

# إدارة مطامر المخلفات الصلبة

proceedings

## LANDFILL MANAGEMENT



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إدارة مطامر المخلفات الصلبة في سورية

WORKSHOP  
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## Landfilling as a Necessary Element of modern Sustainable Waste Management

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Every year, millions of tons of materials are being exploited from the earth crust, and processed into consumer and capital goods. After decades to centuries, most of these materials are „lost“. With the exception of some pieces of art or religious relics, they are not engaged in the consumption process anymore. Where are they?

This question is both of economic and environmental relevance. Except for gold, plutonium and a few others, we do not know the answer. It is amazing, how little is known about the *metabolism of the anthroposphere*, a newly emerging discipline relevant to environmental science and pollution control. In order to make best use of materials and to prevent long-term environmental pollution, comprehensive information is needed about the flows of materials into, within and out of the anthroposphere. In particular, it must be ensured, that only such flows leave the anthroposphere, for which there are appropriate final sinks available. Compared to the well known millions of tons of minerals exploited from the earth crust, the amount of corresponding materials which have been disposed of in appropriate final sinks is hardly known and estimated to be quite small.

For future materials management in view of resource conservation and environmental protection, the following first assessments of today's anthropogenic metabolism have to be taken into account:

- The rate of anthropogenic utilization of many materials exceeds the natural, geogenic flow rates of erosion and weathering. This rate is still increasing despite global recession and efforts of „dematerialisation“. Thus, regionally and in some cases even globally, the large man made flows interfere with geogenic flows and stocks. It can be assessed, that for some materials, the limits to consumption are set rather by the need for dissipation and for appropriate final sinks for the residues than by the scarcity of the resources. Examples are carbon and the corresponding greenhouse gas CO<sub>2</sub>, CFC's and the depletion of the stratospheric ozone layer, the use of lead in gasoline and others.
- Because of the introduction of cleaner production, emissions from final consumption are becoming *relatively* larger than emissions caused by production activities. In the long run, the abatement of emissions from consumption processes will appear more important and more difficult than from production processes. This is due to their non-point source character and because of the need for completely new systems, e.g. for energy supply, transportation or surface protection.
- The input of goods into the anthroposphere is much larger than the output, resulting in a rapidly growing stock of materials in urban areas. Today's emissions to the environment (including wastes) are small when compared to the input into the anthroposphere. Most materials, which have been exploited in the past centuries, are still „hibernating“ somewhere in the anthroposphere. This huge stock will have to be managed carefully, because the potential for future flows to the environment as well as for future resources is high. An example of this large stock is, that even after twenty years of prevention and avoidance strategy, the amount of heavy metals flowing through urban waste management is still the same.

In summary, a first rough answer to the question posed in the first paragraph is, that most of the materials ever exploited are still within the anthroposphere. They will be determining our future as resources as well as pollutants, too. If the bulk of these materials is dissipated to

water, air and soil instead of being transported to appropriate final sinks, the future loadings of the environment will be unacceptably large and increasing.

As a consequence, a new material management is needed. Environmental science must become an essential part of material science. Ecological evaluation of materials should include potential changes in the speciation during the life-time of a product as well as during storage of the material in the intermediate or final sinks soil, sediment and landfill. They both may change considerably over long time periods due to natural as well as anthropogenic impacts, e.g. acidification and eutrophication. Hence, a sink may not be a final sink in long-term perspectives!

The new goals for the design of products, processes and systems are, that only three kinds of residues are generated: „Clean“ products for recycling, sustainable emissions (which eventually will be mineralized or transported to final sinks), and residues with final storage quality. All stocks and pathways including dissipative flows and waste flows, flows to intermediate sinks etc. have to be taken into account in future design. Decisions about material alternatives can be taken only if the fate of a material from the source to the final sink is known. Analysis and modeling of total material flows and stocks for long time periods needed. The search for the final sink for all materials used in goods, processes and systems will be an important design consideration. If no appropriate final sink can be assigned to a material, it should be phased out and replaced.

Recycling is only an intermediate solution for such materials. It does prolong the residence time in the anthroposphere, but for thermodynamic reasons, recycling cannot prevent the final need for an ultimate sink. Recycling can be an excellent means to reduce the overall environmental impact of those materials, for which an appropriate sink can be assigned to. The primary production of a material is usually the most energy and materials intensive step in a production chain. Thus, the increase of the use of a material by extending the lifetime and/or by recycling can decrease both emissions and the need for new primary energy and materials, as well as the need for final sinks. So far, recycling has been looked at from a process technology point of view. In future, it has to be integrated on a large scale into the design of new goods and systems. The minerals in a modern urban system can be extracted efficiently only if there is information available about the density and location of these minerals. As in geological exploration of natural resources, specific tools are needed to identify and locate valuable „urban ores“. Future urban areas may well develop their own methods to design and manage their material resources, including appropriate final sinks.

The most important “final sink” for many materials are landfills. It is one of the main objectives of sustainable waste management to direct materials that cannot be recovered to such landfills. However, ordinary landfills containing municipal solid wastes (MSW) are not final sinks (see papers by Döberl and by Fellner), they leach materials such as organic carbon compounds, nitrogen compounds, salts and under certain circumstances heavy metals for very long time periods (>1000 years). In order to become a “final sink” (or “final storage landfill”, as they are sometimes called), a landfill has to fulfill the following prerequisites: 1. Wastes have to be mineralized and transformed prior to landfilling so that they become immobile, non-soluble, “stone-like” materials that cannot be transformed to soluble substances in a landfill environment. 2. The landfill has to be located in an area that is not subject to heavy erosion or other geological and tectonic activity. Such “final-storage” landfills are able accommodating pollutants and residues that either cannot be recovered or that are products from waste management not suitable to enter a next economic cycles. These landfills are a necessity for any modern economy since these economies are based on the production and utilization of hazardous materials, too, and since these dangerous materials have to be disposed of safely and environmentally sound.

# **Ideal Feature of Landfill in Recycle Oriented Society - Japan's Strategy -**

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## **ABSTRACT**

"The Basic Law for Establishing the Recycle-oriented Society" was enacted in May 2000 in order to change Japan to the Recycling-based Society in the 21st century. Quantitative national target regarding reduction of waste disposed of into landfill has been set clearly. Hereafter, various attempts will certainly be made for achieving it. However, waste to be disposed of into landfill will never be eliminated completely, so landfill will exist as an indispensable infrastructure even in recycle-oriented society. As a matter of fact, to construct landfill has been becoming extremely difficult in Japan, today. This is because severe opposition from resident always arises despite the condition that candidate site is limited. Dealing with current situation by conventional concept of landfill is no longer promising. A drastic paradigm shift is requested to us. The landfill research group in Japan Society of Waste Management Experts (JSWME) conducted a research aiming at establishing future concept of landfill suitable for recycle-oriented society. This report is intended for introducing outline of the research. Therefore, after showing current state of waste management in Japan, various issues we are facing now are explained. Then, important conditions that future landfill should fulfill are provided, and new concept of landfill proposed in this research is presented, finally.

## **1. INTRODUCTION**

The waste problem had become a big social issue in the end of 20th century in Japan, because many unfavorable incidents became obvious, such as illegal dumping of industrial waste, improper waste treatment, emission of dioxin from incinerator, suspicion of leachate leakage from the controlled-type landfill site, etc. These incidents made the construction of waste management facilities more and more difficult. Especially, siting new landfill has been put in an extremely difficult situation because of severe opposition from residents. Although waste generation has been maintained at almost constant level in a last decade, capacity of disposal site hardly increased. It was serious situation that there is only tiny exit for huge amount of wastes generated. Interim measures of minimizing and stabilizing wastes by advanced treatment technologies has been taken. However, these countermeasures were quite costly. The issue was not settled fundamentally, better solution had been desired.

With this situation as a turning point, "The Basic Law for Establishing the Recycle-oriented Society" was enacted in May 2000, in order to change Japan to the Recycling-based Society in the 21st century. It aimed to switch social system of Japan from the society of mass production, mass consumption, and mass disposal, to the society of appropriate production, appropriate consumption, and minimum disposal. In this Law, the first priority is awarded to reduce of waste production. If production of wastes is not avoidable, wastes are regarded as recyclable resources. Then reuse and recycling of them are given second priority. If it is not possible to reuse/recycle, recyclable resources have to be appropriately disposed of at suitable treatment/disposal facilities. This appropriate disposal is located at third priority. Such hierarchical concept is almost the same as the fundamental strategy of some other developed countries.

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Ideal Feature of Landfill in Recycle Oriented Society - Japan's Strategy -

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Because the lack of landfill capacity is major issue particularly in Japan and landfill tends to be considered as environmental burden, reduction of the amount of wastes going into landfill is recognized as one of the most important problem so that quantitative national target was set. In the past few years, the amount of waste disposed of in landfill tends to decrease gradually. However, it is evident that entirely vanishing wastes from our world is not possible even if its reduction is promoted along the national target, because some residues are inevitably generated. In that case, how can we procure requisite landfill capacity? By what means can we sweep away negative image held by citizen? What type of landfill is suitable for managing the wastes generated from recycle-oriented society? In order to answer these questions, it seems to be necessary to establish new concept of landfill different from conventional one. It may perhaps include proposals for up-stream industry, or requests of revolution to whole waste management system, because the system should be optimized for fulfilling the condition of sustainability.

Landfill research group in Japan Society of Waste Management Experts (JSWME) had set "Ideal feature of landfill in Recycle-oriented society" as a theme of research project in order to find the solution to various problems now we are facing. And the project was carried out from 2002 to 2004 by Japanese experts engaged to landfill. This report is intended to introduce some parts of the project.

## 2. CURRENT STATE OF SOLID WASTE MANAGEMENT IN JAPAN

In this section, definition of solid waste and classification of landfill is described first, because this information seems to be indispensable for understanding the current situation in which we stand. Then, generation of waste, trends of waste treatment, and situation of final disposal are explained, based on statistics of Japan Ministry of the Environment.

### 2.1 Definition of solid waste

By the Law, solid waste is classified into two categories; 1) Municipal waste, or General waste, and 2) Designated industrial waste (DIW). The latter consists of 19 kinds of solid waste generated from industrial activity and a stabilized waste of them for final disposal. Municipal solid waste (MSW) consists of household waste, city cleansing waste and business waste other than designated industrial solid waste. The classification of MSW is different in each municipality. But typical classification is shown in Figure 1.

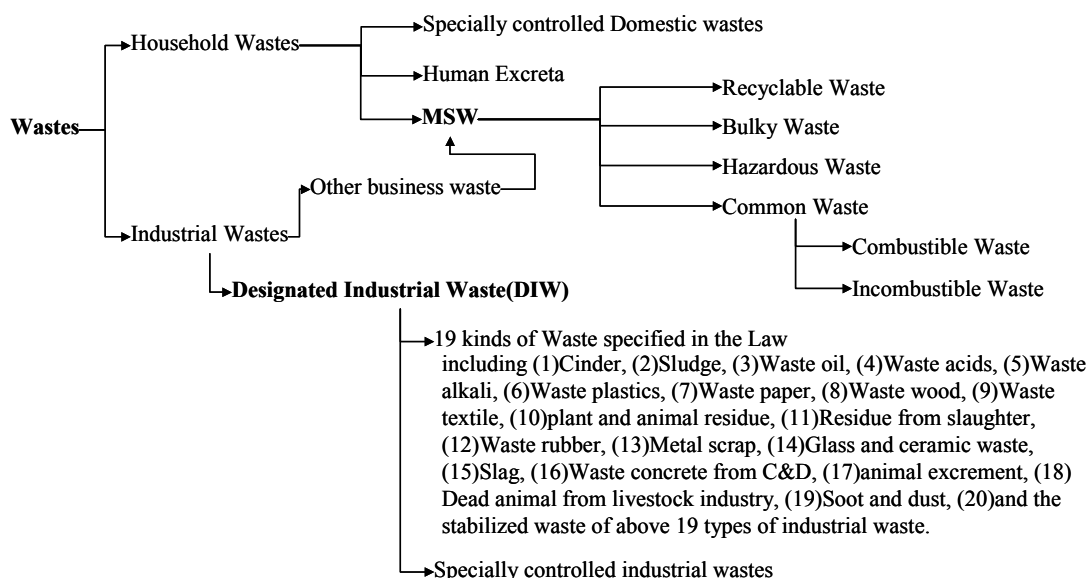


Figure 1 Classification of solid waste in Japan under the "Waste Management and Public Cleansing Law"



## 2.2 Classification of Landfill

There are three types of landfill in Japan according to the degree of control: Least controlled type (Type-1), Controlled type (Type-2), and strictly controlled type (Type-3). Although each landfill is not numbered in the Law, I assigned number to each for facilitating identification.

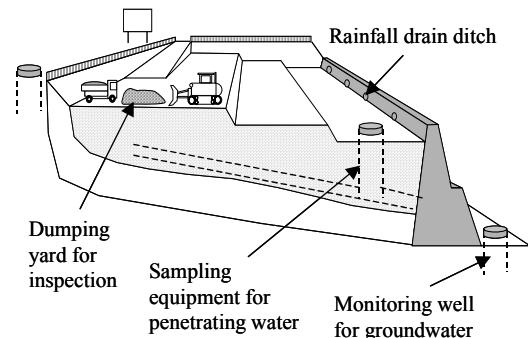
As mentioned above, there are almost 20 categories in industrial solid waste. It is defined that each of them has to be disposed of into specified landfill. Among the 20 kinds of the DIW, five kinds of wastes are specified as having stable/inert characteristics in the Law. Only this kind of wastes is permitted to be disposed of in the least controlled site (Type-1). On the other hand, DIW, which has hazardous characteristics, has to be disposed of in the strictly controlled landfill (Type-3). Hazardous characteristics of the wastes are judged by acceptance criteria (Table 1) of Type-2 by conducting the leaching test (JLT-13). Other industrial waste and municipal solid waste are landfilled in the Type-2. Required structure, operation method, and monitoring protocol are regulated by technical standard for each type, respectively. Figure 2 shows the conceptual diagram of each type of landfill. The outlines of each landfill are as follows.

Table 1 Acceptance criteria of waste for the controlled site (Type-2)

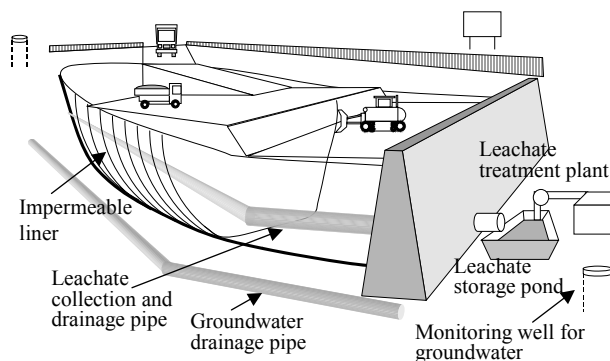
Element/Compound	Limit value Unit: mg/L
Alkylmercuric compound	N.D
Mercury	0.005
Cadmium	0.3
Lead	0.3
Organic phosphorous	1
Cromium(VI)	1.5
Arsenic	0.3
Cyanide	1
Polychlorinated biphenyl	0.003
Trichloroethylene	0.3
Tetrachloroethylene	0.1
Dichloromethane	0.2
Carbon tetrachloride	0.02
1,2-dichloroethane	0.4
1,1-dichloroethane	0.2
cis-1,2-dichloroethylene	0.4
1,1,1-trichloroethane	3
1,1,2-trichloroethane	0.06
Dichloropropen	0.02
Thiuram	0.06
Simazine	0.03
Thiobencarb	0.2
Benzene	0.1
Selenium	0.3

### Type-1: Least controlled landfill

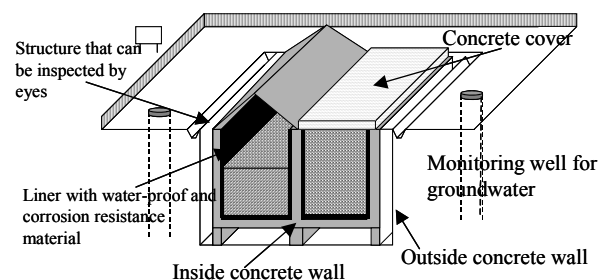
Since inert and non-hazardous wastes are disposed of and they are supposed not to cause any pollution, the least controlled landfill does not have to equip leachate collection and treatment system. Moreover, they don't have to equip lining system. The following wastes are allowed to be disposed of in this type of landfill: i) Waste plastics. ii) Waste rubber. iii) Waste metals. iv) Waste glass and ceramics. v) Waste concrete from C&D work. A dumping yard to inspect waste characteristics has to be provided to check wastes. Inside pore water and outside groundwater should be analyzed on a regular basis to monitor the impact on environment. Wastes from C&D work of which IL exceeds 5% is also prohibited for landfilling.



Type-1: Landfill for inert (stable) DIW, (Least controlled site)



Type-2: Landfill for non-hazardous DIW and MSW, (Controlled site)



Type-3: Landfill for hazardous DIW, (Strictly controlled site)

Figure 2 Conceptual diagram of each type of landfill

### Type-2: Controlled landfill for non-hazardous waste (MSW landfill)

In this type of landfill, solid waste, which is non-hazardous but results in organic burden, can be disposed of. Leachate collection and treatment is required whether or not there is a chance of water pollution. Wastes which fulfill the acceptance criteria (Table 1) is allowed for landfilling. If it exceeds the criteria even in no more than one item, the waste has to be disposed of in Type-3. It is also necessary to equip the lining system and gas ventilation pipes. Furthermore, leakage detection system is usually installed at recent landfill. Because the disposal of wastes containing organic substance is allowed, semi-aerobic structure that is thought of as suitable for early stabilization is widely used in Japan. When active operation period comes to an end, landfill will be closed. However, post-closure care is obligated. During post-closure care period, ordinary maintenance is continued, and leachate constituents, gas composition and temperature within landfill have to be monitored. If these indices fulfill the criteria for terminating post-closure care, maintenance will be allowed to cease. However, it will be designated as "specified land which used to be a landfill" by the Law. Hence, regular use will be restricted. As a matter of fact, it is considered that this principle is one of significant causes making siting of new landfill difficult.

### Type-3: Strictly controlled landfill

Strictly controlled landfill is a landfill to be isolated from water body and ground water because waste contained in this type of landfill has hazardous characteristics. There is a controversy over whether strictly controlled landfill is a landfill or not. Wastes contained in this type of landfill will not be stabilized. Long-term maintenance is necessary to prevent the occurrence of risk. Therefore, there is strong opinion that the strictly controlled landfill should be considered as temporary storage.

## 2.3 Current situation of waste management in Japan

Hereinafter, recent trend of generation and treatment of MSW and DIW are described, respectively.

Trend of Municipal Solid Waste (MSW) generation and proportion treatment is described in Figure 3.

Generated amount of MSW has been kept at almost 50Mt/y, which is corresponding to 1.1kg in per capita per day basis. And from this figure, it can be said that nearly 80% of MSW is incinerated and this level has slightly increased during the last 13 years. The proportion of direct landfilling has been decreased from 20% in 1989 to 4% in 2002 on the one hand. In contrast, the proportion of recycling increased. This tendency is thought of as affected by the enforcement of various recycling Law.

Figure 4 indicates the trends of generated amount of DIW and proportion of treatment/disposal.

Generated amount of DIW has been also kept at 400Mt/y for last decade. The quantity of DIW is almost eight times to that of MSW. As for treatment/disposal of DIW in fiscal year 2002, 45% were put into recycling process, another 45% of them diminished through

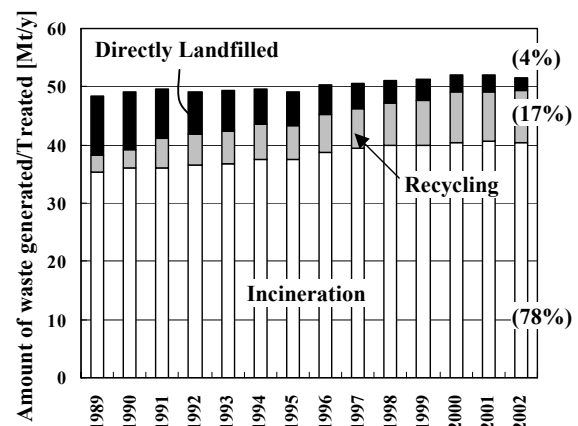


Figure 3 Trend of Municipal Solid Waste (MSW) generation and proportion of major treatment

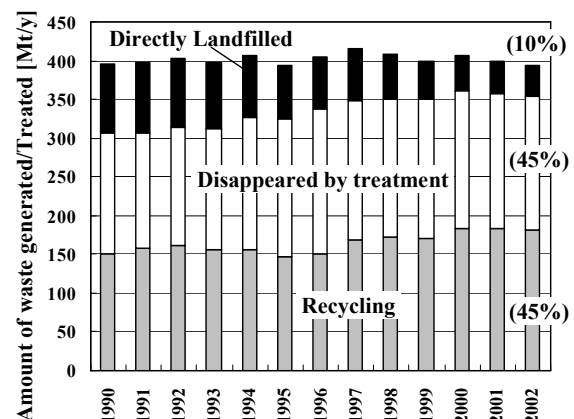


Figure 4 Trend of Designated Industrial Waste (DIW) generation and proportion of major treatment

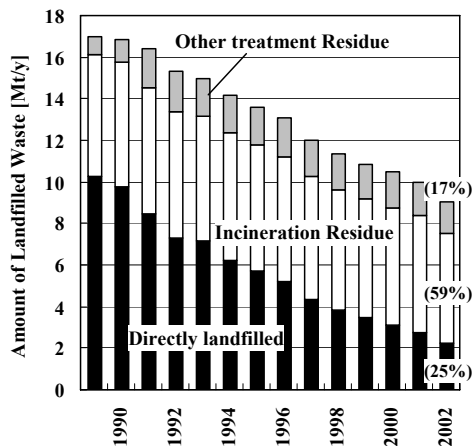


Figure 5 Amount of MSW landfilled and its components

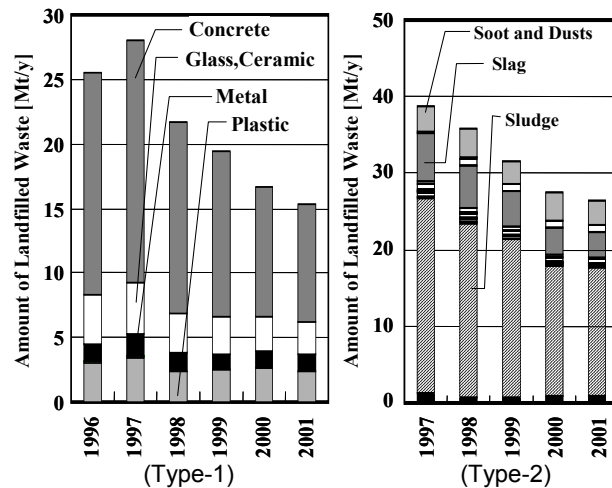


Figure 6 Amount of DIW landfilled and its components

various treatment processes such as dewatering, drying, incineration, etc., and remaining 10% were disposed of in landfill directly.

The total amount of landfilled MSW has decreased gradually from 1989 as shown in Figure 5. Especially, decrease of direct landfilling is notable, in contrast to the quantity of incineration residue that has been kept at constant level (almost 5-6Mt/y). As described hereinbefore, industrial wastes are designated to be disposed of in specified type of landfill by each item. Figure 6 shows the composition of DIW disposed of in Type-1 and Type-2 landfill each other. The total amount of waste disposed of in both landfills tends to decrease for the last few years. In Type-1, concrete accounts for 60%. And waste glass/ceramic and waste plastic account for 15% in 2001, respectively. In Type-2, 60% of landfilled waste is accounted for by sludge, and the remaining majority is soot/dust and slag. When paying attention to the amount of waste landfilled, both MSW and DIW has become half within the last 15 years, though the amount of waste produced has been maintained at the same level. This fact indicates that promotion of recycling and various intermediate treatments brought about some advantages to the reduction of landfilled waste. However, the remaining capacity of landfill is 12 years for MSW and 4.5 years for DIW as shown in Figure 7.

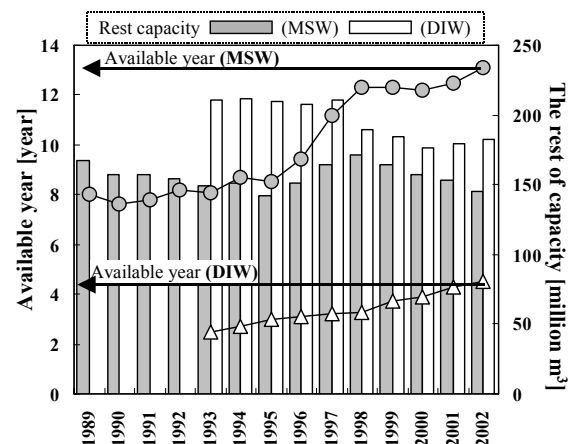


Figure 7 Available year and remaining capacity of landfill

### 3. ISSUES THAT WE ARE FACING NOW AND WILL FACE NEAR FUTURE

The deficiency of landfill capacity is critical situation. But available land for siting new landfill is limited in Japan because land area is narrow. Moreover, due to severe opposition from residents, we can hardly have prospects that we will be able to keep on securing landfill in future.

Since the conventional landfill is no longer applicable to tackle current situation, we may need to convince ourselves that now we are being urged to review it. Therefore, to advance toward the promising future, it is necessary to establish new concept of landfill. In order to go for it, first of all, we have to identify the structure of the problem we face now, and find a clue for solving problem. The one is to estimate how much capacity we should secure practically in the future. And the other is to reflect on the reason why creating new landfill has become so difficult. Hence, in this section, constitutive problems are assembled from four points of view: 1) Quantitative problem, 2) Public concern, 3) Quality of wastes landfilled, and 4) Costs.

### 3.1 Quantitative problem

In March 2003, the Government of Japan established "Fundamental Plan for Establishing a Sound Material-Cycle Society" in accordance with the Basic Law. It sets forth three quantitative targets as shown in Figure 8. As for the reduction of landfilled waste, it declares that the Final Disposal Amount should be about 28 million tons in the year 2010 (almost 50 percent reduction from about 56 million tons in the year 2000). In addition, the interim report presented by 'Council on Economy and Fiscal Policy' indicated further target of decreasing the amount of final disposal to 1/10 (almost 5.6 million tons) until the year 2050. However, even if the amount of landfilled waste is reduced along the target, it is easily predictable that it won't vanish completely. Required capacity can be calculated as shown in Figure 9, assuming that landfilled waste will decrease along the lines of the target. Lines in the Figure 9 indicate that the capacity of 240Mm<sup>3</sup> for MSW and that of 890Mm<sup>3</sup> for DIW need to be ensured until the year 2050. At present situation, the remaining capacity is 145Mm<sup>3</sup> for MSW landfill and 180Mm<sup>3</sup> for DIW landfill. Landfill for industrial wastes is absolutely scarce.

<b>(1) Resource Productivity = <math>\frac{\text{GDP}}{\text{Total Input of Natural Resources}}</math></b>	
<b>=&gt; increase to \$3,714 / t (2,870 euro) in 2010 (40% up)</b> <b>(RP = \$2,000/t in 1990, \$2,667 in 2000)</b>	
<b>(2) Resource Recycling Rate = <math>\frac{\text{Amount of Recycle}}{\text{Total Input of Resources}}</math></b>	
<b>=&gt; increase to 14% in 2010 (4% up)</b> <b>(RR = 8% in 1990, 10% in 2000)</b>	
<b>(3) Quantity of Final Disposal</b>	
<b>=&gt; Decrease to 28 million tons in 2010 (to make it half)</b> <b>(110 million tons in 1990, 56 million tons in 2000)</b>	

Figure 8 Three quantitative national target set by "Fundamental Plan for Establishing a Sound Material-Cycle Society"

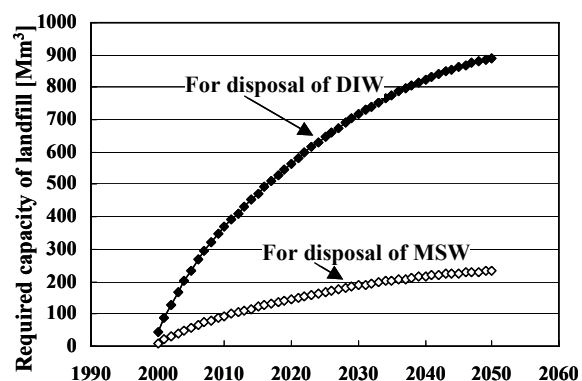


Figure 9 Requisite landfill capacities until the year 2050

### 3.2 Public concern

Limited siting space is a major issue for constructing a new facility, and social opposition by neighbors is another. Particularly in Japan, where SWM (Solid Waste Management) facilities are usually located not far from residential areas, opposition of residents is vitally significant in siting new facilities. Essentially, such opposition is originated from demand for better environmental quality of people. But adverse sense (NIMBY) held by them is also underlying as a principle cause. Above all, important fact as background is that landfill is disfavored from residents. So, the study to investigate structure of resident's attitude was done. The result of questionnaire survey regarding the image of residents toward landfill is explained here as an example (Figure 10). The survey was conducted to investigate difference of image toward incineration facility and final disposal site. In the figure, items in both upper and lower horizontal axis indicate terms associative from these facilities. Terms at upper axis and lower axis have opposite meanings, each to each. The term in upper axis has relatively positive image but it in lower axis has negative image. From

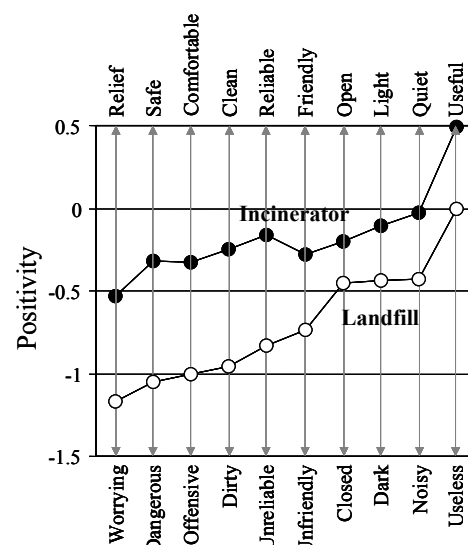


Figure 10 Image of SWM facilities held by residents

this figure, it is obvious that the impression of landfill is rather negative for whole item compared with incineration facility. And residents have images of worrying, dangerous, offensive, dirty and unreliable with regard to landfill.

We have to perceive that changing present image of landfill and dispelling people's concern are indispensable to increase people's acceptance level if we intend to build landfill further. To that end, not only to elucidate the safety of landfill scientifically but also to make landfill secure by freeing people from their anxiety has great importance. And condition of "secure" must be recognizable by people intuitively.

### 3.3 Quality of wastes landfilled

The Soil Contamination Countermeasures Law was promulgated in 2002. This Law stipulates that the soil, which can't meet the environmental standard of soil, is regarded as "Contaminated Soil" and the land containing contaminated soil is registered as "Specified Land". And it also stipulates that, if the soil is suspicious to endanger human health or environment, appropriate countermeasure must be taken. Judgment on whether the soil is contaminated or not is determined by its leaching characteristics and its content, so that there are criteria for both eluate and content. Table 2 indicates the criteria regarding the content.

*Table 2 Soil environmental standard (content)*

	(mg/kg)
Cadmium	150
Chromium(VI)	250
Cyanide	50
Mercury	15
Selenium	150
Lead	150
Arsenic	150
Fluorine	4000
Boron	4000

Landfill has been driven to the wall by these criteria, especially concerning content. Because, in contrast to the expectation on which eluate criteria will be satisfied (i.e. emission will adequately decrease over the long-term), landfill is likely to not comply with criteria regarding content. For that reason, final disposal site is not subject to this Law as long as it is controlled as waste landfill (i.e. it is considered to be separated from natural environment). But this paradoxically means that landfill has to "eternally" be controlled and be separated from the natural environment, for not being identified as "Specified land".

This caused heated debates on whether disposing of wastes in landfill is the same as creating contaminated land or not, when thinking about the state of landfill having terminated aftercare. As for this regard, it can be said that fundamental problem comes from quality of waste. In addition, people's anxiety is also caused by uncertainty of quality of wastes, such as what waste is disposed, what substances are contained in landfill, and how much they are contained. Namely, quality of wastes disposed of is significant from the viewpoint of both soil contamination and people's concern.

There are statistics on how much waste of each category disposed of. However, there are not any information about kinds of substance being contained in wastes and overall amount of these substances flowing into landfill. What substances and how much of them are flowing into landfill should be clarified.

In this project, to grasp quantity of substance flowing into landfill, quality of every kind of wastes was investigated at MSW landfill, and Type-1 and Type-2 of DIW landfill. Landfill of Type-3 for DIW was not targeted. In the survey, special attention was paid on organic content and metallic content. First, every kind of wastes was sampled at each landfill, and then analyzed on physical composition, ignition loss, elemental composition, metallic content, and leaching amount. After representative value of each category was obtained, overall amount of substances flowing into landfill was calculated by multiplying analytical value to the amount of wastes. In this report, only the results regarding metal content are explained.

Figure 11 shows metal content in waste disposed of in three MSW landfills. The data was obtained from dividing the total quantity of each metal flowing into landfill by total amount of waste disposed of. The total quantity of each metal was calculated by summing up each product of metal content of each waste and the amount of each waste disposed of. In order

to seize the difference between wastes and natural soil, Clarke Number corresponding to metal content of earth crust was plotted. From the result, the following character were identified: (1) Content of Ca, Fe, Al, Na, Mg, and K is almost the same as Clarke Number, (2) Zn, Cu, Pb, Cd, and Se contained in wastes are one to two order higher than Clarke Number, and (3) Content of Sb in landfilled waste is three order higher than Clarke Number.

Metal content in DIW landfill are shown in Figure-12. These results were obtained by the same manner as MSW landfill. The patterns look similar to the result of MSW landfill. That is to say, alkali metals and some metallic elements, which are major components of soil such as Fe and Al, are contained at same level in both wastes and soil. However, hazardous metals, such as Zn, Cu, Pb, and Sb are contained much in landfilled waste. Their contents in Type-1 are slightly higher than that in Type-2, although least control is only required in Type-1. These results imply that landfill, in which now we are disposing of waste, will be what is different from ordinary soil. This can be said in common for both types of landfill.

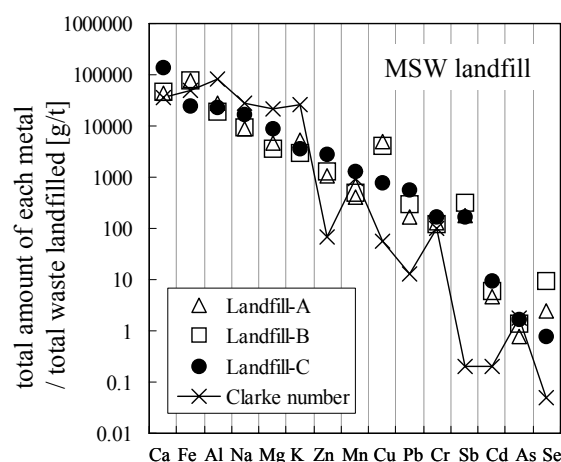


Figure 11 Metal content of landfilled waste disposed of in three MSW landfill

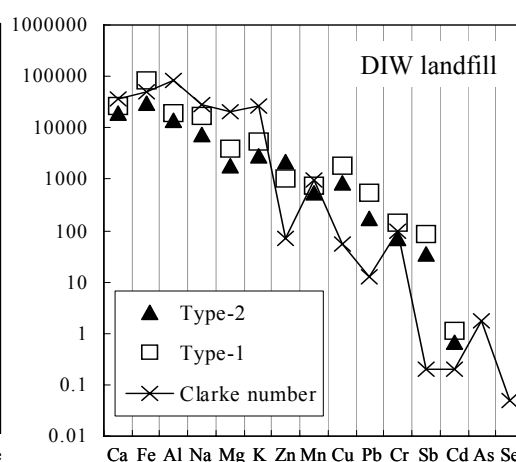


Figure 12 Metal content of landfilled waste disposed of in DIW landfill

Each landfill type was defined by taking into account active phase of the landfill including operation phase and aftercare phase. Also, kinds of wastes acceptable for each landfill as well as technical standards for operation procedure were defined from the thought of minimizing environmental impact during the life of landfill. In other words, they were not basically defined from the viewpoint of future prospects. Namely, definition of landfill was to have had to be established with taking into account the aspect of when landfill ultimately end its life. Waste landfill is not a transient facility, but will be to remain at that place forever.

In the past when every waste was to have been assimilated to soil, end of life of landfill meant reacquisition of natural land. However, today, many wastes are different from soil so that assimilation of them into soil is hardly expected. Therefore, we have to reconsider definition of landfill in combination with characteristics of waste that should be disposed of.

### 3.4 Cost

An environmental impact assessment (limited to air, water pollution, odor, noise, and vibration) has been mandatory for all landfills regardless of size since 1997. For environmental protection, "The standard of landfill structure and maintenance" was revised and became stricter. Effluent quality must be lowered enough than standard and higher performance is required in order to receive a subsidy from the government. As consequences, construction costs have soared recently as shown in Figure 13.

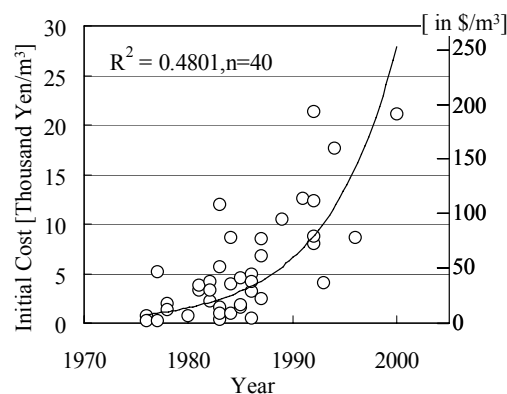


Figure 13 Increase of initial cost as for MSW landfill (Type-2)

Administrative and maintenance expense is also going up with increase of construction cost. Therefore, the charge for disposing of waste in landfill is soaring. For example, it costs from 10,000 yen to 40,000 yen (\$90-\$360) at landfill of Type-1 for disposal of 1 ton of waste. And it costs more in Type-2: from 20,000 yen to 50,000 yen (\$180-\$450) for 1 ton of waste. This charge has to be paid by person who brings wastes to landfill. As results, such a sharp rise of disposal charge has caused illegal dumping.

#### 4. CURRENT MOVEMENT

Various measures are being taken to contend with serious situation explained hereinbefore. In this section, current movements of these countermeasures are outlined.

The crucial deficiency of landfill and severe opposition from residents for construction of new landfill are forcing us to choose the following two alternatives: 1) To provide over-instrumented landfill, 2) To eliminate waste to be landfilled. Both approaches are being taken nowadays.

##### 4.1 Feature of landfill recently accepted by residents

From the planning phase at when explanation to local residents is mandatory, there is no hope for conventional type of landfill to receive acceptance from residents. Thus, recent landfill has to be heavily-loaded facility, such as to install over-tight liner system, to equip excessive-stringent monitoring system, and to have a roof and wall made of steel. Figure 14 shows external and internal view of facility with roof, so-called "Closed system landfill". The number of this type of landfill is increasing little by little at the place where demand for environmental conservation is high. Kinds of wastes disposed of are not hazardous one but ordinary waste commonly disposed of in Japan, such as incineration residue, shredded residue, etc. The disposal site of this type is aiming at decreasing environmental burden by covering the site with the roof and the artificial ground so as to form the closed space from the surrounding. The feature is to promote waste stabilization and to wash off constituents contained in waste by supplying artificially controlled rainfall. Moreover, it is said that the upper part of the facility is available for various applications even when landfill work is in operation. Figure 15 shows conceptual diagram.

Figure 16 shows state of the art lining system which is comprised of seven geosynthetic liners. Nowadays,



Figure 14 External and internal view of landfill with roof, so-called "Closed type landfill"

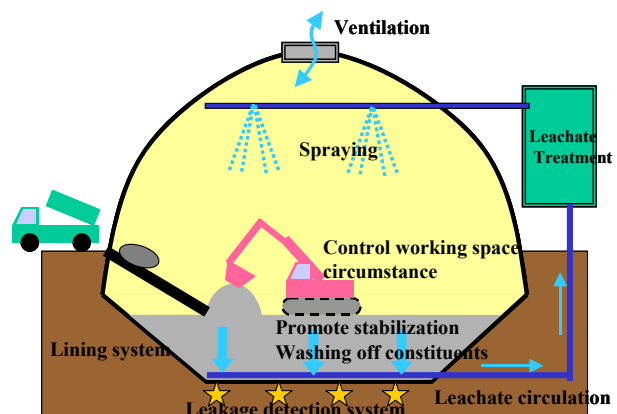


Figure 15 Conceptual diagram of closed type landfill



combination of two impermeable membrane liner and leakage detection liner between them are usual. Leak-proof layer which has capability of patching up by itself is also becoming popular one.

However there is a question whether those landfill and equipments are really necessary for disposing of ordinary waste.

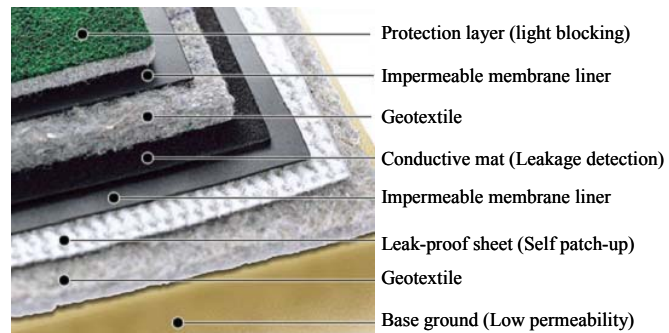


Figure 16 State of art lining system in Japan

## 4.2 Efforts to eliminate landfilled waste

One of the approaches is to conduct thorough recycling. Pouring much energy, wastes are turned into resources. One example is vitrification process. In this process, substances inputted in furnace are melted at high temperature and turned into slag. It is intended that the slag can be utilized in construction work. Heavy metal vaporized and is condensed in fly ash. It is also expected that valuable metal resource is able to recover by bringing fly ash back to the smelter. The concept of waste management and recycling system on which melting-process is centered is shown in Figure 17. The number of ash-melting furnace and gasification-melting furnace are increasing recently. Figure 18 shows recent trend of their increase. Especially, gasification-melting furnace are being favored by small municipalities which had to shut down their small incinerator due to dioxin problem. But, in fact, many furnaces are encountering trouble concerning operation. Also, the quality of slag is not better than having been expected so that utilization of them is not spreading at present.

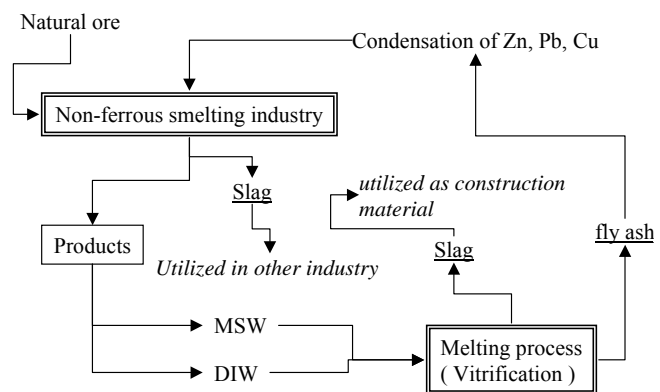


Figure 17 Schematic diagram in which melting process is centered

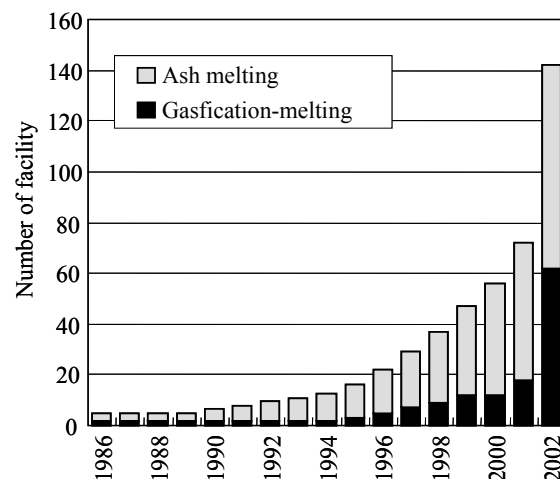


Figure 18 Number of melting facility constructed in Japan

Cement industry and iron industry are interested in waste management. Cement industry has been treating several industrial wastes, such as blast furnace slag from steel plant, coal dust from thermal power plant, etc. as feedstock of cement. They are promoting receiving of other wastes, like incineration residue. Iron industry is receiving waste plastics as alternative reductant of coke.

Promotion of recycling is thought to be suitable for recycle-oriented society in one side. However, too much recycling with pouring a lot of energy is being asked whether it is sustainable, in another side.



## 5. PROPOSAL FOR IDEAL FEATURE OF LANDFILL

In section 3, the important points that have to be kept in our mind on searching for ideal feature of landfills in the recycling-oriented society were discussed. These points are as follows;

- 1) It will be necessary to secure required capacity of landfill even if the amount of waste is decreased along national target.
- 2) It will be necessary not only to prove safety of landfill scientifically but also to offer the resident the sense of relief.
- 3) We should never make our landfill a kind of land equivalent to contaminated land.
- 4) In order to make the society sustainable, the cost and energy pouring into waste management system should not be disregarded.

Landfill that can satisfy these conditions is thought of as the ideal landfill favorable to the recycling society. If so, what sort of landfill do we have to create practically? To answer it, we had discussed future landfill concept in detail, and finally proposed several concrete types of landfill in this project.

### 5.1 Requirements that should be met

First of all, what should be emphasized on the establishment of future concept is thought to be the following two: 1) whole system including landfill, waste management system and social system should be sustainable, and 2) we should not leave the adverse heritage to next generations. These two conditions are absolute necessary to be fulfilled. So, these two points were set as important requirements in the concept of a future landfill.

### 5.2 Definition of fundamental role and function of landfill

Next, what should be considered was to define the essential role and function of landfill. It is thought that there are two ideas in the concept of the substance cycle. One is a large substance cycle by the ecosystem of nature, and the other is a cycle artificially driven by human being. Reuse and recycling belongs to the latter, and landfill is likened to the restoring process by which material is returned to the large cycle of the former. Thus, so to speak, landfill should play a role of an interface of a natural cycle and an artificial cycle. When thinking like this, the role and function of landfill is definable as the soil restitution (substance restitution to nature). If we define the role of landfill as such, the quality of waste able to dispose of to landfill is naturally determined. That is, it is the one that is returnable to nature (assimilation into soil is possible). In other words, substances which are never assimilated into the soil or which are eternally aliens to the surrounding soil must not come to the entrance of landfill. Such materials should be recycled within an artificial cycle, or should be stored in the facility with controlled condition (this facility is not regarded as landfill) if recycling is not possible.

Moreover, substances which cannot be recycled even within an artificial cycle or which must be kept for long time in the facility until a suitable recycling method is developed, should not be produced. It may seem that this kinds of thought looks a bit radical. But we concluded that to make a suggestion from the standpoint of landfill against upstream social system is important in order to overcome the current situation and to create ideal society.

### 5.3 Separation of landfill and storage facility

Assuming that substances that enter landfill certainly return to nature, landfill will never be a contaminated land because it means that landfill will become normal land comprised of natural soil in future. For the sake of realizing it, to define the scope of the quality of acceptable wastes is necessary. And the unacceptable substance other than acceptable one should be kept in controlled storage facility and then be merged into the flow of artificial cycle.

Hence, the definition that clearly separates the role of landfill and storage facility is needed. Storage facility plays one part of artificial substance cycle. From the past experience represented by the issue of PCB, it is unfortunately evident that human being can hardly take the responsibility for the long-term storage. Therefore, the storage facility should be intended to store substance only for short-term or middle-term. Moreover, it should be a structure that can be clearly distinguished from nature.

#### 5.4 Types of future landfill and their concept

The conditions that should be fulfilled by landfill are the following; contained material in it will completely return to a soil, and it will not be a contaminated soil in future; and such landfill will not impose a burden of maintenance for next generation. So, the acceptable wastes to landfill should be what have similar characteristics of soil from the initial state or be what will be the same as soil during a generation, i.e., during 20-30 years. To meet this requirement, some landfill can be proposed.

One is a kind of inert waste landfill. But it is not the same as conventional Type-1 landfill. It accepts only wastes similar to the soil at the time of acceptance. The kinds of acceptable waste might include inert waste and waste of final storage quality. But the waste is restricted not only by its emission potential but also its content.

The second is a landfill, which can make wastes stabilize during 20-30 years by using microorganism activity and let wastes assimilate to normal soil. For that purpose, wastes acceptable to this landfill are as follows: 1) wastes should be crushed enough, and recyclable materials such as metals should be removed; 2) amount of plastics should be minimized; 3) organic matters should be controlled at several percent to keep biodegradation active; 4)

Table 3 Outline of proposed landfill

Class	Acceptable waste	Landfill type	Explanation
1	Inert/Stabilized Waste	Least controlled type / Landfill for inert waste	Acceptable wastes are limited only to inert or stable wastes. Their characteristics are almost same as those of the natural soil. Landfilling is regarded as land formation.
2	Only waste that corresponds to non-contaminated soil as a content with low degradable organic content.	Landfill for early stabilization: Controlled type aiming at early stabilization	This landfill accepts wastes to which the amount of the organic matter is limited so that the early stabilization is possible and the wastes that don't correspond to the contaminated soil as a content. Stabilization should be achieved within 30 years from 20 years. It will be realized by utilizing semi-aerobic bioreactor landfill structure.
3	Waste that corresponds to non-contaminated soil as a content but contains comparatively a lot of organic matter	Landfill for accelerated stabilization: Bioreactor Landfill	This landfill accepts wastes that don't correspond to the contaminated soil as a content. But organic content of them is not restricted. So, various measures for promoting waste stabilization are taken. Landfill has to be designed to equip instruments to accelerate biodegradation, such as aeration system, leachate circulation system, etc. Stabilization should be achieved within 30 years from 20 years.
4	Waste that corresponds to contaminated soil as a content	Long-term storage facility: (Only necessary for transition period)	This landfill accepts waste corresponding to the contaminated soil as a content but non-hazardous as a leaching characteristics. It means that prevention of harmful impact to environment is possible during operation/maintenance period as long as emission potential is low, but assurance of safety is not possible after it ends its operation/maintenance. Long-term management is necessary. It should not be landfill but storage facility. Conventional controlled-type landfill (Type-2) is corresponding to this.
5	Hazardous waste but not containing biodegradable organic matter	Containment storage facility: Isolated type (Only necessary for transition period)	This landfill accepts waste equivalent to hazardous waste. Strict control is necessary. This is absolutely not a landfill but a storage facility intended to use for short-term. Conventional type-3 landfill is corresponding to this. We should shut down this kind of facility and convert them into the facility recovering materials.

hazardous chemicals such as heavy metals and DXN should be minimized. At present, incineration residue is thought to be a major target to be disposed of. A lot of studies from the elucidation of process such as mineralization, soilification, weathering, etc., to the development of pretreatment system such as washing, separation, etc., are in progress to examine the feasibility of this type of landfill. And semi-aerobic landfill that is major landfill structure in Japan is expected to function effectively for early stabilization of waste. We named this type of landfill as "Sustainable semi-aerobic bioreactor landfill with low organic matter".

The third is similar to the second one. It does not accept wastes containing hazardous substance, and materials that are alien to natural soil. But it accepts organic substance without limitation and accelerates their stabilization by active method. This type of landfill is corresponding to the "Bioreactor landfill" where the stabilization of the organic substance is artificially achieved in a short term by the forced aeration, the leachate circulation, etc.

To our regret, the technologies are not advanced enough for us to make complete definition of waste which should be excluded from landfill at present, i.e., even if landfill exclude unacceptable waste, it is not always ensured that there is a way putting them into artificial cycle because adequate recycling method is not available. Therefore, ambiguous facilities (though this is almost the same as conventional containment type landfill) standing at the middle of landfill and storage facility are inevitably needed for the transition period.

Arranging of above concepts, five types of landfill/facility can be proposed taking into account the transition period as shown in Table 3. Overall image including the relation of the landfill/facility with the society is shown in Figure 19, conceptually.

### 5.5 Concrete image regarding whole life of proposed landfills

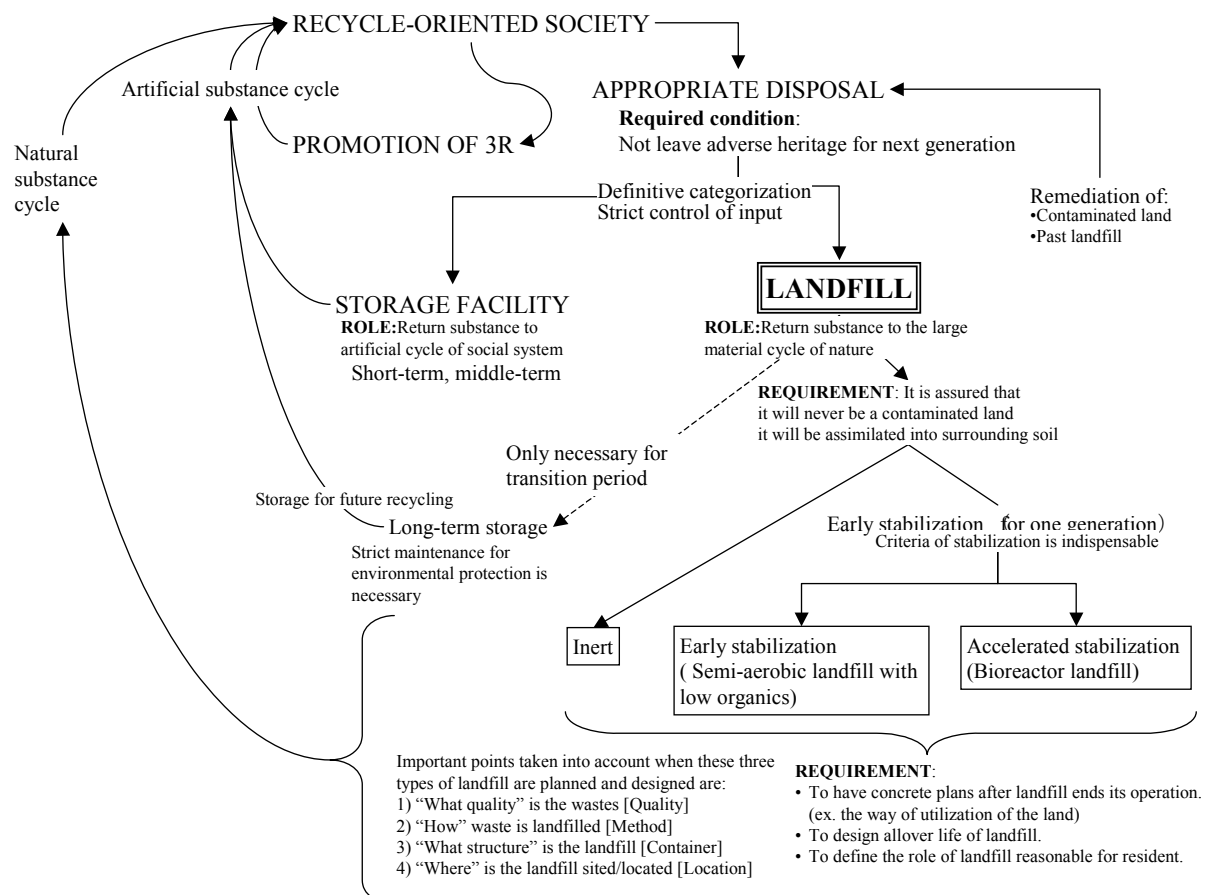


Figure 19 Overall image including the proposed landfill/facility in the Recycle-oriented society

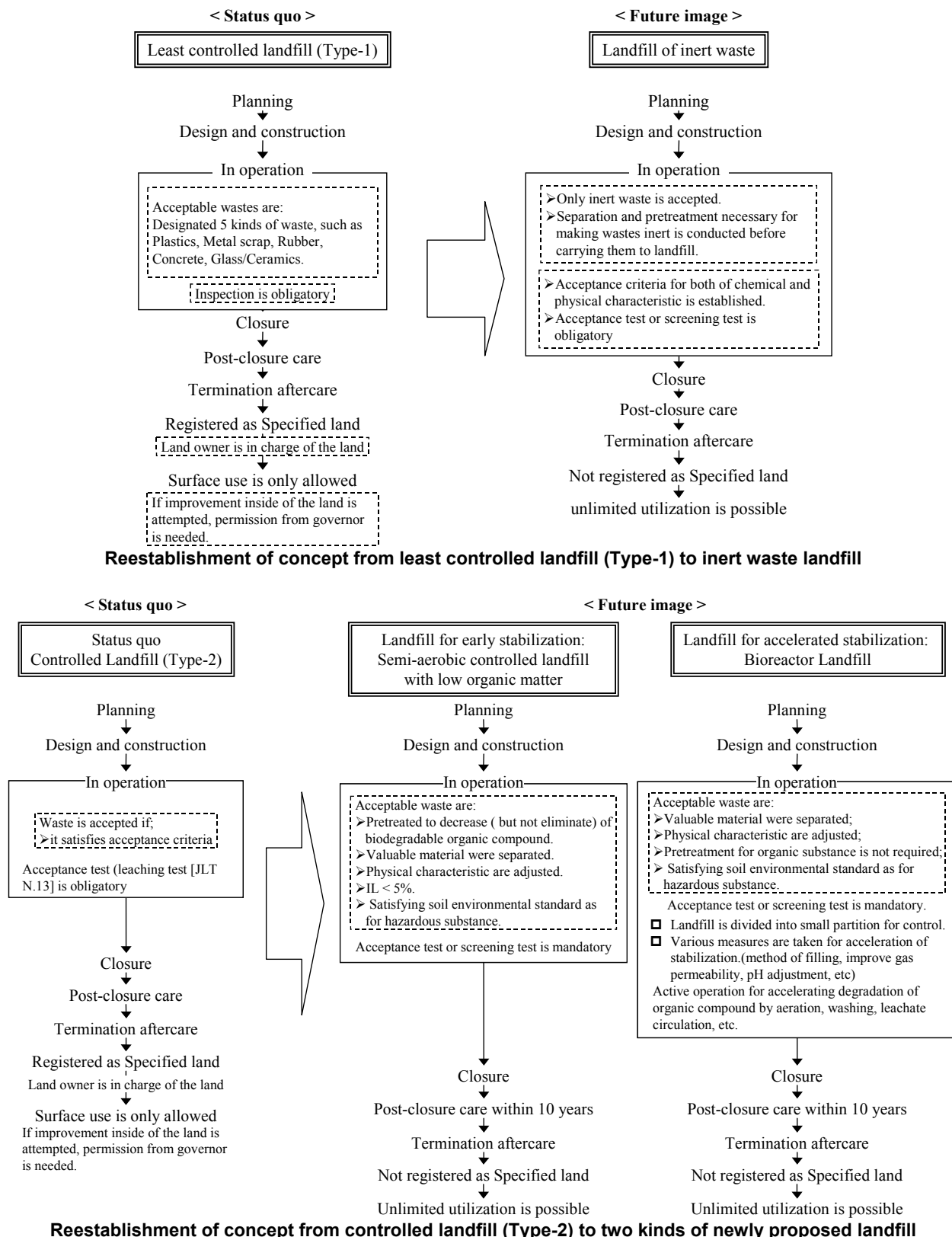


Figure 20 The image of whole life of each type of proposed landfills

Reestablishment of the landfill concept suitable for recycle-oriented society has been discussed and the concrete image was proposed. The image of whole life of these landfills is provided in Figure 20 with the comparison to conventional landfill.

## Summary

In this report, a research entitled "Ideal Feature of Landfill in Recycle-Oriented Society" conducted by the landfill research group in JSWME was introduced. Purpose of the research was to seek for the future concept of landfill suitable for recycle-oriented society. It was confirmed that the following points are significant to have a view of future concepts.

- 1) Hereafter, almost 1100Mm<sup>3</sup> of landfill capacity will need to be secured in 50 years, even if the amount of waste is decreased along national target.
- 2) Disgust of residents toward landfill is stronger than that toward incineration facility. It can be said that anyhow improving the image of landfill is requisite. Moreover, it will be necessary not only to prove safety of landfill scientifically but also to provide residents a sense of relief.
- 3) In order to not leave adverse heritage for next generation, we should never make our landfill a kind of land equivalent to contaminated land. To that end, quality of waste should be well thought from long-term point of view.
- 4) The cost and energy pouring into waste management system should be optimized for the society to be sustainable.

Then, ideal image of future landfill was pursued on the premise that it should fulfill these conditions. As consequences, it concluded that the role of landfill should be assigned as the interface of artificial substance cycle and large substance cycle of nature. Namely landfill should be regarded as the process of substance restoration to nature. Conventional landfill neither has provided a function of restoring substance to nature cycle nor has played a part of the artificial substance cycle, i.e. its role was ambiguous. Thereby, distinct definition of landfill and storage facility is quite important. Finally, several concrete concepts of landfill was proposed and their necessary functions were defined.

This research project was conducted from 2002 to 2004. Unfortunately, the project was not able to reach a complete ending. Representative of this project, Prof. Tanaka, had passed away on this March, on the way of summing up this project. So, I wrote major part of this report from his memorandum.



## Waste Management in Syria

Amir Alboukahri, Director of Public Cleaning , Damascus

واقع إدارة النفايات الصلبة في الجمهورية العربية السورية

المهندس أمير البخاري

مقدمة:

- تمثل النفايات الصلبة إحدى المشاكل المتفاقمة التي تواجه الوحدات الإدارية في الجمهورية العربية السورية وقد أدت قلة الموارد المالية وطبيعة البنية التحتية غير الملائمة وعدم تواجد الكفاءات المدربة إلى ضعف في إدارة ومعالجة النفايات الصلبة في هذه الوحدات. وقد حاولت بعض المدن الكبيرة في سوريا خلال العقد الأخير إيجاد بعض الركائز لتحسين إدارة النفايات فيها من خلال إيفاد العديد من المختصين لاتباع دورات في الدول المتقدمة إضافة لمساهمة عدد من المنظمات الدولية في إعداد دراسات ميدانية في بعض مدن القطر مما ساعد على وضع قاعدة لإدارة النفايات الصلبة وفق أسس علمية ومدروسة لمواجهة مشاكل هذه النفايات. و ليس المطلوب فقط مواجهة مالية وتكنولوجية بل إن هناك بعض الاعتبارات العامة القانونية والاجتماعية والاقتصادية التي يجب أن تؤخذ بعين الاعتبار في التخطيط والتنفيذ والإشراف والإدارة للتخلص من النفايات.

- تقسم أراضي الجمهورية العربية السورية إدارياً إلى 14 محافظة يتبع لهذه المحافظات عدداً من الوحدات الإدارية مكونة مما يلي:

الوحدة	العدد
1 عدد مدن مراكز المحافظات	11/ مدينة
2 عدد المدن	96 / مدينة
3 عدد البلدات	248 / بلدة
4 عدد القرى (شخصية اعتبارية)	207 / قرية
5 عدد البلديات	825 / بلدية
6 عدد القرى	4818 / قرية
7 عدد المزارع	6794 / مزرعة

### الدراسات المعدة حول إدارة النفايات الصلبة في الجمهورية العربية السورية :

المحافظة	الجهة صاحبة الدراسة	عنوان الدراسة	الهدف	التاريخ	ملاحظات
دمشق	JICA	تحسين الشروط البيئية في مدينة دمشق	تقديم آليات جمع النفايات ومعدات للمقلب العام في محافظة دمشق	1995 1996	تم تنفيذ المشروع وتقديم الآليات اللازمة
حلب	JICA	تحسين الشروط البيئية في مدينة حلب	تقديم آليات لجمع النفايات في مدينة حلب وتنفيذ محطة نقل	1998 1999	تم تنفيذ المشروع وتقديم الآليات اللازمة
	COWI	دراسة مشروع إدارة النفايات في حلب	دراسة متكاملة لإدارة النفايات والتخلص منها في مدينة حلب	1999	دراسة لم تنته
اللاذقية	JICA	دراسة إدارة النفايات الصلبة في محافظة اللاذقية	دراسة الوضع الحالي لمحافظة اللاذقية (مدن اللاذقية الحفة- جبلة- القرداحة) ووضع التصورات المستقبلية	2001	دراسة فقط حتى الآن
	MEDURBUS	دراسة عامة لواقع النفايات الصلبة في محافظة اللاذقية	دراسة الوضع الحالي لمدينة اللاذقية ووضع التصورات المستقبلية لحل وضع النفايات الصلبة	1996	الدراسة فقط
حمص	JICA	دراسة واقع النفايات الصلبة في مدينة حمص	دراسة جدوى إنشاء معمل لتحويل النفايات الصلبة إلى سماد في مدينة حمص	2001	دراسة فقط
	بنك الاستثمار الأوربي شركة COWI	دراسة مشروع إدارة النفايات الصلبة في حمص	دراسة واقع إدارة النفايات الصلبة ودراسة واقع المكب الموجود و إعداد دراسة تصميمية للمشروع مع وضع الحلول لمواقع الطمر	1999	دراسة فقط
	G.T.Z	دراسة واقع النفايات الخطرة في حمص	دراسة واقع النفايات الخطرة ووضع الحلول اللازمة	2002 2003	لم تتم الدراسة بعد
السلمية	G.T.Z	تنفيذ معمل معالجة النفايات الصلبة وتحويلها الى سماد	دراسة الواقع العام في المدينة و إعداد الدراسات التنفيذية لمعمل المعالجة	2002	دراسة مع تنفيذ
طرطوس	G.T.Z	واقع النفايات الصلبة البلدية الخطرة	دراسة الواقع مع وضع التصورات لحل مشكلة النفايات الصلبة	2002 2003	لم تتم الدراسة حتى الان



### **الوضع الإداري للنفايات الصلبة في الوحدات الإدارية السورية:**

لا يوجد تقسيم إداري واضح ومحدد لإدارة النفايات الصلبة في الوحدات الإدارية في الجمهورية العربية السورية حيث انفردت محافظة دمشق بتشكيل مديرية مختصة لإدارة النفايات الصلبة ضمن المدينة ومديرية لمعالجة النفايات الصلبة وبدأت محافظات حمص وحلب خلال العام السابق والحالي بتشكيل مديرياتها المختصة ، بينما تتم إدارة النفايات في المدن عن طريق دوائر مرتبطة برئيس مجلس المدينة عن طريق مديرية الشؤون الصحية أما باقي الوحدات الإدارية فيتم العمل فيها عن طريق ورشات نظافة مرتبطة برئيس مجلس المدينة بشكل مباشر أو عن طريق أحد الإداريين الذين يكلفهم رئيس مجلس المدينة.

### **الوضع الفني لإدارة النفايات الصلبة في الوحدات الإدارية السورية:**

- تختلف كميات النفايات الصلبة الناتجة عن الوحدات الإدارية باختلاف عدد السكان و الفعاليات الاقتصادية في الوحدات، وتعتبر مدينتي دمشق وحلب الأكثر توليداً للنفايات حيث تزيد كمية النفايات الناتجة يومياً عن الألف طن في كل منهما ويقدر إنتاج الفرد بحوالي النصف كيلو في اليوم.
- تعتمد المدن السورية في جمع وترحيل النفايات على السيارات الضاغطة والحاويات إضافة للجرارات والقلابات أما الوحدات الأخرى فتعتمد في جمع وترحيل النفايات على الجرارات بشكل أساسي، وتعاني جميع هذه الوحدات من قدم الآليات المستخدمة حيث يزيد عمر معظمها عن خمس وعشرين سنة أما الجرارات المستخدمة فهي من إنتاج وطني.
- يتم جمع النفايات في معظم الوحدات الإدارية يومياً وفي المدن الكبيرة يتم الجمع من خلال أكثر من واردية عمل يومياً.
- ترحل النفايات الناتجة إلى المقالب العامة مباشرة باستثناء مدينتي دمشق وحلب حيث تجمع النفايات في محطة نقل قبل نقلها إلى المقالب العام.
- شارك القطاع الخاص في إدارة النفايات الصلبة في عدد من الوحدات الإدارية السورية حيث تم في مدينة دمشق تنظيم عقدين مع القطاع الخاص لجمع وترحيل النفايات ولمدة ثلاث سنوات إضافة لعقدين لتقديم الآليات لجمع القمامة من الطرقات الضيقة وآليات نقل النفايات من محطة النقل إلى معمل المعالجة. وكذلك نظمت مدينة حمص عقدتين لجمع وترحيل النفايات لمدة سنة واحدة وقامت كذلك بعض الوحدات الإدارية الصغيرة بإجراء عقود صغيرة لجمع وترحيل النفايات منها .
- أما في مجال التخلص من النفايات فقد قامت محافظة ادلب بتنظيم عقد لطمر النفايات في مقالب المحافظة.

### **وضع مقالب النفايات في الوحدات الإدارية السورية:**

الأسلوب الشائع للتخلص النهائي من النفايات الصلبة في أراضي الجمهورية العربية السورية هو الرمي في مقالب غير نظامية حيث يتم رمي النفايات في العراء مما يجعلها عرضة للاحتراق وتطاير النفايات في الهواء وغالباً ما تكون منطقة رمي النفايات غير محددة بسور ولا تتوفر الآليات اللازمة لتجميعها وتكديسها. هذا الأسلوب متبع في جميع الوحدات الإدارية فيما عدا دمشق-حلب-حمص-حماة-ادلب حيث يتم تغطية النفايات بالتراب منعاً من احتراقها وتطايرها في الهواء. و في دمشق وادلب المقالب محاط بسور وهناك بعض الآليات المخصصة للطمر سواء كانت قطاع عام أو بموجب عقود مع القطاع الخاص. ولكن في جميع الأحوال فإن عملية الطمر الأخيرة لا تأخذ بعين الاعتبار تسرب رشح سائل القمامة إلى المياه الجوفية.

وقد تم تنفيذ أول مطمر صحي بطبقات عزل لأرضية المطمر في مدينة دير الزور

### منشآت معالجة النفايات في الوحدات الإدارية :

يغلب موضوع معالجة النفايات الصلبة في الجمهورية العربية السورية بتحويلها الى سماد محسن للتربة ويمكن جرد المعامل الموجودة في الجمهورية العربية السورية على الشكل التالي:

المحافظة	المنشأة	الشركة المنفذة	تاريخ الإنشاء	الكمية المعالجة	الوضع الحالي	ملاحظات
دمشق	معمل تحويل النفايات الى سماد محسن للتربة	BUHLER (SWISS)	1990	طن 500 يومياً	جاهز	هناك دراسة لتطويره
ريف دمشق	محطة فرز	ايفركلين	2004	طن 500 يومياً	جاهز	
حلب	معمل تحويل النفايات الى سماد			/	متوقف عن العمل	
حماة	غربال للاستفادة من النفايات العضوية	شركة دانمركية			متوقف	
اللاذقية	معمل معالجة القمامة	شركة فرنسية		طن 5 يدوي	متوقف بشكل جزئي	
طرطوس	محطة فرز	مجلس مدينة طرطوس		طن 100 يومياً	قيد الإنشاء	
سلمية	معمل تحويل النفايات إلى سماد	شركة ألمانية	تاريخ المباشرة 2003	طن 50 يومياً	قيد التشغيل التجريبي	

**الوضع المالي لإدارة النفايات في الوحدات الادارية السورية:** تعتمد الوحدات الإدارية في تمويل إدارة النفايات الصلبة على رسوم النظافة التي يتم جبايتها من المواطنين والتي تتراوح بين /75/ و /500/ ل.س عن كل منزل إلا أن هذه الرسوم لا تغطي إلا جزءاً قليلاً من موازنة إدارة النفايات مما يستدعي الاعتماد على الموازنة العامة لهذه الوحدات لتغطية العجز وهو ما يؤدي إلى قصور في تقديم الخدمة اللازمة نتيجة ضعف الموارد.

### **التشريعات الصادرة حول إدارة النفايات الصلبة:**

قرارات المجالس المحلية: أصدرت بعض المحافظات قرارات صادرة عن المجالس المحلية تضمنت عدداً من التعليمات حول مواعيد إلقاء النفايات والغرامات على المخالفين لقواعد النظافة العامة. وأصدرت محافظة دمشق إضافة لذلك عدداً من القرارات النازمة لعملية جمع وترحيل النفايات الطبية في المدينة.

قانون البيئة رقم 50 لعام 2002: والذي تضمن في بعض فقراته تعليمات عامة حول النفايات الصلبة. الدليل العام للإدارة النفايات الطبية: تم وضع دليل عام لإدارة النفايات الطبية بالتعاون مع شركة (تايبودين) الهولندية قسم إلى دليل للمنشآت الطبية ودليل للجهات القائمة على الترحيل ودليل للجهات القائمة على محطات المعالجة ويتم حالياً مراجعة الدليل من قبل لجنة محلية.

دفتر الشروط العامة للمنشآت معالجة النفايات: تم وضع دفتر شروط قانونية ومالية وفنية لتنفيذ واستثمار منشآت معالجة النفايات واعتمد من رئاسة مجلس الوزراء وتم تعميمه على الوحدات الإدارية حيث أعلنت مدن طرطوس وحماه والسويداء والحسكة عن مناقصة لتنفيذ معمل سماد إلا أنه لم يتم تقديم عروض لعدد من الأسباب المالية.

قانون نظافة الوحدات الإدارية وجماليتها: تم إصدار قانون يضبط التعامل مع النفايات الصلبة ودور الوحدات الإدارية والمواطن وقد صدر في 2004/12/5 وبدأ تطبيقه في 2005/3/5. نظام إدارة النفايات الخطرة: تم وضع نظام خاص لإدارة النفايات الخطرة في الجمهورية العربية السورية والذي حدد مسؤولية المنتج والناقل والمعالج وشروط التعامل مع هذه النفايات وتم إقراره من مجلس حماية البيئة.

### **- المشاهدات والملاحظات:**

- 1- عدم وجود إدارة فنية متخصصة بإدارة النفايات الصلبة في معظم مجالس المدن
- 2- عدم وجود هيكلية إدارية في مجال إدارة النفايات حيث ترتبط ورشات العمل برئيس مجلس المدينة مباشرة في بعض الأحيان و أحياناً ترتبط بأمين السر أو المحاسب الإداري وهكذا
- 3- نقص عمال النظافة في العديد من المدن
- 4- نقص الآليات الخاصة بجمع القمامة وقدم معظمها حيث تعود لأكثر من خمس وعشرين عاماً وعجز معظم البلديات عن تأمين تكاليف شراء وإصلاح الآليات
- 5- عدم وجود مكبات نظامية حيث يتم رمي النفايات في مواقع غير مجهزة وغير صالحة فنياً إضافة إلى حرقها بشكل عشوائي
- 6- معظم إعلانات مناقصات تنفيذ معامل تحويل القمامة إلى سماد لم تنجح لسبب عدم إعداد دفاتر الشروط الخاصة بشكل مقبول ورفض العارضين فكرة دفع تأمينات نهائية تحبس لمدة طويلة
- 7- تحسين وضع مقالب النفايات في حمص ودير الزور من خلال الاستفادة من المشروع تبديل الدين
- 8- تواجد القطاع الخاص في بعض المدن ساعد في حل العديد من مشاكل إدارة النفايات فيها

### **الإجراءات التي اتخذتها الوزارة والمحافظات في مجال النفايات الصلبة:**

- قامت الوزارة بالتنسيق مع وزارة الإسكان والتعمير وبرنامج إدارة التنمية الحضرية UMP بإعداد دراسة متكاملة لإدارة النفايات الصلبة في محافظات ريف دمشق: بلدات (جديدة عرطوز – المليحة – عين الفيجة)
- قامت الوزارة بعقد العديد من الندوات والدورات التدريبية في مجال إدارة النفايات الصلبة
- قامت الوزارة بإيفاد العديد من المهندسين العاملين في هذا المجال لإتباع دورات تدريبية خارجية
- قامت بعض المحافظات بإجراء عقود مع القطاع الخاص لتأمين نظافة بعض المواقع وقد لاقت هذه التجربة نجاحاً وقبولاً من المواطنين.

### المخطط التوجيهي لإدارة النفايات الصلبة

تم التعاقد مع شركة تريفالور الفرنسية بالعقد رقم 68/1/م/و/2 تاريخ 2004/1/13 لإعداد المخطط التوجيهي لإدارة النفايات الصلبة وذلك بعد تحقيقها للسعر الاقتصادي الأفضل بين الشركات التي تقدمت بعروضها وهي إضافة للشركة المذكورة شركة سوغرياه وشركة كابينت ميرلان الفرنسيين علماً أن قيمة العقد تبلغ 210.000 يورو ومدة العقد ثمانية أشهر وقد تم تقسيم العمل إلى أربعة مراحل

**المرحلة الأولى :** دراسة الواقع الراهن لإدارة النفايات الصلبة في سورية وتتضمن:

تحديد البيئة المحلية وكمية النفايات المتولدة وتحليلها إلى أنواعها الرئيسية كماً ونوعاً وطرق تجميع النفايات بأنواعها ومواقع المعالجة والتخلص من النفايات وتوصيف مواقع طمر النفايات وتضمنت وثائق هذه المرحلة :

- الجزء الأول : تحليل تفصيلي للواقع الراهن في سوريا من خلال المدن التي تمت زيارتها شمل طريقة العمل المتبعة والكوادر البشرية والآلية والحاويات الموجودة في تلك المدن بالإضافة لتحليل مكونات هذه النفايات ومصادر تولدها وحملات التوعية التي قامت بها مجالس المدن , كما تم تحديد موازنة كل مدينة فيما يتعلق بالنفايات وكلفة الشخص الواحد , وطريقة التخلص من النفايات الناتجة ومواقع المقالب ووضعها الفني ومشاكلها.
- الجزء الثاني : وتضمن :

- التوزيع السكاني في سوريا وتزايد عدد السكان
- وضع النفايات في سوريا – أنواع وكميات
- جمع وترحيل ونقل النفايات البلدية
- معالجة النفايات قبل التخلص منها ومن ثم التخلص من النفايات في المقالب والمطامر
- التكاليف الحالية لإدارة النفايات البلدية

**المرحلة الثانية :** تقديم دراسة لمقترحات الخطة الوطنية لإدارة النفايات الصلبة في سورية وتتضمن :

تحديد أهداف وغايات الخطة الوطنية لإدارة النفايات والتقنيات الممكنة والمقترحات التي يمكن تنفيذها في مجال معالجة النفايات الصلبة مع تحديد الخيار الأفضل بالتنسيق مع اللجنة الوطنية في سوريا

- الجزء الأول :

- العوائق الأساسية المأخوذة بعين الاعتبار في المخطط - يهي مع تحديد المشاكل والحلول
- الفرص الممكن الاستفادة منها في إدارة النفايات مع ميزات وألوان الاستنتاجات ( توفر أسواق المواد المدورة - إنتاج السماد في المنزل - مقالب النفايات الموجودة حالياً )
- التشريعات السورية في مجال - آليات الصلبة ومقارنته لتشريعات الأوروبية
- توفر الأسواق للمواد المدورة يشجع على إنشاء معامل الفرز

- مبادئ إعداد المخطط التوجيهي لإدارة النفايات الصلبة في سوريا (جميع أنواع النفايات البلدية مأخوذة بالحسبان في الدراسة مع معالجة خاصة لكل نوع من هذه النفايات – تخفيض النفايات – التسلسل المرحلي لجمع ومعالجة النفايات – السيطرة على تكاليف إدارة النفايات )
- تطور تدفق النفايات بين عامي 2004 – 2014 باعتبار تزايد عدد السكان وتغير خواص النفايات ومعدل إنتاج الفرد من هذه النفايات
- الأهداف الكمية التي تعنى بتحديد الكميات من النفايات الناتجة بما فيها النفايات العضوية والمواد القابلة للتدوير والنفايات الخطرة وكذلك كميات المواد الناتجة من المعالجة
- شبكة معالجة النفايات الصلبة في سوريا مع أخذ المنشآت الموجودة بعين الاعتبار وتقسيم المحافظات إلى مجموعة من المناطق المترابطة
- وصف تقني للسيناريوهات السبع المقترحة لإدارة النفايات الصلبة في سوريا مع مقارنة بينها
- الجزء الثاني ويتضمن :

- الحلول الوقائية ( تخفيض النفايات – إنتاج السماد المنزلي – منع استخدام أكياس النايلون )
- الجمع المنفصل للنفايات ( الفرز من المصدر )
- نقل النفايات ( إنشاء محطات النقل )
- معالجة النفايات ( منشآت الفرز - المعالجة البيولوجية - التحويل إلى سماد - استخلاص الميثان - الحرق - الطمر الصحي - النفايات الطبية - النفايات الخطرة البلدية )

### المرحلة الثالثة : إعداد خطة المشاريع ودراسة الجدوى الاقتصادية وتقديم المخطط التوجيهي النهائي

وتتضمن :

- الجزء الأول:

- مخططات لجميع المحافظات تشمل توضع منشآت إدارة النفايات الصلبة في سوريا وقد لحظت المخططات عدد السكان وكمية النفايات المتوقعة عام 2014 وتقسيم المحافظة إلى مناطق
- جداول نتائج المعلومات التقنية والاقتصادية للمخطط التوجيهي اعتماداً على الحسابات والتقديرية خلال مدة الدراسة في نهاية عام 2004 وتشمل هذه الجداول المنشآت المقترحة والمعدات والقوى العاملة والتكاليف السنوية الإجمالية وللشخص الواحد
- جداول المعلومات التقنية والاقتصادية للإجراءات الميكانيكية في المراكز المتكاملة قبل تحويل النفايات إلى سماد وتتضمن:
- تصميم المنشآت بما فيها البناء والمعدات
- تكاليف الإنشاء والتشغيل ويشمل مخطط انخفاض التكاليف طردياً مع ازدياد الكمية .

- جداول المعلومات التقنية والاقتصادية لمنشآت التحويل إلى سماد متضمنة تصميم هذه المنشآت إضافة لتكاليف الإنشاء والتشغيل.
- الشروط التقنية لإعادة تأهيل مكبات النفايات متضمنة إعادة تأهيل الموقع والدراسات اللازمة لاستكمال تجهيز المكب والمعالجات المحددة بما فيها معالجة الرشاحة الناتجة وطبقات العزل
- الجزء الثاني : ويتضمن الحلول النهائية والتوصيات
  - \* تخفيض توليد النفايات من خلال حملات التوعية وفرز النفايات والتحويل إلى سماد منزلياً
  - تحسين جمع النفايات وتحديد عدد الحاويات والآليات اللازمة وعدد العمال المطلوب في المناطق الحضرية والريفية مع أخذ الجمع المنفصل بعين الاعتبار
  - تطوير نقل النفايات وتشمل شبكة محطات النقل المقترحة وتكاليف إنشاء وتشغيل هذه المحطات
  - تحسين معالجة النفايات المنزلية وتشمل أهداف المعالجة وشبكة معامل الفرز للجمع المنفصل والمختلط متضمنة تكاليف الإنشاء والتشغيل ومقارنة بين الطريقتين والمراكز المتكاملة وشبكة المطامر الصحية وتكاليف إنشاءها وتشغيلها
  - دراسة فنية لإدارة النفايات في التجمعات الصغيرة متضمنة طرق الجمع والنقل والتكاليف
  - إستراتيجية النفايات الخطرة البلدية متضمنة جمع وتخزين ومعالجة هذه النفايات والتكاليف
  - التكاليف التفصيلية والكلية للمخطط التوجيهي لإدارة النفايات البلدية ويتضمن تكاليف الإنشاء والتشغيل لمنشآت معالجة النفايات الصلبة وآليات الجمع والقوى العاملة بما فيها النفايات الطبية والخطرة وذلك في حالتي الجمع المنفصل والمختلط
  - تنفيذ المخطط التوجيهي وتحديد الجهات المعنية بالتنفيذ ( وزارة الإدارة المحلية والبيئة – الهيئة الوطنية للنفايات – البلديات ) وتمويل إدارة النفايات من ناحية الإنشاء والتشغيل
  - برنامج التنفيذ حيث تم اعتماد تنفيذ المشروع خلال عشرة سنوات بمعدل 2.2 مليار ليرة سورية سنوياً لتغطية التكاليف البالغة 22 مليار ليرة سورية والتكاليف الكلية السنوية 11.5 مليار ل.س

**المرحلة الرابعة:** تقديم الوثائق الخاصة بأعمال التلزم والتعاقد مع القطاع الخاص بما في ذلك التصميم والإنشاء والتمويل والتشغيل وتحديد النقاط وتقييم كل مقترح وتتضمن هذه المرحلة المواضيع التالية :

- القسم الأول: مقترح لتشكيل هيئة وطنية لإدارة النفايات تكون بمثابة الأداة لتنفيذ المخطط التوجيهي لإدارة النفايات الصلبة إضافة لتقديم التوجيهات الفنية للوحدات الإدارية ومراقبة تنفيذ المشاريع وتدريب عناصر وطنية في المحافظات وإنشاء مركز معلومات حول النفايات الصلبة .

- القسم الثاني: وثائق نموذجية لعقود مشاركة القطاع الخاص بنظام ال B.O.T بما فيها دفاتر الشروط القانونية والمالية الخاصة والعروض المطلوبة ونظام المناقصات .
- القسم الثالث : ملاحظات على دفتر الشروط العامة الذي أعدته وزارة الإدارة المحلية والبيئة والمصدق بكتاب رئاسة مجلس الوزراء رقم 2457 /أ تاريخ 2002/4/23 وتم فيها الإشارة لبعض البنود الواردة في دفاتر الشروط والتي كانت سبباً في عدم استجابة شركات القطاع الخاص .

### تكاليف تنفيذ المخطط التوجيهي

عدد السكان المتوقع : 23600000

كمية النفايات المتوقعة : 5400 000 طن/سنة

المشروع	الاستطاعة	كلفة الإنشاء مليون ل.س	الكلفة السنوية الكلية (مليون)
1 عمال	30755		6660
2 آليات جمع وترحيل	1687	6672	
3 حاويات		95	
4 معامل فرز ( 38 )	454000 طن/سنة	2286	191
5 معامل فرز ميكانيكي (26)	4085000 طن/سنة	4182	542
6 معامل سماد ( 22 )	3108000 طن/سنة	3590	751
7 محطات نقل(110)	3480000 طن/سنة	1732	282
8 مطامر ( 40 )	3400000 طن/سنة	2283	2200
9 نفايات طبية		268	36
10 نفايات خطرة		115	850
المجموع		21222	11500

الكلفة السنوية تشمل الإنشاء والتشغيل ( باعتبار البناء 15 سنة والآليات 10 سنوات )

### المقترحات والتوصيات:

- 1- زيادة الملاك العددي للعاملين في إدارة النفايات الصلبة بما يتناسب مع حجم الأعمال
- 2- تحسين ظروف العاملين المادية والاجتماعية.
- 3- إعطاء موضوع إدارة النفايات الصلبة الاهتمام المطلوب من قبل الجهات الإعلامية بمختلف فعاليتها (صحافة- إذاعة- تلفزيون) ووضع برامج إذاعية وتلفزيونية للتوعية.
- 4- تفعيل دور المنظمات الشعبية والمهنية ولجان الأحياء لرفع الوعي لدى المواطنين للالتزام بقواعد النظافة.
- 5- إجراء حملات التوعية العامة حول مواضيع النظافة وما يتعلق بمساهمة المواطن فيها
- 6- تأمين الآليات الحديثة والمناسبة باستمرار و تنسيق الآليات القديمة والتي تكلف صيانتها مبالغ طائلة سنوياً
- 7- تنفيذ منشآت معالجة النفايات الصلبة حرصاً على حل المشاكل البيئية الناجمة عن تجميع النفايات في مقالب مكشوفة عشوائية

- 8- تأمين الموارد اللازمة لتغطية العجز المالي في الوحدات الإدارية في مجال إدارة النفايات الصلبة
- 9- تشجيع المدن لإجراء عقود مع القطاع الخاص لجمع وترحيل ومعالجة النفايات الصلبة
- 10- تأهيل العاملين الفنيين في الوحدات الإدارية عن طريق دورات تدريبية داخلية وخارجية
- 11- تنفيذ دراسة المخطط التوجيهي المعد من قبل شركة تريفالور .



# Management and operation of the Landfill site in Damascus

Riad Kabikli, Director of composting plants, Damascus

إدارة وتشغيل مطمر النفايات  
في محافظة مدينة دمشق  
أعداد المهندس رياض القابلي

## أولاً: مقدمة البحث :

إن موضوع النظافة والتخلص من النفايات هو من الموضوعات التي تحتل مكان الصدارة بين سائر اختصاصات المدن والبلدان ليس فقط لأنه يستأثر بالنصيب الأكبر من الميزات ويستخدم معظم القوى البشرية فيها ولكن لأنه من أكثر الأمور تأثيراً بالحياة اليومية للسكان , فبواسطته يمكنهم أن يعيشوا في راحة واطمئنان , وهو أيضاً يمكن أن يكون سبباً في تقدير صفو معيشتهم وتنغيص شتى شؤون حياتهم وبوسع كل منا أن يتصور مدى القلق والإزعاج الذي يمكن أن يسببه تراكم نفايات مدينة ليوم واحد فقط في العراق .

وتلعب عادات الناس وسلوكهم وما ألفوه من أساليب التخلص من نفاياتهم دوراً هاماً سلباً أو إيجاباً في إقامة أو دعم جهود الأجهزة المعنية بالنظافة وتحويل السلبيات إلى إيجابيات أمر يتطلب من الجهد أضعاف ما يبذل في عملية النظافة نفسها.

مدينة دمشق هي عاصمة الجمهورية العربية السورية وهي أكثر المدن السورية تعداداً للسكان حيث يبلغ عدد سكانها حوالي 3/ مليون نسمة وتصل نسبة الزيادة السنوية حوالي 0.3% من عدد السكان إضافة للهجرة من الريف إلى المدينة .

إن ازدياد الخدمات في المدينة والنمو الاقتصادي والتجاري فيها يؤدي إلى استقطاب وجذب سكان الريف والمدن الأخرى مما أدى إلى نمو عمراني عشوائي أحدث اختلالاً في الخدمات والمرافق العامة كما أدى إلى فقدان المدينة للبيئة النقية وجعلها عرضة للتلوث .

## ثانياً: مما تتكون النفايات :

ينتج عن الاستهلاك اليومي للمواطنين في المنازل ومختلف المؤسسات كميات كبيرة من النفايات وبشكل مستمر وفي حال لم تعالج هذه النفايات بالطرق السليمة فإن من شأنها أن تسبب تلوثاً للبيئة إضافة إلى تفشي الأوبئة المختلفة.

ولكي تتم معالجة النفايات بشكل فعال يجري في مرحلة أولية تحليل مكونات النفايات قبل معالجتها وذلك لتحديد نوعها ومحتواها والنفايات تفرز بشكل عام إلى ثلاثة أنواع :

- \* - المواد القابلة لإعادة التدوير التي تحول إلى منتجات جديدة .
- \* - المواد العضوية التي تحول إلى أسمدة يستعمل في التربة الزراعية.
- \* - العوادم أو المواد التي لا تصلح لإعادة الاستعمال ولا يمكن معالجتها تحول إلى المطمر الصحي 0

إن الأسلوب الذي ينتهجه بني البشر للعيش في المواقع التي يستقرون بها والأنشطة الاجتماعية والوظيفية التي يقومون بها، تخلف كميات متفاوتة من النفايات التي تثير مشكلة كبيرة في تصريفها والتخلص منها ، ففي المناطق الحضرية والقروية والصناعية وحتى في مناطق الترويح والاستجمام ، تبرز دوماً مسألة النفايات الصلبة التي يجب جمعها والتخلص منها بشكل دوري . ويختلف معدل النفايات للشخص الواحد يومياً حسب سوية التحضر وإمكانية الرفاهية المتاحة التي يتنعم بها المجتمعات المختلفة بدرجات شديدة التفاوت. تهدف عملية التخلص من النفايات الصلبة إلى الإقلال من حجمها ووزنها شريطة أن يتم ذلك بسرعة ضمناً لتحويلها إلى وضع أقل ضرراً يمكن تصنيف النفايات الصلبة إلى ما يلي :

النفايات الزراعية - النفايات الطبية - النفايات الصناعية - النفايات التجارية - النفايات المنزلية

### ثالثاً : مبادرات المحافظة:

إزاء هذا الوضع المضطرب أولت محافظة دمشق اهتماماً كبيراً بموضوع النظافة العامة من حيث تجميع النفايات والتخلص منها وجعلته اختصاصاً أصيلاً من اختصاصات المحافظة حيث تم تشكيل إدارة خاصة بمعالجة النفايات الصلبة مهمتها معالجة كافة أنواع النفايات بدء من تجميعها و تخليص المدينة من جميع أنواع النفايات المنزلية والصناعية والتجارية والطبية وغيرها وفق أسس علمية مدروسة علماً بأنه قبل ذلك كانت النفايات تجمع بوسائل تقليدية قديمة وترحل إلى مكب غير نظامي للنفايات عدا عن الخلل الإداري الحاصل نتيجة تشتيت فعاليات إدارة النفايات الصلبة بين أكثر من جهة إدارية وعدم وجود الوعي المطلوب لدى المواطنين عن مدى أهمية التخلص من النفايات ومعالجتها بشكل لا يؤثر على الصحة والسلامة العامة .

وقد ساهمت وزارة الإدارة المحلية ووزارة البيئة وهيئة تخطيط الدولة وبالتنسيق مع محافظة دمشق من خلال استقدام عدد من الخبراء من دول مختلفة بالإضافة لتأمين المشاركة في مؤتمرات وندوات متعددة داخل وخارج القطر في وضع النقاط الأساسية لهذه المبادرة ومن ثم تحديد الأسبقيات المطلوبة حيث قامت محافظة دمشق بتأمين الكادر الإداري والبشري والآلي اللازم ومن ثم تم إجراء عدد من الدراسات لتنفيذ العمل بالتقنيات المناسبة وتستمر المتابعة حتى تاريخه للوصول بهذه المبادرة للمستوى المطلوب .

وقد تحددت أهداف هذه المبادرة كما يلي:

- تشكيل مديرية تهتم بنظافة المدينة وأخرى تهتم بمعالجة النفايات الصلبة بكافة أنواعها.
- تأمين الكادر الإداري والفني اللازم.
- تأمين الآليات اللازمة.
- إيجاد الطرق المناسبة لتجميع النفايات وترحيلها حسب طبيعة المنطقة الجغرافية.
- إيجاد الطرق المناسبة لمعالجة النفايات الصلبة.
- تشجيع إعادة استخدام النفايات وتطوير إعادة التدوير للنفايات.
- زيادة الوعي لدى المواطنين والعاملين لتحسين التعامل مع النفايات

وقد تم حشد الدعم السياسي لهذه المبادرة من خلال السلطة المحلية والمتمثلة بمحافظة دمشق ووزارة الإدارة المحلية والبيئة. ومن ثم تم بشكل متتابع تأمين الموارد المالية والقوى البشرية والمعدات الآلية من ميزانية المحافظة وبعض المساهمات من بعض المنظمات الدولية .

وقد أعدت الأهداف بالتعاون ما بين الإدارة الفنية بإجراء الدراسات الفنية والاقتصادية لهذه الأهداف والسلطة التشريعية المتمثلة بمجلس المحافظة وعلى رأسه محافظ المدينة. بعد ه قام المعنيون في مديرية النظافة ومديرية المركبات والرحبات ومديرية معمل معالجة النفايات الصلبة بتولي أدوار القيادة الفنية لتنفيذ هذه المبادرة بالشكل المطلوب.

ومن أهم المشاكل التي واجهت هذه المبادرة هي:

- تأمين التمويل اللازم لتأمين الآليات والمعدات والمشتريات اللازمة لبناء معمل معالجة القمامة والمطمر الصحي .

- تجاوب المواطنين مع هذه المبادرة في رفع مستوى الصحة والسلامة العامة وتحسين الظروف البيئية للمدينة.

بعض المشاكل الإدارية الناتجة عن تغيير البنية الإدارية لفعاليات إدارة النفايات الصلبة.

وضع الخطة التخديمية العامة للمدينة في مرحلة الإقلاع من حيث التوافق والترابط بين الحيز الجغرافي والحاويات المختارة والآليات المناسبة للتخديم.

#### رابعاً: الإجراءات المتخذة في سبيل إنجاح المبادرة:

وقد تم التعامل مع هذه المشاكل والتغلب عليها من خلال الإجراءات التالية:

1- فيما يتعلق بتأمين التمويل والآليات:

تم تمويل معمل معالجة القمامة من خلال قرض البنك الإسلامي للتنمية والبنك العربي للتنمية الاجتماعية والاقتصادية.

قامت الوكالة اليابانية للتعاون الدولي ( جايكا) بتقديم منحة لتوريد آلات جمع وترحيل النفايات

2- لوحظ في الآونة الأخيرة ازدياد أدراك المواطنين لأهمية موضوع النفايات الصلبة منها وذلك خلال الندوات والمقابلات الإذاعية والتلفزيونية والصحفية مع المعنيين ونشـرات التوعية والإعلانات التلفزيونية واللقاءات الشعبية.

3- تنظيم العمل الإداري وفق سلسلة هرمية تبدأ من العامل الفعلي للتنظيفات والمراقب المشرف على العمل ومن ثم الإدارة المرتبطة مباشرة مع محافظة دمشق.

تم إخضاع بعض الفنيين في مديرية النظافة ومعمل معالجة القمامة ومديرية المركبات والرحبات لدورات داخلية وخارجية ساهمت في رفع مستوى الأداء.

أما المشاكل المتبقية والتي تطلب الحل فيمكن تعدادها حسب التالي:

عدم وجود خطة شاملة لإدارة النفايات الصلبة التي تستند إلى وجود القوانين الملزمة لمنتجي النفايات ومن ثم اعتماد مبادئ الإنتاج النظيف أو الاهتمام بنفاياتهم من المهد إلى اللحد وذلك بالتعاون مع إدارة النفايات الصلبة.

البحث في إمكانية تطبيق المبادئ اللوجستية في إدارة الآليات والعمال المنتشرين في شوارع المدينة.

نتيجة الجمع المختلط للقمامة من المدينة نجد بأن نسبة 50% من النفايات هي غير عضوية وبالتالي لا يمكن تحويلها إلى سماد الأمر الذي يؤدي إلى انخفاض إنتاجية المعمل واسـتـهـلاك الكهرباء ، من هنا تتضح أهمية فصل القمامة إما من المصدر مباشرة الأمر الذي يصعب تحقيقه في الوقت الحالي أو الفرز بواسطة محطة يتم تصميمها لهذه الغاية 0

4- نقص التأهيل للكادر الفني على جميع المستويات 0

#### خامساً: معالجة النفايات الصلبة في محافظة دمشق:

مع نهاية عام 1990 تم تدشين معمل معالجة القمامة وتحويلها إلى سماد والذي يعتبر بحق النواة الأولى لإدارة معالجة النفايات الصلبة بكافة أشكالها قبل هذا التاريخ لم يكن سوى مقلب للقمامة وهو عبارة عن حفر كبيرة تم ملؤها بالنفايات دون الأخذ بعين الاعتبار لأي إجراء احترازي لحماية البيئة ( ماء و تراب وهواء) كما أن النفايات الطبية كانت تجمع مع النفايات المنزلية ويتم معالجتها بالطمر الصحي الذي لم يكن صحيحاً بعدها توالى الإجراءات للبحث في إيجاد السبل السليمة لمعالجة أنواع النفايات المنزلية أنواع النفايات الصلبة كل على حده بعض من هذه الإجراءات تحولت إلى ممارسات حين توفرت المصادر للتنفيذ.

من هذه الممارسات التي يقوم بها معمل معالجة النفايات الصلبة الآن والتي لها تأثير على البيئة بشكل عام وصحة المواطن بشكل خاص يمكن إيجازها بما يلي:

#### 1- تحويل القمامة إلى سماد:

تبلغ كمية القمامة الناتجة عن مدينة دمشق بحدود 1000/ طن يومياً تزداد صيفاً بحيث تصل إلى 1200/ طن ويمكن أن تصل شتاءً إلى 800/طن يومياً ويتم تجميعها في محطة التجميع الرئيسية يتم نقلها بواسطة سيارات خاصة تحمل كل منها 22-25م3 0 وتجدر الإشارة إلى أنه فقط المادة العضوية الموجودة في النفايات هي التي يتم تحويلها إلى سماد ويتم معالجة باقي مكونات النفايات بطريقة الطمر الصحي .

تتكون النفايات المنزلية على الغالب من مواد عضوية إضافة إلى مواد أخرى مثل البلاستيك إضافة إلى بعض المكونات الأخرى مثل بحص ورمل وبعض - القماش - الورق - الزجاج المعادن اللدائن الصناعية هذه المكونات تختلف من بلد لآخر ومن فصل لآخر فمثلاً نسبة المادة العضوية في قمامة مدينة دمشق تتراوح بين 45- 55% كما أن هذه النسبة تنخفض في فصل الشتاء عنها في فصل الصيف.

الطريقة المتبعة في دمشق لتحويل القمامة إلى سماد هي التخمير الهوائي والتي تتبع المراحل التالية: المرحلة الأولى: وهي مرحلة تهيئة المادة العضوية للتخمير وذلك من خلال عملية الطحن والغربلة لتفتيق المادة العضوية وهي القابلة للتخمير من بقية المواد المرفوضة مثل أكياس النايلون والقماش الخ من المواد التي لا تتحول إلى سماد والتي يبلغ حجمها بعد الطحن قطر فتحة ...والورق والحديد ثقب الغربال (6سم) وتجدر الإشارة هنا إلى أن عملية الفصل هنا هي فصل حتمي وليس نوعي بمعنى أنه لا يمكن استبعاد المواد غير المرغوب بتواجدها ضمن المادة العضوية وبالتالي سوف تخرج إلى ساحة التخمير.

المرحلة الثانية: وهي مرحلة التخمير الهوائي ضمن ساحة مكشوفة مزودة بفتحات تهوية أسفل الكومة وبآليات لتقليب الكومة من موضع للموضع الذي يليه إلى أن تجتاز الكومة ستة مواقع خلال فترة ( المنطلق عن التخمير في CO<sub>2</sub> ستة وثلاثون يوماً تتم خلالها مراقبة درجة حرارة الكومة ونسبة غاز ) نهاية هذه المرحلة تكون المادة العضوية قد تحولت إلى سماد طازج المرحلة الثالثة: وهي مرحلة التنقية من الشوائب للسماد الطازج وذلك بإتباع عملية الغربلة بواسطة غربال دوار قطر فتحاته (2) سم وبعدها تتم عملية الطحن حيث نحصل على سماد نخب ثاني وبعدها يذهب جزء من هذا السماد إلى غربال آخر قطر فتحاته (1.2) سم ومن ثم يذهب هذا السماد إلى أجهزة الفصل الزجاج والحجارة لنحصل على سماد نخب أول وتجدر الإشارة هناك إلى أن 700 / طن من القمامة التي هي استطاعة المعمل تنتج كمية 300 / طن سماد من كلا النخبين الأول والثاني والباقي هو عبارة عن المرفوضات التي لا تتحول إلى سماد والماء الذي يتبخر في الهواء .

بتطبيق هذه الطريقة في معالجة القمامة تكون كمية القمامة المرسله للمعالجة بالمطمر الصحي قد انخفضت بحدود الثلث تقريباً وبالتالي تكون قد قلصت المساحة المخصصة للمطمر الصحي عدا عن أنها وفرت مادة الكومبوست التي تعطي وفر في المحصول وتحسن من الخواص الفيزيائية للتربة.

## 2-مقلب القمامة القديم :

يقع المقلب القديم على مساحة تقدر ب (500) دونم كان قد وضع في الاستخدام عام 1980 إلا أنه لم يأخذ بعين الاعتبار الشروط الصحية والبيئية الواجب توفرها في مثل هذا النوع من المطامر كما لم يتوفر فيه شروط العزل لمنع تسرب السائل الناتج عن القمامة إلى المياه الجوفية كما لم يكن متوفراً فيه التجهيزات اللازمة لتغطية القمامة بالتراب لمنع تكاثر الذباب والحشرات الطائرة وانبعاث الدخان والغازات المتولدة من تخمر القمامة واحتراقها ذاتياً.

قامت الإدارة لاتخاذ عدد من الإجراءات لزيادة عمر استخدام هذا المطمر منها :

1- وضع سور مرتفع حول المقلب لحمايته من نابشي القمامة الذين كانوا يعيثون بالقمامة ولا يتورعون من إشعال الحرائق في سبيل البحث عن أشياء يمكن الاستفادة منها كما أنه بهذا الإجراء فقد تم حمايته من بعض الرعاة الذين يجدون في المواد الطازجة والخضراوات مجالاً لتأمين الرعي لقطعانهم من الماشية .

2- الإعلان عن بيع القمامة المتخمرة والمغطاة بالتراب إلى الفلاحين الذين كانوا يستخدمونها كسماد عضوي للحفر التي مضى على تغطيتها أكثر من ثلاث سنوات مما يسمح بإعادة استخدام مكان الحفرة لتعبئتها مجدداً بالقمامة وطمرها وفق الأصول. 3- وكان لآليات المنحة اليابانية المقدمة من قبل الحكومة اليابانية من خلال الوكالة اليابانية للتعاون الدولي ( جايجا ) دوراً كبيراً في المساعدة في إعادة تأهيل المطمر القديم وهذه الآليات هي :

- بلدوزر كاتر بلر D 8
- بلدوزر كاتر بلر D 7
- باكر هيتاشي جنزير

وقد ساعدت هذه المعدات الهندسية في :

- \*- تجهيز حفر فنية جديدة تمهيداً لوضعها كمستودع لتجميع النفايات 0
- \*- تأمين التراب اللازم للطمر وتغطية النفايات بعد دحلها 0
- 4- وضع الفائض من التراب على أكتاف الحفر مما ساعد في زياد عمق الحفرة وبالتالي عمر الحفرة الفنية الجاهزة لاستقبال القمامة .
- 5- حفر قنوات تجميع للمياه الجوفية الناتجة عن عصارة القمامة على محيط مكان ردم القمامة مع جر هذه المياه إلى أحواض ترسيب كبيرة يمكن أن تساعد السطوح الكبيرة فيها بتبخير المياه الموجودة في العصارة مما يساعد في تخفيض كبير في حجوم وكميات المياه المراد معالجتها.
- 6- حفر آبار تهوية لاستخلاص الغازات الناتجة عن التخمر تخفيفاً من خطرهما وتمهيداً لإمكانية الاستفادة منها وحالياً يتم التحضير لدراسة جدوى تجميع هذه الغازات تمهيداً للاستفادة منها في تجميع هذه الغازات
- 7- كما هو جار في كثير من دول العالم تم الاتجاه نحو الارتفاع في جبال القمامة المغطاة بالتراب وقد وصل الارتفاع بأكثر من (20م) في أماكن كثيرة 0
- 8- في إطار تحسين الشروط البيئية للمناطق المحيطة بالمطمر ومعمل المعالجة القريب منه فقط تم زراعة أكثر من (25) ألف شجرة حراجية ومثمرة ( زيتون) مما ساعد في تنقية الهواء المحيط .
- 9 - تم إجراء تجارب على زراعة سطح المطر بعد تغطيته بالتراب .

### الآليات العاملة ضمن المطمر العام

نوع الآلية	تاريخ الصنع	جاهزية الآلية	ملاحظات
8 Dبلدوزر كاتر بلر	1996	جيدة	منحة من جاكا
7 Dبلدوزر كاتر بلر	1996	=	منحة من جاكا
باكر هيتاشي جنزير	1996	=	منحة من جاكا
بلدوزر كوماتسو 355	1983	=	
كمبكتر كاتر بلر 816	1978	=	
باكر دايو دولاب	1996	=	
مرسيدس قلاب	1990	=	
مرسيدس قلاب	1990	=	
فيات قلاب	1978	=	

يتم العمل في المطمر القديم على ثلاث ورديات موزعة على الشكل التالي :

الورديات	سائقين	عمال	كاتب	مراقب عام
الأولى	10	3	1	1
الثانية	1	3	1	-
الثالثة	-	3	1	-

### ج- مقلب القمامة الجديد:

تم بالتعاون مع جامعة دمشق دراسة إنشاء مقلب صحي للقمامة يأخذ بعين الاعتبار الشروط النظامية لمنع تلوث المياه الجوفية والهواء حيث تم إحاطة الموقع بسور بيتوني وإشادة بناء خدمات وبوشر بحفر

حفريات الطمر الصحي التي سوف تأخذ بعين الاعتبار جميع سائل رشح القمامة تمهيداً لمعالجتها لاستخدامها في سقاية الأشجار المزروعة في المنطقة 0

### د- معالجة النفايات الطبية:

يوجد في مدينة دمشق ما يزيد عن أربعين مشفى بين عام وخاص وتتراوح الطاقة الإنتاجية لها بين عشرة أسرة إلى ما يقارب من ألف سرير ويوجد في هذه المشافي نوعين من النفايات : النفايات المطبخية ويتم جمعها مع النفايات المنزلية لنفس المنطقة التي يوجد فيها المشفى ونفايات طبية بعد أن كانت هذه النفايات يتم نقلها ومعالجتها بالطمر تم بالتعاون مع وزارة الصحة نقل ثلاثة من محارق النفايات الطبية من بعض المشافي التابعة للوزارة هذه المحارق تم تركيبها في معمل معالجة النفايات الصلبة ويتم استخدامها الآن في حرق النفايات الطبية مع باقي أنواع النفايات المتولدة عن هذه المشافي وقد جرى تخصيص حاويات خاصة بالنفايات الطبية ذات لون مختلف عن الحاويات الأخرى، هذه الحاويات يتم تفريغها ونقل محتوياتها إلى موقع المحارق بواسطة آلية نقل قمامة خصصت لهذه الغاية تعتبر هذه الخطوة هي الخطوة الأولى في معالجة النفايات الطبية .  
وتجري الآن أعمال تركيب نظام معالجة متكامل للنفايات الطبية 0 -

### سادساً - طموحات تحسين المطمر النهائي القديم :

في إطار تحسين الشروط الفنية للعمل في المطمر النهائي القديم التابع لنظام الإدارة المتكاملة لمعالجة النفايات الصلبة فإننا نسعى لتحسين الشروط البيئية في المطمر العام وتخفيض الحد الأدنى للتلوث من جميع النواحي من خلال :

- \*- إعداد دراسة لتنفيذ شبكة متكاملة للغازات الناتجة عن تخمر النفايات في المطمر تميداً لإعلان مشروع تجميع جميع هذه الغازات وتوليد الطاقة الكهربائية منها 0
- \*- إعداد دراسة متكاملة لشبكة تجميع المياه الراشحة تميداً لإعلانه مشروع تجميع هذه المياه ومعالجتها وبحث إمكانية الاستفادة منها في السقي 0
- \*- البدء بأعمال زراعة سطح المطمر بعد تغطيته بالتراب بشكل كامل تمهيداً لتشكيل محمية طبيعية متكاملة حراجية بعد الانتهاء من أعمال الزراعة بشكل كامل 0

### سابعاً- خطط مستقبلية وتوصيات :

- خلصت الورقة إلى مجموعة من النتائج يأتي أبرزها فيما يلي
- 1- إن عمليات التخلص من النفايات بواسطة الردم والحرق ما هي إلا إهدار لمواد قد تكون ذات قيمة اقتصادية كبيرة وأن هذا الهدر يصاحبه الكثير من الآثار السلبية من تلوث الهواء أو التربة أو المياه أو ارتفاع درجة حرارة الأرض ويتطلب إعادة تأهيل البيئة مبالغ طائلة بالإضافة إلى مبالغ أخرى لعلاج الآثار الصحية الناتجة عن تلوث البيئة والتي من أفضل استخداماتها في المزيد من التنمية .
- 2- تلعب البحوث والدراسات أهمية كبرى في التصدي لمشاكل التعامل المستقبلي مع النفايات وللوصول لقرارات سليمة فيما يتعلق في تطوير تقنيات الاستفادة من النفايات وتطوير أسواق

- المواد المسترجعة لا بد من تحديث البيانات الخاصة بإنتاج النفايات وتدويرها بالإضافة إلى المعلومات البيئية الأخرى كما أن الاستفادة من تجارب الدول الأخرى في قضايا التعامل مع النفايات تعتبر ذات أهمية كبيرة في مجال إدارة النفايات .
- 3- القطاع الخاص يحتاج إلى التشجيع من قبل الجهات الحكومية والهيئات الأخرى كما يحتاج للمساعدة من الجمهور في إتمام عمليات التخلص من النفايات وإعادة تصنيعها في إطار المحافظة على سلامة البيئة.
- 4- التعامل مع النفايات في المستقبل يحتاج لتضافر وتكامل الجهود الرسمية والخاصة والشعبية لأن قضية المحافظة على البيئة قضية مشتركة وتهم الجميع بنفس القدر .
- 5- هناك نوع من التفرد في التعامل مع النفايات من مجتمع لآخر . وأن تقنيات وإدارة النفايات والتعامل معها يرتبط بالمناخ والأحوال الاقتصادية ومستوى الرفاهية أو درجة التقدم الاقتصادي والثقافي . والثقافة المحلية يمكن أن تلعب دوراً بارزاً في استقطاب الجمهور لصالح برامج البيئة وذلك من خلال برامج التوعية الدينية والاجتماعية.
- 6- أن عملية الاستفادة من النفايات قد تكون ذات مخاطر عالية فيما يتعلق بالاستثمار وتتطلب معرفة مكثفة بالأسواق المختلفة للسلع ونتيجة لذلك فإن الورقة توصي بضرورة عمل التالي :
- 1- وضع خطة للاستفادة من النفايات من خلال إعداد برنامج مشترك ومتكامل بين القطاع الخاص والحكومة للاستفادة من النفايات الصلبة وذلك يتطلب :
- تحديد الأهداف
  - توفير البيانات عن الوضع الحالي .
  - ضرورة مساهمة البلديات والجهات الأخرى في مسح وتجميع البيانات .
  - اتساق القرارات المتعلقة بتجميع وتسويق معالجة المواد المسترجعة .
  - ضرورة مساهمة الجمهور الإيجابية والفعالة.
  - تحديد المواد التي سيتم الاستفادة منها وذلك بتحليل أحجامها وكمياتها وإمكانية تسويق هذه المواد واقتصاديات التعاون معها .
  - أن تكون التأثيرات البيئية للاستفادة من النفايات في حدها الأدنى.
  - التحليل الدقيق للخيارات التقنية المتاحة على ضوء الموارد والأهداف .
- 2- تبني استراتيجية إعلامية بيئية متكاملة تجعل الوعي البيئي جزءاً من المهام المنوط بتنفيذها الأجهزة المؤسسات ، الدوائر والتنظيمات العامة والخيرية والخاصة .
- 2- ضرورة تشجيع القطاع الخاص العربي على الاستثمار في تدوير النفايات واستخدام أحدث التقنيات المستعملة في الدول المتقدمة بالإضافة إلى إزالة كافة المعوقات التي تواجهه للقيام بدوره الهام في المحافظة على البيئة والاستغلال الأمثل للنفايات .

أنتها

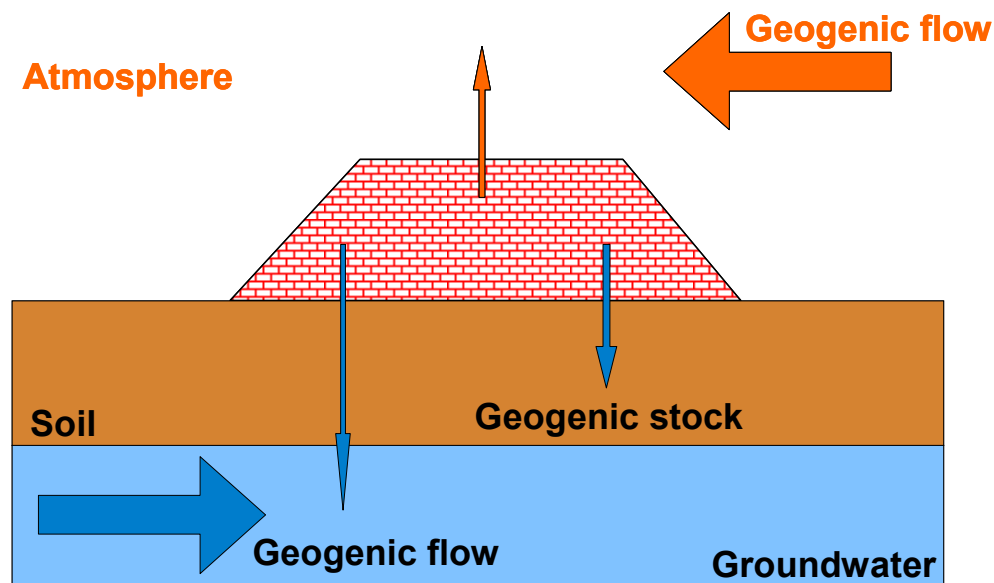


# Understanding the Landfill as a Reactor

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## 1 INTRODUCTION

This paper deals with landfills for municipal solid waste (MSW) and their short and long-term behaviour as reactors. Reactor landfills in general are characterised by reactions, chemical and/or physical, causing emissions, which are not environmentally sound. The counterpart of a reactor landfill is called final storage landfill – emissions from a final storage landfill should not change natural (geogenic) flows and stocks in water, air and soil significantly during short (years), mid (decades) and long-term (centuries and millennia) periods (Baccini, 1989). However, up to now final storage landfills and final storage quality of waste are just concepts.



modified after Brunner (1993)

Figure 1: Principle of a final storage landfill

Residues from today's MSW treatment technologies (mechanical-biological and incineration plants) are not of final storage quality yet. And therefore landfills are constructed with technical barriers to prevent harmful substances from entering the environment. But it has to be kept in mind, that it will not be possible to prevent the interaction of the waste material with the atmosphere, hydrosphere, and geosphere over long-term periods by encapsulating the waste.

Three emission paths from landfills can be identified:

- Atmosphere (via landfill gas): local, regional and global (the global warming potential of the greenhouse gas methane is 21 times higher than the one of CO<sub>2</sub>) impacts
- Soil (via leachate): local impacts
- Groundwater and surface water (via leachate): local and regional impacts

## 2 FROM “BLACK-BOX” TO “GREY-BOX”

### 2.1 General

Often landfills and their potential harm to the environment are reduced to gaseous and liquid emissions, i.e. landfills are dealt with rather at a black-box level. However, to estimate future emissions from landfills and to assess their hazardous potential, information from various fields is required:

- Waste input (e.g. MSW, construction & demolition waste, etc.)
- Amount of water infiltrated
- Water flow pattern (moisture distribution)
- Physical-chemical conditions (pH, redox)

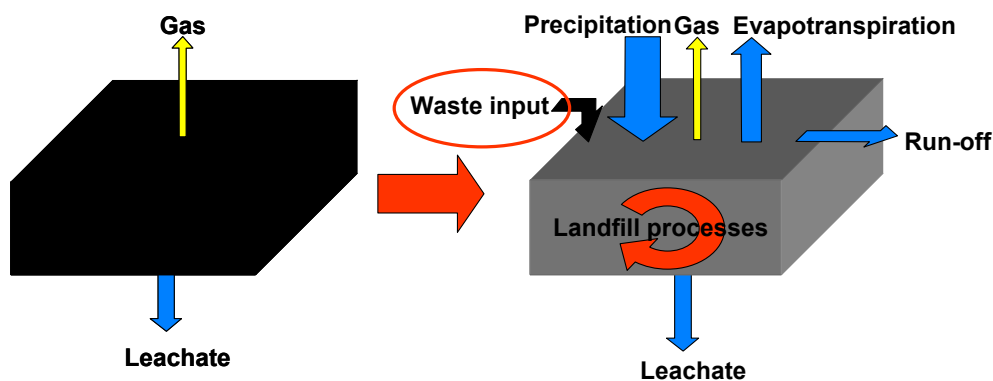
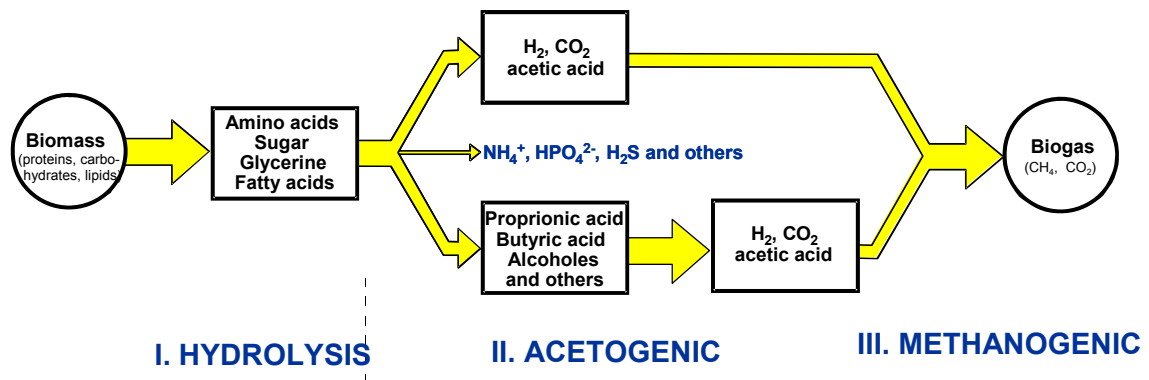


Figure 2: From a “black-box”-model to a “grey-box”-model

Only if this information is available, i.e. only if the black-box model can be extended to a grey-box model, the processes within the landfill can be assessed. Among these processes the following are the most important ones:

- Physical processes – e.g. elution of readily soluble salts; adsorption
- Biochemical processes – e.g. aerobic and anaerobic degradation of organic matter (see figure below); formation of humic substances
- Geotechnical processes – e.g. consolidation processes (settlements)
- Chemical processes – e.g. redox-reactions; acid-base reactions; precipitation, etc.
- Geochemical processes – e.g. formation of secondary compounds; weathering processes
- Geological processes – e.g. erosion



Schobert (1978)

Figure 3: Anaerobic biodegradation in a MSW-landfill

## 2.2 Landfills as Chemical Reactors

### Waste composition

Processes within landfills are mainly influenced by the waste composition, which varies regionally and seasonally. The figure below shows the differences in the composition of MSW from the eastern Mediterranean region on the one hand and central Europe on the other hand.

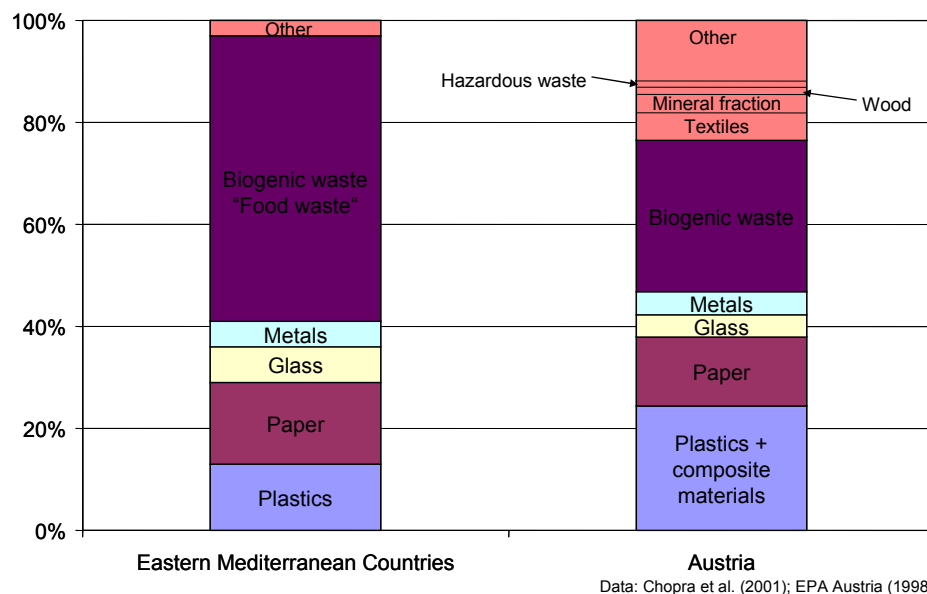


Figure 4: Comparison of MSW composition in Eastern Mediterranean Countries and Austria.

To estimate e.g. the gas emission potential, it is useful to know the waste composition rather at a "chemical" level, like it is shown in following figure (from this diagram information about the biodegradability of the different compounds can be deduced easily).

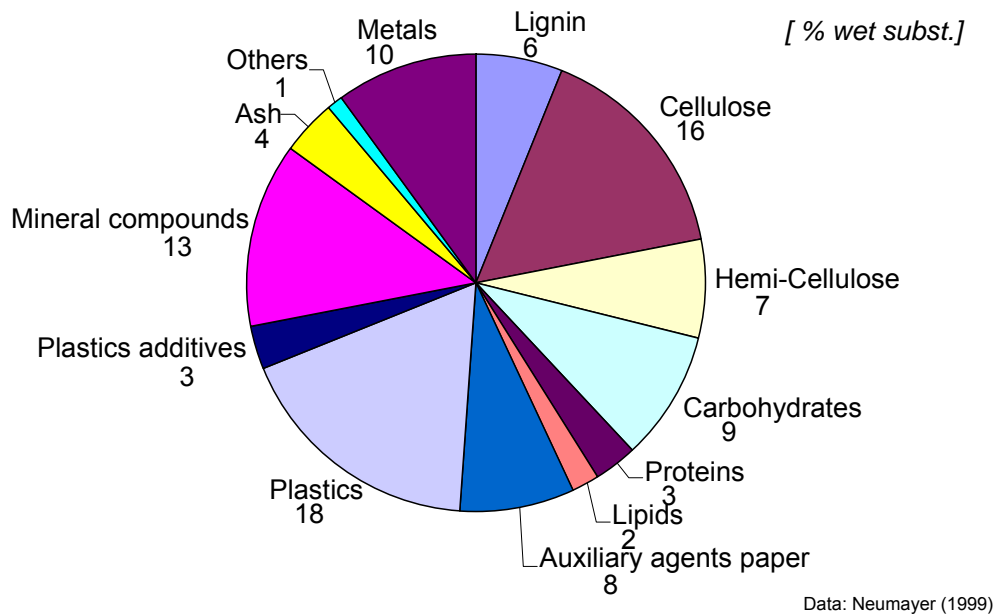
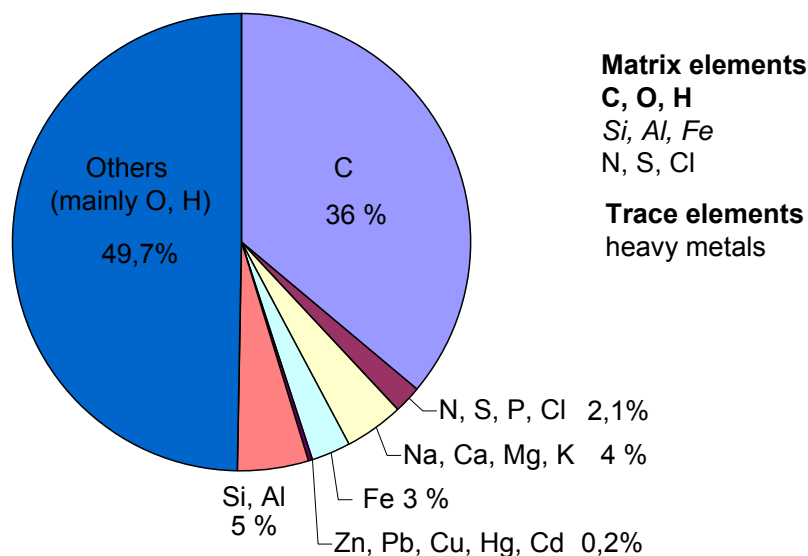


Figure 5: Composition (chemical compounds) of MSW in Austria

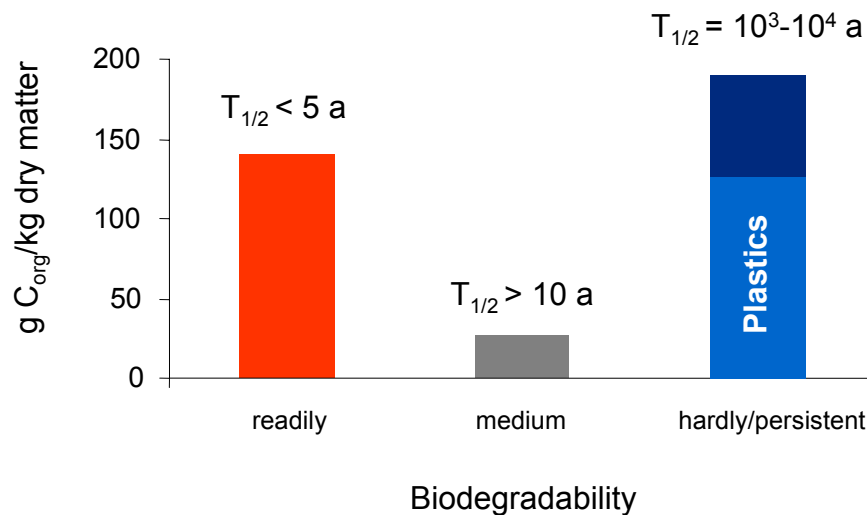
For substance balances, e.g. to determine the remaining emission potential, information about the chemical composition is necessary:



Data: Fehring et al. (1997); Zimmermann et al. (1996)

Figure 6: Composition of MSW (chemical elements) of MSW in Austria/Switzerland

It can be seen that the matrix of MSW mainly consists of 3 elements – C, O and H – and it is the matrix, which determines the main reactions. The following figure shows the breakdown of organic carbon, as the main matrix element, according to its biodegradability: In theory about 50 % of the total carbon content is available for biodegradation, the rest is either hardly degradable (like lignin) or at least within centuries nearly persistent (like plastics). In chapter 2.3 it will be shown that an extension of the landfill model from a chemical towards a “hydraulic” reactor results in another reduction of the availability of organic carbon due to the water flow pattern in landfills.



Data: modified after Neumayer (1999)

Figure 7: Biodegradability of the carbon-matrix of MSW

It is the waste composition, together with the amount of water infiltrating the landfill, which determine landfill emissions. In the table below typical leachate emissions from MSW landfills are shown (3 compartments of Breitenau landfill near Vienna, which is operated as an experimental landfill by TU Vienna):

		Mean 1987-2002			Maximum 1987-2002			Minimum 1987-2002			Mean 2001-2002			Discharge standard
		Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3	Comp 1	Comp 2	Comp 3	
El. cond.	[mS/cm]	7,5	9,9	14,1	28,5	23,5	26,5	3,5	6,0	9,8	4,6	7,2	10,7	
BOD5	[mgO2/l]	1.475	483	143	32.000	16.500	1.700	6	30	70	21	52	104	10
COD	[mgO2/l]	3.498	1.765	1.454	57.000	29.000	4.500	170	280	800	278	679	1.077	50
TOC	[mg/l]	1.279	707	503	19.655	10.000	1.552	60	130	276	145	252	389	
TKN	[mg/l]	678	780	1.010	2.150	2.150	2.550	210	390	600	302	479	765	
NH4-N	[mg/l]	491	731	835	2.000	1.900	2.500	190	340	520	263	434	680	10
NO3-N	[mg/l]	0,7	1,6	1,2	3,4	21,5	12,3	0,0	0,3	0,0	0,2	21,5	12,3	35
NO2-N	[mg/l]	1,99	2,96	3,30	7,82	7,43	9,77	0,98	1,64	0,40		4,00	0,40	
P tot	[mg/l]	3,1	3,7	5,4	10,0	11,6	12,0	1,1	1,9	2,4	2,0	2,7	5,4	
PO4-P	[mg/l]	2,4	2,9	4,4	8,0	9,3	9,6	0,3	1,5	1,9	0,7	2,0	4,6	
S tot	[mg/l]	140,5	138,2	132,5	293,1	292,7	280,8	0,5	2,2	3,4	2,7	7,0	9,8	
SO4-S	[mg/l]	47,6	46,9	45,5	98,2	97,6	93,7	0,0	0,8	0,8	1,2	3,9	3,1	
Cl	[mg/l]	623	999	1464	3125	2500	2438	260	530	820	338	677	973	
Ca	[mg/l]	273	117	54	3.600	2.300	130	23	15	10	170	141	86	
Cd	[mg/l]	0,001	0,001	0,001	0,020	0,020	0,010	0,000	0,000	0,000	0,000	0,000	0,000	0,1
Cu	[mg/l]	0,023	0,036	0,119	0,200	0,550	0,400	0,000	0,000	0,000	0,001	0,008	0,016	0,5
Pb	[mg/l]	0,081	0,040	0,067	0,600	0,500	0,200	0,000	0,000	0,000	0,000	0,000	0,001	0,5
Zn	[mg/l]	0,648	0,286	0,258	14,000	5,000	1,800	0,000	0,000	0,000	0,007	0,025	0,010	0,5
Fe tot	[mg/l]	46,8	8,2	2,4	840,0	250,0	12,0	4,0	0,0	0,8	17,7	6,0	1,8	
Na	[mg/l]	499	799	1.184	2.500	2.000	1.950	200	420	510	268	532	944	

Data from Breitenau-landfill: Döberl et al. (2002)

Landfill emissions (leachate as well as gas) are characterised by an exponential decrease, which results in graphs like the following. It can be seen that after 20-25 years emissions are not environmentally sound. In case of organic carbon they are about one order of magnitude above legal standards, in case of ammonia even more.

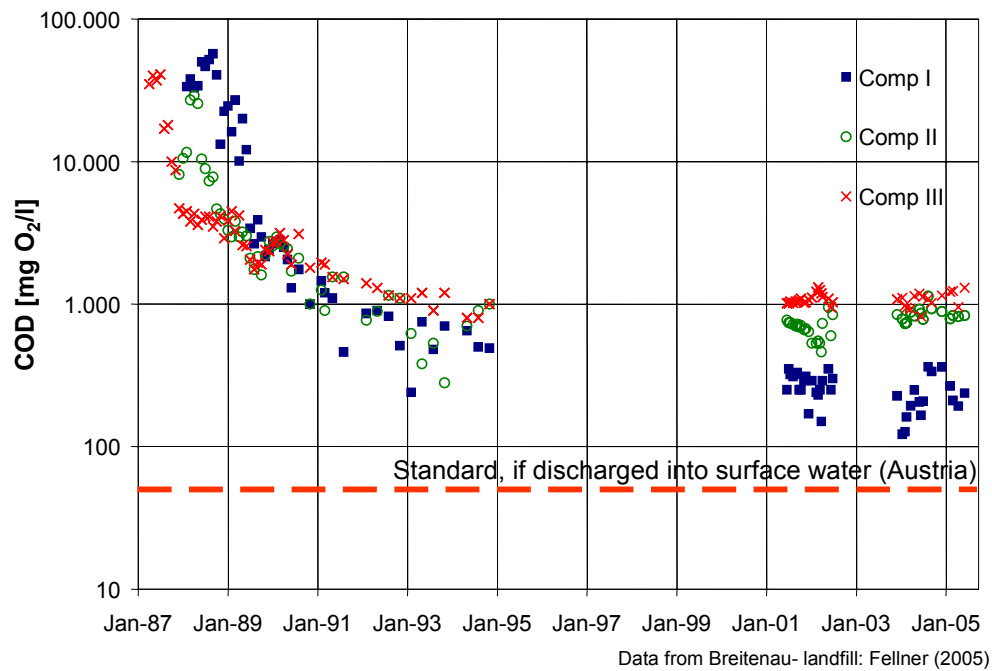


Figure 8: Trend of leachate emission from a MSW-landfill

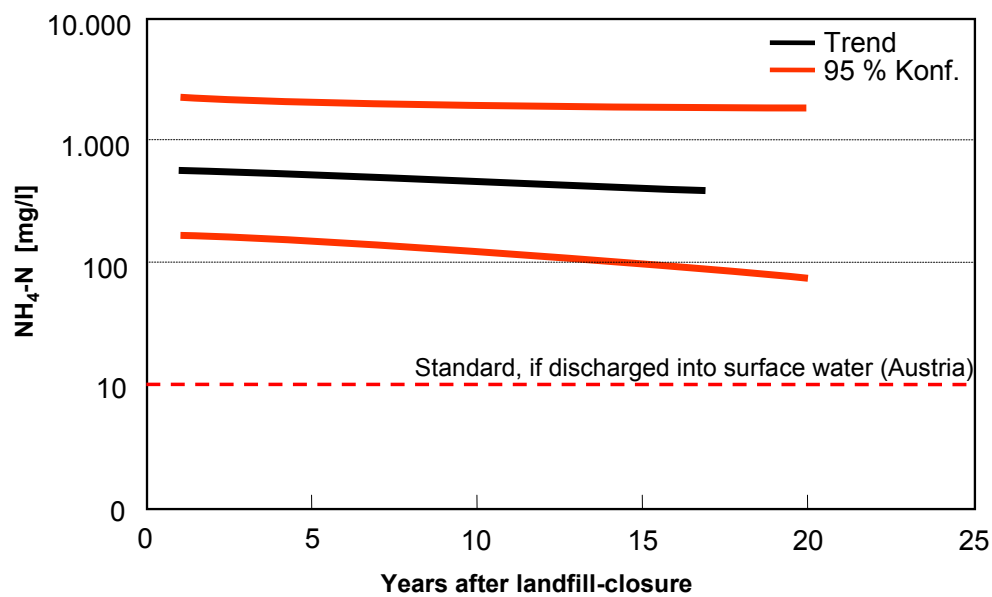


Figure 9: Trend of leachate emissions from MSW-landfills

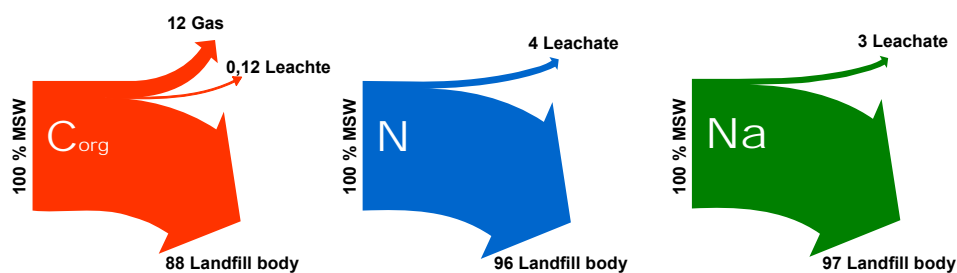
Various authors assessed the time necessary to reach environmentally sound leachate emissions (see table below) and concluded that the after-care period of MSW landfills will theoretically last for centuries.

Table: Years to reach environmentally sound leachate emissions from MSW landfills

	Belevi & Baccini (1989)	Kruse (1994)	Heyer et al. (1997)	Krümpelbeck & Ehrig (2000)
C <sub>org</sub>	500 - 1 700	-	-	-
COD	-	280	80 - 360	65 - 320
N <sub>tot</sub>	55 - 80	-	-	-
TKN	-	815	120 - 450	-
NH <sub>4</sub> -N	-	-	-	Decades - centuries
Cl <sup>-</sup>	100 - 150	210	90 - 250	25 - 130
AOX	-	-	30 - 210	40 - 100
Heavy metals	-	-	-	<10

From a substance balance's point of view after 1-2 decades only a small amount of the initial substance load has been emitted via landfill gas or leachate (see next figure). In case of heavy metals this amount is even lower (max. 1 %). Mainly three reasons can be identified for this phenomenon.

**Substance flows of a 15 years old MSW landfill**  
**100 %: total amount of substance in MSW**



Huber et al. (2002)

Figure 10: Substance balance of a MSW-landfill

### 1. Total versus available substance load

Only the easily soluble/degradable fraction of a substances is available within short to mid-term periods. Like mentioned above, this amount is up to 50 % in case of organic carbon and about 20 % in case of sodium (about 18 % of Na have been emitted after 15 years, if only the available amount is taken into account).

## 1. Total vs. available amount of substances

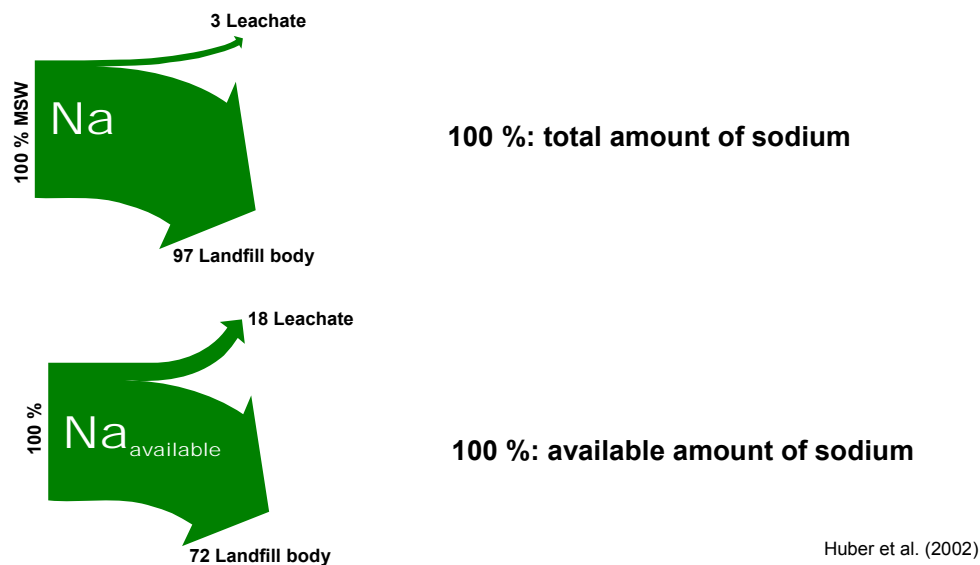
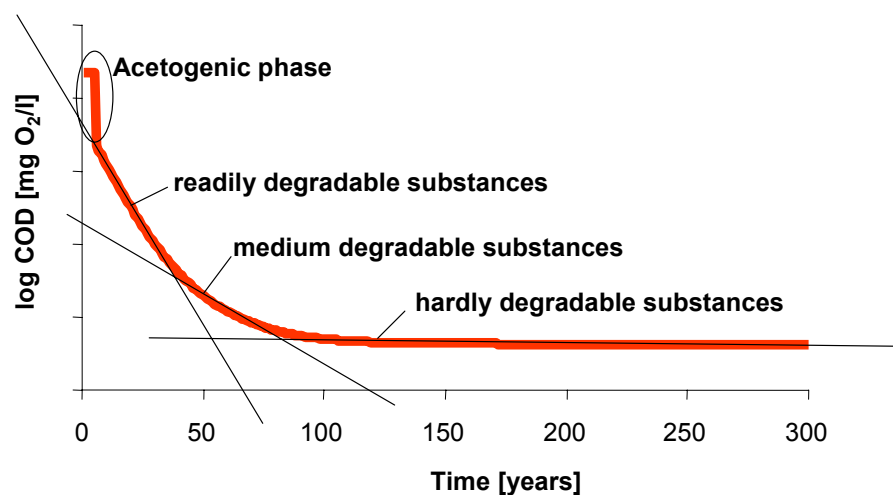


Figure 11: Total substance amount vs. available substance amount

Looking at heavy metals the physical-chemical conditions in the methanogenic stage (pH >7; anaerobic) prohibit the mobilisation of most heavy metals.

## 2. Kinetics of biodegradation/elution

### 2. Kinetics of biodegradation



Döberl (2004)

Figure 12: Different stages during biodegradation of MSW

## 3. Landfills as “hydraulic” reactors

See following chapter



## 2.3 Landfills as “Hydraulic” Reactors

The third reason for the relatively low amount of discharged substances is a result of the specific hydraulic regime in landfills. It is characterized by matrix areas with low hydraulic conductivity and high retention capacity and preferential flow paths with high hydraulic conductivity and low retention capacity. This water flow pattern is similar to karst systems.

### 3. Landfills as “hydraulic” reactors

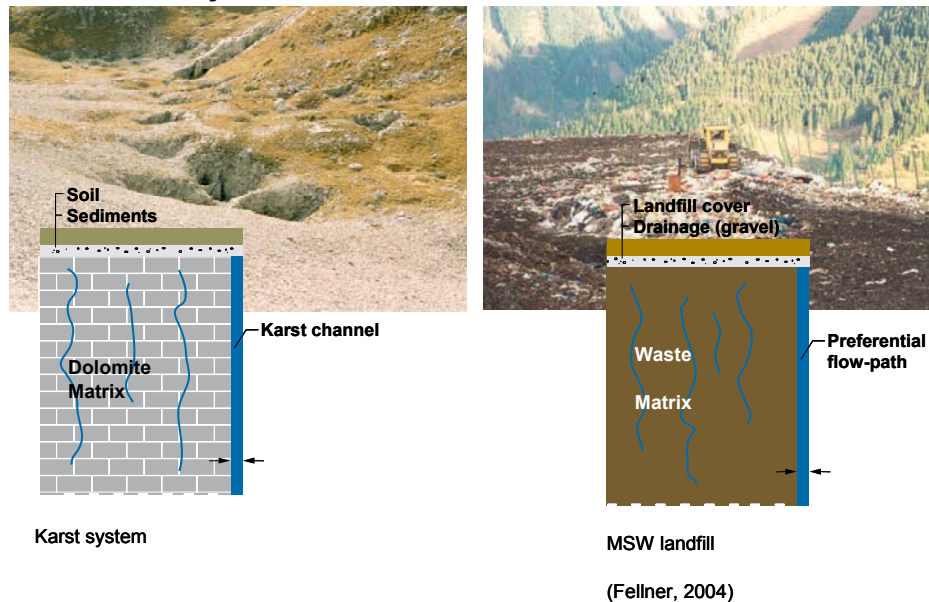
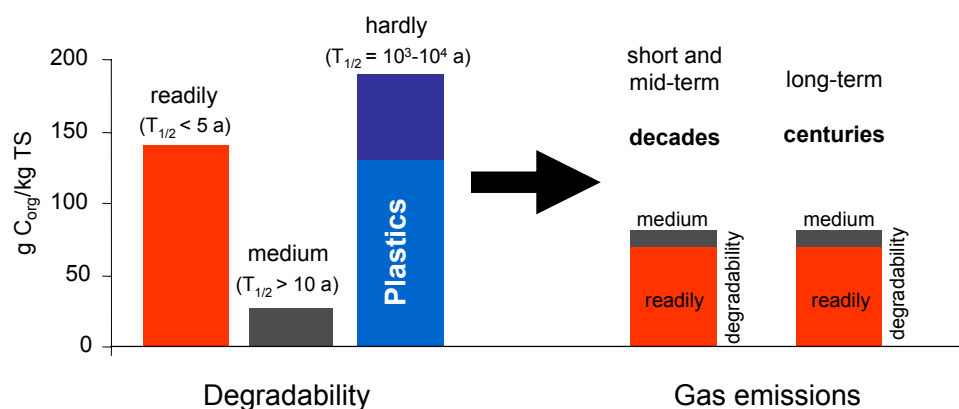


Figure 13: The water flow pattern in landfills is similar to karst systems

Due to this heterogeneity only 30 % - 50 % of the landfill volume contributes to degradation and leaching processes. This results in the phenomenon that even the easily degradable carbon fraction will not be emitted during short and mid-term periods but will remain in the landfill and will cause emissions during centuries as well by a progressive development of new preferential paths.

### Estimated gas emissions of MSW landfills



Döberl (2004)

Figure 14: Biodegradability of carbon-matrix and heterogeneity of landfill together determine future emissions

### 3 CONCLUSIONS

When assessing future landfill emissions and the hazardous potential of landfills, it is necessary to understand landfills as reactors – as chemical reactors on the one hand, because mainly the waste composition is responsible for quality and quantity of emissions. On the other hand landfills should be seen as “hydraulic” reactors as well. First, the amount of water acts as a driving force for all processes within the landfill. Additionally, the “degree of heterogeneity” in the water flow regime, i.e. degree of non-uniform water distribution, turned out to be decisive for the substance balance: The more homogeneous the water flow, the higher the amount of substances discharged. On the other hand, high water flow rates, e.g. when flushing the landfill, cause a high discharge via preferential flow paths. This leads to a relatively fast decrease of leachate concentrations, which could be interpreted, misleadingly, as a proceeding stabilization process of the whole landfill body. However, it has to be kept in mind that the leachate concentration is just a result of the areas surrounding the preferential flow paths. An increase of the water flow rate does not inevitably result in a higher substance outflow. If the leachate amount of two landfills is equal, the heterogeneity defines the future emission behaviour significantly. Since the “degree of heterogeneity” may enhance or reduce the effects gained by flushing or leachate recirculation significantly, it should be quantified prior to the application of methods to shorten the after-care period of landfills.

In addition, this conclusion has an impact on the widely spread recommendation to use leachate concentrations for assessing the remaining emission potential of landfills. Because of the recent research on the Breitenau landfill it is recommended not to restrict assessments concerning the future emission potential of landfills on leachate concentrations, but to include investigations representing the remaining substance load in the landfill body as well.

# Management of Leachate and Gas in Landfills

*Johann Fellner, Vienna University of Technology, Austria*

## INTRODUCTION

Land disposal of waste has been practiced for centuries. In the past it was generally believed that leachate from waste is purified by soil and groundwater, and hence contamination of groundwater was not an issue (Bagchi, 1990). Thus, disposal of waste in the form of open dumps at all type of sites (e.g., gravel pits, ravines, etc.) was an acceptable practice until the early 20<sup>th</sup> century. However, with increasing concern for the environment in the late 1960s landfills become under scrutiny. Within a decade several studies (e.g. Andersen & Dornbusch, 1967; Nöring et al., 1968) showed that landfills do significantly contaminate groundwater.

As a result of this finding, steps from open dumping of wastes towards sanitary landfills were made. Regulations concerning technical equipment, site characteristics and operation of landfills were enacted and improved with time. Landfill technology has become increasingly sophisticated over the past few decades.

However, in spite of all claimed technical facilities of landfills, gradients of matter and energy between landfill and the surrounding environments still exist. By simply referring to the second law of thermodynamics, of spontaneous increase in entropy, it can be stated that, with time, the energy level in a landfill will approach the level of the surroundings. This means that in a long term, matter and energy will leave the landfill unless their storage is maintained by a continuous input of energy. Since long term records of the mass flow out of landfills are not available it can only be speculated how long it may take before equilibrium is reached, that is when the energy level in the landfill is equal to that of the surrounding environment. The rate of matter leaving the landfill depends on the mass and energy gradient as well as on the “flow resistance” between landfill and the surroundings, whereby the term “flow resistance” represents physical and chemical barriers, respectively. The aim of modern landfill management is to equilibrate the energy gradient between landfill and the surrounding environment in a controlled manner to a “final storage quality”, where the emissions are considered not significantly contribute to natural substance fluxes in soils, air and water (Brunner, 1992). Thereby the landfill can become an integrated part of the environment.

Existing landfills of municipal solid waste (MSW) are far from requirements of “final storage quality”. Major environmental concerns associated with MSW landfills, containing high content of biodegradable organic matter, are related to the generation of leachate and biogas (see Figure 35). Effects of leachate emissions from landfills are local for underlying groundwater and soils, whereas production and emission of methane gas poses a global pollution potential since it is a greenhouse gas. It is estimated that solid waste landfills contribute 10 % of the global anthropogenic methane emissions (Watson et al., 1996).

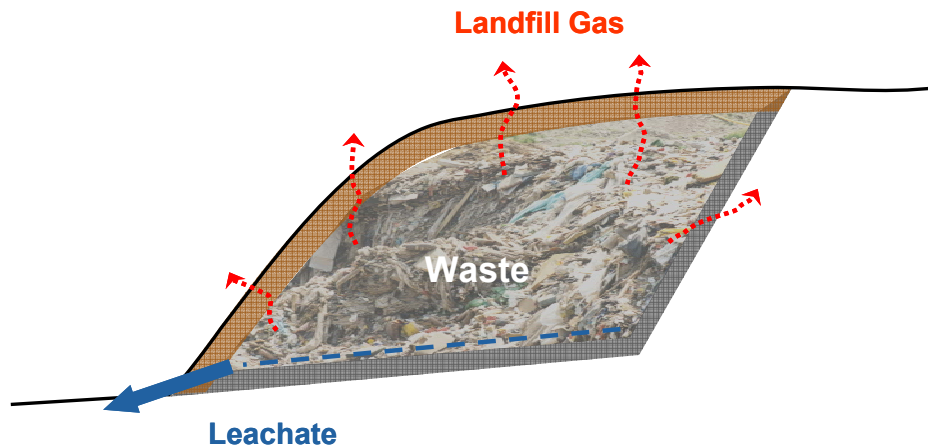


Figure 15 Emissions from municipal solid waste landfills

Quantity and quality of leachate and biogas formed, depend on the characteristics of the waste, the design and the operation of the landfill and the climatic conditions (temperature, precipitation, and evapotranspiration).

Contrary to factories or industrial plants emissions from landfills are not restricted to the operation period (see Figure 36) only. For instance leachate emissions from MSW landfills will stay on an environmentally incompatible level for hundreds of years (Belevi & Bacchini, 1989; Krümpelbeck & Ehrig, 2000).

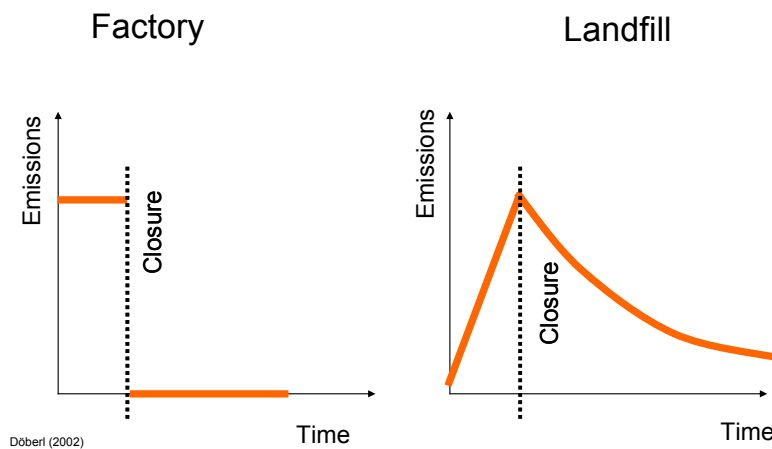


Figure 16 Landfill emissions versus time (after Döberl, 2002)

## LEACHATE MANAGEMENT

Leachate is generated as a result of the percolation of water through the waste. It can be defined as a liquid that is produced when water comes into contact with waste.

The quality and quantity of leachate generated are important in managing a landfill.

- **Leachate Quantity**

The amount of leachate generated depends on the climatic conditions (precipitation, temperature, air humidity, wind speed) and the design of the final cover (soil cover or sealing and the vegetation).

The leachate volume can be estimated performing a simple water balance (see Figure 17).

Water is introduced into the landfill through the moisture of the landfilled waste (WC), as precipitation (P) and in some landfills by recirculation of leachate (RCL). Some of the precipitation may run off as overland flow (R), and some may evaporate from the waste material or be removed by transpiration from the vegetation cover (ET). The remaining water accumulates (water storage S) or must be discharged by drainage (leachate L).

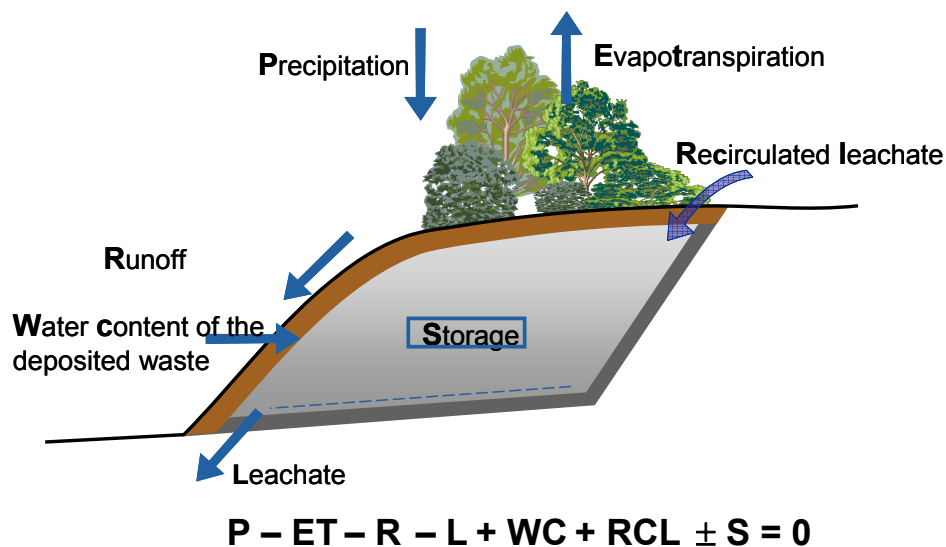


Figure 17 Water balance – landfill

Simple water balance calculations for different sites in Syria performed with the computer model HELP - Hydrologic evaluation of the landfill performance (Schroeder et al., 1984) lead to the following results:

At a landfill located in Latakia (with an average annual precipitation of 800 mm) leachate generation rates are around 300 mm per year, whereas in Damascus (annual precipitation: 200 mm) water is hardly leached from the landfill (< 10 mm/a).

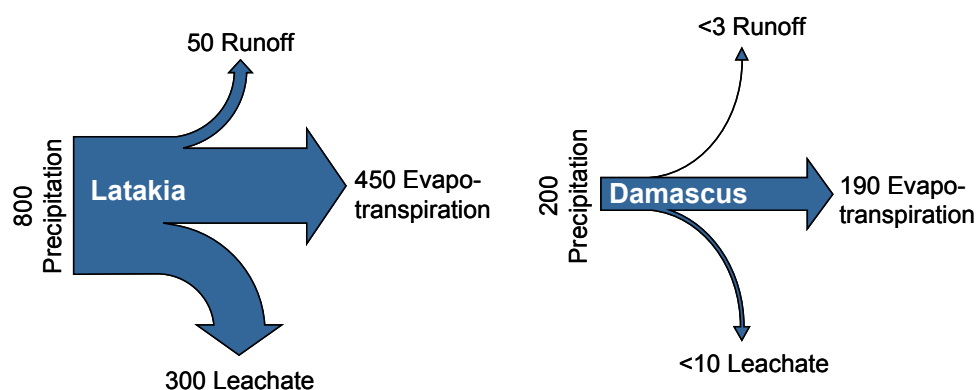


Figure 18 Water balance for landfills at different locations in Syria (Values in mm/a)

The results indicate that proper leachate management options could be completely different. In Latakia ground water pollution through landfills is an important issue, therefore leachate collection and treatment is required, whereas in Damascus the hazard of leachate is little, as a result even the leachate collection system could be omitted.

### • **Leachate Quality**

Leachate quality is influenced by the following factors:

- waste composition
- elapsed time (decreasing concentration with increasing time)
- leachate quantity (decreasing concentration with increasing quantity)
- available moisture

Typical leachate qualities of municipal solid wastes are included in Table 1. The main pollutants are organic substances, ammonia, salts, and heavy metals.

Table 1 Leachate qualities (after Brunner et al., 2001)

Parameter	unit	Acidogenic phase		Methanogenic phase	
		medium	maximum	medium	maximum
pH-value		6,1	5,5	8,0	8,5
BOD <sub>5</sub>	mg/l	13.000	30.425	180	383
COD	mg/l	22.000	38.100	3.000	4.340
Iron	mg/l	925	2.120	15	29,3
Zinc	mg/l	5,6	68,4	0,64	3,78
Chloride	mg/l	500	15.000	200	10.000
....					

Hence, leachate usually shows high pollution, it can not be discharged directly into surface water bodies. It requires appropriate treatment before it returns to the environment.

The variation of leachate characteristics (in a short and long term) makes the design of a treatment system difficult. In order to even discharge rates at least, a storage basin for leachate collection is essential.

### **Leachate treatment**

The following traditional techniques for waste water systems are also used for treating landfill leachate:

- biological treatment (aerobic stabilization)
  - aeration tanks
  - constructed wetlands
- physical/chemical treatment (precipitation, adsorption, chemical oxidation, and reverse osmosis)

Additionally, leachate recirculation is also promoted as a method for treating leachate. Although the concentration of organic pollutants (BOD, COD) can be reduced by leachate recirculation, the concentration of metal and salts increases (Stegmann, 1979). Furthermore recirculation can reduce the volume of leachate due to increased evapotranspiration. Problems noticed with leachate recirculation are reduction in the permeability of the landfill cover and arising odor.

Another option for leachate management is to minimize the water volume entering the waste by appropriate landfill cover design. Prevalent design concepts are sealing or the

construction of an evapotranspiration layer. The first concept increases the runoff from the surface, whereas the second one enhances the water loss from the landfill through a dense vegetation cover, which promotes evapotranspiration.

The lifetime of sealings are finite (merely decades), which leads to a time limited measure by prevention of leachate generation using top sealing. Thus, aftercare of leachate emissions is only shifted into the future.

Leachate management options can be divided according to techniques used and the investments necessary.

Table 2 Summary of leachate management options

Low-Tech Measures	High-Tech Measures
<ul style="list-style-type: none"> <li>• reduction of leachate volume (landfill cover: evapotranspiration layer)</li> <li>• leachate recirculation</li> <li>• leachate treatment using               <ul style="list-style-type: none"> <li>○ constructed wetlands</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• reduction of leachate amount (landfill cover: top sealing)</li> <li>• leachate treatment using               <ul style="list-style-type: none"> <li>○ aeration tanks</li> <li>○ percolating filter</li> <li>○ adsorption</li> <li>○ reverse osmosis</li> </ul> </li> </ul>

Figure 19 shows options of leachate collection and treatment.



Figure 19 Leachate treatment (collection basin, constructed wetlands, reverse osmosis)

## LANDFILL GAS MANAGEMENT

Decomposition of organic material in a landfill generates landfill gas, which typically consists of 45-60% methane, 40-60% carbon dioxide and traces of other organic compounds (less than 1%). If the landfill is not controlled, the organic compounds can cause odor nuisance, and escaping landfill gas can reduce the oxygen content in soil to limit plant growth. Other potential impacts from landfill gas include contribution towards the greenhouse effect and the risk of explosions in confined spaces.

The amount of biogas generated depends mainly on the waste composition, in particular on the content of degradable organic carbon and the time after waste disposal. Furthermore the environmental conditions for the microorganisms, such as moisture content, pH-value and redox-potential play an important rule for the gas generation rate.



According to Tabasaran & Rettenberger (1987) landfill gas production can be calculated as follows:

$$G = 1,868 \cdot \text{TOC}_b \cdot (0,014 \cdot T + 0,28) \cdot m_w$$

$$G(t) = G \cdot (1 - 10^{-(t \cdot k)})$$

G	total amount of landfill gas [m <sup>3</sup> ]
G(t)	landfill gas produced [m <sup>3</sup> /a]
TOC <sub>b</sub>	biodegradable organic carbon content [kg C/ t] (~ 150 kg/t)
T	temperature inside the landfill [°C] (~30°C)
m <sub>w</sub>	deposited waste mass [t]
t	time [a]
k	degradation rate [a <sup>-1</sup> ]

For municipal solid waste landfills in Syria (waste composition after to Mohamad & Urban, 2003: content of biodegradable organic carbon around 150 kg C/t) the total amount of landfill gas produced is around 200 m<sup>3</sup> per ton waste.

Figure 20 gives an example of the characteristics of gas generation at a landfill, where 100.000 tons of waste per year have been deposited over a period of 20 years.

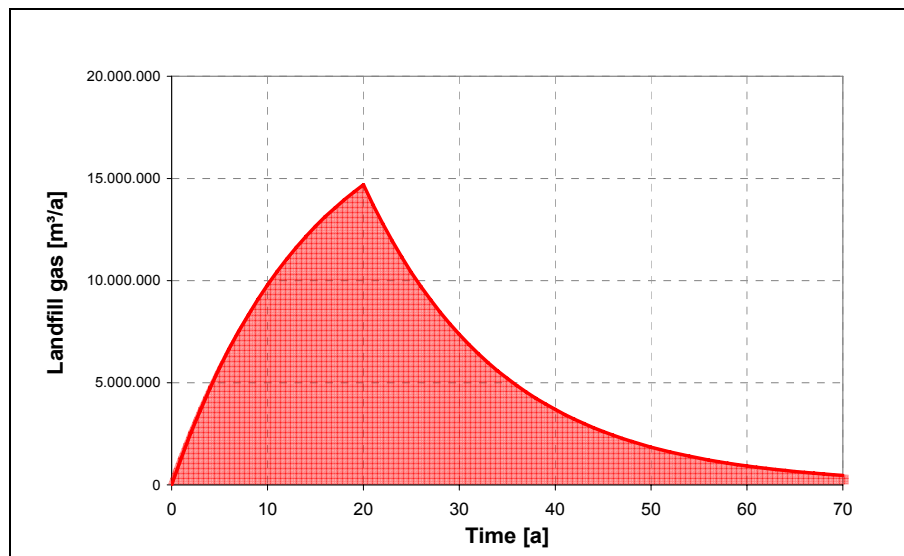


Figure 20 Gas generation at a landfill (operation time – 20 years)

Maximum gas production rates are observed immediately after landfill closure. Analogous to the leachate also quantity and quality of landfill gas varies considerably over time. In particular methane concentration is reduced gradually after reaching a peak value short time after landfill closure. The time dependencies of the overall gas generation rate and also the percentage of methane are critical for landfill gas recovery and reuse projects.

The goals of landfill gas management include

- preventing landfill gas emissions into the atmosphere
- preventing subsurface off-site migration
- minimizing odorous emissions associated with landfill gas
- recovery of energy from the gas



These objectives can be achieved through

- venting
  - active venting (by applying negative pressure to gas extraction wells)
  - passive venting (gas is migrating to zones of high permeability)
- treatment (oxidation of methane and organic compounds)
  - gas turbine,
  - gas flaring
  - biofilter
- and energy recovery (electric generator)

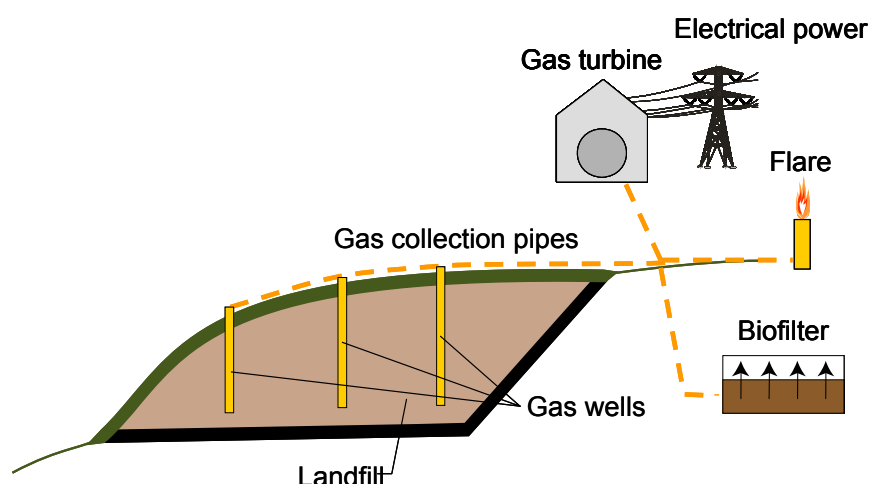


Figure 21 Landfill gas utilization (active venting with different treatment options)

The proper strategy for landfill gas management depends on:

- gas generation rate (depend on waste composition, landfill size and age)
- gas quality (in particular methane concentration)
- economic conditions, and
- infrastructure at the landfill site

Since methane concentration is dropping with time after landfill closure, active venting of landfill gas incorporating energy recovery is only possible 15 up to maximum 20 years after landfill closure. After this time passive venting and treatment in biofilters can be considered as state of the art practice.

Enhanced methane oxidation in cover layers represents a special case of biofilters, where the landfill cover is used for methane oxidation. This “treatment” concept is only promising in case that gas generation rates are small and soil temperatures well above 5 C (Börjesson et al., 2001).

According to the techniques used and the investments necessary landfill gas management options can be divided as follows:

Table 3 Summary of landfill gas management options

Low-Tech Measures	High-Tech Measures
<ul style="list-style-type: none"> <li>• passive venting</li> <li>• enhanced methane oxidation               <ul style="list-style-type: none"> <li>○ “compost” cover layers</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• active gas collection system               <ul style="list-style-type: none"> <li>○ gas extraction wells</li> </ul> </li> <li>• gas treatment using               <ul style="list-style-type: none"> <li>○ gas turbine</li> <li>○ gas flaring</li> <li>○ biofilter</li> </ul> </li> </ul>

Figure 22 shows different options of landfill gas collection and treatment.



Figure 22 Landfill gas utilization (gas well, gas turbine, gas flare and biofilter)

## REFERENCES

- Andersen, J.R. and Dornbusch, J.N., 1967. Influence of Sanitary landfill on Ground Water Quality. *Journal of American Water Works Association*, 59: 457-470.
- Bagchi, A., 1990. *Design, Construction, and Monitoring of Sanitary Landfill*. John Wiley & Sons, New York.
- Belevi, H. and Baccini, P., 1989. Long-Term Behaviour of Municipal Solid Waste Landfills. *Waste Management & Research*, 7: 43-56.
- Börjesson, G., Chanton, J.P. and Svensson, B.H., 2001. Methane Oxidation in Two Swedish Landfill Covers Measured with Carbon-13 to Carbon-12 Isotope Ratios. *Journal of Environmental Quality*, 30(2): 369-376.
- Brunner, P.H. 1992. Wo stehen wir auf dem Weg zur "Endlagerqualität? - How far have we got on our path towards a "final storage quality?", *Österreichische Wasserwirtschaft* 9/10, 44, p. 269-273.
- Brunner, P.H., Döberl, G.; Eder, M.; Frühwirth, W.; Huber, R.; Hutterer, H.; Pierrard, R.; Schönback, W., and Wöginger, H., 2001. *Bewertung abfallwirtschaftlicher Maßnahmen mit dem Ziel der nachsorgefreien Deponie (BEWEND)*. Band 149, Umweltbundesamt GmbH Wien, Wien.
- Krümpelbeck, I. and Ehrig, H.-J., 2000. Nachsorge von Deponien - wie lange? *Wasser und Abfall*, 1-2: 12-17.
- Mohamad, A. and Urban, A., 2003. Untersuchungen zu den Auswirkungen einer mechanisch-biologischen Abfallbehandlung (MBA) auf die Errichtung und den Betrieb einer Deponie in Al-Salamieh/Syrien hinsichtlich ökonomischer und ökologischer Kriterien, Fachgebiet Abfalltechnik, Universität Kassel, Kassel.
- Nöring, F. et al., 1968. Über Abbauvorgänge von Grundwasserverunreinigungen im Unterstrom von Mülldeponien. *GWF*, 109(6): 137.
- Stegmann, R., 1979. Leachate Treatment at the Sanitary Landfill of Lingen, West Germany - Experiences with the design operation of aerated lagoons. *Proc. 2nd Annu. Madison Conf. Appl. Res. Pract. Munic. Ind. Waste*: 456-471.
- Tabasaran, O. and Rettenberger, G., 1987. *Grundlage zur Planung von Entgasungsanlagen*, Müllhandbuch. Erich Schmidt Verlag, Berlin.
- Watson, R.T., Zinyowera, M.C. and Moss, R.H., 1996. *Technologies, Policies and Measures for Mitigating Climate Change - IPCC Technical Paper I*, Geneva, Switzerland.

## Landfill Operation in Austria

Gerhard Ganster, A.S.A. (Abfall Service AG), Austria

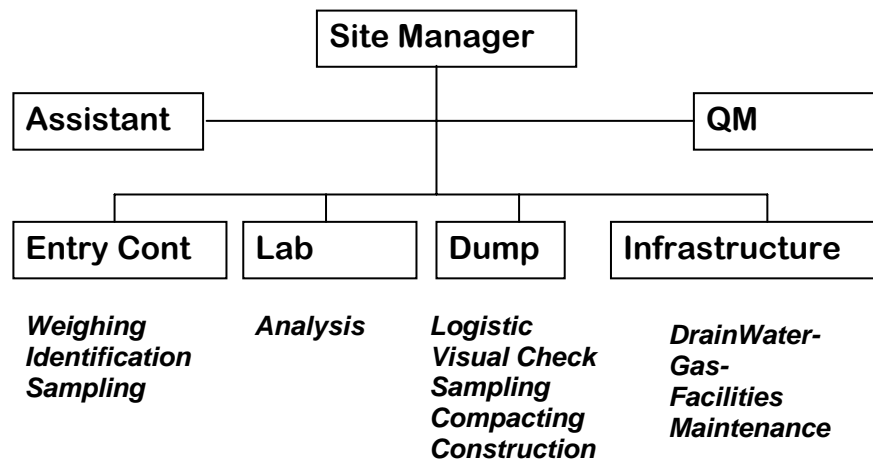
### Model Halbenrain (A)



### Development of the Site

- 1978 Start-up
- 1988 Expansion with the technological standard of today
- 1990 Active Degazing
- 1994 Start-Up Drainwater Treatment Plant, Power Generation
- 1994 Qualitysystem ISO 9000
- 1995 Sorting and Composting Facility
- 1998 Start-Up of drying/stabilization facility
- 2003 Mechanical-biological Treatment Plant

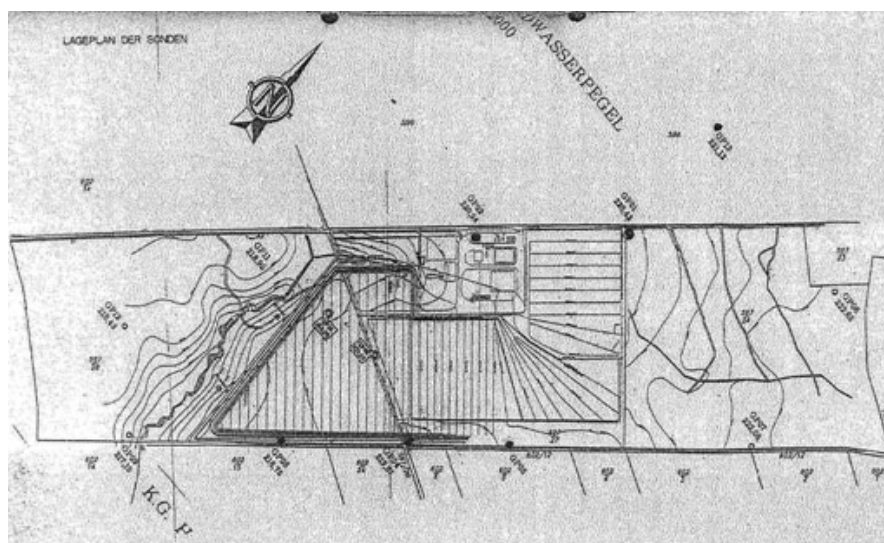
## Organisation



## Qualifications and training procedures

- Site Manager
  - High technical education, add.economic and legistic skills
- Quality Manager
  - Technical Education, specialist on quality assurance
  - Audit of organisation,reporting
- Entry Control
  - Administrative, special training on waste identifikation
- Lab
  - chemistry
- Dump
  - Knowledge about constr.machinery, waste identifikation
  - Construction work
- Infrastructure
  - Electrician, chemical tests

## Monitoring Area





## Supervision program

- Monitoring
  - GroundWater (chemistry,temp,levels)
  - SuperficialWater (amount,chemistry))
  - DrainWater(amount,chemistry)
  - Bioindicator(chemistry)
  - Gas Inlet and Exhaust Gases of Gasmotor,
  - Effluent of DrainWaterTreatment
  - Weather Station
- Checks
  - Density of DrainWaterDucts and Storages
  - Cleaning of Drains, Optical Inspections
  - Geometry of the landfill body

## Probe



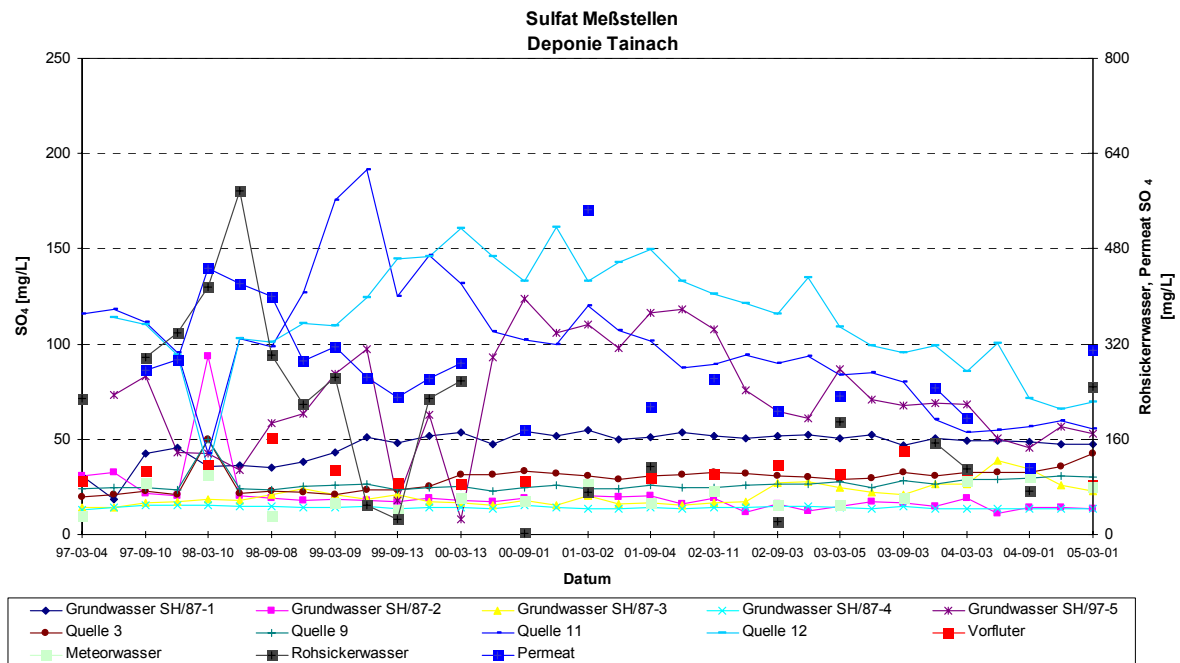
## Weatherstation



## Documentation

- Operational Diary
- Protocol of Deliveries
- Collection of waste declarations
  - Waste producer, process, main features, analysis
- Reports
  - Weather data
  - Effluents
  - GroundWater Data
  - Data on Bioindicator network
  - Performance of gas and LeachateWaterTreatment

## Groundwater typical analysis



## Equipment

- Weighing Area
- Intermediate Storage Area
- Storage Area for construction material
- Construction machinery (Loader, Compactor, Truck)
- Maintenance Area
- Fuel station
- Workshop for small repairs
- Lab with different equipment
  - Area for samples
- Weather Station

## Entrance Area



## Administration



## Lab





**Drive way****Unloading****Visual Control**



## Compacting



## Compactor Machinery



## Collection of Hazards



## Maintenance

- Construction machinery
- Engines (pumps, motors , measuring devices)
- Cleaning
  - Dustbinding, superficial waterchannels
  - Nets
  - Ducts underground
- Maintenance of recultivation plants and lawns
- buildings

# Site Investigation & Landfill Construction I

*Gernot Döberl, Vienna University of Technology, Austria*

## 1 GENERAL

In Austria most regulations regarding landfills are outlined in the Austrian Landfill Ordinance (1996), which focuses mainly on three fields:

1. Definition of landfill types
2. Allocation of wastes to landfill type
3. Landfill construction and operation

### Types of landfills in the Austrian Landfill Ordinance

- Landfills for excavation waste
- Landfills for demolition and construction waste
- Landfills for incineration residues (bottom ashes, filter ashes) (TOC < 5 % DM)
- Landfills for residues of mechanical-biological pre-treatment

“Old landfills” containing municipal solid waste (MSW) without pre-treatment are not part of the Landfill Ordinance.

Geotechnical and hydrogeological investigation methods are outlined in detail in the Austrian Standard (ÖNORM) No. S2074-1 – “Geotechnical investigations for waste disposal facilities; site investigations”.

### 1.1 General requirements for landfill sites

#### Following sites are not suitable for landfills

- Water protection areas
- Important groundwater resources
- Areas, where highest level of groundwater-table is less than 1m below surface
- Aquifers with piezometric surface
- Jointed rocks with unknown groundwater flowing-directions
- Flood plains
- Areas near mass-movements
- Areas with non-uniform geotechnical soil/rock-properties

Any landfill, except landfills for excavation waste, has to be sited above a so-called “Geological barrier” (geological and hydrogeological homogenous, low hydraulic conductivity < 1.0E-07 m/s). This barrier has to fulfil following properties:

**minimum thickness, if  $k_f < 1.0E-07$  m/s but  $> 1.0E-08$  m/s : 5 m**  
**minimum thickness, if  $k_f < 1.0E-08$  m/s: 3 m**

## 2 SITE INVESTIGATION

### 2.1 Hydrogeological Investigations

#### Properties to be determined

- Groundwater table, groundwater flowing-direction, hydraulic gradient, groundwater velocity (permeability)  
*Method: at least 3 drillings, tracer experiments*
- Hydraulic conductivity (horizontally and vertically) or transmissivity (max. and min.), porosity  
*Method: Drillings, wells, pumping tests, water-pressure tests, conductivity tests, grain-size analyses*
- Position, depth and thickness of aquifers and non-aquifers  
*Method: Drillings, dynamic probing, interpretation of facies*
- Groundwater chemistry  
*Method: Drillings, sampling by pumping, chemical analyses*
- Influence of short-term and long-term lowering of groundwater table  
*Method: Pumping tests, groundwater modelling*
- Influence of surface water (streams)  
*Method: erosion studies*
- Rainfall, evapotranspiration, surface run-off

Table 4: Summary of methods for hydrogeological site investigations (ÖNORM S2074-1)

Hydrogeological Site Investigations				
Method	Field/Lab	Rock	Soil	Purpose
Drillings	F	y	y	Determination of (full) thickness and position of aquifers and non-aquifers
Water table wells	F	y	y	Determination of groundwater-level and hydraulic gradient
Pumping tests	F	n	y	Determination of hydraulic properties such as: Hydraulic conductivity, porosity, transmissivity, permeability, size of cone of depression
Water-Pressure-Tests	F	y	y	Determination of hydraulic properties such as: Hydraulic conductivity, porosity, transmissivity, permeability
Seepage-tests	F	y	y	Determination of hydraulic properties such as: Hydraulic conductivity, porosity, transmissivity, permeability
Tracer-Experiments	F	y	y	Determination of groundwater-flow direction and velocity
Conductivity tests	L	n	y	Determination of hydraulic conductivity and porosity
Grain-size analysis	L	n	y	Assessment of hydraulic conductivity and porosity
Chemical analysis	L	y	y	Determination of groundwater quality

- Darcy:  $Q = k_f \cdot A \cdot I$        $I = \frac{h}{l}$

$$k_f = \frac{Q}{A \cdot I}$$

Q volume of water flowing in unit time through a cross-section [m<sup>3</sup>/s]

$k_f$  hydraulic conductivity [m/s]

A area of cross-section [m<sup>2</sup>]

I hydraulic gradient

- $k_f$  is not a velocity!!

- other properties: permeability ( $v_f$ ), groundwater flowing velocity ( $v_a$ )

$$v_f = \frac{Q}{A} = k_f \cdot I \quad [\text{m/s}]$$

$$v_a = \frac{v_f}{P^*} \quad [\text{m/s}]; P^* \dots \text{effective porosity}$$

## 2.2 Geotechnical Investigations

### Properties to be determined (sediments)

- Composition of sediment, thickness and succession of layers
- Position and facies of layers
- Mineralogy
- Porosity  
*Method: geological-geomorphologic mapping, drillings, dynamic probing, test pits, interpretation of facies, grain-size analyses, bore-hole and surface geophysical methods*
- Hydraulic conductivity  
*Method: see above.*
- Erosion- and suffusion-resistance  
*Method: grain-size analysis, clay-mineral determination, erosion-test (ASTM)*
- Shear-strength  
*Method: geotechnical in-situ and lab tests on undisturbed samples, uni- and triaxial tests*
- Retention capacity of contaminants  
*Method: grain-size analysis, clay-mineral determination*

### Properties to be determined (rocks)

- Type of rock, mineralogical composition, stratigraphic unit
- Weathering and weathering tolerance
- Physical-chemical resistance
- Jointing
- Tectonic and petrographic anisotropies
- Karst  
*Method: geological-geomorphologic mapping, drillings, interpretation of facies, bore-hole and surface geophysical methods, dilatometer,*

- Deformation behaviour  
*Method: uni- and triaxial tests*
- Permeability/Conductivity  
*Method: water-pressure test*

Table 5: Summary of methods for geotechnical site investigations (field) (ÖNORM S2074-1)

Geotechnical Field Tests			
Method	Rock	Soil	Purpose
Natural outcrops	y	y	Determination of: Type of rock or soil consolidation
Test Pits	n	y	weathering, decomposition
Dynamic Probing Penetration Tests	n	y	faulting sampling (undisturbed)
Drillings	y	y	geotechnical tests (field or lab) to get geotechnical properties (see next transparency)
Geophysical methods geoelectrics, seismic	y	y	Assessment of thickness and position of layers and groundwater-table

Table 6: Summary of methods for geotechnical site investigations (lab) (ÖNORM S2074-1)

Geotechnical Laboratory Tests		
Method	Rock	Soil
Grain-size analysis	n	y
Water content	n	y
Atterberg limits	n	y
Organic content	(y)	y
Proctor density	n	y
Triaxial test	y	y
Uniaxial test	y	y
Mineralogical-petrographical investigations	y	y
Clay-mineralogical investigations	y	y
Lime content	y	y
Grain density	n	y
Conductivity test	n	y

### 3 LANDFILL BASE

Landfill-base (subgrade): treated or untreated even surface of site with uniform geotechnical behaviour

#### Improvement of soil-properties

- Compaction (surface): smooth drum rollers, vibratory rollers
- Soil stabilization (lime or cement)
- Backfilling: thickness of layers depends on grain-size (max. 20-30 cm)

#### Standards to be met

- Thickness (testing method: test pit)  
Minimum thickness (kf  $1.0\text{E-}07$  m/s): 5 m  
Minimum thickness (kf  $1.0\text{E-}08$  m/s): 3 m
- Hydraulic conductivity (testing method: stand-pipe-test)  
Minimum conductivity if thickness > 5m: kf  $1.0\text{E-}07$  m/s  
Minimum conductivity if thickness 3-5m: kf  $1.0\text{E-}08$  m/s



Figure 23: Stand-pipe test

- Incline: 2-3 % (geodetic control)
- Compressibility (proctor density –  $D_{Pr}$ ) and plasticity (modulus of elasticity –  $E_{v1}$ )



Table 7: Limiting values for compressibility and plasticity of landfill sites

	$D_{Pr}$	$E_{v1}$ [MN/m <sup>2</sup> ]
Coarse grained soils	$\geq 100 \%$	$\geq 30$
Mix grained soils	$\geq 98 \%$	$\geq 15$
Fine grained soils	$\geq 95 \%$	$\geq 7.5$

### Testing methods

#### Compressibility: Proctor-Test (for fine and mixed grained soils)

- fine grained soils: compressibility (e.g. dry unit weight  $\gamma_d$  in kN/m<sup>3</sup>, density) depends on water-content (in case of constant compactive work)  
too wet: pore water pressure prevents compaction  
too dry: capillary cohesion  
determination of correlation between water content  $w$  and  $\gamma_d$  via Proctor-test
- practical testing: compactive work (same as in field with compaction equipment) simulated: defined mass ( $F=24,9$  N) dropped 25 times from defined height (30,5 cm) on sample with certain water content (modified Proctor-test: 4,5 times higher mass); compaction measured

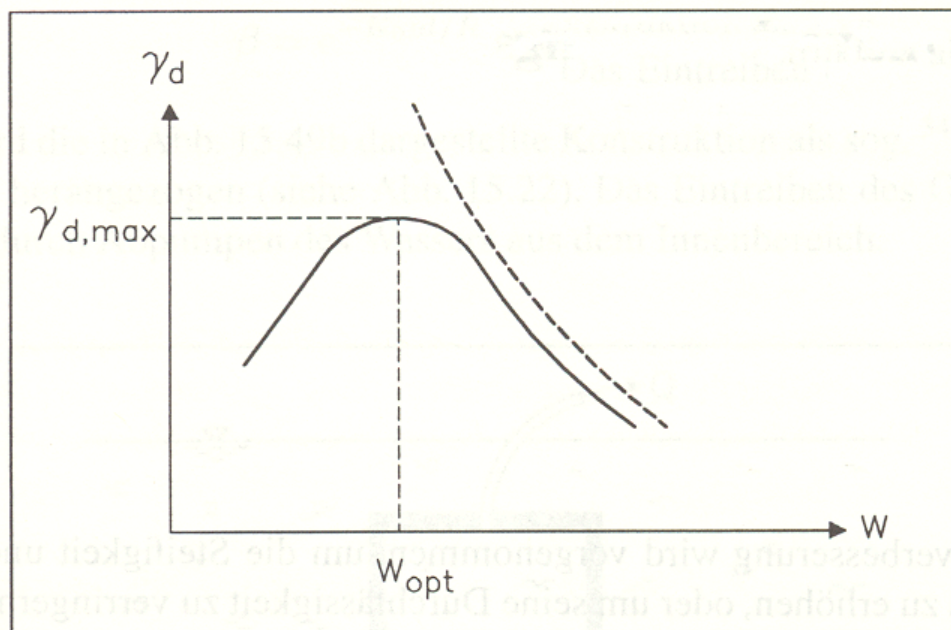


Figure 24: Result of a Proctor Test (Kolymbas, 1998)

#### Plasticity: Load-Plate-Test

- round plate of steel, diameter = 30 cm pressed into the site, 3 arms with trans-placement transducers registering settlements
- increasing pressure( $\sigma$ ), if settlements become low
- testing: 0,1 und 0,2 MN/m<sup>2</sup> ( $\Delta\sigma=0,1$  MN/m<sup>2</sup>)
- calculation of  $E_{v1}$  after first and  $E_{v2}$  after second loading procedure
- E-Modulus is not constant for a soil but correlates to  $\sigma$  and  $\Delta\sigma$





Figure 25: Load-plate test

## 4 BASE LINERS

### 4.1 Standards (Landfill Ordinance)

For any landfill (except landfills for not contaminated excavation waste) base liners at bottom and slopes are required.

Table 8: Liners required for different landfill types (Austrian Landfill Ordinance)

Type of landfill	Base liner	No. of layers in mineral liner	Thickness of layers	Total thickness of mineral liner	Thickness of HDPE
			[cm]	[cm]	[mm]
Excavation waste	n	-	-	-	-
Demolition waste	y	$\geq 2$	20-27	$\geq 50$	-
Incineration ashes	y	$\geq 3$	20-27	$\geq 75$	2.5
MSW	y	$\geq 3$	20-27	$\geq 75$	2.5

or alternative systems.

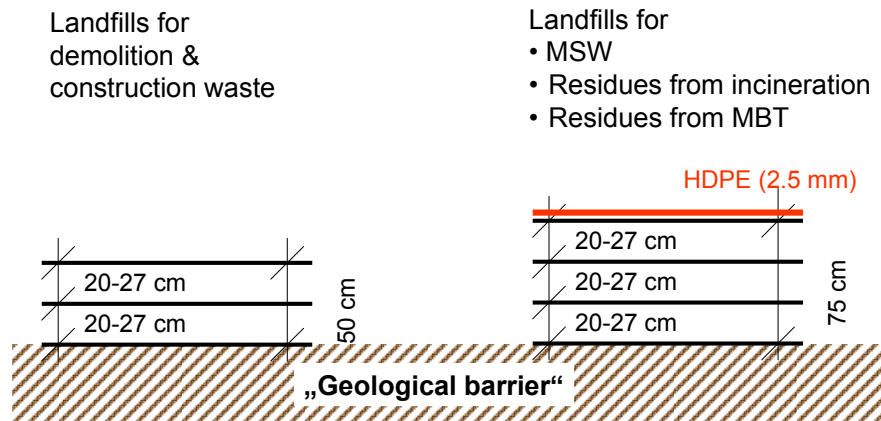


Figure 26: Base liners required after Austrian Landfill Ordinance

## 4.2 Mineral liners (ML)

### 4.2.1 Standards

Table 9: Summary of properties of mineral base liners to be determined (ÖNORM S2074-2)

	Test	Limiting value
Conductivity (lab)	conductivity test	$k_f \leq 5.0E-10$ m/s if $i=30$
Conductivity (field)	stand pipe test	$k_f \leq 1.0E-09$ m/s decreasing $i$
Suffusion resistance	grain size analysis	
Clay content	grain size analysis	Fraction $< 0.002$ mm $\geq 20$ M-%
Clay mineral content	X-ray diffraction	CM-content $\geq 50$ M-%
Most coarse grain	grain size analysis	$d_{100} < 63$ mm
Most coarse grain (surface)	grain size analysis	$d_{100} < 20$ mm
Ignition loss	600°C	$V_{GI} \leq 5$ M-%
Plasticity	shrinkage limit etc.	
Erosion resistance	grain size analysis, erosion test	
Natural water content	ÖNORM B 4410	$\leq 4\%$ higher than $w_{opt}$
Grain density	ÖNORM B 4413	$\geq 2.5$ Mg/m <sup>3</sup>
Proctor-density	Proctor-test	$D_{Pr} = 1.7$ Mg/m <sup>3</sup>
Shear strength etc.	ÖNORM B 4416	$\varphi \geq 30^\circ$ ; $c=0$ $\varphi \geq 25^\circ$ ; $c=10$ kN/m <sup>2</sup>

### 4.2.2 Construction and quality control of ML

#### Material

- natural rocks (clays not suitable for compaction), bad shear strength etc., mix grained soils resistant to precipitation and desiccation
- Artificially produced mixes (uS, uG) improved with bentonite ( $> 3$  M-%);  
Mixed-in-place: spreading bentonite, mixing bentonite and soil with high performance rotary hoes  
Mixed-in-plant: better for homogeneity, better control of water content
- Residues from gravel production: attention! High carbonate content in clay fraction (too less clay-minerals)!

## Construction

- testing field
- material 35-40 cm thickness (before compaction)
- if mixed-in-place: with high performance rotary hoes
- compaction with non-smooth drum rollers
- compaction with smooth drum rollers
- water content slightly higher than  $w_{opt}$  (about  $w_{95}$  on wet branch of proctor-graph)
- quality control
  - stand-pipe tests for in-situ control
  - conductivity tests
  - compaction control



Figure 27: Compaction of a mineral base liner

## 4.3 Geomembrane

### 4.3.1 Requirements

- **HDPE (High-Density-Polyethylen; PE-HD)**
- 2.5 mm thick
- Physical Properties (water content, resistance to punctiform load, resistance to tear propagation, tensile strength (uni- and polyaxial), low and high-temperature behaviour, seam strength [shear strength and peel resistance], weathering behaviour)
- Biological resistance (resistance to roots, microorganisms and rodents)
- Chemical resistance
  - Leachate (acidic and alkaline; 6 weeks at 40°C)
  - weak solutions (amines, alcohols), acids (sulphuric acid) und alkali (NaOH) - 12 wks
  - strong solutions (NaCl, hydrocarbons) - 12 weeks
  - stress-crack causing substances (tensides)

### 4.3.2 Construction and quality control

#### ÖNORM S 2076

- seams have to be produced with welding machines (width of a geomembrane-roll: 4-10 m)
- overlap 45-85 mm (better 100 mm)
- welding: double seam with test-channel

Quality control of seams (in-situ without destruction)

- Compressed air in test channel: (3-4 bar, 15 min, decrease of pressure max. 20%)
- Ultra-sonic test, if no double-seam
- Peel-test (lab; destructive): strength of seam.

Protection of geomembrane (punctiform loads from drainage gravel): needle-punched non-woven geotextile > 1200g/m<sup>2</sup>

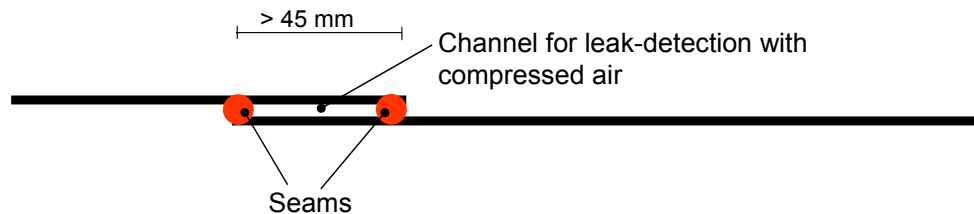


Figure 28: Double-seam principle (welding of two HDPE geomembranes)

## 4.4 Alternative Liners

### 4.4.1 Asphalt liners

- Asphalt = mix of grains (S, G) and bitumen (product from petroleum, no PAH)
- advantage: barrier for permeation, resistant to weathering, construction of steep slopes (up to 2:3)
- disadvantage: very weak resistance to organic solvents
- construction: S/G 0/20, 7-8% filling material, 5,5-5,8% bitumen B100; 2 layers à 7,5 cm; density Isotope-testing (max. porosity: 1,5-2%)
- in Switzerland used in landfills for MSW incineration products
- in Germany used as surface liner for landfills for C&D-waste



Figure 29: Construction of an asphalt liner

#### 4.5 Base liners in Austrian landfills

Table 10: Landfill liners – situation in Austria (EPA Austria, 1998)

Type	Construction	Number of landfills
Mineral liners	30-200 cm (k: 1.0E-08 to 1.0E-10 m/s)	22
Composite liners (mineral and geomembrane)	4 landfills meet ordinance standards 22 landfills: 3*20 cm ML + 2 mm HDPE („State of the Art“ before ordinance)	37
HDPE geomembrane	2-2,5 mm	7
Asphalt and HDPE		1
Asphalt	15-18 cm	4
no base liner	5 landfills without base liner or containment	17
But containment with:		
Chamber system	slurry trench or thin diaphragm wall	4
Slurry trench wall	40-100 cm	4
Thin diaphragm wall	6-12 cm	4



## 5 LEACHATE COLLECTION SYSTEM

- Drainage layer: thickness: min. 50 cm  
16/32, rounded,  
lime content max. 30 M-%, (limestone, dolomite will precipitate)  
kf min.  $1,0E-02$  m/s,  
topped by non woven
- Leachate pipes gradient 2-3%  
resistance to leachate  
30 m distance



Figure 30: Construction of the drainage layer

## 6 FINAL COVER (CAPPING SYSTEM)

### Standard cover after Austrian Landfill Ordinance

- **Compensation layer:** filling uneven landfill surface (min thickness: 0,5 m)
- **Gas-collection layer:** min thickness: 30 cm, max lime content: 30 m-%
- **Composite liner (mineral and HDPE-cover)** (like base-liner): min. thickness: 50 cm + 2,5 mm HDPE  
max kf (i=30):  $1,0E-09$  m/s, gradient 4%
- **Surface run-off collection layer:** min. thickness: 0,5 m; like leachate drainage
- **Recultivation layer:** min thickness: 0,5 m

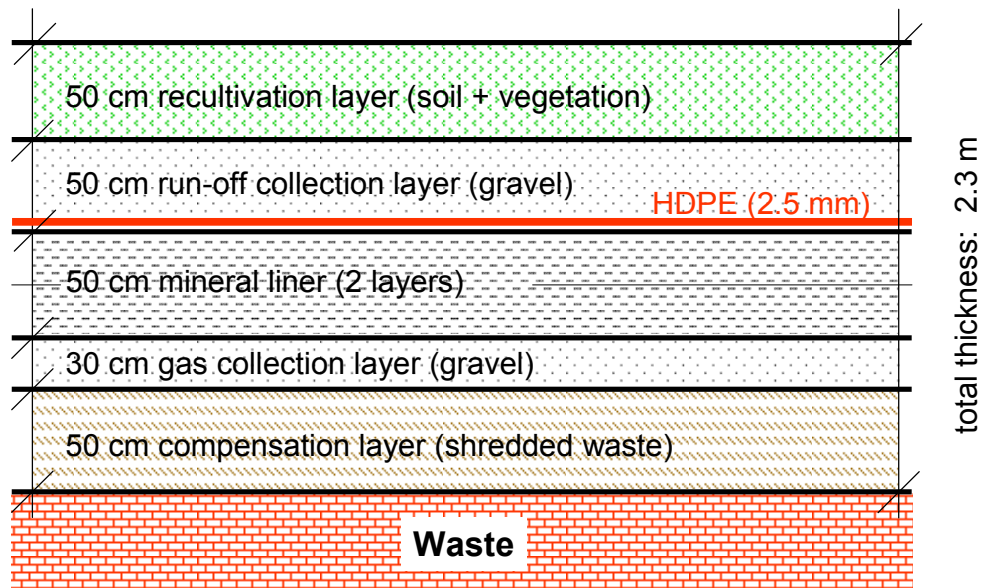


Figure 31: Standard cover after Austrian Landfill Ordinance

#### Alternative covers

- Geosynthetic clay liners (bentonite)
- Asphalt liners
- Capillary layers
- Evapotranspiration layers

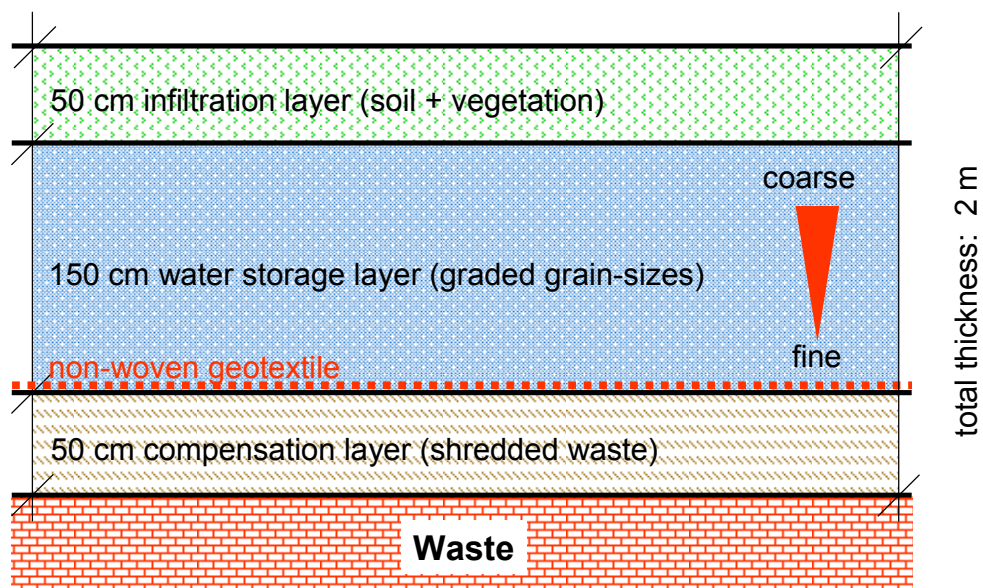


Figure 32: Example for an Evapotranspiration layer

## 7 GEOTECHNICAL CHARACTERISTICS OF MSW

### Main failure mechanisms

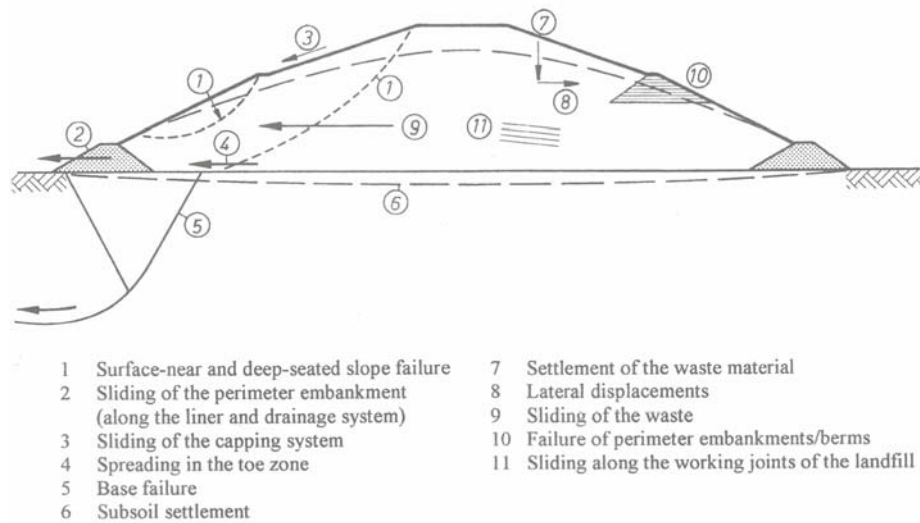


Figure 33: Main failure mechanisms of landfills

### Grain-size distribution

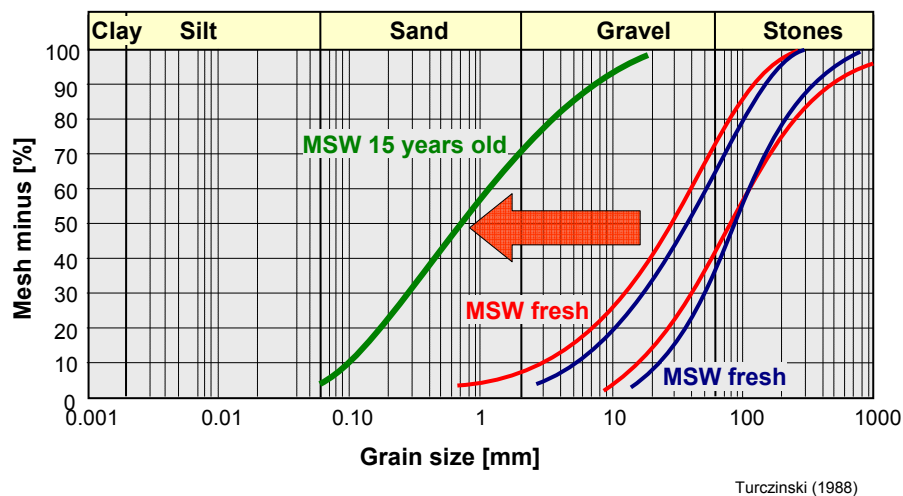


Figure 34: Development of grain-size distribution during time

### Geotechnical properties of MSW

- Density:  $\rho = 0.4$  (not compacted) – 1.3 (highly compacted)
- Shearing angle:  $\phi = 40^\circ$  (fresh MSW) –  $26^\circ$  (15 years old MSW)
- Cohesion:  $c = 50 \text{ kN/m}^2$  (fresh MSW) –  $10 \text{ kN/m}^2$  (15 years old MSW)

### Settlements

- Consolidation settlements (max. 25 % of overall settlement)
- Settlements due to biodegradation
- Subsoil settlements



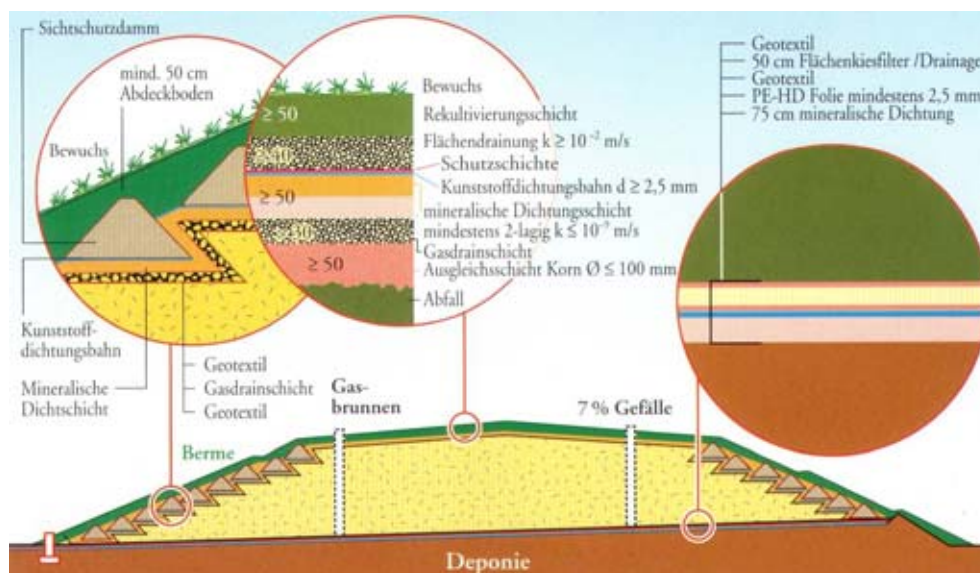
## Landfill Construction II

Gerhard Ganster, A.S.A. (Abfall Service AG), Austria

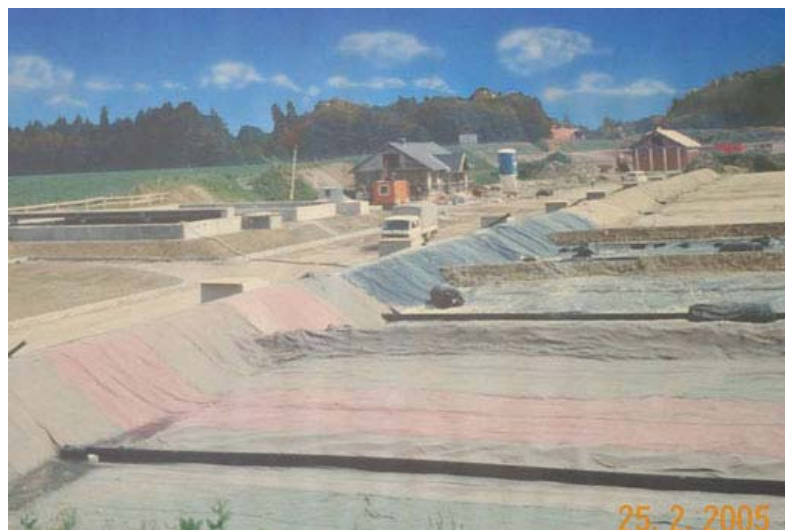
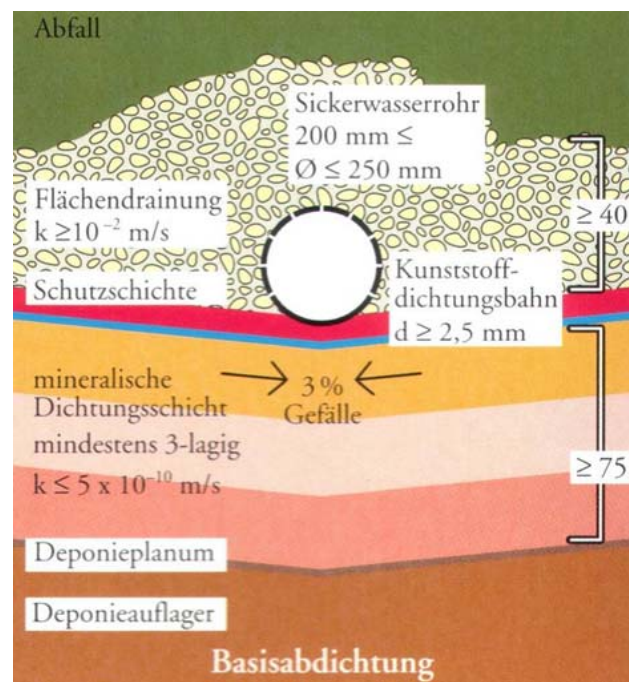
### Construction work during operation

- Ground preparation
- Side Walls
- Sealing and recultivation of flanks
- Gas Wells and connecting ducts
- Temporary Torch
- Road Construction
- Topsealing
- Final surface and recultivation

### Construction work during operation



## Ground Situation



## Ground Preparation



## Construction in Layers



## Surface





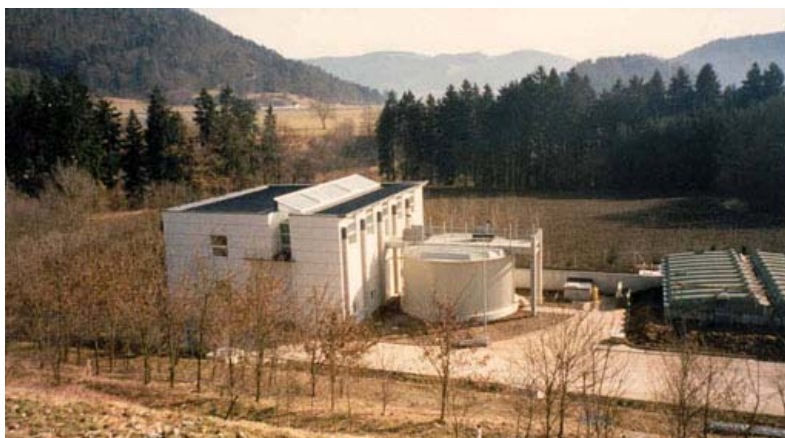
### Drain Water Collector



### Leachate Water Storage



### Leachate Water Treatment





## Leachate Water



## Gas Well



## Gas Collector



## Gascompression



## Gascompressor Inside



## Gasanalyser





## Gas torch



## Gas motor







# Landfill Strategies as a Function of Economic Conditions

*Johann Fellner, Vienna University of Technology, Austria*

## INTRODUCTION

Globally per capita amounts of municipal solid waste generated vary significantly. Economic standing is one primary determinant of how much solid waste is produced.

Figure 35 shows waste generation rates of more than 50 countries. It is conspicuous that rising Gross Domestic Product (GDP) results in higher waste production. However, the increase in waste generation is much lesser than the rising of GDP.

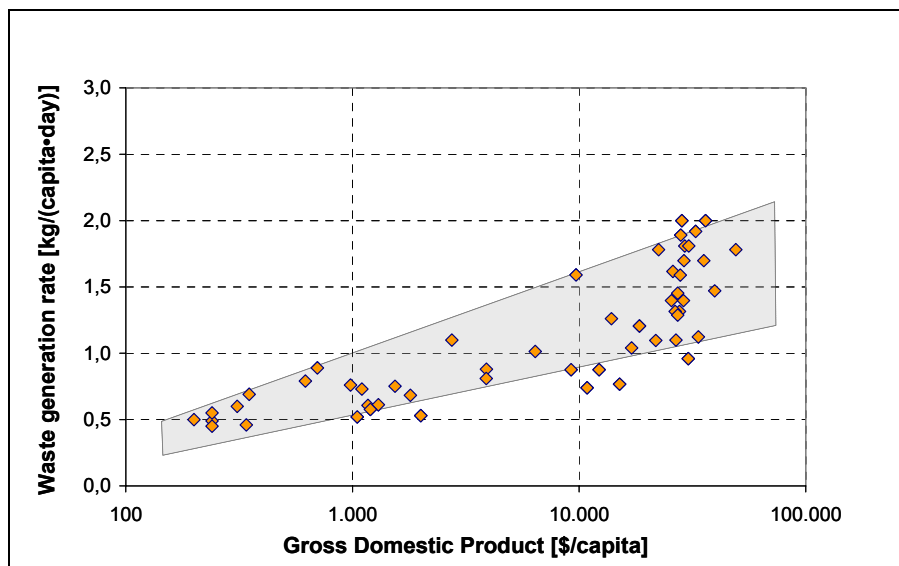


Figure 35 Waste generation rate versus Gross Domestic Product (GDP) (World Bank, 1999; METAP, 2000; OECD, 2005)

The greatest part of the solid waste generated world wide is deposited. Operation and management of disposal site vary considerably.

Factors determining the characteristics of landfill sites respectively the strategy of disposal are:

- economic conditions of the municipality (GDP)
- public awareness of waste
- acceptance
- technology
- education
- legislation

In the following section existing landfill strategies are summarized and their impact on the environment is discussed.

## DIFFERENT LANDFILL STRATEGIES

The ultimate goal of waste disposal is to dispose unwanted materials safely, so that human being and environment are protected, in a short and long term view. The achievement of this objective depends mainly on the chosen landfill strategy.

Figure 36 gives an overview of existing landfill strategies and shows the incremental improvements to reach the landfill objective. The figure represents also the historical development of waste disposal in high income countries (Rushbrook & Pugh, 1999).

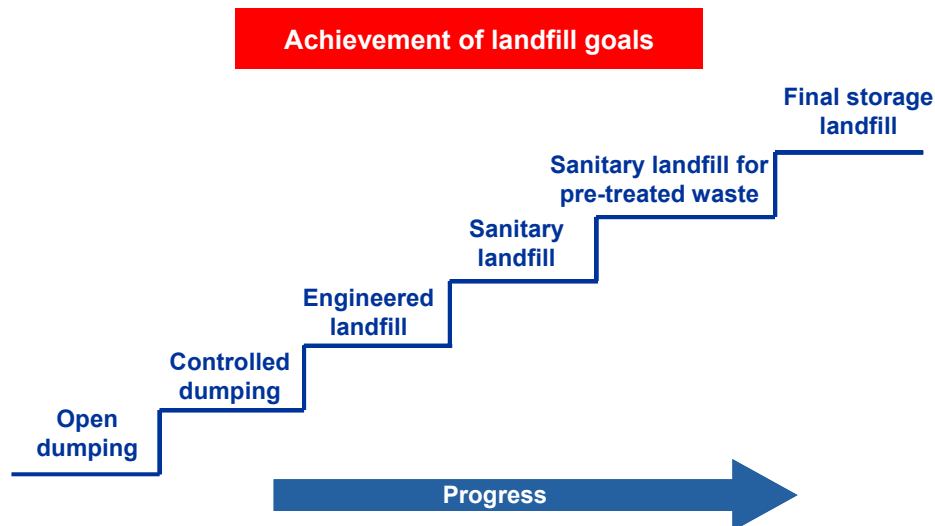


Figure 36 Landfill Strategies (adopted after Rushbrook & Pugh, 1999)

### 1. Open Dumping

Open dumping is the uncontrolled land disposal of waste. The site is not managed and there are no controls over access of unauthorized persons (e.g. scavengers), animals or environmental pollutions. Additionally no consideration has been given to the geological or topographical suitability of the site. Most likely, the location of the dumpsite was chosen because it was the cheapest land available that did not affect interest groups within the municipality. No preparatory earthworks or site engineering has taken place and almost no control is exercised over the site operations or the manner in which the waste is deposited. Fires, pests, unconstrained horizontal spread of the landfill surface and slope failures are commonplace.



Figure 37 Open dumping (Scavengers and grazing animals)

## 2. Controlled Dumping

The main features of a controlled dumpsite are:

- reduction of the disposal area of the site to a smaller and more manageable size;
- soil cover of exposed waste on unused or closed parts of the site
- prevention of fires
- interception of surface water entering the waste using simple measure
- rules of on-site work with workers, drivers and scavengers (if the latter cannot be removed).

The advantages of these operational improvements (in comparison to the open dumps) are that they can be introduced quickly, need little or no additional investment and they lead to the concept of 'control' and 'isolation' into the waste disposal operation.



Figure 38 Controlled dumping site in Perm (Russia)

## 3. Engineered Landfill

An engineered landfill is characterized as a disposal site where engineering techniques are applied to control one or more of the following points:

- avoidance of surface water entering the deposited wastes by installing a surface drainage system
- extraction and spreading of soil materials to cover wastes
- spreading and compacting wastes into thin layers
- collection and removal of leachate away from wastes into lagoons or similar structures
- passive venting of landfill gas out of the wastes
- isolation of wastes from the surrounding geology
- new parts of the landfill are prepared before receiving wastes

This means that planning has to be done before construction, which includes beside the design of construction elements such as liners or the leachate collection system, also waste disposal plans showing how the site will be filled with waste and closed, subsequently.



Figure 39 Engineered landfill (preparation of base sealing and waste compaction)

#### 4. Sanitary Landfill

Compared to engineered landfills sanitary landfills are characterized by an increasing complexity in engineering design and construction techniques. Sanitary landfills typically have many additional features to those found on engineered landfills, for example:

- pre-planned installation of landfill gas control and utilization systems
- extensive environmental monitoring
- well-qualified work force
- detailed record-keeping about the deposited waste and the environmental monitoring
- leachate treatment
- specialized mechanical equipment
- complex lining systems to isolate waste from the surrounding geology
- post-closure plan
- aftercare management

Sanitary landfills can be operated according to different concepts, for instance as flushing bioreactor (forced water entry into the wastes) or dry tomb (top sealing). The operation concept has major impact on the actual and also future emission level of landfills.

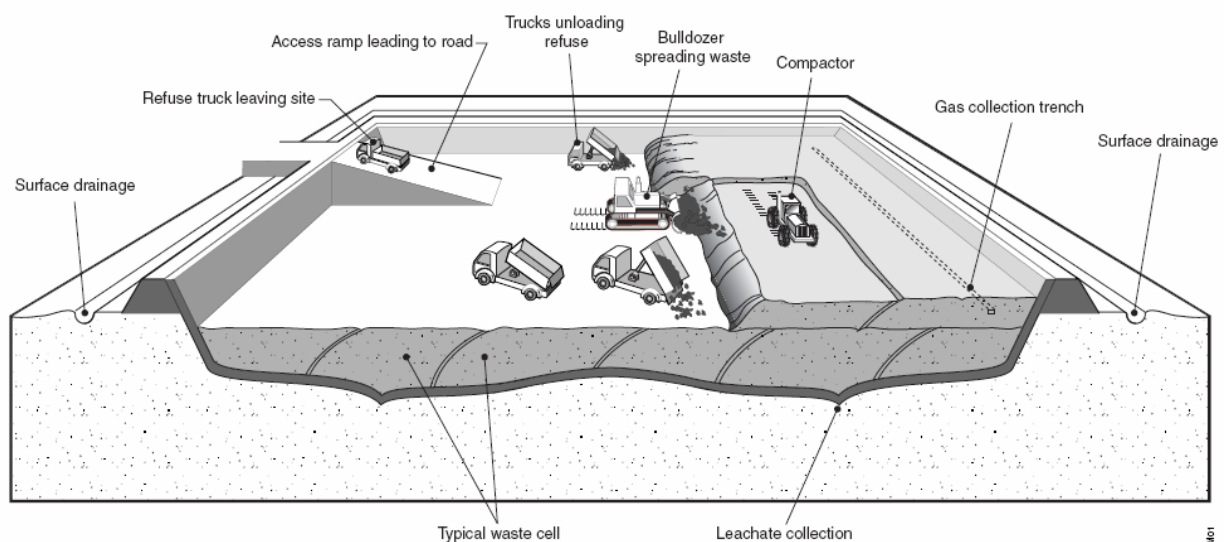


Figure 40 Sanitary landfill – Scheme (Ali et al., 1999)

Although emissions are controlled and properly treated at the sanitary landfill, this disposal strategy has still the major drawback that the treatment must be upheld throughout decades or even centuries. This time of necessary treatment of emissions is called aftercare period. In order to minimize aftercare measures the reactivity potential of the waste deposited needs to be reduced. Such reduction is achievable by waste pretreatment prior landfilling.

## 5. Sanitary landfills for pretreated waste

The strategy of waste pretreated before landfilling derives from the claim of long-term maintenance-free landfills, where, contrary to municipal solid waste (MSW) landfills, there will be no after care necessary once the landfill is closed.

The prevalent concepts of waste treatment prior disposal are *incineration* or *mechanical biological pretreatment*. The residues of both processes show lower reactivity than fresh municipal solid waste. However, emissions from sanitary landfills filled with residues from waste incineration or mechanical biological pretreatment plants are still not “environmentally sound” and need therefore proper treatment. Nevertheless, aftercare measures are reduced compared to MSW landfills. Additionally landfill equipment can partly be omitted, for instance: at a landfill for incineration residues no gas collection system is required.



Figure 41 Scheme of waste pretreatment and disposal of residues

## 6. Final Storage Landfill

A final storage is a landfill whose emissions into water, soil, and air are “environmentally sound” in the short and long run (i.e. thousands of years). According to Brunner (1992) anthropogenic flows (emissions) can be described as “environmentally sound” if they have no impact on geogenic material flows and storage, which means that they must be smaller by two orders of magnitude than natural flows.

Final storage quality (Baccini, 1989) can be achieved using typical “geochemical engineering” techniques: Selection of favorable milieu conditions for the deposition of large-volume wastes such as dredged materials, selection of additives for the solidification and stabilization of hazardous waste materials, optimization of elemental distribution at high-temperature processes, e.g. incineration of solid waste materials combined with high-temperature processing of incineration residues treatment (shown in Figure 42), and chemical leaching procedures.

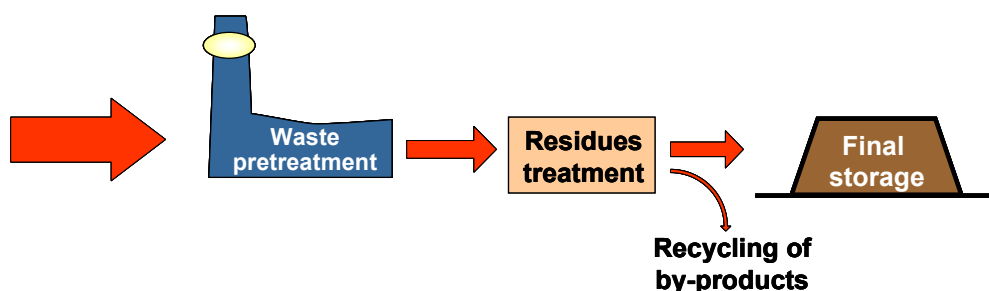


Figure 42 Production of residues with final storage quality



A summary of discussed landfill strategies (without waste pretreatment prior landfilling) is given in Figure 43.

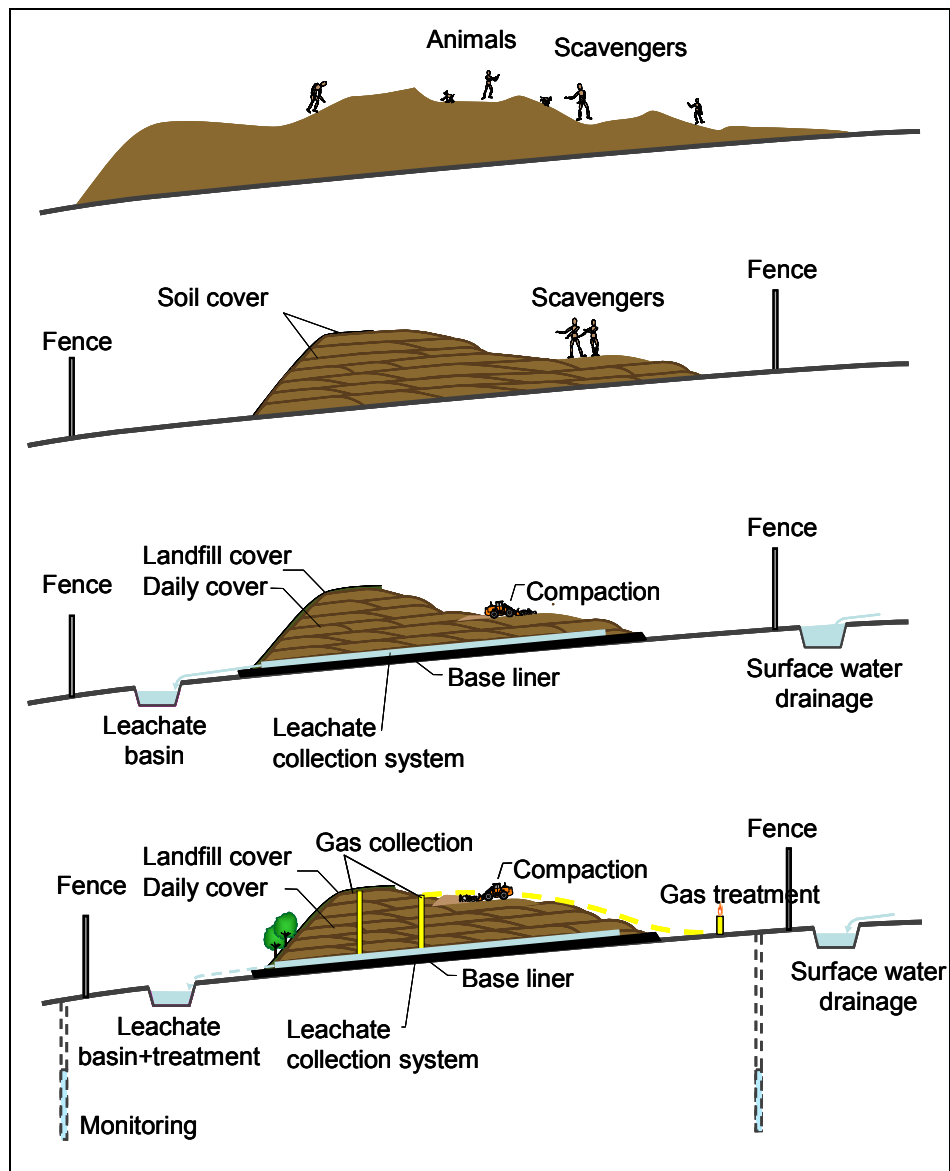


Figure 43 Summary landfill strategies (open dumping, controlled dumping, engineered landfill, and sanitary landfill)

## ECONOMIC IMPACTS

The costs of waste disposal options are depending on the:

- general landfill strategy
  - necessity landfill equipment
  - technology for emission treatment
- geological and climatic characteristics of the location
- gross domestic product (GDP), and the
- capacity of the disposal site

Figure 44 gives ranges for the disposal costs of different landfill strategies against the gross domestic product. The upper values refer to small sites (waste disposal rates < 300 tons/day), whereas the lower values are representative for large sites with a daily disposal rate bigger than 2.000 tons.

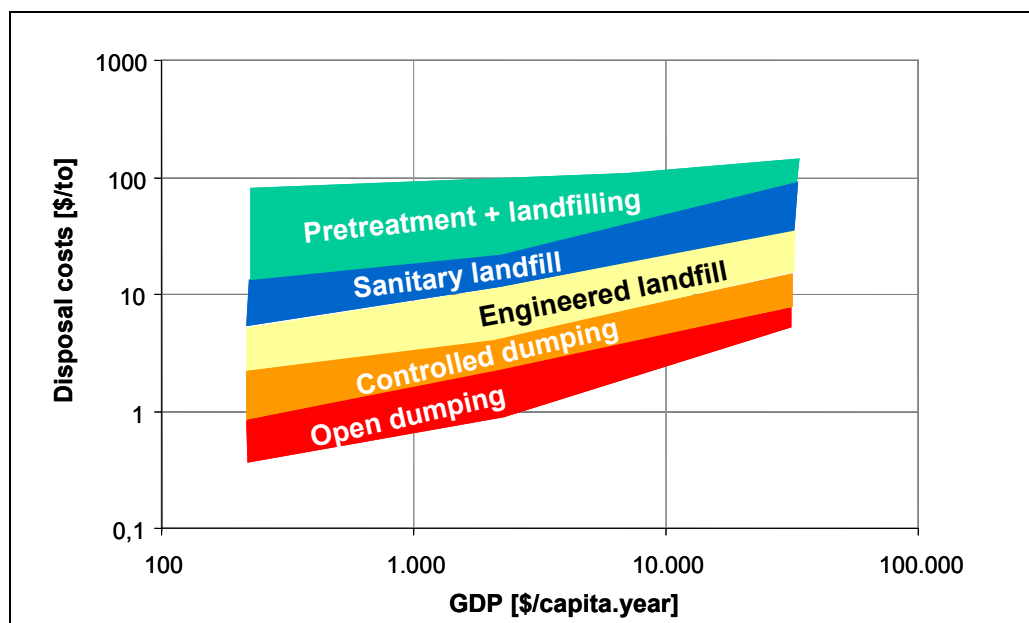


Figure 44 Disposal costs of different landfill strategies (modified after UNEP, 1996 and Olley, 1997)

Current expenses (1998) of solid waste management in Syria are shown in Figure 45. For the final disposal of waste, only 10 to 20% of the overall waste expenses (equals 1 to 2 \$/to waste) are available. Thus, prevalent landfill strategy found in Syria (1998) is controlled dumping.

In order to fulfill WHO recommendations (0,5 % of GDP should be spent for waste management activities) the current expenses should be more than doubled up to 25 \$/ton waste. Assuming, that from this amount 10 \$/ton are available for the disposal, a high standard of engineered landfill, (including base sealing, leachate collection, waste compaction, ...) would be affordable.

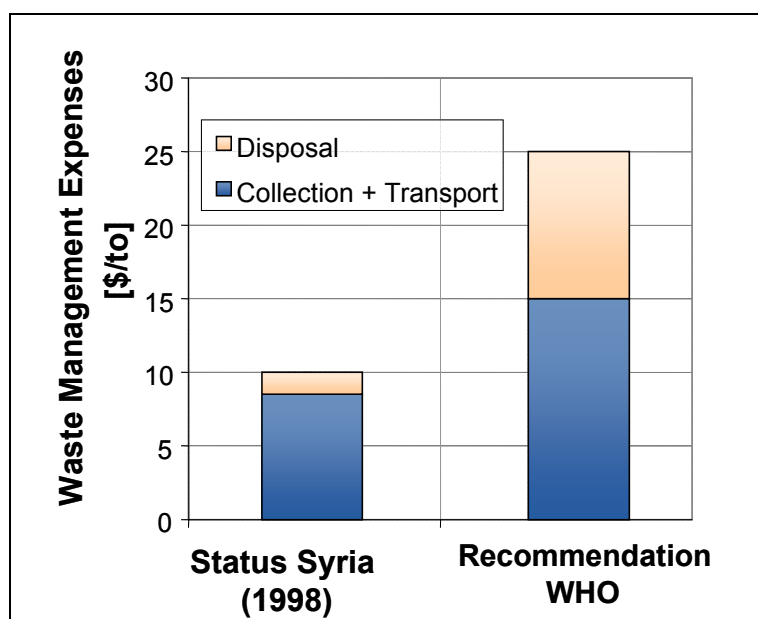


Figure 45 Waste Management Expenses Syria (METAP, 2000)

Better achievement of landfill objectives (protection of human being and environment) by enhanced landfill strategy is a long term development, since the policy of small incremental improvements in landfill design and operation over several years is more likely to succeed than attempts to make a single large technology leap.

## REFERENCES

Ali, M., Cotton, A. & Westlake, K., 1999. Down to Earth. Water Engineering and Development Centre, Loughborough University.

Baccini, P. 1989. The landfill - reactor and final storage. Springer Berlin.

Brunner, P.H. 1992. Wo stehen wir auf dem Weg zur "Endlagerqualität? - How far have we got on our path towards a "final storage quality?, Österreichische Wasserwirtschaft 9/10, 44, p. 269-273.

ISWA (International Solid Waste Association), 1992. 1000 Terms in Solid Waste Management, ISWA, Copenhagen.

Mediterranean Environmental Technical Assistance Program (METAP), 2000, Municipal Solid Waste Management Strategy for Metap Mashreq and Maghreb Countries.

Rushbrook, P. & Pugh. M. 1999. Solid Waste Landfills in Middle- and Lower-Income Countries, A Technical Guide to Planning, Design, and Operation. Technical Paper 426. Washington, USA: World Bank.

OECD 2005. OECD Factbook - Environment - air, water and land - municipal waste. Paris.

Olly, J.E. 1997. Appropriate Landfilling in Low and Middle Income Countries – a Literature Review. IWM Proceedings, 15, p. 3-6.

The World Bank, 1999. What a Waste? Solid Waste Management in Asia. World Bank report. Washington.

UNEP (United Nations Environment Program), 1996. International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management. ITEC Technical Publication Series 6. Osaka/Shiga Japan.



## Introduction of two Landfill sites in Syria

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In general solid waste management in Arabic country have been characterized by the collect and dump approach that has focused primarily on removal of waste from community and the subsequent disposal without regard to its environmental impact.

In Syria the solid waste issues are consequently currently considered in the social and economic planning. The achievement of the master plan on solid waste management is an important step regarding solid waste management in Syria. In general, the mechanical biological solid waste treatment approach is an appropriate methodology for the communal solid waste treatment in Syrian. The establishment of compost plans, separation stations and sanitary landfill sites are big challenges in Syria.

### Landfill sites in General

The landfills can be divided regarding the disposed wastes into the following classes

- Landfills for Urban Solid Wastes;
- Landfills for Hazardous Wastes;
- Landfills for Inert Wastes.

Regarding the development of the landfills, the following approaches are to be mentioned

- Open uncontrolled dumping
- Controlled dumping
- Engineered landfill
- Sanitary landfill

### Status quo regarding landfill operation in Syria

The establishment of sanitary landfills in Syria is newly adopted as a standard of the landfill operation, with the aim to avoid or at least minimize the risks for public health and environmental pollution. Regarding the master plan, 40 sanitary landfill sites and 22 compost plans and 38 separation stations are to be established in the various governorates in Syria.

### Dumping site management in Homs Governorate

The level of the operation and management system at the dumping site, Dir Baalba, is one of the best systems in Syria

### General information regarding solid waste management in Homs

The annual quantity of the solid waste in Homs is about 292 000 t / year, 800 t / d, it includes garbage from households, commercial and public sectors and consists of the following substances:

- Organic matter about 75%,
- Glass, metal and wood less than 2%,

- Plastic about 9 %,
- Cardboard paper 8%,
- Textiles and other 5%,
- Glass, metal and wood less than 2%.

Regarding the available garbage collection vehicles at the governorate, wastes are collected twice per day in the city and twice per week in the villages.

### **Description of Dir Baalab Dumping site**

Dir Baalbah is located 5 to 6 km away from the city centre, nearby Tal Al Nasser. It has been in operation since 1946.

The amount of waste transported to the landfill is about 410 000 t/year (1 100 t/d).

The site is lying on a layer of sandstone and chalky limestone. Analysis on samples have show water is slightly polluted, the underlying layers are clayey.

The main groundwater table is estimated to be about 70 m below the soil surface.

Since 2001, the municipality started with the implementation of the pilot project “the rehabilitation of the dumping site Dair Baalba”, with the aim to increase its capacity and to eliminate the offensive odours, open fires, and decrease the ground water pollution.

Before the rehabilitation operation, wastes were dumped randomly on the site in piles with small, narrow roads that hardly allowed normal circulation. Open fires were regularly lighted.



*Dir Baalba Dumping site before 2001*

### **The rehabilitation operations:**

The rehabilitation of the dumping site was partially carried out on a yearly basis from 2001 to 2005.

The first stage of the rehabilitation had been started in 2001, in the part No.1, which is to be seen on the layout plan of the site.

The rehabilitation procedure of this part was carried out as follow:

- Collecting all random wastes existing on this part of the landfill with an area of 160,000 m<sup>2</sup> to form a layer, reaching 6 meters in height
- Pressing and leveling the waste

- Covering the waste with two layers of soil the first is composed of slightly permeable materials 50-60 cm thick and the other of agricultural soil 50 cm deep
- Building 35 wells as bio-gas outlets
- Planting the top layers with trees, and instillation of drip irrigation net.
- Building an entrance and a fence to surround the dumping site in order to keep the homeless animals out of it and to prevent the scavengers from entering
- Establishing fixed and temporary lighting systems

The following pictures show some of the rehabilitation projects, which have been carried out on the site



*View of the rehabilitated area close to the entrance*



*The fence of the dumping site (2 m high)*



*The Bio-gas outlet*

After finishing the rehabilitation of the first part, a temporary discharge area of 3000 m<sup>2</sup> was established, which is to be used in winter when the trucks may not be able to reach waste collection location.

The rehabilitation of the second part started in 2002 and the rehabilitation of third part was achieved during 2003-2004. The rehabilitation of the last part was started at the end of 2004 and will be completed at the end of 2005.

### Daily work schedule at the dumping site

The waste collection from Homs city and its surrounding areas achieved with 40% by private sectors' open trucks and with 60% by the governorate collection vehicles.

The operation of the landfill site is proceeding by the private sector under the supervision of the municipality of Homs.

The employees of the dumping site are one engineer, two workers and nine guards.

The available vehicles are one bulldozer and one truck.

The work schedule at the landfill consists of three working periods .The first one goes from 8:00 am until 3:00 pm, the second from 3:00 till 11:00 pm, and the main period is from 11:00 pm till 4:00 am.

The daily collected waste, which is to be transported to the dumping site should first monitored by the entrance guards, then it should be transported on the one-way to there have to be hard-pressed and leveled, after that the covering operation is started and the pressed area will be covered by soil.

The leached water is to be collected in the northern area, as seen in the picture , the collected leached water does not have a treatment facility, except that the collected leached water is pumped to the nearest waste body.

Comment:

- Only one road exists for the entering and coming back of the trucks.
- No impermeable layer is exists.
- No treatment system for the leached water exists.

### Alhafeh Dumping site:

In the Syrian rural areas, most existing dumping sites are only open dumping site. There is not any pretreatment and separation operation exists. In Alhafeh dumping site, the dumping procedure of the collected waste is as follow:

The wastes have to be transported to the dumping site and to be pressed and covered with soil.

At the dumping site there is no quality or quantity control of the waste.

The covering operation in Alhafeh was already started at the beginning of this year.

The following pictures show a short view on the site and its location near the dam Al-Thawra.



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