SURVEY OF
SOLID WASTES MANAGEMENT PRACTICES

World Health Organization

International Reference
Centre for Wastes Management
Dübendorf, Switzerland

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by

D. Stickelberger, chief editor, with the assistance of H.R. Wasmer who prepared chap. 2.4.

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C H A P T E R 1 I N T R O D U C T I O N

PREFACE

Whenever municipalities or public interest groups intend to plan their solid wastes disposal, many problems and questions emerge that need explaining and coordinating.

The present paper is an attempt to outline the essential measures to be taken in the methodical disposal of wastes. Any suggestion for improving on this attempt will be welcome.

Instead of describing the test procedures, we refer to the "Methods of Sampling and Analysis of Solid Wastes", edited by the Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG), CH-8600 Dübendorf (Switzerland), Department of Solid Wastes Disposal, 1970.

It is therefore advisable to consult the mentioned "Methods" besides the present paper.

Abbreviations:

Meth. = "Methods of Sampling and Analysis of Solid Wastes"

Lit. = Bibliography at the end of this paper

Chap. = Reference to the respective chapters of the present paper

1.1. BACKGROUND

Several publications have appeared on the problems of solid wastes. A very useful and extensive book of reference which is continually broadened and up-dated is the handbook "Müll- und Abfallbeseitigung" edited by W. Kumpf, K. Maas and H. Straub and published by Erich Schmid Verlag, Berlin. In USA "Municipal Refuse Disposal" and "Refuse Collection Practice" both prepared by the Committee on Refuse Disposal, American Public Works Association and published by the Public Administration Service review past and present disposal practices and discuss administrative and management problems.

The ISWA Information Bulletin appearing in English, French and German is the only international periodical on solid wastes. The reports given at the 3rd and the 4th International Congress of the International Research Group on Refuse Disposal (IRGR) are published in two respective volumes 1965 and 1969.

The reference books mentioned are examples from among the abundant literature on the subject; a short bibliography is given at the end of the present publication.

Despite the plethora of technical literature an easily understandable review of the main viewpoints, not limited to a specific country, was missing.

The present survey is meant to give an impression of the problems and their possible solutions.

Prof. Dr. W. Stumm
Dir. WHO/IRC
Director, Federal Institute for Water Resources and Water Pollution Control
Dübendorf

Prof. Dr. R. Braun
Ass. Dir. WHO/IRC
Research Secretary of the "International Solid Wastes and Public Cleansing Association, Dübendorf

1.2. OBJECTIVES

The objectives of these guidelines are twofold namely:

1) To assist the official responsible for waste management, enabling him to:

   - define the scope of the problem of waste disposal
   - tackle the problem on a broad basis
   - develop preliminary alternative solutions

2) To provide a reference for carrying out standard test and analytical procedures.

   To achieve this ultimate goal, experts are invited to give their comments on this draft and to submit suggestions for further improvement.

1.3. ACKNOWLEDGEMENTS

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CHAPTER 2 QUANTITY OF SOLID WASTES

2.1. CLASSIFICATION OF SOLID WASTES

It is essential that any waste material considered in a solid wastes survey is properly defined. Waste categories, e.g. domestic, municipal or trade wastes, may not include the same waste components since the composition of refuse differs from country to country. The SOLID WASTES THESAURUS compiled by the WHO-International Reference Centre for Wastes Management will give a list of necessary references for technical terms. Detailed surveys, as required for industrial wastes management, may include any waste material generated during the production of goods. For industrial wastes, reference is often made to the Standard Industrial Code used in various countries.

Table No. 1 gives a general view of the processing channels in wastes disposal (page 6).

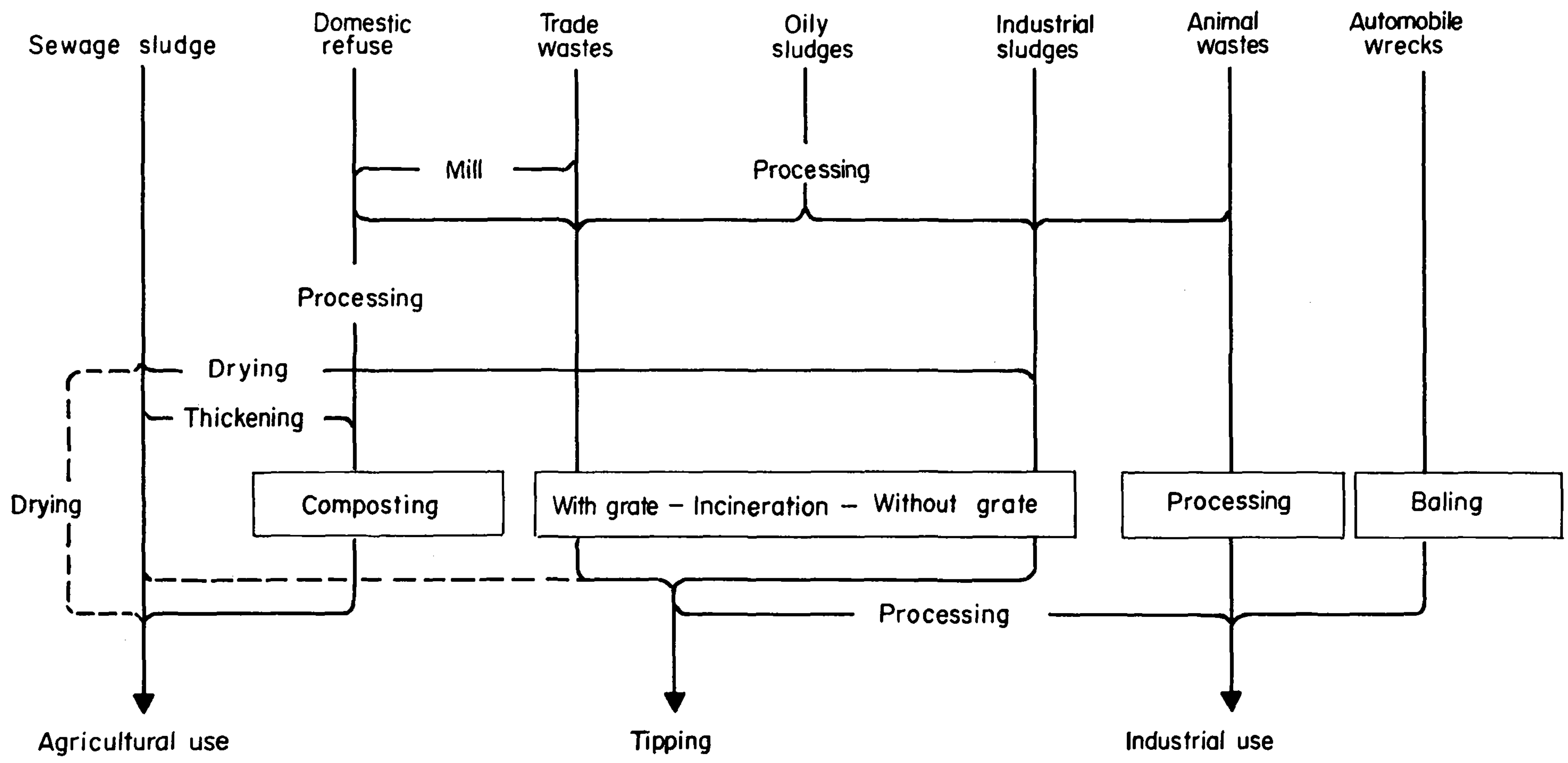
2.2. EXISTING WASTE LOADINGS

Three basically different classes of wastes are chosen to show how to gauge the quantities to be expected.

2.2.1. MUNICIPAL SOLID WASTES [lit. 1]

To determine the amount of municipal waste to be disposed of per year, one week is to be chosen as testing period. There are great variations not only between the amounts collected on different weekdays, but also from season to season (winter - summer, transient visitors, tourists).

Processing Channels in Wastes Disposal



EAWAG

Section for Solid Wastes

Table No I

As a fairly acceptable approach it is supposed that a week's collection figures are representative of one month, (one month = 4.33 weeks). Thus 12 weekly tests have to be carried out. The total amount of a year's collection is calculated as follows:

$$Ry = \left(\sum^{12} R_w\right) \cdot 4.33 \text{ in tons per year (t/y)}$$

Ry = Refuse per year

R_w = Refuse per week

To find out the total amount for the entire city or sanitation district the weighings must be carried out at the same time in every quarter of the city or each settlement of the district.

If collection services are not provided regularly in the entire survey area, careful consideration must be given to those wastes disposed of irregularly through private contractors or individual waste generators.

2.2.2. INDUSTRIAL SOLID WASTES

Industrial wastes surveys have to be carried out in accordance with typical production programs and every effort must be made to obtain data on production rates as well as data on wastes generation. Attention ought to be given to lag periods beween production and wastes discharge.

Out of experience it can be said that the amounts indicated are mostly underestimated. Controlling measurements of the firm's dumping ground to verify statements made on questionnaires may be useful.

Very often the enterprises asked find reasons for not stating the total amount of their refuse, be it in order to conceal a clandestine practice of private waste disposal or to keep their future contribution to the general disposal costs as small as possible. These circumstances have to be taken into account.

When fixing the nature of trade and industrial refuse the following classification may be useful [lit. 2]:

1) Waste that is very difficult to dispose of
2) Waste that can or must be tipped
3) Waste that is fit for composting
4) Waste that can or must be incinerated
5) Sewage and other water-soluble wastes
6) Waste with a potential for salvage or reuse

A questionnaire must be prepared for the region to be tested. A simplified version is given in table No. 2 (page 9).

2.2.3. AGRICULTURAL SOLID WASTES

Wastes from agricultural activities indicate strong seasonal variations, and surveys should not be carried out for peak loads only. One year has to be chosen as a survey period. It is recommended that surveys be carried out on a particular waste material (e.g. nut shells, tree trimmings, manure) at several places (at least ten) simultaneously. Any data on waste loadings should be gathered together with relevant figures on production rates. This will provide a basis for predicting future waste loadings. Possible relations may be as follows: manure tonnage vs. number of animals, fruit or vegetable wastes vs. total harvest, fruit or vegetable wastes vs. acreage cultivated.

Table 2

Inquiry into the amount and the kind of trade and industrial waste

Information on the enterprise — Address:

Name:

Products manufactured:

Employees (date): — Change of employees per year:

			Amount					Kind of disposal				
Nr.	production rate	kind of refuse per year	combustible		not combustible		water-soluble	present			future	
			solid	liquid	solid	liquid		Site of tipping	kind of inciner-ation	utilization	Partaking in central plant	the enter-prise's own disposal
			t	com	t	com	yes/no					
1												
2												
etc.												

Remarks on the nature of the refuse No. .... — Date:

Name and signature of the enterprise's competent expert:

Under "kind of refuse" one asks for:

wood (also package) wood dust,
paper cardboard
textiles, leather, rubber
plastics (also package)
oil, grease (also containing water)
solvents, leaching solutions
(detailed information necessary)
ash, cinder (what origin)

scrap iron, scrap metal,
carbide sludge
sludges from galvanic vats
tar, bitumen, pitch
glass, ceramics
dusts, bleaching earths
dyes, paints, laquers, resins
tires, rubble, slaughterhouse waste
carcasses, agriculture refuse

Table 2

2.2.4. DATA EVALUATION

Data on solid waste loadings are plotted on probability charts for every season. Mean values as well as extremes are thus obtained for the particular season, which provide essential information for the design of wastes management facilities.

2.3. VOLUME [lit. 1]

The volume of refuse at various stages of processing does not provide useful reference figures, due to the variable compressibility of wastes. Nevertheless it is indispensable to know the volumes for dimensioning the size of equipment or disposal sites.

For this purpose the weight per unit volume (specific gravity) must be determined. As it is influenced by the degree of compaction, the density of refuse dumped out of a collecting vehicle - its system being immaterial - is generally taken as a criterion for measuring the volume of solid wastes.

To find out the weight per unit of volume, a full collection vehicle is emptied on a level surface or into a measuring bin. The volume of the emptied refuse - weighed before discharging - is gauged. The contents of 4 to 5 vehicles are determined in this way.

The measurement of one, respectively of various vehicles is to be repeated 3 to 4 times a day. In the course of a month these measurements must be repeated 4 times, for better reliability 6 to 8 times; 15 to 30 monthly test results are thus at hand.

The volume increases in proportion to the growing percentage of paper in the refuse. The weight per unit of volume differs from 0.4 t/m^3 in smaller communities to 0.2 t/m^3 in big cities.

Data on waste volumes are evaluated in the same way as data on waste loadings.

2.4. FORECAST OF FUTURE WASTE LOADINGS

The principal factors to be considered in determining future needs for solid wastes management are industrial development, population growth and land use planning. Forecasts are usually developed on a regional or inter-regional basis and required information for project areas should be deduced from general forecasts.

2.4.1. DEMOGRAPHIC PROJECTIONS

Population growth depends on many factors which are not discussed here. Several methods are used in forecasting future population, and the following paragraphs include a brief summary of these techniques.

A simple method consists of plotting past population data, drawing a curve of best fit, and extrapolating population values for future years.

In arithmetic projection it is assumed that the change in population is a constant. This constant can be determined by averaging past census data. The expression is

$$\frac{dP}{dt} = K_1$$

P = population
t = time
K_1 = constant

Geometric projection is based on the assumption that the rate of population growth is proportional to the existing population at any time.

$$\frac{dP}{dt} = K_2 \cdot P$$

P = population
t = time
K_2 = constant

The technique of graphical comparison makes use of existing data on similar but larger communities. The area selected for comparison must have demographic determinants similar to the study area.

The logistic curve method is suitable for confined areas with geographical boundaries. S-shaped curves, like the growth curve, reflect a rational basis. An obvious consequence of this method is the introduction of the term "saturation population".

Population forecasts can often be obtained from other agencies. It is recommended, however, to check the figures carefully. Forecasts should be re-done, if the rationale, i.e. how the figures are derived, is not stated clearly [lit. 3].

2.4.2. ECONOMIC PROJECTIONS

To determine current and projected future waste production by type and by source, data on the projected economics must be gathered in terms of commercial, industrial and agricultural development and gross output, as well as data on future employment.

Economic projections are sometimes available for larger fields and data for a particular study area may be deduced from such general forecasts.

2.4.3. LAND USE PLANNING

Data on future land use provide invaluable information for wastes management planning. Because population growth, economic development and land use are all interdependent, they should not be treated separately in any survey.

Information on land utilization can be organized into several broad categories and this may provide a basis for wastes management as indicated in table No. 3.

Table 3 Land Use and Wastes Management

Land Use	Information relating to Wastes Management
Residential	resident population, waste loadings, type of waste, distribution of wastes
Commercial	non-resident population, waste loadings, type of waste, distribution
Industrial	non-resident population, type of waste, waste loadings, disposal sites
Agricultural	type of waste, distribution and seasonal variation, disposal sites
Recreational	non-resident population, disposal sites (i.e. reclamation of land for recreational purposes)
Traffic	collection and transport, disposal sites

2.4.4. INTER-AGENCY COMMUNICATION

Whenever an agency responsible for wastes management has to make forecasts with regard to population, economic growth or land utilization, it is highly recommended that the agency gets in contact with other bodies also interested in such forecasts. Much effort can usually be saved when these bodies are consulted before the agency dealing with wastes management starts its own investigation. Among the various sources to be contacted are:

- Bureau of Statistics
- Public Works Departments
- Traffic Departments
- Department of Economics
- Planning Departments
- Water Resources Agencies
- Telephone Companies
- School Districts

At all events close cooperation between the authorities engaged in water and wastewater management and those occupied with solid waste disposal is indispensable.

2.5. PLANNING OF WASTE DISPOSAL FACILITIES

2.5.1. DESIGN PERIODS

The usual design periods for waste disposal facilities vary from 10 to 40 years and the most important factors to keep in mind are:

1) "Useful life of component structures and equipment, taking into account obsolescence as well as wear and tear.
2) Ease, or difficulty, of extending or adding to existing and planned works, including consideration of their location.
3) Anticipated rate of population growth, including possible shifts in community, industrial, and commercial development.
4) Going rate of interest on bonded indebtedness.
5) Performance of the works during their early years when they will not be loaded to capacity".

2.5.2. COOPERATION BETWEEN COMMUNITIES

Public interest groups are sometimes difficult to run, as each municipality belonging to it wants to obtain the best for its particular interest. In these cases it is advisable that the most important member of the group takes the initiative and develops various organizational alternatives. Experience has shown that solutions can be found that include majority desires while protecting minority rights [lit. 4].

2.5.3. DIMENSIONING FOR POTENTIAL FUTURE USE

When building a plant for the necessities of wastes that will be collected after 10 to 20 years, the capacity cannot be fully utilized and therefore the invested capital does not turn to account. If the plant is built for the actual amount of refuse only, the future quantities will soon outgrow the installations.

In order to make the best of the invested money it is advisable to secure the area necessary for the treatment of the refuse after 20 years. On the other hand, the capacity of the plant should not much exceed the actual possibilities i.e. the plant work 8 to 16 hours a day.

The remaining time can be fully utilized when the quantity of refuse increases.

The surface for a second furnace and/or a second composting installation being already at hand, the enlargement of the plant can be projected in time. Furthermore, two sets of treatment machines are preferable in order to ensure the running of the plant in case of a break-down of one set.

Thus the mechanical assembly technique (MAT) can be applied to waste management.

CHAPTER 3 CHARACTERISTICS OF SOLID WASTES

When planning a waste disposal plant, it is indispensable to determine the amounts of refuse expected. On the other hand, a detailed analysis of the refuse composition is only necessary in special cases. To find out whether the refuse is to be incinerated, composted or treated and utilized by combining both systems, other factors are determining: large cities with the possibility of heat recovery may choose to incinerate the totality of their waste. Composting without incineration is possible if there are enough potential compost clients as well as sufficient dumping ground for the screening rejects. In most cases, when composting is chosen, it is combined with incineration of the residue and bulk refuse. Sanitary landfill of the totality of solid waste may answer the purpose when plenty of land is available without the danger of ground-water pollution.

These reasons, independent of a detailed analysis, determine the method of treatment.

The method of treatment being fixed, research may in most cases be limited to finding out the necessary design and capacity of incineration or composting plants.

3.1. SAMPLING PROCEDURE

Taking into account the seasonal fluctuations of the quantity and composition of the refuse, it is advisable to carry out as many tests as possible, well distributed over one year. Metropolitan areas need at least 12 samplings per year; in medium-sized and small towns 6 or 4 samplings respectively, seasonally distributed, may be sufficient. Continual tests should take place during 2, preferably 5 days (= 1 week), at the same period as determination of the waste amounts (Chap. 2.2.1.).

The value of the testing results depends particularly on the collection of representative, average test portions. The sampling must therefore be carefully prepared and carried out.

The entire area being serviced must be divided into districts. For each district - in proportion to the number of existing dust bins - the number of containers for receiving the samples must be fixed. When sampling a special vehicle covers the different districts, collecting the refuse from the proposed number of garbage cans.

The total weight of the test material has to amount to at least 1000 kg. Of course, this amount will be limited by the capacity of the testing equipment.

After mixing the collected test material a sample of 100 to 200 kg is separated and crushed; any loss of water must be avoided (Meth. 111). The resulting substance is called the crude sample.

3.2. DETERMINATION OF THE MOISTURE CONTENT

1 to 2 kg of the crude sample is necessary for the determination of the moisture content (Meth. 121).

3.3. SEPARATION INTO WASTE FRACTIONS

When composting is stipulated, it is advisable to test the proportion of siftings i.e. the compostable material on the one hand, and the screen residue to be incinerated or tipped on the other hand.

To this end the non-crushed part of the testing material (800 to 900 kg) is separated into two portions by means of a revolving screen with an aperture of 40 mm. The rate of travel must be so timed that a perfect separation is guaranteed. The weight of the two portions is determined to the kilogram.

3.4. REFUSE COMPONENTS

From the residue portion (Chap. 3.3.) the following groups of material are separated by hand:

a) Iron and non-ferrous metals
b) Stones, pieces of brick, glass and ceramics
c) Textile wastes
d) Paper, cardboard, straw
e) Wood, leather
f) Rubber, horn, bones, plastics

The iron and the non-ferrous metals as well as the materials specified under e) and f) are equally selected from the screenings.

These selected materials are weighed to the kilogram. The inert materials specified under a) and b) are not examined further; they must be considered when making the final calculation.

The other materials of the residue together with the substances of the screenings specified under e) and f) are joined to the residue. These combustible substances, not fit for composting, are screened out more or less according to the desired degree of fineness when upgraded on a large scale, and finally tipped or incinerated.

3.5. SAMPLING FOR THE HEATING-VALUE DETERMINATION

The screen residue and the combustible materials added are thoroughly mixed. 100 to 200 kg of this mixture are crushed (crude sample) and dried. Determination of the water content (Meth. 121).

3.6. PULVERIZATION OF THE DRIED CRUDE SAMPLE

The dried crude sample is pulverized to a farinaceous homogenous powder, called sample (Meth. 122).

3.7. HEATING VALUE

The sample resulting from 3.2. or from 3.6. is used depending on whether the total amount of the solid waste or only the screen residue is to be incinerated.

The heating value increases with the growing percentage of cardboard, paper and specially of plastics in the refuse (Meth. 141.7.).

3.8. CHLORINE AND HYDROCHLORIC ACID

Polyvinylchloride (PVC), due to its resistance to physical and chemical attack and its low price, is used more and more as a packaging material, and the percentage of wastes it represents is increasing rapidly. When incinerated, the high chlorine content in the PVC may cause boiler corrosion and, as flue gas, damage to the vegetation. Chlorine as well as hydrochloric acid are not removed by electrostatic precipitators but in part by wet cleaning.

The choice of the gas cleaning system - at least in smaller plants - may depend on the proportion of PVC in the incinerated waste.

Instead of determining the concentration of PVC itself - an extremely complicated task - a method has been developed to find out the concentration of chloride and chlorine in the sample (Meth. 148).

3.9. COMBUSTION RESIDUES

The quality of the incineration residues is of special interest because these residues have to be disposed of further, usually on land. A non-objectionable combustion residue should not contain any fermentable matter and the water-soluble compounds should be sintered in the slag.

When mixing the screenings of combustion residue with compost, a lower average incineration temperature and consequently a higher percentage of ash and organic matter might be advantageous (Meth. 241.2).

C H A P T E R 4 LANDFILLING

Disregarding landfilling with slag and ash and the application of compost in gardening and farming only landfilling with unfermented and unburnt refuse is dealt with in this chapter [lit. 5].

4.1. INCONVENIENCE AND DANGERS

In the USA 65 % of the cities with more than 10,000 inhabitants dispose of their refuse by means of sanitary landfilling, 15 % use open dumps, 18 % incinerate and 2 % use other methods. Yet the author of these statistics, the American Public Works Association (APWA), admits that about 90 % of the cities specified under sanitary landfilling cannot claim the expression "sanitary", as they practice open dumping or perhaps "modified open dumping" [lit. 6, 7].

The corresponding statistical data of 534 municipalities and cities with more than 10,000 inhabitants in Western Germany show that 97 % of solid wastes are tipped, 2.3 % incinerated and 0.8 % composted [lit. 8]. Apart from some exceptions, tipping certainly means open dumping.

Owing to a lack of covering material, similar difficulties have emerged in Great Britain. Experts complain about the difficulties in controlling even the smallest fires and preventing the smell of smoke and putrefaction [lit. 9]. The frequency of spontaneous ignition in tippings is a function of the higher standard of living, because paper consumption has increased many times during the last few years [lit. 10]. It can therefore be presumed that tipping sites which could be called controlled not so long ago are no longer sufficient under today's conditions.

The danger of water pollution as well as the inconveniences of smoke, bad odors, vermin and flies must be avoided when filling a site. A very serious problem is the development of methane gas that might cause explosions if left uncontrolled [lit. 11, 12].

4.2. LANDFILLING WITH AND WITHOUT CRUSHING

Crushing the refuse before disposal seemed to solve some of the problems mentioned in the last paragraph. When spreading pulverized refuse without compacting it, the burnable and non-burnable components are evenly distributed and the pore volume reduced. Thus, rodents are deprived of their preferred habitat, spontaneous ignition is prevented and the volume can be reduced by up to 50 % [lit. 13]. Furthermore it was stated that crushed refuse absorbs water from rainfall and accordingly prevents percolation [lit. 14]. Last but not least, refuse crushing and compaction becomes an economic necessity when long-distance hauling is practiced in combination with transfer stations. This economic reason was cited by the Assistant Commissioner of Sanitation, City of New York, where pre-treatment of refuse will soon be practiced [lit. 15]; otherwise pre-treatment is scarcely utilized in the USA.

A similar situation is found in Great Britain, where pre-treatment of refuse is also discussed, only the reasons in favor of reducing the refuse volume are different : "the need to conserve tipping capacity within short hauling distance of urban areas and the difficulty of adequately controlling the tipping refuse, a difficulty which we feel will steadily increase as refuse becomes lighter and bulkier, lead us to the view that the tipping of untreated refuse should cease as soon as practicable". [lit. 16] Though it is admitted by another British expert that vermin is kept from the tipping ground when pre-treated, the other advantages, especially the presumed volume reduction, are questionable [lit. 17]. It has also been proved that percolation is not prevented by crushing [lit. 18].

4.3. SPACE REQUIRED, SELECTION OF SITE, ULTIMATE FORMATION

Landfilling needs space. Consequently possible volume reduction plays an important part. It has not been proved as yet that a higher degree of reduction is achieved in the long run by crushing if compared with disposal without pre-treatment.

4.3.1. ESTIMATION OF SPACE REQUIREMENTS

In Manchester (UK) a rule of thumb has been established showing through many years of experiences that 3 days after tipping and spreading untreated refuse with a bulldozer, the density of the refuse together with the cover material is 665 kg/m^3, even if at the beginning the volumes of the different types of refuse vary to a high degree. Thus, multiplying the cubic meters by 2/3 the corresponding tons can be calculated [lit. 16].

Measurements made in New York City showed a reduction of the original fill height in the first year of between 5 and 14 % with an average of 9 %, with second and third year figures averaging 3 % per year. It has been estimated that settlement will total about 33 % over the years [lit. 15]. The figures evaluated in New York after the first year are considerably lower than those verified in Manchester where the density after tipping increased during the first year from 0.63 t/m^3 to 0.77 t/m^3 [lit. 17].

Refuse with an original density of 0.133 to 0.166 t/m^3 was found to have a density of an average of 0.530 t/m^3 after wetting and pulverizing (hammermill)[lit. 19].

The ultimate specific weight - if the estimation of 33 % is correct - will therefore presumably reach a specific gravity of 1 in any case.

Although this ultimate density after decomposition and settling may be reached, the safety margin created by underestimating the life or capacity of the tip is a useful safeguard against delays in finding alternative sites; and it is probably wise to use the specific gravity immediately after tipping at least for estimate purposes[lit. 19] Table No. 4 (page 26a).

4.3.2. LANDSCAPING

As to the utilization of space, the general guidelines edited by the Ministry of Housing and Local Government in Great Britain propound that the surface of the controlled tipping site should not rise above the surroundings [lit. 17]. Contrary to these instructions the Public Health Administration (Bundesgesundheitsamt) of Western Germany recommends the formation of waste mounds in so far as they do not constitute an eyesore. Coneshaped tippings are mostly alien to the landscape and the natural angle of repose makes it difficult to plant. The shape of table-mounds are generally more adequate, whereby the gradient of slope must not exceed 1 : 3. The lower part should be shaped less steeply to avoid any conspicuous brim and to afford a smooth transition to the surrounding grounds. The shaping of intermediate berms (terraces) allows for suitable drainage, good setting with plants and the laying-out of walks. The berms should be at least 4 meters wide, and the vertical distance from berm to berm must be 5 to 10 meters according to the total height. All the walks and roads on the slope should be inclined towards the hillside, which provides drainage.

Mounds of waste on flat ground may be heaped up in order to separate residential areas visually and acoustically from highways. Generally, land use planning can profit by controlled tipping to elevate the ground level. Principally waste mounds may reach almost any height if the transition to the grounds is gradual enough.

In view of the definite formation of the tipping ground, an operation plan will fix the distribution and the chronological sequence of the fill. The character of the landscape and its topography determine the definite height and shape of the tipping site. If the total surface is sufficiently large, it is advisable to finish the landfill part and set it with plants. Thus, refuse can be heaped under the protection of the mound of planted waste. If set with plants needing much moisture, percolation can be diminished.

Native soil must be stored apart and used for ultimate covering. The deposition of rubble should be included in the operation plan and used for increasing the solidity of the waste mound. The site to be chosen depends on the local situation. Remaining surfaces after road construction are specially suitable. The lateral space of the newly built highway can often be shaped by landfilling and then planted. Excavations and fissures produced by the extraction of gravel, sand and clay may be filled up and used as before. Marsh areas with impervious subsoil may also be suitable. Filling the area behind dikes and barrages facilitate the transition from the dam to the ground and in some cases landfilling can help integrate industrial buildings harmoniously into the landscape [lit. 21].

Table 4

Volume Reduction Data for Refuse without Pretreatment

(Density = t/m^3, Depth and Depression of tips in meters)

	Density	Without cover	Density with cover					Depth of tips				Depression after compressing by wheeled loading shovel 5,5 tons							
	mixed refuse	light, bulk, office, shop refuse	mixed refuse									generally				near the tip edge			
			A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D
Untreated refuse		0,083 *																	
Immediately after tipping and spreading	0,27							1,83	1,83	1,74	2,03								
Compressed by bulldozer		0,42 *										0,10	0,07	0,05°	0,20	0,38	0,25	0,05°	0,45
After 3 days	0,63						0,62												
After 1 year	0,77																		
After 2 years											1,00								
After 3 years								1,60	1,67	1,52									
After 4 years											0,95								
After 5 years			0,90	0,93	0,91	0,96		1,52	1,64	1,50									

lit. 20

* Relation untreated: treated = 1 : 5

°"spongy" surface

4.3.3. ACCESSIBILITY

The tipping grounds must be easily accessible. It may often be necessary to decide on long-distance hauling if a nearer site, equally suitable, has no highway connection.

It can be presumed that there will be no inconveniences as described under 4.1. if the operation is run correctly. On the other hand the local situation such as prevailing winds, the frequency of temperature inversion, the condition of the grounds or screening woods will be decisive with regard to the distance of residential areas. A well-timed marginal plantation will serve as protection when work is interrupted. Furthermore marginal plantation protects against the inevitable unsightliness connected with landfilling operations.

4.4. WATER POLLUTION CONTROL

Preventive measures are

a) locating the site at a safe distance from streams, lakes, wells, and other water sources,

b) avoiding site location above permeable subsurface stratification that will lead the leachate from the landfill to water sources, i.e. fractured limestone,

c) using a bottom layer cover that is nearly impervious,

d) providing suitable drainage trenches to carry the surface water away from the site [lit. 22].

Measures for increasing evapotranspiration can be taken

- by shaping flat extensive slopes facing insolation and the chief direction of the wind,
- by disposing of cover material like clinker, cullet, which does not diminish the evaporation rate [lit. 21], though this measure

contrasts with the traditional opinion demanding a cover-soil with compaction characteristics like sandy loam containing about 50 % clay [lit. 22],

- trees.

Special attention should be given to low-lying sites that might be drainage basins for surrounding areas. In this case the installation of drainpipes and of a collecting shaft may be suitable: the collected leachate can be drained or pumped through a filter-bed into the nearest receiving water or wastewater system.

Separate stratification of different types of waste is not recommended because of the different water-permeability and the impossibility of controlling the lateral leakage [lit. 21]. In any case, information on subsoil structure is a fundamental necessity.

4.5. DIFFERENT LANDFILL METHODS

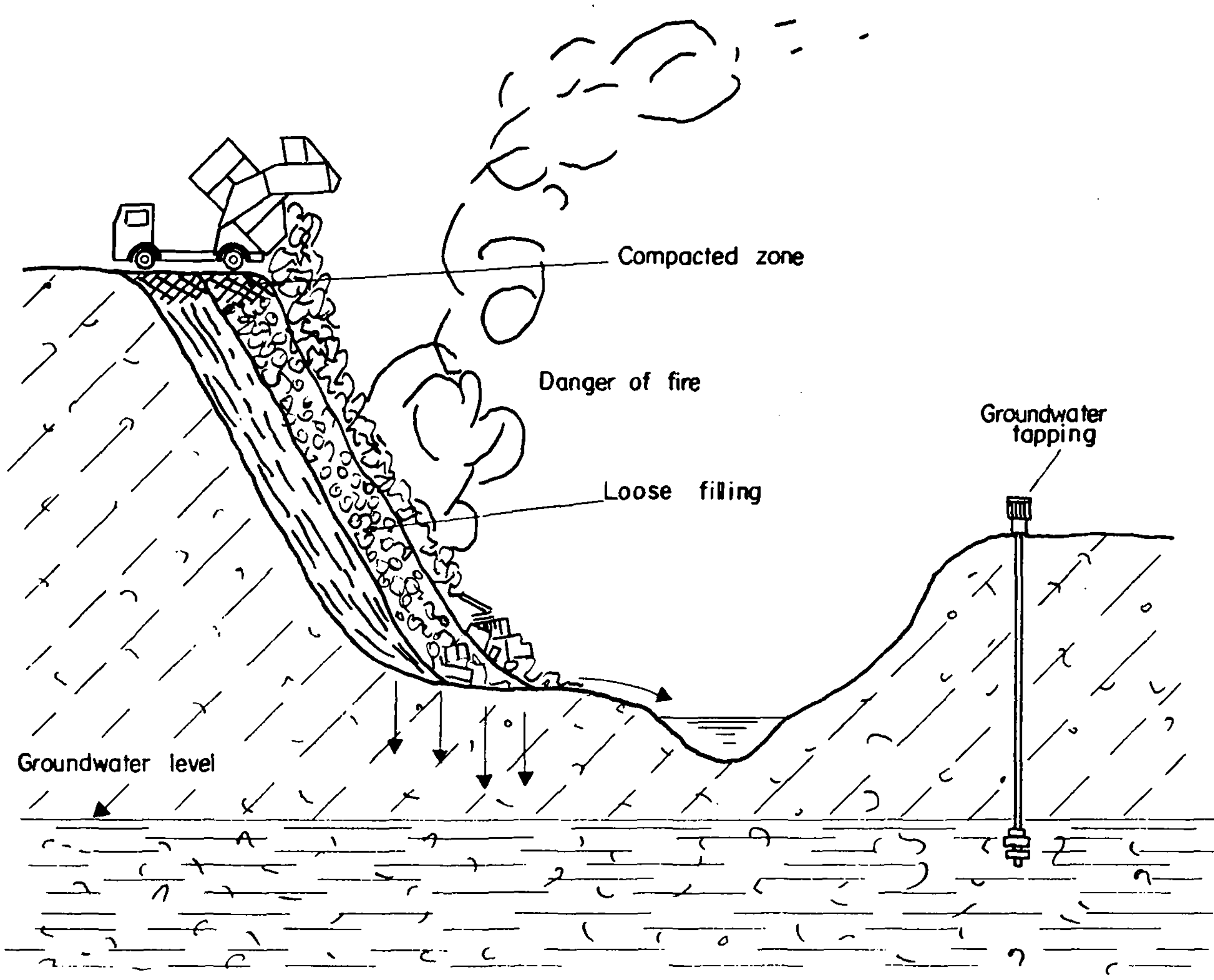
Reviewing the American, British and German methods the following classification may be useful:

4.5.1. OPEN DUMPING

Denotes the use of a reasonably well-defined area for the disposal of any or all of the separate classes of refuse without cover and usually with spontaneous combustion. This is to be rejected (Table No. 5, page 29).

EAWAG	Section for Solid Wastes	Table No 5

Uncontrolled Tipping



Disadvantages :

Unsightliness

Danger of fire, development of smoke, odor nuisance

Breeding-ground for insects and rodents

Contamination of surface water and groundwater

4.5.2. CONTROLLED BURNING DUMPING [lit. 23]

Refuse is unloaded onto a prepared dirt bank, usually about 4 m (12 feet) high with a slope of approximately forty degrees. The dump operator uses a hook to distribute any piles of refuse evenly on the bank, and then sets fire to each load on the downwind edge. Usually tin cans are processed further by heating to remove the tin or other protective coatings and shredded before shipment to the copper-mines. This method is common in the Southwestern states of the USA and serves a population of up to 80'000. Because of the inevitable air pollution this system is not recommended.

4.5.3. REFUSE FILLING

This is a systematic and periodic operation conducted to compact and cover the refuse on less than a daily basis. Operational techniques are the same as those utilized at sanitary landfills, with the exception that equipment is not used to cover the refuse each day [lit. 23].

4.5.4. PRIMARY CRUSHING

This method has been previously discussed in paragraph 4.2.

4.5.5. SANITARY LANDFILL

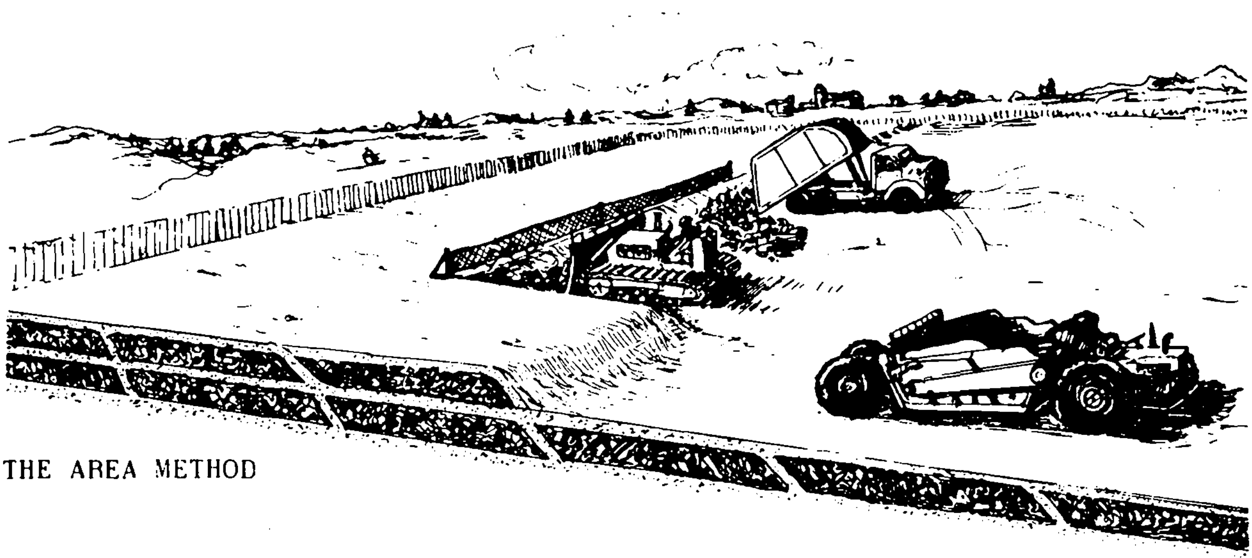
The cover material is spread over the refuse at least 6 inches (15 cm) thick and carefully compacted to form a tight seal or cover to perform several vital functions:

- preventing flies from laying eggs on the refuse
- preventing rodents from invading the fill
- reducing the possibility of having the refuse blown and scattered about
- reducing the fire hazard
- helping to produce a dense, stable fill (Table No. 6, page 33)

Three types of sanitary landfill are distinguished in the USA:

1. The area method

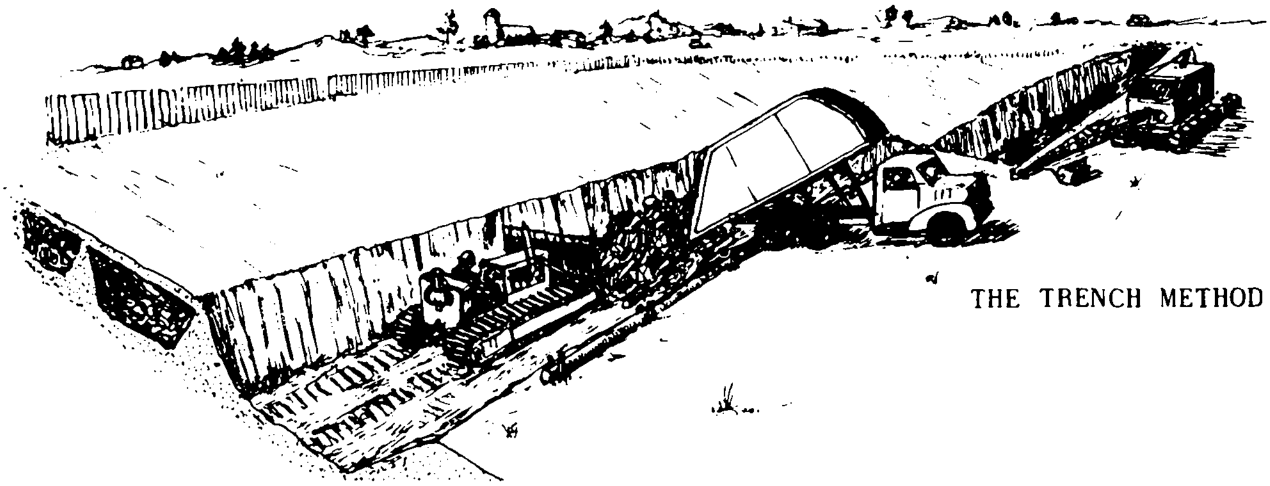
   The bulldozer spreads and compacts a load of solid wastes. The scraper is used to haul the cover material at the end of the day's operations. A portable fence catches any debris fluttering about.



THE AREA METHOD

2. The trench method

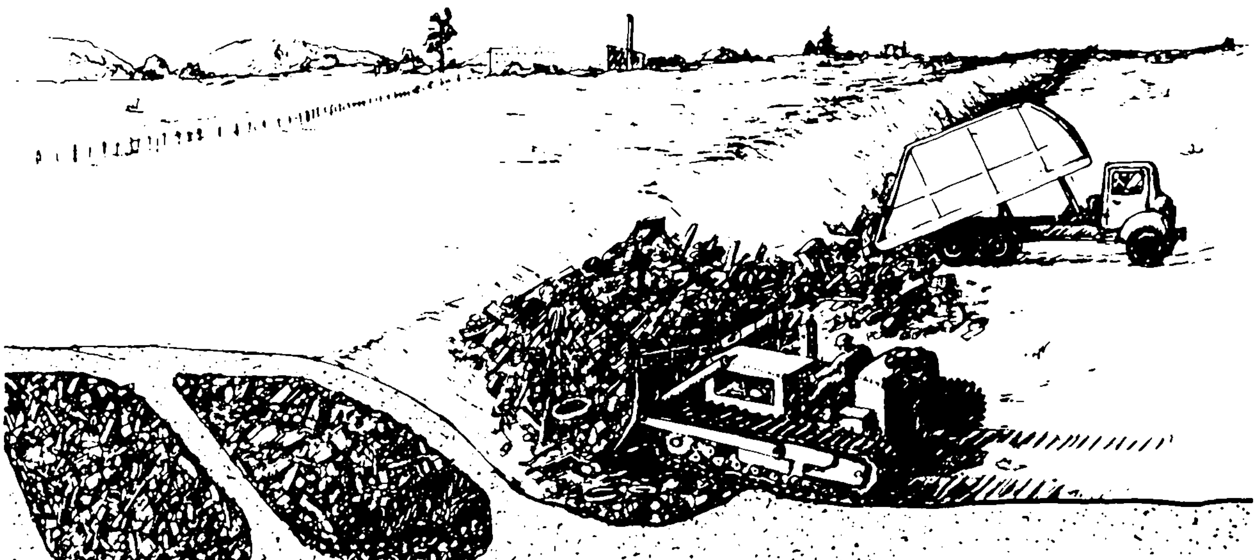
   The waste collection truck deposits its load in the trench where the bulldozer spreads and compacts it. At the end of the day the dragline will excavate soil from the future trench for use as the daily cover material. Trenches can also be excavated with a front-end loader, bulldozer, or scraper.



THE TRENCH METHOD

3. <u>The ramp variation</u>

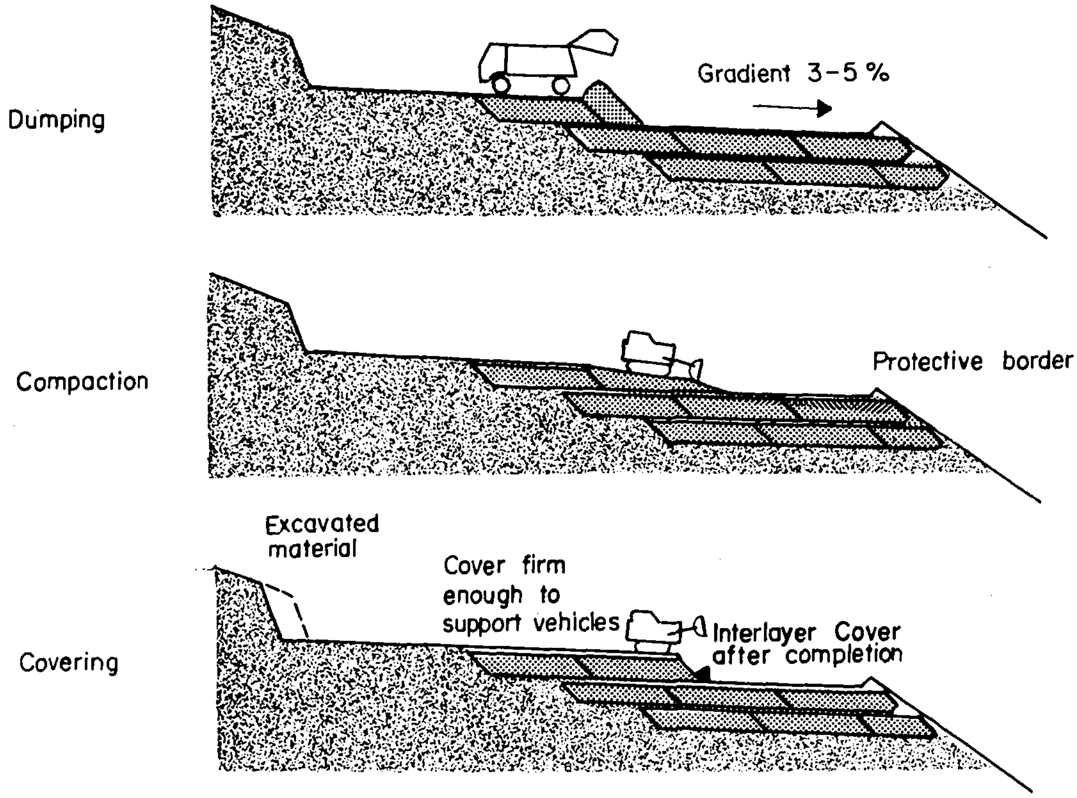
The solid wastes are spread or compacted on a slope. The daily cell may be covered with earth scraped from the base of the ramp. This variation is used with either the area or trench method [lit. 22].



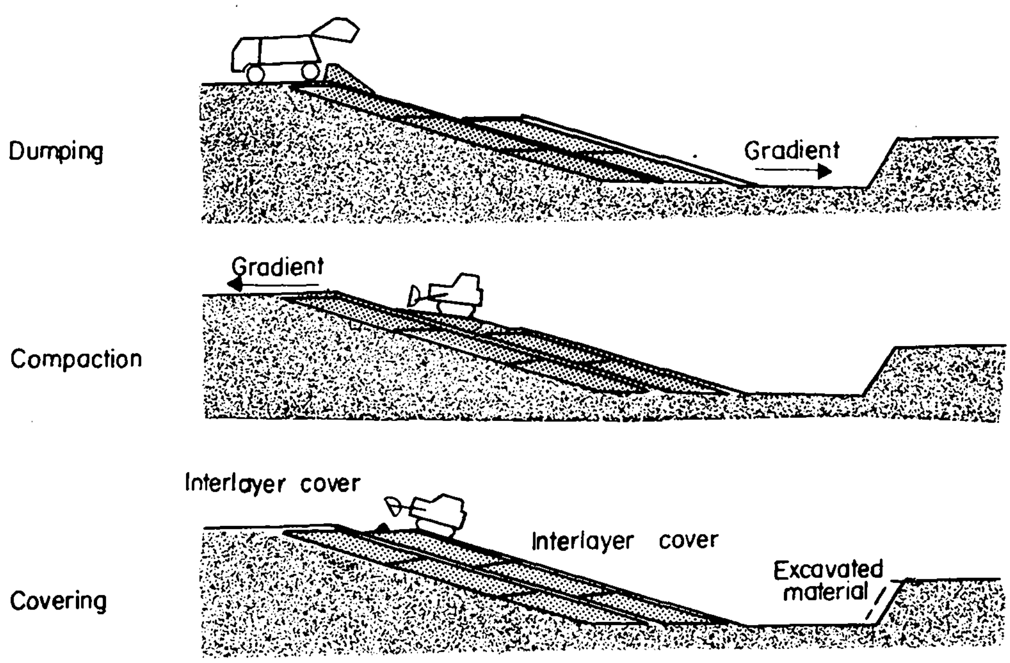
THE RAMP VARIATION

EAWAG	Section for Solid Wastes	Table No 6

Controlled Tipping Operations



The three phases of tipping in slightly inclined layers (on slopes)



The three phases of tipping in steeply sloping layers (on level land)

Source : K. Wuhrmann : The Importance of Controlled Tipping "Der Städtetag" Book 6, 1967

4.5.6. SANITARY LANDFILLING - COMPOSTING (Rotte-Deponie)

This new method has recently been developed in Germany [lit. 24, 25]. Contrary to other systems of landfill primary fermentation takes place in the presence of air. Thus, only small quantities of methane are produced.

Refuse discharged from the collection vehicles should not be compacted by driving over it. They discharge their load from a road loop. The spreading bulldozer with caterpillar drive will form a layer of about 2m (3 feet) in thickness, compacting it just slightly. To avoid vermin and scattering debris the surface is covered with non-binding materials such as cullet and slag so as not to impede evaporation. At the end of fermentation, after 4 to 6 months indicated by the falling temperature, the collecting vehicles drive over the layer in order to compact it. Experience has shown that during the first 4 to 6 months almost no percolation takes place due to the water retaining properties and the high evaporation rate of the self-heated refuse bulk. When, after this aerobic period, percolation in the compacted refuse begins, a new self-heated, water retaining layer absorbs the meteoric water and even considerable quantities of added non-dehydrated sewage sludge.

The proponents of "Rotte-Deponie" claim effective prevention of water pollution and decontamination of infected sludges.

4.6. CRITICISM OF SANITARY LANDFILLING

When reviewing the advantages and disadvantages of landfilling the decision-making authorities must always take into consideration that this method of waste disposal only makes sense if sufficient submarginal land is available, which can be reclaimed for use as parking lots, playgrounds, golf courses, airports, or any kind of recreation area. Otherwise, any other system of refuse disposal enabling the recycling of the inherent values would be more adequate, though it must be mentioned that every system leaves some material to be disposed of on land.

Disregarding the possibility of salvaging and considering landfilling exclusively from the viewpoint of municipal cleansing, the following evaluation may be of use. (The expression "sanitary landfilling" will be used as a collective name for systems that meet all hygienic requirements)

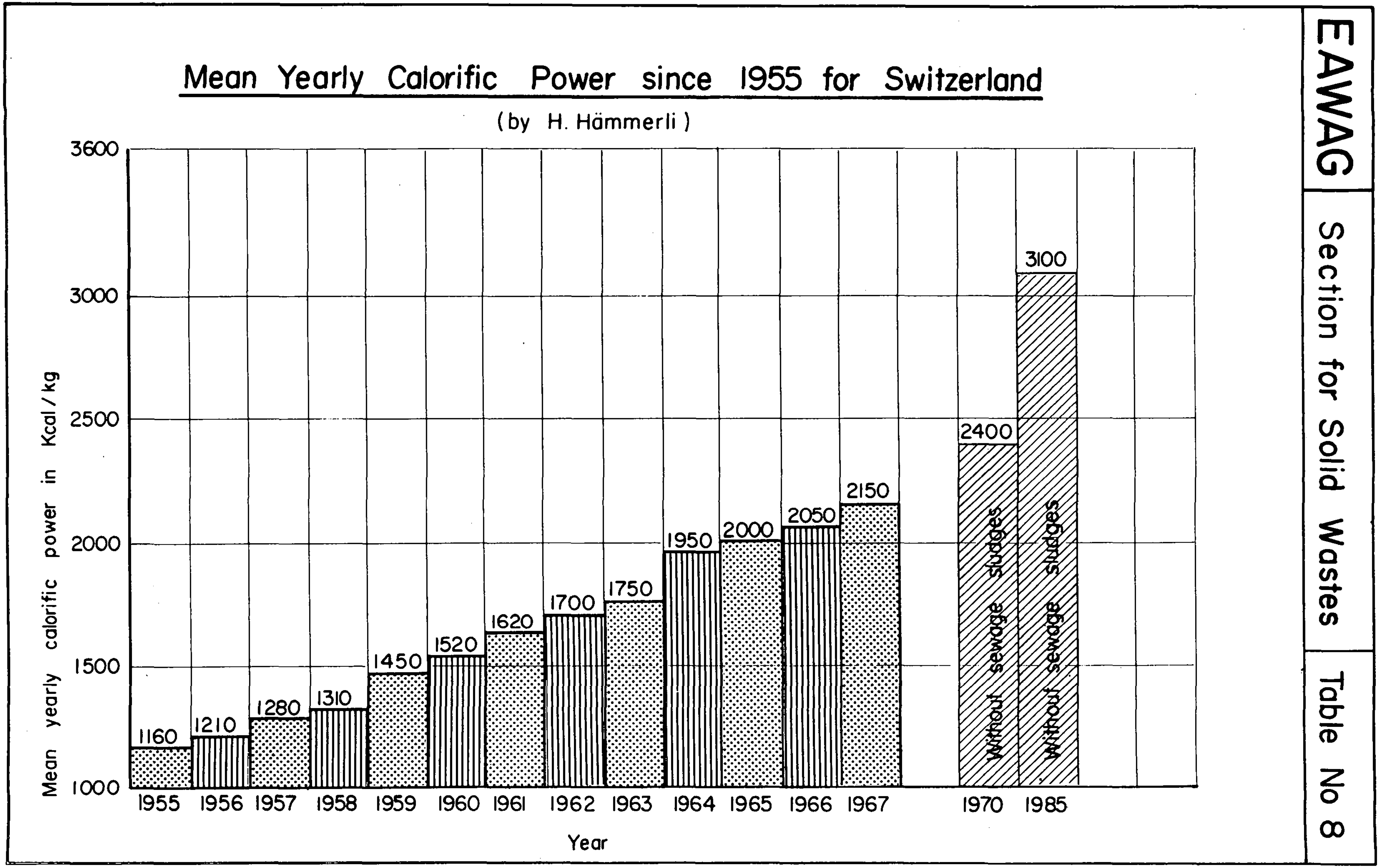
4.6.1. ADVANTAGES

- Where land is available, sanitary landfilling is usually the most economical method of solid waste disposal.
- The initial investment is low compared with that of other disposal methods.
- Sanitary landfilling is a final disposal method as compared with incineration and composting, where residues remain which require further disposal.

4.6.2. DISADVANTAGES

- If proper controlled tipping standards are not adhered to, the operation may result in an open dump (2.1.)
- Location of sanitary landfilling sites in residential areas can lead to resolute public opposition.

- Special design and construction must be utilized for buildings constructed on completed landfills because of possible subsidence of the ground.
- Methane, an explosive gas, and other gases produced by the decomposing wastes may become a hazard or nuisance and interfere with the use of the completed landfill[lit. 12, 22].
- In sanitary landfill the wastes of our civilization - compacted through high pressure - are conserved; we impose costs and nuisance problems on our descendants that should be carried by our generation [lit. 26].


Mean Yearly Calorific Power since 1955 for Switzerland
(by H. Hämmerli)
Mean yearly calorific power in Kcal / kg
3600
3000
2500
2000
1500
1000
1160
1210
1280
1310
1450
1520
1620
1700
1750
1950
2000
2050
2150
2400
3100
Without sewage sludges
Without sewage sludges
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1970
1985
Year
EAWAG
Section for Solid Wastes
Table No 8

Furthermore the amount of steam produced by the refuse incineration plant is rather small compared with that of the power station so that in case of a disruption at the refuse incineration plant the breakdown can easily be offset by the power station.

The inconvenience of this system lies in the high operating pressure (up to 85 atm.) and the high temperature (about 550°C) of the boilers. Owing to the large amount of ash and water in the refuse it is not easy to maintain operating temperatures of more than 400 °C [lit. 57].According to a recent investigation, refuse boilers that must be run at temperatures higher than 400°C are more liable to corrode than those operated at lower temperatures (Chap. 6.3.).

If a power station is willing to take the steam from a refuse incineration plant, the following approximate conditions were established for indicating the point at which heat recovery begins to pay. In case these conditions are not fulfilled, incineration without heat recovery is preferable.

- The waste processed during one year must amount to at least 30,000 tons.
- The selling price of electricity must be on the same level as that produced conventionally; it must be guaranteed during a period of 20 years.
- The electricity must be taken by the power station unconditionally at all hours, day and night.
- Possible additional deliveries must be taken at any time at the same conditions as agreed upon the original quantity of current.
- If the incineration plant is temporarily not in a position to deliver, no compensation must be paid.
- All stipulations of the contract must be valid for at least 20 years [lit. 57].

6.2.2.2. THERMAL ENERGY FOR INDUSTRIAL AND HEATING PURPOSES

The most convenient way to deliver thermal energy for industrial purposes is to locate the incineration plant in the neighbourhood of a heat-taking industry, though additional boilers and heat wasting equipment are indispensable (Chap. 6.2.2.). The heat must be taken all year round and the incineration plant ought to be built very close to the industry.

Another possibility of using the heat produced directly is the feeding of a long-distance heating system. Obviously, a considerable inconvenience must be overcome, as in winter a heavy heat demand must be met, whereas in summer less than 10 % of the yearly average is consumed. Additional equipment is therefore indispensable in order to offset the difference between supply and demand.

The installation of a turboset for the utilization of the summer energy is only suitable if the described conditions are fulfilled and the power authorities agree to accept the electricity being produced.

Generally speaking the length of the tube necessary is the determining factor, regardless of whether the heat energy be fed as steam or as hot water. Steam tubes should be short. They can only be operated with a water separator and are therefore more expensive than the conventional hot-water tubes. In general, steam pipelines are more delicate especially at the outset.

For long-distance heating systems usually only hot-water pipelines are advisable with operating temperatures of 140 to 160°C.

Apart from the difficulties mentioned in feeding heat from a refuse incineration plant, long-distance heating on its own and in combination with waste disposal helps protect the environment in so far as the air is less polluted than through conventional heating:

- there is only one chimney
- the chimney is provided with a flue gas cleaning device
- the utilization factor of the fuel is higher so that less soot leaves the chimney
- the emission of flue gas takes place outside residential areas
- in general an elevated site with favorable meteorological conditions can be chosen
- natural gas can be combined with long-distance heating; the danger of explosion - imminent for individual furnaces when combined - is avoided [lit. 57].

6.2.2.3. REFUSE-SLUDGE INCINERATION

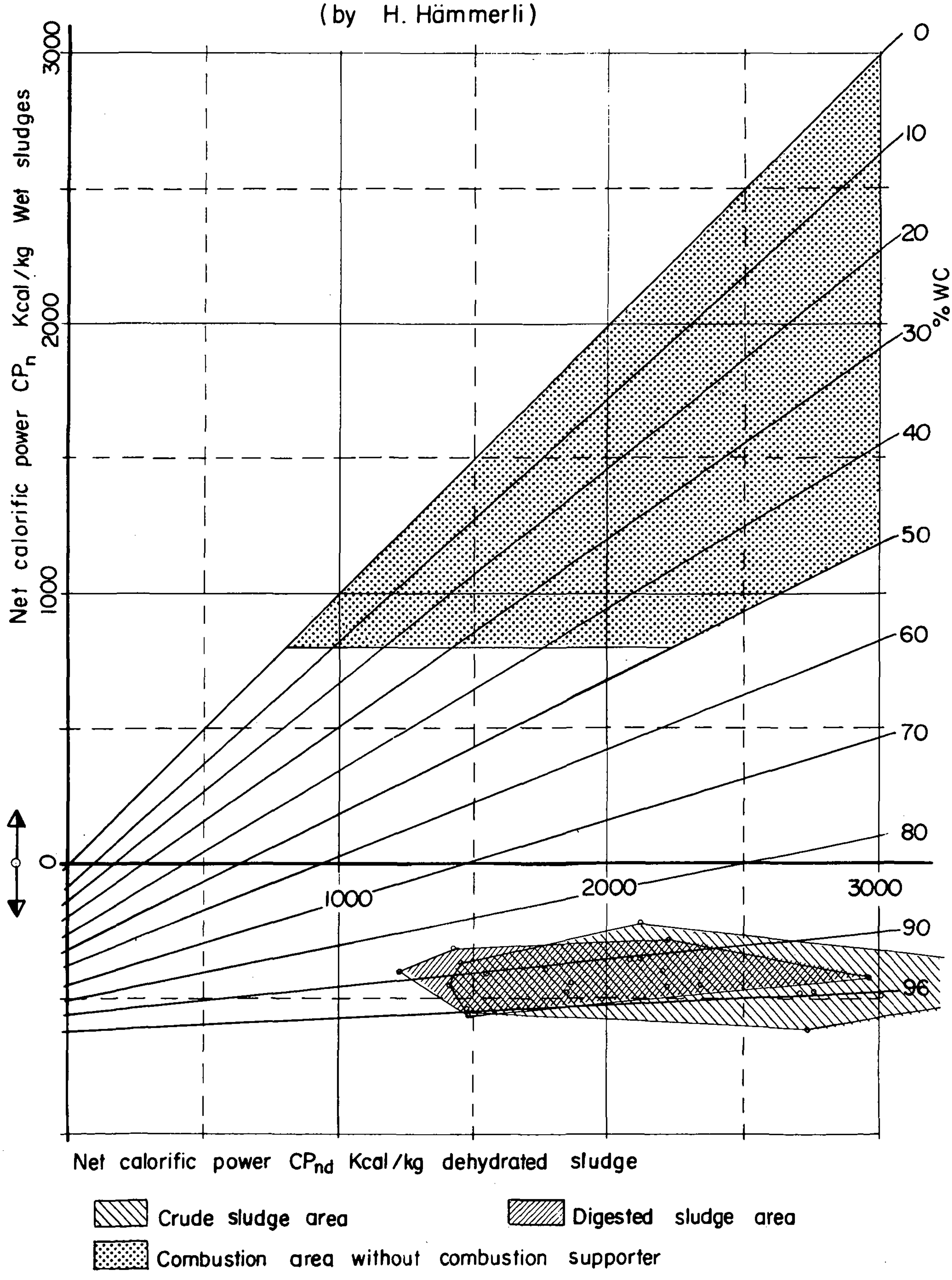
Instead of using the thermal energy produced for the generation of electricity (Chap. 6.2.2.1.), heating purposes (Chap. 6.2.2.2.) or instead of wasting the heat (Chap. 6.2.1.) the resulting energy may be used for drying the sludge generated in a sewage treatment plant. For this purpose a multiple hearth furnace, where municipal and industrial refuse, pumpable sewage sludge and waste oils may be incinerated simultaneously, is suitable. (Table No. 9, page 57)

The surplus heat from the refuse is used to pre-dry the sludge on the upper 5 stories. Underneath, on the following two stories, the refuse and dried sludge are incinerated at 850°C. The flue gases generated there pass through the 5 upper stories and - by drying the sludge - are cooled down to 300°C and evaporate the moisture. Subsequently, they discharge their fly ash content by passing through an electrostatic precipitator [lit. 59].

EAWAG	Section for Solid Wastes	Table No 9

The Calorific Power of Sewage Sludges as a Function of its Water Content

(by H. Hämmerli)



Cooled flue gases of screen residue furnaces may be piped to the windrows of the composting plant, delivering the missing heat in winter into the aeration system in order to maintain the necessary fermentation temperature [lit. 60].

6.3. DAMAGE THROUGH FLUE GASES

Up until recently sulfur compounds were considered to be the main cause of incinerator and boiler corrosion, as well as - by way of flue gas emissions - the origin of damage done to plant leaves. It seems now that the influence of hydrochloric acid, which is increasingly being generated by burning discarded PVC, causes more corrosion in the boiler as well as damage to the vegetation, [lit. 61, 62] although this question has not been definitely answered. Other experts still hold that sulfur compounds are more troublesome [lit. 63].

Up to a certain point it is possible to avoid these corrosion-inducing conditions by:

- crushing of refuse and subsequent mixing in order to obtain a homogeneous fuel and steady combustion. The formation of reducing, smoldering gases is therefore impeded.
- provision of a counter-air current in order to protect the exposed heating surfaces. It prevents the reducing gases from desintegrating the oxide layer.
- limitation of steam temperature preferably to 250^{o}C or lower.
- parallel-flow combustion, i.e. flue gases and refuse pass through the furnace in the same direction. Although counter-flow combustion has the advantage of drying the refuse more rapidly, it is more likely to develop smoldering gases [lit. 61].

6.3.1. DAMAGE TO THE VEGETATION

Although technical means may be used to prevent corrosion to a considerable extent, the damage done to the environment continues, with gases still being discharged from chimneys. Wet cleaning eliminates a certain percentage of the flue gases, but as it implies enormous water consumption, only small plants (for instance residue incineration of composting works) can cope with it (Chap. 6.2.1.).

It seems that sulfur compounds can be tolerated by the vegetation to a greater extent than chlorine and hydrochloric acid. Apart from PVC with a chlorine content of more than 50 %, there are traces of chlorine (from 0.032 % to 0.14 %) in other packaging materials such as cardboard. In paper manufacturing chlorine serves as a bleacher. Thus, burning packaging material at 800 to 1000°C leads to bleaching effects which affect garden plants and crops as well as woods, bushes and wild plants in the surrounding area [lit. 62].

6.4. CRITICISM OF INCINERATION

Perhaps because burning means purification of rotten and infected material, incineration of solid wastes was often thought of as the only really efficient solution to the refuse problem. One has only recently become aware of the fact that decontamination must be dearly purchased with air pollution.

This does not mean that incineration has grown obsolete but only that, in many cases, recycling is more advantageous if all factors are taken into consideration.

6.4.1. ADVANTAGES

- Incineration provides for the greatest volume reduction; this is specially important when handling wastes in metropolitan areas.
- Comparatively little need of space.
- Decontamination of infected material.
- The organic material that resists the composting process can be broken down.
- Heat recovery is more economical in big plants.

6.4.2. DISADVANTAGES

- Air pollution can be avoided to a certain degree, but the endeavor to spare the environment at all costs necessarily makes incineration expensive.
- 40 to 50 % by weight and 10 to 20 % by volume must be disposed of in the form of slags and ashes.
- Wastes are heterogenous and their heat value changes constantly.
- Incineration releases corrosive material contained in the fuel (chlorine in PVC).
- At smaller plants the heat produced must be destroyed by means of expensive installations.

C H A P T E R 7 PARTICULAR DISPOSAL POSSIBILITIES

Not all solid wastes can be dealt with in an ordinary waste disposal program.

7.1. SEWAGE SLUDGE

Sewage sludges turn to solid wastes when they are dewatered or thickened.

Table No. 10 (page 62) indicates some of the possibilities for processing and disposing of sewage sludges and table No. 11 (page 63) shows the different alternatives for sludge disposal.

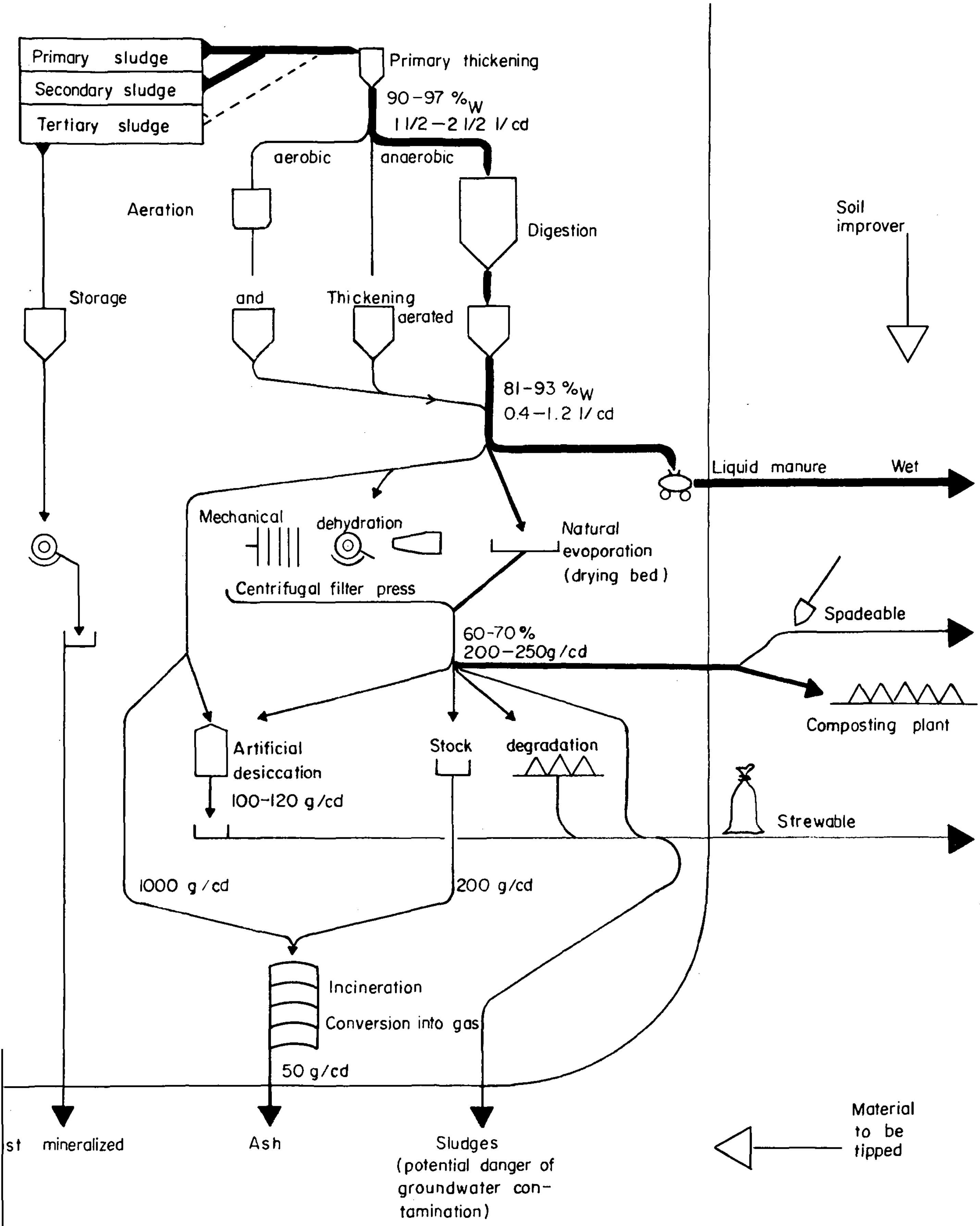
Some miscellaneous wastes, which do not fall under the usual waste categories, must be taken into consideration. For the incineration of tires and other bulky refuse, for instance, a large loading aperture of the furnace and hydraulic shears for cutting are necessary.

The combustion of waste oil, slaughterhouse wastes and dead animals presupposes special mechanical devices in the furnace. This kind of waste is often treated separately.

As to industrial sludges and further noncombustible wastes like galvanic residue, lacquers, varnish removers, etc., it has been shown that these substances are absorbed to a certain degree in the composting process, [lit. 64] although it has not yet been proved whether compost with the addition of industrial sludges (specially heavy metal salts) is suitable for cultivating food-plants.

Table No 10

Possibilities for Sludge Treatment and Disposal



Possibilities of Sludge Disposal

Type of Sludge		Tipping		Use in Plant cultivation: Pastureland		Arable land		Gardening		Composting		Incineration	
		h	pc	h	pc	h	pc	h	pc	alone	with refuse	alone	with refuse
Crude sludge	Wet	r	r	P	yes*	r	yes*	r	yes*	—	s.q	—	s.q
	Dewatered	r	r	P	yes	r	yes*	r	yes	yes	yes	—	yes
	Dried thermally	yes*	yes*	yes	yes	yes*	yes	yes*	yes	—	yes	—	yes
Digested sludge	Wet	r	r	P	yes*	r	yes*	r	yes*	—	s.q	—	s.q
	Dewatered	r	r	P	yes	r	yes	r	yes	yes	yes	—	yes
	Dried thermally	yes*	yes*	yes	yes	yes*	yes	yes*	yes	—	yes	—	yes
Aerobically stable Sludge	Wet	r	r	P	yes*	r	yes	r	yes*	—	s.q	—	s.q
	Dewatered	r	r	P	yes	r	yes	r	yes	yes	yes	—	yes
	Dried thermally	yes*	yes*	yes	yes	yes*	yes*	yes*	yes	—	yes	—	yes
Sludges — ashes		yes*	yes*	yes	yes	yes	yes	yes	yes	—	yes	—	—
Liquid faeces		r	r	P	yes*	r	yes*	r	yes*	—	s.q	—	s.q

Legend:

- yes* = provided it is correctly applied
- r = with reservations, that is, if groundwater conditions or hygienic and aestetic parameters are heeded.
- s.q = only in small quantities
- P = only if pasteurized or hygienized
- h = from the hygienic point of view
- pc = from the pollution control angle

Demolition wastes hardly cause any water pollution and are therefore discharged without the intermediary of a disposal plant.

CHAPTER 8 COSTING

Much data have been collected to find a common denominator for comparing the investment and operating costs of various incineration or composting systems in order to have a point of departure for a costing comparison between the three main ways of waste disposal, i.e. landfilling, composting, incineration. A very elaborate attempt was made in this direction by the Ministry of Health in Western Germany. Their approach to cost comparisons [lit. 65, 66] was based on techniques used in the science of industrial management. But, as it is almost impossible to collect accurate basic data from different plants, the conclusions are not completely reliable.

In place of precise comparative data, which are not available, an approximate costing range is given below (Chap. 8.1.). On the other hand, adequate and standardized information on the costs of landfill, composting and incineration based on a reliable accounting system is urgently needed. An indication to this effect will be given in Chap. 8.2. Once the accounting system has been established in several plants, the results can be put down on the cost sheet and compared with one another (Chap. 8.3.).

8.1. APPROXIMATE COSTING RANGE

Table No. 12 (page 66) represents an extract from literature regarding the costing basis of ultimate waste handling. Although it is obvious that it cannot be used for accurate costing purposes, the considerable amount of data collected may serve as a guideline for costing ratios. In most cases the bibliographic appendix (numbers in parentheses) indicates the year of inquiry, or at least the year the inquiry was published.

Table 12

Disposal System	lit.	Tons per year	Inhabitants	Investment costs per ton/year	Investment costs inhab./year	Operating costs per ton/year	Operating costs inhab./year	Total current costs per ton/year	Total current costs inhab./year
Sanitary Landfill									
without pulverizing	67	-	-	-	-	-	-	-	DM 1.50 - 3.-
" "	68	70,000	-	-	-	-	-	DM 1.93	-
" "	69	-	-	-	-	-	-	$ 0.70 - 1.50	-
" "	70	less than 50,000	-	-	-	-	$ 1.25-5.-	-	-
" "	70	more than 50,000	-	-	-	-	$ 0.75-2.-	-	-
not specified	71	8,000	-	DM 6.-	-	DM 7.4	-	DM 13.4	-
" "	72	-	-	-	-	-	-	DM 1.- - 10.-	-
" "	73	-	-	-	-	-	-	DM 1.55 - 5.20	-
with pulverizing	67	-	-	-	-	-	-	-	DM 2.50 - 5.-
" "	73	-	-	-	-	-	-	-	DM 10.50
" "	74	-	-	-	-	-	-	DM 17.60	
Composting									
without incineration	67	-	-	-	DM 20.-70.-	-	DM 3.20 - 9.50	-	-
" "	72	-	-	DM 80-200	-	DM 4-25	-	-	-
" "	75	-	-	-	-	-	-	DM 15.- - 23.-	-
" "	73	-	-	-	-	-	-	DM 17.- - 24.-	-
" "	76	20,000	-	DM 100.-	-	DM 45.-	-	-	-
" "	76	50,000	-	DM 60.-	-	DM 19.-	-	-	-
" "	77	6,000	-	Fr 233.-	-	Fr 17.50	-	Fr 35.-	-
" "	77	8,000	-	Fr 195.-	-	Fr 11.70	-	Fr 27.-	-
With incineration	77	6,000	-	Fr 334.-	-	Fr 23.-	-	Fr 48.-	-
" "	77	18,000	-	Fr 256.-	-	Fr 14.-	-	Fr 33.-	-
" "	78	-	-	-	-	DM 27.-	-	-	-
" "	79	-	100,000	Fr 185.-	Fr 32.50	-	-	-	-
(Compost tipped) " "	80	-	250,000	-	-	-	-	DM 20.60	DM 7.20
(Compost given gratis)"	80	-	250,000	-	-	-	-	DM 16.40	DM 5.70
(Comp. price DM 4/t) "	80	-	250,000	-	-	-	-	DM 13.60	DM 4.-
(Comp. price DM 8/t) "	80	-	250,000	-	-	-	-	DM 10.70	DM 3.80
Incineration									
without heat recovery	81	-	-	DM 50-150	DM 10 - 30	-	-	-	-
with heat recovery	81	-	-	DM 100-250	DM 20 - 50	-	-	-	-
not specified	72	-	-	DM 100-500	-	DM 10-40	-	-	-
" "	75	-	-	-	-	DM 30-36	-	-	-
" "	67	-	-	-	DM 50-130	-	DM 16.50	-	-
" "	76	20,000	-	DM 300.-	-	DM 42.50	-	-	-
" "	76	50,000	-	DM 160.-	-	DM 28.-	-	-	-
" "	76	100,000	-	DM 120.-	-	DM 22.-	-	-	-
" "	78	-	-	-	-	DM 27.-	-	-	-
" "	73	-	-	-	-	-	-	DM 28.- - 35.-	-
" "	80	-	250,000	-	-	-	-	DM 32.80	DM 11.70
" "	77	6,000	-	Fr 400.-	-	Fr 26.-	-	Fr 44.-	-
" "	77	18,000	-	Fr 234.-	-	Fr 14.-	-	Fr 32.-	-

$ = US Dollar
DM = Deutsche Mark (Western German currency)
Fr = Swiss Franc
1 US $ = DM 3.70 = Fr 4.30

8.2. ACCOUNTING SYSTEM

An accurate costing system must be based on the efficient collection and transmission of all relevant operation data of the present as well as previous years or other communities. A breakdown and description of operations is required to facilitate analysis.

The Bureau of Solid Waste Management, USA, has recently published two studies on this subject, which supply all the elements necessary for establishing an adequate accounting system. By means of the proposed system excessive costs and inefficiencies can be traced to a functional activity and therefore eliminated. It could also be an excellent common denominator on an international basis for comparing different systems of waste handling. It is therefore suggested that these two papers be studied by experts all over the world and - if approved - translated into practice. A third paper concerning composting, drafted on the same basis, would be very useful.

The corresponding bibliography is cited below:

- Eric R. Zausner "An Accounting System for Sanitary Landfill Operations", Washington D.C., 1969, Public Health Service publication No. 2007
- Edited by U.S. Department of Health, Education and Welfare, Public Health Service, Environmental Health Service, Bureau of Solid Waste Management; Public Health Service publication No. 2032

  For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. - Price 35 cents.

8.3. COST SHEET

Setting up the cost sheet depends on the reference standard, i.e. the average operating expenses - including annuities (interest plus capital amortization) - and should be established per ton of refuse and per inhabitant. These data can easily be made out from the standardized accounting system (Chap. 8.2.) once it has become operative.

Interest rates, salary costs, evalutation of land, etc., may differ considerably within a country. It is therefore advisable to establish a standard for metropolitan areas and another for small towns and rural areas.

On the other hand, the difficulties in comparing the constituents mentioned on an international basis would be almost insuperable and the results never realistic. Thus, each country has to establish its own standards; the guidelines for drafting a schedule is given hereafter.

The costs are to be established for 50,000 inhabitants and for different multiples of this number including the annuities for road construction and the acquisition of land for tipping purposes.

Each of the three possible ways of waste management - sanitary landfill, incineration, composting and incineration of residues - should be calculated separately, taking into account that the totality of wastes must be disposed of. Domestic waste, bulky refuse, sewage sludge, waste oil and slaughterhouse refuse can be more or less standardized according to the number of inhabitants connected. Only trade and industrial refuse depends entirely on the specific region and must be added separately.

CHAPTER 5 COMPOSTING

As far as wastes management is concerned we live in a closed environment, which comprises soil, water and air. Disposal of wastes means discharging them into one or more of these sectors of the biosphere and polluting any or more of them. Thus, proper wastes management involves deciding which of these sectors can accept refuse without detriment. [lit. 27] Causing damage must not necessarily be a fait accompli when managing waste:

40 to 80 % of domestic refuse consist of fermentable matter, which - if possible together with sewage sludge - can be transformed into compost, i.e. into a material, readily accepted by the soil as an allied substance. The same fermentable matter, incinerated, merged in water or compacted underground means incorporating foreign substances into air, water or earth and consequently pollution.

Unfortunately these plain relations are not as simple as they may seem. The technical, biological and marketing problems were often underestimated and led to subsequent disillusionment. Sometimes also the knowledge of biological processing could not keep pace with the technical outlay and, last but not least, waste composting was thought of as a business.

5.1. GENERAL STATEMENTS ON COMPOSTING

Considering the affinity between fermentable waste and soil, it is advisable to provide for composting mostly in conjunction with the incineration of screen residue whenever compost can be applied effectively. Its usefulness, the distribution of costs as well as technical and biological treatment with the addition of sewage sludge whenever circumstances allow must be subject to careful assessment and planning.

Thus, the vicinity of sewage treatment plants to the composting plant is most appropriate, the common processing of both kinds of waste by means of fermentation being a very economical way of sludge treatment.

The potential users of compost are generally not informed about the possibilities of compost application. Therefore, when investigating the potential market for compost in the area, there might be no demand at all.

Sometimes farmers are even irked at being considered the citizens' dump. Prejudices must therefore be overcome by efficient marketing, by keeping compost prices for bulk deliveries low and by offering a perfectly mature and fine-grained compost quality.

To neglect approaching potential users might spell failure for the planned compost plant. The compost applicability is therefore discussed in the first place:

5.2. COMPOST PROPERTIES

Mature compost, applied properly, has a manifold influence on cultivated soil:

1. Preventing water- and wind erosion [lit. 28, 29]
2. Retaining soil moisture during dry periods [lit. 30, 31]
3. Increasing the permeability of water during rainy periods [lit. 30, 32]
4. Vivifying properties (Thienemann's Law) hence crumb structure of the soil [lit. 33, 34, 35]

5. Supplying trace elements, well-balanced through the buffer action of the accompanying humus substances [lit. 36, 37]
6. Remarkable content of nutrient elements (N, P, K, Mg, Ca) though this feature not being primordial [lit. 38, 39]
7. Making phosphorus more readily available to growing plants [lit. 40]
8. Preventing leaching of soluble inorganic nitrogen [lit. 40]

These more or less verified properties can be followed up with other presumed features which need further verification.

9. Diversifying botanically and improving the ecological stability of pasture-land which has been impoverished by the excess use of chemical fertilizers (or liquid manure), hence prevention of cattle diseases (fertility problems, pasture-tetany) [lit. 41, 42]
10. Preventing parasitic diseases by making the cultivated plants more resistant [lit. 43]

5.2.1. INTENSIVE CULTURES

The best known and most thoroughly tested field [lit. 44] of compost application is that of viticulture. Since the vines generally grow on uncovered soil and are often cultivated on a slope, prevention of erosion plays a very important part.

With any other culture without a humus protecting plant-cover, compost is welcome:

Horticulture
Cultivation of vegetables
Fruit-culture
Tree nursery and forestry

5.2.2. EXTENSIVE AGRICULTURE

The use of compost in extensive agriculture is often thought of as uneconomical, as spreading compost on large areas is expensive. Since the citizen must shoulder the burden of waste disposal costs, the hauling distance from the plant must be carefully calculated with a view to freight costs; it should also be taken into account that leaving the compost lying on a cultivated field - contrary to other ways of discharging wastes, their residue, flue dust and gases - is beneficial.

The use of compost is advantageous when cultivating hoed vegetables (potatoes, turnips and sweet turnips, etc.); compost may be used for cereals but with less efficacy.

As yet, compost has scarcely been used on pastures. Possibly, extremely small amounts per unit of area are sufficient to achieve results (3.1.1.). In any case, verification is still open and research work in this field needed.

5.2.3. MISCELLANEOUS COMPOST APPLICATION

In metropolitan areas compost application is useful for the care of

public recreational areas
football fields
private gardens

For the latter purpose, a retail distribution service, high grade fineness (the compost possibly mixed with peat) and suitable and appealing packaging are recommended.

A very interesting use for waste compost is pig breeding. Piglets are often anaemic; if fed on specially treated compost - which they greedily eat - their anaemia and diarrhoea can be prevented [lit. 45, 46, 47].

5.3. TRIAL TIME

In general, the potential users are not aware of the possibilities inherent in compost (3.1.). On the other hand, in most cases it will be difficult to procure the necessary amount of compost for introduction within the farming and gardening population before putting the plant into operation.

In order to overcome these difficulties, provisions should be made to place an adequate amount of compost at the disposal of potential users within an average hauling distance of 25 km for a trial period of two years; this should be free of charge to the user and included in processing costs. In cooperation with the agricultural and local municipal authorities, a site has to be fixed in each municipality, where the farmers can fetch compost. Distribution on their fields can be done by means of a manure-sprinkler at an average rate of 100 tons per ha, i.e. 2 1/2 acres (a layer of 1 cm). To make the difference between the treated and the untreated area obvious, only half of the farmer's land is to be treated, the other half is worked as usual. As the case may be, loading the farmer's vehicles on special days by means of a tractor shovel can also be included in the budget of the first two years.

Experience has made it plain that not only the potential users but also the agricultural authorities are becoming open-minded when approached beforehand, as outlined above. When they are faced with the problem of suddenly taking over huge amounts of compost, they are less accessible.

5.4. MARKETING AS A FUNCTION OF COSTING AND QUALITY [lit. 48]

Wastes management obviously falls within the sphere of competence of the local authorities and is to the debit of the taxpayer. On the other hand, compost is a soil improvement agent and must be paid for as such by the consumer. When discussing costing (3.4.) we tried to find out the point 0 where the responsibility of the authorities ceases and the business of a salesman begins.

It is advisable to make a strict separation between wastes and sales management. The reasons are that local officials will rarely become efficient salesmen and that a substance which, before treatment, was as repugnant as refuse will hardly be in great demand. Therefore, the staff handling the compost and starting in at the point 0 has to develop another psychological attitude divorced from any reminiscences of refuse. It is indispensable to give the costing problem as well as the question of quality, which is so closely connected with marketing, careful scrutiny.

5.4.1. BULK CARGO

The selling price for compost in bulk ought to be the same within a certain district and independent of the client's distance from the plant. If different composting plants cover a certain area, it is advisable to centralize the sales managements as well as the quality-checking laboratories.

5.4.1.1. COMPOST IN BULK

For a minimum of 15 tons of mature, fine-screened, carriage paid, compost in bulk a reasonable price would be U 5.- per ton. The transport expenses - when calculating with U 3.- per ton - could cover an average range of 50 to 60 km including loading.

Customers willing to fetch the compost at the plant should pay not less than U 3.-.

The costing sheet would be as follows:

1 ton mature compost in bulk, fine-screened		
1 ton screened through coarse sieve (25 mm)	U*	0.30
1 ton screened through a fine sieve (screening loss) 30 %	U	0.40
Charges for screening and incineraticn the screen residue	U	0.60
Cost-price ex-plant	U	1.--
Loading	U	0.10
Transport	U	3.--
Advertising	U	0.50
Reserve item for possible dead stock to be tipped	U	0.40
Price carriage paid	U	5.--

5.4.1.2. MOULD IN BULK

It may be advisable to dispose of a mixture of peat or moor-earth and compost for neutralizing the pH. Screening difficulties through too much moisture may be overcome by mixing with peat.

* To demonstrate the cost relations without considering any money value, a neutral money unit (U) is used instead of $, £, DM or Fr

500 kg mature compost screened through a coarse sieve (25 mm)	U	0.15
500 kg screened through a fine sieve (screening loss 30 %)	U	0.20
Charges for screening and incinerating the screen	U	0.30
500 kg moor-earth or peat	U	4.--
Mixing and loading	U	0.50
Cost price ex-plant	U	5.--
Transport	U	3.--
Advertizing	U	1.--
Reserve stock for possible dead stock to be tipped	U	0.20
Price carriage paid	U	9.20

5.4.2. BRANDNAME ARTICLES

Unmixed compost as well as mould may be launched as branded articles in different sizes. The following calculation is an example of a small package for pot plants:

5.4.2.1. CALCULATION OF A RETAIL PACKAGE

Branded article mould 2 kg		
Cost price (U 5.- per ton)	U	0.01
Plastic bag	U	0.02
Sacking	U	0.01
Forwarding	U	0.05
	U	0.09
Advertising approx. 30 % of the retail price	U	0.13
Price to the wholesaler	U	0.22
Wholesale margin	U	0.05
Price to the retailer	U	0.27
Retail margin	U	0.13
Retail price	U	0.40

5.4.2.2. PIG-BREEDING

A special compost brand for pig-breeding in bags of 25 kg [lit. 45, 47] can be launched:

Branded article of compost for pig-breeding		
Cost price (U 1.- per ton)	U	0.025
Additional screening through fine sieve	U	0.025
Perforated plastic bag	U	0.04
Sacking	U	0.01
Forwarding	U	0.15
	U	0.25
Advertising	U	0.25
Resale margin	U	0.20
Selling price to the consumer	U	0.70

In case a quality control (4.1.7.) through an official institute can be carried out, an indication on the package "Continually tested through the .... Institute" will help selling.

5.4.3. COMPOST QUALITY

As yet literature on compost application leaves much to be desired, because there is no coordinated convention regarding the state of maturity, degree of fineness and percentage of added substances. For practical purposes, these three criteria need standardizing because they will enable the evaluation of compost-quality reliably.

The determination of the percentage of fermentable organic substances (Meth. 141.3) nitrogen, other macro-elements (Meth. 142, 143, 144, 145, 146), as well as the pH (Meth. 147) may be added to the three mentioned criteria, if more precision is needed.

An appendix at the end of the present paper gives some detailed suggestions on quality systematics and investigation still to be done.

5.5. CRITICISM OF COMPOSTING

Composting has caused much disillusionment, perhaps because the approach to recycling was either too amateurish or focused on technology to the exclusion of biology and marketing. Failure was also due to profit-motivation and odor nuisance. After all, composting still represents the most significant possibility for the reuse of waste if done properly.

5.5.1. ADVANTAGES

- Significant reuse.
- Agriculture is in need of humus; as a result of water and wind erosion there is a shortage of it wherever land is cultivated intensively. Contrary to the by-product of incineration there is no way of producing humus more economically: heat is much cheaper when produced from fuel.
- No environmental pollution apart from residue disposal (15 to 40 %).
- Less area required compared with sanitary landfilling (about 0.2 m^2 per inhabitant).
- More economical than incineration if composting machinery is not conceived of as an elaborate end in itself with high technical performance neglecting or simplifying the biological aspects.
- The taxpayer is treated with clemency if the plant is managed rationally, and a reasonable selling price covers part of the expenditures.

- Composting decontaminates infected material [lit. 52].
- Reuse of sludge, economical sludge handling if the sewage treatment works are combined with or in the vicinity of a composting plant.
- Composting may absorb a certain percentage of toxic industrial mineral refuse, which cannot be disposed of otherwise [lit. 53, 54].

5.6.2. DISADVANTAGES

- Marketing must be planned on a long-term basis.
- The application of compost is limited to a radius of about 70 km because of the transport costs (except packaged branded articles.
- Odor nuisance in case the composting process is not handled according to methods that exclude emissions.
- Residues must be disposed of.
- Needs a larger area than an incineration plant.

CHAPTER 6 INCINERATION

Up until very recently annihilation of refuse was the goal of wastes management. It has been disregarded that an-nihil-ation - "nihil" Latin for nothing - is impossible and that the trend of destroying necessarily implies an additional polluting factor to the water, air or earth. War production, which caused a dearth in raw material, forced the European countries to economize and reuse wastes during both World Wars. After those years of restriction, the luxury of throwing away and destroying everything that was not branc new or up-to-date was a natural reaction. Today the situation has changed again, as the by-products of affluence pollute the environment. Therefore, the question is no longer:

> "Which way is more economical, the production of an object from newly gained raw material or from wastes?"
>
> but
>
> "How can wastes be reused most economically in order to prevent them from polluting the environment?"

The new goal is to minimize pollution by managing solid wastes and improving the reuse and recycling of discarded material [lit. 55].

Incineration always causes air pollution, the extent depending on the degree of flue gas extraction and the amount of smoke nucles not caught by the filter system. Thus incineration should only be chosen if reuse is out of the question or if the residues of re-cycling are to be processed.

6.1. CHARACTERISTICS OF COMBUSTIBILITY

The three components water, ash and combustibles determine the heating value of waste (Chap. 1.4., Meth. 14 - 141). Unobjectionable combustion without additional fuel must meet with the following conditions:

Ashes and slags	: 60 % maximum
Combustibles	: 25 % minimum
Water	: 50 % maximum

The three-component diagram (table No. 7, page 50) shows inside the hatched area the range of refuse composition in which combustion can be maintained without additional fuel [lit. 56].

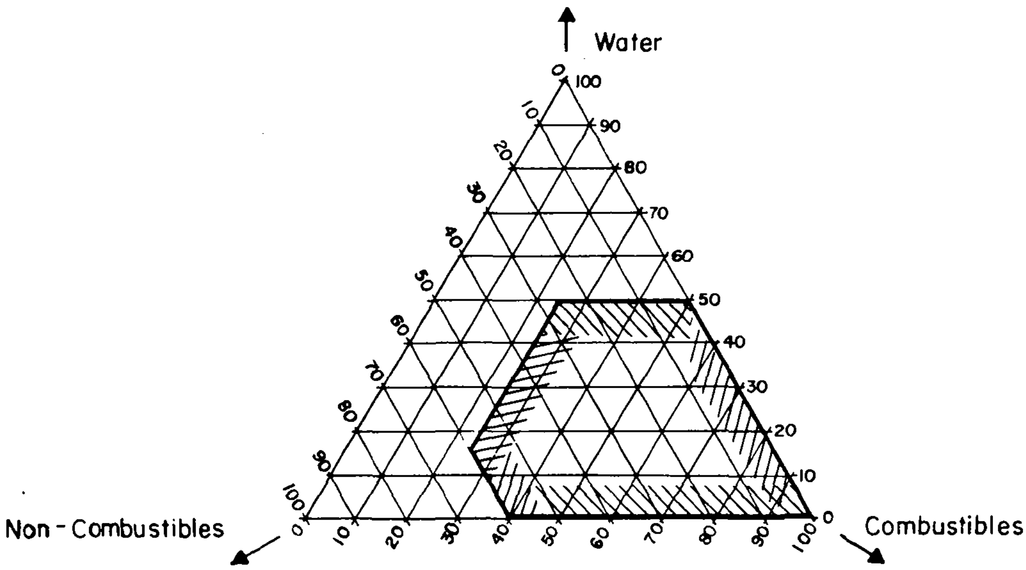
6.2. APPROACHES TO INCINERATION

Incineration without additional fuel by no means implies the economical use of the waste heat, in fact, incineration will never be a profitable business. Indeed, the proceeds derived from the sale of the waste heat does not cover the prime costs of the incineration plant disregarding the collecting service. This fact is relevant even for the biggest plants.

Of course, the operating costs can be reduced by the proceeds from the waste heat recovered: the higher the throughput capacity, the greater the cost reduction. Nevertheless there is a limit at about 1200 tons per day and plant but not because of the shortcomings of combustion engineering. It is the transport problem that does not keep pace with the possibilities of processing: The vast numbers of collecting vehicles going to the plant are liable to obstruct traffic and the large amounts of ash and slag transported from the plant imply an additional traffic encumbrance on the highways.

EAWAG	Section for Solid Wastes	Table No 7

Three Component – Diagram



6.2.1. INCINERATION WITHOUT HEAT RECOVERY

If heat recovery is not economical (Chap. 6.2.2.) the heat produced by incineration must be destroyed (exception Chap. 4.2.2.3.). Plants of this character are frequently used for incinerating the screen residue of composting installations (Chap. 1.4.1.), and municipal incinerators with capacities below 100 tons per day.

The hot flue gases are cooled down by mixing atmospheric air with the flue gases. A stronger cooling effect is attained by connecting the outlet to a wet cleaner. Precooling through the recuperator is advisable, as it may prevent the generation of significant flue gas plumes. These are produced by washing very hot gases.

Contrary to electrostatic precipitation which filters only solid particles, wet cleaning may dissolve a considerable part of the gases themselves. This is important since chlorine and hydrochloric acid are generated when burning PVC. The incineration of other substances contained in wastes may cause the emanation of fluorine and SO_2. These gases, too, are partially washed out.

On the other hand, washing involves enormous water consumption: about 10 to 15 m^3 per ton of refuse. Thus wet cleaning is only suitable for relatively small plants.

6.2.2. INCINERATION WITH HEAT RECOVERY

Apart from the use the recovered energy is put to, it is indispensable to have a purchaser willing to take the thermal energy during the whole year. In most cases the quantity of refuse and its heat value will increase continuously, thus raising the thermal energy at disposal. This surplus is to be taken over by the partner because the processing capacity of the refuse plant must always be in accordance with the amount of waste collected. The purchaser must therefore be in a position to adapt his needs to the amount of heat offered at all times. In most cases this demand is unacceptable. Either there is too much heat or not enough of it. Equilibrium between supply and demand is scarcely feasible (exception Chap. 6.2.2.1.). Thus a compensation must be found by locating an additional boiler in case of an insufficiency in the heat supply, or a heat wasting apparatus if too much heat is produced. In practically all cases both additional apparatuses are necessary. These raise the costs of energy production which are already extremely high due to the complexity of boiler plants producing heat from waste. Refuse incineration with heat recovery will therefore never be self-supporting [lit. 57]. When comparing the results of wastes disposal by incineration with those by composting, it is obvious that the soil conditioner "compost" cannot be replaced by any other means, whereas heat is produced cheaper and easier from fuel [lit. 58] (Chap. 3).

Nevertheless, assuming favorable conditions, the processing costs of refuse may be reduced. The decision of whether an incineration plant should be built with or without heat recovery depends chiefly on the local conditions as described above. General guidelines with a specific on-the-spot study are not commendable. In any case, the production of heat must never be the main point in decision-making (Table No. 8, page 53).

6.2.2.1. THE GENERATION OF ELECTRICITY

The most favorable conditions for heat recovery are given when the incineration plant can be established within the premises of a power station. The amount of steam produced can in these cases be used all year round without the installation of an additional boiler plant since it already exists in all power stations.

A special schedule may be set up for incineration with heat recovery, adding a column for regained kilowatt hours.

Once the standard cost sheet per inhabitant and per ton is established, the cost-relations between the different ways of wastes management are roughly known. Given the case that the wastes management up to the stage of crude compost (including screen residue incineration) costs the same as total incineration up to the stage of slags left lying outside the furnace, hauling to the definite site of deposition must in both cases be charged additionally.

The volume loss on incineration is about 80 % and that on fermentation about 40 %. Thus the remaining volume of incineration residues (20 %) totals one third of the volume of mature compost (60 %). With a hauling distance of 30 km and the ton kilometer costing U 0.07, the expenses for hauling are U 2.10 per ton. In relation to incineration costs and given the same distance, the compost must be charged with 2/3 of the hauling expenses, i.e. U 1.40. Or the compost can be credited with 1/3 = U 0.70 per ton.

Reckoning with U 1.- for fermentation and sifting through a coarse screen (25 mm) the mature compost would cost U 0.30 per ton, if the compost customer were debited with the hauling; thus the reduced price offsets the transport costs of the incineration residues which are always paid by the taxpayer. If dehydrated sewage sludge is included in the composting process, the price of U 0.30 per ton could still be lowered.

CHAPTER 9 CONCLUSION

In the USA the problems of waste management have long been neglected, and in Europe any suggestion of re-using refuse was thought of as unreasonable, reminiscent of war times.

Only when in 1965 under President Johnson the "Solid Waste Disposal Act" became effective, impetus was given to the ecological approach to the waste disposal problem. Five years later, 1970, in his State of the Union Message President Nixon described the situation as follows:

> "The great question of the seventies is, shall we surrender to our surroundings, or shall we make our peace with nature and begin to make reparations for the damage we have done to our air, our land, and our water?
>
> Restoring nature to its natural state is a cause beyond party and beyond factions. It has become a common cause of all the people of this country. It is a cause of particular concern to young Americans - because they more than we will reap the grim consequence of our failure to act on programs which are needed now if we are to prevent disaster later".

This message is not only of concern to Americans, it is valid wherever modern civilization is correlated with nature.

APPENDIX

SUGGESTION FOR A COMPOST QUALITY SYSTEMATICS

A. Degree of fermentation (abbr. = F)

For practical purposes it is to differentiate between three degrees of fermentation:

B. Mature compost (abbr. = Fm)

Compost-maturity has often been discussed, but definite conformity could not yet be attained. The most unequivocal maturity-proof is certainly the seedling-test (Meth. 171), only there is the disadvantage of incomparability, as personal experience, and therefore subjective features, can hardly be eliminated.

Maturity may be objectively determined:

- when no place in the windrow, under any circumstances, exceeds the temperature of the surrounding atmosphere (Meth. 152)
- when $-NH_4$ generation has passed over to $-NO_3$ generation [lit. 49]
- when H_2S generation has ceased (no blackening of lead-paper) [lit. 49]
- when C/N relation is below 19 (Meth. 151)
- when the Chaetomium count is below 300 (Meth. 151)

Mature compost can cause no damage to soil or plants and is therefore foolproof. Except for specific situations, exlusively Fm-compost should be produced. Immature compost, misapplied, brings compost into discredit.

C. Crude compost (abbr. = Fc)

Crude compost has undergone the first phase of fermentation, reaching temperatures of 60 to 70 centigrades. Pasteurized, Fc-compost is thus exempt from pathogenic germs. It must be spread superficially and should only be used in viniculture, fruit-growing and forestry. It must never be applied to young plants. Gardeners may terminate the composting process on their own premises.

D. Heat-producing layer (abbr. = Fh)

In order to take advantage of the released heat, generated through fermentation, freshly crushed domestic refuse can be used for forcing frames and hothouses. Two loose layers of 15 cm each, between a layer of a material penetrable by air such as straw, and over it 10 cm of earth are prepared at winter's end, especially for the cultivation of cucumbers and melons. Heat will be delivered for about 6 weeks [lit. 50].

E. Degree of purity (abbr. = P)

To economize one can, of course, sell a coarse quality, but experience has shown that it is advisable to dispose only of compost which is more or less exempt from cullet and other foreign particles. Compost must never look like refuse. The coarse qualities are only suitable when erosion must be prevented (melioration, viniculture, etc.).

The Dutch "Vuil Afroer Maatschappij" (VAM) distinguishes between three degrees of purity as shown in F, G and H.

F. Coarse quality (abbr. = Pc)

Pc-compost passed through a mesh aperture of 15 mm which should not contain more than 1.5 % of slivers larger than 13.6 mm Ø. In the Netherlands this quality has been withdrawn from sale.

G. Medium quality (abbr. = Pm)

Pm is only used for bulk deliveries to consumers who are not particular about the esthetics, i.e. professional gardeners and other plant growers whose chief concern is economy. In any case, the cullet content is independent of the degree of maturity and therefore has no effect on plant growth. But it must always be realized that the foreign particles have a negative effect on the reputation of compost.

Pm-compost should not contain more than 0.5 % of slivers larger than 6.8 mm.

H. Fine quality (abbr. = Pf)

Pf is suitable for playing-fields, private gardens, potted plants, etc. and generally for branded goods. It is recommended to use during the trial-time (Chap. 5.3.) and wherever new customers are welcome exclusively Pf. This fine quality compost should pass through a mesh size of 4 mm.

I. Mixtures (abbr. = M)

A mixture which has proved to be useful is 25 % compost and 75 % peat (turf) or moor earth. Other mixtures or additions such as sand and fertilizers, may be suitable. According to the percentage of added substance the corresponding abbreviations should run as follows:

25 % compost, 75 % peat = Mt75
25 % compost, 75 % moor earth = Mm75
1/3 compost, 1/3 peat, 1/3 moor earth = Mt33m33
40 % compost, 20 % peat, 20 % moor earth, 20 % sand = Mt20m20s20

In general, it is preferable to spread fertilizers separately; if they are added, percentage and composition must be stated in extenso.

K. Quality definition

Any kind of compost or mould can now be defined and the different aspects of quality discerned.

A mature compost devoid of cullet and mixed with 40 % peat, 20 % moor earth, 10 % sand would be determined as follows: FmPfMt40m20s10.

In most cases the formula will be much shorter.

L. Prevention of bad odors

The classical theory of composting states that aeroby throughout the entire composting process must be maintained. Recent experiments seem to indicate the necessity of a fermentative hydrolysis [lit. 40] at the beginning of composting with restrained respiration [lit. 51] in order to secure rapid maturation. This implies full water capacity and little air in the beginning and no repiling until the anaerobic phase is over. Thus, the spreading of odors can be prevented.

M. Objective, practical and expedient maturity tests

There are several maturity tests (B), each of them indicating one aspect of maturity (physical, chemical, biological) and not all of them easy to carry out. What is still missing,is a simple reliable test covering every aspect, which can be executed by the plant's foreman within a short laps of time. The "Federal Institute for Water Resources and Water Pollution Control" is now trying to work out a test of this kind.

N. Dehydration of compost and screening problem

Efficient screening without leaving an excess of residue depends chiefly on a low moisture content. It seems that the full water capacity of mature compost does not exceed about 45 %. This would mean that really well-matured compost poses no difficulty in screening.

Also crude compost, (C) saturated with fungi, contains little water and can easily be screened.

Difficulties often emerge between these two phases, especially when the compost contains a high percentage of organic matter.

Verification of these statements and further experience in this field is desired.

SURVEY OF SOLID WASTES MANAGEMENT PRACTICES

lit.

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