Biological pretreatment of MSW as a measure to save landfill volume and deter birds

Florian Koelsch, Ph.D., Massachusetts Institute of Technology, CEE 1-176, Cambridge, MA 02139, USA
Richard T. Reynolds, P.E., 77A Revere Street, Boston, MA 02114, USA

Abstract
Biological pretreatment of municipal solid waste is a well-established waste management method in Germany. It reduces waste mass and volume and changes the biochemical waste properties, which improves the leachate quality after disposal. However, two other “side-effects” have found the interest of US landfill operators: Pretreated waste does not attract birds and it can be used as a daily earth cover material. This presentation introduces the principle of biological waste treatment. Showing the landfill of Wilhelmshaven (Germany) as a practical example the procedure of establishing a plant, as well as the costs, benefits and experiences of the operation are demonstrated.

Keywords: Waste treatment, bird control, daily earth cover, landfill volume, leachate quality

Situation

Landfill operators often spend more effort in deterring birds than in essential landfill matters such as leachate control or gas extraction. Since landfills are often located close to airports, to avoid threatening air traffic, bird control has become a big issue. One method of control is to constantly hide the waste under daily cover, but this certainly drains a landfill operator’s budget. It also uses up to 20% of the nations' landfill volume. Additionally the operator may try to rapidly place the waste in thick lifts to minimize the exposed surface of waste. This drastically reduces the opportunity to compact the waste and results in lower waste densities. Further, the lower waste density increases the risk of fires inside the landfill, by giving air an easier access to penetrate the waste – the major requirement to cause a fire. Biological pretreatment of municipal solid waste provides a new way to achieve bird control and higher waste densities. At the same time, it can provide other benefits like improving leachate quality.

Basics of biological pretreatment

The biological pretreatment of municipal solid waste (MSW) was pioneered in the late 1970's in Germany at the model landfill at Schwaebisch-Hall. After 20 years, biological pretreatment cells at 14 landfills are handling 900,000 t/yr of MSW. Presently 15 additional sites are designed or under construction. By 2002 approximately 1.8 mil t/yr or 5% of Germany’s MSW will be biologically pretreated.

Figure 1: MSW in the landfill, biologically pretreated (below) and untreated (above)

The treatment process is based on an aerobic decomposition of the organic components in the waste, somewhat similar to composting. Like composting, air and water need to be supplied to the waste to maintain the process. Unlike composting however, the MSW requires several special measures due to its wide range of materials and the large size of the waste pieces. Generally, moving or handling the waste during treatment should be avoided. Therefore, the most popular composting methods like heap composting, where the air supply is provided by repeatedly turning the heaps, can not be used for treating MSW. Nevertheless, some 10 different biological pretreatment systems have been developed especially for MSW treatment. They can roughly be classified into two groups, passive aeration or low-cost systems and active aeration or high-efficiency systems. An example of each system is presented later in this article.

Benefits

In the early years of biological pretreatment, the noted benefits were:

- Reducing the waste mass by about 15% due to degradation of organic components
- Improving the leachate quality (COD to about 500 mg/l, BDD_5 < 20 mg/l)
- Increasing the waste density from 1350 lb/cy (0.8 t/m^3) up to 2000 lb/cy (1.2 t/m^3)

The experience of the last 10 years, using biological pretreatment shows another interesting benefit. Birds are not attracted to the pretreated waste. Figure 1 shows two areas at the Stendal landfill (Sachsen/Anhalt, Germany), which were constructed to compare the overall waste properties before and after pretreatment. The upper photo shows untreated waste, while the lower shows an area containing biologically pretreated waste.

Variations on the biological pretreatment process show that soily materials can be recovered from the pretreatment output by combining the biological process with a mechanical step. Thus the finer fraction can be separated from the waste by running the waste over a 1'' to 1½" screen. The biochemical and geotechnical properties of the finer fraction are quite similar to soil. Some specific parameters (average values) of the finer fraction are given in Table 1.

	Biologically pretreated MSW	Finer fraction <1¼"	Light fraction >3"		Untreated MSW	Soil
Portion of output [%]	100	60-70	Up to 15			
Ignition loss [mass %]	40	25	>80		75-85	-
Total Organics [mass %]	11	7	23		27-32	5-15 (agric.)
Heat Energy [MJ/kg]	11500	5000	24000		13000	-
Density (average) [lb/cy]	2000	2500	N/A		1350	2600+

Table 1: Average parameters for pretreated waste fractions, untreated waste and soil

As Table 1 illustrates, every parameter for the finer fraction of the biologically pretreated waste output is more like soil than untreated MSW. To the naked eye and nose it looks and smells somewhat like topsoil. Because it satisfies the important requirements for daily cover, such as minimal odor, non-susceptibility to wind, and is not attractive to birds, the finer fraction can be used for this purpose. The high calorific waste components like paper and plastics can be recovered from the coarse fraction, as a so-called light or high calorific fraction. Typically, about 15% of the pretreated waste (by weight) will remain on a 3" screen. The heat energy of this fraction averages about 24000 MJ/kg, which is almost twice the value of untreated, fresh MSW and is nearly comparable to fossil fuels. Thus, the light fraction could be routed to an incinerator to further reduce the volume and possibly gain some benefit from the fraction's intrinsic energy.

Systems in use: The chimney-effect system

The simplest and cheapest way to biologically pretreat MSW is to use the so-called chimney-effect system. This is the archetype of all aerobic treatment methods. In waste pretreatment, it has been literally unchanged since its first application about 20 years ago. In contrast to the more advanced methods, the chimney-effect system is passively aerated using the natural tendency for warm air to rise. A cross-section of a chimney-effect pretreatment stockpile is shown in Figure 3. To cause the biological process, fresh waste is placed in heaps up to 8 ft. high. The base of the stockpile must consist of a permeable material like bulky waste, palettes or similar materials (crushed tire parts might also be suitable). This base layer maintains the airflow into the waste. The airflow is driven by a temperature gradient between the outside and the inside of the stockpile. Once the aerobic process has started, the temperature inside the stockpile rises up to abut 160^0 F. The warm air inside the stockpiles rises and draws in colder air from the bottom and from outside. The time for pretreatment ranges from about 9 to 18 months and depends on the degree to which biological treatment is desired. As a first design value an area requirement of 1 yd^2/ton of MSW can be assumed. It is recommended that the bio-heap be covered with previously treated waste, fine material, wood chips or similar inert material to guard against odors, birds, and wind. The use of synthetic materials like geotextiles is currently being investigated. To guard against the biological condition turning anaerobic, sufficient drainage needs to be provided at the toe of the bio-heap to keep the toe of slope dry. Nevertheless, sufficient moisture needs to be maintained within the bio-heap to maintain the biological process. Simple irrigation systems like agricultural sprinklers are sufficient.

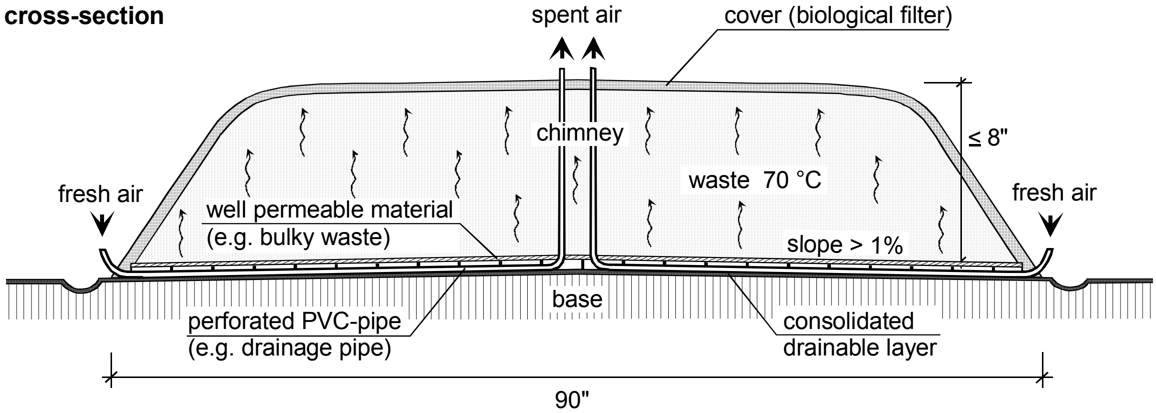

Figure 3: Stockpile for biological pretreatment by chimney-effect system (Turk,1998)

An example of a successful application of the chimney-effect system is demonstrated at the Wilhelmshaven-Nord landfill (Germany). Figure 4 shows an aerial view of the landfill. The pretreatment process was intended to be as simple as possible while still achieving a maximal benefit/cost ratio. The major goals were to save landfill airspace and to reduce the leachate loading. The waste stream amounts to about 250 tons/day including 70 tons/day waste water sludge. The landfill owner, the City of Wilhelmshaven computes that the costs of the entire biotreatment efforts are under 25 DM ($13) per ton.

The treatment plant comprises several steps:
- Visual check and rejection of hazardous waste components
- Separation of larger wood and metal pieces by excavator
- Shredding of bulky waste
- Mixing of shredded waste, MSW and sludge by front-end loader
- Placing of waste in bio-heaps using shredded wood as base layer
- Covering and irrigation

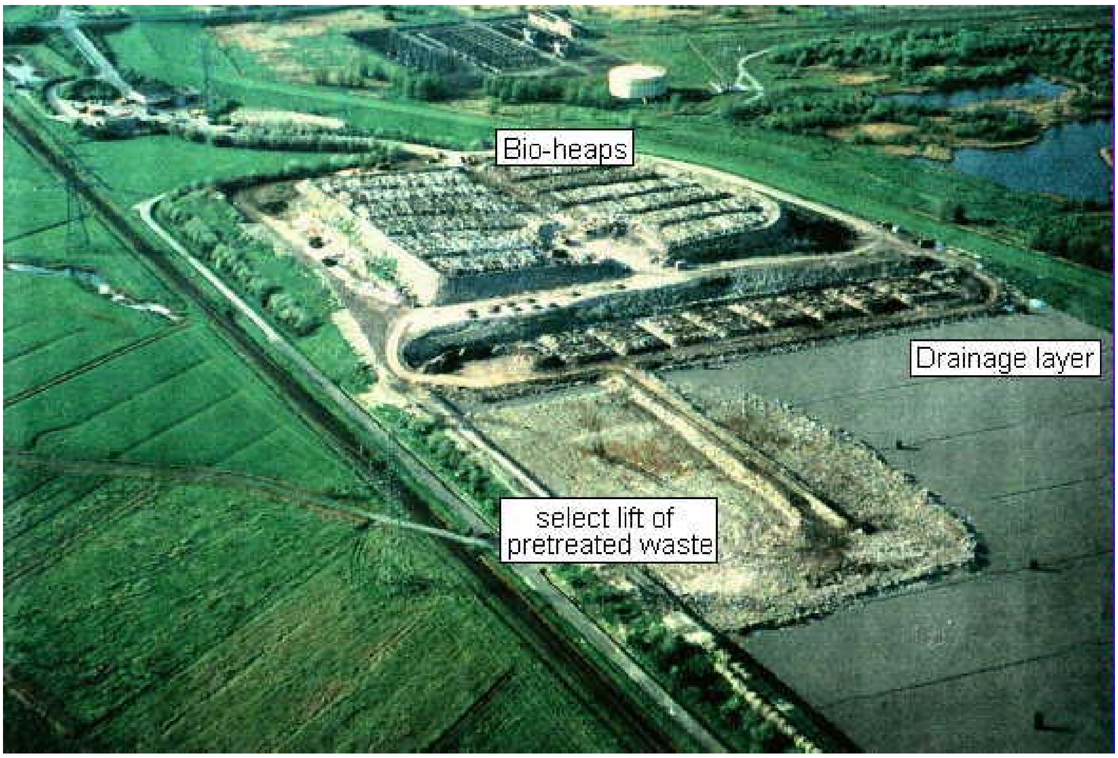

Figure 4: Chimney-effect system at the Wilhelmshaven-Nord landfill (Germany). A dozen active bio-heaps can be seen on top of the existing (grandfathered) landfill in the upper part of the photo. Near the center of the photo and at the toe of the grandfathered landfill are 9 additional bio-heaps. Newly pretreated waste is being spread over the drainage layer in the lower part of the photo.

After a treatment period of 9 to 12 months, the biologically pretreated waste is excavated and compacted in lifts in the permanent landfill area. The next piles are then placed upon the previously pretreated and compacted waste. The required area for a 12-month treatment period of 60,000 tons of MSW is about 13 acres. The first area used for the pretreatment was on top of the "grandfathered" part of the landfill (top of figure 4). Once the expansion area was completed (Figure 4, lower right), bio-heaps are also going to be placed on this area. Wherever the pretreated waste is close to the liner, a select lift of less compacted pretreated waste is placed on the drainage system to prevent damage from the front-end loader driving on it. Generally, the pretreatment period can be varied somewhat to match the demands of the waste delivery schedule and area available for treatment. The operator has found it is easy to improve the process by implementing additional treatment steps like screening.

After 2 years of using the biological pretreatment process at Wilhelmshaven, an assessment of the process was conducted by the Technical University Braunschweig (Germany). Large-scale compaction tests indicated that the average compacted density of the pretreated waste was about 2000 lb/cy, while the average density of non-treated MSW was 1350 lb/cy. This resulted in a saving of about 40,000 cy of airspace at the landfill. The impact of the biological pretreatment process on the leachate chemistry is shown in Table 2. The table compares the leachate from Wilhelmshaven to typical values from a conventional anaerobic landfill and to values from a site with even more extensive biological treatment, the landfill at Meisenheim (Rheinland-Pfalz/Germany).

Parameter	Wilhelmshaven	Meisenheim	Anaerobic landfill
COD [mg/l]	600-1200	500-900	2500-40000
BDD_5 [mg/l]	<20	<5	230 (average)
NH_4-N [mg/l]	150-250	5-25	740 (average)

Table 2: Leachate chemistry from biologically pretreated and non-treated waste landfills

Neglecting other effects like reducing bird control costs, the calculation of the benefits depends mainly on the cost of airspace. The cost per ton for pretreatment is about $13. Considering an average density of 1350 lb/cy for non-treated waste, 1 ton of waste requires a volume of 1.48 cubic yard. With a weight loss of 15 % by degradation and an increase in waste density to 2000 lb/cy, the same waste can be placed in just 0.85 cy after the biotreatment. The volume saving amounts to 0.63 cy/t and the break-even cost for airspace is about $20/cy. If the airspace cost exceeds $20/cy, the benefit/cost ratio will exceed 1.0. Note that these calculations do not consider the post-closure benefits derived from waste pretreatment. Since a high percentage of the degradable organics is decomposed during the pretreatment process, long-term gas production and leachate loading will be less, reducing the duration, intensity and costs of post-closure measures. Therefore, higher operating costs of a pretreatment site could actually be accepted, considering that a positive B/C-ratio can be accomplished in the long-term.

Plants in use: The Biopuster

Advanced biological waste pretreatment methods have been developed within the last few years, driven by the need to minimize treatment areas, gas extraction, leachate treatment and post-closure costs. These kinds of plants compete on a cost and output quality basis with waste-to-energy incinerators.

The most recently introduced system is the so-called Biopuster (i.e. "bio-puffer"). Originally, the Biopuster was developed for soil remediation and on-site waste stabilization. The system basically actively aerates the waste or soil instead of relying on passive aeration as in the chimney-effect systems. A major distinction between the Biopuster and other active aeration systems is that air is not continuously flushed into the waste, but pressure thrusts are produced in single impulses, which enable the air to diffuse at high speed. Therefore, the air supply to the waste is improved. If desired, the air can be enriched with oxygen. Additionally, the moisture content of the air can be changed to control the waste moisture. To prevent uncontrolled emissions and odors as well as to improve the efficiency of the aeration process, a gas extraction system is installed and the waste is covered by an unpermeable layer like a thin geomembrane. The collected gas is directed to Bio-filters. The improved aeration process allows the construction of stockpiles that are much higher than the passively aerated bio-heaps. Thus, the area demand is much less compared to a chimney-effect system. The temperature inside the heap may exceed 190º to 200º F. As the biological process proceeds in the so-called hyperthermophile temperature range, even the less biodegradable materials are decomposed, being weakened by physical attack and specific microorganisms.

Figure 5 shows the Biopuster treatment plant at the Stendal landfill in Sachsen-Anhalt (Germany). The waste is placed in two cells that are surrounded by rows of sheet piles. Each cell measures 25 ft by 160 ft in plan. The height of the waste pile can be up to 26 ft. The waste is placed loosely into the cells using a front-end loader or an excavator. An attempt is made to keep the waste density below about 850 lb/cy (0.5 t/m^3). In total, the cells have a load capacity of 3300 tons. The aeration starts immediately when the first waste is delivered. Due to the biological process, the temperature inside the heaps rises up to about 200° F. The treatment period ranges from 12 to 15 weeks, depending on the treatment goals. The capacity of the Stendal landfill plant ranges from about 13,000 to 14,000 tons/yr. After removing the waste from the cells, it is either compacted immediately or placed in bio-heaps for post-treatment biological stabilization.

The output from the Biopuster is almost entirely decomposed. It smells like soil or compost, and organic components and paper can no longer be identified. Even if it is highly compacted, it usually does not undergo further decomposition or generate methane gas. It also does not attract birds. Nonetheless, just like agricultural soils or compost, the pretreated waste still contains organic carbons. These compounds, however, usually remain as non- or low- degradable substances. The total operating costs of the Biopuster plant at Stendal have not been calculated yet. The initial estimates, however, indicate costs of about $24/ton, but these do not include the cost for recommended ancillary pretreatment steps, such as shredding and homogenization (improved mixing). On the other hand, it appears that the aeration process can be improved, which would reduce the cost of purchasing oxygen.

Figure 5: Biopuster pretreatment plant at Stendal (Germany)

Developments in US

The accomplishments of the European biological pretreatment sites are beginning to attract the attention of landfill operators within North America. The achievements regarding bird control seem to be quite attractive. At the Anguilla landfill on St.Croix (US Virgin Islands) a pretreatment feasibility study is underway. The landfill is located about 1 mile from the St.Croix airport. After the planned runway extension, the distance will decrease to about 1000 ft. Right now, the bird population at the Anguilla landfill does not seem to be extraordinarily high and it currently does not threaten the air safety. This is mostly due to a copious and rapid placement of daily cover, using more soil than even the regulations require. But both the cost and the limited availability of soil on the island will probably force the operator to change this policy. Additionally, the daily cover is using up a big portion of landfill airspace and the way it is used may even be promoting landfill fires. Therefore, the landfill operator, the Island's Department of Public Works, is looking for alternative measures. Two other sites in northern New England are also being considered. Each is located close to an airport. For multiple reasons it is expected that chimney-effect systems would be used at each of these sites. Recently the U.S. EPA was contacted to seek their opinion regarding the use of biological pretreatment. While obtaining a blanket approval without site specifics would be an unreasonable expectation, the agency did indicate it did not foresee major approval problems.

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PhD-Thesis at Technical University Braunschweig. (in German)