Environment Protection Engineering

Vol. 25 1999 No. 3

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MECHANICAL-BIOLOGICAL WASTE STABILIZATION BY THE DOME AERATION METHOD

Disposal sites are necessary parts of waste management systems for disposing that waste which cannot not be recycled. However, landfills operated in the past and partly being still in operation until now cause a wide variety of problems. Mainly the anaerobically degradable components of the waste have to be "rendered harmless" prior to disposal. The erection of thermal treatment plants is very time-consuming and expensive. Therefore effective transitional solutions are necessary. The biological stabilization of waste could be a very effective method, even by means of a simple technology. Since 1994 a mechanical-biological waste treatment has been carried out as a field test on an East German disposal site. The composting is performed in open windrows directly upon the landfill area. A convective self-aeration is achieved by an appropriate windrow construction and special dome aeration devices. Additional aeration means are not necessary. Meanwhile the technology is applied also at other landfill sites and to other waste types. One of the main advantages is that this approach is a low-cost technology. Therefore it seems to be very suitable for application at East European landfills.

1. INTRODUCTION

There have been tremendous innovations in the municipal waste treatment in the last ten years. This is true for both thermal and biological treatment methods. Such a situation can be explained by two reasons: an increasing ecological awareness and an enormous pressure of public opinion on all elements of the waste management system. However, the amount of waste generated is too large, both relatively per capita as well as in absolute figures. And a vast amount of this waste is still not treated properly.

The erection of thermal waste treatment plants is very time-consuming. Costs of these plants are huge. Therefore a transition time of several years could be expected. Especially in Germany, but obviously also in other smaller industrialized countries,

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disposal space is lacking. German landfills are packed and offer only disposal volume for very limited terms. Under the present conditions waste export has to be refused, both because of ecological and moral reasons. In addition, there is the problem of long-term risks caused by disposals. The extremely stringent requirements of the new waste act amendments in Germany are unambiguously addressed especially to those risks. It is widely conceived that waste disposal does not mean its annihilating (or eliminating), but only vanishing from sight. This is much more dangerous, because establishing a disposal in fact means the "installation" of a huge long-term bioreactor in environment.

Many of the landfills, which operated in the past and partly being still in operation until now, cause a wide variety of problems. Most of these have their origin in the anaerobic degradation of organic waste components in the landfill. Characteristic intermediate and end products of this process are organic acids and methane. Primary consequences of the anaerobic degradation are emissions of methane-containing disposal gas and leachate water contaminated by organics as well as settlements of the landfill body. Secondary consequences, e.g. the mobilization of heavy metals caused by the decreasing pH values, are not so easy to describe.

In the last years, there have been many efforts to apply the mechanical-biological waste treatment (MBWT) processes to municipal solid wastes (MSW) prior to their disposal. Due to these processes the amount of MSW as well as the environmental problems related to MSW disposal could be remarkably reduced. Though there are some further advantages of MBWT, e.g. improvements in settling characteristics and the possibilities of separating the recyclables, one of the major disadvantages of that treatment is the natural (and much more the technical) limit to the reduction of the organic content. Even by long-term biological treatment the minimal achievable content of organic matter, expressed in terms of ignition loss, is about 20 percent by weight. This organic content may still cause some disposal problems. Only by thermal treatment processes (e.g. incineration) the organic content could be further reduced to values of about 5%, which are e.g. prescribed by German disposal law. Furthermore, the stabilization by MBWT allows us to lose the calorific value of the digested organic content. Thus, an integrated application of MBWT and incineration should be in the focus of our interest and can really be effective (BRUMMACK [5]).

Meanwhile MBWT has become an alternative to simple disposal. In Austria, some 14 plants were already built with a capacity of about 400,000 t/a (PILZ, RANINGER [7]). Many more are planned to process about 50% of the whole MSW in Austria by 2009. In Germany, a lot of federal states are supporting the concept (Lower Saxony, Brandenburg, Hessia), likewise in Austria, and a comparable number of plants is already working (BILITEWSKI, HEILMANN [1], BRAMMER et al. [2]). The technologies applied are very similar and may differ in the complexity of the approach and the equipment and devices. Since 1994 several experiences have been collected on an East German disposal site. A relatively simple MBWT windrow process is successfully applied there. The aeration equipment developed and the knowledge gained are now transferred to other landfill site applications and to other types of waste.

2. LONG-TERM PRACTICAL MBWT APPLICATION TO A LANDFILL

In several field and long-term application tests, a simple and low-cost MBWT technology was developed and improved on an East German landfill for about four years (BRUMMACK et al. [3], WOTTE et al. [10], BRUMMACK et al. [4]). The minimum equipment requirements, the achievements and main economic factors have been studied. Meanwhile the process is applied under German environmental legislation permits and readily used for treatment of different municipal wastes with certain organic content.

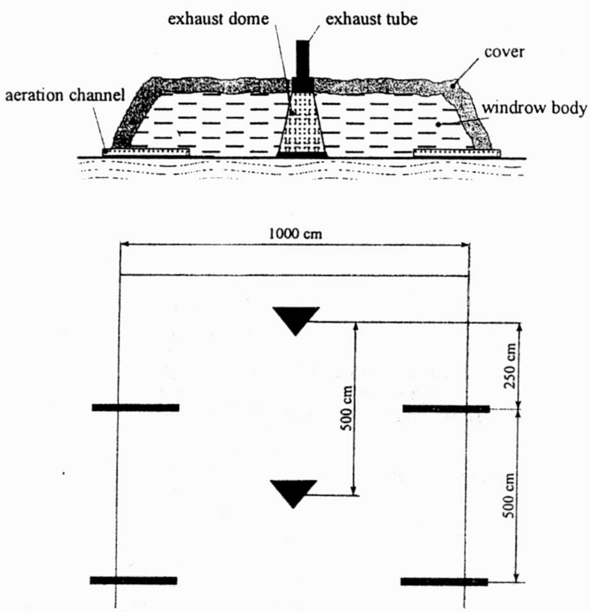

Fig. 1. Windrow construction with dome aeration devices

The process, which is relatively quickly and simply set in motion, consists of a combination of mechanical separation processes and a windrow composting step. This process has the advantage of an almost immediate accessibility of appropriate disposal sites. It can easily be carried out just with the available disposal site equipment and consists of the following steps (BRUMMACK et al. [3]):

1. The composting matter is prepared by mixing municipal solid waste, selected dosages of appropriate bulky waste, and sewage sludge. Mixture portions depend on waste

and organic contents. In such a way, certain optimal parameters of biochemical processes, e.g. a moisture content and sufficient homogenisation, are obtained. Depending on the type of waste being processed, an initial separation of coarse material could generate a high calorific fraction for incineration. Very coarse material might be crushed.

2. The biochemical reactions are carried out aerobically, i.e. by composting the wastes in an open windrow, directly on the existing compacted disposal body (figure 1). The windrow construction should be such that no additional turning the matter up is necessary during this stage of composting process. Aeration of the composting matter is provided making use of the chimney effect of exhaust domes, induced by the heat of the exothermic composting reaction.

3. There is the option of a subsequent separation (> 80 mm) of recyclables (plastics, textiles, metals) or troublesome and inert agents. The fine-size fraction (< 10–30 mm) is utilized as surface cover for the windrows, providing a heat- and water-insulating layer as well as a sort of biofilter to reduce odour emissions. In addition, also the medium-size fraction (of about 35–80 mm) could be further sorted to remove metals. Some organic materials could again be returned to the composting process for further degradation.

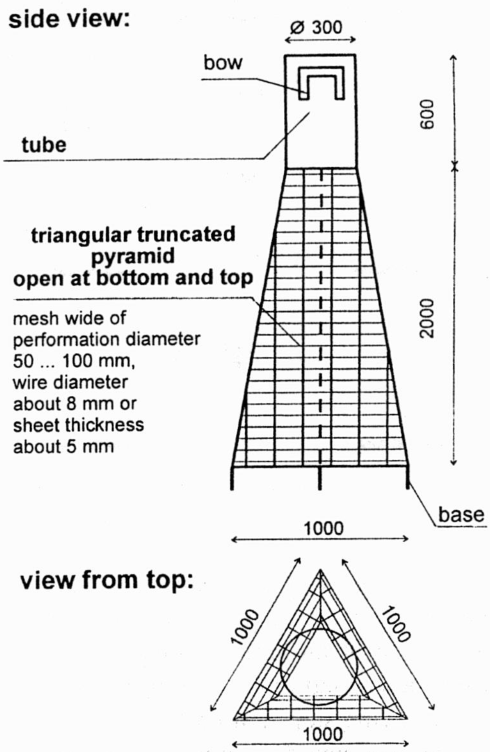

Fig. 2. Exhaust dome for windrow venting

The key element is the optimal aerobic digestion of waste material. Only this gives the real opportunity to stabilize properly it prior to final disposal. Furthermore, also such compounds as plastics and fabric materials as well as aggregates can be digested biologically. Thus:

a) a subsequent separation is successful,

b) the disposal characteristics of landfilling are substantially improved (by increasing waste compaction and reducing the consequences of biological digestion processes in the landfill body.)

In order to improve the aerobic digestion, especially in such a simple windrow process, a special dome aeration system was developed (see figure 2). To protect this system its owner took out a German patent on it [8]. The optimized windrow aeration system has a superior performance compared with other systems; both simple perforated plastic piping and improved separated tubes are of the highest quality (BRUMMACK et al. [3]). The grid design has much greater open area for air exchange. The number of the aeration devices applied can be decreased without reducing aeration effectiveness. In addition, it ensures much greater construction stability. The grid or perforated sheet metal design also withstands the harsh conditions of disposal operation.

Therefore also windrow building and covering is facilitated. It is simple to produce and reusable. One of the main advantages of this aeration system lies in the fact that the system itself and the MBWT process can be considered as low-cost technology. Hence, they should be applied also to East European landfills.

3. TECHNOLOGICAL DATA AND RESULTS OF MBWT PROCESS

Four year experience and a number of expertises proved the practical serviceability of the system. General treatment, i.e. windrow digestion, lasts for about 6 months. Due to the effective aeration system, no further windrow turning up is necessary. Also an all-year (summer and winter) operation is easily possible with no reduction in digestion efficiency. Some main characteristics of start and final parameters are summarized in table 1.

The grid dome construction permits, among others, an optimal aeration, i.e. supply of oxygen and removal of carbon dioxide and volatile metabolic compounds, by free thermal convection. Figure 3 shows temperature as well as the concentration of oxygen and carbon in the exhaust air of a dome versus the time of composting. It can be seen that the aeration system restricts the exhaust air temperature to less than some 70 °C–75 °C, especially in the starting phase of the composting process. This substantially reduces the risk of the digestion overheating and inhibiting. Even in the critical phase of intensive digestion during the first 5 days, oxygen can be held well above 10 volume-% and carbon dioxide below 8 volume-% (except for the very first day). This reduces significantly any retardation or inhibition of aerobic digestion

(BRUMMACK et al. [4]). With the elapse of time, the compost bioactivity (oxygen demand, carbon dioxide generation and temperature) is reduced. Easily degradable organics are consumed and only some more persistent organics are available. The composting process is retarded and the material is going to be stabilized.

Table 1

Characteristic parameters of MBWT process

Parameter (waste material or leachate)	Start value	After 4–9 months
Ignition loss [percent by weight]	55	20–30
Moisture content [percent by weight]	adjusted to about 45	32–38
Bulk density of waste [t/m^3]	0.6	1.3–1.8
Total organic carbon (TOC) [mg/dm^3]	> 300	100–300
Conductivity [mS/cm]	2.0	1.5
pH value	7.5	7.5
Cadmium [mg/dm^3]	< 0.02	< 0.02

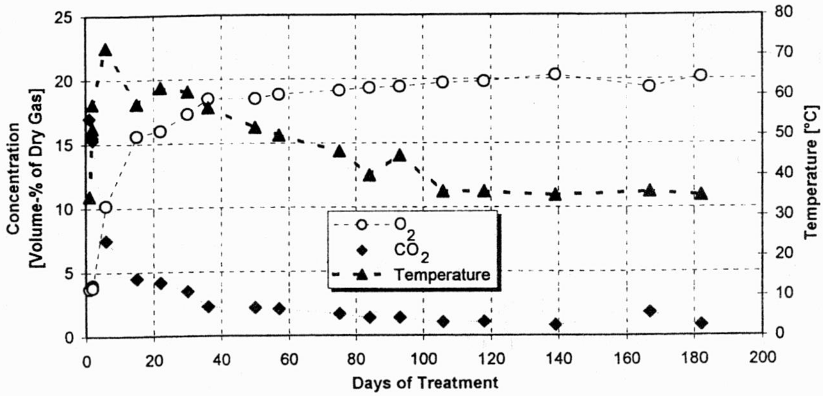

Fig. 3. Temperature, oxygen and carbon dioxide contents in exhaust air of an MBWT aeration dome

Even with those enhanced aeration and degradation rates the emission problems are not made worse. All windrows are covered with a layer of fine material which is the finer product (< 30 mm) of sieving after the composting process. It acts as a temperature and moisture regulator, and additionally as an emission trap and a biofilter. Thus, only in the starting period we have observed higher emissions, compared to the emissions from a landfill sector in the same area with freshly disposed material (WOTTE et al. [10]). A number of volatile halogenated and non-halogenated hydrocarbons (VOC, BTEX) have been detected in the windrow emissions (table 2). All measurements proved that in the case of all relevant toxic compounds (e.g. trichlorotrifluoroethane and tetrachloromethane as the most toxic substances of class I), the maximum emissions (of about 10.4 mg/m^3 for the compounds mentioned) were well below the permissible German limits (which is 20 mg/m^3 for class I). They decrease strongly with composting time for the MBWT process, whereas the landfill emissions remain the same (4–8 mg/m^3 for class I) or increase only slightly.

Table 2

Maximal measured emissions during MBWT process

Substance class	Substances	Maximum concentration (mg/m^3)		Mass flow (kg/h)	
		Measured	German limit	Calculated for about 50,000 t/a	Minimal flow for German concentration limit
I	trichlorofluoromethane, trichlorotrifluoroethane, tetrachloromethane	10.4	20	0.03	0.1
II	1,1-dichloroethane, trichloroethene, toluene, ethyl benzene, *m*-, *p*-, *o*-xylene	5.4	100	0.05	2
III	dichloromethane, trans-1,2-dichloroethene, cis-1,2-dichloroethene	3.5	150	0.04	2

Also the odour problem is not so troublesome as within the conventional landfill area (table 3). In this case, the nuisance is caused especially by volatile anaerobic digestion products of untreated and unstabilized waste. Hydrogen sulfide and other organic sulfur compounds like mercaptans, as well as organic acids like butyric acid are the main compounds responsible for landfill odour. All these substances are not generated under a strict aerobic regime. That is why a proper MBWT process drastically reduces odour emissions. The corresponding odour measurements according to German standards were carried out during the application of MBWT process for a period of 50 days (HOLZBAECHER [6]). The maximum odour emissions (the 4th day of starting an intensive phase of composting) are much smaller than those from a landfill area of equal surface area of about 405 m^2 (7 compared with 31 million relative odour units per hour).

Table 3

Maximum concentrations of odour substance (in relative odour units (ROU) per m^3) for MBWT windrow (4th day of composting) and landfill sector of the same surface area of 405 m^2

	Odour concentration (ROU/m^3)		Total emitted flow of odour substance (10^6 ROU/h)
	Surface	Aeration domes	
Windrow with aeration domes and cover of fines	28	582	7
Landfill sector with freshly disposed waste	132	–	31

Though the windrows are constructed directly on a landfill site, there is always the problem of leachate, especially during flooding, even if they have a basement lining. Because of the intensive composting and evaporation losses, generally the net water demand is larger than the intrinsic water generation by the composting process and the average precipitations. Instead, an average process water demand of about 0.7 (up to 2) mm/d for the windrows could be calculated and measured from long-term precipitation and air humidity values (TURK [9]).

4. SUMMARY AND CONCLUSIONS

Based on all practical results and the experience of about four year field testing and two year practical field application, it can be concluded that the presented simple low-cost MBWT windrow process significantly improves disposal characteristics and reduces the risk of landfill. This is almost possible with any additional equipment other than usual disposal machinery. The related emissions are very limited and well below the German emission standards. With the exception of the first intensive composting phase of about 5 days, the emissions are smaller than those from an equivalent landfill surface area. By doubling the compaction density of waste, disposal space is saved. Thus, besides the ecological advantages, the process may even generate an economic profit. Therefore this simple process is applicable in a transition period, while implementing an appropriate waste treatment technology and meeting disposal guidelines. With some modification the process can easily be integrated into a sound management concept using both biological and thermal waste treatment.

Studies of aerobic decomposition of waste in a composting drum could remarkably improve the stabilization effect. Furthermore, the process can be integrated into a sound waste management concept prior to incineration. However, the process duration should be decreased to minimize the loss of calorific value. One major goal of corresponding investigations will be the test of the application of an intensive composting to reduce the waste moisture content before a consecutive thermal treatment.

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MECHANICZNO-BIOLOGICZNA STABILIZACJA ODPADÓW METODĄ NAPOWIETRZANIA

Wysypiska odpadów stałych są niezbędnym ogniwem systemu gospodarowania tymi odpadami, które nie mogą być recyrkulowane. Jednakże wysypiska działające w przeszłości i częściowo czynne i dziś stwarzają wiele problemów. Przede wszystkim odpady rozkładane w procesach beztlenowych powinny być unieszkodliwione, zanim będą składowane. Budowa zakładów termicznej przeróbki odpadów trwa długo i dużo kosztuje. Dlatego niezbędne są skuteczne rozwiązania przejściowe. Biologiczna stabilizacja odpadów może być efektywna nawet wtedy, gdy korzysta się z prostej technologii. Od 1994 r. na wysypisku odpadów we Wschodnich Niemczech przeprowadza się polowe testy opierające się na mechaniczno-biologicznej przeróbce odpadów. Kompostowanie odpadów odbywa się w otwartych pryzmach usytuowanych bezpośrednio na terenie składowiska. Konwekcyjne samonapowietrzanie może odbywać się dzięki odpowiedniej konstrukcji pryzm i zastosowaniu specjalnych urządzeń napowietrzających. Dodatkowe instalacje napowietrzające nie są potrzebne. Obecnie ta technologia jest stosowana również na innych wysypiskach, na których składuje się odpady innego typu. Jedną z podstawowych zalet tej metody są jej niskie koszty. Wydaje się, że ta technologia może być wykorzystana na wysypiskach Wschodniej Europy.