EVALUATION OF THE UN-HABITAT VACUTUG DEVELOPMENT PROJECT

PIT LATRINE EXHAUSTING TECHNOLOGY

UN HABITAT
FOR A BETTER URBAN FUTURE

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Maputo in December 2012

Executive Summary

Why encourage people in low-income high density-areas to build latrines if they have no means to continue using them after filling up?

This report is the final draft in a series of reports aiming at an evaluation of the Vacutug Mark II latrine emptying machine and outlining the way forward towards sustainable sanitation in low-income high-density areas through mechanical emptying of sanitation facilities.

This evaluation summarizes the experiences from four selected countries where the machine has been used, namely Bangladesh, Kenya, Mozambique and Senegal. The evaluation has been undertaken in four steps: 1) in-country assessments in the four selected countries by local consultants. 2) These reports were then summarised in a draft summary report of in-country findings. 3) Thereafter country visits were undertaken by the consultant for verification and filling of gaps, 4) after which a Stakeholders Workshop on Innovative Sludge Management Technologies was held in Dhaka, Bangladesh to summarize findings and suggest ways forward.

The Vacutug Mark II emerged out of the need for sustainable sanitation in high-density low-income areas. The need prompted the development of a mechanical device that hygienically and efficiently could exhaust and transport latrine sludge to a place for temporary storage and/or transport to a suitable disposal or treatment site.

On the initiative of UN-Habitat the Vacutug Mark II was developed in 2003 and has been on unmonitored trial in a number of countries in Africa and Southern Asia, to find out how the machine would function on its own before scaling up the programme.

It has been concluded that, with minor modifications and promotion, the machine is ready for large-scale production and application. In this context an applied research and development programme needs to be undertaken to assure efficient and cost effective implementation of the latrine emptying programmes.

Major constraints were identified during the study, but they are however, not very much technology oriented, but human factors like organizational and financial management, maintenance and monitoring of emptying activities.

This report concludes with the following recommendation for the way forward:

1. Fundraising for continued development and implementation
2. Support to already initiated but unsupported Vacutug projects including rehabilitation of existing non-functional Vacutugs in the evaluated national programmes
3. Development of smaller Vacutugs to reach the denser areas that the Vacutug Mark II does not reach.
4. Development of a GPS based monitoring system
5. An economic viability study to assess to which point further development and expansion realistically can happen, considering especially the need for initial capital but also the assessing economic gains of expected health impacts.
6. Testing of a semi centralized programme management and policy development
7. Development of latrine technologies adapted to easy and effective emptying
8. Sector investigation to assess alternatives and possible markets
9. Promotion and expansion of the programme
10. Programme Monitoring and Evaluation

Table of contents

1 Introduction

1.1 Messages to UN-Habitat and interested donors

This final report starts with three messages from slum dwellers in Kibera, in Nairobi[1], the biggest slum area in Africa, where the soil is so full of holes that it is impossible to dig a replacement latrine. They tell us that mechanical pit emptying in an organized way makes a lot of sense:

> **"Why should we build latrines if we cannot continue to use them? Access to latrines is an absolute necessity and we are prepared to pay the cost for latrine emptying — just give us the possibility".**
>
> **"Manual latrine emptying is not a decent job. The boys are often drunk and working at night to avoid being seen".**
>
> **"Nobody likes manual pit emptying. It is messy and we don't know where the boys are pouring the sludge. With the Vacutug, emptying is clean and we know that the sludge is safely removed".**
>
> *From a group interview with key informers in Kibera*

1.2 This report

This report is the fourth deliverable under this consultancy and presents the consolidated findings from the research phase of the evaluation. In addition, an article will be prepared on the subject for international publication.

Previous deliverables have been:

1. Inception report
2. Consolidated findings from the in-country reports
3. Findings and Conclusions from the Stakeholders Workshop on Innovative Sludge Management Technologies

In all its simplicity the Vacutug project is a success given that the technology has been in use for the last 20 unsupported, this was clearly demonstrated in Bangladesh, Kenya and Mozambique. In unplanned areas of Dhaka, Senegal, access routes were too narrow for usage by any kind of vehicle or even the Vacutug Mark II and buildings too permanent to allow for any modification. The Senegal case confirms that the Vacutug Mark II cannot be the only solution but is a useful step in the struggle for sustainable sanitation in low-income high-density peri-urban areas.

By design, the Vacutug Mark II is a compromise to meet the most common conditions. A total of 6 versions are available from the manufacturer Maipur Agricultural and Training Workshop (MAWTS) in Bangladesh only confirming that conditions vary widely from site to site and that there is a scope for local development of appropriate Vacutugs.

The main problem with the use of Vacutug is not the technology but maintenance, management, training and organization — human factors, rather than technological ones.

[1] Group discussion on mechanical pit emptying in Kibera November 2012

The *Background, The Assignment* and *Overall Objective* presented below are identical in the three reports and originate from the Terms of Reference.

1.3 The Big picture

Latrine emptying today is a big issue. Assuming that we have 4 billion people in the developing world of which 1% would be producing an average of 1 litre, pumpable latrine sludge and that the capacity of a Vacutug in a well organized scheme is 4 m3 per day, it can be assumed that 20,000 Vacutugs are needed to meet the demand. To this figure comes the increase caused by urban growth and more people using water for anal cleansing, but also a possible reduction caused by development and implementation of new technologies.

1.3.1 A summary of the situation in the four countries

Bangladesh: The 'homeland' (global production centre) of the Vacutug, has many Vacutugs in operation and apart from Mark II, four more versions have been developed. All the new versions are bigger in size and tank capacity.

Kenya: Two machines in the Kibera slum of Nairobi and are stalled after vandalism and theft of essential spares including the pumps and the engine heads. Longer and better hosepipes are requested and stronger machines were on the list of requests for a new type. The two CBOs implementing the programme regret deeply that the machines no longer are operational, as many families have been obliged to revert to manual pit emptying. The possibility of a semi decentralized organization for emptying latrines in Kibera was welcomed by the CBOs as well as the coordinating NGO Maji na Ufanisi. Training was a repeated request from the NGO as was the need for preparing the CBOs in terms of sense of project ownership and communal value.

Mozambique: Two machines are in operation. There are institutional problems with the Municipality who are irregular in filling their commitments, i.e. in hauling sludge from transit tanks to the treatment station. Problems with spares have temporarily been resolved by transfer of parts from stalled machines as well as ad hock repairs using local mechanics. Financial sustainability is a problem, as 'social pricing' does not allow reserves for repairs and eventual replacement.

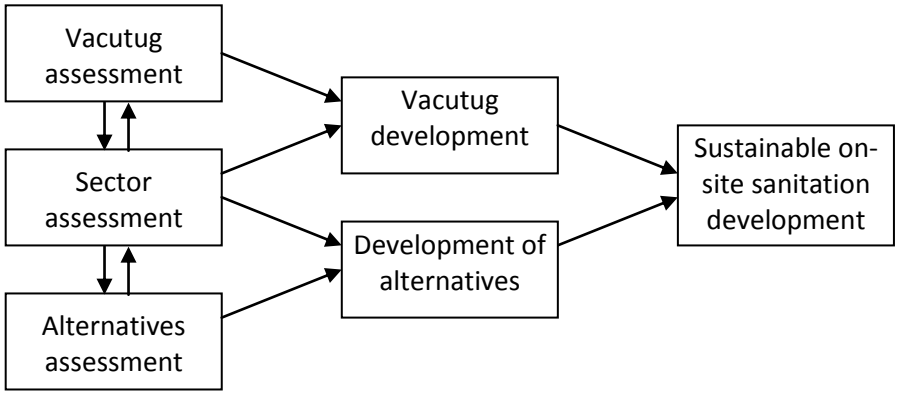
Senegal: There are four machines in good working conditions but have since not been operationalized as foreseen result of local situation in Dakar; small-bore sewers have been installed as the Vacutugs were too big for their narrow alleys. They need big tankers with long hoses to reach large retentions tanks[2]. Exhaustion of consolidated sludge from septic tanks now used as retention tanks may cause a problem in the future and constitute a need for research.

1.4 Research and The Way Forward

Presently one specific technical option of the programme, the Vacutug Mark II, has been evaluated. Four countries were selected and in these countries the selected areas together give a reasonable but still limited range of conditions, big enough to assess possibilities and

[2] Information from professional septic tank emptiers in Dhaka state that longer pipes than 30 m are not desirable as the pumps may get damaged, leaving Dhaka unplanned areas in a potential crisis when existing retention tanks fill up.

constraints. Experiences from Mozambique, Bangladesh, Senegal and Kenya show that the Vacutug Mark II is a solution, however with limitations, given the purpose it was intended. Its main limitations were mainly speed (it was designed to move at a speed of 5km per hour) and tank capacity, problems that are being addressed by the new Vacutug range developed by the manufacturer in Dhaka. What remains to be addressed is the access to the most condensed areas where a smaller version is needed. Smaller machines need to be developed and alternatives to the Vacutug concept need to be explored.



The way forward

As a way forward there would be need to include further assessment of the sector to identify important gaps in order to avoid any duplication in the future.

Though the objective is to improve sanitation service provisions in low-income high-density areas, economic viability of the project may however be realised by addressing needs beyond the targeted areas. Considerable savings can also be made by introducing zone-wise pit emptying and emptying contracts.

2 Background

According to the TOR to this study, the UN-HABITAT Vacutug project evolved out of the need for a low cost and fully sustainable system for emptying latrine pits in the unplanned or peri-urban areas of the cities in developing countries. Its development goes back nearly 30 years to a research project, which was set up by International Reference Centre for Waste Disposal (IRCWD) in Botswana in 1983 resulting in the development of the Brevac[3] and consequent developments of the Micravac[4] and Mapet[5] systems which evolved out of the experiences gained in these Botswana trials.

[3] The Brevac was a big (10 000 lit) high-powered exhauster designed to evacuate all types of pit latrines. It was also designed to transport the contents to a place for final disposal or treatment. The Brevac principle of heavy airflows may be a solution to empting latrines at longer distances.

[4] The Micravac was a smaller version (2000 lit) of a normal vacuum exhauster mounted on the body of a land rover able to reach deeper into the congested areas but still far too big for the narrow lanes.

[5] The MAPET was a small (200 litres) exhauster which was hand pushed and hand powered which would transfer the sludge to a hand dug pit in the vicinity of the latrine.

The need was identified for a low cost latrine emptying system which could reach into areas with difficult access, could suck out the dense wastes found in latrine pits, and transport these wastes short distances for disposal. In addition, the system was to be affordable for small entrepreneurs providing services in unplanned peri-urban areas around cities in developing countries. UN-HABITAT became directly involved in research on pit-latrine exhaustion in 1995 with the development of a prototype UN-HABITAT Vacutug MARK I, recognising the need for a system, which could be manufactured locally in countries where it was most needed. A consultancy company was commissioned by UN-HABITAT to undertake the design work for this demonstration project. The first prototype worked for more than five years in Kibera slum in Nairobi (Kenya). To assess how sustainable such a system could be in such slum situations, this first prototype was deliberately operated under conditions where there was very little technical back up, low skills level and thus almost no support was provided. The prototype demonstrated that it had a very significant earning potential, thus justifying its sustainability as a community-based micro-enterprise.

Technical problems detected with MARK I led into an improvement of the system and design that produced a second generation (Mark II) of the prototype, which was developed in Bangladesh in 2002 with funds from the British Development Fund for International Development (DFID) as part of the Engineering Knowledge and Research Programme and Irish-Aid. Kenya, Bangladesh, Senegal, Tanzania, India, Mozambique, South Africa, and Ghana were the beneficiaries of the Mark II. The trials in these countries began in 2003.

3 The assignment

The consultancy is required to evaluate the technical and socio-environmental aspects of the operations and maintenance related suitability versus bottlenecks to overcome in order to improve the operations of MK II UN-HABITAT Vacutug pit latrine exhauster technology. The Consultant was to review and consolidate assessment reports developed by in country consultants on the Vacutug technology, review other secondary data including data on the Omni-ingester technology[6], and was to undertake field visits to selected participating countries for further corroboration of the engineering operations and other related technological aspects of the MKII Vacutug machines. The assignment also included identification of key stakeholders to be involved in the process. The stakeholders were to review and validate the draft assessment report, which was to further be developed as a manuscript (to be peer reviewed) for publication in an international journal. The final report which was to include the recommendations for the next phase evolution of this technology was to be submitted for publication to UN-HABITAT for wider dissemination.

4 Overall Objective

The main objective of this assignment [has been] to review the operation and maintenance and mechanical functionality of the MK-II UN-HABITAT Vacutug pit latrine exhausting technology by assessing its effectiveness as an environmentally sound and cost effective option for sludge management in latrine based urban settlements.

Considering the need for pit emptying all over the developing world under a wide range of conditions the consultant has chosen to see the Terms of Reference also in a general needs perspective with focus on operation and management.

[6] This information turned out not to be available at the time of the evaluation.

5 Methodology

This report was developed in five-steps: 1) Inception report based on the TOR and other secondary data, 2) Summarizing the findings from the in-country reports, 3) Country field visits to Mozambique, Kenya, Senegal and Bangladesh 4) Interviews with key informers, and finally 5) a joint Stakeholders Meeting on Innovative Sludge management technologies in Dhaka (Bangladesh)

Inception

The study was foregone by on the ground assessments in the four countries, presented in four in-country reports. The inception report was based on a review of the in-country reports and secondary data from earlier works in sanitation in general and specifically emptying of pit latrines.

Summary of Findings from the In-Country Reports

The summary report is a consolidated summary of the different in-county reports, to see the findings from a wide range of perspectives. Given that no predefined list of contents was given, the country reports together gave a wide-angle overview of both problems and possibilities related to pit emptying with focus on the Vacutug Mark II.

Field visits Interviews with key informers

Guided by the objectives of this study the consultant undertook field visits to the four selected countries for direct observation and group/key informer interviews, hence filling gaps and identifying new possibilities.

Joint Stakeholders Meeting in Dhaka

On the 28-29 of November 2012 a joint Stakeholders Meeting on Innovative Sludge Management Technologies was held in Dhaka Bangladesh with participants from UN-Habitat (Inviting organization), Gates foundation (funding organization) Manus Coffey Associates (Technical design), MAWTS (manufacturer), country representatives, in-country consultants and other relevant stakeholders.

Dhaka was chosen as the venue for the stakeholders meeting for a number of reasons, including the fact that Bangladesh was the only production centre for the UN-Habitat Vacutug equipment in the world and it happened that it is the only country with the highest number and different version of the technology in the world.

Findings from the stakeholders meeting have been reported separately but also integrated in this report.

6 Findings

Findings have been drawn from a number of sources, including but not limited to in country reports, other secondary reports, site visits, consultations with local actors, users, clients, the design engineer, the production manager and finally from the Joint Stakeholders Meeting in Dhaka.

Principal findings are as follows:

- Sanitation in peri-urban urban areas is a rapidly growing sector where densification and settlements in high water table areas particularly in the informal housing developments is an increasing problem[7]
- The existing range of Vacutug equipment has not yet solved the latrine emptying problems in the areas of highest population density.[8]
- Technology is not the main problem in the use of Vacutug but maintenance and management, training and organization.[9]

Operation of a Vacutug is a straightforward and simple process: Transport, suction, hauling and emptying. In spite of the simplicity, problems have been experienced that are mainly attributed to lack of training and management skills. The need for training featured prominently, especially during group discussions in the field. Technical problems were also reported, touching on design[10]. Maputo case in particular praised the first version of the Vacutug Mark II that was directly donated by UN-HABITAT but also noted that later versions directly procured from the manufacturer were reported to have more problems.[11]

Manus Coffey, the designer engineer for the first batch of Mark II notes that specifications for the latter batches somehow changed in the process, by the manufacturer probably with the objective to reduce costs. These changes may not be felt in Bangladesh, where the machines are produced and spares easily available, but may cause serious after sales servicing problems in countries like Kenya, Mozambique and others far away from Bangladesh.[12]

The management problem is principally that latrines are emptied on demand based order, prompting Vacutugs to travel longer distances between each emptying session, hence wasting time fuel and causing wear and tear on the machine which had not been designed for longer distance transports. [13]

Using mobile transit tanks and emptying in zones may solve the problem of the long distance transports. This issue will be further addressed in this report.

6.1 The size of the problem

With some four billion people in Africa and southern Asia, and an ever-increasing urban population, the need for pit emptying and sludge transport cannot be underestimated. It has been concluded that, with millions of potential users spread all over the developing world, a

[7] Saywell, D., PowerPoint presentation to the USAID Sanitation Working Group on December 12, 2012

[8] Conformed in all in-country reports and country visits

[9] Brandberg, B., 2012, Findings from the Dhaka Stake Holders Meeting

[10] Specifications have been modified over the years in order to reduce costs. This has resulted in a somewhat weaker product and maintenance problems.

[11] It was also observed that the reason for so called weak design referred to poor organization and excessive transport of the Vacutug.

[12] Manus Coffey at the MAWTS factory visit.

[13] Brandberg, B., 2012, Findings from the Dhaka Stake Holders Meeting

wide range of different Vacutugs and other latrine emptying equipment would still be on demand.

Table 1: Estimate of the total Market in Africa and Southern Asia, including China and India today

Population	**4,000,000,000**	**people**
Need for emptying	1%	portion of total
Serviced pop	40,000,000	people
Sludge/person	1	lit/day
Volume/day	40,000,000	lit
Capacity of Vacutug	4,000	lit/day
No of Vacutugs	10,000	at 100% efficiency
Real efficiency	50%	
Total need	**20,000**	**Vacutugs**

Note:
This estimate is based on the situation today. It contains a number of assumptions, which may need further research, but it shows clearly that a high number of units are needed. Production and marketing may become constraints and alternatives and better solutions may appear. With an annual growth of 5% additional 1000 new Vacutug equipment would be required annually.

6.2 Expectations on the system

The in-country reports present a long list of expectations for a new and possibly better Vacutug. As much as the expectations may be justified they are commonly conflicting, why a single model would not fit all conditions, especially if costs should be kept at an affordable level for small-scale private operators.

Table 2: Consolidated list of suggested improvements

- Larger capacity
- Narrower width
- Better stability
- Greater manoeuvrability
- Higher speed
- Better traction
- Improved stability on rough and sloping ground
- Ability to extract denser sludge
- Ability to drive itself in reverse
- Ability to travel over rougher roads

Note:
The above listed issues have been commented on by Manus Coffey in his report[14]. More details to be found in the in-country reports.

14

The list contains a number of conflicting requirements. All problems cannot be solved by one model only. As mentioned above faster and larger models have been developed by MAWTS but a smaller version is still needed. Manus Coffey has mentioned the possibility of pumping into 200 lit plastic barrels with tight fitting lids and a separate pump as a low cost solution. Manual extraction may be necessary but is considered a highly inappropriate solution. Modification of latrines to become better adapted to mechanical emptying has also been discussed.

The problem of extracting denser sludge can be solved by annual zone-wise emptying as described below, since the sludge will not have the time to consolidate (it takes approximately two years for sludge to thicken up in the bottom of a pit not easily suckeable by the existing exhausters). Emergency emptying in between the yearly intervals can be charged at an emergency rate, consequently higher, as not included in the more cost effective zone-by-zone emptying scheme.

6.3 Peri-urban conditions

Peri-urban conditions vary from extreme high-density areas with narrow access paths to relatively disbursed settlements with longer hauling distances or rocky ground and sloping terrains, which makes it difficult for the Vacutug to reach all areas where latrines are even with long suction hoses. Different soil conditions and different anal cleansing practices affect the quality of the sludge hence also a limiting factors. Consolidated sludge and solid objects, rags, sanitary pads, plastic, sticks bottles and etc., at times make emptying difficult. Heavy rainfall and poor drainage or loose sand can cause serious problems for the Vacutug on move with heavy load.

The design engineer, Manus Coffey, states that the Vacutug Mark II by design is a compromise, adapted to suit the vast majority of situations as much as possible. For maximal coverage, a range of Vacutugs has been developed by MAWTS, but so far do not include a smaller version with better access to the most difficult areas, possibly with a modular system aiming at satisfying all situations. Development of various technological options will provide a menu of selection suitable to different local conditions.

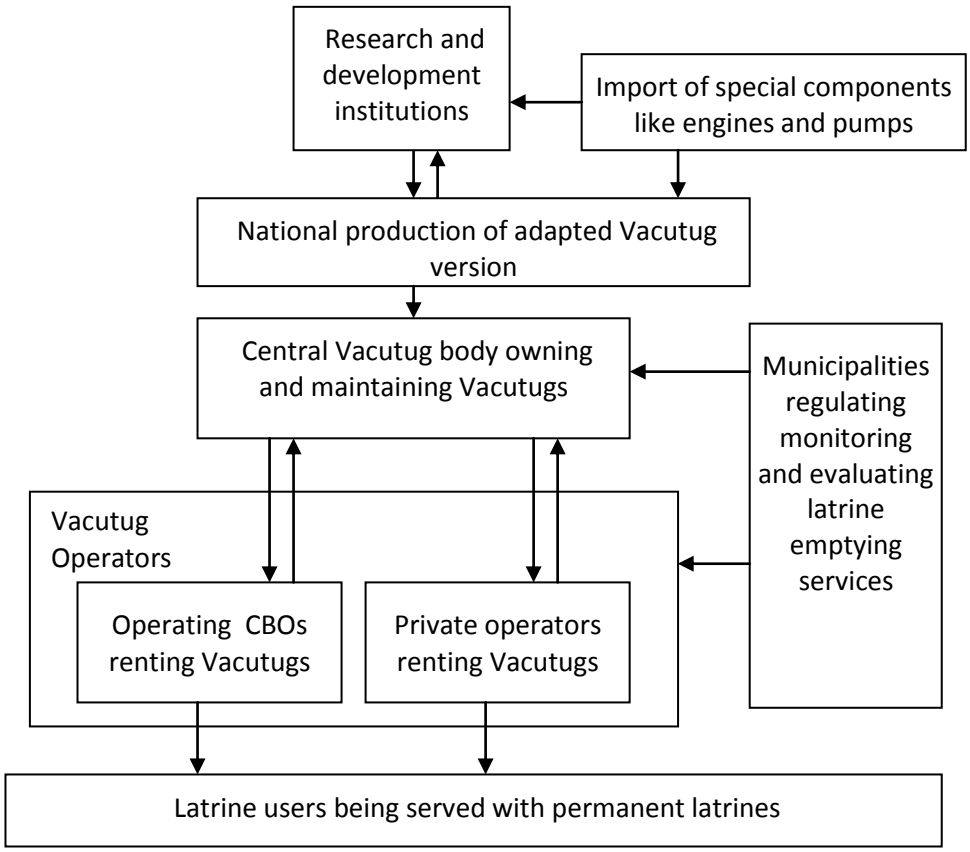
The relative failure of the Vacutug in Senegal was not due to the technology, but to the built environment with permanent houses, with two or three floors and very narrow alleys, better suited for municipal small bore sewers than for Vacutugs. The alleys were too narrow for any kind of vehicle and buildings are too permanent to allow for any modifications. New models may however suit peripheral areas in Dakar. The Dakar situation with dense permanent unplanned housing and small-bore sewers may need a separate study on how to exhaust huge retention tanks with sludge consolidated that have in most cases already thickened at the bottom.

6.4 A Range of Vacutugs

In order to keep stock of spares down and at the same time allow for a considerable variety of Vacutugs, a module based system has been discussed where maybe three sizes of engines, three types of tanks with chassis, etc, can be combined, hence reducing costs and multiplying the number of possible varieties. (I.e.: ‘Tiny’ a small exhaustion machine that can be hand-carried to the latrine in the most difficult areas, ‘Climber’ for rough and sloping paths, ‘Super Exhauster’ for areas with septic tanks and multi family latrines, ‘Runner’ for long hauling distances etc.

6.4.1 Production at scale and local production

As for any industry of a reasonable size, a variety of products on the market is necessary, not only to develop better products but also to reduce costs.[15] Consequently a range of Vacutugs and different manufacturers need to be mobilized through UN-Habitat or other organizations. Given that conditions vary not only from country to country but from one area to another, a menu of different models would suffice. Local production of customized Vacutugs, designed to suit local conditions is therefore recommended. This system would make it easier to keep spares locally and reduce after sales servicing costs associated with importation of spare parts mainly from Bangladesh to every other region of the world.



Organogram for the Vacutug sector

6.4.2 Transit tanks and vehicles

Normally 7-10m3 suction vehicles are used for long hauling distances from the transit tank to the treatments station. Vacutugs have been used on the road, but they are a traffic hazard since they move at walking speed and the staff will have difficulties to adapt to the rhythm of the traffic and considering especially that operators may be unqualified labourers.[16]

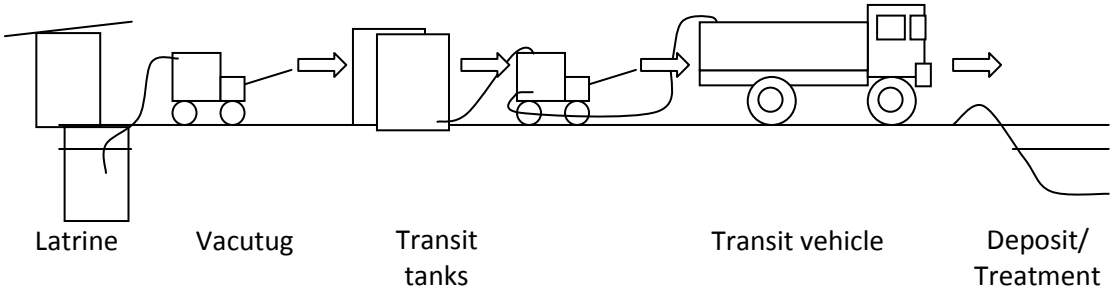
[15] A multi-purpose machine is by necessity more costly than a specialized one.

[16] A bad accident happened in Maputo when a Vacutug run into a new car that had to stop because of the traffic in front. The driver of the Vacutug is also walking behind the Vacutug completely unprotected from the surrounding traffic.

6.4.3 'Mother and baby' solutions

A private latrine emptier in Maputo is using a 3-ton truck with a horizontal plastic tank as a combined transit vehicle and transit tank, receiving sludge from semi manual gulpers and transporting it directly to the treatment plant when full. This has essentially reduced his capital need, at the same time as he can operate independently. His equipment however has a small capacity compared to the potential market.

When using a Vacutug, loading a simple transit vehicle could be as simple as off loading to a transit tank on top of a flat bed truck as it can 'offload" by gravity. When not in use it can be pulled off with a simple hoist.



The emptying process

6.5 Organizational systems

Many of the problems encountered are due to lack of organization or demand-based servicing of latrines. The solution to these is four-fold approach:

1. Use of transit tanks and transit haulage
2. Zone-wise servicing of latrines
3. Contract emptying
4. Emptying in municipal sewers

Emptying in municipal sewers has proven appropriate in Dhaka and Nairobi but has been banned in Maputo.

6.5.1 Transit tanks and transit haulage

Technically transit haulage is a simple operation. A suction tanker arrives to the transit tank, and using its own suction system empties the transit tank and continues to the point of disposal, where it empties by gravity. For zone wise emptying the transit tanks can be moved form zone to zone.

Transit haulage requires transit vehicles, which would normally cost more than the Vacutug. Hiring or buying a transit vehicle (suction tanker) is expensive unless combined with emptying of septic tanks at a commercial rate, which would become a new business with additional management problems. Transit haulage is a commercial problem, which can only be solved by commercial prices, which may not be in line with the pro-poor ambitions of the programme. On the other hand, systems that are not based on commercial prices have a tendency to become non sustainable.

Emptying in municipal sewers could substantially reduce the need for long transit haulage.

6.5.2 Zone-wise servicing of latrines

Zone-wise emptying and contract emptying requires organization and information to the clients and will have initial problems but considerable benefits if properly operated. Transit tanks can either be movable from zone to zone or stationary. WaterAid (Maputo) claims that stationary transit tanks are unpopular, as households complain of smell. It can also be assumed that there is a social stigma related to being a neighbour to a tank with latrine sludge.

5m3 plastic tanks are movable, but can also be stolen. Alternatively, 10m3 plastic tanks which are not easily stolen, could be used, but would be difficult to move from place to place.

With the semi centralized system a possibility exist that the Vacutug Centre/Depot owns one or more transit vehicles. The risk is however that if the depot works on a commercial basis its capacity might be absorbed by emptying private septic tanks and it will have limited or irregular capacity to service the transit tanks of the latrine empting programme.[17]

A third option is tanks on wheels. Mobility would be easy and theoretically they could be used also for hauling sludge directly from the Vacutugs to the treatments place. This means that Vacutug hauling distances could be very short, since the mother tank could find new places each time it returned form the treatment station. A disadvantage would be the idle time for the Vacutug when the mother vehicle is going to the treatment station for disposal of the sludge.

As an alternative, two 5 m3 transit tanks per Vacutug would be quite flexible as they have the volume of the 10m3 tank and the movability of the 5m3 ones. The risk for theft can be solved by leaving some sludge in the tank. One solution may not suit all situations, as space may be a problem and hauling distances to the treatment plant will vary from area to area. Double 5 m3 tanks chained to each other, or to the ground, could be a simple solution to prevent theft. Testing of alternative setups is recommended.

6.5.3 Contract emptying and zone wise servicing of latrines

According to Manus Coffey, consolidation of latrine sludge takes two years. He also mentions that no suction equipment easily suck stiff consolidated sludge, but merely make holes in it.[18] Assuming that zone-wise emptying of latrines is the most cost effective use of time and pumping equipment, two-year cycles could be an appropriate interval to maintain a constant latrine volume. This assumes however that the latrines have an effective volume that copes with a two-year cycle.

Dividing the areas of service in 12 zones and moving the transit tanks on monthly basis could increase effectiveness accordingly, reduce wear and tear on the machines, operation and maintenance costs, and allow for savings to meet the cost of repairs and eventual replacement and expansion of the programme. Emergency requests from outside the actual

[17] This is a problem experienced in Mozambique were the emptying of transit tanks is made by the Municipality on an irregular basis.

[18] WaterAid Mozambique claims that the consolidated sludge can be fluidized by stirring in water. An appropriate tool may look like a rake. According to Manus Coffey fluidizing might be achieved with liquid soap.

zone could be serviced at higher rates, hence motivating people to sign a contract and joining the zone based emptying programme.

Zone-wise servicing of latrines and contracting go well together. The household signs a contract with a service provider for annual emptying of the latrine. The annual emptying will guarantee that stiff sludge does not build up (since it takes two years to consolidate). The system is cost effective for the service provider and one less serious problem for the client. Contracting also reduces the risk for servicing latrines 'off the record', as the operator is works in a defined zone and is therefore relatively easy to monitor.

6.5.4 Private freelance emptying of latrines

Another system, used worldwide, is renting out equipment per day or week, and it is up to the operator to make the best use of the equipment the days he is paying for. The operator pays a deposit[19] and at the end of the period he returns the equipment and receives his deposit back minus the day fee and the cost for any repairs required. In this case, the operator is not responsible for the maintenance of the equipment since this becomes the responsibility of the owner.

6.5.5 Emptying in municipal sewers

In, Nairobi, and Dhaka emptying was done in manholes to municipal sewers, which is a cost effective way of transporting the sludge to the treatment works. In Maputo the municipality did not accept this due to risk of blockages. As to whether the risk is real or not remains to be verified, but a way of completely excluding such a risk is to install a retention tank for emptying the sludge from the Vacutug the retention tank would then empty into the manhole and the sewer. The retention tank should be emptied annually to avoid built up of consolidated sludge.

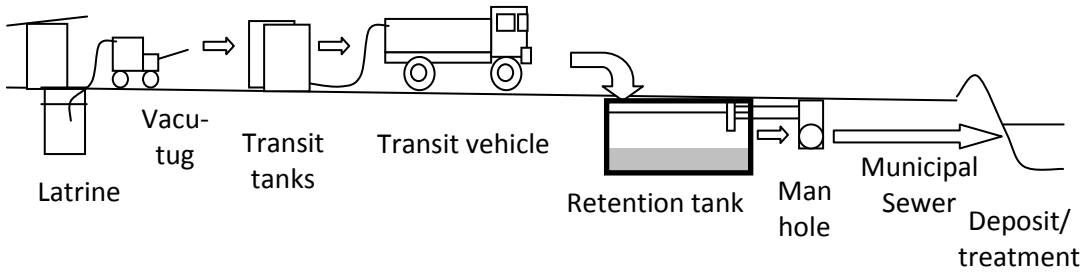


Figure 3: Retention tank to protect municipal sewer

Practically the process is reduced to two steps: Emptying of the latrine and the transit tanks. The rest of the process is automatic except for annual cleaning of sediments in the retention tank.

6.6 Human factors

Though appropriate technology is a precondition for a successful programme, the main constraints have been management and human factors. This is a logical consequence of the testing strategy of non-supported implementation, but has led to a demand driven disorganization, where the Vacutugs have been travelling back and fourth over the targeted

[19] The possibility of the depot signing up for a theft and disaster insurance would make it easier for the operator to rent a Vacutug as the deposit could be limited to the deductible.

areas, consuming fuel and valuable time. Also resulting in excessive wear and tear on the Vacutugs which were designed for moving shorter distances only. Furthermore, due to lack of financial management training, CBOs have applied a social charging system without any savings to meet the cost of maintenance and repairs or replacement of the Vacutug once it has come to the end of its useful life.

6.6.1 Ownership, maintenance and theft

The question of ownership has been discussed at length. Private ownership using micro enterprises has been suggested in the Bangladesh report while the Kenyan NGO Maji na Ufanisi intensively defended CBO ownership based on needs assessment and awareness building in the communities to enlighten them on the communal value of the equipment. Examples given were convincing, but do not contradict the fact that the Kibera Vacutug programme today is stalled due to theft of spares and vandalism of the two Vacutugs.

6.6.2 Maintenance

Leaving the equipment in the hands of different operators easily results in the equipment being abused. Operator ownership is no guarantee for good maintenance, since they lack the knowledge and are tempted to use the cheapest possible technician to service the machine, and especially the engine. A diesel engine for example has a very sensitive injector system, which should only be maintained by a specialized technician with sophisticated equipment.

Maintenance can be solved with the proposed semi-centralized system of centralized ownership and decentralized operation where CBOs and possibly private operators rent the equipment for a limited period. Maintenance responsibility would then rest with the central body as the owner. If required, the Vacutug could be rented out with a trained operator while non-specialized staff would be provided by the CBO. All the income goes to the CBO who will pay for the use of the machine (with or without any profit).

All maintenance and small repairs are now taken care of by the deposit owner who also ensures that he builds up a fund reserve for repair or replacement of machines.

6.6.3 GPS control of the machines

A big loss for the CBOs is latrines being emptied 'off the record'. One or two latrines are commonly reported to be emptied per day while in reality up to eight latrines might have been emptied and the charged amount shared by the operators. Technically GPS control of emptying locations can be installed on the machines sending a signal to a computer that automatically positions the information on a web-site for full transparency and easy monitoring of performance.[20]

Such data can also be used in the promotion of the Vacutug technology as it would help the municipalities and government to monitor the progress as required and donors to gain confidence in that funds are used in an appropriate way

6.6.4 Consumer satisfaction and sustainability

Consumer satisfaction is as a rule reported to be very positive with increasing demand for emptying services. The possibility of increasing fees should be explored not only to cover

[20] If required a password system may be installed reducing the transparency to password holders.

operational costs but also maintenance and replacement of equipment at the end of its economic and functional life.

A common complaint is that solid sludge is not removed. With a contract system and annual emptying latrines would last forever. Accumulated sludge would not be the household's problem as long as the contract is respected.

6.7 Management

Poor management has been mentioned as a problem in all the reports and interviews but with no further explanation as to the kind of management problems encountered. This is natural as the objective was to test the technology with limited or no support.

The private sector has a tendency to follow the more profitable business model leaving the poor and the serious environmental problems behind. CBOs, on the other hand, tend to become unsustainable because of their social concerns. The strong commitment of the CBOs indicates that they may absorb and implement management training in the long-term interest of their constituencies.

6.7.1 Management training

Management training is required, possibly including all steps in the implementation cycle such as financial management, human resources, financial planning and maintenance. Alternatively, as discussed in Senegal, Vacutugs could become the responsibility of small-scale entrepreneurs. The question of spare parts needs to be looked into very carefully.

6.7.2 A proposed Vacutug Centre/Depot

The idea of institutions, public, civic and private, is that they should do what they are good at. CBOs are good at working with communities but they are poor at maintenance, administration and financial management. Consequently CBOs should work with communities. Maintenance, administration and financial management of the Vacutug system could better be handled by a Vacutug Centre/Depot managed by an NGOs like Maji na Ufanisi in Nairobi, WaterAid in Maputo and DSK and PSTC in Dhaka.[21]

A Vacutug Centre/Depot could:

- Be the owner of the Vacutugs
- Rent them out to the CBOs and possibly private entrepreneurs
- Undertake maintenance and repairs of the Vacutugs
- Keep stock and import spares as required
- Undertake trainings of CBOs
- Undertake monitoring and evaluation

6.8 Social and ecological aspects

6.8.1 Social aspects

Manual pit emptying is giving a livelihood to a considerable number of people in the peri-urban areas. It is a dangerous low status job and it is messy not only for the emptiers but also for the households as it results in considerable spillage of latrine sludge in the emptying

[21] Interest to be confirmed

process. As operations are often carried out at night by youths who are often drunk (to have the courage to do the job) there is no control of where sludge eventually ends up.[22]

Emptying with Vacutugs is safe gives dignity to all parties involved. One question raised was what should happen to the latrine-emptying workers once the extended mechanized emptying system takes over their clients. The Kibera CBO members were all of the opinion that manual emptying in principle should be banned. During a transit period the two systems would exist in parallel where the manual cleaners would gradually be incorporated in the Vacutug teams after training, and conditional to performance[23].

6.8.2 Ecological aspects

Ecology is a question of survival. In high-density slum areas the question of survival is day-to-day, and the need for a safe place for defecation is now. It is fruitless to talk about sanitation in a longer perspective to people who have no place to go. Kibera, for example, needs sustainable and dignifying sanitation now.

Sludge from pit emptying can be integrated with sludge from sewers. In Dakar (Senegal) the sludge was discharged in one of the municipal manholes. The same principle is used in Kibera where a main municipal sewer is cutting through the area. In Dakar, the treated sludge from the municipal treatment works is dried and sold for agricultural purposes as is the treated sullage water. Adding latrine sludge to the municipal waste water would increase the fertile value of the waste water without adding much to the volume of the treated waters.[24]

6.9 Scaling up

In order to reach and serve some 120,000 unserved people of Kibera, scaling up is an urgent necessity. Other slum areas around Nairobi and other cites have the same needs. Only in Kibera the programme needs to extract approximately 1,200 litres of sludge every day. In a well-organized emptying scheme, one Vacutug can evacuate up to 4,000 litres per day requiring approximately 50 Vacutugs. Including other areas with similar problems, the number will double or more. Similar situations will be found in other cites world wide.

Even if Kibera is considered the biggest slum area in Africa, it is small compared with for example Mumbai in India. The list could continue to include all the mega cites in the developing word and not even reach 50% of the need. Furthermore, cities are growing every day and with that the latrine emptying problems too. To quote Darren Saywell of Plan International “It is time to get real or really worried”. [25]

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[22] It should be noted that the water in open drains at all times is black and obviously heavily contaminated by faecal sludge.

[23] A problem arises for manual emptiers seriously addicted to alcohol who might have difficulties to integrate themselves in a system based on organization and discipline. The programme has to make a balanced decision on social needs of recovery of latrine emptiers and environmental needs for safe sanitation.

[24] Urban households with flush water toilets produce between 50 and 100 litres per person per day while the corresponding figure for peri-urban areas with sludge disposal from latrines is around one litre per person per day.

[25] Quote by Darren Saywell, Plan International USA in *Urban Frontiers for Sanitation Programs* (PowerPoint presentation to the USAID Sanitation Working Group on December 12, 2012)

Given the size of the problem and the rapid urban growth a number of actions need to be taken:

1. Increase the present production and distribution of Vacutugs and promote the system with increased funding to cover initial costs.
2. Increase the range of Vacutug models to serve conditions in different areas
3. Research alternative and complementary solutions, like small bore sewers and possibly innovative technologies like small bore 'gulp and push' systems, insensitive to topographical limitations. [26]
4. Expand.

Worldwide over 20.000 Vacutugs may be required.[27]

6.10 Finance

The public benefits of improved sanitation are well documented. Sanitation is a human right and duty. Individuals and institutions are obliged to use their resources to protect communities from contagious diseases. To which point the states through the municipalities and/or the donor community should assist financially has been discussed. The World Bank (WSP-Mozambique) indicates that there is considerable public economic interest in sanitation[28]. Hutton *et al* (2006) on behalf of WHO has estimated that for each dollar invested in improved sanitation 6-9 dollars will return to the national economies[29]. WB-WSP papers indicate that about 50% of the benefits of improved sanitation go to the public sector. [30] WB-WSP also indicates that public investments in sanitation stimulate private investments[31]. Governments and Municipalities should therefore be encouraged to prioritize and support sanitation improvements. For the individual, incentives are better hygiene, privacy and dignity.[32]

The public value of emptying latrines is generally accepted in the targeted areas and this has influenced their pricing. "CBOs should not make a profit." This positive attitude has however become a threat to survival of the emptying system. Social pricing has commonly not taken into consideration the need of reserves for maintenance, repairs and eventually replacement of the Vacutugs and expansion of the system. How much of these costs should be covered through public sources and how much should be charged to the clients can be

[26] A system still on the Manus Coffey drawing board.

[27] See table 1. Note that the figures show the today-situation. To that comes urban growth and densification of inner fringe areas, which per se is alarming, especially considering the space problem.

[28] Trémolet S. et al: Financing On-Site Sanitation for the Poor; A Six Country Comparative Review and Analysis

[29] Hutton et al, UNDP/WHO (2006) 'Economic and health effects of increasing coverage of low cost sanitation interventions', Human Development Report Office occasional paper.

[30] WSP-Mozambique, Economic Impacts of Poor Sanitation in Africa; Mozambique loses MZN 4 billion annually due to poor sanitation, World Bank Water and Sanitation Programme, July 2011

[31] Sijbesma, C., Sanitation financing models for the urban poor, 2011,

[32] Jenkins, M., (1999) claims that health was not and important driver for latrine adoption. This is consistent with the belief that health is commonly not the most important aspect of latrines to users (UNICEF 1999)

discussed. But, as long as the households critically depend on functional latrines, costs not covered by public sources, if any, must be covered by the households.

6.10.1 Contracts

The possibility of making maintenance contacts with the households has not been discussed, but zone-wise latrine emptying provides an excellent opportunity. Payments could be made in advance on monthly basis, hence spreading out the cost over the year.[33]

6.10.2 The need for capital and the proposed Vacutug Centre/Depot

Given the large amount of new machines needed and that CBOs cannot afford to buy new machines out of their own money, raising initial capital is a must. In a semi centralized model, funding to the proposed Vacutug Centre/Depot as a soft loan could be well justified assuming that the Vacutug Centre/Depot would set their prices in such a way that capital is accumulated for servicing the loans and pave the way for replacements and expansion.[34]

The Vacutug Centre/Depot system also helps the CBOs to defend new prices to the clients. The accumulation of capital for maintenance, repairs and replacement no longer needs to be the responsibility of the CBOs but is taken over by the Vacutug Centre/Depot.

6.11 Training

Members of the CBOs repeatedly requested more and better training. Manuals have been supplied together with the machines but may have been lost or simply ignored. Furthermore, manuals also need to be adapted to the levels of respective staff categories. Management manuals and accounting manuals also need to be produced.

In order to avoid operators becoming negligent with the machines and in reporting of their emptying activities the CBOs in Kibera requested that more people be trained than actually needed to keep operations floating,[35]

Training is recommended to start ad-hock and hands-on and findings documented and reworked into manuals for testing and revision.

7 Conclusions and recommendations

7.1 Conclusions

There are very limited benefits of latrine building in high-density areas if the households cannot continue to use them after they have filled up, and especially if it is not possible to build a replacement. Also, pit emptying is cheaper than building new latrines, which is

[33] This method is commonly used for payment of basic food where the full month's worth of food is paid in advance to the grocery shop, hence avoiding crises if the money unexpectedly finishes too early. Savings at home do not last long in poor families.

[34] A business perspective in the management of the Vacutugs was recommended in the Dhaka meeting

[35] The possibility to install GPS system for controlling use of the machines has been mentored earlier in this report.

important for low-income families who are always short of capital. Other conclusions are as follows:

- Vacutugs have successfully been used for 20 years and it is urgent to scale up the availability and use of the technology. The failures recorded are not due to the technology, but maintenance and management problems, to be solved by training and organization.
- Peri urban housing is growing at a very fast rate. Urban low-income high-density areas continue to densify to a point where it is impossible to build new latrines. Even manual pit emptying becomes impossible as any free space is covered with recently buried sludge.[36] Further, manual latrine emptying is dangerous, unhygienic and humiliating.
- Liquid sludge is best transported in closed hydraulic systems (sewers). While waiting for sewer systems to be implemented, if ever, mechanical pit emptying is the most viable option. Given the variation of conditions in density, inclination and ground stability, a wide range of different suction machines is required. These should preferably be developed or 'composed'[37] locally to fit local conditions.
- The Vacutug Mark II has been especially developed for mechanical emptying of latrines in low-income high-density areas. It is the smallest in a range of five models produced by MAWTS in Bangladesh and used in some 10 countries. It has wide applications, especially in high-density areas where access is a problem. It can be used also for other purposes, like emptying of septic tanks and clearing of blocked pipes in both domestic and industrial settings.
- Though relatively small, the Vacutug Mark II needs to be followed by an even smaller version, in order to reach the most difficult sites.
- CBOs should work with communities. Maintenance, administration and financial management of the Vacutug system could better be handled by a Vacutug Centre/Depot.
- A preliminary assessment of the need of Vacutugs is estimated to 20,000 units plus an other 1,000 per year to coop with an annual growth of 5%.
- Assuming that each Vacutug Centre/Depot can manage 20 Vacutugs 1000 Vacutug Centre/Depots would be required plus a growth of 50 centres per year
-

"It is time to get real, or really worried"

[36] As an illustration of the situation: A multi-family latrine in Maputo (Bairro Chamanculo) was emptied manually so many times that the ground level around the latrine has raised forming a funnel towards the pit, causing it to overflow each time it rains. The amount of urine entering the latrine also caused it to overflow, obliging the early user to empty it manually.

[37] Components like engines and pumps are better imported based on availability of spares on the local market.

Table 3: SWOT assessment of alternative sludge management solutions

Item	Strengths	Weaknesses	Opportunities	Threats	Comments
Vacutug Mark II	Manoeuvrability Low investment cost	Low speed Low volume Does not cover all situations Stability and strength in hillside areas	To be used together with transfer tanks and hauling vehicles. Installing permanent suction tube with coupling to the pit	Transmission system not adapted to longer hauling distances	A smaller version with better manoeuvrability need to be developed as a complement to Vacutug Mark II
Vacutug Mark III-IV	Bigger tanks Higher speed	Poor manoeuvrability Do not cover all situations Contaminated end of hose	Servicing of septic tanks and latrines in medium density areas	High transport cost for hauling to far distance sludge deposit or treatment	Medium to low density areas Vacutug Mark I has been replaced by Vacutug Mark II
Small bore sewers	Can be fitted in most high density areas with some gradient	Management of the system may require cooperation of many households.	The retention tank of the small bore sewers can be fitted with a stirrer to replace regular emptying	Cooperation of households for installation and maintenance of the system	experience in Dakar, Kibera and other areas recommended to be evaluated in a Vacutug perspective.
Gulper	Low investment cost Can reach most latrines	Manual transport of sludge Contamination of latrine site	Suitable for local entrepreneurs	Low capacity Can not lift consolidated sludge	Might become a good complement to Vacutug II
Other alternatives			Modified latrines adapted to mechanical pit emptying Omni Ingester?		To be discovered or developed

Note: All these solutions have difficulties to exhaust consolidated sludge. A modular system is about to be developed at MAWTS, combining components to form new models.

7.2 Recommendations

Developments: The Vacutug needs minor modifications and adjustments as appointed in the Manus Coffey report. Further the following developments are needed:

- Development of a smaller Vacutug that can reach even the densest points
- Development of equipment for fluidization of consolidated sludge
- GPS emitter fitted in the Vacutug that sends a signal when the pump is in use and monitoring software.

Promotion: The Vacutug needs to be promoted principally through active publishing of successful demonstration programmes.

Demonstration projects: The present testing of the technology in un-supported implementation has proved that supervision and training is required.

Alternatives: Given the magnitude of the need for emptying of latrines, alternatives exist and will appear.

- The Omni Ingester is a new technology not yet published. It should be investigated.
- Small bore sewer systems are being implemented at an increasing rate and the Vacutug can be used to clear blockages and retention tanks.
- Semi-manual systems like the Gulper should be evaluated as a complement to the Vacutug system.
- Technologies for fluidizing and exhausting consolidated sludge need to be developed.

Policy development: Should be considered but not formalized until robust and praiseworthy demonstration programmes have been implemented and published.

7.3 The way forward

In order to get the programme into a dynamic phase the following steps should be considered:

1. **Demonstration projects**

   Support to already initiated programmes in order to demonstrate the true potential of the Vacutug Programme for massive fundraising.

   The testing phase of the Vacutugs indicated clearly that management training is required. A manual on operation and maintenance exists, but must be adapted to relevant literacy levels and complemented with hands-on training. Manuals need to be developed also for the management of the programme at national and local level; programmes need to be supervised until effective national management capacity has been developed.

   Combining the Vacutug emptying system with sewered systems is an urgent need, which should be confirmed as a safe and economic praxis.

2. **Economic viability study**

   The study has to take into consideration not only cost recovery from users but also environmental benefits in terms of improved hygiene and health and related funding mechanisms.

3. **Fundraising for continued development and implementation**

The following activities are all set-up costs without which a sustainable system cannot be built.

- **Rehabilitation of existing non-functional Vacutugs in the four evaluated national programmes.**

  A considerable number of Vacutugs are standing idle, principally in Mozambique and Senegal. These should be rehabilitated and integrated in functional programmes. Questions of ownership and right of use may need to be addressed prior to rehabilitation and use.

  Trainings should include more than the absolute minimum number of staff, in order to avoid abuse due to shortage of key staff.

  In a second phase the possibility of local production of local varieties of the Vacutug Machines should be examined.

- **Testing of semi centralized programme management and policy development**

  Semi centralized management has been discussed as a possibility to strengthen sustainable and efficient operation. This is most urgent in the Kibera slum in Nairobi but is relevant for other countries as well.

- **Development of alternative latrine technologies**

  Workshop findings indicated that latrines can be adapted for optimized programme performance. This may include sludge fluidizing, suction from the bottom and optimization of pit volumes for latrines in controlled zone-based emptying.

- **Promotion and expansion of the programme**

  Once the initial problems have been overcome the programme will be ready for expansion, which will require publishing and international marketing.

- **Sector investigation to assess alternatives and possible markets**

  Given the size of the problem, alternative methods will appear. Small bore sewers have been mentioned, which may need Vacutugs for clearing blockages and emptying of retentions tanks. The industrial sector may also need equipment for clearing industrial sludge. Use of Vacutugs in refugee camps is already underway. More markets may be discovered as possible markets are explored.

- **Programme Monitoring and evaluation**

  Activities will need to be monitored and evaluated for continuous information to be gathered and analysed, quantitatively as well as qualitatively and economically. This activity should produce background material for continuous programme development, publication and marketing. To be useful the monitoring system should be set up early, as data are needed for feedback and promotion.

4. **Applied research and development for rapid expansion of Vacutug implementation programmes**

The need to access especially dense areas has been highlighted. This will require a smaller version of the Vacutug. The removal of consolidated sludge is also a priority.

An important aspect of the technology development is GPS monitoring of the use of the machine to avoid non-reported abuse of the Vacutugs.[38]

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The MAWTS production manager Hamidul Bari (Centre) discussing the transmission system with the design engineer Manus Coffey

For UN Habitat and the Vacutug evaluation team
In December 2012

Björn Brandberg
Low-cost sanitation adviser

[38] The technology does not yet exist but the components and similar functions do. A prototype can be developed in a few months (Personal information, from Rajesh Shah <rajesh@peerwater.org>, Peer Water Exchange, Bangalore, India in December 2012).

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