Application of the Dome Aeration Method in South Africa

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Abstract

The Dome Aeration Method, developed at the Technical University Dresden, is an accelerated composting method for the pre-treatment of domestic solid waste before landfilling. It is particularly suitable for developing countries because it is based on low-technology. This paper explores the suitability of this method for application in rural South Africa.

Keywords

Waste disposal, landfill, pre-treatment, composting, dome aeration, domestic solid waste

1 Introduction

South Africa is a unique country in many ways. On the one hand we have a first world community driving a vibrant economy with excellent opportunities for entrepreneurs; on the other hand we have a third world community largely unaffected by the world economy.

The first-world community enjoys excellent infrastructure comparable to that of first-world countries; the third world community lives to large extent as they did for many centuries.

Figure 1 Landfill in

In the first-world part of the community waste disposal is regulated by the Government's Minimum Requirements for Waste Disposal, of which the fourth version was published in 2005. In the country's economic heart, the province of Gauteng, and in the other major metropolitan areas such as Durban and Cape Town, municipal solid waste is disposed of in state-of-the art landfills which are properly designed and managed. These landfills probably handle a major proportion of the Municipal Solid Waste (MSW) generated in South Africa, but they nevertheless number only about 600 out of the estimated total of 15 000 refuse dumps scattered all over the country.

Figure 2 Rural waste disposal in South Africa

Where these two worlds meet a variety of problems are created.

Third world communities used to generate waste of natural origin which could easily be assimilated by nature; this waste was disposed of by simply throwing it away, which is an appropriate disposal method because this waste would be assimilated by nature within a matter of days.

On the other hand, first world communities use, and dispose of, high-technology products and materials which can not be assimilated by nature; in fact, these materials are often toxic. Such materials require advanced disposal technologies to avoid environmental deterioration. When the products of first world technology become available to third world communities a problem is created: because these products can not be assimilated by nature, they have to be disposed of in a way foreign to these people. However, old habits are not easy to change, so people from a third world background who now have access to first world products continue to discard these products in the time-honoured way of just throwing it away. The result is an environment littered by plastics, metal cans and other products of modern technology which take decades or more rather than days to decay.

This method of disposal does not only create an unpleasant environment, but also an unhealthy one because dissolved toxins get washed into rivers where they enter the food chain. A few individuals in these communities have become aware of the undesirability of maintaining these waste disposal practices. However, on their own, they are unable to change the situation. Some people have realised that a lot of valuables are disposed of together with the waste and have set up waste separation systems to retrieve some of these valuables. However, the country lacks the proper infrastructure and bureaucratic drive to implement proper waste disposal practices, including recycling. More innovative methods must therefore be sought to handle these problems.

While the littering problem probably requires a public awareness and education drive on a non-technological level, supported by proper legislation, this paper describes an effort to use a simple first-world technology in an effort to reduce the negative impact of waste dumps on the environment in a third-world community.

2 The Dome Aeration Method briefly Described

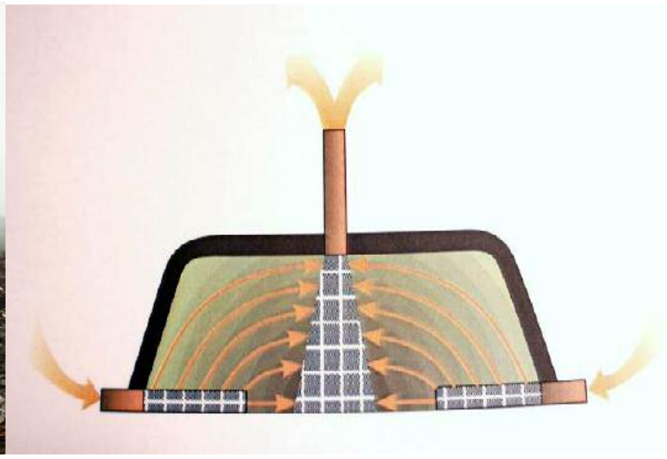

Figure 3 Ventilation of windrow **Figure 4** Building a windrow at Cottbus

At the Cottbus landfill all of the approximately 50 000 tons of waste reaching the landfill was carefully mixed to get a desireable proportion of roughage (to ensure proper internal ventilation). This waste is mechanically shredded, its water content is adjusted to 60% by adding water to the shredded material, and it is then used to build windrows as shown in figure 3. The windrow is ventilated using a passive ventilation system as shown in figure 4 (extracted from Paar)

About 3 to 4 months later the windrow material is landfilled after some of it had been removed and sieved to be used as cover material for both the landfill and for new windrows.

3 Applying the Dome Aeration Method at Hatherley Landfill, Pretoria

Figure 5 Collecting roughage and waste

As mentioned in the introduction, a method was sought which would solve the incredible waste disposal problems in rural South Africa and at the same time be sustainable by being financially attractive. It was therefore imperative that the windrow should be built using only equipment which would be available on a landfill, and not the specially built equipment used at, for example, Cottbus. Even so, it should be kept in mind that many rural communities would not even have the means to purchase the most basic of landfill machinery, so would have to build such windrows using manual labour and hand tools.

There was also the concern of whether the system would actually work in the warm and dry South African climate, since it is driven by a temperature gradient only and the South African climate differs substantially from the Cottbus climate.

Figure 6 Building the intermediate windrow

One of the requirements to make the system work is to mix the domestic solid waste (DSW) with the right amount of roughage to avoid the windrow becoming so dense that air could not pass through it. For that reason the waste coming in to the landfill was separated into garden waste (to provide the required roughage) and domestic solid waste. A ration of approximately 1 part of roughage to 2 parts of DSW by volume was maintained. These two types of material were then loaded onto a tipper truck which tipped it into a long intermediate windrow, as shown in figure 6.

Figure 7 Watering the crushed waste

This process was continued until the intermediate windrow was about 30 m long and 4 m high, with a base width of about 8 m.

This windrow was the flattened and the roughage crushed by repeatedly driving a compacter over it. Figure 7 shows the flattned and crushed intermediate windrow beinf watered from a water cart, and figure 8 shows the crushed and watered waste being inspected.

Figure 8 Inspecting the crushed and watered waste

This waste was then once again being loaded onto the tipper truck and transported to the adjacent site where the real windrow was being built. In this case the waste was dumped in position by the tipper, with a normal excavator being used to postion it correctly in relation to the aeration channels and ventilation domes.

Figure 9 Starting the windrow **Figure 10** Inserting TDR probe

As the windrow progressed, some Time Domain Refectometry (TDR) probes were inserted into the waste so that the moisture content in the windrow could be read during the composting stage. As we have determined before that these probes gave notoroiusly inaccurate readings when inserted directly into the waste we inserted each probe into a pocket of soil to ensure good contact and reliable information on the moisture content. The probe and its pocket of soil is shown in figure 10. Naturally, the mositure exchange between the waste and the soil pocket does not stabilise when the two media reached the same moisture content, but rather when the pore suction in the two media became the same. It was therefore also necessary to do pressure plate tests on both waste and soil and to read the moisture content of the waste from these curves. This process is described on our web page at www.landfill.co.za.

Figure 11 Completed windrow

When the windrow was finished, it was covered by a 200 mm layer of the soil used as daily cover on the landfill. At Cottbus the purpose of the cover was probably to protect the composting waste against excessive heat loss to the cold environment; at Hatherley its purpose was probably more towards protecting the waste from excessive water loss through evaporation into the warm and dry Pretoria climate. The windrow was constructed during winter when the daily temperature was varied between about 7° C at night up to around 17° C by day. It was broken up in mid-summer when the temperature varied between around 16° C and 28° C. Figure 11, which shows the completed windrow, also shows some leachate flowing from the windrow as well as some steam coming from the chimneys.

Figure 12 Hammering pipes into windrow

To enable us to measure temperatures and gas composition inside the windrow a number of 20 mm pipes, piched closed at the bottom end with a few holes drilled into them, were hammered into the windrow (figure 12). Some of these pipes were 1,0 m long, others 2,0 m long, so that conditions could be measured at various depths inside the windrow.

Finally, after some 4 months, the windrow was broken up (figure 13) and some of the waste was transferred to a 4,5 m deep lysimeter in the laboratory (figure 14) for further analysis.

Figure 13 Breaking up the windrow

On breaking up the windrow the material had no odour, and looked remarkably similar to commercially available compost, except that it contained very high proportions of plastics, glass and metal containers.

Figure 14 The lysimeter

In the laboratory the waste was put in the lysimeter to a depth of about 4,0 m and covered with some cover material. Finally a micro-irrigation system was installed so that the behaviour of the waste could be studied as if it were in a landfill. The irrigation system was used to simulate regular rainfall, and the leachate which flowed through the waste was collected and analysed.

4 Analysis of the Windrow

One has to somehow determine the rate of the aerobic reaction within the windrow as an indicator of when the conversion of organic material has completed. Paar (2000) used, amongst others, the oxygen content in the chimney gas. In her windrow the oxygen content exceeded 10% after 7 days and 15% after 21 days. The Pretoria data is shown in figure 15, and is scattered almost as much as the data presented by Paar. A distinguishing difference between the two sets of data is the high initial oxygen content in the Pretoria windrow, for which several possible explanations may be offered. However, if the data is smoothed by drawing an empirical trend line to eliminate variations due to a variety of factors, it would seem that the oxygen content in the Pretoria windrow's chimneys exceeded 15% after around 15 to 20 days, and was never as low as the 10% reported by Paar.

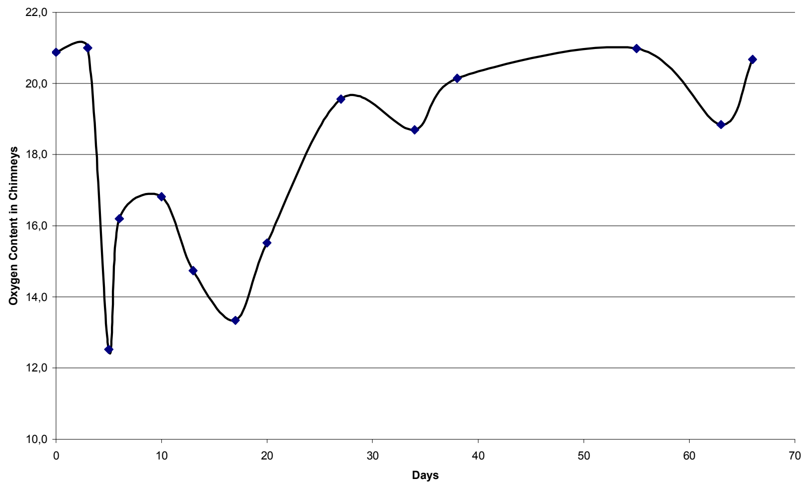

Figure 15 Oxygen Content in Chimney Gas

It was probably as a result of non-availability of equipment that Paar did not measure the moisture content in the windrow. However, such equipment was avaliable for the Pretoria experiment, and several TDR probes were inserted into the windrow when it was constructed. Figure 16 shows the trend of moisture content changes with time typical of these measurements. The moisture content scale does not reflect absolute values because the TDR gives volume/volume results (in contrast to the mas/mass normally used), and a correction still has to be made for the difference in pore suction between the waste and the soil pocket into which the TDR probe was installed. However, it shows that, not unexpectedly, the moisture content decreased until it stabilised after about 40 days.

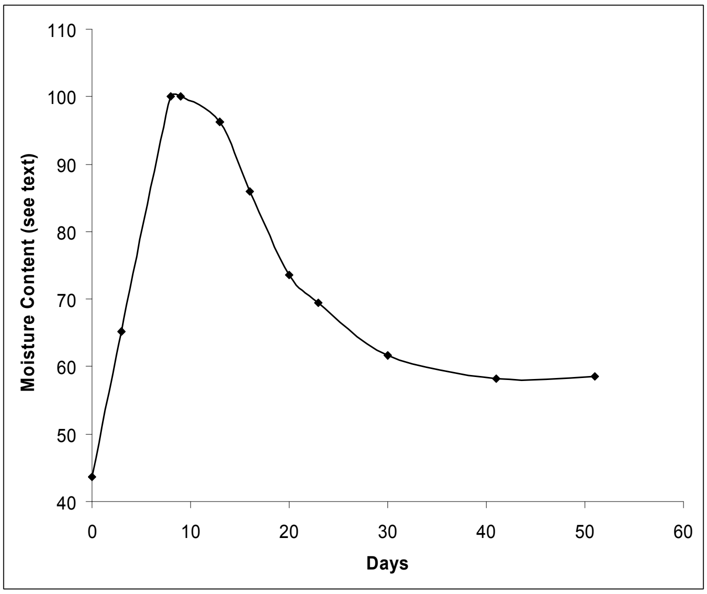

Figure 16 Moisture Content of Windrow

Whichever of these parameters are used, one can conclude that the composting process would be virtually complete after about 40 - 50 days. This statement is also supported by the emission of visible steam from the chimneys: it started within 24 days after covering the windrow, reached a peak after about 10 to 15 days, then decreased steadily over the following 6 weeks.

5 Analysis of the "Compost"

When the windrow was broken up after about 4 months its contents was relatively dry, practically odour-free, and resembled compost except for the presence of plastics, metal, glass and otrher foreign objects.

A full chemical analysis of the contents of the windrow was carried out, the objective being to determine its suitability for use as compost. Naturally, this would involve removal of all the unwanted material (glass, plastics, metal and large objects) before it could be sold. The results of this analysis were evaluated by a consultant who specializes in plant nutrition. South African legislation requires that material sold as compost should have a moisture content of less than 40% and an ash content of less than 40%. The windrow-material contained very little organic material with 93,7% classified as "ash". However, it was sundried before analysis, which brought its moisture content down to around 1%. In the process its chemical composition was probably also altered. Taking this into consideration the consultant's conclusion was that that the material was probably comparable to commercially available compost, and may therefore have some commercial value. However, the preparation of the material would require physical removal of unwanted ingredients first, which should not really be a problem in an environment where unskilled labour is abundant and unemployment rampant.

6 Analysis of the Leachate

Some of the material from the windrow had been transferred to a large lysimeter where it was kep under simulated landfill conditions. After 18 months some of the leachate from the lysimeter was analysed. Table 1 compares the results of this analysis with similar results given by Qasim and Chiang (1994) for leachates from landfills of various ages.

In this table, the column "Hatherley" refers to a leachate sample extracted from a 1000 litre sump on the floor of the Hatherley landfill. This landfill was approximately 15 years old when the sample was extracted, and most of this leachate probably comes from the lower layers of waste, being forced out of the waste by the surcharge of waste added at a later stage, about 5 years before the sample was taken.

Table 1 Comparison of Leachate Characteristics

	Qasim and Chiang			Hatherley	Lysimeter (18 months)
	1 year	5 years	16 years		
BOD (mg/l)	7500 - 28000	4000	80		280
COD (mg/l)	10000 - 40000	8000	400	592	1766
TDS (mg/l)	10000 - 14000	6794	1200	4150	3760
pH	5,2 - 6,4	6,3		6,7	7,3

The column "Lysimeter (18 months)" refers to leachate collected from the lysimeter after the pre-treated waste had been in it for about 18 months.

The hatherley data is comparable to the information given by Qasim and Chiang, and is remarkably similar to the lysimeter data with the exception of the COD. It can therefore be concluded that pre-treatment of the waste accelerated decomposition so that characteristics similar to that of waste of about 12 - 15 years in an anaerobic landfill could be obtained within about 18 months.

Analyses also contained information on iron, magnesium and other ingredients, but this information is probably very dependent on the waste composition and therefore not really relevant in this context.

7 Conclusion

The objective of introducing this method of waste disposal into rural areas is to decrease environmental pollution by landfill leachate (without having to resort to unaffordable synthetic liners and treatment plants) and to ensure sustainability by a financial incentive, in this case the sale of compost as a by-product.

It would seem that the product of this type of pre-treatment would be considerably more enviromentally compatible than normal fresh waste, and that reduction of environmental pollution could therefore be achievable.

As far as the financial aspects are concerned the picture is not as positive. In most rural areas the market for compost is be limited unless it can be stimulated by the simultaneous introduction of sound agricultural practices, which is at present non-existent, the main objective being subsistence and not necessarily as a commercial enterprise.

At the same time one should ideally have a system of waste separation before pre-treatment so that, on the one hand, valuables such as glass, paper and metals can be salvaged and, at the same time, to ensure a better quality of compost.

Once these hurdles have been overcome the system may be viable, being simple and easy to operate and not requiring, for example electricity.

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