Testing and developing of desludging units for emptying pit latrines and septic tanks

Results of nine months field-testing in Blantyre - Malawi

SUMMARY

In this report we present the findings of nine-months field work in Malawi on desluding of 'difficult' pit latrines with 'difficult' sludge. 'Difficult' in relation to pit latrines refers to the fact that the latrines are difficult to reach due to small, often narrow, unpaved and/or sloping roads. 'Difficult' pit latrines also refer to the fact that the squat holes are small and/or the squatting plates are fragile. 'Difficult' in relation to sludge means that the sludge is 'thick' meaning that it has low moisture content and/or is mixed with solid waste.

The objective of the fieldwork was to recommend a reliable desludging kit suitable to empty pit latrines in emergency situations.

The significance of this topic stems from a water and sanitation gap analysis in which more than 900 professionals from over 40 countries were consulted. In this gap analysis, desludging of pit latrines was identified as one of the 12 most significant gaps in the emergency WASH sector. The significance comes also from the fact that there is a growing realization that - in order for sustainable sanitation to be achieved, especially in peri-urban areas - the complete sanitation chain, including the safe removal, transportation and disposal or reuse of faecal sludge, must accompany the promotion of hygienic toilets.

Within the framework of the Emergency Sanitation Project (ESP) and S(P)EEDKITS, WASTE - with the support of the IFRC the Netherlands Red Cross and the Malawian Red Cross - tested three types of desludging equipment and recommended improvements. The equipment was tested in peri-urban, high-density housing areas and institutional toilets in Blantyre, Malawi, over a nine-month period in 2013 and 2014. The three types of desludging equipment were:

- A vacuum-operated machine with an integrated high-pressure pump for fluidizing sludge and an 800 litres holding tank (called ROM 2).
- A vacuum-operated machine with a 500 litres holding tank (called Vacutug Mk2).
- A diaphragm sludge pump.

We also tested other supporting equipment, including two types of transfer stations (a 3 m^3 rigid sludge tank and a 13m^3 bladder); an independent high-pressure water pump (Karcher) for sludge fluidization; and a variety of nozzles to test for optimal performance. The desludging equipment was tested over 500 times in over 200 lined and unlined pit latrines and a few septic tanks with the removal of over 430 m^3 of sludge.

Fig 1: ROM 2.

Fig 2: Vacutug Mk2.

Fig 3: Diaphragm sludge pump.

SUMMARY

The desludging equipment was tested over 500 times in over 200 lined and unlined pit latrines and a few septic tanks with the removal of over 430 m³ of sludge.

After extensive modifications we found that it is possible to empty 'difficult' pit latrines with 'difficult' sludge in an effective and efficient way with one of the three machines. This machine is capable of handling most sludge in lined and unlined pit latrines and in septic tanks and able to access a high percentage of toilets. The key components of this vacuum-operated 'mobile desludging kit' include:

- A fluidizer that can spray high-pressure water at around 60-100 bar.
- Fishing equipment such a hooks to remove rubbish.
- A vacuum pump capable of creating a vacuum of 0.5 bar, with a capacity of at least 2000 litres per minute.
- Three-inch flexible suction and outlet hoses in order to avoid frequent blockages by un-fished rubbish.
- A holding tank of 800-1000 litres to store and transport sludge. The inside of the tank should be easily accessible in case the discharge port becomes blocked.
- The kit should be mounted on a small truck or trailer and the length of the suction pipe and fluidizing hose need to be at least 30 metres to assure accessibility.

Improvements in the logistics of operating the kit, including access to localized disposal (or a transfer station), would make it possible to desludge up to eight pits in one working day.

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1.1 Background

During emergencies, the standard solution to deal with sanitation is to dig new pit latrines. When the emergency takes place in existing urban environment, the use of existing latrines could be beneficial in covering the needs. However, often existing latrines are already (partially) full and also new latrines can fill up quickly. Specially in areas were the construction of pit latrines is difficult due to limited space or difficult soils (e.g. rocks) it can be required that latrines need to be emptied. The emptying of existing latrines can be cumbersome as the existing latrines are difficult to access, the sludge in the latrines is 'thick', or the availability of desluding trucks is limited. Hence, the 'normal' procedure to apply vacuum trucks does not work satisfactory. So, not surprisingly, desluding is high on the agenda of humanitarian organizations. The 2013 Humanitarian Innovation Fund 'Gap Analysis' notes: *"Sanitation was high on many of the ranked lists, especially urban and early response sanitation. General sanitation gaps included sanitation promotion and sanitation and hygiene in fragile and conflict-affected environments. Key challenges related to the difficulties in building latrines on rock/snow/ sand/collapsible soils and desludging issues including lack of appropriate equipment, how to extend the use of latrines through desludging and how to treat the sludge or, indeed, use it to advantage (biogas, compost etc. and recycling of wastewater). The need for eco and environmentally friendly latrines was raised more than once."*

Within the framework of the Emergency Sanitation Project (ESP) and S(P)EEDKITS, WASTE with the support of the Malawian Red Cross, the International Federation of Red Cross and Red Crescent Societies (IFRC) and the Netherland Red Cross (NLRC) tested three types of desludging equipment and recommended improvements. The equipment was tested in peri-urban, high-density housing areas and institutional toilets in Blantyre, Malawi over a nine-month period in 2013 and 2014. We report on the findings in the presented report.

1.2 Acknowledgements

We would like to extend thanks to the Blantyre City Council for their cooperation. This report was prepared by WASTE Advisers (The Netherlands and Malawi), the International Federation of Red Cross and Red Crescent Societies (IFRC) and the Netherlands Red Cross as part of the Emergency Sanitation Project (ESP), funded by OFDA/USAID, and the S(P) EEDKITS Project, funded by the EU. Part of the funding was provided by The Netherlands Red Cross and SPA (Sanitation in Peri-Urban Areas in Africa), a project implemented by WASTE Advisers and funded by the Dutch Government.

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1 INTRODUCTION

1.3 Objective of the report

The purpose of this report is to document the findings of the field trials of the selected equipment used for desludging, transportation and temporary storage of sludge.
This report focuses on the following practical issues:

- Testing of the 3 desludging kits i.e. the ROM 2, Vacutug Mk2 and the Diaphragm Sludge Pump. The report includes:
  - Original design features including fittings.
  - Importation into Malawi and mobilisation of the equipment.
  - Report on their use in desludging septic tanks and lined and unlined pit latrines.
  - Recommendations to modify the equipment.
- Testing of 2 sludge storage containers:
  - The Sioen PVC bladder with 13m^3 capacity.
  - A rigid GRP sludge tank of 3m^3 capacity, which comes as a flat pack.

1.4 Difficult sludge

'Difficult sludge' has the following criteria in terms of consistency, access of the equipment to the toilet, and access to the sludge in the pit:

- The sludge is semi solid and hard to remove: i.e. thick sludge with more than 15% solids and mixed with rubbish.
- The toilet facility is hard to access: narrow lanes, bumpy roads, steep slopes, muddy roads, obstacles such as other buildings, trees, fences, etc.
- The sludge is hard to access in the pit: small drop hole, fragile drop hole (i.e. mud slab), unlined pit (may collapse during emptying), small door, low roof (hampers fishing), etc.

1.5 For the reader

We present the methodology we used in Chapter 2 and the general processes in Chapter 3. The tests on the ROM2 are elaborated in Chapter 4. Chapter 5 describes the Vacutug MK2 and Chapter 6 the Mechanized membrane pump. In a later phase we purchased a pressure washer, a Karcher. Our experiences with the pressure washer are in Chapter 7. Intermediate storage is described in Chapter 8 (the SIOEN bladder) and Chapter 9 (GRP tank). Our Conclusions and Recommendations are summarized in Chapter 10.

2 METHODOLOGY USED

The methodology involved the use of desludging equipment in the following settings:

- Lined and unlined pit latrines.
- Septic tanks.
- Domestic and institutional toilets.
- Urban and rural areas.
- Pits in current use and those abandoned when full.
- Pits with old sludge (10 years old) and fresh sludge (up to 2 weeks).
- Emptying with and without fluidising.

2.1 Overview Equipment tested

The equipment tested included:

- 3 types of desludging equipment.
- 2 types of storage tanks.
- A standalone high-pressure washer.

2.1.1 Desludging equipment

The following desludging equipment was imported into Malawi and tested during the trials:

- ROM2 manufactured by ROM BV, The Netherlands.
- Vacutug Mk 2 manufactured in Bangladesh.
- Diaphragm sludge pump supplied by Butyl products, Great Britain.

The equipment was pre-selected based on the functional requirements developed in 2012 .

See Table 1 for details.

Table 1: Technical specifications of desludging equipment

Specification	*ROM 2*	*Vacutug Mk 2*	*Diaphragm sludge pump*
Description	Petrol driven vacuum pump with pressure pump for fluidising. Steel holding tank.	Diesel driven vacuum pump. Steel holding tank.	Diesel driven diaphragm pump. GRP holding tank
Shipment gross weight and volume	500kg; pallet L. 200 x W. 140 x H. 160 mm (4.48m^3)	869 kg; 5.69 m^3	808 kg; 4.69 m^3
Propulsion	Truck mounted or trailer	Self-propelled, 3 – 4 km/hr	Truck mounted
Engine type and power	Honda 6.6 kW. Electric or manual start	Chinese diesel, 9.1 KW, electric / manual start	Lombardini diesel engine. Manual start
Vacuum pump capacity	2,500 litres/min, Kevlar vanes (+ spares). Additional oil reservoir	Make: Pagani 2,750 litres/min Relative pressure: 1.5 bar Vacuum -0.91 bar Max power 7kW	
Pressure pump capacity	Speck Brand 140 bar – maximum pressure - unloaded set on 60 bar. No need for pressurised water inlet. Power requirement 4.1 kW. Capacity 15 litres / minute. Water filter: ½"	n / a	n /a
Holding tank capacity	800 litres	700 litres	3000 litres
Water tank holding capacity	200 litres	0	0
Suction hose diameter	2" and 3"	3"	3"
Suction hose length	15m	2 x 15 m	30 m

Table 1 (continued)

Specification	*ROM 2*	*Vacutug Mk 2*	*Diaphragm sludge pump*
Hose connectors	Plastic cam locks	Quick release, Metal	Bauer Quick release, Metal
Ball valves	Plastic	Metal	Metal Bauer
Instruction and maintenance manual	Yes	No	No
Spares	Engine spares kit. Vacuum pump spare blades. Hose repair kits	Engine spares kit No vacuum pump spares Hose repair kits	Engine spares kit Spare Diaphragm

2.1.2 Sludge storage equipment

2 sludge storage containers were supplied for testing – i.e. for deployment, assembly, transportation and use (i.e. filling, prolonged storage and emptying).

- The Sioen bladder – made from two layers of PVC and a capacity of 13m^3.
- A sludge-holding tank of 3m^3 capacity – flat pack made of GRP.

In addition the team made extensive use of IBCs (intermediate bulk container) of 1m^3 capacity.

2.1.3 A high pressure washer

A Karcher brand high-pressure washer was purchased in order to test the diaphragm sludge pump and the Vacutug as none of them had fluidising capacity.
The Karcher has AN adjustable pressure band between 0 and 300 bar.
In addition 3 additional nozzles were supplied in order to establish the most efficient pressure and nozzle configuration.

2.2 Overview tests performed

Requirements for desludging in emergency situations

During the inception phase of the project, a questionnaire was developed which resulted into valuable input of 14 different humanitarian organizations, who prioritized and commented the preliminary version of the list of requirements. This list was further refined during a sector-wide workshop.

To structure the list of requirements, the following distinctions have been made:

- Operation and maintenance requirements.
- Costs requirements.
- Production requirements.
- Acceptance requirements.
- Transportation requirements.

The trials included detailed evaluations of the above requirements. The results are tabulated in Annex A.

2.3 Assembly and Deployment

The shipping dimensions of the equipment are detailed in Table 1. It is essential to note that the following equipment required the services of a forklift:

- The ROM2.
- The Vacutug.
- The sludge pump.
- The flat pack sludge tank.

2.4 HAZOP

A HAZOP (hazardous operations) procedure was developed at inception stage.
During the project:

- Potential Hazard.
- Consequence.
- Safeguard.
- Actions to prevent or remedy consequence.

See annex B for details.

3 DESLUDGING OF PIT LATRINES (GENERAL PROCESSES AND EQUIPMENT)

This section covers:

The processes that must accompany the emptying of latrines with difficult sludge, i.e.:

- fluidising;
- fishing.

The essential equipment, i.e.:

- suction pipes;
- valves;
- fittings / couplings;
- clamps.

3.1 Fluidisation

Why is fluidising sludge so important?

The use of vacuum pumps only is insufficient to empty pit latrines. This has long been acknowledged by vacuum tank or *'honey sucker'* owners who kept to septic tanks and avoided pit latrines because the pit sludge has too much rubbish that frequently blocks the suction pipe, and sometimes the discharge pipe.

The remedy to this is to 'fish' out the rubbish. The fishing operation often required that the hard sludge be softened or fluidised. In any case, the hard sludge is too solid to be pumped out, and requires *'fluidising'*. This is traditionally done by adding large quantities of water to the pit sludge and by stirring with a stick. However, this method is not very effective or efficient as the use of water adds significantly to the cost of the operation (especially in added transport costs which are considerable). It is also observed that this method results in removal of what clients call "coloured water" i.e. not thick sludge. The use of so much water can also render unlined pits unstable and liable to collapse.

In this research we trialled the use of high pressure water varying nozzle configuration and water pressure to obtain the most efficient and effective results. The idea of using a high-pressure washer is based on using one of the properties of sludge called thixotropy:

> *"Thixotropy is the property of certain gels or fluids that are thick (viscous) under normal conditions, but flow (become thin, less viscous) over time when shaken, agitated, or otherwise stressed".*

In this case we have used high-pressure water to stress the sludge. The variables that we have played with include: water pressure and spray patterns from the nozzles.

The results have been quite effective in over 200 pit latrines (see Annex C for details):

- The team achieved 100% success in taking significant amounts of sludge from every latrine they were invited.
- None of the latrines collapsed during the desludging debunking fears that high-pressure water would cause unlined pits to collapse. However, examination of the sludge contents showed that the sludge from unlined pits contained a lot of soil, gravel and even large stones from the pit wall. It was not clear if some of this was a result of the fluidising process.
- The team also managed to empty several pit latrines with good infrastructure yet had been abandoned for several years due to the pits being full.
- The amount of water used was between 15 – 20% of the sludge content. The removal of 800 litres of sludge (volume of the ROM pressure tank) was sufficient to empty the average household pit latrine. So the composition of the sludge was roughly 650 litres sludge and 150 litres water. The consistency of the sludge removed after fluidising was still 12 – 15% total solids.

Figure 1: Spray pattern using a 4 jet nozzle at 100 bar.

Figure 2: The water jet is also essential for cleaning the toilet slab and the desludging equipment.

- Also contrary to popular belief, fresh sludge (as found in emergency camps) also required fluidisation and had post fluidisation total solid content of 15% in market toilets with high usage and no introduction of water into the pit due to ablutions with water.
- Several fluidising operations are required – and at least 2 sessions – one before the first fishing and one after each subsequent fishing session as the sludge quickly sets back from semi liquid to semi solid. The initial fluidising lasts for 10 – 15 minutes, while the fluidising after fishing takes about 5 minutes.

A full report on testing of different fluidising nozzles and pressures in given in Chapter 7.

3.2 Fishing

Fishing of rubbish is one of the most import steps to ensure efficient removal of sludge from a pit latrine or septic tank. It is also the most unpleasant and hazardous part of the operation, but until different pump technologies are developed, or households refrain for disposing of garbage in pits, it will remain a necessary operation. The amount and type of rubbish found in a pit must be seen to be believed. Out of 54 pits we fished 2840 litres of rubbish, which averages about 50 litres per pit (see Annex C). Fishing is time consuming, taking on average 30 minutes per pit, sometimes more. The fishing tool is a 1.6 m to 1.8 m, 12mm GI pipe with 3 x 6mm grapples welded to it. See Figure 3.

The rubbish consists mainly plastic bags and cloths (including menstrual cloths and pads and increasingly disposable baby nappies) and these easily block the suction pipe if not removed beforehand. Shoes, sticks, maize cobs, stones, plastic bottles and charcoal have also been found. The team became very proficient in fishing and with time experienced few blockages of the suction and also fewer blockages of the discharge port. In part this is also because the team has learnt the limitations of both fishing and of the equipment and avoid situations, which cause problems (e.g. pits filled with stones, etc.).

However in spite of the teams proficiency, it is impossible to fish out the smaller objects or larger objects such as stones and these can occasionally block the suction side (remedy is to switch vacuum pump to *'pressure'* setting, and blow out. It sometimes occurred that the smaller rubbish blocked the discharge pipe in which case the only remedy was to access the inside of the holding tank.

3.3 Essential equipment for the suction side

Essential equipment for the desludging equipment includes:

- suction pipes;
- valves;
- fittings / couplings;
- clips.

Suction hoses and accessories.

It is essential that the suction hoses and the fittings (clamps, couplings and valves) be of the best quality possible. They lead a hard life (sludge with stones, sharp objects etc.; rough handling during use and transport; tropical heat and exposure to UV). Even minor leaks result in appreciable loss of vacuum and drastic reduction in performance.

As outlined in our report, in order to access as many toilets as possible it is recommended that the suction pipes be of 3" diameter and 30m length. For ease of handling it is suggested they come in 2 lengths of 15m.

Figure 3: Fishing tool.

Figure 4: Items fished out include plastic bags and cloth rags used for menstrual hygiene.

Figure 5: Per latrine 50-100 litres of rubbish is fished out. This takes more than 30 minutes.

The suction hose

Specifications:

- The normal ICRC specification reads "Heavy-duty PVC suction hose, reinforced with a hardened PVC spiral helix". However it is recommended that EPDM (ethylene propylene diene monomer) which is stronger than PVC, and is recommended for rough and long-term daily use. PVC is cheaper and is also available in different qualities but for durability the best quality should be bought, and definitely UV protection.
- Smooth inner surface.
- Temperature range: -25°C up to 60°C.
- Operational pressure: min 3 bar, 6 bar for 20°C or better.
- Resistance to vacuum at 20°C: 90%.

In addition it is recommended that the hose comes with a hose repair kit in case of damage.

Couplings

The best couplings tested were the metal Camlocks supplied with the desludging kit supplied by Butyl – they were very durable. The PP fittings supplied with the ROM were not durable.

It is recommended that each coupling comes with a set of spare rubber gaskets. The gaskets should be of *'vacuum'* specification.

Valves

The equipment has 2 x 3" ball valves – 1 at vacuum side of the tank and 1 at the discharge side of the tank. In order for the tank to reach adequate vacuum (0.5 bar) or pressure (1.0 bar) it is essential that both valves are completely leak proof.

Poor quality valves have the following problems:

- They wear out due to abrasive action of the sand and grit.
- They become extremely hard to open or close.
- They lose their seal making desludging inefficient.

While the valves supplied with the Vacutug wore out very quickly (less than 10 cycles) the ones supplied with the sludge kit (and were fitted to the ROM2) went through an 'open-and-close-cycle' of around 2000 times with little problem.

Figure 9: Female Coupling Bauer.

Figure 10: Male coupling.

Figure 6: The ball valves should be of best quality to ensure efficiency of the machine and long service life.

Figure 7: The coupling should be firmly anchored to the suction pipe using a high torque clamp band. Definitely don't use "jubilee clips"!

Figure 8: Camlock couplings should be of best quality in order to ensure efficiency of the machine and long service life.

4 ROM2

The ROM2 is manufactured in the Netherlands and was manufactured specifically for the project and shipped to Malawi by air.

4.1 Description equipment

The following table describes the ROM2 as specified, manufactured and received for trials for the project, while the 'locally improved ROM2' is the machine with the recommended specifications following the results of the trials.

Table 2: Technical specifications of desludging equipment

Specification	*ROM 2*	*Locally improved ROM2*
Description	Petrol driven vacuum pump with pressure pump for fluidising. Steel holding tank.	Petrol driven vacuum pump with pressure pump for fluidising. Steel holding tank.
Shipment gross weight and volume	500kg; pallet L. 200 x W. 140 x H. 160 mm (4.48m^3)	500kg; pallet L. 200 x W. 140 x H. 160 mm. (4.48m^3)
Propulsion	Truck mounted or trailer	Truck mounted or trailer
Engine type and power	Honda 6.6 kW. Electric or manual start	Honda 6.6 kW. Manual start
Vacuum pump capacity	2,500 litres/min, Kevlar vanes (+ spares). Additional oil reservoir	2,500 litres/min, Kevlar vanes (+ spares). Additional oil reservoir
Pressure pump capacity	140 bars –maximum pressure - unloader set on 60 bar. No need for pressurised water inlet.	140 bars –maximum pressure - unloader set on 60 bar. No need for pressurised water inlet.
	4.1 kW. 15 litres / minute. Speck Brand Water filter: ½"	4.1 kW. 15 litres / minute. Speck Brand Recommend: increase water filter capacity to 1 ¼".
Holding tank capacity	800 litres	800 litres
Water tank holding capacity	200 litres	200 litres
Suction hose diameter	2" and 3"	3"
Suction hose length	15m	30 m (15m x 2)
Drain hose	3" diameter, 2.4 m length	3" diameter, 2.4 m length if discharging to disposal site 5m length if discharging to a transfer station
Hose connectors	Plastic cam locks	Quick release, Metal
Ball valves	Plastic	Metal
Instruction and maintenance manual	yes	yes
Spares	Engine spares kit Vacuum pump spare blades Hose repair kits	Engine spares kit Vacuum pump spare blades Hose repair kits

Figure 11: The ROM2 was shipped on a standard pallet.

Figure 12: The ROM2 was easily deployed but required lifting gear.

Figure 13: The ROM rig should be firmly bolted on its transport.

4 ROM2

4.2 Deployment

The ROM2 was airfreighted and on delivery required offloading and loading with a forklift.

For the convenience of the project we developed lifting equipment, as it was also necessary to lift the equipment (especially the ROM2 and the sludge tank on to a lorry. The chain block capacity is 2 tons. The lifting gear served for lifting all equipment (except the assembled Vacutug which is too high) and performed adequately.

The ROM2 was almost ready to deploy, with the following tasks required:

- Checking and filling engine oil, vacuum pump oil, pressure pump oil.
- Fitting the battery took over 2 hours. For the 'LOCALLY IMPROVED ROM2' it is recommended to have only manual start as the battery was more of an inconvenience.
- The ROM2 then needed to be mounted on the load bed of a truck using bolts with angle iron brackets on the wooden underside of the truck bed. It is more convenient to load the ROM onto a towed trailer that can be towed by a 1 ton capacity pickup truck.

4.3 Tests performed

The ROM2 was tested under the following conditions:

- 16 Septic tanks;
- 19 Lined pit latrines in households and schools;
- 60 Unlined pit latrines in households and schools;
- abandoned pit latrines.

Table 3 summarises the number of toilets and volume of sludge removed by the ROM. Full data is detailed in Annex C.

Table 3: Overview facilities emptied by ROM2

	Number of facilities	*Volume of fluidising water (litres)*	*Volume of rubbish fished (litres)*	*Number of ROM tanks filled*	*Volume of sludge removed (litres)*
Total facilities emptied by ROM2	189	30,130	6,880	355	283,000

Results:

- The average household pit produced 23 litres of rubbish.
- The average volume of water used in fluidising was 102 litres.
- The average percentage of fluidising water in the sludge is 13%.

The ROM2 was also tested with the 2" kit and the 3" kit, as well as with the plastic Camlocks and plastic ball valves.

In order to operate the ROM2 it was necessary to conduct the ***fluidising and fishing*** procedures in order to empty a pit latrine (which are

Figure 14: The 3 ton truck carrying 700 / 800 litres sludge in the ROM and 1000 litres sludge in the IBC for disposal at the Blantyre Sewage treatment plant. No spillages en route.

Figure 15: The 2" kit was blocked even with septic tank sludge as menstrual management materials are often flushed down the toilets.

essential for any vacuum operated pumps). For these procedures refer to Chapter 3.

The suction kit: 2" or 3" hose. Plastic or metal components?
The ROM2 came equipped with both 2" and 3" suction kits (i.e. lances, connectors, valves, and hoses. It was quickly established that while the 2" kit may be suitable for emptying some septic tanks, it is completely unsuitable for emptying pits due to the amount of rubbish in pit latrines. Even with extensive fishing, the 2" suction kept blocking making the operation extremely inefficient. Having a 3" suction is simply superior having more than twice the collection area (i.e. 32 vs. 22).

The following issue the team encountered was the plastic components – i.e. the lances, connectors and ball valves: they did not prove sufficiently durable for such a harsh environment – both the nature of the sludge which apart from trash also contains so much sand which either abrades components or prevents adequate sealing.

For more detailed analysis refer to section 3.3.

4.4 Test results

As supplied the ROM2 was unable to perform efficiently until some modifications were made. These included:

- Abandoning the 2" suction system in favour of 3" system exclusively.
- Exchanging the plastic couplings and ball valves for more durable metal ones.
- Making the suction side more ergonomically suitable through making it lighter, more compact.

These modifications are detailed in section 4.5.

The ROM2 performed very well in the desludging of pit latrines full of difficult sludge. The team did not fail to desludge any pit requested of them including some pits that had been abandoned for some years. The ROM2 had the following performance characteristics:

- After fishing (approx. 30 minutes) and fluidising (approx. 15 minutes) could desludge 800 litres from a pit in 4 minutes.
- Could desludge from a maximum tested distance of 30m and an elevation of 2 m.
- Can discharge the sludge in less than 1 minute.
- Has excellent fuel economy of an average of less than 0.2 litres fuel per pit.
- Very reliable – only faults were the drive belts and the pressure hose and water filter.

Figure 16: The plastic ball valve showed signs of abrasion after only a few operations and the threads were easily crossed by operators.

Figure 17: The 2" lance is far too long to be used in normal pit latrines.

Figure 18: Due to the small doors, the lance and the suction pipe had to be assembled inside the toilet.

4 ROM2

4.5 Modifications made to the ROM2 system provided

The ROM2 proved to be an excellent machine, however we have faced several challenges that required modifications that we did ourselves, but there are some modifications that must be done in the factory.

4.5.1 Suction pipe

One of the main challenges we faced was the setup of the suction pipe that came with the ROM2. Table 4 provides a list of the issues, with the recommended solutions. One of the main problems was the operation of the lance. The lance is too heavy and too cumbersome the use. There are too many operations: apart from ROM2 operating the emptying the operator has to control the valve for the pressure washer and the valve for the suction pipe. We removed the valve and the fluidiser at the suction side. For smaller toilets the lance has to be assembled in the toilet otherwise it cannot enter the drop hole. See Figures 19 and 20.

Table 4: Problems and Solutions suction pipe ROM2

Problems experienced	Recommended modifications
The setup of the suction probe is too cumbersome: • It is too big to fit into most toilets and needs to be assembled outside of the toilet. • The valve at the suction side makes the probe too heavy for the operator – not only during suction but also during fluidising. • The fluidizing nozzle is about 4" in diameter making it too big to fit into many drop holes. • There are too many leaks in the suction system – and the plastic valve set up and the plastic clamps are not durable.	To make the suction easier to handle • Replaced the suction pipe which was supplied with the ROM2 with the one supplied with the Vacutug Mk2. This makes it lighter for the operator and easily fits into any toilet building and most drop holes. • Placed the suction ball valve at the engine side so it operated by the engine operator. • Removed the fluidiser and the pipe and fixed it to a separate lance. • There are now metal joints that have less leakages and the metal clamps and valves are more durable.

Figure 19: Cumbersome lance.

Figure 20: Cumbersome lance.

Figure 21: The plastic clamps were not durable and we experienced air leaks.

A summary of the modifications to the suction pipe is:

- Changeover to metal clamps and eliminate excessive number of joints.
- Ball valve shifted to tank side.
- Extended length of suction pipe from 15m to 30 m.
- Separated the high-pressure hose from the suction hose in order to make fluidising easier.

These modifications have worked well and the operation is now much more effective, easier and safer.

4.5.2 Discharge of sludge from the ROM2

The discharge set up as supplied with the original machine has the following shortcomings:

- Short discharge pipe means difficulty in discharging the sludge at the municipal sewage works, or in the rural areas into the sludge pit.
- The discharge port blocks after prolonged use due to buildup of thick sludge and other solid items that either cannot be fished out or escape fishing process.

We adapted the discharge by fitting a clamp fitting and a 15m suction pipe (3”).

Figure 22: We changed to a metal and have observed they are more durable and have no air leaks. We changed the suction valve from plastic to metal. It is easier for the truck side operator to control the suction valve. The elbow somehow restricts the flow of the thick sludge.

Figure 27: The combination of the fluidiser with the suction hose makes the fluidising cumbersome.

Figure 28: We separated the fluidiser from the suction pipe to make it an easier operation.

Figure 23: Use of new set up.

Figure 24: Use new set up.

Figure 26: The length of the suction pipe is now 30 m (2 x 15 m) so we can access more toilets – while the suction is still very good. We are able to fill the tank in about 4 minutes.

Figure 25: The original length of 3”suction pipe supplied is 15m, and is too short to access many toilets.

Normally, using the pressurised tank, it takes less than 1 minute to empty the ROM2 of thick sludge.

In a rural area, which is very far from a waste disposal plant, we dispose of the sludge into a pit and then cover with lime, ash and soil at the end of the day. Alternatively the sludge may be emptied into a transfer stations such as sludge tank, IBC or bladder (see chapters 8 and 9).

4.5.3 Blockages to the ROM2 tank

With the new setup of simplifying the suction pipe, and with efficient fishing there were few blockages at the suction side.

However blockages on discharge are being experienced after prolonged use of the machine (i.e. 30 or more pits) due to build-up of very thick sludge, and smaller items, that are not removed from the tank on every discharge.

In November a serious blockage occurred where even pressurising was ineffective. We removed the inspection cover from the top and fished out several plastic medicine bottles, which were causing blockage with thick sludge such as stones, charcoal, etc. When the top inspection hatch was opened it was observed only one plastic bag, which was jamming the ball valve of the level indicator. This shows that while the fishing process is highly effective there are smaller items that cannot be fished out and will accumulate in the tank. In order to make the cleaning of blockages easier it was recommend to install an inspection hatch /man hole be fabricated on the end of the tank.

See figures 35 and 36.

Figure 29: We fitted one of the plastic couplings.

Figure 30: Increased length of discharge pipe – to make it safer and easier to discharge into a sewage disposal or pit.

Figure 31: Disposal rural areas.

Figure 32: Coverage with lime, ash and grass.

Figure 33: Some of the blockages were easily removed using a wire hook: in this case a pair of panties were removed fROM2 the discharge side.

Figure 34: Items blocking discharge port include ARV bottles which escape fishing process – and we counted 4 bottles.

4.5.4 Problems encountered with the ROM2:

During the desludging and filling and emptying the ROM holding tank more than 355 times we encountered the following problems:

1. After more than 280 uses, the ***pressure hose*** burst. It was found that the pressure relief valve for the pressure pump was set at 120 bar, and it was reset to 50 – 60 bar. A new pressure hose was made using the same connections, just replacing the sleeves and hose. The job took less than 30 minutes by a specialist (Bearing and Machinery) and cost less than Euro100. In emergency situations, such a repair may not be readily available and it is suggested that the regulator is set and sealed to 60 bar to prevent a rapture in the first place and the pressure gauge is always set to be more visible to the operator. It is recommended that the pressure regulator be permanently set to 100 bar.
2. After 350 uses the ***drive belts*** for the vacuum pump and pressure pump broke. The 3 belts were readily available locally and cost €12 to replace. In an emergency situation, however they may form part of the spares kit.
3. ***The pressure washer system:*** After fixing the pressure hose to the ROM as permanent feature (first with 15m then with 30 m hose), we are no longer experiencing frequent nozzle blockages due to dirt entering the hose when the system was dismantled. However, we still experience an occasional blockage of one of the nozzles.

Figure 38: The filter body housing and the filter dismantled. The gauze of the filter has been perforated and there was a lot of sediment found in the filter housing.

Figure 39: The drive belts broke and were replaced after 300 operations.

Figure 35: Dismantling top hatch.

Figure 36: Jammed ball valve.

Figure 37: The pressure hose burst – it was seen that the pressure regulator was mistakenly set too high.

4 ROM2

To improve access to difficult to reach toilets, in addition to the 30m suction hose and pressure hose, the ROM2 was mounted on a trailer to be towed by any vehicle with a towing capacity of 1200 kg. The towed unit was tested on the public roads as well as off road and proved stable, but has yet to be tested in crowded areas such as townships.

One of the advantages of the ROM2 is that it is shipped almost ready to use, and being mounted on a trailer would be a useful option. 'Bakkies' are a very common form of transport in Africa and Asia.

The inspection cover was fitted towards the end of March by Mike's Welding, at a cost of approximately €330. We will test this for airtightness and for ease of cleaning the ROM2 tank from blockages affecting the gauge and the discharge on site during operations as well as for general maintenance.

Figure 42: Trailer prototype using either 15" or 16 " wheels for compatibility with towing vehicle. The trailer proved very stable on and off road. The 'bakkie' is also convenient for carrying 45m of 3" pipe (30m suction and 15 m delivery) plus equipment like safety clothes, buckets for rubbish, sprayer, fishing tools, etc.

4.5.5 Design features of Locally improved ROM2

The following specifications should be considered in the next development of the Locally improved ROM2 (summary in the table) .

The vacuum tank:

- Manhole made at lowest point of Vacuum tank.
- Only 3" metal connections to be used – no plastic (PP) fittings.
- Ball valves fitted to the tank. The suction and discharge valves should be metal, and best quality possible (Bauer).

The Engine drive:

- To improve the refuelling system.
- Manual start - No electric start due to battery problems (transport, fitting and preventing electric shorts during rough transportation).

Suction and discharge system:

- 3" hoses, couplings and fittings such as clamps and couplings should be of metal, and of best quality possible as leaks will significantly effect the performance.
- 30m of 3" suction hose.
- 15m of 3" discharge hose.
- Only metal ball valves (Bauer type).
- Only metal connectors (Camlocks) with spare sealing gaskets.

Fluidising system:

- High Pressure hose to be provided at separate reel. 30 m of high pressure hose.
- The end of the High Pressure lance is to be fitted with an ENZ Pointed nozzle, with 4 nozzles angled upfront.
- Secure the unloader to prevent pressures above 100 bars (100 bar to be set as an absolute maximum).

Figure 40: The Toilet is 30 m away – and inaccessible by the truck. Pressure hose to the right of the suction pipe.

Figure 41: 30 m suction hose with 30 m high pressure hose (to the left) – distance was no problem either for pressurising nor for suction.

- The manometer more clearly visible to the operator.
- Water supply to high-pressure pump fitted with 1 ½ " filter.

4.5.6 Maintenance of the ROM2

The following maintenance is required to keep the ROM in top performance.

General Maintenance

Daily:

- Checking oil level of the Honda Engine.
- Check the oil level in the reservoir for the vacuum pump.
- Check the water filter.
- Check that the pressure output of the nozzles is adequate.

Weekly:

- Inspecting the interior of cleaning the water filter from the tank to the pressure washer pump.
- Cleaning the oil trap.
- Cleaning the air filter for the vacuum pump.
- Cleaning the exterior of the machine.
- The tank through the inspection cover.
- Check the suction pipe for damage.

After 250 uses:

After very hard use of the ROM2 in a difficult environment we would recommend a general maintenance after 250 uses:

- Service the engine – oil, change, plugs, air filter, etc.
- Change the 2 drive belts.
- Tighten all pipe clamps.

Figure 43: The inspection cover supplied by ROM was welded on by a local welding shop.

Figure 44: One can see stones, charcoal and other debris through the inspection cover. The tank will now be easier to clean and service in case of can blockages or sticking full / empty gauge.

5 VACUTUG

The Vacutug was the second of the desludging pumps to be selected for comparison in the trials. It is a diesel-powered vacuum pump with a 500 litres steel holding tank. The diesel engine also provides motivation for the self-propulsion. It does not have a separate fluidiser, and it was later tested in conjunction with an independent fluidiser (the Karcher).

5.1 Description Vacutug MK2

Table 5 details the specifications of the Vacutug Mk2.

5.2 Deployment

The Vacutug was air freighted to Malawi. It was offloaded from the MRCS truck using a forklift to the WES premises. The lifting rig that was made for the ROM2 was also useful for lifting the Vacutug to enable its assembly.

The Vacutug came unassembled and took 3 people almost 6 hours to unpack and assemble. The assembly instructions supplied from the factory were not clear and the required a lot of adjustments to belt drives and engine controls.

Table 5: Technical specifications Vacutug Mk2

Specification	*Vacutug Mk 2*
Description	Diesel driven vacuum pump. Steel holding tank.
Shipment gross weight and volume	869 kg; 5.69 m^3
Propulsion	Self-propelled, 3 – 4 km/hr
Engine type and power	Chinese diesel, 9,1 KW, electric / manual start
Vacuum pump capacity	Make: Pagani. 2,750 lt/min Relative pressure: 1.5 bar Vacuum -0.91 bar. Max power 7kW
Pressure pump capacity	n / a
Holding tank capacity	700 litres
Water tank holding capacity	0
Suction hose diameter	3”
Suction hose length	2 x 15 m
Hose connectors	Quick release, Metal
Ball valves	Metal
Instruction and maintenance manual	no
Spares	Engine spares kit. No vacuum pump spares. Hose repair kits.

Figure 45: Offloading the Vacutug.

Figure 46: Unpacking the Vacutug.

Figure 47: Lifting the Vacutug for assembly using lifting gear.

5 VACUTUG

5.3 Tests performed

The Vacutug could only be tested on pit latrines after the procurement of the high-pressure pump (Karcher). While it worked fine on septic tanks, vacuum pumps without fluidising capacity are ineffective on hard sludge.

The manufacture recommended to fluidise in the following way: the pump should be first set to vacuum, then after sucking some sludge to set the pump to pressure and then blow back into the pit. However this is not suitable for pit sludge in Malawi as the liquid content is too low. In any case, such a violent action may cause unlined pits to collapse.

Due to the frequent breakdowns and the lack of mobility of the Vacutug only few tests on pits were performed.

The Vacutug was tested on 10 toilet facilities all unlined pits, removing a total of 7100 litres of sludge.

The table, summarises the number of toilets and amounts of sludge removed by the Vacutug Mk2. Full data is detailed in Annex C.

5.4 Tests results

In conjunction with the fluidiser the Vacutug was able to empty pits with difficult sludge from a maximum tested distance of 30m and an elevation of 2m. Even though the number of tests conducted was small, the team is confident of the performance of the Vacutug, however the team had serious reservations about the design and quality of the rig.

5.4.1 How the Vacutug works

Under suction, the vacuum pump is quite powerful, delivering more than minus 0.5 bar pressure (the diesel motor is 7kW). Follow the arrows from the suction pipe (Figure 50), the tank being emptied of air to the vacuum pump exhausting air. We also demonstrate the operation under pressure – to empty the tank of sludge.

Figure 48: Assembly took 3 people 6 hours.

Figure 49: The assembled Vacutug Mk2.

Table 6: Facilities emptied by the Vacutug MK2

	Number of facilities	*Volume of fluidising water (litres)*	*Volume of rubbish fished (litres)*	*Number of IBCs*	*Volume of sludge removed (litres)*
Total facilities emptied by Vacutug	10 unlined pits		640	10	7,100

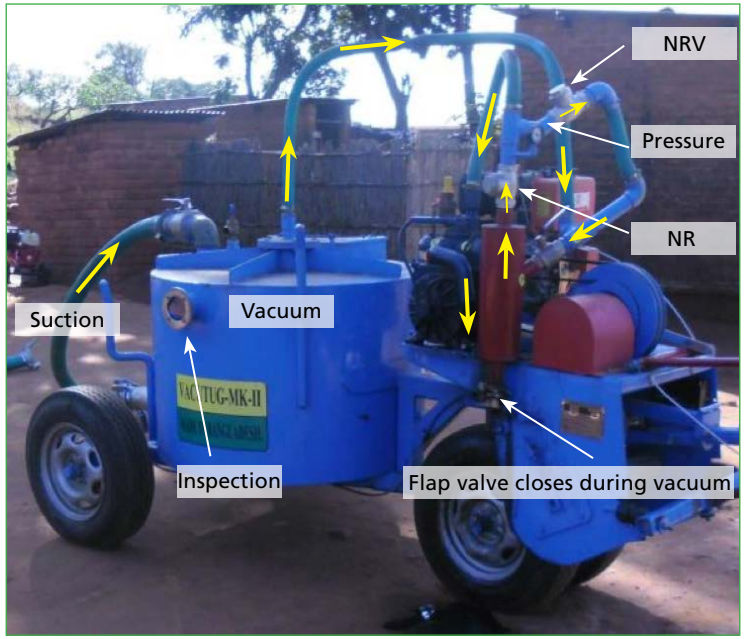
5 VACUTUG

The Vacutug under vacuum

- This setting is used to empty sludge form latrines and septic tanks.
- Under vacuum (pump turned to Vacuum, and the ball valve opened at "V", the flap valve is lifted manually and remains closed due to the vacuum.
- The ball valve at both delivery and suction should be closed.
- The vacuum is measured from the pressure gauge – once the vacuum is about 0.5 bar, and with the suction hose in the sludge the suction ball valve is opened and the sludge is pumped into the tank.
- Make sure that the tank is not overfilled, as the sludge will damage the vacuum pump.

The Vacutug under pressure

- This setting is used to empty the holding tank of sludge and to clear any blockages in the delivery or suction pipes;
- The Vacutug should operate under pressurised conditions when the operator wants to empty the tank from sludge, or even if the suction pipe i blocked and needs unblocking;
- Under pressure the pump turned to Pressure and the ball valve closed at "P", the flap valve is open position;
- The ball valve at both delivery and suction should be closed;
- The pressure is measured from the pressure gauge – once the pressure is about 0.5 bar, and with the delivery hose in the sludge disposal tank, the delivery side ball valve is opened and the sludge is pumped out of the tank.



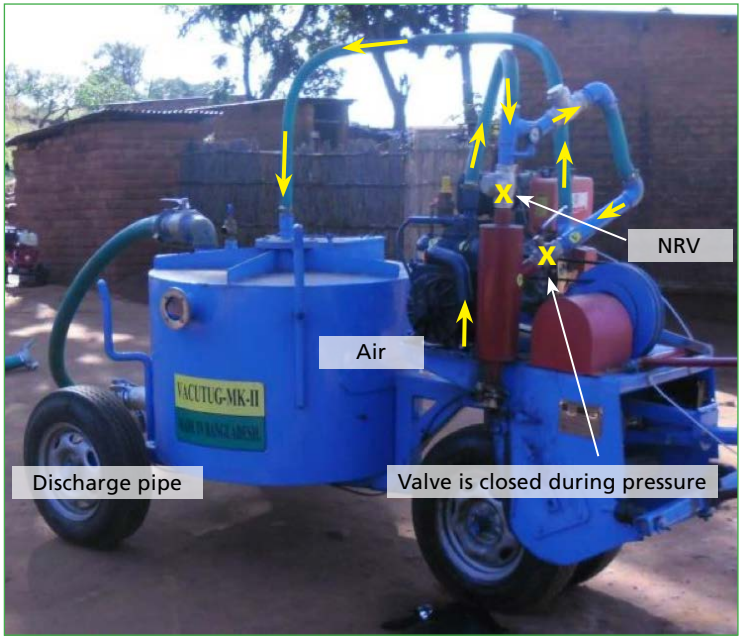


Figure 51: The flap valve of the pressure chamber is open (under gravity). In this position a lot of oil is spewed from the pump.

Figure 52: For the pressure chamber to be under vacuum the flap valve should be shut by lifting manually – it will remain sealed to maintain the vacuum.

Figure 50: Vacutug and elements.
Figure 53: Vacutug under pressure.

5.4.2 Problems with the Vacutug

We encountered several problems with the Vacutug:

- Under its own power (self-propelled) the Vacutug is very slow at 4kph. It cannot handle even mildly rough terrain or mild slopes, and is unstable. It cannot be licenced to operate on the public roads and cannot keep up with traffic. Due to the slow speed work progresses very slowly.
- Towing the Vacutug proved slow and dangerous – towing over 15 km took over 4 hours and at one point it tipped over damaging the pressure chamber bracket and breaking the vacuum pump pulley.
- The starter system of the diesel engine failed – the manual pull started spring broke so that we could only start using the battery. Then the battery failed completely.
- During the short time it operated under self-propulsion the suction pipe from the tank to the vacuum pump fell on the hot exhaust pipe and melted.

After several months of facing problems with the Vacutug, including a lack of a high-pressure fluidiser, we managed to get the Vacutug back to work:

- Dismantling the 2 parts solved the issue of transporting the Vacutug: the tank and the driving side. The tank was towed using a one-ton pick up at normal speed and it proved stable. The driving side (i.e. two narrow wheels, engine, pumps etc.) were placed on the deck of the 'bakkie'.
- As the manual starter broke, and the original battery failed, we used another battery from the ROM.
- After attempting repairs on the pulley (poor quality workmanship) we fabricated a new pulley from aluminium stock (Non ferrous Industries) at Euro 70. After fitting, the engine and pump ran very well.
- The vacuum pump is very effective, and we manage quite a good vacuum (-0.6 bar compared to -0.5 bar with the ROM) – so initially it least, it is performing well.
- However, the Vacutug cannot be driven, so we empty into an IBC and then use the ROM to transfer the sludge from the IBC to the bladder.

Figure 54: The hose melted halfway on contact with the hot engine exhaust pipe.

Figure 55: The manual pull start mechanism broke and had to be removed.

Figure 56: The original Vacutug pulley broke – and we failed a decent repair and could not find an off the shelf replacement.

Figure 57: The newly made pulley made by a local workshop.

Figure 58: The pulley fitted on the machine. Note that the pulleys and belts are unprotected.

5 VACUTUG

5.5 Conclusion and recommendations

The team experienced several problems with the Vacutug namely:

- The design – i.e. not having a fluidiser.
- The self-propulsion mechanism is unsuitable for the hilly, bumpy tracks found in high density, low income areas.
- The quality is very poor – resulting in long periods of down time of the machine.

5.5.1 Challenges and recommendations of the Vacutug

The following table details the challenges and recommendations for the Vacutug.

Table 7: Challenges and recommendations Vacutug

Challenges	*Recommendations for improvement*
No assembly or operators or service manuals	Provide clear manuals for assembly, operation and servicing
Poor safety for operators and environment	• "Three wheeler" is unstable on uneven roads • Engine has no emergency stop switch • Pulleys and belts should have safety guards • The vacuum pump spews oil
Under self-propulsion it is too slow, underpowered to climb a modest slope and too unstable	• Fit to a trailer towed by a 1 ton bakkie
Some items are poor quality and fragile- e.g. starter mechanisms, battery, bracket for pressure chamber, pulley, ball valves	• Improve quality of fittings
No fluidising capacity suitable for very dry sludge	• Needs to have high-pressure pump and nozzle kit and water tank. The pressure pump can be driven by the diesel motor instead of the self-propulsion, which is not very useful.
Low tech Chinese engine has poor reliability and economy and spares are unavailable	• Use a mainstream engine that is more reliable, economical and with dealer network – eg Honda

5 VACUTUG

Table 8 details the ''likes' and comments for the Vacutug.

Table 8: Likes and comments Vacutug

Likes	*Comments*
Torquey diesel motor	But need to improve quality of some parts – e.g. starting, emergency stop, and guards.
High capacity vacuum pump	This is very powerful (more than ROM) but oil spew is a serious concern. Adjusting the oil flow control controls this.
Inspection cover	This is important for cleaning the tank and removing blockages from the discharge.

Figure 59: Vacutug 2000 litres holding capacity.

5.5.2 Recommendations

If the Vacutug would be considered as a mainstream machine it is recommended to consider including the following specifications:

- A fluidiser that can spray high-pressure water of around 60bar in the latrine sludge. The fluidiser can be mounted on the same chassis as the vacuum pump and driven by the same engine (similar to the ROM 2).
- Improving the quality of the engine that is reliable, economical and has a good dealer network (putting a Honda Unit as an option).
- Improving the safety of the drive system – i.e. operators should be protected from the belts with belt guards and an emergence stop button that is easily accessible is essential.
- A holding tank of around 800 – 1000 litres to store and transport sludge. Our experience is that this size tank is sufficient to make an impact in emptying an average household pit latrine yet remain manoeuvrable in congested areas.
- A gauge (an not merely an eyeglass) should indicate the filling progress.
- The unit should be mounted on a small trailer. The company already manufactures and markets a 2000 litre unit mounted on a trailer. See Figure 59.

6 MECHANIZED MEMBRANE PUMP

The third type of equipment was the diaphragm (membrane) pump supplied by Butyl.

6.1 Description equipment

Table 9 lists the specifications of the pump.

6.2 Deployment of the diaphragm sludge pump

The sludge pump was delivered (together with the sludge tank as a kit) and required lifting equipment to offload from the delivery truck.

It took 4 people about 1 hour to offload, unpack and assemble.
The engine was filled with lubricant and fuel and then started.

6.3 Tests performed diaphragm sludge tank

Table 10 number of facilities emptied.

The sludge pump was only trialled on septic tanks as it failed to operate effectively even on fluidised pit sludge.

The pump was used in only one pit latrine, which happened to have a lot of rubbish in it. Thereafter its use in pits was abandoned due to frequent breakdowns.

The diaphragm pump is perfectly useable with septic tanks in which there is not rubbish and don't require fluidising. In fact for such an application it is the best of the 3 machines.

Table 9: Specifications membrane pump

Specification	*Diaphragm sludge pump*
Description	Diesel driven diaphragm pump. GRP holding tank.
Shipment gross weight and volume	808 kg 4.69 m^3
Propulsion	Truck mounted
Engine type and power	Lombardini diesel engine. Manual start
Vacuum pump capacity	
Pressure pump capacity	n/a
Holding tank capacity	3,000 litres
Water tank holding capacity	0
Suction hose diameter	3"
Suction hose length	30 m (2 x 15m)
Hose connectors	Bauer Quick release, Metal
Ball valves	Metal Bauer
Instruction and maintenance manual	No
Spares	Engine spares kit. Spare Diaphragm

Figure 60: We were unable to offload the truck mounted tank and the sludge pump delivered by SDV.

Figure 61: The sludge pump being serviced before use.

Figure 62: The suction lance has 25mm perforations to prevent large objects such as stones entering.

6 MECHANIZED MEMBRANE PUMP

Table 10: Number of facilities emptied

	Number of facilities	*Volume of fluidising water, lts*	*Volume of rubbish fished, lts*	*Number of IBC filled*	*Volume of sludge removed, lts*
Septic tanks emptied by the sludge pump	18	0	0	145	145,000
Pit latrines emptied by the sludge pump	1	100	40	1	200

Figure 63: The pump requires priming with water.

Figure 64: Testing the pump.

Figure 65: Dismantling, cleaning and reassembly of the 2 ports takes 30 minutes.

6.4 Test results

The diaphragm sludge pump

The sludge pump is fitted with a *'sieve'* at the suction side – i.e. 4 holes of 25mm diameter to prevent entry of debris such as stones and rags, plastic sheet, bottles and paper that can affect the performance of the pump action – i.e. especially the valves – see later).

6.5 Performance of the pump

We had good a experience with the performance of the sludge pump on 17 septic tanks emptying 144 m^3. However the *'sludge'* in septic tanks cannot be characterised as *'difficult'*.

We also emptied a market toilet with fresh sludge into 7 drums, total of 140 litres (but in a controlled environment – i.e. minimal trash in the pit).

Over 2 days less than 200 litres of sludge was pumped:

- On the positive side: the performance of the pump on the fluidised (but thick) sludge in our toilet was very good – i.e. it can handle the thick sludge once it is fluidised. It could pump about 50 litres per minute.
- Challenge: the pump could only operate for a maximum of 2 minutes before it stopped pumping.

Problem

On dismantling the pump ports we found small pieces of trash stuck in the ports thus causing the suction side and the delivery side not to seal – therefore the pump was unable build up any pressure – so the sludge just moved back and forward with the diaphragm action but did not move forward. The dismantling and reassembly of the port took ten minutes – a simple operation. The repair of both ports and cleaning took 30 minutes. But the pump kept blocking in 2 minutes.

We dismantled the ports 4 times.

Note: it is not possible to fish this small trash out, and neither is it possible to put a smaller size sieve, as the suction would block all the time.

6.6 Conclusions and recommendations membrane pump

Our experience with the sludge pump on use in septic tanks is very good – and we did not experience any problems.

For use in pit latrines, the sludge pump can cope with thick, fluidised sludge for short periods of time, but the ports easily lose their seal due to small pieces of trash that can neither be fished out nor be sieved.

We expect that the sludge pump can be effective in removing fluidised pit sludge that has no trash.

The supplier of the pump has agreed with the report's findings and has designed a macerator pump that is suitable for use with hard sludge with rubbish. The macerator pump has yet to be tested in field conditions.

Note: in both pictures, the sludge is quite thick – so the pump has the capacity to pump; the problem is the rubbish in the sludge, which cannot be fished out.

Figure 68: The delivery side port valve was also not sealing due to small pieces of cloth.

Figure 66: Suction port is not sealed due to a small piece of cloth.

Figure 67: Suction port is not sealed due to a small piece of cloth.

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

As neither the Vacutug MK2 nor the Diaphragm sludge pump came with an integrated fluidiser, a separate fluidiser and accessories (Karcher Brand) was purchased.

In addition, 3 different nozzles were supplied.

7.1 Description equipment

7.1.1 Specifications of the Karcher pressure washer

In Table 11, the Karcher specifications are listed in comparison to the pressure pump fitted to the ROM2.

Table 11: Comparison Karcher and ROM pressure washer

	Karcher HD 1040 B	*High pressure pump in the ROM 2 – SPECK brand*
Power supply	Honda 340	Honda 390: 6.6 KW engine
Power requirement		4.1 kW.
Max pressure	Adjustable 10 - 210 bar (depends on nozzle design)	140 bar –maximum pressure - unloader set on 60 bars
Max volume / minute	Adjustable from 3 - 15 litres / minute	15 litres / minute
Access to toilets	Very portable so can be wheeled to toilets that are difficult to access.	The Locally improved ROM2 is very compact and mounted on a trailer. Suction pipe and the high-pressure hose are 30m long.
Comments	• Designed for connection to a water tank even 1 m below machine with special ¾" feed. • No filter supplied (only sieve) – so minimal protection of pump from damage. Filter is available as an option. • Adjustable pressure regulator. • Pressure gauge – rough graduations.	• Designed for low-pressure water feed (i.e. uses overhead tank). • Has heavy duty ½ filter to protect pump from debris in water. • Regulator pre-set to 60 bar. • Graduated pressure gauge.

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

7.1.2 Specification of the 4 nozzles

As stated before, of the 2 variables we tested, water pressure was one, and spray pattern was another. Therefore part of the test procedure was to use the different nozzles under different pressures.

Due to safety concerns, the maximum pressure was set at 100 bar. It was agreed to use the equipment at 20 – 30 bar, at 50 bar and at 100 bar. However setting at 20 – 30 bar proved to be ineffective (taking too long to fluidise and using too much water). Our basic objective was to make pressure and nozzle recommendations. According to the principles of thixotropy, the more the stress (i.e. higher pressure and diffuse spray pattern) the more readily the sludge would be fluidised.

Table 12: Variety of nozzles tested

The standard Karcher nozzle fitted without problem to the lance (also Karcher)

The standard Karcher nozzle fitted without problem to the lance (also Karcher)

The ROM rotating nozzle required an adapter to be manufactured

The ROM pointed nozzle also required an adaptor to be machined – it was different to the adaptor for the rotating nozzle

7.1.3 Deployment

Setting up the Karcher was easy and took very little time (check engine oil).

Figure 69: Deployment Karcher. The Karcher was checked to make sure that it was serviceable (lubricants for engine and pressure pump and fuel). Water supply should be ideally from the mains supply – but this is unlikely in emergency work, so we connect it to a filled drum.

The water inlet to the pump was from a 200 lt drum, via 12mm plastic hose, with gravity feed (1 m). We eventually had to upgrade from ½" to ¾" hosepipe to increase the output pressure from the nozzles.

Figure 70: Details Karcher pressure washer. The pressure pump came already lubricated – inspection glass.

Figure 70: Details Karcher pressure washer. The pressure of the water jet is regulated by the knob.

Figure 71: Details Karcher pressure washer. The pressure gauge is calibrated in 50 bar, 100 bar, 200 bar etc. On the right set to operate at 50 bar.

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

7.2 Tests performed

The nozzles were tested with the Karcher in pits with hard sludge. The pressures were set to 50 and 100 bar after setting the pressure to 20 bar proved ineffective in fluidising. The 3 new nozzles were tested in over 20 pits toilets (Annex C for table).

7.3 Test results

The results are shown in Table 13.

Table 13: Testing 3 nozzles and comparing with the standard ROM2 nozzles

Nozzle type	*Picture of spray pattern*	*Operating pressure*	*Time to consume 25 litres water (mins:secs)*	*Comments*
Standard ROM2		60 bar		Engine at Full throttle. Stable pressure. Pump pressure 120 bar max, but regulator set to 60 bar.
Karcher standard		50 bar	4:00	Operating pressure 50 bar, engine at half throttle.
		50 – 75 bar	4.56	Engine at half throttle. The operating pressure kept pulsating between 50 – 75.
		75 – 100	4:05	Engine at HALF throttle. The operating pressure kept pulsating between 75 – 100 .

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

Nozzle type	*Picture of spray pattern*	*Operating pressure*	*Time to consume 25 litres water (mins:secs)*	*Comments*
				We could not exceed 75 bar.
ROM rotating nozzle		50 bar	2:06	Full throttle, pressure was stable at 50 bar.
		60 bar	3:06	Full throttle, pressure was stable at 60 bar – but we could not increase the pressure further.
ROM pointed nozzle ENZ		0 (ie lowest setting)	5:16	Engine at Full throttle. Stable pressure.
		60 bar	4:15	Full throttle, Stable pressure.
		70 bar	2:30	Full throttle, Stable pressure. We could not get higher than 70 bar due to hosepipe restrictions.

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

7.4 Results of Field Trials

The team has built up quite a bit of experience in emptying pits with difficult sludge:

- Using the ROM 2 and the modified 'Locally improved ROM2', with its integrated fluidising system for over 400 times. The main modifications that we recommend for future designs of the ROM (i.e. the 'Locally improved ROM2') include:
  - Setting the pressure regulator to 100 bar maximum.
  - Aligning the pressure gauge so that it is easily visible to the operator (who can monitor the output pressure.
  - Detaching the high pressure fluidising hose form the suction pipe to make it independent.
  - Increasing the length of the high pressure hose to 30m to access more toilets.
  - Increasing the capacity of the water filter form ½ inch to 1 ¼ inch.
  - Daily maintenance of the water filter.
- Using the Karcher and the 3 new nozzles in over 20 pits. We had initially planned to fluidise 25 pits with each of the Vacutug and the diaphragm sludge pump. This target was not possible for 2 reasons explained in chapter 5 and 6.

Refer to Table 13 for a detailed report on the performance of the 3 nozzles with the Karcher pressure washer.

7.4.1 Which operating pressure and which nozzles are best?

In the teams' experience of desludging over 400 pits, one thing is very clear: that it is not possible to make quantifiable, objective assessments regarding pit sludge. The team developed a saying that "each toilet has its own personality" meaning no 2 toilets are exactly the same.

However, based on the perceptions of experienced operators and businessmen, a consensus can be reached based on perceptions relating to efficiency (the concern of a business operator) and effectiveness (the concern of the pit emptiers and the clients).

Efficiency

This is a measure of how cost effectively the pump and nozzle set up do the job: i.e. how quickly (saving labour and fuel); what is the turnaround time (ie able to empty more toilets in a given time); as well as the amount of water used (water is expensive to buy, to transport to and from the toilet site).

Effectiveness

This is a measure or assessment of how good the pump and nozzle set up does the job, and is of interest to the client and the employees operating the unit. (i.e. it is a measure of the *'supply'* side).

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

Table 14: Result field trials pressure washers

Criterion	*Comment*
Emptying full toilets	• Both the ROM2 and the Karcher as well as all 4 nozzles performed well. The preference was for the pointed and Karcher nozzles at 100 bar. • The percentage of water to sludge removed was average of between 18 – 25%. • The team did not fail to fluidise any difficult sludge. • The operators perception was that the rotating nozzle eroded the soil walls of unlined pits.
Abandoned toilets – re-useable	• The team was assigned to "rehabilitate" several toilets that had been abandoned due to full pits. The Karcher nozzle managed to rehabilitate 3 pits at 100 bar using average 200 litres of water (and fishing 100 litres of rubbish). Percentage of water to fluidise was 25% of sludge. • The Pointed nozzle would have also been effective.
Cleaning toilets	• Only the rotating nozzle is not recommended for this activity.
Customer satisfaction (i.e. owner and users of toilets)	• All clients were amazed at the effectiveness of the equipment in emptying the sludge from the pits, leaving no mess and no smell.
Operators satisfied with equipment – not laborious, gives status etc.	• The operators preferred the Karcher Nozzle set at 100 bar as the best all round nozzle to use for fluidising and cleaning. The pointed nozzle was also acceptable.
Opinion of the Business owner	• The business owner preferred the pointed nozzle operating at 100 bar. Main reason is that this appears to be the most efficient nozzle.
Opinion of WASTE researcher	• WASTE recommends the use of the pointed nozzle with smaller holes operating at 100 bar.

7 KARCHER HIGH PRESSURE WASHER FOR FLUIDISING SLUDGE

7.4.2 Summary of fluidising on desludging performance

Without any fluidising, none of the equipment was able to perform well in removing difficult sludge. The diaphragm sludge pump was very sensitive to any rubbish in the sludge, so as equipment for desludging pits, this equipment must be ruled out.

With an integrated fluidiser the ROM2 was able to handle most types of sludge – although extensive fishing of rubbish is required.

The time taken to fluidise a pit full of difficult sludge typically takes 10 minutes, usually done 3 times in between fishing, which takes about 30 minutes. The amount of water varies between 100 – 200 litres; the amount of rubbish between 50 – 100 litres and the amount of sludge removed is usually 800 liters. Experience indicates that there is little point in removing more than 800 litres of sludge in a household pit as the pit already appears empty and the useful life has been extended.

When operated with a fluidiser, both the ROM 2 and the Vacutug were able to effectively pump out difficult sludge. While the detailed performance characteristics of these machines is given in another report it can be summarised that with fluidising both vacuum machines were tested to their limits and could pump sludge using a 30m suction hose and a 2m elevation form the toilet slab. The picture below shows how with effective fluidising (as well as fishing) pit latrines can be effectively and safely emptied.

Figure 72: With fluidising the Vacutug was able to access and empty hard toilet sludge from a distance of 30m and an elevation of 2m. The Karcher fluidiser is next to the toilet (white building in the background). Otherwise the toilet would have been inaccessible.

Figure 73: With the ROM2 a 30 m suction hose with 30 m high pressure hose (to the left) and performance was good.

Figure 74: The sludge is often so thick and solid that rocks like this are suspended and are loosened during the fluidising process.

Figure 75: Fluidising is an essential part of pit emptying – including fishing out of rubbish from the now softer sludge and the pumping out the sludge.

Figure 76: The fluidiser - with the pointed nozzle is essential for the safe cleaning process.

7.4.3 Cleaning up

The high-pressure washer and nozzles are also essential equipment to help the pit emptying team to clean up the toilet slab after the operation (especially after the fishing of rubbish). It is also used to clean the equipment (hoses, fishing tools) as well as the desludging equipment. The high pressure is also useful for cleaning the inside of the vacuum tank of the ROM2 and the Vacutug) to remove blockages. Operators have found the use of the pressure washer to clean the toilet slab after emptying the pit to be a good selling point and increase customer satisfaction. In this picture the pointed nozzle is being used.

7.4.4 Safety issues

The operators clearly prefer 100 bar operating pressure as it makes the desludging process and the cleaning up procedure relatively effortless and fast. The business owner's preference is also 100 bar, as it is perceived to be more efficient and use less water and fluidise in less time. There was no observed impact of the higher water pressures on unlined pit latrines.

Although there may be concerns about operator safety that 100 bar is too high and may cause injury, our experience shows that with some training this is a safe operating pressure. If the water jet hits the skin at more than 1 m from the nozzle, pain will be felt. The team considers that injury may occur if the water jet is aimed directly on the human skin at a distance of less than 1m.

Therefore the team can recommend the use of water jets at 100 bar – with the caveat that the regulator is set to this pressure setting and that all the system (pressure hoses and fittings) comply with the pressure rating. Previously it was reported about the damage to a pressure hose in the ROM2 due to adjusting the regulator upwards.

7.5 Conclusions and recommendations Karcher high pressure pump for fluidizing sludge

Without the assistance of fluidising equipment, it is not possible to empty a pit latrine using a vacuum pump due to the solid nature of faecal sludge in many, if not most pit latrines, even when it is "fresh". Fluidising equipment may come in various forms. The technology we opted for was high-pressure water with nozzles having a wide spray configuration. The pressure washer may be integral part of the machine, as in the case of the ROM2 or Locally improved ROM2, or it may be standalone equipment such as the Karcher.

An integrated washer is more cost effective (capital and operating costs), easier to use and maintain, and easier to manoeuvre to less accessible toilets as a complete unit (i.e. desludging pump and fluidising).

Based on the team's experience, the higher the pressure, the more efficient the fluidisation of the sludge will be, however for safety reasons a limit of 100 bar is recommended.

In terms of nozzle design, the nozzle should have a combination of low water consumption, low-pressure drop and a wide enough spray pattern (e.g. 150) to ensure that the sludge is sufficiently "stressed". The nozzle should ideally also be used for cleaning the toilet slab and the desludging equipment (e.g. suction pipes, fishing tools, holding tanks, etc.).

The 'best' nozzle remains a matter of perception. From the operators' perspective, they were happy with the Karcher nozzle at 100 bar. due to perceived advantage of performance. From the business owner's perspective, the best was the pointed nozzle (ENZ) due to its perceived advantage of economy.

8 INTERMEDIATE STORAGE IN 13 M³ SIOEN BLADDER

8.1 Description equipment

The Sioen bladder is constructed from PVC and has a capacity of 13m³. It included 2 inlet and 2 outlet couplings (PP Camlocks).

8.2 Tests performed

The Sioen bladder was used as a transfer station – and was filled and emptied it about 4 times. It has been transported 3 times. It was noticed that there was some damage each time it was transported. We acknowledge that rough handling by the operators causes the damage, but this is normal field operating conditions. A repair kit was ordered, and this is very easy to use if the bladder has a tear only on the outer layer. It is impossible to make a repair on the inner layer if the bladder is completely punctured.

8.3 Test results

The bladder was filled directly from the ROM2 (even from 30 m) and from IBCs filled from the diaphragm pump. It was estimated it was filled with about 10m³ of sludge. Even though the bladder was left full overnight, there was very little disturbance from odours. Even spillage was minimal.

Figure 79: Operating the bladder.

Figure 77: Heating the hose to fit the Camlock.

Figure 78: Fitting Camlock.

8 INTERMEDIATE STORAGE IN 13 M³ SIOEN BLADDER

A vacuum truck of 3.5m³ capacity was used to empty the bladder. The suction pipe required the fitting of a Camlock (see Figure 77). Emptying was simple and quick – the truck took just a couple of minutes to empty between 3,000 and 3,500 litres. 3 trips were required - so that the volume of sludge in the bladder was between 9,000 – 11,500 litres.

The vacuum tanker disposed of the sludge in the sewage treatment plant over 25 km away, and cost €50 per trip, total €150, which is a consideration in terms of time and money.

On one occasion almost 6m³ of sludge was left in the bladder for 4 weeks (due to a breakdown of the vacuum truck). When the truck was eventually repaired, all that was required was a quick application of pressurised water with the ROM 2 in order to fluidise the sludge in the bladder, which was pumped out easily

8.4 Problems encountered

The main problems encountered was that of:

- Damage to the bladder.
- Rolling of the bladder when full.

Damage

The bladder was subject to damage during transport – due to friction with some bolts on the trailer bed. A repair kit would be useful. However, due to the double layer the bladder did not leak.

Rolling of the bladder

Although the bladder was placed on a gentle slope, once it was filled with sludge, it appeared to be *'rolling'* downhill. It is not sure that it would have rolled very far, but as a precaution one corner was tied to a tree!

In a later operation the bladder was placed in a shallow trench of about 15cm (as a HAZOP precaution in case of rupture due to vandalism) and there was no movement.

Figure 80: Operation of bladder.

8 INTERMEDIATE STORAGE IN 13 M³ SIOEN BLADDER

8.5 Making the repairs

We found a couple of tears and punctures on the bladder, at the bottom side.

Figure 81: Rip outer layer.

Figure 82: Repair with repair kit.

Figure 83: Puncture: The bladder had a small puncture at the bottom that went through both layers – a stone in the sludge probably caused this.

8.6 Conclusions and recommendations

Advantages

- As a transfer station the bladder is very useful, especially due to its large capacity and easy deployment.
- It is easy to fill and empty with the correct couplings and with no or little spillage.
- Even if the sludge stays for a long period in the bladder, there was no offensive smell.

Disadvantages

- The bladder should be only used in one place and should not be relocated to another area as it is easily damages.
- Due to the double layer, if the PVC membrane is damaged the inner layer is not possible to repair and sludge accumulates between the layers.
- As the bladder may be damaged due to vandalism security is required, and for safety reasons the bladder should be positioned in a trench – ideally 30cm deep.

Recommendations

The bladder should certainly be considered as a sludge *'transfer station'* due to its large capacity and easy of deployment. It is sufficiently durable to be filled and emptied many times. However the following should be observed:

- The bladder should have a maximum of only 2 connections (not 4 as was ordered).
- The bladder should be placed in a trough of at least 15 cm to contain the sludge in case of serious leakage due to rupture.
- The bladder should be planned to be used in on location only and should not be planned to be moved around due to high risk of puncturing during the deployment.

Figure 84: We opened the outer layer puncture in order to repair the inner layer, but found that sludge had leaked from the bladder in between the layers. This meant we could not access the inner layer for repairs. We just repaired the outer layer.

Figure 85: The active carbon cartridge has completely deteriorated……but the plastic cover will only fit the cartridge.

9 FLAT PACKED GRP SLUDGE TRANSPORT TANK

9.1 Description equipment

The 3m³ truck mounted sludge tank required lifting equipment to offload, or else it can be unpacked from the box and the panels offloaded separately. It appears that the wooden packing box is much heavier than the actual tank.

Offloading, unpacking and assembly took 4 people seven hours.

The tank requires lifting equipment to mount on a truck – we used the equipment designed to lift the ROM. The tank was mounted on a truck of 3 ton capacity and which also carried the ROM.

The tank has already been deployed in the desludging exercise.

We have a serious reservation with the design in that due to the high position of the discharge valve from the base, about 0.5 m³ of sludge will remain in the tank, and the tank is unable to be completely emptied.

Assembling the tank took 4 people almost 7 hours .

The tank has a meter for determining

9.2 Conclusions and recommendations flat packed GRP transport tank

- It is suitable to fit to a 7 ton lorry.
- The tank should be inclined at an angle i.e. front higher than the back - to ease emptying – (as done in normal vacuum tankers).
- It is not possible to empty completely as the discharge valve is about 10 -15 cm from bottom, with 200 – 300 litres sludge remaining.
- Lifting gear is required to lift the tanker on and off the truck.

Figure 86: The tank was mounted on a 3 ton lorry, together with the ROM2. However it is advisable to mount the tank and possibly desludging pump in a 7 ton lorry.

Figure 87: Due to the position of the discharge port, the tank cannot be wcompletely emptied of about 0.5 m³ sludge.

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

After some major modifications to the equipment, the team found that effective and efficient emptying of pit latrines under a wide range of conditions and with difficult sludge is possible. We tested and modified equipment that was able to take significant amounts of sludge from pits up to 3 meters in depth in a safe, quick and cost effective manner.

Importance of fluidising

In general, the nature of the sludge found in most of the test pits and the location of the toilets fulfilled the definition of 'difficult'. To be able to handle the sludge a process of fluidising with pressured water and specially designed nozzles was developed. Without fluidising none of the equipment managed to remove significant amounts of sludge from the pit latrines. In most cases the amount of water used during the fluidisation process was about 15% of the total sludge removed. After fluidisation it was found that the solids content of the sludge was around 20%. More testing to find optimum nozzle configuration and water pressures to fluidise with the least volume of water is ongoing.

Role of solid waste removal – 'fishing'

The sludge was found to invariably contain various forms of solid waste and rubbish, which must be mechanically removed after fluidising but before mechanical pumping of the sludge. Most households throw rubbish in the pit because of a lack of solid waste collection services. Examination of the fished out products, revealed items as old clothes, shoes, bottles, plastic carrier bags, maize cobs menstrual cloths, medicine bottles (eg ARVs), and rubbish from the pit structure itself: gravel, stones and even large rocks falling from the pit wall. Therefore while fishing is an essential part of the emptying process to remove the larger rubbish that would simply block the suction or discharge pipes, it was found that the equipment can also get blocked during disposal by the smaller items (eg medicine bottles, cloths, plastic, stones, etc.) that could not easily be removed during the manual fishing process but accumulate inside the holding tank.

Pumping and transportation

The Diaphragm pump required an auxiliary high-pressure pump to fluidise and has been proven to be the most sensitive to rubbish. Though it functioned well in septic tanks with no rubbish, it was not possible to pump significant amounts of sludge from pit. The requirement of a separate holding tank (we used an IBC) also put it at a disadvantage. The Vacutug MK2 also lacked an integrated fluidiser, and though designed to be self-propelled, it was slow and impractical when needed on difficult terrain or to cover longer distances. Otherwise it was effective in removing fluidized sludge. The ROM2 performed the best in terms of effectiveness, but required major modifications to make it more efficient for the operator; and the machine was subsequently tested with these modifications – now we have a Locally improved ROM2. Given these basic requirements it is now possible to recommend a design of a transportable pit-emptying machine that can handle most sludge in lined and unlined pit latrines as well as septic tanks, and can access a high percentage of toilets.

Significance and impact

The equipment has been tested in over 300 pit latrines of paying customers and has managed to remove significant amounts of sludge from all these toilets and thus prolong their useful life and this was done with the safety for the operator and environment in mind. Apart from the fishing process, there was no spillage or contact with sludge between the emptying of the pit and the disposal of the sludge. The Locally improved ROM2 proved durable and required repairs (to the drive belts) only after emptying 200 pits. It is considered that the modified equipment represents a reasonable business model and therefore a sound investment for both the emergency sector and a sanitation enterprise. Long-term prospects of the business model require testing and validation.

Other challenges remain

Importing such equipment can be costly, so local production of a unit using the stated design features and assembled using imported basic components may prove more cost effective to the business operator. Due to the relative small capacity of the holding tank transportation to a disposal site is expensive and results in loss of operational efficiency.

Therefore setting up of decentralised disposal sites would make the operation more efficient and reduce risks of an accident. The presence of so much rubbish in the sludge will remain a challenge and fishing remains a dirty and dangerous job until equipment that can make fishing less necessary is made available. Market analysis indicates that few pit latrine owners are aware of modern emptying services and most clients are surprised to find the equipment so effective in emptying the pit.

10.2 Recommendations

10.2.1 Key features of the pump

The key features of a vacuum operated machine targeting the emptying of toilets with "difficult sludge" should compromise of:

- A fluidiser that can spray high-pressure water of around 60 bar in the latrine sludge using special lance and nozzle. Optimising the nozzle design and operating pressure can make for more efficient fluidising but due to safety concerns pressure should be less than 100 bar.
- A vacuum pump that can create a vacuum of 0.5bar and a capacity of at least 2000 litres per minute.
- 3 inch flexible suction and outlet hoses in order to avoid frequent blockages by un-fished rubbish and with good quality quick release connectors.
- A holding tank of around 800 litres to store and transport sludge. The inside of the tank should be easily accessible to clean any blockages. A gauge should indicate the filling progress.
- The unit should be mounted on a small trailer and the lengths of the suction pipe and fluidising hose increased to 30 metres to increase accessibility to toilets.

10.2.2 Operators: Basic skills requirements and training

The operators should have some mechanical and practical aptitude. It was found that a team of 2 operators is sufficient and between them they should have the following basic skills:

- Driving licence.
- Basic mechanic skills (e.g. checking oil levels, cleaning filters, cleaning equipment).
- Basic building skills – in order to assess of a toilet is safe or unsafe to desludge.
- Ability to relate to clients in order to explain to them the desludging process as well as safety requirements (e.g. no children playing around the machinery or workers during the desludging).

Ideally the operators should have some training in the basic operations of fishing out rubbish from the sludge, fluidising the sludge, and operation of the desludging equipment.

10.2.3 Operational Health and Safety

The operators should also have the following training:

- Training on hygiene and protocols for cleaning clothes and equipment.
- Know how to mix various concentrations of HTH solutions for different applications according to the table.

Table 15: Preparation of chlorine solution

Concentration of the solution in % chlorine	*Preparation with 65% HTH*	*Indications*	*Proceedings*	*Notes*
0.05%	0.75gr for 1 liter 7.5gr per 10 liters	- Washing hands and skin	Clean and dry your hands and then rub it with a chlorine solution for 30 seconds. Allow to dry	0.05% solution is stable for 24 hours and must be renewed every day. Never mix the solution with detergent
0.2%	3g for 1liter 30g per 10 liters	- Disinfecting floors and bathroom walls - Spraying equipment and truck. (Pipes, wheels, cleaning cloths door handles etc.) focus on the elements that were in direct contact with the sludge - Disinfecting the clothes by soaking for 10 minutes before washing with soap and water	First sweep floors and wash with soap and water. Then apply the 0.2% chlorine solution. Leave in contact for 10 minutes rinse and let dry	Rinse and dry the mop, cloth and brush 0.2% solution is stale for 24 hours and must be renewed every day. Never mix the solution with detergent
2%	30g to 1 liter 300g for 10 liters	- Disinfection of vomitus and stool (for use in buckets of feces) and in case of leaks or accidents	Spray directly vomit and feces with the 2% solution	The 2% solution is stable for one week if the solution is stored correctly. Never mix the solution with detergent

Source: MSF cholera guidelines (2004), based on the WHO Standards.

Safety equipment and safety wear

The operators should have the following safety wear:

- 2 sets of one piece overalls made of washable fabric (less chance of getting sludge than 2 piece overalls);
- rubber gloves, 2 sets;
- rubber boots;
- face masks (nose and mouth) – disposable. One for each toilet;
- eye protection;
- soap for washing hands.

Cleaning of toilets and equipment.

Safety equipment should include a backpack sprayer for spraying the toilets and equipment with chlorine solution after the desludging.

The toilet slab and equipment should be cleaned using the pressure washer and then sprayed with chlorine solution.

10.2.4 Improving work flows

By improving the operations logistics including access to localised disposal site (or a transfer station) – then it is possible to desludge up to 8 pits in 1 working day.

This means that the workflow should be as follows:

- All equipment on site, i.e.: desludging equipment, transfer station or disposal pit, fishing equipment including buckets for rubbish.
- Sufficient staff: 2 operators of the desludging equipment and 2 other staff to do the fishing and cleaning up.

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

(Numbers in red the left hand column indicate ranking by field practitioners *before* the field trials and report. 5/5 is ranked highest importance)

A: Operation and maintenance requirements

	REQUIREMENT *Operation and maintenance*	*field operation findings* *Comments & Recommendations*
A1 3.4/5	***Safety and health*** Ease of adhering to safety, health and environmental norms and standards during operation and maintenance	1. Important for the operators to wear safety equipment (full one piece work suits, rubber gloves, wellington boots, and face mask). 2. The most "dangerous" operation is the fishing of rubbish. This should be collected in a bin with a lid – sometimes 1 pit can yield more than 50 lts - and either buried or taken to a disposal site). 3. None of the 3 machines leaked any sludge during the pumping process (either desludging of toilet or disposal to site or container) this is because the suction hoses were relatively new and the quick release connections very effective 4. Unblocking any three of the machines from rubbish exposed the operators to sludge. 5. As the ROM 2 has a pressure sprayer this is useful for cleaning the toilet slab and the equipment after the operation. 6. The slab and the equipment are sprayed with 2% HTH (300g of HTH 65% in 10 lts water). Any spillages are collected with a spade, and also sprayed with 2% HTH.
A2	***Installation*** Ability to deploy the device within short period upon arrival in the field.	1. When the ROM 2 and the Diaphragm pump are mounted on a truck deployment is quick. Same as when the ROM2 is mounted on a trailer. The Vacutug, though self-propelled is very slow. 2. With localised sludge storage or disposal, and an organised team, the ROM 2 can manage up to an average of 1 pit per hour or up to 8 pits in a working day.
A3	***Processing*** The device has the ability to handle different types of sludge: ie liquid, semi liquid and solid sludge.	1. All equipment managed to empty liquid sludge typically found in septic tanks 2. Only the ROM 2 managed to empty semi-liquid and solid sludge due to inbuilt high pressure fluidiser.

	REQUIREMENT *Operation and maintenance*	*field operation findings* *Comments & Recommendations*
3.3/5		3. With an external fluidiser the Vacutug MK2 and the Diaphragm pump managed semiliquid and solid sludge.
A4 3.0/5	***Ability to handle other materials*** The device can handle objects in the sludge of different types of materials (like menstrual cloth, stones, and bottles).	1. None of the equipment could handle pit sludge without fishing out of the larger items of rubbish. This is because even 3 inch suction pipes would get blocked. 2. The ROM2 and the Vacutug MK2 handled rubbish best, but the Diaphragm pump could not handle any rubbish as even small pieces of cloth or plastic affected the rubber port valves rendering the pumping action ineffective. 3. Even with effective fishing the ROM2 was affected by smaller rubbish that could not be fished out. Most often this rubbish either accumulated in the suction pipe (remedy: pressurise the ROM2 and blow out) or else the accumulated rubbish would block the discharge and at times block the movement of the gauge indicating the level of sludge in the tank. The remedy was to modify the ROM2 so that the inside of the tank would be accessible to unblock the discharge port or clear the float gauge.
A5	***Discharge rate*** Discharge rate of faecal sludge removal from sludge container to be between 20 lts and 500 lts / minute.	1. All 3 pumps could empty sludge form a septic tank at a rate of at least 200lts / minute. The fastest was the diaphragm pump as it could be connected directly to a storage container (eg $1m^3$ IBC, $3m^3$ sludge tank, or $13m^3$ bladder). 2. The ROM2 was the quickest in emptying pit latrines – with effective fishing and fluidising, it could take 4 minutes to fill the 800 lts tank with sludge. but both the ROM2 and the Vacutug have relatively small holding tanks (800lts and 500 lts respectively).
A6	***Operational depth*** Maximum operational (suction) depth of desludging device is 3 meters, or possibility to lower the unit into the sludge.	1. All 3 pumps managed septic tanks of 3m depth with pumps at ground level. 2. The ROM2 and Vacutug Mk2 easily managed pits of more than 2m depth at ground level. They also managed to desludge when elevated more than 2m above the level of the slab (ie in hilly areas).

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

	REQUIREMENT *Operation and maintenance*	*field operation findings* *Comments & Recommendations*
A7 3.3/5	***Operational distance*** Ability to move the sludge over a distance of 10 meters to sludge transport unit.	1. With relatively new suction pipes (used more than 400 times) all 3 machines could move sludge over 30 m (suction pipe). 2. In addition the diaphragm pump could move with 15m suction and 15m delivery into an intermediate storage container or other (eg sludge tank).
A8 3.2/5	***Diameter suction hose*** Diameter (minimum radius: 76mm = 3inch) and flexibility of suction unit to penetrate into sludge holding unit.	1. The ROM2 unit came with 2 pipe sizes – 2" and 3". The 2" was adequate for emptying septic tanks with no rubbish. The 2" was completely defeated by rubbish in pit latrines and blocked in seconds. 2. ONLY a 3" pipe is suitable for emptying pit latrines. 3. The suction side should be as simple and as light as possible in order to easily access toilets and the drop hole. In only one occasion was the 3" pipe unable to enter the holding unit (due to small drop hole).
A9 3.0/5	***Labour*** Requirement of limited physical exertion by operators.	1. Once deployed all 3 machines were relatively easy to use by the operators. 2. The ROM2 had to be modified from the design it was delivered by removing the solid suction pipes and the ball valve at the suction side as it made the unit too heavy for the operator.
A10	***Labourers needed*** The device can be operated by a crew of maximum 2 persons.	1. All 3 machines could be operated by a crew of 2. 2. If a high turnover is required, additional staff are required to prepare the toilets for the machine crew and do the cleaning up.
A11	***Skills needed*** The device is easy to understand and operate (low/ medium skill level required).	1. The best mix of qualifications for the crew includes a mechanic and a builder. Preferably both should have a drivers licence; apart from being able to deliver the unit on site, it gives the operators some mechanical aptitude. 2. All crew would require training, especially in safety, customer relations, in operating the equipment and in maintenance of the equipment.

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

	REQUIREMENT *Operation and maintenance*	*field operation findings* *Comments & Recommendations*
A12	***Conditions*** Capacity to empty latrine without risk of collapsing of unlined latrines (for instance by adjusting operating pressure) .	1. It is essential to make an inspection of the toilet before starting the emptying exercise to ensure that the slab and the superstructure are safe from collapse. Special regard to ensure that the slab is well sealed to the top of the pit (lined or unlined). 2. More than 350 lined and unlined pits were emptied. There was no danger of collapse even with the use of high pressure fluidiser. 3. It was observed that in unlined pits, some of the gravel or stones from the pit wall were also pumped out with the sludge. not sure if these were dislodged during construction, during put use or during the emptying procedure.
A13 3.3/5	***Robustness*** Device is sufficiently robust to withstand extreme conditions in terms of weather (extreme cold and heat, humidity, dust, etc.), handling, and transportation.	1. The ROM2 was very robust being able to handle rough terrain, heat, rain, and even one tipping over. 2. The diaphragm pump is also very durable. 3. The Vacutug is very fragile and cannot easily handle rough terrain. The engine experienced problems with the starter (both electric and manual start), and the self-propulsion mechanism was also difficult to maintain.
A14	***Repairing*** Spare parts need to be locally available. The device can be repaired and maintained locally.	1. The ROM 2 was used more than 300 times. Manual start is recommended (not electric) in order to avoid the use of a battery. The drive belts broke after 200 uses. The water filter was damaged after 250 uses. The water pressure hose broke (pump setting was too high) but a replacement was made locally in an engineering workshop – so the pump should be set to 100 bar maximum. The Honda engine is reliable and spares and service items easily available. The vacuum pump comes with a kit to replace worn blades. 2. The diaphragm pump was not used enough to determine durability. The lombardini engine is very good quality. A spare diaphragm may be required (reportedly last 5000 hours).

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

	REQUIREMENT *Operation and maintenance*	*field operation findings* *Comments & Recommendations*
A14	***Repairing*** Spare parts need to be locally available. The device can be repaired and maintained locally.	3. The most difficult to repair would be the Chinese engine installed with the vacutug as it is not a commonly known brand so spares are not easily available. 4. Just as important as the mechanicals of the desludging pump, it is essential to effect repairs to the suction pipes and the connectors (eg seals) as if these are not well maintained, then vacuum is lost reducing their pumping capability, and sludge will leak from the damaged areas.
A15 3.4/5	***Modular configuration*** Ability to deploy the device in modular mode in accordance with different population settings and densities.	1. The most versatile of the 3 units is the Locally improved ROM2 (ie the modified ROM2) as it can handle the most difficult sludge and access most toilets, especially if it is mounted on a small trailer, and accompanied by a temporary storage container.

B: Costs requirements

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

B: Costs requirements

	REQUIREMENT *Costs*	*Comments*
B1	***Affordability*** Product Costs (CAPEX: Capital Expenditures (cost between $5000 - $25,000)	**ROM 2 (May 2013)** • Basic unit (ie tank ; petrol engine, vacuum pump, pressure pump), 15m suction hose not including 2" options = €11,256 ($15,308) (the high pressure pump and hose option costs $2,700) • Air freight from Netherlands to Malawi – €3420 ($4,651) • Total €14,766 = ($19,959) • Construction of trailer in Blantyre €694 ($944) **Locally improved ROM2 (June 2014)** • €17,216 ($23,400) ex works (ie includes all modifications recommended to ROM2, including 45m suction hose and 30 m high pressure pipe). **Vacutug** • Ex works $9,733. • Freight – $4,310; chargeable weight from Bangladesh to Malawi 2000 kgs. • Total = $ 14,043. • (note with a high pressure pump, hoses and nozzle add about $2,700 based on ROM2 quote). **Diaphragm sludge pump – truck mountable kit** • Diaphragm pump, diesel powered plus 3m^3 GRP tank. • Consignment weight 800 kgs. • Ex-works UK plus air freight £15,270.00 =($22,844).
	Affordable operation costs The desludging device has low and affordable operational costs (OPEX), A transparent calculation is included in the tender. The ratio OPEX: CAPEX is part of the evaluation of different solutions.	1. Over 300 pits the ROM2 consumed average of 1 lt petrol per toilet. Repair costs included replacement drive belts and repair to pressure hose. The vacuum pump requires replenishing with gear oil. 2. The Diaphragm pump averaged less than 1 lt diesel for every 1m3 of septic sludge. 3. The Vacutug averaged a consumption of 5lts diesel for each toilet (quite heavy). Maintenance and repair costs are also high.

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

C: Production requirements

	REQUIREMENT – production	*Comments*
C1	***Intellectual property*** Ability to manufacture without limitations due to intellectual property rights.	1. The most versatile machine is the pump with the key features (outlined in the executive summary), with fluidising and fishing operations. This can be made by ROM (as the Locally improved ROM2) or else designed and manufactured as a generic machine.

D: Acceptance requirements

	REQUIREMENT – acceptance	*Comments*
D1	***Context*** Ability to fit within social and cultural settings found within the majority of emergency settings.	1. The most versatile machine is the pump with the key features (outlined in the executive summary), with fluidising and fishing operations. This can be made by ROM (as the Locally improved ROM2) or else designed and manufactured as a generic machine.

E: Transportation requirements

	REQUIREMENT – transportation	*Comments*
E1	***Transport capacity*** Capacity to convey sludge to alternative (e.g. pre-positioned) transport unit while using a certain desludging device. (transport unit, option 1 minimum volume 1.5m^3; option 2 minimum 6m^3)	1. The holding tank capacity for the ROM is 800 lts, while that of the Vacutug Mk2 is 500 lts. 2. A 1m^3 IBC, a 3m^3 sludge tank (butyl) and a 13m^3 bladder were used for temporary storage or transport (the IBC). They were emptied using a large vacuum truck. Such temporary storage makes the logistics of desludging very efficient.
E2	***Context*** Ability to move the device within confined spaces, poor road conditions sloping terrain etc.).	1. The most versatile machine is the pump with the key features (outlined in the executive summary), with fluidising and fishing operations. This can be made by ROM (as the Locally improved ROM2) or else designed and manufactured as a generic machine.

ANNEX A: EMERGENCY SECTOR REQUIREMENTS

	REQUIREMENT – transportation	*Comments*
E3	***Flooding*** Ability to move the device within flooded areas.	1. This was not tested as no floods occurred during the trials. In principle if a 4x4 can access, then so can the Locally improved ROM2 which is towed.
E4 3.2/5	***Transport weight*** The desludging device (without transport unit) has a favourable weight of max 50 kg to allow common handling and transportation available in the field (man power and pick-up truck).	1. The diaphragm pump is about 50kg. 2. The trailer weight of the ROM at the tow bar is about 20 kgs (ie the ROM on a trailer is easy to handle, even when full).

ANNEX B: HAZOP – ROM UPDATED NOVEMBER 2013

Potential Hazard	*Consequence*	*Safeguard*	*Action*	*Report by WASTE Malawi (September 2013) November 2013 report additions*
Contact fresh faecal sludge, electrocution, trapped info moving parts, fire, burning, theft, etc.	See table 4	See Table 4.	See Table 4.	• Training of staff on operation. • Mounting of ROM securely on transport. • Protective clothing purchased. • HTH and sprayer purchased.
The ROM2 800/200 is too wide.	Cannot be employed in narrow streets.	• Check area before hand. • Turn equipment 90 degrees.	• Do not empty.	• Plan to mount ROM on land cruiser. • Plan to make simple trailer to mount ROM. • Use of 30 m suction pipe. • We will try addition of another 15m to bring length to 45m.
No equipment to place squid on pick-up.	Equipment cannot be transported.	• Bring tripod and pulley.	• Lift by hand.	• Too heavy and bulky for tripod and pulley. • Gantry and chain block fabricated at around Euro 500. • Suitable for other equipment like Vacutug and drums . • Lifting gear should be transportable.
• Roll-over of equipment at steep hills. • Equipment shoves aside.	• Broken equipment. • Injury of persons.	• Bring straps for good fixation. • Instruction how to attach equipment to car.	• Empty petrol tank. • Switch off electricity. • Use tripod and pulley to replace it.	• Mount rom securely on truck using bolts not straps. • Report contains mounting instructions. • Can strap extra drums to vehicle. • Survey roads before accessing! • Some operators should be trained mechanics.
Handle vacuum pump on pressure instead of vacuum.	• Faecal sludge is being blown over the place.	• Colour code for inlet / outlet. • Clear instructions.	• Switch off immediately immediately. • Turn handle. • Clean the area.	• Training.

ANNEX B: HAZOP – ROM UPDATED NOVEMBER 2013

Potential Hazard	*Consequence*	*Safeguard*	*Action*	*Report by WASTE Malawi (September 2013) November 2013 report additions*
Hose is blocked by rubbish.	• No sucking possible	• Fishing. • Protective case. • Bring equipment to remove rubbish (hooks and long poles) • Ensure overpressure in vacuum tank. Be aware that faecal sludge will come out of the end of the hose.	• Stop machine. • Clean hose. • Remove blockage.	• Main problem is menstrual cloths. • Switch off machine. • Allow tank pressure to reach ZERO. • Point suction into pit to avoid blow over. • Switch to pressure. • Start machine to blow out rubbish. • After emptying pit, we lift the suction above sludge so that the suction hose is cleaned from sludge. • Efficient fishing (we managed this very well). • ROM should come with inspection hole.
Suction hose or couplings damaged or worn.	Loss of vacuum.	Maintenance of hose and couplings, cleaning and packing after use.		• Seals in couplings easily fall off and can get lost – need to stick them with silicon. • Need spares seals and spare hose clips (locally available clips are very poor quality). • We did not like the plastic couplings and replaced them with metal ones from the Vacutug.
Possibility of collapse of toilet pit.	Results in severe injury of operator.	Operator should inspect condition of toilet infrastructure before starting work.	The operation should be abandoned and the owner recommended to demolish toilet and construct new one.	• See report.

ANNEX C: DATA BASE OF ALL TOILETS (DESLUDGED DURING PROJECT PERIOD, BY EQUIPMENT AND TOILET TYPE)

		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
1	02/05/2014	Kaphuka Sch. Mr Kamanga	Septic Tank (IBC)	1	Full	Diaghram			9	9,000	Minimal rubbish with hard sludge.
2	02/06/2014	Kaphuka Sch. Administration	Septic Tank (IBC)	1	Full	Diaghram			14	14,000	Minimal rubbish with hard sludge.
3	02/07/2014	Kaphuka - Managing Dir. House	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Full of rubbish, such as clothes, bottles etc.
4	02/11/2014	Kaphuka Sch.	Septic Tank (IBC)	1	Full	Diaghram			12	12,000	Minimal rubbish with hard sludge.
5	02/12/2014	Mr Nkhata - Machinjiri	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
6	13/2/2014	Mr Nyirenda - Machinjiri	Septic Tank (IBC)	1	Full	Diaghram			9	9,000	Minimal rubbish with hard sludge
7	14/2/2014	Mr Chimang'anda - Chirimba	Septic Tank (IBC)	1	Full	Diaghram			9	9,000	Minimal rubbish with hard sludge.
8	14/02/2014	Ms Samalani - Zingwangwa	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
9	15/02/2014	Manja Sobo plant	Septic Tank (IBC)	1	Full	Diaghram			9	9,000	Minimal rubbish with hard sludge.
10	20/02/2014	Mrs Mwangala- Chirimba	Septic Tank (IBC)	1	Full	Diaghram			6	6,000	Minimal rubbish with hard sludge.
11	21/02/2014	Majamanda - Chirimba	Septic Tank (IBC)	1	Full	Diaghram			7	7,000	Minimal rubbish with hard sludge.

ANNEX C: DATA BASE OF ALL TOILETS (DESLUDGED DURING PROJECT PERIOD, BY EQUIPMENT AND TOILET TYPE)

		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
12	23/02/2014	Mr Isaac - Chirimba	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
13	24/02/2014	Mr Chigwalu - Chrimba	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
14	26/02/2014	Mr Msiska Machinjiri Area 7	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
15	27/02/2014	Mr Chonzi Bangwe	Septic Tank (IBC)	1	Full	Diaghram			6	6,000	Minimal rubbish with hard sludge.
16	03/04/2014	Mr Davison Mwanza - Bangwe	Septic Tank (IBC)	1	Full	Diaghram			8	8,000	Minimal rubbish with hard sludge.
17	03/04/2014	Mr Yuda Bangwe	Septic Tank (IBC)	1	Full	Diaghram			7	7,000	Minimal rubbish with hard sludge.
18	06/02/2014	Mr Chiwona Milare Police	Septic Tank	1	Full	Diaghram	0	12	1	4000	Minimum rubbish with hard sludge.
19	06/05/2014	Mr Fondo Milare Police	Latrine - unlined	1	0.3	Diaghram	100	40	1	900	Full of rubbish, such as clothes,stones etc.
20	27/02/2014	Bangwe Market - Student sludge	Latrine	1	0.6	ROM 2	50	25	1	800	Rubbish, such as clothes, plastics etc.
21	03/08/2014	Mr Hussen - Bangwe	Latrine	2	0.3	ROM 2	120	75	4	3,200	Full of rubbish, such as clothes, bottles etc.
22	20/11/13	CHIMWEMWE - HOSTEL	Latrine - Unlined	1	0.1	ROM2	350	70	3	2,400	Full of rubbish, such as clothes, bottles etc.

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		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
23	24/11/13	KUFATSA - HOSTEL	Latrine - Unlined	1	0.2	ROM2	350	70	2	800	Full of rubbish (clothes, bottles etc.).
24	24/11/13	MTENDERE - HOSTEL	Latrine - Unlined	1	0.2	ROM2	250	50	1	400	Full of rubbish (clothes, bottles etc.).
25	25/11/13	CHIKONDI -HOSTEL	Latrine - Unlined	2	0.1	ROM2	700	120	4	3,200	Full of rubbish (clothes, bottles etc.).
26	25/11/13	FAITH - HOSTEL	Latrine - Unlined	1	0.3	ROM2	400	40	3	2,400	Full of rubbish (clothes, bottles etc.).
27	25/11/13	KONDWANI - HOSTEL	Latrine - Unlined	1	0.2	ROM2	300	60	1	400	Full of rubbish (clothes, bottles etc.).
28	27/11/13	KALIZA - HOSTEL	Latrine - Unlined	1	0.1	ROM2	300	60	2	800	Full of rubbish (clothes, bottles etc.).
29	27/11/13	JAILOSI - HOSTEL	Latrine - Unlined	1	0.1	ROM2	400	60	2	800	Full of rubbish (clothes, bottles etc.).
30	27/11/13	MBEMBA - HOSTEL	Latrine - Unlined	1	0.1	ROM2	300	60	2	800	Full of rubbish (clothes, bottles etc.).
31	27/11/13	POLICE OFFICE	Latrine - Unlined	2	0.4	ROM2	600	120	4	3,200	Full of rubbish (clothes, bottles etc.).
32	29/11/13	NTONIO - HOSTEL	Latrine - Unlined	2	0.1	ROM2	200	120	4	3,200	Full of rubbish (clothes, bottles etc.).
33	29/11/13	GIRTON - SCHOOL	Latrine - Unlined	2	0.1	ROM2	250	120	4	3,200	Full of rubbish (clothes, bottles etc.).
34	30/11/13	WHESTEAD - SCHOOL	Latrine - Lined	28	0.4	ROM2	5,200	1,400	46	36,800	Full of rubbish (clothes, bottles etc.).

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		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
35	12/02/2013	ADMINISTRATION	Latrine - Lined	8	0.6	ROM2	1,500	400	16	12,800	Full of rubbish (clothes, bottles etc.).
36	12/02/2013	POLICE HOUSES	Latrine - Lined	2	0.7	ROM2	250	90	4	3,200	Full of rubbish (clothes, bottles etc.).
37	12/03/2013	MR PHIRI's HOUSE	Latrine - Unlined	1	0.2	ROM2	200	60	2	1,600	Full of rubbish (clothes, bottles etc.).
38	12/03/2013	MR MWAFURILWA's HOUSE	Latrine - Unlined	1	0.2	ROM2	200	60	2	1,600	Full of rubbish (clothes, bottles etc.).
39	12/03/2013	MR SILESI's HOUSE	Latrine - Unlined	1	0.4	ROM2	200	60	2	1,600	Full of rubbish (clothes, bottles etc.).
40	12/04/2013	MR NYATI's HOUSE	Latrine - Unlined	1	0.3	ROM2	150	60	2	1,600	Full of rubbish (clothes, bottles etc.).
41	12/04/2013	MR FRANK's HOUSE	Latrine - Unlined	1	0.6	ROM2	150	60	2	1,600	Full of rubbish (clothes, bottles etc.).
42	12/04/2013	MR BILIATI's - HOUSE	Latrine - Unlined	1	0.4	ROM2	120	60	2	1,600	Full of rubbish (clothes, bottles etc.).
43	12/04/2013	MR KAWINJO's HOUSE	Latrine - Unlined	2	0.2	ROM2	100	65	4	3,200	Full of rubbish (clothes, bottles etc.).
44	12/04/2013	DOCTOR's HOUSE	Latrine - Unlined	1	0.5	ROM2	160	90	2	1,600	Full of rubbish (clothes, bottles etc.).
45	12/04/2013	NTONIO - HOSTEL	Latrine - Unlined	1	0.3	ROM2	140	40	2	1,600	Full of rubbish (clothes, bottles etc.).
46	12/04/2013	MR SATHAWA's HOUSE	Latrine - Unlined	1	0.4	ROM2	200	50	2	1,600	Full of rubbish (clothes, bottles etc.).

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47	24/11/13	CHIKONDI - HOSTEL	Septic Tank	1	Full	ROM2			3	2,400	Minimal rubbish with hard sludge.
48	28/11/13	MTENDERE - HOSTEL	Septic Tank	1	Full	ROM2			3	2,400	Minimal rubbish with hard sludge.
49	28/11013	CLINIC - CAMPUS	Septic Tank	1	Full	ROM2			4	3,200	Minimal rubbish with hard sludge.
50	28/11/13	BILIATI - HOSTEL	Septic Tank	1	Full	ROM2			3	2,400	Minimal rubbish with hard sludge.
51	28/11/13	NTONIA - HOSTEL	Septic Tank	2	Full	ROM2			6	6,800	Minimal rubbish with hard sludge.
52	30/11/13	FAITH - HOSTEL	Septic Tank	1	Full	ROM2			3	2,400	Minimal rubbish with hard sludge.
53	26/11/13	FATSANI - HOSTEL	Septic Tank	1	Full	ROM2			2	1,600	Minimal rubbish with hard sludge.
54	30/11/13	ADMINISTRATION	Septic Tank	1	Full	ROM2			3	3,400	Minimal rubbish with hard sludge.
55	12/03/2013	GUEST HOUSE	Septic Tank	1	SEMI	ROM2			1	800	Minimal rubbish with semi-liquid sludge.
56	12/09/2013	MR PEMBA - BANGWE	Septic Tank	1	Full	ROM2			2	1,600	Full of rubbish (clothes, bottles etc.).
57	12/10/2013	MR NAZOMBE - BANGWE	Septic Tank	1	Full	ROM2			2	1,600	Full of rubbish (clothes, bottles etc.).
58	**12/10/2013**	OZONE CLUB - CHIRIMBA	Latrine - Lined	1	0.2	ROM2	150	90	2	1,600	Full of rubbish (clothes, bottles etc.).

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59	**12/11/2013**	MR CHIGWENEMBE ; BANGWE	Latrine - Unlined	1	0.2	ROM2	150	80	2	1,600	Full of rubbish (clothes, bottles etc.).
60	12/12/2013	MRS MAINJINI - BANGWE	Latrine - Unlined	1	0.2	ROM2	150	90	1	800	Full of rubbish (clothes, bottles etc.).
61	12/12/2013	MRS CHIPUNGU - BANGWE	Latrine - Unlined	1	0.2	ROM2	150	90	1	800	Full of rubbish (clothes, bottles etc.).
62	18/12/13	MR CHITEDZE - MANJA	Latrine - Unlined	2	0.2	ROM2	170	100	4	3,200	Full of rubbish (clothes, bottles etc.).
63	21-Dec	UMODZI CLINIC	Latrine	4	0.04m	ROM2	800	90	8	6,400	Stones and plastic bags.
64	21-Dec	BOYS' TOILET	Latrine	3	0.3m	ROM2	2400	60	9	7,200	Stones, plastic balls and clothes.
65	22-Dec	GIRLS' TOILET	Latrine - Lined	3	0.3m	ROM2	2550	60	9	7,200	Stones, plastic papers and clothes.
66	22-Dec	ADMINISTRATION OFFICE	Latrine - Lined	1	0.4m	ROM2	900	60	2	1,600	Stones, plastic papers and clothes.
67	22-Dec	MR MWALE	Latrine - Lined	1	0.1m	ROM2	400	60	3	2,400	Clothes and plastic paper.
68	22-Dec	STUDENTS TEACHERS' HOUSES	Latrine - Lined	1	0.2m	ROM2	400	60	3	2,400	Stones, plastic papers and clothes.
69	22-Dec	MADAME KAINGA	Latrine	1	0.1m	ROM2	400	60	2	1,600	Clothes and plastics.
70	22-Dec	MR CHISEMA	Latrine	1	0.2m	ROM2	400	65	2	1,600	Clothes and plastic paper.

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		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
71	22-Dec	MR CHIKODZERA	Latrine	1	0.2m	ROM2	400	90	2	1,600	Clothes and plastic paper.
72	30-Dec	MR Chipeta - Machinjiri	Septic Tank	2	0.04m	ROM2			12	9,600	Hard Slufge and rubbish.
73	30-Dec	Mr John Phiri - Machinjiri	Septic Tank	1	0.3m	ROM2			5	4,000	Hard Slufge and rubbish.
74	30-Dec	Julius - Machinjiri	Septic Tank	1	0.3m	ROM2			4	3,200	Hard Slufge and rubbish.
75	31-Dec	Mr Adam- Chilomoni	Septic Tank	1	0.4m	ROM2			4	3,200	Hard Slufge and rubbish.
76	31-Dec	MR MWALE	Latrine - Unlined	2	0.1m	ROM2	400	60	4	3,200	Clothes and plastic paper.
77	25/01/14	Mr Khalika - Bangwe township	Latrine	1	0.4	ROM2	200	70	2	1,600	Full of rubbish (clothes, bottles etc.).
78	27/01/14	Mr Fachi - Zingwangwa township	Septic Tank	1	full	ROM2			6	4,800	Minimal rubbish with hard sludge
79	31/01/14	Mr Davie - Bangwe township	Latrine - Lined	1	0.5	ROM2	200	50	2	1,600	Full of rubbish (clothes, bottles etc.).
80	01/03/2014	Ms Sinjirani - Bangwe township	Latrine - Lined	1	0.2	ROM2	180	40	1	800	Full of rubbish (clothes, bottles etc.).
81	02/03/2014	Kaphuka Sch. Principles house	Latrine - Lined	1	0.3	ROM2	300	75	1	800	Full of rubbish (clothes, bottles etc.).
82	02/04/2014	Kaphuka Sch. Science T. house	Latrine - Lined	1	0.5	ROM2	250	80	1	800	Full of rubbish (clothes, bottles etc.).

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83	02/07/2014	Bangwe Market - Student sludge	Latrine	1	0.7	ROM2	180	40	2	1,600	Full of rubbish (clothes, bottles etc.).
84	8-10/2/2014	Kphuka SCH. Boys Hostels	Latrines	18	0.8	ROM2	800	50	41	32,800	Full of rubbish (clothes, bottles etc.).
85	02/11/2014	Kaphuka Sch. Teacher House	Latrine	1	0.3	ROM2	120	50	2	1,600	Full of rubbish (clothes, bottles etc.).
86	02/12/2014	Chimthinya House - Bangwe	Latrine	1	0.3	ROM2	210	50	2	1,600	Full of rubbish (clothes, bottles etc.).
87	19/02/2014	Bangwe Market - Student sludge	Latrine	1	0.8	ROM2	50	25	2	1,600	Full of rubbish (clothes, bottles etc.).
88	25/02/2014	Mr Kambelengende Area 7	Latrine	1	0.4	ROM2			2	1,600	Rubbish, such as clothes, plastics etc.
89	25/02/2014	Mr Kambelengende Area 7	Latrine	1	0.7	ROM2			2	1,600	Minimal rubbish with hard sludge.
90	22/04/2014	Bangwe Market	Latrine - Lined	1	06	Locally improved ROM2	50	70	1	800	Minimal rubbish with hard sludge.
91	29/04/2014	Mtopwa H.H. Toilets/ Poly	Latrines	5	0.6	Locally improved ROM2	500	50	5	4000	Full of rubbish (clothes,stones etc.).
92	30/04/2014	Mtopwa H.H. Toilets/ Poly	Latrines	5	0.5	Locally improved ROM2	500	50	5	4000	Full of rubbish (clothes,stones etc.).
93	05/05/2014	Milare H.H. Toilets/ Poly	Latrines	6	0.3	Locally improved ROM2	600	50	6	4800	Full of rubbish (clothes,stones etc.).
94	05/07/2014	Milare H.H. Toilets/ Poly	Latrines	4	0.3	Locally improved ROM2	400	50	4	3200	Full of rubbish (clothes,stones etc.).

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		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
95	05/09/2014	Mr Jalison Bangwe	Latrines	1	0.6	Locally improved ROM2	100	60	1	800	Full of rubbish (clothes,stones etc.).
96	05/12/2014	Bangwe Market	Latrine - Lined	1	0.5	Locally improved ROM2	100	70	1	800	Full of rubbish (clothes,stones etc.).
97	26/05/2014	Mr Hoseya Chilimba	Latrines	1	0.5	Locally improved ROM2	50	50	1	800	Full of rubbish (clothes,stones etc.).
98	28/05/2014	Mr Wayison Chilimba	Latrines	1	0.5	Locally improved ROM2	75	50	1	800	Full of rubbish (clothes,stones etc.).
99	29/04/2014	Mr Phiri Mbayani	Latrines	1	0.6	Locally improved ROM2	60	50	1	800	Full of rubbish (clothes,stones etc.).
100	30/05/2014	Mr Yakwaniya Mbayani	Latrines	1	0.3	Locally improved ROM2	60	50	1	800	Full of rubbish (clothes,stones etc.).
101	06/03/2014	Mr Magombo Milare Police	Latrine - unlined	1	0.3	Locally improved ROM2	80	40	1	800	Full of rubbish (clothes,stones etc.).
102	20/06/2014	Mr Kwanjawire Milare Police	Latrine - unlined	1	0.3	Locally improved ROM2	150	70	1	800	Full of rubbish (clothes,stones etc.).
103	26/06/2014	Chilimba Market	Latrine lined	1	0.6	Locally improved ROM2	40	60	1	800	Full of rubbish (clothes,stones etc.).
104	07/03/2014	Bangwe Market - Student sludge	Latrine lined	1	0.6	Locally improved ROM2	40	40	1	800	Full of rubbish (clothes,stones etc.).
105	07/12/2014	Bangwe Market - Student sludge	Latrine lined	1	0.6	Locally improved ROM2	40	40	1	800	Full of rubbish (clothes,stones etc.).
106	17-19/07/14	Fellowship Church Chilomoni	Latrines unlined	9	0.5	Locally improved ROM2	1350	450	12	9600	Full of rubbish (clothes,stones etc.).

ANNEX C: DATA BASE OF ALL TOILETS (DESLUDGED DURING PROJECT PERIOD, BY EQUIPMENT AND TOILET TYPE)

		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
107	21/07/2014	Mr Phinifolo Ndirande	Latrines unlined	1	0.6	Locally improved ROM2	60	40	1	800	Full of rubbish (clothes,stones etc.).
108	21/07/2014	Mr Sawala Ndirande	Latrines unlined	1	0.3	Locally improved ROM2	50	50	1	800	Full of rubbish (clothes,stones etc.).
109	22/07/2014	Mrs Alice Mwale Ndirande	Latrines unlined	1	0.3	Locally improved ROM2	50	60	1	800	Full of rubbish (clothes,stones etc.).
110	24/07/2014	Ndirande Mosque	Latrines unlined	2	0.4	Locally improved ROM2	90	30	2	1600	Full of rubbish (clothes,plastics etc.).
111	30/07/2014	Mr Alufandika Ndirande	Latrines unlined	1	0.3	Locally improved ROM22	60	60	1	800	Full of rubbish (clothes,stones etc.).
112	30/07/2014	Bangwe Market - Student sludge	Latrine lined	1	0.6	Locally improved ROM2	50	40	1	800	Full of rubbish (clothes,stones etc.).
113	04/03/2014	Bangwe Market	Latrine - Lined	1	0.6	Locally improved ROM2	75	60	1	800	Full of rubbish (clothes,stones etc.).
114	04/08/2014	Mr Buleya Bangwe	Latrines	1	0.4	Locally improved ROM2	50	50	1	800	Full of rubbish (clothes,stones etc.).
115	06/06/2014	Mr Katsekera Milare Police	Latrine - unlined	1	0.3	Vacuutag	60	60	1	700	Full of rubbish (clothes,stones etc.).
116	06/07/2014	Mr Kwalira Milare Police	Latrine - unlined	1	0.3	Vacuutag	50	60	1	700	Full of rubbish (clothes,stones etc.).
117	06/09/2014	Mr Magaleta Milare Police	Latrine - unlined	1	0.6	Vacuutag	60	70	1	600	Full of rubbish (clothes,stones etc.).
118	06/10/2014	Mr Zakaliya Milare Police	Latrine - unlined	1	0.3	Vacuutag	80	70	1	600	Full of rubbish (clothes,stones etc.).

ANNEX C: DATA BASE OF ALL TOILETS (DESLUDGED DURING PROJECT PERIOD, BY EQUIPMENT AND TOILET TYPE)

		Name/locality	Type of facility	Numer of facilities	Sludge level (m)	Machine	Volume of fluidi-zation water (LTRS)	Volume of rubbish fished out (LTRS)	Numer of ROM's/ IBC filled (LTRS)	Total sludge volume remo-ved (LTRS)	Comments
119	06/11/2014	Mr Makoma Milare Police	Latrine - unlined	1	0.3	Vacuutag	75	70	1	900	Full of rubbish (clothes,stones etc.).
120	06/12/2014	Mr Matabwa Milare Police	Latrine - unlined	1	0.5	Vacuutag	100	60	1	700	Full of rubbish (clothes,stones etc.).
121	13/06/2014	Mr Chiwona Milare Police	Latrine - unlined	1	0.4	Vacuutag	120	60	1	800	Full of rubbish (clothes,stones etc.).
122	16/06/2014	Mr K. Banda Milare Police	Latrine - unlined	1	0.3	Vacuutag	120	60	1	800	Full of rubbish (clothes,plastics etc.).
123	17/06/2014	Mrs E. Juma Milare Police	Latrine - unlined	1	0.3	Vacuutag	80	60	1	600	Full of rubbish (clothes,stones etc.).
124	20/06/2014	Mr Gomondo Milare Police	Latrine - unlined	1	0.3	Vacuutag	80	70	1	700	Full of rubbish (clothes,stones etc.).
		TOTAL		218					511		

ANNEX D: PERFORMANCE OF SLUDGE EMPTYING (USING KARCHER PRESSURE WASHER AND DIFFERENT NOZZLES)

location	*toilet type*	*Des-ludging machine used*	*nozzle used*	*opera-ting pressu-re, bar*	*num-ber of fluidi-sing*	*time to fluidise, mins*	*volume of water, lts*	*num-ber of fishing*	*time to fish, mins*	*volume of rubbish, lts*	*number of de-sludge*	*time to de-sludge, mins*	*volume of sludge remo-ved, lts*	*notes*
Milale Police Barracks	unlined pit	vacutug	pointed ROM	100	1	10	130	0	0	0		5	200	no fishing as pit was too deep > 2m. 30 m suction pipe
Milale Police Barracks	lined pit	vacutug	pointed ROM	50	2	10	150	1	23	20	2	28	200	30 m suction & vacutug was 2m above slab. Vacutug suction clogged with rubbish
Milale Police Barracks	unlined pit	vacutug	pointed ROM	100	4	17	145	4	7	9	3	10	400	30 m suction & vacutug was 2m above slab. Vacutug suction clogged with rubbish
Milale Police Barracks	unlined pit	vacutug	pointed ROM	50	1	5	75	0	0	0	1	5	200	30 m suction & vacutug was 2m above slab. Vacutug suction clogged with rubbish. No fishing, pit too deep
Milale Police Barracks	unlined pit	Locally improved ROM2	rotating ROM	50	4	18	150	3	25	25	4	13	300	ROM at 2 m above slab level + 15m suction pipe
Milale Police Barracks	unlined pit	Locally improved ROM2	rotating ROM	100	1	8	75	0	0	0	1	3	100	at slab level + 15 m suction pipe
Milale Police Barracks	unlined pit	Locally improved ROM2	Karcher	100	4	18	175	2	13	20	3	7	600	
Naperi	unlined pit	Locally improved ROM2	Karcher	100	1	6	70	0	0	0	1	4	100	no rubbish in sludge
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	50	2		150	2		100	2	5	800	church toilets - with household complex and daily meetings. a lot of rubbish

ANNEX D: PERFORMANCE OF SLUDGE EMPTYING (USING KARCHER PRESSURE WASHER AND DIFFERENT NOZZLES)

location	toilet type	Des-ludging machine used	nozzle used	operating pressure, bar	number of fluidising	time to fluidise, mins	volume of water, lts	number of fishing	time to fish, mins	volume of rubbish, lts	number of de-sludge	time to de-sludge, mins	volume of sludge removed, lts	notes
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	50	3		250	3	0	100	2	8	1,000	church toilets - with household complex and daily meetings. a lot of rubbish. Ladies' toilet - a lot of menstrual cloths and disposable nappies which expanded and were difficult to remove
Chilomoni Michiru	unlined pit	Locally improved ROM2	rotating ROM	100	2		150	2	0	100	1	5	800	church toilets - with household complex and daily meetings. a lot of rubbish. Ladies' toilet - a lot of menstrual cloths and disposable nappies which expanded and were difficult to remove
Chilomoni Michiru	unlined pit	Locally improved ROM2	rotating ROM	50	2	12	200	2	0	100	2	7	800	church toilets - with household complex and daily meetings. a lot of rubbish
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	100	2		200	2		100			800	full toilet that was abandoned for some years and church requested rehabilitation once they saw how effective equipment is
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	100	2		200	2		100			800	full toilet that was abandoned for some years and church requested rehabilitation once they saw how effective equipment is
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	100	2		200	2		100			800	full toilet that was abandoned for some years and church requested rehabilitation once they saw how effective equipment is

ANNEX D: PERFORMANCE OF SLUDGE EMPTYING (USING KARCHER PRESSURE WASHER AND DIFFERENT NOZZLES)

location	*toilet type*	*Des-ludging machine used*	*nozzle used*	*opera-ting pressu-re, bar*	*num-ber of fluidi-sing*	*time to fluidise, mins*	*volume of water, lts*	*num-ber of fishing*	*time to fish, mins*	*volume of rubbish, lts*	*number of de-sludge*	*time to de-sludge, mins*	*volume of sludge remo-ved, lts*	*notes*
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	100	2		300	3		150			1000	functional toilet
Chilomoni Michiru	unlined pit	Locally improved ROM2	Karcher	100	2		300	2		100			800	functional toilet
Ndirande	lined pit	Locally improved ROM2	Karcher	100	2		100	2		100			800	functional toilet - disposable nappies
Ndirande	lined pit	Locally improved ROM2	Karcher	100	2		150	2		100			800	functional toilet
Ndirande	lined pit	Locally improved ROM2	Karcher	100	2		150	2		100			800	functional toilet