CO-DISPOSAL AND COMPOSTING OF SEPTIC TANK AND PIT LATRINE SLUDGES WITH MUNICIPAL REFUSE

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Report to the Water Research Commission

by the

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1 EXECUTIVE SUMMARY

1.1 BACKGROUND AND MOTIVATION

In South Africa in the 1990s there has been and will continue to be a major focus by government and development agencies on the provision of basic services to developing communities. Important amongst these for health, quality of life, accessibility and convenience are domestic and institutional water supplies and sanitation facilities. For many subsidized schemes this means the provision of communal standpipes or yard taps for water supplies, and on-site sanitation systems such as pit latrines or septic tanks/digesters.

An important operation and maintenance aspect of the on-site sanitation systems is the disposal of the sludges from the pit latrines and septic tanks when these are full and can be emptied. Where large sewage treatment works are located nearby, the on-site sanitation sludges could be added to the inlet of the works without significantly affecting the operation of the works. However, in many cases the closest treatment works is small and the addition of the sludges could significantly disrupt the biological processes of the works, or alternatively there is no sewage treatment works in close proximity to the site. In such cases past practice has been to either move the latrine superstructure to a new site without emptying the old pit (in the case of pit-latrines), or to bury the sludges. Some unscrupulous contractors have gone so far as to dump the sludges in open veld, old open pits or dongas, or even into large river systems. Reports from other parts of Africa indicate that the latter option is chosen in certain cases even by larger municipal authorities.

In legislating and enforcing more environmentally acceptable sludge disposal methods, penalties should be balanced by incentives. Incentives can be in the form of options for cost savings or even the production of a useful product through recycling processes. One such incentive is the composting of the sludges to produce an acceptable, safe soil conditioner and fertilizer. This is all the more significant in rural and peri-urban areas where agricultural activity forms a significant part of daily activities and food sustainability.

However, sludges cannot in general be simply composted on their own. It is necessary to ensure that pasteurization temperatures are achieved during the composting process to ensure that pathogenic organisms are eliminated, and weed seeds are made non-viable. To achieve such temperatures the following conditions are required:

- A bulking agent to maintain pores and channels throughout the compost windrow for the continuous penetration of oxygen.
- A method of promoting the flow of air through the windrow to support the active organisms responsible for the breakdown of the organic matter.
- An insulating layer on the surface of the windrow to maintain internal temperatures and to trap malodours.

Where air cannot easily penetrate the heap, the activity of the organisms is inhibited and the generation of the high temperatures required for the pasteurization of pathogenic organisms will not be possible. Options for bulking agents include wood chips, grass cuttings, garden refuse, and domestic refuse. In the tests carried out in this project, domestic refuse, garden refuse, and grass cuttings were used as bulking agents, and wood chips were used to cover and insulate the heaps or windrows.

Previous sludge composting work had been focused on the treatment of off-site sewage treatment sludges. These included activated sludge plant sludge, biofilter sludge, and bucket latrine sludge. These had generally been successful and a number of municipalities in South Africa and elsewhere now compost their sewage sludges on a large scale. However, few tests had been conducted on the composting of sludge from on-site sanitation systems, particularly using more low-cost methods.

Following a visit by members of the Swiss agency IRCWD in early 1994 in which particular concern regarding practices in parts of Africa were raised, the Water Research Commission agreed to fund the CSIR to conduct tests on the composting of such sludges with domestic refuse as bulking agent. Dr Brian la Trobe who had had extensive experience with the co-composting of bucket latrine sludges with domestic refuse agreed to act as advisor for the project. If the project was successful, it was proposed that a training programme would be formulated to train operators in the construction, operation, and production aspects of similar composting plants.

1.2 OBJECTIVES

The objectives of the project were stated as follows in the initial proposal approved by the Water Research Commission:

i. to establish that composting can be a safe and low cost disposal method for the sludges from septic tanks and pit latrines;

ii. to establish the operational parameters for such a disposal process, especially where domestic refuse is used as the bulking agent;

iii. to assess the economic and environmental implications of such a process; and

iv. to assess the viability of this method of disposal for developing communities in more remote areas.

However, during the project execution it was found that additional tests would need to be conducted to better establish the conditions required to achieve the high temperatures needed in the windrows. In particular the following new objectives were agreed by the steering committee:

v. evaluation of different bulking materials after pure domestic refuse was unable to sustain temperatures when a weak sludge was used;

vi. evaluation of sludge thickening options;

vii. field assessment of one option for composting where electrical power for aeration systems is not available.

In order to achieve these additional objectives, and because the composting facility had to be moved to three different sites during the programme, the training programme had to be curtailed. It was agreed that this objective would be changed to the production of an operational manual as opposed to the full development of a training programme.

1.3 RESULTS AND CONCLUSIONS

Composting of pit latrine and septic tank sludge with domestic refuse, particularly garden wastes, is a viable method for the disposal and recovery of useful products from these wastes. Considerable cost savings could be achieved in terms of both disposal costs as well as transport costs for the transport of these wastes to suitable disposal sites. The final product can also serve as a useful agricultural resource, particularly for small producers and for soils with poor water holding capacities. Co-composting serves as both an environmentally friendly disposal method, as well as a method of recycling these wastes for useful purposes.

1.3.1 Suitability of system for use in urban areas

The main concern with respect to the use of this system in urban areas is the generation of odours during construction of the windrow, and the associated attraction of flies. However, if the compost site is more than 500m from residential and commercial areas, the system will be highly suitable for use in these areas. The proximity of the system to both adequate sources of refuse and sludge, and to potential users of the compost as may exist in pen-urban areas, makes this possibly the most sustainable application of the technology.

1.3.2 Suitability of system for use in rural (remote) areas

In rural area or in more remote dense settlements, the system can be readily applied. However an important consideration is the availability of sufficient sludge to make the system viable, particularly related to the investment required. However, in view of the unfavourable capital and operating costs for alternative sewage and/or sludge treatment systems for small communities, co-composting of sludges could be the most viable method for the disposal of sludge from the sanitation systems. This also applies to communities with a higher sanitation service level (e.g. septic tank systems).

1.3.3 Economic considerations

The costs for setting up and operating a composting facility will vary depending on a number of factors. Included in these are the following:

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COST ITEM	COST RANGE	COMMENTS
Civil Works		
Site Preparation	R100 - R 2,000	to clear site and fence if required
Land cost	R 0 - R 100,000	in many cases there is no cost
Composting area	R200 - R5,000	level and install slotted pipes
Maturing area	R200 - R 1,000	level piece of land
Roads	R0 - R 10,000	high grade road not required
Water Supply	R0 - R 15,000	simple connection to mains
Sludge storage tank	R1,000 - R 3,000	5000ℓ tank recommended
Drainage	R0 - R500	to drain excess water and bypass rainfall runoff
Electrical installation	R0 - R10,000	3-phase ± 5kW recommended
Miscellaneous buildings (office, store room, wash rooms, toilets)	R0 - R150,000	usually none required
EQUIPMENT		
Electrical control system	R500 - R 10,000	to switch blower on and off auto.
air blower	R1,000 - R3,000	750W to 2,000W
screening assembly	R2,000 - R10,000	cylindrical rotating screen recom.
front-end loader	R500 - R1,500/d	use when build & strip windrow
workshop tools & safety clothing	R200 - R1,000	equipment for pipe connections & maintenance of equipment
air-pipe work	R500 - R2,500	slotted and connector pipes
minimum laboratory equip	R250 - R2,500	thermometer, scale
STAFF & LABOUR		
part time supervisor	R200 - R 1200/month	supervisor only reqd during building of windrow
1 labourer per 3 m^3 compost handled/d	R800 - R1,500/p/month	a minimum of 2 labourers reqd
OPERATING COSTS		
Electricity	R50 - R 500/month	less if passive aeration system
Water	R0 - R50/month	up to 10kℓ/windrow/month
Transport	R0 - R3,000/month	high if sludge must be transported by tanker
Fuel for front-end loader	R0 - R500/month	approximately 100ℓ /day
Maintenance	R50 - R 1,000/month	say one item/month

Note that to set up the test facilities, it cost approximately R20 000 for materials and equipment. This did not include the cost of the land or the cost of buildings, electrical points, roads, water supply, or front-end loaders (although in some cases these were hired).

Operating costs would of the order of R1000/month for part-time supervision, labour, and other costs.

1.3.4 Promotion and training needs

The co-composting technology is not widely known amongst potential users of the concept, and it will therefore be important to develop suitable promotional programmes and information brochures to make decision makers aware of its potential for use in communities.

In addition, once sufficient interest has been generated in the concept, a training programme and operation manual should be developed to train planners and operators of the systems. A number of sites in Gauteng are suitable for offering such a programme.

1.4 CONTRIBUTION VALUE OF THE PROJECT

The project has been successful in so far that the composting of pit latrine and septic tank sludges has been shown to be both possible and economically feasible for the disposal or re-use of these sludges. The project has also lead to a clearer understanding of the options for bulking materials and the moisture requirements, and the construction of the windrows for the development of adequate temperatures in the compost heap. Furthermore, an alternative aeration system which does not require electrical or mechanical power was shown to be very successful. This passive alternative aeration technology is the concept of Dr. Brian la Trobe. This also lead to an evaluation of a plastic covering for composting windrows, and an appreciation of its advantages in terms of insulation, maintenance of moisture in the heap, minimisation of fly problems, and protection from adverse weather.

With the operational manual, the project will offer practical guidance to authorities and other bodies wishing to follow this option for the safe disposal of on-site sewage sludges.

1.5 RECOMMENDATIONS FOR FURTHER RESEARCH AND TECHNOLOGY TRANSFER

The following options for further research in this field could be considered:

i) Evaluation of the agricultural applications for compost from sewage sludge arising from pit latrines and septic tanks. While this may be very similar to other composts made from sewage sludges, its use should be demonstrated to rural and/or peri-urban communities.

ii) Further evaluation of "passive" aeration systems for compost windrows employing sewage sludge.

iii) Development and assessment of alternative appropriate pit-emptying technologies.

iv) Pilot project on sewage sludge composting with a rural and a peri-urban community.

Regarding the transfer of the technology, it is recommended that the manual be used as a medium for technology transfer, and that it be promoted through appropriate advertising, and its presentation at a conference and/or seminar. A draft guideline for the manual is attached as annexure A to the report.

ACKNOWLEDGEMENTS

The research in this report emanated from a project funded by the Water Research Commission and entitled:

"CO-DISPOSAL AND COMPOSTING OF SEPTIC TANK AND PIT LATRINE SLUDGES WITH MUNICIPAL REFUSE "

The Steering Committee responsible for this project consisted of the following persons:

Dr NP Mjoli	Water Research Commission
Mr HC Chapman	Water Research Commission
Dr B La Trobe	Enviro Options (Pty) Ltd
Mr T du Rand	Grahamstown Municipality
Mr D Ketley	Johannesburg City Council
Ms S Banister	Greater Johannesburg Transitional Metropolitan Council
Mr L Bredenhann	Department of Water Affairs and Forestry
Mr B Taylor	Environmentek, CSIR
Mr I Pearson	Environmentek, CSIR
Mr FP Marais	WRC, Committee Secretary
Mrs CM Smit	WRC, Committee Secretary

The financing of the project by the Water Research Commission and the fruitful contribution of the members of the Steering Committee is acknowledged gratefully.

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- ERWAT for the support and use of a site at their Hartebeesfontein Water Care Works to carry out tests, including the provision of equipment and materials;
- CSIR for support and use of a site at their Daspoort test site, including the provision of equipment and materials;
- CSIR laboratories for the analysis of various samples from time to time;
- ARC soils laboratories for the analysis of compost samples.

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1. INTRODUCTION

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Composting is an accepted safe method for recycling of human wastes for beneficial use on land. However, the conditions required to produce a good compost from different sources of human wastes is a critical consideration in ensuring the effective destruction of harmful pathogens during the composting process. The primary factor governing the destruction of pathogens is the temperature-time relationship. This project made use of known temperature-time criteria for the destruction of pathogens, and evaluated the composting process for recycling of previously untested (in South Africa) sewage sludges, namely septic tank and pit latrine sludges. Furthermore, alternative types of compost bulking material, including domestic solid wastes and garden refuse, were used in the assessments.

This report describes the results of the tests carried out, and makes recommendations for the adoption of composting for the safe disposal and recycling of human wastes from these particular sources.

1.2 Description of pit latrine and septic tank sludge disposal practices

On-site sanitation systems are in widespread use in South Africa and indeed in most of Africa. This is particularly widespread in the rural and peri-urban areas. There are distinct advantages in using on-site systems in developing countries, including significantly lower capital and operation and maintenance costs, reduced institutional requirements for the management of the systems, and reduced dependency on other infrastructure (water supply, sewers). However, all of the on-site sanitation systems do generate sludge with time which must also be dealt with through some or other disposal or reuse method. The following methods are commonly adopted:

Pit Latrines:

- abandoning the pit and moving the privy structure to a new hole;
- adding water, or water and an enzyme, to the pit to facilitate the breakdown of the sludge;
- covering the pit for 3 to 5 years during which time a second pit is used, and then digging the sludge out of the first pit by hand and disposing of the now dry contents on land;
- removing the wet sludge directly from pits with a vacuum tanker, and disposing of the contents in a sewage treatment facility, or by spreading on land, or by burying.

Digesters/septic tanks:

- removing the wet sludge directly with a vacuum tanker, and disposing of the contents in a sewage treatment facility, or by spreading on land, or by burying;
- flushing out the tanks with excess water (but usually blocking the soak-away in the process);
- manually removing the sludge with buckets (at least the scum layer) and burying this.

Where sludge is removed from the sanitation system, the potential for contamination and the spread of disease is enhanced. Even sludge that has been stored in a pit for a number of years may contain hardy pathogens like *Ascaris* eggs. Therefore care should be exercised in the handling and use of sanitation sludges. Sludges should be disposed of either in a safe place where they will not lead to contamination of the environment, or alternatively they should be subject to further treatment to render them safe, and even usable for other purposes such as agriculture.

The following treatment methods can be applied to render sludges safe for further handling and use:

- i) Anaerobic digestion with additional heating;
- ii) Aerobic digestion (e.g. composting);
- iii) Chemical treatment (e.g. lime stabilization);
- iv) Direct heating (e.g. incineration, pyrolysis).

The most appropriate method is site specific and depends on factors such as availability of other resources (land, energy, chemicals, bulking materials, etc.) and the possible uses/demand for the final product.

1.3 Previous co-composting of sludge research and practice in South Africa

Municipal sewage treatment plant sludge

Extensive work was carried out in the 1980s on the co-coniposting of municipal sewage sludges. The research supported by the Water Research Commission was carried out initially by the CSIR at Belville in the Cape where wood-chips were used as bulking agent (Nel and Ross 1987), and later by the Johannesburg municipality. This, together with information from other similar activities internationally, has lead to a number of co-composting plants being set up in South Africa. The largest of these is in Johannesburg, but a number of other successful plants have also been set up by smaller municipalities. Most notable are those at Stellenbosch and Roodepoort. At Stellenbosch the compost is sold for a nominal fee to the public. Many more municipalities are now considering this option, particularly in view of the potential cost savings related to transportation of sludge and refuse (which can be used as the bulking agent) to land fill sites. The composting process generally adopted is forced aeration using mechanical blowers.

Night soil from bucket latrines

In the late 1980s and early 1990s a large scale plant for the co-composting of night soil with domestic refuse was set up at Rini near Grahamstown in the Eastern Cape. This followed successful pilot testing of the process supported by the Water Research Commission (La Trobe and Ross 1991). The plant ran as a viable economic operation for 3 years (based on treatment and transport cost savings) before being closed down. The reason for closure of the operation was primarily due to the municipality phasing out bucket latrines and replacing them with a water-borne sanitation system with aerobic treatment.

Industrial and agricultural wastes

A number of difficult industrial waste sludges have been successfully composted in test and some full-scale operations in recent years. These include abattoir wastes from one of the largest abattoirs in the country, and dairy wastes (Le Trobe - personal communication).

1.4 Recent developments in co-composting internationally

In Europe, the United States, Asia and other parts of the world co-composting of sludges is a viable option for the treatment and disposal of sewage sludges and other municipal wastes. In Europe presently some 3% of sludges are composted as a primary step in the stabilization of sludges, and subsequently used in agriculture (Hall *1995)*. Although a large percentage (37%) of sludge is utilised by agriculture directly, the benefits of pre-composting are viewed as significant in terms of odour and health risk minimization.

The primary composting methods are forced aeration or mechanical turning of windrows, but an increasing number of mechanized reactor systems are being used. Reactor systems enable a higher level of control to be maintained during the process, but have a high associated capital cost. Much simpler and cheaper passive aeration systems are also being investigated. Anaerobic composting with the production of methane gas has been investigated and utilised in a number of countries (Obeng and Wright - 1987).

1.5 Motivation for this project

The problem faced by developing countries is the disposal of sludges from sewage systems in an environmentally sustainable yet low cost method. Composting of sludges with other wastes has been viewed as a viable option. However the composting of onsite sanitation sludges had not previously been assessed. Presently the disposal of these sludges, particularly in the developing countries, is an issue of major concern to environmentalists, health officials, and development agencies.

A proposal was submitted to the Water Research Commission with the objectives of assessing whether composting could be used as a safe method for the disposal of septic tank and pit latrine sludges, to establish the operational parameters for such a composting process, and to assess the viability of the process in developing communities.

Discussions on this topic were held with the Martin Strauss of the Swiss LRCWD. During these discussions it was felt that with South Africa's experience and interest in sludge composting, the possibility of carrying out these tests on on-site sanitation sludges in South Africa should be promoted. The subsequent setting up of a demonstration and training facility, which could also be utilised for training personnel from other African countries facing these problems, was also mooted.
The Water Research Commission supported this proposal and funded the CSIR to undertake the investigations in collaboration with Dr. B.E. La Trobe.

2 HEALTH CONCERNS IN THE HANDLING AND USE OF SLUDGE

2.1 Pathogens and toxins in sludge

Sludge from sanitation systems will usually contain a number of various types of excreted pathogens. These are viruses, bacteria, protozoa and helminths. Most viruses, bacteria and protozoa do not survive longer than about 3 months in sludges, but the eggs of certain helminths, notably *Ascaris lumbricoides*, can survive for many months under ambient conditions (20 - 30^{0}C). Hence sludges from on-site sanitation systems, particularly pit latrines and septic tanks, can be expected to have relatively low levels of pathogens, related mainly to the previous 3 months of use, but will contain persistent helminth eggs. The key factors determining the survival of pathogens are the temperature-time interactions. Various temperature-time survival relationships have been determined for selected pathogens in sewage sludge and night soil. Figure 1 below from Feachem et al (1983) displays these relationships graphically. This indicates that maintaining a temperature above 50^{0}C for 2 to 3 days continuously should be sufficient to eliminate pathogens from the sludge.

Other toxins that may be found in significant quantities in sanitation sludges include certain heavy metals and organic toxins. However, since the sludges dealt with in this project are mainly derived from domestic wastes, heavy metals which are mainly from industrial processes, have not been considered. In the case where all the sanitation wastes from a community are considered for composting, it will be necessary to assess which if any commercial or industrial wastes may be produced in the community and which could end up in the process. Of particular concern are small workshops and petrol stations.

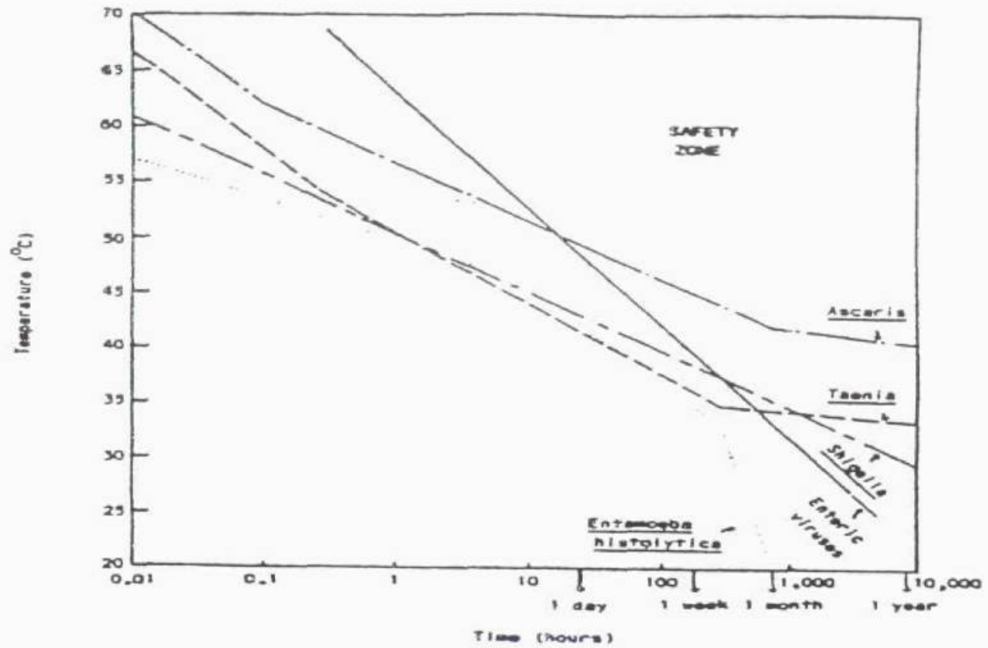


Figure 1: Survival of pathogens at different temperature/time regimes.
Feacham et al (1983)

2.2 Handling of sludge and refuse

Although the composted product will be safe and free of pathogens, the raw material inputs to the composting process will generally be highly contaminated. Workers should consequently be provided with protective clothing in the way of boots, overalls and gloves. Water should be available nearby for washing.

Furthermore, sewage sludge and refuse will attract large quantities of flies and rodents if left exposed to the atmosphere. The sludge and refuse will also produce odours which will not be acceptable in close proximity to residential or other areas where people spend a portion of their day. It is therefore important that the construction and commissioning of composting windrows be well planned and organised so that the windrows can be developed and covered within one day. Alternatively the process should be planned in sections so that each section can be completed within one day.

2.3 Use of sludge for agricultural purposes

Sewage sludge that has been composted in a process where the heat generated is sufficient, and has been allowed to mature, is safe to use for all agricultural purposes (Obeng and Wright 1987). Mature compost contains trace and essential elements \, including nitrogen, phosphorus, potassium and sulphur. These are necessary for crop production and are released by the compost in the years following application to the soil. Although the concentrations may not be as high as in inorganic fertilizers, compost has a humus-like quality that makes it even more useful as a soil conditioner.

Where possible, the characteristics of the soil should be determined from time to time to ensure that the pH balance remains within optimal zones of the crops being planted, and similarly with nutrient levels. Supplementary inorganic fertilisers or lime may be required from time to time. Where too high levels of nitrogen compounds are applied, the possibility of contamination of the groundwater should be assessed.

Sewage sludge can be considered as a low-grade fertiliser in agriculture (Korentajer 1991). The composition of sludges is extremely variable, but in general contains all the major and minor plant nutrients, except for potassium. However, in comparison with commonly used inorganic fertilisers, the concentration of plant nutrients in sludge is low, typically by a factor of 10. Associated with this is the high cost of transportation of the sludge. Hence sludge compost should preferably be used close to the production facility.

It can be expected that the yield of most plants will improve following the application of sewage sludge and/or compost. But the economical use will probably be limited to areas close to the source of the sludge and/or composting facility.

Sludge on its own or as compost will also provide soil condition improvements, particularly to rapid draining sandy soils. Sludge and compost will increase the organic content of soils and improve the physical status of soils, reducing erosion and improving water-holding capabilities.

For on-site sanitation systems, composting facilities should, to the extent possible, be located close to both the source of sludge and bulking materials, and close to agricultural lands where the compost can be utilized. This is generally possible for most rural and peri-urban communities.

3 COMPOSTING OPTIONS

3.1 Introduction

The co-composting of sewage sludge with refuse has originated out of the need to treat and dispose of ever-increasing amounts of sludge. The process is now a viable alternative in many developing and developed countries. These waste materials can be reused and recycled through composting, thereby improving the urban or settlement environment and increasing the productivity and quality of soils.

Co-composting can be carried out in either reactor or nonreactor systems. Nonreactor systems are best suited to areas where the refuse does not require much sorting and pulverising, and where funds are limited. It is therefore more appropriate for developing countries where labour and land may be cheaper and costly capital equipment (usually imported) cannot be justified.

Reactor systems vary from batch cell systems to continuous drum systems. The compost is usually conditioned in terms of particle size, moisture content, and mix proportions, before being placed in the reactors. The compost is kept in the reactors for 2 to 5 days, and then matured in windrows. Temperatures of above 60^0C can usually be easily attained.

Non-reactor systems are more appropriate to South Africa and other developing countries, and if constructed and managed well, can achieve similar temperatures and levels of organic conversion as reactor systems. They may also be more labour intensive and hence congruent with the needs of developing countries.

3.2 Forced aeration composting

Forced aeration is when air is mechanically driven through a compost windrow to ensure that the aerobic microorganisms responsible for the breakdown of organic materials into humus remain active. The construction of the windrow must be such that air can enter or be extracted from the bottom of the windrow. This is achieved by placing perforated pipes on the ground and building the windrow over these. Alternatively any system which will allow air to flow to the underside of the windrow may be used. Air is then drawn through the heap with fans connected to the pipes or ventilation system.

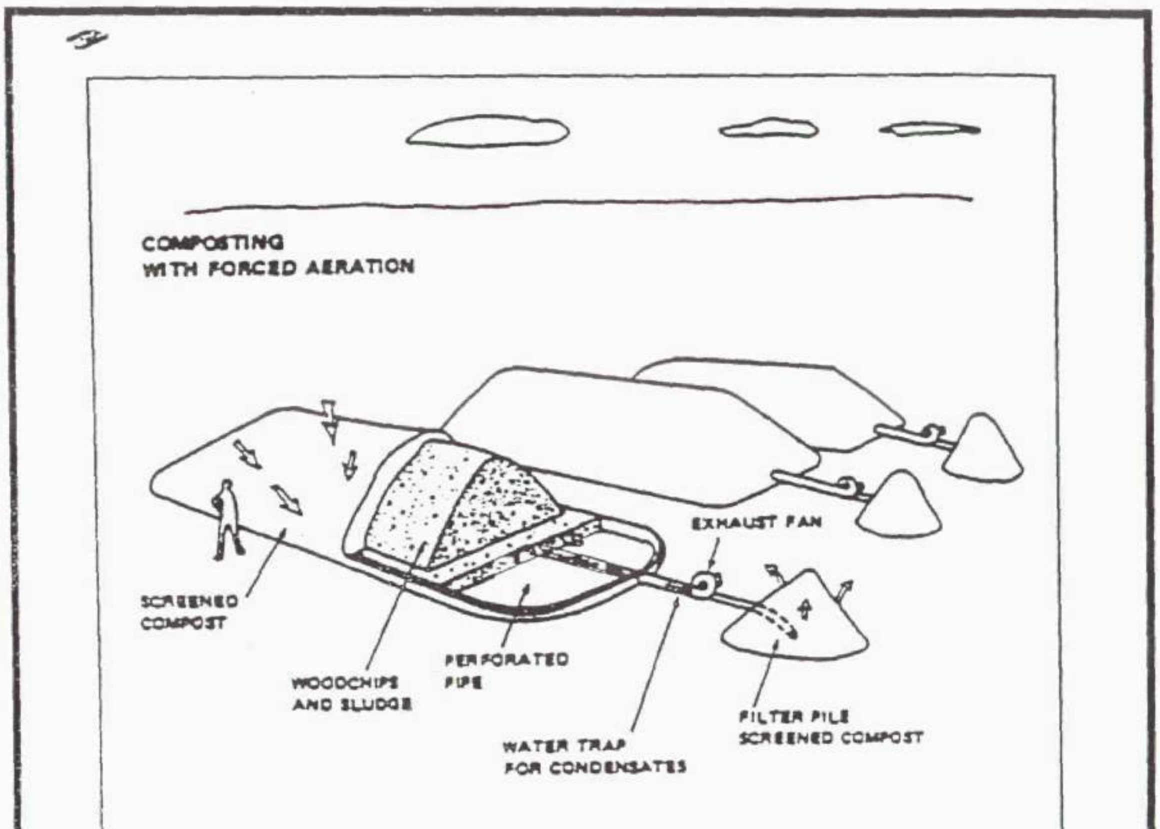


Figure 2: Typical aerated pile composting system

3.3 *Manual or machine turned composting*

An alternative method of aerating a compost windrow is to turn it by hand or by machine on a regular basis. Turning is carried out every 2 to 5 days over a 4 to 6 week period. A comparison of different systems reported in Obeng and Wright (1987) has indicated that turning is a less efficient method of producing good compost than forced aeration. This is primarily because of the difficulty of attaining thorough mixing by turning.

3.4 *Anaerobic composting*

Anaerobic composting has the advantage that it does not require energy and machinery for aeration, and could in fact produce an energy source in the form of methane gas. Anaerobic composting can be operated at a semi-dry high solids composition (25 -30%). However, energy in the form of heat (e.g. through hot-water pipes) may need to be added in order to achieve thermophilic conditions. In order to recover the methane gas, sealed reactor containers are usually required. The stabilization of the wastes can be enhanced by multi-stage digestion (e.g. 3 stages), or through a sequential process with anaerobic digestion followed by aerobic composting.

4 FORCED AERATION COMPOSTING TESTS

Following previous experience of successful co-composting in South Africa, the forced aeration composting process was adopted as the optimum process for the conversion of septic tank and pit latrine sludges to an organic compost.

The following factors are important in the composting process and govern the rate of decomposition:

moisture content	optimum	50-60%
temperature	optimum	$55\text{-}65^0C$
oxygen supply	optimum	5-15% of air and $0.5\text{-}2.5m^3 1d$ air per kg solids
particle size	optimum	10-50mm
nutrients	optimum	C:N ratio = 30:1
pH	optimum	6-8

Note that an important aim in the process is to destroy all pathogens by maintaining the temperature above 50^0C for at least 48 hours continuously throughout the heap.

4.1 *Construction of the windrows*

The compost facility consisted of the construction of triangular aerated windrows with a base width of 4m, a height of 2m, and a length varying from 6 to 18m. The windrows were underlain with a single perforated pipe in the center of the base. The windrows were constructed with approximately $4m^3$ of material per meter length of windrow.

The windrow was constructed by placing the bulking material in layers of *0.5* to lm thick, and then saturating each layer with the sludge to be tested. Excess fluids drained through the heap and out via a floor drainage system.

During the composting process the windrow tended to gradually settle to give a final height of some 1 .2m and a volume of separated compost of approximately $2m^3$ per meter length. The perforated pipe was connected to a blower which was operated by an electronic timer such that the aerator could be programmed to switch on for variable periods of 1 minute up to several hours, at similarly variable time intervals. Figure 3 below shows the general cross section of a windrow.

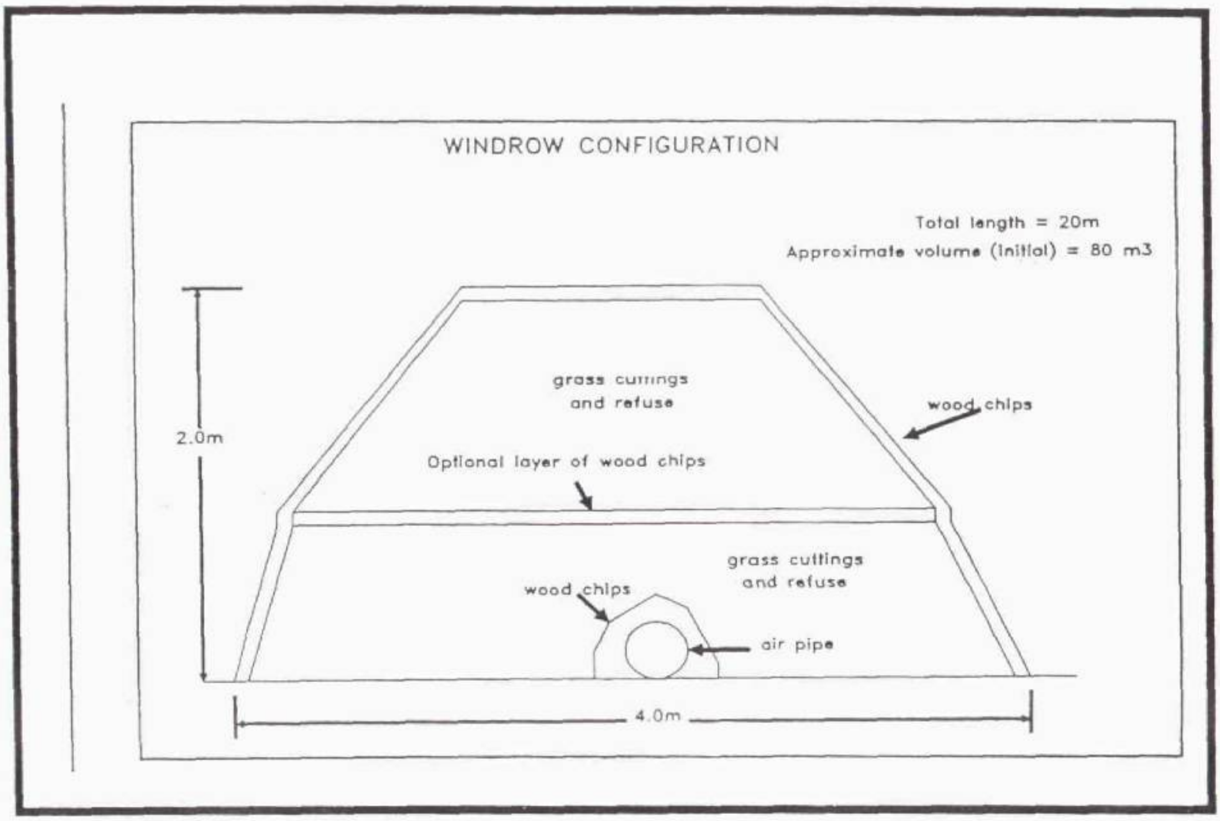


Figure 3: Cross section of compost windrow

4.2 Daspoort tests

Following agreement at the initial WRC steering committee meeting that the tests should be carried out at Daspoort in Pretoria, a pilot test facility was set up. The first test was the composting of domestic refuse with septic tank sludges.

Although a number of tests were initiated on the compost plant, no full composting run was achieved.

Refuse was obtained from the municipality of Pretoria (from the Pretoria North section). This refuse had a very high content of non-biodegadables including glass, plastics, metal pieces and various other bulky materials. The material proved to be difficult to manage with hand labour, as well as being unhygienic (attracting large quantities of flies), and producing obnoxious odours.

A number of loads of septic tank sludges were obtained from the sewage collection tankers of the company "The Drain Surgeon". This company carries out this service for the Pretoria Municipality. The sludges were emptied into a 10 000ℓ tank. After settling, the thickened sludge was piped by gravity onto the windrow.

Without exception all of these sludges were very dilute with a very low solids content. Even when the sludge was allowed to stand in the tank for several days, the settled sludge concentrate remained very weak. When placing the sludge onto the windrow composed of domestic refuse, the high water content of the sludge resulted in most of the sludge being washed strait through the windrow and into the filter drain below. Thus on top of the weak sludge concentration in the tankers, a significant proportion of the available sludge was washed out of the system during loading. In addition the high inorganic content of the refuse meant that the bulking material had a low capacity to absorb and contain the liquid sludge.

Despite the difficulties encountered in the establishment of an acceptable heap, the composting process was initiated with the setting of the blower to switch on for some 1 to 5 minutes at intervals of 15 minutes to 2 hours. Temperatures were measured using a temperature probe which could be inserted into the heap at various places. However, the maximum temperature recorded was 42^0C, well below what was required for pasteurization. The windrow was subsequently stripped and rebuilt a number of times using additional sludge, but no improvements were achieved.

The conclusions from this set of tests were as follows:

- the bulking material used in the construction of the windrow must contain at least 50 to 60 % organic material (e.g. grass cuttings);
- common household refuse is generally unsuitable as a medium for composting, unless mixed with sufficient additional organic material
- the sludge to be applied must be reasonably thick (say > 5% solids).

Because the sludge which was being transported by the company could not meet the requirements, it was necessary to move the test programme to an alternative site.

4.3 Isando tests

Following difficulties in obtaining a successful compost process when a very diluted septic tank effluent was used on a purely domestic refuse windrow at Daspoort in Pretoria, the Steering Committee approved the transfer of the test to Isando. At Isando the Kempton Park municipality undertook to supply domestic garden refuse and septic tank sludge for a second set of tests.

The Kempton Park municipality showed a strong interest in the project, and gave approval for the tests to be conducted at their Isando refuse transfer station.

The equipment from Daspoort was transferred to the Isando site, and Kempton Park Municipality constructed a suitable platform for the windrow. Kempton Park municipality also supplied a 10 000ℓ tank for the initial storage and partial thickening of the sludge before it was placed onto the windrow.

Building of the windrow

Garden refuse was used as the main absorbent and bulking agent for the sludge. However it was found that the garden refuse collected from public disposal sites actually contained considerable amounts of normal domestic wastes, including plastics, bottles, fabrics and clothing, paper, etc. Only the large plastic bags and pieces of fabric were removed during the building of the windrow. Wood chips were used around the air pipe to disperse the air, at an intermediate level to provide an additional air dispersion section and to provide structural strength to the heap, and as a cover to the heap to control odours and to act as a rain water protection. Sludge was obtained from septic tanks. Some of the sludge was also obtained from larger conservancy tanks which the municipality controlled. The first tanker of sludge (8000ℓ) was placed directly onto the windrow when half its height, but the second consignment (± 8 000ℓ) was first placed in a tank and allowed to thicken. After 36 hours the bottom 3 000ℓ was placed on the windrow, and the remaining ± 5 000ℓ of dilute grey water was disposed of in the drain.

4.3.1 Isando plant results

The compost windrow at Isando was aerated for a period of 4 weeks. Temperatures were measured at 8 points in the heap almost daily. The results are given in the attached table. It was found that temperatures at all measuring points remained above 50^{0}C for the initial 8 days, while certain sections remained above 65^{0}C for 21 days. However, the test was run during the exceptionally high rainfall period with more than 200mm falling during that period.

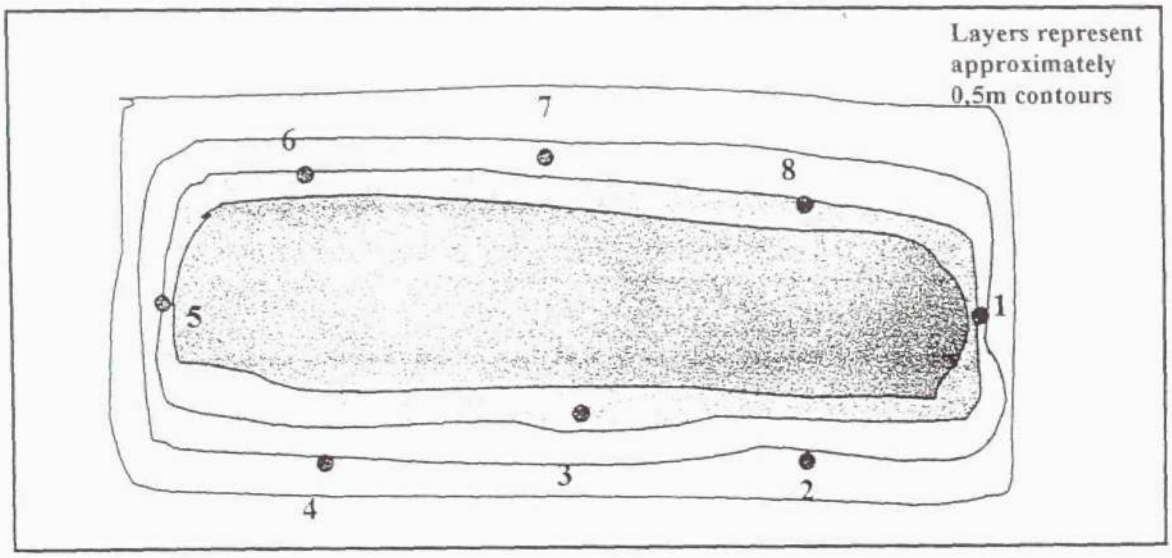
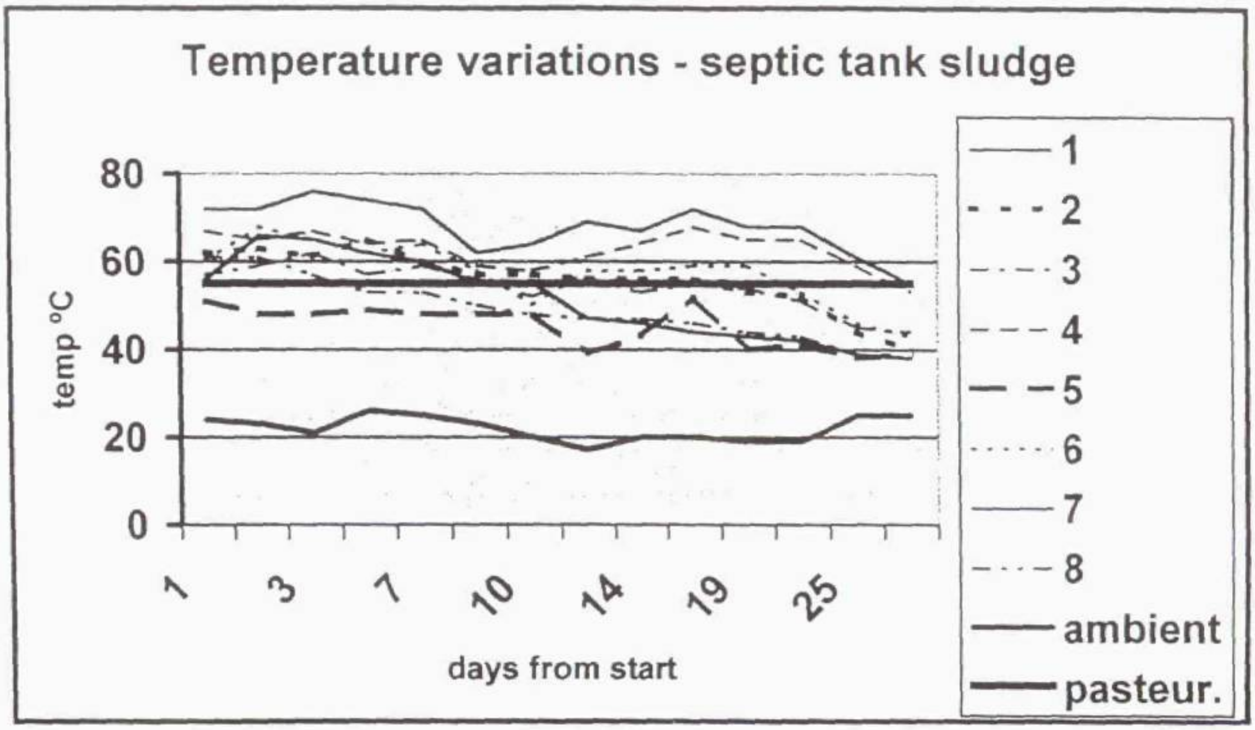


Figure 4: Temperature measuring points

The effect of the exceptionally high rainfall was to increase the moisture content of the windrow above what was hoped for, thereby preventing effective temperature build-up in certain parts of the windrow. This effect was mainly noticed at the ends of the windrow.

Fig 5: KEMPTON PARK - ISANDO FORCED AERATION COMPOSTING PROJECT

Date Started 23 January 1996 Date Completed 20 February 1996



In terms of the rate controlling factors, the following were measured:

Variable	mid-period sample from middle of heap	final sample at coolest end	final sample from middle of heap
moisture content	72%	76%	56%
oxygen supply	approximately 1.0m^3/d air per kg solids		
particle size	varied between 0.5 to 150mm		
Nutrients			
C:N ratio		7.7	11.6
carbon %		33.1	17.9
TKN (g/kg)		43.1	15.5
P (g/kg)		5.7	2.7
K (g/kg)		9.9	7.1
solids			
total solids		25%	44%
volatile solids		60%	32%
micro-organisms			
faecal coliforms/g	1.24x10^5	1.74x10^3	1.33x10^3
salmonellae		ND	ND
coliphage/g		0	0
ascaris ova/20g	0	0	0

giardia/g		ND	41
cryptosporidium/g		70	81

ND = not detected

Other comments

The die-off of ascaris ova indicates that the composting process was successful for the elimination of helminths. The faecal coliform counts would have been very high initially ($>10^6$/g). Although not all coliforms were eliminated, the high level of die-off from mid period to the final sample (a 2-log reduction) indicates that there is significant pasteurization occurring within the windrow. Coliform die-off could have been expected to be higher in less rain-soaked conditions. Coliforms will further die-off when the compost is allowed to mature for 3 to 6 months (see figure 1).

The conclusions from this set of tests were as follows:

- the bulking material used in the construction of the windrow was significantly better than in the Daspoort tests. In this case the windrow consisted of some 75% grass cuttings and other organic materials;
- the sludge applied had a significantly higher solids load than the Daspoort sludge, and hence provided an important carbon content to the windrow;
- pre-thickening of sludges is recommended in all cases;
- temperatures rose to levels of above 50°C within a few hours;
- some evidence of microbiological contamination remained in the compost at the end of the process, although these levels were low and may have been linked to the exceptionally high rainfall experienced.

4.4 Hartebeesfontein tests

At the conclusion of the Isando test, Kempton Park municipality elected not to allow the continuation of tests at the Isando site. However, they did arrange for a new test site at ERWAT's Hartebeesfontein sewage treatment works. ERWAT supported the construction of the windrows with the use of their front-end loader and the provision of grass cuttings. Kempton Park continued to supply refuse and wood-chips for the windrow.

Two parallel windrows were constructed on a similar basis to that at Isando but with different bulking materials and sludges origins as follows:

4.4.1 windrow 1 (pit latrine sludge):

The windrow was divided into three horizontal sections, each approximately 6.5m long, composed of the following bulking materials:

i) grass and garden refuse only
ii) domestic refuse mixed with grass/garden refuse
iii) domestic refuse only

5 000 ℓ of pit latrine sludge was collected from Soshanguve and was applied to the initial layer (approximately lm thick). However, the physical nature of the sludge tanker was such that the truck had to be driven or towed onto the heap to discharge the sludge from the rear valve under the tanker. This resulted in the first layer being excessively compacted by the tanker, and it was not possible to get the truck onto the heap to discharge a second load when the windrow had been constructed to a height of 2m. In order to get enough moisture into the heap, a tanker of weak sludge from Kempton Park which could discharge sludge at a higher level was obtained.

However, as may have been expected, it was not possible to achieve acceptable temperatures in the heap during the following week. The factors giving rise to the low temperatures were the following:

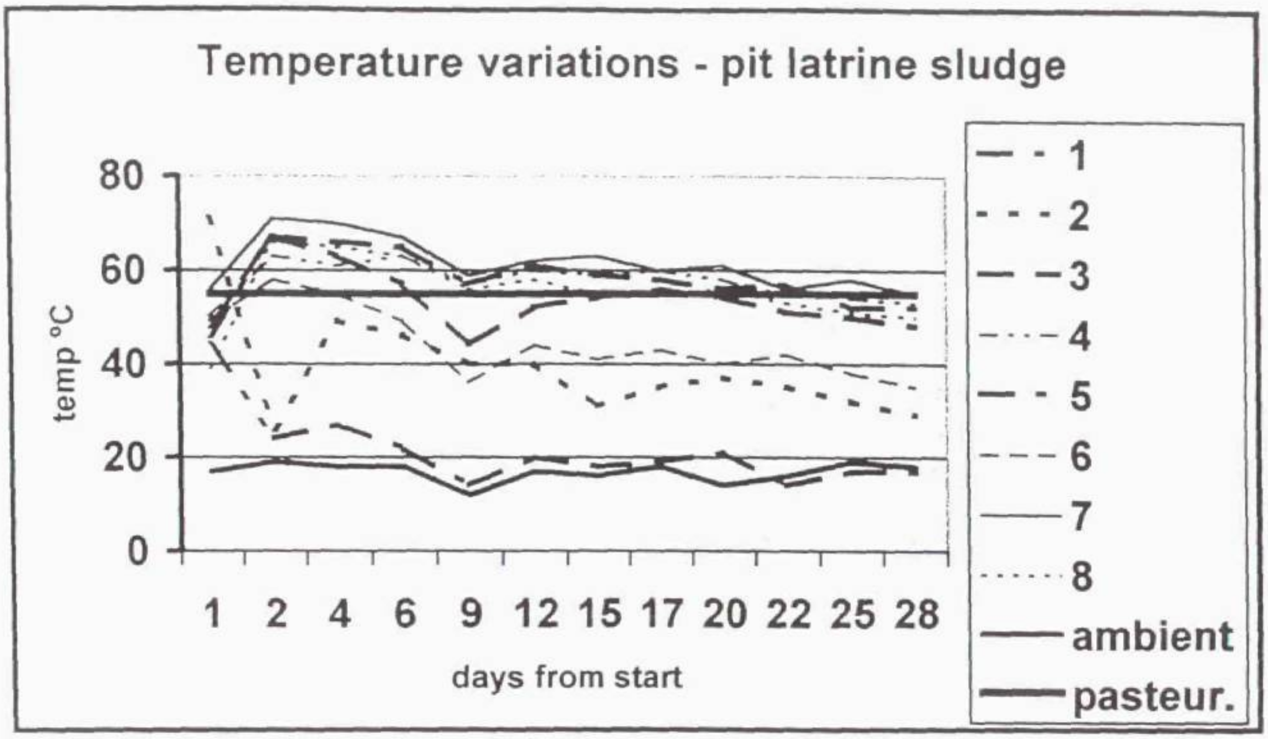
- problem of compaction of the heap by the tanker, thereby preventing sufficient airflow through the pile, and
- a lack of readily biodegradable material in the upper layer of the heap. The grass obtained from the farm at Hartebeesfontein was too coarse and required additional carbon and nutrients to be able to biodegrade rapidly.

Subsequently the windrow was stripped and spread out over a large area to enable the tanker to easily drive over it. An additional 5000ℓ of pit latrine sludge was brought and discharged evenly over all of the compost bulking material. The windrow was then reformed using a front-end loader such that there was no compaction of the heap. In this case the test was successful as acceptable temperatures were rapidly achieved in the heap.

This compost windrow was aerated for a period of 4 weeks. Temperatures were measured at 8 points in the heap as at Isando at 2 to 4 day intervals. The results are depicted in the following figure. It was found that temperatures at all measuring points remained above 50^0C for the initial 8 days, while certain sections remained above 65°C for 21 days. The test was run during the very cold winter period.

Figure 6: HARTEBEESFONTEIN FORCED AERATION
1. PIT LATRINE SLUDGE TEST WINDROW (15 000ℓ sludge)

Date Started: 3 July 1996 Date completed: 5 August 1996



In terms of the other rate controlling factors, the following were measured:

VARIABLE	FINAL SAMPLE FROM MIDDLE OF HEAP
moisture content	35%
oxygen supply	approximately $1.0m^3$/d air per kg solids
particle size	varied between 0.5 to 150mm
nutrients C:N ratio carbon % TKN (g/kg) P (g/kg) K (g/kg)	 10.7 12.3 11.5 7.0 4.5
solids total solids volatile solids ash	 94.6% 27.8% 66.8%
micro-organisms faecal coliforms/g coliphage/g giardia/g cryptosporidium/g	 $2.35x10^3$ 0 0 0

The conclusions from this set of tests were as follows:

- The bulking material used in the construction of the windrow was significantly drier and more coarse than in the Isando tests. In this case the windrow consisted of some 50% coarse grass cuttings from the Hartebeesfontein farm, and 50% domestic refuse.
- The sludge applied had a significantly higher solids load than the Isando sludge, and was primarily pit latrine sludge.
- It was not possible to obtain high temperatures (>55°C) throughout the windrow due to the uneven nature and distribution of bulking material (there were sections of very thick, compact material which could not be adequately aerated or saturated). However certain sections were well aerated and maintained very high temperatures.
- Pre-thickening of the pit latrine sludges was not undertaken, but what was supplied was acceptable and was usable without pre-thickening.
- Temperatures rose to levels of above 50°C, but could not be maintained in all section of the windrow.
- Some evidence of microbiological contamination remained in the compost at the end of the process.
- The sludges from pit latrines results in a significantly higher phosphorous content in the final compost than with sludge from septic tanks.

4.4.2 windrow 2 (Olifantsfontein sewage treatment works filter press sludge):

A relatively homogeneous windrow with grass/garden refuse was placed in layers with thickened sludge from the Olifantsfontein sewage works. Some 12 tons of filter-press sludge were applied. Additional water was required due to the dryness of the sludge.

Exceptionally high temperatures (>70^0C) were measured at points in the windrow over an extended time period. However, other points in the heap remained cool. The improper mixing of the sludge with the grass was the main reason for the variation in temperatures found. The sections with a high content of sludge generated very high temperatures, and those with mainly coarse grass remained cool. Improved mixing of the sludge with the grass or other bulking materials would solve this problem.

4.4.3 windrow 3 (Ollfantsfontein sludge with garden refuse, with passive aeration system)

A third smaller test windrow was constructed using an alternative aeration system which made use of a passive aeration system that does not require an electrical power source. The aeration system consists basically of a network of packed bricks as a base which permitted the flow of air under the entire base of the windrow. The windrow is then built on top of the brick base. A metal frame was placed over the windrow and covered with a plastic membrane. Air outlets were fitted into the top of the frame, through the plastic membrane. Installing windmasters or venturi type devices onto the air outlets facilitated air suction from the top of the heap.

In this case the test was very successful as high temperatures were achieved throughout the heap. The bulking material used was selected grass, and the sludge was well mixed by hand before building the windrow. It should be noted that all lessons learnt from the previous tests regarding the composition and building of the windrows were applied with success on this test. The windrow measured 4m x 2m, and consisted of some 10 m^3 of material.

This compost windrow was aerated for a period of 3 weeks. Temperatures were measured at 6 points in the heap at 2 to 4 day intervals. The results are given in the following figure. It was found that temperatures at all measuring points remained above 50°C for almost the entire period, while certain sections remained above 65°C for 21 days.

Figure 7: HARTEBEESFONTEIN PASSIVE AERATION
2. PASSIVE AERATION TEST WINDROW

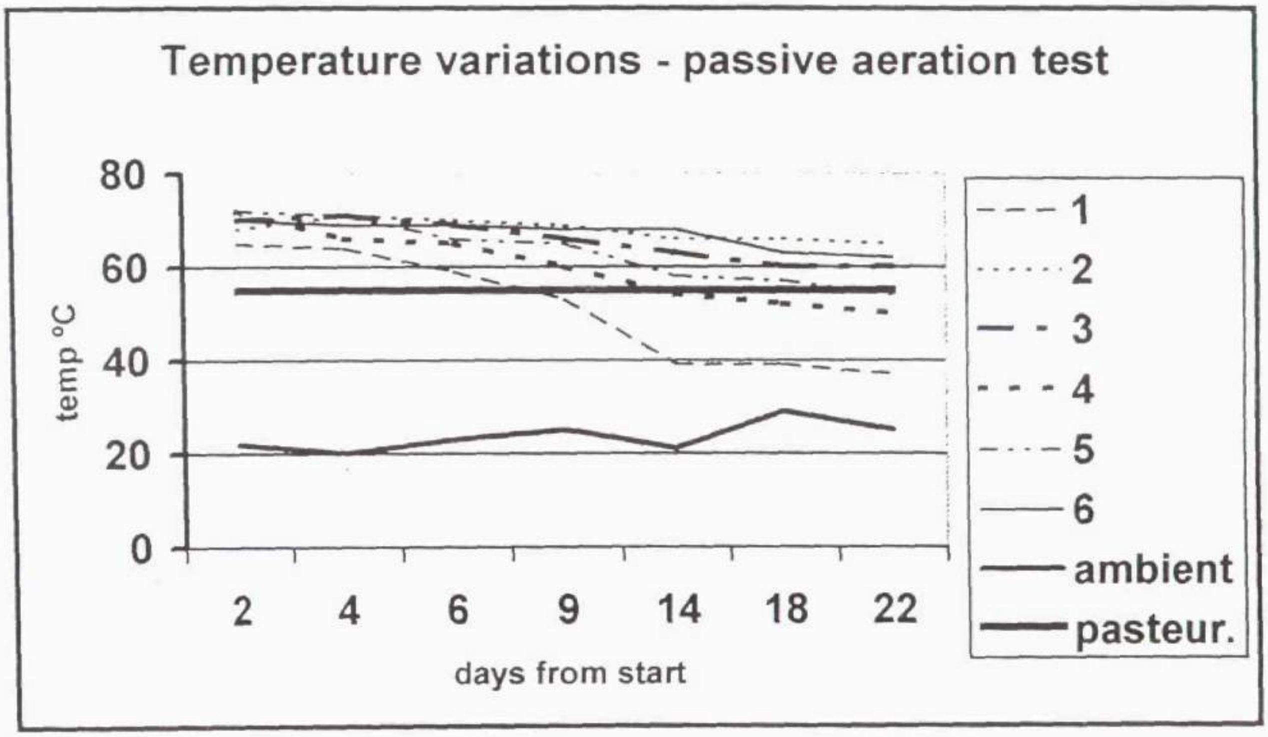


Figure 8: HARTEBEESFONTEIN PASSIVE AERATION
Temperature points and windrow contours (0.5m)

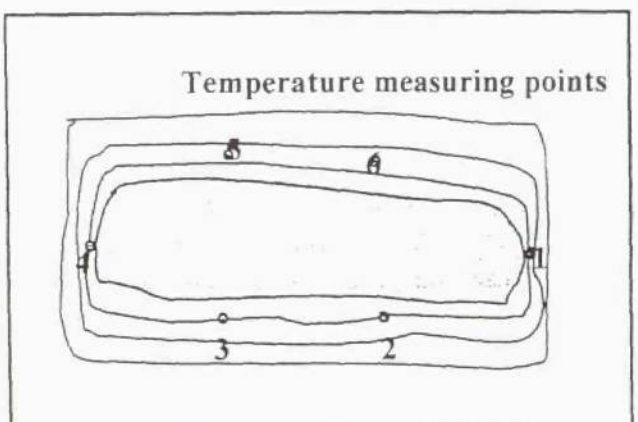
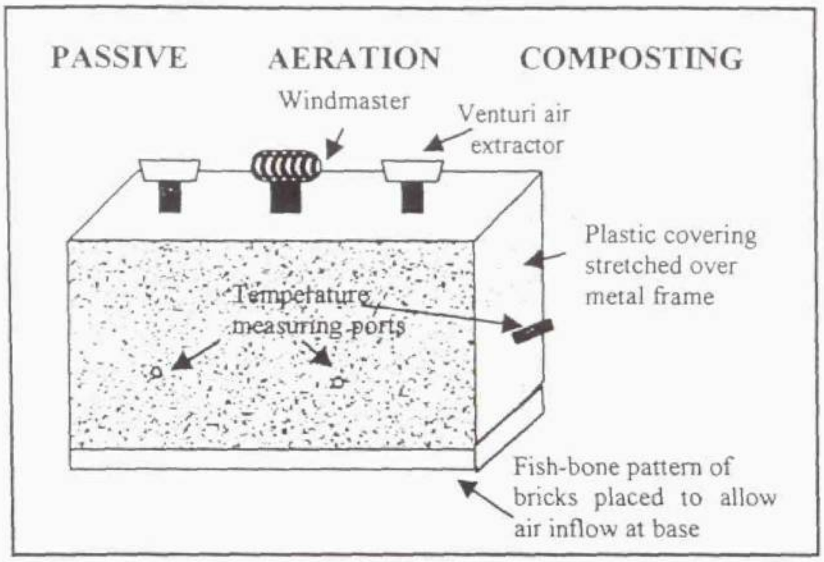


Figure 9: Passive aeration compost system (sketch)



5 ANALYSIS OF RESULTS

5.1 Bulking materials

The conclusions from this set of tests were as follows:

- The bulking material used in the construction of the windrow was selected grass cuttings which were well suited to good air flow and self decomposition, no domestic refuse was used.
- The sludge applied was compacted sewage plant sludge which had a high organic content, providing good energy source for the composting process.
- The bulking material and sludge were mixed by hand prior to the construction of the windrow. This enabled good mixing to be ensured.
- It was possible to obtain high temperatures (>55°C) throughout the windrow due to the even nature and distribution of bulking material. All sections were well aerated and maintained very high temperatures.
- The passive aeration system provided sufficient air to ensure full activity of the compost windrow at all times.
- The plastic cover over the compost provided a good hot and humid environment inside the compost, minimising heat and moisture loss to the atmosphere.
- The small system could manage to compost the contents of up to 5 full pit latrines, or 4 septic tanks, within a period of 3 weeks.

The bulking materials which are most successful are those which are relatively small in size, and which have their own potential to readily form compost under suitable conditions of sufficient moisture and oxygen supply. These include a large portion of domestic refuse (i.e. the organic portion), almost all garden refuse, and other grass cuttings provided these are chopped to a small size (25-50mm) before use. Where less suitable bulking materials only are available, the sludge should be considerably thicker and a heavier unit load placed in the heap.

5.2 Nature and composition of sludge

Pit latrine and septic tank sludges can be readily composted by means of this process. However, the sludge should be thickened before being placed on the windrows. This is all the more important where bulking materials are not directly suitable for making compost on their own.

5.3 Construction of the windrow

The windrow can be constructed in layers, saturating with sludge as each layer of bulking material has been placed. Alternatively the sludge can be mixed with the bulking material on the side, and then the mixture used to construct the windrow in one process. Important factors to consider while constructing the windrow are:

* the air supply system (e.g. slotted pipe) at the base of the windrow should be covered with a layer of coarse material to allow maximum air flow (wood chips were used in these tests);

* the windrow should be constructed loosely without any soil or materials that could block the flow of air (large plastic sheets, etc.);

* bulking materials which provide structural strength to the windrow and hence minimise the gradual compaction of the heap should be included (e.g. thin branches, bottles);

* an insulating layer should be used to cover the windrow when completed (wood chips were used in the Isando and Hartebeesfontein tests, but compost produced previously would also be effective);

- sufficient water must be present both initially and during the whole composting process, and will usually mean that additional moisture must be added at approximately weekly intervals (initially the moisture content should be approximately 65%, reducing to 40-45% at the end of the process).

5.4 Aeration systems

Aeration is essential to achieve the temperatures to ensure pasteurization of the windrow. The simplest method to achieve this is the forced aeration system with a fan/blower controlled by an electronic timer. For areas where electricity is not available, the alternative system in which the windrow is enclosed but with air spaces below the base and some form of passive venting system above the heap did prove to function above expectations. The primary concern regarding the enclosed windrow is its vulnerability to the elements, especially strong winds. However with better design these limitations could be addressed.

Manual or machine-turned windrows could be acceptable in South Africa, particularly if the heap was allowed to mature for an extended period after the initial period (say up to 6 months). This method of aeration was not evaluated in these tests due to the high costs associated with hiring of the machine and payment of labour, but where facilities and/or manpower is available, this method could both successfully aerate the windrow and provide additional employment opportunities.

5.5 Insulation layer

An insulation layer is required to cover the heap to maintain adequate temperatures within the compost. This could be either a layer (±300mm thick) of previous produced compost, or alternatively wood chips as was used during these tests. The windrow that was covered with plastic sheeting does not require an additional insulation layer.

5.6 Composition of the final compost

Sewage sludge or composted sewage sludge can be considered as a low grade fertiliser and an excellent soil conditioner in agriculture. The composition of sludges are extremely variable, but in general contains all the major and minor plant nutrients, except for potassium levels which remain very low. However, in comparison with commonly used inorganic fertilisers, the concentration of plant nutrients in sludge is low, typically by a factor of 10. Associated with this is the high cost of transportation of the sludge.

Hence although the yield of most plants will improve following the application of sewage sludge and/or compost, its economical use will probably be limited to areas close to the source of the sludge and refuse or other bulking materials, and close to where the compost can be applied to fields for agricultural use. Ideally composting facilities should be set up close to the source of materials (sludge and bulking materials), but also close to agricultural lands, particularly for small market gardeners or other small scale producers.

6 CONCLUSIONS AND RECOMMENDATIONS

Composting of pit latrine and septic tank effluents with domestic refuse, particularly garden wastes, is a viable method for the disposal and recovery of useful products from these wastes. Considerable cost savings could be achieved in terms of both disposal costs as well as transport costs for the transport of these wastes to suitable disposal sites. The final product can also serve as a useful agricultural resource, particularly for small producers and for soils with poor water holding capacities. Co-composting serves as both an environmentally friendly disposal method, as well as a safe method of recycling these wastes for useful purposes.

6.1 Suitability of system for use in urban areas

The main concern with respect to the use of this system in urban areas is the generation of odours during construction of the windrow, and the associated attraction of flies. However, if the compost site is more than 500m from residential and commercial areas, the system will be highly suitable for use in these areas. The proximity of the system to both adequate sources of refuse and sludge, and to potential users of the compost as may exist in peri-urban areas, makes this possibly the most sustainable application of the technology.

6.2 Suitability of system for use in rural (remote) areas

In rural area or in more remote dense settlements, the system can be readily applied. However an important consideration is the availability of sufficient sludge to make the system viable, particularly related to the investment required. However, in view of the unfavourable capital and operating costs for alternative sewage and/or sludge treatment systems for small communities, co-composting of sludges could be the most viable sanitation system for communities with a higher sanitation service level (e.g. septic tank systems).

6.3 Economic considerations

The costs for setting up and operating a composting facility will vary depending on a number of factors. Included in these are the following:

COST ITEM	COST RANGE	COMMENTS
<u>Civil Works</u>		
Site Preparation	R100 - R 2,000	to clear site and fence if required
Land cost	R 0 - R 100,000	in many cases there is no cost
Composting area	R200 - R5,000	level and install slotted pipes
Maturing area	R200 - R 1,000	level piece of land
Roads	R0 - R 10,000	high grade road not required
Water Supply	R0 - R 15,000	simple connection to mains
Sludge storage tank	R1,000 - R 3,000	5000ℓ tank recommended
Drainage	R0 - R500	to drain excess water and bypass rainfall runoff

COST ITEM	COST RANGE	COMMENTS
Electrical installation	R0 - R10,000	3-phase ± 5kW recommended
Miscellaneous buildings (office, store room, wash Rooms, toilets)	R0 - R150,000	usually none required
EQUIPMENT		
Electrical control system	R500 - R 10,000	to switch blower on and off auto.
air blower	R1,000 - R3,000	750W to 2,000W
screening assembly	R2,000 - R10,000	cylindrical rotating screen recom.
front-end loader	R500 - R1,500/d	use when build & strip windrow
workshop tools & safety clothing	R200 - R1,000	equipment for pipe connections & maintenance of equipment
air-pipe work	R500 - R2,500	slotted and connector pipes
minimum laboratory equip	R250 - R2,500	thermometer, scale
STAFF & LABOUR		
part time supervisor	R200 - R 1200/month	Supervisor only reqd during building of windrow
1 labourer per 3 m^3 compost handled/d	R800 - R1,500/p/month	a minimum of 2 labourers reqd
OPERATING COSTS		
Electricity	R50 - R 500/month	less if passive aeration system
Water	R0 - R50/month	up to 10kℓ/windrow/month
Transport	R0 - R3,000/month	high if sludge must be transported by tanker
Fuel for front-end loader	R0 - R500/month	approximately 100ℓ /day
Maintenance	R50 - R 1,000/month	say one item/month

Note that to set up the test facilities, it cost approximately R20 000 for materials and equipment. This did not include the cost of the land, nor the cost of buildings, electrical points, roads, water supply, or front-end loaders (although in some cases these were hired).

Operating costs would of the order of R1000/month for part-time supervision, labour, and other costs.

6.4 Promotion and training needs

The co-composting concept is not widely known amongst potential users of the concept, and it will therefore be important to set up adequate promotional programmes and literature to make decision makers aware of its potential for use in communities.

In addition, once sufficient interest has been generated in the concept, a training programme and operation manual should be developed to train planners and operators of the systems. A number of sites in Gauteng are suitable for offering such a programme.

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ANNEXURE A

BRIEF GUIDELINES ON THE DEVELOPMENT OF A CO-COMPOSTING PROGRAMME FOR DEVELOPING COMMUNITIES

1. Typical applications

The following may be typical situations where the application of co-composting methods may be considered:

Type of community	sanitation systems	population	Composting technique
Remote rural	pit latrines	500 - 10 000	Passive aeration small (5 – 15 latrines per month)
Rural town	pit latrines + septic tanks	10 000 - 100 000	Passive aeration or forced aeration windrows (15 – 150 latrines per month)
Peri-urban community	pit latrines + septic tanks or aquaprivies	5 000 - 50 000	Passive aeration or forced aeration windrows (10 – 100 latrines per month)
Town	water - borne + pit latrines + septic tanks	5 000 - 100 000	Passive aeration or forced aeration windrows (5-50 latrines + 1-20T treatment plant sludge per month)
Urban centre	water-borne + septic tanks + aquaprivies	100,000 - 1,000,000	Passive aeration or forced aeration windrows (50-200 tanks + 10-50T treatment plant sludge per month)

2. FACTORS WHICH MAY GOVERN THE DECISION TO OPT FOR COMPOSTING

The decision on whether to adopt co-composting as a method for the disposal/reuse of sewage sludge will be based of a number of factors, including the following:

FACTOR	IMPLICATION
1. Present method of handling sludge	If an investment has already been made which is successfully dealing with sludges, no additional investment may be considered until the current equipment becomes obsolete or inadequate
2. Availability of bulking material	In some areas suitable bulking materials may be unavailable. The concept of obtaining re-usable bulking materials (e.g. wood chips) may then be considered.
3. Availability of sludge collection and transport equipment	Usually a vacuum tanker is required to empty pits and septic tanks or digesters. Large tankers are costly to hire. In some cases small trailor mounted tanks have been successfully developed and applied.

FACTOR	IMPLICATION
4. Environmental concerns with respect to the disposal of sludge	Composting prevents the adverse environmental impacts associated with the disposal of sewage sludge, and has a positive environmental impact by building up soils.
5. Affordability levels of communities may be low	The costs to set up and operate a composting process can be very low compared to other methods, with the operating costs being at least partly covered by the sale of the compost produced.

3. SETTING UP A COMPOSTING FACILITY

Setting up a composting facility is not a major task, but does require the following components:

- land - minimum of 0.5 ha (should be close to services agricultural lands);
- access - a gravel or earth track should be sufficient
- water supply - approximately 1000 ℓ/day per windrow, - a connection to the distribution system, or alternatively a dedicated supply from a stream or borehole (not necessarily purified water)
- cleared, level or slightly sloping windrow sites approximately 20m x 8m each (these may be lined with concrete)
- air equipment (blower, manifold pipelines, slotted pipes, or alternatively floor components and windmasters for passive aeration system)
- Electrical connection and controls (for mechanical blower system)
- monitoring equipment (thermometer, scale, rain gauge)
- bulking material (refuse, agricultural wastes, wood chips, ...)
- (slightly elevated) sludge tank for pre-settling
- sludge distribution piping
- cylindrical rotary sieve
- availability of sludge collection tanker
- availability of manpower for labour and supervision

3.1 Land

A level or preferably slightly sloping piece of land approximately 0.5ha (for up to four windrow systems) should be selected. This land should be reasonably close to the source of the sludge (i.e. homes), but not closer than 500m from the nearest home. It is preferable to have a slope (up to 5m elevation difference) on the land to allow for good drainage of rainwater, and to enable the sludge tank to function by gravity. The land should in addition be fenced off to prevent cattle and children entering the area.

3.2 Access

An access road is required to the site. There will be minimum traffic on the road, but tankers should have easy access when required.

3.3 Water supply

A reliable water supply is required during the building and aeration period of the composting process. This is to ensure the correct moisture content of the windrow. Up to 1000ℓ per day may be required for each windrow during this period.

3.4 Windrow sites

The sites where the windrows are to be built should be cleared and leveled. A slight slope is desirable to allow excess water to drain to a single point. The area required for a standard windrow is 20m x 4m, with sufficient space surrounding it for labourers to work and for a front-end loader to maneuver. In some cases a concrete base is cast for the compost windrow. Separate areas are required for stockpiling bulking material and for maturing compost after aeration.

3.5 Air equipment

A blower, manifold pipelines, and slotted pipes are required for a mechanically aerated system. The blower should be approximately 0.75kW able to deliver 0.2 to 0.6 m^3/second of air. The air connections should be at least 150mm.

Manifold piping can be 150mm PVC, leading from the blower to the slotted pipe at the base of the windrow(s). The slotted piping can also be 150mm PVC with slots cut to approximately half the pipe diameter every 50 to 100mm. Figure 1 depicts a typical arrangement.

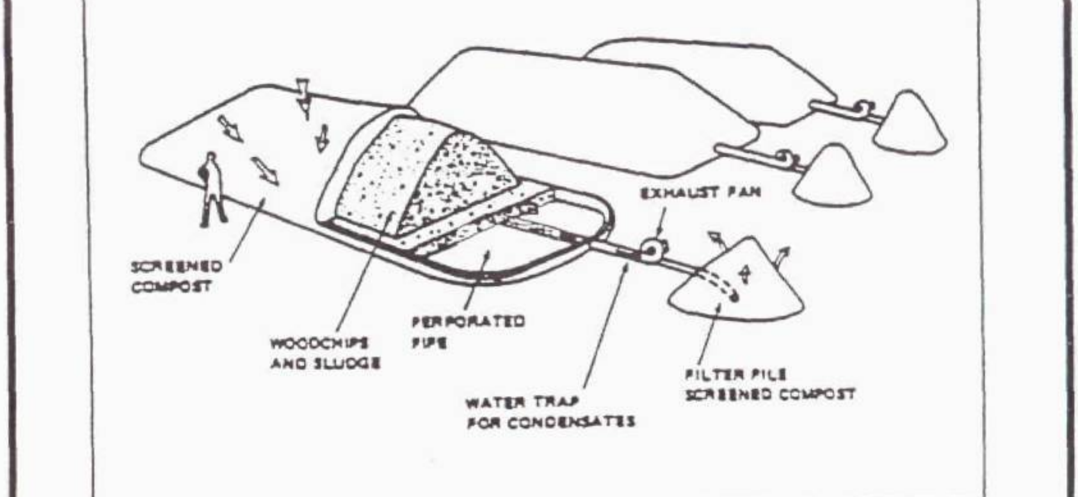


Figure 1: Typical aeration set-up for forced aeration composting

In the case of a passive aeration system, the aeration equipment comprises three main components:

- highly porous floor (e.g. loosely packed bricks)
- windmasters for withdrawing air from the top of the windrow
- plastic covering with frame to enclose windrow and force airflow through the windrow.

3.6 Electrical connection and controls (for mechanical blower system)

A minimum of a 5 kVA 3 phase electrical power point is recommended. In addition a time control switch is required for the blower. The time switch must be capable of on and off periods from 5 to 60 minutes, and 24 hour continuous operation.

3.7 Monitoring equipment (thermometer, scale, rain gauge)

The most important equipment required for monitoring of the composting process is a thermometer (0 - 100°C) with a meter long probe, a rain gauge to measure rainfall on a daily basis during the aeration stage, and a scale (e.g kitchen scale) to measure the moisture content of the compost.

Moisture content is measured by taking a sample of compost (approx 1 kg) and weighing it. The sample is then dried (either by the sun over a few days, or by putting it into an oven). After drying the compost is again weighed. The moisture content is then calculated as:

$$\text{moisture content \%} = \frac{\text{wet weight - dry weight}}{\text{wet weight}} \times 100$$

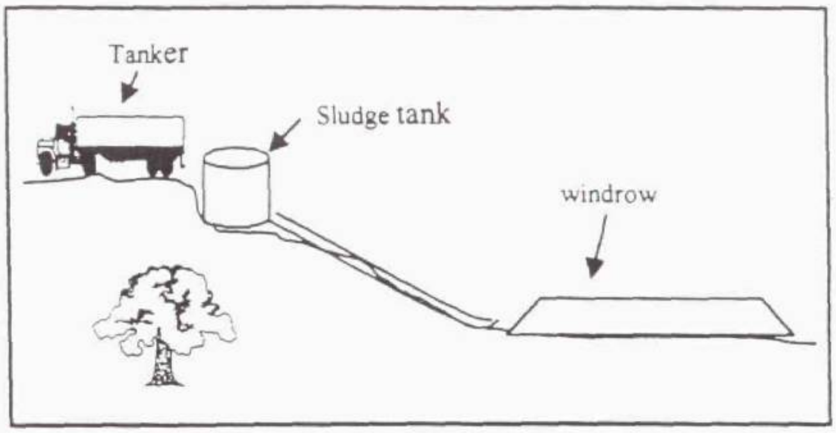
3.8 Bulking material (refuse, agricultural wastes, wood chips, ...)

Bulking material should be absorbent and of not too large a size. Ideal size of bulking materials is 10 to 50mm. This could be a combination of refuse, kitchen and garden wastes, and agricultural wastes. It may be necessary to specifically source bulking materials if these are not readily available. This could be by chopping bush or cutting grass, or collecting wood-chips from a sawmill. Where available bulking materials are too large, these should preferably be chopped smaller, either by hand or with a mechanical shredder.

3.9 Sludge tank for pre-settling of sludge

It is recommended that a tank be erected for the per-settling of sludge before it is placed onto the windrow. The tank will need to be placed at a higher level than the windrow so that the sludge can be piped by gravity to the windrow after settling. The tank itself must have a ramp for the transport tanker to be able to empty into the tank.

The supernatant water from the settled sludge could be retained and used to add to the windrow from time to time to increase the moisture content as required, or it could be disposed of into a drain. If this water is to be placed directly onto agricultural plots, it should receive some prior treatment. Treatment could be in the form of chlorine addition (say 5g per m^3 i.e. 100ml Jik or one spoon HTH), or first passing through a grass or gravel bed).



3.10 Cylindrical rotary sieve

A sieve is required to screen the final product after composting. This is required to be able to remove solid refuse which may still be in the compost, and all materials larger than about 75mm size. The refuse materials can usually either be sold or recycled (glass, metal, plastic, cans) or reused as bulking materials. In some cases there will be no nearby market for these products, and they may need to be buried.

3.11 Availability of sludge collection tanker

The collection and transport of sludge could be one of the major resource requirements for the composting process. Where a local council is already carrying this out, a tanker will be available, either owned by the council or hired under contract. However in many situations tankers are not presently available and are very costly to hire for a small municipality.

Alternatives include the following:

- use of scrap water tanks attached to a trailer, with a small petrol operated vacuum pump;
- purchase of specifically designed vacuum tanker, shared amoungst a number of municipalities;
- Use of a trailer with sides into which the absorbent bulking material is already placed. A small petrol sludge pump could be used to empty the pits or tanks directly into the trailer.

3.12 Availability of manpower for labour and supervision

It is estimated that after training, one supervisor and two labourers, probably on a part-time basis, will be required to operate the composting process.

4. OPERATION

The windrow should be built step wise in layers of approximately 200 to 400mm. A layer of bulking material is first placed and evenly spread. Large items like plastic bags, cloth, metal pieces must be removed, and compact bundles or clods broken up. The layer should then be soaked in sludge before the next layer of bulking material is placed. In some cases the mixing of the bulking material and sludge could be carried out on the side of the windrow, and then the mixed material placed on the windrow. The final height of the windrow should be approximately 2m.

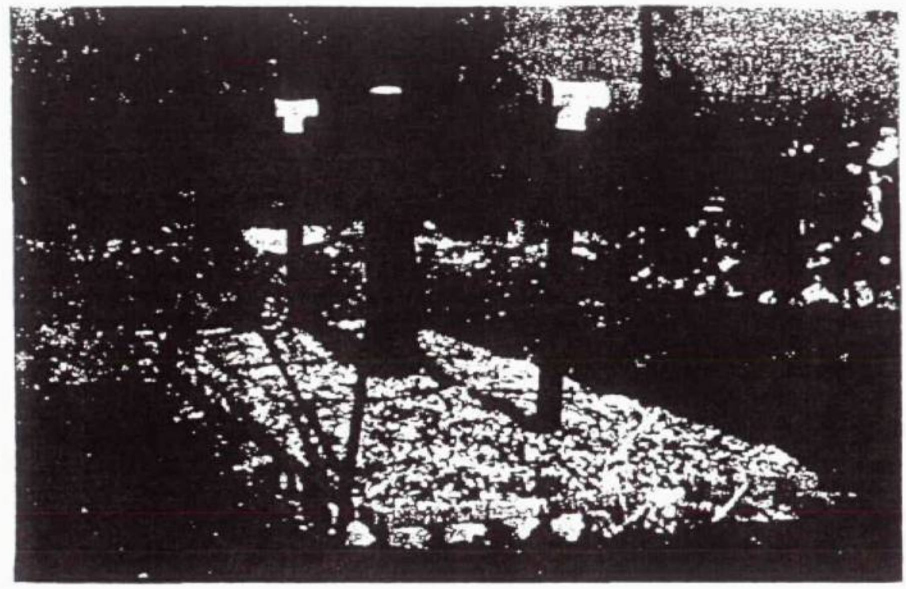
The initial moisture content should be determined, and if necessary additional water added to the windrow. The initial moisture content should be 60 to 70 %.

When the windrow has been completed, a layer of insulating material (wood chips, grass, compost, ...) must be placed to cover the whole windrow. The layer should be approximately 200mm thick. With the passive aeration system, this layer is not necessary, but the plastic covering is then placed over the windrow. All air connections are then made and the aeration system set into operation.

The temperature within the windrow should be measured at various points on a daily basis and recorded. At approximately one weekly intervals, a compost sample should be taken at approximately 1m depth and the moisture content determined. If the moisture content drops below 40%, additional water should be added to the windrow.

After 4 weeks the aeration system can be stopped and the windrow moved to an alternative site to mature. Maturing for at least 3 months is recommended. The compost can be gradually sieved during this process.

Photo 1: Framework for passive aeration system. Note the "fishbone" layout of the bottom layer of bricks, the woodchips on top of the bricks, and the air vent systems. The air inlets of the air vents are just below the top of the frame, and not at the base as it may appear.



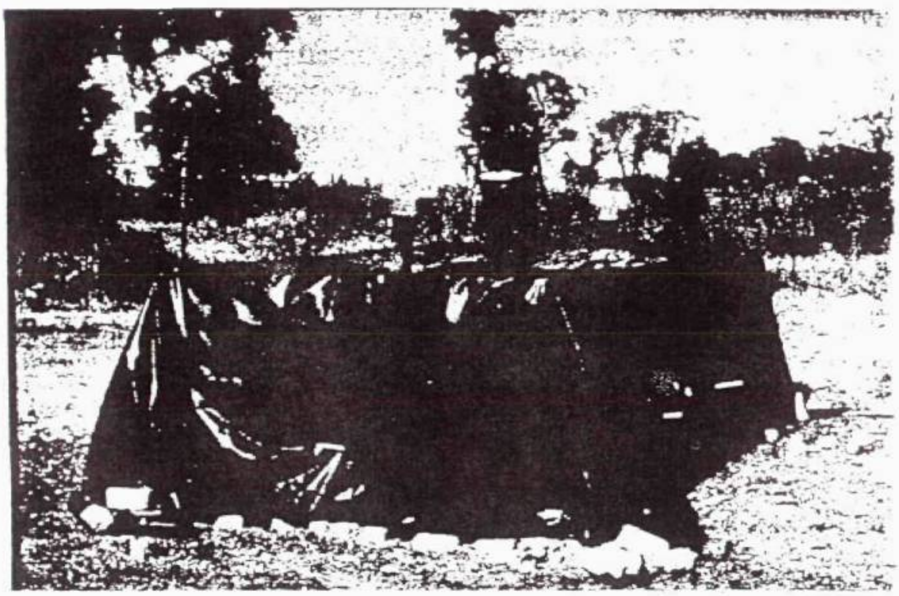


Photo 2: **Passive aeration compost system under operation**. Note the air temperature measuring points as white conduit piping on the sides.