Small Scale Sewage Treatment and Wastewater Reuse System for Pakistan

Principal Investigators

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Introduction

- Water scarcity is a major problem in the world
  - 60% of world population will experience it by 2025.
  - The situation is much worse in developing countries.

    (Causes 80-90% of all diseases and 30% of all deaths)

- Millions of people, especially those living in poorly developed countries have little access to proper sewage disposal.

- The presence of different contaminants in untreated sewage is a major source of contamination of freshwater resources.

- Proper treatment of sewage, and reclamation and reuse of wastewater is becoming a sustainable solution for clean water.

Objectives

- The objective of this research was to develop an efficient method for treatment of sewage, and reuse of the wastewater and biosolids, which will improve public health and sanitation, as well as reduce water shortage.

- Four treatment systems were proposed for investigation in this study. They were:

  (i) Dual Digestion.

  (ii) Trickling Filter System.

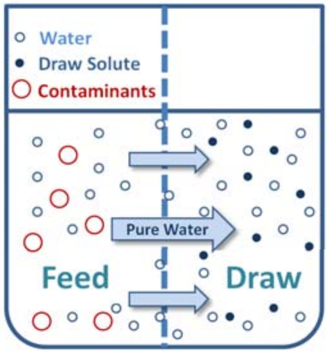
  (iii) Constructed Wetland System.

  (iv) Membrane Bioreactor System.

Membrane Reactor System

Forward Osmosis

- An osmotic process that uses semi-permeable membrane for separation of water and solute.
- Concentrated draw solution generates high osmotic pressure that pulls clean water from wastewater.



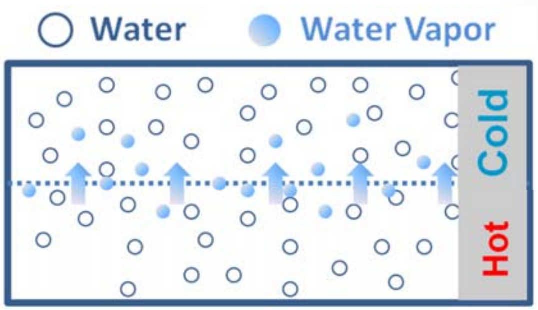
Advantages

- Driven by natural osmotic pressure, thus eliminating need of high hydraulic pressure.
- Consumes 20-30% less energy than other desalination processes.
- Low-fouling potential and high physical cleaning efficiency.
- High rejection of ions.

Membrane Reactor System

Membrane Distillation

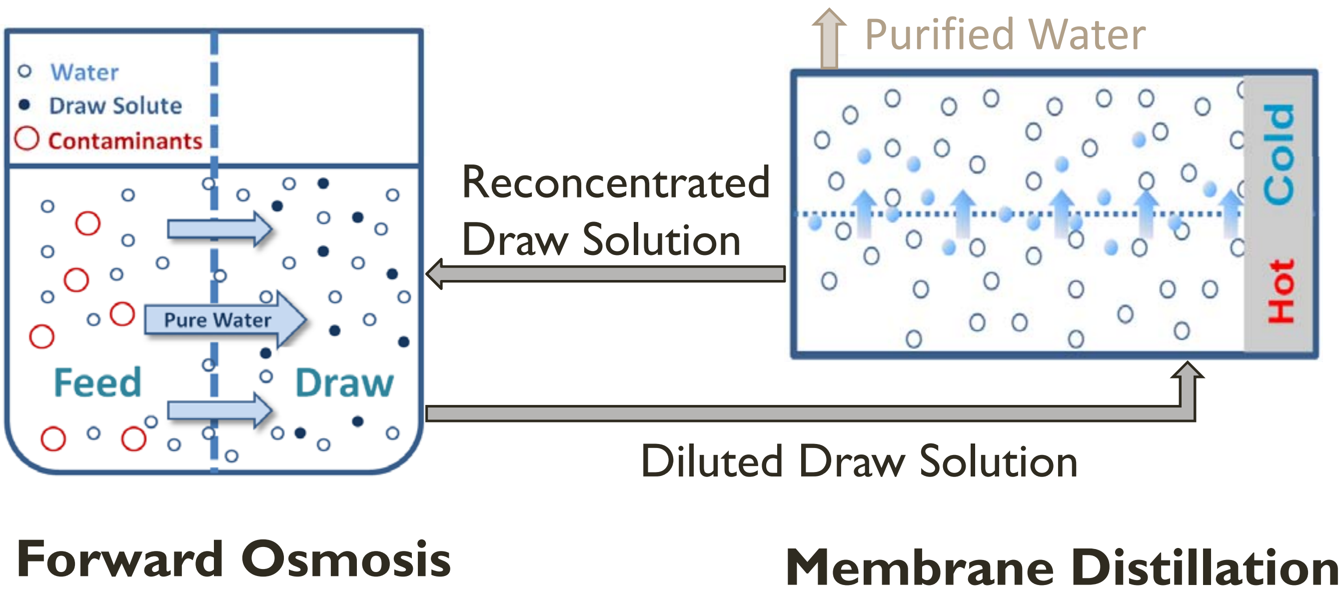
- A thermally driven separation process that use hydrophobic, micro-porous membrane
- water evaporates through the membrane and condenses on the other side of the membrane.



<u>Advantages</u>

- Driven by low-degree temperature gradient (20-30 ^{o}C).
- Low-grade heat (e.g., waste heat, geothermal heat, and solar heat) as energy input.
- Very high rejection of non-volatile water contaminants.

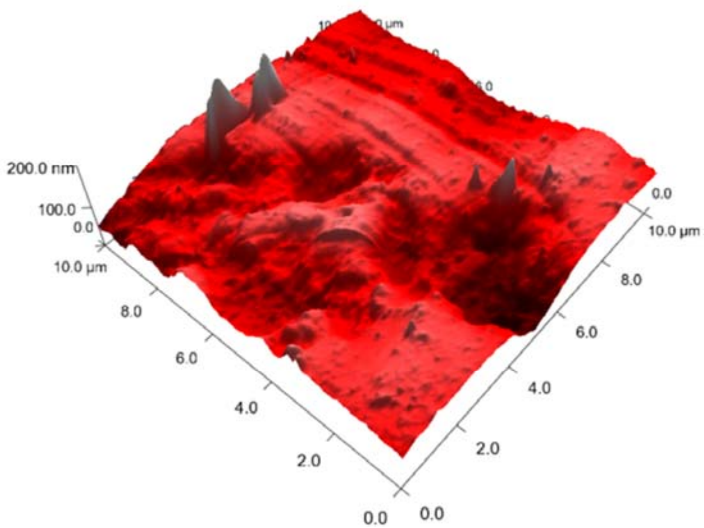
Membrane Reactor System

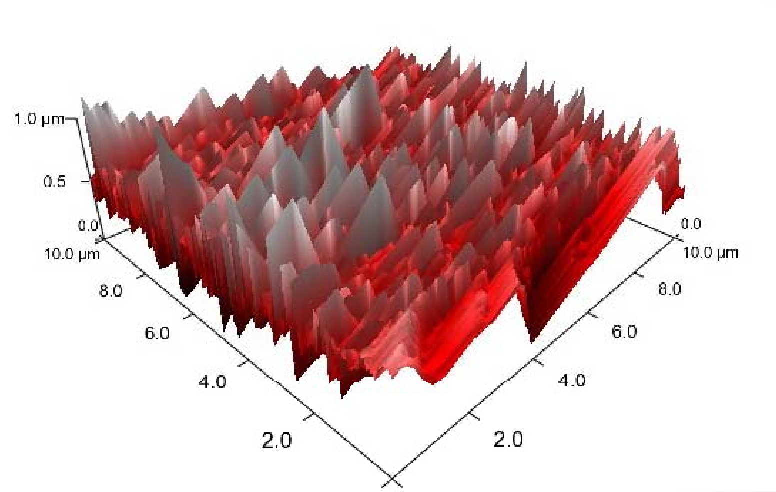


Membrane Characteristics

FO Membrane
- Cellulose acetate membrane
- Asymmetric structure

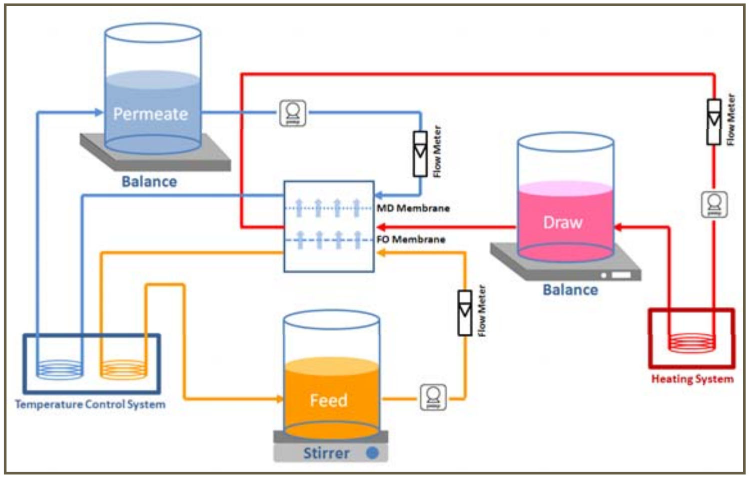
MD Membrane
- Polypropylene (PP) membrane
- Porosity: 0.2 µm
- Asymmetric structure

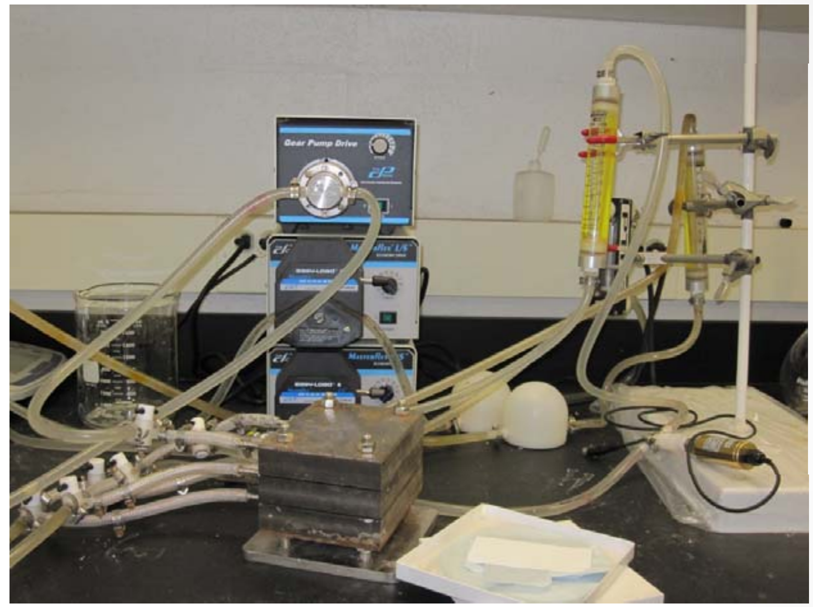


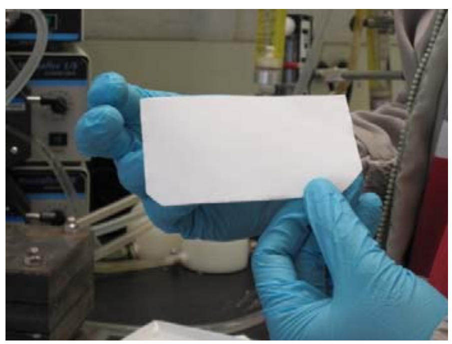


AFM Images of FO and MD membranes

Membrane Reactor System







Laboratory setup

Membrane Reactor System - Results

- Rejection of NH_4^+ and COD

	NH_4^+ Conc. (ppm)		COD (mg/L)
Initial (Feed)	300	495	1800
Final (Permeate)	0	0.178	0
Rejection	100%	> 99.9%	~ 100%

* COD was added to the feed solution using non-fat dry milk

- Rejection of Arsenic

	As (mg/L)		
	Feed	Draw	Permeate
Initial	187.5	0	0
Final (As III)	202.3	19.6	0
Final (As V)	39.4	0.3	0

* Source of Arsenic in Feed: Sodium Arsenite (NaAsO2)

Membrane Reactor System - Results

- Synthetic Wastewater Feed

	Low Strength		High Strength	
	Initial	**Final**	**Initial**	**Final**
Feed	699.98	3895	1295	5130
Draw	47130	42590	47130	50190
Permeate	< 10	< 10	< 10	< 10
Rejection	> 99.9%		> 99.99%	

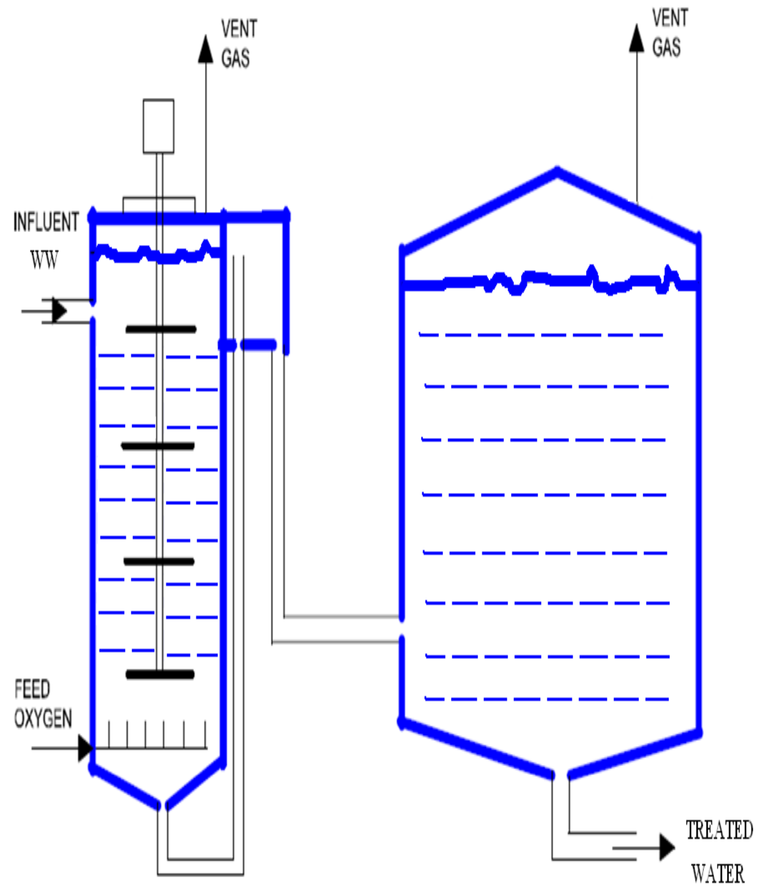
* Total Conductivity Measurements in uS/cm

Observations:

- More than 99.9% removal of all tested contaminants
- Some contaminants (i.e. arsenic) that pass the FO system are rejected by the MD system, thus make this dual layer filtration very effective.

Dual Digestion

- Biological treatment process
- Combination of aerobic and anaerobic digestion processes
- Aerobic digestion
  - *Aeration (air or pure oxygen)*
  - *Consumption of organic components by microbes as their food & energy source*
  - *Partial degradation through fermentative metabolism*
- Anaerobic digestion
  - *Oxygen free environment*
  - *Full stabilization of organic waste*



Schematic Diagram of Dual Digestion System

Single-stage lab-scale anaerobic digester

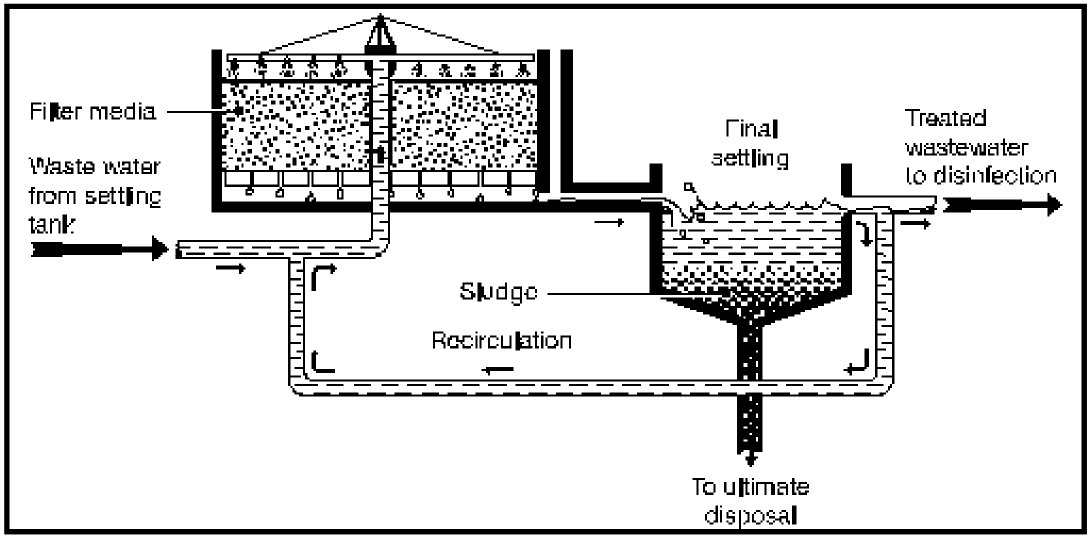
Lab-scale temperature phased anaerobic digestion

Lab-scale Dual Digestion System - Results

- Treatment of wastewater at 25 and 45^{o}c
  - Significant decrease in the BOD (95%), COD (90 – 95%), TKN (99%), turbidity (100%), color (100%), pathogen count, and other contaminants.
- Thermophilic anaerobic digestion at 55^{o}C
  - The quality of sludge improved significantly in term of reduction in COD (81%) and BOD_5 (82%), TSS (81%), TS (75%), higher biogas production and efficient reduction of pathogen after 8 days treatment.

Trickling Filter

- The trickling filter or biofilter consists of a bed of inert medium of either rock or plastic.
- Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Periodically, portions of the film slough off the media.



Polystyrene media

Rubber media

Lab-scale Trickling Filter

PVC pipe

Side view of TF

Water Pump

Plastic container

Steel cage with hooks

Stone media

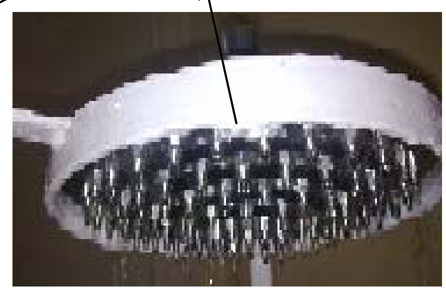
Plastic media

Polystyrene media

Tire derived rubber media

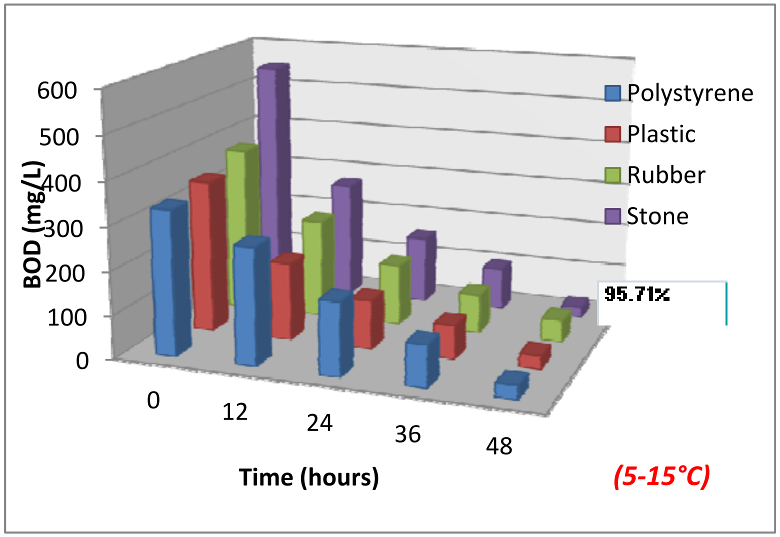
Top view of TF

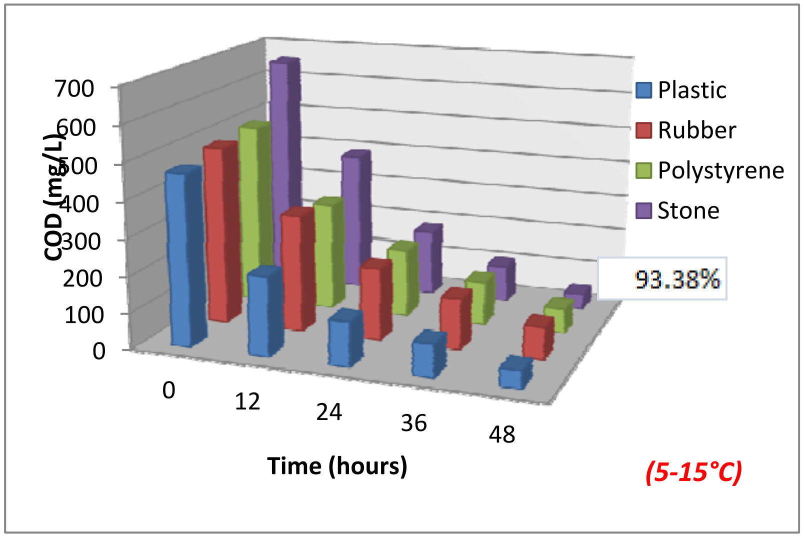
Shower

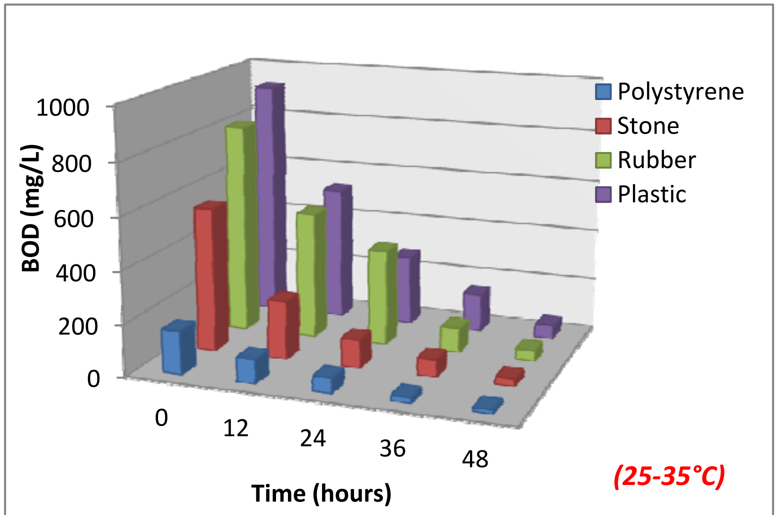


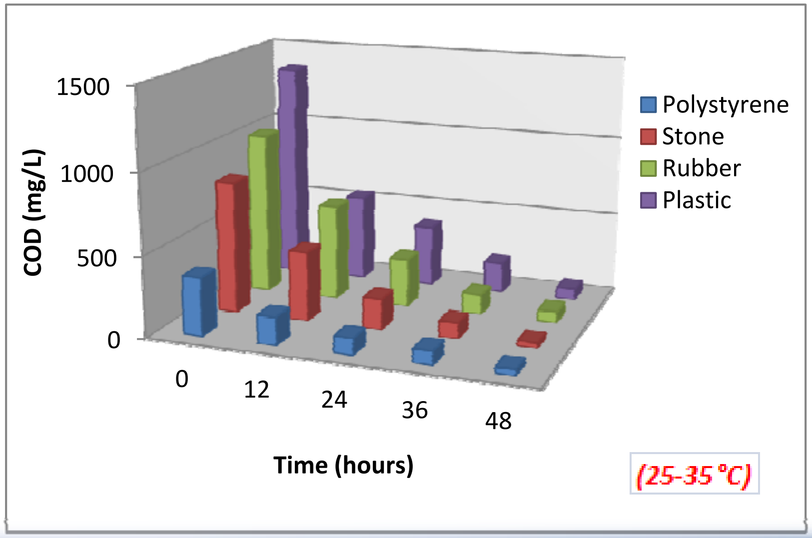
Lower view of Shower

Trickling Filter System - Results









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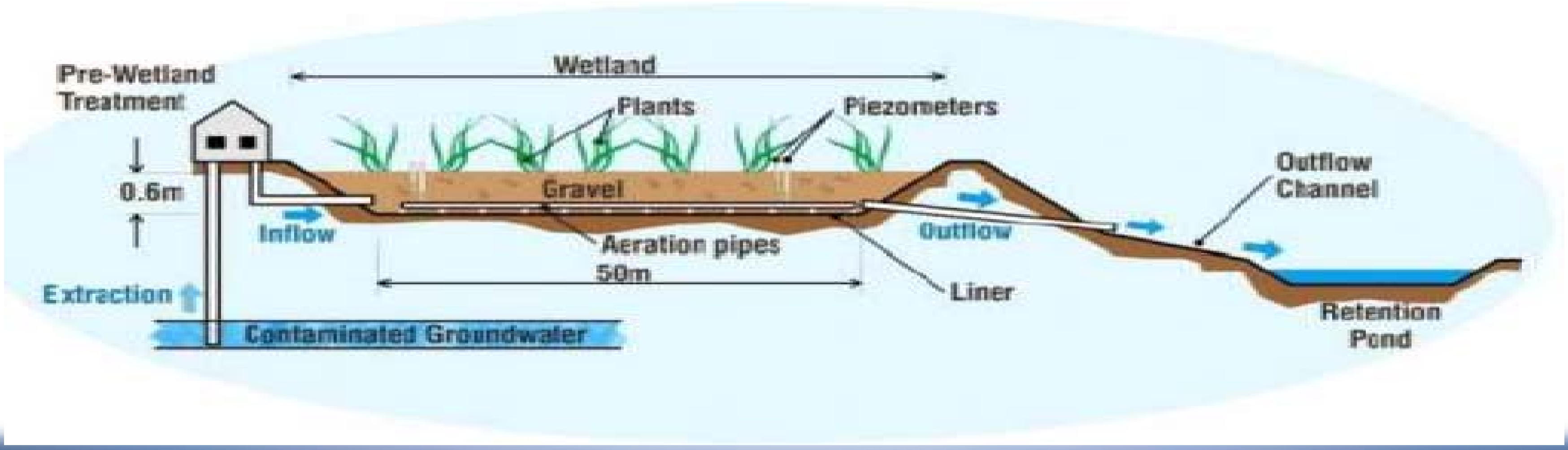
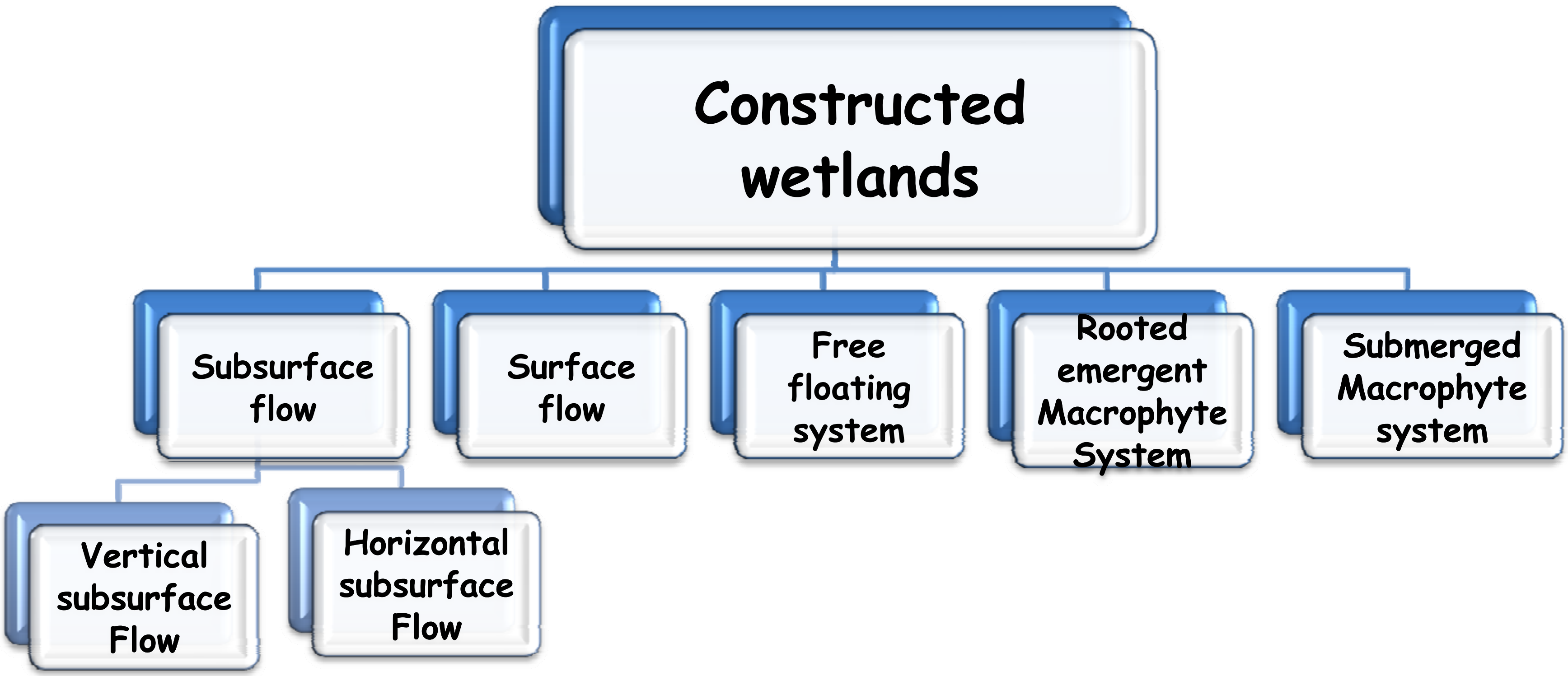
Constructed Wetland

- These are artificially engineered systems,
  - Imitate natural systems
  - Use a combination of soil, microbes and plants
  - Treatment under more controlled conditions.



Types



Hybrid CW

Advantages/Disadvantages of Constructed Wetlands

Advantages

- Low energy
- Easy to operate
- Environmental friendly
- Cost effective
- Simple maintenance
- High Efficiency
- Effluent can be reused
- Aesthetically appealing

Disadvantages

- Large area required
- Easily affected by seasonal variations

Lab Scale Hybrid Constructed Wetland

Sequentially Arranged Units of Hybrid Constructed Wetland

Wastewater Composition: Determinants

- **Organic pollution**
  - BOD
  - COD
  - TOC
  - SS, TSS, Settleables
- **Nitrogen Pollution**
  - NH_4-N, NO_3-N, NO2-N
- **Phosphorous Pollution**
  - Ortho-phosphates
  - Total phosphates
- **Heavy metals**
  - Hg, Ag
  - Cd, Zn
  - Cu, Ni
  - Pb, As
  - Cr,
- **Pathogenic Microorganisms**
  - Coliform bacteria

Constructed Wetland - Results

- Free water surface CW
  - a significant reduction was observed in parameters, e.g. BOD_5 (97.69%), COD (97.69%),), turbidity (100%), odour (100%), and pathogens (100%).
- Hybrid CW
  - More than 95% improvement in BOD_5, COD, turbidity, odour and pathogen.
  - The bacterial population was most abundant and diverse in the rhizosphere .

1st Year

- Design and construction of efficient plastic media Trickling Filter (TF) for treatment of domestic and chemically contaminated water

- Design and construction of lab-scale Constructed Wetland (CW) for treatment of domestic sewage

- Evaluate the efficiency of sequential aerobic-anaerobic Dual Digestion (DD).

2nd Year

- Two types of filter media - polystyrene and rubber cubes, were used in the attached growth (TF) bioreactors.

- A laboratory-scale hybrid CW with vertical and horizontal flow, was used for treating domestic wastewater.

- Sequential aerobic-anaerobic treatment (DD) was assessed for domestic wastewater.

3rd Year

- Continue lab-scale studies for the treatment processes developed.
- Construction of Wetlands and Tricking filters at pilot-scale at QAU for treatment of wastewater.
- Visit of researcher from QAU to GWU for training and research on membrane bioreactors.
- Full scale Hybrid wetland construction in collaboration with NBS (Nano Bio-solutions) at QAU.

Workshops and Seminars Conducted

- ”Evaluation Of Various Wastewater Treatment Processes For Municipal Wastewater And Sludge,” Environmental Engineering Workshop, Civil & Environmental Engineering Department, George Washington University, August 10, 2011.

- One Day International Seminar on “Wastewater treatment and its Reuse,” Quaid-i-Azam University, Islamabad, May 17, 2012.

International Publications

- Abdul Rehman, Iffat Naz, Zia Ullah Khan , Muhammad Rafiq, Naeem Ali, and Safia Ahmed (2012). Sequential Application of Plastic Media Trickling Filter and sand Filter for Domestic Waste Water Treatment at low temperature Conditions. British Biotechnology Journal, 2(4):179-191.
- Rabia Aamir, Shama Sehar, Naeem Ali, Abdul Hameed, Safia Ahmed (2012), Effect of Hydraulic Retention Time on Wastewater Treatment Efficiency of a Laboratory Scale Hybrid Constructed Wetland. Environmental Monitoring and Assessment (under review)'
- Ziaullah Khan, Iffat Naz, Shama Sehar, Abdul Rehman, Naeem Ali, Abdul Hameed and Safia Ahmed. Removal of pollution indicators from sewage by fixed film bioreactor and sand filter at low temperature. Submitted for publication in "Water and Environment".
- Sadaf Shabbir, Naeem Ali, M. Ishtiaq, Safia Ahmed and Abdul Hameed. Effect of hydraulic loading rate on treatment efficiency of a small-scale constructed wetland. Submitted for publication in Canadian Journal of Microbiology.

Future Collaborations

- Capital Development Authority, Islamabad
- Nano Bio Solutions Pvt., Islamabad
- Environmental Protection Agency, Islamabad

Acknowledgements

- USAID – Pakistan-US Science and Technology Cooperation Program.
- Higher Education Commission, Pakistan.
- All the students and faculty involved in this research at QAU and GWU.


THANKS