RMIT UNIVERSITY

worldskills

# WATER INNOVATION CHALLENGE

SINGAPORE, 2014

## Community Brief One Report

# Innovative solutions for local communities

## TEAM AUSTRALIA

# Innovative solutions for local communities

## CONTENTS

# 1 EXECUTIVE SUMMARY

This report presents the Team Australia design solution for a costed and sustainable sanitation system for a rural village in northern Bangladesh as specified in the Water Innovation Challenge brief. The report also provides details of the design process followed and the rationale for selecting the final design and rejecting others as either environmentally or economically unsuitable for conditions in northern Bangladesh.

The project team has researched and designed a system to manage human waste in a way that would enable residents of a rural village to have access to clean water and improved sanitary conditions

The design features a composting toilet, selected as the most effective means to address collection and storage of human waste under the climatic conditions of northern Bangladesh, and to mitigate against regular heavy monsoon rain, flooding and a high water table.

The design also features a constructed wetland system in which selected plants are used to treat liquid waste. This solution also offers residents a new source of stock feed in the form of the azolla used to purify the liquid waste, or under conditions where there is heavy metal contamination, an environmentally friendly strategy for absorbing the metals.

The report comprises three files:

- Team_Aust_WiC_brief1_mainreport
- Team_Aust_CAD_brief1
- Team_Aust_brief1_userguides

# 2 TEAM AUSTRALIA

## 2.1 Process of Team Selection

RMIT staff, Associate Professor Patricia McLaughlin and Dr. Helen Smith promoted the Water Innovation Challenge 2014 across degree offering and vocational schools in RMIT’s college of Science, Engineering and Health. They sent invitations asking higher education and vocational teachers to participate and promote the challenge to their students. Staff from the following areas of RMIT University came together to support the project:

- Science, Engineering and Health College Office
- School of Aerospace, Mechanical and Manufacturing Engineering
- School of Civil, Chemical and Environmental Engineering
- School of Applied Sciences
- School of Vocational Education
- School of Media and Communication
- Office of the Executive Director Vocational Education.

The project was promoted to students via email and class visits. Over 20 interested students were interviewed and a team of participants and supporters was assembled. Out of 20 interested students, who were interviewed, four students were selected as the team to compete in Singapore. The support team, known as the “pit team”, comprised of three RMIT Plumbing teachers, other students and staff. The team is also supported by WorldSkills Australia’s Graphic Design expert, who provided advice and design input to the final report.

*Members of Team Australia with a model of the sanitation prototype*

**The core team comprises the following:**

- two plumbing apprentices
- three sustainable systems engineering students
- a science graduate undertaking an environmental engineering degree
- the RMIT plumbing program manager and two plumbing teachers
- a graphic design teacher with CAD expertise
- a graphic design student
- a professional writing student.

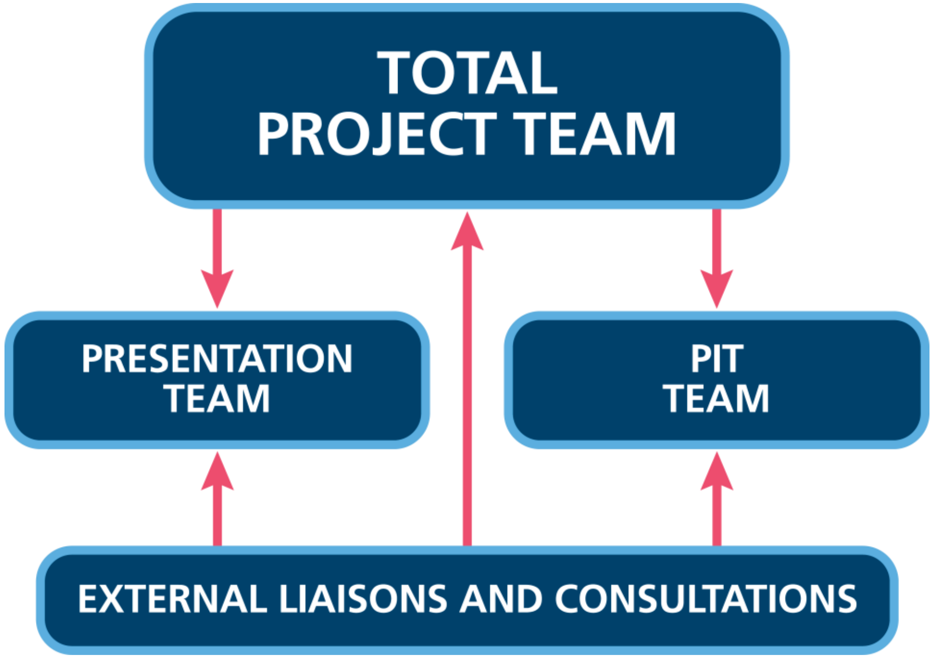



*Figure 1:. Team Australia structure*

**Each team member agreed to specific roles and responsibilities at the first meeting:**

**Helen Smith —** RMIT WorldSkills coordinator, liaison with WorldSkills, central liaison RMIT, team budget, resourcing

**Sean Mundy —** plumbing, sewerage liaison with Victorian works, worm research, crop and plant research, pumps, practical assembly

**Ali Suleman —** design engineer and presenter

**Nurul Driver —** Google Drive site set up and maintenance, liaison with film crew, media, social media, administration, research cultural and ethnic issues, timeline

**Leo Santilli —** engineering models, research water and plant types, worm and insect research, topography, weather

**Jack Featherstone —** dimensions, figures, modelling

**Wayne Ellerton —** model making, research local conditions, toilet parts, equipment, pumps, plumbing liaison, equipment costing

**Sebastian La Rocca —** sewerage advice, toilet models, costings, practical applications

**Catherine Ciavarella —** CAD, 3 D modelling, drawings

**Sarah Jones —** report writing, media, graphics

**Dale Fisher —** cartoons, drawings, handbook

**Tricia McLaughlin —** college office liaison, media

**Warren James —** compost toilets, existing Bangladesh sewerage research

**David Duddy —** sewerage research, fish and animal research, plumbing, practical models, drawings

*Checking last minute details at the final meeting*

*The Deputy Vice Chancellor Engagement & Vocational Education, Mr. John Barnes meets the team and reviews the design process*

# 3 THE DESIGN PROCESS

## 3.1 Development of Concept Design

The total project team commenced with a two hour brain storming session to flush out ideas, problems, team strengths and weaknesses as well as develop initial ideas.

At the first session the following main themes were discussed:

- methods to reclaim water, and treat and separate raw sewerage
- lagoonal waste water treatment
- compost toilet options
- cultural and ethical issues
- financial concerns
- investigation of environmental elements relevant to both models
- demographic and climatic data
- materials and availability
- timelines
- team members areas of expertise
- goals and objectives
- project management

The team agreed to form sub-groups to pursue these ideas and concepts. The weekly meetings then became a drawing-together of the work of the various sub-groups.

## 3.2 Weekly Project Meetings

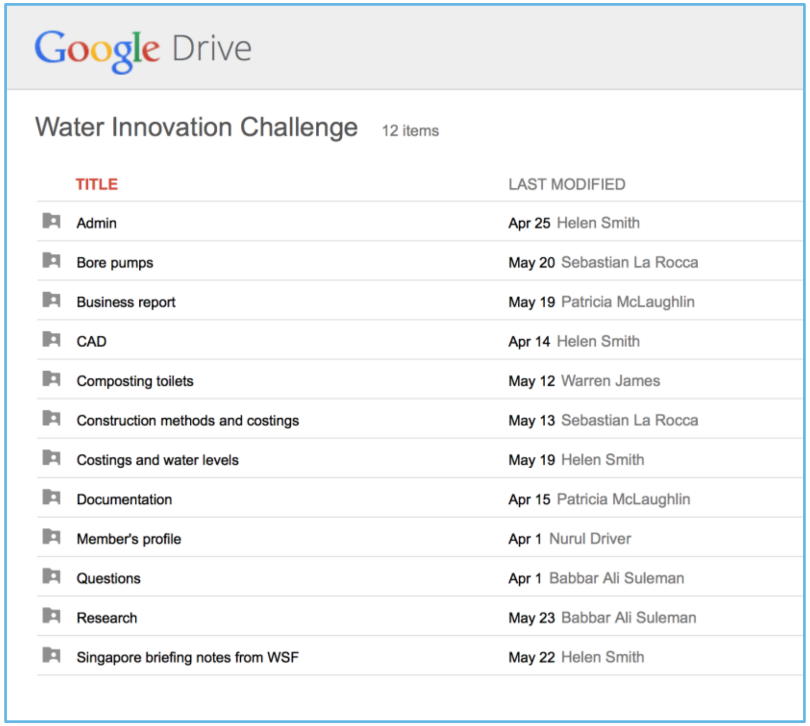
The team met over 6 weeks from early April until in the end of May. Project team meetings were well attended, even though not compulsory. Communication was supported by the Google Drive site, which was maintained throughout the 6 week period. The Google Drive site contained all meeting minutes and task action sheets.

One team member managed the Drive site and organised it to correspond with key deliverables:

- Bore pumps
- Business report
- CAD
- Documentation

– Composting toilet
– Construction methods and costing

- Meeting minutes/actions
- Members profile
- Questions
- Research



Google Drive

Water Innovation Challenge 12 items

| TITLE | LAST MODIFIED |
|---|---|
| Admin | Apr 25 Helen Smith |
| Bore pumps | May 20 Sebastian La Rocca |
| Business report | May 19 Patricia McLaughlin |
| CAD | Apr 14 Helen Smith |
| Composting toilets | May 12 Warren James |
| Construction methods and costings | May 13 Sebastian La Rocca |
| Costings and water levels | May 19 Helen Smith |
| Documentation | Apr 15 Patricia McLaughlin |
| Member's profile | Apr 1 Nurul Driver |
| Questions | Apr 1 Babbar Ali Suleman |
| Research | May 23 Babbar Ali Suleman |
| Singapore briefing notes from WSF | May 22 Helen Smith |

*Figure 2. Screen capture of the Team Australia Google Drive site*

## 3.3 Sub-Meetings

The sub-meetings, addressing particular themes, topics and project requirements were held each week.

- **Plumbing sub-meetings**

Meetings covered: plumbing, pan prototypes, models, sewerage systems, pipes, water, composting, toilet equipment, Bangladesh climate and topography, and ethnic and cultural concerns.

- **Engineering sub-meetings**

Meetings covered: plant and animal assistance/barriers to models, lagoon models of sewerage, movement of sewerage, statistics for scalability, cultural issues, topography, climate, temperatures, compost breakdown, minerals and recycling.

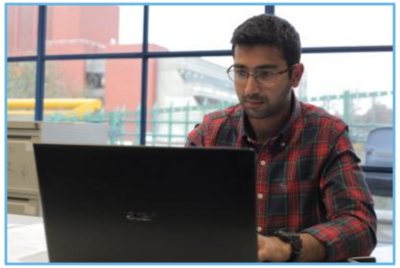
- **CAD sub meetings**

Meetings covered: drawings and the models for both the written report and the presentation.

- **Administration, Media & Resourcing**

Meetings covered: project media, equipment, resources, media, team needs, travel, documentation and project management.

*Nurul*



*Ali*

A range of guest speakers and research consultations assisted the project team:

- **Sarah Jones — Graphic Designer & TAFE Teacher**

– previous WorldSkills competitor
– current WorldSkills international expert
– information about report and research topics
– advice on presentation
– final report documentation.

- **Grant Stewart — WorldSkills Australia**

– advice regarding the competition
– technical details of the challenge.

- **Prof. Aidyn Mouradov — Algae and water plants Scientist**

– advice on water, plants and photosynthesis
– metal extraction plants
– water ecosystems.

- **Catherine Ciavarella — School of Design: RMIT University**

– CAD advice
– drawings and model making advice

*Tricia, Warren & Sam*

*Sean modelling the uniform*

# 4 OUR UNDERSTANDING OF THE PROJECT BRIEF

In the rural north of Bangladesh, drinking water is regularly polluted due to human waste entering the water table. This water is pumped from shallow wells by local families, and subsequently is a major cause of ill health and mortality – particularly in the young.

Existing local waste water systems have proven to be unsuccessful.

## 4.1 Current local environment

Northern Bangladesh is a rural area with housing dispersed across agricultural fields. A minimum of 10 people in any extended family share single dwellings. There are no toilets, personal washing facilities, or cooking utensil washing facilities in the region and the local community has requested all of these.

High water table conditions (near ground level) extend from May to October. For the rest of the year, the water table drops to a depth of 1.5m.  below village ground level. Village living areas are built up above field areas to prevent flooding. Hand pumps from shallow tube wells provide drinking water.

Limited transport is available. SAFE Bangladesh is the local partner.

## 4.2 Locally available materials

The local materials available are:

- cement stabilised earth blocks
- fired brick
- hand-mixed cement/concrete
- treated bamboo
- metal sheeting for roofing
- basic plumbing supplies, including pipes, taps, connectors and Asian type toilet pans
- basic hand tools
- cement tiles.

Electrical powered tools are limited so portable generator would be required

# 5 RESEARCH INTO THE LOCAL ENVIRONMENT

## 5.1 Physiography:

The extremely flat Bangladesh landmass was created by the delta-building activities of the three major rivers, the Ganges, the Brahmaputra and the Meghna, with some upland in the north-east and the south-east. The great plain lies almost at sea level along the southern part of the country and rises gradually towards the north. Land elevation in the plain varies from 1 to 90 metres above sea level from south to north. The maximum elevation is 1230 metres above sea level at Keocradang hill in Rangamati hill district.

The geo-morphology of the country comprises of a large portion of flood plains (79.1%), some terraces (8.3%) and hilly areas (12.6%).

## 5.2 Topography/soil

It is assumed that Northern Bangladesh will be where the final project solution will be so the soil tracts for the following districts have been explored: Rajshahi, Dinajpur and Bogra. The tract, called the Barind tract, has similarities with the Madhupur tract of Dhaka and Mymensingh districts.

### 5.2.1 Rajshahi, Dinajpur and Bogra districts (Barind tract):

Barind tract comprises parts of greater Rajshahi, Dinajpur and Bogra districts. The tract belongs to an old alluvial formation, which is usually composed of massive argillaceous beds of pale reddish brown, and often turns yellowish on weathering. Kankar and pisolitic ferruginous concretions occur throughout the tract. In the numerous depressions in the tract transplanted winter paddy is grown.

The nutrient status is below the average standard for Bangladesh. The soil is deficient in lime, nitrogen and phosphorous like the red soils of Madhupur Jungle tract and the PH varies from 6 to 6.5.
The manurial responses are the same as for the red soils of Madhupur Jungle tract.

### 5.2.2 Madhupur tract:

Red soil tract, or Madhupur tract, comprises parts of greater Dhaka and Mymensingh districts and extends through isolated tracts in Comilla and Noakhali towards south in Chittagong. This tract represents red lateritic soils of Madhupur Jungle area - a high land tract above the flood level intersected by numerous gentle depressions locally known as "Beels" that are highly valued for aman paddy.
The soils are very clayey containing numerous ferruginous concretions and are deficient in nitrogen, organic matter, phosphate and lime, i.e., they are low in plant nutrients. The analytical figures for these nutrients in these soils are below the standard of the Bangladesh average; however, these soils are relatively rich in iron and aluminium and are highly aggregated. The PH value lies between 5.5 and 6.
The soils have low base exchange capacity and high phosphate fixing capacity. Addition of organic matter is always helpful. For rice cultivation these soils give good response to the application of nitrogenous and phosphatic fertilisers. Bulky organic manures, such as cow dung, compost and town compost, provide a better response than chemical fertiliser. For sugar cane cultivation in addition to nitrogenous and phosphatic fertiliser, lime has to be added to these soils. Potassic fertilisers are in addition required for fibre crops. For vegetables, combinations of bulky organic manures, lime and chemical fertilisers supplying nitrogen and phosphorous are necessary for successful and profitable agriculture.

*ICID – Irrigation & Drainage in the World – A Global Review 3*

# 5.3 Local agriculture

Research conducted about Bangladesh soil and crops found the following:

**Native soils:**

Bangladesh soil has some of the lowest organic matter (OM) content in the world, average 1.75%. This is one of the main constraints on Bangladesh agriculture. Low lying areas have an OM of 5.5% and peat of at least 20%. The soils are generally deficient on nitrogen, phosphorus (rated as low to medium), potassium and sulphur (except in the coast, but the north especially). The average Bangladesh soil has a pH of 5.5-6.5, while the Gangetic alluvial soils have pH of 7.3-8.3.

**Rice:**

- Soil pH: 5.5-8
- Harvest: half of the harvest happens during aman, which occurs during November and December. The other harvest, aus, is sown in April or March and harvested in the summer

**Jute:**

- Soil pH: 5-8.6
- Harvest: Sown in March or April, harvested in spring

**Other crops include:**

- Fallow fields are sown with vegetables, peanuts, pulses, or oilseeds.
- Spices such as: onion, garlic, turmeric, ginger, chilli
- Fruits such as: jackfruit, pineapple, jujube, guava, banana, lemon and papaya

# 5.4 Pollutants and soil contamination

Soil in Bangladesh contains a large number of contaminants. Research has been conducted in regards to utilising local plants in order to reduce the amount of arsenic in the soil.

"Soil and water contaminated with arsenic (As) pose a major environmental and human health problem in Bangladesh. Phytoremediation, a plant-based technology, may provide an economically viable solution for remediating the As-polluted sites. The use of indigenous plants with a high tolerance and accumulation capacity for As may be a very convenient approach for phytoremediation." (Mahmud, Inoue, Kasajima, & Shaheen, 2008)

Figures 3 and 4 below show commonly available land and water plants with high accumulation capacities.

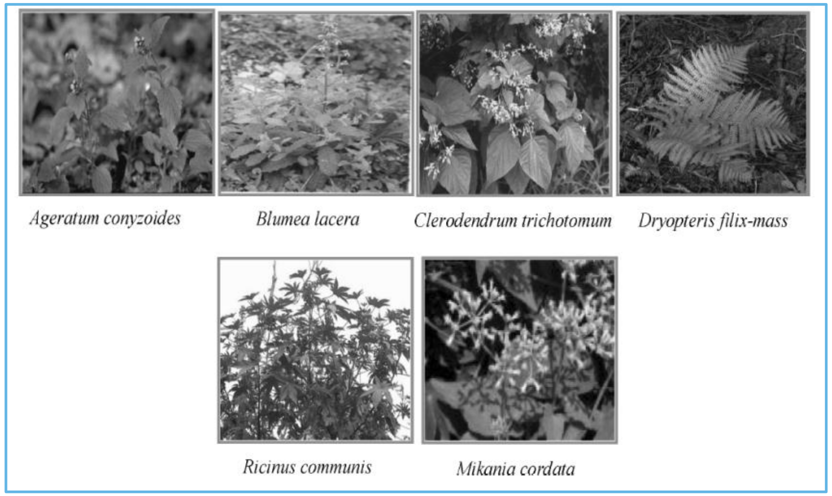



*Figure 3. Effective arsenic hyperaccumulating land plant species*

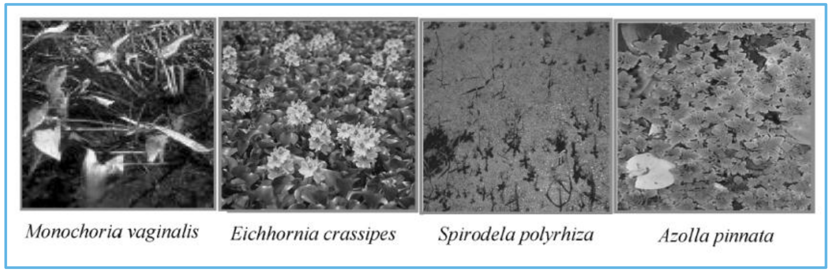



*Figure 4. Arsenic hyper-accumulating wetland and floating plant species*

## 5.5 Weather

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max. Temp (°C) | 25.4 | 28.1 | 32.3 | 34.2 | 33.4 | 31.7 | 31.1 | 31.3 | 31.6 | 31.0 | 28.9 | 26.1 |
| Min. Temp (°C) | 12.3 | 14.0 | 19.0 | 23.1 | 24.5 | 25.5 | 25.7 | 25.8 | 25.5 | 23.5 | 18.5 | 13.7 |
| Rainfall (mm) | 07.0 | 19.8 | 40.7 | 110.7 | 257.5 | 460.9 | 517.6 | 431.9 | 289.9 | 184.2 | 35.0 | 09.4 |

*Figure 5. Average annual weather patterns in Bangladesh*

Bangladesh is prone to heavy rainfall and flooding throughout the year. The following is an excerpt from research conducted in regards to rainfall mapping:

“Bangladesh is a flood prone country where huge damages take place every year. Therefore, to minimize flood extremes, it is important to control the flood peaks at the upstream area through suitable watershed management practices...Extreme rainfall events cause flood disasters and damage life, socio-economic infrastructures, and heritages. Bangladesh is a developing country and vulnerable to frequent natural disasters caused by floods and cyclonic storms. In recent years, it has been observed that extreme rainfall is the individual phenomena that creates catastrophic floods where and when river or flash floods are not a concern. Dhaka, a capital city of Bangladesh, experienced its heaviest rainfall of 341 mm in a day (on September 12, 2004) (Tawhid 2004). Due to this rainfall event, the city was waterlogged for the next few days and severe drainage congestion occurred, along with sewerage overflow, which caused health hazards and immense suffering of human life....Subsequently, in October of 2008, in the south-western part of Bangladesh, Satkhira and Jessore districts faced severe flooding that caused nine villages to be submerged. Crops were destroyed, shrimp enclosures were washed away and 8,000 people were rendered homeless when a section of the flood protection embankment on the Kobadak in Satkhira near the Sundarbans was destroyed.” (Rahman, Sarkar, Najafi, & Rai, 2013)

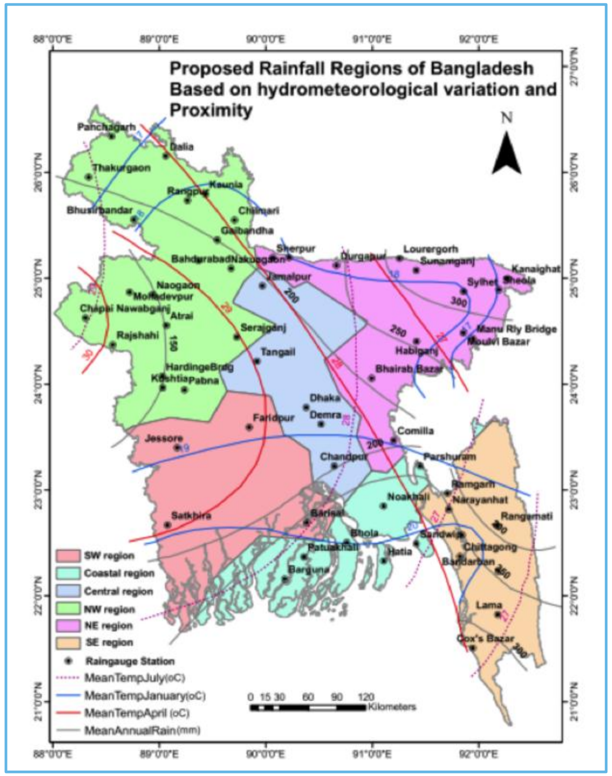



*Figure 6. Spatial distribution of rainfall across 68 stations*

## 5.6 Ground water conditions

Unconsolidated sediments, which range in age from tertiary to recent, mainly underlie Bangladesh.

The sediments are generally thick over most of the country. There are two aquifers in the country: the upper aquifer and the main aquifer. In most areas these two aquifers are probably hydraulically interconnected. The main aquifer in most parts occurs at depths of less than five meters in the northwest.

Ground water levels are highest from August through October and lowest in April and May. A sharp rise in water level generally begins in May and continues until July. The range of fluctuation is from three to six metres in most areas. After July, the rate of rise decreases, and in many areas ground water levels remains almost stationary from August to October, indicating rejection of recharge because the aquifer is filled to capacity. The rejected recharge varies from place to place and depends upon several factors, including permeability of surface materials, rainfall amount and intensity, and the time factor.

*ICID – Irrigation & Drainage in the World – A Global Review 5*

Recharge to ground water occurs primarily through direct infiltration of rainfall. Actual recharge is considerably less than potential recharges. Highest potential recharge occurs in Dinajpur, Mymensingh, Sylhet, Noakhali and Chittagong. The lowest potential recharge occurs in western Bangladesh in Rajshahi, Kushtia and Pabna.

*http://www.icid.org/i_d_bangladesh.pdf*

## 5.7 Septic Tank Sewerage in Bangladesh

The use of septic tanks is the most ancient decentralised human waste treatment system, based on the principle of percolation through soil as a means of progressive purification. This septic system, consisting of a sedimentation tank and an absorption field, is used in Bangladesh.

However, because of the high groundwater table and consistent heavy rainfall, the result is not only septic tank failure but also contamination of shallow groundwater aquifers, which is a major source of drinking water supply for rural communities.

# 6 ASSUMPTIONS UNDERLYING THE TEAM AUSTRALIA DESIGN

The project has been designed with the following assumptions.

### 6.1.1 Community Size

The concept design is fit for purpose for 10 people.

### 6.1.2 Community Design

The concept design is scalable.

### 6.1.3 Weather

Average Bangladesh rainfall and temperature conditions assumed.

### 6.1.4 Project Timing

Project will commence and be completed outside Monsoon season (October – June).

### 6.1.5 Toilet Pans

Vitreous china pans (separated squat pan) are available and produced locally.

### 6.1.6 Cultural Assumptions

The ethnic and cultural breakdown is approximately 83% Muslim, 16% Hindu and 1% others.

### 6.1.7 Local Assistance

Local equipment/tools/labour as described in the project brief.

### 6.1.8 Topography

Topography soil and weather conditions are as per recorded trends.

### 6.1.9 Individual Waste Accumulation

Human waste will accumulate at 2000 litres per person per annum.

### 6.1.10 Sewerage System Usage

The sewerage system is in 24 hours, 7 days per week usage.

### 6.1.11 Toilet Configuration

Toilets will be Communal.

7 PROJECT SOLUTION

## 7.1 Summary

The project solution will deliver ownership of communal composting toilets to the local Bangladesh community. The solution consists of 4 separate toilets, with the basement at an elevated level to secure the system from flooding.

The composting toilet has been selected for our design, because it can mitigate high ground water level and will enable treatment of human waste in the least hazard and risk prone method. The communal toilet being designed for northern part of Bangladesh includes 4 toilet cubicles housed in a communal facility to accommodate the local population, assuming they have no toilet facilities in their private dwellings. Each toilet will be fitted with a ceramic separator squat pan, where the faecal matter drops and undergoes aerobic digestion i.e. treatment of solid waste, while the urine discharge is funnelled into a pipe for storage and collection as a liquid fertiliser.

Any leachate collected in the form of grey water is drained out through the composting containers and passed into a macro sized constructed wetland for further treatment and finally to discharge as environmental flow or collection and use as irrigation water.

Figure 7 shows the key components of a standard model for a composting toilet.

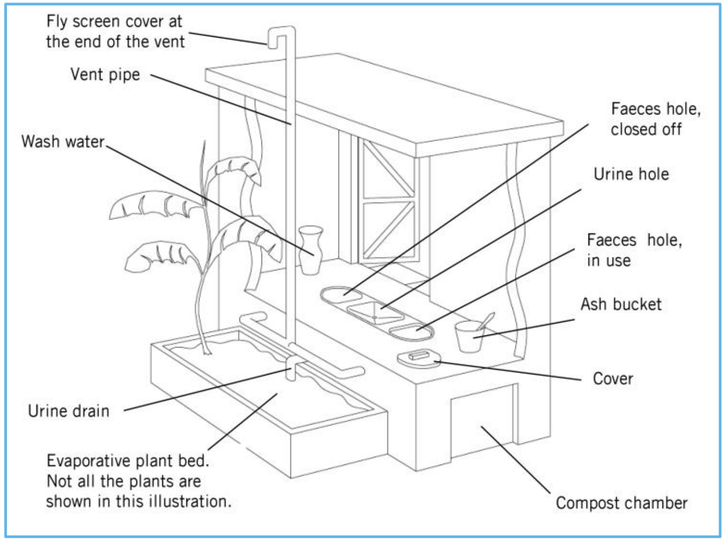



*Figure 7. Key components of a composting toilet*

## 7.2 Cultural and economic considerations

### 7.2.1 Culture

It was decided that for cultural and religious reasons the final project solution would utilise squat toilets over sitting toilets. 83% of the Bangladesh population is Muslim, 16% Hindu and 1% comprises of other religions. Various sources state that Muslims more commonly use squat toilets and that there are health benefits to using a squat toilet.

http://www.factrover.com/people/Bangladesh_people.html

http://www.yanabi.com/index.php?/topic/429225-squatting-toilets-are-better-for-your-health/

http://www.toilet-related-ailments.com/squatting.html

### 7.2.2 Reuse of solid and liquid waste on crops

With appropriate treatment, both solid and liquid human waste can be safely used as a fertiliser for crops. Table 1 below indicates how much annual excretion is required in order to produce fertiliser for cereal crops. Based on the average production of waste per person, the planned system can produce sufficient fertiliser for cereal production for the villagers, plus the potential for cash crop production.

**TABLE 1:** ANNUAL EXCRETION OF ONE HUMAN, COMPARED WITH THE AMOUNT OF FERTILIZER NEEDED TO PRODUCE CEREAL

| Fertilizer | 500 liters urine | 50 liters feces | Total Excreta | Fertilizer needed for 230 kg of cereal |
|---|---|---|---|---|
| Nitrogen | 5.6 kg | 0.009 kg | 5.7 kg | 5.6 kg |
| Phosphorous | 0.4 kg | 0.19 kg | 0.6 kg | 0.7 kg |
| Potassium | 1.0 kg | 0.17 kg | 1.2 kg | 1.2 kg |
| Total (N+P+K) | 7.0 kg (94%) | 0.45 kg (6%) | 7.5 kg (100%) | 7.5 kg (100%) |

*Source:* Wolgast (1993), quoted in Austin & Van Vuuren (2001)

*Figure 8. Table of annual excretion compared of one human compared with the amount of fertiliser need to produce cereal.*

### 7.2.3 Opportunities for local economic enterprise

Bangladeshi villagers currently makes a living out of recycling plastic bottles and exports the after-products, such as tableware and kitchenware, pet bottle, chair, table, bathtub, jug, mug, bucket, container, food box, flasks, plates, glasses, spoons, soap case, toilet brush, pan, toys, artificial flowers and clocks. The project can make use of this existing and already-thriving industry by utilising the recycled plastic materials for the toilet pan. Providing the design to the Bangladeshi industry optimises local labour, provides more jobs and makes an all-round contribution to the economy and sanitation of not only the local village but also the country. This would be a better solution than using expensive materials or imported materials such as the Bill & Melinda Gates Foundation toilet pan.

*http://www.environmentalleader.com/2008/08/11/bangladesh-turns-plastic-bottles-into-export-industry/*

### 7.2.4 Promoting Sanitation Awareness

Providing an awareness of improving the village's sewage treatment facilities we can optimize the full effect of our project. We are aware of existing successful schemes to promote sanitary awareness – for example the Village Education Resource Centre program (see appendix for further details). Team Australia awareness programs will adopt and adapt strategies used in these successful programs.

We aim to approach this in a number of ways:

1. Getting local students involved with the project as sanitation champions. a Activities include:
    - reproducing the user manual as a 'fresco' in the toilet building itself – or on the outside walls;
    - designing leaflets and posters to promote the new system to the village.
    - leading community awareness workshops.
2. Work with village leaders to develop a community education program.
3. Work with leaders to identify a member of the community willing to take on the role of toilet attendant to maintain the wellbeing the facility and its users.
4. Providing the community with an illustrated manual to understand the system (see the User Guide file).

# 7.3 Evolution of the design

Figures 9-12 illustrate the process of adapting this model to the conditions appropriate for the environmental and cultural conditions in northern Bangladesh

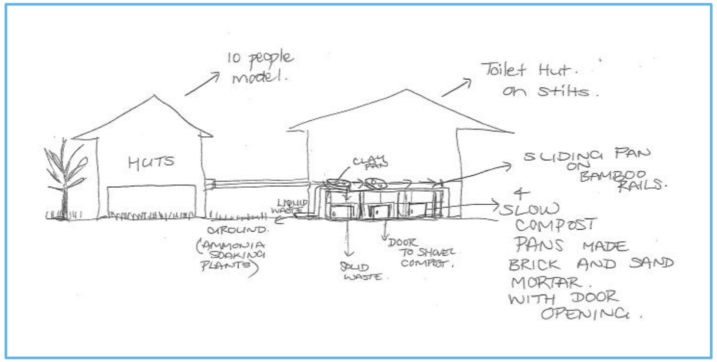



*Figure 9. An early design sketch showing the suggested configuration of the toilet block in relation to village dwellings.*

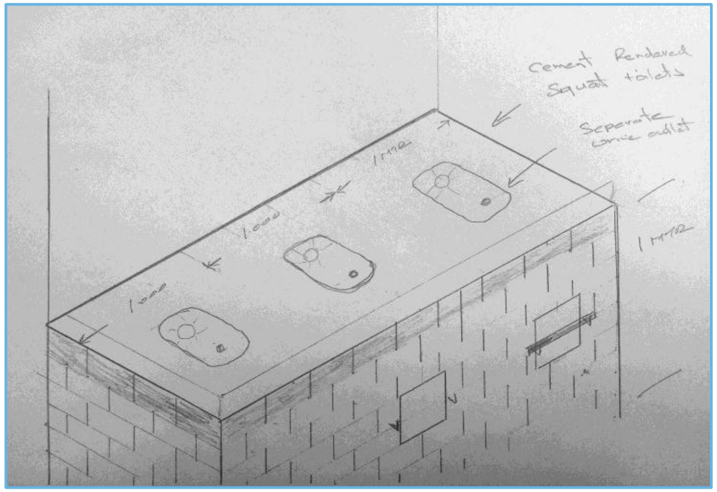



*Figure 10. Construction of the latrines*

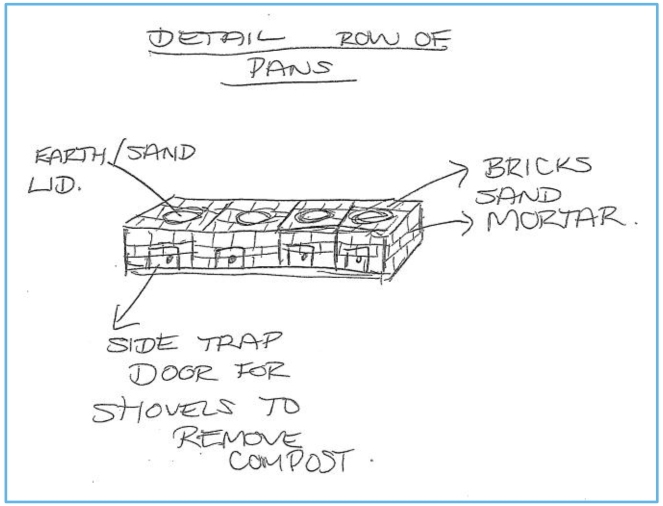



*Figure 11. The four latrine configuration*

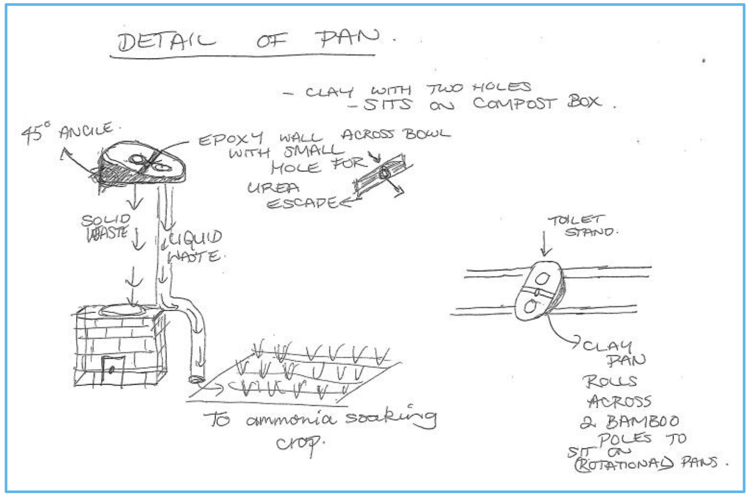



*Figure 12. Working out the separation of solid and liquid waste*

## 7.4 Design elements considered and rejected

A range of design elements were considered during the design phase, including the development of a bladder-based ‘lagoon and the use of fish or worms to break down the sewage sludge; and a range of variations on the standard composting toilet model.

The lagoon model was rejected on the following grounds:

- practicality - in particular the difficulty in sealing and aerating the system:
- unpleasant odours
- land excavation issues
- size of land required
- availability of resources
- emphasis on water reuse rather than solid waste storage and usage
- maintenance
- natural flooding, disasters
- risk of animals or children falling into water
- pest infestation.

Utilising fish, specifically Silver carp, to break down the sewage sludge was considered for the lagoon model. Silver Carp is a filter feeder, meaning that they’re very good at controlling the quality of water by breaking down microorganisms. They also have a high reproduction rate which lowers the risk of them being eliminated by animals feeding on them.

It was decided fish were not the best option as Silver carp are a freshwater fish and, since the lagoon would be filled with high concentrations of urea, the lagoon would be uninhabitable for them to survive. In addition, a study conducted stated that 216 different species of Silver Carp had parasitic infestation, which is a major threat to aquaculture.

*About carp: http://www.fao.org/fishery/culturedspecies/Hypophthalmichthys_molitrix/en*

*Parasite link: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3520457/*

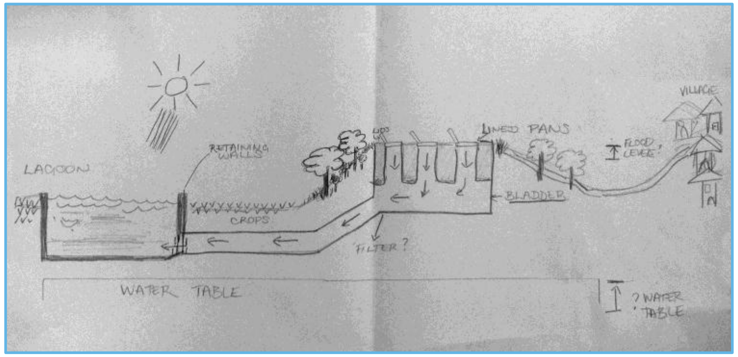



*Figure 13. Conceptual diagram of the lagoon option.*

The use of windmills and solar pumps to aerate the system was also ultimately rejected on the grounds that we could not guarantee the availability of materials and solar infrastructure, and because this option added complexity to the maintenance of the system

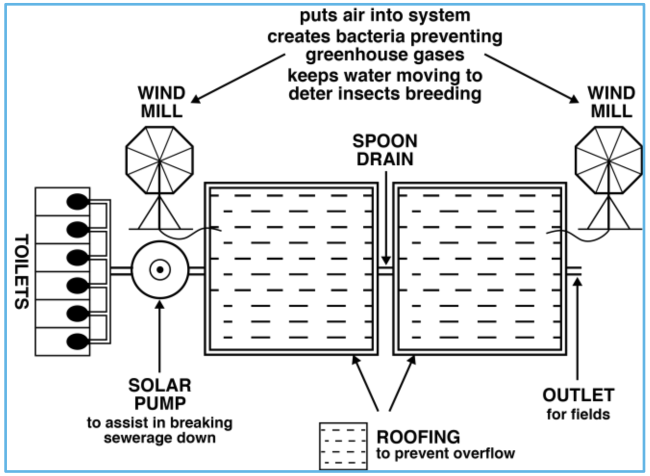



*Figure 14. Infrastructure requirements for the use of windmills and solar power*

## 7.5 Design of treatment options for human waste

### 7.5.1 Solid waste treatment

**Aerobic Composting**

Biodegradation of human excreta in the presence of oxygen is termed aerobic and in the absence of oxygen is anaerobic (Hickman, 1999). Composting toilets make use of aerobic processes with the aid of micro-organisms for the treatment of solid waste, reduction in E.coli and other harmful pathogens, into more stable and useable products such as fertilisers for use on crops, and as a soil conditioner where it improves soil chemical and physical properties.

**Stabilisation & Maturing**

Stabilisation is the decomposition of easily degradable organic matter causing rapid temperature increase over a few days; whereas maturing is the decomposition of slowly degradable organic matter resulting in gradual temperature decrease over a period of approximately 3 months.

**Parameters for Aerobic Composting**

Human waste is broken down by oxygen utilising microorganisms, during this reaction a large amount of chemical energy is released as heat (Dahi, 1997). There are several parameters that control the extent of the process. When designing a compost toilet for use in developing countries conditions are unlikely to favour high growth rate of microbes that are responsible for the decomposition of organic matter; however conditions such as moisture content, oxygen and the carbon/nitrogen ratio can be manipulated in order to increase the rate of decomposition and as a result rise the temperature of the compost.

**Temperature**

Aerobic decomposition is an exothermic process, capable of releasing a large amount of heat. It is this heat which is responsible for the destruction of pathogens in the compost (Bitton, 1999).

**Carbon/ Nitrogen ratio**

Micro-organisms that are responsible for the exothermic decomposition require relatively large amounts of carbon and nitrogen; consequently, these elements are crucial to microbe reproduction and a balance of the two is needed for optimum microbial activity.

Stabilisation phase requires a relatively large carbon ratio compared to nitrogen of approximately 30:1. The ratio is very important for the function of the system as without excess carbon the system will not attain the high temperatures, which are vital for the removal of harmful pathogens. Excess nitrogen gives pungent odours by converting free nitrogen or ammonia gas.

**Aeration**

The general reaction that describes the aerobic decomposition of organic matter can be written as CaHbOcNdSe +O2→ CO2 + H2O +NH3 + SO4 2-

In the absence of oxygen the reaction rate for the breakdown is reduced and high temperatures are not attained, which are essential for pathogen destruction. Therefore it is important for the composting container to be fully aerated by allowing air to flow through the compost pile and to be mechanically turned for complete aeration.

Moisture is another crucial factor in aerobic decomposition and also has a significant impact on the effect of temperature obtained within the composting container.  Excess moisture saturates the human waste and inhibits air circulation and oxygen passage

The recommended moisture content for the effective aerobic decomposition is in the range of 40-60 percent.

**Removal of waste from ground**

Waste will be removed with a shovel via access doors when it is ready for harvest.

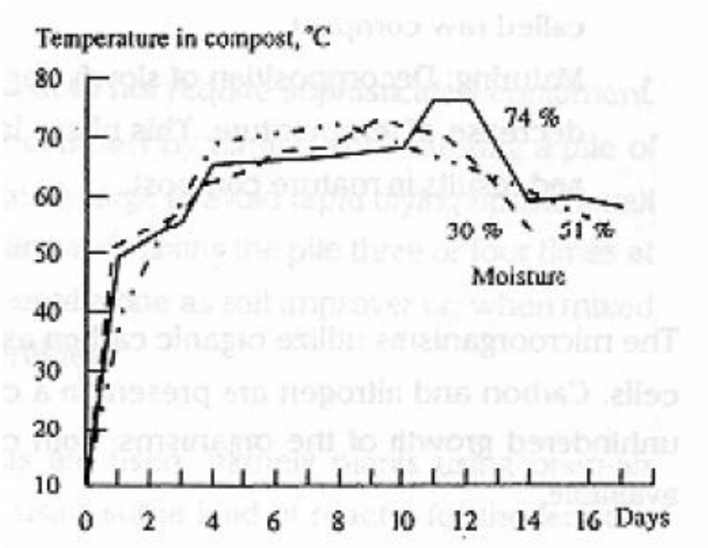



*Figure 15. Temperature increase during the composting of organic waste (Dahi, 1997)*

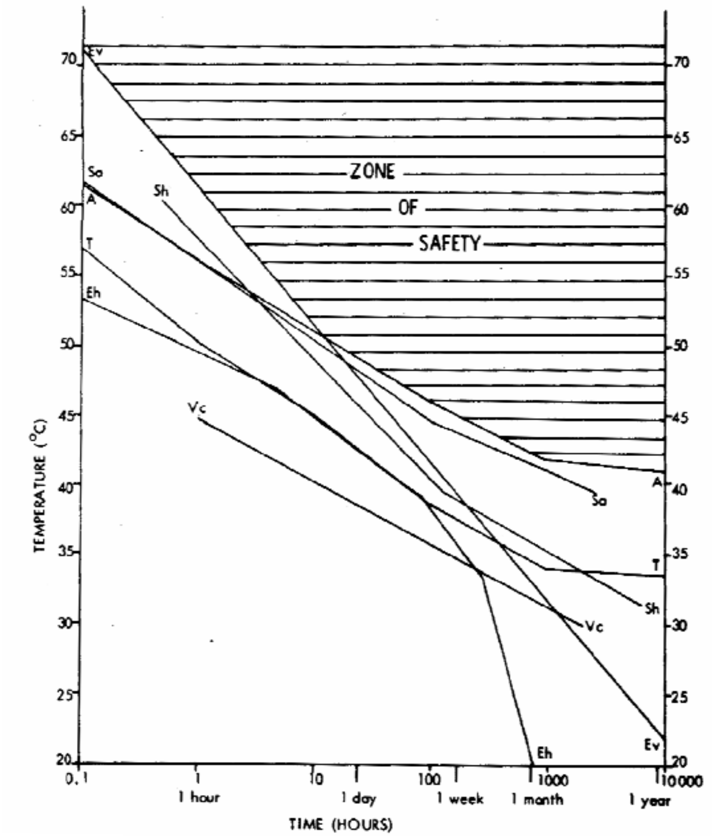
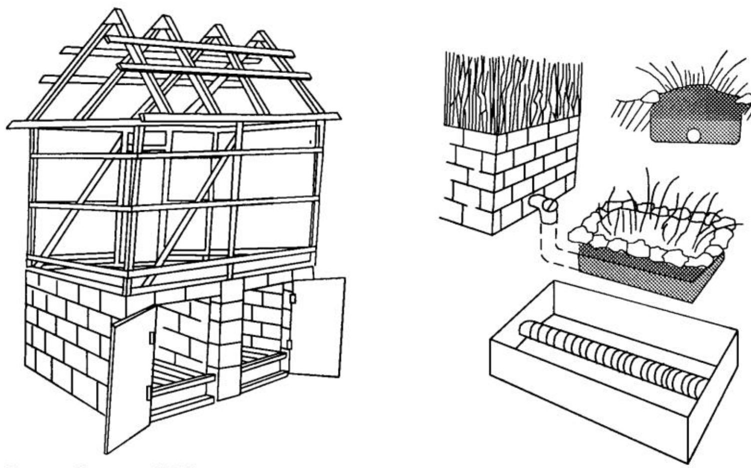



*Figure 16. The influence of time and temperature on a variety of excreted pathogens*

## 7.5.2 Treatment of liquid waste

Wetlands have been selected for the treatment of industrial and agricultural effluent. Constructed wetlands emulate natural wetlands due to their ability to significantly improve water quality through a combination of complex physical, biological and chemical interactions that is usually achieved in treatment facility, which are very expensive to build, operate and maintain as well as being very unsustainable through the entire life cycle of the plant.



Source: Crennan, 1996

*Based on an owner-built design used in Australia.*

*Figure 17. Illustration of a standard liquid waste treatment set-up*

Constructed wetland technology is not new; it is a technology that has been used for many years and currently experiencing a resurgence. Constructed wetlands can potentially be designed for flow operations that range from less than 4m$^3$/d to over 75,000m$^3$/d (Melbourne Water, 2014); therefore, the capacity to delivery reusable water is technically achievable.

Wetlands not only significantly improve water quality but also provide recreational, environmental and educational benefits. Constructed wetlands are classified according to the life form of the dominating macrophyte in the wetland into (a) free floating macrophyte-based systems (b) emergent macrophyte-based systems and (c) submerged macrophyte based systems (Brix, 1993a). Each has its advantages and disadvantages.

The decision to use a decentralised treatment such as wetlands is primarily due to the highly variable pollutant species produced in human waste.

## 7.6 Designing a Wetland Treatment Process

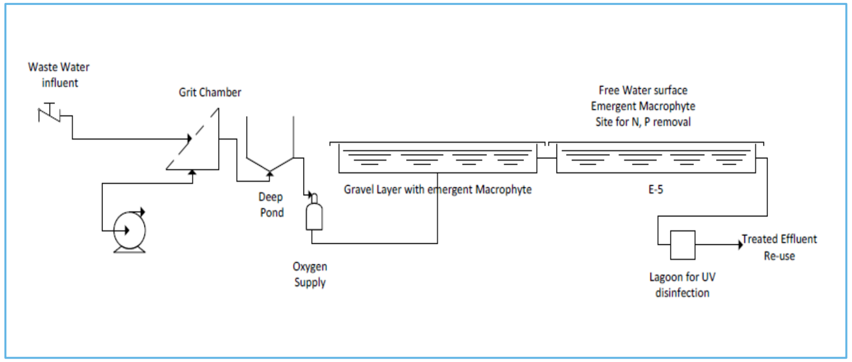
Wetlands are classified into two general types: horizontal flow systems and vertical flow systems. Horizontal flow systems are further divided into (a) free water surface flow system and (b) subsurface flow systems.

Free water surface flow systems flood the land and the water surface is exposed to the atmosphere, whereas with the sub-surface flow system the water level is maintained below the surface of the medium of placed beds, which usually composed of soil, gravel or sand (Brix, 1994).

Both systems have their flaws and merits and engineering systems can be established to minimise risks such as mosquito breeding, which is discussed by (Greenway, 2005) explaining how aquatic organisms can reduce the risk by predation on mosquito larvae. Subsurface wetland treatment requires substantial gravel fill which can be very cost intensive and prone to clogging, thereby reducing the life of the wetland (Vymazal, 2005). This flaw in design can be minimised by introducing grit chambers and deep ponds within the treatment chain which act and function as clarifiers.

The following constructed wetland systems make use of both horizontal flow systems in its treatment chain. Unlike natural wetlands, constructed wetlands treat wastewater in a highly controlled environment. The treatment chain proposed consists of the following units as shown in the figure on the following page.

*Figure 18. The functional schematic of a constructed wetland treatment system*




### 7.6.1 Role of plants in waste water treatment

The most significant function of wetland plays with water purification is the physical effect brought by the presence of plants. The plants provide a enormous surface area for the attachment and growth of microbes that are essentially the power-house for wastewater treatment. The physical components of the plant stabilise the surface of the beds, slow down the water flow thus assist in sediment settling and trapping processes and finally increase water transparency.

Wetlands plants play a vital role in the removal and retention of nutrients and help in preventing the eutrophication of wetlands. A wide range of wetland plants assist in the breakdown of wastewater. These plants have a large biomass both above and below the surface substrate. The subsurface plant tissue grows horizontally and vertically, creating an extensive matrix which binds to soil particles creating large surface areas for the uptake of nutrients and ions.

Hollow vessels in the plant tissue enable oxygen to be transported from the leaves to the root zone and to the surrounding soil (Armstong et al, 1990). This enables the active microbial aerobic decomposition process and the uptake of pollutants from the water sytem to take place.

**The roles of wetland plants in wetland systems can be divided into 5 categories:**

1. **Physical:** Macrophytes stabilise the surface of plant beds providing good conditions for physical filtration and a huge surface area for attached microbial growth. Macrophytes growing reduces current velocity, which allows for sedimentation and increase in contact time between effluent and plant surface area. This increases the removal of nitrogen.
2. **Soil hydraulic conductivity:** Soil hydraulic conductivity is improved in an emergent plant bed system. Turnover of root mass creates macropores in a constructed wetland soil system which allows greater percolation of water. This increases effluent and plant interactions.
3. **Organic compound release:** Plants have been shown to release a variety of organic compounds through their root systems at a rate up to 25% of the total photosynthetically fixed carbon. This carbon release may act as a source of food for denitrifying microbes (Brix, 1997). Decomposing plant biomass also provides durable, readily available carbon source for microbial populations.
4. **Microbial growth macrophytes:** Microbial growth macrophytes have above and below ground biomass to provide large surface areas for growth of microbial biofilms. These biofilms are responsible for a majority of microbial processes in a constructed wetland system, including nitrogen reduction (Brix, 1997).
5. **Creation of aerobic soils:** Macrophytes mediate the transfer of oxygen through the hollow plant tissue and leakage from root systems to the rhizosphere where aerobic degradation of organic matter and nitrification takes place.

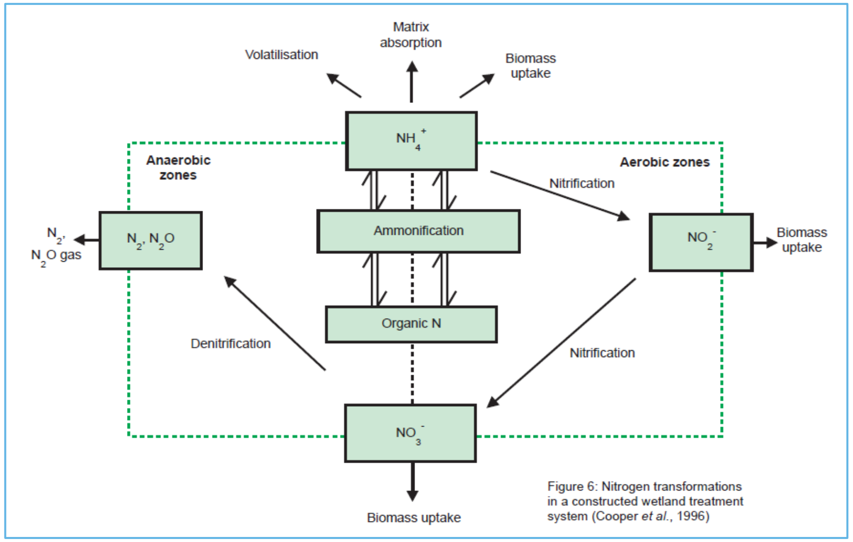
### 7.6.2 Nitrogen Removal Mechanisms

Nitrogen exists in various forms: ammonical nitrogen ($NH_3$ & $NH_4^+$), organic nitrogen and oxidised nitrogen ($NO_2^-$ & $NO_3^-$). The removal of nitrogen is achieved through nitrification/de-nitrification, volatilisation of ammonia ($NH_3$), storage in detritus, sediment and uptake by wetland plants, and storage in plant biomass (Brix, 1993). Majority of the nitrogen removal occurs through either plant uptake or de-nitrification. Nitrogen uptake is significant if plants are harvested and biomass removed from the system.

At the root soil interface, atmospheric oxygen diffuses into the rhizosphere through the leaves, stems, rhizomes and roots of the wetlands plants thus creating an aerobic layer similar to those that exists in the media-water or media-air interface. Nitrogen transformation takes place in the oxidised and reduced layers of media, the root media interface and below ground portion of the emergent plants. Ammonification takes place where organic N is mineralised to $NH_4$+-N in both oxidised and reduced layers. The oxidised layer and the submerged portions of plants are important sites for nitrification in which ammonical nitrogen is converted to nitrite ($NO_2$-) by the nitrosomonas bacteria and eventually to nitrate ($NO_3$-) by the nitrobacter bacteria which is either taken up by the plants or diffused into the reduced zone where it is converted to $N_2$ and $N_2O$ by de-nitrification process.

De-nitrification is the permanent removal of nitrogen from the system; however the process is limited by a number of factors such as temperature, pH, redox potential carbon availability and nitrate availability (Johnston, 1991).

*Figure 19. Aerobic and anaerobic elements of the nitrogen cycle*




*(Cooper et al 1996)*

### 7.6.3 Phosphorous Removal

Phosphorous is present in waste waters as orthophosphates, dehydrated orthophosphates (poly-phosphates) and organic phosphates. The conversion of most phosphates to the orthophosphate forms ($H_2PO_4$-, $PO_{42}$-, $PO_{43}$-) is caused by biological oxidation.

Most of the phosphorous component is fixed within the soil media. Phosphate removal is achieved by physical and chemical processes, by adsorption, complexation, and precipitation involving calcium, iron and aluminium.

Substantial amounts of phosphorous are removed by plant and the rate of the removal is most dependent on plant harvesting (Brix, 1994).

### 7.6.4 Metal Removal

Metals such as zinc and copper occur in soluble or particulate associated forms and the distribution in these forms are determined by physio-chemical processes such as adsorption, precipitation, complexation, sedimentation, erosion and diffusion. Metals accumulate in a bed matrix with organic material, which is directly taken up by the vegetation.

### 7.6.5 Pathogens

The treatment mechanisms for the removal of pathogens are mainly by sedimentation, filtration and absorption by biomass or through natural die-off or predation (Ref). Viruses can be removed by adding lagoons to the treatment chain where the virus is treated with UV light from the sun, a sustainable technology.

### 7.6.6 Selection of Wetland Plants

The selection of wetlands plants is the integral component for the successful treatment of wastewater effluent and can be divided into deep rooted and shallow marshes.

*Figure 20. Aquatic Floating Macrophytes: Duckweed & Azolla*

Duckweed, elodea and water clover are known for their ability to uptake Se and heavy metals from Se-rich mining wastewater. Growth of these plants species covers different depth zones of water ponds and wetlands.

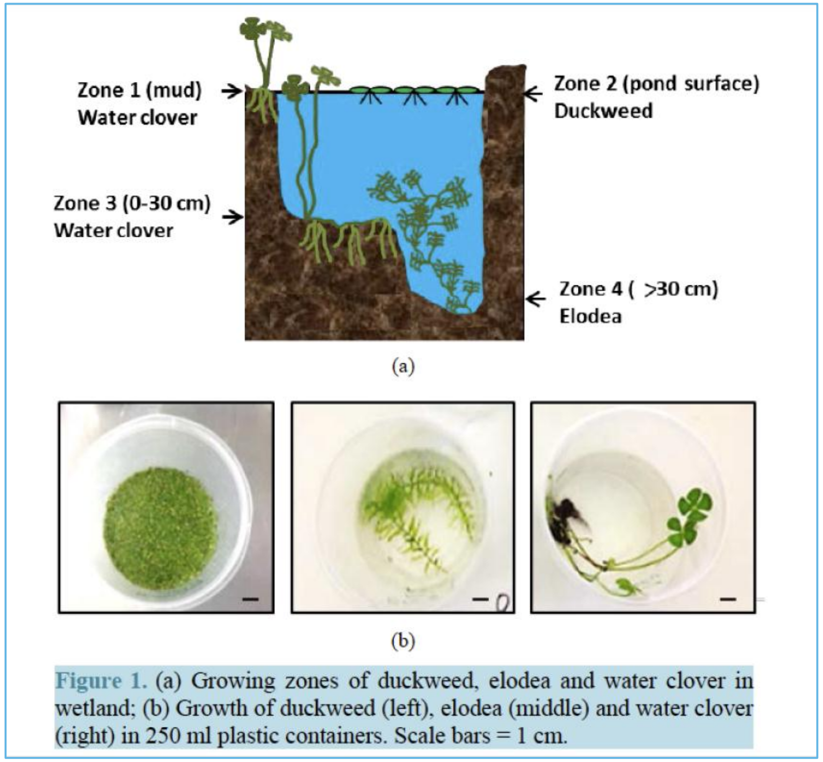



*Figure 21. Application of Aquatic Plants for the Treatment Wastewater and Production of Renewable Fuels and Petrochemicals: Ana F. Miranda, Nazim Muradov, Amit Gujar, Trevor Stevenson, Dayanthi Nugegoda, Andrew S. Ball, Aidyn Mouradov*

On the recommendation of Professor Aidyn Mouradov, Team Australia has opted to use azolla in the treatment of liquid waste. Azolla is a natural wastewater treatment option: It feeds on nitrogen and phosphate organic pollutants with absorption rates: total N: 9.1 t/ha-year ; total P: 0.8 t/ha-year. It can also absorb and concentrate heavy metals. Duckweed is one of the fastest growing plants, which doubles its biomass every two days. It will grow in water temperatures above 5$^{o}$C. This means that duckweed can supply feedstock for a full year. Other attractive properties include:

- High in starch (up to 40% of dry weight). Almost free of lignin which maximizes the utilisation of biomass.
- An inexpensive, earth-friendly source of the biofuel ethanol and butanol. Unlike corn, duckweed requires minimal human-made energy to grow and it doesn't deplete the world's food supply.
- A clean fuel. Duckweed plants intensively absorb $CO_2$ as they grow.
- High in protein and dietary minerals, and easily harvested. The plant is cultivated as a feed supplement for chicken, livestock, and farmed fish.

(Aidyn Mouradov: Wastewater as Renewable Source of Clean Water, Food and Renewable Energy — RMIT in India - Moving Forward (PowerPoint, 2014)

Muradov *et al. Biotechnology for Biofuels* 2014, **7**:30
http://www.biotechnologyforbiofuels.com/content/7/1/30

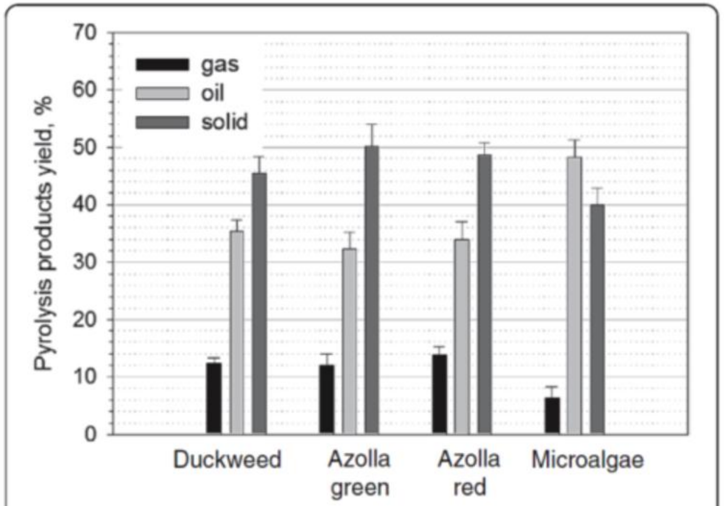



**Figure 6 Production of bio-oil, bio-gas and bio-char after pyrolysis of duckweed, azolla and microalgae.**

*Figure 22. Comparitive analysis of the biofuel capacity four sub-types of nitrogen & phosphorus absorbing water plant.*

**Table 1: Classification of water related diseases.**

This table shows the related diseases through faecal matter (directly and indirectly). By bringing this to their attention they'd be more likely to want to change the way they handle their current sanitation method and be more likely to get involved.

| Type of Water Related Infection | Examples | Morbidity around the world | Mortality/year |
|---|---|---|---|
| **Faecal-oral Diseases** | (a) Diarrhoea<br>(b) Cholera<br>(c) Typhoid fever<br>(d) Roundworm<br>(e) Hepatitis | (a) 1,000 million episodes/year<br>(b) >300,000<br>(c) >500,000<br>(d) 20-40% rate of infection in developing countries like Bangladesh | (a) 3.3 million<br>(b) >3,000<br>(c) >25,000 |
| **Strictly Water-washed** | (a) Trachoma<br>(b) Skin Infections<br>(c) Scarbies<br>(d) Conjuctivities | (a) 6-9 million blind<br>(b) Very common, in millions | |
| **Water-based (intermediate host parasite)** | (a) Schistomiasis<br>(b) Guinea-worm | (a) 200 million<br>(b) 1989- 890,000,1996- 35,000<br>- Still significant amount in developing countries | (a) >200,000 |
| **Water Related Insect Vectors** | (a) Malaria<br>(b) Filarisis<br>(c) Dengue<br>(d) Blindness | (a) 300-500 million cases<br>(b) 128 million<br>(c) 30-60 million infected/year | (a) 1.5-1.7 million |

**Table 2: Sanitation related disease and the likely effect of interventions.**

This table shows the impact of how hygiene promotion can change the amount of excreta related illnesses that occur after the awareness promotion.

| Category | Example | Dominant transmission mechanism | Likely effect of sanitation alone | Likely effect of hygiene promotion alone |
|---|---|---|---|---|
| **Faecal-oral** (non-bacterial) | Hepatitis A<br>Amoebic dysentery<br>Rotavirus<br>Giardiasis | Person to person contact<br>Domestic contamination | Negligible (as very low infective dose required) | Moderate |
| **Faecal-oral** (bacterial) | Cholera<br>Salmonellosis<br>Shigellosis<br>Many forms of Diarrhoea | Person to person contact<br>Domestic contamination<br>Water contamination<br>Crop contamination | Slight to moderate | Moderate |
| **Soil-transmitted helminthes** | Hookworm<br>Roundworm<br>Whipworm | Yard contamination<br>Communal defecation areas<br>Crop contamination | Great | Negligible |

# 8 BUDGET

**Table 3: Budget for the development and installation of a sanitation system in northern Bangladesh**

| Inaugural Water Project Northern Bangladesh | | | | |
|---|---|---|---|---|
| **Number** | **Material Description** | **Quantity** | **Unit Cost BDT** | **Total BDT** |
| 1 | Tank footings 4 toilet, 1 Urinal. | 15 L/M | 100 | 1500.00 |
| 2 | 200 x 150mm Brick chamber walls | 860 | 8 | 6880.00 |
| 3 | Bamboo slab supporting form work | 4 | 200 | 800.00 |
| 4 | Rendering internal chambers | 5 | 600 | 3000.00 |
| 5 | Concrete / chamber foundation slab | 1.5m3 | ea | 1600.00 |
| 6 | Concrete / chamber lid | 1.5m3 | ea | 1600.00 |
| 7 | Concrete mesh /foundation & floor slab | 19m2 | 2000 | 4000.00 |
| 8 | 25mm Urinal outlet valve & connector | 1 | 1000 | 1000.00 |
| 9 | 5m x 100mm PVC pipe (Urinal) | 1 | 1000.00 | 1000.00 |
| 10 | 100mm PVC Tees | 3 | 100.00 | 300.00 |
| 11 | 100 x 90dg PVC bends | 2 | 80.00 | 160.00 |
| 12 | PVC to squat pan urinal adaptors | 4 | 574 | 2296.00 |
| 13 | Squat pan lids cut from plain timber sheet/hinges & fixings | 4 | 230 | 920.00 |
| 14 | Vitreous china squat pans | 4 | 1395 | 5580.00 |
| 15 | 5m x 100mm PVC leaching line | 1 | 1000 | 1000.00 |
| 16 | 6 x 100mm PVC Chamber vent piping | 1 | 1200 | 1200.00 |
| 17 | 100mm vent cowl & mesh | 1 | 300 | 300.00 |
| 18 | 100 x 90dg PVC bends (vent) | 4 | 80 | 3200.00 |
| 19 | 100mm PVC tees | 3 | 100 | 300.00 |
| 20 | 100mm PVC pipe fixings | 4 | 40 | 160.00 |
| 21 | Chamber access panels/hardwood, rubber seals & hinges | 4 | 120.00 | 480.00 |
| 22 | Cost of a treated bamboo house with a thatch roof 4.8m x 1.8/ 9m2 | | | 6250.00 |
| 23 | Entrance/Brick steps with earth infill | 250 | 8 | 2000.00 |
| 24 | Sundries’ | | | 3000.00 |
| | | | **Total BDT** | **48,526.00** |
| | | | **Total EUR** | **459.32** |

It is anticipated that the project will require the labour of 3 persons with basic construction skills including concrete block work skills to prepare the installation.

# 9 MAINTENANCE

The maintenance of the system is based upon 4 key areas and it is anticipated that up to 3 people, with no prior skills, will be required to maintain the system (allowing for retention). The only maintenance tools required will be a bucket for flushing and a shovel.

The picture strip will be used to explain the use and maintenance of the system from the user's viewpoint.

The following areas will need to be maintained weekly and the project team will provide training to local workers.

- compost boxes
- air vent checks
- liquid waste tank
- wetlands area/plants

### 9.1.1 Compost Boxes

There needs to be a weekly review through the side trap doors of the compost toilet boxes to check the decomposition state of the waste.
This can be done by using a shovel. The material is ready for use when it is solid enough to sit on shovel and has little or no odour.
The pipe allowing liquid drainage from toilet boxes should also be checked weekly for blockage.

### 9.1.2 Air Vent Checks.

There needs to be a weekly review of the air vent to the toilet boxes to prevent blockage and ensure the net cap is secure on top to stop birds or vermin entering the toilet box vent.

### 9.1.3 Liquid waste tank

There needs to be a weekly review of the liquid waste tank and the bamboo pipes feeding into the tank for blockage control. This can be done by sight and with another bamboo pole for blockage removals.

### 9.1.4 Tending wetlands Area/Plants

There needs to be a weekly review and tending of the wetlands garden for survival of algae, duckweed and other plants necessary for removal of hazardous materials in liquid. This review also needs to ensure that sunlight and rainwater are controlled to the garden. The wetlands garden needs to be bounded and the border must be weekly checked.

# 10 TRAINING AND SUPPORT FOR LOCAL COMMUNITY MEMBERS

Training of local community members will be include installation and maintenance. There will be two sessions of training taken in a series of steps. The training guides will be provided in pictorial steps and will be printed on plastic sheets to be stored in the community. A summary of the training steps is below.

### 10.1.1 Installation Training

Training for the installation will cover:

- build of the toilet 'boxes'
  (4 boxes of cement blocks with trap doors, top holes)
- build of the hut housing the blocks.
  (simple covered, open air bamboo structure with air vents out of toilet boxes)
- build of the bamboo drains and pipes (climate liquid waste)
- build of the tank to collect liquid waste (two inlets into storage tank and one outlet to wetlands garden)
- excavation and set up of the wetlands garden.

### 10.1.2 Maintenance Training

Training for maintenance will take two hours and will cover:

- weekly review through side trap doors of compost decomposition state and liquid drainage from toilet boxes
- weekly review of air vent to prevent blockage
- weekly review of the liquid waste tank and bamboo pipes for blockage control
- weekly review and tending of the wetlands garden for survival of algae, duckweed and other plants.

### 10.1.3 User and maintenance guides

A user guide will be produced in graphic format, suitable for distribution to community members and also for laminating and attaching to the toilet wall. Alternatively the user guide can be adapted by local students as illustrations on the external and/or interior walls of the toilet block.

It is envisaged that the maintenance guide will also be in graphic format and will be developed in consultation with the community.

Prototype samples showing the approach to the design of user and maintenance guides are included in the file named Team_Aust_User_Guide_brief1.

# 11 APPENDIX

## 11.1 Selected sources of data

**Plastic toilet pans are being constructed in Bangladesh:**

“Plastic industries in Bangladesh can proudly claim to be one of the fastest growing industries in the country. From 1980 till date, this sector has been successful in manufacturing nearly all the plastic items that are being used in our households and other uses. Nearly all the packaging materials that are used by the exporters of the country are now being manufactured here in Bangladesh. Below are some of the plastic products being manufactured in Bangladesh:

Household uses: Tableware and kitchenware, pet bottle, chair, table, bathtub, jug, mug, bucket, container, food box, flasks, plates, glasses, spoons, soap case, toilet brush, pan, toys, artificial flowers, clock,etc.”

*http://www.thefinancialexpress-bd.com/old/index.php?ref=MjBfMDFfMjNfMTNfMF8xODVfMTU3ODg0&feature=c3VwcGxlbWVudE5ld3M=&na=OHRoIERoYWthIEludGVybmF0aW9uYWwgUGxhc3RpYywgUGFja2FnaW5nICYgUHJpbnRpbmcgSW5kdXN0cmlhbCBGYWlyIDIwMTM=*

**Community Led Total Sanitation (CLTS)**

Since 2000, Village Education Resource Centre and Water Aid Bangladesh have been helping to make big changes in toileting habits through a community-led total sanitation program. Facilitators would walk around the village with community members, introducing them to the health and environmental dangers of fields being used as toilets. They visited regular toileting sites and broke down social taboos by talking openly about faeces, or ‘pooh’. There was usually plenty of laughter. Together, they drew diagrams showing that after rain faeces could flow from open sites into ponds, canals and wells, and eventually onto cooking utensils during washing, as well as onto food itself through flies. With shame and disgust the community members realised that they had probably been regularly eating their own – and other people’s – faeces.

After one such introduction, the villagers of Mosmoil in northern Bangladesh quickly decided to adopt 100% sanitation. It was time, they said, to end the age-old practice of open defecation. They learned how to make a latrine, which confined excreta and prevented faeces contaminating surrounding areas. Within a short time every household in the village had such a sanitary latrine. Villagers pledged to always use their latrines instead of going to the toilet in open areas, and to wash their hands straight afterwards.

The villagers soon noticed that these health measures saved them time and money because they didn’t get sick. Clean fields meant growing rice and collecting fuel were more enjoyable tasks and children had more space to play. Women were pleased to have the convenience and safety of being able to go to the toilet whenever they needed to.

At school, children learned about washing hands and the need for all people to use the latrines. They took action with a public-shaming campaign. They kept watch, and used flags naming the adults who were still going to the toilet in public areas to embarrass them and encourage them to change their toileting habits.

**Benefits to the community**

The benefits of being known as a ‘100% open defecation free area’ village attracted positive attention and neighbouring villages quickly followed the practice. It took only six months for neighbouring villages to also become open defecation free areas. Soon officials from other parts of Bangladesh and other countries such as India, Pakistan and Indonesia visited to learn about the rapid improvements. The villagers felt surprised but proud.

Over time the people have dug new pits or adopted improved models when their latrines were full; further evidence of the sustainability of the program and commitment to preserving a sanitary environment. Taking control of their lives has led to other changes. Some people are now able to earn a living from making and selling low-cost latrine components, such as concrete rings for lining pits and plastic pipes.

**Achieving goals**

The government of Bangladesh has financially supported the spread of the program and promoted sanitation awareness. Sanitation coverage in Bangladesh has increased from 33% of households to over 70% and those who practise open defecation are criticised.

*http://www.arpnjournals.com/jeas/research_papers/rp_2006/jeas_1006_24.pdf*