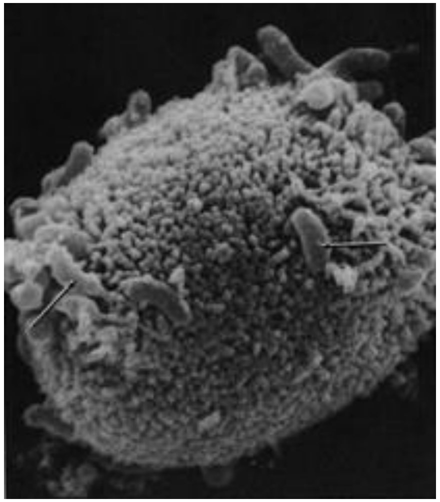
Productive Ecological Sewage Water Treatment Systems

Presentation by Paulo Mellett
in a Water Retention Landscape Design Education
in Tamera/Portugal, 2013

The Global Water Crisis



- 25 million people die each year from contaminated water. That is equivalent to the population of Canada.

- Every 8 seconds a child dies from contaminated water.

- 1.4 billion people have no access to safe drinking water.

- 2.4 billion people have no access to sanitary systems - one person in three.

Source: Troubled Water by Anita Roddick and Brooke Shelby Biggs, 2004

The Problem: Black Water

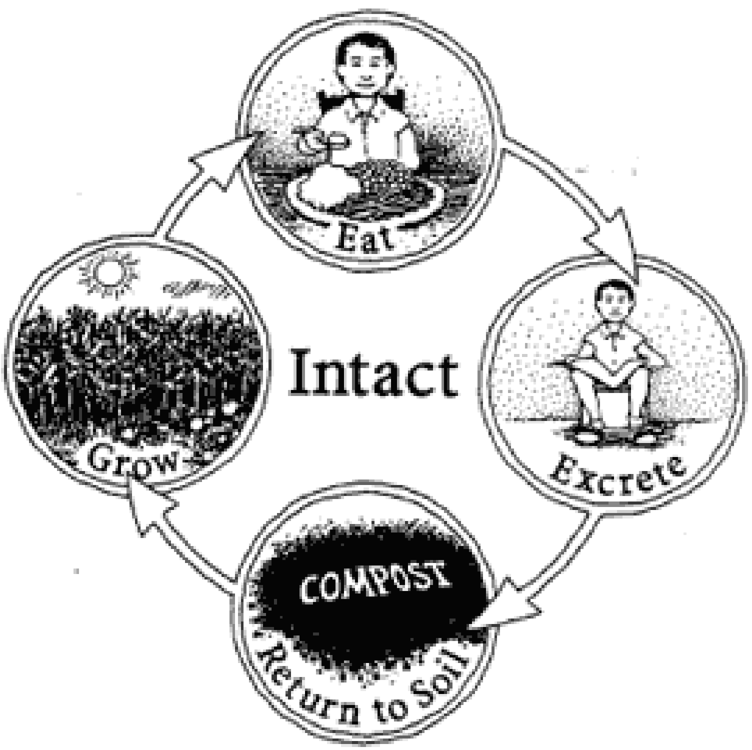
- We cannot talk of water without our responsibility to clean the majority of the contaminated water we have created, and continue to create

- “Black water” is that contaminated by human faeces. “Grey water” is everything else (shower, sink, kitchen). When black and grey are mixed, it can all be considered to be black water – this is sewage.

- Contaminated water still one of the biggest killers of humanity

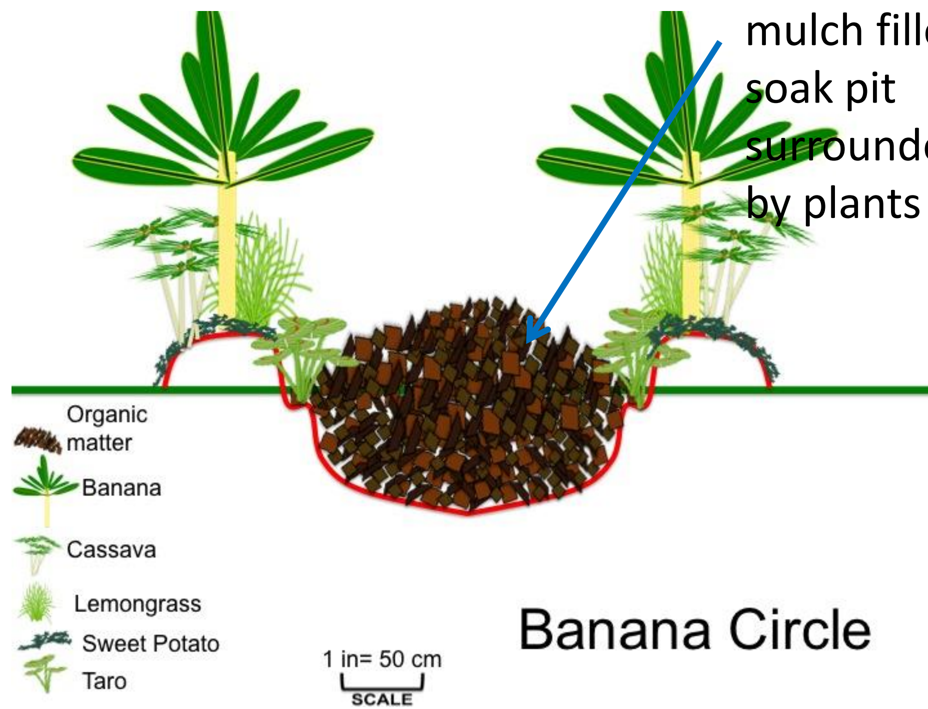
1st priority: DON'T CREATE IT

- Compost toilet and greywater for irrigation as main priority



http://humanurehandbook.com/

Greywater piped into mulch filled soak pit surrounded by plants



2nd priority: deal with sewage safely

- Retrofitting conventional systems
- Where space is limited or sewage system already established?
- Urbanisation >50% of humanity live in cities
- 6% of population of live in slums in Brazil (2010): 11.4 million
- In India slum population has more than doubled in the past two decades and now exceeds the entire population of Britain: 93 million in 2011.

Keystone

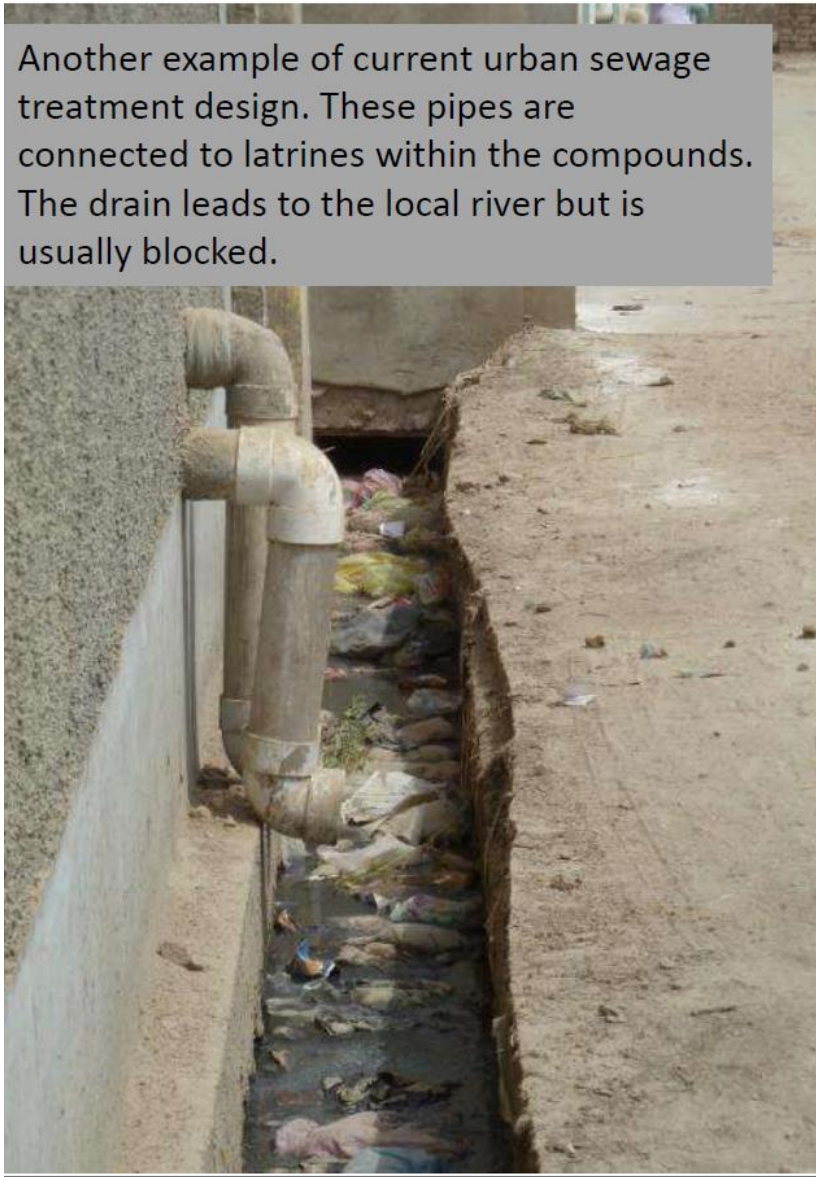
A young girl walks to her home in a slum area in New Delhi, India. Nearly 930 million people worldwide now live in slums and this figure is growing at an accelerated rate. Residents of urban slums like this one face particularly serious obstacles to attracting funds for sewerage and water infrastructure. Uncertainties over settlement durability and lack of land tenure security are strong deterrents to investment.

This is “normal” for more than a billion people.

Slum formalization in Brazil: before and after images of the same place.

The government helps to make channels, paths and enclosed pipes to keep people away from sewage. But where does the sewage go?

Another example of current urban sewage treatment design. These pipes are connected to latrines within the compounds. The drain leads to the local river but is usually blocked.

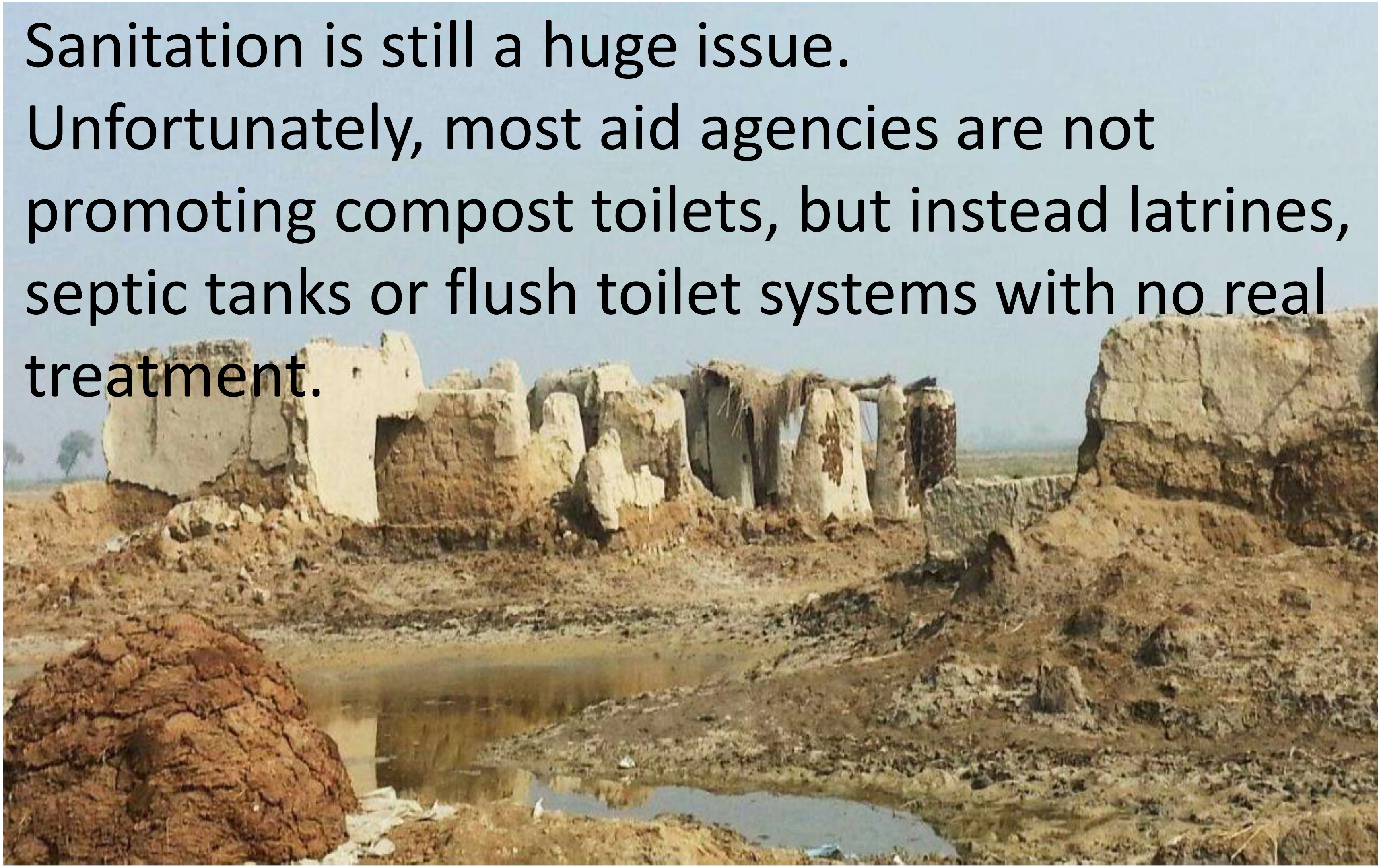


This is a compound in a Pakistani suburb. But it still drains into an open waterway.

Again, causing this kind of problem

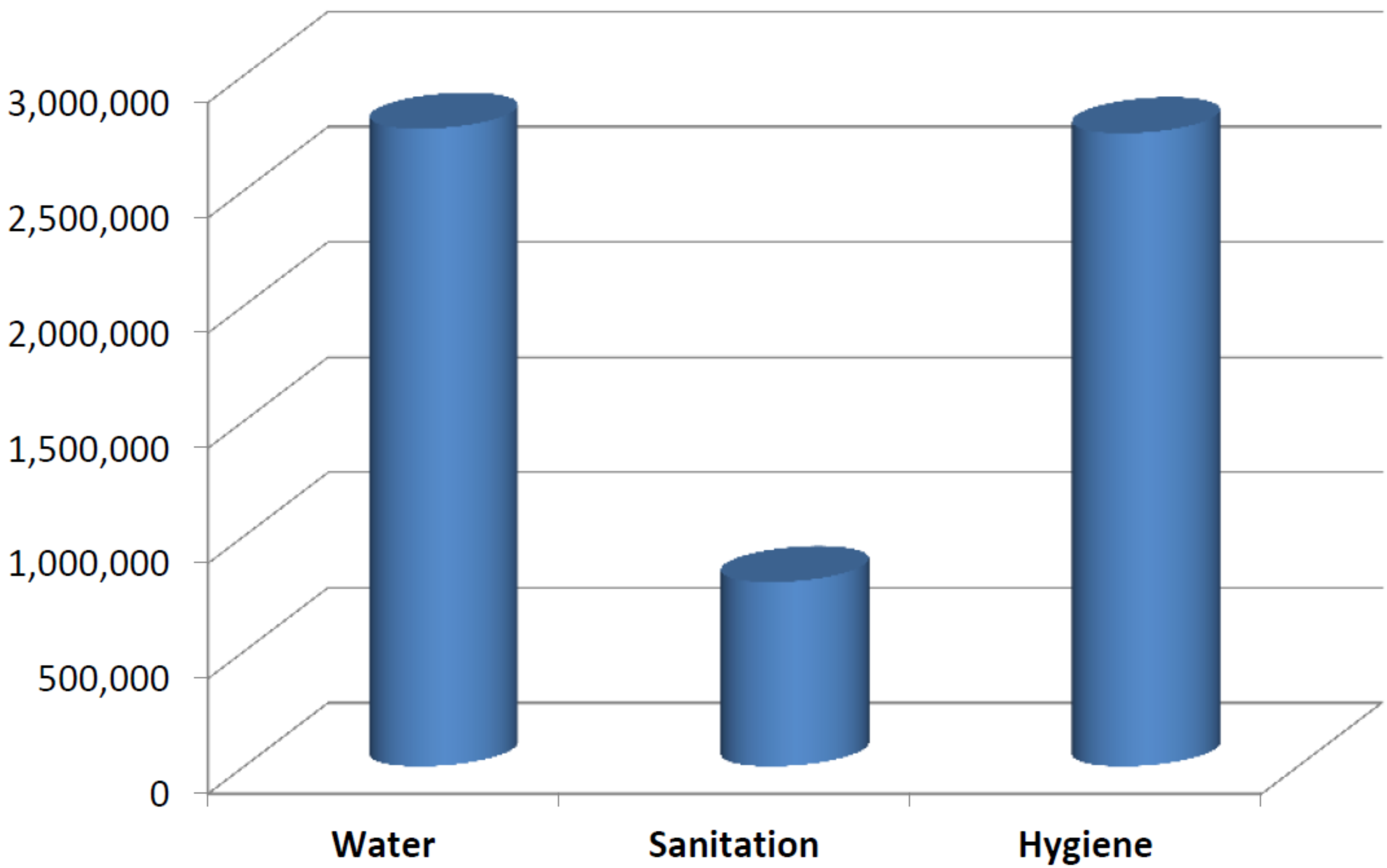
Major Floods in Pakistan 2011 to 2013

- My friend Magnus is the DFiD UK aid funding coordinator.
- One of the biggest ever recorded disasters in terms of numbers of people affected.
- They are trying to help hundreds of millions of people rebuild after this.


Sanitation is still a huge issue.
Unfortunately, most aid agencies are not promoting compost toilets, but instead latrines, septic tanks or flush toilet systems with no real treatment.

People reached per sector –

DFID funded WASH projects post 2010 floods



Poorly designed overflow from septic tanks

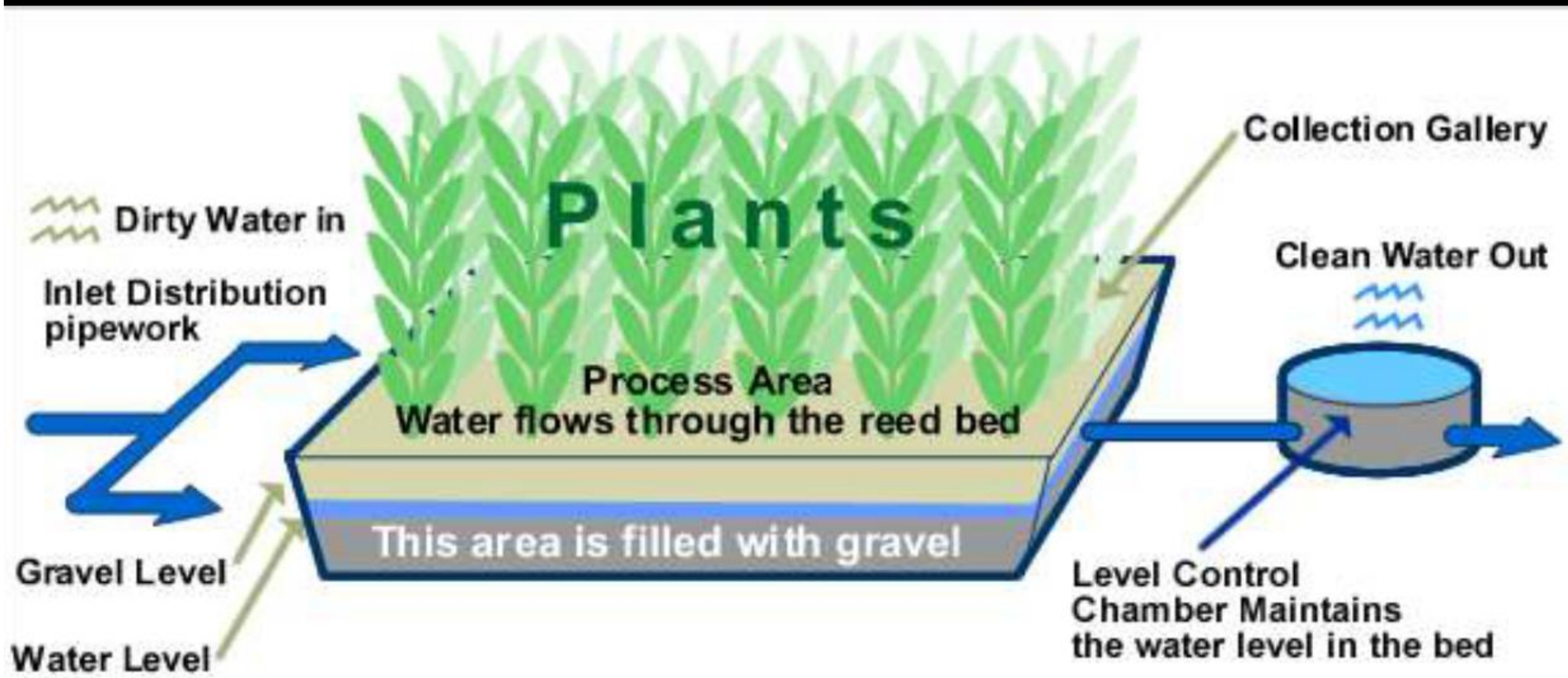
A common sight all over Pakistan

A serious public health problem has been created, not resolved.

Conventional “Progress”

District Bahawalpur. We visited this 2011 (non-DFID) UNICEF WASH project as part of an assessment of better sewage management options – for current DFID-UNICEF WASH programmes in other districts; also for DFID-Education team to consider for schools WASH management

There are alternatives!
For example: constructed wetlands



But, high embodied energy materials, and has problems with soil formation and clogging of stones, which leads to pooling of sewage on surface.

So called “Sustainable”monoculture solutions

Bahawalpur village 2. This “constructed wetland” was built as part of (non-DFID) UNICEF sanitation programme. At around £5,000 this is extremely expensive and impossible to replicate. Although the design concept is good and environmentally sound, the VfM is poor and better options need to be considered for schools and flood affected villages.

Actually cost closer to £7000 = €8200

This is what reed beds look like when they are functioning. They can work, but they still use only one species of plants (monoculture)

They also have significant maintenance requirements and use materials that gradually degrade and need replacing. Still too similar to conventional technological systems.

Conventional Systems

- Average 15 year life and then needs to be rebuilt.
- High embodied energy
- Expensive
- Consumes energy to run
- Often break down

Tanks and pipes with little or no life – too much engineering thinking in these designs.

Ecological Engineering

Natural Water Treatment Systems: Ecology as the ‘Tool Box’ of Design

Plants

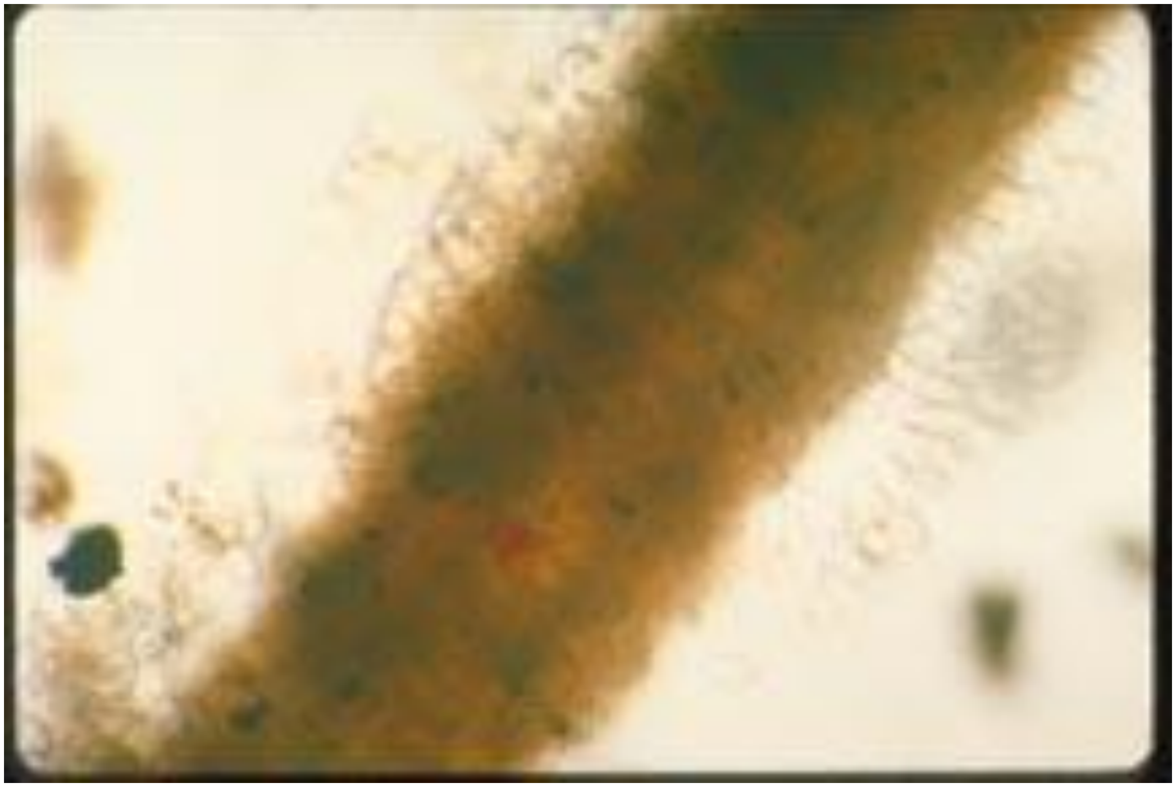
Microorganisms

Filtering Animals

Fungi

PLANTS!

Surface Area on Plant Roots



Gives a high surface area for microorganisms to live on and some also provide oxygen to microorganisms.

LIVE SUBSTRATE

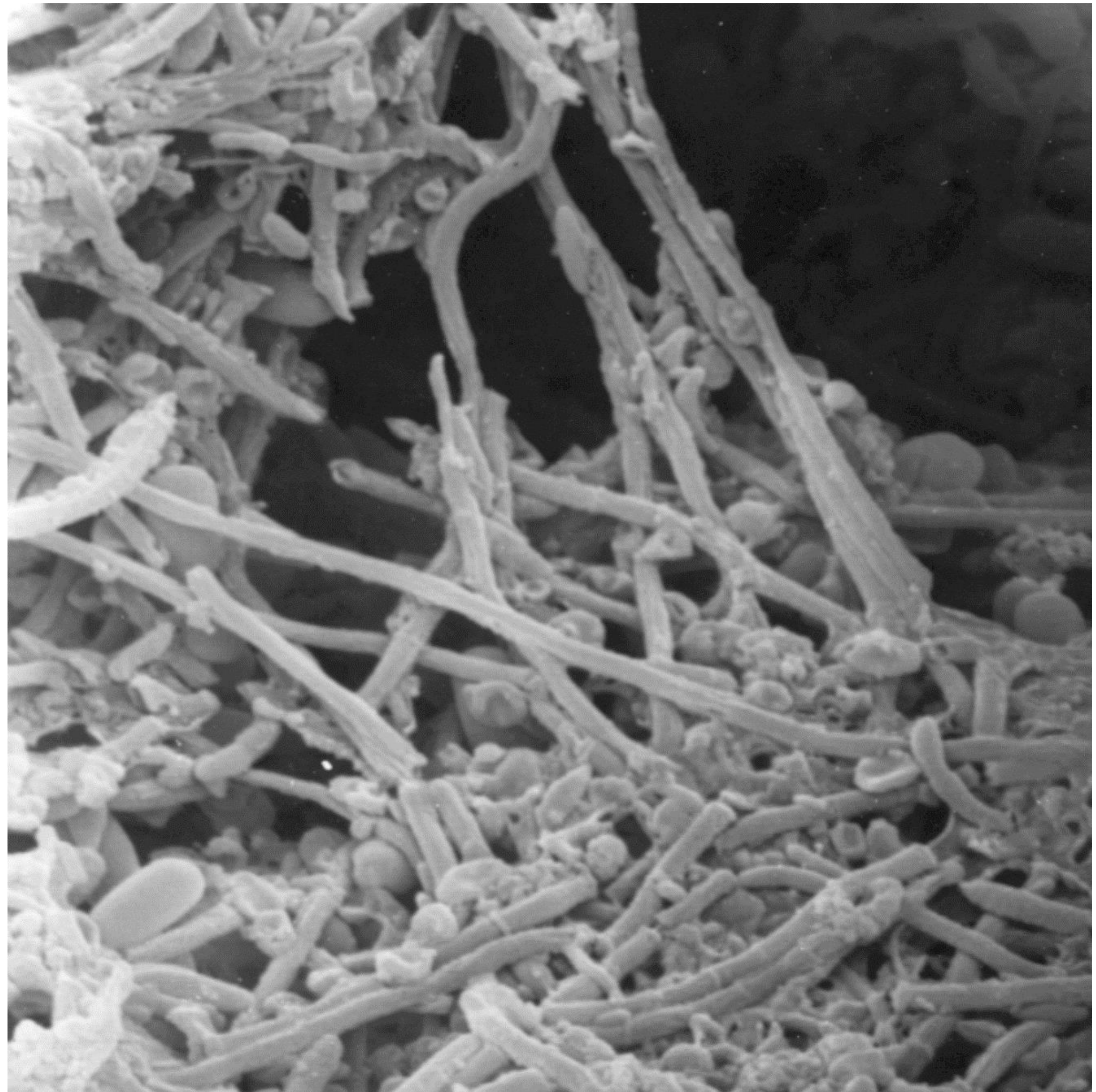
Attached growth on a **live** substrate significantly increase the efficiency and stability of the biofilm.

This is the living filter that cleans the water, whether floating in the water or in soil.

BIOFILM STRUCTURE

Large amounts and high biodiversity of organisms in the biofilm eat nutrients and pathogens in dirty water.

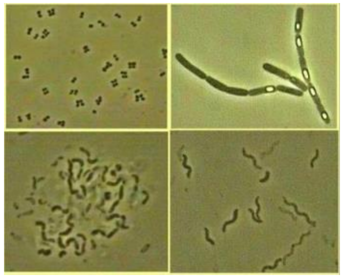
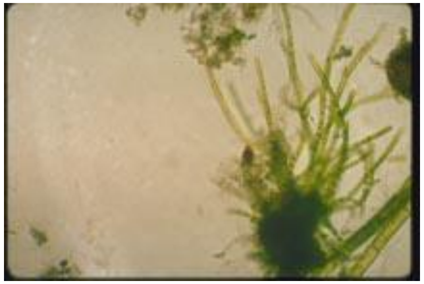
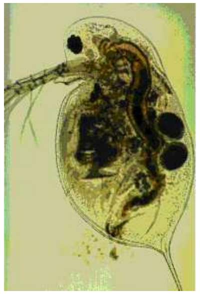
The root mass acts as a large BIOFILTER that traps and consumes pathogens and nutrients.



One of the denizens of the biofilm: Collotheca (Rotifer). Eats pretty much everything.

Rotifers eat algae and other protists, bacteria, and even other rotifers. One the left it is about to swallow up a bacteria.

Microorganism diversity

There are many, many other types in the biofilm. The general principle is, the more diversity we give nature to work with (or the more we allow nature to express diversity), the quicker it achieves a healthy balance: and that means clean, living water.

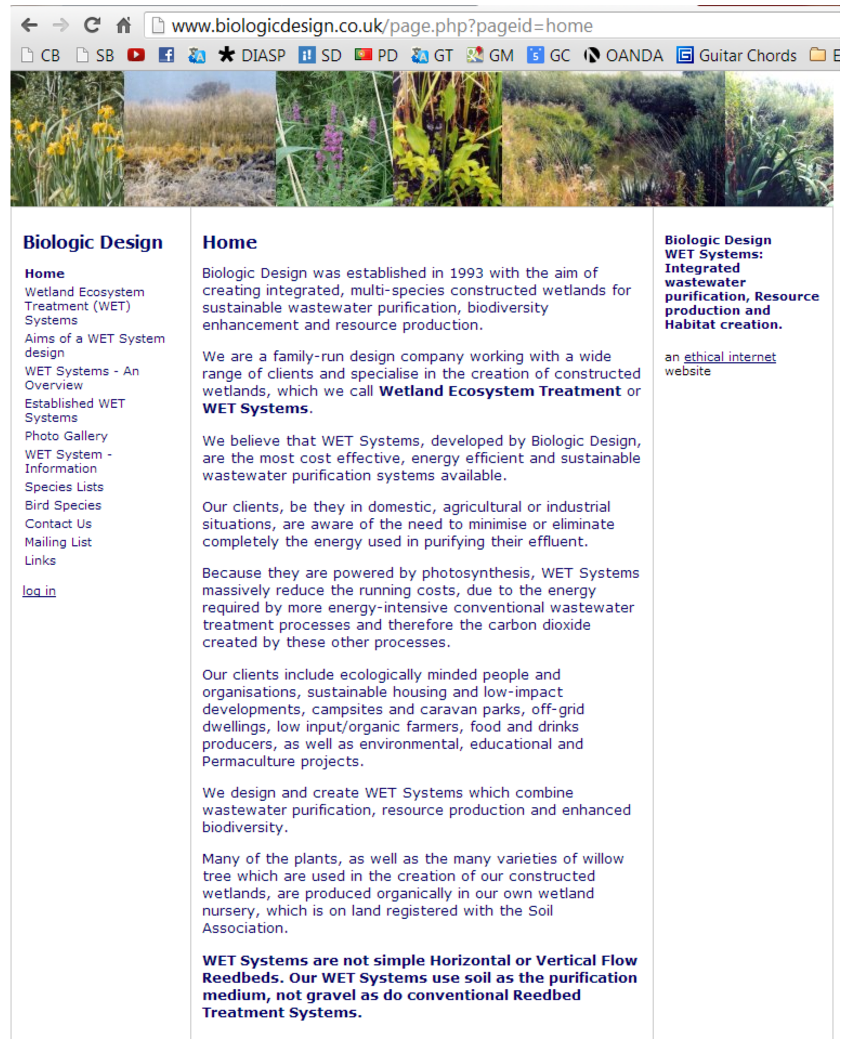
The longer a pathogen or parasite has to spend outside its host in this environment of ferocious competition and surrounded by predators, the quicker it is dealt with.

We need to think like an ecosystem, not like a machine. This is a W.E.T. system

- Gets better and more developed as it gets older
- Soil based system without concrete and tanks
- Little cost after initial investment (payback time shorter than life of conventional sewage system)
- Uses gravity and solar energy
- Never breaks down, adapts and evolves continually

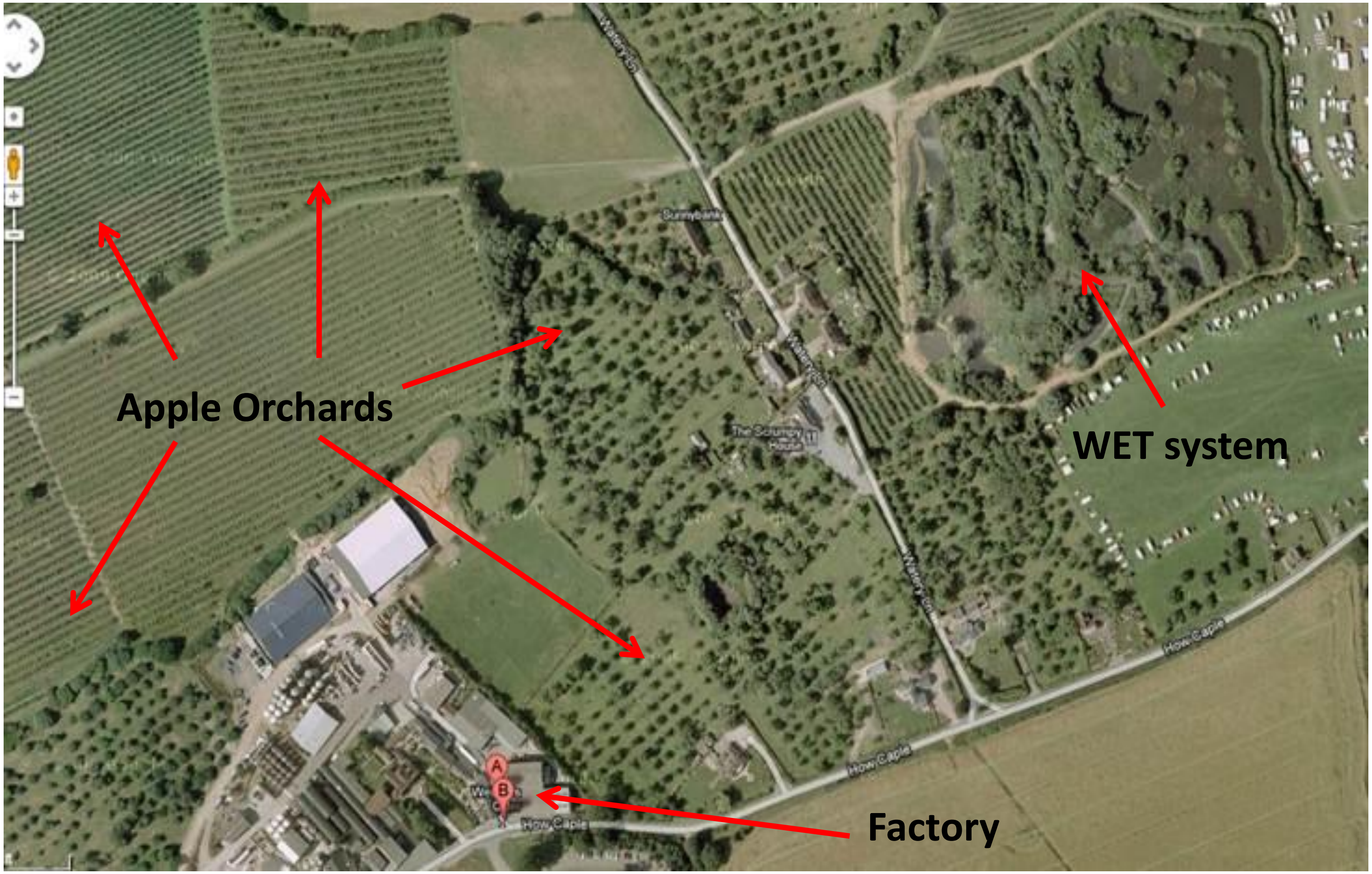
Wetland Ecological Treatment (WET) systems

- Treats not just sewage, but all bio effluent.
- Company “Biologic Design” >90 systems installed in the UK, which has some of the strictest waste water laws in the world.
- Household, farm and industrial scales.
- Outflow to rivers and evapotranspiration.
- High biodiversity and wildlife habitat enhancement



- A newly built system: when mature, water will not be visible – it will look like a forest.
- Square pond is initial algal lagoon for solids settlement.
- Subsequent ponds are “swales” – long ditches on-contour with soil berms in between, at 90 degrees to the slope.
- Sewage soaks slowly through sequential berms being filtered by soil microbes on plant roots.
- Plants consume nutrient and transpire water into the air. Layout designed to maximise “edge” and area for plants.
- Small overflow capacity from clean end pond into groundwater
- Spongelike capacity can absorb heavy rainfall without flooding.

A WET system for a large Cider factory



…lets zoom in

- Waste has a pH of 4.5 (very acidic!)
- > 10,000 litres per day
- Factory had to build new waste treatment system. This was a cheaper option than a conventional system.
- As business has grown, so has treatment capacity of WET system

Final pond of cider factory system

Same system from side angle

The system is built using earth moving equipment. Topsoil is removed and the subsoil is compacted to create an impermeable layer if it contains enough clay.

If there is not enough clay, then a geosynthetic clay liner (GCL) is used – these have been developed for use in lining solid waste landfills.

http://en.wikipedia.org/wiki/Geosynthetic_clay_liner

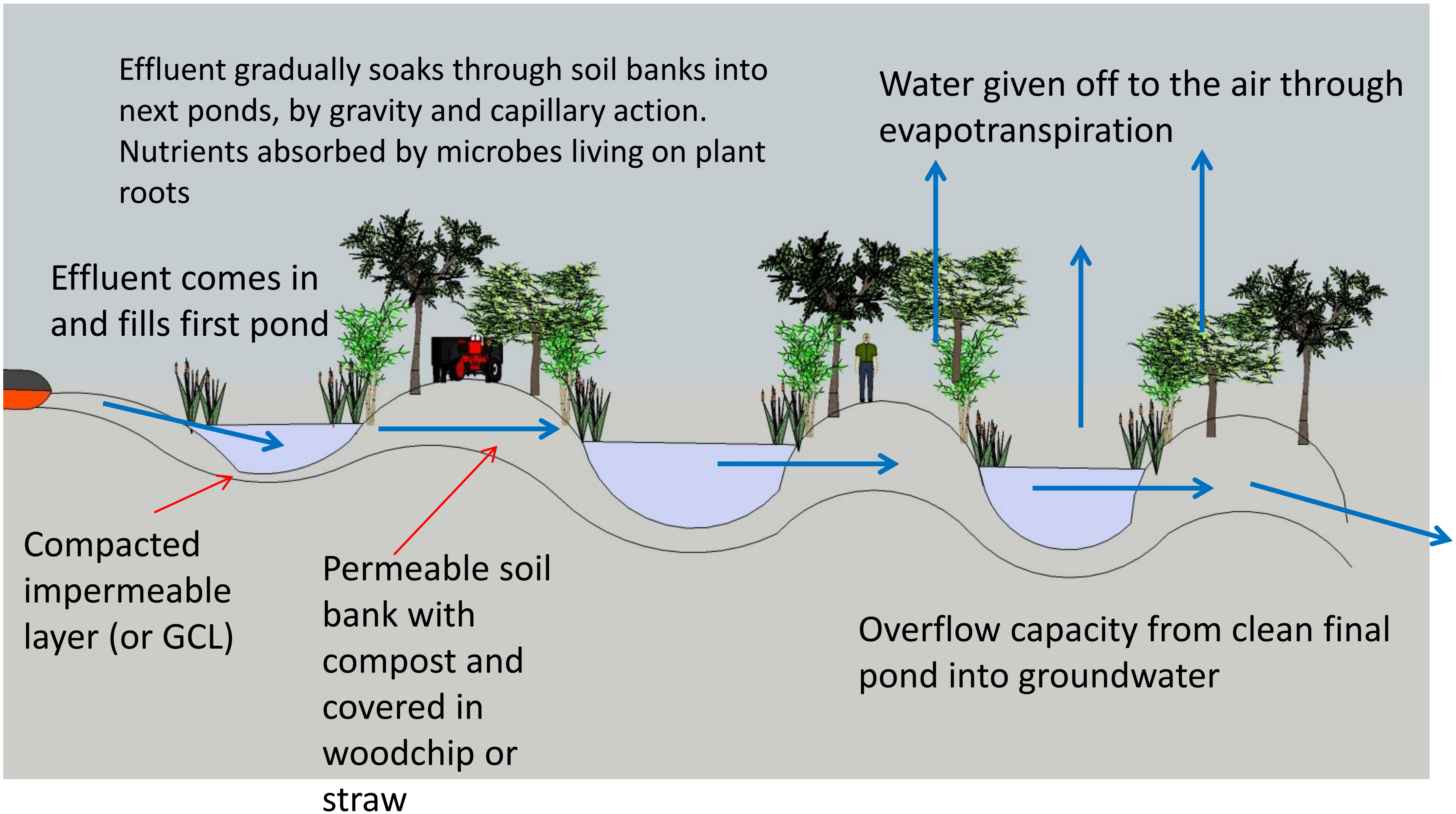
Highly Biodiverse: UK species list

Wetland plant species

- ***Alisma plantago-aquatica*** Water Plantain
- ***Butomus umbellatus*** Flowering Rush
- ***Callitriche spp.*** Water Starworts
- ***Caltha palustris*** Marsh Marigold
- ***Carex paniculata*** Great Tussock Sedge
- ***Carex pendula*** Pendulous Sedge
- ***Carex pseudocyperus*** Cyperous Sedge
- ***Carex riparia*** Greater Pond Sedge
- ***Carex sylvatica*** Wood-sedge
- ***Carex remota*** Remote Sedge
- ***Ceratophyllum demersum*** Rigid Hornwort
- ***Cyperus longus*** Galingale
- ***Deschampsia cespitosa*** Tufted Hair-grass
- ***Eupatorium cannabinum*** Hemp Agrimony
- ***Filipendula ulmaria*** Meadowsweet
- ***Geranium phaeum*** Dusky Cranesbill
- ***Geranium pratense*** Meadow Cranesbill
- ***Geum rivale*** Water Avens
- ***Glyceria maxima*** Reed Sweet Grass
- ***Hottonia palustris*** Water-violet
- ***Hydrocharis morsus-ranae*** Frogbit
- ***Iris pseudacorus*** Yellow Flag Iris
- ***Juncus spp.*** Rushes
- ***Luzula sylvatica*** Great Wood Rush
- ***Lychnis flos-cuculi*** Ragged Robin
- ***Lysimachia vulgaris*** Yellow Loosestrife
- ***Lythrum salicaria*** Purple Loosestrife
- ***Mentha aquatica*** Water Mint
- ***Menyanthes trifoliata*** Bogbean
- ***Myosotis scorpioides*** Water Forget-me-not
- ***Myriophyllum spicatum*** Spiked Water Milfoil
- ***Nymphoides peltata*** Fringed Water Lily
- ***Petasites hybridus*** Butterbur
- ***Phalaris arundinacea*** Reed Canary Grass
- ***Phragmites communis*** Common Reed
- ***Potentilla palustris*** Marsh Cinquefoil
- ***Pulicaria dysenterica*** Fleabane
- ***Ranunculus lingua*** Greater Spearwort
- ***Ranunculus flammula*** Lesser Spearwort
- ***Schoenoplectus lacustris*** Clubrush
- ***Scirpus sylvaticus*** Wood Clubrush
- ***Scrophularia auriculata*** Water Figwort
- ***Silene dioica*** Red Campion
- ***Sparganium erectum*** Branched Burr-reed
- ***Stratiotes aloides*** Water Soldier
- ***Symphytum officinale*** Common Comfrey
- ***Tanacetum vulgare*** Tansy
- ***Tussilago farfara*** Coltsfoot
- ***Typha latifolia*** Greater Reedmace
- ***Veronica beccabunga*** Brooklime

- **Plus 36 different types of willow (Salix)**

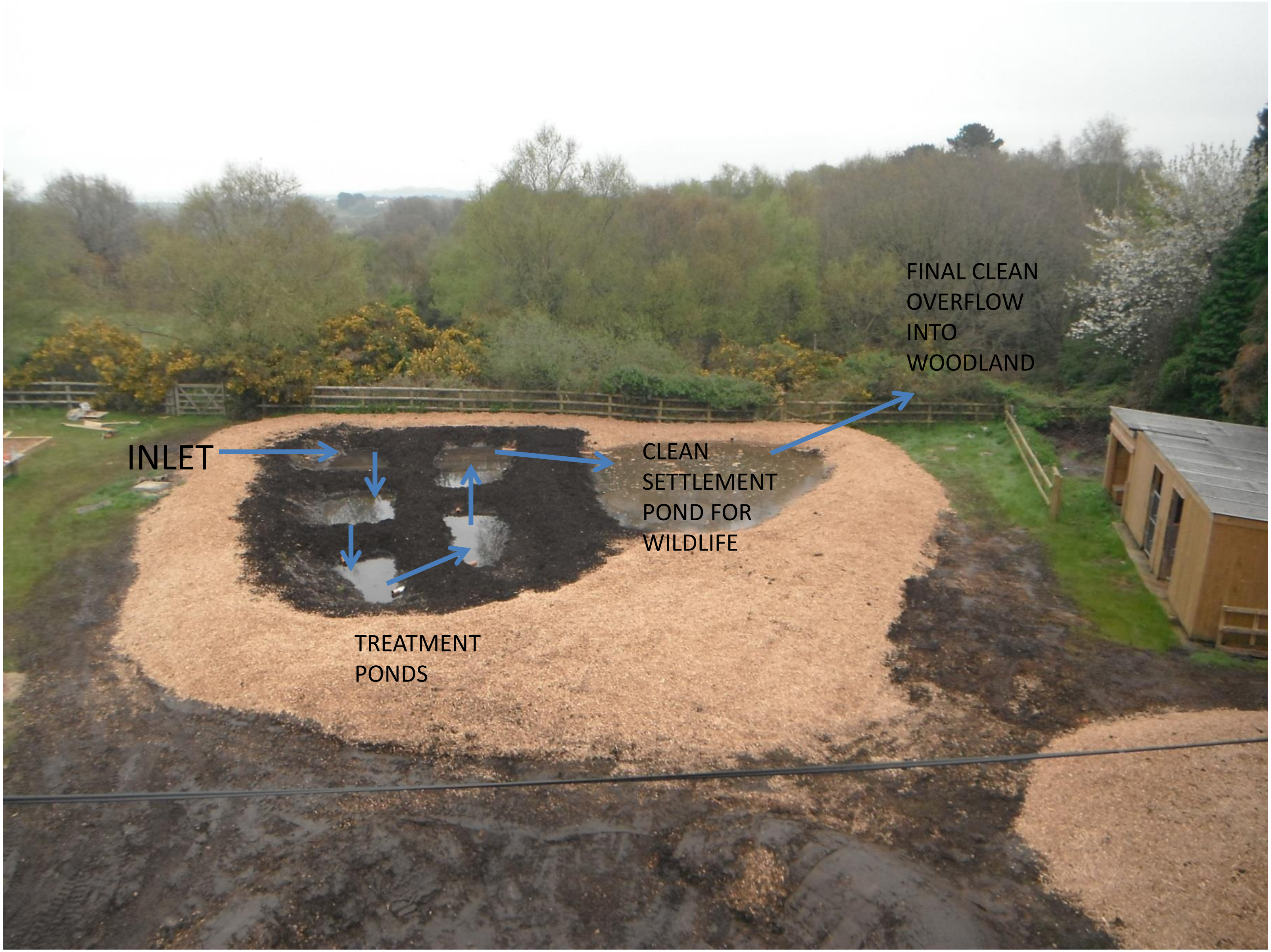
Anatomy of a WET system



This is a step-by-step construction process of a small off-grid system for a household in the UK for all its black and greywater. Ignore the straw covered garden beds in the foreground: they are not a part of the system.

Inlet: the leachate pipe from the house's septic tank system. We could (should) convert the septic tank into an anaerobic digester for biogas.


Pipes will later be removed
once planting has stabilised
the soil and compost and
the water can flow through
the soil beds without
washing them out.


FINAL CLEAN
OVERFLOW
INTO
WOODLAND
INLET
CLEAN
SETTLEMENT
POND FOR
WILDLIFE
TREATMENT
PONDS


6 Months after planting

11 months after planting

Initial 5 treatment ponds are now invisible.

This was also a year where there was almost no summer – heavy rain and very little sunlight.

These are the treatment ponds

Fruit trees planted around perimeter are fruiting in 2nd year and grew almost 1 meter!

This is how it started, one year previously

WET systems and productive potential

- Compare to conventional, leaking, non-functioning and expensive
  - Upstream from Portugal green gathering site.
  - Energy and money
- Soil based systems
  - Less aggregate and concrete used
- Importance of the edge effect (aquaculture and forestry most productive systems on earth). The more edge we have the more capacity for production.
- Implications for turning waste into resource to support communities

Maximising edge effect

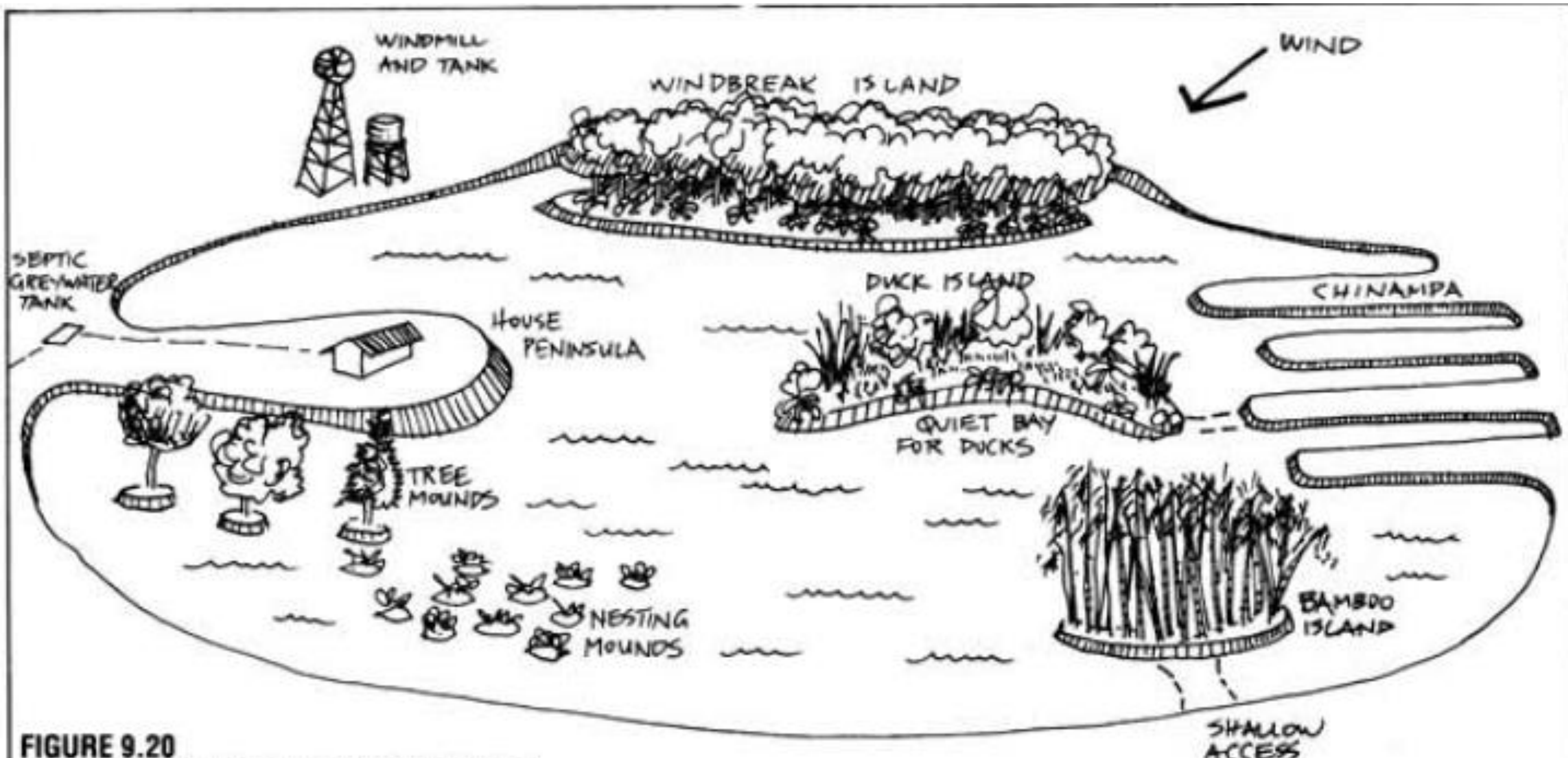


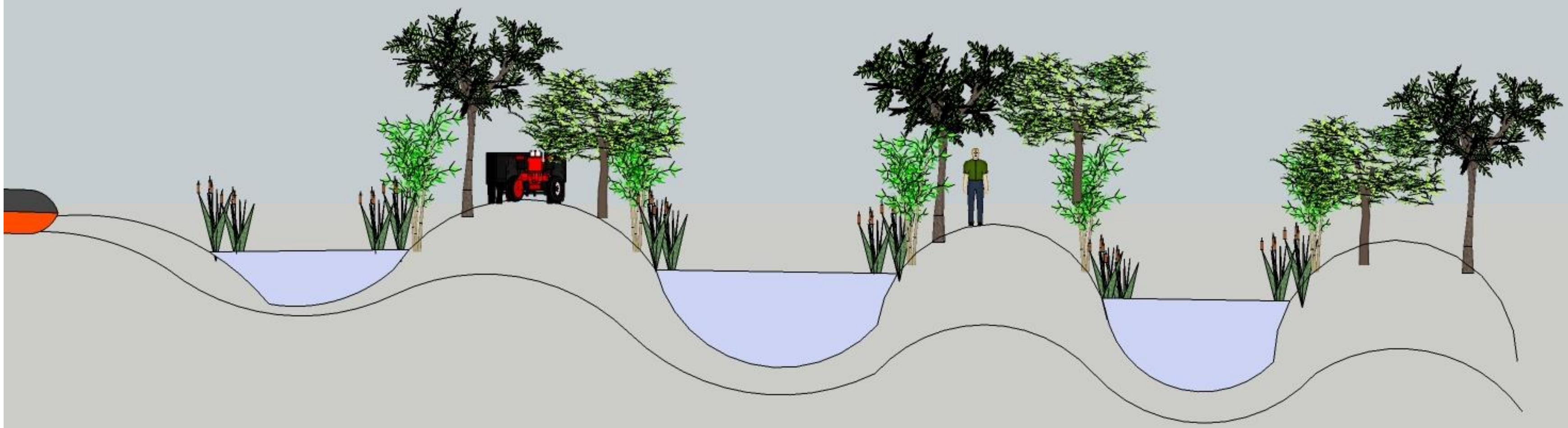
FIGURE 9.20
EARTHBANKS AND ISLANDS IN MARSHES;
several useful structures in and around water provide many niches for plants, animals, and people.

3rd Priority: Turn waste into resources

- Building materials
  - Timber
  - Bamboo
  - Roof thatch palm and grass
- Food
  - Fruit and nut trees
  - Animal fodder
  - Vegetables and fish possible in end stage
- Fuel
  - Firewood
  - Ethanol crops – typha species
  - Connected to outflow of plug-flow biogas systems

Anatomy of a WET system

Soil banks can be sized to allow access on top for harvesting: either on foot or with wheelbarrow or a cart or vehicle



A range of different crops can be cultivated at different areas of the edge – from in the water, and at the various levels up the bank and around the entire system perimeter

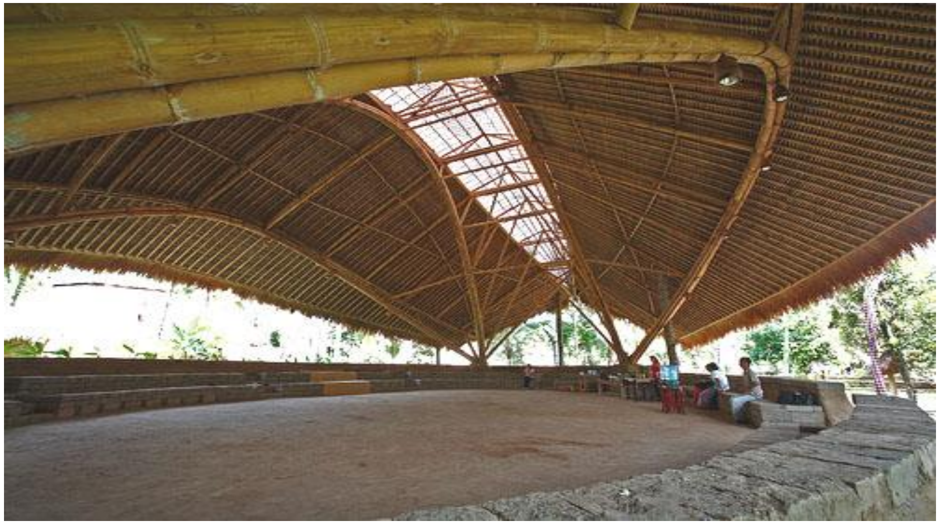
Dendrocalamus gigantus

Grows to full maturity after 3 years and can be used for large building projects.

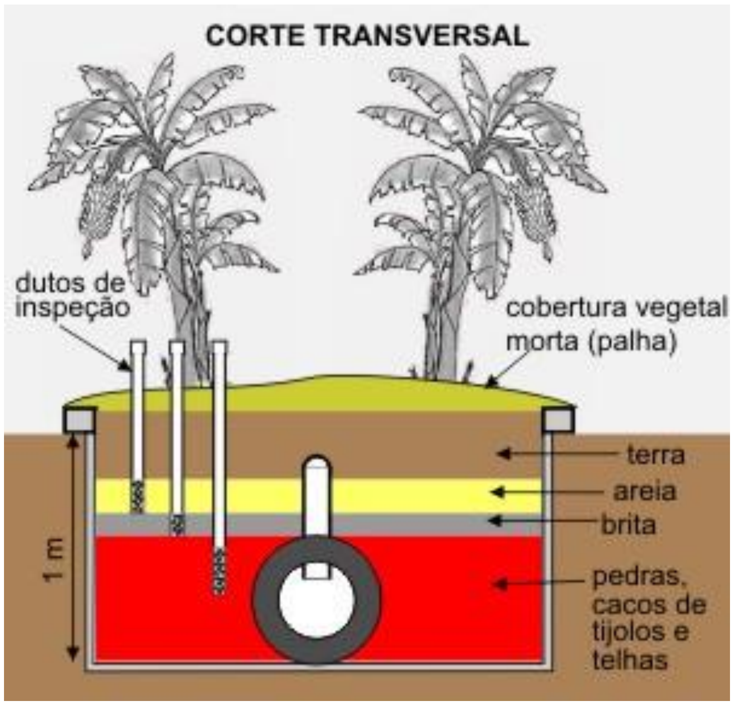
Stronger than steel beams.

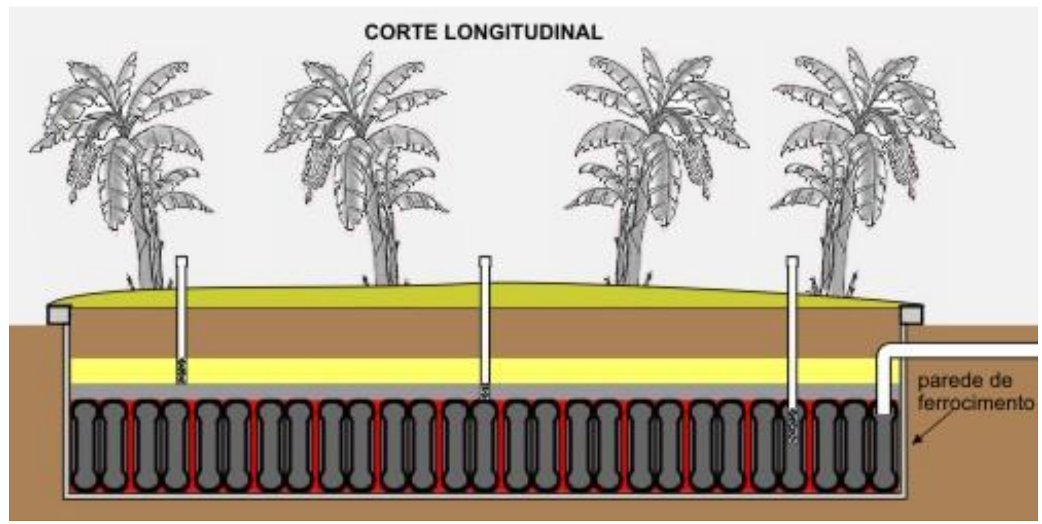
Now a growing industry in Brazil

And already very well established in Colombia and Asia.

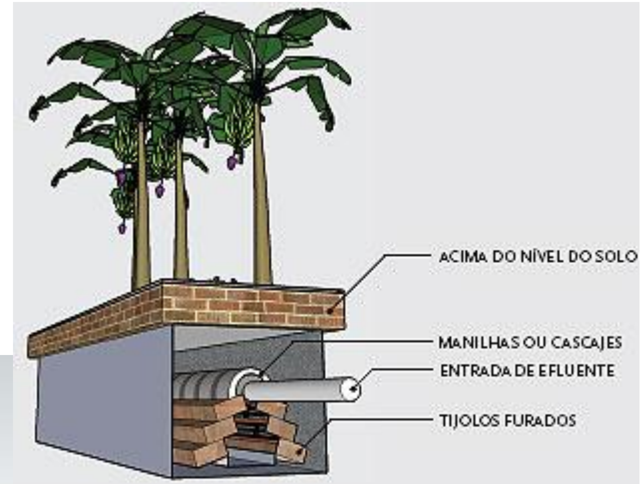


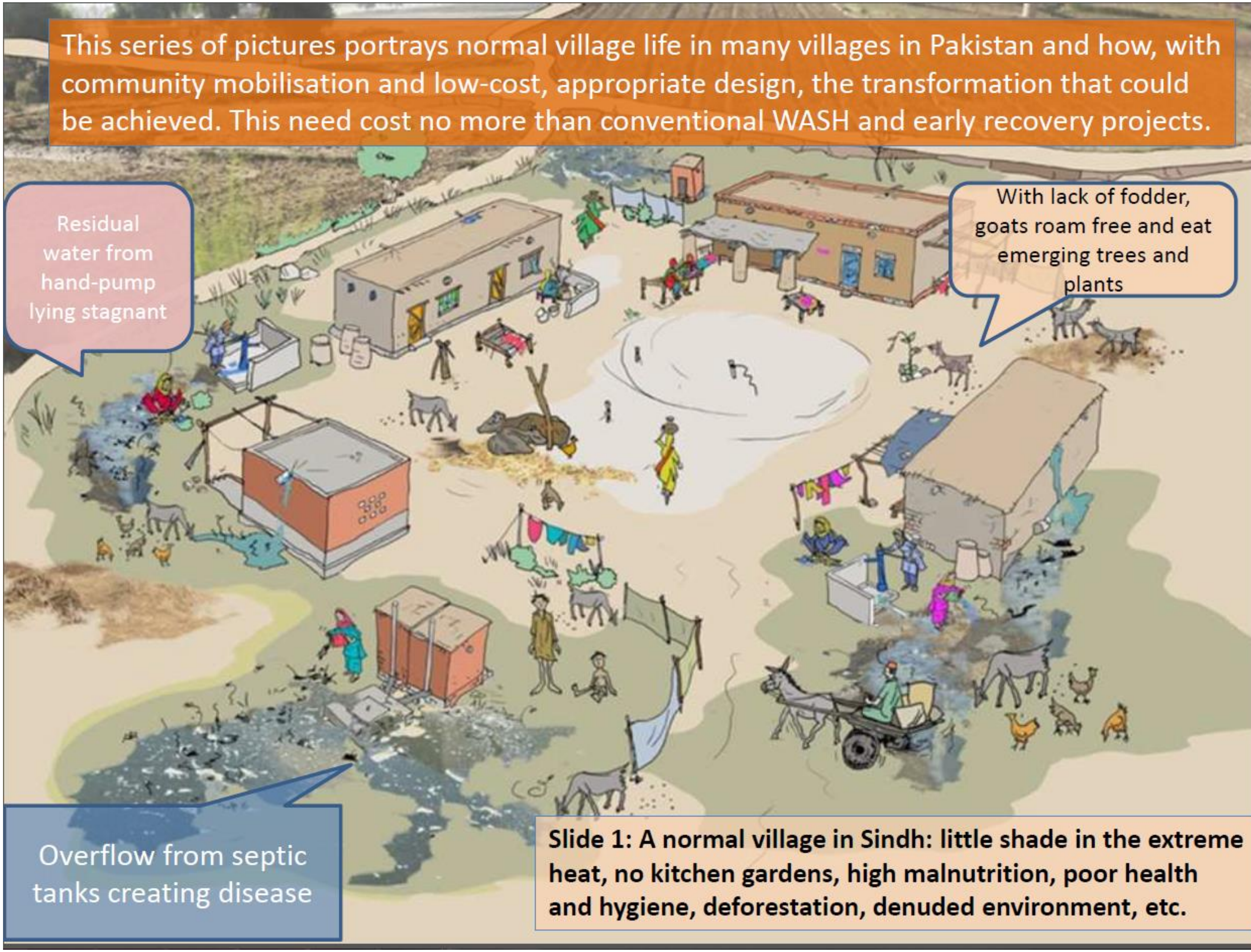
Other options: Fossa Bioseptica – Evapotranspiration Basin





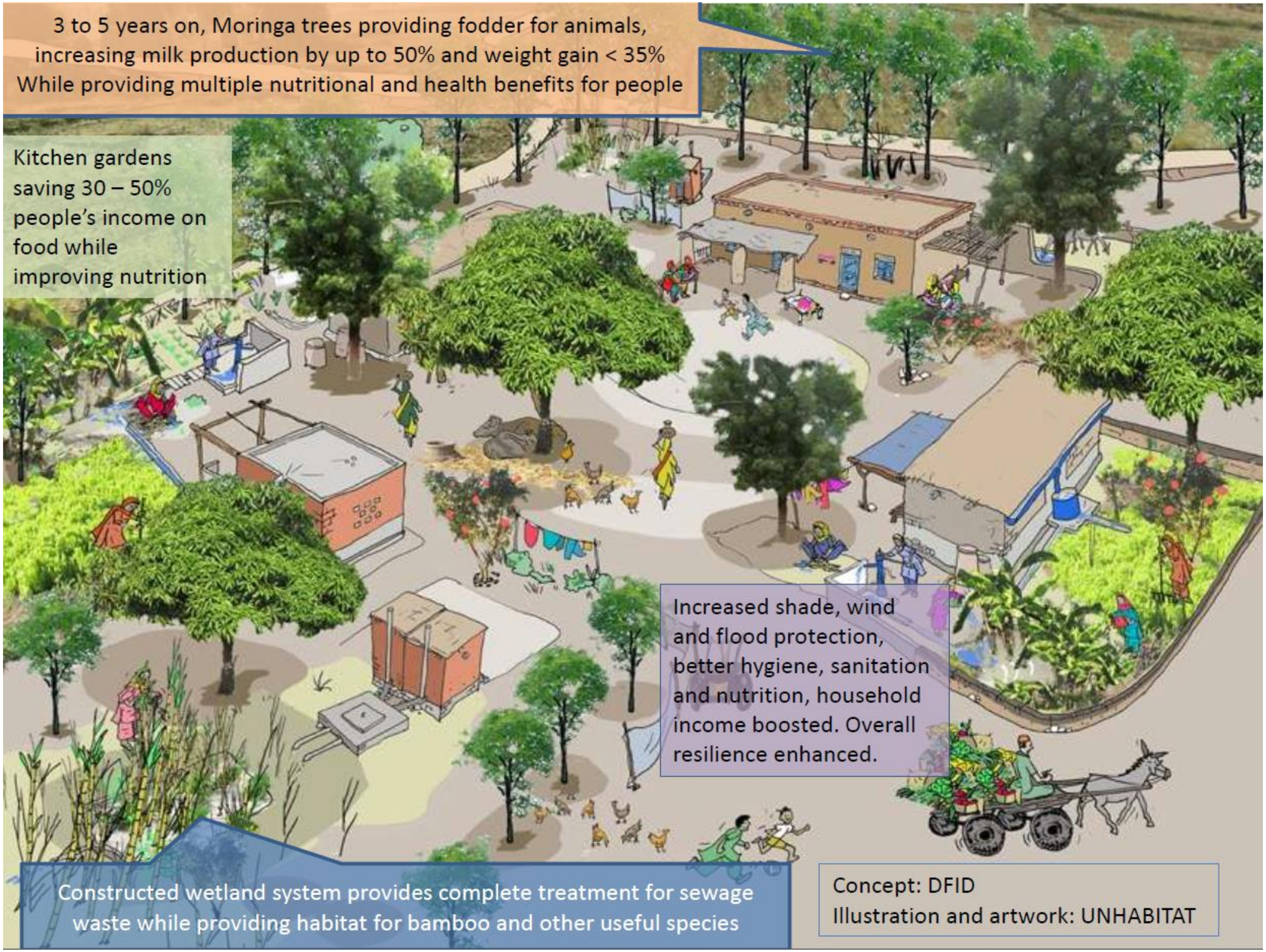
This is Brazilian design for transforming a septic tank system into a productive biological treatment system: http://www.youtube.com/watch?v=nhz0qzDVLkc


ACIMA DO NÍVEL DO SOLO
MANILHAS OU CASCAJES
ENTRADA DE EFLUENTE
TIJOLOS FURADOS


This series of pictures portrays normal village life in many villages in Pakistan and how, with community mobilisation and low-cost, appropriate design, the transformation that could be achieved. This need cost no more than conventional WASH and early recovery projects.
Residual water from hand-pump lying stagnant
With lack of fodder, goats roam free and eat emerging trees and plants
Overflow from septic tanks creating disease
Slide 1: A normal village in Sindh: little shade in the extreme heat, no kitchen gardens, high malnutrition, poor health and hygiene, deforestation, denuded environment, etc.

Slide 2: Hand-pump residual water directed to sunken "sponge" gardens, planted with bananas or other species; septic tanks linked to constructed wetlands; key tree species planted, rainwater collection initiated.

Slide 3: Goats enclosed and controlled. Sunken beds below hand-pumps planted. Kitchen gardens have started; constructed wetland for septic tank operational; specific native trees planted around the compound, including mango / other fruits, neem and moringa species for multiple nutritional and health benefits.


3 to 5 years on, Moringa trees providing fodder for animals, increasing milk production by up to 50% and weight gain < 35% While providing multiple nutritional and health benefits for people
Kitchen gardens saving 30 – 50% people's income on food while improving nutrition
Increased shade, wind and flood protection, better hygiene, sanitation and nutrition, household income boosted. Overall resilience enhanced.
Constructed wetland system provides complete treatment for sewage waste while providing habitat for bamboo and other useful species
Concept: DFID
Illustration and artwork: UNHABITAT