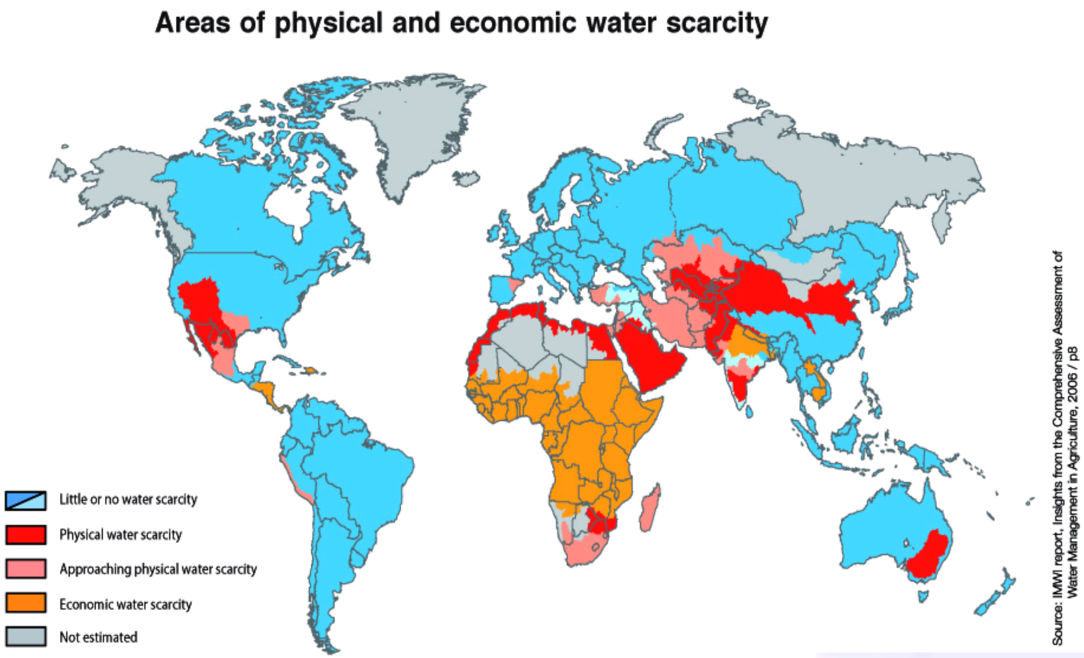
Greywater Treatment System for Wastewater Problem in Indonesia

Mayrina Firdayati

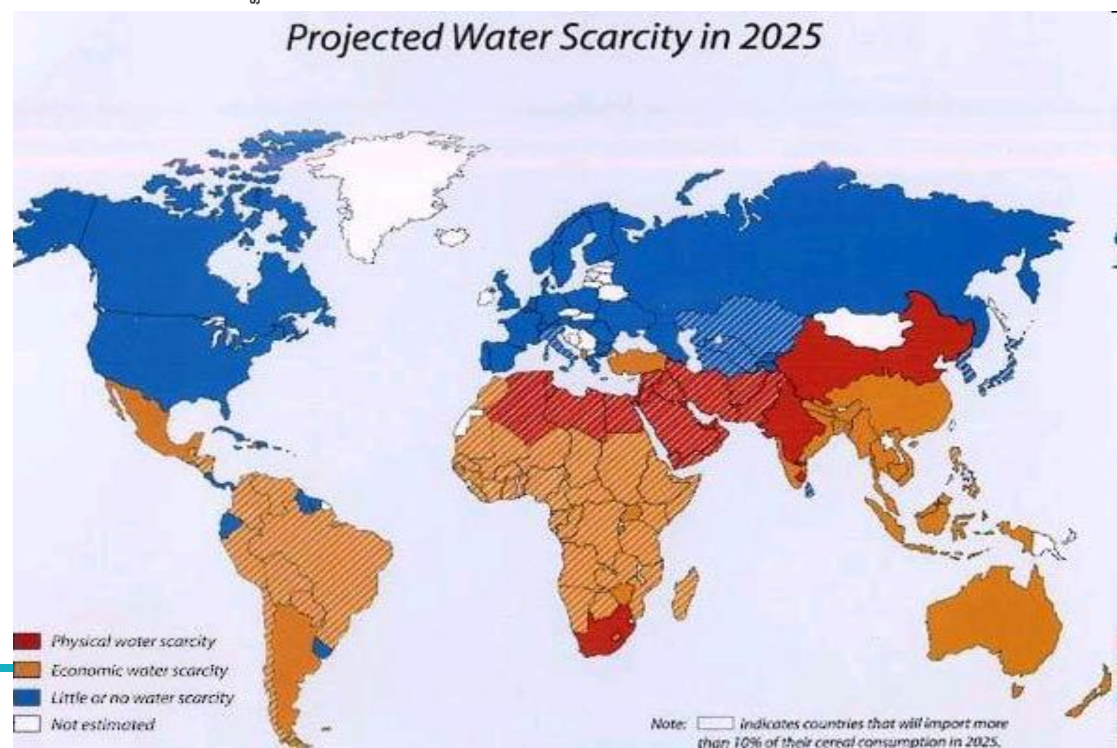


Little or no water scarcity : abundant water resources relative to use, with less than 25% of water from river withdrawn for human purposes

Approaching physical water scarcity : more than 60% of river flows are withdrawn.These basins will experience physical water scarcity in the near future

Economic water scarcity : human, institutional and financial capital limit access to water even though water in nature is available locally to meet human demands

Physical water scarcity :water resources development is approaching or has exceeded sustainable limits.More than 75% of the river flows are withdrawn for agriculture, industry, and domestic purposes



WATER AVAILABILITY INDEX

Background (2)

Indonesia is one of the lowest levels of sewerage connection and sanitation coverage in Asia. This is causing widespread contamination of surface and groundwater (World Bank, 2003).

Today, only 11 cities have centralized sewerage system that is capable of providing service to 2.3 % people in urban area

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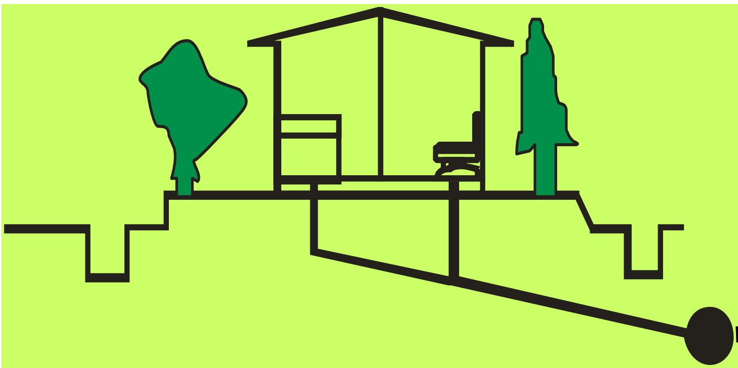
Existing Condition of Wastewater Management in Indonesia

OFF SITE SANITATION (SEWERAGE AND WASTEWATER TREATMENT PLANT /WWTP)

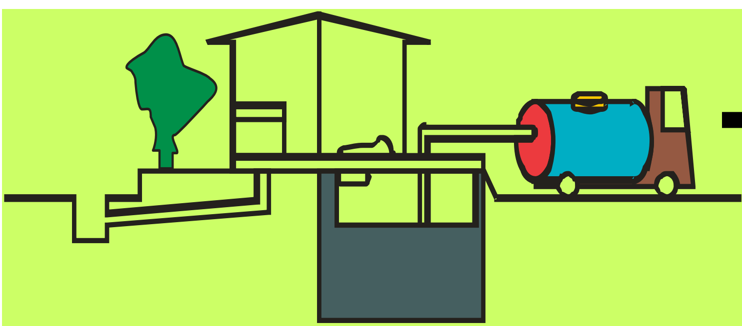


PEOPLE SERVED BY THE OFF SITE SANITATION : 2,33 % (only in urban area)

WASTEWATER TREATMENT PLANT (WWTP)

Majority not well operated

ON SITE SANITATION



FECAL SLUDGE TREATMENT PLANT (FSTP)

PEOPLE SERVED BY THE SAVE ON SITE Sanitation System is about **71,06% of urban population and 32,47 % of rural population**

Effluent from the septick tank infiltrate to the ground,

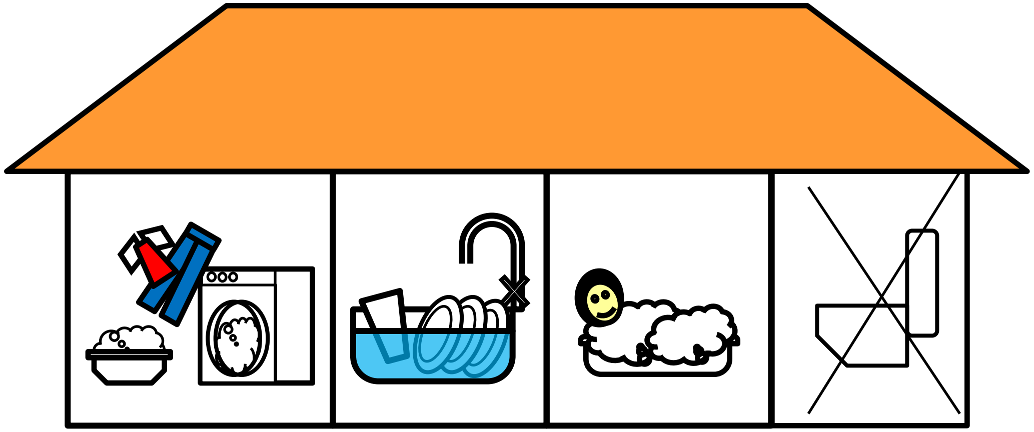
5,6 Million TON/DAY UNTREATMENT WASTEWATER, INFILTRATE TO ENVIROMENT

SOURCE: SUSENAS 2007

Existing Condition of Wastewater Management in Indonesia

- Domestic wastewater estimated to contribute about 70% of organic loading in rivers in urban areas in Indonesia
- Most of domestic wastewater comes from greywater (GW), which is flowing through the sewer or drainage system without treatment, from where it mainly flows into aquatic system
- Combination with inappropriate waste management, GW contaminates river that have function as source of drinking and clean water
- Contamination of the water body by constituents from domestic wastewater and the higher cost of water supply production are inavoidable

- Greywater (GW) is household wastewater streams that generated from the kitchen , bathrooms and laundry



50-80 % of water consumption

- Untreated greywater, though less contaminated than other wastewater sources, does contain pathogens, salts, solid particles, fat, oil and chemicals.

- GW is not given due attention in water management and sanitation campaigns in developing countries, mainly focus on construction of latrines or sewers.

Sanitation Facility : study case in Bandung

- 83 % respondents :septic tank (individual or community)
- 75 % resp.:separate GW and BW
- Greywater production : 60-178 L/p/day (water consumption :111-180 L/p/day)
- Disposal mode of untreated GW :

  58 % to city drainage, then go through river

  30 % directly to the river

  12 % to septic tank
- Separation of greywater plumbing that exist in urban areas is an advantage. For all scenarios of greywater treatment system, separate greywater plumbing is a prerequisite


58 %


12 %


30 %

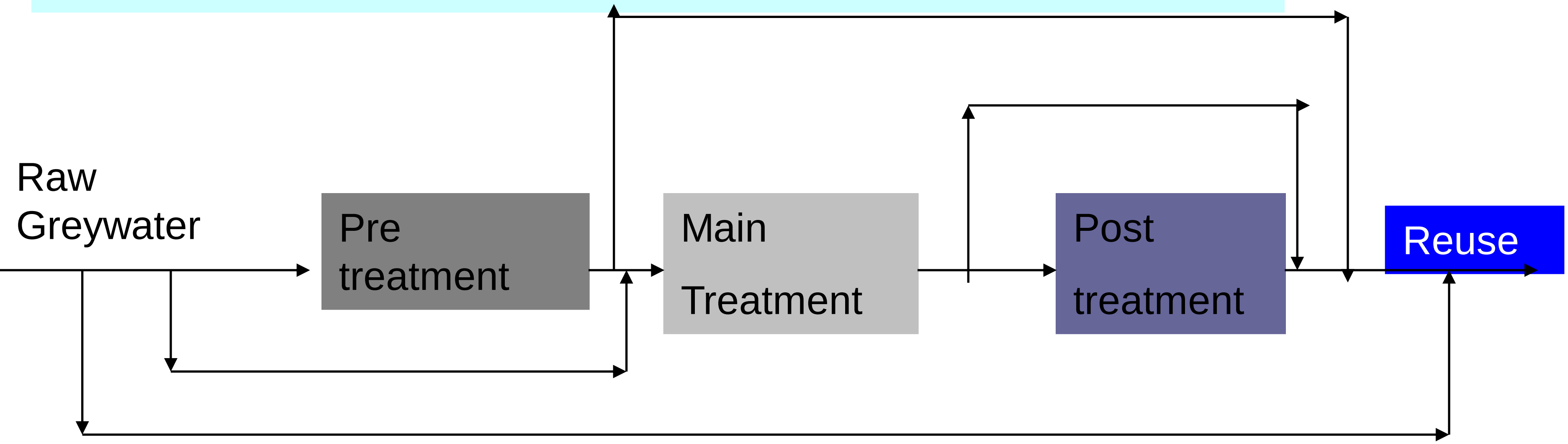
Greywater Characteristic and National Standard

Parameter	GW (1) INA	GW (2) INA	GW Vietnam	INA guideline PP 82/2001	China : toilet flushing	China : cleaning car	China : Lawn irrigation
pH	7-7.5	5.5-8.8	7.1	5-9	6-9	6-9	6-9
COD (mg/L)	530-1220	189-1171	208	100			
BOD (mg/L)	200-490	111-690	151	12	10	15	20
TSS (mg/L)		27-194	63	400			
TN (mg/L)	14-129	4-113	24.2		10	10	20
TP (mg/L)	6-11	0.8-48	4.9	5			
FC (cfu/100 ml)	$(1.6-2.9) \times 10^{13}$	$240-(2.4 \times 10^{9})$	6.6×10^{3}	2000			
O & G (mg/L)		53		10			

Greywater Treatment System

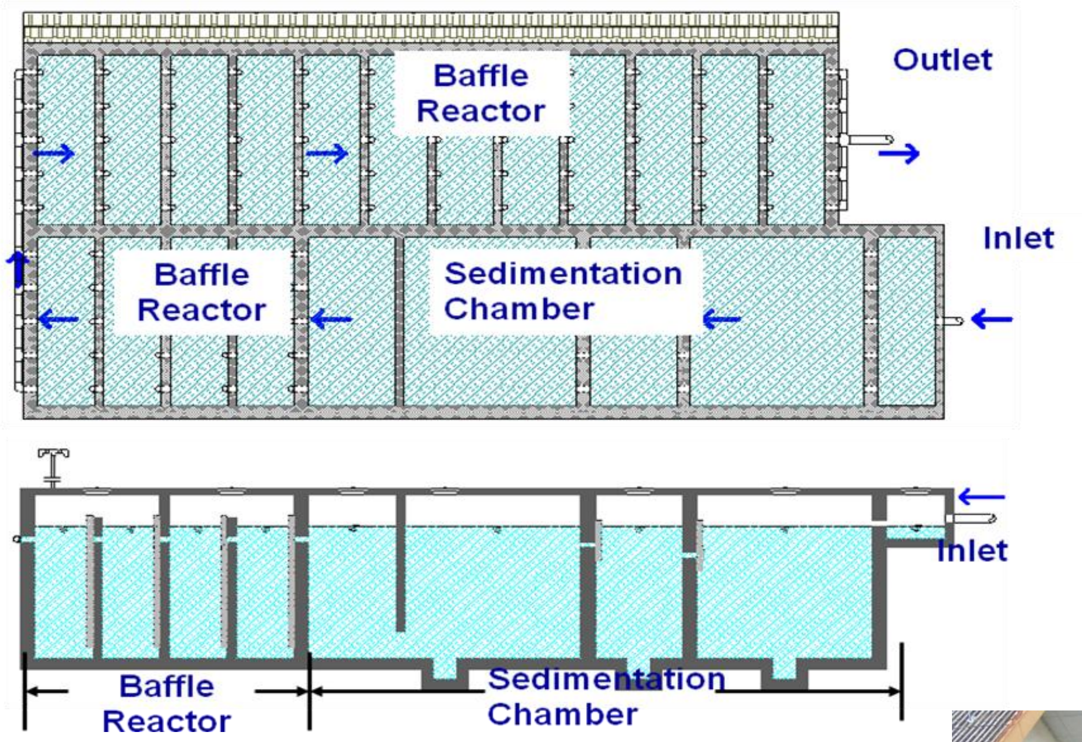
(Adopted from Lina Abu Ghunmi ,2009)

GW recycling and treatment, possible steps and tracks



1. Filtration and Physicochemical process
2. Modified filters : (a) Soil filters and constructed wetland; (b) Biofilters; (c) Chemfilters
3. Biological Treatment : (a) Aerobic attached growth processes; (b) Aerobic suspended growth processes; (c) Anaerobic biological Processes

Anaerob System : Sanimas

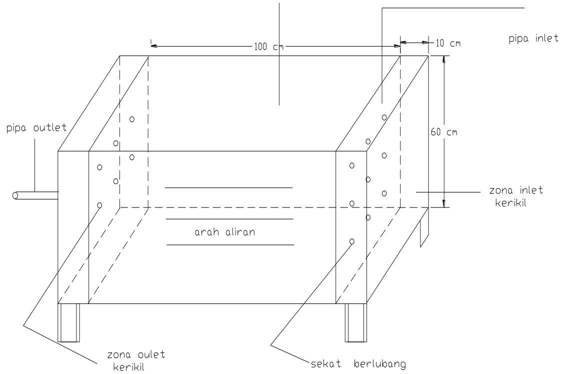


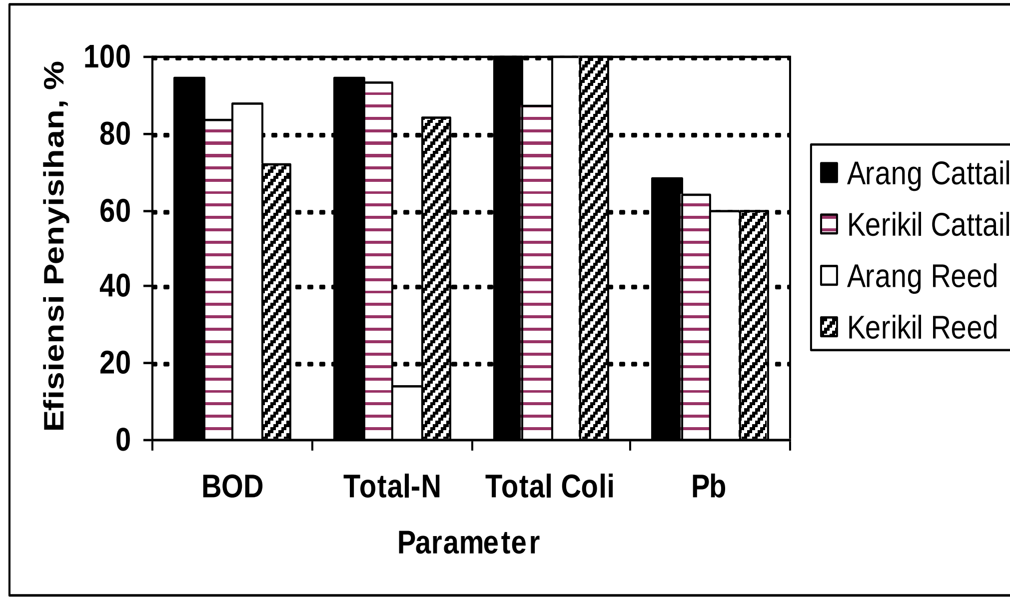
- ABR requires only around 80-150 m2 for around 100 HH (around 400 inhabitans) quite small compared to the constructed wetlands
- the treatment plant were built underground so the upper part can still be used (in some very dense area the ABR built under the small road between houses.

Anaerob System : ABR and AF

- Combination of Anaerobic Baffled Reactor (ABR) and Anaerobic Filter(AF)
- Experiment show ABR-AF Reactor was not suitable for treating GW because the organic loading is not high enough to reach sufficient organic loading rate
- Better result when high concentration of COD and longer detention time
- Presence of filter help COD degradation but not detergen (LAS) degradation

Constructed Wetland : PUSDAKOTA Surabaya



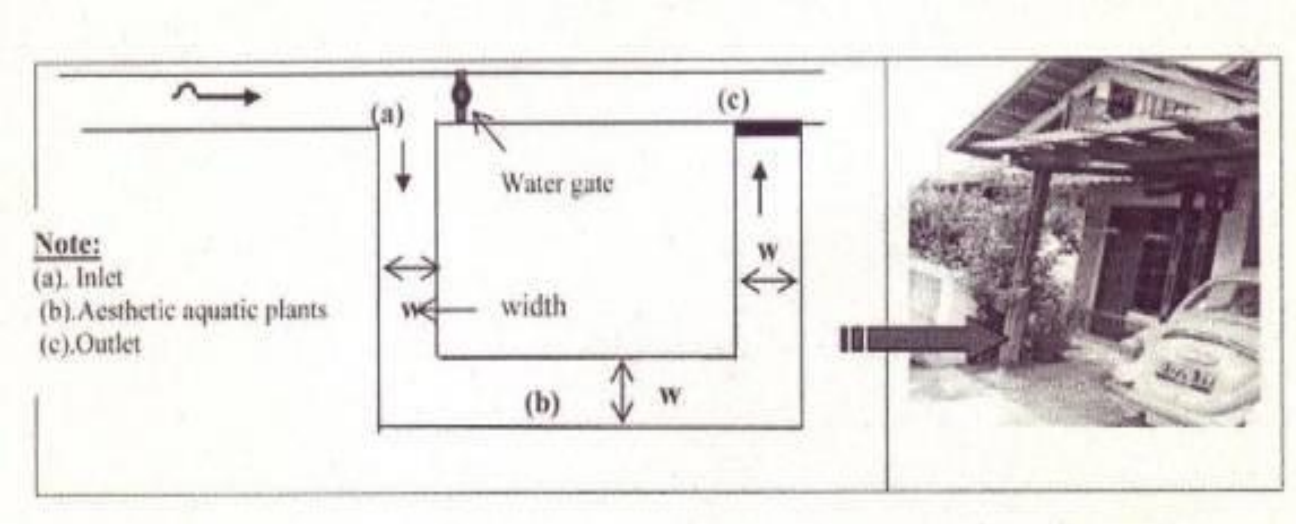


1. Cattail give better performance in reducing the concentration of amonium and phosphate, except COD where reeds give better.

2. Type of media : gravel performed in general better for reduction amonium and phosphate, but charcoal for reduction COD and BOD5.

Constructed Wetland : Ecotech Garden

(Ratna Hidayat, PUSAIR)



-Lower percentage of pollutant removal; need enlarge surface area, difficult in urban house

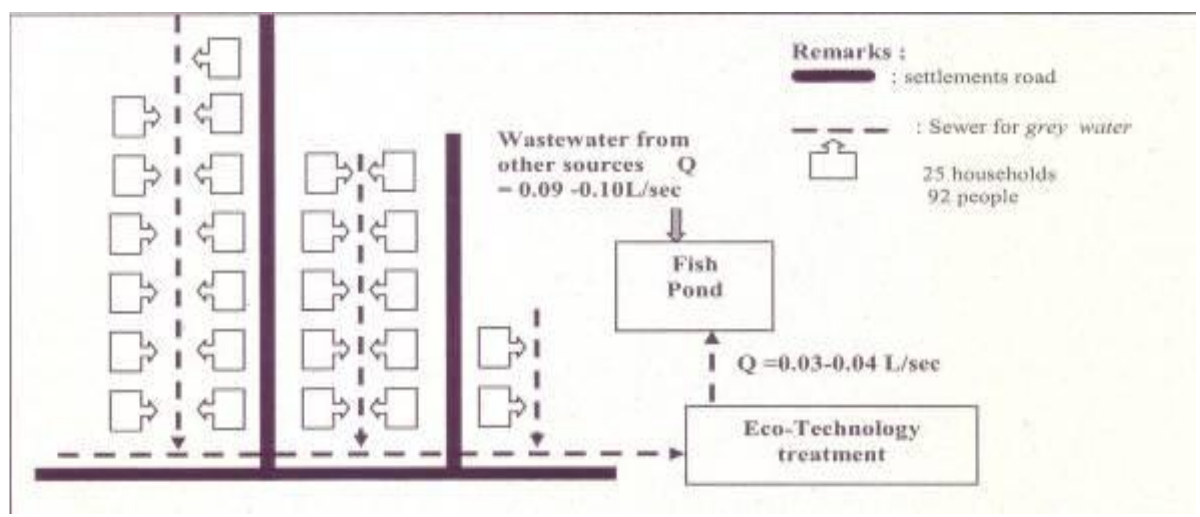
-Advantage : improve garden aesthetic, decresing pollutant concentration of disposal GW to drainage, additional income

-Construction cost : US$ 15/sqm

GW mixed with water from rice irrigation drainage gave lower efficiency.

Detergent reduction reach 87 %, 44% for BOD, 60% for COD and 64 % for TP reduction.

Improve protein consumption and income for the fish pond owner



Constructed Wetland : Wastewater Garden

Source : http://www.seacology.org/news/display.cfm?id=4031

- Popular in Bali for government office, school and hotel
- 1.25 m2-2.5 m2/capita
- Investment cost depend on land availability
- Eficiency of reduction: BOD 80-90%; COD 86-96%; TSS 75-95%; Total N 50-70%; Total P 70-90%; Coliform 99 %

- Submerged Aerobic Biofilter (SAB)
- SAB consist of :
  - aeration system to supply air
  - fixed media for microorganism growth
- Has higher efficiency than activated sludge (low organic loading).Need more Energy compared to anaerobic condition
- Aeration mode affect efficiency of ammonium removal
- Intermittent aeration could reduce the use of energy

Discussion

- Average water consumption is high resulting high quantity of greywater
- Indonesian GW can be categorized as middle and high strength wastewater.

- Constructed Wetlands (CWs) could be good option because Indonesia has rich biodiversity of aquatic plant and microorganisms, many sources of media (charcoal, woodchip, activated carbon), cheaper cost than ABR, O&M easier
- By community in urban area : ABR more likely chosen because need less space than CWs, can be constructed underground, cost competitive, depend on community willingness
- Anaerobic pre treatment of GW is recommended

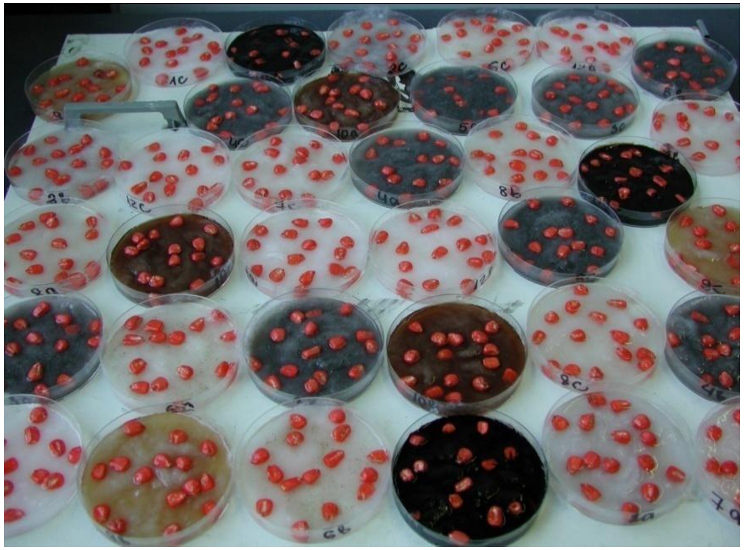
- Existing GW treatment mostly have been done with high initial cost and support from third party. This could be challenge to develop further implementation and replication of low cost greyawter treatment and reuse.

- Pathogens
- Harmful chemicals content
- Contact with human

I. Effect of GW on the Seed Germination

-Treatment : Kontrol (1), TGW(2), Raw GW (3),25% RGW(4), 50% RGW(5), 75% RGW (6)

- 3 replicates
- Dark, 30 C, 7 days
- Germination was scored for the seed which showed koleoptil > 2cm and root length> 5 mm



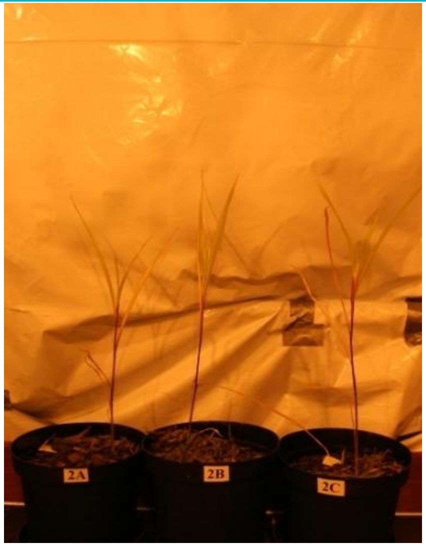
II. Plant experiment with Maize (2)

- Same treatment with Exp.1
- Soil : 100% woodchips
- Fertilizer : NPK : 2 %, 85 %, 13 % (12.964 g/pot)
- Plant analysis : Plant height,Leaf number, Biomasse (wet and dry)

Result Plant Experiment with Maize

Parameter :

1. Plant height
2. Leave number
3. Biomass



Control

Untreated greywater

Treated greywater

With NPK

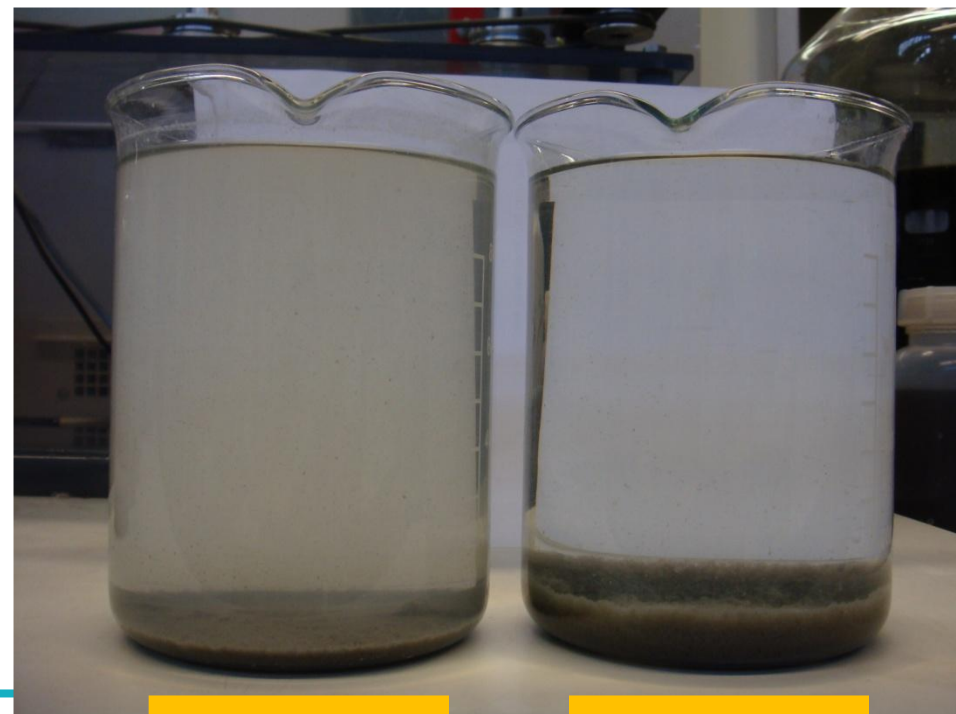
Moringa oleifera

Comparison between coagulants

pH

Initial pH of Raw greywater in average: 7,78
M.Oleifera Powder treated water: pH between 7,6 – 7,72
M.Oleifera Solution treated water: pH between 7,27 – 7,71
Alum Sulfate treated water: pH between 6,72 – 7,6

Sludge Volume



Lab scale experimental results (1)

Average Results

No	Parameter	Unit	Raw Greywater	Treated w/ *M.Oleifera*	Efficiency (%)	Treated w/ *Alum*	Efficiency (%)	Requirment for irrigations
1	**Turbidity**	NTU	480.00	198.00	58.75	130.00	72.92	
2	**TSS**	mg/L	189.00	80.00	57.67	58.00	69.31	-
3	**pH**	-	7.06	7.10		6.80		6-9*
4	**Temperature**	Deg Celcius	20.10	20.10		20.10		-
5	**Conductivity**	mS/cm	1.10	1.12		1.18		<1,3**
6	**SAR**	-	2.86	2.97		2.95		<18**
7	**Zinc**	mg/L	0.80	0.28	65.00	< 0.15	> 81.25	<2**
8	**Total Coliform**	/100 ml	2 x 10^6	10^4		2 x 10^6		< 200
9	**Average Oil & Grease**	g/L	0.65	0.22	65.84	0.30	53.84	
10	**Detergent (MBAS)**	mg/L	12.52	4.36	65.18			-

Irrigation Methods

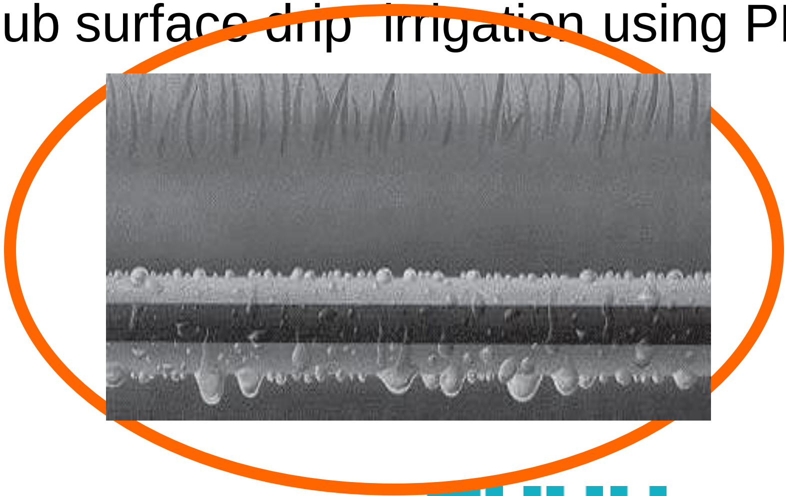
- Furrow irrigation

University of Arizona. Credit: John C. Palumbo

- Sprinkler irrigation

- Drip irrigation

- Sub surface drip irrigation using PP

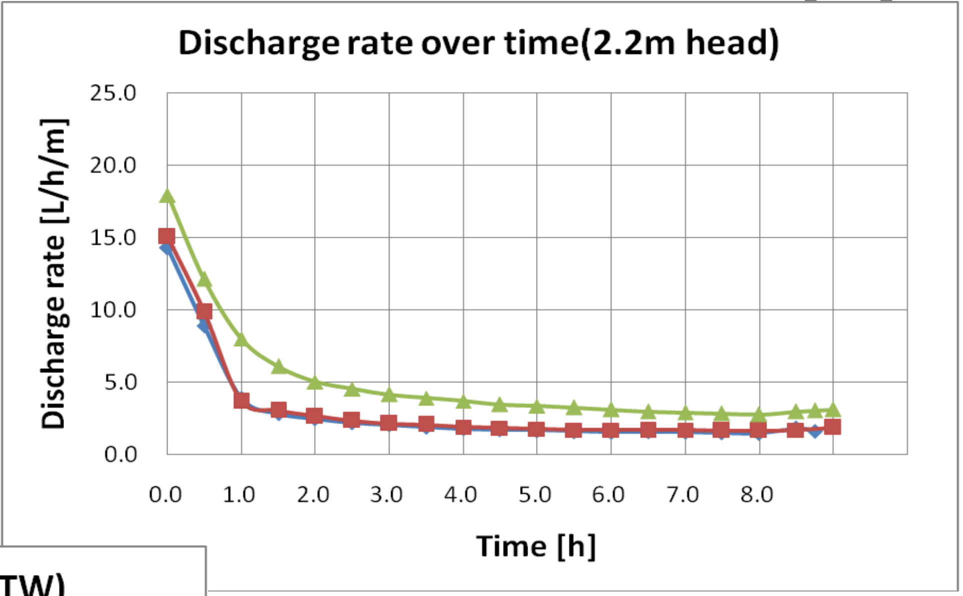


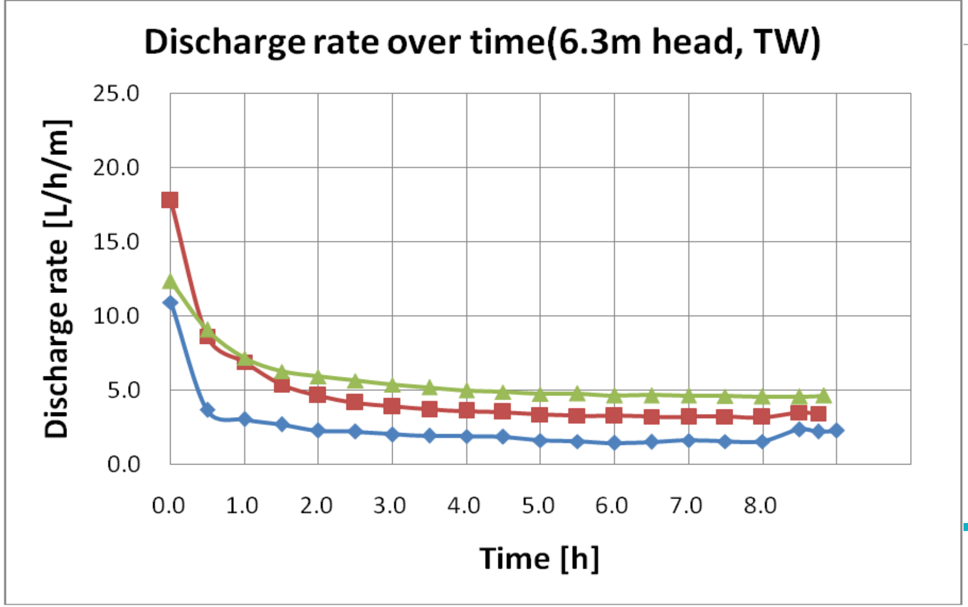
Introduction

Benefits of Subsurface Drip Irrigation using Porous Pipe (PP)

- Suitable for different type of plants
- Save more than 50% water compares to conventional irrigation
- Watering process could be done unattended
- Yield improvement

Porous pipe





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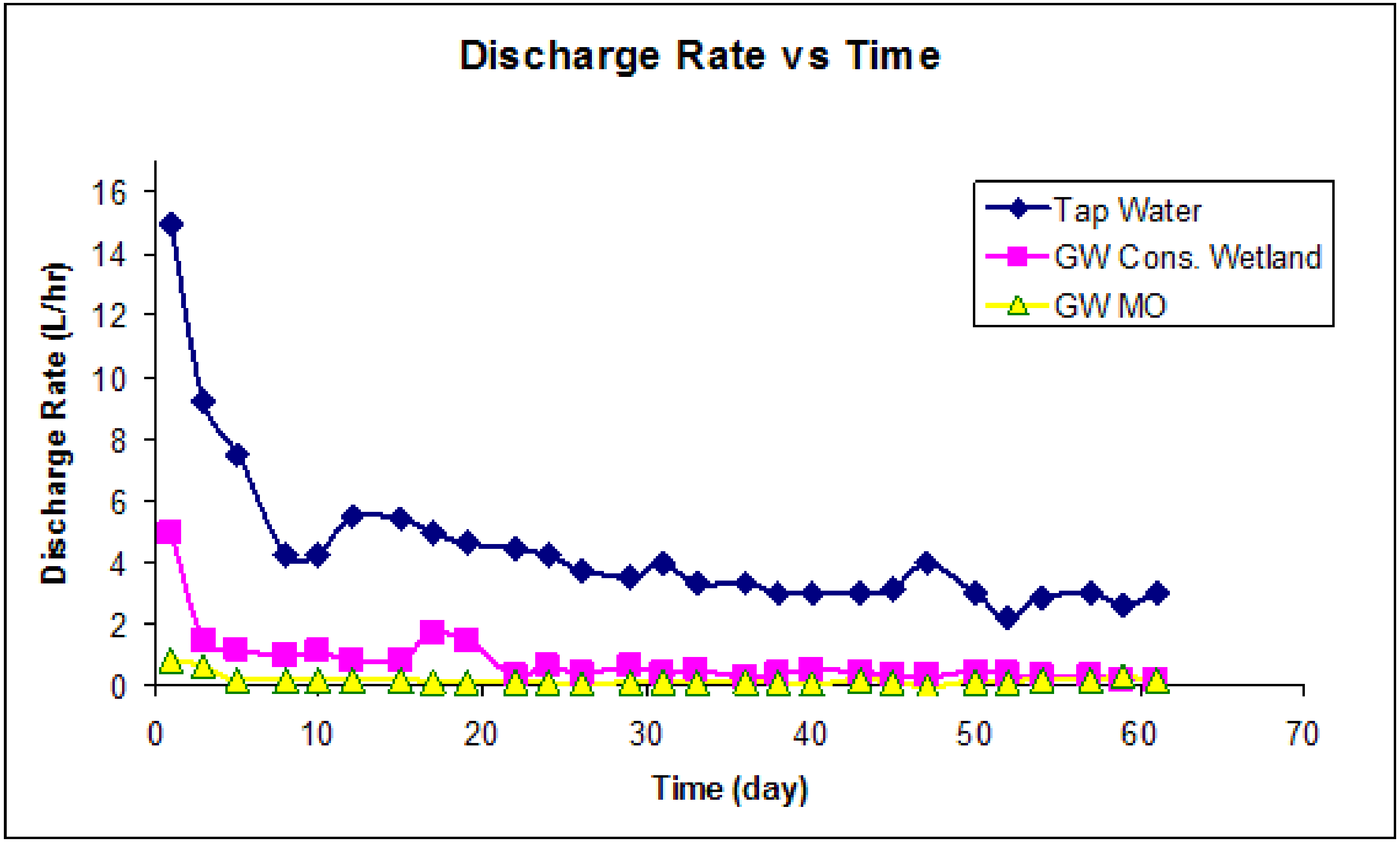
- **Discharge Rate**



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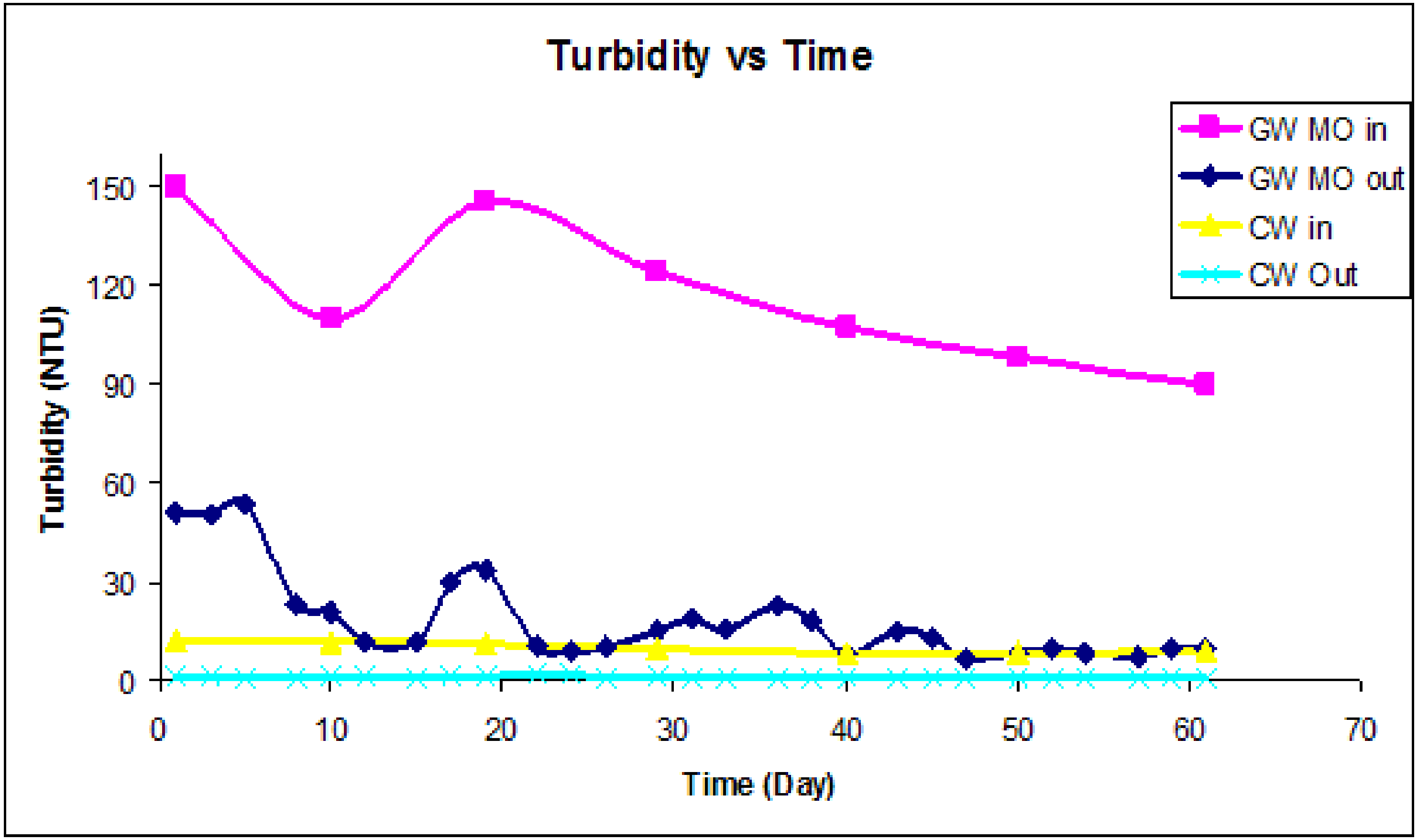
Result and Discussion

- **Turbidity**



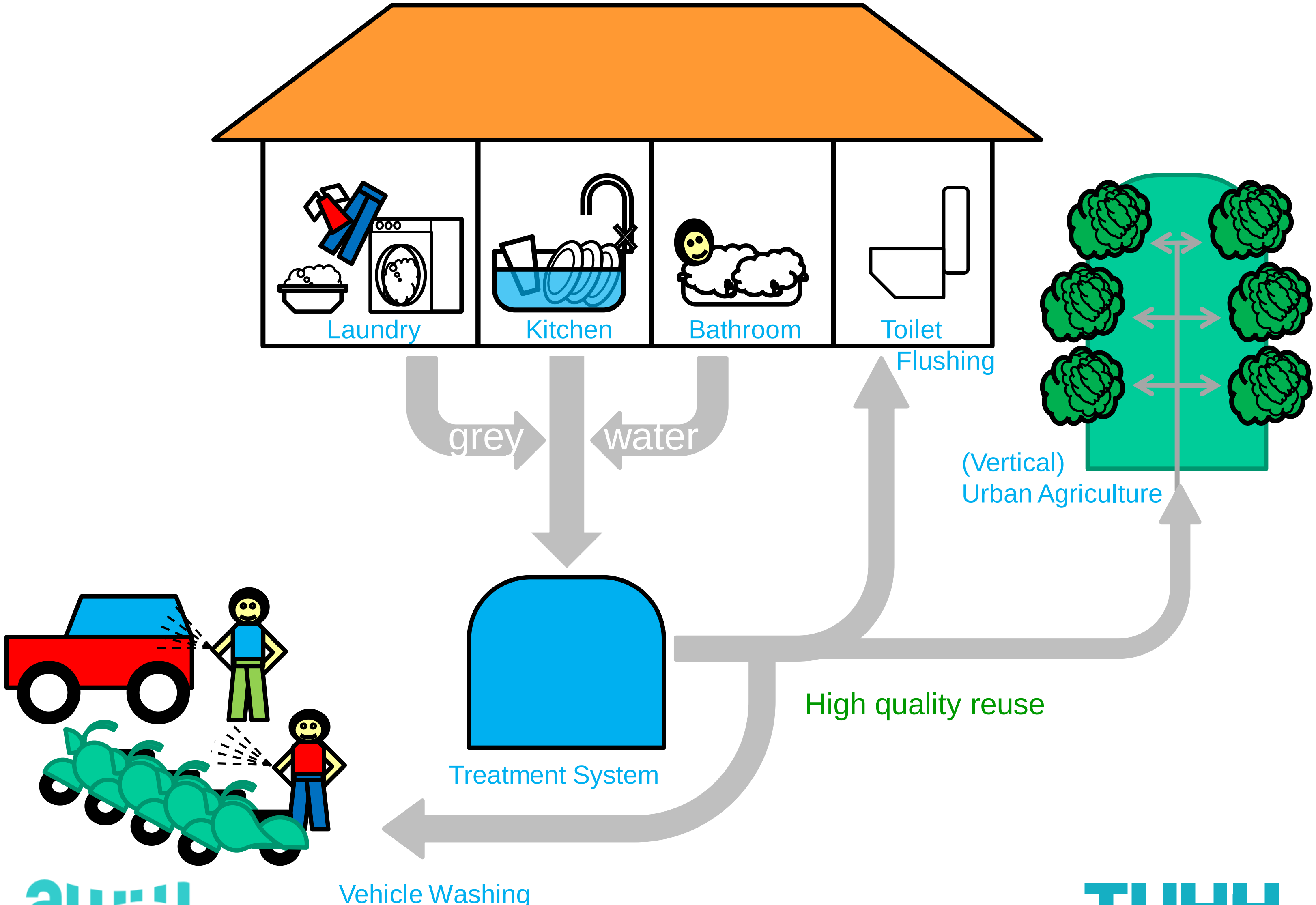
Result and Discussion

- **Coliform bacteria**

Type of Bacteria	Coliforms Bacteria of greywater treated with *MO* (CFU/mL)				
	Day 0 (in)	Day 1st (out)	Day 19th (out)	Day 40th (out)	Day 61st (out)
Total Coliforms	2100	2000	1600	1300	1300
E. coli	40	40	10	0	0

- **Oil and Grease**

Day 0 (in)	Day 1st (out)	Day 15th (out)	Day 30th (out)	Day 47th (out)	Day 61st (out)
170 mg/L	130 mg/L	104 mg/L	64 mg/L	< 2mg/L	< 2 mg/L



Laundry
Kitchen
Bathroom
Toilet
Flushing
grey
water
(Vertical)
Urban Agriculture
Treatment System
High quality reuse
Vehicle Washing

Thank You

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Experiment

a. Material

- Water source (5 liter/day) :
  - Tap Water
  - GW effluent from Constructed Wetland (CW)
  - GW treated with Moringa Oleifera (MO) *seed*

- **Porous Pipe**

Treated Greywater Characteristic

Treated with *MO*

- **pH: 7.10**
- **EC : 1.1 – 1.2 dS/cm**
- **Turbidity: 160 NTU**
- **SAR : 2.97**
- **TOC : 111 mg/L**

(Indiyani, 2011)

Constructed Wetland (CW)

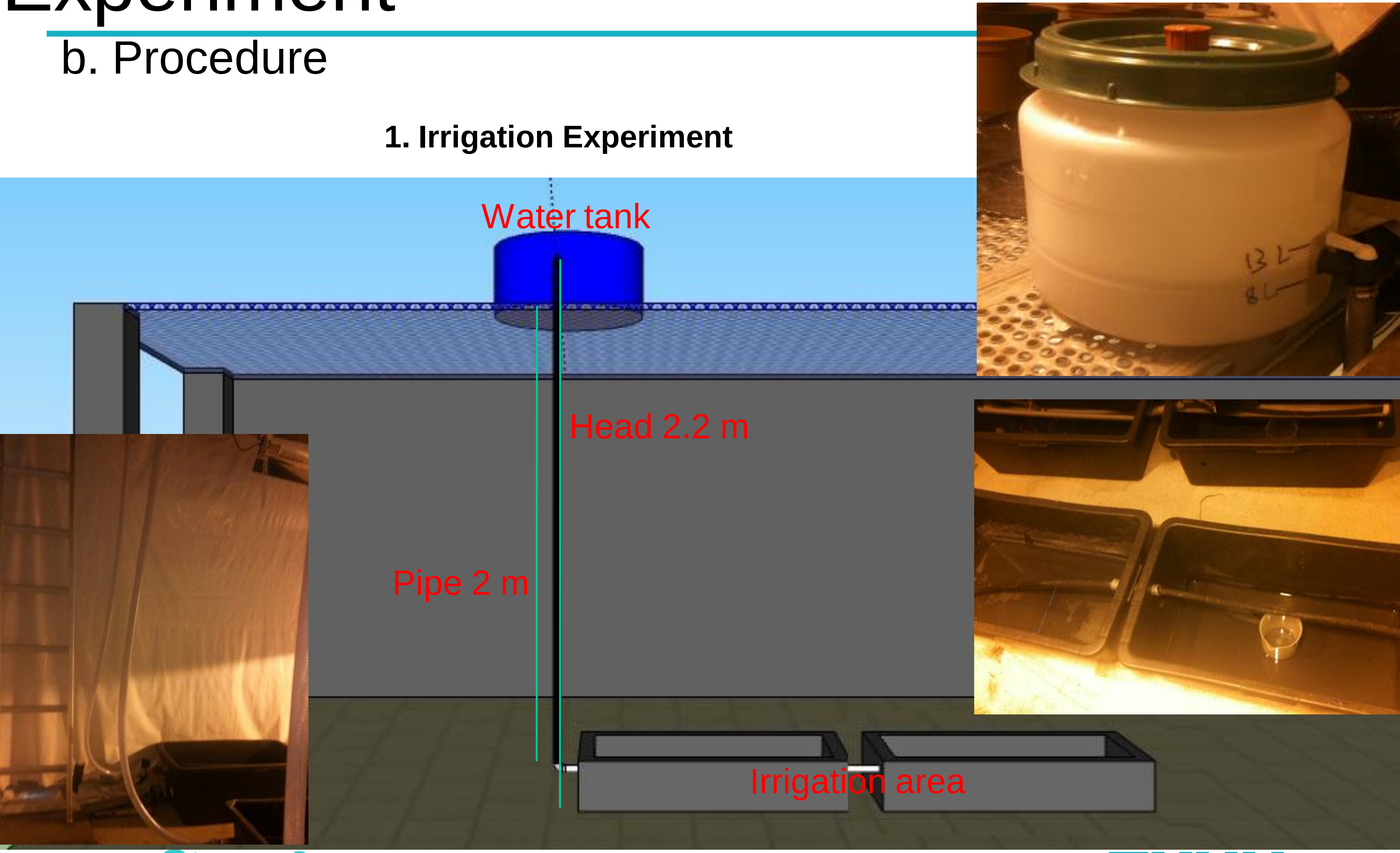
- **pH: 7.89**
- **EC : 1.1 – 1.2 dS/cm**
- **Turbidity: 8 – 12 NTU**
- **SAR : 3.2**
- **TOC : 12.5 mg/L**

(Firdayati, 2009)

Experiment

b. Procedure

1. Irrigation Experiment



- **pH**

  7 – 8.6

- **EC**

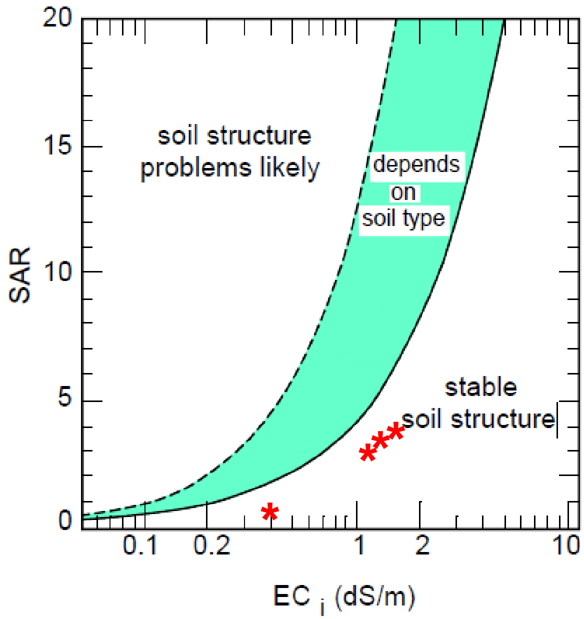
  Tap Water : 0.2 – 0.3 dS/cm

  Treated Greywater : 1 – 1.2 dS/cm

- **SAR**

  Tap Water : 0.4 – 0.55

  CW and *MO : 3.9 – 4.4*



Potential irrigation problem	Units	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity				
Ec_w	dS/m	< 0.7	0.7 - 3.0	> 3.0
or				
TDS	mg/l	< 450	450 - 2000	> 2000
Infiltration				
SAR = 0 - 3 and EC_w		> 0.7	0.7 - 0.2	< 0.2
3 -6		> 1.2	1.2 - 0.3	< 0.3
6-12		> 1.9	1.9 - 0.5	< 0.5
12-20		> 2.9	2.9 - 1.3	< 1.3
20-40		> 5.0	5.0 - 2.9	< 2.9
Specific ion toxicity				
Sodium (Na)				
Surface irrigation	SAR	< 3	3 - 9	> 9
Sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)				
Surface irrigation	me/l	< 4	4 - 10	> 10
Sprinkler irrigation	m^3/l	< 3	> 3	
Boron (B)	mg/l	< 0.7	0.7 - 3.0	> 3.0

GUIDELINES OF WATER QUALITY FOR IRRIGATION (FAO, 1985)

Result and Discussion

- Specific Toxic Ion

Boron

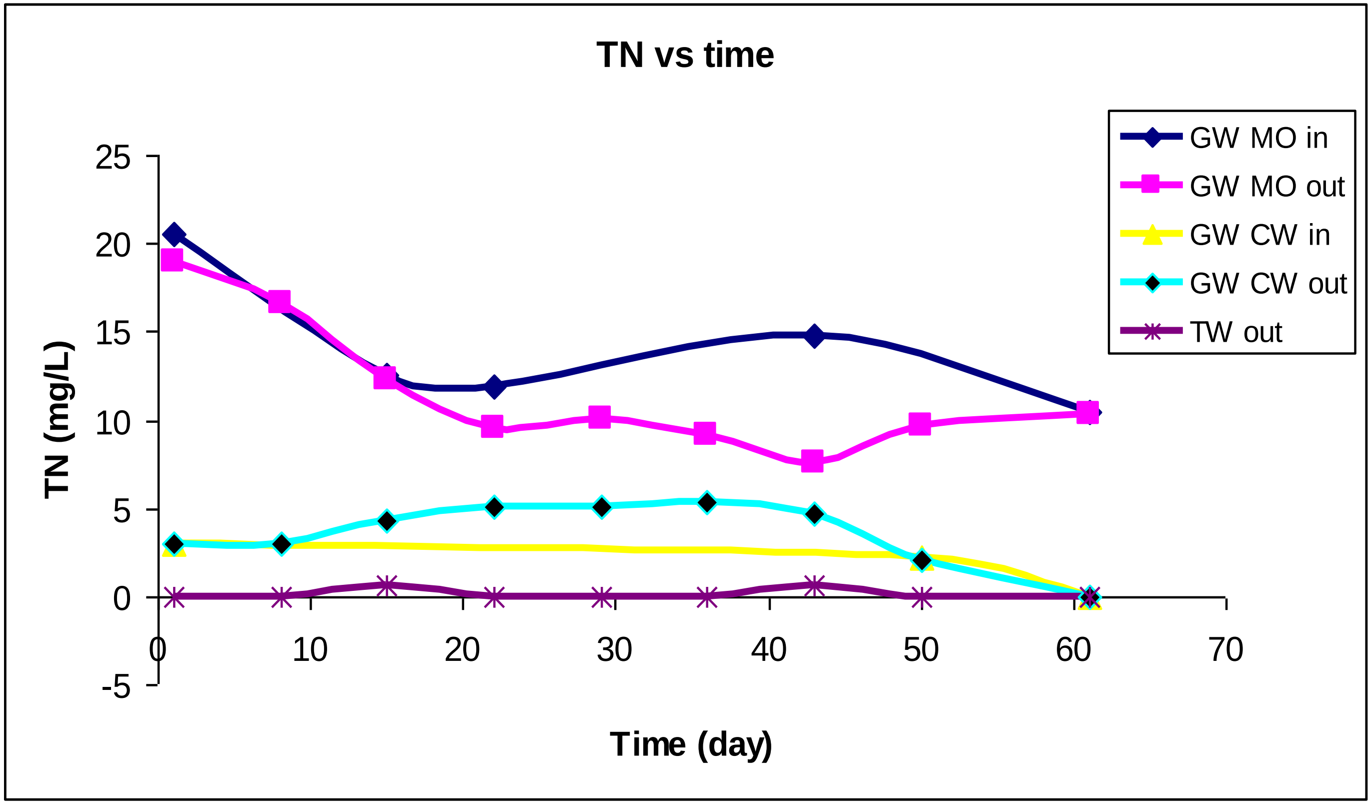
Type of Water	Boron Concentration (mg/L)			
	Day 0 (in)	Day 1st (out)	Day 24th (out)	Day 61st (out)
Tap Water	**<0.001**	**<0.001**	**n.d.**	**n.d.**
GW treated with *MO*	**0.38**	**0.35**	**0.34**	**0.41**
GW treated with CW	**0.37**	**0.43**	**0.42**	**-**

Chloride

Type of Water	Chloride Concentration (mg/L)			
	Day 0 (in)	Day 1st (out)	Day 24th (out)	Day 61st (out)
Tap Water	**10.6**	**11.2**	**n.d.**	**n.d.**
GW treated with *MO*	**91**	**93**	**96**	**97**
GW treated with CW	**93**	**91**	**105**	**88**

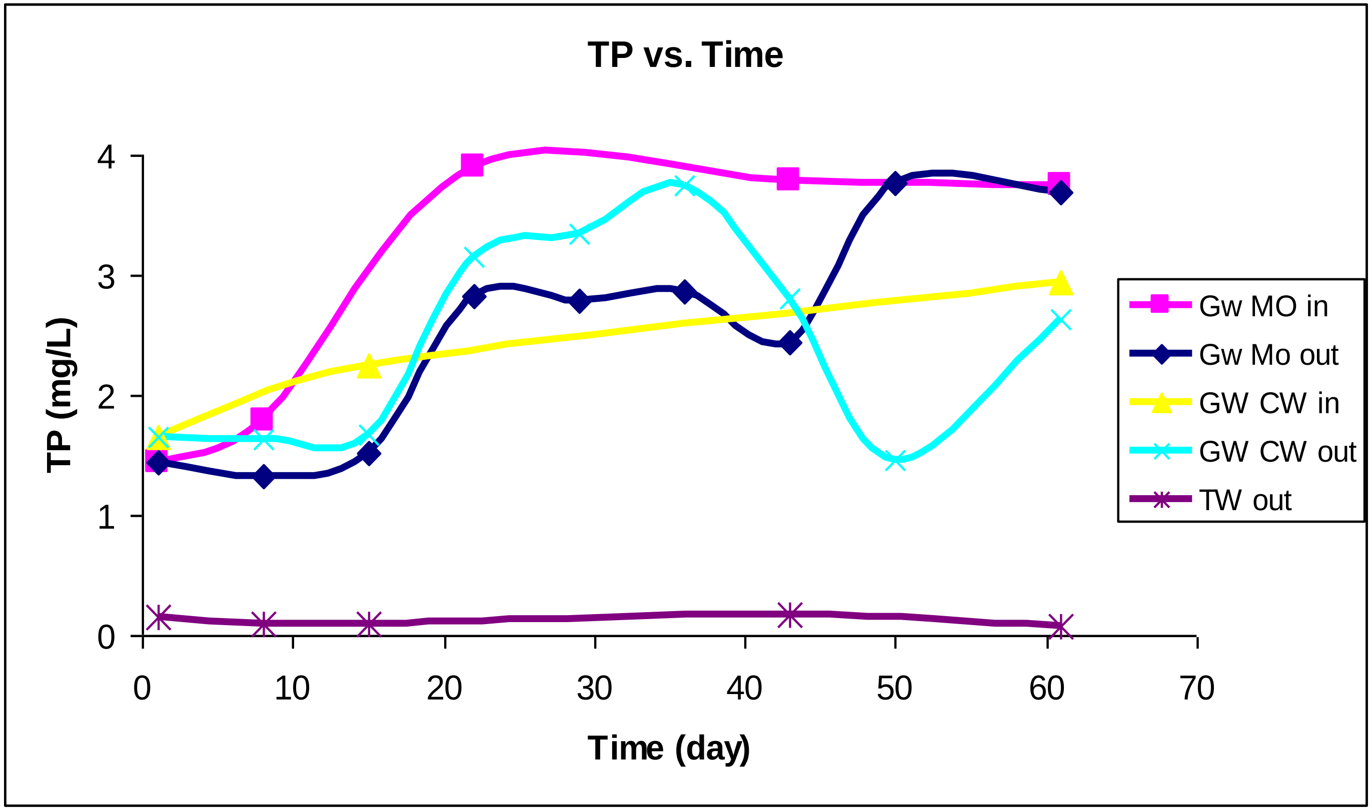
Result and Discussion

• Total Nitrogen



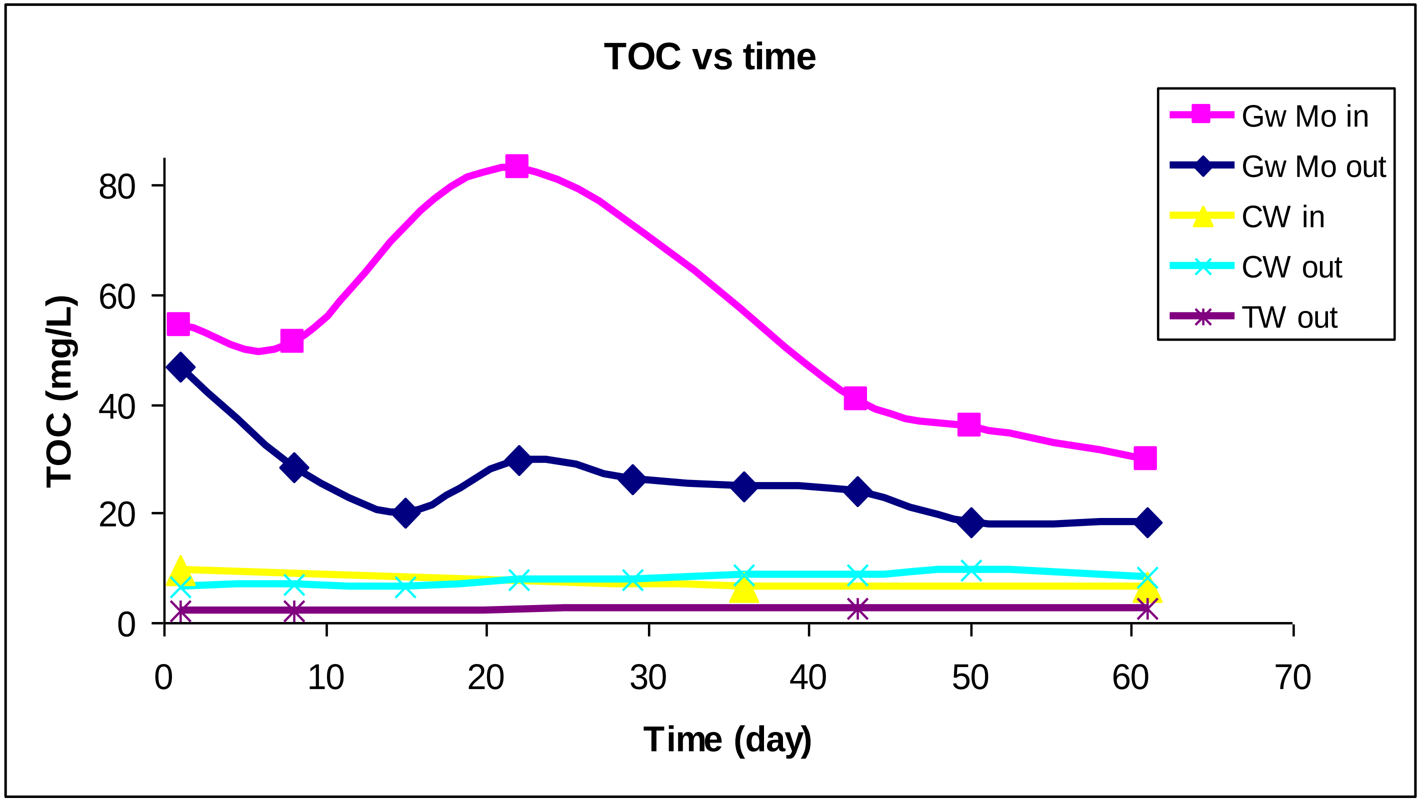
Result and Discussion

- Total Phosphorous

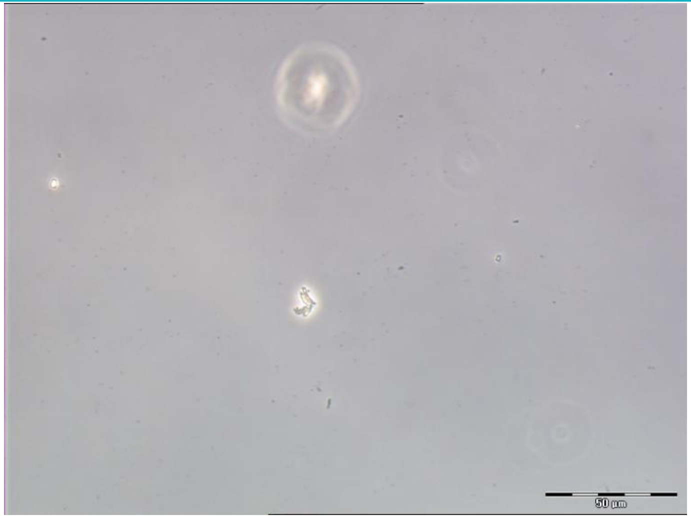


Result and Discussion

- Total Organic Carbon (TOC)

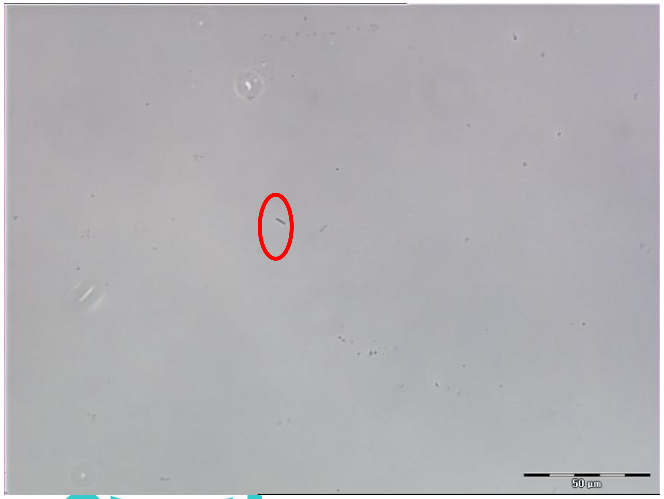


- **Biofilm Formation**
  - Tap Water

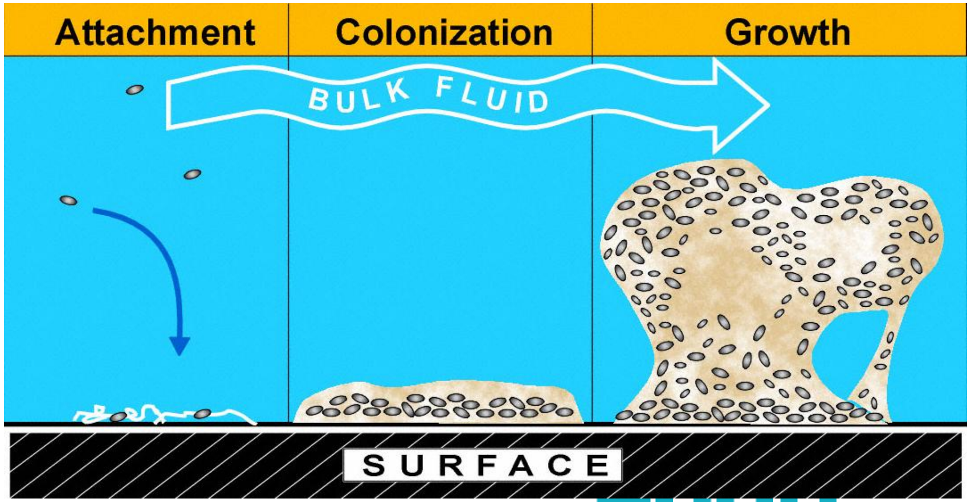


  - GW treated CW

  - GW MO



  - Biofilm formation



(http://www.uweb.engr.washington.edu, 2011)

Result and Discussion

- **Leachate Test**
  - Quantitative Leachate Measurement of Zn

Type of Water	Concentration (µg/L)	Effluent from PP day 61 (µg/L)	Previous Experiment (µg/L)	FAO guidelines (mg/L)
DI PP	659	< 20	434	2 mg/L
CW PP	2.74 mg/L		471	
DI	<10		8	
CW	<10		13	

- Half Quantitative Leachate Measurement

  Si, K, Ca, Zn, Ca, Mg

- Non-target organic trace material

  Benzothiazole, 1H-Isoindole-1,3(2H)-dione (or isomer), 2(3H)-Benzothiazolone, Hydroxydiphenylamine, 1,4-Benzenediamine,

Conclusions

- All water used in this experiment are save for irrigation purpose
- In this experiment, PP reduces some parameters in water such as Oil & grease, Turbidity, TOC and total coliforms; meanwhile conductivity and ions are not decrease
- Except of Zn leak, there is no other high concentration contents appears