

DISCUSSION OF DIFFERENT LANDFILL CONCEPTS FROM OPEN DUMP TO MBP LANDFILL

R. STEGMANN

Institute of Waste Management, Hamburg University of Technology, Harburger Schloßstr. 36, 21079 Hamburg

SUMMARY: Open dumps are a permanent hazard to people and the environment. There is a great need to operate controlled landfills with low emissions. Investigations of the long term behaviour of landfills show that it is necessary to reduce also the emission potential of a landfill during the operation and post operation phase and cap the landfill only when this goal has been reached. This paper shows different ways how to operate such a landfill for different kinds of waste input materials.

1. INTRODUCTION

Worldwide landfill technology is very different. In many countries with low income open dumps still are in operation. This means that no emission control takes place, the waste is not compacted, the sites are not chosen in regard to reduce environmental impact and slopes may be very steep. This way of dumping results in a variety of problems, as there are mechanical instability, fires, littering, odours, uncontrolled leachate and gas emissions etc. It is an enormous task to clean up to a certain level these dumps in order to reduce their danger and to build new landfills using the experiences from those countries which have a long tradition in this field. Mistakes made in the past should be avoided.

In industrialised countries the problem of the old landfills becomes more and more evident. After closure still leachate has to be treated and gas has to be controlled. The landfills have to be further inspected and if necessary repaired. With these activities high costs are associated which would be lower if the landfills could have been operated f.e. as a bioreactor reducing the emission potential as early as possible

2. LANDFILLING IN ECONOMICALLY DEVELOPING COUNTRIES

At many dumps there is the problem of the scavengers on the landfill sites that are subjected to different kinds of hazards either from the landfilled waste (hazardous waste, clinical waste, etc.) as well as from the gas emissions which often contain toxic trace components. The scavengers have to leave the landfill site and other ways of involving them in the recovery of materials from

the waste have to be found, where the conditions are more favourable (f.e. separate area for separating reusable waste compounds which is prepared for this task)

Under financially very restricted situations adequate landfill siting may reduce the environmental impact of the landfill significantly. Often waste is thrown f.e. into rivers, lakes or downhill which creates enormous environmental problems and may result in a low mechanical stability of the dump.

As a conclusion those areas should be favoured for building a landfill where the subsoil is of low permeability where no surface water can enter the landfill and where the ground water table is either very low and/or the quality of the water is too poor to use it for drinking water (e.g. high natural salt content). Landfills should preferably not be built in pits but as mounds so that a natural drain of the leachate out of the landfill can take place.

If there are no resources for the construction of a base liner, in any case a collection system consisting of coarse stable material (f.e. gravel) emplaced on the roof shaped natural soil that may be compacted in order to reduce its permeability should be built. If in addition the slopes of the landfill (mound) are controlled (f.e. at 1:3) and the waste is highly compacted, still uncontrolled leachate and gas emissions will occur, but the mechanical stability has been achieved and many operational problems as f.e. fires, vermins and littering above are avoided resp. reduced. If there are leachate emissions above ground f.e. through the slopes of the landfill or the installed leachate collection system this should be captured and treated. Recirculation of the leachate on top of the landfill with the aim to evaporate as much leachate as possible should be considered. In this case the recirculated leachate may be partly treated f.e. in a lagoon esp. when the leachate is from a young landfill. For this procedure the climatic situation is of great importance. If there is a large lagoon available (e.g. for biological leachate treatment) water can be stored during wet seasons and recirculation back to the landfill should only take place during times of high evaporation (f.e. dry seasons). During recirculation the distribution of the leachate should be done equally over the landfill surface where spraying f.e. using sprinklers may be considered (esp. during the night). Potential toxic trace compounds in the leachate should be respected. Transportation and distribution of leachate using tankers might be also a solution. The amount of leachate being recirculated should be similar to the average weekly natural evaporation rate for the specific time period. Leachate recirculation should not be practised during the operation hours.

Under economically very restricted conditions at least a reduction of the bio-degradable organics and – if possible – also of the nitrogen should be achieved by leachate treatment f.e. in lagoons or constructed wetlands.

Landfill gas extraction and utilisation may also be practised under these conditions. At larger landfills gas extraction systems should be installed and the gas should be used to gain energy. Possibilities of CO₂ –trading-system should be investigated. How a gas extraction in general is designed and operated is described elsewhere (Christensen et. al., 1994). Beyond others the main principles have to be respected:

- no air should be sucked into the landfill or transportation pipes
- landfills settle during their lifetime by more than 20% dependent upon the kind of refuse landfilled and the degree of initial compaction reached
- landfill gas is water-saturated and condensate will be produced and has to be transported out of the pipes by means of adequate slopes and condensate traps
- in most cases there are organic trace components in the gas that may cause corrosion in gas utilisation plants
- explosion control systems have to be installed

A controlled landfill has to be lined at the bottom, leachate and gas have to be captured and controlled which means that the leachate has to be treated up to a specific discharge quality

given by the authorities prior to the discharge into natural waters. The aim is a sustainable landfill where also the long term emissions are minimised.

The state of the art of landfilling has been developed in the U.S.A and Europe. It is based on the long term experiences and profound research. These standards are often directly applied to landfills in tropical countries with high temperatures and severe rainfall. In addition the waste has a different quality. Research with the aim to optimise landfilling under these conditions is lacking. Based on legislation where it is prescribed that the landfill or landfill sections have to be immediately capped when they have been filled to final height, the operation of a dry tomb landfill was discussed (Stegmann, 1993). Due to the problem that the surface liner may not be effective forever, the emissions from the landfilled waste may occur after decades when there is no landfill operation resp. supervision any more. This landfill concept may only be applied to non-biological degradable waste as there are mechanically or thermally pretreated waste, hazardous waste and other kinds of inert waste. For waste with degradable compounds (MSW) the bioreactor concept should be used.

2. BIOREACTOR LANDFILL

In order to enhance the anaerobic degradation processes the landfills should be operated as a reactor landfill. The enhancement of the biological processes in the landfill reduces the emission potential of a landfill much faster, high gas production is more concentrated to a shorter time period and leachate concentrations are significantly reduced at an earlier time. There is a lot of mystery about bioreactor landfills, but what it means in most cases, is that leachate is recirculated in a more or less controlled way.

Leachate recirculation enhances the biological processes in order to achieve the methane phase at an early stage by means of the following effects:

- enhanced leaching of easy biodegradable compounds
- increase of the water content to avoid inhibition of biological processes due to low water contents
- increase the waster flux which transports the residues from biological degradation processes out of landfill. By these means the possibility of an inhibition affected by the fermentation products may be reduced.

The emplacement of the MSW should take place in thin lifts (± 50 cm) which are highly compacted. The operational area should not be too small in order to allow some aerobic processes on the surface of the just landfilled easy degradable waste compounds. Daily cover is for reasons of enhancement processes not necessary but due to regulations in many countries, daily cover has to be applied also for esthetical reasons. In any case it should be avoided to use low permeable soil as a daily cover (Stegmann, 1995).

In order to reduce the organic leachate concentrations the author recommends what has proven to be effective at several landfills in Germany, to built up a 1-2 m layer of composted MSW which still has sufficient structure material on top of the gravel layer of the leachate collection system. This composted waste layer acts as an anaerobic filter for the migrating leachate from the upper waste layers. By these means the easy degradable organics are partly anaerobically converted to biogas (Stegmann, 1995). Another positive effect of this composted MSW layer is the reduction of incrustations in the leachate collection system since these are very much associated with high organic acid concentrations in the leachate (Brune et al., 1991).

Further measures as the controlled air injection, the semi-aerobic landfill and a pretreatment of the MSW prior to landfilling are in discussed later.

How can the readily degradable organics in the waste be reduced as a prerequisite to reach the methane phase in the landfill at an early stage?

If the amount of biological degradable organics in the waste is reduced f.e. by means of separate collection of the kitchen and yard waste the acid phase in the landfill can be shortened. The emplacement of MSW in thin lifts - as proposed earlier – with an increased exposure to the atmosphere also may result in a partly aerobic degradation of readily degradable organics.

If the methane phase shall be reached earlier a kind of pretreatment on the landfill site may be considered. Results from laboratory scale experiments show that an aerobic pretreatment of 15-30 days is sufficient to reduce the readily degradable organics in the MSW and as a consequence the lag phase of methane production may be significantly reduced (Spendlin, 1991).

On-site aerobic pretreatment may be practised using windrows on top of the landfill where drain pipes at the bottom of the windrows may improve the aeration (chimney effect). In order to avoid odour emissions and the development of vermins, the windrows are covered with composted material and from time to time artificially wetted (Spillmann and Collins, 1982).

Another option which has been practised to the knowledge of the author only in experiments is the on-site two stage anaerobic process, where the first stage is practised outside the landfill. After a certain period the material is excavated and transported to the landfill where the material is landfilled (see also Lagerkvist, 1991; Chynoweth et al., 1992).

In order to further enhance the anaerobic degradation processes, but also to elute soluble compounds out of the waste, leachate recirculation may be practised. The semi-aerobic landfill with an enhanced leachate recirculation process (“flushing”) is promoted also. Results from half technical scale experiments show a relatively fast biological stabilisation process (Cossu, et. al., 2001).

The reactor type landfill should be finally covered with an “impermeable” liner when the biological degradation processes have slowed down to very low levels. This can be seen from the gas production which may be reduced to less than 10% of the total production potential due to the remaining not readily degradable organics in the landfill. Long-term gas extraction of low volumes may be necessary also after the landfill has been capped.

A research project is initiated in Florida, USA, in order to make detailed investigations on a section of a full-scale landfill which may tell more about different effects on the enhancement of biological treatment processes in landfills to operate a “real” bioreactor landfill (Jain et al., 2005).

3. SEMI-AEROBIC LANDFILL / ROTTEDEPONIE

Another way to enhance degradation processes is the semi-aerobic landfill operated at many sites in Japan and other places. In this case pipes are emplaced at the bottom of the landfill open to the atmosphere which are built as a chimney inside the landfill and create the so called chimney effect where due to higher temperatures in the landfill body air is sucked into the landfill from the bottom. Initially this system has been used at Japanese landfills where the landfilled waste has a comparatively low organic content. Nowadays this concept is also applied in some Asian landfills where the organic content of the landfilled waste is significantly higher (Matsufuji, 2004). Not too many results describing the efficiency of this process at full-scale landfills are available.

In the 1970-80's there was a so called “Rotteponie” operated in Schwäbisch-Hall, Germany. The idea was to reduce the readily degradable organics mainly aerobically and then install anaerobic conditions. In order to achieve this the raw waste was landfilled in about 2m lifts without compaction. After about 1-2 years the waste was then highly compacted where as a

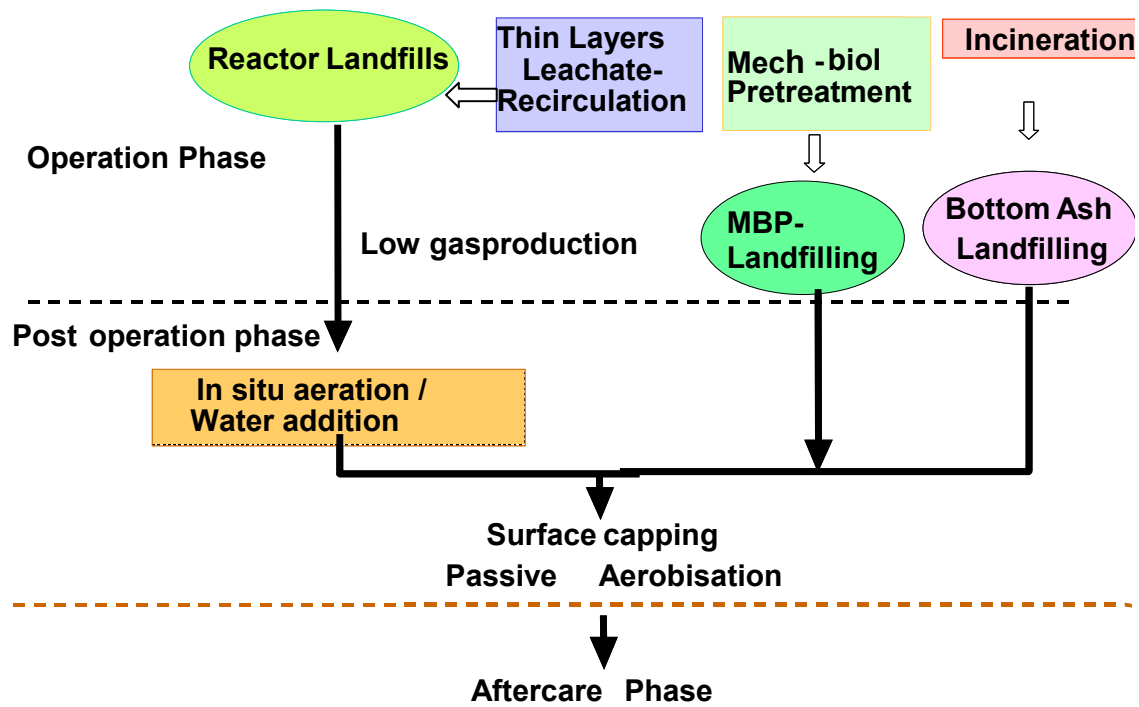


Figure 1: Sustainable Landfill Concept

consequence anaerobic conditions occurred. The anaerobic methanogenic phase was reached after a relative short time after compaction. As a result the produced leachate had relatively low BODs- and COD-concentrations. This is due to the fact, that the produced organic acids are directly converted into biogas. The no-compaction of the waste may result in problems as there may be greater risks of fires as well as the development of large amounts of insects, rats etc. which only can be controlled by high compaction. So the process is working but the associated problems let this concept fail. Nowadays this concept has been further developed by – as already mentioned - aerobic pretreatment of the waste which is practised in large windrows on the landfill surface aerated by means of the chimney effect where the windrow surface is f.e. covered by means of composted waste or a semi permeable membrane. Under these conditions the vermin problem is supposed to be solved (Collins and Spillmann, 1974).

If the landfill is completed and the gas production has decreased to low levels that an utilisation is not feasible anymore an in-situ aeration may be advantageous to further reduce the non-easy degradable organic compounds (Stegmann, 2004). With this method a similar status as MBP-landfills have reached relatively early (see Figure 1).

4. LANDFILLS FOR MECHANICALLY-BIOLOGICALLY PRETREATED WASTE

In Europe esp. in Germany and Austria mechanical biological pretreatment (MBP) prior to landfilling is practised. During mechanical pretreatment the high calorific value fraction of the municipal solid waste (MSW) is removed, so that the biologically stabilised waste contains almost no structure material and looks more than a soil. This material has a low emission potential and landfilling is difficult especially when the water content is either too high or too low. The experiences so far are very different. The achieved compaction rates are from medium to very high. At higher water content the compactors or rollers may sink into the waste. There are contradictory experiences regarding the amount of surface water run-off to be expected (Doedens, 2004). Bale landfilling may be an option for the landfilling of this material.

If mechanical biological pretreatment is practised respecting the German or Austrian Guidelines a biological stable waste is landfilled which means that only little gas production will occur and leachate concentrations are comparatively low. Since about 80 - ±90 % of the degradable organics have been degraded during the biological pretreatment step the landfill can be capped immediately after the landfill operation has come to an end. Residual gas should be biologically oxidised in the landfill top cover. Reduced settling rates can still be expected (Stegmann and Heyer, 2002).

5. LANDFILLS FOR BOTTOM ASHES

Bottom ashes are in Germany often recycled f.e. as a construction material for building roads. In this case they may be pretreated by elution with water or storage over periods of 3-4 months for chemical stabilisation. Otherwise ashes with or without pretreatment have to be landfilled.

Bottom ashes from waste incinerators have an emission potential and therefore these ashes cannot be described as “inert”. Lichtensteiger (1995) described a bottom ash landfill as an active landfill since chemical/physical processes take place while high temperatures (up to 80 – 90 °C) may occur. In addition hydrogen gas may be produced. There are not many leachate quality data available from monolandfills filled with bottom ashes but the existing data show relatively high chloride, carbonate and sulphate concentrations (in the range of grams/litre) but especially in the beginning also elevated concentrations of nitrogen and DOC (< 100mg/l) can be expected. Little is known about the long-term behaviour of these landfills and their proper management (e.g. dust production). Such landfills have to meet the same criteria regarding siting, construction, lining etc as they are prescribed for MSW – or inert waste landfills (German Category I or II) (Anonymous, 2000).

The concept in Germany for this kind of landfills is conservation of the waste by means of surface capping once the landfill is filled up.

Following this concept “no” leachate will be produced. On the other hand the emission potential of such a landfill will be preserved. As a consequence the landfills have to be controlled and if necessary repaired even after they are closed.

What are the alternatives?

- open landfill subject to precipitation and leachate production. By this option over at least some decades leachate with a high salt content and other pollutants have to be collected and probably treated.
- pretreatment of the bottom ashes by means of allowing the ashes to chemically/physically react before landfilling. As one result less heat will be produced inside the landfill. An additional pretreatment option is preelution or washing with water in order to significantly reduce the salt content before the bottom ashes are landfilled. Another principal option is the vitrification of the ashes by means of post-treatment or high temperature thermal treatment (Lichtensteiger, 1995), which is practised more and more in Japan.

6. CONCLUSIONS

Due to the very high emission potential of landfills where raw MSW is disposed off and due to the long term emissions that last for decades or even longer, the biological processes in the landfill should be enhanced and the emission potential has to be reduced as early as possible. Either in-situ (Bioreactor Landfill, In-Situ Aeration) or ex-situ measures (mechanical biological or thermal pretreatment) should be practised where the latter is actually the more consequent

approach. The landfill should be capped only when the degradation rates have come to an end and the emission potential is low. Only those landfills where biologically or thermally pretreated waste as well as hazardous and inert waste is disposed off should be capped directly after a landfill or a landfill section has been completed.

It should be always kept in mind that landfills are a long-term problem. That means also after closure and capping the landfill still has to be operated and/or controlled. When and under which construction a landfill can be released from aftercare cannot be answered today. It is obvious that this is possible for a MBP-landfill at an earlier stage as for a bioreactor landfill. The aftercare phase for "normal" landfills without any enhancement of the biological processes also having low water infiltration rates will be significantly longer. Hazardous waste landfills and some types of inorganic waste landfills cannot be released from aftercare in the opinion of the author. The functionality of the liner and associated parts of the landfill has to be guaranteed forever.

In the future there should be more and more waste avoidance and recycling so that landfilling of waste can be steadily reduced. On the long term landfills are not the appropriate method for waste management.

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