The Development of Low Cost Landfilling Techniques for Emerging Countries

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Abstract

The paper reports on the progress to date of a project commissioned by the UK Department for International Development, with the aim of demonstrating and evaluating through field trials improved low-cost landfilling techniques suitable for application in developing countries. The field-scale landfills are located in Thailand and South Africa, to enable the assessment of tropical and temperate climates on the landfilling techniques used.

The design of each pilot landfill and the techniques demonstrated for landfilling, using simple, readily available plant, are discussed. Data gained from the operational period, including machine performance and initial densities achieved, are presented and compared with conventional landfilling. Lessons learned from the work to date for landfill disposal in emerging countries are discussed.

Keywords - low cost landfilling; pilot-scale landfills; landfilling techniques; Thailand; South Africa; emerging countries

1. INTRODUCTION

1.1 The current situation in emerging countries

Disposal of solid wastes to land in emerging countries is typically by dumping: whether in designated dumpsite areas or simply onto any convenient unused piece of land. Disposal is rarely accompanied by any form of waste spreading, compaction, or covering with inert soils (by hand or with machinery), and generally lacks any form of supervision of operations, monitoring, or control over the types of deposited wastes. In many instances as-deposited wastes are sorted through by waste pickers/scavengers, themselves not controlled by site staff or other municipality officials.

Partly through uncontrolled scavenging activities, and partly through spontaneous combustion of organic matter in waste piles, such sites are frequently easily recognisable through on-site fires and/or smoke plumes.

This depressing state of affairs inevitably results in adverse impacts on the local air and water environments and on the health of anyone on or around the dumpsites. There are institutional and financial barriers to improving disposal practices. However, the levels of institutional development and financial support needed, to ensure the simplest of improvements, are minimal. Low-cost managerial and technical interventions could make substantial impacts.

1.2 The DFID Project

The UK Department for International Development (DFID), as part of its aim to eliminate poverty, supports an active Knowledge Generation and Research (KAR) programme. Engineering KAR currently covers a number of sectors, of which water and sanitation is a major theme.

Under the theme "Combating Degradation of Water Resources", DFID recognises that in many parts of the developing world, water resources are under threat from pollution derived from, among other sources, waste, which if not managed sensibly, can lead to significant and persistent degradation to the environment and the water resource.

As part of this theme's programme DFID commissioned a research project under the title: *Development of low -cost landfilling techniques for developing countries.* The research project is being implemented by AEA Technology plc in association with Binnie Black & Veatch. It

commenced at the beginning of 1999 and is scheduled for completion in the spring of 2002. A number of countries were identified for implementation of the project, based primarily on their climatic regime and the availability of local partners. Pilot facilities are being constructed, operated and monitored in Thailand and South Africa, to provide representative landfilling conditions in tropical and temperate climates respectively.

This paper describes the development of the project in each country, its implementation to date, and the initial findings from the extensive data recorded during the operational phase in Thailand. A follow-up paper, to be presented to the Eighth International Waste Management and Landfill Symposium (Sardinia 2001), will report on the implementation of the project in South Africa and draw comparisons between the two sub-projects.

2. DESIGN OF THE PILOT-SCALE LANDFILLING PROGRAMME

2.1 Key parameters to be researched

Following a detailed literature review of appropriate low-cost landfilling for developing countries (Campbell, 1999), two potential technical approaches for investigation were formulated:

(1) To investigate the most basic low-cost landfill improvements of direct relevance to the smallest and/or poorest communities. This might involve:
   a) the construction of simple trenches, placing and tamping down waste, covering with soil; and
   b) the use of a small, designated area onto which wastes are placed in thin layers and covered with soil.

(2) To demonstrate techniques applicable to larger sites serving urban communities with inputs of perhaps>100 tonnes day^{-1}. This approach would be inherently more sophisticated but would still demonstrate managed landfill disposal in defined areas as in a) or b). Greater attention would need to be given, in addition, to:
   c) site selection and environmental assessment with respect to groundwater protection;
   d) engineering and drainage of landfill base; and
   e) provision of natural or synthetic liners.

Given the level of environmental protection that would need to be demonstrated in any application for (statutory) approval to implement the project in either of the selected countries, it was clear that the project would need to follow the second approach.

The construction and filling of pilot-scale landfills in the two countries, using limited resources, would enable comparative assessments to be made, *inter alia,* of:

- the ability to achieve an acceptable level of control of a small landfill site
- the sustainable level of activity (tonnes per day of waste input) using the resources available
- the ease (or otherwise) of operation of a multi-lift landfill
- the operational performance of the mechanical plant used
- the initial density achieved and the settlement characteristics of the completed landfill.
- the qualitative and quantitative biological behaviour of the landfill
- the impact of the pilot-scale landfill on the local environment.

2.2 Approach to the siting and design of the pilot-scale landfills

The expectation of problems in securing the necessary permissions to develop even a pilot-scale landfill on a green-field site anywhere in the host countries in a short space of time, focussed the search for adequate space within currently operating or at least an already permitted landfill sites.

Programme and budget limitations dictated that the capacity of each of the pilot-scale landfills should be limited to ensure that it may be constructed and filled within a period of six months. In order to ensure that:

1. anaerobic conditions characteristic of landfills could be established and maintained; and
2. the operational difficulties of travelling over previously landfilled wastes could be assessed,

the design depth of the pilot-scale landfill needed to be at least 5 metres. With a daily input of the order of 100 tonnes per day, the indicative site area required, allowing for some vehicle circulation, was about one hectare.

Other principal factors in the siting and design of each pilot-scale landfill included the need to have:

- hydrogeological independence from any potential impact from other deposited wastes for at least two years (for groundwater monitoring)
- a sufficient supply of municipal solid waste and cover materials
- access to (on- or off-site) a weighbridge facility
- the active support of the host municipality/site operator.

The sites that were finally selected for the project were the Saensuk Landfill in Chonburi, Thailand and Rooikraal Landfill in Greater Germiston, Johannesburg, South Africa.

3. IMPLEMENTATION OF THE RESEARCH PROGRAMME

3.1 Saensuk Landfill, Thailand

The pilot-scale landfill is located within the first phase area of a newly opened landfill that was fully lined with a composite HDPE/clay liner. The pilot landfill occupies the upper end of the catchment of one of the (four) existing leachate collection drains (Figure 1). The Phase 1 area of the Saensuk landfill has a finished base level approximately 2.5m below surrounding ground level.

Material excavated from the Phase 1 area, described as a loose-structured, predominantly medium sand (Paul Consultants, 1993), had been stockpiled locally for use as cover material and was available for use as daily and final cover. The site operates an electronic weighbridge that was used to record each input to the pilot-scale landfill (waste and inert material).

The pilot-scale landfill was filled over a 22-week period, six days per week, in the first half of 2000. The landfill was constructed in two “lifts” of about 2m thickness of waste: the first bringing the site up to the original, and surrounding ground level. Refuse collection vehicles (RCVs) were directed to bring wastes for Lift 1 across the protected base of the Phase 1 area to the working area of the project site (Figure 1). Once discharged, waste was spread and compacted by a hired-in wheeled backhoe loader. The machine chosen was a JCB 3CX with a standard shovel, supplied and maintained by a local plant hire company.

Wastes in Lift 1 were compacted from the base of the site upwards, using standard onion skinning techniques. In view of the width of the pilot-scale landfill (46 metres east to west) and the low rate of input, it was decided to construct Lift 1 working northwards in two east-west strips). Daily cover was provided only to the finished areas of Lift 1: the working slope being left open at the end of each day (and over the one-day weekend).

In order to comply with the overall layout design of the Saensuk Landfill, the area for Lift 2 was prepared by constructing a perimeter bund on the east and south sides, to form the outer corner of the Phase 1 area. Filling of Lift 2 was achieved, again in two strips, by directing RCVs up the soil access ramp and discharging close to the edge of the advancing working area. The development of the working face in Lift 2 is illustrated in Figure 2.

Lift 2 was formed to design slopes, including a graded top surface, using a locally fabricated adjustable profile and spirit level, and provided with daily cover. The whole of the pilot-scale landfill was then provided with an additional 40cm of compacted cover material to create a 60cm thick final cover. Placement of this additional material was controlled by the use of sight rails and boning rods. The completed site was then instrumented for gas monitoring by installing three drive-in type piezometers (Figure 3).

The site was subsequently grassed over its western half to monitor its effectiveness to limit scouring of the surface by heavy rains. Construction of an intermediate leachate monitoring access chamber over the leachate collection drain at the toe of (Lift 1) wastes, to measure flows and take samples, had to be delayed until early October. This was because the main site became flooded (up to the toe of the pilot-scale landfill) as a result of a protracted failure of the leachate pumping station (Figure 1) that drained the leachate collection system installed in the Phase 1 area.

The filling programme was supervised and extensively monitored. Detailed daily records were kept of:

- inputs (waste, cover material, fuel and consumables)
- activity of the wheeled backhoe loader (every 15 minutes)
- performance of the wheeled backhoe loader (qualitative and quantitative)
- site performance (qualitative)

Daily rainfall has been recorded from the commencement of filling, but landfill gas and leachate monitoring was delayed until September and October respectively, for lack of installed facilities for measurement.

3.2 South Africa

The planned pilot-scale landfill will occupy a corner of the yet-to-be-started second phase of an operating landfill. A small cell will be constructed, excavating the base and constructing the liner system to the same design as recently permitted for this part of the site. The site has been designated by the Regulator, the Department of Water Affairs and Forestry, as Class B-. This means that the site is expected to produce only sporadic leachate and, provided the Minimum Requirements for the siting, design and operation (Department of Water Affairs and Forestry, 1998) are met and only dry waste is disposed of, no leachate management system should be necessary.

Notwithstanding the designation, Phase 2 of the site is to be provided with a clay liner and blanket leachate collection system. The pilot-scale landfill will therefore be provided with the same standard of leachate management system.

The pilot-scale landfill area will be filled to a similar overall depth as that in the Saensuk landfill (i.e. two lifts of municipal solid waste), using a different model wheeled backhoe loader to that used in Thailand. Different landfilling techniques will be investigated for comparison. Comprehensive daily records will again be made, and the completed cell monitored for a period of two years following completion.

The contractor operating the Rooikraal site has encouraged local entrepreneurs (referred to as "Previously Disadvantaged Individuals") to undertake, under sub-contract, peripheral activities at the site, including recycling, composting, tyre cutting and operating a public off-loading area at the site entrance for small loads. Their impact on the operation of the landfill site will be reviewed as part of a general assessment of the waste stream.

4 PRELIMINARY FINDINGS

The research programme has yielded some interesting preliminary results from the work in Thailand. Despite having full-time supervision of the filling operation, the project suffered a number of operational difficulties that are commonly experienced in less well-managed landfills in emerging countries.

The total input of wastes to the project site during its construction was 2 906 tonnes (2 254t in Lift 1 and 652t in Lift 2).

The overall daily capacity of the wheeled backhoe loader was found to be much lower than anticipated: only 33 tonnes per day for Lift 1 and 17 tonnes per day for the much smaller Lift 2. This reflected, in part, the low availability of the machine for landfilling activities (52% of total site operating time). Half of the non-landfilling time was downtime: predominantly waiting for service from the off-site plant hire workshop. The majority of downtime was the result of punctures. Initially the rate of punctures was one for every 56 tonnes of waste landfilled. During the second lift, a liquid puncture sealant was injected into each tyre, resulting in an improvement in the rate to one in 98 tonnes of waste.

The overall cover-to-waste ratios for each lift were high: 0.50 (tonnes per tonne of waste) for Lift 1, and 1.39 for Lift 2. The very high figure for Lift 2 reflected the very small working area and the need to use extra soil to fill wet spots and to correct a poor start to the lift.

An unexpected finding was the very high in situ densities achieved: 0.95 tonnes of waste per cubic metre of landfill for Lift 1, and 0.82 t/m^3 for the two lifts. These densities are significantly higher than expected and indeed are on a par with densities that are generally accepted as achievable in developed countries using landfill compactors. This can only be ascribed to the wet, organic nature of the waste and the need rigorously to compact the wastes in order to withstand the higher pressures exerted by the wheels of the backhoe loader. The protracted compaction activity needed also contributed to the low productivity rate.

As indicated earlier, leachate data could not be obtained until late-October. Early indications from gas composition monitoring are that the waste, in Lift 1 at least, is decomposing anaerobically. Monitoring of leachate, gas composition and settlement will continue for a period of two years.

The findings in Thailand will be compared with those from the project in South Africa and broad conclusions will be made available through future conferences and via the Internet.

5 ACKNOWLEDGEMENTS

The authors wish to thank the Department for International Development for permission to publish this paper and to Saensuk Municipality, Thailand and Greater Germiston Council, South Africa for their co-operation and support in implementing the project at their respective landfills.

The views and opinions expressed in this paper are those of the authors and do not reflect the policies of DFID or either of the consultancy organisations.

6 REFERENCES

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FIGURE CAPTIONS

Figure 1 **Location of pilot-scale landfill within Phase 1 area**

Figure 2 **Development of the working face for Lift 2**

Figure 3 **Extent of filling on completion of the work**