PROPOSAL FOR LOW COST

MECHANISED LATRINE EMPTYING SYSTEM

ENGINEERING BY DESIGN

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MECHANISED LATRINE PIT EMPTYING. DECEMBER 1994

BACKGROUND.

In 1983 a series of trials were carried out in Botswana by the World Bank/UNDP Technology Advisory Group (Tag) under the supervision of IRCWD into the technical aspects of the mechanised emptying of latrine pits in developing countries. These trials included tests on hand pumps, powered pumps and vehicles from a number of countries around the world. They included the BREVAC vacuum tanker specially developed for this purpose by the United Kingdom Building Research Establishment and the Zimbabwean "BUNI" pump. The trials demonstrated that there was nothing available in the world at that time which could:

(a). Suck out the dense wastes found in latrine pits.

(b). Could reach into areas with difficult access.

(c). Was affordable by developing countries.

Manus Coffey Associates Ltd (MCA) had previously designed a very small and low cost latrine emptying vehicle to solve some of the problems in the hill slope areas in Trinidad. This vehicle had a capacity of 680 litres of sludge and an overall width of 1.3 metres. In 1985 MCA were commissioned by the World Bank/UNDP Tag to design a latrine emptying vehicle which would meet the technical requirements which had been identified during the Botswana trials.

Studies in Nairobi in a number of peri-urban townships including Mathari Valley, Kibera and Kawangware had found that, although access was a very important factor, an "off road" vehicle with a width of 1.6 metres could reach within 100 metres of more than 80% of the peri-urban houses. The specification was therefore drawn up for a vehicle which had the ability to suck dense latrine wastes over distances of up to 100 metres with a width limitation of 1.6 metres and the ability to travel on rough and soft ground.This resulted in the development of the MICRAVAC latrine emptying vehicle which was first introduced into Kenya in 1986 and has since been introduced into other countries around the world.

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At the request of the World Bank a special company was set up to manufacture these vehicles in 1988 but MCA relinquished all interest in this company in 1991 and the vehicles are now manufactured by RJE Engineering Ltd in the United Kingdom.

In 1988 WASTE CONSULTANTS of The Netherlands started a project to develop a manually operated vacuum pump and a 200 litre haul tank (MAPET) with particular relevance to the problems encountered in Dar es Salaam. During 1991-1992 trials were carried out to compare the performance and applications for the different systems under Tanzanian conditions. These trials were monitored by IRCWD as a continuation of the Botswana trials but the results were incomplete and have never been published.

Although all these trials and experience gained in other countries, has demonstrated quite clearly that none of the three technologies which have been developed to date can provide a satisfactory solution to the majority of the problems encountered in developing countries a lot of experience has been gained, both from the trials and from the use of latrine-emptying pumps and vehicles all over the world, which can now be used to bring the whole technology of latrine-pit emptying a step forward.

As soon as a cost effective and sustainable latrine emptying system has been introduced questions must also be raised about the future designs of latrine pits for situations where mechanised emptying may be used and smaller, shallower and lower cost latrine pits may be found to be cost effective. Pre-cast concrete latrines may also be considered.

Thus the various designs and trials carried out during the past eleven years can point the way to both cost effective and sustainable latrine emptying systems as well as to improved latrine designs. The lessons which can be learned are as follows:

1. CONVENTIONAL VACUUM TANKER TRUCKS.

Conventional vacuum tanker trucks are designed to handle the relatively low density wastes found in septic tanks. They can only reach into areas with easy access and hard road surfaces. They cannot suck the denser wastes found at the bottom of latrine pits which have not been emptied for a number of years. A typical conventional tanker will have a width of 2.5 metres, a pumping capacity of 3,000 litres of air/minute and a cost of around US $ 75,000 for a commonly available type with correspondingly high fuel and operating costs.

2. BREVAC VACUUM TANKER TRUCK.

The BREVAC, a very high vacuum capacity tanker truck developed by the British Building Research Establishment, can suck out dense latrine pit wastes over quite long distances. The high capacity pump can suck up to 18,000 litres of air per minute. However these vehicles are extremely costly at around US $ 100,000 and can only operate in areas with very easy access. Operating, maintenance and capital costs are excessive.

3. MICRAVAC LATRINE EMPTYING VEHICLE.

The MICRAVAC mini tanker was developed in association with the World Bank / UNDP Technology Advisory Group as a result of the experience gained during the Botswana trials. It is designed to pump out the dense wastes found at the bottom of deep pit latrines using the "plug and gulp" technique and it can reach into many areas which are inaccessible to conventional vacuum tanker trucks. However there are still some areas where it cannot reach although a narrower version could be made which would reach into most areas.

It was originally intended that the vehicles should be manufactured locally in the countries where they were needed but it was found that the numbers were insufficient to make this cost effective. Thus the vehicles are imported from Europe and this has resulted in a relatively high capital cost of around US S 30,000, including shipping costs, compared with the original expectation of a cost of around $20,000 for vehicles locally manufactured in the countries where they are needed.

Recent studies carried out in Kenya have shown that a charge of between Ksh 500 and Ksh 700 per 2,000 litre load (US $ 5.50 to $7.80 / m3) would be fully sustainable and there is a willingness to pay such charges. In practice most customers only ask for one load to be removed. Typically each person produces around 40 litres to 50 litres of sludge per annum so this works out at between $ 0.22 and $ 0.35 per capita/annum for the emptying service.

Although this vehicle can earn high enough fees to make it a fully sustainable system, it has been found in practice that, even if the charge rates set are adequate, during the first year or two of operation it will require very little maintenance and it is extremely difficult to sustain the discipline whereby substantial funds are put aside during this period so that they are available after two years or so when they are required for costly replacement parts.

A trial project in Kibera township in Nairobi, Kenya carried out by KWAHO (Kenya Water and Health Organisation) and subsequent studies demonstrated that the system could operate effectively at an affordable cost. However, the Kibera experiment also demonstrated clearly that any community based system, using the MICRAVAC is unlikely to be sustainable due to the problems of maintaining these relatively costly vehicles where there is no personal incentive for any individual to do so. The Kibera experiment showed that, whilst the vehicle would be able to charge enough to generate a satisfactory surplus during the first year or two of it's operation, it is almost impossible to retain this surplus against all the other demands of the community, so that it will be available two years later when the vehicle needs costly maintenance and tyre replacements.

The MICRAVAC has a vacuum pump capacity of 9,000 litres per minute and can suck dense wastes effectively using the "plug and gulp" technique over long distances. However in practice it was found that this technique is seldom used and the high volume suction capacity is only rarely required, although the ability to build up a fast vacuum in the tank is an advantage. "Plug and gulp" pumping is slow and while there is sufficient demand for the service from latrines that are easy to pump there is a tendency by the operators to avoid the more difficult sites where this technique and long hose lengths are required and simply claim that they cannot service them.

4 MAPET MANUAL LATRINE EMPTYING SYSTEM.

The MAPET (Manual Pit Emptying Technology) uses a hand pump to suck out the wastes from latrine pits into 200 litre containers. The concept behind this technology was to develop a very low cost, manually operated vacuum pump which could be used by the "frogs" who have traditionally emptied latrine pits by hand in Dar es Salaam by climbing down into the pits. This is a degrading and dangerous occupation and so an alternative must be found.

Housing densities in Dar es Salaam are relatively low so that there is generally space alongside the latrine pit which enables the "frogs" to dig a hole into which they bucket the wastes from the latrine pit. Thus, the wastes are simply moved from one pit to an adjoining point and a considerable amount of latrine wastes are exposed in the process.

It can reasonably be argued that wherever there are soils which do not necessitate lined latrine pits and wherever there is space such as is commonly found in Dar es Salaam, it would be much more hygienic to simply move the latrine a few meters. However, due to the high investment in the lined latrines commonly found in Dar es Salaam people want to have these latrines rehabilitated.

In Dar es Salaam large and high-cost latrine pits have traditionally been used with typical capacities of 10,000 litres or more. Each house will have its own pit and so it takes a long time for the original pits to fill up. The pits are relatively shallow but large in diameter due to the prevailing soil conditions. The pits are traditionally lined and so the investment in the original latrine pit is very high. (In comparison in Lesotho, for example a typical pit will hold 1,500 litres and will be lined with concrete. In Trinidad the pits are typically made from two 200 litre oil drums welded together thus holding only 400 litres).

The MAPET system normally relies on the same on-site disposal method as presently used by the "frogs" although the wastes can be hauled short distances by hand where the road conditions are suitable and there are no steep gradients. In steep areas putting the wastes back into relatively shallow holes in the ground, may result in run-off onto the plots below after heavy rains.

In Dar es Salaam it was found that, as the pits will have a typical capacity of 10,000 litres and will generally only service a single family, emptying is not required for a considerable time after the initial building of the pit. However, when emptying takes place with the MAPET pump 25% of the householders were only able to afford to have 400 litres to 600 litres removed ($ 5.0 to $ 7.50) and a further 50% asked for only 800 litres to 1,400 litres to be removed ($ 10.0 to $ 17.50). Thus for 75% of the pump outs only between 6% and 14% of the wastes was removed from each pit.

The above costs, for operating the MAPET system with on site disposal of the wastes are based on a charge of $ 2.50 per 200 litre load or $12.50/m3. If the MAPET system is used for sucking the dense sludge from pits it will have a cost of around $ 0.50 per capita per annum for on-site disposal and more for off-site disposal. However, in most situations where only small amounts of wastes are removed, and especially in areas where shower or wash room wastes enter the pits or where there are high water tables and flooding during wet seasons there is a tendency to remove only the more liquid wastes consisting predominantly of water from the top of the pit with a gradual building up of solidified wastes in the bottom and costs per capita may be considerably higher.

The Botswana trials showed how latrine wastes progressively increase in density during storage until they reach an un-pumpable consistency after around five years.Thus although a short term improvement can be made by pumping small quantities from the top of the pits, if the material from the bottom of the pits is not removed it will progressively increase in density and thixotropy until it is impossible to pump.

Eventually there must be a need for the pits to be emptied again by hand and the whole concept of building and servicing large latrine pits must be put into question when considering the way forward.

It was found during the trials that the MAPET system was only practical in situations where there is sufficient space to dig a hole alongside the pit for disposing of the wastes. This situation, although found in many parts of Dar es Salaam, is not typical of many other cities (such as Nairobi for example) where space requirements in the low income areas are very limited.

Alternative systems using fixed transfer stations are proposed where the wastes can be disposed of by the MAPET teams for subsequent pick up by a vacuum tanker truck. However, the 200 litre MAPET tank carts which are pushed by hand, will only operate over very short distances and cannot operate on muddy roads, soft sand or steep slopes. This again rules out many applications for the MAPET system and further restricts its applications.

Mobile transfer systems are under consideration using tractor trailers to transport the wastes but again the cost implications must be considered and there are considerable difficulties in transferring the wastes from the MAPET tank carts into the trailers.

Thus the MAPET system can only be seen to have applications in situations where there is a comparatively low housing density, a low water table and relatively level ground conditions and the costs per capita per annum are more than twice that of other systems.

The MAPET trials, however, clearly showed that, although the cost of removing the wastes from the pits was very high at $2.50 per 200 litre tank load, there was still a demand for the service. Although the cost of the service was very high in volume terms the relatively smaller amounts of money required for a particular service makes the system attractive. A further attraction is that the householder can negotiate directly with the contractor and does not have to pay in advance for a service which may not materialise.

The MAPET system can reach into areas where other systems cannot reach with an overall width of only 0.8 metres although it cannot suck over any significant distance due to its very limited pump capacity.

SUMMARY OF DIFFERENT TECHNOLOGIES.

To summarise the alternative systems:-

- CONVENTIONAL VACUUM TANKERS are 2.5 metres wide and can only travel on well surfaced roads. They can only suck wastes over relatively short distances due to the limited vacuum pump performance, typically 3,000 litres free air/minute. Travel speeds of up to 50 Kph are possible on good roads and long haul distances are possible. Typical capacities are in the order of 6,000 litres per load with capital costs of around $75,000.

- Vacuum tankers such as the BREVAC are available at around US $ 100,000. These have very high capacity vacuum pumps up to 18,000 litres/minute enabling them to suck dense wastes over long distances but have even greater access problems than conventional tankers and higher operating and maintenance costs.

- The MICRAVAC is 1.6 metres wide and can travel over soft and uneven ground. With a pump capacity of 9,000 litres/minute it can suck waste over long distances (up to 100 metres) so that it does not have to reach right up to the pit but the handling and cleaning down of long lengths of hose is time consuming. The travel speed of 30 Kph is adequate for medium haul distances (typically up to 10 km). It has a load capacity of 2,000 litres.

  A smaller version of the Micravac as developed in Trinidad would have a width of 1.3 metres, a pump capacity of 2,000 litres/minute, a tank capacity of 680 litres and a travel speed of 15 kph. The cost of such a system would be in the order of $15,000.

- The MAPET system is 0.8 metres wide and can reach into areas which are only serviced by foot paths. The hand pump can suck between 80 and 120 litres of air/minute and with this limited suction capacity it must reach close up to the pit for effective pumping and is effective where there is sufficient space for on-site disposal of the wastes and in flat ground areas with low water tables. If it is used as a haul system it has a haul capacity of 200 litres of wastes and a typical road speed of 3 kph. It can only operate effectively over haul distances of a perhaps 300 metres unless road conditions are good.

  The MAPET system costs around US $3,000 but may require back up transport to bring it to the areas to be serviced which will add to costs. If a transfer system is to be used the capital costs will be still higher.

It can thus be seen that none of the presently available systems can meet all the requirements for an effective community based or privatised latrine emptying service.

(The above comments are not intended to decry any of the above systems in any way but only to define the limited conditions under which each one is applicable).

REQUIREMENTS OF EFFECTIVE SYSTEM.

Any community based service operating a relatively high-cost vehicle is unlikely to be sustainable and, although the vehicle can earn sufficient income to provide what should be a sustainable service, the high capital cost of the vehicle inhibits the private sector from entering this field.
Municipally operated systems have seldom proved effective due to the lack of personal incentive and the constant problems in most municipalities in providing funds for proper preventative maintenance and for obtaining spare parts.

What is fundamentally needed is a system which can fulfil the following criteria:

(a) It must have a capital cost which is low enough to encourage the private sector to enter this field.

(c) It must be suitable for local manufacture in any developing country with a minimum of technical skills utilising commonly available parts. (Wherever there is local manufacture, service, spare parts and maintenance will be available).

(b) Spare parts must be available at a low enough cost to enable the equipment to be repaired and maintained as required out of the revenue earned without the need to accumulate a maintenance fund over a long period.

(d) It must be able to reach into areas with limited access and unsurfaced roads or tracks.

(e) It must be able to transport the wastes from the collection point to a local disposal point or main road access with haul distances of up to 1.km.

(f) It must be able to achieve high vacuums to enable dense and thixotropic sludge to be pumped.

(g) It should have a relatively high air flow capacity in relation to the tank volume to enable "plug and gulp" pumping to be carried out effectively. (However, if the tank capacity is relatively small the pump capacity needed to effect this need not be high).

PROPOSED ALTERNATIVE LATRINE EMPTYING SYSTEM

The attached sketches show a proposal for an alternative latrine emptying system comprising three separate components, each of which can be manufactured out of readily available parts in a developing country.

1. VACUUM TANKER TRAILER.

A vacuum tank/trailer can be manufactured locally using used car wheels and a simple fabricated tank The tank will include a check valve, a sight glass and a 75mm inlet valve and suction pipe. Typically such a tank will have a capacity of around 400 litres of sludge, although larger tanks may be appropriate where there are no steep slopes. The trailer is designed to be towed either by a conventional vehicle or by a special tug. The tank will have an overall width of around 1.0 metres and will be narrow enough to reach into almost all areas with difficult access.

2. TUG / VACUUM PUMP.

A small, readily available, petrol engine, typically around 3.5 kw (5 hp) is mounted on two used car wheels with a handle to enable it to be wheeled around by hand. A simple belt drive from the engine to a friction grip, roller-drive on the wheels will enable the engine to be used to power the wheels where required at a typical walking speed of up to 5 kph. This will give a theoretical tractive effort of around 2,250 newton (230 kg).

The engine will also drive a simple vacuum pump (as commonly used on farm milking-machines) with a typical capacity of 1,500 litres/minute and a vacuum capacity of 0.8 bar. The choice of engine and pump will depend upon local availability and as a simple belt drive is used it will be possible to fit an alternative engine or pump at any stage. The belt will be interchangeable between the wheel drive or vacuum pump as required.

The engine will be mounted on a hinged plate with a cable linkage to apply tension to the drive belt. This will act as a simple clutch. A brake as used on a motorcycle will be fitted to the friction roller drive with a hand brake lever from a used car. A motorcycle hand throttle will be used to control the engine.

The overall width of the tug/vacuum pump will be around 0.6 metres.

3. TRANSFER VEHICLE

Where required a conventional small truck can be fitted with an additional haul tank together with a draw bar to enable the vacuum trailer tank to be towed on ta road.

Alternatively a small farm tractor with a trailer tank can be used. This has the advantage that the trailer can be dropped off as required and the tractor used for other purposes or a single tractor can be used to service two trailers.

COST OF SYSTEM.

It is estimated that the tug/vacuum pump and the vacuum trailer can be manufactured in most developing countries for around $4,000 using locally available parts throughout. The transfer vehicle, where required, will use any readily available truck or tractor.

OPERATION.

There are a number of different ways in which the above system can be operated:-

(a). DIRECT SUCTION / DIRECT HAUL.

The tug/vacuum pump can be used to tow the trailer tank to the latrine pit with an access width requirement of 1.0 metres. Where it cannot reach right up to the latrine an extended hose can be used. The system can then be used to suck out 400 litre tank loads of latrine wastes and transport them short distances (typically up to 1 km) to a disposal or transfer point.

For direct suction the engine can be run at low speed and it should take no more than 2 minutes to suck out a full load of sludge. The tug will then haul the trailer at speeds up to 5 kph.

A maximum suction up to 0.88 bar will be achievable allowing relatively dense wastes to be sucked from deep pits.

(b). TRANSFER TO HAUL VEHICLE.

The above system can be used to haul the wastes to a transfer vehicle. The transfer vehicle will be fitted with a tank and fittings to take the suction hose from the trailer tank. The vacuum pump can then be used to suck the wastes from the vacuum trailer into the haul vehicle.

(c). PLUG AND GULP SUCTION.

The relatively large pump capacity in relation to the small trailer tank will enable the system to achieve a vacuum of 0.5 bar in the tank in around 15 seconds. This will enable a "plug and gulp" pumping technique to be used wherever there are dense wastes. It should be possible to gulp around 10 litres of wastes per gulp or 40 litres/minute. It will thus take 10 to 15 minutes to suck a full tank load of dense sludge.

(d). DIRECT SUCTION TO HAUL VEHICLE.

Wherever the haul vehicle can reach close up to the latrine pit the vacuum pump can be used to create a vacuum in the transfer tank and suck the wastes directly into the haul vehicle. In this way full loads, depending on the size of tank on the haul vehicle, can be sucked out directly and hauled to the disposal site.

(e). DIRECT PUMPING TO DISPOSAL POINT OR HAUL VEHICLE.

The vacuum trailer and vacuum pump can be used for direct pumping of sludge to a disposal point or haul vehicle. In this case the vacuum trailer is located near to the pit to be emptied and a long length of hose transfers the wastes to the disposal point. The vacuum trailer is alternatively evacuated to fill it with wastes and then pressurised up to 1.0 bar so as to suck in and discharge a 400 litre tank load at each sequence. (for this system to be used a second inlet with a check valve must be fitted to the vacuum trailer tank).

DRAFT SPECIFICATION FOR VACUUM TRAILER.

TANK.	400 litres capacity fitted with 3" inlet valve, sight glass and primary check valve with 1" vacuum hose fitting. Tank 700mm dia x 1,000 mm long with dished ends made from 2.0mm mild steel. (Tank, sight glass and primary check valve made locally).
AXLE/WHEELS.	Wheels and hubs from small car fitted with 135 x 13 tyres. (Second hand).
PARKING BRAKE.	Hand brake lever from second hand car operates brake on car wheels.
DRAWBAR.	Fold up drawbar for towing behind truck. Turntable Drawbar for towing with tug.
VACUUM HOSE.	4 metres X 3" PVC vacuum hose. Kanaflex or equivalent.
HOSE COUPLING.	3" irrigation coupling. Bauer or equivalent.

DIMENSIONS.

Length overall.	1.5 metres.
Width overall.	1.0 metres.
Height overall.	1.4 metres.
Capacity.	400 litres. (Up to 800 litres where appropriate).
Weight.	90 Kg, (est).

DRAFT SPECIFICATION FOR TUG/VACUUM PUMP.

ENGINE.	5 Hp (3.75 kw) industrial engine. Torque 10.2 Nm @ 3,000 rpm. (Typical. Briggs & Stratton model 132237) (Cost $ 240 ex works U.K.)
VACUUM PUMP.	Sliding vane pump, Capacity 1,700 litres/min @ 1,400 rpm. (Cost $ 210 ex works Italy.)
WHEELS/HUBS.	Second hand small car wheels & hubs. 135 x 13 - 4PR.
PUMP DRIVE.	SPA Vee belt. 2.6/1 reduction.
WHEEL DRIVE.	Vee belt to idler on vacuum pump. 2.6/1 Chain drive from idler to friction roller drive on wheels. 4.5/1. 1/2" roller chain. Friction roller drive on wheel tyres with toggle engagement.
BRAKES.	Motorcycle brake on idler shaft with hand lever on handle bar.
CLUTCH.	Hinged spring loaded engine mounting with flexible cable control.
THROTTLE.	Motor cycle type on handlebar.
TOWING PIN.	Towing pin with safety pin and turntable plate to match vacuum trailer.

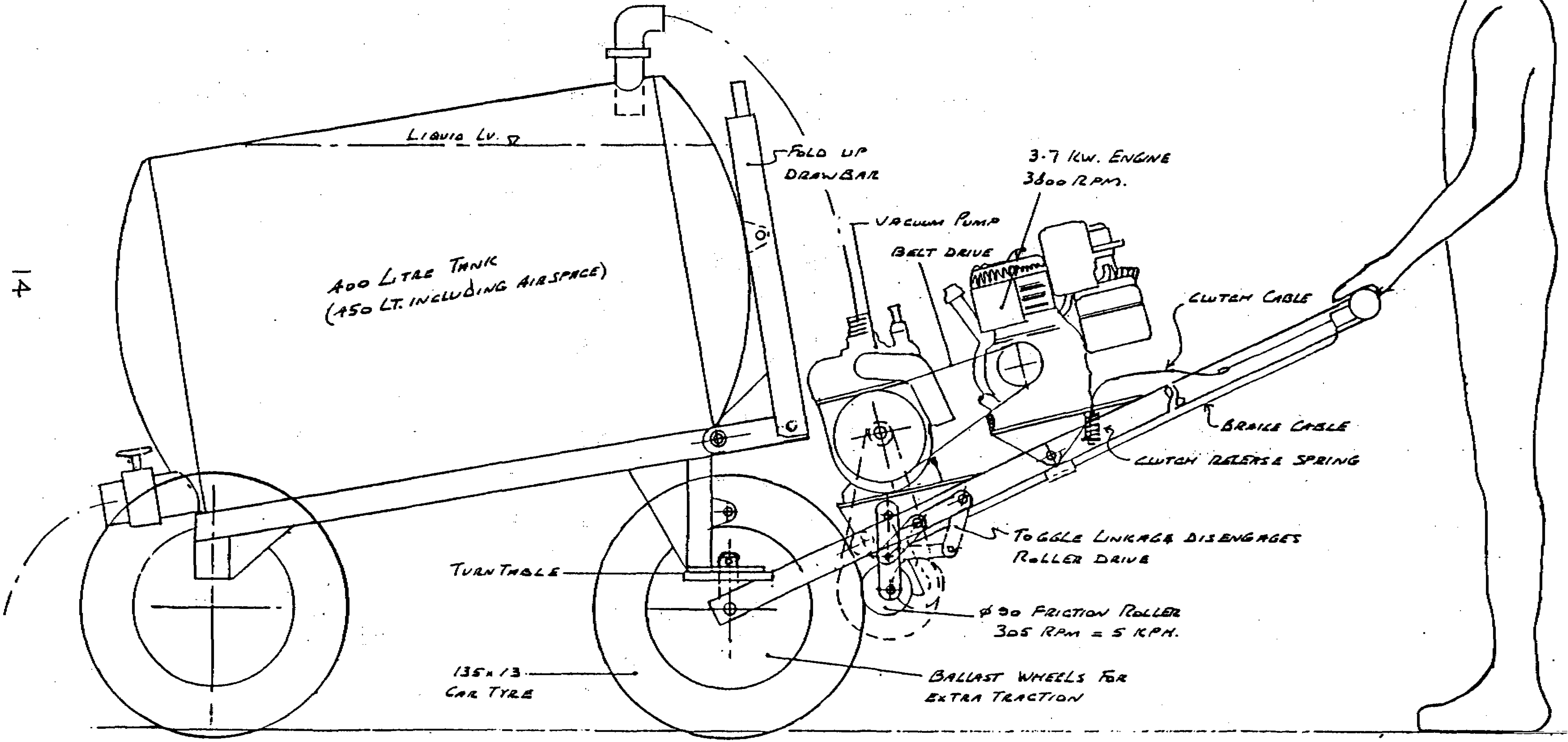
PERFORMANCE.

VACUUM.	1,700 litres free air/min. 0.88 bar.
PRESSURE.	1.0 bar.
SPEED.	5.0 Kph.
TRACTION.	230 Kg. (depends on surface).
GRADABILITY.	35% at 600 Kg GVW (depends on surface & weight transfer).
FUEL CONSUMPTION.	Pumping. 1.2 Litres/hr. typical Hauling. 4.5 km/litre typical.
WEIGHT.	75 Kg (Est).
WIDTH.	0.6 metres.
LENGTH.	1.7 metres.
HEIGHT.	0.75 metres.

DIFFICULT ACCESS

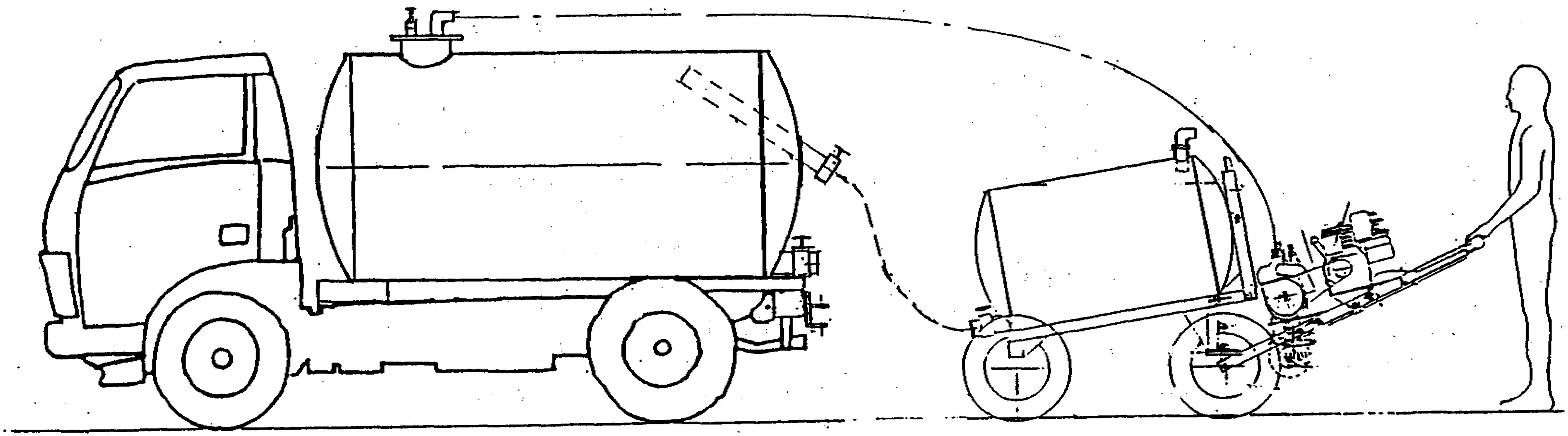
1. SUCKING WASTES FROM LATRINE PIT & TRANSPORTING TO DISPOSAL POINT OR TRANSFER VEHICLE.

TRAVEL SPEED 5 KPH. 400 LT. CAPACITY.



TRAILED TANK & TUG/VACUUM PUMP UNIT.

3. TRANSFERING WASTES FROM TRAILER TO TRANSPORT TRUCK

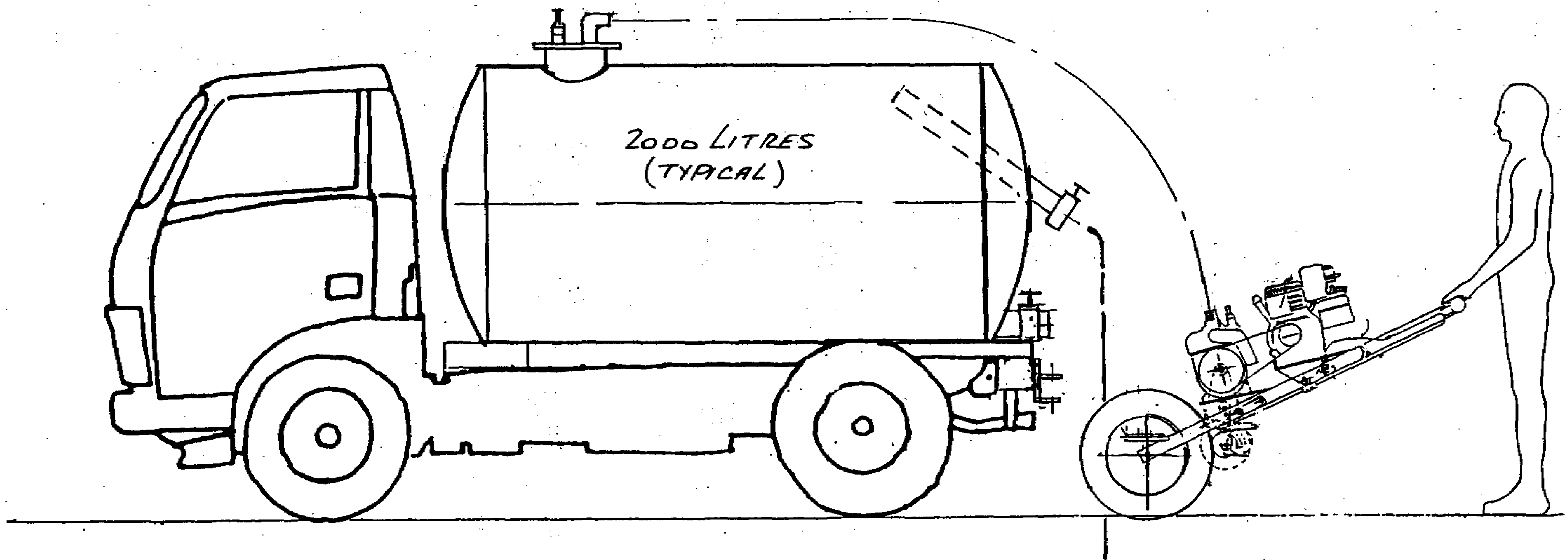


TANK & TUG/VACUUM UNIT.

EASY ACCESS

2. SUCKING WASTES DIRECT FROM LATRINE PIT INTO TRANSFER TANKER (TRUCK OR TRACTOR TRAILER)

TRAVEL SPEED 50 KPH 200 LT. CAPACITY.



TANK ON CONVENTIONAL TRUCK OR TRACTOR TRAILER

TUG/VACUUM PUMP UNIT.

4. TRANSPORTING WASTES TO DISPOSAL SITE.