Process Report for the Pit Life Extender and Mobile Treatment Units

Prepared for Water for People

Date   14

November 2016

water for people

Document History

Reference Number: W4P 1

Client Name: Water for People

This document has been issued and amended as follows:

Version	Date	Description	Created By	Verified By	Approved By
Draft	14-12-16	Draft for Review	D Peters	S Sugden	

Contents

Tables

Figures

Acronyms and Abbreviations

NF	Nanofiltration
RO	Reverse Osmosis
MF	Microfiltration
NF	Nanofiltration
PLE	Pit Life Extender
FSM	Faecal Sludge Management
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UF	Ultrafiltration
GAC	Granular Activated Carbon
WFP	Water for People
WASHi	Water, Sanitation and Hygiene Institute
MLD	Megalitres per Day
kL/d	Kilolitres per Day

Project Background

In many developing countries, the primary method of removing faecal sludge from septic tanks or pit latrines often involves some form of manual handing. This is an intrinsically unhygienic process which poses considerable risks to the operators and is usually considered illegal. The manual pit emptying process always results in highly pathogenic waste being indiscriminately dumped in the nearest drainage channel or piece of open land, causing significant public health risks.

The use of vacuum trucks to remove the sludge from tanks and pits is the usual customer preferred method, but this option is out of the price range for many people. In addition, in many parts of India there are insufficient treatment plants and the vacuum tanker removal process also results in the indiscriminate dumping of waste. In order to enable a move away from manual handling, Water for People is actively researching and developing cost effective, safer and more hygienic alternative approaches

Previous work undertaken by Water For People on the sludge profiles of septic tanks and pit latrines with the Ball Penetrometer has shown that a significant portion of what makes up the volume within both septic tanks and pit latrines is low solids water. This is due to the combined impacts of poor infiltration into the subsoil, high water tables, excessive use of cleaning water after defecation and excessive numbers of users per latrine. The need to transport this water to a treatment plant after it has been removed from the tank or pit represents a major inefficiency that artificially increases the cost of pit/tank emptying. Dewatering sludge also has a beneficial impact on the follow on processes in the sanitation value chain and on processing sludge for reuse as compost or fuel briquettes.

Membrane technology provides an avenue for solid/liquid separation. Initially membrane technology was prohibitively expensive, however the high uptake of under-sink water filters and the subsequent development of domestic membrane manufacturing n India has brought the costs of the membranes down to a point that the integration of membrane technology into Faecal Sludge Management (FSM) is becoming a commercially feasible option.

Using membranes to separate and treat the supernatant part of septic and pit latrine sludge offers a high potential method of improving the way septic tanks and pit latrines are managed, whilst at the same time meeting the needs of the relevant effluent discharge requirements. The Water, Sanitation and Hygiene Institute (WASHi) have developed a Pit Life Extender (PLE) that uses filtration and Granular Activated Carbon (GAC) to treat the water from the pit. Their aim was to develop a low cost option that could be installed within households and giving them the ability to reduce the level of water within their tanks. The pilot PLE is shown in Figure 1.

Figure 1 Pit life extender

WASHi have also developed a mobile treatment unit that uses a combination of centrifugation, filtration and GAC to treat septic tank water. The size of the system is designed to target larger septic tanks as opposed to pit latrines, with a target capacity of 3,000 L/h. The treatment process, design and arrangement of both systems was based on research and testing undertaken by WASHi, in order to determine which components were required for achieving the required product water quality. A photo of the Mobile Treatment Unit is given in Figure 2. The MTU was disassembled at the time of the November visit due to modifications being made to the centrifuge.

Figure 2 Disassembled mobile treatment unit

Whilst the combination of the Pit Life Extender and Mobile Treatment Unit do not represent a complete solution for Faecal Sludge Management (FSM), they will have a positive impact on the costs required to manage sludge, particularly in areas with high loading on the tanks/pits, or where water infiltration is a significant issue, such as in West Bengal.

Both systems have undergone initial testing at the WASHi facility in Dindigul and at surrounding locations. Three pit life extenders have been installed in nearby properties, and the Mobile Treatment Unit was tested on the WASHi septic tank and a series of other tanks in the local area. The results of this testing are summarised below, and were presented in the WASHi report on Pit Life Extending technology.

Water for People are seeking to understand both systems, and apply the current information, testing and research to the future expansion of Pit Life Extension technology, both in India and internationally. As Water for People are interested in developing a product that can be used within a commercial Faecal Sludge Management framework, the technology will need to be accessible to the current industry, namely the manual emptiers , well as robust enough so as to guarantee that the relevant discharge quality limits will be achieved.

Outline of Membrane Technology

2.1   Membrane Overview

Membrane filtration refers to the use of a material as a barrier to separate one class of species from another. Most commonly this is used in water treatment to separate everything from suspended particles to dissolved ions from water, however it has also seen applications in gas separation and low temperature distillation. The summary that follows focuses on the technologies of Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis which are used in water filtration.

Membranes are generally defined by their poor size, with the nominal pore size ranging from 10 µm for Microfiltration, to less than 0.001 µm for Reverse Osmosis. The pore sizes for different technologies, and what these technologies filter is shown in Figure 3.

Figure 3 Membrane filtration cut-off chart

The membrane systems used in water filtration are dependent on the feedwater quality, flows that are required and required product water quality. Whilst a Reverse Osmosis membrane will filter everything from a water source and produce drinking water quality, without proper pre-treatment by screening, UF and biofouling control, the system will block within minutes and become useless. Looser membranes also allow more flow through than tighter ones at any given pressure, resulting in proper membrane selection being vital for maintaining operating cost efficiency. This information is summarised in Table 1.

Table 1 Membrane systems and their filtration targets

Process	Pore size	Filtration Pressure Estimate	Filtration Removes
Standard Filtration	> 10 micron		
Microfiltration (MF)	10 – 1 micron	< 100 kPa	Larger bacteria, yeast, some suspended particles
Ultrafiltration (UF)	100-2 nm	100 kPa – 1 MPa	Large organic molecules, bacteria, suspended solids
Nanofiltration (NF)	2-1 nm	300 kPa – 2 MPa	Viruses, divalent ions, some colour
Reverse Osmosis (RO)	< 1 nm	1 MPa – 8 MPa	Dissolved salts and small organics

Most membranes are made of organic polymers which are cased in such a way that water can be pushed onto the feed side of the membrane and the filtered water collected through a separate port. Some membranes are designed to operate with a steady crossflow that recirculates, as well as with backwashing in mind to prevent a build-up of solids on the surface and to maintain flow across the membrane surface. Reverse Osmosis and Nanofiltration membranes are unable to be backwashed and must operate with a constant cross flow, as well as cleaned periodically to prevent foulant building up. Membrane systems are arranged in a process train from largest pore size to smallest.

All membrane systems should have primary screening to prevent debris that could damage membrane integrity from having contact with the membrane, screens can be automatically backwashed or manually cleaned by operators.

2.2   Microfiltration

Microfiltration has the largest pore size of the membrane technologies used in water treatment, with a nominal pore size range of 10 μm to 1 μm. Microfiltration is used to remove suspended solids, macromolecules and some pathogens from water. A Microfiltration system can operate in either cross-flow or dead end filtration mode, depending on the size of the flows that are being treated and whether it is intended for the membranes to be continually operated or replaced when fouled. Any large scale treatment plant will operate in some sort of cross flow arrangement due to the costs of full membrane replacements.

Microfilters can take the form of hollow fibre membranes, flat membrane sheets or wound cartridges. The Microfilters that Water for People will likely deploy in the field are the wound cartridge style filters due to the low cost of replacement and wide distribution of the filters. These are designed to operate in dead end mode, with backwashing having only a minimal effect on performance recovery. Due to the dead-end filtration, proper pre-screening is essential to prevent rapid fouling. As the Microfilter cartridges are easily replaced, it is often beneficial for the cartridge filters to act sacrificially and protect downstream GAC, Ultrafiltration and Reverse Osmosis units.

Monitoring of Microfiltration is done through measuring flow, as well as upstream and downstream pressures. Measuring flow allows for calculation of the membrane flux, a measure of flowrate per unit of membrane area, which indicates membrane fouling, but may be impacted by other factors such as fluid viscosity and temperature. Differential pressure is also a measure of membrane fouling rates, with a differential pressure level usually being set as the replacement, backwashing or cleaning setpoints for membrane systems.

2.3　Ultrafiltration

After Microfiltration comes Ultrafiltration, which refers to membranes with nominal pore sizes between 0.1 μm and 0.002 μm. Ultrafiltration forms a strong barrier against bacteria in a water stream, generally having a 3 – 4 log removal rate depending on the pore size of the membrane used. It can also be used to remove the remaining suspended solids that pass through the Microfilter, and large organic molecules like fats and greases. As with Microfiltration, Ultrafiltration can operate in cross flow or dead-end filtration modes, with the same advantages and limitations existing for both systems.

Ultrafiltration membranes are generally configured as either hollow fibre or spiral wound modules, with an active membrane layer made of Polyvinyl Difluoride (PVDF). As with Microfiltration, the most likely Ultrafiltration membranes that Water for People will use are designed to operate in dead end mode, with a hollow fibre structure. Again backwashing having only a minimal effect on performance recovery, however chlorine cleaning may go some way to improving membrane performance. Pre-treatment to remove high organic loads using systems like GAC or Aeration is recommended to prevent the Ultrafiltration pores from blocking up rapidly. The smaller pore size makes Ultrafiltration membranes far more susceptible to fouling than Microfiltration membranes.

Monitoring of Ultrafiltration is and done through measuring flow, as well as upstream and downstream pressures for the purposes of measuring flux and differential pressure. The integrity of Ultrafiltration membranes should be consistently monitored through periodic testing of bacterial removal across the membrane. High effluent bacteria readings may indicate that the membrane requires cleaning or replacement.

Hollow fibre UF membranes can be combined with a traditional aeration biological nutrient reduction system to form a membrane bioreactor, which has a better effluent quality than traditional methods of biological reactors, however these systems require significant operational experience and are comparatively complex, requiring aeration, backwashing, cleaning and integrity management to operate well.

Ceramic ultrafilters are a more recent development that continues to become more cost competitive. Ceramic filters have advantages of superior abrasion resistance, chemical resistance and membrane flux, however they are not yet cost comparable with polymer based membrane systems.

2.4　Nanofiltration

Nanofiltration is rarely used in water filtration, generally finding applications in the treatment of complex industrial effluent streams. Nanofiltration membranes contain pore sizes between 1 nm and 10 nm, which are structured in such a way that they pass through a membrane at 90°. The pore sizes are far lower than Microfiltration and Ultrafiltration, and the membranes are generally made of polymers. Nanofiltration systems are used to remove viruses, some colour and divalent ions from water. The ability of Nanofiltration to remove Ca^{2+} and Mg^{2+} from water makes them effective at water softening. Monovalent such as Na^+ and Cl^- will pass through the membrane.

Nanofiltration membranes are no longer cheaper than Reverse Osmosis membranes, nor as readily available. At this stage it is unlikely that Nanofiltration will form part of the treatment systems used within an FSM framework.

2.5   Reverse Osmosis

Reverse Osmosis is the membrane technology with the finest pore size, working down to an atomic level. Reverse Osmosis membranes will remove almost all species from feedwater, with the exception of approximately 0.5% of the Na+ and Cl- ions in the feed. Commercially, RO systems are used to provide drinking water quality water across the world, particularly in places where water is scare and must be desalinated from seawater such as the Middle East. RO membranes are almost all spiral wound with a polyamide filtration layer.

Reverse Osmosis membranes are extremely sensitive to fouling, pressures, chlorination and other damage. Because of this, they should only be used after thorough pre-treatment with primary screening, ultrafiltration and disinfection. Biologically active systems are particularly ill suited to using RO membranes without robust pre-treatment as biofilm will rapidly block the membrane rendering it useless.

Reverse Osmosis also requires high pressure to operate at a high enough recovery to be used as part of water management. The readily available units used for domestic water purification only operate between 10% - 15% recovery due to this, and will produce a large amount of reject water that needs to be managed. A general rule of thumb is that if you need to drink it, then RO is good, if not, other technologies will better suit your purposes.

Pit Life Extender Design

3.1 Overall Process and Required Water Quality

The PLE process is shown in Figure 4. A 7" pipe that is 6" long sits in-place within a septic tank or pit latrine, the lower 2' of pipe is perforated and wrapped with a porous cloth filter. This filter prevents large solids or debris from reaching the centre of the pipe, as well as providing additional filtration through the build-up of a sludge blanket. Within the pipe, a submersible pump provides flow to a cartridge filter which acts as the microfilter as well as the GAC filter. A booster pump is installed after the GAC filter to provide the additional pressure required to push flow through the ultrafiltration membranes. All filtration operates in dead-end mode, with no backwashing available within the system. There is currently no means of flushing the system in-between runs, which should be addressed to prevent a build-up of biofouling when the unit is idle. A detailed breakdown of the equipment used is given in Appendix A.
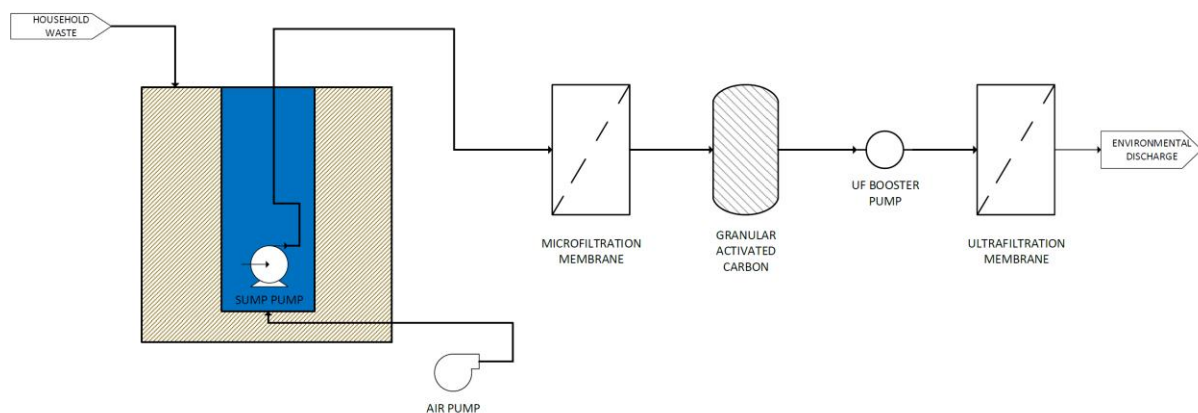
Figure 4 Pit Life Extender Process Flow Diagram

This process has been designed to remove Suspended Solids, Chemical Oxygen Demand (COD) and Pathogens from water extracted from a septic tank or latrine pit. The raw water quality as measured in the septic tank at the WASHi facility is shown in Table 2. This water quality serves as an indication of what raw water qualities the PLE will have to treat, however it should not be taken as representative of all septic tanks and pit latrines as significant variation is likely, additionally, the WASHi septic tank contains more liquid than would be expected in other septic tanks. Latrine pits are likely to have a harsher water quality across the board, which needs to be tested as part of future works. There is no flow measurement on the system, nor is there any data on throughput and it's relation to effluent quality, performance or flowrate. This should be addressed in future research.

Table 2 Raw water quality as measured in the WASHi pit

Raw Water										
pH	7.1	7.1	6.8	6.9	6.9	7	6.8	6.8	6.7	6.9
TSS (mg/L)	650	649	666	654	654	650	660	666	656	654
BOD5 (mg/L)	165	162	170	169	168	170	170	171	173	165
COD (mg/L)	640	638	654	652	643	649	650	643	630	641
Coliform (CFU/100mL)	9000	9000	9040	9100	9040	9160	9200	570	9240	9100

The required water quality in India as of November 2016 is shown in Table 3, however more stringent state requirements may supersede these values, and need to be accounted for on a State by State basis.

Table 3 Effluent discharge standards

Pollutant	Unit	Guideline Value
pH	pH Units	6 - 9
BOD	mg/L	30
COD	mg/L	100
Total suspended solids	mg/L	50
Total coliform bacteria	CFU/100mL	400

In order to gain an appreciation of the function that each unit was performing, samples were taken on the system that WASHi had installed and running in the pit. The results of these tests are given in Table 4 and will be referenced in the subsequent process unit sections.

Table 4 Interstage sampling results on existing PLE

	Sample Location (After the process unit)				
Analyte	Septic Tank	Cloth Filter	Microfilter	GAC	Ultrafilter
COD (mg/L)	1100	210	60	120	90
BOD (mg/L)	750	90	36	20	18
TSS (mg/L)	900	56	24	23	11

Part of the work undertaken was the assembly and testing of a new system to analyse the performance at start up, as well as the water quality over a short period of operation. The approximate 3 days of testing showed that there was already an increase in product water COD, TSS and BOD after 66 hours, with the GAC becoming spent between 22h and 66h, equivalent to a flow throughput of approximately 1000 – 3000 L). These results will also be discussed in the subsequent sections and are detailed in Table 5. It should be noted that the results in Tables 4 and 5 are based off single samples and an individual test run for each scenario, and by no means constitute a robust dataset or enough information to gain a full process understanding. They are best used as potential qualitative indications of the process unit functions.

Table 5 Product water quality and flow results from the newly assembled unit

	Permeate Sample Time (h)					
Analyte	0.25	2	4	20	22	66
Flow (L/min)	0.68	0.63	0.73	0.76	0.76	0.83
COD (mg/L)	42	48	32	24	56	80
BOD (mg/L)	28	20	12	8	11	15
TSS (mg/L)	12	14	14	13	16	22

3.2   In-pit Cloth Filter

The in-pit cloth filter is wrapped around the lower two feet of a 7" diameter, 6' long PVC pipe, which is a standard diameter. 25mm holes are drilled on the pipe in a roughly gird fashion with a separation distance of approximately 100mm. The cloth filter, which is a polymeric mesh with a pore size of approximately 150 μm to 300 μm, is wrapped around the filter and glued in-place. The pipe is then submerged into the septic tank or latrine and the submersible pump is placed inside the pump. An air pump is used to provide air to the inside of the cloth filter, but it is unclear why this was designed in, and the size of the pump would only result in a level of aeration that had a minimal or non-existent impact on the process. The pipe and filter are shown in Figure 6.

Figure 5 Pipe wrapped in cloth filter showing perforations

Table 4 shows that the cloth filter is responsible for the bulk of the COD (~80%), BOD (~85%) and TSS (~95%) removal from the raw water. This is incredibly advantageous as the cloth filter is notionally a static system that will not require significant ongoing maintenance or replacement. There is also a large reduction on the pollutant load that is required to be removed by the other process units, which to require maintenance and replacement.

There has been no information provided on the testing of sludge build-up rates, backwashing requirements or sludge permeability with respect to the sludge layer on the outer filter surface. There is the potential for the sludge blanket in high solids pits or latrines to lose permeability and limit the amount of water that filters through to the centre of the pipe. Additionally, the testing on the actual removal rates of suspended solids, and the size of particles that are rejected from by the filter and sludge blanket, have not been tested as this stage. These are potentially critical issues as the removal of the pipe requires the breaking of the seal at the top of the tank, which may be made of concrete, making frequent cleaning impractical.

3.3   Microfiltration

The Microfilter used for the PSL is a standard candle style wound fabric filter. This filter sits within a standard 4" cartridge housing, and is a relatively inexpensive and simple to replace consumable. The Microfilter will take out suspended solids that make it through the cloth filter, but are larger than the nominal 5μm pore size of the cartridge filter. The cartridge filter is important in preventing the GAC and Ultrafiltration from blocking up prematurely and reducing flow. Generally the level of fouling across a membrane, and therefore the replacement point and frequency of the cartridge filter are determined through reading the pressure upstream and downstream of the filter and calculating the differential pressure (DP). A fouled microfilter taken out of the existing WASHi system is shown in Figure 6.

Figure 6 Microfilter after 60 hours of continuous operation (approx. 450L throughput)

The Microfilter is currently removing approximately 75% of the COD remaining after the cloth filter according to the test results in Table 4. It also removes a significant portion of the TSS and BOD. This shows that the Microfilter remains effective regardless of the level of fouling, and may only be limited in the amount of flow that can be pushed through the filter when fouling does build up on the surface.

The current estimated change out frequency of the cartridge filter is unknown, there is no record on how frequently the filters had to be changed out during the preliminary testing of the PLE, neither were there upstream or downstream pressure gauges. Future testing should include the installation of the gauges as they are vital in understanding the effectiveness of the cloth filter, as well as developing a relationship between Total Suspended Solids (TSS) and Microfilter fouling, which is vital for the accurate modelling of the system for a future rollouts.

3.4   Granular Activated Carbon

Granular Activated Carbon forms the main means of COD removal in the PLE. Some COD will be filtered out through the cloth filter and the Microfilter, however it is anticipated that the insoluble portion of the COD will be far smaller than the soluble COD which will pass through the system. The GAC is stored in a small housing that is contained in a standard 4" cartridge. The GAC housing contains approximately 200g of GAC, which is a comparatively small volume for the levels of COD that have to be removed from the system.

The consumption rates of GAC are not currently well understood. WASHi testing showed that COD was always under the required discharge COD level, however there is no information on the frequency of GAC replacement, or the actual PLE runtimes. In order estimate the GAC required to remove the COD from the effluent, different COD levels, corresponding to the 5th, 25th, 50th, 75th and 95th percentiles of COD as measured in the WASHi septic tank, were compared against various flow totals at a conservative GAC COD capacity of 400mg COD/g GAC. The results of these calculations are shown in Table 6.

Table 6 Estimated GAC consumption

GAC Capacity (mg/g)		Flow (L)				
400		25	100	250	500	1000
COD (mg/L)	634	0.04	0.16	0.40	0.79	1.58
	640	0.04	0.16	0.40	0.80	1.60
	643	0.04	0.16	0.40	0.80	1.61
	650	0.04	0.16	0.41	0.81	1.62
	653	0.04	0.16	0.41	0.82	1.63

The results in Table 2 show that approximately 1.6kg of GAC will be consumed per thousand litres of water that runs through the system. This needs to be tested comprehensively in the field, as the estimated GAC requirements are prohibitive under the current design and arrangement for the PLE. The GAC would need to be replaced approximately 8 times per 1000L if these estimates are required.

The process unit testing shown in Table 4 indicates that the GAC actually released COD instead of captured it. This could be the result of COD that had been captured by the media leaching out as the media was at capacity, or a result of the single sample that was gathered. More testing is required to verify this. Table 5 indicates that the 200g of GAC can treat between 1000L and 3000L of wastewater before being consumed.

GAC was also intended to remove the odour from the effluent, however basic smell tests, followed by a more significant odour study showed that the impact was negligible to non-existent. To determine the ability for GAC to remove odour from the Microfilter filtrate, a test procedure was developed that would rank the odour of the final effluent against standard solutions made up of raw septic tank water. The concentrations of the standard solutions are detailed in Table 7. Through directly comparing the odour from the effluent samples with the two effluent sample solutions, an effluent odour score was able to be generated. The two Samples that were tested were taken from the PLE at WASHi, one with the existing GAC and one with the GAC replaced with a new batch in order to detect any degradation over time.

Table 7 Odour testing standard contents

Standard Solution	Clean Water Concentration	Septic Water Concentration
1	100%	0%
2	87.5%	12.5%
3	75%	25%
4	50%	50%
5	0%	100%

Six people participated in the test, all were blindfolded then instructed to compare the sample against the standards to determine whether smelt worse, the same, or better than the standard solutions. The results of this smell testing are presented in Table 8.

Table 8 Odour test results

Test Participant	Sample 1	Sample 2
1	4-5	4
2	4-5	4
3	4-5	5
4	5	5
5	4-5	5

Figure 7 shows the difference between the different standard solutions and the test samples.

Figure 7 Odour test sample solutions

3.5   Ultrafilter

Ultrafiltration is used to remove any additional suspended solids and bacteria from the effluent. The Ultrafilter used in this case operates in dead-end mode, meaning that there is no capacity for in-situ backwashing or cross-flow that are used in commercial systems. This arrangement increases the simplicity of the system, but introduces the risk of rapid fouling if there is a significant breakthrough in the pre-filtration. The current modules used are off the shelf items with very little information available, so it is not possible to estimate membrane flux, pore-size or anticipated flowrates across the membranes. As with the Microfiltration, there is no means of measuring upstream and downstream pressure, which is vital in estimating membrane life and the efficacy of upstream treatment.

The membrane modules used in this early design are hollow fibre membranes with an approximate diameter of 0.1mm that operate on an outside-in basis. This is ideal as outside in is more tolerant of fouling than the alternative. The GAC effluent passes across the UF membrane, with permeate collected from the head of the module, where the membrane fibres are potted in resin. Figure 8 shows the UF membrane with the casing removed, exposing the fibre cluster. The permeate flows through the potted head at the bottom of the photo.
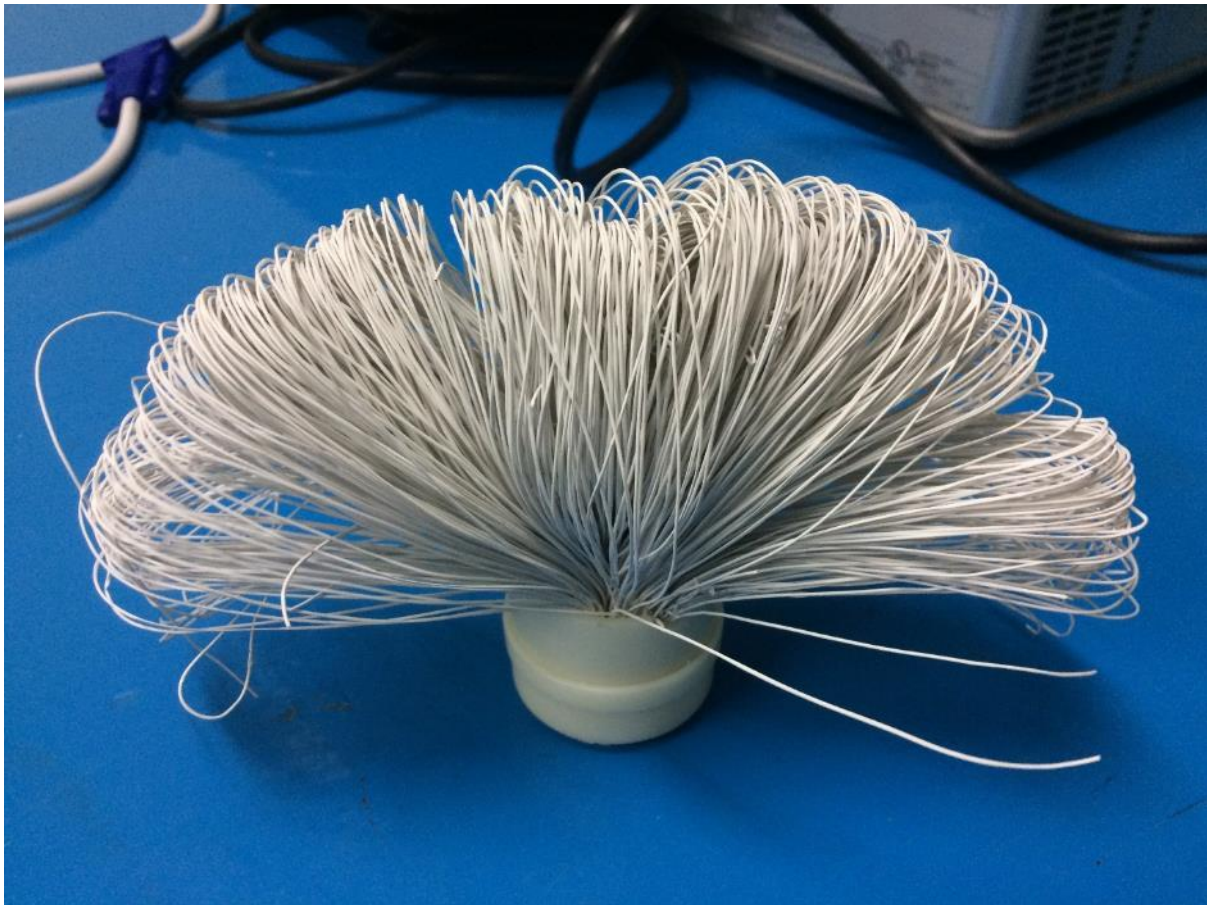
Figure 8 Ultrafiltration membrane removed from plastic casing

As with other areas of the design, there is a lack of information on UF membrane performance, lifespan and product water quality. The 1.3 log bacteria reduction from the feed to the effluent is far lower than could normally be expected from ultrafiltration (3 – 4 log reductions are common), which highlights the need for more information on the product that is being installed. Additionally, methods of cleaning the membranes with sodium hypochlorite should be investigated

3.6   Key Points for Further Investigation

There is a great deal of performance information that is unknown at this stage which is vital for the successful implementation and rollout of the PLE, the information gaps are detailed below.

Overall System and Water Quality

- Expected feedwater quality, encompassing a broad sample of potential water sources, taken from different localities.
- Total system capacity and achievable throughput, flow based performance measurement.
- Effluent quality over time.
- Ability to achieve required water quality.

Cloth Filter

- Impact of the air pump.
- Impact and characterisation of the sludge blanket.
- Suspended solids removal across the filter with and without the sludge blanket.
- Robustness and sensitivity of the cloth filter to debris and turbulence within the pit/tank.
- Discharge pressure of the submersible pump over time.

Microfilter

- Differential pressure across the microfilter, estimating fouling rates.
- Microfilter filtrate water quality.
- Information on Microfilter pore-size.

Granular Activated Carbon

- GAC consumption rates.
- Ability of GAC to remove odour, other potential odour removal methods.
- GAC supply and quality.
- COD removal rates compared to filter bed size, design of GAC filter.

Ultrafiltration

- Technical information on the membrane.
- Membrane differential pressure and flow measurement.
- Membrane cleaning.
- Detailed effluent quality and log bacteria removal rates.

Mobile Treatment Unit

4.1   Overall Process

The Mobile Treatment Unit (MTU) is essentially a large scale version of the pit life extender, with a target flowrate of 3,000 L/hr (3 m^3/hr). The likely feedwater qualities will be similar to those experienced with the pit life extender, and the effluent qualities will be identical. The unit is intended to be driven to a septic tank or pit, the waste from the pit treated by the unit and discharge water of sufficient quality to meet discharge standards. The vehicle that the unit is placed on it shown in Figure 9.

Figure 9 Mobile Treatment Unit vehicle

A submersible pump is used to pump water from the pit or septic tank being emptied into a 1m3 holding tank. A centrifuge is used to dewater the high solids portion of the water is pumped up, before a pump attached to the tank pumps the water from the tank through to the Dual Media Filter. The centrifuge will continue to operate during this time, taking water from the bottom of the tank where settling is likely to cause a higher solids concentration. Centrate from the centrifuge is returned to the holding tank.

Water is passed through the Dual Media Filter and through a GAC carbon filter to remove COD and BOD, before flowing through a dual Microfilter arrangement and finally an Ultrafiltration membrane before being discharged. Solids are from the centrifuge are returned to the septic tank or pit that is being treated. Both the Dual Media Filters and the GAC are capable of being backwashed.

The effluent quality produced by the system during initial testing by WASHi conforms to current Indian federal discharge requirements. At the time of the Water for People visit, the Mobile Treatment Unit was disassembled as the centrifuge was being modified. It was reported by WASHi staff that the unit operated well on 7 of 8 additional tanks tested, however the 8th had thicker sludge and caused a complete blockage within the system. It is unknown how much flow was treated by the Mobile Treatment Unit for any of its tests.

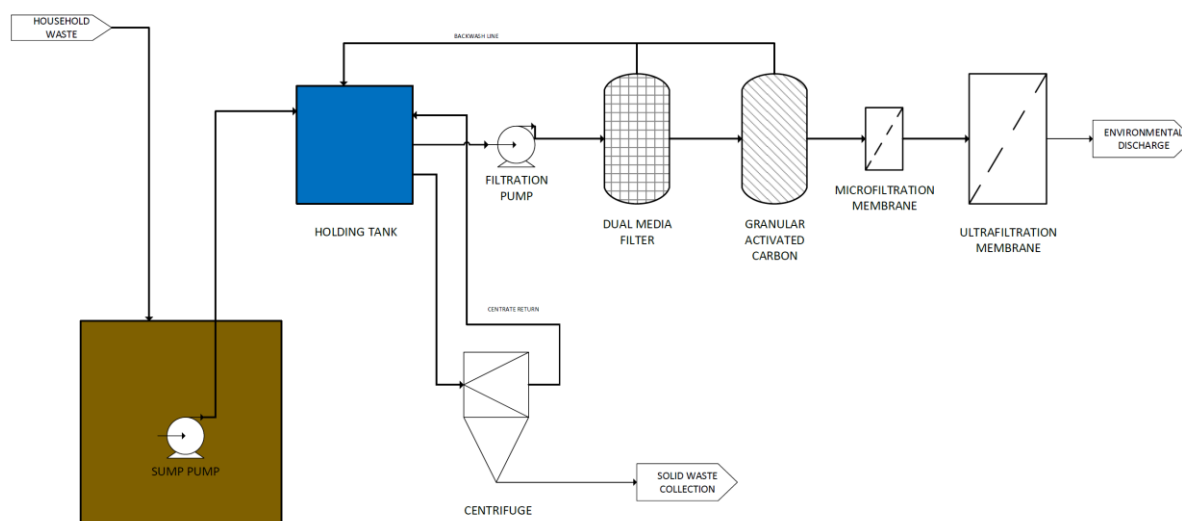A Process Flow Diagram of the Mobile Treatment Unit is provided in Figure 10.

Figure 10 Mobile Treatment Unit Process Flow Diagram

4.2 Equipment Breakdown

4.2.1 Centrifuge

The centrifuge used in the process was not at the WASHi facility at the time of the visit, so information on the equipment was not available. The Centrifuge was off-site undergoing modifications to improve the capacity of the system for an unspecified reason. The design intend behind the centrifuge is to use it to continually dewater solids drawn from the water at the bottom of the holding tank, which should notionally have a higher concentration than the top due to settling within the tank.

The centrifuge does not currently use polymer dosing, flocculation or other chemical additions that can assist with the dewaterability of the sludge. The solids from the centrifuge can either be collected in sludge bags or discharged back into the tank the raw water is extracted from.

4.2.2 Dual Media Filter

The Dual Media Filter uses a common Sand/Anthracite combination to dewater solids that have passed through from the water holding tank. The sand and anthracite are able to be backwashed from the filter through modulating a valve at the top of the vessel, returning backwashed water into the feed tank. The Media Filter housing is made of Fibreglass Reinforced Plastic (FRP) and has a nominal volume of 200L. It was reported that the filter required backwashing every two runs of the unit.

A pressure gauge is installed at the top of the filter, allowing an operator to check on the feed pressure of the media filter, which will increase as filter fouling increases. Generally this would then be used to determine appropriate backwash trigger points.

4.2.3   Granular Activated Carbon

The Granular Activated Carbon is stored within an identical FRP vessel to the Dual Media Filter. As with the Dual Media Filter, the GAC vessel can also be backwashed, however it is unlikely that this would be required frequently as the Dual Media Filter should filter out anything that is large enough to block the activated carbon bed.

Based on the figures provided in Section 3.4, the GAC filter has sufficient capacity to treat 125 m3 of septage whilst producing effluent COD levels that satisfy discharge requirements. This is equivalent of approximately 45 – 50 households.

4.2.4   Microfiltration

Microfilters are installed after the GAC and before the UF to protect the UF module from premature fouling or damage. The Microfiltration in this unit is done through two cartridges that are installed in series and housed in standard 4" housing upstream of the ultrafiltration. The design of these cartridges are similar to the candle style shown in Figure 6 in Section 3.3. The cartridges were not installed at the time of visiting.

4.2.5   Ultrafiltration

Ultrafiltration is performed by 4" hollow fibre module shown in Figure 11. The membrane operates in a cross flow arrangement, with retained water being returned to the holding tank. The module has the ability to be backwashed manually, but no in-situ backwashing is available. The UF module was not installed at the time of visiting.
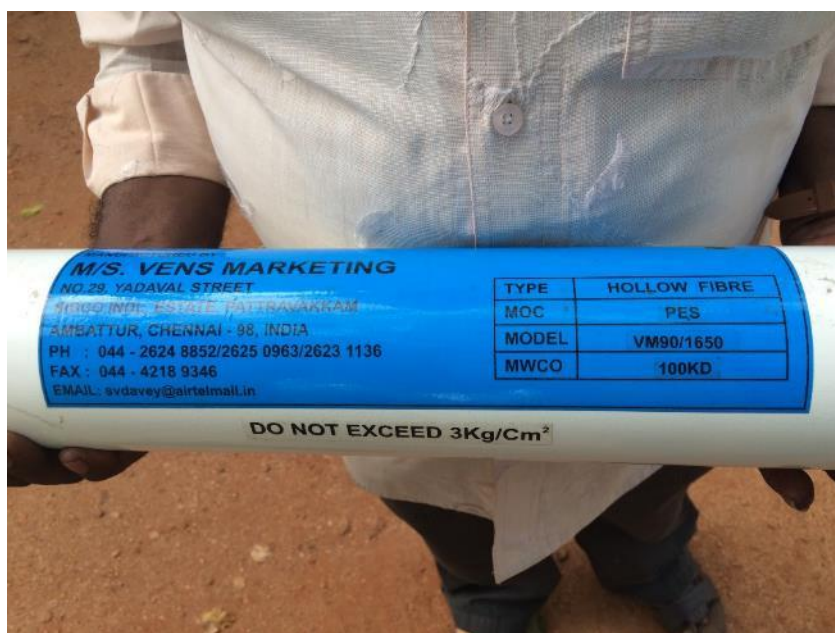

Figure 11 4" UF module used in the Mobile Treatment Unit

4.3   Outstanding Issues

Overall System and Water Quality

- Expected feedwater quality, encompassing a broad sample of potential water sources, taken from different localities.

- Total system capacity and achievable throughput, flow based performance measurement.

- Effluent quality over time.

- Ability to achieve required water quality.

- System robustness, how susceptible is it to high solids water.

Centrifuge

- Performance data on the centrifuge.

- Measurement on the settleability of the solids within the holding tank.

- Moisture content of returned sludge.

- Suspended solids remaining in the centrate.

- Information on centrifuge capacity.

Dual Media Filter

- Differential pressure across the Dual Media Filter, estimating fouling rates.

- Dual Media Filter filtrate water quality.

- Quantity of water treated before backwashing.

Granular Activated Carbon

- GAC consumption rates.

- Differential pressure across GAC, estimating fouling rates.

- Ability of GAC to remove odour, other potential odour removal methods.

- GAC supply and quality.

- COD removal rates compared to filter bed size, design of GAC filter.

Microfilter

- Differential pressure across the microfilter, estimating fouling rates.

- Microfilter filtrate water quality.

- Information on Microfilter pore-size.

Ultrafiltration

- Technical information on the membrane.

- Membrane differential pressure and flow measurement.

- Information on the membrane configuration and backwashing impact.

- Membrane cleaning.

- Detailed effluent quality and log bacteria removal rates.

Future Testing Framework

5.1   Pit Life Extender

The future testing of the pit life extender should seek to more clearly design the operating parameters of the equipment used within the systems, as well as utilise data collection in a way that can be used to support operating models, cost estimates and product water quality guarantees. Previous testing on the unit has only focussed on testing the feed and product water qualities, with no information gathered on the other process characteristics.

Future testing can be split into three categories:

- Water Quality Testing – including inter-stage testing;

- Pressure Testing – measuring differential pressures across the relevant units in order to understand fouling rates; and

- Flow testing – testing the product water flows over time to understand the practical unit production rates.

Table 9 details what testing should be undertaken for each process unit, including the chemical tests that are required. The testing is selected based on what performance parameters and water qualities are relevant to each of the process unit. If possible, Ball Penetrometer analysis should be incorporated into the testing to characterise the septic tank or pit latrine being tested.

Table 9 Pit Life Extender tests

Process Unit	Sample Point	Water Quality	Differential Pressure	Flow
Septic Tank/ Pit Latrine	1	TSS, COD, BOD, pH, Faecal Coliforms		
Cloth Filter	2	TSS, COD		
Microfilter	3	TSS, COD	√	
GAC	4	COD, BOD	√	
Ultrafiltration	5	TSS, COD, BOD, pH, Faecal Coliforms	√	√

The Pit Life Extenders used for piloting should be updated to allow for the testing to be completed without excessive manual intervention or potential for contamination. It will also need to have pressure gauges installed to measure differential pressures. Figure 12 shows an updated Pit Life Extender design that will allow for this testing to be easily undertaken, a larger version of this drawing is provided in Appendix B. The modifications require the addition of 5 pressure gauges and four sample valves. The flow measurement can be done through measurement of the time taken to collect a set volume in a calibrated vessel at the Ultrafiltration outlet.
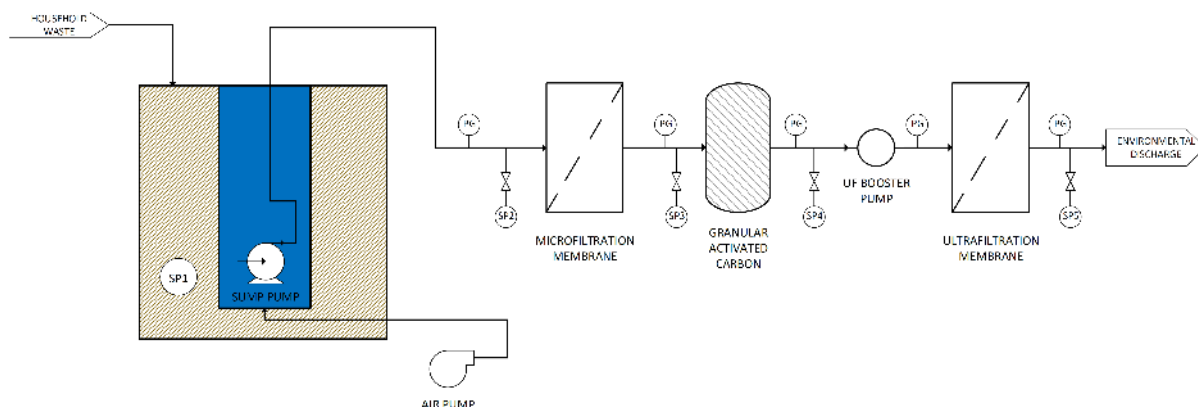
Figure 12 Updated PLE for pilot testing

One major issue with the testing thus-far is the limited range of pits that have been tested, this should be rectified in the next stage of testing. Three PLE units should be modified according to Figure 12 and distributed. One with WASHi in Dindigul, one in Pune and one with Water for People in Kolkata. Water quality testing should be done by an appropriate institution in close proximity to where the testing is undertaken to minimise issues with COD and BOD degradation. The tests should be split evenly between Pit Latrines and Septic Tanks if possible.

Initial testing should be undertaken at 10 sites for each of the three areas selected for testing. Each of the tests should take place over two consecutive days, with the PLE running for four hours each day. Pressure and flow readings should be taken every half hour, sampling for the tests detailed in Table 9 should be taken every two hours.

This initial testing will then provide data that can be analysed and utilised in developing any modifications or future testing framework. If the data is positive, then a larger scale rollout may be feasible immediately.

5.2   Mobile Treatment Unit

As with the Pit Life Extender, future testing of the Mobile Treatment Unit needs to be targeted to better understand the performance and limitations of the Unit. Previous testing on the unit has only been done on the Septic Tank at WASHi, as well as on 8 other Septic Tanks. No information other than the feed and effluent water quality was captured during initial testing.

As with the PLE, future MTU testing can be split into Water Quality, Pressure and Flow testing.

Table 10 details what testing should be undertaken for each process unit on the Mobile Treatment Unit, including the chemical tests that are required. As with the PLE, the testing is selected based on what performance parameters and water qualities are relevant to each of the process unit, with the addition of centrifuge solids testing. Ball Penetrometer analysis should be incorporated into the testing to characterise the septic tank or pit latrine being tested.

Table 10 Mobile Treatment Unit Tests

Process Unit	Sample Point	Water Quality	Differential Pressure	Flow
Septic Tank	1	TSS, COD, BOD, pH, Faecal Coliforms		
Dual Media Filter	2	TSS, COD	√	
GAC	3	COD, BOD		
Microfilter	4	TSS	√	
Ultrafiltration	5	TSS, COD, BOD, pH, Faecal Coliforms	√	√
Centrate	6	TSS, COD		√
Solids	7	TSS, COD, BOD, Faecal Coliforms, Moisture Content		√

The Mobile Treatment Unit should be modified from the current design to more easily facilitate detailed piloting. The unit should have Sample Points and Pressure Gauges will need to be added as per Figure 12, a larger version of this drawing is also provided in Appendix B. The modifications require the addition of 5 pressure gauges and four sample valves. The flow measurement can still be done through measurement of the time taken to collect a set volume in a calibrated vessel at the Ultrafiltration outlet.
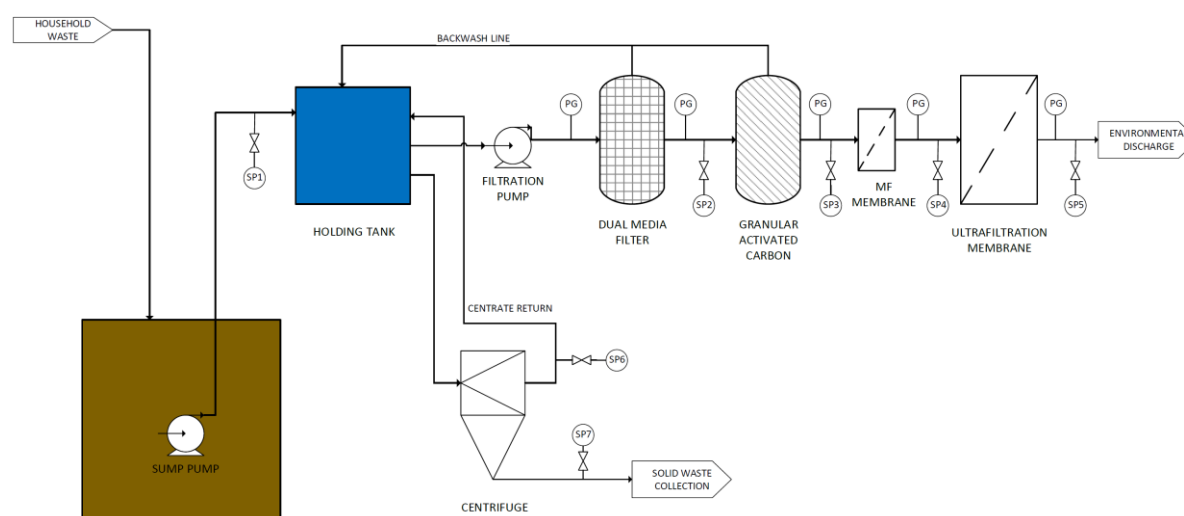

Figure 13 Updated MTU for pilot testing

As with the Pit Life Extender, the testing thus-far is the limited range of pits that have been tested, which should be rectified in the next stage of testing. As the Mobile Treatment Units are far more expensive than the Pit Life Extenders, it is only feasible to have two units in operation. One Mobile Treatment Unit should be tested by WASHi in Dindigul, and another by Water for People in Kolkata. The water quality testing should continue be done by an appropriate close. The testing of the Mobile Treatment Unit should aim for equal testing of Septic Tanks and Pit Latrines.

Initial testing should be undertaken at 30 sites for each of the two areas selected for testing. Each of the tests should take place over two consecutive days, with the PLE running for two hours each day. Pressure and flow readings should be taken every half hour, sampling for the tests detailed in Table 10 should be taken every hour.

The results of this testing can be used to decide what modifications, if any, should be made on the units. It is also likely that the testing will show that the Mobile Treatment Unit is limited in the range of solids concentrations that it can reasonably manage. Ball penetrometer testing that coincides with the Mobile Treatment Unit testing will allow for a more accurate estimate of these limits.

Future areas of development

Future testing and development will need to be focussed on solutions that are more sustainable, robust and produce better water quality than the current PLE/MTU technology. There are several technologies in development that may be utilised to achieve these outcomes in the future, however they are not currently cost effective or understood comprehensively enough to roll out for Faecal Sludge Management in the poorer parts of the world.

These technologies include:

- Ceramic ultrafilters – which may replace all other filtration steps in one go;

- Hollow fibre Nanofiltration – which can take the place of the Ultrafilter and produce better quality product water; and

- Solar power driven RO – removing the bulk of the RO cost associated with running an RO unit, but not the complexity.

Appendix A
Equipment List

Item No.	Component	Approximate Unit Price (Rs)	Component Cost (Rs)
1	7 " Pipe (around 6 ft but depends on requirement)	100/ft	600
2	Fabric Filter (mesh size 300μm) 1 m	50/m	50
3	End caps for 7" pipe (2)	185 each	370
4	Flexkwick	50	50
5	Msp 800 pump(used in air cooler)	800	800
6	Screw (made to fit)	20	20
7	5m Pipe (1/4")	50/m	250
8	5m Pipe (sizes below 1/4")	30/m	150
9	Microfilter	400	400
10	Activated Carbon Filter	350	350
11	UF Filters (2)	1400	1400
12	Filter Housing (4) & Elbows	250	1000
13	RO pump	1400	1400
14	Aerator	350	350
15	Mounting structure	150	150
16	Electrical fittings	200	200
17	Assembling charge	500	500
		Total	8040

Appendix B
Process Flow Diagrams

SEPTIC TANK/PIT
LATRINE   CLOTH FILTER   AIR PUMP   MF MEBRANE   GAC   BOOSTER PUMP   UF MEMBRANE

HOUSEHOLD
WASTE

SUMP PUMP

AIR PUMP

MICROFILTRATION
MEMBRANE

GRANULAR
ACTIVATED
CARBON

UF BOOSTER
PUMP

ULTRAFILTRATION
MEMBRANE

ENVIRONMENTAL
DISCHARGE

WATER FOR PEOPLE   WASHI

WASH INSTITUTE

DRAWING COMPLETED AS PART OF THE PROCESS
ASSESSMENT ON THE PIT LIFE EXTENDER

WATER FOR PEOPLE – PIT LIFE EXTENDER PFD

				SIZE	FSCM NO	DWG NO	REV
				A3	0	W4P-1	0
0	DRAFT	09/11/16	DP				
REV.	DESCRIPTION	DATE	BY	SCALE	NTS	SHEET	1 OF 1

SEPTIC TANK/PIT
LATRINE

HOLDING TANK

DUAL MEDIA FILTER

GAC

MF MEBRANES

UF MEMBRANE

HOUSEHOLD
WASTE

BACKWASH LINE

FILTRATION
PUMP

DUAL MEDIA
FILTER

GRANULAR
ACTIVATED
CARBON

MICROFILTRATION
MEMBRANE

ULTRAFILTRATION
MEMBRANE

ENVIRONMENTAL
DISCHARGE

HOLDING TANK

CENTRATE RETURN

SUMP PUMP

SOLID WASTE
COLLECTION

CENTRIFUGE

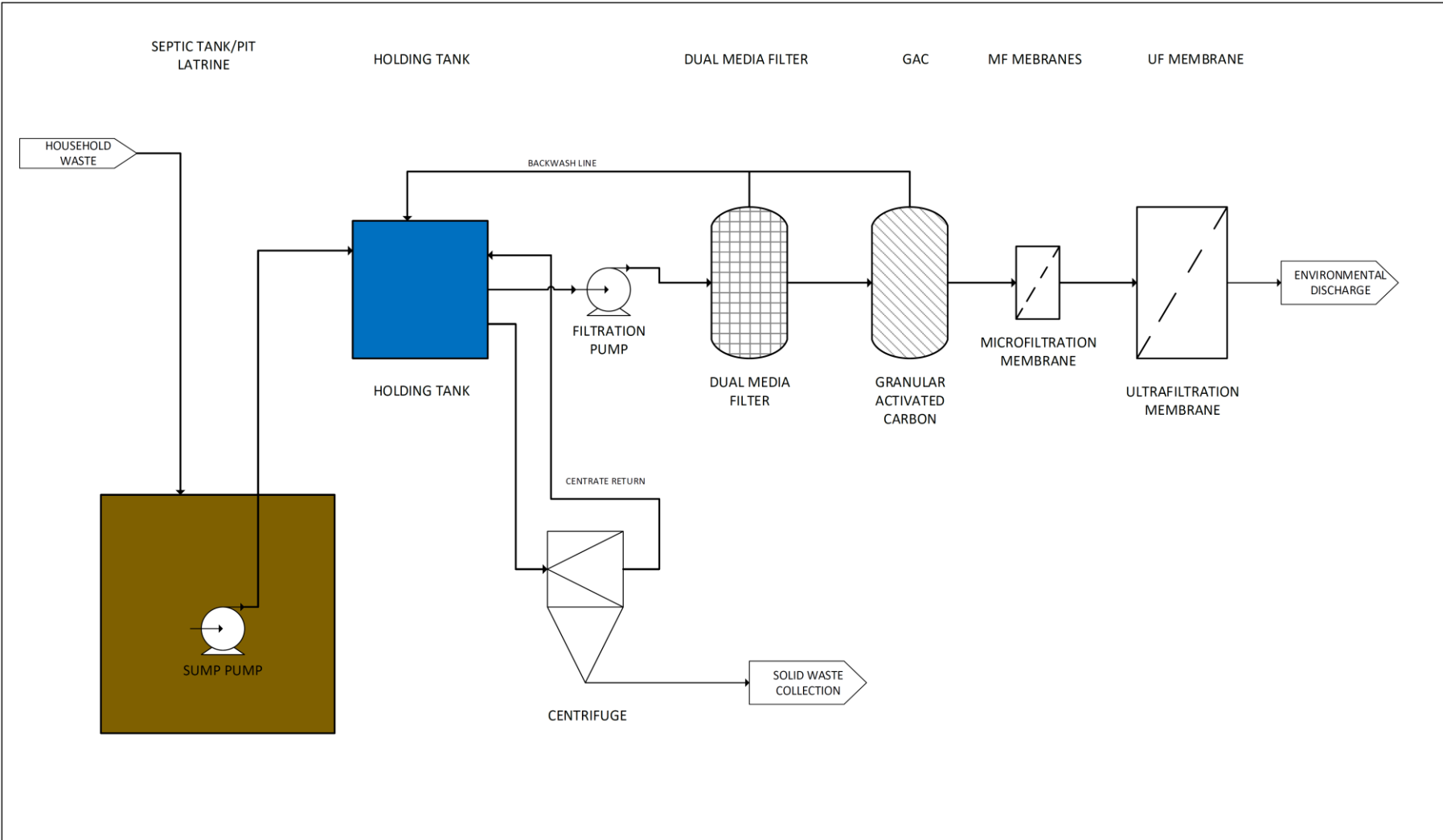|			
0	DRAFT	09/11/16	DP
REV.	DESCRIPTION	DATE	BY

DRAWING COMPLETED AS PART OF THE PROCESS
ASSESSMENT ON THE PIT LIFE EXTENDER

WATER FOR PEOPLE – MOBILE TREATMENT UNIT PFD

SIZE	FSCM NO	DWG NO	REV
A3	0	W4P-1	0
SCALE	NTS	SHEET	1 OF 1