SOIL BIOTECHNOLOGY OF IIT, BOMBAY

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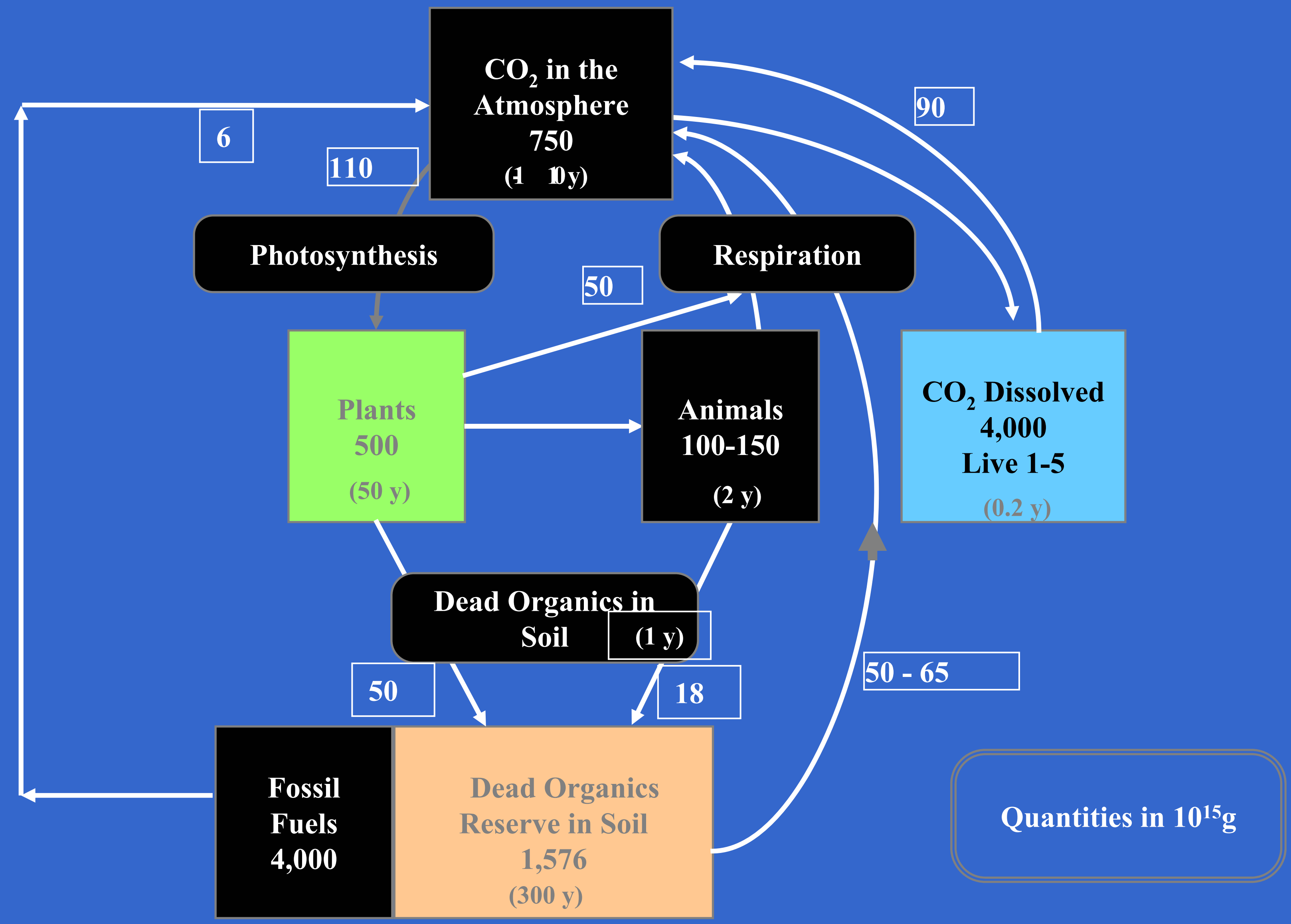
CONTENTS

A natural water body

A river system once a life line now in distress due to nutrient overload from agriculture

A natural water body in the process of decay

A natural water body converted to land due to nutrient overload



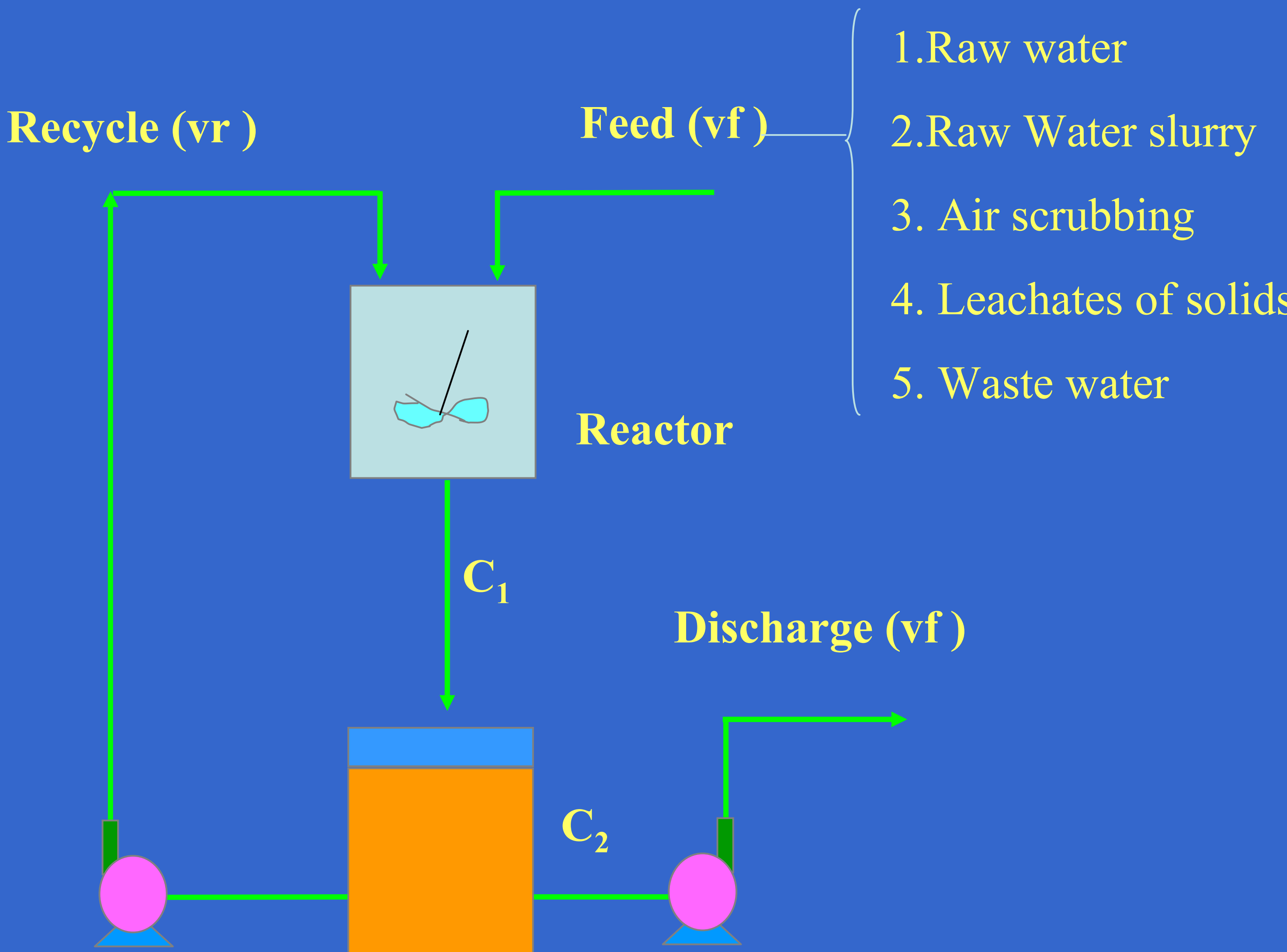
Global Carbon Cycle (Meilli, 1995)

Source: Encyclopedia of Environmental Biology, Vol.1, Academy press, 1995, pp.235-248

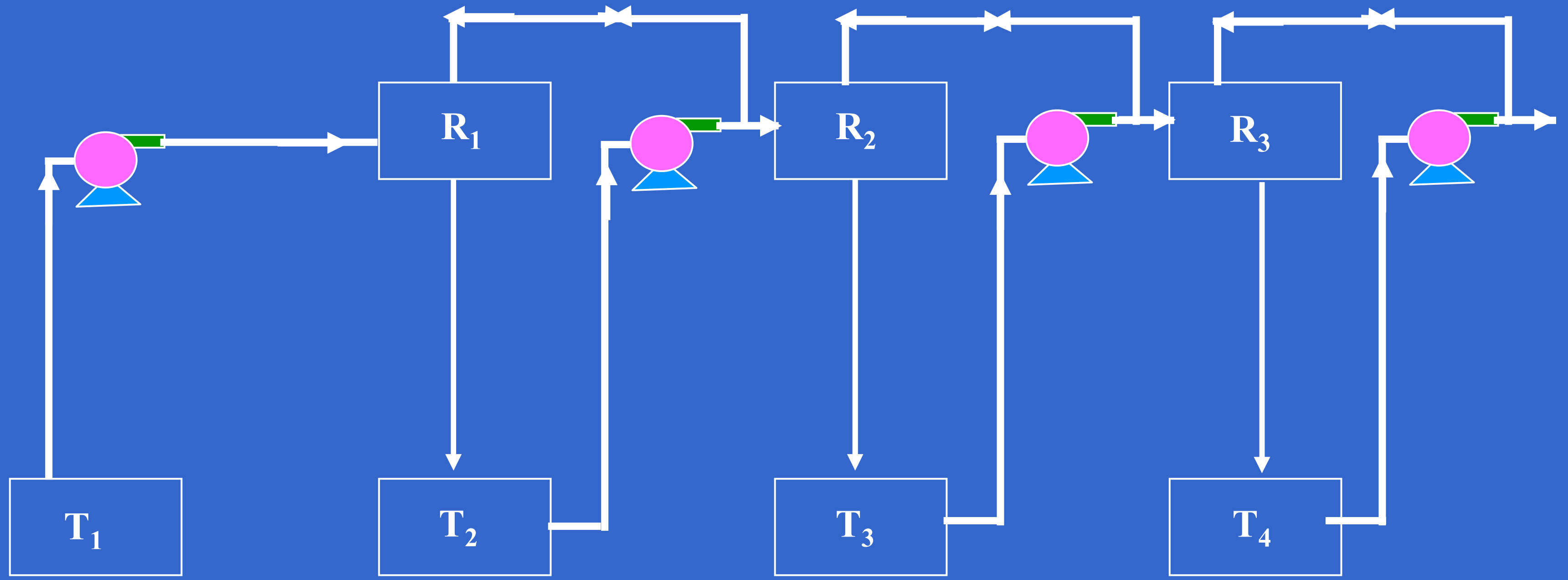
ENERGY CONSUMPTION IN DIFFERENT HABITATS

1. Water	500 kJ/g live C. yr
✓2. Land	3 kJ/g live C. yr

SCHEMATIC OF WATER RENOVATION



SCHEMATIC OF MULTISTAGE PURIFICATION



LARGE SCALE FACILITY FOR SEWAGE RENOVATION

MAJOR CHEMICAL REACTIONS AT WORK

Respiration

$(CH_2ON_xP_yS_zK_yQ)_n + nO_2 + nH_2O$ + Micro-organisms =

$nCO_2 + 2nH_2O$ + Mineral (N, P, S, K,Q) + Energy

Photosynthesis

$nCO_2 + 2nH_2O$ + Minerals (N,P, S,K,Q) + Sunlight =

$[CH_2ON_xP_yS_zK_yQ]_n + nO_2 + nH_2O$

Chemical Mineral weathering

$CO_2 + H_2O = HCO_3^- + H^+$

Primary mineral + $CO_2 + H_2O = M^{+n} + n\ HCO_3^-$ + soil/sand/clay

BIOMASS YIELD, MINERAL CONTENT, NITROGEN CONTENT, WATER CONSUMPTION FOR SOME CROPS

Crop	Mineral % DM	N % DM	Water ton / ton DM	Yield ton DM / ha
Subabul	0.5 – 0.8	Small	50	20
Sugarcane	1.5 – 2.0	Small	400	18
Corn	5.0 – 6.0	0.3 – 0.5	200	14
Wheat	9 – 11	0.3 – 0.5	600	12
paddy	18 - 20	0.3 – 0.5	1000	9
	*	*		
DM – Dry Matter				
Yield is total biomass-grain, straw etc.				

CHEMISTRY OF SBT

Respiration

$(CH_2ON_xP_yS_zK_y)_n + nO_2 + nH_2O = nCO_2 + 2nH_2O + \text{Mineral (N, P, S, K)} + \text{Energy}$ (1)

Photosynthesis

$nCO_2 + 2nH_2O + \text{Minerals (N,P, S,K)} + \text{Sunlight} =$
$[CH_2ON_xP_yS_zK_y]_n + nO_2 + nH_2O$ (Photosynthesis) (2)

Nitrogen Fixation

$N_2 + 2H_2O + \text{Energy} = NH_3 + O_2$ (in soil) (3)
$N_2 + 2H_2O + \text{Light} = NH_3 + O_2$ (in water) (4)

Acidogenesis

$4C_3H_7O_2NS + 8H_20 = 4CH_3COOH + 4CO_2 + 4NH_3 + 4H_2S + 8H^+ + 8e^-$ (5)

Methanogenesis

$8H^+ + 8e^- + 3CH_3COOH + CO_2 = 4CH_4 + 3CO_2 + 2H_2O$ (6)

Adding 5 and 6 give overall biomethanation chemistry

$4C_3H_7O_2NS + 6H_20 = CH_3COOH + 6CO_2 + 4CH_4 + 4NH_3 + 4H_2S$ (7)

Mineral weathering

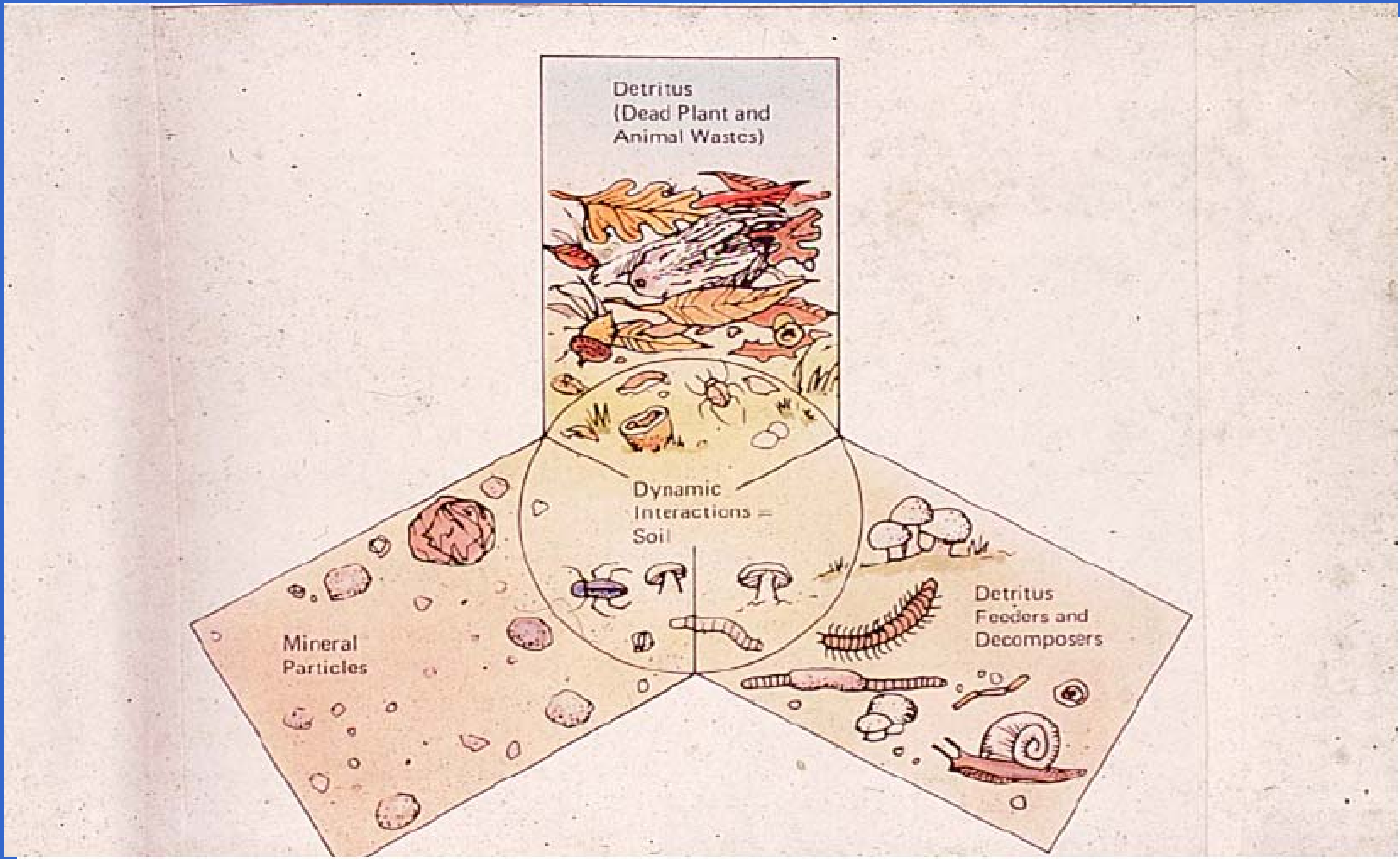
$CO_2 + H_2O = HCO_3^- + H^+$ (8)
Primary mineral + $CO_2 + H_2O = M^{+n} + n\,HCO_3^-$ + soil/clay/sand (9)

Nitrification

$NH_3 + CO_2 + 1.5O_2 = \text{Nitrosomonas} + NO_2^- + H_2O + H^+$ (10)
$NO_2^- + CO_2 + 0.5O_2 = \text{Nitrobacter} + NO_3^-$ (11)

Denitrification

$4NO_3^- + 2H_2O + \text{energy} = 2N_2 + 5O_2 + 4OH^-$ (12a)
$NO_2^- + NH_4^+ = N_2 + H_2O + \text{energy}$ (12b)

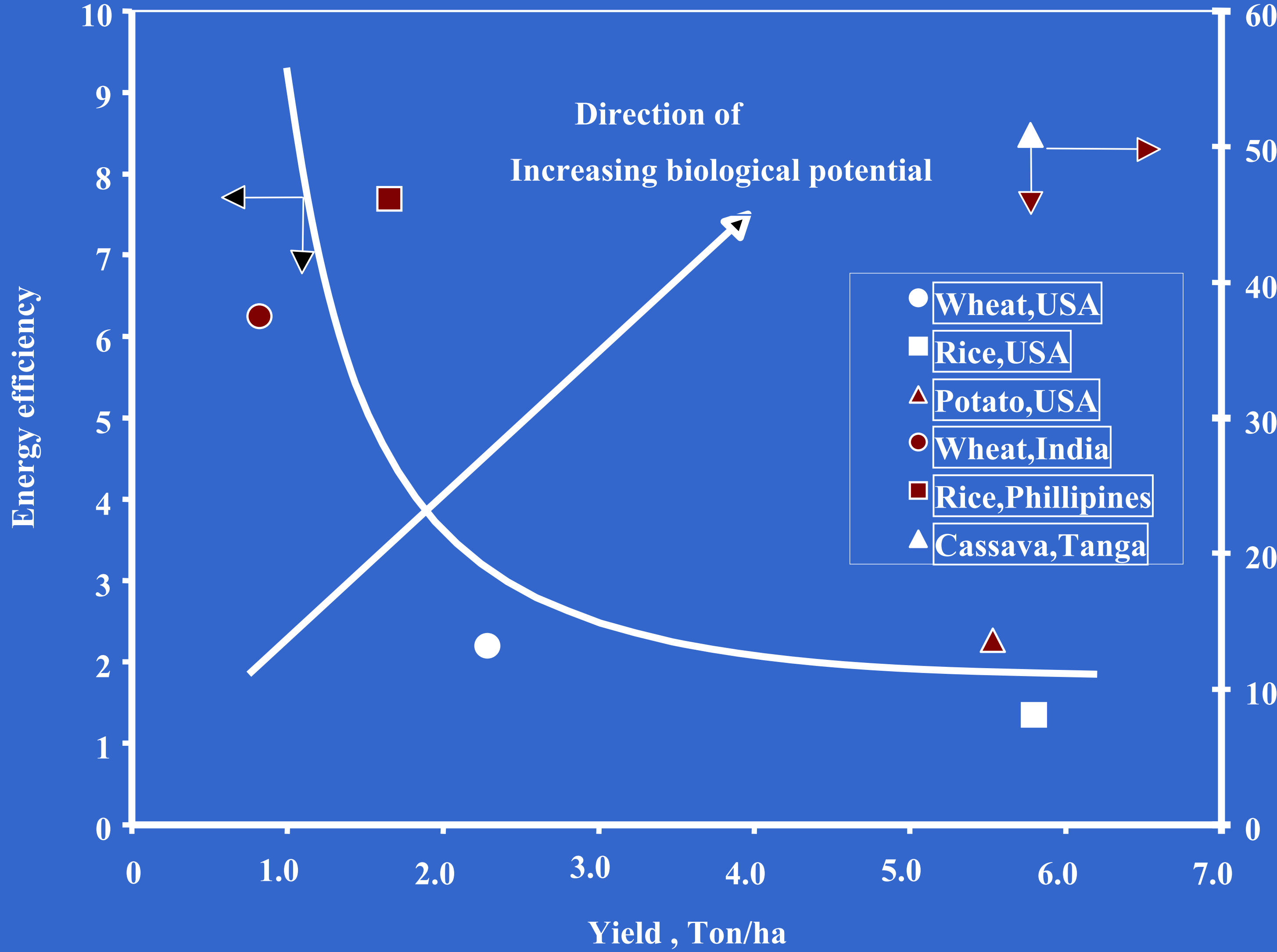


The trinity – showing importance of combining organics, inorganics & suitable life forms to derive value from wastes

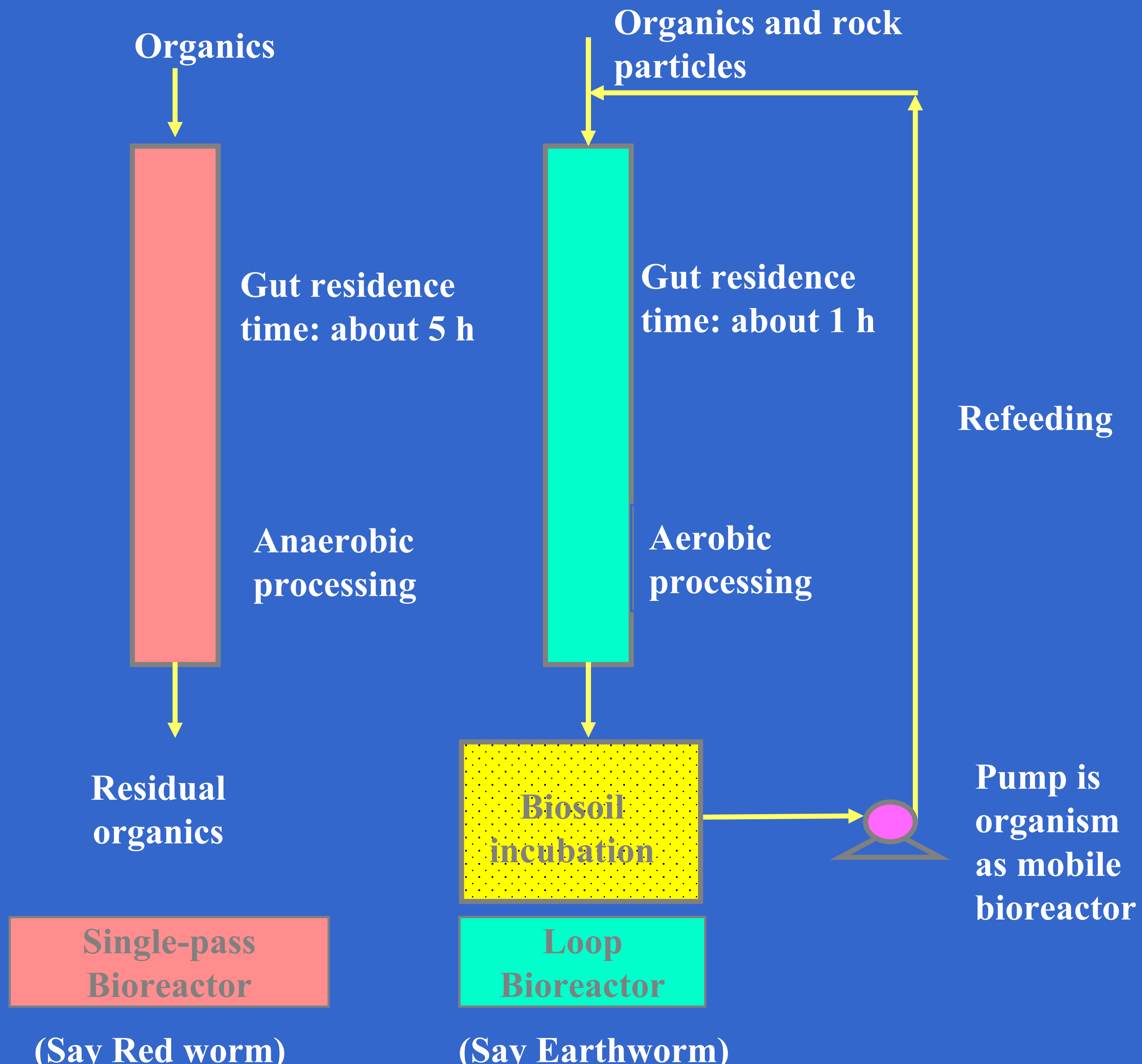
ENERGY CONSUMPTION FOR FOOD CROPS

Crop	Energy Input M k cal / ha			Yield kg / ha	Output M cal / ha	Efficiency (-)
	Fossil	Labour	Total			
Wheat (USA)	3.77	0.002	3.772	2284	7.5	2.2
Wheat (India)	0.256	0.1845	0.4405	821	2.7	6.25
Rice (USA)	15.536	0.009	15.545	5796	21.0	1.35
Rice (Phil)	0.582	0.1728	0.754	1655	6.0	7.69
Potato (USA)	8.90	0.018	8.92	26208	20.2	2.27
Cassava (Tanga)	0.016	0.385	0.401	5824 (Dry)	19.2	50.0

Source: Energy in agriculture, Lockeritz (ed.) International Congress energy in agriculture Missouri, 1975-76



Yield -Efficiency correlation for some crops



Bioprocessing by the two types of organisms
Source: Bhawalkar (1996)

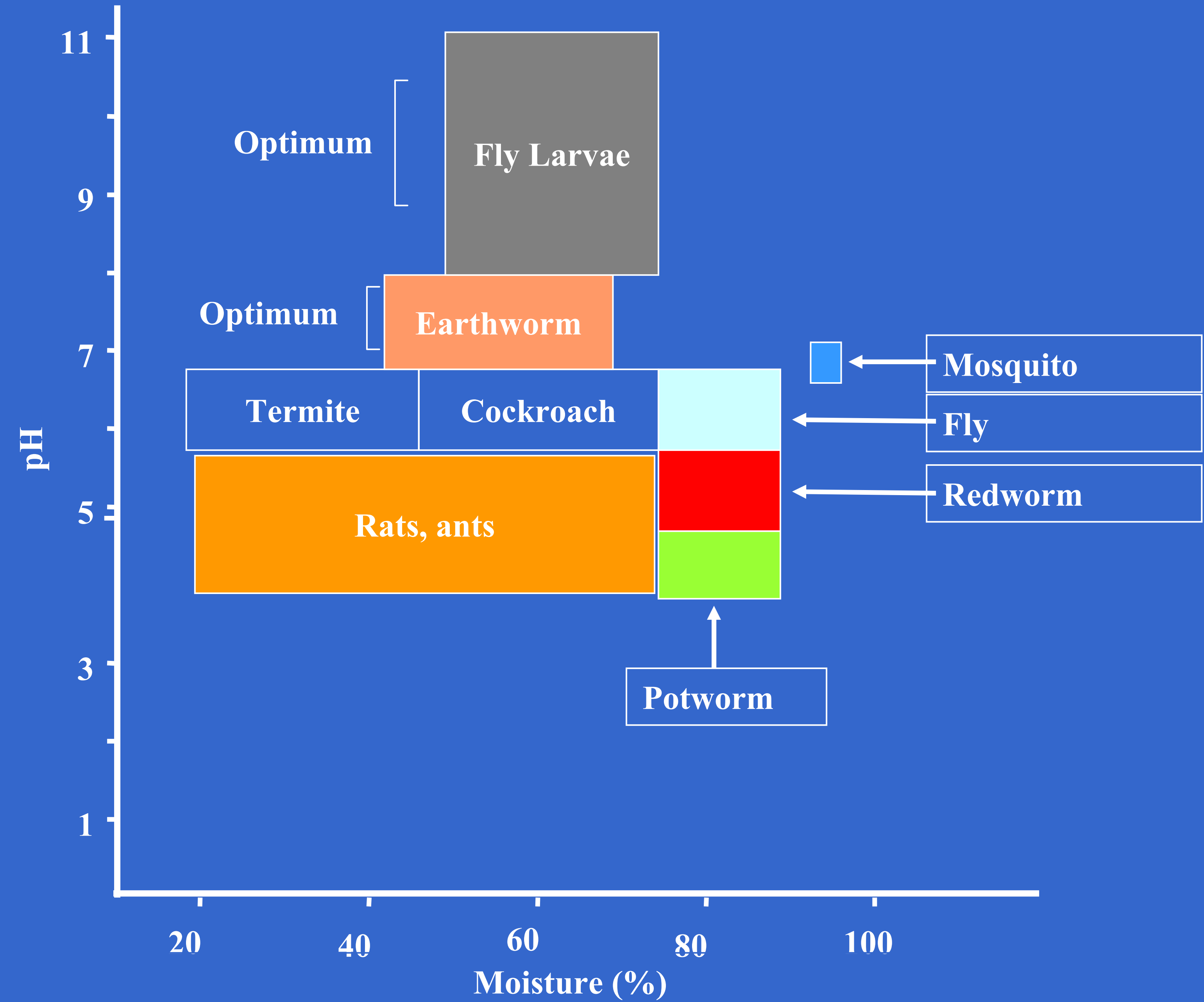
ECO-ENERGETICS OF AN EARTHWORM (Lavell, 1974)

Fresh Weight mg/individual	1025
Ingestion (J/g.d)	1570
Assimilation (J/g.d)	140
Production (J/g.d)	10
Respiration (J/g.d)	130
Egestion (J/g.d)	1430

EXPONENTIAL GROWTH OF BACTERIA IN EARTHWORM GUT

(no. in million) (Parle, 1959)

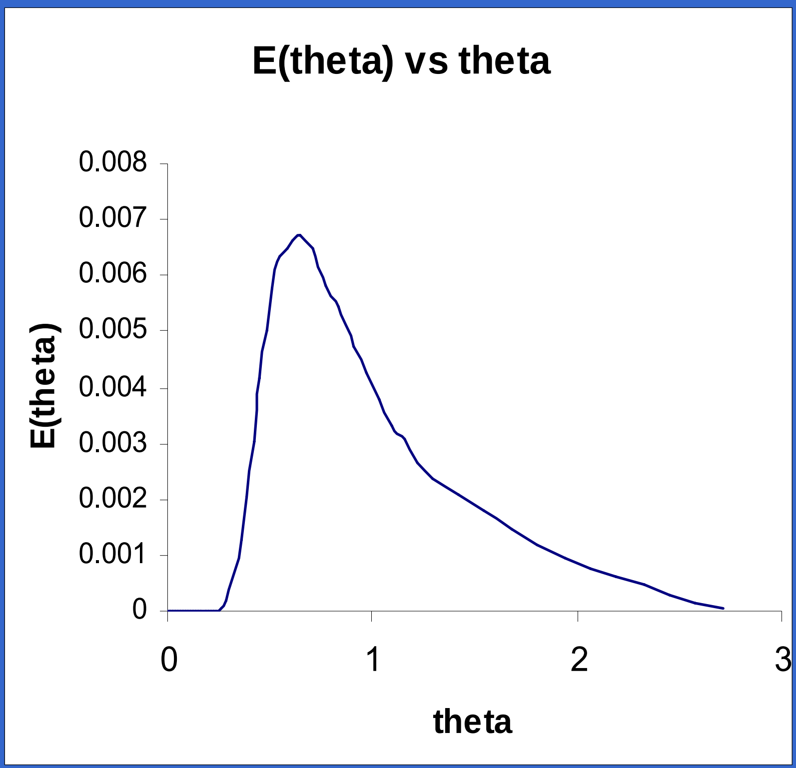
	Forgut	Midgut	Hindgut
All Bacteria	475	32900	440900
Actinomycetes	26	358	15000



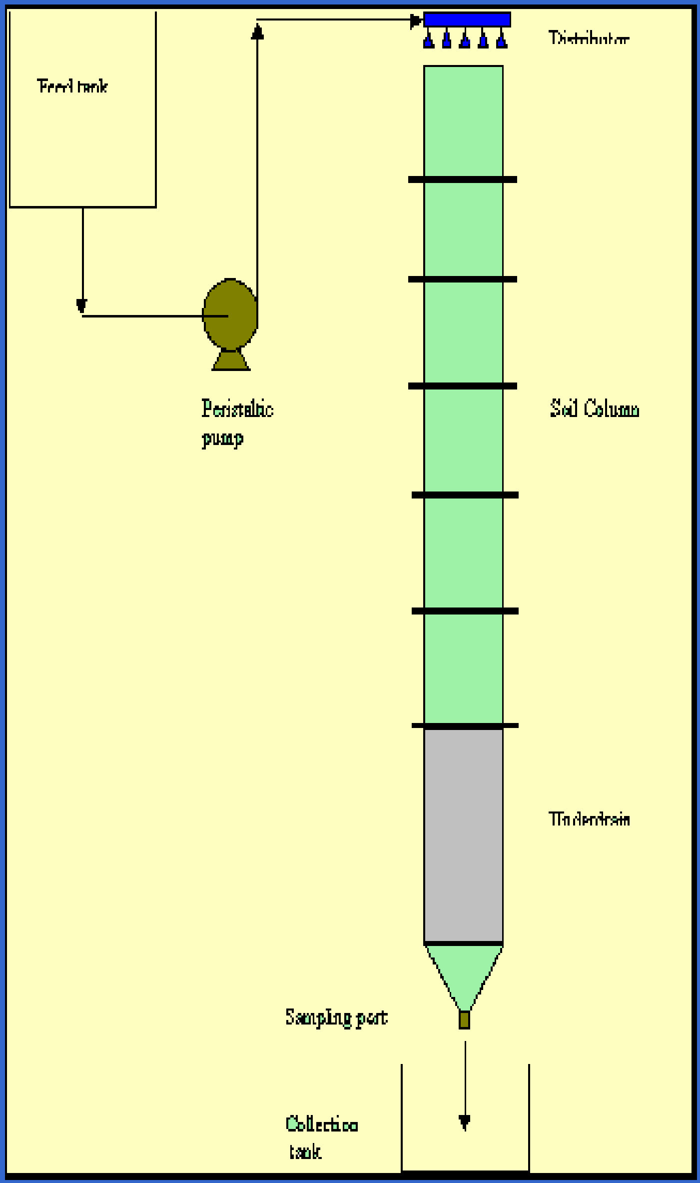
Niches of Earthworms and Pests (Bhawalkar, 1996)

A picture of red worms – r selected organisms in waste environment

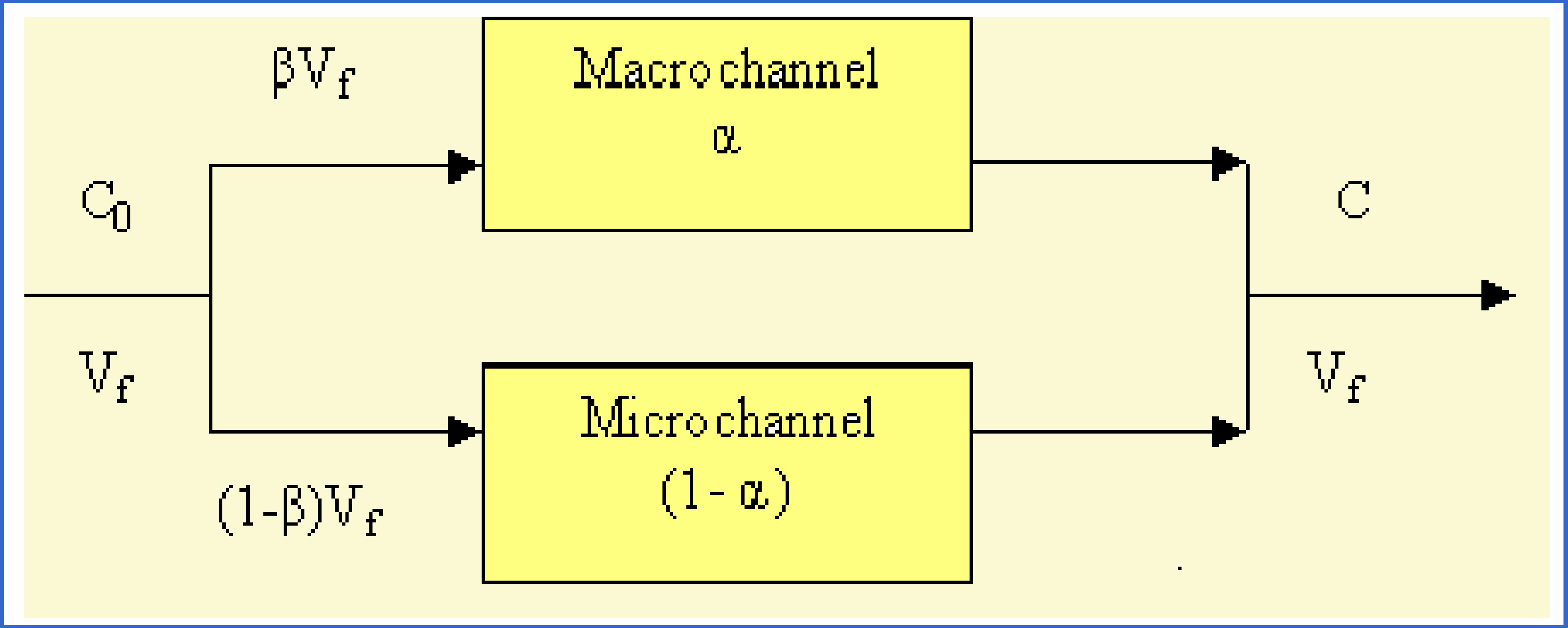
EXPERIMENT SET -UP



Concentration vs Time Plot



TWO CHANNEL MODEL



α = fraction of holdup in the macrochannel

β = fraction of tracer that enters the macrochannel

TWO CHANNEL MODEL

$$E(\theta)=\frac{\beta^2}{\alpha}\frac{1}{2\sqrt{\frac{\pi\theta_1}{Pe_1}}}\exp\left(-\frac{\left(1-\frac{\beta\theta_1}{\alpha}\right)^2}{\frac{4\theta_1}{Pe_1}}\right)+\frac{(1-\beta)^2}{(1-\alpha)}\frac{1}{2\sqrt{\frac{\pi\theta_2}{Pe_2}}}\exp\left(-\frac{\left(1-\frac{(1-\beta)\theta_2}{(1-\alpha)}\right)^2}{\frac{4\theta_2}{Pe_2}}\right)$$

$$\tau_1=\frac{\alpha}{\beta}\tau \qquad \tau_2=\frac{(1-\alpha)}{(1-\beta)}\tau \qquad \theta_1=\frac{t}{\tau_1} \qquad \theta_2=\frac{t}{\tau_2}$$

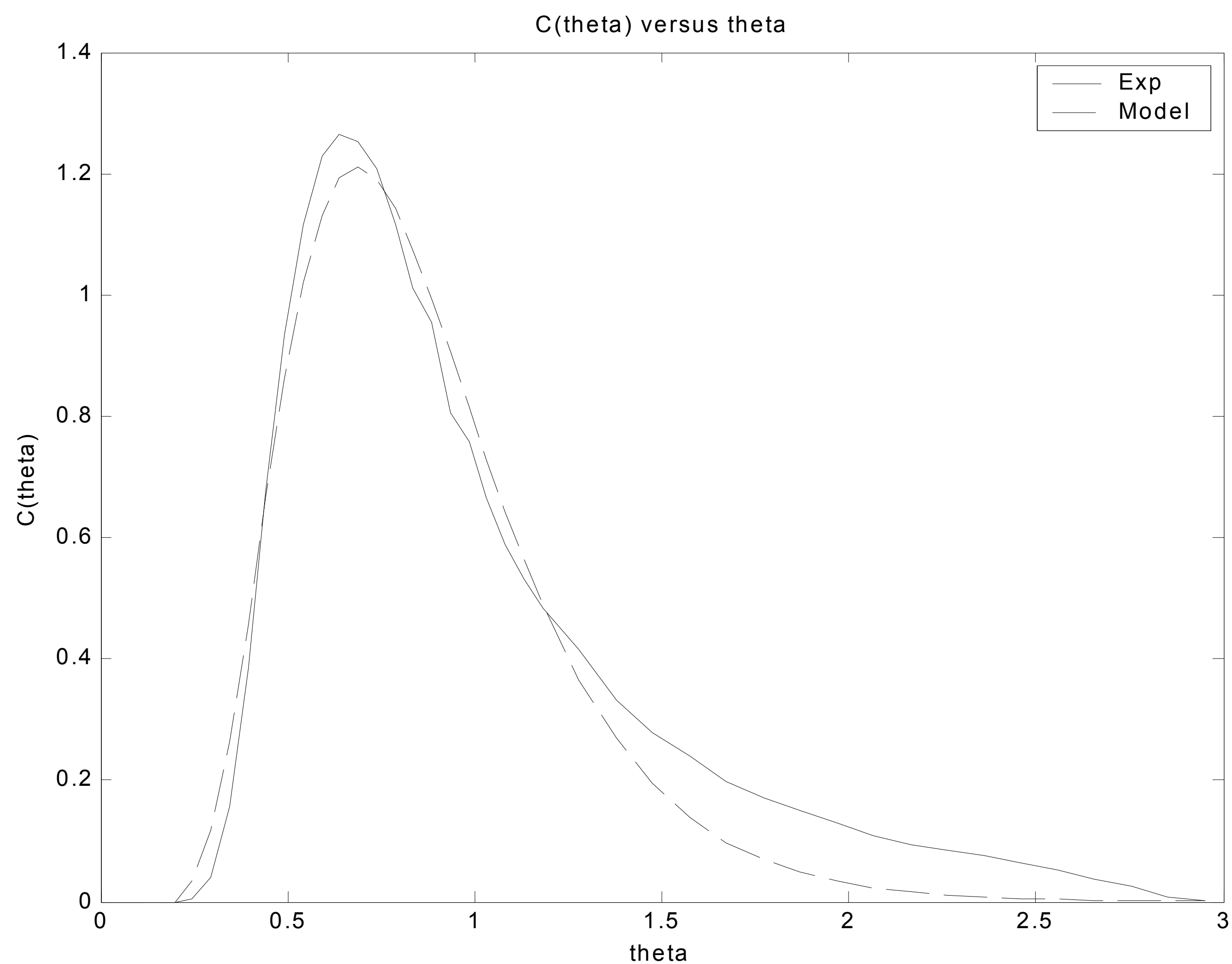
$$Pe_1=\frac{\beta}{\alpha}Pe \qquad Pe_2=\frac{(1-\beta)}{(1-\alpha)}Pe$$

THEORETICALLY CALCULATED PARAMETERS

Diffusivity $$D = \frac{RT}{F^2}\frac{\lambda_{io}}{\left|z_i\right|}$$ = 1.9 * 10^{-5} cm/s^2

Film Thickness $$\delta = \sqrt[3]{\frac{3\mu Q}{\rho g W}}$$ = 0.1 mm

Peclet Number $$Pe = \frac{uL}{D}$$ = 6 - 14

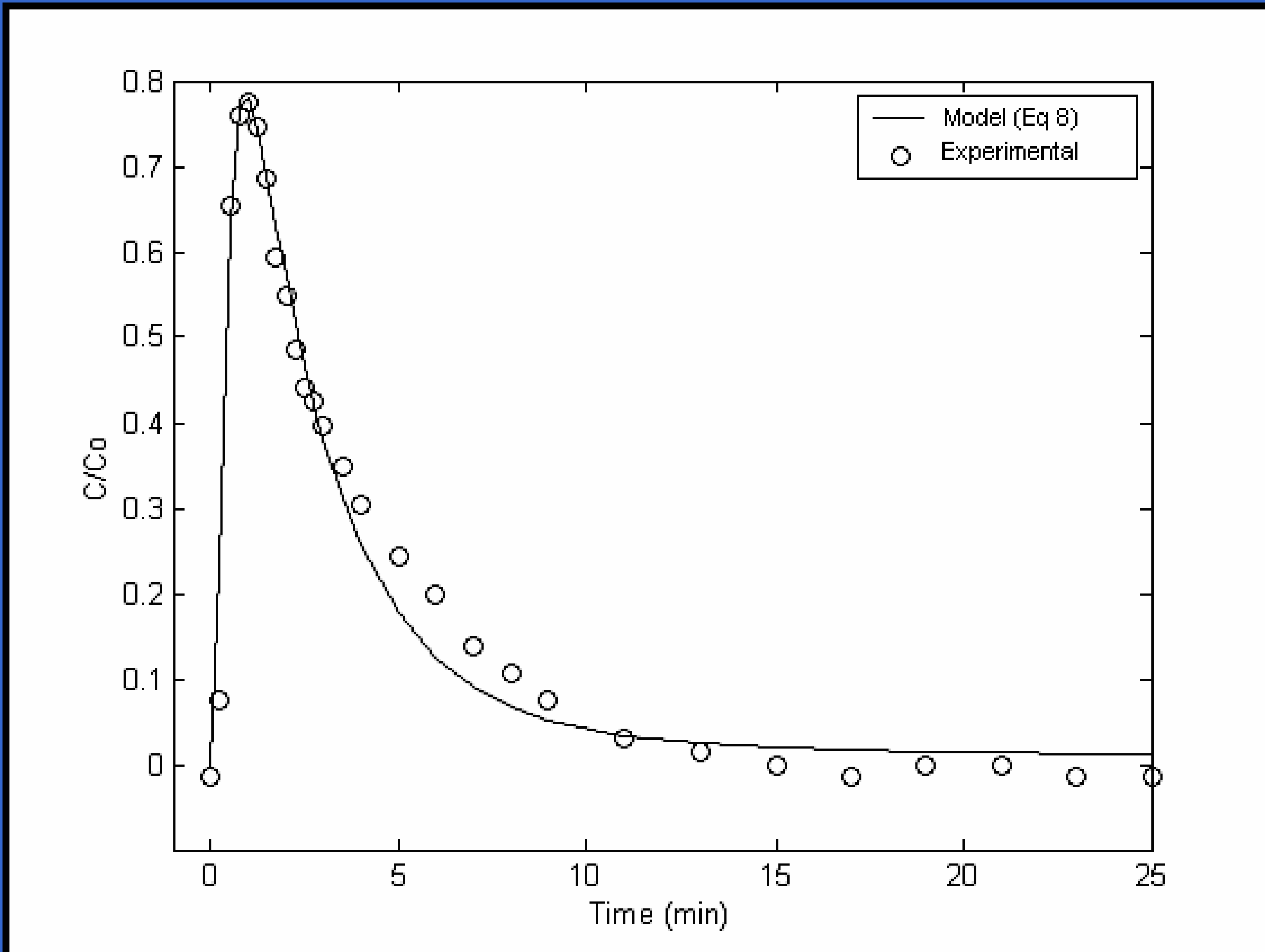


RTD Plot of normalized concentration (C/Co) vs. Time for 2m soil filter showing fit to Dispersion model equation (8) for Run 2a (22.3 cm/h) with fitted parameters α=0.67, β=0.9, Pe=9

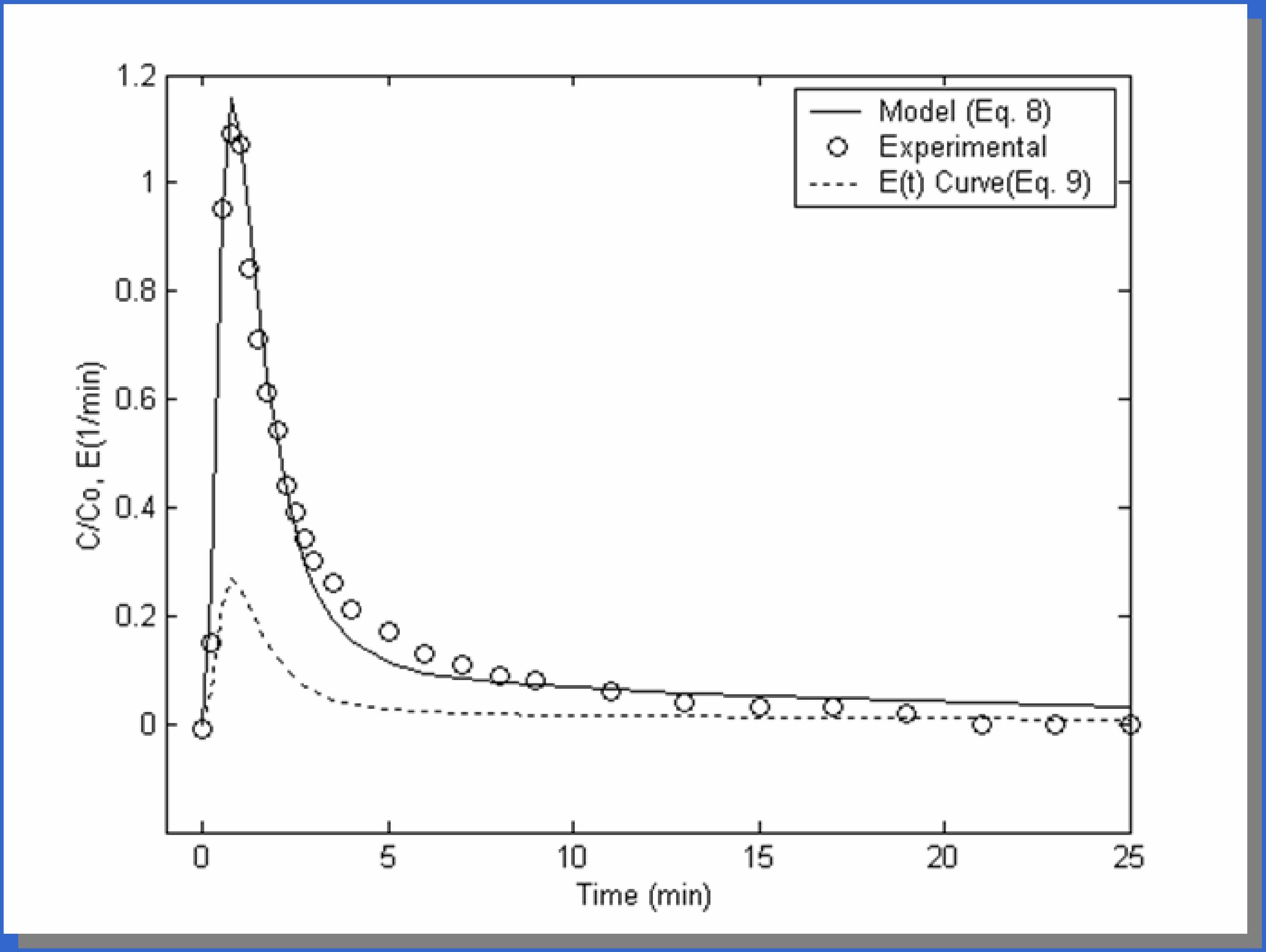
EXPERIMENT AND THEORETICAL PARAMETERS

Run No	Q (ml/min)	τ (min)	α	Pe
I	95	155	0.73	12.1
II	100	153	0.69	18.3
V	125	133	0.63	9.7
III	155	102	0.75	10.1
VI	182	91	0.68	12.3
IV	200	90	0.68	11.5

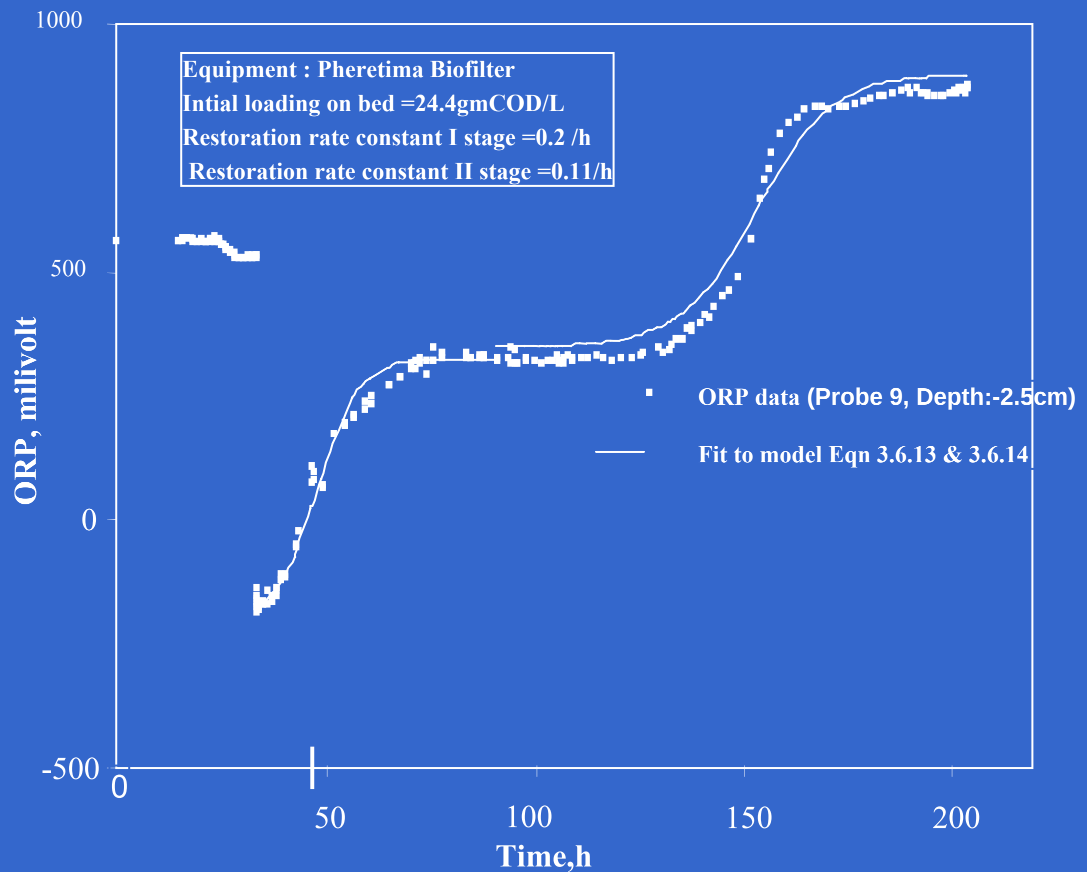
Run No	Q (ml/min)	τ (min)	δ (mm)	H (lit)	A (m^2)	u (m/s)	Pe
I	95	155	0.06	14.72	245	6.46×10^{-9}	6.1
II	100	153	0.06	15.3	255	6.53×10^{-9}	6.2
V	125	133	0.07	16.62	237	8.79×10^{-9}	8.4
III	155	102	0.07	15.81	226	11.4×10^{-9}	10
VI	182	91	0.08	16.56	207	14.6×10^{-9}	13.9
IV	200	90	0.08	18	225	14.8×10^{-9}	14.1



RTD Plot of normalized concentration (C/Co) vs. Time for soil filter showing fit to Dispersion model equation (8) for Run 2a (22.3 cm/h) with fitted parameters α=0.25, β=0.68, Pe=0.83

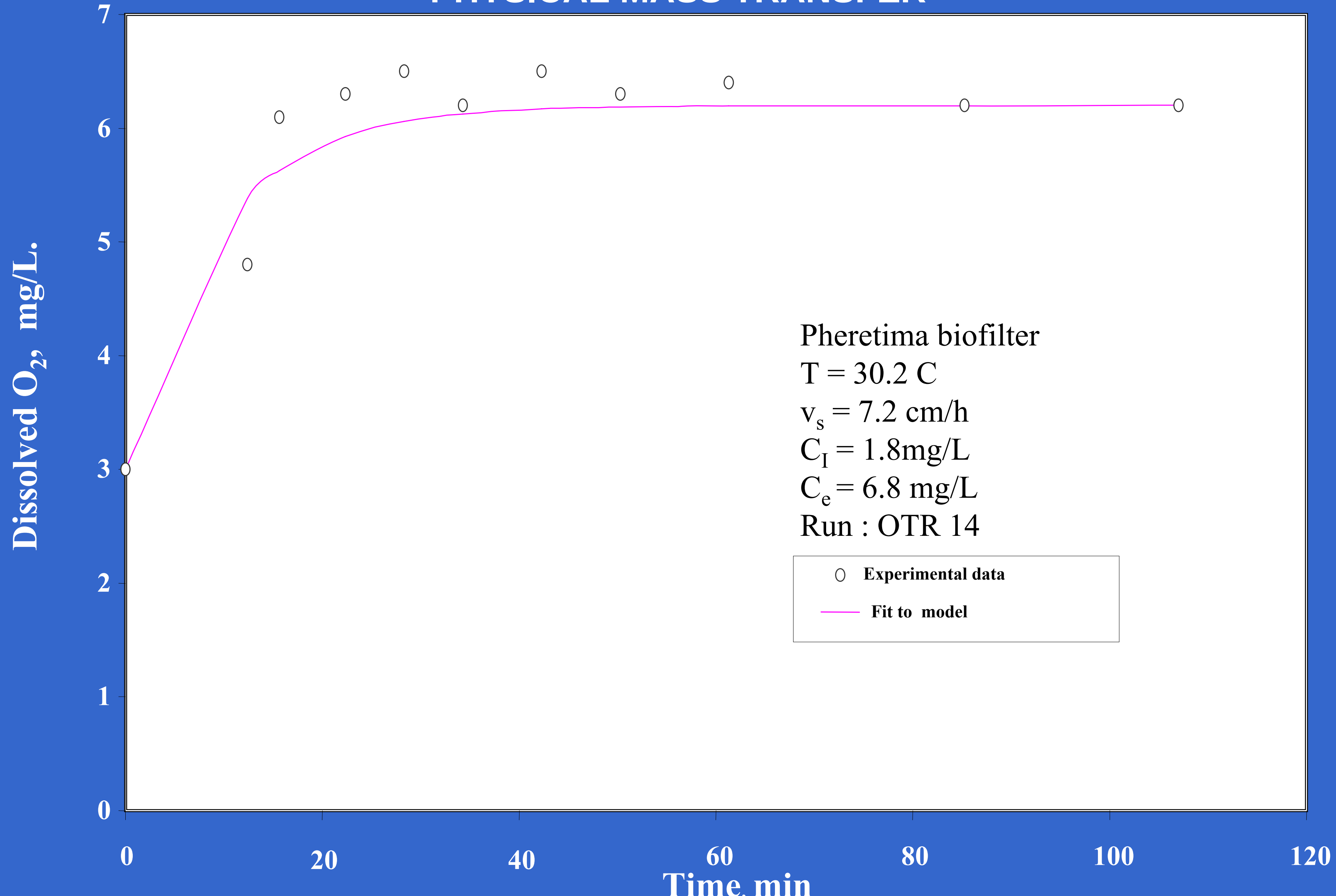


Plot of normalized concentration (C/Co) and RTD function E (t) vs. Time for soil filter showing fit to Dispersion model equation (8) for Run 1a (7.2 cm/h) with fitted parameters α=0.09, β=0.40, Pe=0.89



ORP (Reference calomel electrode+244 mV) restoration profile showing fit to model Pattanaik, B.R. (2000)

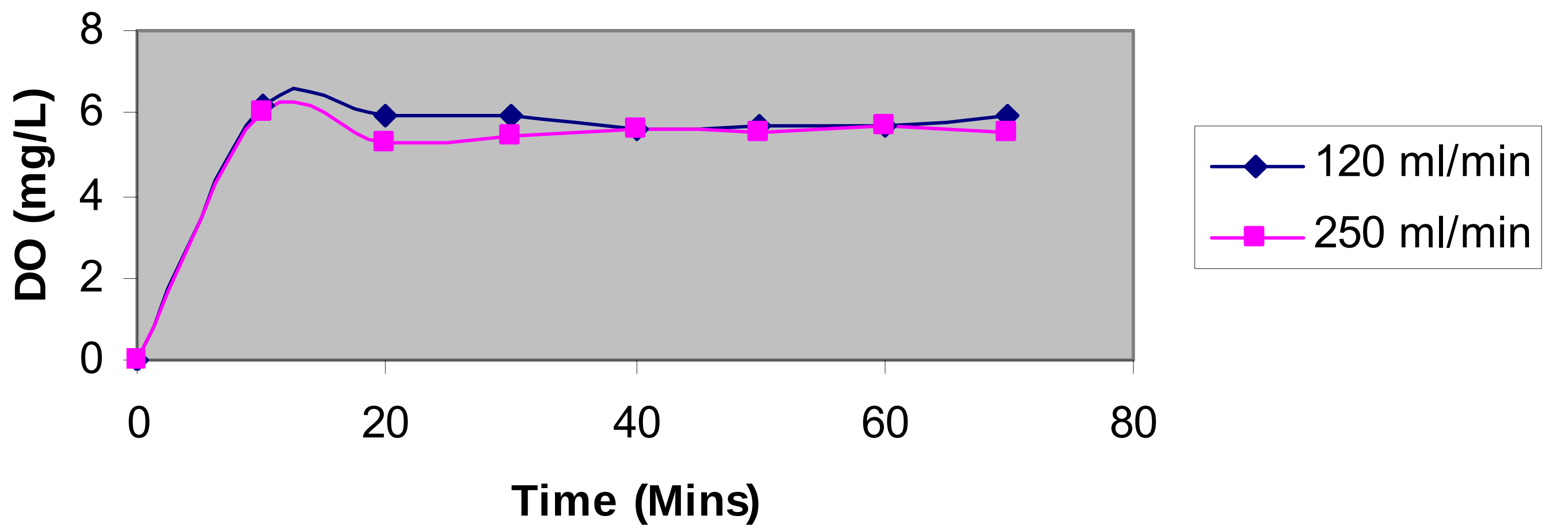
PHYSICAL MASS TRANSFER



Variation of outlet O_2 concentration with time as per single cell model

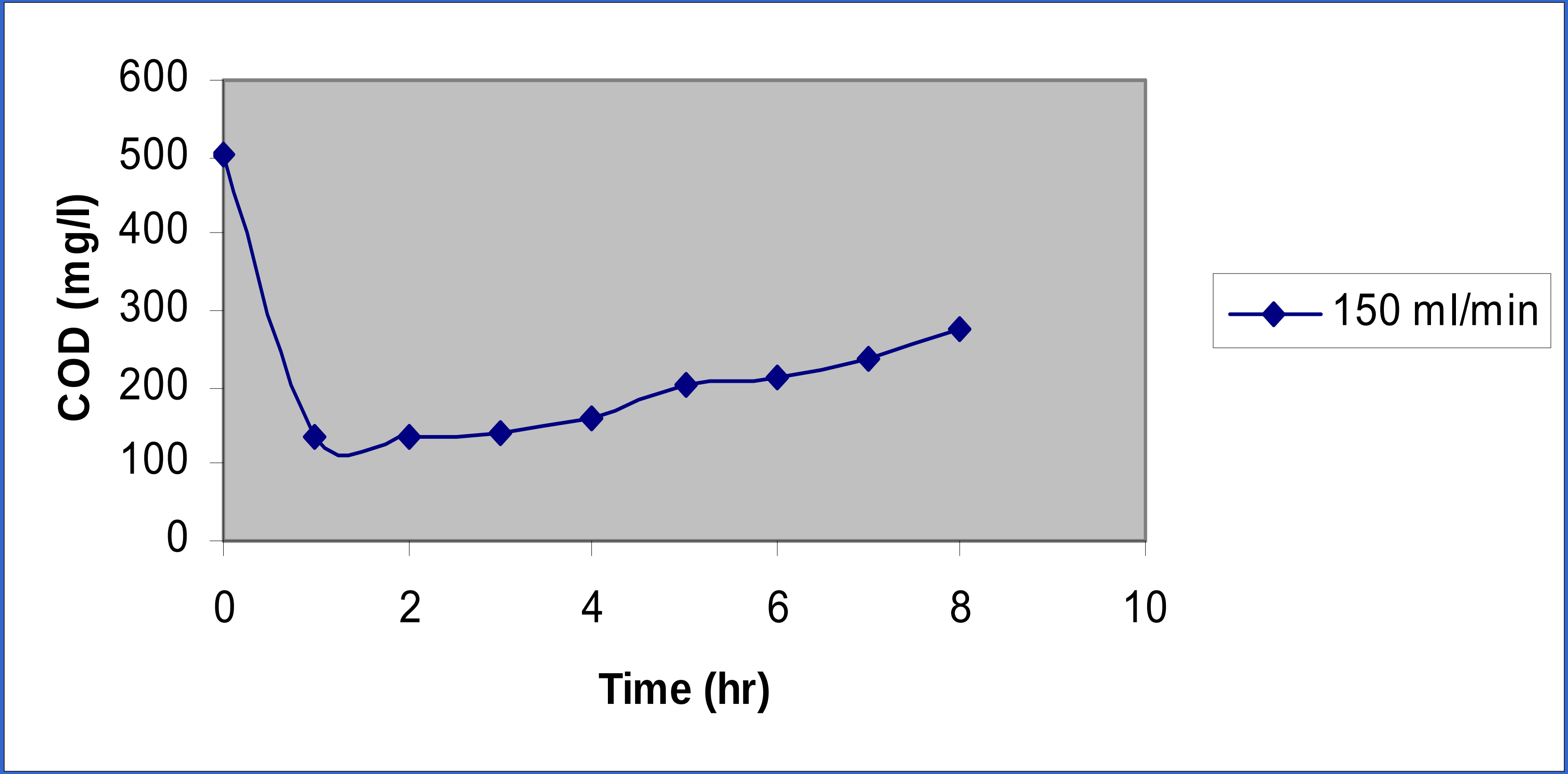
Pattanaik.,(2000)

PHYSICAL MASS TRANSFER



Variation of outlet O_2 concentration with time, Sathyamoorthy(2006)

COD REMOVAL



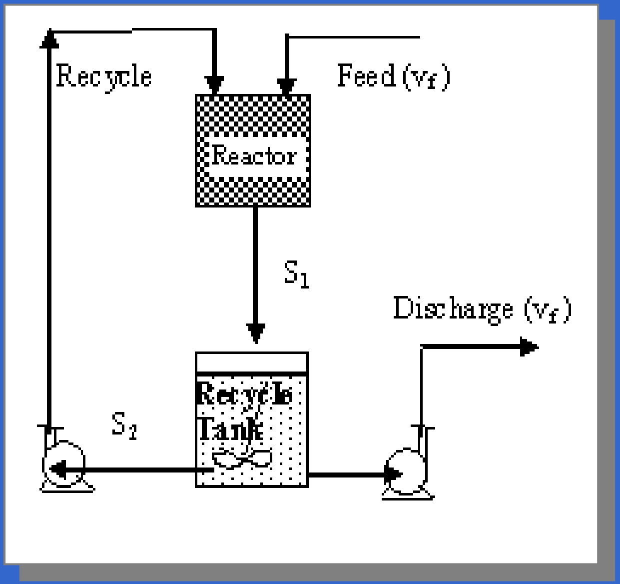
COD concentration with Time Kadam.(2005)

COMPARISON OF AIR TO WATER OXYGEN TRANSFER COEFFICIENTS

Agitated & sparged vessels **10^{-3} to 10^{-2} /sec**

- This work **5×10^{-3}/sec**
- Quiescent fluids **10^{-5}/sec**

GOVERNING EQUATIONS



1. Continuity Equation $$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \bar{v}) = 0$$

2. Momentum balance

$$\frac{\partial (\rho \bar{v})}{\partial t} + \nabla \cdot (\rho \bar{v} \bar{v}) = -\nabla p + \rho \bar{g} + \bar{F}$$

From Darcy's Law

$$\bar{F} = -\frac{\mu}{\alpha} \bar{v}$$

3. Species Transport Equation

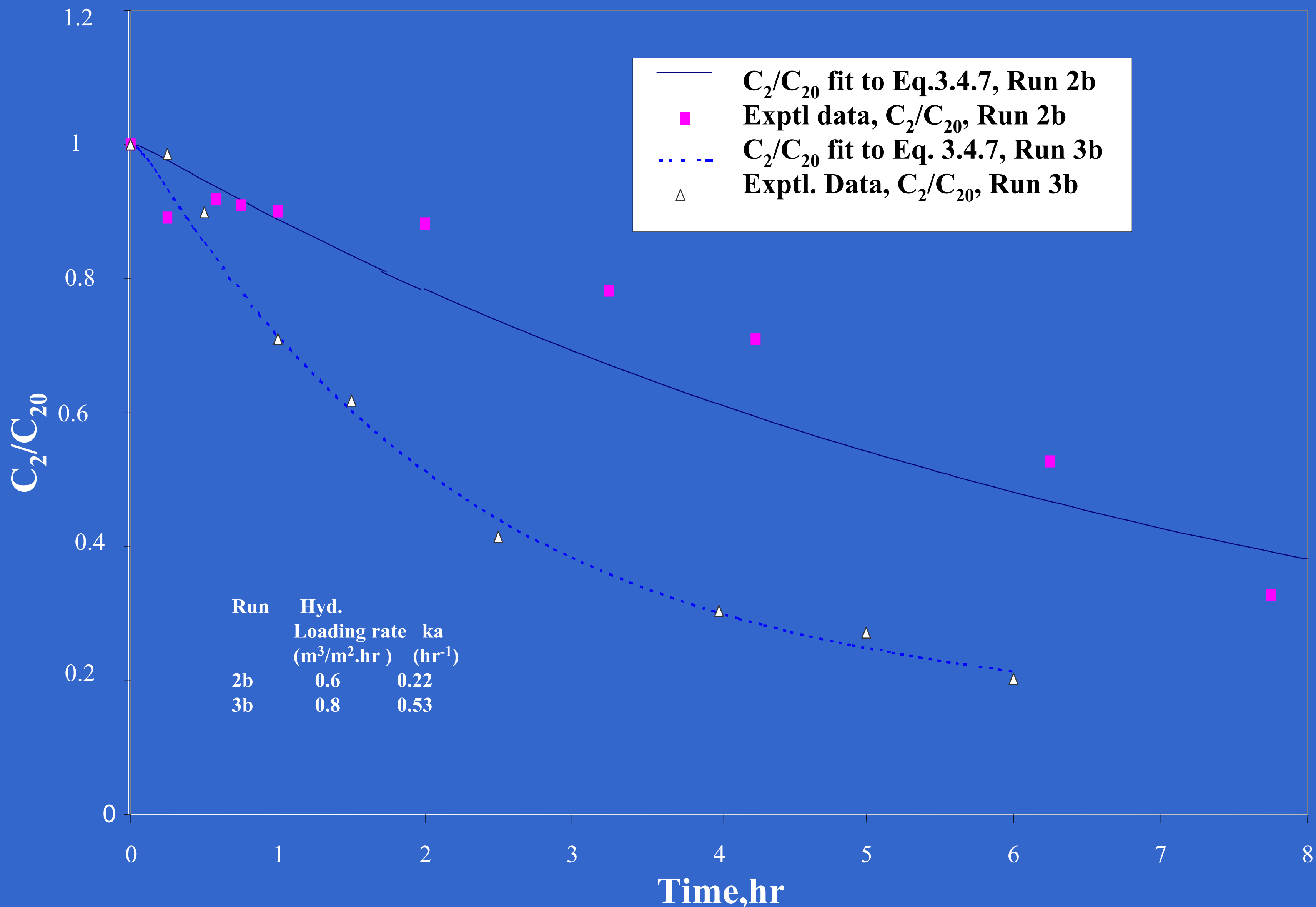
$$\frac{\partial C_i}{\partial t} + \nabla \cdot (\bar{v} C_i) + \nabla.(D_{i,m} \nabla C_i) - R_i = 0$$

4. conc. balance in holding tank

$$\tau_h \frac{dS_2}{dt} = S_1(t) - S_2(t)$$

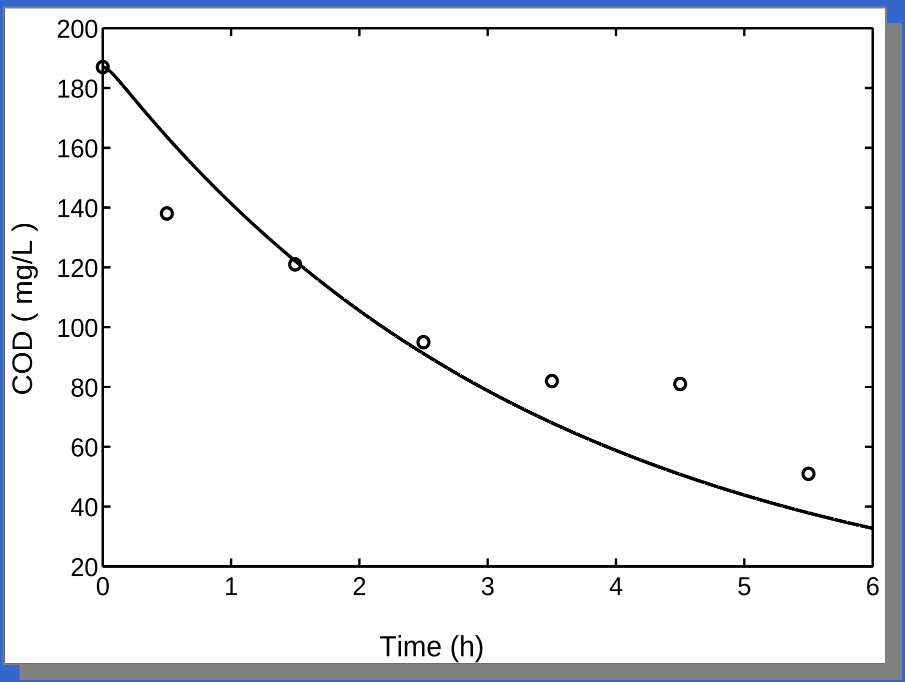
Rate equations for substrates

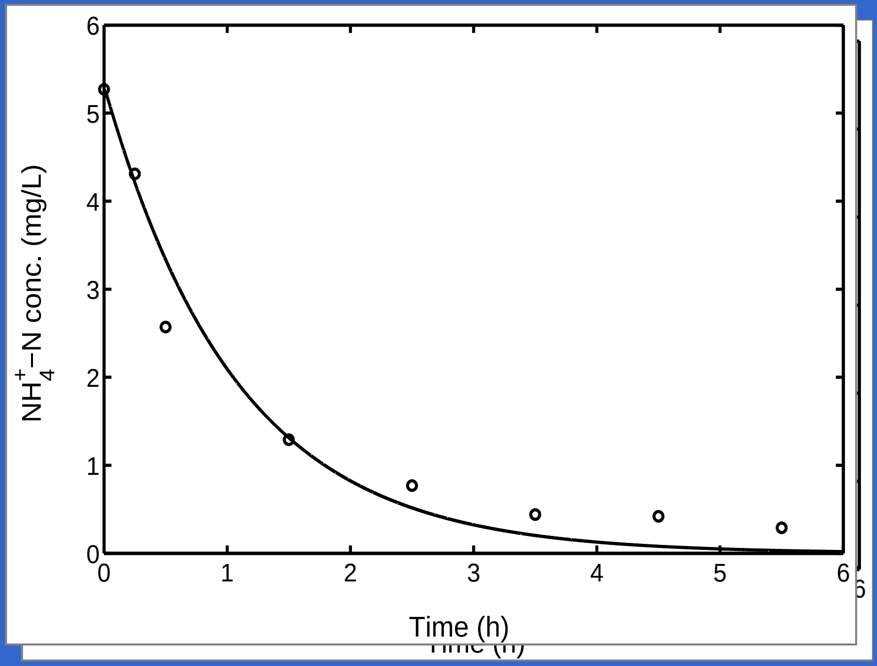
Substrate	Description	Rate Equation
COD	Mass Transfer	$K_{ac}(C_1-C_1^*)$
COD	Oxidation	$K_c C_s$
NH_4^+-N	Mass Transfer	$K_{an}(C_2-C_2^*)$
NH_4^+-N	Nitrification	$K_N N_s$



Effect of hydraulic loading on distribution of liquid on biofilter

CFD MODEL VALIDATION: COMPARISON WITH EXPERIMENTAL DATA

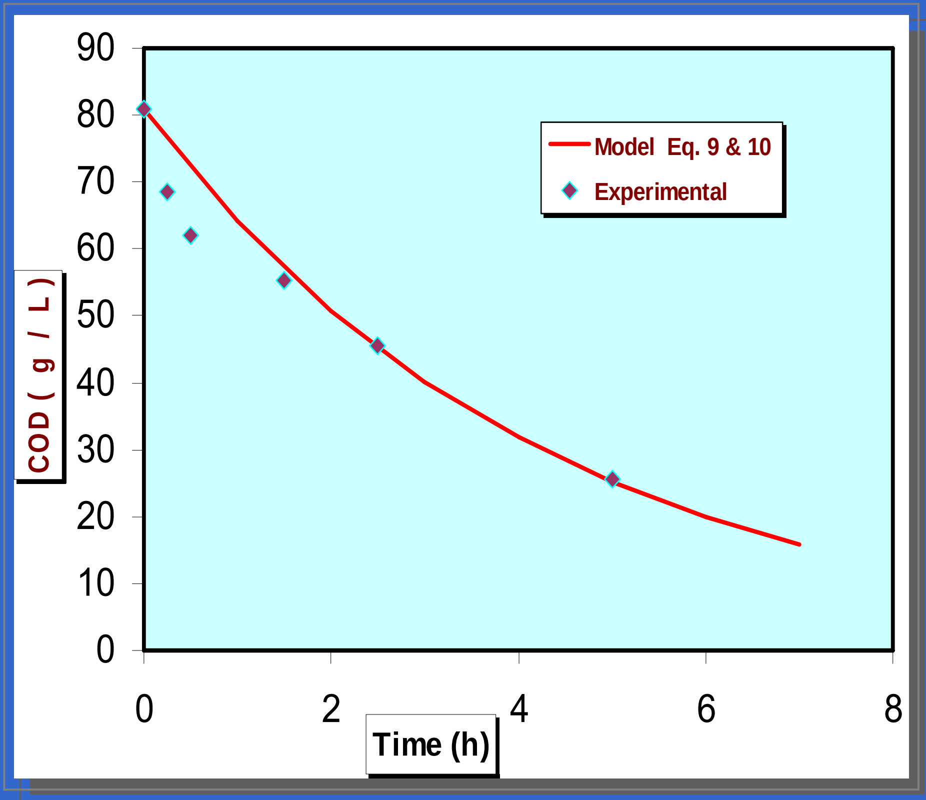


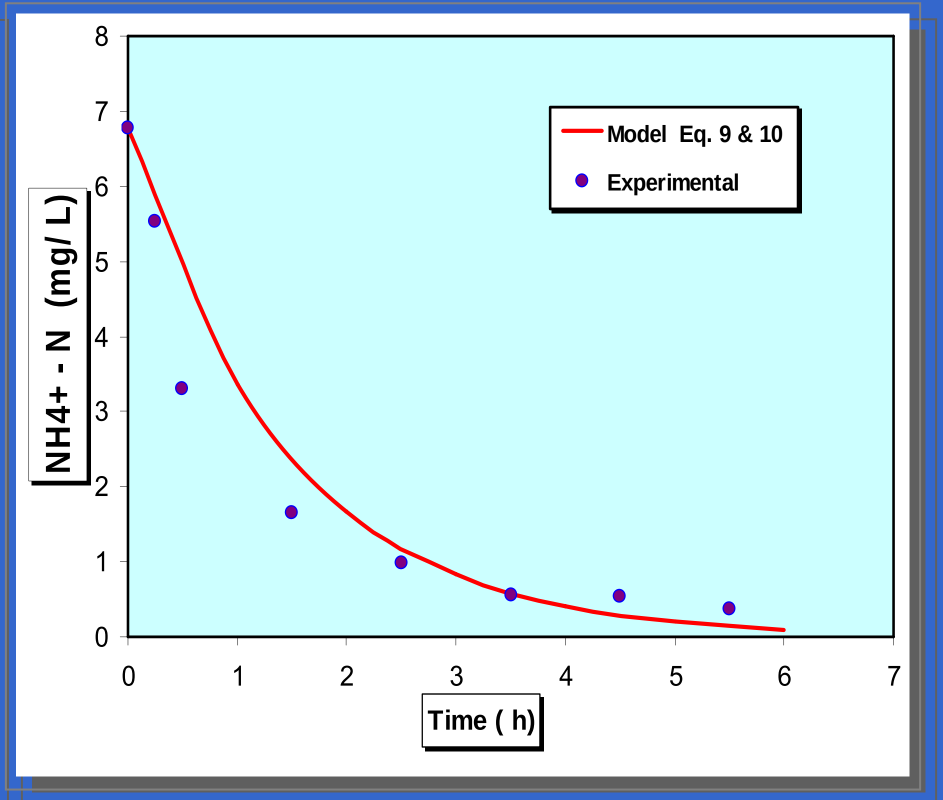


V_b =13 L, V_l = 30 L, v_r = 5x 10^{-5} m^3/m^2h

k_{ac} = 2.7 h^{-1}, k_C = 0.05 h^{-1}, k_{an} = 11 h^{-1}, k_N =1.5 h^{-1},

Comparison between Dispersion model prediction and reactor performance data for sewage





Model Parameters: V_b =13 L, V_l = 30 L, v_r = 5.1 m^3/m^2 h
α = 0.32, β = 0.81, ε_d = 0.25,

Pe = 0.18, k_{ac} = 1.5 h^{-1}, k_{an} = 11 h^{-1},

DISTILLERY SPENT WASH

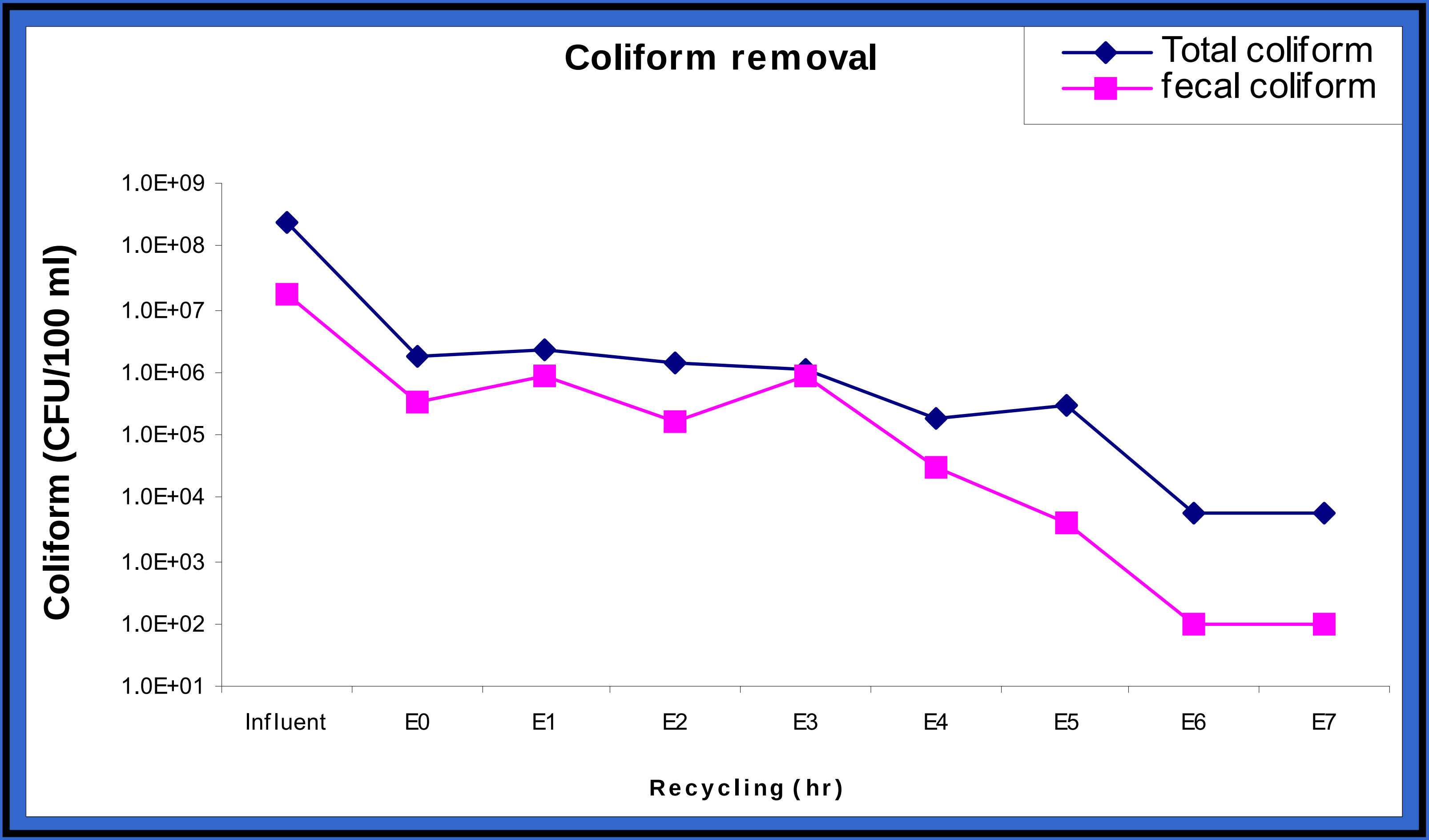
Before SBT Processing

COD: 12,160mg/L

After SBT Processing

COD: 64 mg/L

COLI FORM REMOVAL

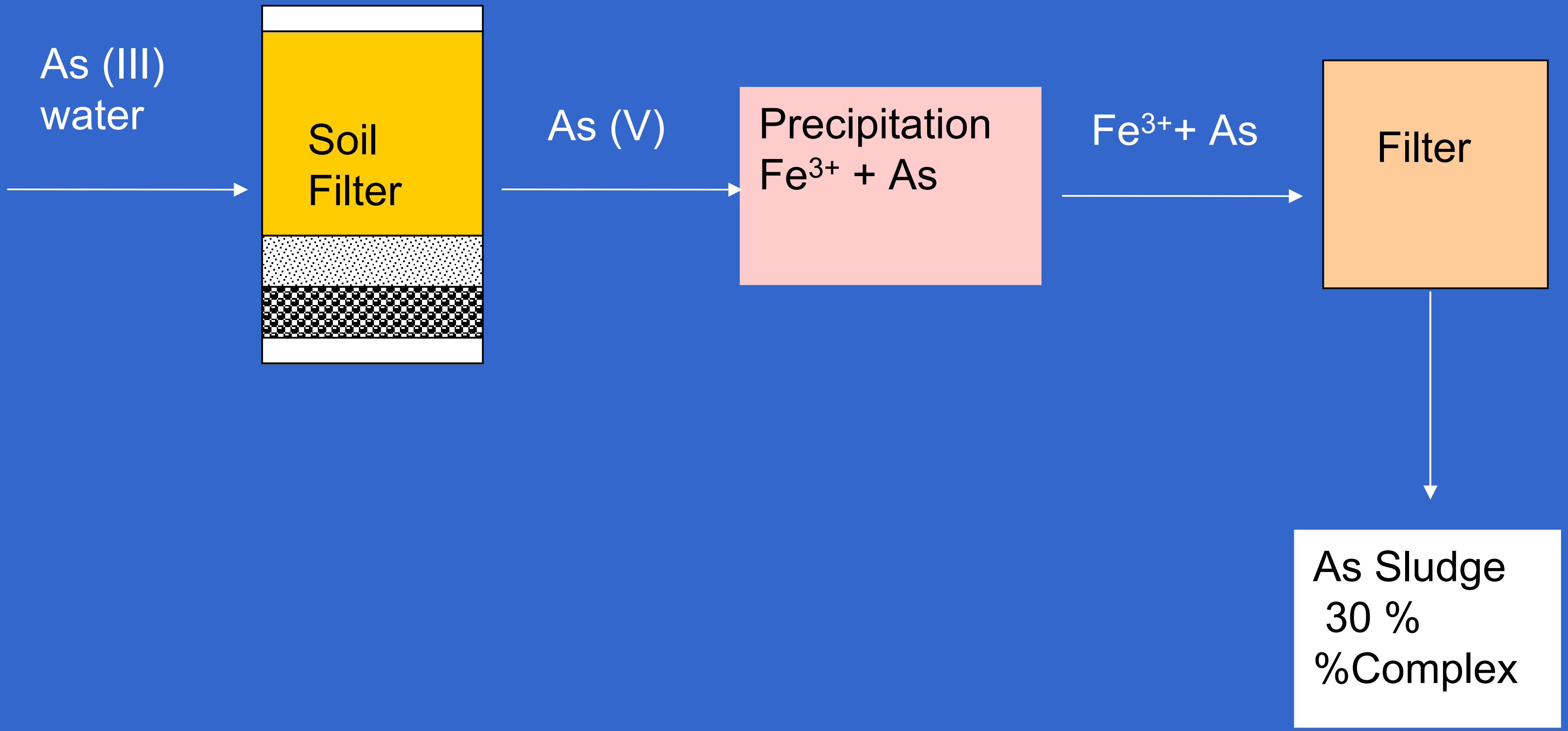


Effect of recycling on micro-organism removal;
E0: Effluent 0 hr, E1: Effluent 1 hr etc Kadam., (2005)

ARSENIC REMOVAL BY SOIL FILTER

- As(III) oxidation and removal As(V) via precipitation as ion complex with Fe(III).
- These results show that <10 ppb As are attained via natural oxidation and chemical precipitation revealing typically 0.3 mg As (III)/lit.hr.
- These natural rates of removal sustain via the natural aeration of the

PROCESS DIAGRAM FOR ARSENIC REMOVAL FROM WATER



ARSENIC REMOVAL IN SOIL FILTER SYSTEM

Initial As(III)=500 μg/l; Filter bed volume=17 lit;
Flow rate = 60ml/min,
Total volume of water passed per day = 30 lit, which constitute one run.

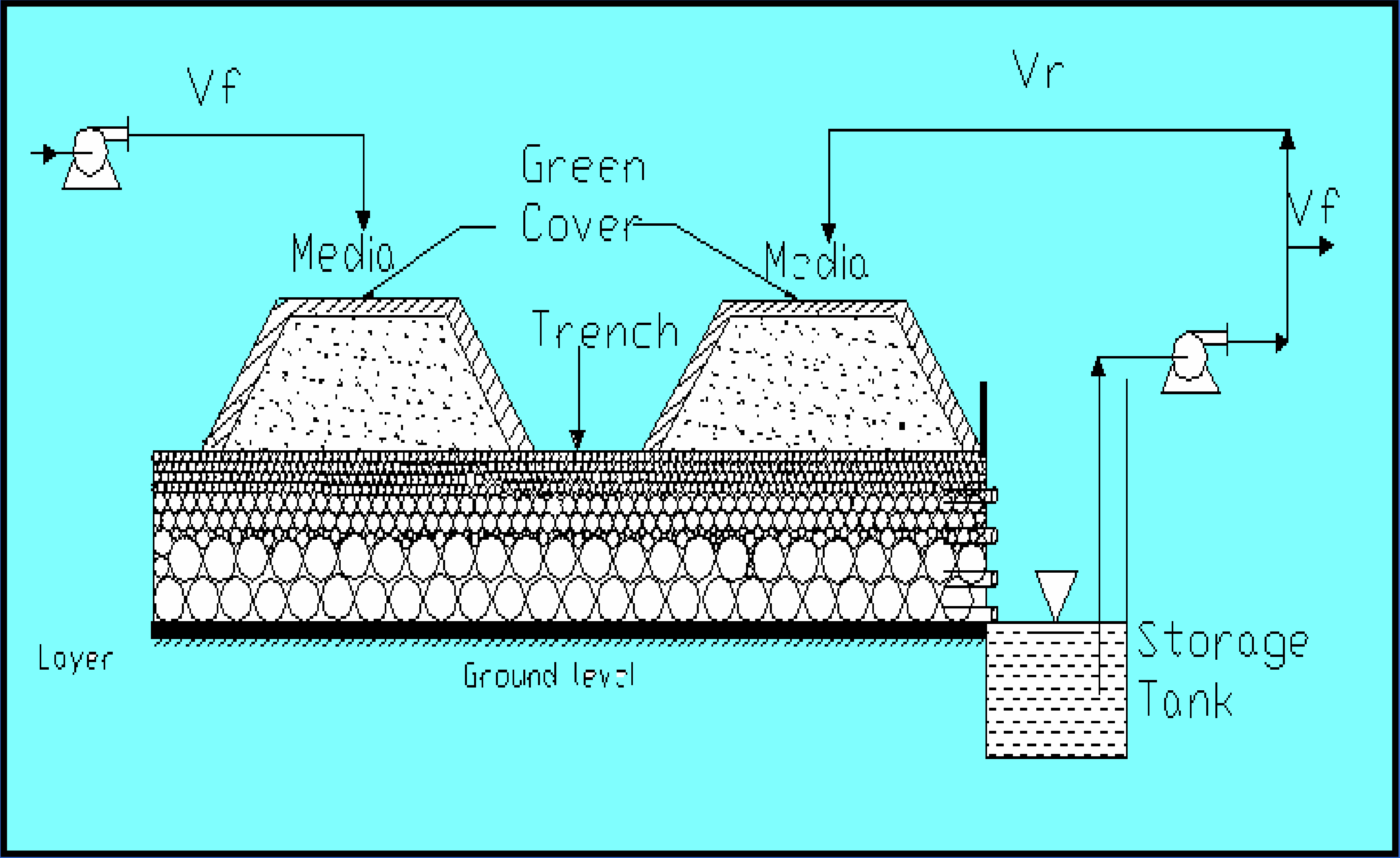
Expt. Run No	Initial Arsenic Conc. μg/l	Residual Arsenic μg/l
1	500	8
2	500	8
3	500	8
4	500	8
5	500	8
6	500	8
7	500	3
8	500	6
9	500	5
10	500	4
11	500	4
12	500	4
13	500	4

COMPARISON OF ARSENIC REMOVAL RATES

- Zero Valent iron 0.85 mg As/lit.hr(Leupin et al., 2005)
- Iron coated sand 0.75 mg As/lit.hr (Joshi and Chaudhari, 2004)
- Activated Alumina 0.15 mg As/lit.hr (Pant and Singh, 2005)

✓ Soil filter process 0.30 mg As/lit.hr

LAY OUT OF SBT MEDIA



Effect of Feed Distribution arrangement on Fluid distribution
Contours of Velocity Magnitude (m/s)

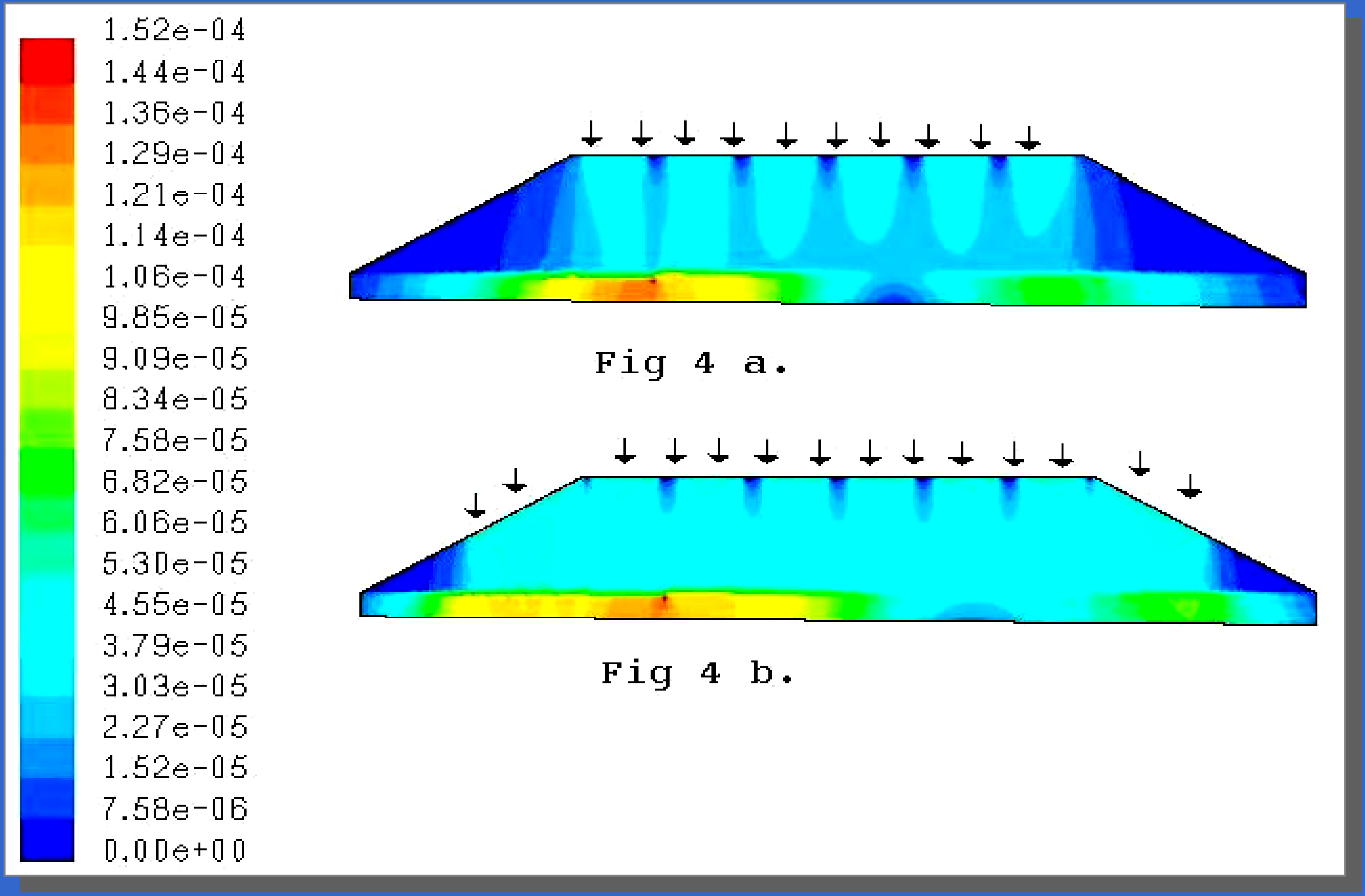
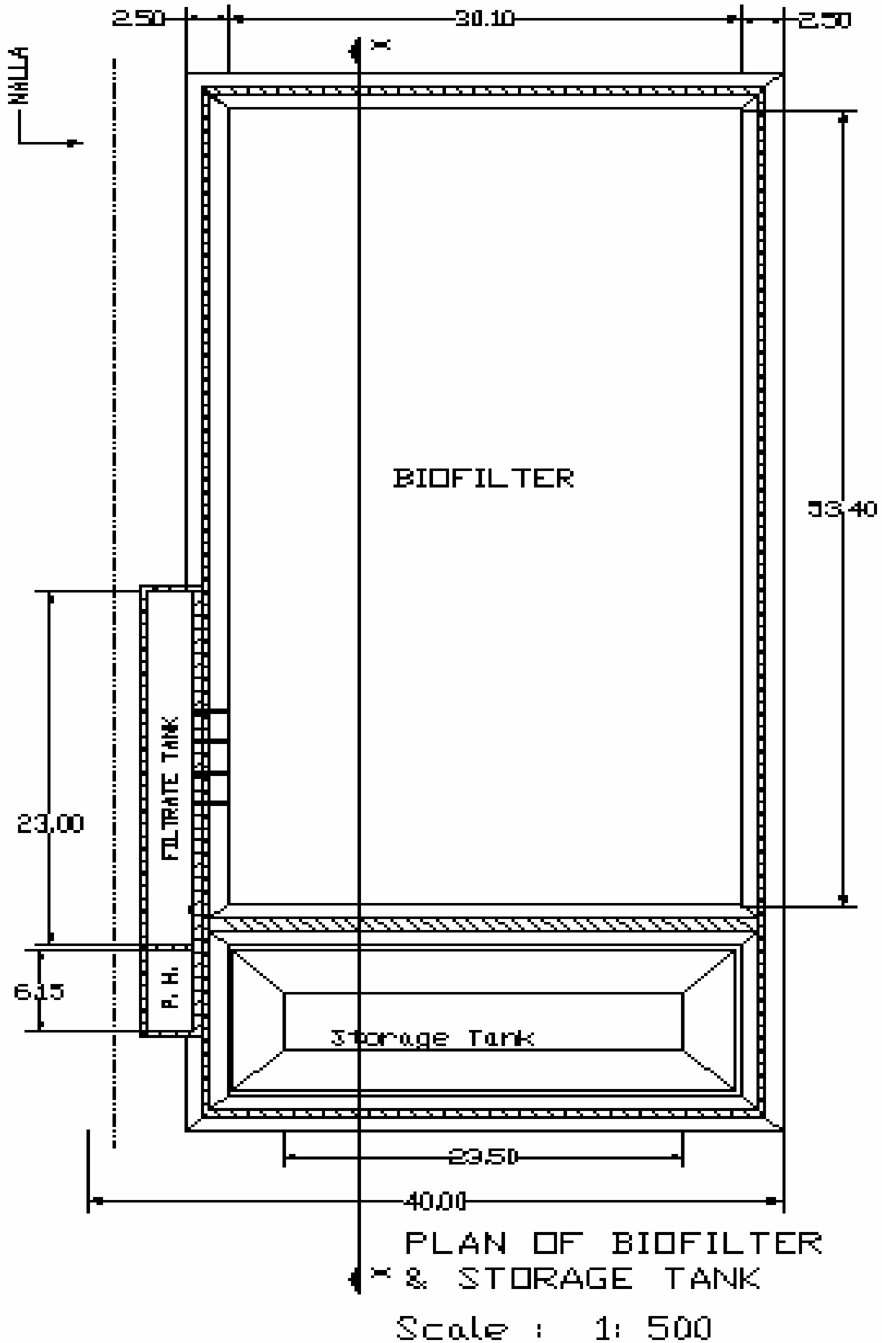


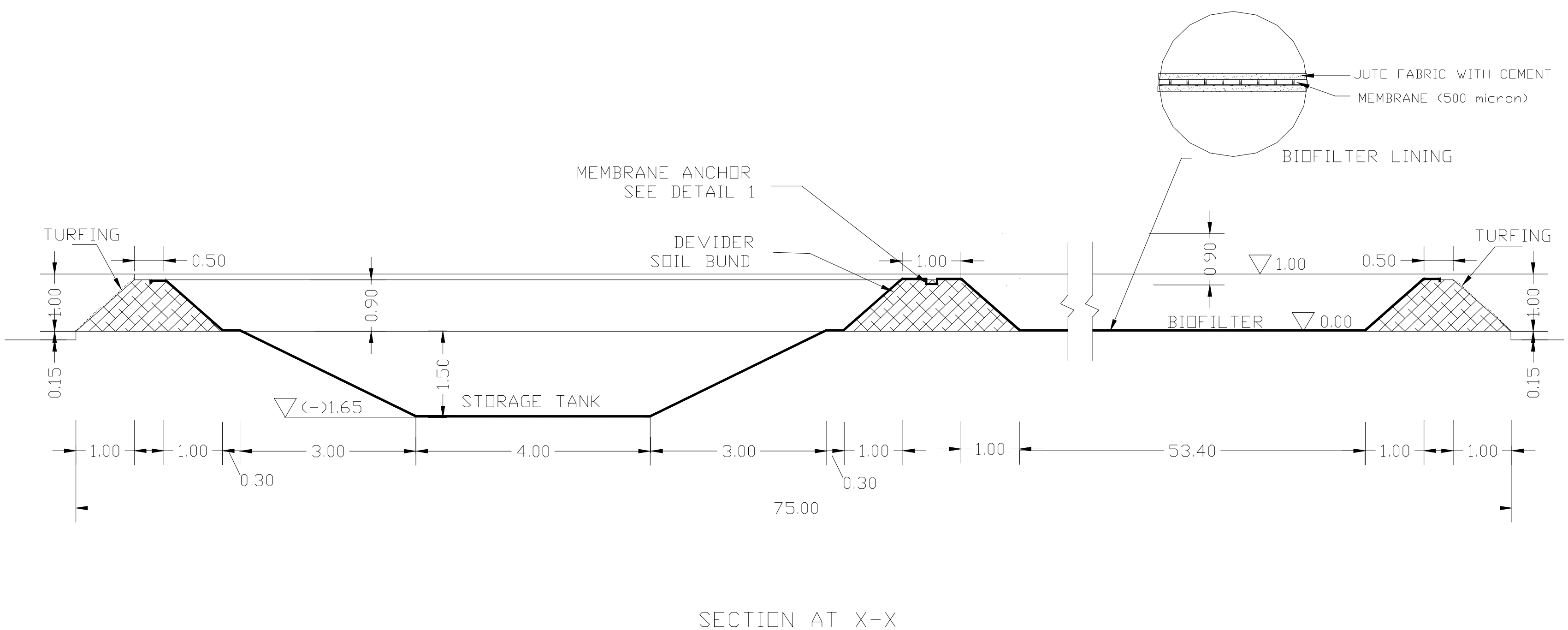
Fig 4a: Feed From Top surface only

Fig 4b: Feed From Top & Slopes $v_r = 0.15\ m^3/m^2h$

SBT PLANT
TOP VIEW



PLANT ELEVATION



500 m3/day BPGC Plant for wastewater treatment

SBT PLANT

3MLD Sewage purification in Corporation Of Bombay

WATER QUALITY ANALYSIS OF SBT PLANT

PARAMETERS	INFLUENT	EFFLUENT
Temp. (^{0}C)	31.4	31.3
pH	6.91	8.26
Conductivity (micro S/cm)	2160	987
DO (mg/l)	0.85	7.01
Turbidity (NTU)	145	5.32
COD (mg/L)	352	64
BOD	211	7.04
Ammonia (mg/L)	33.4	0.010
Phosphate-P (mg/L)	0.474	0.0016
SS(mg/l)	293.3	16
Alkalinity(mg/L)	212	148
Fecal coliform(cfu/100ml)	$145*10^5$	55
Total coliform(cfu/100ml)	$150*10^8$	110

PROCESS FEATURES

- Very low energy use intensity due to high Natural oxygen transfer in process. (0.06 kWh/kL sewage).
- Very low space intensity of 0.8-1.0 sqm/kL per day sewage.
- An engineered evergreen natural process with no moving parts except for pumps.
- No sludge due to ecology at work.
- Very high bacteria, BOD, COD, suspended solids, colour, odour, ammonia removal.
- Practically maintenance free.

SBT PLANT

3MLD Sewage purification in Corporation Of Bombay

SBT PLANT

3MLD Sewage purification in Corporation Of Bombay

SBT PLANT

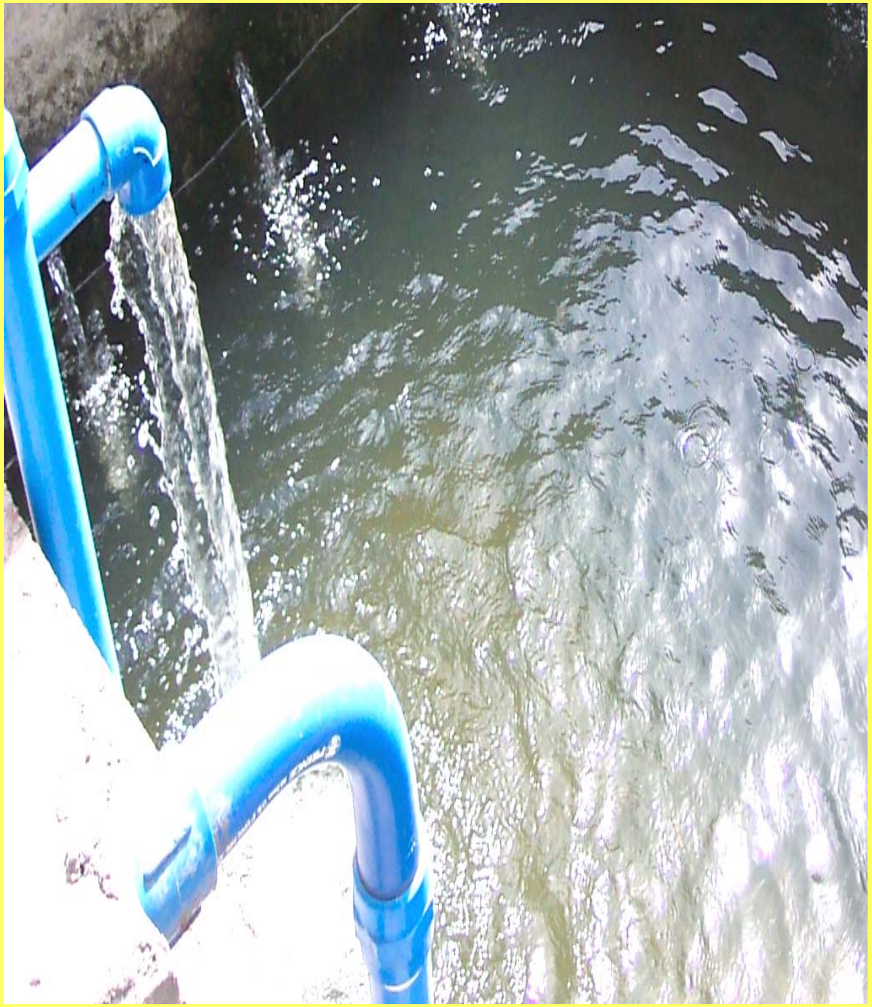
3MLD Sewage purification in Corporation Of Bombay

SBT PLANT

Renovation of colony sewage for irrigation in sports complex

REUSABLE WATER FROM WASTEWATER

Wastewater



Treated Wastewater

SBT PLANT

Colony sewage treatment showing untreated & treated water

SBT PLANT

Renovation of septic tank waste water for irrigation in a Research Center

SBT PLANT

Retrofitting of idle activated sludge plant

SUMMARY OF SBT PROCESS FEATURES FOR SEWAGE TREATMENT

Item	Features
Organic loading	150-200 g / sqm.d
Oxygen transfer	150-200 g / sqm.d
Heat generation	600-800 k.cal / sqm.d
Conversion	As required
Hydraulic loading	0.05 - 0.25 cum/sqm.h
Shear rate	0.01 – 0.1 per sec.

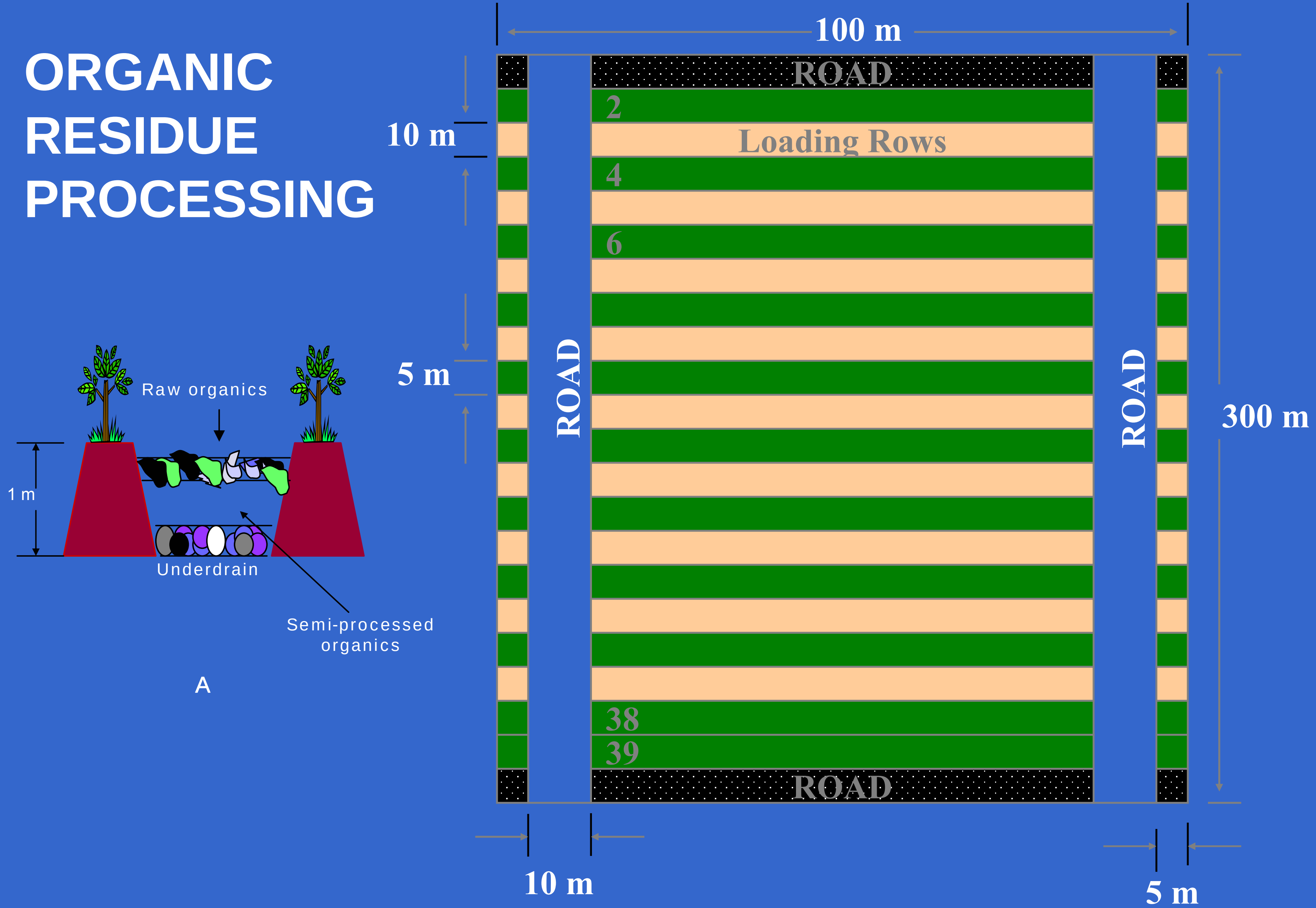
OPERATING FACILITIES

- Bombay Presidency Golf Club
- Naval Housing Colony, Bombay
- Vazir Sultan Tobacco, Hyderabad
- Jindal Steel, Delhi
- Taj Kiran, Gwalior
- IIT Bombay
- Beru Ashram Badlapur
- Delhi Travel Tourism Dev Corporation
- Bombay Municipal Corporation (in progress)
- University of Hyderabad (in progress).

SBT PLANT

Close up of solid waste processing

ORGANIC RESIDUE PROCESSING



Schematic of organic residue processing.

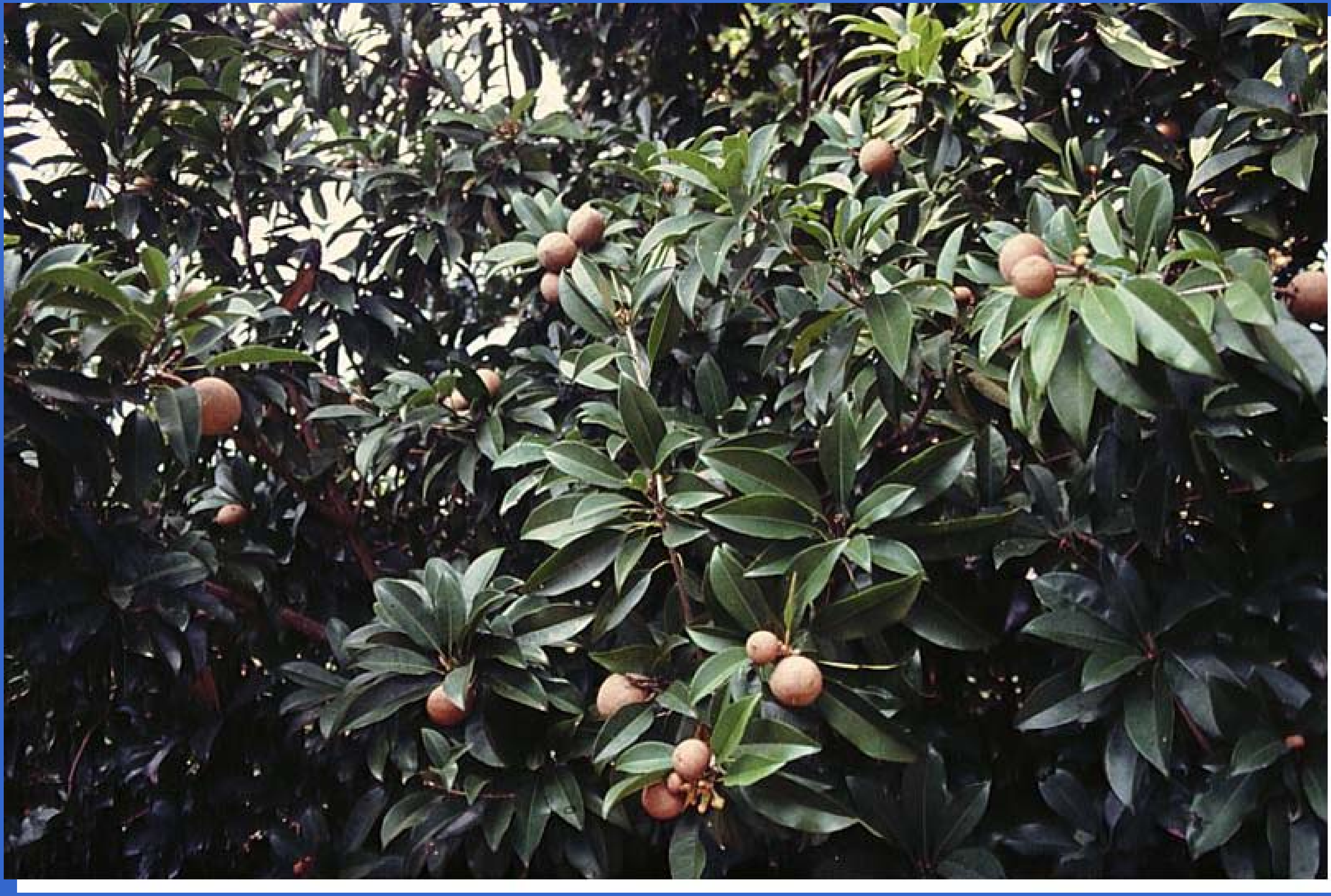
Restoration of municipal dumping grounds

Processing chicken offals

SUMMARY OF PROCESS FEATURES FOR ORGANIC SOLID CONVERSION

Item	Features
Organic loading	150-200 g / sq.m.d
Oxygen transfer	150-200 g / sq.m.d
Heat generation	600-800 k.cal / sq.m.d
Conversion	20-30%
Product Yield	0.375 – 0.500 kg / kg
Products	fertilizer/culture/soil

Chickoo plant affected by fungal disease



Chickoo plant after restoration of soil

ECONOMICS FOR SEWAGE TREATMENT

Item	Unit	Capacity (m^3 / d)						
		5	50	100	200	500	3,000	10,000
1. Space	m^2	40	250	400	600	1500	3500	10000
2.Civil, mech., Elec.	Rs. Mil	0.10	0.5	0.9	1.0	1.5	12	25
3.Bioreactor	Rs. Mil	015	0.6	1.0	1.5	2.5	17	50
Total (2 + 3)	Rs. Mil	0.25	1.1	1.9	2.5	4.0	29	75
4. Power	Rs./d	10	100	200	400	800	1200	4000
5. Additives	Rs./d	20	100	250	500	1250	5000	15000
6. Staff	Rs./d	250	250	500	500	1000	2500	5000
7. Miscellaneous	Rs./d	10	50	50	150	200	300	500
Total (5 to 7)	Rs./d	340	600	1000	1550	3250	9000	24500

US $ = Rs. 47.00; Power Rs. 4 per kWh ; Mil – Million; additives – Rs. 5 / kg

ECONOMICS FOR MUNICIPAL ORGANIC SOLIDS

Item	Unit	Features			
Capacity	Ton/day	1	10	20	100
Space	Sq.m	2000	15000	20000	50000
Civil, mech., elec.	Rs. mil	0.5	2.5	4.5	15
bioreactor	Rs. mil	0.2	1.0	1.5	5.0
Total (3+4)	Rs. mil	0.7	3.5	6.0	20
production	Ton/year	150	1500	3000	15000
Labour	Rs./day	450	3500	5000	10000
Power fuel	Rs./day	-	-	1000	5000
Additives	Rs./day	400	4000	8000	20000
Misc.	Rs./day	50	200	500	1000
Total (6-8)	Rs./day	850	7500	15500	36000

mil. – million
mech. – mechanical
elec. – electrical
Rs. – Rupees (1US$ = Rs.47)

APPLICATIONS

- Rain water harvesting via storm water conservation
- Primary purification of drinking water
- Primary purification of swimming pool water

- Sewage treatment for reuse in construction, cleaning & gardening, ground water recharge, make up water for swimming pools & industries etc
- Industrial wastewater treatment,
- Industrial air purification

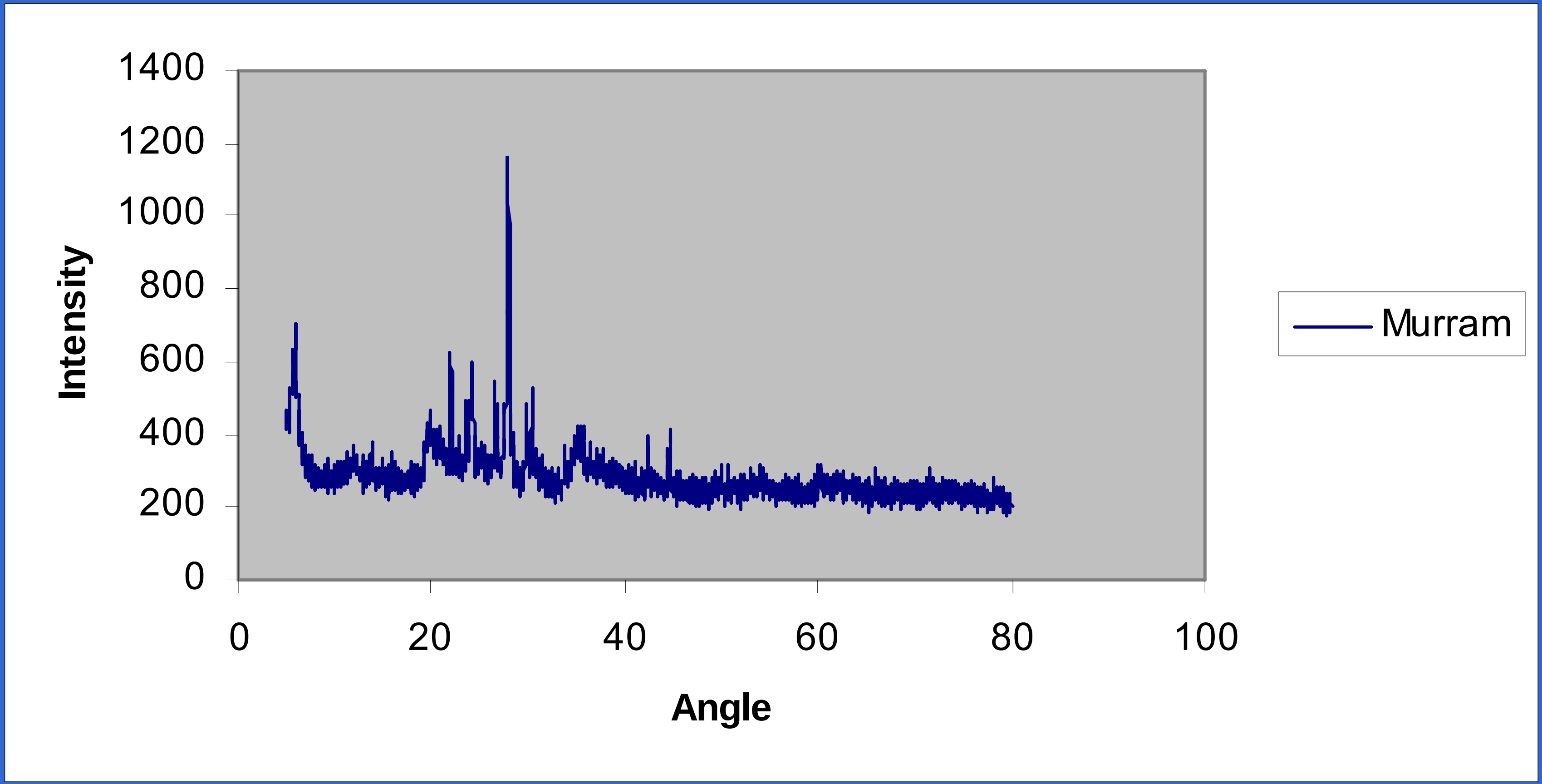
- Organic solid waste conversion
- Municipal solid waste processing
- Commercial production of Soil
- Animal House waste processing
- Hospital waste disposal

SUMMING UP

- **Engineered natural oxygen supply**
- **Evergreen Environment**
- **No moving parts**
- **No biosludge**

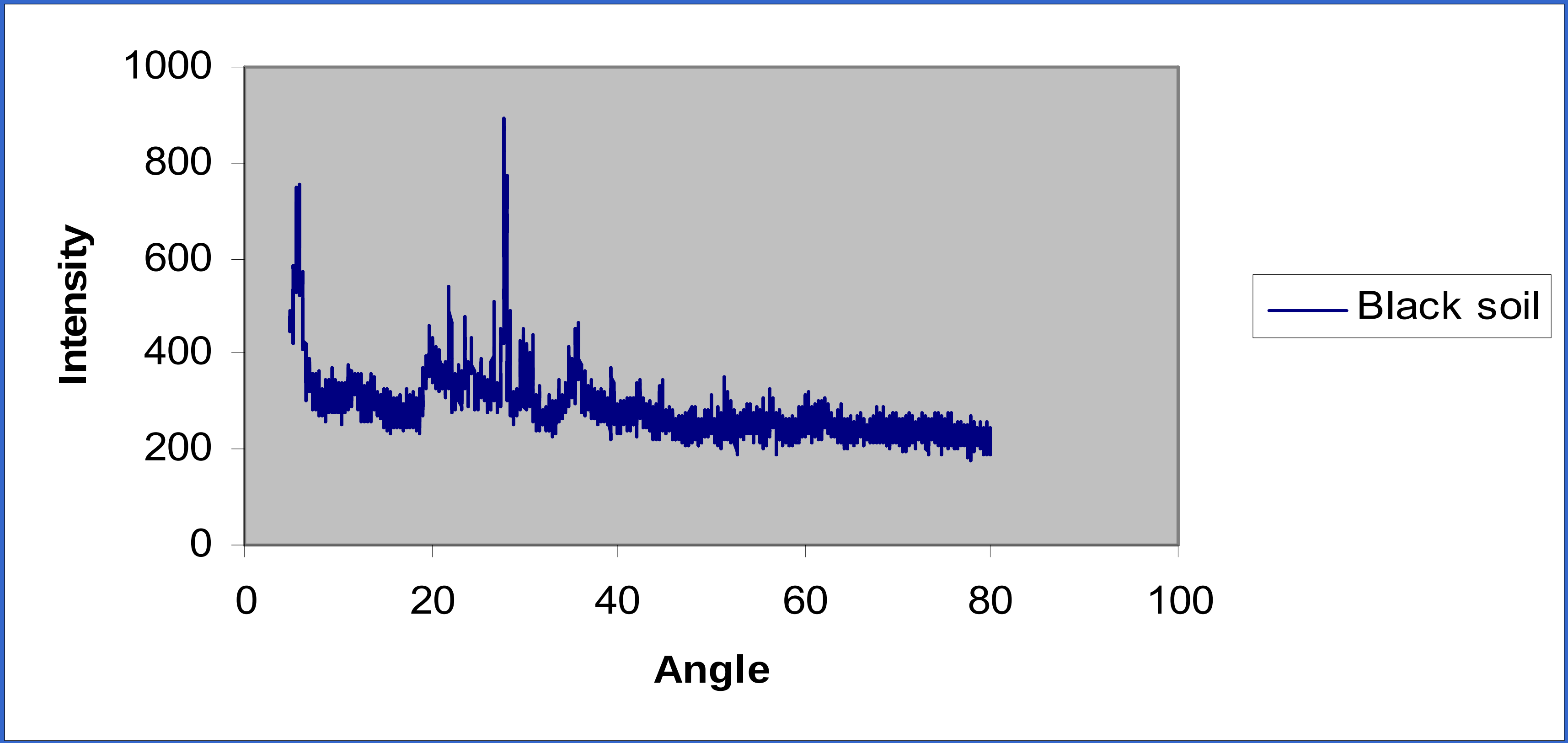
THANK YOU !

XRD ANALYSIS



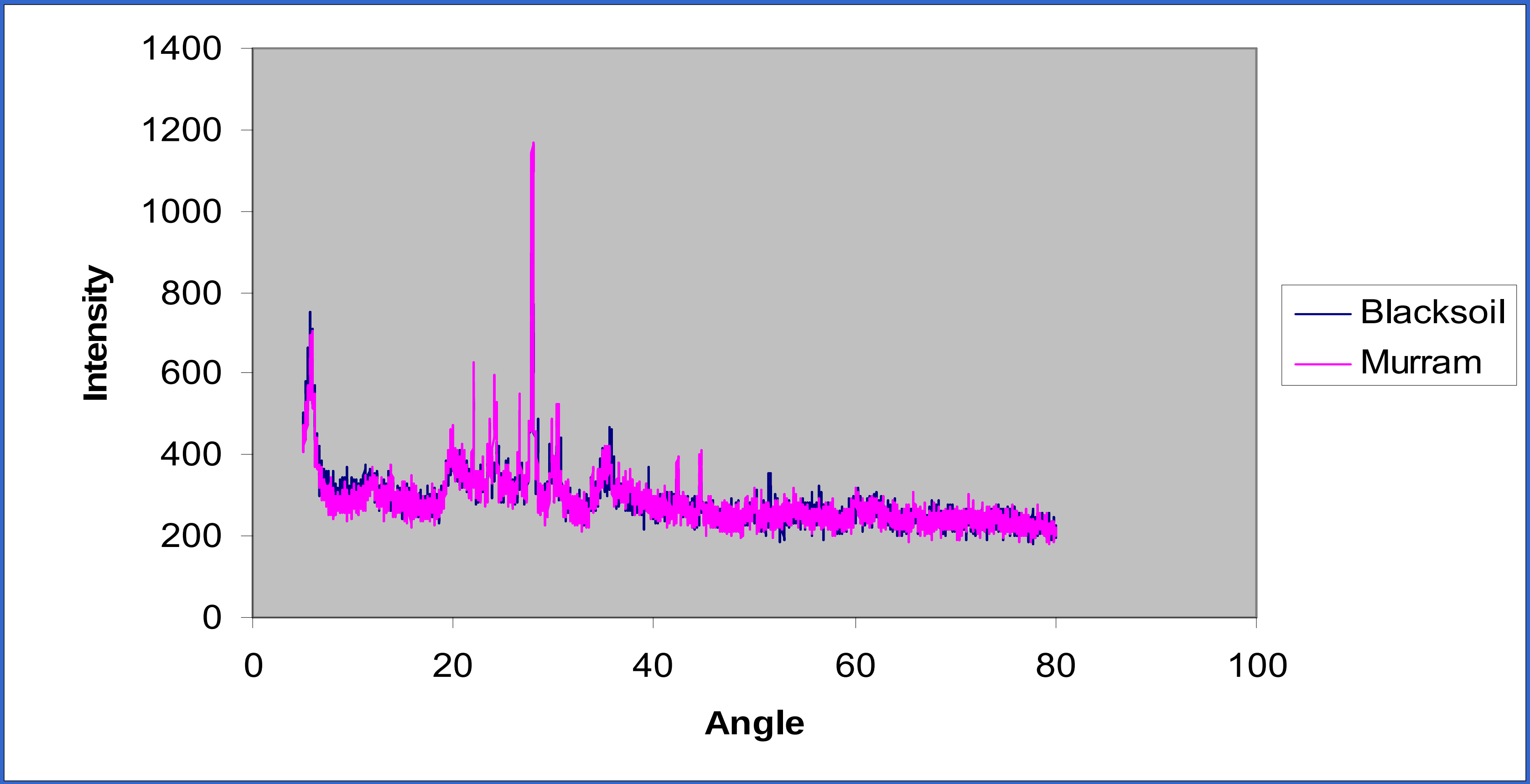
Partially weathered Rock (Murram)

XRD ANALYSIS



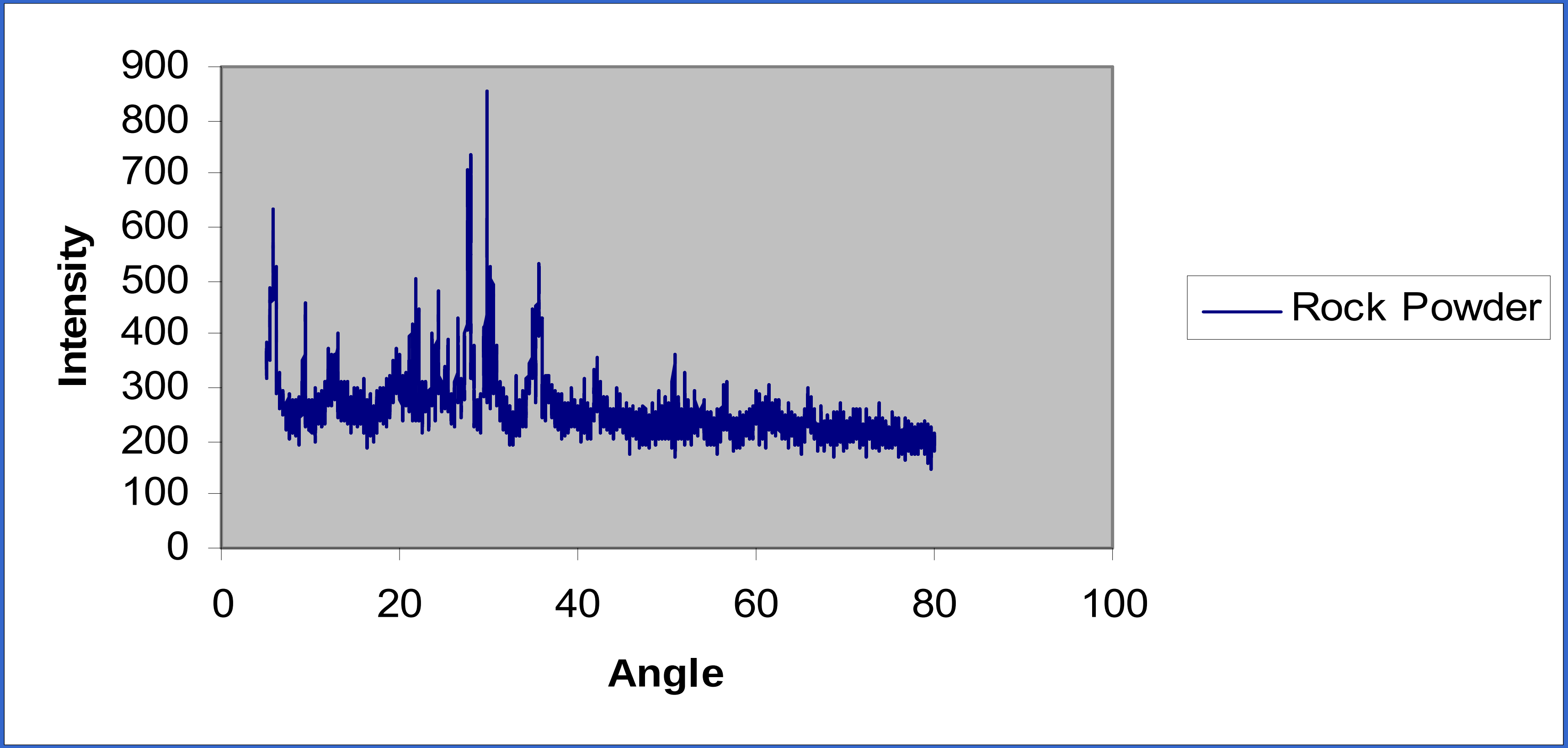
Artificially weathered Rock (Black soil)

XRD ANALYSIS



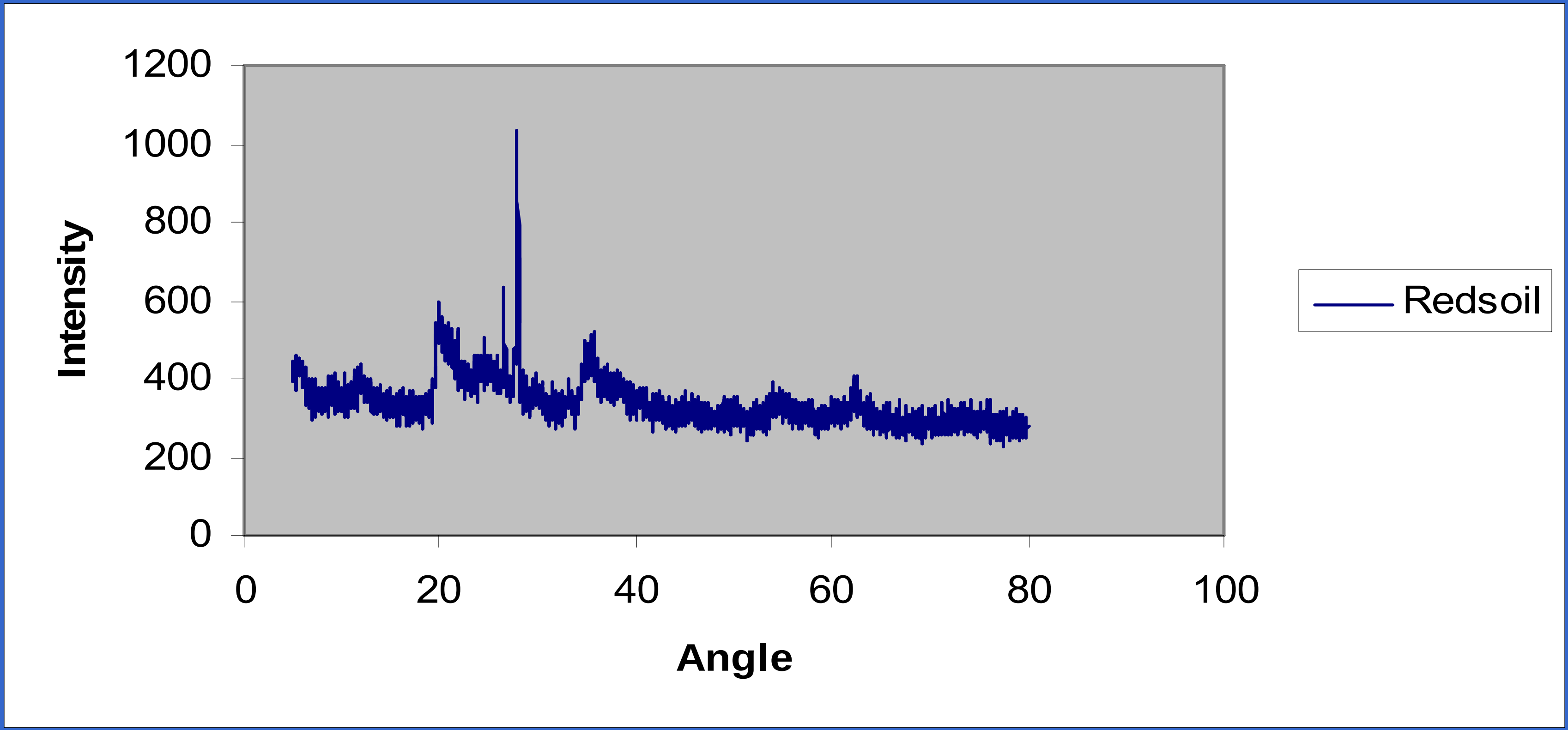
Comparison of Artificially weathered Rock (Black soil) with Murram (partially weathered Rock)

XRD ANALYSIS



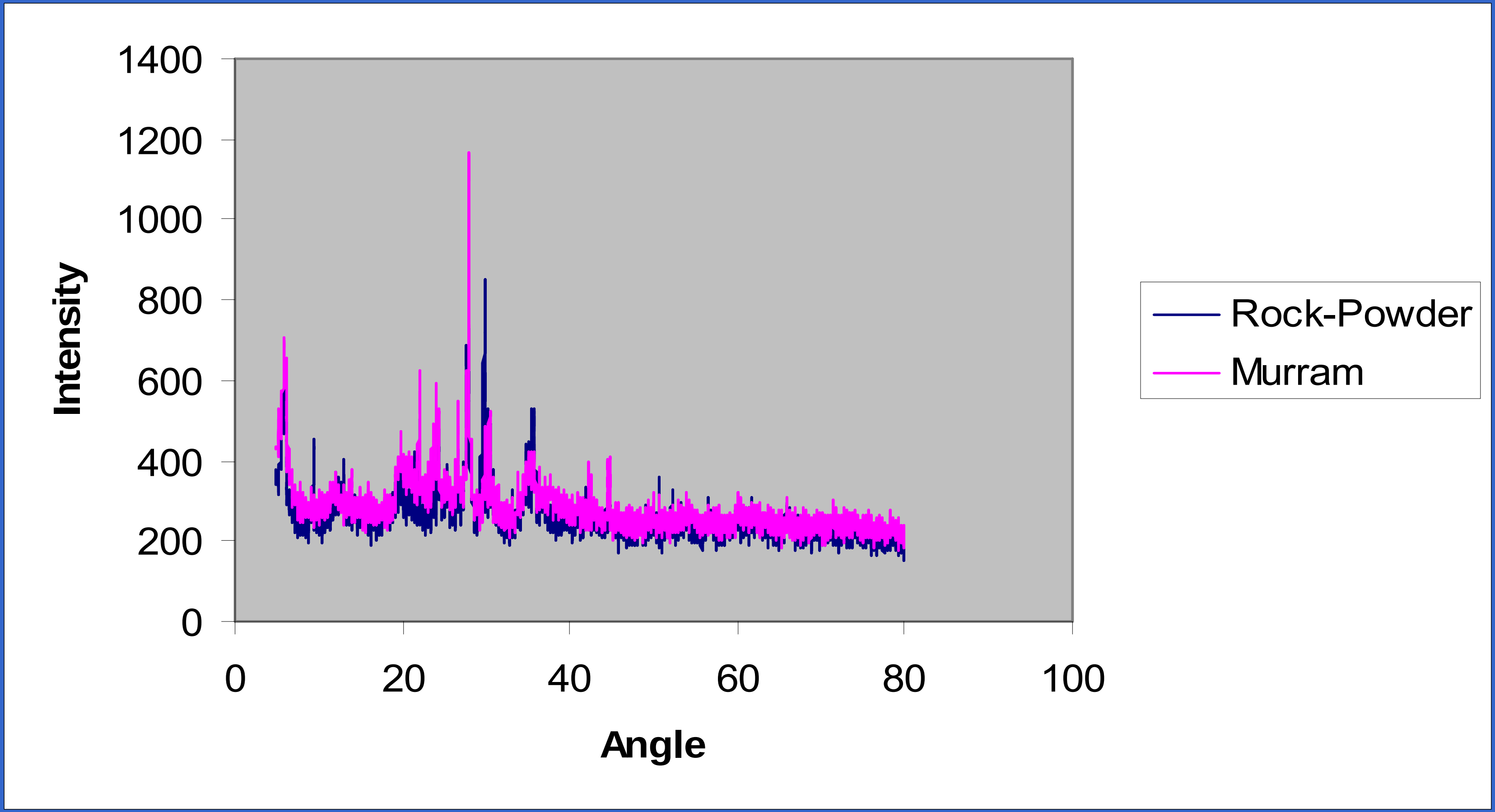
Primary mineral (Rock powder)

XRD ANALYSIS



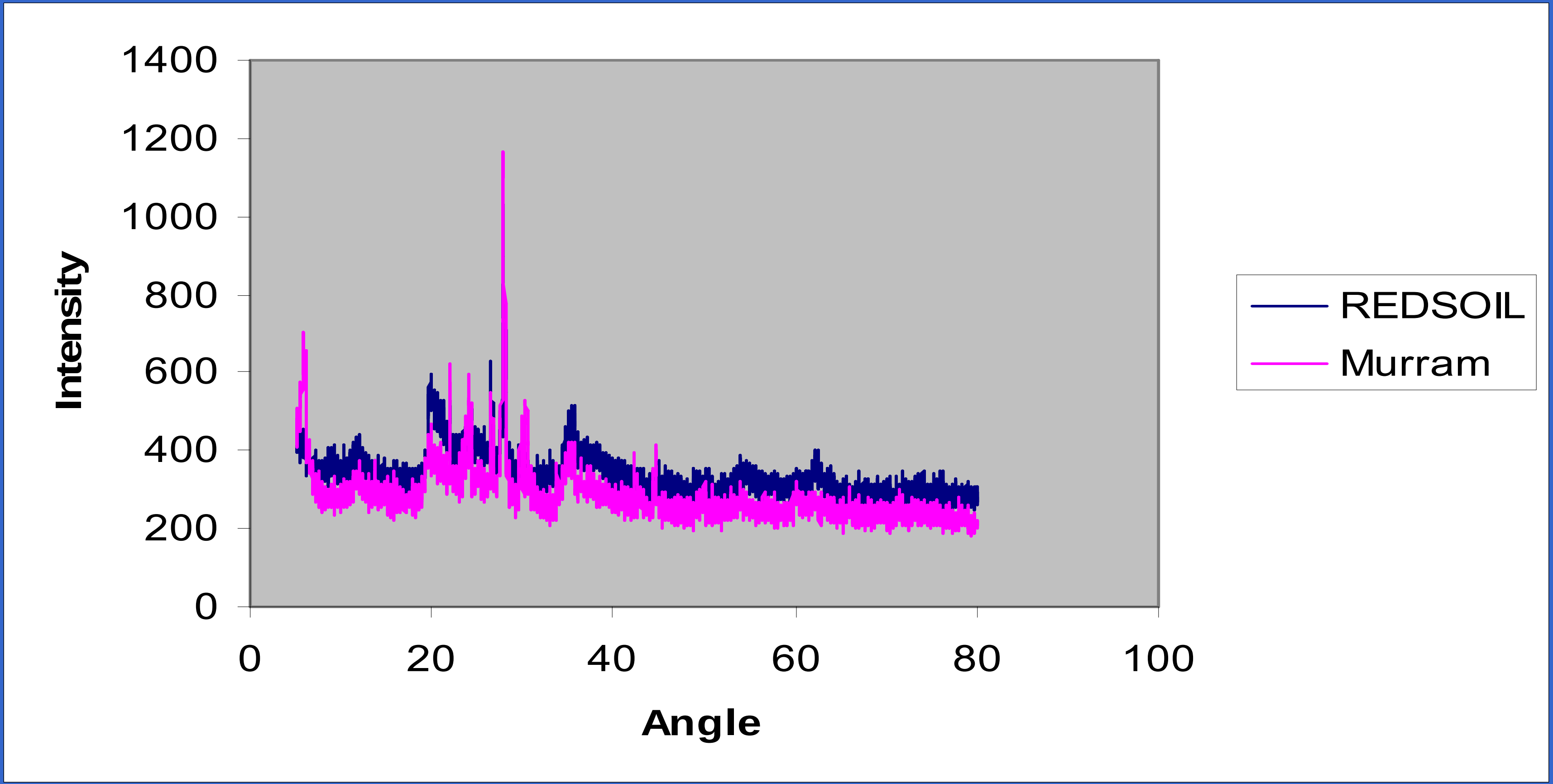
Naturally weathered Rock (Red soil)

XRD ANALYSIS



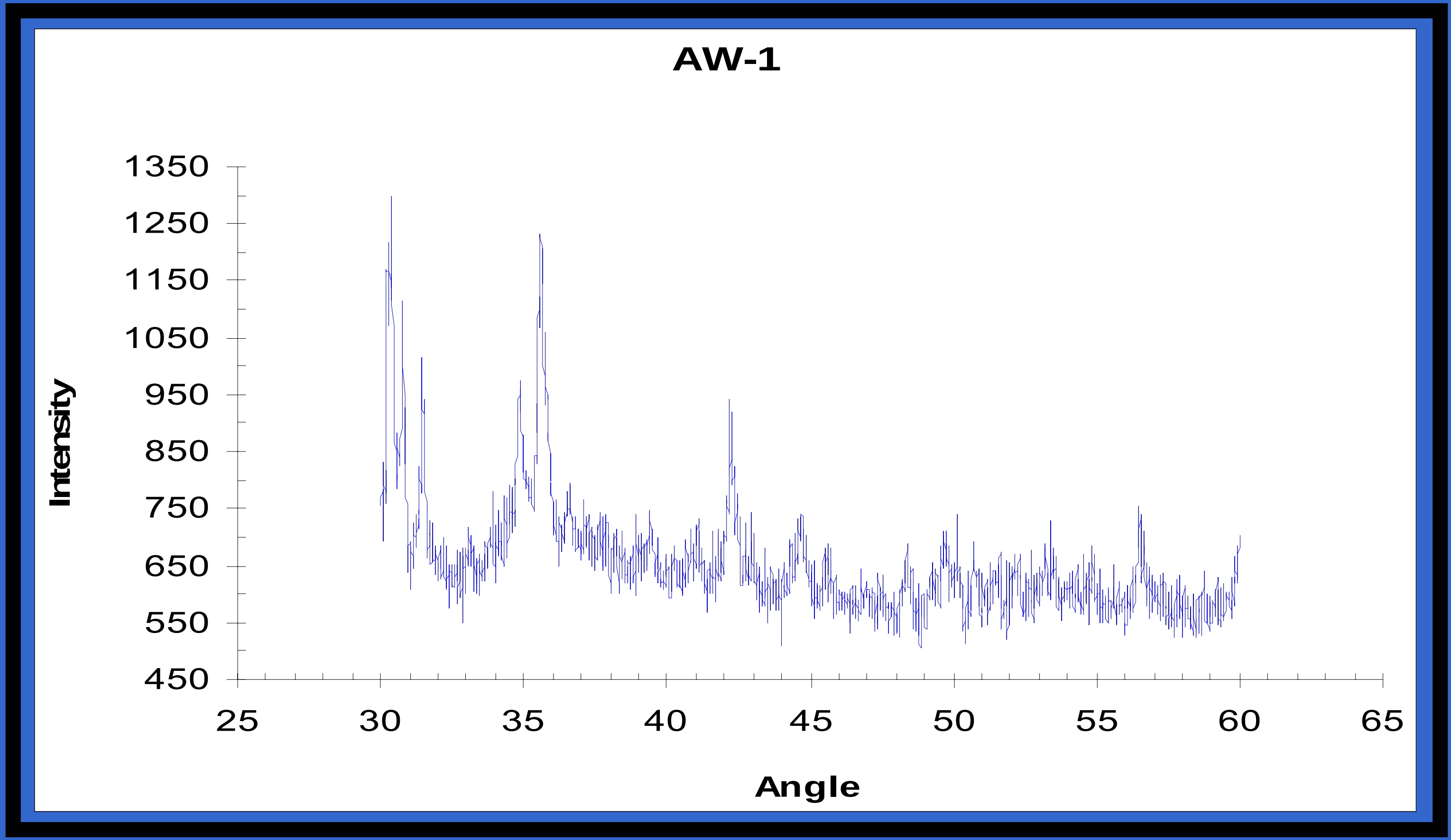
Comparison of Primary Mineral (Rock powder) with Murram (Partially weathered Rock)

XRD ANALYSIS



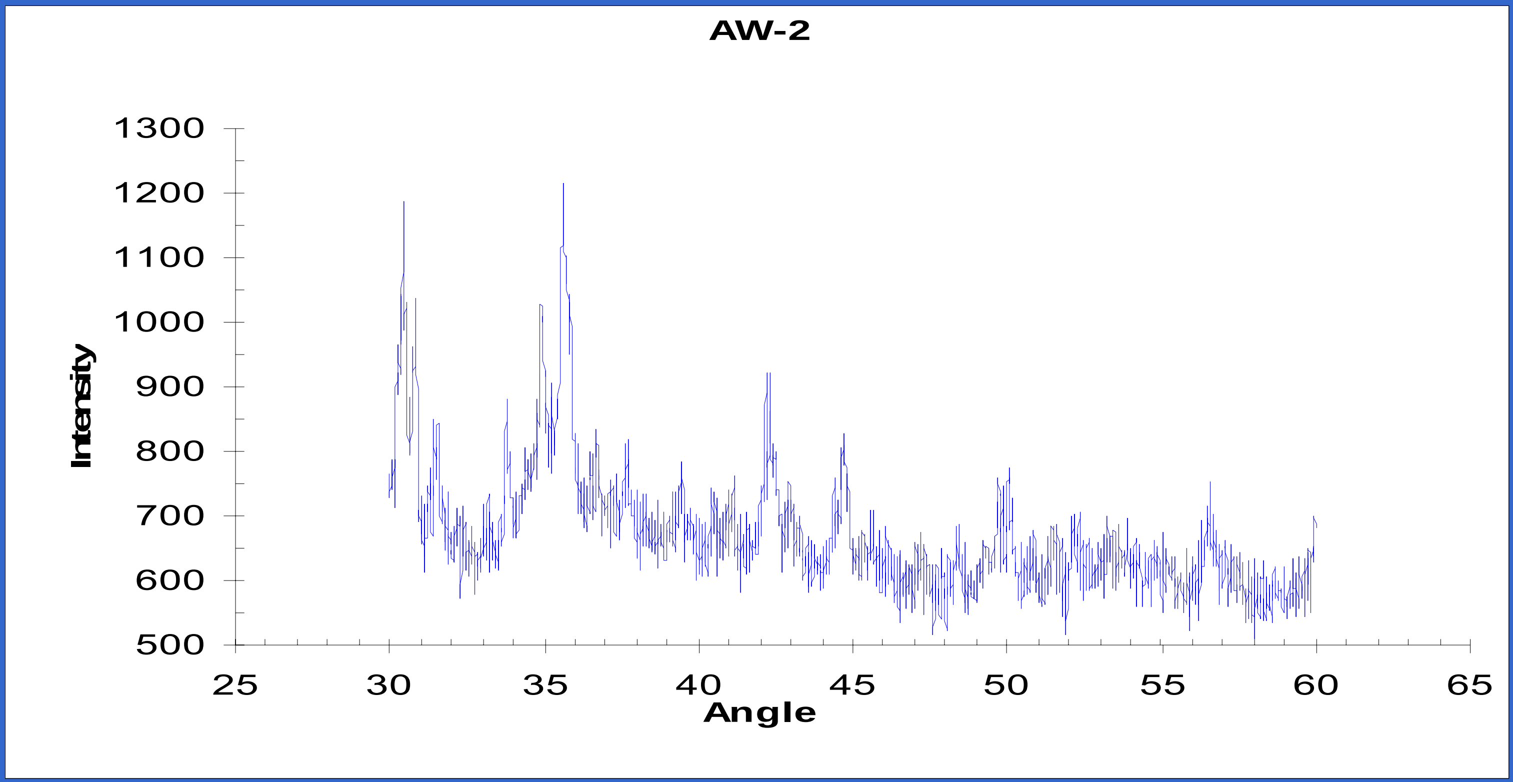
Comparison of Naturally weathered Rock (Red soil) with Murram (partially weathered Rock)

XRD ANALYSIS



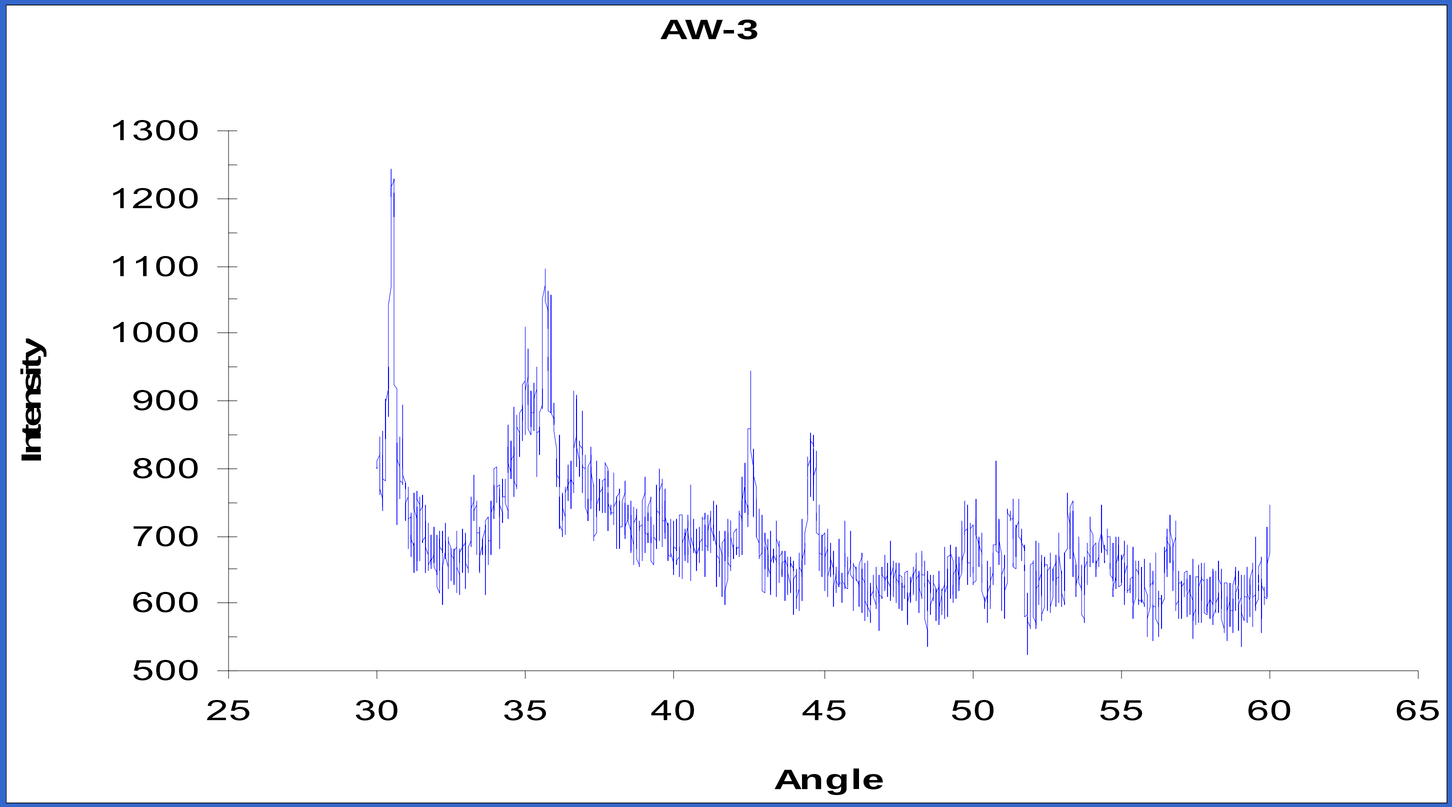
Artificially weathered Rock - 1

XRD ANALYSIS



Artificially Weathered Rock - 1

XRD ANALYSIS



Artificially Weathered Rock - 2

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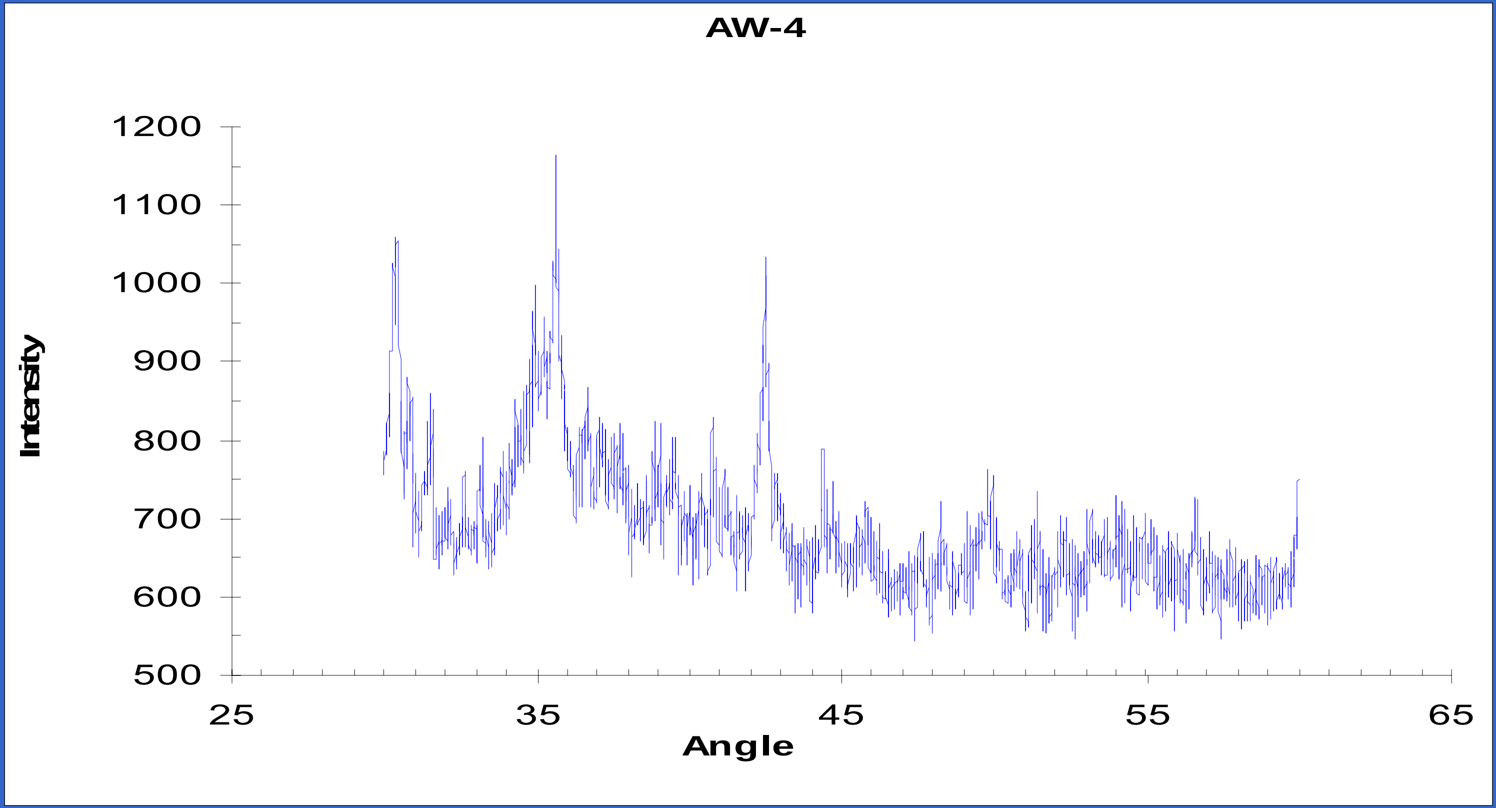

Artificially Weathered Rock - 2

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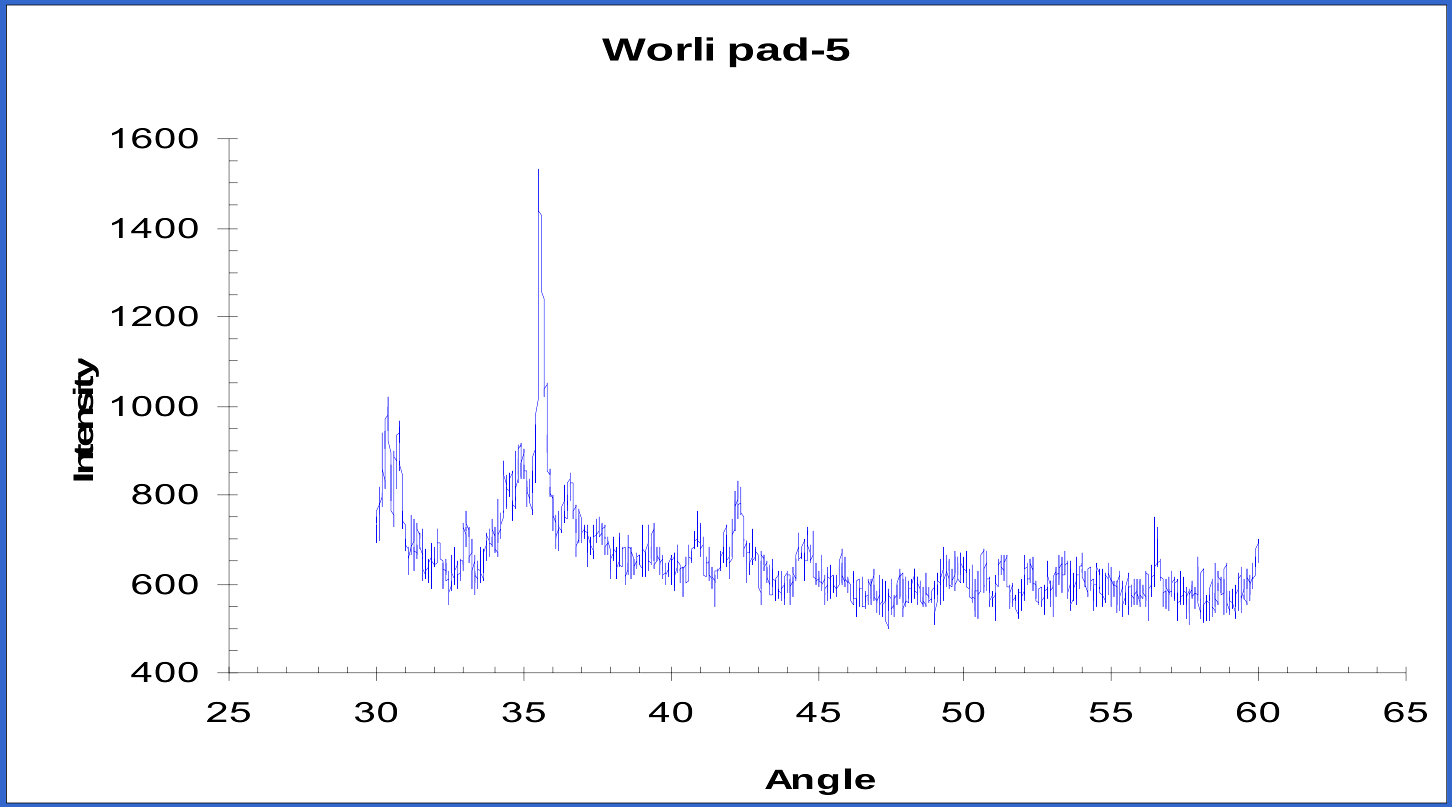
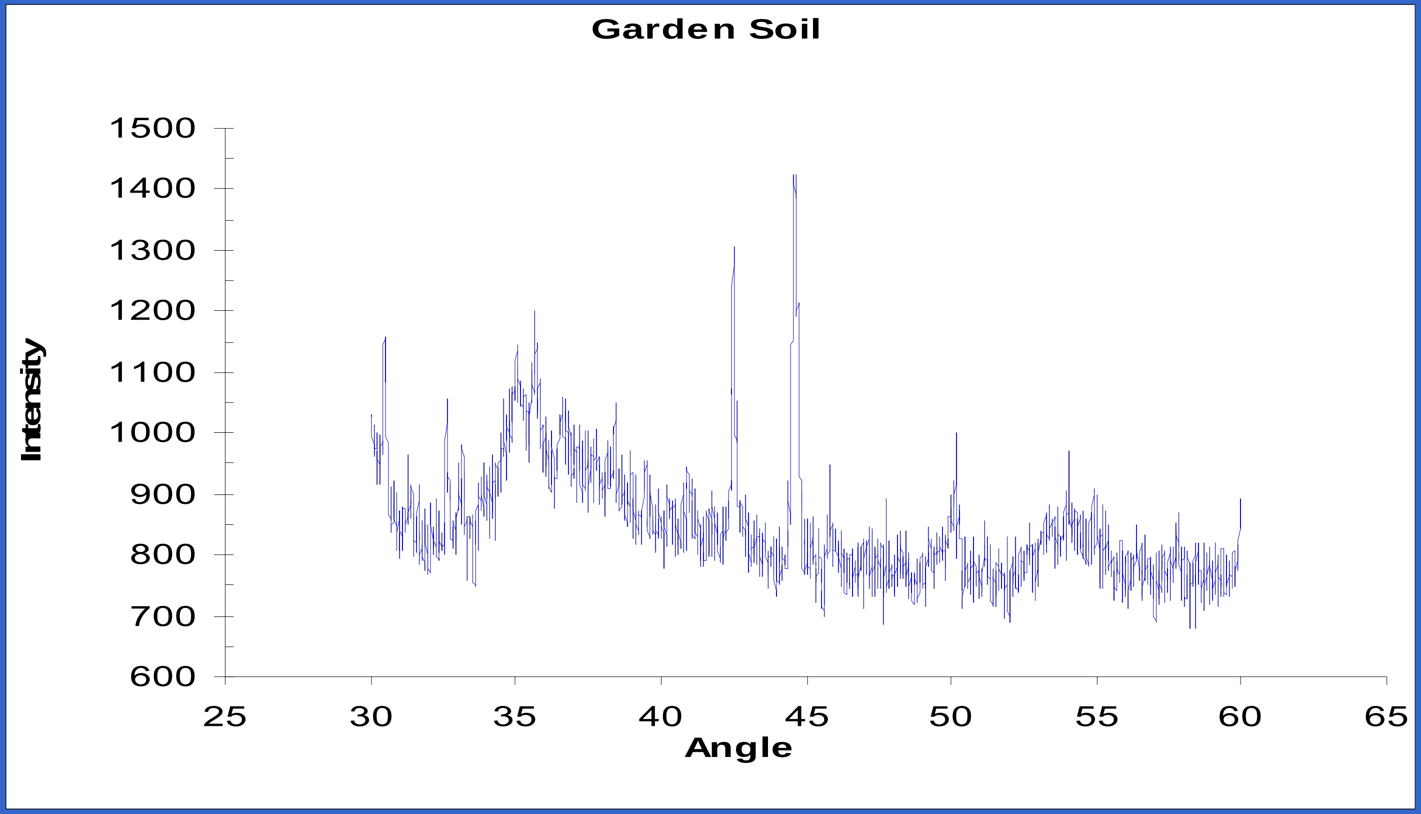


Artificially Weathered Rock

XRD ANALYSIS



Artificially Weathered Rock

PATENTS AND PUBLICATIONS

1. **US Patent No: 6890438 " Process for treatment of organic wastes" H.S.Shankar, B.R.Patnaik, U.S.Bhawalkar, issued 10 May 2005**

2. **"Process for treatment of Organic residues" India Patent Application MUM/384/26 April 2002, H.S.Shankar, B.R.Patnaik,U.S.Bhawalkar**

3. **" Process for treatment of waste water" India Patent Application MUM/383/26 April 2002, H.S.Shankar,B.R.Patnaik,U.S.Bhawalkar**

4. **Patnaik, B.R., Bhawalkar, U.S., Gupta, A., Shankar, H.S., "*Residence Time Distribution model for Soil Filters, Water Environment Research, 76(2), 168-174,2004*"**

5. **Patnaik, B.R., Bhawalkar, V.S., Shankar, H.S., "*Waste Processing in Engineered Ecosystems*", 4th World Congress on Chemical Engineering, 23-27, September 2001, Melbourne, Australia**

6. **Patnaik, B.R., Bhawalkar, U.S., Kadam, A, Shankar, H.S., "*Soil Biotechnology for Waste Water Treatment and utilization*", 13th ASPAC 2003, International Water Works Association Conference 13-18, October, 2003, Quezon City, Philippines**

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7. Kadam,AM,Ojha,Goldie., Shankar,H.S Soil Biotechnology for Processing of waste waters, 9 th International conference, Indian Water Works Association, Bombay 26-27 Nov2005
8. Yeole,U.R., Patnaik,B.R.,Shankar,H.S.," Soil Biotechnology process simulation using computational fluid dynamics" Session Advanced Computations for Environmental Applications II" AIChE Annual Meeting, 7-12 Nov 2005,Austin Texas, USA
9. Pattanaik., B.R.(2000),” P*rocessing of Wastewater in Soil Filters”, Ph.D.* Dissertation, Dept of Chemical Engg., IIT Bombay
10. Yeole,Umesh Prabhakar"Soil Biotechnology Process Simulation using Computational Fluid dynamics" 2004
11. Bhuddhiraju,Sudheendra., "Soil Biotechnology Process simulation using Computational Fluid dynamics" 2005

MEDIA AND CULTURE

US Patent: *Process for treatment of organic wastes*; US Patent no: 6890438, www.uspto.gov; Issue date: 10 May 2005 ;

- **Underdrain:-** Stone rubble of various sizes ranging upto Gravel (200.0-2.0 mm), Very coarse sand (1.0-2.0 mm), Coarse sand (0.5-1.0 mm), Medium sand (0.25-0.5 mm), Fine sand (0.1-0.25 mm)

- **Media:-** Formulated from soil as required and primary minerals of suitable particle size and composition

- **Culture:-** Geophagus (Soil living) worm Pheretima elongata and bacterial culture from natural sources containing bacteria capable of processing cellulose, lignin, starch, protein, also nitrifying and denitrifying organisms. Anaerobic organisms for methanogenesis. For industrial wastes, development of appropriate culture required

- **Additives:-** Formulated from natural materials of suitable particle size and composition to provide sites for respiration, CO_2 capture

- **Bioindicators:-** Green plants particularly with tap root system

EXTRACT FROM VISION 21 DOCUMENT OF WHO

Current sanitation solutions contribute, either directly or indirectly, to many of the problems faced by society today: water pollution, scarcity of fresh water, food insecurity, destruction and loss of soil fertility, global warming, and poor man health as well as loss of life.

In summary, we divert excreta away from land, consuming a limited resource – fresh water, into receiving water bodies causing water pollution. We then try to treat the water we drink. Both processes create health hazards. By diverting nutrients away from land, artificial fertilizers are added to land, creating even more water pollution, which is difficult and expensive to treat.

We must find another way. We have to design and build new systems, which promote waste as a resource and envisage local solutions and cultural attitudes and contribute to the solving society's most pressing problems.

Source: Esrey, S. & Anderson, I., Vision 21- Environmental Sanitation Ecosystems Approach, report published by Water Supply and Sanitation Collaborative Council (WSSCC) World Health Organization, United Nations, 1993

AS (III) TO AS (V) CONVERSION IN SOIL FILTER SYSTEM

As(III) =1000 µg/l As(III); Flow rate= 130 ml/minute; Filter bed volume = 17 lit; Precipitation with Fe(III); (FeCl3) dose as Fe added 55 mg/l.

Time minute	Total As µg/l	As(III) conversion to As(V) in Soil Filter		Precipitation of $FeCl_3$
		As(V) µg/l	Residual As(III) µg/l	Residual Total As µg/l
0	995.50	150.00	640.00	18.5
30	986.67	636.67	350.00	15.65
60	1020.00	783.33	236.67	13.34
90	1003.33	826.67	176.67	11.25
120	1000.00	926.67	73.33	7.75
150	1026.67	973.33	53.33	5.85
180	1016.67	983.33	33.33	7.00
210	1013.33	950.00	63.33	7.42
240	1016.67	933.33	83.33	7.40