# REMEDIATION OF DISUSED LANDFILL SITES THROUGH EXCAVATION/ REDEPOSITION AND TREATMENT

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SUMMARY: Landfill mining, including the excavation, transfer or processing of buried material, is today an internationally recognised technology for use in site remediation as well as in the reclamation of landfill capacity. Projects in Germany, Austria, Canada, the USA, Korea and the Czech Republic have attracted much international attention and have demonstrated the feasibility of the processes employed while also allowing realistic conclusions to be drawn with regard to engineering aspects and costs. A critical element in site reclamation is the transformation of anaerobic to aerobic conditions in the landfilled waste in order to minimise its environmental impact as well as hazards to operatives employed in site reclamation. As processing of the reclaimed material in several stages results in the recovery of landfill capacity, landfill mining finally generates even economic benefits.

## 1. INTRODUCTION

It is generally known that the biological reactions occurring inside waste disposal sites produce gases which, mainly because of their odour, are offensive to the ambient environment. It is equally well known that opening of old disposal sites allows such gases to escape, causing an enormous odour problem. For this reason, working at the opened site and acceptance of such measures by nearby residents become very difficult or close to impossible. The quantity of odour produced depends mainly on the material disposed and its moisture content, not so much on the age of the material. The biological anaerobic decomposition process in the disposal site leading to odour formation starts soon after tipping of the material. Such decomposition processes continue for decades and can be prevented or reduced only by lack of moisture or the absence of organic material. Minimisation of odour emissions is thus the primary task in the remediation or restoration of waste disposal sites. Experience gained in other projects shows that odour-containing measures are necessary even in waste disposal sites with a high content of demolition waste, low filling height, and relatively dry contents. It is therefore obvious that odour minimisation measures resulting in a reduction of odour emissions must be taken prior to opening of an old waste disposal site, particularly when a site holds residential and commercial waste with a relatively high portion of biogenic material.

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## 2. THE BASIC PRINCIPLE

From the relevant literature, our own testing experience and odour stabilisation methods implemented within the framework of other projects we know that odour is minimised very quickly or its substance changed when the biological conditions in the waste disposal site are changed. The anaerobic bacteria that cause the odour emissions cannot exist in the presence of oxygen, which therefore reduces or puts a stop to the production of odour and leads to the development of an aerobic decomposition process. The basic principle of odour stabilisation therefore aims at changing the biological conditions within that section of the waste disposal site the is to be opened. The activity of anaerobic bacteria is stopped by oxygen or air that is forced into the waste disposal site. At the same time the air-gas mix is drawn off and deodorised. In addition, the development of an aerobic atmosphere is supported by feeding in aerobic bacteria together with the fresh air. Aeration with heated air that is saturated with aerobic bacteria therefore leads to a rapid development of aerobic conditions while preventing at the same time the propagation of anaerobic bacteria.

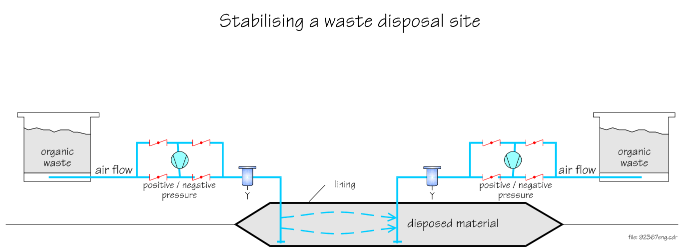


Figure 1. The basic principle

A major problem in odour stabilisation is water retention. A 12 to 15 year old waste disposal site lined with impermeable material is very moist inside. This moisture is entrained when the gas-air mixture is sucked off. It then condenses in the pipes and causes problems inside the compressors and blocks air ducts. With the new process, water retention is controlled by reversing the direction of the air flow through the lances at one-hour intervals. The flow direction is changed by reversing valves switching lances at one-hour intervals from positive mode (forcing air into the waste disposal site) to negative mode (drawing off waste gase) and vice versa. A critical factor in odour stabilisation is adequate supply of oxygen and aerobic bacteria to the disposed material. The lances are pressed into the disposal site in a grid-like pattern, 5 to 6 m apart, and down to a depth of 3.5 m. We have found that reversal of the air flow every hour largely avoids channellisation inside the waste disposal site and enables an adequate supply of oxygen to the disposed waste.

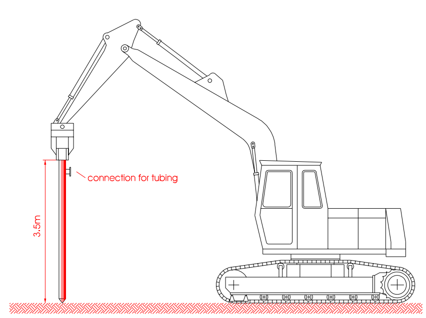

Figure 2.

Steel lances are pressed into the waste disposal site by means of a vibratory hammer. Insertion of the lances takes about 5 to 10 minutes. To avoid blocking of the lances air that is supplied by a mobile compression unit and passed through flexible tubing is blown through the openings of the lances. Tubing linking the lances with the compressor unit is attached with quick-fitting couplings. Installation of one lance can be completed within 10 to 15 minutes. Tubing must be sloped to make sure that condensate will always run off towards the lances. When aeration is started high methane peaks are recorded during the first day. After one day the change from anaerobic to aerobic conditions within the area to be excavated is completed and emissions show greater uniformity. Fresh air is sucked in through the bio-filters, where it is heated and provided with aerobic bacteria. The gas-air mixture drawn off from the site is forced through the bio-filters, which absorb the odour.

The bio-filters and the treated section of the waste disposal site are in an equilibrium with regard to the water balance: the water entrained is needed for wetting of the bio-filters; owing to the high temperature inside the bio-filter the moisture is then transformed into vapour and returned again to the waste disposal site. As a result, during one full year of operation it was not necessary a single time to regulate the water content in the bio-filters by external intervention, let alone change the filter media. The bio-filter used consisted of several layers of material forming a special system with great odour reduction efficiency. Even during the coldest winter months the temperature in the bio-filter was satisfactory. Equally surprising was the fact that the system did not freeze a single time during the winter months. This can certainly be explained by the heat that is supplied from the waste disposal site and generated in the bio-filter.

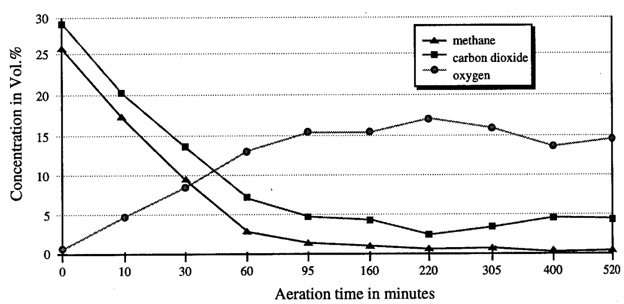


Figure 3. Change in landfill gas concentration in the site on aeration

## 3. RESULTS OF MEASUREMENTS

The data shown below were obtained from measurements taken at the site of the Burghof demonstration project in the rural district of Ludwigsburg in southern Germany. This project involved restoration of an old waste disposal site ("landfill-mining"), in the context of which odour containment was a crucial requirement. Intensive scientific monitoring under the direction of Prof. Rettenberger (Stuttgart-Trier) has yielded an abundance of data demonstrating the effectiveness of this biological stabilisation process.

### 3.1. Odour measurements

Regular odour measurements over one year based on the VDI olfactometric principle confirmed the effectiveness of the process. The results obtained were compared against the odour emissions occurring when fresh residential waste is tipped. The mean values determined were as follows:

Table 1. Results of odour measurement (mean values)

| Type of measurement | $OE/m^3$ |
|---|---|
| Odour of bio-filter (plant not in operation) | 30 |
| Waste air from bio-filter (plant in operation) | 62 |
| Excavation section 1 (right at the excavation site) | 72 |
| Excavation section 2 (area not being excavated at the time measurements were made) | 74 |
| Treatment plant INPUT material | 157 |
| for comparison filling of fresh residential waste | 3264 |

It can be clearly seen that the level of odour emissions caused by the excavation of old material was reduced dramatically after the treatment. Even after excavation and transportation to the treatment plant only slight odour emissions were recorded.

**3.2. Emissions of landfill gas**

The odour stabilisation system is designed to achieve a drastic reduction of landfill gas concentrations in the exhaust air. Gas concentrations were measured regularly at the following emission sites: bio-filter, area being excavated, and treatment plant. These data are listed in following table.

Table 2. Data from measurements of landfill gas (with FID, mean values)

| Type of measurement | Landfill gas concentration in ppm |
|---|---|
| Exhaust air from bio-filter | 50 |
| Area excavated | 200 |
| Treatment plant | 70 |

Continuous measurements at the exhaust duct of the odour stabilisation system and daily measurements at the bio-filters yielded surprising results. It was clearly demonstrated that the methane peaks recorded at the exhaust were buffered or eliminated by the bio-filters. Methane emissions from the bio-filters are continuous and uniform. Breakdown of the filter action during or after placement of new lances has not been observed.

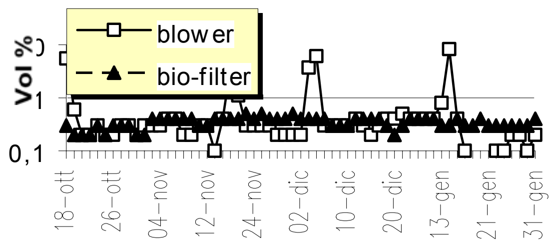


Figure 4. $CH_4$ concentrations Oct. 93 - Jan 94

This is explained on the one hand by the adequate dimensioning of the bio-filters and on the other hand by the biological transformation processes that also occur in the bio-filters, leading to a reduction of $CH_4$ emissions to $CO_2$.

Another objective in using odor stabilization system is the reduction of microorganism emissions from the area excavated, which are believed to be caused by a reduction of biological activity in the waste disposal site.

It can be seen that the concentrations of bacteria thriving under aerobic conditions and of fungi ranged between $10^2$ and $10^3$ KBE/$m^3$ of air (Table 3). Without exception, the results are at very low levels and only slight differences were found compared with the control sample. The expert opinion concludes that workers at that site, with very high probability, are not exposed to higher micro-organism concentrations than other workers employed in waste and recycling operations.

Table 3. Microorganism concentrations (mean values) in KBE (micro-organism concentration units)/m3 air.

| Type of Micro-organism | Control Sample | Area Excavated |
|---|---|---|
| Total number of germs | | |
| Special impinger | $3.3 \times 10^2$ | $6.5 \times 10^3$ |
| RCS plus | $7.8 \times 10^2$ | $1,1 \times 10^3$ |
| Staphylococcus aureus | - | - |
| Anaerobic sporifers | - | - |
| Enterobacteriaceae | - | - |
| Total fungi | | |
| Special impinger | $6.8 \times 10^2$ | $2.4 \times 10^3$ |
| RCS plus | $7.9 \times 10^2$ | $2.2 \times 10^3$ |
| Aspergillus fumigatus | _ | $6.8 \times 10^2$ |

### 3.3. Excavation and haulage

The landfilled material is mined either by means of excavators digging below ground level or by front-end loaders removing the buried waste layer by layer see figure 4. For digging below ground level, the excavator is placed on the ground and excavates material down to a depth of 2 - 3 metres. The truck hauling the material away, usually an all-wheel drive dumper, is positioned on the upper level or sideways for filling by the excavator. When excavating layer by layer, a front-end loader is used to remove the landfilled material in layers of 0.5 m thickness at a time. This method is generally used when the buried waste includes a very high proportion of inerts (building rubble). The important thing is for all equipment being used to be fitted with tightly sealed cabs and forced-air ventilation systems to prevent operators from getting into contact with bacteria and/or other pollutants.

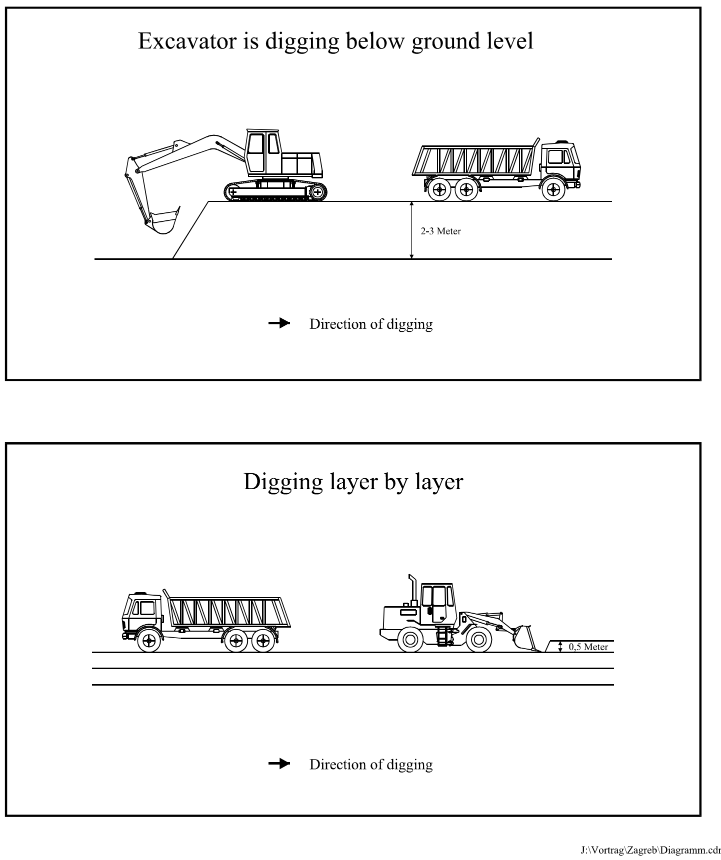


Figure 5. Digging of landfills

### 3.4. Processing and recycling

The extent to which material excavated from landfill sites is processed is in essence a function of the costs involved. In principle, processing may comprise the following steps:

- Size reduction and screening
- Inspection and removal of hazardous wastes
- Recovery of resources such as metals, plastics, etc.
- Recovery of combustible materials

Processing basically includes screening, classification, removal of stones by gravity separation, air classification of the fine fraction, separation of the light fraction by means of ballistic separators, removal of hazardous and other undesirable materials by robots, size reduction, etc.

The treatment plant is made for flexible modular part which are compatible to different usage.

The requirements has to defined and they could be:

- only restoring (sanitation material, infrastructure)
- screening of fine fraction as landfill-coverage
- production of soil products
- winning of new volume
- sorting of light material, wood, metal, rocks
- thermal treatment of light material
- detoxication through sorting out of hazardous parts.

Each of these processing stages is associated with a gain in landfill capacity.

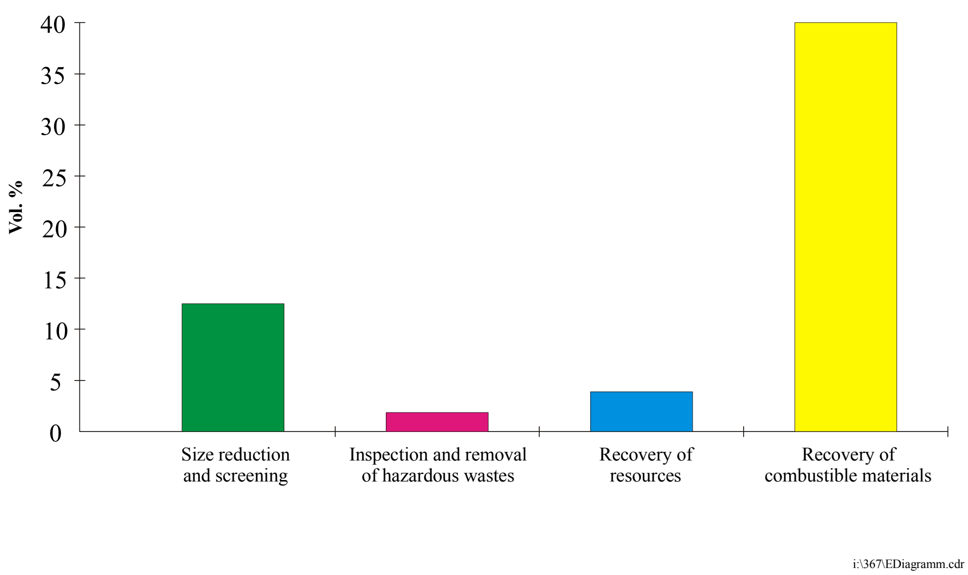


Figure 6. shows the average increase in capacity gained by the different treatment processes.

Frequently, site remediation involves only a physical transfer of the landfilled material. In such cases, the capacity gain may even turn out to be negative as excavation may lead to loosening of the landfilled material, causing its volume to expand. Such expansion may amount to up to 10 – 15% and must therefore be taken into account in planning any action of this type.

On the other hand it is possible to reach an optimal density of the removed fraction by re-putting. As example screened fine fraction will reach a moisture of 1,86 $Mg/m^3$ which can also re-put in the landfill as well as fraction with high density. The decreasing of volume through organic decomposition process can be covered by this system to turn the landfill in its origin position.

It is not possible to project any kind of revenues from the utilisation of recovered resources such as metals, plastics or wood, nor indeed of refuse-derived fuel. Normally, one must expect to incur expenses in marketing such items.

### 3.5. Costs

The costs incurred vary greatly with the location of the site and, most importantly, with annual excavation volumes. Cost projections moreover have to include a variety of expenses for processing of the mined material. The following table provides a summary of costs for an annual excavated volume of about 300,000 m³ of landfilled material.

| Activity | Cost in DM/ m³ of landfilled material 300,000 m³ p.a. |
|---|---|
| Odour stabilisation | 4.20 – 6.00 |
| Excavation and haulage | 6.00 – 8.50 |
| Processing | |
| Size reduction and separation | 6.00 – 8.50 |
| Removal of hazardous material | 2.00 – 3.50 |
| Recovery of resources | 1.00 – 2.00 |
| Recovery of combustible material | 1.50 – 2.80 |
| All costs net of VAT ! | |

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