CHAPTER 5

PRINCIPLES OF SIPHONS AND SEDIMENT TRANSPORT

"Imagination is more important than knowledge."

Albert Einstein

CHAPTER 5: PRINCIPLES OF SIPHONS AND SEDIMENT TRANSPORT

5.1 SIPHONIC THEORY

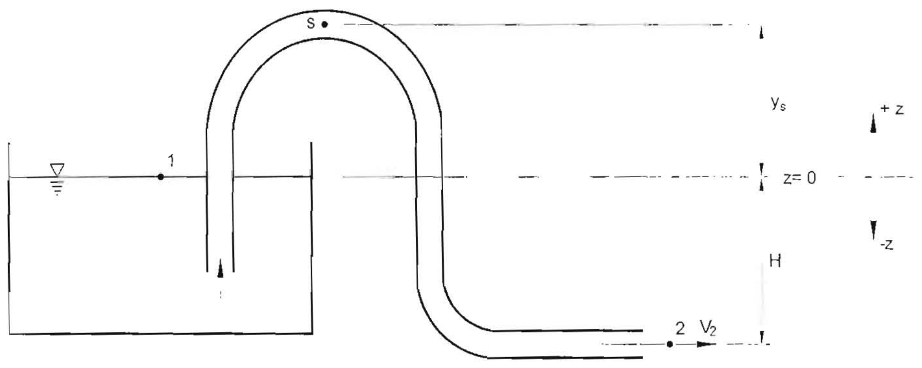


Figure 5.1: The simple siphon

Consider the simple siphon illustrated in Figure 5.1 above. Assuming that the siphon is flowing full, with a continuous liquid column throughout, application of Bernoulli's energy equation between points 1 and 2 yields (Streeter 1951)

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + \text{losses}_{1\text{-}2} \quad \text{(units in m)} \quad \text{.....................(5.1)}$$

where

$\frac{P}{\gamma}$ = pressure head, with suffixes referring to respective measuring positions

$\frac{V^2}{2g}$ = kinetic energy head, suffixes referring to respective measuring positions, and

z = potential energy head.

The loss term (loss in kinetic energy) can be expressed as

$$k \cdot \frac{V_2^2}{2g}$$, where k is a dimensionless coefficient

In other words, the losses are expressed as a factor of the velocity at point 2.

This equation results in

$$H = \frac{V_2^2}{2g} + k. \frac{V_2^2}{2g}$$

The losses are usually minor and can be neglected, unless precise work is required (Streeter 1951).

Therefore $$V_2 = \sqrt{2gH} \qquad \text{.......(5.2)}$$

where V = fluid velocity, m/s
g = gravity constant, m/s^2 and
H = pressure head, m

Therefore the exit velocity V_2 is proportional to the square root of the head H (V decreases as the tank empties).

Using the same symbols as before, and also neglecting the minor losses, between point 1 and the siphon summit S the energy equation yields

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_s}{\gamma} + \frac{V_2^2}{2g} + y_s \qquad \text{.......(5.3)}$$

i.e. $$\frac{P_s}{\gamma} = - y_s - \frac{V_2^2}{2g} \qquad \text{.......(5.4)}$$

P_s is thus negative (gauge pressure) and is proportional to y_s and V_2^2 (i.e. P_s decreases as the tank empties).

The low pressure at the summit S, which causes the siphon to discharge water from the tank, is produced by the length of the water column y_s + H (Streeter 1951). Discharge will take place as long as y_s plus the vapour pressure is less than the local atmospheric pressure expressed in length of fluid column (approximately 9 m for water, less losses). It is assumed that air is excluded from the siphon.

5.2 HYDRAULIC TRANSPORT OF SEDIMENT

5.2.1 General

In order to transport solids hydraulically, they have to be kept in a state of suspension by the liquid medium. In conventional sewers the solids will remain suspended only for as long as there is a large enough volume of liquid flowing at a suitable velocity through the pipeline. The specific gravity of the solids is also an important factor, as light solids will be transported more easily than heavy solids.

Effluent flow in the upper reaches of a pipe system is marked by extended periods of minimal or no flow interspersed by short periods of high discharge (Reed 1995). Further down in the network the increasing number of branch pipelines contributing to the discharge produces a virtually continuous effluent flow which varies throughout the day. The flow usually tends to be a minimum sometime during the night and a maximum at some time during the day. The exact time at which the maximum and minimum flows occur will depend on the local patterns of domestic water use, the quantity and type of industrial effluent present and the distance the effluent has to flow to reach the sewer. For the purposes of this investigation, only domestic effluent is considered, i.e. effluent discharging from septic tanks in residential areas.

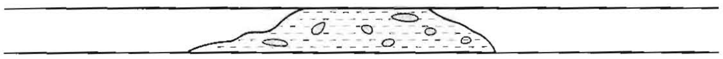
The scope of this project and dissertation required only a limited investigation into sediment transport theory. The purpose of the experimentation was to test the hypothesis that it is possible to extract sludge from a domestic septic tank by means of a simple siphon. This hypothesis was proved to be valid. In the laboratory where the experimental equipment was set up, the length of pipeline along which the suspended sludge was transported after passing through the siphon was only 8,0 m (see figure 6.12), and moving the sludge for long distances was thus not required. The investigation of sludge transport over longer distances will be the focus of a further research project. For this dissertation, therefore, only the basic principles of sediment transport are given, which are sufficient for an understanding of the processes taking place. However, some further study into the physical laws governing sediment transport, which will form the basis for the further investigations, was undertaken. This is included in this dissertation as Appendix C.

5.2.2 Solids transport in the upper reaches of a pipeline

When effluent is discharged into a sewer it produces a short, highly turbulent wave which may fill most of the pipe section (Reed 1995). This is illustrated in Figure 5.2 (a). As the wave travels along the sewer, boundary layer friction causes the top of the wave to flow faster than the bottom, which has the effect of attenuating the wave (Figure 5.2 (b)). When solids are being carried along in the effluent, they are kept in suspension initially by the turbulence in the wave (Figure 5.2 (c)). As the wave attenuates, the solids settle to the bottom and are pushed along by the pressure of the water behind them, as long as the flow is sufficient (Figure 5.2 (d)). Eventually effluent upstream of the solids drains away and the solids are left behind – they will be moved further along the sewer by successive effluent waves until they reach an area of continuous flow, whereupon they will remain in a state of permanent suspension as long as the flow velocity is sufficient.

(a) Discharge profile close to source

(b) Discharge wave further downstream attenuated by friction



(c) Wave close to source carrying solids in suspension

(d) Attenuated wave pushing solids along pipe invert

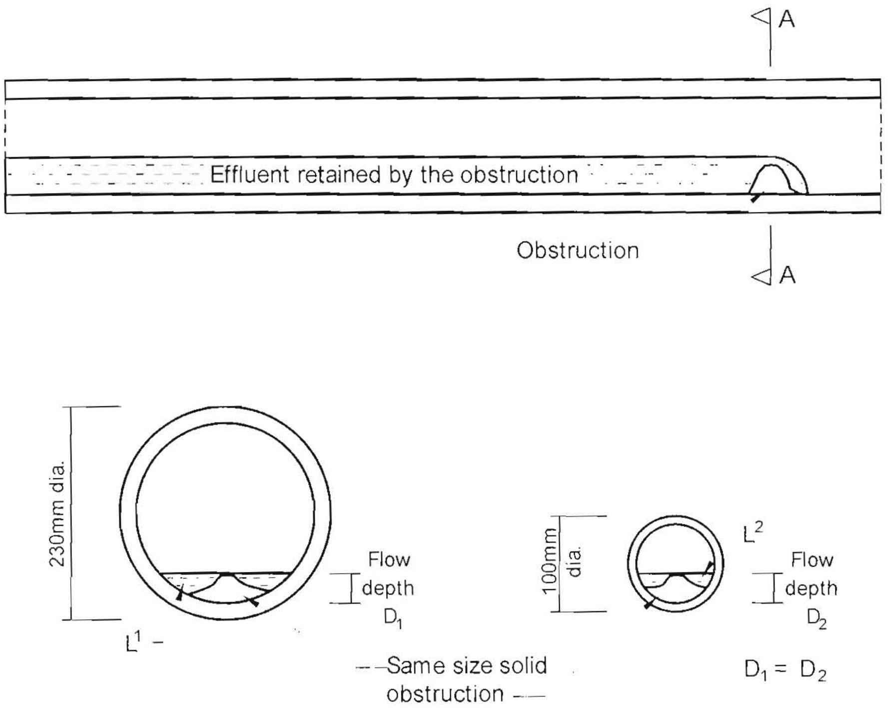
Figure 5.2: Solids transport mechanisms in the upper reaches of a sewer network
(Reed 1995)

5.2.3 Solids transport in the lower reaches of a pipeline

Further down the system the flow is virtually continuous. Most solids will be kept in suspension and transported by the flow. Heavier solids will either be pushed along in a way similar to that produced by the attenuated flow or else they will be re-suspended during the periods of peak flow (Reed 1995).

5.2.4 Effect of different pipe diameters

In the upper reaches of sewerage systems solids are, as described above, transported by hydraulic forces. Figure 5.3 illustrates how, in the case of solids which have been deposited in a pipeline, larger diameter pipes require a greater volume of effluent to produce the same depth of upstream flow as a smaller pipe, and there is a greater amount of "leakage" around the solids. For a given flow rate, smaller pipes have a higher liquid flow velocity and thus a greater momentum to act on the transported solids (Reed 1995).



Note: In a large sewer, the area of effluent (L[1]) surrounding an obstruction is greater than that surrounding an obstruction of the same size in a smaller sewer (L[2]), assuming the same depth of flow for each (the flow rates and pipe slopes will not be the same for both cases). Effluent in a large sewer will generally drain away faster than in a smaller one, because of the greater "leakage" around the solids. As it is the effluent trapped behind the obstruction that moves it along the pipe, movement of the solids will tend to take place easier in the smaller pipe (Reed 1995).

Figure 5.3: Effect of pipe diameter on solids movement efficiency.
Top: section through pipe length; Bottom: alternative cross-sections through A-A
(Reed 1995)

Sludge particles are of a particulate nature, low specific gravity, and unlike the type of solid matter usually encountered in conventional waterborne sewerage systems. The "sludge siphon" concept is therefore based on the supposition that the sludge which is siphoned out of a septic tank is not dependent on strict minimum pipe diameters and gradients for its suspension and transport in a fluid medium. Rather, the fluid/sludge mixture is assumed to be homogenous (i.e. a continuum) and the sewer can therefore be designed using hydraulic principles.

CHAPTER 6

METHODOLOGY FOR DEVELOPING THE SLUDGE SIPHON

"Scientists explore what is; engineers create what has never been."

Theodore von Karman (1911)

CHAPTER 6: METHODOLOGY FOR DEVELOPING THE SLUDGE SIPHON

6.1 INITIAL EXPERIMENTATION

The first objective was to cause a siphon immersed in a container of water to discharge automatically when additional water was poured rapidly into the container. This was to simulate the situation hypothesised in Figure 4.5, where the entry of liquid into the septic tank inlet would cause the siphon at the outlet to commence discharging effluent into the outfall pipeline.

A 50 litre plastic container was fitted with a siphon fabricated from 50 mm diameter uPVC water pipe (Figure 6.1). The siphon consisted of two vertical legs joined to a horisontal branch by means of elbows. The longer leg of the siphon extended through the bottom of the container to form the effluent pipeline. The container was first slowly filled up to the level of the invert of the horisontal pipe branch, until the water just started to flow from the pipe outlet. At this stage additional water was poured rapidly into the container so that the soffit of the horisontal pipe became completely immersed. Although this additional water drained out of the tank via the outlet leg of the pipe system, the siphon did not charge itself and start emptying the container as expected. It was assumed that air had probably become trapped in the elbows, thus preventing the siphon from activating.

Figure 6.1: 50 ℓ container and 50 mm diameter prefabricated pipe system intended to simulate a siphonic-type outlet

In order to test this assumption, the pipe system was first fully charged with water, in order to expel all air bubbles, before being inserted into the container. On this occasion, when the container was rapidly filled up again, the siphon commenced operation and emptied the water from the tank. It was thus deduced that, for the siphon to commence emptying the container without itself first needing to be charged with water, it would be necessary to improve its design. Either all air trapped inside it would need be expelled while the container was filling or, alternatively, any air bubbles still inside the pipe should not interfere with the operation of the siphon. After various attempts, the pipe configuration illustrated in Figure 6.2 was found to operate satisfactorily without requiring to be charged with water first. As the container was filled above the soffit of the "horisontal" branch of the pipe system, the siphon commenced discharging and continued doing so until the container had been emptied. It was concluded that the air bubble trapped inside the pipe had been forced into the highest point of the system, into the very corner of the top elbow, so that it no longer interfered with the free flow of water through the siphon.

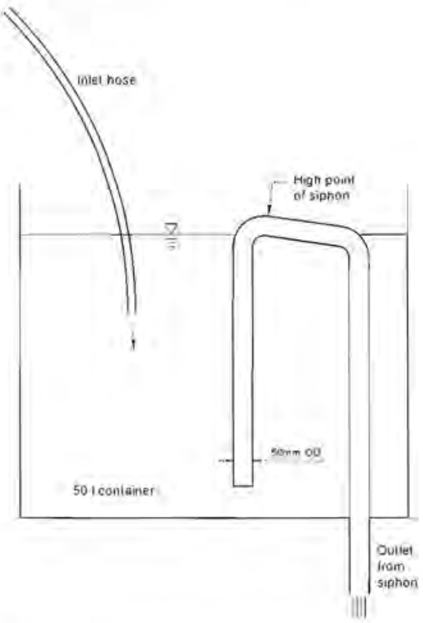
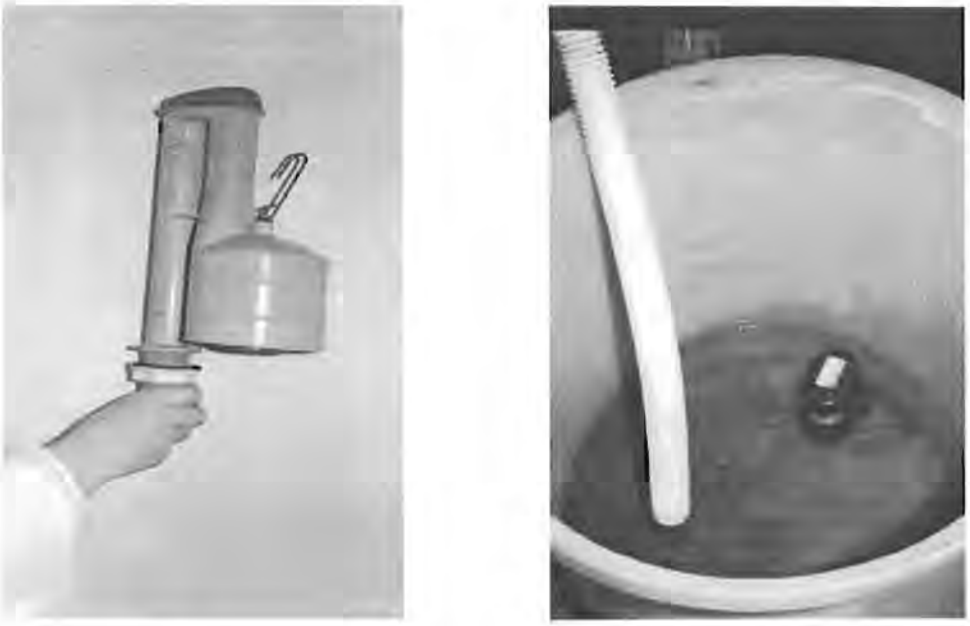


Figure 6.2: Modified pipe configuration in order to negate effect of air bubbles on activation of siphon

It became clear that a moulded pipe system, i.e. one which had smooth bends instead of prefabricated elbows, would reduce the likelihood of air bubbles being trapped in the system and interfering with the activation of the siphon. For this purpose a standard plastic siphonic cistern valve was taken and the top part cut off in order to serve as the summit of the siphon arrangement in place of the uPVC pipe and elbows. This is illustrated in Figure 6.3. The basic shape of the valve summit is similar to the configuration adopted in Figure 6.2. It was found that this device worked excellently – upon rapid addition of water to the container the siphon charged itself and emptied the container without any problems occurring.



(a) (b)

Figure 6.3: Standard siphonic cistern valve forming outlet mechanism of container:
(a) unmodified valve shown separately; and (b) the summit of the valve cut off and fitted into the bottom of the container.

It was now necessary to simulate this effect in a larger container, with a water surface area closer to what it would actually be in, say, a small septic tank. This step was required in order to determine the minimum volume of water needing to be fed into the tank in order for the siphon to automatically commence discharging. The greater the water surface area in the tank, the greater the amount of additional water required to activate the siphon. Initially, a plastic tank with a diameter of 530 mm was fitted with the pipe system used previously. The result was satisfactory in so far as the siphon worked as desired, except that the minimum flush volume required was found to be not less than 14 ℓ for this specific tank size. This presented a problem, as it implied that the siphon could not be activated merely by a toilet cistern being flushed, as insufficient water would be discharged into the tank in this case, especially if a tank with a larger water surface area was being used. A plumbing unit which could rapidly discharge a larger amount of water would be required, for example a bath. However, basing the design of the system on the use of something the size of a bath would effectively prevent all dwellings without large in-house plumbing fixtures from incorporating such a system into their sanitation arrangements.

It was therefore necessary to devise a system which would enable the siphon to charge itself and commence emptying the tank without an unnecessarily large volume of water being required. It was perceived that if the system could be made to work by emptying a fixture like the washtub illustrated in Figure 4.6, Chapter 4 (about 25 - 35 ℓ) into the tank, then the scope for implementation of such a system could be broadened considerably to include communities of virtually all income levels. A different pipe arrangement would be required, whereby the effective functioning of the outlet siphon could be made independent of the size of the tank, i.e. one that would work with a flush the size of a washtub (or greater) irrespective of the size of the septic tank.

The very high inflow rate required to activate the siphon, without the concomitant use of large quantities of water, required a different type of inlet mechanism. The configuration shown in Figure 6.4 was eventually adopted. In this system the toilet wastes would still enter the tank via the standard T-piece inlet, but larger volumes of greywater (e.g. from a washtub or larger unit) would enter a separate, smaller compartment on the side of the tank, above the siphon. This separate compartment, which would be connected to the main tank by an opening, would be able to charge the siphon with a minimum amount of water, because the water level would rise rapidly above the summit of the siphon, i.e. faster that what it would flow into the tank itself. This would then cause the siphon to charge itself and start emptying water from the tank. The system was found to operate perfectly – water discharging from the washtub into the side compartment of the tank immediately caused the water level to rise above the summit of the siphon and initiate the flush. It was also found that the volume of water flushed from the tank could be controlled by making a hole in the side of the siphon leg, which allowed air to enter the system when the water surface fell to this level. This nullified the pressure differential around the summit and caused the siphon to stop discharging.

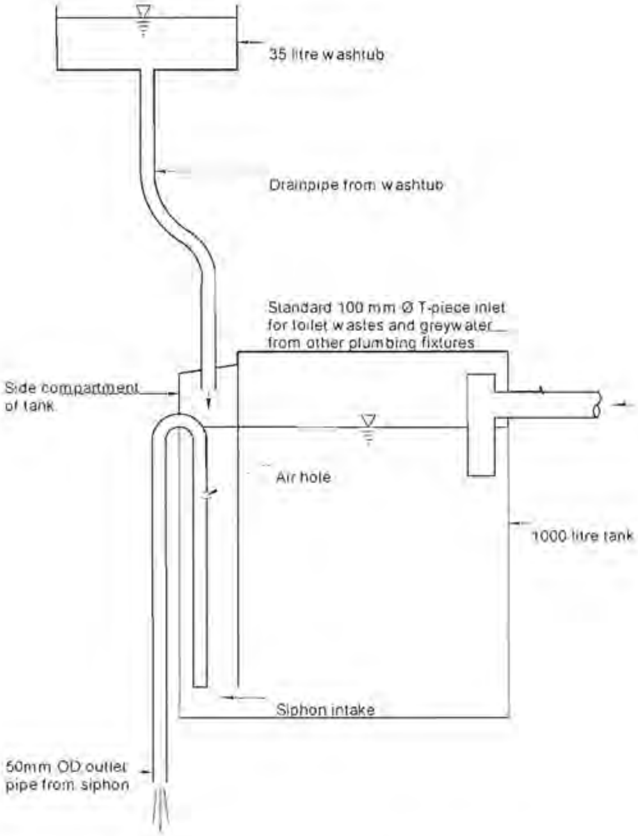


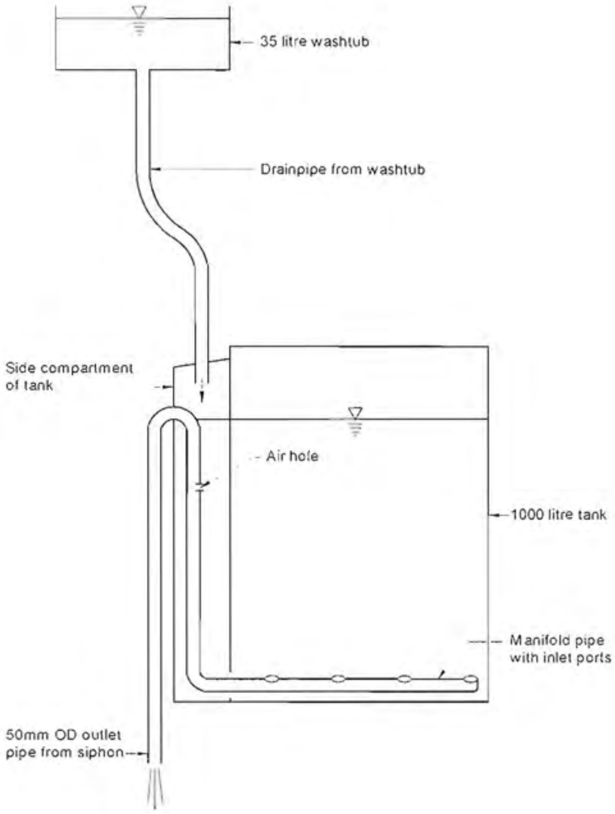
Figure 6.4: Modified outlet arrangement to facilitate charging of the siphon

6.2 EXPERIMENTATION WITH "SIMULATED SLUDGE"

Having achieved satisfactory results with a self-activating siphon which proved to be capable of extracting any desired amount of liquid from the tank, the next step was to experiment with a mixture of water and suspended sediment. Due to the fact that septic tank sludge is a dangerous substance to work with, it was decided to postpone the testing thereof and initially use an inert material which would reasonably simulate the physical characteristics of the fine, particulate sludge matter. Then, once it was certain that the siphonic outlet arrangement worked as intended using this "simulated sludge", the testing could be continued with actual septic tank sludge.

Because septic tank sludge is a material with a low specific gravity, which settles very slowly to the bottom of the tank, it was necessary to find a material which behaved similarly in water. Sawdust was found to work satisfactorily and the experimentation was continued using water mixed with suspended sawdust. A tank with a volume of 1 000 ℓ was set up on a platform with the 35 ℓ washtub above it in the same configuration as before, except that the floor was made sloping towards the siphon intake with the intention of assisting the movement of sawdust. This system did not work satisfactorily; the mass of saturated, settled sawdust tended to remain piled up on the floor of the tank with only a portion around the siphon intake being drawn out of the tank. The remainder of the sawdust was not drawn towards the siphon intake at all.

It became clear that a single inlet into the siphon was not sufficient and that a multiple-inlet type of pipe system, similar to a manifold, would be required in order to withdraw the sawdust effectively from the tank. Towards this end the arrangement shown in Figure 6.5 was assembled. By providing a total of seven inlet ports it was hoped that any sawdust building up to above the level of the manifold pipe would be withdrawn from the tank. This proved to indeed be the case – sawdust deposited into the tank built up to the level of the top of the manifold, but any excess was sucked into the siphon via the multiple inlet ports and removed from the tank. Figure 6.6 illustrates the successful tank and outlet arrangement. The maximum available head, measured from the summit of the siphon to the outfall pipeline, was 1,0 m in this case.



(a)

(b)

Figure 6.5: Multiple siphonic intake for withdrawing settled sawdust from tank (a) schematic illustration; (b) photograph of manifold inside tank

Figure 6.6: Working arrangement with washtub draining into the tank and siphonic outlet discharging into the pipeline
(available hydraulic head between summit of siphon and outfall pipeline = 1,0m)

6.3 EXPERIMENTAL EQUIPMENT AND PROCEDURE

The 1 000 ℓ tank with fabricated manifold, siphon and side compartment was erected on a platform with the 35 ℓ washtub installed in position above it in order to simulate an actual washtub draining into a septic tank, such as illustrated in Figure 4.6, Chapter 4. A 46 mm internal diameter perspex pipe was connected to the siphon outlet to form a transparent outfall pipeline. Numerous buckets of sawdust were added to the tank which was simultaneously filled with water up to the level of the siphon outlet. After a minimum period of a day all the sawdust had settled to the bottom of the tank and covered the manifold ports. Although the sawdust could not, strictly speaking, be equated physically to digested septic tank sludge, the two materials were similar enough for the purposes of this experimentation. What was required was a light, particulate material which would settle slowly to the bottom of the tank and be easily re-suspended upon agitation. An inert material was preferable to a hazardous substance such as septic tank sludge. Once the design of the sludge siphon had been refined and any operating problems ironed out, then further experimentation and observation could be continued using actual sludge obtained from functioning septic tanks.

The equipment setup is illustrated in Figure 6.6. The perspex pipeline was suspended from the roof of the laboratory by means of adjustable steel hangers (Figure 6.7). The first and last hangers were related by absolute levels measured from the concrete floor; the pipeline could then be set at any desired slope by adjusting the height of the other hangers according to a taught length of building line stretched between these two. The length of pipeline was about 8 m and at the end it drained the fluid/sawdust mixture into a holding tank for subsequent reuse.

When the plug was pulled out of the full washtub, the water entering the side compartment of the tank charged the siphon which, in turn, extracted the settled sawdust from the bottom of the tank. At the same time the water in the tank drained down to the level of the air hole, when discharge ceased. The volume of water drained from the tank could be predetermined by adjusting the level of the air hole. The volume could be selected according to the quantity of settled sawdust extracted. An ideal situation was reached when the top of the settled sawdust dropped to the level of the inlet ports on the manifold and the siphon continued pumping water from the tank. The result was a "plug" of relatively clean water which followed the sawdust and thus largely flushed the pipeline clean. Figure 6.7 shows the water/sawdust mixture discharging from the siphon leg into the pipeline, while Figure 6.8 illustrates the small amount of sawdust left on the invert of the pipe after completion of the flush. Subsequent flushes resuspended this remaining sawdust and transported it further down the pipeline again. The result was that the sawdust never had an opportunity to accumulate on the pipe invert.

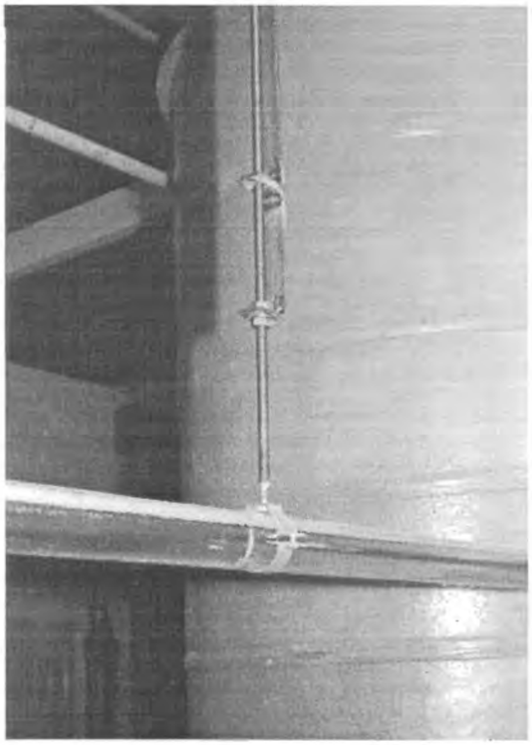


Figure 6.7: Adjustable pipe hanger and clamp attached to roof of laboratory. Pipe is discharging a mixture of water and sawdust.

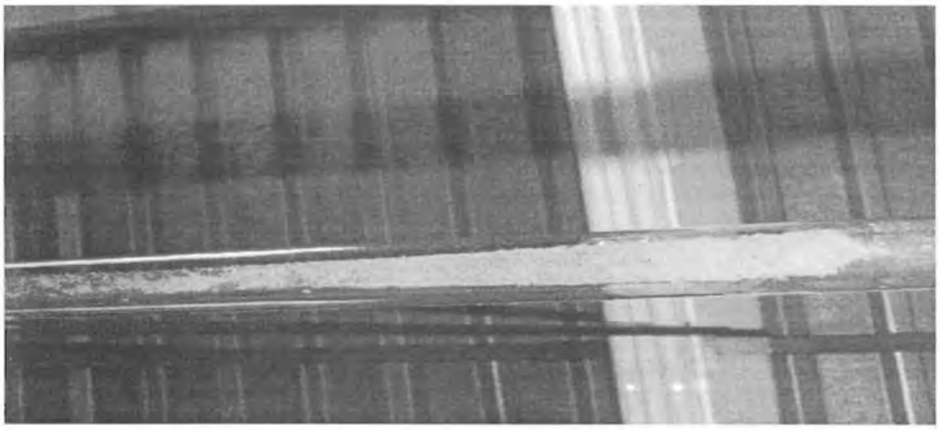


Figure 6.8: Small amount of sawdust left on invert of pipe after completion of flush (seen from underneath). Direction of flow is from right to left.

The testing equipment illustrated was full-size. The washtub, tank, manifold, siphon and pipeline used were not scaled-down models, and therefore no interpretation or manipulation of the results in order to account for scale factors was required. The measured flows and velocities during the siphonic flush could therefore be accepted as those which would actually occur under normal operating conditions.

6.4 OBTAINING TRUE SEPTIC TANK SLUDGE

Once the siphon had been proved to operate satisfactorily with suspended sawdust, the project team was prepared to proceed with the real purpose of the project – getting the siphon to extract actual sludge from the tank. The necessary health precautions were taken: team members were vaccinated against hepatitis and cholera, and wore protective clothing, including gloves, whenever working with the substance, even if only pumping it from one tank to another.

It was decided to experiment with sludge from a middle-income household initially. Septic tank sludge from various communities can be expected to differ somewhat in composition. This is due not only to the people's differing diets but because low-income families often use sand or grit to scour pots and pans while washing them. This material then finds its way into the tank. Due to its different physical characteristics such as density, particle size, etc, it was thought that it could possibly exhibit different flow behaviour when compared with sludge particles obtained from higher-income households.

Sludge was initially obtained from a domestic septic tank at a plot in Cynthiavale near Wonderboom Airport, north of Pretoria. The existing situation inside the tank was first investigated by means of the perspex coring tube illustrated in Figure 6.9. Using this apparatus the depth of sludge, supernatant and scum inside a tank can be ascertained by extracting a sample core of the material. The brass rod is inserted into the tank until it reaches the bottom, whereafter the perspex tube is inserted over it and the wingnut on top tightened in order to seal the contents inside. The tube is then withdrawn from the tank and a perfect sample of the contents is obtained. Figure 6.10 shows the core extracted from the tank - it was observed that the tank was operating well, without any problems.

The septage (mixture of sludge, scum and supernatant liquor) was extracted from the tank by means of a small sludge pump. The mixture was pumped into a storage tank on the back of a light delivery vehicle before being transported to the laboratory. In Figure 6.11 the process of extracting the septage is illustrated.

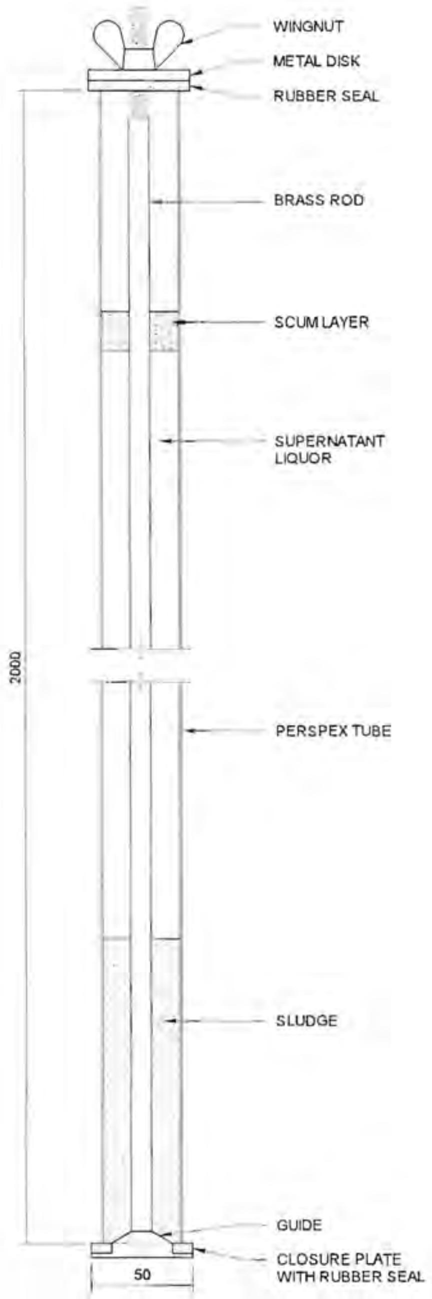
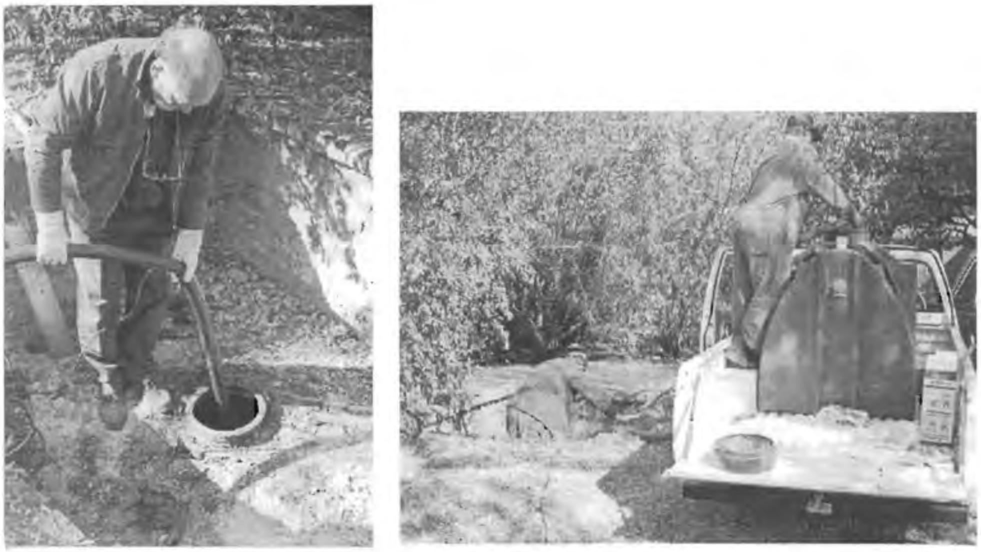


Figure 6.9: Perspex coring tube used to examine contents of septic tank

Figure 6.10: Sample core extracted from septic tank on plot near Wonderboom Airport



(a) (b)

Figure 6.11: Extracting septage from a septic tank:
(a) lowering the sludge pump into the tank; (b) pumping septage into the storage tank on the back of the vehicle

At the laboratory the equipment shown in Figure 6.12 was assembled. The septage was first pumped across from the transporting tank on the back of the vehicle into a holding tank on the floor of the laboratory. From this holding tank the septage was pumped up to the siphon tank on the platform beneath the washtub. This configuration was used for all subsequent tests: the septage, after being siphoned out of the top tank, flowed into the holding tank at the end of the pipeline, from where it could again be pumped to the top tank in order to repeat the procedure. The available hydraulic head between the summit of the siphon and the 46 mm diameter outfall pipeline was 1,0 m.

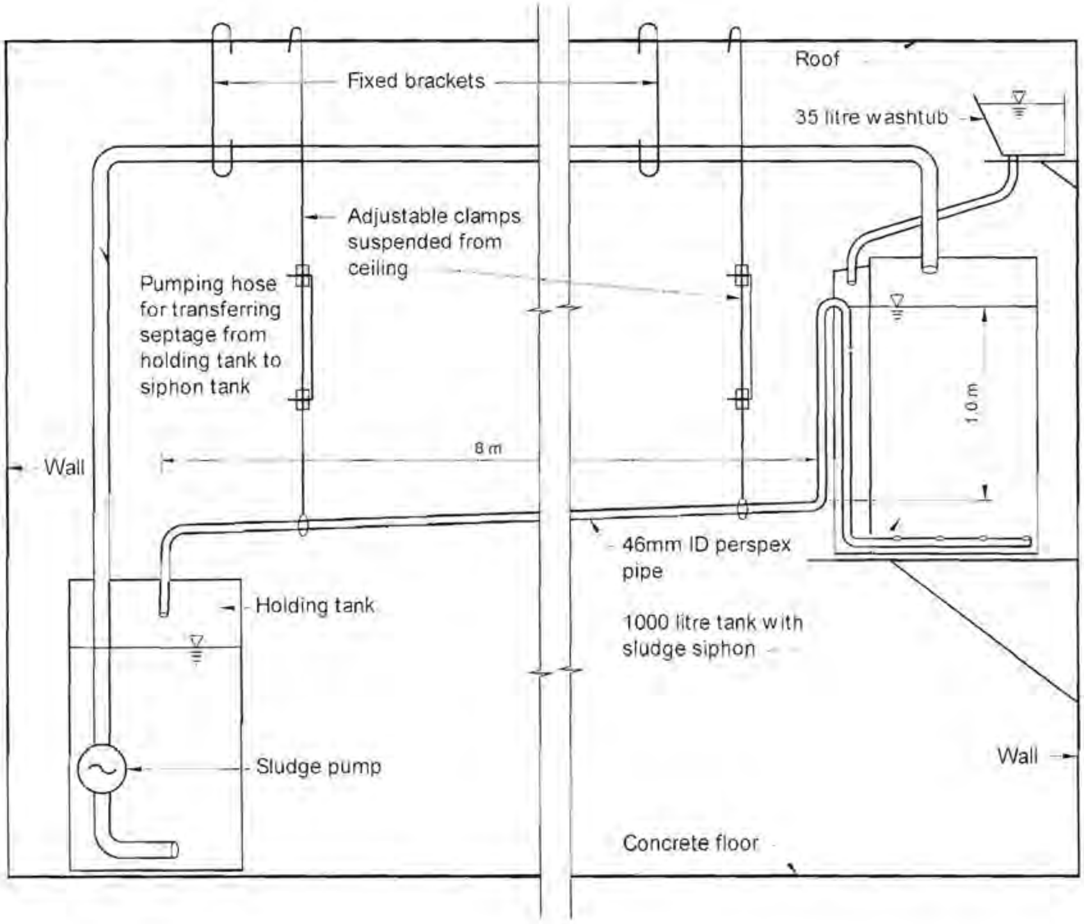


Figure 6.12: Equipment setup for testing of sludge siphon, utilising actual septage

6.5 PROPERTIES OF DOMESTIC SEPTIC TANK SLUDGE

6.5.1 General

For the purposes of studying the flow of septage in a pipeline, it is useful to understand its physical, chemical and biological characteristics. Septage is the combination of sludge, scum and supernatant liquid pumped from individual on-site wastewater disposal systems, mainly septic tanks and cesspools (Metcalf and Eddy 1991). The actual quantities and constituents of septage vary widely, with the greatest variations being found in communities which do not regulate the collection and disposal thereof. They also vary with the tank size and frequency of pumping. Information on septage properties is not readily available; however, some data on the constituents of septage in the USA are presented in Table 6.1. Most are presented for general interest only – the characteristics of importance for hydraulic transportation of the sludge particles are generally confined to the physical properties relating to the amount of solids present in the septage.

Table 6.1: Typical characteristics of septage in USA (Metcalf & Eddy 1991)

Constituent	Concentration, mg/ℓ	
	Range	Typical
Total solids (TS)	4 000 - 100 000	40 000
Suspended solids (SS)	2 000 - 100 000	15 000
Volatile suspended solids (VSS)	1 200 - 14 000	7 000
Chemical oxygen demand (COD)	5 000 - 80 000	30 000
Total Kjeldahl Nitrogen (TKN as N)	100 - 1 600	700
Ammonia, NH_3 as N	100 - 800	400
Total phosphorus, as P	50 - 800	250
Heavy metals	100 - 1 000	300
Grease	5 000 - 10 000	8 000

6.5.2 Specific sludge data

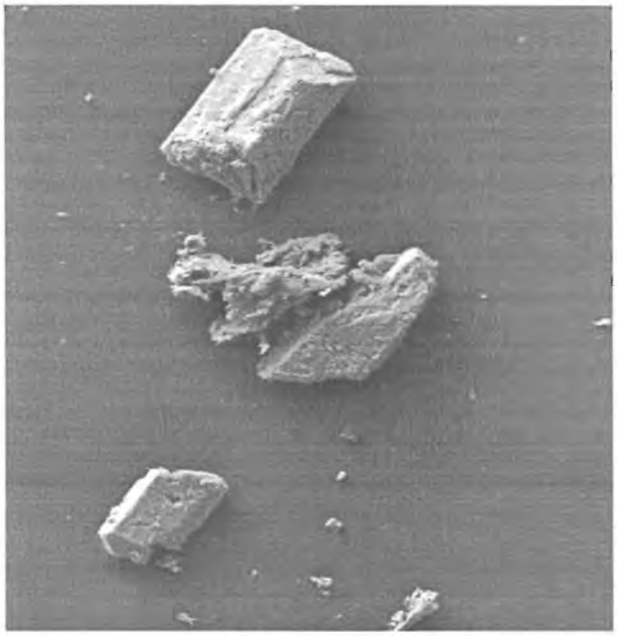
Due to the paucity of available information concerning the constituents and properties of the solid fraction of septage, it was decided to analyse the sludge obtained from the septic tank near Wonderboom Airport which was actually used in the original laboratory tests. Furthermore, because the characteristics of septic tank sludge will in all probability, as explained in section 6.4 above, differ between communities in varying income groups, tests were also conducted on sludge emanating from a poor community. For this purpose, sludge was also extracted from a septic tank in the village of Mogogelo, approximately 60 km from Pretoria in North-west Province. Table 6.2 presents a summary of the analyses, which were carried out at the CSIR Division of Materials Science and Technology. Only the relevant physical properties were analysed, and these should be seen in the context of the average concentrations shown in Table 6.1.

Table 6.2: Summary of sludge analyses

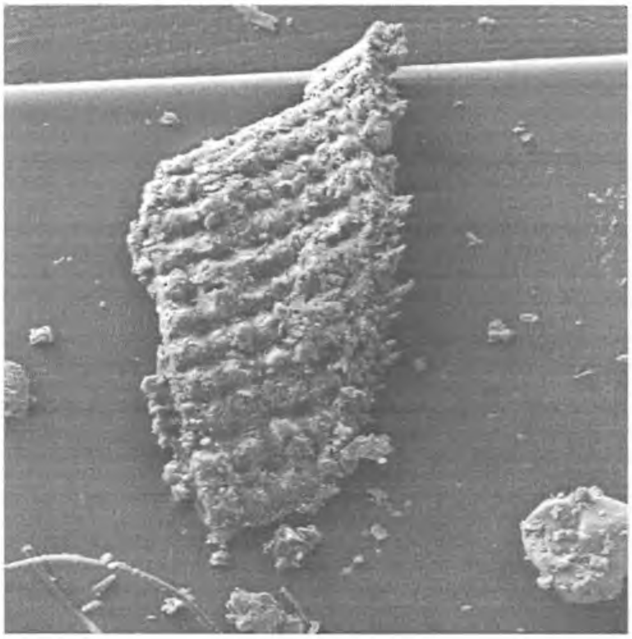
Parameter	Sample A: Sludge from middle-income family (Cynthiavale, Pretoria)	Sample B: Sludge from poor community (Mogogelo, NW Prov)
Density: Density of supernatant Density of wet solids Density of dried solids	 0,99 g/mℓ 1,00 g/mℓ ±0,20 g/cm^3	 1,00 g/mℓ 1,01 g/mℓ ±0,20 g/cm^3
Amount of inorganic elements in dried solids (mostly silicon & calcium)	12 g per 100 g	23 g per 100 g
Particle size distribution: Mean particle size, dry state Mean particle size, wet state	 8,84 μm 11,92 μm	 16,30 μm 12,71 μm

Scanning electron microscopy results:

The specific constituents which make up sludge particles are of some interest in terms of the type of substances which have to be transported hydraulically. Selected inorganic particles were subjected to qualitative scanning electron microscopy (SEM) and the relevant photographs are shown in Figure 6.13 . The scale of the photographs is indicated in each case.

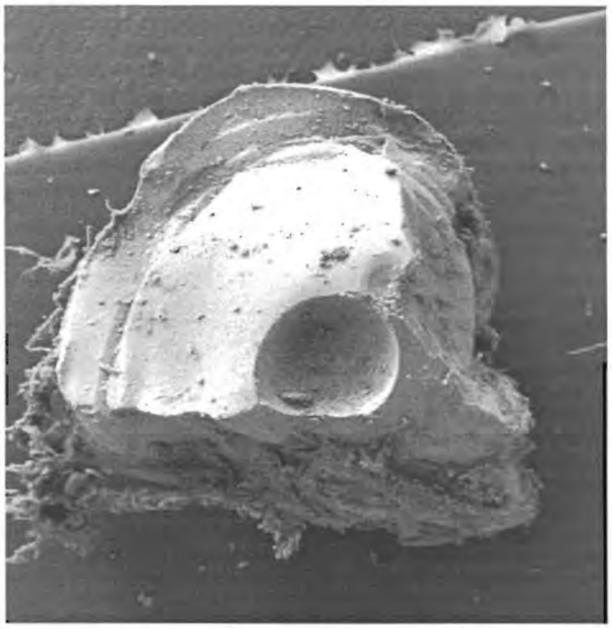


(a) Crystalline, white flakes: Main constituents: P, Mg, Ca
(Magnification 59X)

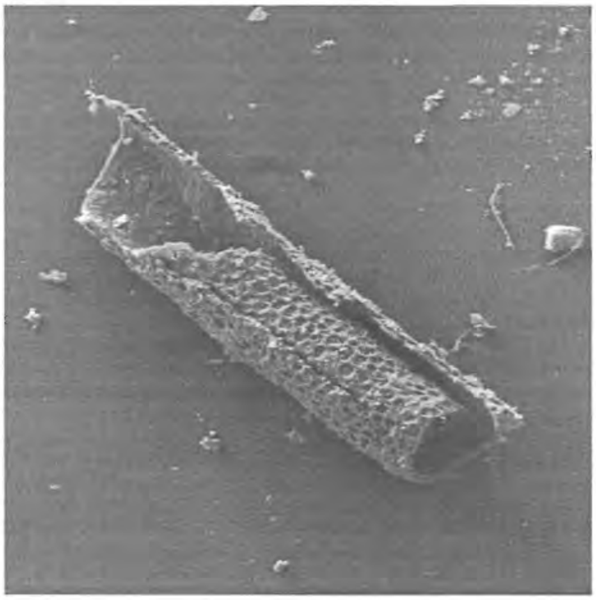


(b) Knobbly particle: Main constituents: Si, Cl, Ca, K, S, P, Fe, Al
(Magnification 57X)

Figure 6.13: SEM photographs of inorganic particles in septic tank sludge



(c) Shiny black particle: Main constituents: Fe, Si, Ca, Mn, K, Cr, S, Al (Magnification 43X)



(d) Curled particle: Main constituents: S, Ca, Si, P, Cl, K, Al, Fe (Magnification 35X)

Figure 6.13 (cont): SEM photographs of inorganic particles in septic tank sludge

6.5.3 Interpretation of results of the physical analyses of sludge samples

The physical properties of the samples of sludge tested indicated that the following assumptions could be made with reasonable confidence:

- The small size of the sludge particles implied that the flow containing the suspended particles was likely to be pseudohomogenous, i.e. flow where the particles are uniformly distributed over the pipe cross-section. This aspect was not specifically tested, however. Aspects of pseudohomogenous flow are described more fully in Appendix C.

- The very small difference between the densities of the supernatant liquid and the wet solids meant that the sludge particles would be very easily suspended and hydraulically transported. This was supported by the visual observation (described in section 6.6 below) that any sludge particles deposited on the pipe invert after the flow had ceased were immediately resuspended by the following flush and transported further along the pipeline. The mixture was thus largely of the non-settling type. Settling and non-settling mixtures are explained in Appendix C.

- Most importantly, from the point of view of the sediment transport theory and experimental work described in Appendix C, it is seen that very little of this work is actually applicable to domestic septic tank sludge. Much of the literature deals with sediment which is either spherical in shape, or of a constant size or uniform grading, while the SEM photographs clearly show the wide variety of particle shapes and sizes found in the sludge. Although the sludge from the poor community contained practically double the quantity of inorganic material, the very small differences in particle sizes and distribution meant that little, if any, differences in flow behaviour between the two samples could be expected.

  While the basic theory of bed-load movement, critical shear stress, settling and non-settling mixtures, etc still applies, it is clear that there will be very little point in attempting to predict the precise hydraulic behaviour of the sludge particles by theoretical means. All results obtained and predictions made in this project were therefore based on observation and measurement.

6.6 EXPERIMENTATION WITH SEPTIC TANK SLUDGE

6.6.1 General

The previous experimentation, which was conducted using sawdust, was now repeated using actual sludge from the septic tanks in Cynthiavale (middle-income community) and Mogogelo (poor community) respectively. The sludge siphon concept proved to operate well in the laboratory and fulfilled all the original expectations. Using the setup shown in Figure 6.12, the sludge was successfully extracted from the tank via the manifold, while at the end of the flush, when the flow ceased, there was a deposition of particulate matter on the invert of the pipeline (Figure 6.14). Subsequent flushes were found to resuspend this material and transport it further down the pipeline, with the result that the deposited material never had a chance to accumulate.

There was no discernable difference between the flush, flow and deposition characteristics of the two samples of sludge. This was to be expected, given the relatively small differences in composition, particle size, etc. However, this observation does not rule out the possibility of sludge samples from other communities containing much coarser or heavier sediment exhibiting different deposition and re-suspension characteristics. Nevertheless, it seems unlikely that the overall performance of the sludge siphon will be affected to any great extent.

Figure 6.14: Actual septic tank sludge deposited on invert of pipeline after completion of flush (seen from underneath). Pipe gradient = 0,25 %; pipe ID = 46 mm.

For economy in the installation of a sludge siphon system, it will be advantageous if the effluent pipeline can be buried as shallow as possible. A test was therefore also carried out with a head of only 0,5 m (Figure 6.15). There was no visible difference in the sludge-carrying ability of the effluent, which was relatively clear by the time the flow had ceased. For the full duration of the flush, the suspended sludge was easily transported along the pipeline between the upper and lower tanks. Due to the very low specific gravity of the solids (see section 6.5 above) the effluent was easily able to keep the particles suspended, and only deposited its load when the flow had virtually ceased. Although the length of pipeline was only 8 m, the initial results obtained would seem to indicate that the sludge particles could in actual fact be transported very much further than that. This specific aspect will be the subject of a further research project at the Division of Building and Construction Technology, CSIR.

The minimum volume of water needing to be discharged from the washtub in order to activate the siphon was found to be 21 litres. The average inflow rate was experimentally determined to be about 1,6 ℓ/s.

Figure 6.15: Apparatus set up to produce a discharge head of 0,5 m

6.6.2 Graphic representation of flows

In order to establish the velocities and quantities of effluent discharging from the tank, it was necessary to resort to physical measurements. Theoretical calculations based on Bernoulli's equation were inapplicable in this case because the tank depth and outflow velocity in the pipeline were constantly varying. The following series of graphs were drawn up by means of visual observations aided by a stopwatch, and were repeated a number of times in order to obtain good average values. In all cases, time zero was taken when the plug was pulled out of the washtub to start the flushing process.

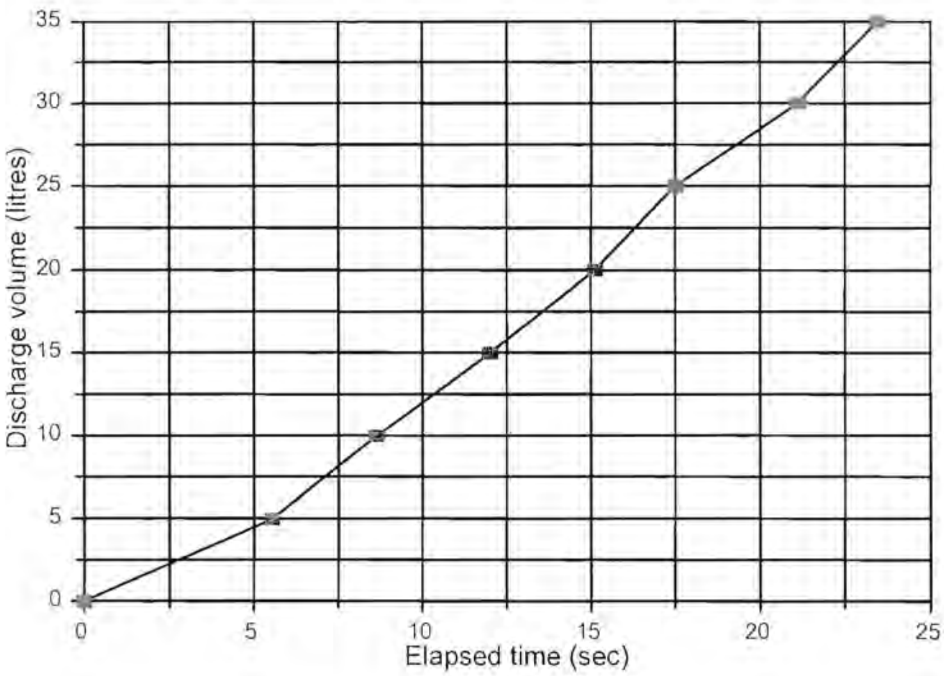


Figure 6.16: Discharge from washtub

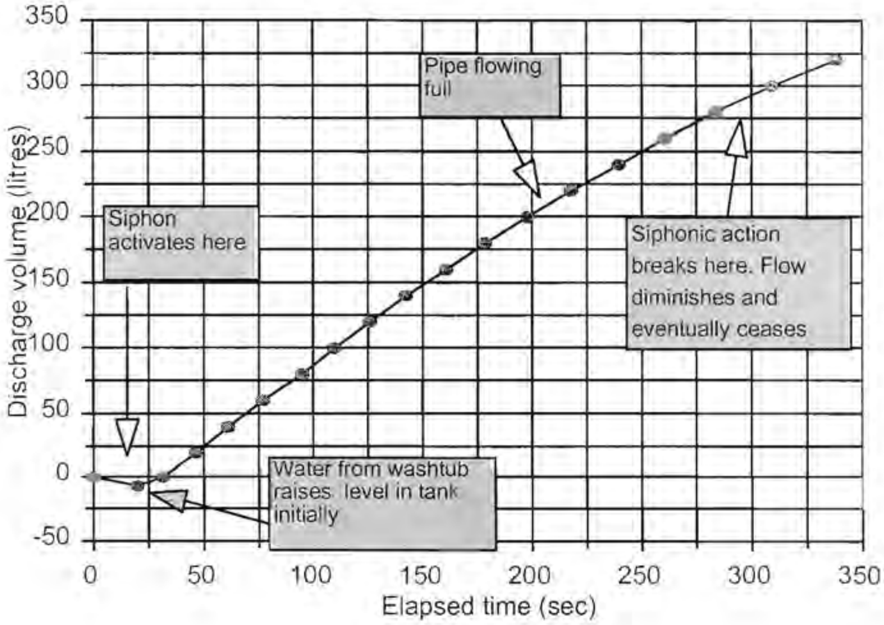


Figure 6.17: Discharge from tank

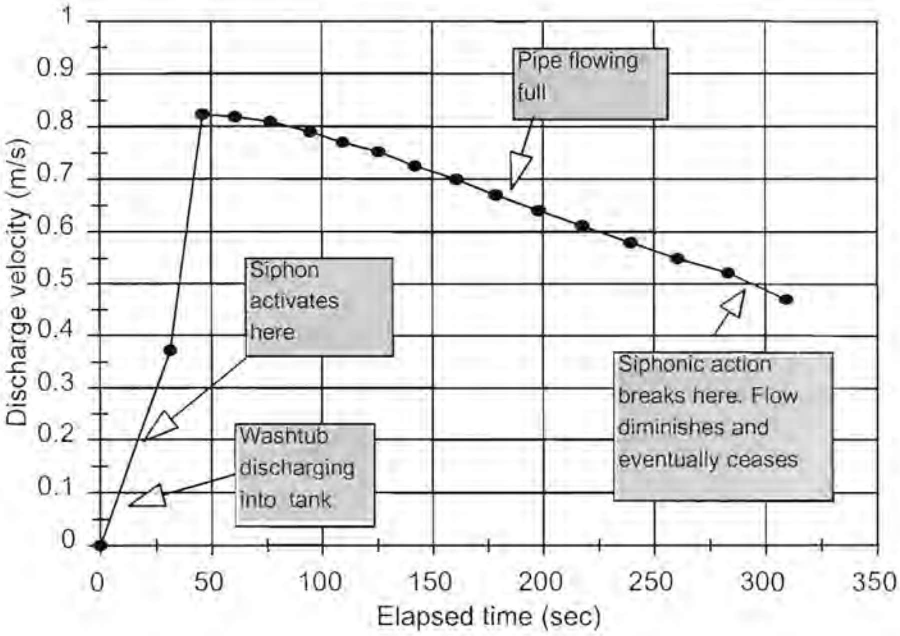


Figure 6.18: Outflow velocity from tank

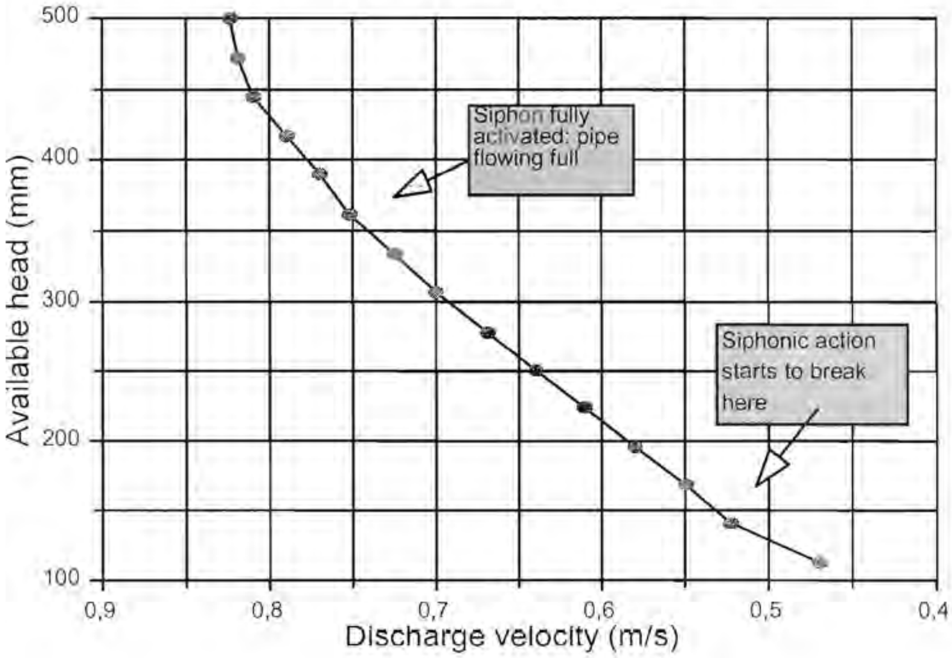


Figure 6.19: Variation in discharge velocity relative to available head

6.6.3 Observations

- The siphon activated after about 21 litres had flowed out of the washtub. It was perceived that this volume could possibly be reduced by improving the design of the inlet compartment at the side of the tank.

- Flow behaviour was much as expected – the rate of flow (as evidenced by the volume and velocity) became progressively less as the available head in the tank decreased.

- Flow behaviour became erratic at about the time the siphonic action started breaking. Although the flow velocity was still sufficient to allow sediment transport to take place, the carrying capacity of the liquid obviously started to diminish from this point. However, there was no visible lessening of sediment-carrying ability of the flow for the full duration of the siphon activation, even with a relatively small available head.

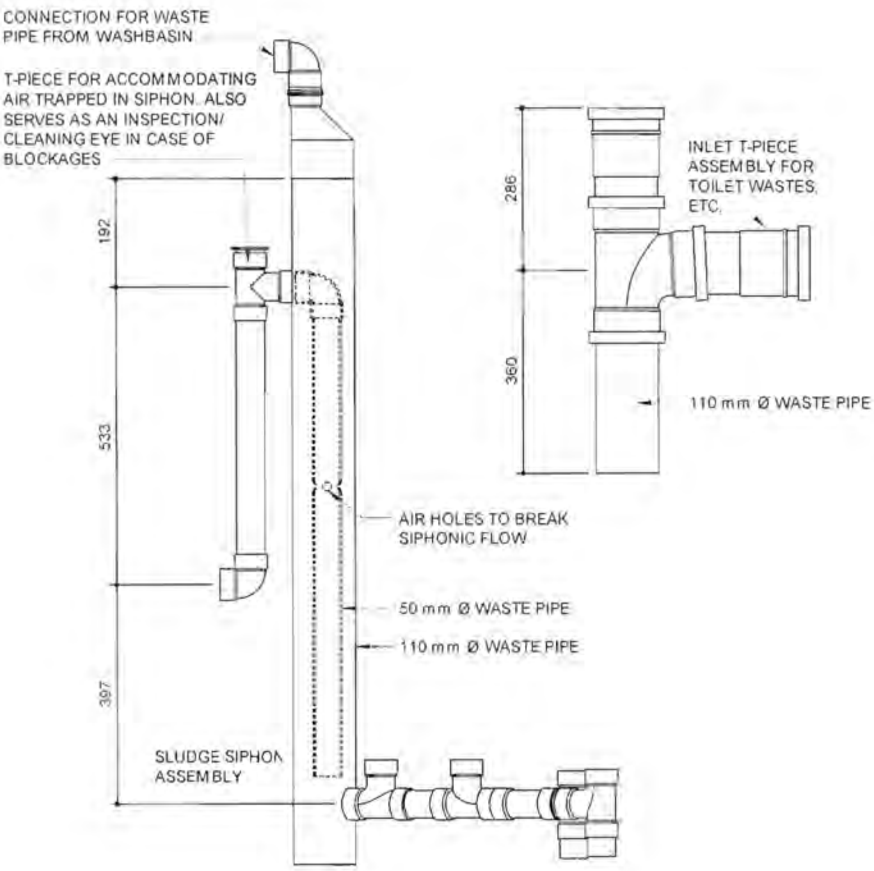
6.7 DEVELOPMENT AND TESTING OF FIRST PROTOTYPE UNDER ACTUAL FIELD OPERATING CONDITIONS

6.7.1 Background

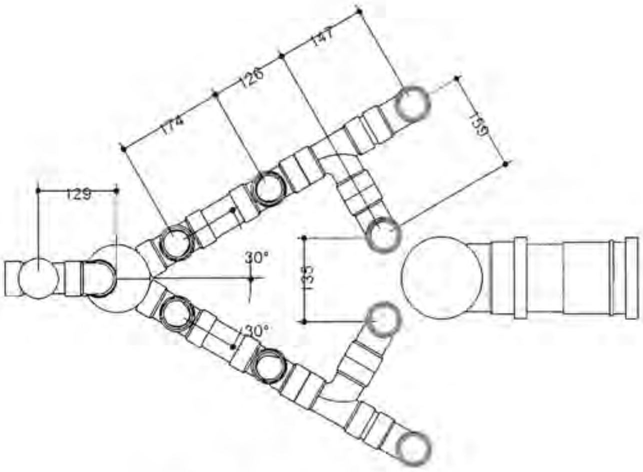
After it had become evident that the sludge siphon performed satisfactorily in the laboratory, and indeed fulfilled all the design team's expectations, it was necessary to proceed with the following phase of the project. This was to develop a prototype model of the system for testing under conditions which would normally be expected in a settled sewage scheme – connection to an actual domestic-type wastewater system where it would have to handle fresh toilet wastes and sullage instead of "ready-made" sludge from another septic tank. The prototype tank would then be expected to settle and digest the solids to produce its own sludge – in effect, it would have to perform exactly as a conventional interceptor tank in a settled sewage system.

Using the experience gained in the development of the initial laboratory model of the sludge siphon, the arrangement illustrated in Figure 6.20 was designed and assembled. The total volume of the tank was 780 ℓ, while the available retention volume, measured from the bottom of the tank to the apex of the siphon, was 620 ℓ. In Figure 6.21 photographs of the various parts making up the complete system are shown. The siphon assembly was put together using ordinary uPVC sewer fittings, and incorporated a simple device to accommodate any trapped air so that it would not interfere with the activation of the siphon. This took the form of a standard T-junction fitting, which could also serve as an inspection eye to clean out any blockages which might occur. As will be described later, the system was found to operate satisfactorily. Adverse operating conditions causing differences in performance of the system, including non-activation of the flush (i.e failure of the system) were identified, and the preliminary guidelines in Appendix A were drawn up accordingly. These included factors such as the length of unhindered straight pipeline run before an inverse gradient was encountered, and the distance between the washtub and tank. These are important considerations for the correct installation of a sludge siphon system. The height of the washtub above the tank was found to have a negligible effect on the operation of the siphon, probably due to the fact that no (or very little) flow attenuation could occur because of the vertical drop experienced by the inflowing wastewater.

The latter factor is important due to the flow attenuation which actually does take place over the horisontal length of inlet pipeline. This aspect is discussed further in section 6.7.3 below.

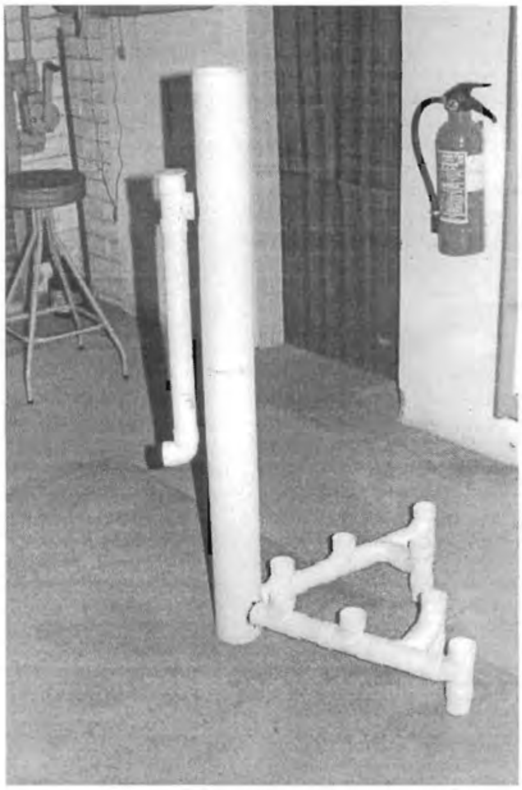


(a) Section

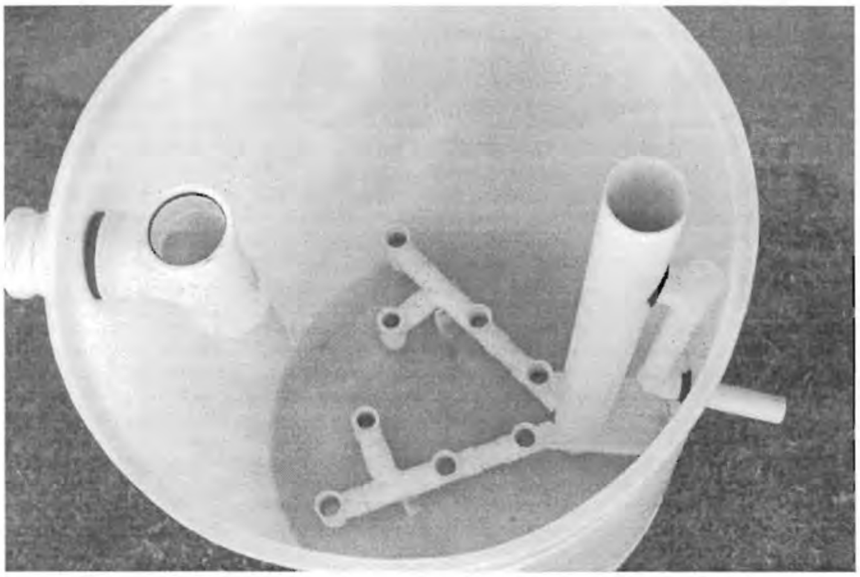


(b) Plan

Figure 6.20: Arrangement of waste inlet and sludge siphon assembly

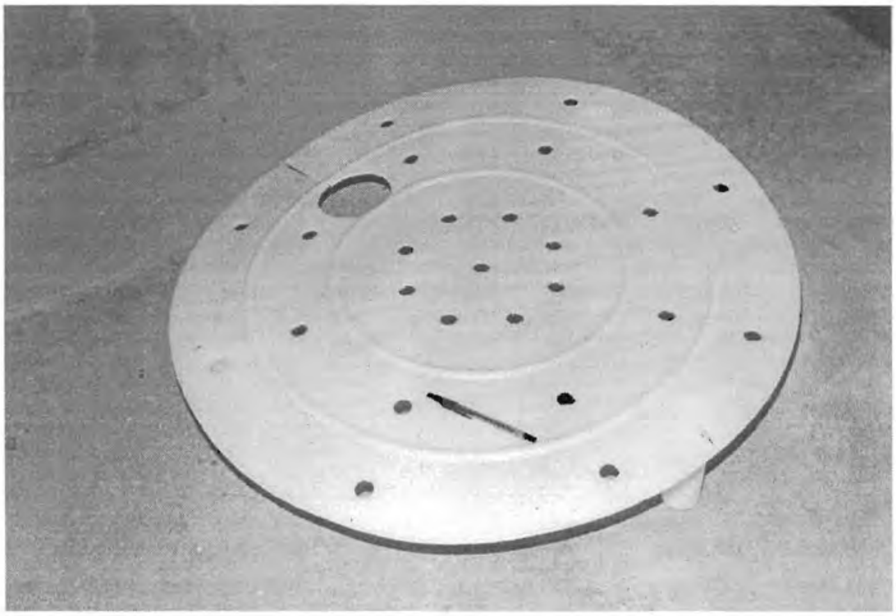


(a) The sludge siphon assembly

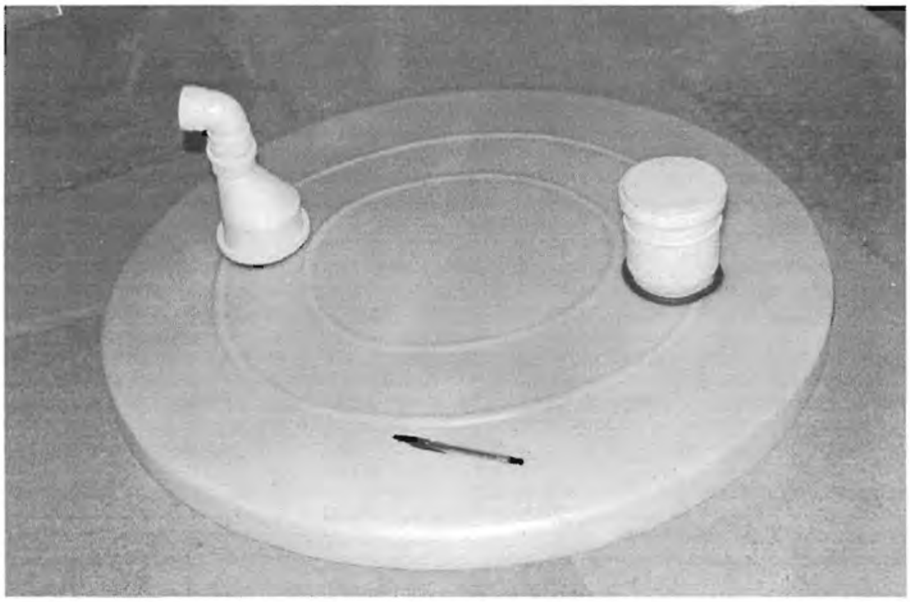


(b) Siphon assembly and conventional waste entry pipe fitted into tank

Figure 6.21: Photographs of various parts making up the complete tank



(c) Grille which fits above manifold. It was found to be necessary to drill many more holes than those shown, in order to allow efficient operation of the siphon.



(d) Lid of tank showing entry point for pipe from washbasin (left) and inspection eye above entry T-piece of toilet wastes, etc (right).

Figure 6.21 (cont): Photographs of various parts making up the complete tank

(e) The complete tank, fully assembled

Figure 6.21 (cont): Photographs of various parts making up the complete tank

6.7.2 Design and construction of the site installation

A suitable location on the CSIR campus at Scientia was found where experimentation with the prototype could take place. The CSIR day-care centre for pre-school children was ideally situated on a hillside, with the outfall sewer from the premises easily accessible next to a stone retaining wall where the tank could be placed and connected. The photographs in figure 6.22 illustrate the experimental layout. A survey established that the average number of people at the centre at any one time was 10 adults and about 70 children, which was obviously not representative of a normal domestic situation. Measurements of the average daily flow revealed that the tank would only be able to provide a retention period of about one hour under these circumstances, which was not sufficient. It was considered important to have a retention period of about 24 hours in order to ensure adequate settling and digestion of the solids, as would be the case in a properly designed and operated domestic septic tank. A Y-junction was therefore inserted in the main sewer pipe which diverted a smaller amount of waste into the tank. A special valve was also fabricated and installed in the Y-junction assembly in order to "choke" the flow, thereby regulating the influent to ensure that the required retention time was obtained.

The effect of the manipulations described above was that the normal design procedure for sizing an interceptor tank, as described in chapter 4.3, was carried out in reverse: the tank size was already fixed, so the inflow had to be adjusted to suit. With a retention volume of 620 ℓ in the tank, it was necessary to reduce the average inflow rate to ensure that this volume was not exceeded in a 24 hour period. After some experimentation with the valve, a suitable setting was obtained which produced the desired flow rate. Other than these experimental settings, there was no difference between the operating conditions of this setup and a normal interceptor tank in a settled sewage scheme. The centre produced wastewater containing human excrement, toilet paper, food scraps, sullage from washing machines and kitchen sinks, etc, all being entirely representative of a conventional domestic situation.

Figure 6.22 also illustrates how the outflow pipe from the sludge siphon was arranged on adjustable supports. This was done in order to provide conditions for experimentation with variable pipe gradients, and to produce places where pressure flow could take place. It was essential to be able to realistically reproduce conditions which would occur naturally in a working settled sewage system, and to ascertain whether the sludge could be efficiently transported under all these circumstances.

The washtub mounted on the retaining wall was responsible for activating the sludge siphon. Sections of transparent perspex pipe were installed in the outfall pipeline at strategic places in order to be able to observe the behaviour of the effluent flow. Due to the relatively long period of time required for sludge to build up to above the level of the inlet ports in the manifold (approximately two to three weeks), it was necessary to recover the sludge extracted from the tank in order to reuse it again for further experimentation. It was therefore allowed to settle in a second interceptor tank while the liquid effluent drained into the existing sewer pipe from the centre. From the second tank the sludge was pumped back into the main tank. In this way it was possible to repeat a number of experiments on a regular basis, without having to wait weeks for more sludge to develop each time.

(a) General view from above

(b) Tank / washtub inlet and outlet assembly (before installation of valve in Y-junction)

Figure 6.22: Experimental layout of prototype interceptor tank with sludge siphon at the day-care centre on the CSIR campus

(c) Butterfly valve ready for insertion into the Y-junction

(d) Y-junction with valve in place

Figure 6.22 (cont): Experimental layout of prototype interceptor tank with sludge siphon at the day-care centre on the CSIR campus

(e) Adjustable support for altering pipe gradient

(f) Flow emerging from tank before activation of flush (i.e. normal overflow from influent)

Figure 6.22 (cont): Experimental layout of prototype interceptor tank with sludge siphon at the day-care centre on the CSIR campus

The design of the siphonic assembly shown in figures 6.20 and 6.21 was such that, assuming an unhindered pipeline run for at least 12 m, an outflow volume of only 16 ℓ from the washtub was required to initiate the flush. This represented a significant improvement of nearly 24 % over the initial amount of 21 ℓ required in the laboratory experiments. Where pipeline conditions such as 90 degree bends and negative gradients close to the tank were introduced, the required minimum flush volume was found to increase accordingly. The increased resistance caused by the bends, as well as by standing water and sludge at low points in the pipeline, caused a delay in activating the flush. The reason for this is thought to be that more water from the washtub was forced into the main chamber of the tank while the initial resistance in the pipeline was being overcome, thus requiring additional water to activate the siphon. This aspect is discussed further in section 6.7.3 below. This section also describes the experimentation carried out on the site. Various hydraulic and other factors which influenced (or were thought might influence) the performance of the system, are discussed in detail.

Figure 6.23: Calibration of the water volume in the washtub

6.7.3 Experimentation carried out on the site

(a) Deposition and resuspension of sludge particles:

In a properly operated sludge siphon system, the sludge level should remain more or less static at the height of the manifold openings. Only the "excess" sludge building up above this level will be removed from the tank when the siphon activates. In a normal domestic situation (i.e. where the tank is not biologically overloaded), activating the siphonic flush as little as once or twice a week will ensure that the sludge level never has an opportunity to increase by more than a few centimetres above this level. The result will, in most cases, be that the sludge/water mixture siphoned out of the tank will generally be relatively dilute – much more so than in the laboratory experiments, where a large amount of sludge was intentionally deposited in the tank, resulting in the effluent being fairly concentrated.

However, in an attempt to simulate less favourable conditions than what would normally be expected in practice, the sludge was allowed to accumulate to about 10 or 15 cm above the grille level before initiation of the flush. Figure 6.24 illustrates a typical sludge sample cored from the tank during the testing process. It was observed that the solid matter was not always fully digested by the time a test was carried out, and often still contained small undegraded pieces of paper, food scraps and faeces. As this served to make the situation even less favourable for efficient operation of the siphon, it was considered advantageous for testing purposes.

Figure 6.24: Typical sludge sample cored from the tank before testing of the system (the core represents the sludge accumulated above the level of the grille).

The extraction of sludge from the tank, and its subsequent deposition on cessation of the effluent flow, followed much the same pattern as in the laboratory tests. No problems were encountered with the re-suspension of sludge deposited on the invert of the pipeline. Activation of the siphonic flush was, however, adversely affected if a negative gradient was encountered within 12 m of the tank outlet (see (b) below). It was also observed that the algae which formed inside the perspex pipeline (due to it being exposed to direct sunlight) was also removed by the scouring action of the sludge particles. It is expected that this scouring action will be beneficial in removing any accumulations of biological slime which may be deposited on the walls of the effluent pipeline in practice.

(b) Pressure flow with a negative gradient:

In practice, sections of pipeline in a settled sewage scheme may be laid with inverse gradients (see chapter 4.1). The implication of this for a sludge siphon system is that, not only will sludge be deposited on the pipeline invert after cessation of the flush, but a "dam" of septage will actually collect in the low points formed by the change from a positive to a negative gradient. This will result in a substantially increased resistance to a new effluent "plug" moving along the pipeline, because the inertia of the standing septage must first be overcome before normal pipeflow can resume.

Obviously, if the obstruction caused by the standing septage is far enough removed from the tank outlet, no interference with the activation of the siphonic flush can occur. However, in both the laboratory and the site experiments, it was observed that if there was a change from a positive to a negative gradient within about 12 m from the tank outlet, the siphon would not activate without a substantially greater water volume than normal being supplied (i.e. more than the 16 ℓ usually required). As mentioned in section 6.7.2 above, it is likely that the delay in getting the siphon activated is due to the need for the flow to first overcome the inertia of the standing septage before normal pipeflow can take place. This means that more water is forced into the main chamber of the tank before the water in the siphon can get moving uniformly.

Once the flow was properly underway, of course, a negative gradient merely resulted in pressure flow in the pipeline, and as long as the highest point in the pipe did not rise above the crown of the siphon, no problems were encountered with transporting the sludge. Figure 6.25 illustrates the experimentation carried out with the pipe gradient changing from a positive to a negative value.

The requirement for a minimum distance of 12 m between the tank outlet and the first section of inverse gradient has therefore been incorporated into the preliminary guidelines for the design and installation of sludge siphon systems in Appendix A. It is probable that this distance is related to the design of this specific siphon and tank, and that other values could possibly be obtained with different sizes of siphon assemblies, etc.

Figure 6.25: Experimentation with inverse pipe gradients

(c) *Additional hydraulic or biological loading on the tank:*

The correct sizing of a septic tank is crucial to its effective operation, from both the hydraulic and biological points of view. In a conventional settled sewage system, two criteria govern the required tank volume. The first is settling and digestion of the solids, for which a retention period of about 24 hours is preferably required. The second is a desludging period of at least three to five years, in order to minimise operational costs. The basic design parameter is the number of people expected to use the tank; coupled to this is the expected volume of water consumption, which in turn is dependent on the level of service of the water supply. These aspects of septic tank design have been discussed in chapter 4.

The hydraulic and biological loading of a septic tank are fairly easy to predict in middle to high income residential areas, as these are usually provided with the highest level of service regarding water supply, and calculation of the expected wastewater flow is straightforward. The average number of people expected to use a certain tank will generally also remain fairly stable in these conditions. However, in low or very low income areas, these aspects are notoriously difficult to calculate. Observation by the author of a number of settled sewage schemes in South Africa has shown that tanks in these areas are often undersized. This is seldom due to poor design, however, but more often as a result of unforeseen housing densification taking place after a system has been installed. Additional shacks are erected around the dwelling which has a toilet, in order to provide shelter for extended families, who then also make use of the toilet facility. It is not uncommon for up to 30 people to use one toilet in such cases, and the results are always predictable. Tanks with volumes of 2 000 ℓ and larger have been examined, where the rate of overloading was so great that digestion had ceased to take place and a layer of faeces crud up to 300 mm thick was found floating on top. The situation in such cases is usually exacerbated by unknowing users depositing personal cleansing materials such as plastic bags, thick wads of newspaper and rags into the toilet. Naturally, the tank ceases to operate under such conditions, and the whole settled sewage system is therefore also affected.

Various hydraulic and biological loading rates were also experienced in the prototype tank installed on site. As already explained, due to the large amount of users connected to the system, it was necessary to divide the sewage flow from the day-care centre and install a special valve in the pipeline in order to reduce the loading to acceptable limits for the specific size of tank used. While this experimentation with the flow was taking place, it was clearly seen what effect overloading would have on the system. A high rate of wastewater flow resulted in a very short solids retention time, with digestion being greatly inhibited. This was aggravated by wads of heavy paper towelling (used for drying of hands and general cleansing purposes) being flushed down the centre's toilets, as well as objects such as sanitary pads, etc. Materials of this nature are generally not a problem in a conventional waterborne sewerage system, but are definitely not supposed to go into a septic tank, as they degrade either very slowly or not at all, dramatically increase the rate of sludge accumulation, and negatively affect the operation of the tank. In a sludge siphon system they also block the grille and prevent sludge from being sucked through the manifold ports, which then results in failure of the flushing device.

The guidelines in Appendix A stress that the care and operation of the system should be regarded as being similar to that of an ordinary septic tank, in that the householder is responsible for ensuring that the toilet is used properly, i.e. only soft tissue paper is used for personal cleansing, no objects such as sanitary pads, newspaper or cigarette butts are disposed of in the toilet, and that only approved disinfectants are used, etc. If normal precautions such as these are adhered to, there is no reason why a sludge siphon system should not give the same trouble-free operation as a properly operated conventional septic tank.

(d) Distance between washtub and tank.

While the distance between the toilet(s) and the tank are not a factor in the operation of a sludge siphon system (or any septic tank system, for that matter), the distance between the tank and the plumbing fixture (bath, washtub, etc) feeding the siphon is of cardinal importance. It is essential that the incoming wastewater enters the siphon compartment as rapidly as possible. If this is not done then either the siphon will require a greater volume of influent before it activates, or it will not activate at all, as the influent has a greater chance of being forced into the main compartment of the tank before it is able to charge the siphon. A greater distance between the plumbing fixture and the tank will generally result in the flow being attenuated to some extent, depending on the layout of the waste pipe. It was thus considered necessary to investigate this aspect in order to be able to provide guidelines for the installation of the system.

Figure 6.26 illustrates how the waste pipe was extended in order to conduct the necessary experimentation. The washtub nearest the tank provided a wastewater flow distance of about 1,5 m, which resulted in a volume of only 16 ℓ being required to activate the siphon. The hydraulic head available between the washtub invert and crown of the siphon was 950 mm, and the waste pipes were standard 50 mm diameter. The washtub furthest from the tank provided a flow distance of 7 m, which prevented the siphon from activating, even with a washtub volume of 35 ℓ. In the latter case activation of the flush only occurred when the tub was continually fed with a supply of water from a hosepipe, and an undetermined amount of water had drained into the tank. This implies that a wastewater source this far from the tank will probably require a bathtub or similar fixture to activate the siphon.

Figure 6.26: Testing the effect of different wastewater flow distances on the operation of the siphon.

The furthest washtub was subsequently moved nearer to the tank in one metre increments, and the average volume of water required to activate the siphon determined from a number of trials in each case. The results are shown in Table 6.3.

Table 6.3: Average wastewater volume required to activate flush with various flow distances between washtub and tank

Distance between washtub and tank (m)	Flush volume required to activate siphon (ℓ)
7	> 35
6	25
5	25
4	25
3	25
1,5	16

A few important conclusions can be drawn from the above results:

- For this specific siphon and tank configuration, any flow distance greater than about 6 m will require a volume of water larger than what can be provided by a 35 ℓ washtub (e.g. a bath discharging probably at least 50 ℓ) to activate the siphon. The implication is that this situation would probably only lend itself to application in a house with full plumbing fixtures.

- There is clearly no difference in performance between the 6 m and 3 m washtub positions, although the volume of water required to activate the flush is still considerably greater (approximately 56 %) than that of the closest washtub position. The reason for the required flushing volume being the same over this distance was not investigated, but it is obvious that the flow rate is still sufficient to raise the water level in the siphon chamber quickly enough to activate the siphon. After a distance of about 6 m, the attenuation of the flow becomes such that this does not happen, and a constant feed into the washtub is required. Up to a distance of 6 m, however, the siphon will still activate with a full washtub. Again, this must only be regarded as being valid for the particular siphon and tank configuration under consideration – different tank sizes or pipe diameters will in all likelihood give other results.

- The closer the washtub is to the tank, the easier it becomes to activate the siphon, i.e. the less volume of wastewater is required. Therefore the tank should preferably be buried as close as possible to the plumbing fixture which activates the siphon. With an exterior "aqua-privy" type of arrangement as shown in Figure 4.6, Chapter 4, this will not present any problems. For a dwelling with indoor plumbing, the tank will need to be buried as close as possible to the outside wall of the room (toilet, bathroom, laundry, etc) where the activating fixture is situated.

(e) Height difference between washtub and tank:

The first washtub, which was mounted at a distance of 1,5 m from the tank, was selected for the purpose of determining whether varying height differences between the tank and the washtub would have any effect on the operation of the siphon. It was thought that an increased vertical fall distance for the wastewater, before flowing into the last (almost horisontal) section of the waste pipe, might affect the uniformity of flow, increase the turbulence and possibly lead to an additional amount of wastewater being required to activate the siphon. Figure 6.27 illustrates the washtub arrangement assembled on the site.

Figure 6.27: Testing the effect of varying washtub heights on the operation of the siphon.

During the preliminary experimentation, the height difference between the invert of the washtub and the crown of the siphon was arbitrarily set at about 950 mm. In general, washtub or hand-washing basins are set with their top rims approximately 800 to 900 mm above floor level, and with their inverts (depending on the shape and depth) being between 600 and 700 mm above floor level. Obviously a bathtub's invert is much lower, being roughly the same as the floor level. Assuming the floor level of a house is at least 200 mm above the surrounding ground, and the crown of the siphon about 300 to 500 mm below the ground, the vertical distance between the invert of the bath or tub and the siphon is thus likely to be a minimum of between 700 mm and 1 400 mm – and could very well be much more than this. With a head of 500 mm between the crown of the siphon and the effluent pipeline, the pipeline is likely to be in the order of 800 to 1 000 mm deep at this point.

The washtub on the site was accordingly raised up to a maximum of 2 200 mm above the crown of the siphon, and the volume of water required to activate the flush measured in this case. This was found to average about 25 ℓ. Taking this into account, and considering the results of the horisontal flow distance tests described in (d) above, a minimum flush volume of 25 ℓ is recommended in the guidelines contained in Appendix A.

6.7.4 Conclusions from the site experimentation

The hydraulic design of the sludge siphon is satisfactory. However, there are certain critical requirements which must be adhered to when the system is installed. These are taken up in the guidelines in Appendix A, and the information must obviously be disseminated in the form of an information brochure with each system sold by the manufacturer. The engineers and contractors involved with the design and installation of a settled sewage system will need to take heed of the requirements, as will the builders who actually install the tanks and associated plumbing.

The hydraulic and biological loading on the system must be determined by the designer in the same way as for any septic tank system, with the exception that no allowance needs to be made for sludge build-up. It must also be assumed that the system will be properly operated and maintained, as to over-design the tank with the intention of providing a "safety factor" will merely result in increased capital costs, and unnecessarily so. It will thus be essential, particularly in lower-income areas, to ensure that proper user education is carried out by competent community workers.

It will be necessary, once the commercialisation of the system gets underway, to produce a few standard sizes of tank, in order to allow for the differing requirements of various purchasers. The only factor which will be of importance here is the expected number of users.

For installations where kitchen and similar wastes also go into the tank, it is advisable to install a grease trap in the pipe carrying this wastewater. This is a common practice in many septic tank installations, and will be advantageous in reducing the layer of scum which collects in the tank, as well as in preventing fatty substances from clogging the siphon pipes.