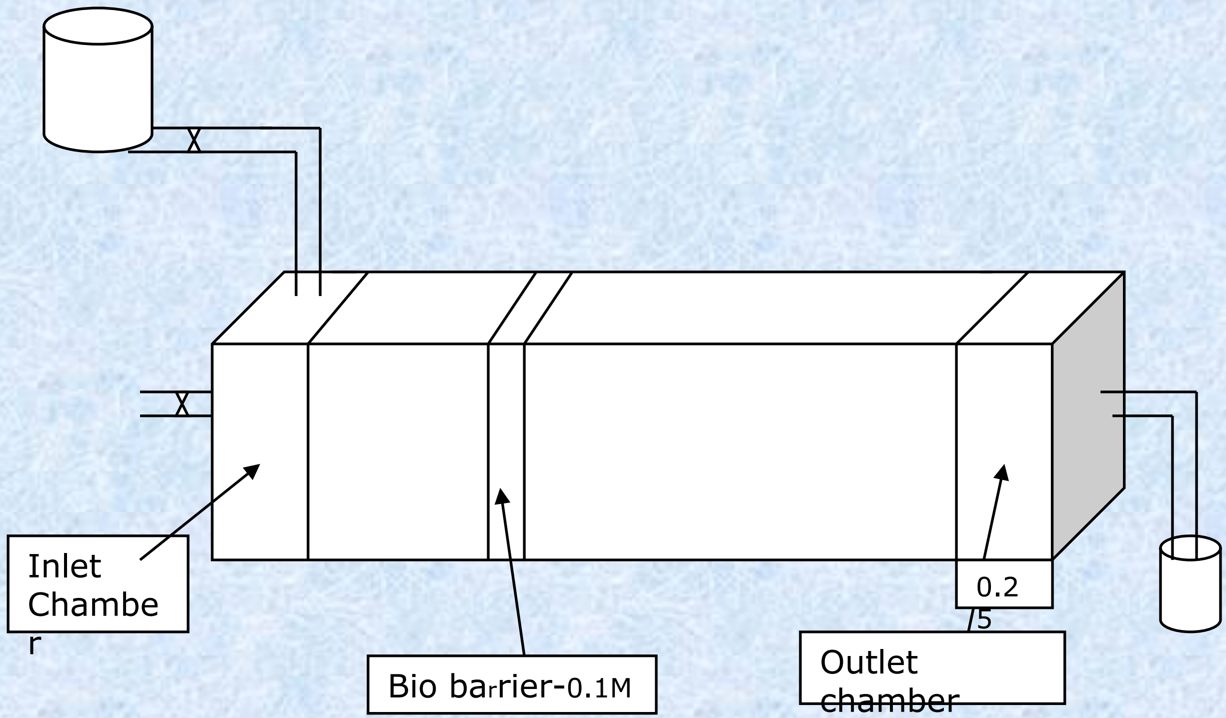
60 cm Port

Shashidhar et al., Jl. of Hazard. Mater., 2007

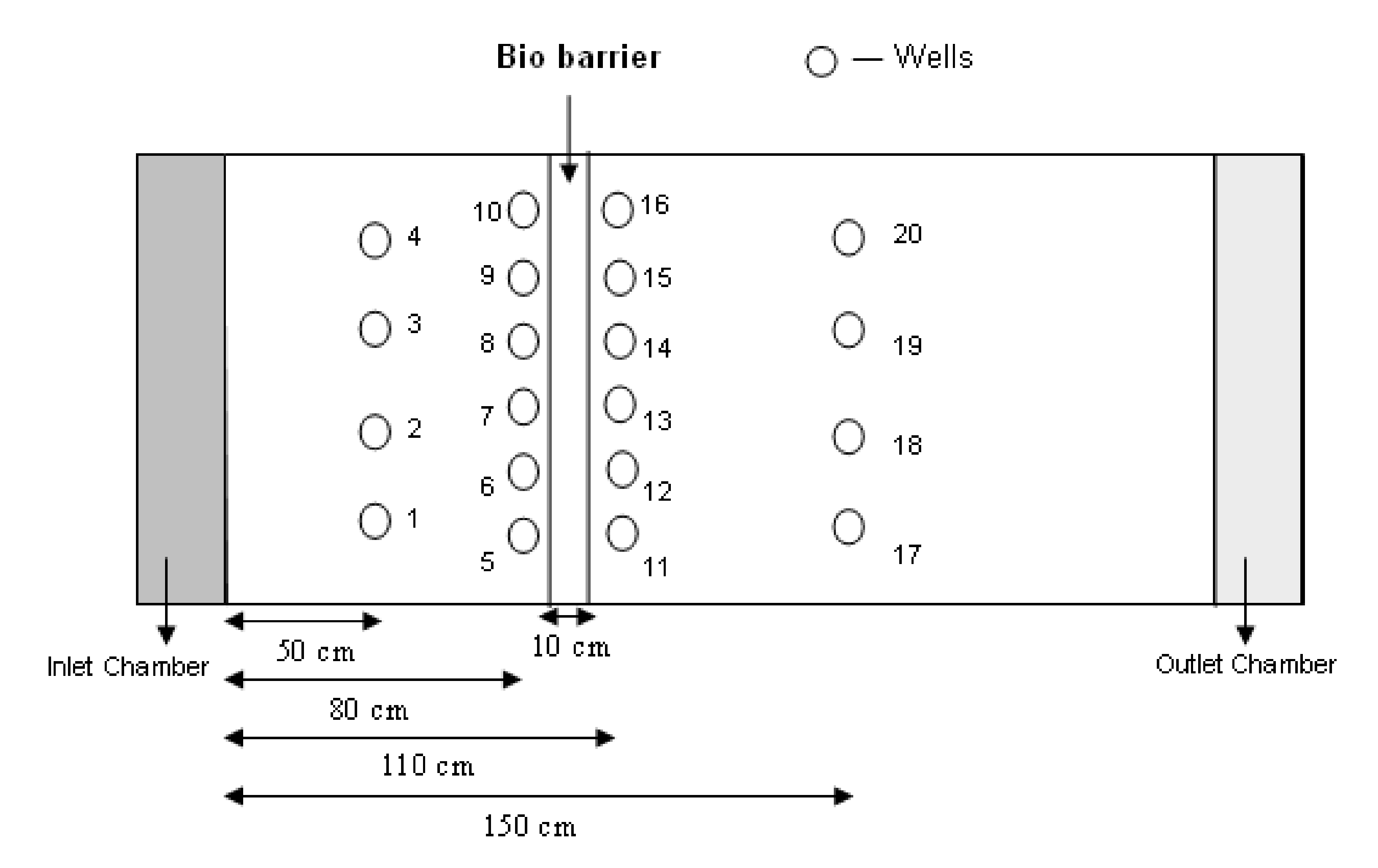
4

PILOT SCALE STUDIES

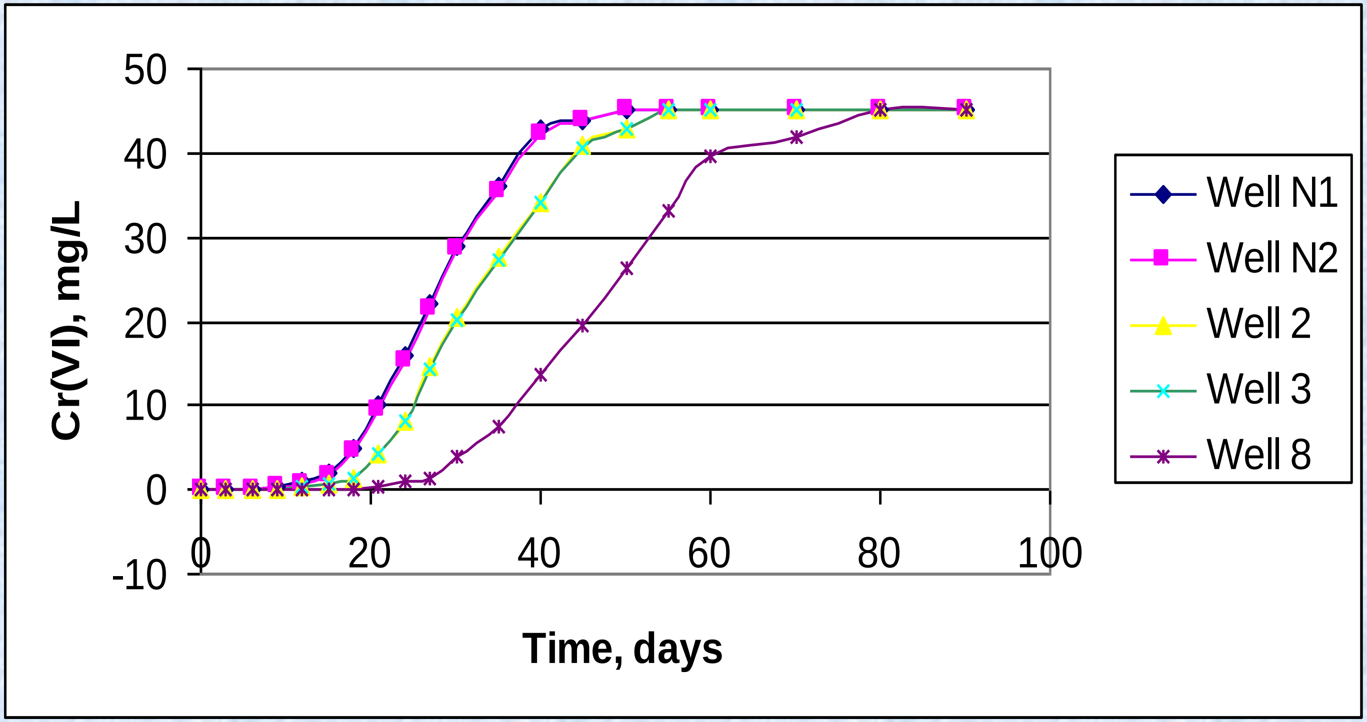
Schematic Diagram of the Reactor



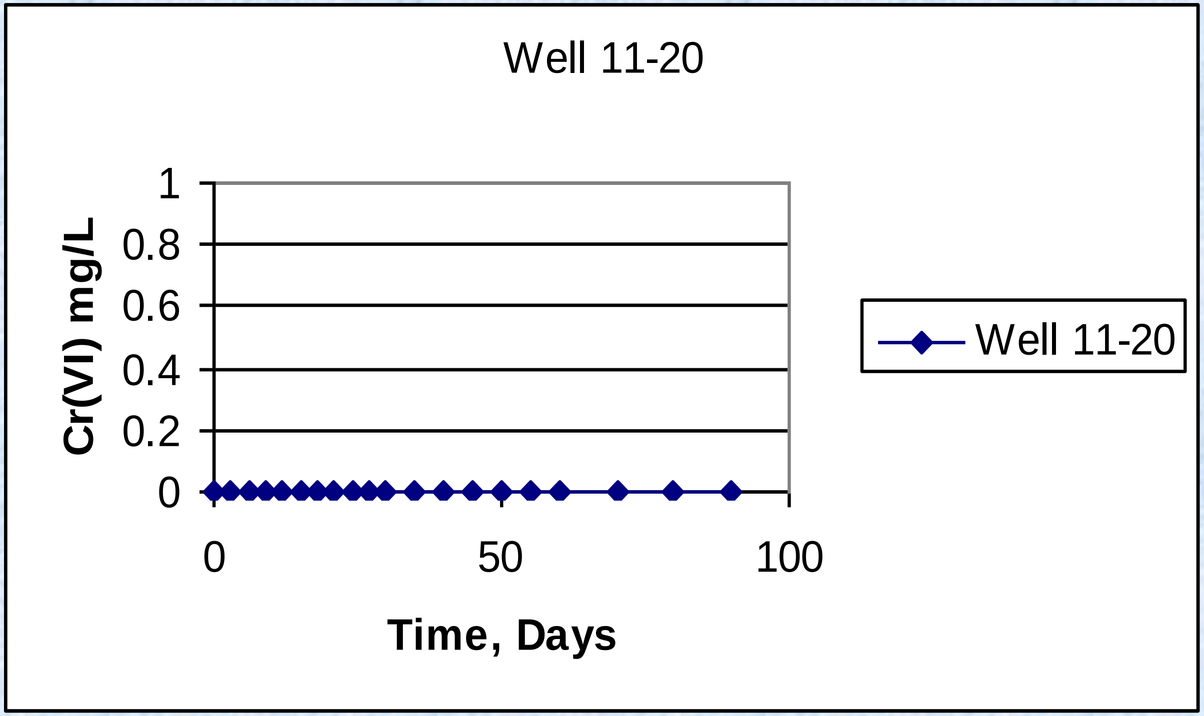
Location of Wells



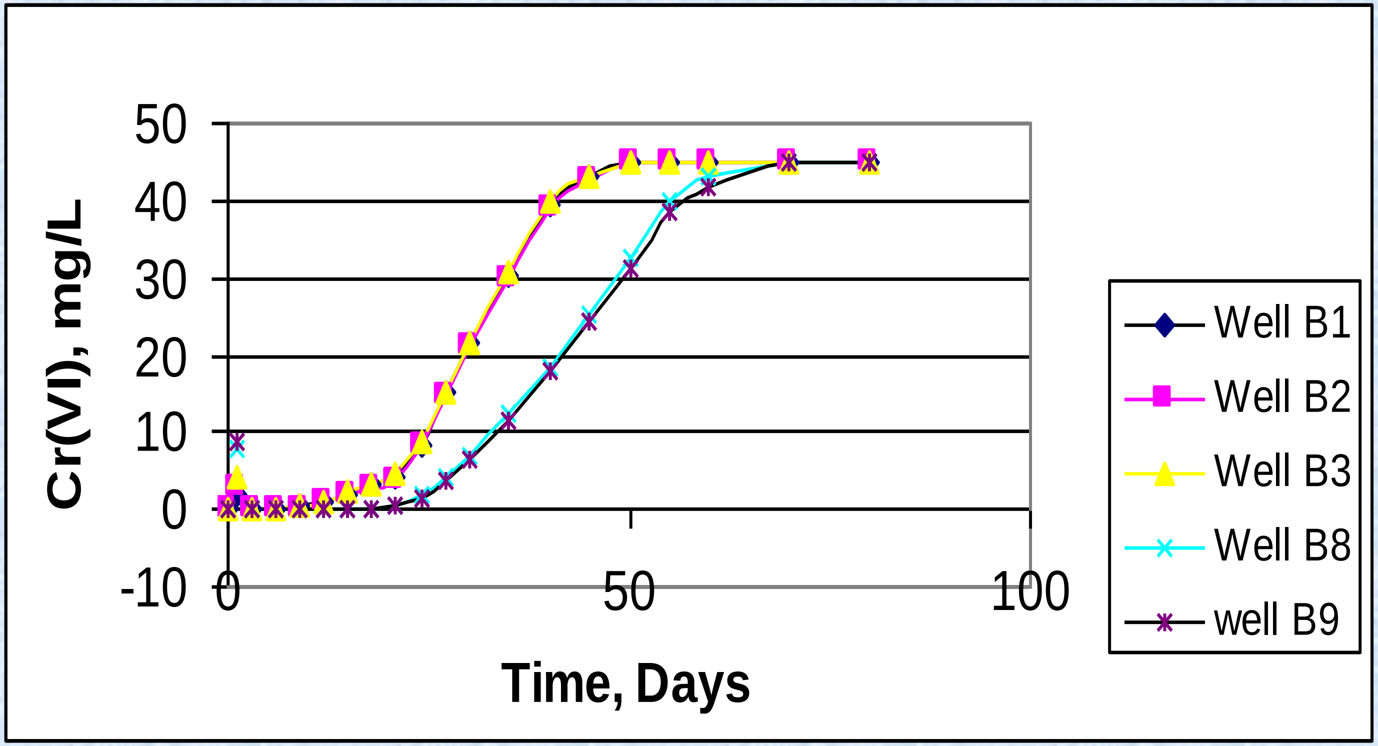
Cr (VI) Concentration before the Bio-barrier in Bioreactor



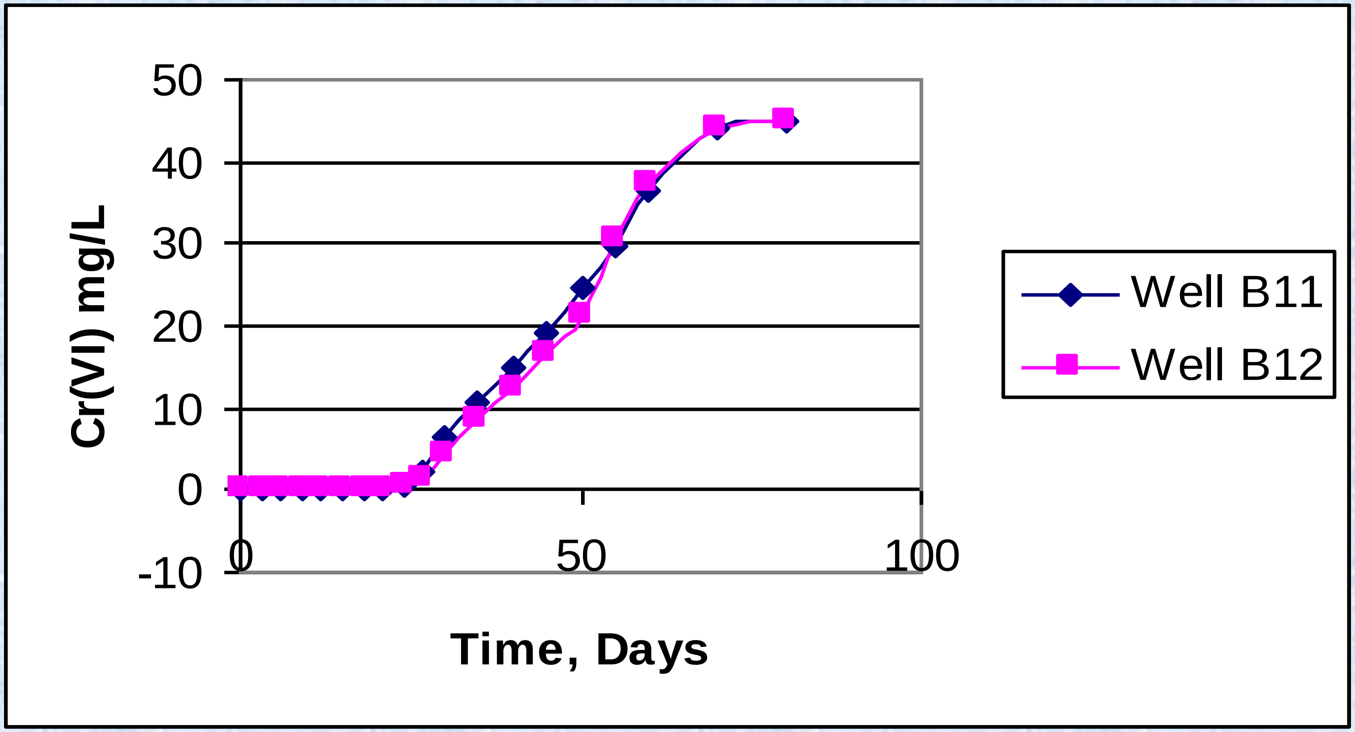
Cr (VI) Concentration after the Bio-barrier in Bioreactor



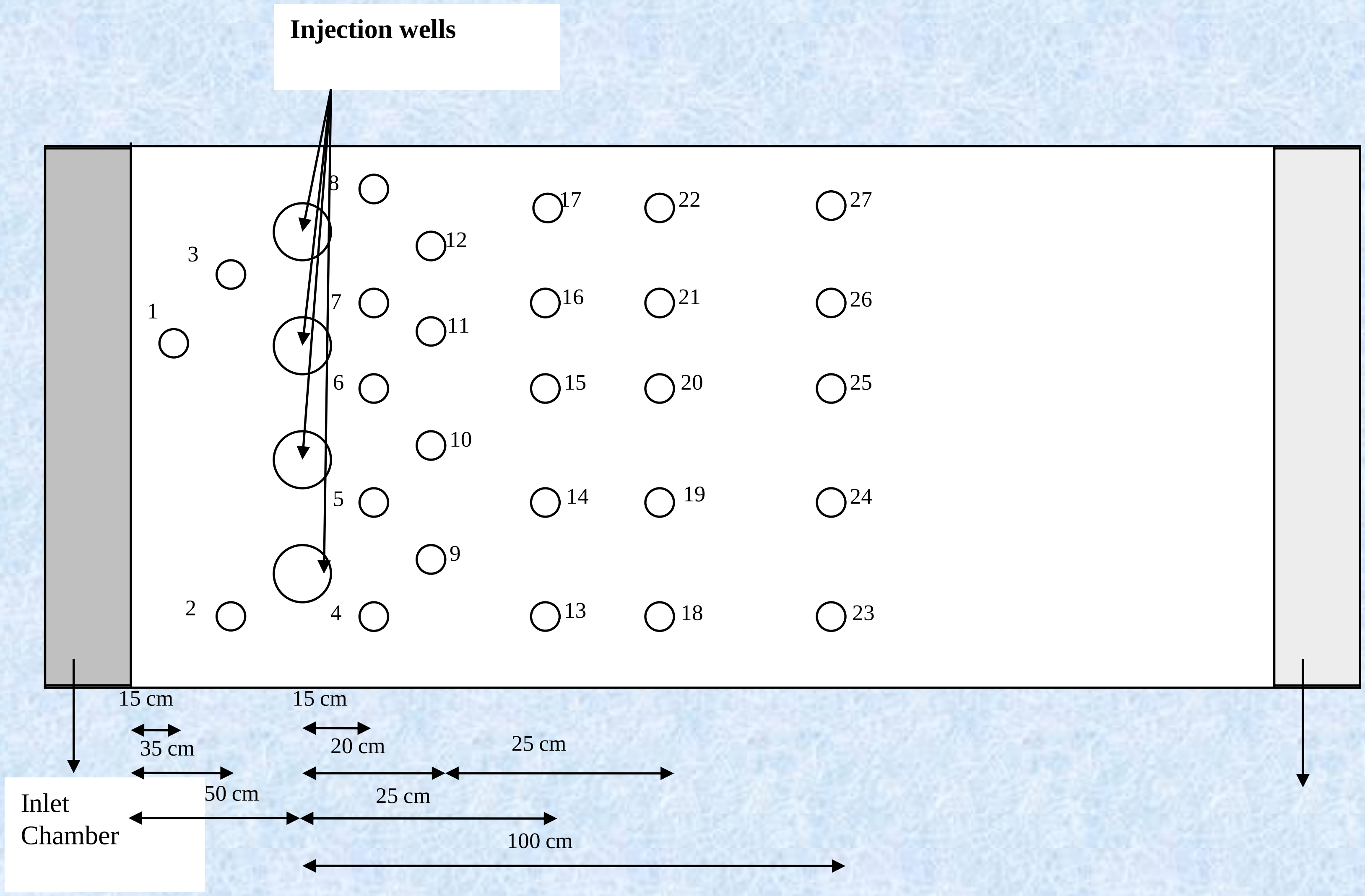
Cr (VI) Concentration in the Blank Reactor before Barrier



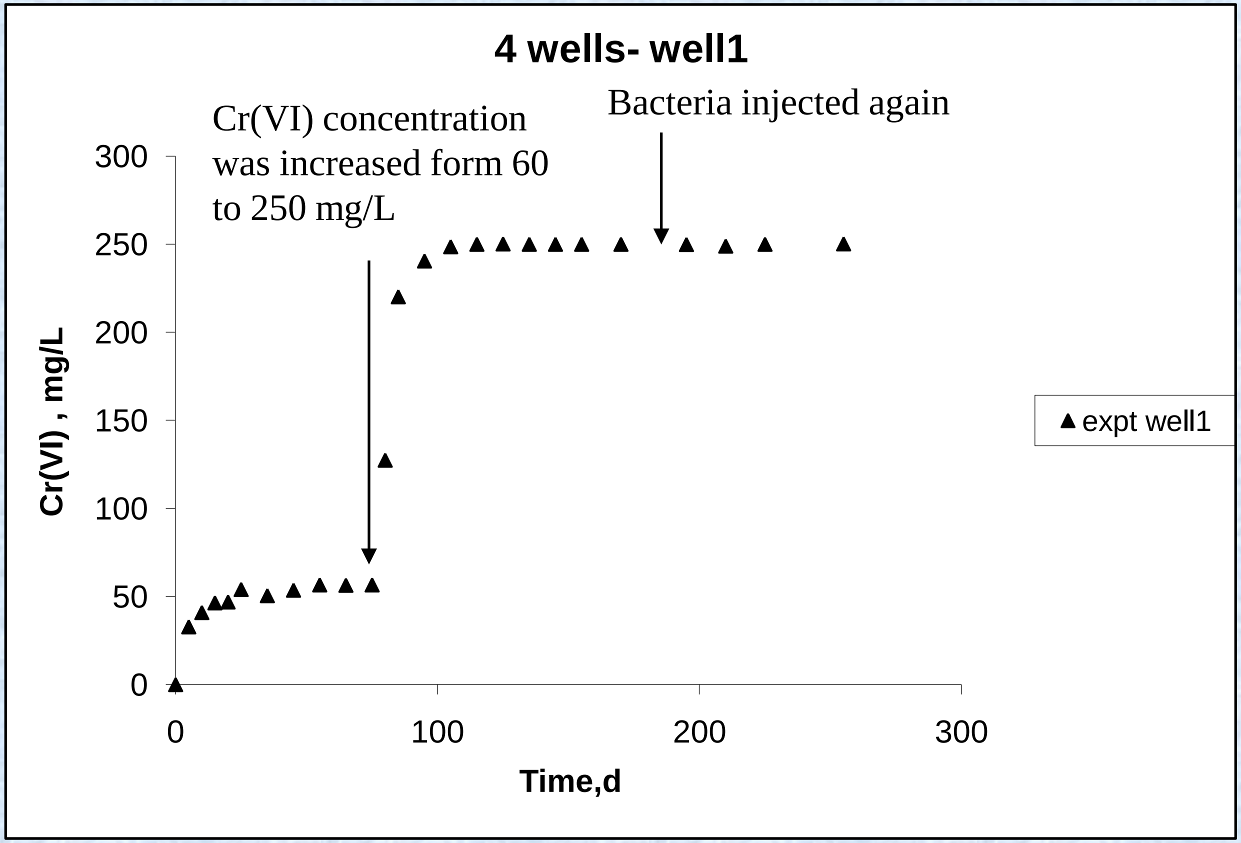
Cr (VI) Concentration in the Blank Reactor after the Barrier



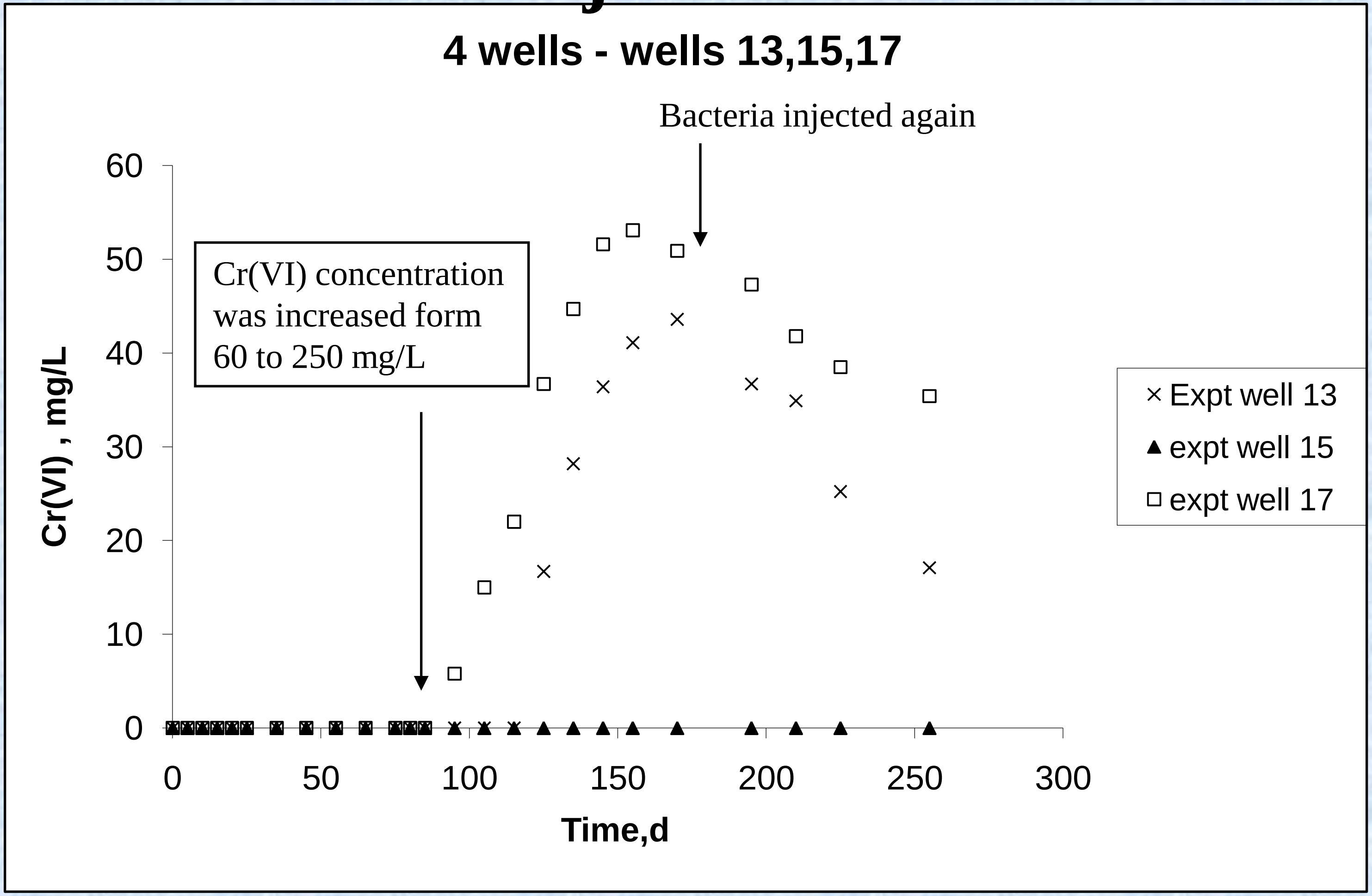
PLAN VIEW OF REACTOR CONTANING FOUR INJECTION WELLS

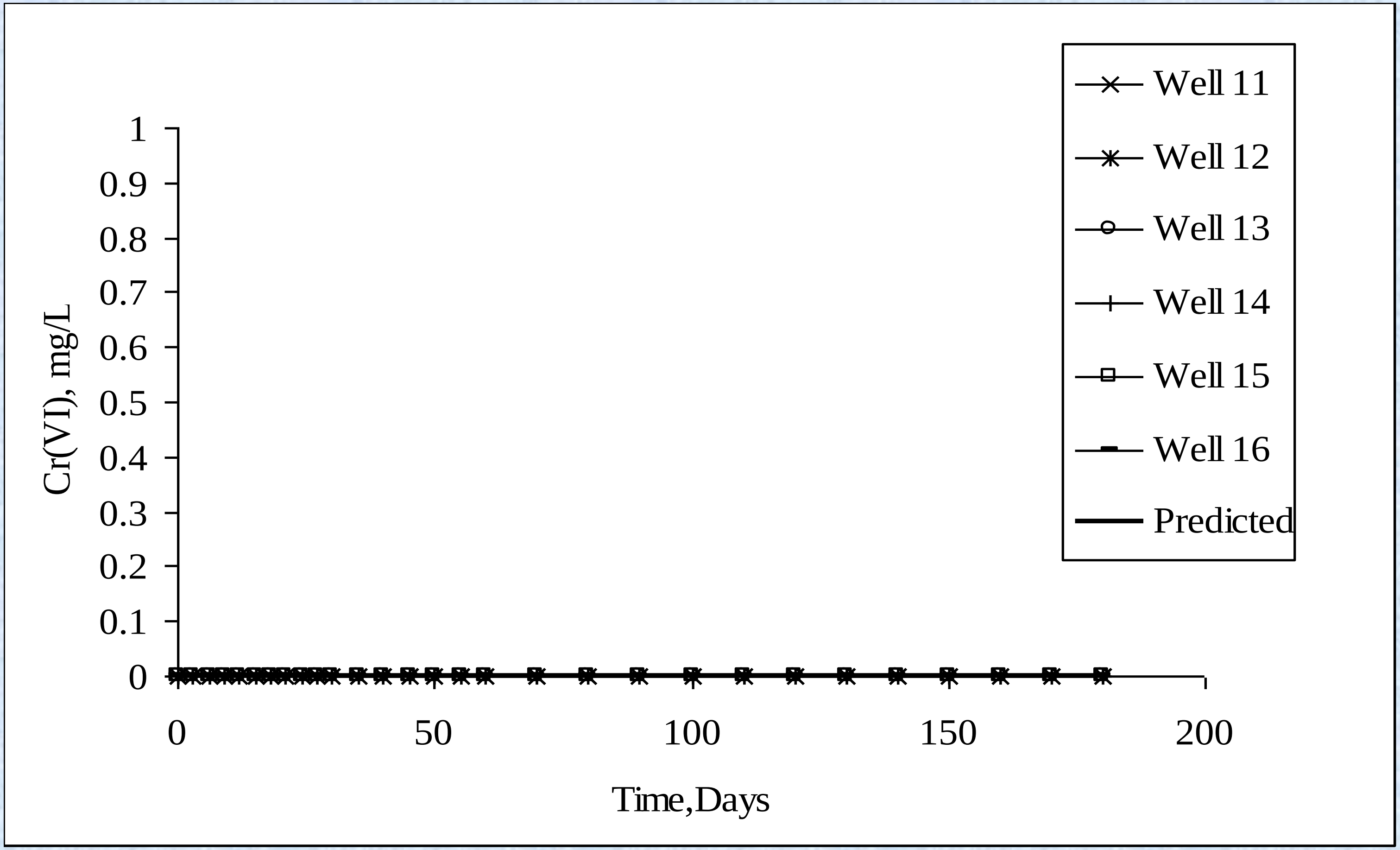


Cr (VI) Concentration in Reactor before four Injection wells



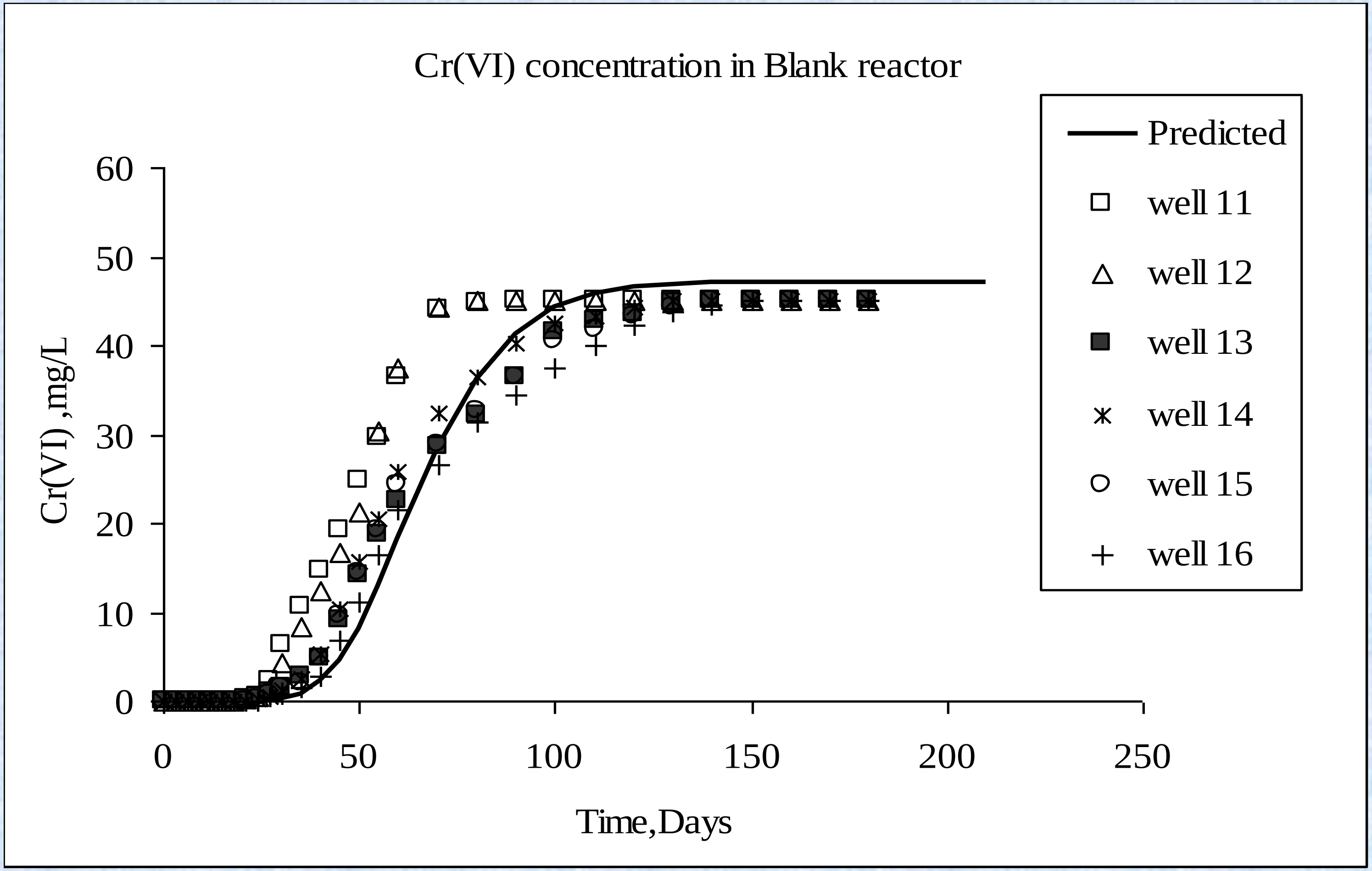
Cr (VI) Concentration in Reactor after four Injection wells





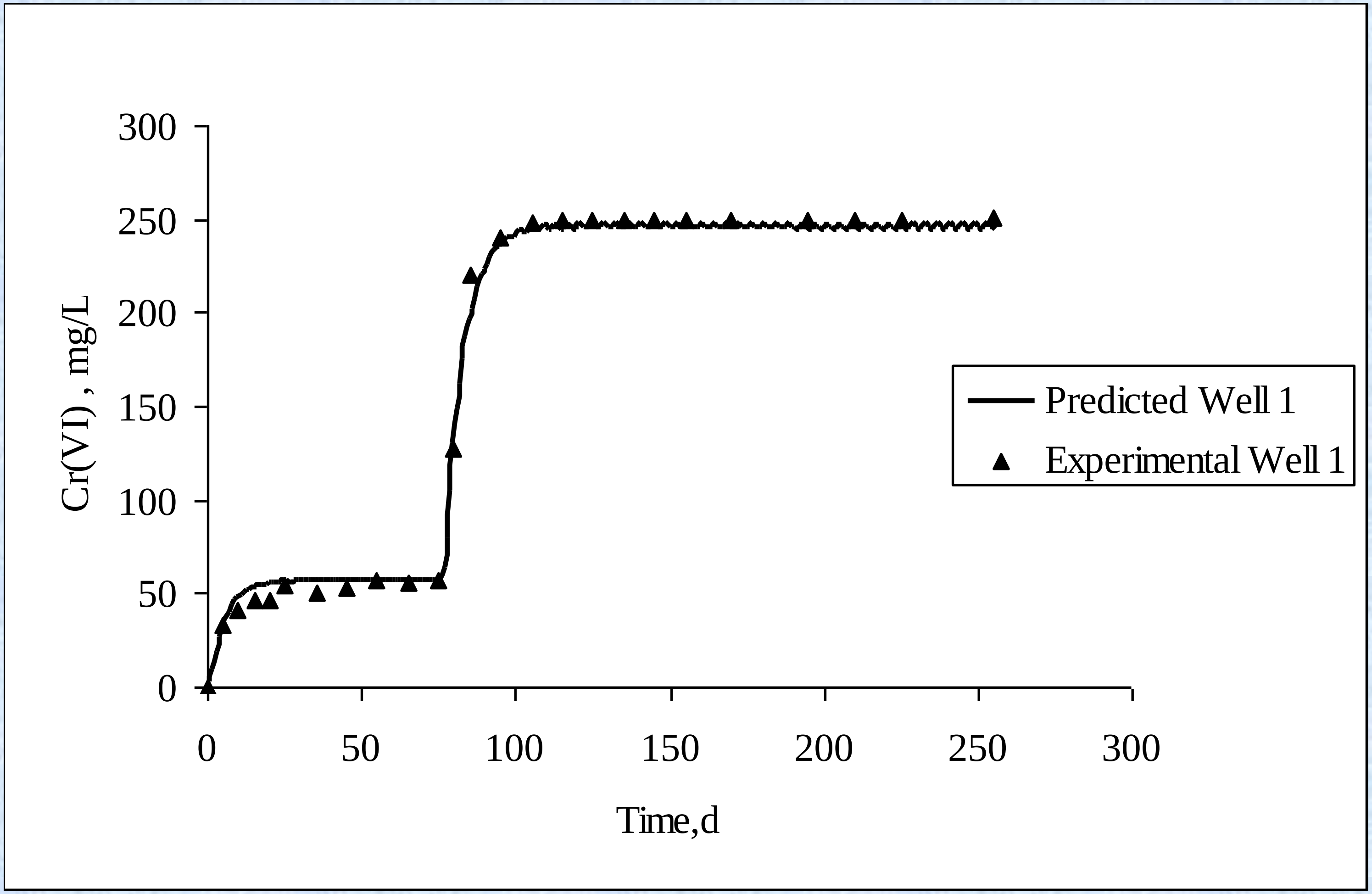
Experimental and modeling results for temporal variation of Cr(VI) concentration in wells 11-16 (at a distance of 110 cm from inlet) in reactor R1

Jeyasigh et al., Chem. Engrg. Jl., 2011



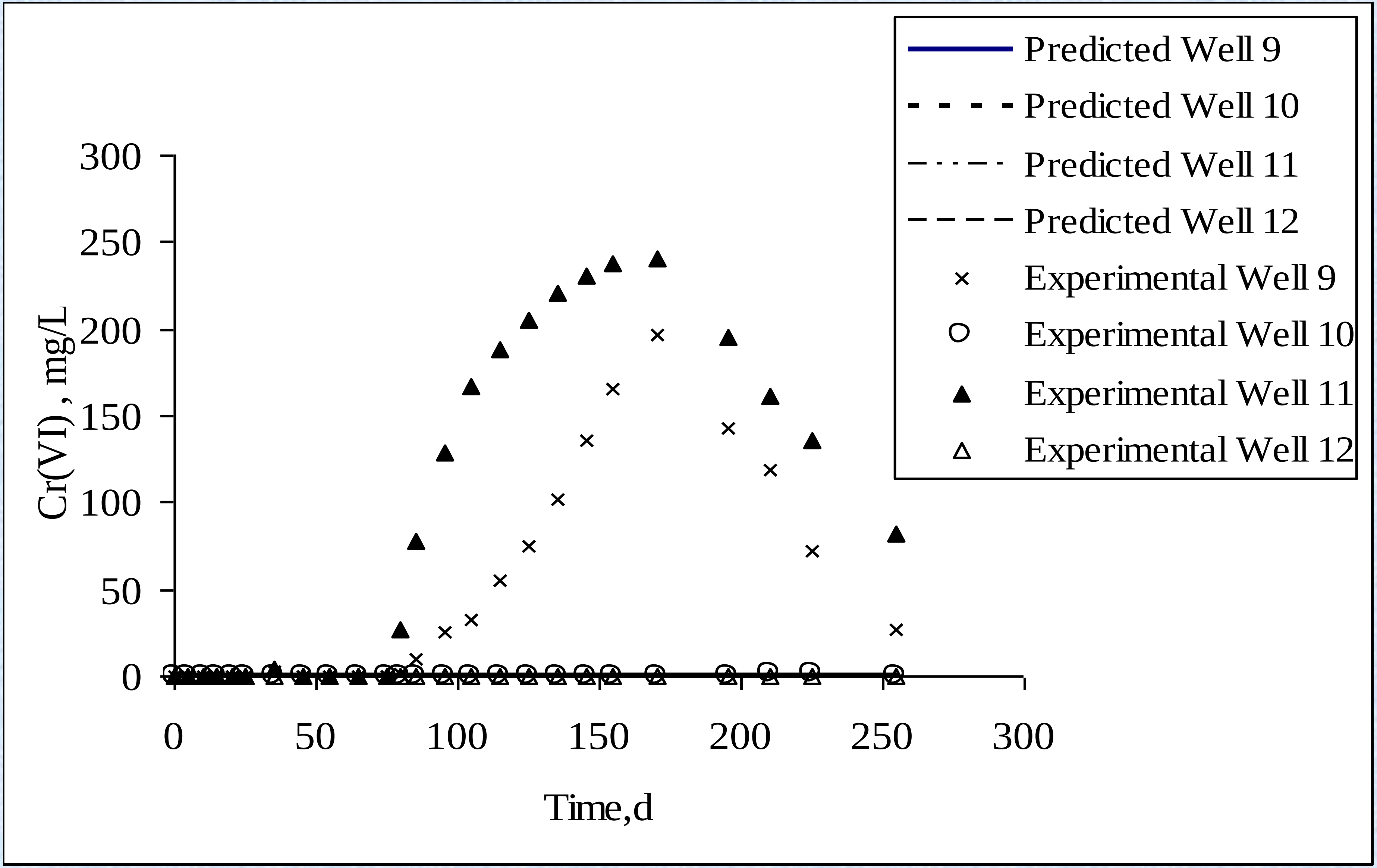
Experimental and modeling results for temporal variation of Cr(VI) concentration in wells 11-16 in reactor R2

Jeyasigh et al., Chem. Engrg. Jl., 2011

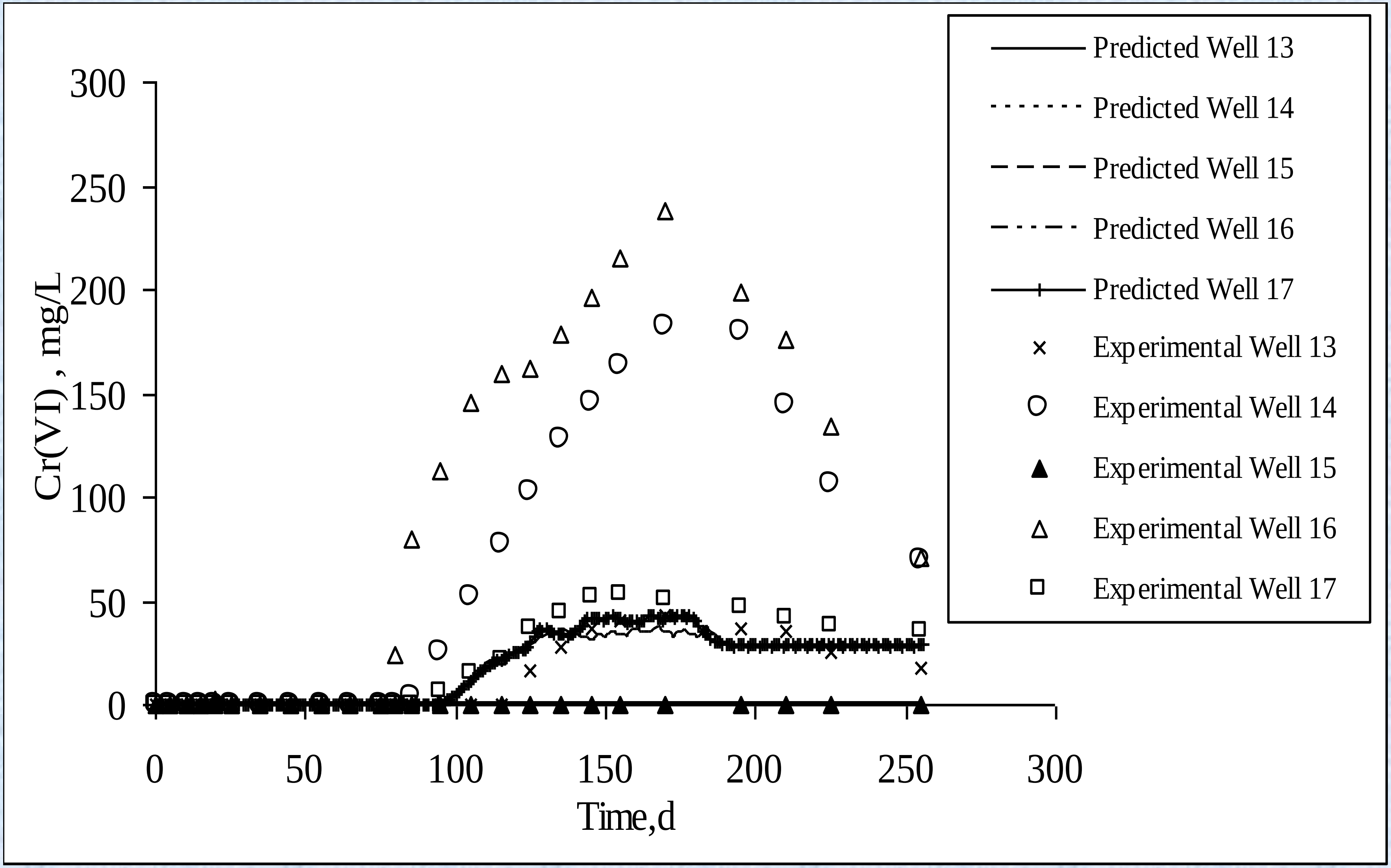


Experimental and modeling results for temporal variation of Cr(VI) concentration at well no 1 in reactor R4 (4 wells system)

Jeyasigh et al., Chem. Engrg. Jl., 2011



Jeyasigh et al., Chem. Engrg. Jl., 2011



Jeyasigh et al., Chem. Engrg. Jl., 2011

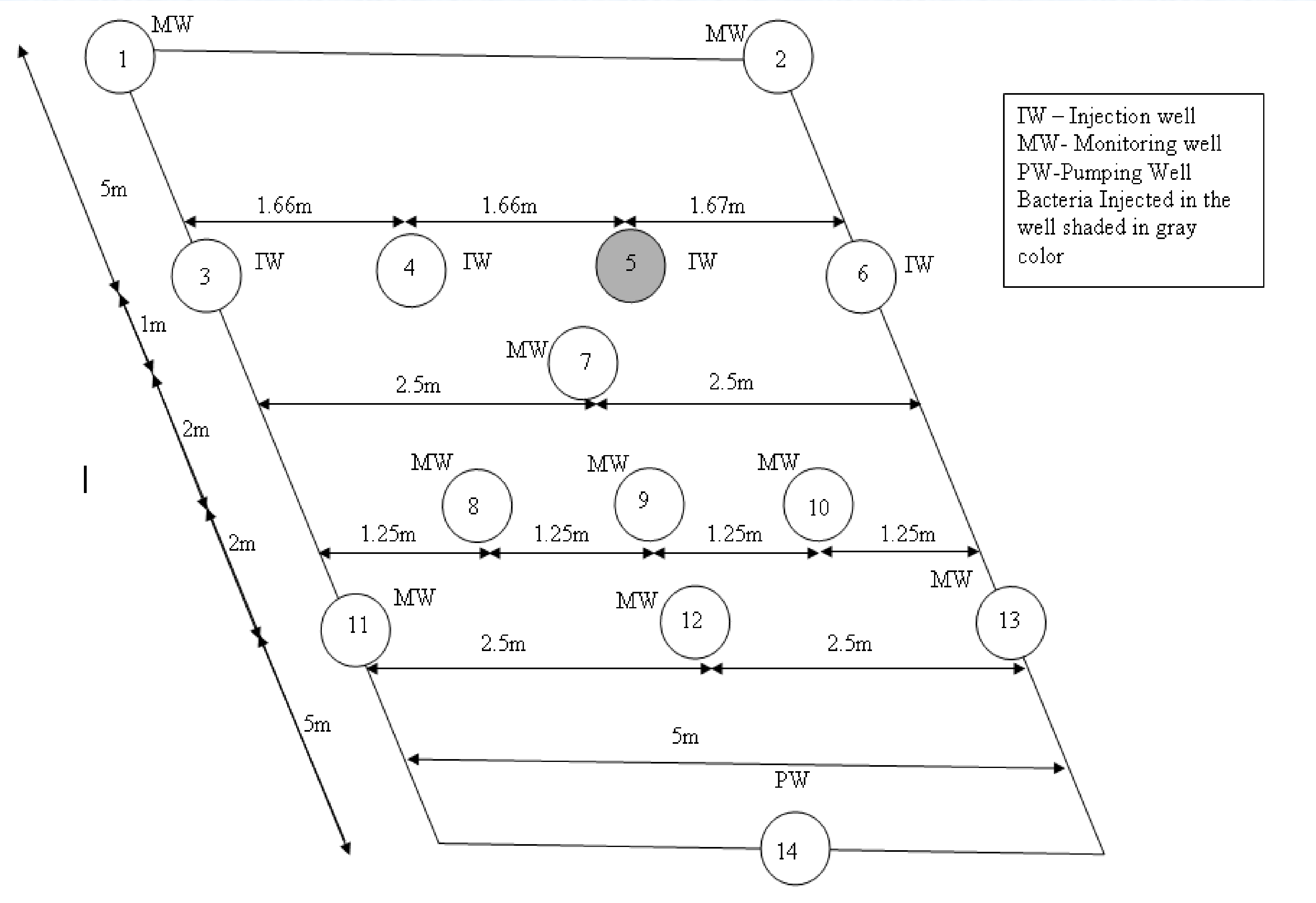
Field Demonstration of Bioremediation of Cr(VI) Contaminated Soil and Aquifer in Ranipet, Tamilnadu

SCOPE

- **Remediation of at least 5 tons of chromium sludge in the vicinity of Tamilnadu Chromates and Chemicals Limited (TCCL) at the site;**

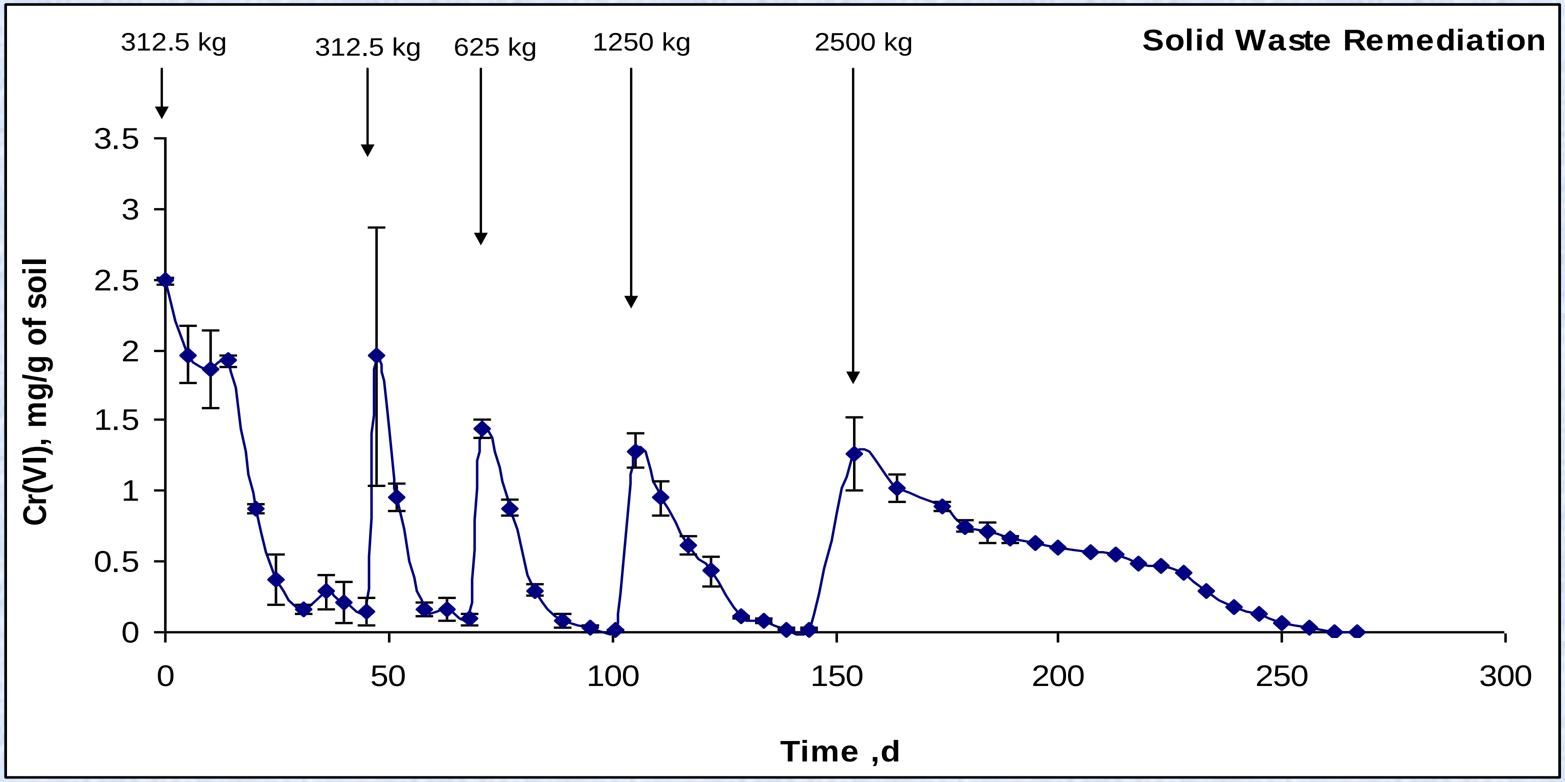
- **Demonstration of in-situ bioremediation of Cr(VI) contaminated aquifer in a 5 m ×5 m area of aquifer in the vicinity of Tamilnadu Chromates and Chemicals Limited (TCCL), Ranipet, by injection well - reactive zone technology;**

Well locations in the experimental plot



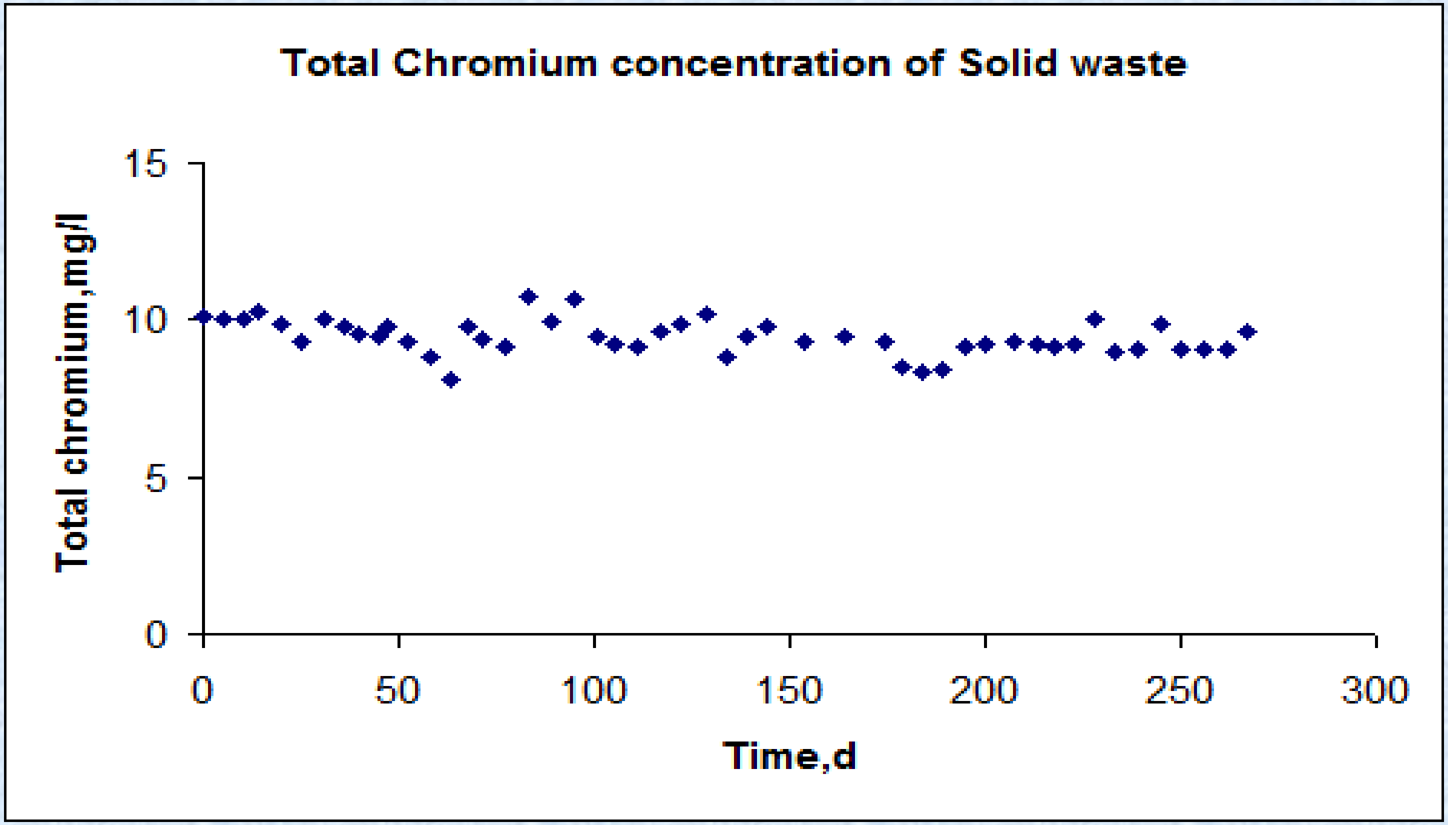
RESULTS

Soil Remediation



Variation of Cr(VI) concentration with respect to time in solid waste remediation (Mass of untreated sludge added at various time is mentioned inside the graph)

Variation of total chromium concentration with respect to time in solid waste remediation



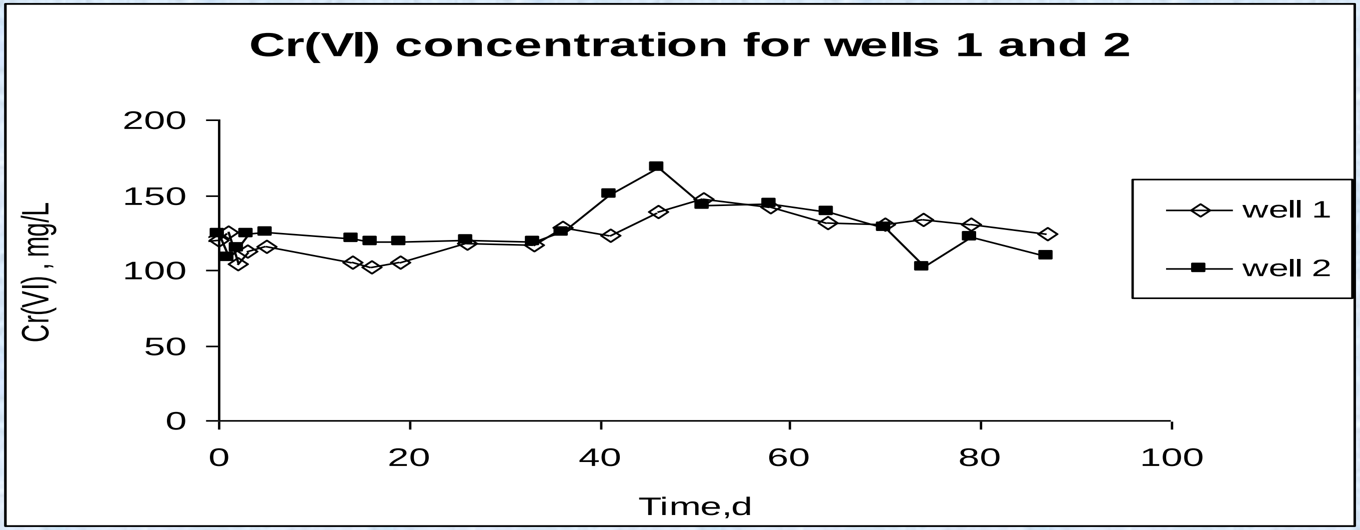
Remediated and un-remediated soils

Five Tones of Remediated Soil
Leachate from remediated soil

Un-remediated Soil and Leachate from un-remediated soil

Aquifer Remediation

Bioremediation using Molasses (Jaggery) as the Carbon Source

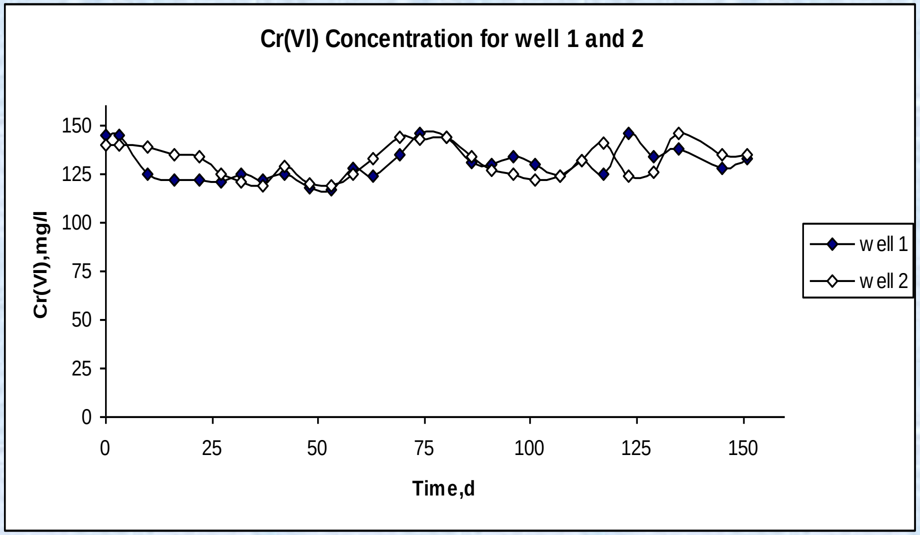


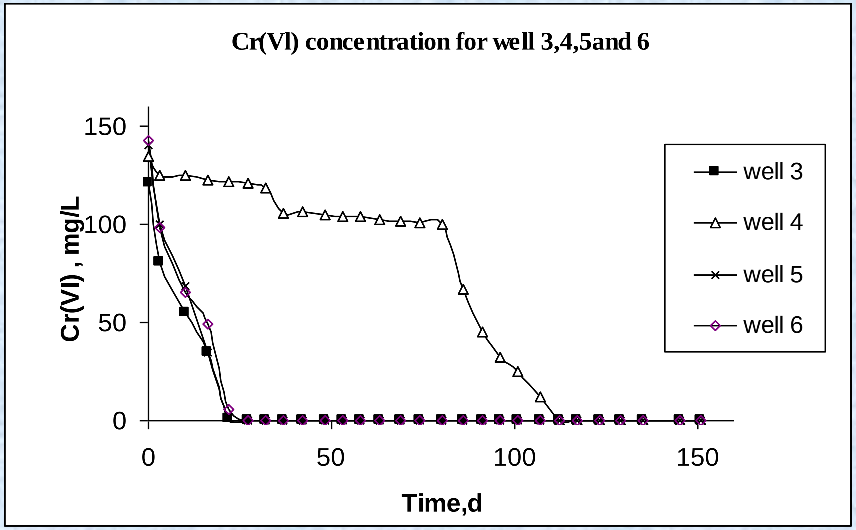
Variation of Cr (VI) concentration with respect to time in wells 1 and 2 (molasses as carbon source)

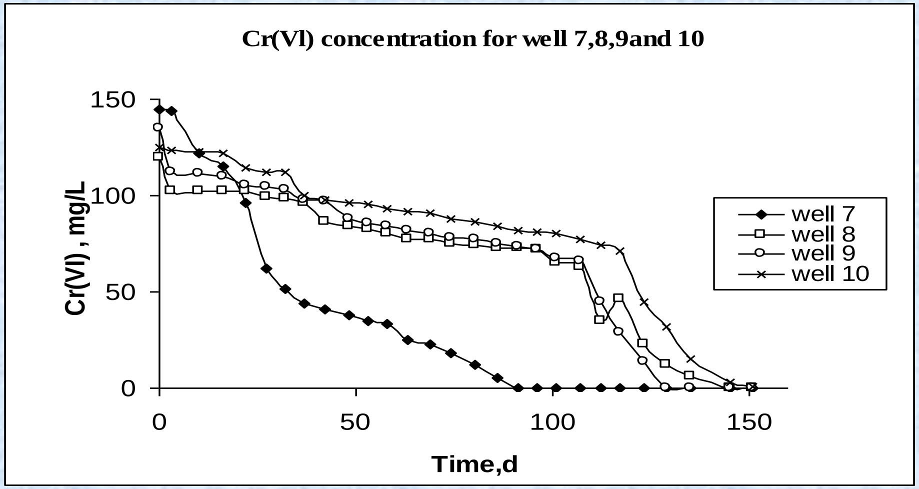
Bioremediation using Sugar as the Carbon Source

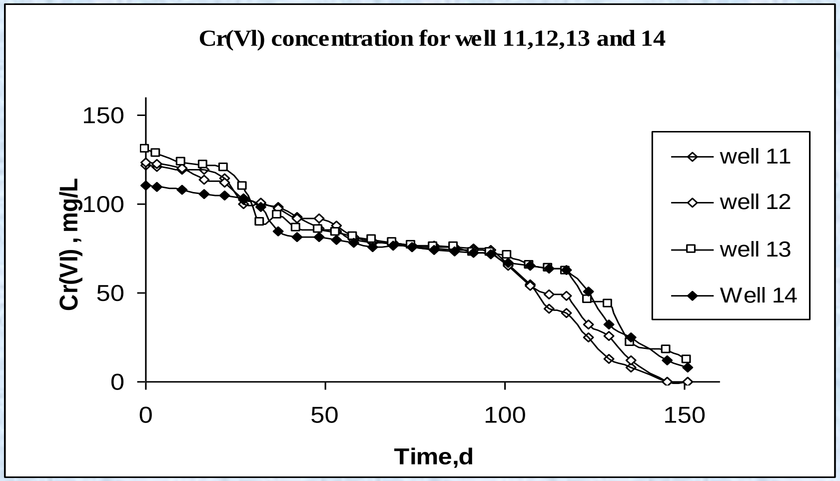
- Remediation of Cr(VI) aquifers were also carried out using sugar as the carbon source.
- For this study the initial biomass concentration was reduced to $1/10^{th}$ of that used in the previous case.
- Carbon source concentration also was reduced to $1/4^{th}$ and feeding interval was increased to 7- 10 days.
- The fate and transport of chromium (both Cr(VI) and Cr(III)), molasses and its derivatives, and microbes during the study period was monitored.

Bioremediation using Sugar as the Carbon Source: Cr(VI concentrations

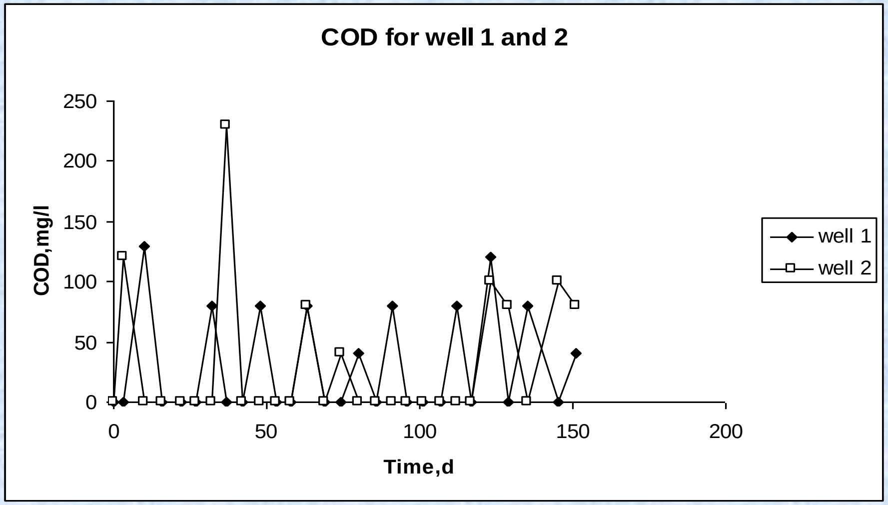


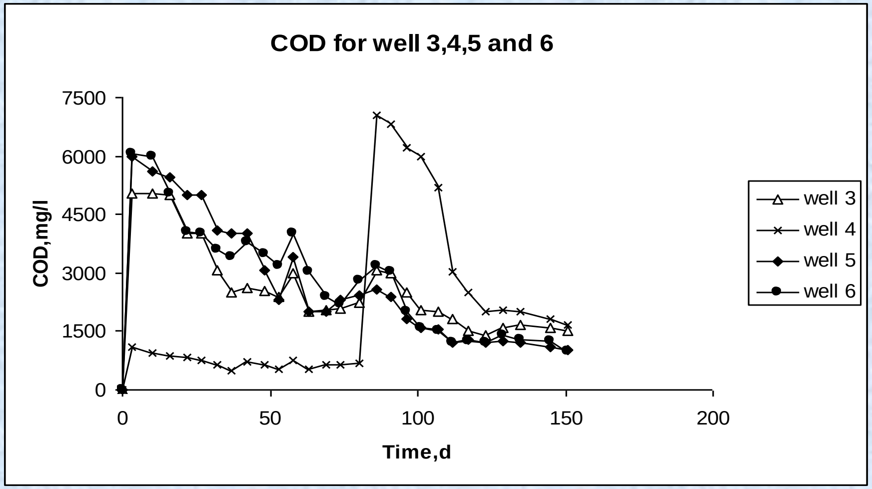


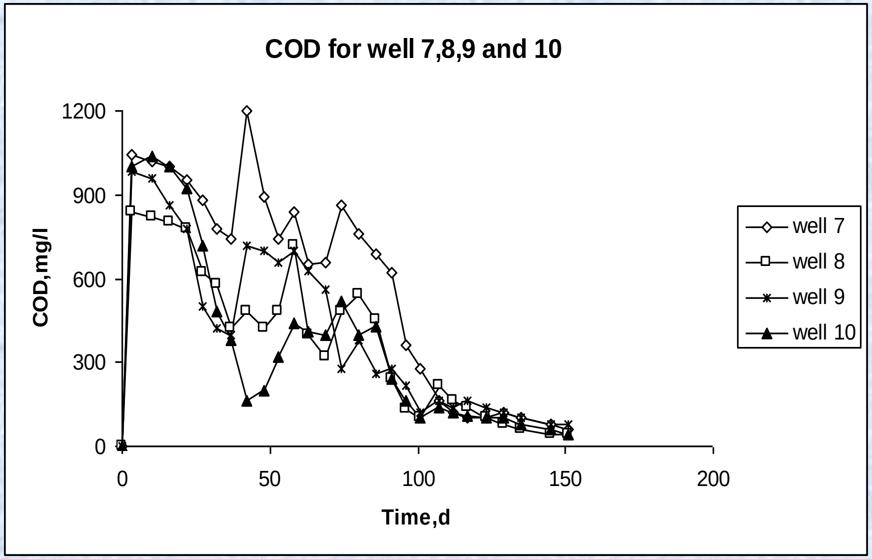


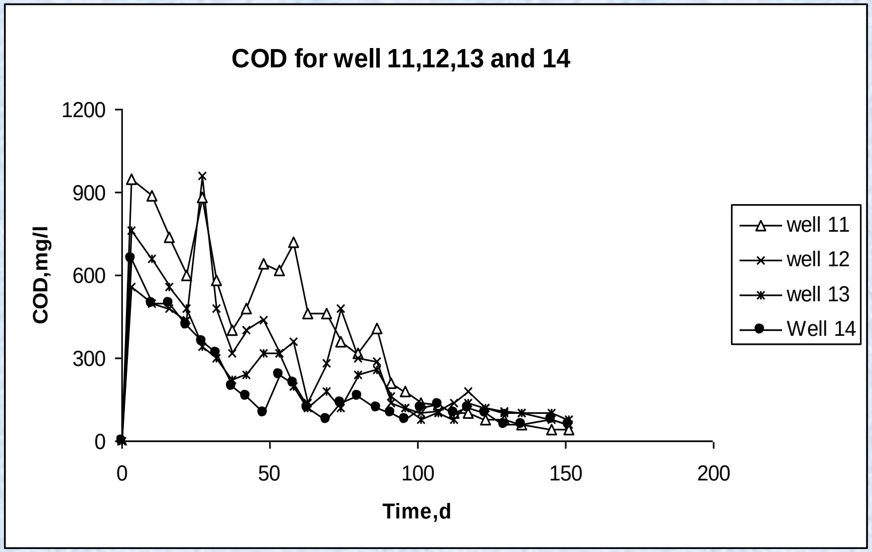


COD concentrations in various wells during bioremediation using sugar as carbon Source

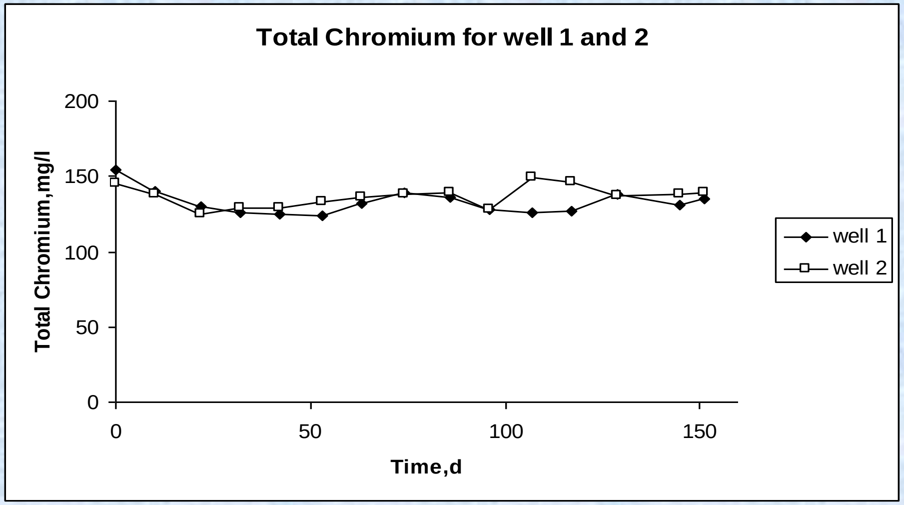


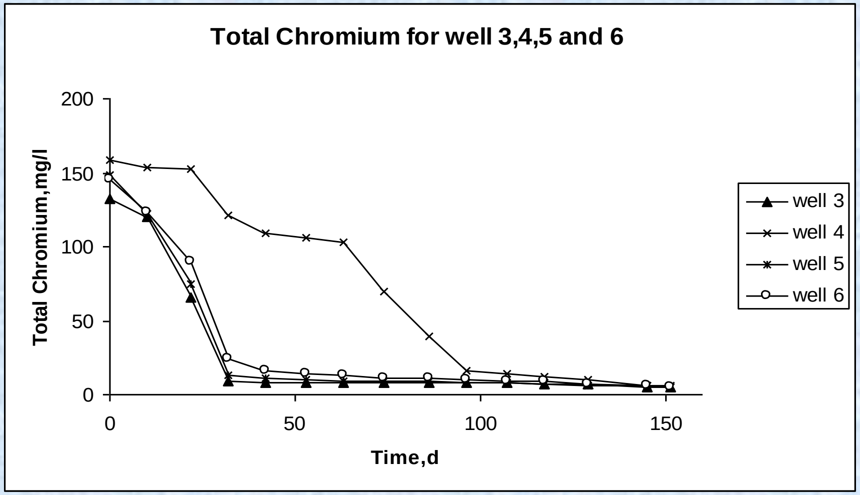


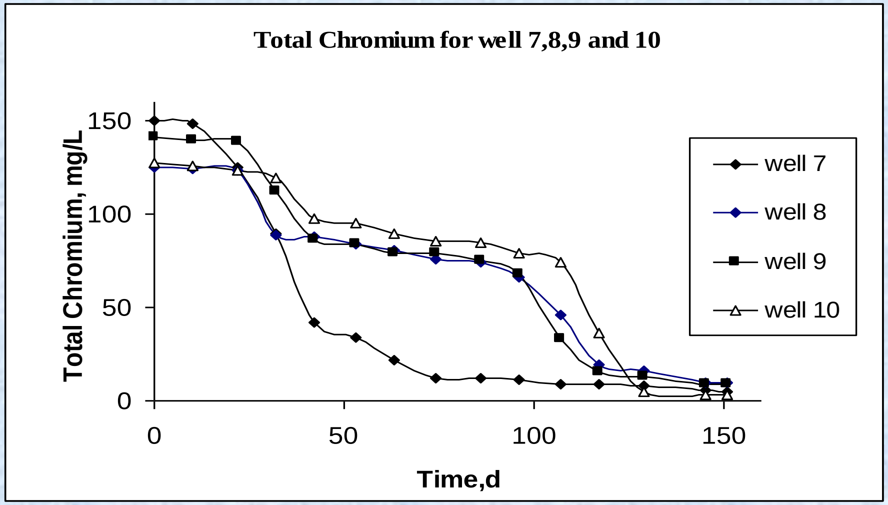


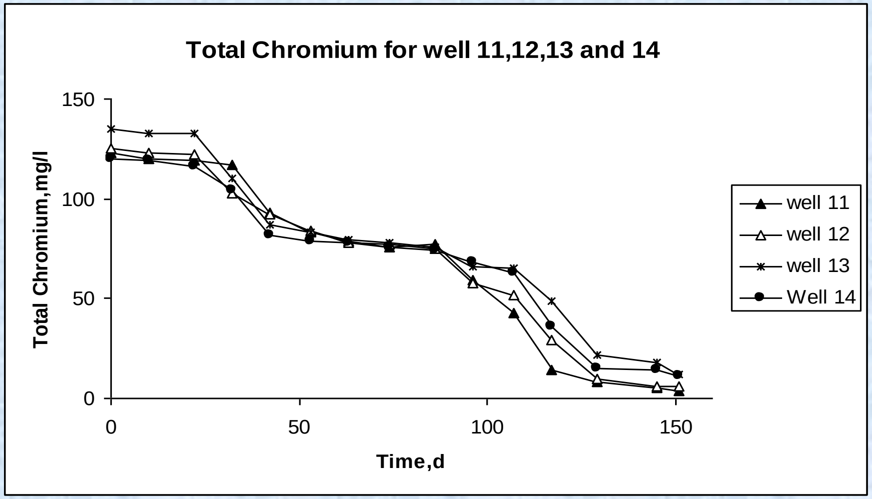


Total Cr concentrations in various wells during bioremediation using sugar as carbon Source

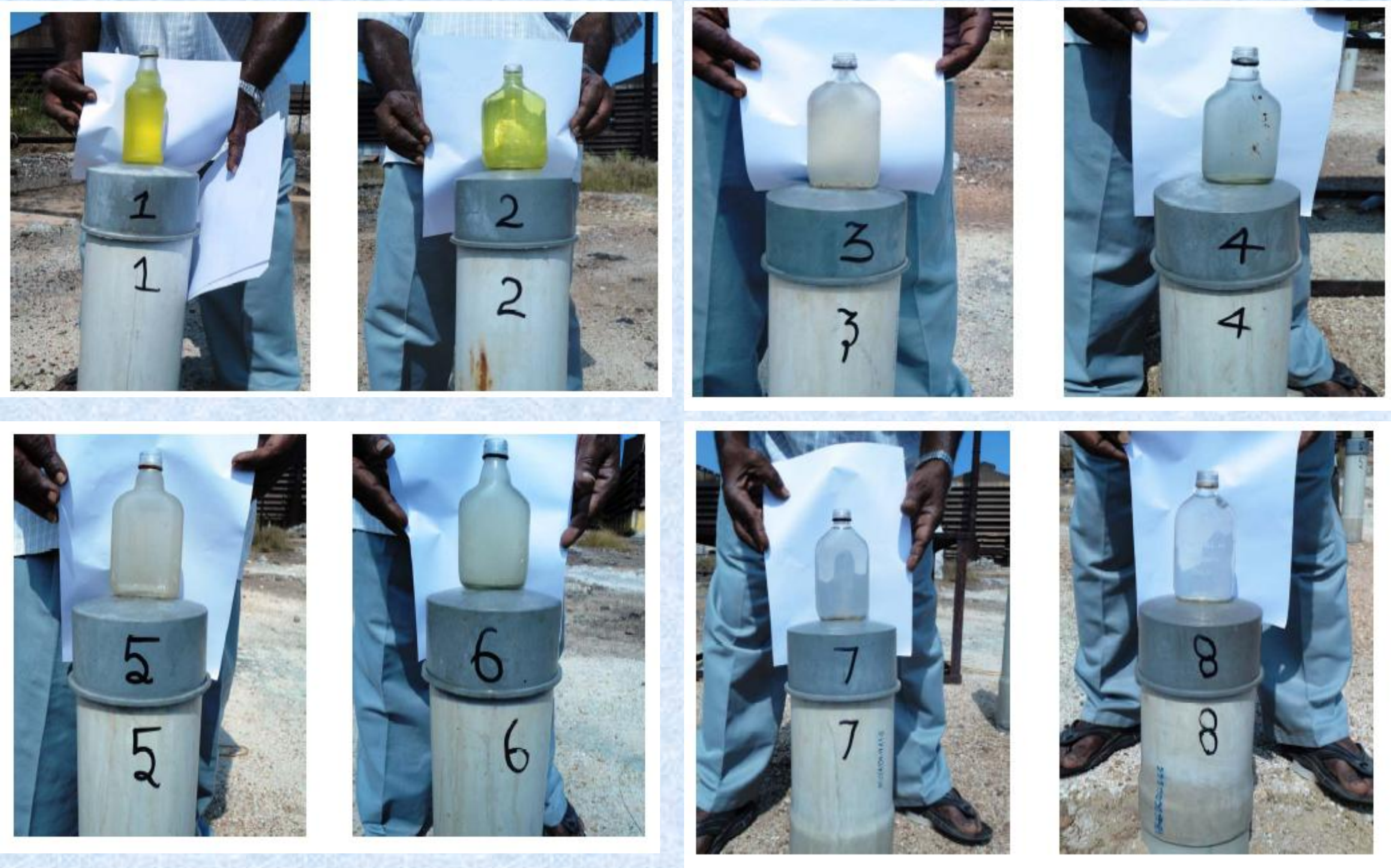




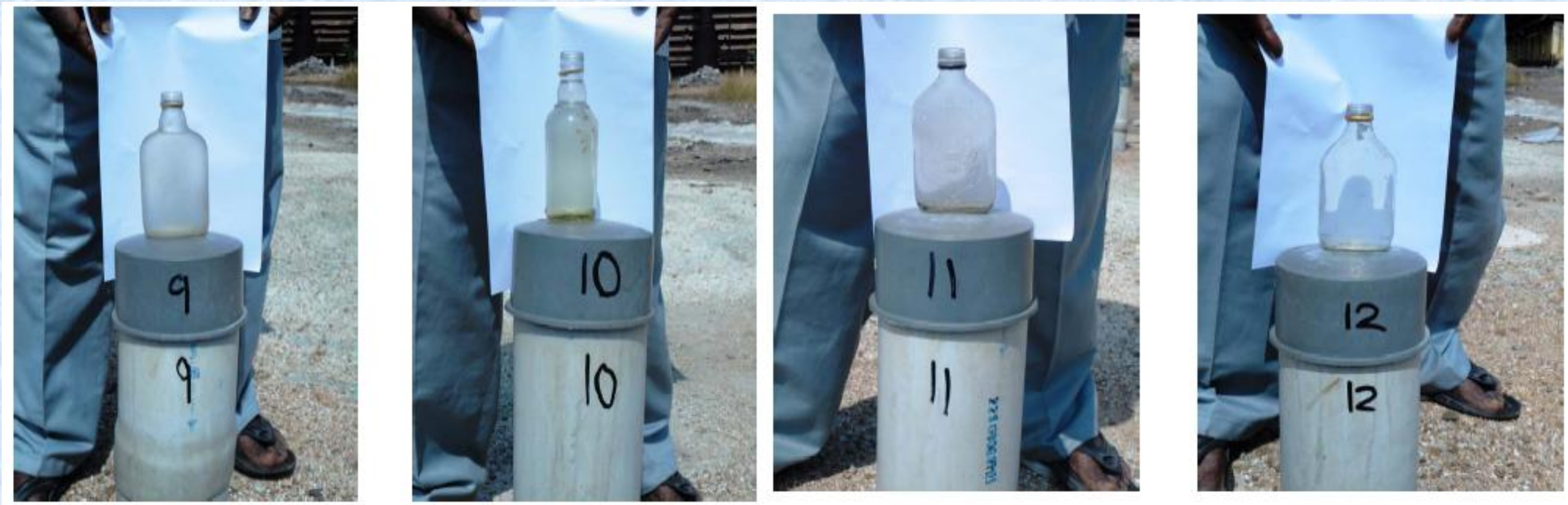




Water samples from various wells after remediation



Water samples from various wells after remediation



Analysis of Heavy Metals in Aquifer

Metals	Well 1 (mg/L)	Well 2 (mg/L)	Well 3 (Injection well)	Well 5 (Injection well)	Well 9	Well 13	Well 14
Copper	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Lead	BDL	BDL	0.0925	0.0775	0	0	0
Manganese	0.065	0.067	0.068	0.057	0.017	0.054	0.05
zinc	0.012	0.017	0.2825	0.2175	0.0225	0.07	0.09
Cr(VI)	145.2	140.2	BDL	BDL	BDL	BDL	BDL
Iron	BDL	BDL	0.017	0.023	0.0487	0.032	0.036
Nickel	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Field Applications: Technology Transfer

Radiant Electroplaters

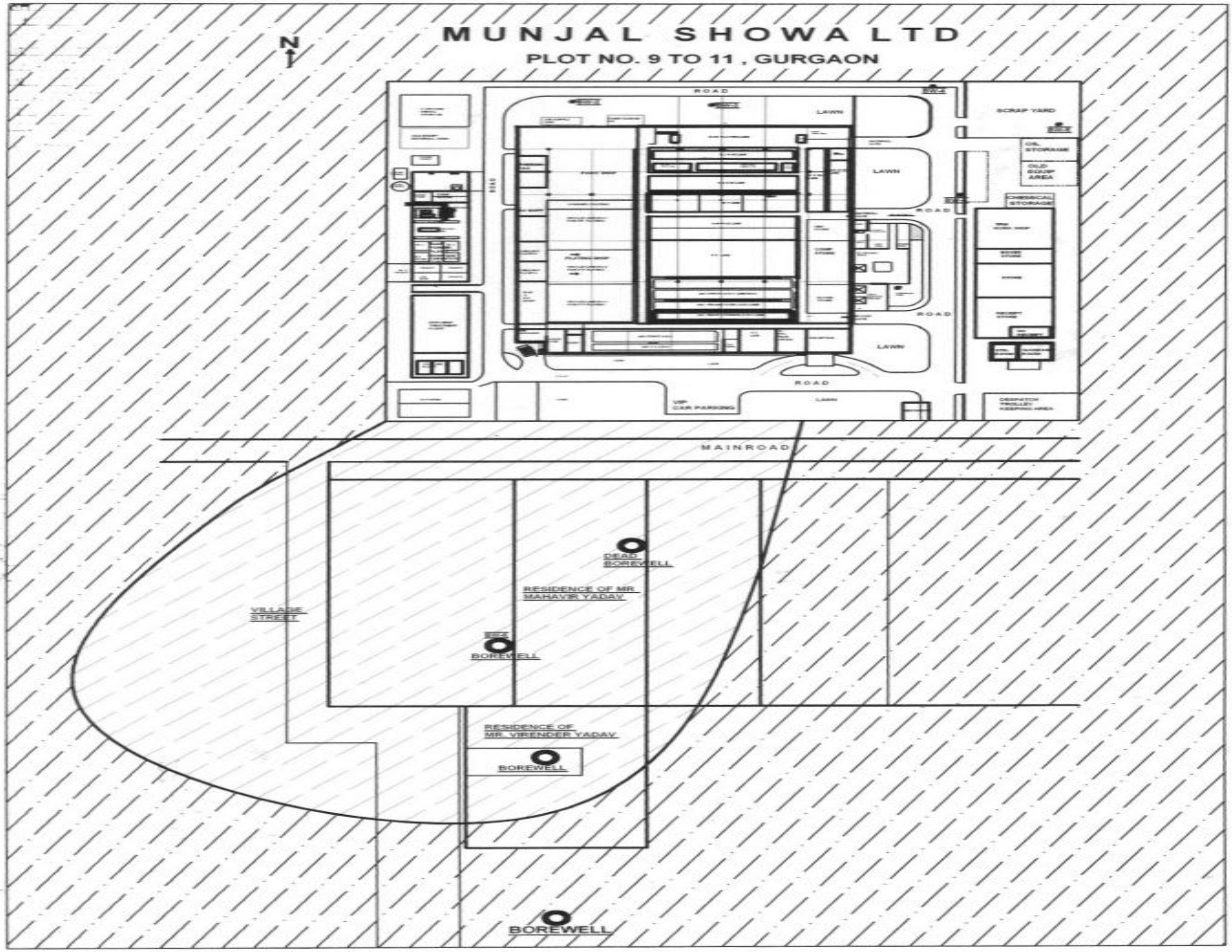
- **MR. ALI AKBAR, Radiant Electroplaters, 32 KMA Garden Road, Kodungaiyur, Chennai-600118**

NGT Case

- **The wastes storage tank breached.**
- **Contaminated the neighboring industrial plot and groundwater**
- **Industry was closed**

Munjal Showa Ltd.,

- Court Order to Close the Industry
- Fine Rs 5 crores.


MUNJAL SHOWA LTD
PLOT NO. 9 TO 11, GURGAON
N
ROAD
LAWN
SCRAP YARD
OIL STORAGE
OLD EQUIP AREA
CHEMICAL STORAGE
ROAD
ROAD
LAWN
ROAD
VIP CAR PARKING
LAWN
DESPATCH TROLLEY KEEPING AREA
MAINROAD
DEAD BOREWELL
RESIDENCE OF MR MAHAVIR YADAV
VILLAGE STREET
BOREWELL
RESIDENCE OF MR. VIRENDER YADAV
BOREWELL
BOREWELL

Hydro-Geological Conditions

TUBEWELL NO.1

DEPTH: 100 MTRS

STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-30 M	HARD CLAY
30-50 M	FINE SAND
50-60 M	FINE SAND
60-80 M	HARD CLAY
80-100 M	FINE SAND

TUBEWELL NO.2

DEPTH: 150 MTRS

STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-30 M	HARD CLAY
30-55 M	FINE SAND
55-65 M	FINE SAND
65-85 M	HARD CLAY
85-105 M	FINE SAND
105- BELOW 150 M	HARD ROCK

TUBEWELL NO.3

DEPTH: 105 MTRS

STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-35 M	HARD CLAY
35-55 M	FINE SAND
55-65 M	FINE SAND
65-85 M	HARD CLAY
85-105 M	FINE SAND

TUBEWELL NO.4

DEPTH: 105 MTRS

STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-35 M	HARD CLAY
35-55 M	FINE SAND
55-65 M	FINE SAND
65-85 M	HARD CLAY
85-105 M	FINE SAND

TUBEWELL NO.5

DEPTH: 105 MTRS

STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-35 M	HARD CLAY
35-55 M	FINE SAND
55-65 M	FINE SAND
65-85 M	HARD CLAY
85-105 M	FINE SAND

TUBEWELL NO.6

DEPTH: 100 MTRS

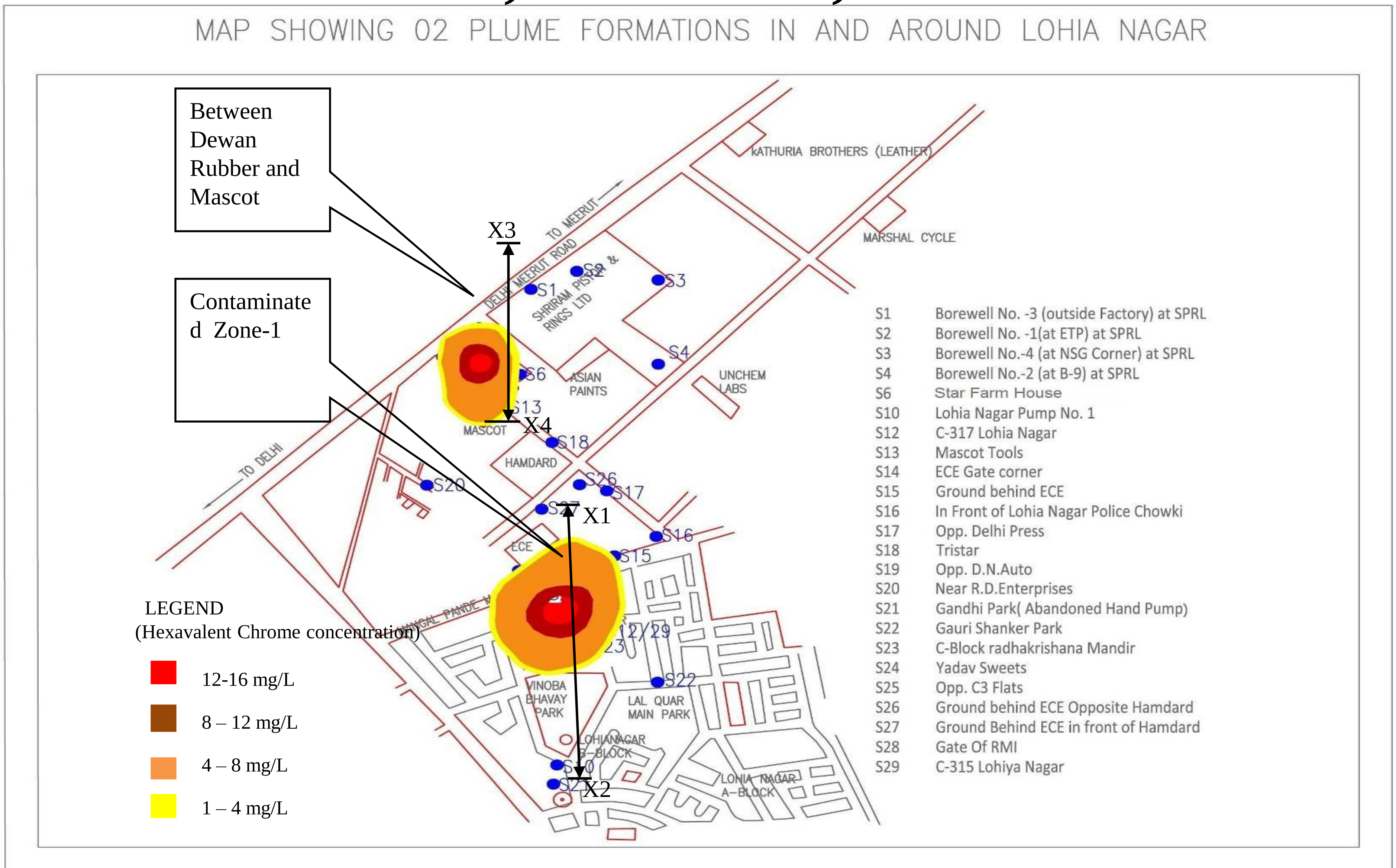
STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-30 M	HARD CLAY
30-50 M	FINE SAND
50-60 M	FINE SAND
60-80 M	HARD CLAY
80-100 M	FINE SAND

TUBEWELL NO.7

DEPTH: 100 MTRS

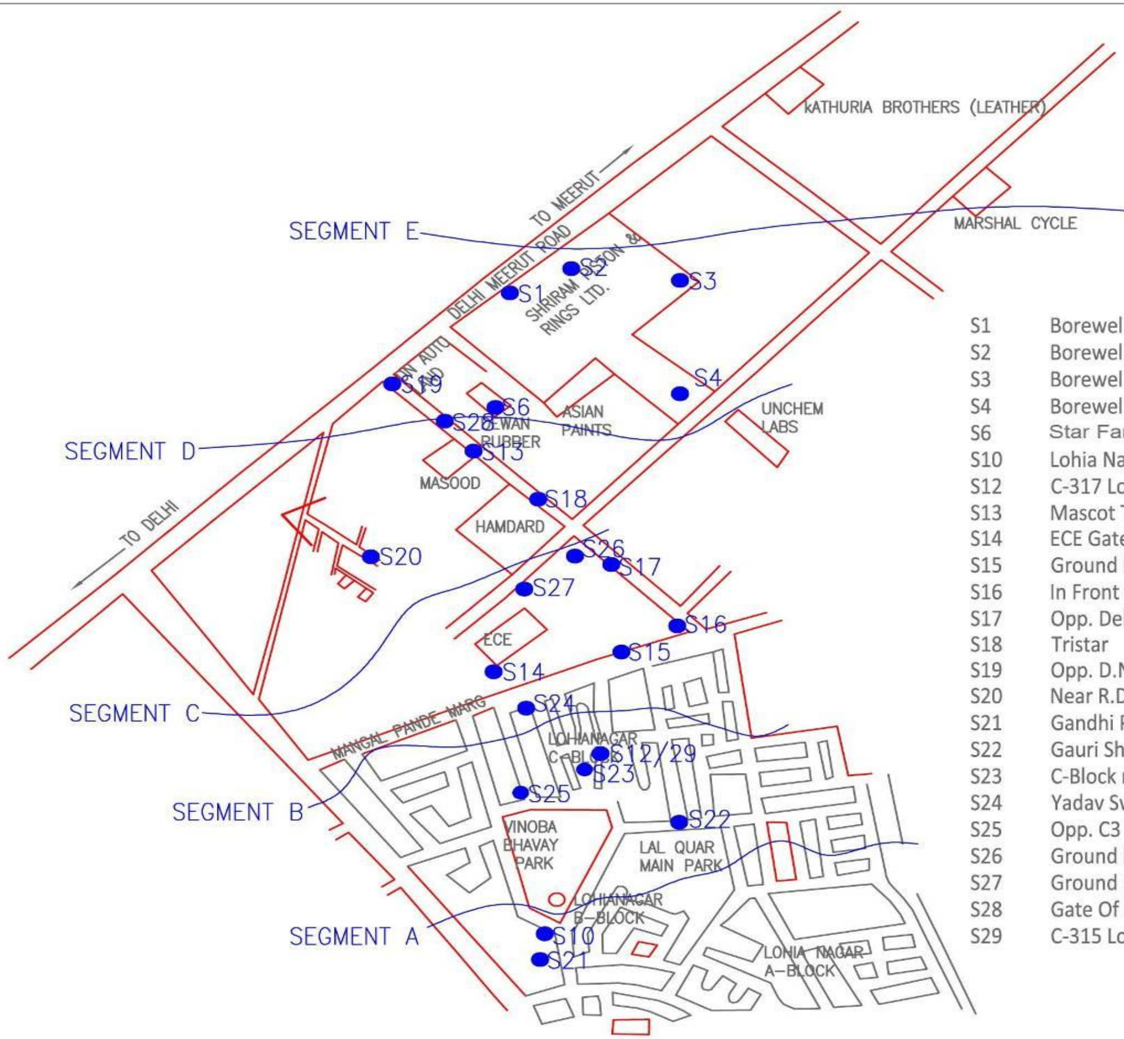
STRATA	TABLE
GL-12.5 M	DRY SAND & CLAY
12.5-20 M	FINE SAND
20-30 M	HARD CLAY
30-50 M	FINE SAND
50-60 M	FINE SAND
60-80 M	HARD CLAY
80-100 M	FINE SAND

Shriram Pistons and Rings Ltd, Meerut Road, Ghaziabad, INDIA



CONTAMINATED ZONE IDENTIFIED FOR SETTING UP ETP

MAP OF LOHIANAGAR AND ADJOINING AREA SHOWING SEGMENTS A – E



S1	Borewell No. -3 (outside Factory) at SPRL
S2	Borewell No. -1(at ETP) at SPRL
S3	Borewell No.-4 (at NSG Corner) at SPRL
S4	Borewell No.-2 (at B-9) at SPRL
S6	Star Farm House
S10	Lohia Nagar Pump No. 1
S12	C-317 Lohia Nagar
S13	Mascot Tools
S14	ECE Gate corner
S15	Ground behind ECE
S16	In Front of Lohia Nagar Police Chowki
S17	Opp. Delhi Press
S18	Tristar
S19	Opp. D.N.Auto
S20	Near R.D.Enterprises
S21	Gandhi Park(Abandoned Hand Pump)
S22	Gauri Shanker Park
S23	C-Block radhakrishana Mandir
S24	Yadav Sweets
S25	Opp. C3 Flats
S26	Ground behind ECE Opposite Hamdard
S27	Ground Behind ECE in front of Hamdard
S28	Gate Of RMI
S29	C-315 Lohiya Nagar

Quantification of Contaminated Groundwater

S. No.	Segment	Quantity of Contaminated Groundwater, Q=A*Wlf*Sp.Y.	Range of Hexavalent Chromium in Mg/L
1	Segment A	69,600 cu.m./yr.	Nil – 3.4
2	Segment B	2,08,800 cu.m./yr.	0.2 – 16.3
3	Segment C	52,200 cu.m./yr.	0.1 -1.3
4	Segment D	1,74,000 cu.m./yr.	1.3 – 15.4
5	Segment E	1,04,400 cu.m./yr.	Nil – 1.3


Thank you
www.keralatourism.org
Photo : Kuttiyapillai