Environmental Bioengineering

Prof. (Adj) Anthony Wong Kim Hooi

Group Managing Director
• Frangipani Hotels & Resorts Sdn Bhd: The Frangipani Langkawi Resort & Spa
  www.frangipanilangkawi.com
Water runoff from the road enters the pathway design for conventional, natural and zero-energy consumption filtering system.
Water footprint

Blue and Grey water footprint for the Industry sector in selected Asian countries

Million of cubic metres per year

82,000

33,000

7,000

The Blue Water Footprint refers to consumption of blue water resources (surface and groundwater) along the supply chain of a product.

The Grey Water Footprint refers to pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards.

More than 2.8 billion people are projected to face water stress or water scarcity by 2025, with annual water supply of less than 1700 m³ per person. The reasons are many and include population growth, global warming, eutrophication and agriculture. Are we heading for a freshwater crisis, and what can be done to prevent it?

Efficient water management in the Frangipani Langkawi resort and spa
Treating Polluted Waste Water To Grade A Using Plants.
Wetlands cycle both sediments and nutrients balancing terrestrial and aquatic ecosystems.

Wetland systems possess bio-filters, hydrophytes and organisms that in addition to nutrients up-take abilities have the capacity to remove toxic substances that come from pesticides, industrial discharges and mining activities.

For example, floating plants [such as *Eichhornia crassipes* (*Water Hyacinth*) and *Lemna* (*Duckweed*)] can absorb and filter heavy metals as well as store iron and copper commonly found in waste water.
Why build a Constructed Wetland?

**Domestic situation**
- If with a single septic tank, the soil percolation may be too high or too low, or other site conditions may be unfavorable for a percolation area alone.
- If soil percolation is too low then the septic tank effluent will not flow down through the percolation area but may instead pond on the surface of the lawn. If percolation is too high then the effluent will travel rapidly through the sandy or gravelly soil and pollute the groundwater. This is particularly undesirable if you or your neighbors have a well supplying their drinking water.

**Industrial situations**
- may find constructed wetlands suitable for dealing with effluents with high volume and relatively low toxicity or nutrient status. Wetlands have been used for the mining industry, food industry sector, metals industries for reclaiming metals and a variety of other wastes.
Wetlands for wastewater treatment are considerably less costly than mechanical treatment systems and have lower running costs.

They can be used for a wide variety of applications, including:

- Domestic sewage treatment
- Agricultural washings, wastewaters and field runoff buffers
- Industrial effluents and yard runoff filtration
- Group housing and municipal sewage schemes and sludge disposal
- Landfill runoff and other long-term low maintenance situations
- Urban and road storm-water runoff, for both flow buffering and water filtration
- Mine tailings and metal reclamation
- Stream, river and lake restoration
- Recreational and amenity applications
- Flood control and habitat enhancement
• Designed for the treatment of wastewater.
• Carefully chosen selection of plants and a specially designed substrate provide the right biological environment for cleansing and re-oxygenating the water.
• Designed to achieve optimum treatment efficiencies.
• Natural wetlands and their plant communities have evolved to thrive on nutrient rich, silted waters.
• Inadvertently, this sewage treatment has been used since the first towns and villages channelled their waste into them.
Advantages of Constructed Wetlands for Wastewater Treatment

- Relatively inexpensive to install and can have low to zero running costs and electricity requirements, as long as pumps are not needed.
- Ideally gravity should bring the effluent down to a constructed wetland and then on to the groundwater or stream.
- Primary advantages
  - They are very adaptable
  - Can function effectively with a variable waste load (e.g. schools or caravan sites where the usage is seasonal)
  - Can also fit in around existing or overloaded systems. This means that it is now possible for small towns and villages to treat their wastewater discharges adequately where only a large septic tank may have existed before.
Importantly, no chemicals to operate, thus keeping maintenance costs and inputs to a minimum.

However, for situations where low phosphate discharges are required, wetland are excellent at capturing the ferric and alum sludge residues from effluent coming from conventional dosing and settling systems.

They are attractive to look at and can attract a host of birds, dragon-flies and other fauna throughout the year.
Reuse Possibilities

- Irrigation of crops
- Watering of garden / golf courses
- Cleaning purposes
- Supply for nature reserve areas
- Habitat for fish and wildlife
- Recreation
- Education
Introduction of Wetland

- A wetland is an area whose soil is saturated with water either permanently or seasonally.
- Wetlands have been categorized both as biomes and ecosystems.
- Wetlands have unique characteristics. They are generally distinguished from other water bodies or landforms based on their water level and on the types of plants that thrive within them.
- The biota of a wetland system includes its vegetation zones and structure as well as animal populations and distribution, which are highly dependent on water chemistry.
CONSTRUCTED WETLAND HAS BEEN IMPLEMENTED SINCE 1991

The Jungle Lodge Alang Sedayu Gombak.
Plants in Wastewater Treatment
Wastewater Flow at The Jungle Lodge Alang Sedayu Gombak

Wastewater → Sedimentation Trap → 2\textsuperscript{nd} Pond → Final Pond

Agricultural & Landscape irrigation
It is used to treat the wastewater in the resort.

It is the first of its kind to be built in Malaysia.

The wetland area is about 0.5855 acres (2.369 sq m) with a maximum depth 1.2 – 1.7 m depending on the season.

The water quality within the wetland is regularly monitored with help from the local public university and private laboratories to ensure that it meets the Malaysian standard for drinking.

There are two types of waste water: black and gray water.

Black water generally refers to sewage waste whilst gray water is the wastewater that is generated by sinks, baths and laundry processes.
Sources of Wastewater in the Wetland

The generation of black water and gray water in the resort are shown in the flow chart below.

Gray water from washrooms, kitchen, baths and laundry

Black water (from Septic Tank)

Wetland for wastewater treatment with nature’s way (plants and microorganisms)
First point
Water mimosa (*Neptunia spp*): to reduce total nitrogen and phosphorus’s values; absorb organic compounds and suspended solids

Second point
*Thalia Geniculata*: absorbs nutrients and stabilizes the suspended solids.

Third point (Final point)
- Water hyacinth (*Eichhornia crassipes*): very efficient in removing suspended materials, BOD, nutrients (nitrogen and phosphorus), organic matter and up take heavy metals (lead, chrome, cadmium, copper, aluminum, nickel, mercury) and pathogens.
- Duckweed (*Lemna minor*): absorbs nitrates, phosphate, potassium, calcium, sodium and carbon
- Vetiver (*Veteveria zizanioides*): helps to regulate the amount of water and filter sediment-bound contaminants (heavy metals and some pesticides residues)
- Water lily (*Nymphaea*): removes cadmium in the water, help reduce algae growth in ponds
- Water spinach (*Ipomoea aquatic Forsskal*): provide a large surface area for the growth of beneficial micro-organisms that can enhance nitrogen removal.
Average flow rate of wastewater from discharge inlet to the inlet to the end of water mimosa 0.0034 m/s (green arrow) and 0.0015 m/sw for Thalia Geniculata until Eichhorniacrassipes (red arrow).

- Total surface area for all the plants used in wastewater treatment system = 1363.73 sq m
- Total surface area for mimosa = 377.77 sq m
- Total surface area for water hyacinth (Eichhorniacrassipes) = 311.09 sq m
- Total surface area for water spinach (Ipomoea aquatic Forsskal) = 58.25 sq m
- Total surface area for water lily (Nymphaea) = 68.83 sq m
- Total surface area for vetiver (Veteveria zizanioides) = 79.20 sq m
- Total surface area for Thalia Geniculata = 65.33 sq m
Function of Microorganism

- A fundamental characteristic of wetlands is that their functions are largely regulated by micro-organisms and their metabolism.

Microbial activities:

- Transforms organic and inorganic substances into innocuous or insoluble substances.
- Alters the reduction/oxidation (redox) conditions of the substrate in the wetland.
Types of Microorganism

- **Aerobic**
  - Take place in the present of free oxygen

- **Facultative Anaerobes**
  - Functioning under both aerobic and anaerobic conditions

- **Anaerobic**
  - Take place in the absence of free oxygen
Also known as vegetated submerged beds, sub surface flow constructed wetlands are designed in a way where the water flows horizontally beneath the vegetation. At the resort, we are working on creating such wetland to grow fruit trees such as edible bananas.
Example of subsurface flow

**PRIMARY TREATMENT**

**SEPARATION OF SOLIDS FROM LIQUIDS**
For organic wastewater: Septic tanks (here on schematic), Faecal bags, Imhoff, screeners,...
For highly polluted wastewater and/or industrial wastewater: system adapted to nature of wastewater
- If using a septic tank: Residence time should be at least 2.5 days.

**SLUDGE SECONDARY TREATMENT AND REUSE**
- If organic: composting, drying-bed, vermicompost, methane production, ...

**SECONDARY TREATMENT**

**WWG Unit**
Subsurface Flow constructed wetland (SFCW)
**NB:** Drawing here is of an horizontal flow CW with a minimum residence time of 4 days
- SFCWs can also be designed to provide PRIMARY treatment or TERTIARY treatment.

**REUSE OR DISPOSAL OF TREATED WATER**
- Small scale systems: drainage trenches filled with gravel adapted to local soil permeability.
- Medium to large scale systems: Tertiary treatment applied or direct disposal in water ways or reuse for additional productive green zone.
Waste Water Treatment (Wetland)
Results for
February 2017
At The Final Point (P3)
# Water Analysis @ Point 3 of the Wetland

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<th>Test Description</th>
<th>Analysis Result(s)</th>
<th>Standard Spec. (A)</th>
<th>Standard Spec. (B)</th>
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<tr>
<td>Test Description</td>
<td>Analysis Result(s)</td>
<td>Standard Spec. (A)</td>
<td>Standard Spec. (B)</td>
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<td>Coliform</td>
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<td>Total Bacteria Count</td>
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Type of Plants in Wastewater Treatment Wetland @ The Frangipani Langkawi
Duckweed

Aquaculture Potentials, Possibilities and Limitations for Combined Wastewater Treatment and Animal Feed.

- Purify water by controlling algae growth
- Converting waste and sewage water into treated water
- Duckweed also reduces water evaporation and keeps water cool.
- A potential high-protein feed resource for domestic animals and fish.
A floating aquatic perennial that roots in the banks or bottoms of water bodies. Its stems grow out of the water surface and are supported by a spongy fibrous material that covers the stems.

The first plant used to treat the water.

Able to reduce total nitrogen and phosphorus’s values; absorb organic compounds and suspended solids because its stems are covered with a spongy fibrons layer.

Has the potential to restrict water flow in creeks and channels, so all the suspended solid can settle down slowly.
Red Stem Flag (Thalia Geniculata)

- Commonly known as Bent Alligator-Flag, it is a forb/herb (a non-woody plant that is not a grass) of the genus.

- Its duration is perennial which means it will grow year after year.

- The second plant used to treat the wastewater.

- Absorbs nutrients and stabilises the suspended solids.
- A free floating perennial plant that can grow to a height of three feet.
- A very aggressive invader and can form thick mats. If these mats cover the entire surface of the pond they can cause oxygen depletions and kills the fish.
- Very efficient in removing a vast range of pollutants from suspended materials, Biochemical Oxygen Demand, nutrients like nitrogen and phosphorus to organic matter.
- Most importantly, it has a high capacity to up taking heavy metals lead such as chrome, cadmium, copper, aluminum, nickel, mercury and pathogens.
Water Spinach

- A mild green vegetable eaten throughout Asia, it has a very similar nutritional value to spinach.
- Also known as swamp cabbage, it is in the same genus as sweet potato, and a member of the morning glory family.
- Grows wild in aquatic environments but can also be grown in well irrigated fields.
- A floating plant, its roots hang down beneath the floating canopy and provide a large surface area for the growth of beneficial micro-organisms that can enhance nitrogen removal.
- Because the plants are floating, they are forced to take their nutrients and heavy metals from the water rather than from sediments.
Vertiver 
(Verteveria zizanioides)

- Known as miraculous grass because it is very beneficial and versatile.
- *Verteveria zizanioides* stiff can stand up to high velocity flows and help to regulate water flow and increase retention time.
- Its thick root growth forms a living porous barrier that can act as a very effective filter trapping both fine and coarse sediments as well as sediment bound contaminants (For example, heavy metals and some pesticides residues).

- Its deep, dense and penetrating root system can also reduce and prevent drainage, improve bed stability and nutrients uptake.
- Its fine structure and massive root system provides an environment that stimulates biological process in the rhizosphere.
- It is highly tolerant to adverse climatic conditions such as frost, heat, draught and flood.
- Provides hiding places for small aquatic creatures.
- Removes cadmium in the water, help reduce algae growth in ponds and add oxygen to the garden ponds itself.
- Its leaves shade the water, keeping it cool and thus allowing for more dissolved oxygen.
Constructed Wetland system in Sungai Satu Batu Ferringhi, Penang.

Source: http://www.themalaysianinsider.com/citynews/georgetown/article/selangor-dredging-lauded-for-cleaning-up-sungai-satu
Population: 3,000 - 4,000 residents + 1.2 million tourists/year
Amount of wastewater treated: 400 m³ day
Treatment plant surface: 6,000 m²

Wetland Koh Pi Pi Don, Thailand
Shanghai Houtan Park

Established Wetland Shenyang, China

Wastewater treatment for 6,000 people

7,500 m² (total area)
Omnilife Stadium is Mexico’s fourth largest stadium. It is also the first major stadium with a total wastewater treatment and reuse system. Approximately 136,000 gallons (515 cubic meters) of wastewater is collected from the stadium during each game. Wastewater is equalized and metered out at 20,000 gallons per day into an onsite treatment system.

BAPEDALDA Govt, Agency has CW treating/toilet faecal water only. Note: unit recently planted.
Constructed wetland, El Salvador

Constructed wetland in El Salvador, designed and installed by Florida International University’s Applied Research Center, is a system composed of both: a subsurface and surface constructed wetlands, in which the native plants’ root systems eliminate waste and purify the water. The system enables treatment of 44,000 gallons of sewage per day. Wastewater entering the constructed wetland completes the purification cycle in just 16 days.
What can wetlands for waste water treatment systems be applied to?

- Domestic sewage treatment
- Agricultural washings, wastewaters and field runoff buffers
- Industrial effluents and yard runoff filtration
- Group housing and municipal sewage schemes and sludge disposal
- Landfill runoff and other long-term low maintenance situations
- Urban and road storm-water runoff, for both flow buffering and water filtration
- Mine tailings and metal reclamation
- Stream, river and lake restoration
- Recreational and amenity applications
- Flood control and habitat enhancement
Advantages of wetland systems

• High treatment efficiency possible.
• Low capital and running costs.
• Minimum maintenance
• Low energy requirements.
• Tolerant of variable loads.
• Beneficial for wildlife.
• Aesthetically pleasing.
• No chemicals necessary.
• Suitable for polishing effluent from existing overloaded systems.

4. “Constructed Wetlands to Treat Wastewater”

References:

• Environmental Protection Agency, Wetland Home Page. Includes wetland information hotline, restoration information, etc.
  www.epa.gov/owow/wetlands

• International Association for Ecology (INTECOL) hosts Wetlands Conferences.
  www.intecol.net

• IUCN-World Conservation Union
  http://www.iucn.org/

• National Wetlands Research Center
  www.nwrc.usgs.gov

• Wisconsin Wetlands Association
  www.wisconsinwetlands.org

• Ramsar International Convention on Wetlands
  www.ramsar.org
• NAHRIM

• UNEP
Question & Answer