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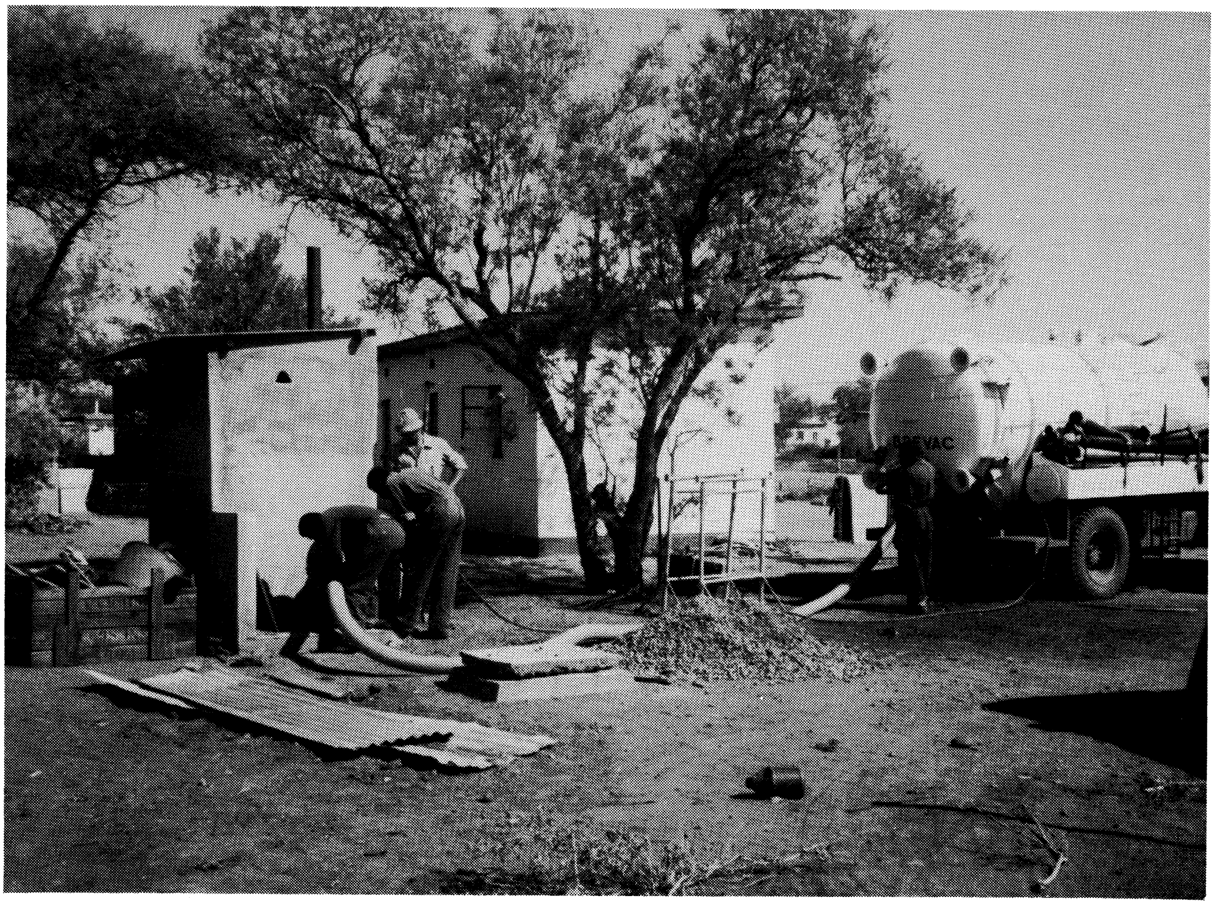
Mechanised emptying of pit latrines

R F Carroll



A BREVAC suction tanker emptying a latrine sludge chamber in Botswana

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SUMMARY

Forms of pit latrine are likely to be the most often installed sanitation system for low-income housing in developing countries. This is due not only to a shortage of money, but is also often due to very limited water resources; both are essential for the installation and operation of conventional sewerage.

Periodic emptying is a way of extending the useful life of pit latrines, obviating the need to build a new latrine when the pit is full. In many countries manual emptying of latrines is unacceptable and therefore there is a growing interest in mechanised options.

Because of the variable nature and handling difficulties of pit sludge, and the inadequacies of conventional vacuum tankers, BRE developed the particularly powerful and robust BREVAC suction tanker, in conjunction with a British company, Airload Engineering Limited. A range of BREVAC tankers is now commercially available in the UK; it is hoped that manufacture or assembly of BREVAC tankers will be established in selected developing countries in order to reduce the tanker's capital cost.

This Note reviews the criteria for on-site sanitation, preferred types of pit latrine and the need for mechanised options for pit emptying. The likely composition of pit sludge is described and a method of categorising a particular sludge is included so that a suction tanker can be specified, capable of handling that sludge. An indication is given of likely pit emptying costs for a BREVAC suction tanker in an organised emptying service.

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BIOGRAPHICAL NOTES

Ron Carroll is head of BRE's overseas sanitation research. He is a chartered mechanical engineer and has previously worked on industrialised building systems and mechanisation for the UK building industry, before starting up BRE's overseas sanitation work in 1976. His work has involved collaborative sanitation projects in several countries, including the development of the range of BREVAC suction tankers.

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MECHANISED EMPTYING OF PIT LATRINES
by R F Carroll CEng MIMechE

1 INTRODUCTION

Protecting and improving public health in low-income communities by developing acceptable forms of sanitation are the objectives of many research organisations and aid agencies. To further these objectives, forms of low-cost on-site sanitation have been developed that are effective alternatives to costly water-consuming sewerage(1). In particular, recent improvements to the basic pit latrine have helped to provide a range of designs that could be suitable for a variety of locations and social preferences(2)(3).

In many developing countries Ventilated Improved Pit (VIP) latrines(2) (Figure 1) are being installed. These latrines incorporate an insect-screened ventilation pipe to the pit that prevents foul odours developing inside the latrine superstructure; this in turn reduces the attraction to insects to enter and breed in the pit.

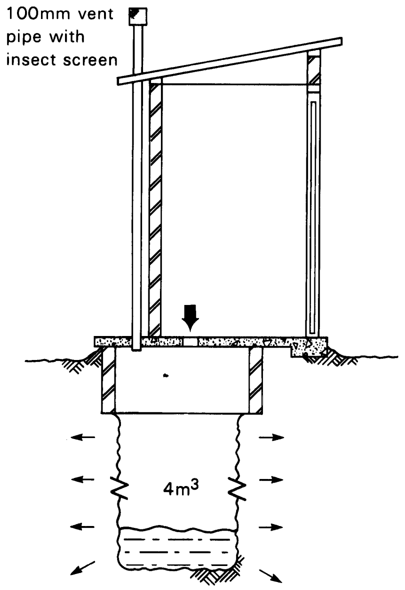

Figure 1 Ventilated Improved Pit (VIP) latrine

Further development of VIP technology by the Building Research Establishment introduced the double chambered pit latrine(4) (Figure 2), which is designed to be emptyable and therefore permanent. The double pit concept incorporates the ventilation pipe of the VIP and the additional feature of external access to both chambers (pits) for periodic emptying, either manually or by suitable suction tanker. Because the excreta in a full chamber are sealed off and retained for about two years while the second chamber is used, the material to be removed will not be a health hazard during emptying and disposal(5).

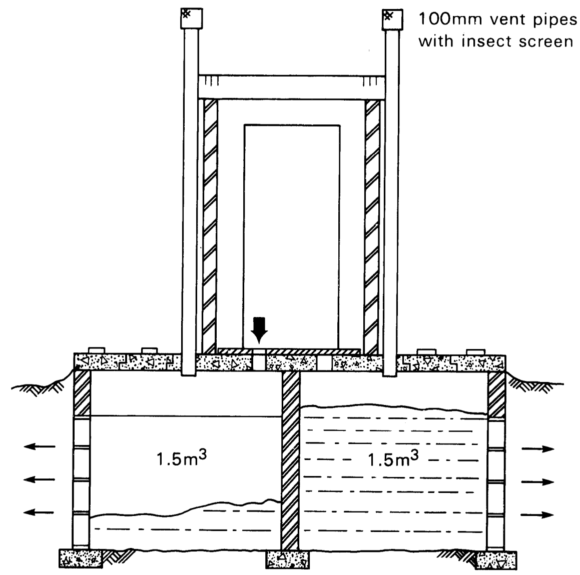

Figure 2 Ventilated Improved Double Pit (VIDP) latrine

Manual emptying of properly operated double pit latrines can be safe, low-cost and can produce a useful soil conditioner for immediate use. However, in many parts of the world contact with human waste is unacceptable, so that manual emptying of sludge chambers is often not an option. Because of this, BRE investigated mechanised methods of emptying pits and tanks. Resulting from this work a series of suction tankers called BREVAC was developed, capable of handling a wide range of pit latrine contents commonly found in developing countries. Field testing of BREVAC tankers commenced in Botswana in 1983 and in Lesotho in 1986. Indications of pit emptying costs are included in this note, based on experience gained during these field trials.

2 NON-SEWERED SANITATION

2.1 System criteria

Considerable literature exists describing the many sanitation systems in use, ranging from nightsoil bucket collection to full sewerage(1)(6). However, there are very few unsewered systems, sometimes referred to as 'on-site sanitation systems', that can satisfy the broad criteria that the system will:

(i) be effective in collecting, storing and/or treating excreta,

(ii) be hygienically and structurally safe,

(iii) be affordable and socially acceptable,

(iv) be simple to build and maintain,

(v) require little or no water,

(vi) minimise pollution of groundwater and the general environment.

With all sanitation sytems that allow possibly polluting liquids to leach to the ground, careful consideration should be given to the risk of groundwater pollution[7]. Pit latrines can be a source of bacterial and chemical pollution, as are septic tanks that discharge settled effluent to a soakaway. Provision of a safe domestic water supply must be ensured and contamination of groundwater and surface water sources must be avoided.

2.2 Design Options
The only sanitation systems likely to fulfill all the criteria at 2.1 are forms of pit latrine designed as:

(i) single pits of limited life, used until full and then resited or rebuilt;

(ii) single pit, emptied mechanically when full;

(iii) double pit, chambers used alternately and emptied after a retention period, either manually or mechanically[3][4].

These pits can be either 'direct drop' or 'pourflush'[1][2][3]. A 'direct drop pit latrine' is a pit in the ground, covered by a floor slab with a pit inlet hole and a superstructure built over it for privacy (Figure 1). It is important to fit a ventilation pipe to such pits, to encourage air to enter through the inlet hole, exhausting with any foul gases above the superstructure roof (VIP types).

A 'pourflush latrine' is basically a pit with a floor slab and low volume waterseal pan set in the floor, forming a seal between the pit contents and the toilet superstructure (Figures 3 and 4). The pan requires flushing after each use, by hand held container, using around 1½ to 2 litres of water. The toilet compartment with the waterseal pan could be located inside the house and connected to the pit by a short length of drain pipe.

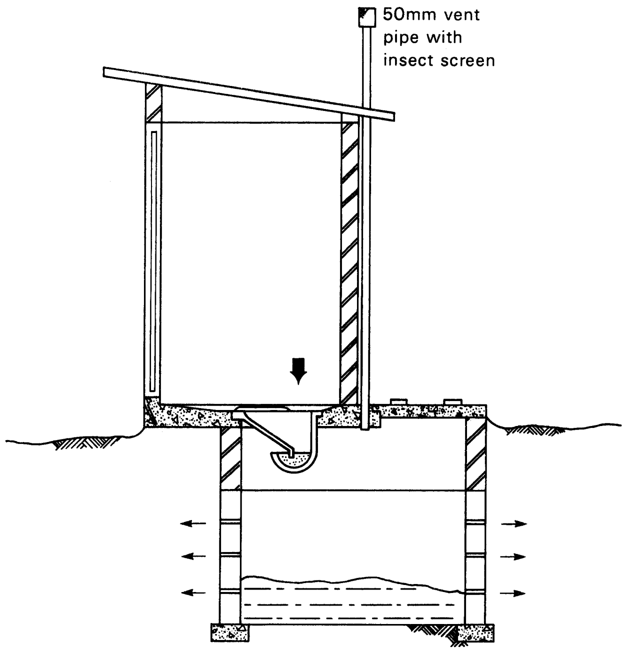

Figure 3 Pourflush latrine, single or double emptyable pit

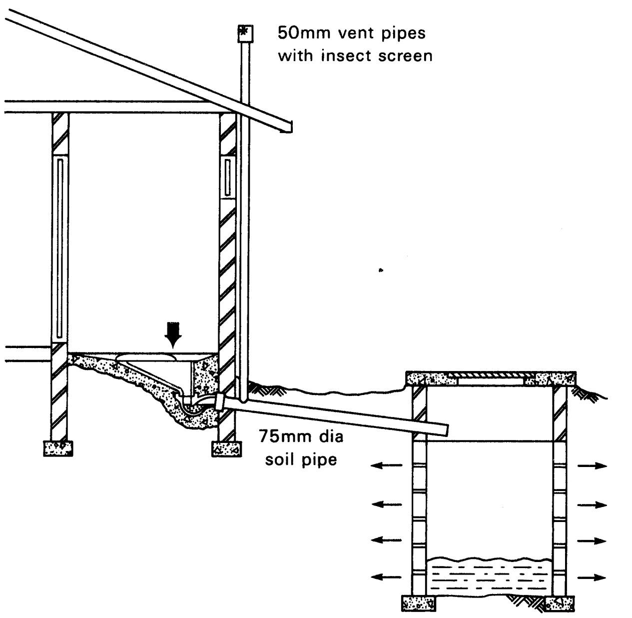

Figure 4 In-house pourflush latrine, single or double emptyable pit

2.3 Lining Pit Latrines
Lining a pit latrine is an important consideration. Heavy superstructures should have adequate support to prevent ground collapse. Support can be provided by a suitable percolating lining, which will also allow leaching of liquids to the ground. A lining can also prevent erosion of pit walls due to the rise and fall of groundwater. Another likely cause of erosion in unlined pits is the effects of a powerful suction hose during emptying.

Linings can be of fired clay bricks, concrete blocks or large stones, with gaps in the vertical joints allowing percolation of liquids to the surrounding ground. Precast concrete lining rings with perforations are sometimes another option, but are likely to be a more expensive system overall.

Purpose-made concrete lining blocks have been developed by the Building Research Establishment[8] (Figure 5). The blocks have angled end faces and a horizontal cored slot through the centre of each block to allow percolation. The blocks are laid end to end, without mortar, and produce a circular lining of 1 metre internal diameter (Figure 6). The top courses are mortared in to form a ring beam supporting the latrine floor. These blocks can also be used for lining soakaways and shallow wells.

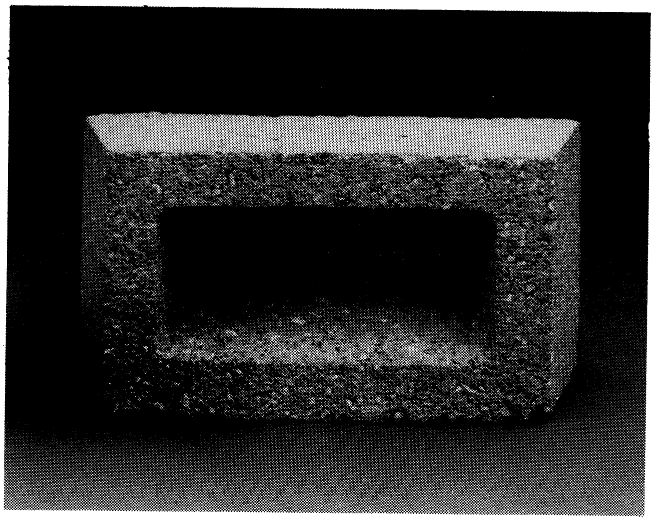

Figure 5 BRE pit lining block

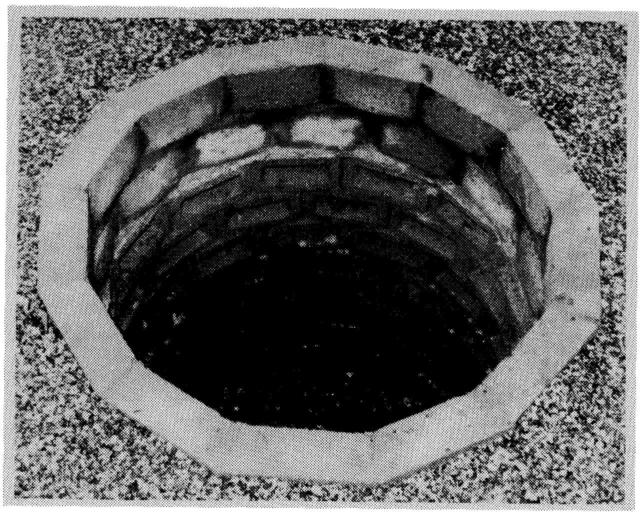

Figure 6 BRE percolating pit lining

3 PIT LATRINE CONTENTS

3.1 Composition

Pit latrines commonly contain a wide range of material, including excreta-based sludge, domestic refuse and wastewater. As a general principle, depositing rubbish in a pit latrine should be strongly discouraged, particularly if the material is non-biodegradable. Vegetable waste in small amounts can be beneficial if the resultant sludge is to be used as a soil conditioner. However, the pit will fill at a faster rate and will require more frequent emptying. This will in turn increase the cost if mechanised emptying is used.

Pit contents decompose and reduce in volume more effectively if retained above the water table and if the water content is not increased by adding wastewater. Putting water into a pit latrine, such as washwater and kitchen wastewater, increases the total burden of water to be leached to the ground. This can be particularly troublesome in clay soils with poor percolation or where there is underlying impervious rock.

Pit latrines can also contain stones, sometimes used for anal cleaning, that could possibly damage a suction emptying system. In unlined pits gritty soil can mix with the organic sludge, either because of erosion of pit walls or because the design permits surface water to wash grit into a pit. Such abrasive sludges can considerably reduce the life of mechanical equipment and hoses.

Table 1 lists typical compositions of pit sludge (averages from surveys in Gaborone, Botswana[9][10], Dar es Salaam, Tanzania[9] and Bangkok, Thailand[9].

Table 1 Typical pit sludge composition

Location	Typical Composition			
	Water %	* Organics %	** Inorganics %	*** Relative density
Gaborone[9]	68	14	18	1.27
Gaborone[10]	53	6	41	1.41
Dar es Salaam[9]	46	31	23	1.45
Bangkok[9]	80	7	13	1.12

* Organic fraction, excreta and sometimes vegetable matter
** Inorganic fraction, mainly grit
*** Sludge density relative to water (1.00)

The table lists average compositions of typical pit sludges, but each is subject to a wide range of variability. For example, in Gaborone[10] the grit and organic material contents combined varied from 11 to 87 per cent, and relative density in some samples was as high as 2.16.

3.2 Sludge classification

A sludge classification system, based on data from the International Reference Centre for Wastes Disposal[9] relates the capacity of vacuum pump necessary to move sludge to the sludge viscosity. The system classifies sludges as having HIGH, MEDIUM or LOW resistence to flow.

In the field, with a little experience, a generally satisfactory sludge classification can be achieved by observing the sludge and sediment characteristics after prodding and stirring with a stick or metal rod. Table 2 provides a guide to the characteristics for LOW and HIGH classifications.

Generally, high water content sludges are easier to pump than less wet sludges; eg septic tank sludge with 95% water content (LOW classification) is relatively easy to pump, compared to a dry pit sludge (HIGH classification) with 25% water content.

However, it should be noted that many combinations of constituents can give similar classifications. With increasing organic content more water could be absorbed, so that the sought-for advantage of improved flow might not necessarily result from adding water.

Table 2 Pit latrine sludge classification

Sludge Feature	Observed feature of sludge (composition)	Typical composition	Resistance to flow classification	Comments
Water content	High free water	80%		
Viscosity	Low viscosity	5 centipoise	LOW	Relatively easy to move with suction hose
Relative density	Low density (grit absent)	1.1		
Water content	Low free water	22%		
Viscosity	High viscosity	10 centipoise	HIGH	Difficult to move; limited flow under gravity; highly viscous
Relative density	High density (grit present)	1.9		

Having assessed the flow characteristics of a sludge, Section 4.3 can be consulted to help define the required capacity of a vacuum pump system that will effectively empty a chamber containing such a sludge.

4 MECHANISED PIT EMPTYING

Since the late 1970s there has been a growing recognition of the need for mechanised methods and equipment for emptying pit latrines. It has also been recognised that mechanisation is not likely to be a 'low-cost technology', more an 'appropriate technology' offering solutions to problems that cannot, in many societies at the present time, be solved by manual methods.

4.1 Constraints on pit latrine emptying

The type of equipment best suited to pit emptying is a suction hose. When compared with other options, such as archimedian spirals (used for water and sewage raising), bucket systems and piston pumps, a suction system has most advantage when the constraints on pit emptying are considered, i.e. —

(i) the nature and range of pit contents, abrasiveness, likelihood of blockages;

(ii) difficult access, both to the housing plot and to the pit contents;

(iii) health risks to operating crew and general public from contact with raw sludge;

(iv) anti-social considerations of the emptying operation, such as odour and fly nuisance.

Suction de-sludging of septic tanks and drainage gulley catch pits is common practice in many developing countries. Septic tank sludges generally contain only up to about 10% solids in water, without the inclusion of general refuse commonly found in pit latrines. Some local authorities in developing countries have tried to desludge pit latrines with a conventional vacuum tanker, but with only partial success. Usually it is free water or light sludge in wet pits that is removed, sometimes reducing the sludge level but not removing the heavy and often compacted sludge further down.

4.2 Pumping equipment

A conventional municipal vacuum tanker comprises a truck chassis with a sludge holding tank and vacuum pump to evacuate air from the tank, producing a partial vacuum. Atmospheric pressure acting on the surface of the sludge forces it up the suction hose into the tank. The rate of air flow through the vacuum pump is also the rate of air extracted from the tank; it also determines the time taken to establish the necessary partial vacuum. If air is drawn in with the sludge, as can occur when handling heavy viscous pit sludge, a high extraction rate is necessary to maintain the tank vacuum and hence the suction capability to move the sludge. Therefore, for suction handling of pit sludge, a vacuum pump is required of considerably higher airflow capacity than that of the usual municipal vacuum tanker. Higher pump airflows can also contribute to sludge flow with an element of pnuematic conveying, more commonly associated with the transport of granular materials through long pipelines.

Vacuum pumps can be of several types. The sliding vane pump is a relatively low-cost vacuum pump and is commonly fitted to vacuum tankers such as cesspit emptyers; the pump has variable length vanes ('sliding vanes'). Another type of vacuum pump, capable of developing high vacuum and high throughput of air, is the liquid ring pump, where sealing of the fixed rotor vanes is effected by a water ring inside the pump casing.

There is another group of pumps that compress the intake air by means of meshing rotating segments, eg the Rootes blower or lobe pump (meshing lobes) and the gear pump (meshing gears). These pumps are precision engineered and hence costly. They require an effective filter system if the air being pumped is contaminated, particularly if grit or other abrasive material could be taken into the pump airflow. For sludge handling, the airstream is likely to contain small amounts of sludge carry-over that can damage most precision vacuum pumps.

For handling sewage and light sludges, eg septic tank sludge, a simple air-cooled sliding vane vacuum pump is common. This pump generates a partial vacuum of around 0.6 to 0.7 bar below atmospheric pressure and a typical air flow of around 170 m^3/hr. Either 75 mm or 100 mm diameter flexible suction hose is used, typically 10 to 15 metres long. For compacted pit latrine sludge a 0.8 to 0.9 bar vacuum is desirable in combination with a much higher air flow, of the order of 1200 to 1800 m^3/hr. A 100 mm diameter sludge hose is recommended to reduce the incidence of blockage due to domestic rubbish in a pit.

High density compacted sludge, with low water and high inorganic content, resists flow under gravity. This 'high resistance to flow' sludge can sometimes be drawn by raising and lowering the sludge hose, allowing alternate plugs of sludge and air to enter the hose nozzle. This results in air entering the system, being drawn into the tank with the plugs of sludge, possibly causing a loss of vacuum and hence stopping the flow of sludge. With an air moving device of sufficient capacity to cater for this leaked air, the essential vacuum can be maintained, allowing a relatively continuous flow of sludge into the tank. This mode of transport, plugs of sludge in an airstream, is sometimes referred to as 'plug drag' or 'plug flow'.

Another benefit of higher air flows (up to 1800 m^3/hr) is where a long hose length is necessary, due to limited access to the sludge chamber, or there is excessive depth to the stored sludge, so that the partial vacuum generated in the sludge tank is insufficient to overcome gravity and friction losses. Sludge can be transported in the high velocity air stream, a process that is a form of pnuematic conveying.

To produce 0.9 bar of vacuum and 1800 m^3/hr of airflow requires a more powerful vacuum pump than is usual for a sliding vane pump fitted to vacuum tankers. As the design capacity is increased for a sliding vane pump, problems of cooling, lubrication and noise generation are encountered. To overcome these problems a 'liquid ring' vacuum pump has proved very effective, using water as the liquid ring or service liquid. This service water seals the rotor blades (fixed vanes) and also serves as circulating cooling water. The only lubrication required is periodic grease packing of the rotor shaft bearings. An important advantage of the liquid ring pump is that there are no closely mating parts that are also in contact with the possibly contaminated air. Any sludge particles contained in the airstream are absorbed by the service water (liquid ring) and most is then removed in a separator outside the pump. Coarse mesh filters should be used however to remove larger items, stones etc. before they can enter the pump.

4.3 Suction tankers for pit latrine emptying
Table 3 relates vacuum pump selection to sludge characteristics and is relevant to the development of tankers in general. Tanker features can vary considerably according to duty requirements:

Sludge tank (vacuum tank). Tank capacity influences the specification of the vehicle chassis and hence ease of access to sludge chambers and manoeuvreability. Generally, the larger the payload (sludge carried) the cheaper the sludge handling cost is likely to be. However, because even on well planned low-income housing sites vehicle access is

Table 3 Vacuum pump selection

Sludge 'resistance to flow'	Length of 100 mm dia sludge hose (m)	Vacuum pump capacity: Vacuum (bar)	Vacuum pump capacity: Airflow (m^3/hr)	Vacuum pump: Pump type	Vacuum pump: Power Required (Kw)
LOW	up to 15	0.8	170	sliding vane or liquid ring	6
	up to 60		700		18
MEDIUM	up to 15	0.8	700	liquid ring	18
	up to 60		1200		26
HIGH	up to 15	0.8	1200	liquid ring	26
	up to 60		1800		37

Data based on suction trials in Botswana (BRE and IRCWD).

limited, a sludge tank capacity of 4.5 to 5.0 m^3 is a practical maximum.

Sludge loading should be via a 100 mm diameter, lever operated gate valve, with a 'quick' toggle action coupling for a flexible sludge hose. Normal sludge discharge should be via a 150 mm diameter screw operated gate valve, to reduce the risk of valve blockage from sticks and rags etc taken in with the sludge. The screw operation on the discharge valve is preferred to the quicker operation of a lever, to safeguard against accidental discharge during transit to disposal and to reduce the chance of leaks past the 'gate'.

Discharge should preferably be by gravity, ie not a pressure discharge, because research has shown that the aerosol effect created could possibly be a health hazard to the operating crew, who might inhale aerosol droplets that could carry disease-causing viruses if they were present in the original latrine sludge(12).

There can be problems in discharging pit contents from a vacuum tanker, due not only to the flowability of the sludge but also due to the discharge valve becoming blocked by larger items of domestic refuse, sticks, rags etc. For these reasons it is recommended that a large rear access door should be provided in the sludge tank and the provision of tank tipping should be considered to assist gravity discharge, particularly if a high proportion of the sludges to be carried is very viscous.

Vehicle chassis. The vehicle chassis is the most expensive part of a vacuum tanker and therefore careful consideration should be given to chassis selection. It is not only cost that is important, but also robustness and long life. Availability of spare parts and maintenance skills in the country where the tanker will work are of high priority.

The chassis engine can be utilised to drive the vacuum pump through a power take-off (PTO) when sufficient power is available. This will obviate the need for a separate 'donkey' engine to drive the pump.

Four-wheel drive can be an advantage but is usually an additional expensive feature. However, the provision of a 'differential lock' facility, for occasional use, can be very helpful to assist traction in soft ground.

Sludge hoses. Hoses should generally be 100 mm diameter for pit latrine emptying, to give a satisfactory flow rate (loading time) and to minimise blockages. Quick couplings of the toggle type are recommended for connecting typically 3 metre lengths of hose. For very long hose runs light gauge galvanised steel pipe can be cheaper than flexible hose. For most pit emptying operations flexible, wire reinforced rubber or PVC hose is convenient. Rubber hose is longer lived, but is heavier to handle and more expensive than PVC. In locations with very high ambient temperatures, lightweight PVC hose can soften and flatten under high vacuum working conditions.

Generally, as short a hose length as possible should be used for desludging work, to keep friction effects to a minimum and to minimise the amount of cleaning after use. A 9 metre hose length is generally suitable if the tanker can be manoeuvred close to a sludge chamber. Hose sections 3 metres long are usually convenient for stowage along the side of a tanker in hose trays. A light alloy tube 1 metre long can be attached to a flexible hose run, as an entry nozzle to save hose wear. Many operating crews however favour using just the flexible hose end, dipped in the sludge.

Washwater. Provision of a washwater tank of around 400 litres with small bore hose and water pump is an essential facility. After desludging a chamber sludge hose and couplings should be washed off and any fouling of the latrine should be cleaned. Dirty water from these operations should be directed into the latrine inlet and the amount should be kept to a minimum.

Trials of a variety of commercial suction vehicles at the Building Research Establishment, drawing materials simulating the more difficult to pump sludges found in the African survey; led to the development of the BREVAC type of suction tanker(11) (Figure 7). These are now commercially available and all incorporate a robust, long-lived liquid ring vacuum pump, with a range of capacities to suit the flow characteristics of the sludge to be handled. They also incorporate the features discussed above for tanks, chassis, hoses and washwater.

Figure 7 BREVAC Mk I (1983)

4.4 Suction emptying with limited pit access

The ability to mechanically empty a latrine sludge chamber has been demonstrated with machines such as the BREVAC suction tanker. However, access to some pit latrines can be very restricted, particularly in urban locations with high density, low-income housing. Many cities in developing countries have fast growing areas of both planned and unplanned low-income housing, with a minimum of vehicle access roads. Many unimproved squatter housing areas have only footway access to housing plots, precluding access by large tankers.

Where direct vehicle access to a house plot is impossible, one pit emptying option is to employ a long hose run from a tanker located on a road and as close as possible to the house plot. It was demonstrated in the Botswana trials that very heavy pit sludge could be drawn by BREVAC through hose lengths of up to 64 metres. However assembling, cleaning and dismantling long sludge hoses and fittings is a laborious and time consuming operation and should not be considered for a regular municipal desludging service. Provision to enable access by pit emptying tankers to sludge chambers, such as pit latrines, is an important planning consideration for non-sewered housing developments.

Another option currently being explored is the development of very small machines to empty difficult to get to chambers. The miniaturisation of sludge tankers is limited when considering the amount of sludge to be removed from a chamber, ie the tanker payload per site visit. Typically for a family of six persons, 700 to 1000 litres of sludge would be removed in a three year emptying cycle. This is typical for a modern emptyable VIDP latrine in ground with reasonably good percolation.

One such 'small vehicle' system is the BREVAC LA (Limited Access) (Figure 8), a concept which comprises a liquid ring vacuum pump system, mounted on a suitable pick-up truck and working

Figure 8 BREVAC LA (limited access) (1986)

with a fleet of mini-tankers to collect and transport pit sludge to disposal. A BREVAC LA experimental system is currently undergoing field trials in Lesotho and uses Land Rover chassis for both Pump and Tank Units.

4.5 Cost of a municipal pit latrine emptying service

Examination of BREVAC vehicle running data and costing exercises confirms that mechanised pit emptying is a relatively expensive operation, in terms of the low incomes of the population receiving the service. Suction systems (vacuum tankers) such as BREVAC have been shown to be very effective but they also have a high capital cost. It is therefore very important that a municipal emptying service is properly planned, to ensure maximum utilisation of the equipment, not only by effective maintenance but also by properly planned periodic emptying of chambers, to minimise distances travelled by the vehicles and time spent on each plot.

From BRE field data in Botswana and Lesotho, a prediction has been made of the likely pit emptying cost for a BREVAC tanker of 5,000 litres nominal sludge tank capacity. This prediction is based on 1986 local costs and estimated equipment costs (see Table 4).

Table 4 Example: Predicted pit emptying cost (BREVAC 1200) in Lesotho

	Annual cost	
	£	%
1 Capital (£46,500 includes shipping UK to Lesotho: 10 year life at 10% p.a.)	7,556	49
2 Fuel (9500 litres/yr)	2,487	15
3 Labour (4 men)	1,885	12
4 Maintenance	2,500	16
5 General Overheads	1,374	8
Total annual cost	15,812	100
Cost per pit emptied (3,380 pits per year)	4.68	
Cost per pit per year (3 year emptying cycle)	1.56	

Raising capital to purchase tankers by the cheapest method is of paramount importance, since up to about one half of the unit pit emptying cost could be the interest on the original capital loan.

Consideration of and planning for sludge disposal is also very critical. Excessive distance from housing plot to disposal point reduces the number of plots serviced per day, as well as increasing the labour, fuel and maintenance cost elements of the final cost of pit emptying.

Methods of paying for an emptying service include:

(i) Direct payment by a householder of the full economic cost at the time of the service. This is often a discouragement to emptying a full pit and can result in increasingly unsanitary conditions.

(ii) A plot levy, which is a form of domestic tax, to recover the full cost of the service. This has the advantage that a service can be planned irrespective of the ability of the householder to pay 'on the day' and does not discourage notification that a pit is full. This system is working in Botswana, where a small element of the monthly plot service charge is allocated to pit latrine emptying by the Local Authority.

(iii) A subsidised service funded by local or central government, by either a reduced direct payment under (i) or a reduced plot levy under (ii). Sanitation by pit latrine is usually the system for lowest income families and a subsidy could be introduced in order to encourage adoption of basic sanitation to protect and improve public health.

(iv) Paying by method (i) or (ii), using donor aid funding to acquire the tankers, thus reducing the unit cost of pit emptying. To cover equipment depreciation however would require provision in the unit emptying cost, but that would be much less than the cost element necessary to cover interest payment on the original capital loan if money is raised on the open market.

5 CONCLUDING COMMENTS

Mechanised emptying of pit latrines and other sludge holding chambers is now an established technology. The development and trials of the BREVAC suction tanker for example, have shown that compacted pit sludge can be handled effectively and hygienically. High initial cost however is still a major drawback to wider application in developing countries. Ways are being sought to reduce equipment costs, by manufacture or assembly of tankers in or near the country where they will be used. Also, as municipal authorities become established, it is likely that more effective planning of pit emptying services will further reduce costs. By establishing organised municipal collection of charges, by local domestic taxes or by house plot levies, there is a greater possiblity of establishing a reliable and properly funded pit emptying service. In the interests of providing basic safeguards to public health, some subsidising of pit emptying services by central or local government may be necessary for the poorest communities.

ACKNOWLEDGEMENTS

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