MUNICIPAL WASTE DISPOSAL: TECHNOLOGY AND POLICY

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ABSTRACT

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TECHNOLOGY AND POLICY

By

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The problems of liquid and solid waste disposal and municipal responsibility concerning them have changed dramatically in the past 30 to 40 years. Americans are producing much more solid waste and using much more water which must be municipally treated than their grandparents did. To deal with these problems there is a great array of waste disposal techniques, some old and some very new. In the area of solid waste disposal these include sanitary landfill, refuse milling, compression, composting, incineration, garbage grinding, and experimental systems such as pyrolisis and oil conversion. In the area of liquid waste disposal such techniques as activated sludge, trickling filters, lagoons, spray irrigation, and complex chemical processes are available to treat wastewater.

This technology is sufficient to dispose of liquid and solid waste efficiently and without causing pollution. It is also sufficient to begin recycling some of the

valuable minerals and organic nutrients which are lost in most present waste disposal processes. The problem is to persuade municipalities which are using environmentally damaging, inefficient, and resource-destroying disposal methods to reasses their situations and adopt better techniques.

This reassessment processes requires a set of community-wide goals endorsing pollution abatement and resource reuse. It also requires a full working knowledge of available disposal techniques and their applicability to various situations. Lastly it requires that waste disposal be integrated into the general planning process to take full advantage of the community's knowledge about its physical, economic, and social make-up. This information will enable municipal decision makers to develop waste disposal techniques which are economically feasible and which further the goals stated before of pollution abatement and resource reuse. As more and more municipalities adopt these goals and go through the reassessment process needed to achieve them, a set of solutions to waste disposal problems will appear which will make the national achievement of these goals possible.

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CHAPTER I

INTRODUCTION

Disposal of liquid and solid wastes has an important part to play in the planning process. Often in the past it has been left to engineers who did not have the resources to relate disposal to other urban needs and services, or it was ignored until a crisis point was reached.

Waste disposal should first be part of general land use and environmental planning. In the same way that a city needs residential, commercial, and industrial land, it needs waste disposal land. Land suitable for the disposal of wastes has certain physical and site requirements which can be delineated. There is a trend in land use planning and zoning best expressed by Ian McHarg. This trend is towards looking at the natural suitability of land for a variety of purposes and managing land use accordingly. Since waste disposal processes have delimitable land requirements, certain sites can be designated as being particuarly suitable for waste disposal. This can then be related to surrounding land uses and certain sites can be picked for acquisition or easement requests. Similarly, waste disposal processes have environmental impacts and these can be used as inputs into any ecological planning framework that is being developed for a particular area.

Waste disposal should be a part of transportation planning because of the requirements of the heavy trucks which collect and haul solid wastes to disposal sites. Liquid waste disposal sites are less dependent upon location adjacent to major roads but are dependent upon adequate sewer easements.

Waste disposal should be a part of social and economic planning for a number of reasons. Solid waste problems are aggravated or alleviated by various patterns of residential, industrial, and commercial development. Solid waste disposal is also greatly affected by collection schedules, burning ordinances, and dumping ordinances, all matters of the police power of local government. Liquid waste is more strongly affected by the rate of development of an area, the pattern of development, and the extent of development than by any other factors. For example, permitting large-scale subdivision of land away from sewer connections can result in water pollution from septic tank overflow. This can only be remedied at a later date by constructing expensive sewer lines out to the development. Rapid development of land can overload sewage treatment facilities more quickly than they can be expanded to meet the demand. Overdevelopment in an area can tax the receiving stream's capacity to accept sewage effluent from the treatment facilities. Disposal of wastes, then, is a planning function intimately related to all other facets of planning for urban areas.

Cities and counties all over the country are presently having to deal with monumental waste disposal problems, generally because waste disposal was not an integral part of their planning process. These problems range from water and air pollution due to poor disposal practices, to a lack of sufficient land to handle ever larger quantities of waste. In the following decade many of these cities and counties will be forced to completely reassess their waste disposal situations and find new answers to their problems. This paper provides a framework for that reassessment.

In the following pages wastes and waste disposal are discussed from a technological point of view in an attempt to answer the question "Are techniques available for disposing of wastes without damaging the environment," and "Can we begin to reuse some of the natural resources now being lost through the waste disposal process."

Once the technological picture is clear, a method is laid out by which each governmental unit charged with disposing of wastes can assess its situation and decide which of the technological options available will best suit its needs.

The waste disposal problem in this country today is one of both quantity and quality. An estimated one billion pounds of solid waste and billions of gallons of waste water are produced each day. The nature of these wastes has changed in past decades. The wet garbage and ashes of our parents day has been replaced by paper and plastic. Exotic chemicals, detergents, and food wastes which were not present thirty years ago now enter the sewage stream. Population growth has accounted for some of the increase in quantity while technology and pre-packageing have accounted for the remainder of the increase plus the changing composition of the wastes. There has been a strong long-term trend towards greater per capita waste production. In 1920 the average person produced less than three pounds of solid waste and used less than twenty gallons of water per day. In 1972 the average person is producing more than five pounds of solid waste and uses between thirty and fifty gallons of water each day.

These trends have recipitated a twin challenge. First we must be able to dispose of this waste safely, without causing pollution of the air, water, and soil. Second, we must find ways to reuse the natural resources which are being irretrievably lost in the waste disposal process. One way to solve both problems might be to return to some of the practices of the 1920's, and indeed this is what the demand for returnable bottles and the movement towards home composting of garbage is all about. In the end, this answer may be the best one, and dwindling natural resources may force us to conserve at home as well as at the community level. In the forseeable future, however, the problems of waste disposal and waste reuse will be dealt with and solved on a large scale. Therefore, this paper does not treat home disposal of solid waste, voluntary recycling movements, or any of the other recently proposed community-effort solutions to waste disposal.

Viewing waste disposal as an isolated problem is a grave mistake. Most urban problems are interlinked and can best be viewed in an ecological context. Waste disposal affects and fits into the physical, social, cultural, and environmental subsystems of the urban whole, just as it is an integral part of planning for these subsystems.

Physical

Waste disposal provides for the physical removal of waste, liquid, and solid. Waste disposal uses urban and rural land both for the transportation of waste and for its ultimate treatment and disposal. Waste disposal costs money and it provides jobs both for the construction of facilities designed to process waste and for the pickup of scattered wastes and their delivery to central locations.

Social

Waste disposal is a social function. People classify certain items as waste and they dispose of them in socially prescribed ways. In some neighborhoods garbage day is on Tuesday, in others garbage is picked up Monday and Thursday. A few years ago plastic garbage bags were unheard of; today, they are rapidly becoming the most common method of household disposal. Waste disposal is a social function which must fit into the urban social system as a whole. Related to this is the way in which waste disposal is linked to production economics. Some segments of our economy require a high rate of turnover in production, and thus a high generation of waste, in order to function.

Cultural

Waste and waste disposal are integrally linked to cultural values. We classify items as either being waste or non-waste (i.e., having some value) in cultural terms. Some containers we view as having reuse value. Others are used only once and thrown away. Some food wastes are considered reusable and others are not. Cultural values tell us when an item such as a piece of clothing or furniture or even a newspaper no longer has value. The item is then discarded. These values are not completely uniform, which is what makes scavenging in junk heaps interesting and profitable; however, cultural standards are consistent enough that every disposal area in this country will contain large quantities of glass bottles, metal cans, and paper. In other countries in the world. bottles may be saved for reuse, cans may furnish a source of metal for tool-making, and paper may be reused or burned. Thus these items will not appear in large quantities in waste heaps.

The other aspect of waste disposal which is most strongly tied to culture is aesthetics. In general, waste is considered ugly and is avoided by most people. However, the types of waste considered most obnoxious and the level of accumulated waste needed to impinge upon peoples' aesthetic sense is culturally determined. Two types of waste are very noticeable on the American landscape, litter, which is composed mainly of paper, plastic, and metal and glass containers, and abandoned automobiles. In Europe, neither type of waste is evident in the same quantities that it is in this country because the level at which these wastes become obnoxious is lower there. In Europe, however, cattle manure and dried sewage sludge are much more commonly seen than they are in this country because in Europe these are not seen as wastes, but rather are valued as fertilizer. While recognizing the fertilizer value of these substances, most Americans classify them as obnoxious wastes and will not tolerate their presence near where they live. In both cases, the types of wastes in evidence are culturally determined.

Environmental

Wastes and waste disposal play an extremely important part in the environmental subsystem of the urban system. First, waste can be unsanitary and its improper disposal can be detrimental to community health. Prior to the introduction of organized solid waste collection in the mid-nineteenth century, rats, flies, and periodic epidemics were part of the normal urban scene. In sections of some cities and in some rural areas today, rats, flies, and the threat of epidemic outbreaks are still a reality. Safe disposal of sewage is even more recent. Although the first sewers were laid in this country during the eighteenth century, complete sewerage and adequate sewage treatment is still not available in many areas. Untreated sewage flowing into a water supply can contaminate it with a variety of dangerous microorganisms.

Second, waste disposal plays a strong role in the ecological system of which man is a part. In order for man to exist he needs air, water, and the products of the soil. Improper waste disposal can affect all three of these. Solid waste leachate and sewage threaten water supplies with contamination. Burning waste can pollute the air, and careless land disposal of both liquid and solid waste can damage the soil. Thus, understanding the problems surrounding waste disposal requires an understanding of the part waste plays in the urban system.

The waste, non-waste dichotomy is an integral part of our cultural, and socio-economic systems, and its disposal affects our health and welfare.

There are many types of wastes produced in this country and many different agencies whose responsibility it is to dispose of them. Probably only a third of the total wastes produced are municipal wastes. However it is these wastes which are causing the majority of all disposal problems, and it is also these wastes which are of most concern to planners.

The following chapter is a classification of wastes by type. Only some types of wastes are urban municipal wastes and it is these products of the city which concern local governments and form the subject matter for this paper. Chapter III is a long and detailed report of the available technology in the field of liquid and solid waste disposal. The purpose of this chapter is to lay the technical groundwork for Chapter IV, a comparison among these disposal systems as to cost, pollution danger, effectiveness, suitability for recycling programs, and a series of other factors. This information is summarized in two matrices which match particular disposal systems against their ratings in these various performance areas. Chapter V takes technology a step further and describes a method whereby any city can choose the waste disposal systems which will best suit its needs.

CHAPTER II

WASTE CLASSIFICATION

In order to deal with waste disposal it is useful to classify wastes into types. The categories most often used are liquid, gaseous, solid, and heat wastes. These often correspond in the real world to different methods of waste disposal.

Solid Wastes

Solid wastes are usually divided into:

a. Garbage, the portion of solid waste that results from food preparation and consumption. "Garbage" also connotes that the material is putrescible and has a high moisture content.

b. Rubbish, non-putrescible solid wastes, both combustible and non-combustible, made up largely of paper, metal, wood, glass, and garden discards. "Rubbish" is sometimes also taken to mean demolition wastes which would include brick, stone, and cement. Discussions of rubbish will include these wastes.

c. Ashes, that portion of wastes which are the residue from burning. In the past, ashes were an important part of the collected waste. They were produced in large quantities in the home, in industry, and in institutions. Since the advent of oil and gas-fired furnaces, however, the domestic and institutional production of ashes has dropped almost to nothing. Industrial production has remained high, particularly in steam generating plants. However, these plants are usually large enough to have their own disposal facilities. The secondary production of ashes has risen in past decades. Incinerators which burn previously collected solid waste are becoming more popular in large cities. Thus the collection of ashes has ceased to be a significant part of the waste disposal picture, although ultimate disposal of ashes remains important.

d. Special Wastes, that portion of waste which requires special handling due to size or limited occurance. Auto hulks, construction debris of large size, appliances, machinery, dead animals, and the solids accumulated in sewage treatment all are considered special wastes.

e. Agricultural Wastes, that portion of solid waste which is produced during farming, dairying, and poultry and cattle raising. Except in limited circumstances, agricultural wastes are not a municipal problem. They are either recycled back to the land or are dealt with specially by the operator. With the exception of a few cases in which agricultural wastes are handled by municipalities, they will not be considered as part of the solid waste problem.

f. Industrial wastes, that portion of waste which is produced in industrial processes. Industrial wastes are usually dealt with specially by the operator of the plant. In general, industrial wastes with economic value such as plastic and metal scraps are recycled directly back to the producer. Exotic chemical and radioactive wastes are handled by special contractors and do not affect the municipal situation. However when industrial wastes are disposed of along with domestic and institutional solid they must be considered as part of the municipal waste problem.

g. Mining wastes, that portion of solid waste which is produced during mining operations. This is by far the largest category of solid waste in this country. Each person produces about 5.5 pounds of domestic solid waste each day. If mining wastes were averaged into the amount, the total would be over 100 pounds per day. However, except for very infrequent circumstances, mining wastes cannot be handled by municipal services and are thus a separate problem.

Liquid Wastes

Liquid wastes are those waste products generated which have the capacity to flow. The largest form of liquid waste is waste water. It is generated domestically as water is used for drinking, cooking, cleaning, and as a medium to carry away garbage and human wastes. It is also generated in large quantities by institutional and industrial sources. These sources add metal ions, organic and inorganic chemicals, heat, and other wastes to the water. Agriculture and land runoff also contribute to waste water, since animal wastes, fertilizers and oils are often carried off by rainfall and irrigation water. Other liquid wastes are those petroleum products and chemicals which are the unusable by-product of industrial processes that are not dumped into the water. In general, only those liquid wastes entering the sewage and storm sewer systems can be considered as part of the urban disposal problem.

Gaseous Wastes

This is a less satisfactory category than the two because it may include such wastes as dust and fly ash which if collected would be considered solid waste. However, the nature of gaseous waste is such that it requires a separate category. This form of waste has a number of sources. Fuel consumption is a major source, contributing hydrocarbon, oxides of sulfur, carbon, and nitrogen, alkali salts, and a number of trace elements to the atmosphere. Some industrial processes release ozone, leads, oils, ammonia, and other chemicals. In addition there is the dust and fly ash mentioned before which results from incineration and some manufacturing processes. Gaseous wastes are almost entirely out of the realm of municipal waste disposal except where they are generated by the disposal process itself. Landfill can create significant amounts of dust and incineration of rubbish creates fly ash and these are distinct municipal concerns.

Heat Wastes

This is a recent addition to the waste disposal problem. Waste heat occurs because in industrialized countries the burning of fossil and nuclear fuels has contributed significant amounts of heat over normal solar energy to particular parts of the environment. The effects of this heat are only beginning to be charted but among the known results are disruptions of fish populations and local weather changes. Waste heat is generally not a municipal concern except as it is generated by either power generation or waste incineration. Waste heat from power generation can be solved on a plant-by-plant basis with existing technology and the disposal of waste heat from incineration is thoroughly discussed in a following chapter.

The concern, then, is municipal wastes; liquid, solid, gaseous, and heat; methods of treating them, and means of ultimately disposing of them; and comparative advantages and disadvantages among the various waste disposal techniques. A flow chart which will aid any municipality in choosing the best disposal techniques for its situation given the inputs of local and national goals, available funds, soil and site analysis, population size served, existing facilities, and future needs has been included. This chart should enable any governmental agency concerned with waste disposal to take a rational systems approach to its disposal problems and determine the best solution to those problems.

CHAPTER III

AVAILABLE DISPOSAL SYSTEMS

There are a great number of techniques for disposing of liquid and solid wastes. Some are centuries old and some have only recently been developed. The following is a technological overview of these systems and provides the basis for a comparison among these systems in Chapter IV.

Solid Wastes

Sanitary Landfill

Dumping on land was probably the first refuse disposal method used by man, perhaps because it was the most convenient.[1] As cities grew and people gathered together in greater and greater numbers, the practice of dumping in the streets and at the backs of houses became increasingly unsatisfactory. Refuse disposal was organized to the point that wastes were hauled to the nearest available open space outside the city and dumped.

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[1]American Public Works Association, Municipal Refuse Disposal, 1961, p. 89.

By 1900 the health dangers of open dumps were clearly recognized but little was done about the open dump situation except to haul the wastes further from town. In some cities in the early 1900's refuse was used to reclaim marginal land along lake and river fronts. Champaign, Illinois, Columbus, Ohio, and Davenport, Iowa all successfully used garbage as fill before 1910. While the dump was being operated it was in no way sanitary. Refuse was simply disposed of and allowed to settle until the desired level was reached. At that point, the refuse was covered with earth and reclaimed.

During the 1930's heavy machinery became commonly available and several cities including New York experimented successfully with compacting the refuse as it was dumped. This saved landfill space and hastened the settling process which enabled land to be reclaimed more quickly after dumping had ceased. During this period also the term "sanitary landfill" was coined in Fresno, California where the cut and cover trench method was first used. The Army Corps of Engineers perfected the sanitary landfill technique during World War II and it came into widespread municipal practice after the War. By 1960, over 1,400 cities had adopted sanitary landfill.

Sanitary landfill is essentially a sophisticated refuse burial system. Refuse is dumped in a trench, gully, marshy diked-in area, or on open ground and thoroughly compacted by bulldozers. A three-to-one compaction ratio over loose refuse is often obtained. At the end of the day's dumping, the refuse surface is covered with earth. Since the refuse is compacted and covered each day, a completed landfill consists of a series of refuse cells, each surrounded by earth. Compaction continues after the refuse is buried due to decomposition but tapers off after two to five years. During this time the landfill is unstable and gas produced by anaerobic bacteria is seeping to the surface.

Sanitary landfill is the easiest, cheapest, and one of the safest methods of refuse disposal available. Actual disposal costs (not including land cost) average about $1.50 per ton. Any skilled equipment operator can run a landfill operation. Rats, flies, and odors are no problem due to daily covering of the refuse by dirt. Dust is sometimes a problem but can be controlled by occasionally spraying the working area with water. Blowing paper can be a serious problem if precautions are not taken. Storm fences and snow fences 6-10 feet high placed downwind of the site will trap most blowing paper. Noise is a definite problem if the site is located in a populated area. Noise protection measures include erecting earth berms around the site, planting dense vegetative screens, and locating fill sites away from populated areas.

The greatest dangers from landfills occur when surface water runs through the site and on into a receiving stream or when surface water percolates through a site and into an acquifer. When these situations exist, the following types of contamination can occur:[2] Virus contamination--refuse, particularly when the refuse includes sewage sludge, contains a large variety of viruses. These viruses can cause polio, hepatitis, gastro-intestinal diseases, and respiratory ailments. Although viruses do not travel far when leachate (the water that has traveled through the fill site) percolates through sand or clay, they will travel long distances through factured rock and in surface water.

Micro-organism contamination--many types of micro-organisms are found in refuse. They may include bacteria, molds, yeasts, algae, rotifers, insect larvae, and worm eggs. These contaminants also will travel only a few feet when percolated through sand or clay but will travel great distances through fractured underground rock and in surface waters.

Inorganic chemical contamination--inorganic contaminants include many metals and salts which become toxic when dissolved. Among the most toxic are lead, mercury, copper, silver, cadmium, zinc, aluminum, arsenic, nickle, antimony, and tin. Other chemicals such as iron, calcium, magnesium, potassium, chloride, iodide, and

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[2] Student Water Publications Club, "Livingston County Solid Waste Study," I (1970), A-2.

bromide are not toxic but harden water and can impart a bad taste. Inorganic chemical pollutants are not as easily removed by filtration through a soil medium as are biological contaminants.

Organic chemical contamination--organic chemicals which contaminate aquifers frequently give a bad taste and odor to the water. Principally they are carbohydrates, fats, proteins, greases, and oils. These contaminants are effectively removed by filtration through sand or clay, but once again, they can travel long distances through fractured rock or in surface water.

The only way to insure protection from leachate contamination is through careful site selection. Once a landfill has been in operation for any length of time, it is nearly impossible to stop subsurface water contamination and difficult to halt surface drainage contamination. However, test wells should be drilled around the site and surface waters nearby should be checked periodically so that dumping can be halted if pollution is detected.

Subsurface water contamination can be avoided by locating the landfill on a site having a base of unconsolidated material 50 feet deep (30 feet is sufficient if no trenching is to be done).[3] This unconsolidated material can be composed of sand, clay, silt, or a

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[3] _Ibid_., p. A-14.

combination of these. There should be no direct way for water percolating through the refuse to reach aquifers below without first filtering through this unconsolidated medium. Below the sand or clay but above the shallowest aquifer should be an impermeable layer to prevent direct contamination of the water-bearing strata. In addition the base of the landfill should be at least two feet above the highest ground water table. This prevents the refuse from being saturated and standing in water.

To prevent surface water contamination, landfill sites should be located away from springs and drainage channels. Any surface drainage which develops as the site is being operated should be routed around the fill area. The heads of gullys make ideal landfill sites as no surface water can pass through the refuse and into a larger stream, thereby contaminating it. Marshy areas should not be filled, due to possible pollution of nearby lakes or rivers. However, since refuse will probably continue to be used as a cheap means of reclaiming land, guidelines can be set which will reduce the risk of contamination. The site area should be diked with an earthen berm and then filled. This will prevent direct contact by the refuse of nearby waters and the berm will act as a filter for sideways percolating water. Tests in Michigan indicate that a five foot earth bank effectively screens out most pollutants.

Ideal sanitary landfill terrain is uneven with gullys that can be filled. The landfill should be located at the head of the gully to prevent surface water from draining through it. The cut and cover trench method is suitable for level ground. With this technique, cover material is excavated from one trench while the previously dug trench is being filled with refuse. The newly excavated trench in turn is filled with refuse and covered with material dug from still another trench. In areas where strip mining or quarrying has taken place, the old excavations can be used provided that they meet the previously mentioned standards with regards to pollution control. Strip coal mines are particularly suitable as ample cover material is available next to the trench.

The problems of site location have probably kept sanitary landfill from becoming the exclusive method of solid waste disposal in this country. In addition to the problems of noise, dust, blowing papers, and water pollution, citizen opposition to location of close-in disposal sites has often prevented sanitary landfill from being economical. Collection costs, no matter what the ultimate disposal method used is, usually average from two-thirds to three-fourths of the total disposal cost. A rule of thumb used by waste disposal experts[4] is that

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[4]Fargo Engineering Company, Regional Plan for Solid Waste Disposal, Jackson County, Michigan, 1971, p. 17.

fifteen miles is the absolute maximum one-way haul distance that collector trucks should make. Beyond that distance, economic factors dictate some form of intermediate bulk reduction process. Because of these problems, and because of the limited distance that collector trucks can economically travel, adequate close-in disposal sites are at a premium in many urban areas. Oftentimes it is not possible to dispose of solid wastes directly by burial simply because in an unreduced state the wastes take up too much space.

Every municipality must have a sanitary landfill somewhere. Whether it uses this landfill to dispose of refuse directly, or whether it uses it to dispose of the ashes after the refuse has been incinerated is dictated chiefly by the availability of good landfill sites. In addition, municipalities need landfills in order to dispose of bulky wastes such as tree stumps and appliances which are difficult to reduce by incineration, and of dangerous special wastes such as chemical sludges, dried sewage sludge, and industrial wastes. If close-in sites are limited or the only landfill sites are distant, a municipality cannot afford to bury refuse directly but must first reduce its bulk.

A rule of thumb used by waste disposal experts is that a city should have one acre per 10,000 people per year for sanitary landfill. At current solid waste generation rates, the acre would be covered with compacted refuse eight feet deep. If significant amounts of refuse are recycled, salvaged, incinerated, or dumped elsewhere, the acreage needed can be reduced. Oftentimes municipalities will dump construction debris in areas such as marsh or tidelands which are unsuitable for mixed refuse. Debris and rubble are normally non-putrescible and do not contain toxic wastes. Cities often also encourage salvage operations at landfill sites. Salvagers remove many bulky metal objects which saves on landfill space.

Reuse of the landfill site should be included in any discussion of sanitary landfills. Sanitary landfill has the potential to reclaim marginal land and to add terrain features to an otherwise flat and dull landscape. In several instances, including a case in Chicago, landfill has been used to create large hills with recreational value. Landfill sites are generally used for parks, schools, golf courses, and occasionally for subdivisions. If the intended use is planned for while the landfill is in operation, the ground can be sculpted by the bulldozers working the site into the desired forms. This can save a great deal of time and money later when the area is put to another use. Immediately after completion, a landfill site should be seeded with grass to check erosion. After several years when gas seepage has subsided, trees may be planted. If trees are planted too early, they may be killed by the methane.

Refuse Milling

Refuse milling or grinding has been used successfully in Weisbaden, Germany, in Montreal, and recently in Madison, Wisconsin.

> Experience in demonstration projects has shown the following: (1) Results have suggested that daily cover is not necessary. In fact it is felt an operation can be satisfactorily run by covering only when final grades are reached. (2) Milled refuse compacts more readily and uniformly than unmilled material often reducing bulk by one half. In addition the lack of required intermediate cover further reduces fill volumes thereby extending the life of the site. Another advantage of increased compaction is that leaching into ground water will be reduced [not proven]. (3) The problem of blowing paper as well as dust is almost entirely eliminated. Milled refuse is easier to handle on a continuous basis; and be transferred on conveyors. (5) Cold and wet weather problems with daily covering operations are eliminated and costly equipment can be put to other uses. (6) Milled refuse can be used as a road bed on the landfill site during inclement weather. Trucks can drive on the material even when wet, with no injury to tires. (7) Milled refuse does not burn as readily as raw refuse and the milling process itself prevents hot ashes from reaching the fill area. (9) Milled refuse does not attract insects and rodents because the organic matter is ground extremely fine [note true] and distributed evenly. . . . (10) Finally, milled refuse can be easily contoured to create an attractive countryside.[5]

Refuse milling, then, is simply a method of making solid waste easier to handle and more compact in a landfill. The claims made for ground refuse being less of a nuisance than unmilled waste has not been proven. Flies and rodents are definitely discouraged by the process, but will cause problems if the refuse is left untended and uncovered.

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[5] Student Water Publications Club, "Livingston County Solid Waste Study," I (1970), D-5.

Odor is not eliminated by milling, but it is controlled by daily covering of the refuse with earth. Refuse is not actually ground extremely fine, at least this is not possible if only one grinding is performed. Commercial hammermills can reduce municipal refuse to pieces that average one inch by one inch after two grindings. A single grinding yields pieces that average three inches by three inches.[6] The average cost per ton processed at the Gainsville, Florida composting plant for primary grinding was $.90. The average cost per ton for secondary grinding was $1.12. A large portion of these costs were labor for maintenance and parts and labor for repairs. It is probable that a carefully run operation could reduce both these costs significantly. However, hammer wear is inevitable when the mill is used to process mixed municipal refuse and hammer surfaces must be rebuilt frequently. If refuse is pre-sorted to remove rubble, large branches and stumps, and large metal objects, this wear can be reduced. However, the pre-sorting represents an added cost. A variety of companies make shredders large enough to handle almost all municipal wastes, although not without the significant wear mentioned previously. The star shredder used in the Gainsville plant could process twenty tons per hour. The Edial shredder mentioned in the Livingston

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[6]Gainesville Municipal Waste Conversion Authority, Inc., Gainesville Compost Plant, 1969, Appendix F.

County, Michigan study could process eighty tons per hour, while the Hazemag shredder could process fifty tons per hour.[7]

In general, then, refuse grinding is only economical when landfill space is at a premium but for reasons of cost or otherwise incineration cannot be considered. Refuse milling may also be practical if extensive landscaping with the solid waste is anticipated. Shredded refuse is more consistent in texture, density, and weight than unshredded refuse and is therefore easier to work. If a project such as "Mt. Trashmore" in James Park, Chicago[8] is comtemplated, shredded refuse may be practical.

Refuse Compression

Refuse compression is not a disposal method but since it can extend the life of a landfill and increase economic hauling distance it should be included in this discussion on variations of the sanitary landfill process. Refuse compressors are available which can squeeze refuse from its loose weight of about 300 pounds per cubic yard to 1,000 pounds per cubic yard, the weight of unconsolidated soil.[9] The compressed refuse can either be baled or hauled

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[7]Op. cit., p. D-4.

[8]Ibid., III, p. W-13.

[9]Richard B. Engdahl, Solid Waste Processing: A State-of-the-Art Report on Unit Operations and Processes, 1969, p. 4.

as is to the landfill site. Sufficiently compacted refuse blocks can be stacked in a landfill without covering because the refuse is not attractive to pests and decomposition takes place slowly. When the landfill is complete, however, it must be covered and should be treated in the same manner as a landfill using on-site compaction.

Packer trucks, introduced about 1950, have made refuse collection more economical by allowing the truck to collect about three times as much refuse as an open truck before proceeding to the disposal site. However, this has not significantly increased the economic one-way haul distance to the landfill. To increase this distance, transfer stations which further compact the refuse to the 1,000 pounds/cu. yard density mentioned above and load it on trains or semi-trailer trucks must be used. Several large cities, including San Francisco, California have contemplated rail-hauling compressed refuse up to 200 miles to a disposal site. Refuse compaction and transfer stations become economically attractive at about the 1,000 tons per day size. Disposal costs for units of this size might be as low as $4 per ton,[10] comparable with incinerators of the same capacity. Because of this, refuse compaction and transfer may become an alternative to incineration for larger municipalities in the future.

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[10] Student Water Publications Club, "Mecosta County, Michigan Waste Disposal Study," 1970, p. 27.

Composting

Composting as a technique for solid waste disposal and reuse has shown so much potential that dozens of demonstration projects have been run in this country in the past twenty years. Unfortunately, the problems have outweighed the benefits so far and as a result there are no permanent composting operations in the United States today.

Composting is a biological aerobic stabilization process. The material to be composted is first adjusted to about 60 per cent moisture. It is then continuously or intermittently aerated for a period of from five days to a month until it is biologically stable. The phrase "biologically stable" means that if the material is again adjusted to 60 per cent moisture and aerated its temperature will not rise greatly. The temperature of unstable compost rises quickly when dampened and aerated.

The biological processes which take place during composting are complex. During the first stage which lasts from two days to one week, various bacteria act upon the material and raise its temperature to between 120 and 140 degrees Fahrenheit. At this point the first populations of bacteria die off and are replaced by thermophilic bacteria which rapidly decompose the material. In two days to a week, the thermophilic stage tapers off and is replaced by the activities of fungi. These attack the remaining cellulose, which is the most difficult portion of refuse to decompose. The last stage continues until all the organic matter or humus has been broken into its constituent elements. This stage, however, can take place in the soil and compost is ready to use about a week after the thermophilic stage has ended. During the thermophilic stage, all known pathogens are killed by the heat and the actions of other micro-organisms. Compost has thus been labeled "sanitary" and is safe for use anywhere. Weed seeds are also killed by the heat and compost will consequently not harm agricultural operations.

To compost effectively the following conditions must be met:

1. Raw materials should have a carbon to nitrogen ratio of 50 to 1 or less. They should have no serious deficiency of essential food elements and should be within a normal pH range of from 5.5 to 8.
2. Material should be mixed and ground (fine for mechanical composting, medium to coarse grind for windrow or area composting).
3. Moisture should be controlled to 50 to 60 per cent throughout the process.
4. Air should be thoroughly dispersed throughout the composting material with an excess of oxygen remaining.
5. Seed compost should be recycled in the amount of about 1 to 10 per cent by weight.

If high-rate composting is used the following additional conditions have been found desirable:

1. Constant slow stirring or intermittent stirring every 5 to 10 minutes or a combination of forced air and less frequent stirring.
2. Temperatures should be controlled throughout the process.
3. The pH should be controlled to prevent nitrogen loss.

4. Digestion should be a continuous flow process in three or four stages, including recycling of seed and thorough mixing for each stage. The last stage may combine slower digestion with natural drying from the heat.[11]

The end product of the composting process is a relatively dry, odor-free substance which has good soil conditioning properties and the approximate fertilizer value of steer manure. This material does not have to be sold at a profit for a composting plant to be economically sound. However the entire end product must be disposed of and the sale of the compost must at least bring the total costs of the process in line with other disposal methods. In Europe where compost is valued as a soil conditioner there has been little problem making the process pay. In the United States where there is now a surplus of steer manure the sale of compost is more difficult.

The best composting mixture is a combination of rubbish (dry solid waste), garbage (wet solid waste, mostly food scraps), and sewage sludge. Sewage sludge is about 97 per cent water and it is used to raise the water content of the refuse from an average of about 30 per cent to the required 50 to 60 per cent. In addition the sewage solids provide a good nitrogen source which helps ensure an acceptable carbon/nitrogen ratio.

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[11] American Public Works Association, Municipal Refuse Disposal, 1961, p. 227.

The refuse is first sorted to remove as much metal, glass, and stone as possible. In areas where the refuse contains a higher percentage of paper as many municipal wastes do in the United States, some paper should be removed to gain an acceptable carbon/nitrogen ratio. If the amount of plastic in the refuse is higher than the usual 1-2 per cent, at least some of the plastic scraps should be removed. Plastic is non-biodegradable and a high percentage of plastic in compost reduces its value. This separation has in the past been done chiefly by hand picking although ballistic separators, magnetic separators, and vibrating screens are available which will mechanically sort refuse. After sorting the refuse is fed into a grinder or series of grinders which pulverize the compostable material. Hammermills and rasps have proven effective in this process. The resultant mass is passed beneath an electronic sensor which determines its moisture content and adds sufficient water or sewage sludge to bring the material up to the required 60 per cent moisture.

At this point the refuse is ready to be composted. If a mechanical composter is used the material is fed into the first stage of the container. Mechanical composters are essentially gigantic drums divided into from three to seven sections. The drum is rotated slowly while air is forced through it. Each day the compost passes from one section to the next until it is removed from the last stage in near-completed form. Windrow and area composting calls for the material to be heaped in piles and turned occasionally during a composting period which lasts several weeks. The resulting material can be sold directly for agricultural use or reground, bagged and retailed to home gardeners.

The problems involved with composting have been detailed in many studies. Composting is a successful process in Europe and its application in this country has been attempted many times since Sir Albert Howard first developed the technique in India in the 1920's. The Dano biostabilizer is a popular European package plant and can be ordered in various sizes to handle a number of different situations. Most United States failures have been blamed on the lack of a ready market for compost. Indeed, this problem is difficult to overcome in a nation of giant farms and few small gardeners. Large farming enterprises have not been interested in soil conditioners, and the small gardener of Europe who cultivates his back yard and nearby vacant lots to raise vegetables is not found in the United States.

The more important reason for the failure of the composting technique in this country is the unsuitable nature of American solid waste to the composting process. The breakdown of a quantity of typical American solid waste by volume is as follows:

corrugated cardboard	7%
newspapers	14%
miscellaneous papers	25%
plastic film	2%
leather, molded plastic, and rubber	2%
garbage	12%
grass, leaves, and dirt	10%
textiles	3%
wood	7%
glass, ceramics, and stone	10%
metallics	8%[12]

Paper does not compost well and the majority of it should be removed before the process begins. Plastic is non-biodegradable and is considered a contaminant. However, if the quantities of plastic are very small they can be left in the compost. Metal, glass, ceramic, stone, and the classification which includes leather, molded plastic, and rubber are all non-compostable. They must be screened, hand picked or ballistically separated from the material to be composted. This leaves garbage, grass, leaves and dirt, textiles, and wood to be composted. These together with a portion of the paper refuse, most of the plastic film, and any ashes which may be present are what enter the composter. They will total between 30 per cent and 50 per cent of typical municipal solid waste. In Europe where composting is commonly practiced, the percentages of paper, plastic, metal and glass in refuse are much lower and the percentages of garbage and other compostables much higher.

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[12]Jones & Henry Enginees Limited, Proposals for a Refuse Disposal System for Oakland County, Mich., 1970, p. 9.

As a result composting can be truly effective as a waste disposal process as well as a means of producing a useful product.

Because less than half of United States refuse is compostable, the problem of what to do with the remainder continues. When non-compostables are separated from compostable material they are usually segregated by the separation process into paper, glass, and stone, ferrous metal and nonferrous metal. This separation process, which requires a combination of hand picking and machine sorting, costs money. In order to recoup the sorting costs, most of the sorted material must be sold. A compost market does exist as can be seen by the large number of soil conditioners available commercially. The city of Milwaukee has for years sold its dried sewage sludge under the brand name "Milorganite." Whether a large enough market exists to handle the great quantities of compost that would be generated by a number of cities composting their solid waste cannot be determined easily. However, the problem of finding markets for the 60 per cent of solid waste which is non-compostable is the larger problem. The difficulties inherent in the salvage method of refuse disposal will be discussed later.

The appeal of composting will remain because it offers the possibility of disposing of solid waste while actually producing a useful material. It is likely that in the future easily compostable substances such as sewage sludge, abbattoir wastes, and institutional garbage may be gathered together and composted. It is also possible that improved sorting methods will lower the cost of composting to make it competitive, even without satisfactory markets, with other methods of solid waste disposal. Until that time, it does not have great potential as a refuse disposal method.

Incineration

There are two basic types of incinerators, on-site and central. On-site incinerators are located at the point of refuse production and central incinerators have wastes brought to them from a wide generating area.

On-Site.--On-site incinerators range from back-yard burners often found in suburban homes to full-scale high-temperature incinerators found in hospitals and large office buildings. On-site incinerators have served well for many years. They are able to reduce the bulk of most refuse to 25 per cent of its original volume and render it innocuous so that it can be spread on the ground or hauled away and dumped. If wastes are segregated into burnables, garbage, and non-burnables, as is the case in some institutions and some cities, incinerators can effectively deal with half of the rubbish and leave almost no residue.

The major problem with on-site incinerators is that wastes do not burn cleanly and the equipment is generally too small to be fitted with effective air pollution devices. Los Angeles in the past required its residents to burn their burnable trash but had such great air pollution problems that the city government was forced to stop home incineration. Larger incinerators such as the one used for years by Michigan State University (closed March, 1972) burn refuse more cleanly than do back-yard burners. Trash is agitated while burning and auxiliary fuel is added when the refuse is wet and not burning hot enough for complete combustion. However, these installations still release large quantities of particulate matter into the air and in cities are rapidly falling out of favor. In rural areas, though, on-site incineration will probably remain an important method of refuse disposal.

Central Incineration.--Central incinerators are used to reduce the bulk and nuisance problems of solid waste and prepare it for disposal in a landfill site. For larger municipalities which are now experiencing a shortage of landfill space, incineration will probably be the method used to handle solid wastes during the next few decades. Many large cities presently use incinerators and have been using them for years. The problem of air pollution long associated with incinerators is rapidly being solved, thus eliminating the major drawback to this technique of refuse disposal.

The advantages of incinerators are:

1. Incineration requires much less land than does the landfill method of disposal. The incinerator itself can be situated on a relatively small parcel of land. Some of the incinerators in Detroit occupy parcels of less than five acres. Residue disposal requires less land than required for landfilling raw refuse--a significant contribution to conserving land resources.
2. A more central location is possible for an incineration plant. The incinerator can be located close to the service area in an industrially zoned, or in some instances a commercially zoned area. A well designed building with attractively landscaped grounds surrounding it will make the operation acceptable in many neighborhoods. Locating a plant near the center of the refuse shed reduces the hauling cost.
3. An incinerator produces a residue that contains small quantities of organic material and is less nuisance than raw refuse. It is often mis-stated that residue from an incinerator is sterile. Recent examinations of incinerator residue indicates that the ash abounds in biological life, but that most of the pathogenic organisms are destroyed by incineration. Residue produced by an incinerator must be covered like raw refuse because of the minute quantities of organic matter.
4. An incinerator plant can burn many kinds of refuse. It will burn most combustibles to an ash and can even reduce the bulk of some non-combustible components of a mixed refuse. The residue of a modern incinerator represents approximately one-third the weight of material introduced to the furnace. At the same time that the weight is being lessened, the volume of material is reduced to approximately one-fifth of the delivered volume. An incinerator cannot, however, handle large objects, those which cause excessive smoke, or explosives.
5. The operation of an incinerator is generally not affected by climate or unusual weather conditions.
6. Some flexibility exists in the incinerator for handling varying amounts of refuse. A plant can operate 8, 12, 16, or 24 hours per day, for example. The operation can also be carried out on a 5, 6, or 7 day burning week. Grate speed in the

furnace may be adjusted within a limited range to regulate the time material remains in the combustion chamber.

7. Waste heat can sometimes be sold to nearby institutions or industry in the form of steam.

The incinerator has several disadvantages which must be weighed against the advantages outlined above.

1. The incinerator is expensive in capital cost as well as operating cost. Depending upon the type and size of unit constructed, the initial cost will vary from $4,000 to almost $10,000 per ton of rated daily capacity, whereas the operating cost can range from $5.00 to $9.00, including residue disposal and amortization.
2. Skilled employees are required to operate, repair, and maintain an incinerator. These men are more in number and generally higher paid than employees at a sanitary landfill.
3. Maintenance and repair costs are also higher because of the type of equipment involved in the furnaces. Equipment is often damaged by wire, fusable metals, abrasives, or explosive objects entering the furnace with the refuse.
4. The combined high capital investment and the costly maintenance and repair for incinerators create a per ton cost for refuse disposal considerably higher than for sanitary landfill.
5. It is often difficult to obtain the best site for an incinerator because refuse disposal operations are not acceptable to many people. Because of heavy truck traffic, the possibility of noise, or other real or imagined nuisances, incinerator locations are frequently confined to industrial areas. Even this precaution will not prevent nuisance complaints from nearby residents.
6. Incineration does not complete the job of disposal of the community's waste. Residue and flyash must be transported to a landfill site for burial.[13]

Incinerators are divided into two major types with numerous minor variations. One constant which holds for all types of incinerators is that they are most efficient when constructed in the 200-400 ton per day capacity range.

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[13]<u>Ibid</u>., p. 21.

Assuming that each person in the service area produces about five pounds of solid waste per day and that the minimum operating time of an incinerator is eight hours per day, five days a week, the minimum service population for an efficient incinerator is 20,000-25,000. Smaller incinerators can be and have been built but they are not nearly as efficient in terms of cost per ton as the larger incinerators.

The two major types of central incinerators are refractory-lined and water wall. These terms refer to the lining of the combustion chamber, the most costly and most easily damaged part of the incinerator. Some classification schemes divide incinerators further into batch-fed and continuous-feed type furnaces. In the batch-fed type incinerator, refuse is placed in the combustion chamber, incinerated, and the ashes removed before more refuse is added. The continuous-feed incinerator performs all processes on a continuous basis. Refuse moves into the combustion chamber on a moving grate and ashes are dumped off the end and removed, all without stopping. The classification system used here does not refer to batch-fed furnaces, however, because in the large furnaces under discussion, the batch-feed system is not used.

Refractory-Lined Furnaces.--The refractory-lined furnace is the type of furnace commonly in use in America today. It is most economical in sizes under 250 tons per day, but can be constructed in sizes up to 300 tons per day rated capacity. Refractory-lined furnaces are lined either with refractory brick or refractory clay. The bricks are made of high quality clay and are able to withstand high temperatures. The clay lining of a clay-lined incinerator is applied like plaster and is heat cured in place. Relining a furnace costs $20-$30 per square foot ($100,000 for a 300 ton per day incinerator) and must be done every two to three years.

Refractory linings deteriorate due to rapid heating and cooling, moisture expansion, and slagging. Refuse is never uniform in quality and its burning produces uneven temperatures inside the combustion chamber. In addition, when the unit is allowed to heat and cool during start-up and shut-down, stresses are created in the brick and furnace frame. These stresses cause movement of the furnace lining, which in turn can chip or break the bricks. Condensation of moisture also occurs when the furnace is cooled. Moisture is absorbed by the refractory lining and when the furnace is brought back to operating temperature, turns to steam. This rapid expansion spalls off the face of the lining. Gases produced during refuse burning can, at high temperatures, cause corrosion to the refractory lining. This is known as slagging.

In order to cool the refractory as well as to insure complete combustion, <u>overfire</u> air is blown into the combustion chamber. The amount of air blown in is usually expressed in terms of the amount needed to burn the refuse plus whatever extra air is blown through the chamber. A refractory furnace usually operates at 150 per cent to 200 per cent excess air. In addition to overfire air, underfire air is blown under the grate in order to cool the metal and insure complete combustion. This underfire air contributes to the total excess air figure.

Just as all the water that passes through the sewage system of a city becomes contaminated, all the air that passes through an incinerator becomes contaminated with fly ash and smoke. Since central incinerators are usually located in populated areas, air pollution control equipment is a necessary addition to the installation. Below is a list of common air pollution control devices and their percentage efficiencies in removing particulate matter from flue gases.[14]

Baffled spary chamber	50%
Wet scrubber	96%
Cyclone	78%
Electro-static precipitator	95%

The first two devices utilize water while the last two are dry. Very good air pollution control is possible with present technology. The cost varies with the technique used, the amount of excess air coming through the furnace, and the individual installation. It can range

[14] Ibid., p. 34.

from $.40 to $2.00 per ton processed. Pollution control devices will be discussed fully below as the type selected has a direct bearing on the type of furnace installed.

Water-Wall Furnaces.--The water-wall furnace eliminates one of the major drawbacks of the refractory-lined furnace in that it does not require huge amounts of excess air to cool the lining. Consequently, air pollution control is easier and cheaper because the scrubbers do not have to process as much air. Water-wall furnaces have not been used extensively in this country although their use is well established in Europe. At the present this type of furnace is operated in Norfolk, Virginia and New York City.

The principle of the water-wall furnace is that the furnace lining itself conducts heat away and thus stays cool. The lining is constructed like a tube boiler with the tubes either welded solidly together or connected by metal fins. Water circulating through the tubes conducts heat away and keeps the tubes from burning through. The waste heat can be sold in the form of steam.

Two additions which are often found on incinerators should also be discussed, rotating kilns and waste heat boilers.

Rotating Kiln.--The rotating kiln is an addition to an incinerator which insures almost complete burnout of combustible materials. After leaving the combustion chamber, the incinerator residue enters a revolving drum through which the hot flue gases are passed. The rotation exposes all remaining unburned material to the hot gas and completes burnout. Since modern incinerators are usually equipped with agitation grates in the combustion chamber which help expose and turn the refuse, little added benefit results from the inclusion of a rotating kiln to the operation.

Waste Heat Boilers.--The flue gases leaving the combustion chamber of a furnace are extremely hot. In order to cool these gases before they pass through air pollution control devices and to utilize the waste heat, waste heat boilers are often installed in the flue between the combustion chamber and the base of the stack. The waste heat boiler consists of tubes through which water is circulated. The water conducts the heat away and cools the gas.

As stated before, air pollution control equipment is capable of high levels of particulate matter removal from flue gases. Each type has certain operating characteristics and requirements and should be carefully matched to the furnace to insure efficient operation. The following is a brief description of the devices mentioned previously.

Baffled Spray Chamber.--The baffled spray chamber forces flue gases through a series of baffles which slow the gases and bring them into contact with water spray.

The spray scrubs the gases and removes much of the particulate matter.

Wet Scrubber.--The wet scrubber removes dust particles from the gas stream by bubbling it through a water bath or injecting water into the gas stream. This method is essentially a much more efficient version of the baffled spray chamber.

Cyclone.--Mechanical cyclone collectors are a dry system which rely upon centrifugal force to separate suspended particulate matter from the gas. The cyclone causes the gas to spiral, throwing solid particles to the outside and leaving a core of clean gas which is allowed to escape. The dust falls down the walls of the cyclone and is removed.

Electro-static Precipitator.--The electro-static precipitator is a highly efficient dry dust collector. The precipitator consists of a series of plates between which wires are suspended. Dust particles receive an electrical charge from the wires, and are attracted to the oppositely charged plates and removed. Rappers vibrate the plates and dislodge the dust which falls into receiving hoppers. Gas temperatures for electro-static precipitators are critical and must fall within the range 350-570 degrees Fahrenheit. Gas velocities are also critical and cannot exceed eight feet per second.[15] Electro-static precipitators should be preceded by cylones which remove the large particles from the gas stream. This will prevent possible short-outs.

In general, then, incinerators fitted with effective air pollution control devices will continue to be a major method of solid waste disposal for medium to large cities in the future. As collection costs increase and open land becomes more scarce the incinerator may become even more economical and favored than it has been in the past.

Swine Feeding

The feeding of garbage to swine is an ancient practice that was probably begun when swine were first domesticated. Garbage was simply thrown in the streets and the pigs were permitted to consume it there. After the advent of organized garbage collection, private contractors often collected garbage from a variety of sources and sold it to nearby swine raisers. In the early part of this century in America the garbage portion of solid waste was often disposed of in this fashion. Old paper was burned in the furnace and bottles and metal were reused. Consequently, for many years municipalities

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[15] Ibid., p. 34.

concerned themselves only with the collection and disposal of ashes and demolition wastes.

The connection between feeding raw garbage to pigs and the incidence of pork infection with trichina worms has long been known. However, it was a swine disease, vesicular exanthema, which brought about regulation requiring that garbage be cooked before it was fed to swine. This disease spread rapidly between 1953 and 1955 and killed over 400,000 pigs.[16] Since then, all garbage fed to swine has been required to be cooked and this has made garbage feeding less economical than it was in the past.

The reason for the decline of garbage feeding, however, has been due more to labor costs, zoning, and technology than to regulations requiring cooking. Home garbage grinders and municipal collection of mixed solid wastes has eliminated domestic garbage as a source of feed. It is not economical to separate the garbage portion of solid waste from mixed wastes after they have been collected. This has left institutions such as schools and hospitals and restaurants as sources of unmixed garbage. Oftentimes today these establishments grind their food wastes and flush them into the sewer system. Also, the costs of collection and hauling garbage have

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[16] American Public Works Association, <u>Municipal Refuse Disposal</u>, p. 243.

gone up, labor costs have risen, and pig farms have moved further out from the city. Strict nuisance laws and zoning have forced swine raisers far into the country where odors will not disturb suburban residents. In the past, swine herds could often be found close to the edge of town.

In general, then, there is no future in swine feeding as a method of garbage disposal. This does not mean that municipalities should discourage the practice where private enterprise is willing to carry it on. However, the method should not be relied upon to dispose of any significant portion of the solid wastes generated in a community.

Garbage Grinding

The home garbage grinder has been in use for forty years and a popular item in new house construction for twenty years. It will grind any food wastes except bone, feathers, husks, and gristle. When used properly it almost eliminates the nuisance factor of household solid waste.

The institutional garbage grinder has become universal in hospital, restaurant and hotel construction and quite popular with grocers and produce handlers. Large grinders eliminate garbage as fast as it is produced, ending the need for storage facilities and garbage pickup.

The garbage grinder works either on the shredding or hammermill principle. In the shredder type grinder garbage is shredded by rotating knives and flushed through a screen. In the hammermill type shredder, rotating swinging hammers tear up the garbage and pulp it against a side plate. Both types produce evenly ground particles that will pass a quarter inch screen.

The effect on sewage treatment facilities is the most important problem associated with garbage grinders. Normal sewer lines easily transport ground garbage without clogging. In fact, with sufficient gradient, ground garbage can have a scouring effect on sewer lines.

> If all garbage were ground at the point of origin and flushed through the sewer system, the suspended solids content would increase by up to 100 per cent, with an average of 50 per cent for any one system. The bio-chemical oxygen demand (B.O.D.) of the sewage will increase up to 65 per cent, with an average of 30 per cent. Ground garbage may increase the amount of grit in sewage by about 40 per cent where home grinders are used and by 80 per cent where central grinding stations are used. . . . In primary tank operation, the volume of scum and sludge can be expected to increase up to 100 per cent, partly as a result of the increase in suspended solids in the raw sewage and partly as a result of an apparent increase in removal efficiency caused by the addition of garbage solids. Primary effluent may increase in suspended solids by 5 to 10 per cent and B.O.D. by 15 to 30 per cent, requiring corresponding enlargement of secondary treatment facilities. Increased facilities for sludge digestion, sludge handling, and digester-gas collection are necessary if ground garbage is added to either the sewage or the digester directly.[17]

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[17] Ibid., p. 225.

Garbage grinding, then, can have a significant impact both on solid and liquid waste disposal needs. In areas where universal home garbage grinder installation occurs, such as new subdivisions, solid waste collection can be reduced from twice to once a week with little fear of a nuisance problem. This can mean a great savings in collection costs. There may be a corresponding doubling of the sludge load upon the sewage treatment plant and this cost must be taken into account. Garbage grinders are not municipally installed but should be municipally controlled. Where sewer pipes are of adequate width and gradient and where grinders can be established in a large percentage of homes and institutional buildings, they should be encouraged or even required. Nearly universal grinder installation can save more money in collection costs then it will require in expanded sewage treatment facilities. Where sewage treatment facilities are already overloaded, however, and no collection cost savings can be gained by requiring grinder installation, municipalities should consider banning their use.

Salvage

Any economic reuse of solid waste is salvage. For instance, incineration, if the resulting heat is sold, is a form of salvage; reclaiming land with refuse is a form of salvage. However, "salvage," when used as a waste disposal term, means the direct recycling of the raw materials in solid waste. Salvage today is an organized, large scale enterprise which usually has little to do with municipal wastes. There are markets for clean, separated paper, rags, metals, glass, rubber tires, some chemicals, and some plastics. In order for the costs of cleaning, separation, and hauling to be below the price that the material will bring on the open market, the sources themselves must be relatively uncontaminated and unmixed. Unfortunately, municipal refuse is both mixed and contaminated. This has made salvage uneconomical for any materials except metal. Since the quantity of metal that can be hand picked from municipal refuse at a disposal site is very limited, the prospects of salvage as a disposal method are very dim. Since most of the components of urban waste can be recycled, however, a discussion of how to increase the percentage of salvaged material is in order. As with composting, a salvage system of disposal would not have to make a profit, it would only have to be competitive with alternate systems in order to become attractive. Efforts in the recycling field have been directed in two opposite ways, production site separation and disposal site separation.

Production Site Separation.--Most salvage that takes place today occurs at the site of production. Factories regularly reuse as much of their wastes as possible and sell others that have market value. Paper, plastic, glass, and metal scraps are produced in large quantities but never leave the confines of their production sites. For years beverage companies have included a deposit on glass containers sold in order to encourage their return in a separated and undamaged condition. Recently this idea has spread and many communities have initiated cooperative recycling programs in which refuse is sorted at home into components with market value and carried to collection points. Although this system relies on countless hours of unpaid labor in order to function and often works only sporadically, it can reduce the amount of waste collected by a municipality significantly. In the future it may be possible to organize and institutionalize this salvage system and rely upon it to dispose of up to half the solid waste produced in a community.

Disposal Site Separation.--Cities have in the past let contracts to scavengers who pick through wastes at the disposal site and remove either manually or mechanically any with market value. This reduces the amount of refuse which must be disposed of and profitably recycles some material. The basic problem with scavenging as a disposal system is that disposal sites are usually not organized or set up to facilitate recycling. They are designed to dispose of refuse by burial or incineration and do not take into account the possibilities of separation and reuse. In the future it may be to the advantage of some municipalities to design refuse disposal systems around salvage. Mechanical sorters can effectively screen refuse for metal and glass and air separation can remove paper. Incinerator residue can be washed and sorted profitably and this may become the most popular technique for recycling in large cities. A ton of incinerator residue contains on the average $15.76 worth of ferrous metal, aluminum, cooper and zinc, and glass. A plant which processed 1,000 tons per day of incinerator refuse could theoretically operate at $1.80 per ton,[18] producing a handsome profit. This quantity of incinerator refuse, however, would only be produced by a large city; smaller cities and towns would have to accept a lower profit or not process their incinerator wastes at all. It is possible that a disposal site separation process could be combined with a simple home separation into burnable and unburnable fractions. This home separation might enable a large portion of the waste paper to be recycled, as well as the metal and glass.

Salvage, then, does not presently have much impact upon the municipal disposal scene. However in the future it could play a significant role as over half of the refuse now produced can be recycled. If salvage becomes

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[18] P. M. Sullivan and M. H. Stanczyk, "Economics of Recycling Metals and Minerals from Urban Refuse," Bureau of Mines Technical Progress Report, April, 1971, p. 10.

widespread as a disposal method the market demand for recycled material will undoubtedly change dramatically. There will be an immediate drop in prices paid for such material as the market is flooded. Following this, however, the demand for recycled raw material should rise as new industries move to take advantage of this cheap source of supply. While these trends cannot be detailed, some account of the changing market prices of paper, metal, and glass should be made before any large-scale municipal recycling project is undertaken.

Experimental Systems

In addition to the above solid waste disposal systems, all of which have been used many times at plant scale, there are a number of experimental projects underway to develop new methods of refuse disposal. Three of these show enough promise to be taken into consideration by municipalities developing new waste disposal systems.

Recycling and Heat Recovery Systems.--Recently a number of private firms in addition to the Federal Government have put money into developing waste disposal systems which would recycle the unburnable portion of solid waste and burn the flamable portion to produce usable heat. These systems are essentially highly technical versions of the salvage method described previously. The Bureau of

Mines describes a system for profitably "mining" incinerator residue.[19] The Aluminum Association (a group of sixty-six manufacturers) are constructing a plant in which trash is shredded, burned for heat, and the remainder recycled.[20] Combustion Power Co., Inc. has produced an incinerator which shreds all trash, air sorts it and burns everything except glass, metal, and stone. The gas drives a turbine and waste heat can be used for a variety of purposes. The remaining metal and glass is recycled.[21] These systems show definite promise for two reasons. First, the thermal content of solid waste has been going steadily upwards for several decades, and by now it constitutes a good source of fuel. Second, the glass and metal percentages of solid waste are far above the percentages of these materials found in nature. If adequate separation techniques can be developed it may become much simpler and more profitable to "mine" refuse than to extract the minerals from the ground.

Pyrolisis Systems.--The Bureau of Mines has recently developed a technique for pyrolyzing (reducing

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[19] Ibid.

[20] "A Solid Waste Recovery System for All Municipalities," Environmental Science and Technology (March, 1968), p. 52.

[21] "Outlook: Converting Solid Wastes to Electricity," Environmental Science and Technology (August, 1970), p. 17.

with heat in a closed container) the burnable portion of solid waste into combustible gas, tar, light oil, liquor (mostly water), and ammonium sulfate. The energy from the gas is more than sufficient to provide the heat for pysolisis, making the system self-sustaining.[22] The unburnable portion of the refuse can be recycled. This system looks promising because it converts heterogeneous refuse into a few simple substances in one self-sustaining process. Hercules, Inc. has also developed a system using pyrolisis and composting to handle refuse. This system is to be tested on a plant scale in Delaware.[23]

Conversion Systems.--The Bureau of Mines had developed a process which holds great promise for disposing of all organic wastes. Cellulose, lignin, other carbohydrates, proteins, and fats can all be converted to oil under 4,000 pounds pressure per square inch at 350-400 degrees C. and in the presence of carbon monoxide and water. The oil yielded is low in sulphur and is suitable for use as fuel or conversion to gasoline or diesel oil. The Bureau of Mines estimated that 2.5 billion tons of organic waste are produced in the United States every year.

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[22] W. S. Sanner, et al., "Conversion of Municipal and Industrial Refuse Into Useful Materials by Pyrolisis," Bureau of Mines Technical Progress Report, August, 1970, p. 11.

[23] "Reclaiming Solid Waste for Profit," Environmental Science and Technology (August, 1970), p. 61.

If two billion tons of this waste were converted to oil it would yield approximately two billion barrels of oil, or half the nation's needs.[24] In other words, solid waste may eventually become an important energy source if the conversion process of the waste to a usable form can be done cheaply enough. Although this technique has not been tried on a plant scale and the economics have not been explored, the potential is so great that municipalities should watch this system for possible use in the future.

Rural Disposal

Disposal of solid waste in rural areas is an increasing problem in many states as people who work in the city buy land and live in the country. Waste disposal in low density areas is a problem in collection rather than disposal. The needs of the city for better refuse disposal techniques have almost overshadowed the need of rural areas for better collection practices. Rural dwellers used to be able to easily dispose of their solid wastes. Garbage was composted or fed to the chickens and what little burnable material there was disappeared into the furnace. Today, however, rural dwellers, particularly those who work in the city, produce, and have problems disposing of, just as much waste as the city dweller.

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[24] H. R. Appell, *et al.*, "Converting Organic Wastes to Oil, A Replenishable Energy Source," *Bureau of Mines Technical Progress Report*, 1971.

The major problem in rural areas is that it is prohibitively expensive to regularly collect trash from houses which are spread over a wide area. Left to their own devices, rural dwellers have disposed of their refuse with mixed results. Old appliances, car hulks, and open dumps dot the landscape contributing to rural blight and creating potential pollution problems. Two solutions to the rural disposal problem were posed in a study done for Oakland County, Michigan.

Convenience Centers.--

> A convenience center will provide a sightly place for rural residents to dispose of their wastes. The center would be enclosed to prevent blowing paper and roofed to keep the weather from the user and the deposited material. All-weather roadways would allow easy traffic movement in all seasons. The convenience center would contain 20 cubic yard to 40 cubic yard portable sanitary containers in which the public could deposit their refuse. . . . Convenience centers would be visited three times daily throughout the week by county crews. A pick up vehicle would collect filled and partly filled containers and take them to a transfer station or a disposal site.[25]

These convenience centers would be located such that they would be within easy reach of all rural residents. Because they would not be manned, the operating costs would be low, and since these would not be actual disposal sites, the acreage needed to construct one would be minimal. Frequent collection would eliminate odor and pest problems.

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[25] Ibid.

Sanitary Landfills.--

> Traditionally, open dumping has been the method of solid waste disposal in rural areas. Consideration of sanitary landfills to replace these open dumps is a natural outcome of the passage of Public Act 87. . . . Sites could be kept open for public convenience over a 12-16 hour daily period. An attendant would serve each site, directing traffic, picking up blowing papers and doing other general site maintenance during the day. Cover and compaction would be provided at each fill by a crawler tractor front end loaded unit suitable for short haul of cover. Each tractor could serve all sites in a township by being hauled from site to site on a low-boy semi-trailer driven by the loader operator.[26]

These disposal sites would essentially be small sanitary landfills, again located within easy reach of all rural dwellers. They would be inexpensive to operate because the heavy equipment needed to compact the refuse and cover it would be hauled from site to site, thus keeping it in almost constant use. Municipalities must keep rural areas in mind when developing solid waste disposal systems, and these two possibilities for organizing rural waste disposal would be good to consider.

Liquid Wastes

Liquid waste, or sewage, is about 1 per cent solids and 99 per cent contaminated water. The contaminants are chiefly organic solids and various nutrient minerals such as nitrates and phosphates. If industries are pumping wastes into the sewage system there may also be a variety

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[26] Jones & Henry Engineers Limited, Proposals for a Refuse Disposal System in Oakland County, Michigan, 1970, pp. 53-55.

of poisonous compounds such as chrome from chrome plating works, salts, and acids such as those used to pickle steel. Where storm sewers and sanitary sewers are combined, sewage may also contain a variety of large solids such as dead rats and pieces of lumber and paper. It will also contain significant amounts of oil from the street and grit. All sewage contains some grit, but the amount is greatly increased in combined systems.

The treatment of sewage has traditionally been divided into three areas, primary, secondary, and tertiary treatment. Although the treatment of sewage is actually more of a continuum than a staging process, the three-part classification is useful and will be used below. In addition to sewage treatment, two related problems, sludge disposal and rural sewage disposal, will be discussed.

Primary Treatment

The term "primary treatment" encompasses a number of treatment techniques from raw sewage dumping to highly effective Imhoff tanks. As the name implies, primary treatment is often the first process that raw sewage undergoes as it is being treated. However, since some one-stage techniques can impart tertiary treatment to sewage, "primary" actually refers to the degree to which the sewage has been treated.

Primary treatment removes the heavier solids and grit from sewage by allowing them to settle out. Depending on the nature of the sewage and the length of settling time allowed, anywhere from 20 per cent to 90 per cent of the solids can be removed in this fashion. One of the most successful primary treatment devices ever built, one which is still in common use in smaller towns and in large cities as a first stage process, was developed by Karl Imhoff about 1900.

> Imhoff tanks are used to remove settleable solids suspended in sewage, and in turn, digest these solids in the lower portion of the same unit. In a properly designed and operated Imhoff tank, 90 per cent of the settleable solids in raw sewage can be removed.[27]

The tank is wide at the top and slopes steeply inwards towards the bottom where a slot permits the solids to settle into a continuous digesting compartment below. Raw sewage is fed in from the top, water is extracted from the center, and digested sludge is extracted below. The process is continuous. Digestion is anaerobic; this means that the organisms decomposing the sludge work without oxygen and produce as their main by-products methane and CO_2. These bubble up to the surface and are either burned or piped away.

The sludge is pumped into drying beds and when dry either burned or disposed of on land. The water is generally piped to a receiving stream, although in some cases it may be used for irrigation. Prior to discharge,

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[27] Water Pollution Control Federation, Operation of Wastewater Treatment Plants, 1961, p. 89.

the water is often aerated to control odor. Anaerobic bacteria produce very unpleasant odors, and when they are present, sewage is said to be septic. Aeration kills these bacteria and eliminates the odor. If the water in the receiving stream is used as a drinking or bathing source, sewage effluent is often required to be chlorinated before being discharged. This is done primarily as a health measure although some odor control also results. Pathogenic organisms are destroyed, leaving the water safe for swimming.

Although primary treatment is far better than no treatment at all, it fails to remove from the effluent many nutrients which can be harmful to the receiving stream. The best-run Imhoff tank removes only 90 per cent of the suspended solids in sewage, and very few plants in operation actually approach this level of efficiency. These remaining solids, when discharged into a river or stream, are attacked by microorganisms that use oxygen and produce as their main by-products CO2 and water. The amount of oxygen needed by these organisms to digest the solids is referred to as Biochemical Oxygen Demand or BOD. The BOD level is actually much greater than that produced by the remaining suspended solids because the aerobic bacteria also attack the organic nutrients in solution in sewage. These nutrients cannot be settled and contribute greatly to BOD. When BOD is high, enough oxygen may be used that

Dissolved Oxygen (DO) levels in the river or stream are reduced to the point that fish cannot survive. When this occurs, the water body is said to be "dead." Large portions of Lake Erie are "dead" because BOD was allowed to become greater than the DO level.

In addition to suspended solids and organic nutrients in solution, sewage contains many inorganic nutrients. These nutrients, also in solution, are used by aquatic plants for food. The most important of these nutrients are the elements nitrogen, phosphorous, and potassium (NPK). High NPK levels produce algae "blooms" which are unsightly and can choke fish gills. As the algae die they produce their own BOD as microorganisms decompose them. Wastewater today has a nitrogen to phosphorous ratio of about three to one. This is much higher than in the past and is due in part to phosphate detergents. Nitrogen and phosphorous are used by algae at a ratio of fifteen to one; thus wastewater contains much excess phosphorous. The excess phosphorous seems to encourage the growth of nitrogen-fixing blue-green algae because they are not limited by a lack of nitrogen. Blue-green algae blooms can occur, followed by green algae blooms as nutrients are released from decomposing blue-green algae cells. The fact that blue-green algae seem to bloom in the presence of excess phosphate is the rationale for removing phosphates from detergents and during wastewater treatment. There are no documented cases of phosphate removal from wastewater reversing eutrophication; however, two cases, one in Madison, Wisconsin and one in Seattle, Washington indicate that diverting wastewater away from lakes can reverse eutrophication.[28] This indicates that much more advanced wastewater treatment than is presently being used throughout most of the country may be needed to revive "dead" lakes.

Secondary Treatment

Secondary treatment is designed to remove most of the remaining suspended solids left after primary treatment is complete, reduce BOD by removing organic nutrients in solution, and sometimes remove inorganic phosphates.

Chemical Treatment.--Chemical separation of water and solids is used when solids are finely divided and hard to settle or when solids are difficult to digest biologically. The chemicals most often used are alum, ferric sulfate and ferric chloride, ferrous sulfate and ferrous chloride, and lime, with or without alum or ferric salts.[29] Chemical precipitation produces much more sludge than biological treatment processes and this sludge can be

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[28]Clair N. Sawyer, "ABC's of Cultural Eutrophication and its Control: Part 2--Wastewaters," Water and Sewage Works, October, 1971, p. 39.

[29]Water Pollution Control Federation, Operation of Wastewater Treatment Plants, 1961, p. 29.

difficult to digest, particularly when lime is used. Chemical treatment is performed either directly to raw sewage or after an initial settling. Up to 97 per cent of the suspended solids are removed plus most of the phosphate if lime is used. BOD is still significant, however, because chemical treatment leaves many organic nutrients in solution plus nitrates and potassium. The sludge from chemical treatment is either digested anerobically in separate tanks and dried or dewatered in a vacuum or centrifugal filter and disposed of by incineration or in a landfill. Oftentimes incineration is preferred when lime is used because much of the lime can be recovered and reused. This process is known as recalcination.

Activated Sludge.--Following sedimentation, which removes most of the solids, sewage water is piped into tanks or channels through which air is bubbled. The remaining solids and organic nutrients in solution are attacked by aerobic microorganisms which form floc (clumps). The floc is removed in a secondary settling tank, part to be piped to sludge digestion tanks and part to be returned to the activated sludge tank to maintain an optimum balance between microorganisms and nutrients. An activated sludge tank does in about four hours what it might take a receiving stream a full day to do. The BOD of the effluent from a well-run activated sludge tank is less than 2 per cent of that of raw sewage. The activated sludge process, like all biological secondary processes, is not able to remove dissolved inorganic nutrients.

Contact Bio-Stabilizers.--This method of secondary treatment is slower than activated sludge but is cheap and simple to operate. It is often included as an addition to sewage lagoons because it speeds lagoon treatment and produces a good effluent. The apparatus consists of a series of disk paddles with holes in them which are attached to mechanical arms. The arms alternately sweep the paddles into the anerobic sludge at the bottom of a lagoon and back out into the air. Aerobic microorganisms clinging to the paddles attack the nutrients in the sludge and stabilize them. Anaerobic stabilization accounts for about 80 per cent BOD removal while the contact paddles remove up to 90 per cent of the remaining BOD.[30]

Trickling Filters.--While not as effective as activated sludge, the trickling filter gives good secondary treatment, particularly in smaller plants. Water that has received primary settling is pumped through rotating sprayers onto a bed of crushed stone about four feet deep. Aerobic microorganisms clinging to the rock surfaces attack

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[30] Jimmie Chitenden and W. James Wells, Jr., "Rotating Biological Contactors Following Anaerobic Lagoons," *Journal of the Water Pollution Control Federation* (May, 1971), 103.

the nutrients in the sewage water and stabilize them. The system is misnamed as no actual filtration takes place.

Intermittent Sand Filters.--Intermittent sand filters give excellent treatment but can only be used at small plants. Sewage water is periodically piped onto sand beds and allowed to trickle through. The sand physically traps some particles and nutrients in the water are attacked by aerobic microorganisms in the sand. The sand must be allowed to partially dry out in between applications of water to keep the bed aerobic. Sand filters thus cannot be used continuously and several must be installed at the same plant. They have a low capacity and require much more land area than do trickling filters or activated sludge tanks.

Lagoons.--Sewage lagoons of many sizes have been used for years as a means of treating sewage. When arranged in series they effectively remove almost all organic and inorganic nutrients from sewage water. The smallest lagoon is the home cesspool which has been used in rural areas for many years. Large lagoons may treat the sewage from communities up to 20,000 in population.

There are two types of lagoons, aerated, and non-aerated. Aerated lagoons have surface agitators or under-water air bubblers which keep the entire lagoon aerobic, much as an activated sludge tank is kept aerobic.

However, since control over the balance between microorganisms and nutrients cannot be maintained at the optimum point, aerated lagoons process sewage much more slowly than do activated sludge tanks. Lagoons give the best results when they are arranged in a series of a minimum of three lagoons. Raw sewage is pumped into the first lagoon and is progressively stabilized as it passes through the series. Good quality effluent with a low BOD passes out of the last lagoon and into a receiving stream. Lagoons are inexpensive to operate but require a great deal of land. They are also affected by weather conditions as they are too large to enclose. Lagoons in northern areas where the temperature drops below freezing must be designed large enough to store the sewage accumulated through the winter.

Non-aerated lagoons stabilize sewage using both aerobic and anaerobic microorganisms. They are most effective in subtropical areas[31] and when arranged in series. Raw sewage is pumped into the first lagoon and the settleable solids sink to the bottom where they are digested anerobically. Algae, utilizing the inorganic nutrients in the water, grow profusely, liberating oxygen, which in turn supports aerobic organisms that attack the suspended solids and dissolved organic nutrients. The

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[31] G. R. Marais, "New Factors in the Design, Operation, and Performance of Waste Stabilization Ponds," World Health Organization, 1966, p. 17.

water passes through the lagoon series and is progressively clarified until, if enough lagoons are used, it passes from the last pond in an almost drinkable state. Non-aerated lagoons are also inexpensive to build and operate but require a great deal of land.

Spray Irrigation.--Spray irrigation is a method of disposing of either primary or secondary treated sewage effluent by applying it to a wide area of ground. In water-short regions of the country it is a tested and common method of disposal. Soil is an effective filter which removes suspended solids and nitrates. Soil bacteria utilize the dissolved organic nutrients, and the phosphates are utilized by the plants growing in the soil. Livermore, California, a city of 45,000 people disposes of all of its secondary effluent during the summer by watering a public golf course with part of the effluent and giving the remainder to a local diary farmer.[32]

Soil Mantle Filtration.--Soil mantle filtration is also a land disposal system for primary or secondary treated sewage. Unlike spray irrigation, however, a large surface area is not needed. What is necessary for this system to work is a thick deposit of easily permeable

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[32]Personal communication with the staff of the Livermore, California Water Reclamation Plant, December, 1971.

unconsolidated soil or sand through which the effluent can percolate. At North Lake Tahoe, California 2.5 million gallons of primary treated sewage a day is disposed of into a volcanic rubble site. Tests at the springs and creeks which run out of this site indicate that the water quality has not been impaired.[33] The soil effectively filters out suspended solids, bacteria and viruses, and nutrients in solution. Phoenix, Arizona charges partially treated effluent into an acquifer through a soil mantle and has the water effectively purified for further use.

Tertiary Treatment

Chemical precipitation, ammonia stripping, and activated charcoal filtration are collectively known as tertiary treatment or polishing. The object of these processes, which are used in conjunction with secondary processes, is to remove the last traces of suspended solids, BOD, bacteria and virus contaminants, inorganic nutrients, and any unpleasant tastes, odors, or hardness which might make the water unfit for reuse. These processes have not been widespread in sewage treatment; they have, however, been commonly used for many years in city water works. It is common for cities to draw their water from rivers into which sewage has been pumped from a source

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[33]Robert Matthews and Alvin L. Franks, "Cinder Cone Sewage Disposal at North Lake Tahoe, Calif.," Water and Sewage Works, October, 1971, p. 41.

upstream. The river acts as a natural activated sludge processor. Water withdrawn from it must have phosphates precipitated out and must be chlorinated to kill pathogens. Any unpleasant tastes or odors must also be eliminated at this time. Tertiary treatment is just the application of these processes before the effluent enters a receiving stream rather than after it is withdrawn.

Chemical tertiary treatment works in three ways, coagulation, stripping, and adsorption. When lime is added to waste water the calcium carbonate reacts with ortho-phosphates to form a precipitating solid which can either be screened or settled out. Adding lime raises the Ph of water and when the Ph reaches 9.5 magnesium hydroxide begins to precipitate, absorbing organic solids as it settles. About 70 per cent of the phosphates in waste water are ortho or polyphosphates, both of which can be precipitated by lime, alum, and the ferric ions of ferric and ferrous chloride and sulphate.[34]

Most nitrogen in raw waste water is in the form of ammonia. During secondary treatment this nitrogen-ammonia is converted to nitrogen-nitrate, one of three inorganic nutrients important to plant growth. It is possible to remove nitrates both chemically and biologically from waste water but the processes are expensive and difficult

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[34] Russell L. and Gordon Culp, Advanced Wastewater Treatment, 1971, p. 19.

to control. It is much simpler and less expensive to remove the nitrogen from ammonia by air stripping. In this process, the Ph of the waste water is raised to eleven and the water is circulated through a cooling tower. Contact with the air strips the nitrogen molecule from the ammonia. This process is difficult to operate at temperatures below freezing, and hard water leaves a scale on the inside of the cooling tower. However, plant-scale experience at South Lake Tahoe indicates that these problems can be overcome without raising the cost significantly. Costs at this 3.75 million gallon per day plant for amortization, operation, and maintenance are about $16.75 per million gallons.[35]

Conventional secondary treatment is capable of removing almost all organic nutrients as measured by BOD but is incapable of removing refractory organic materials as measured by the Chemical Oxygen Demand (COD) test.

> Even well-treated secondary effluents contain 50-120 mg/l of organics. These materials include tannins, lignins, ethers, proteinaceous substances, and other color and odor producing organics, as well as MBAS (methylene blue active substances), herbicides, and pesticides such as DDT. Certain refractory organic substances added to the water in a stream may contribute to algal growth, contribute to fish kills and tainting fish flesh, produce taste and odor in water supplies withdrawn from the stream, and may have cumulative harmful physiological effects if present in drinking water.[36]

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[35] <u>Ibid</u>., p. 51.

[36] <u>Ibid</u>., pp. 133-34.

Activated carbon (charcoal) is capable of absorbing these harmful refractory organics and producing drinking quality water from secondary effluent. Plant-scale experience, again at South Lake Tahoe, indicates that water can be carbon purified for about $36.11 per million gallons.[37]

Ion exchange and reverse osmosis are two other methods which appear as possibilities for tertiary sewage treatment. Ion exchange is the method used in water softeners to remove various chemicals in solution. Water is pumped through a cationic or anionic resin which removes the ionized hardening chemicals. A brine is produced which amounts to about .5 per cent of the throughput water and the resins must be periodically regenerated. Good phosphate and nitrate removal can be obtained at a cost of about $200 per million gallons.[38] A major drawback to the use of this method for treating waste water is that secondary effluent must be filtered before passing through the resin. Since waste water treatment plants do not normally filter secondary effluent this would be an added expense.

In the reverse osmosis process, waste water is passed through a semi-permeable membrane under pressure. The membrane is more permeable to the small water molecules than to any other molecules in solution and the result is relatively pure water. In water-scarce areas this

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[37] _Ibid._, p. 176.

[38] _Ibid._, p. 209.

technique could be adopted both for desalinization and for reusing sewage effluent. The costs of this system are comparable to those for ion exchange, $200-300 per million gallons.[39]

Sludge Disposal

Although most treatment problems stem from the water portion of sewage, disposal of sludge becomes a problem in large plants. Sludge, as it emerges from primary settling tanks, secondary settling tanks, and sludge digesters is often only 5 per cent solids. In small plants, the sludge may be simply disposed of in a landfill; but in larger plants, where sludge production is high, the sludge must be effectively dewatered in order to reduce its bulk and avoid pollution problems. In the past, most sludge was air dried on sand beds and either burned, composted, or dumped. Recently centrifuges, vacuum filters, and filter presses have become popular for dewatering. Air drying can remove almost any amount of water depending on weather conditions and length of drying time allowed. Centrifuges and vacuum filters can produce a filter cake that is 20 per cent solids while a filter press can produce a cake that is up to 40 per cent solids.

In most treatment plants sludge is digested anaerobically in large tanks. Digestion has the effect of

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[39] *Ibid.*, p. 226.

bio-stabilizing the solids, increasing the ease with which the sludge can be dewatered, and liberating significant quantities of methane. The methane can be and often is used for heating within the plant, steam generation, and occasionally for operating internal combustion dual fuel engines.

Composting is another method for stabilizing sludge and has recently been demonstrated to be feasible.[40] Raw sewage sludge has been added for many years to solid waste compost with great success, but there was no attempt to compost the sludge by itself. This has now been done and the result is a humus substance with good soil conditioning properties and the fertilizer value of steer manure. Sludge cake from a vacuum filter was fed directly into a mechanical composter with no reported difficulties. The process killed all pathogenic organisms and weed seeds, making the product suitable for agricultural and gardening use. If dewatered sludge is to be incinerated, there is no need to stablize it; however, if it is to be used as a soil conditioner, the sludge must be free of harmful organisms and in a non-putrescible state.

Final disposal of sludge can be by burial at a sanitary landfill, use as a soil conditioners, incineration, and wet air oxidation. If the landfill is a

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[40] G. L. Shell and J. L. Boyd, "Composting Dewatered Sewage Sludge," U.S. Department of Health, Education, and Welfare, 1969.

properly located one, there is no need to stabilize the sludge before burial. If, however, there is a chance of leakage from the site, public health considerations dictate that the sludge should be digested before disposal. Incineration, even of filter press dewatered sludge requires auxiliary fuel and is therefore expensive. However, in large plants with a high sludge production rate, incineration may be the best method for disposal since it removes the need to truck the sludge to a land-fill. Wet air oxidation is a process recently developed which oxidizes sludge under high temperature and pressure in an enclosed tank. Once the oxidation process has begun, it will continue without auxiliary fuel and this method may eventually prove more economical than incin-eration.

Rural Disposal

Sewage disposal for homes not connected to sewer mains is becoming an increasing problem in this country as more people choose to live in low density rural suburbs. The combined effluent from hundreds of septic tanks can cause steam pollution. The alternative solutions when pollution occurs, connection to the municipal system, upgrading of all existing home disposal systems, or temporary building ban in low density areas, are expensive and difficult to make. However, the situation in which a municipality is called upon to halt pollution in its low density areas is occuring more frequently every year and consequently a discussion of the alternatives to a problem which used to be strictly rural in nature is included.

The two common methods of home sewage treatment are cesspools and septic tanks. In some areas of the country, outdoor latrines can still be found, but these are so infrequent as to be insignificant to most municipalities. The cesspool, as was mentioned earlier, acts like a lagoon in treating sewage. Raw sewage enters the tank and the solids settle to the bottom where they are digested anaerobically. Some of the soluble nutrients are removed by algae and bacteria before the supernatant water flows out the end of the tank and into a drain field or receiving stream. However, since cesspools are not usually arranged in series, little BOD reduction is achieved over that removed by the settling of the heavy solids. In addition, cesspool efficiency is severely hampered by freezing weather.

Septic tanks are essentially a covered version of the cesspool. Raw sewage enters one end of the tank and the heavy suspended solids settle to the bottom where they are digested anaerobically. The supernatant water flows out the other end of the tank into a drain field or receiving stream. Where soil conditions are good, the drain field can disperse the water so that it either evaporates or percolates through the soil to the water table below. Soil with a vegetative cover is capable of removing all the contaminants from waste water, thus eliminating any problems of pollution. When the drain field cannot handle the effluent or the input of sewage exceeds the design capacity of the tank, then effluent can emerge at the surface and run freely to the nearest stream. This effluent has not been treated and has a high BOD and inorganic nutrient load. The combined run-off from many septic tanks can be sufficient to pollute a stream.

There are several alternatives to conventional septic tanks and cesspools which can lessen the danger of pollution. The Cromar Company has designed a single-house sewage treatment plant made of plastic. It uses compressed oxygen which is bubbled through the sewage by a pump located above ground. BOD is reduced 80-95 per cent as compared with 35 per cent for septic tanks. The tanks can be manufactured in several different design capacities and can treat the sewage from one to up to five homes. It can also be used by restaurants, resorts, or motels.[41]

Another alternative for low density subdivisions, resorts, and other rural sources of sewage is lagoons. Sewage lagoons, discussed previously, thoroughly treat sewage when linked in a series. They require little maintenance, are not aesthetically offensive, and are ideal

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[41]"Is There a Future for the Single-House Sewage Treatment Plant?" House and Home (February, 1968), p. 68.

in areas where land is plentiful.[42] As few as ten to twenty residences can combine to build a small lagoon and pipe their sewage to it.

For slightly larger numbers of people, the package treatment plant may be the answer. Package plants utilizing extended aeration and spray irrigation are available in various sizes to handle the sewage from 1,000 people or less. Initial cost and maintenance costs are higher than the lagoons, but the plants give excellent treatment and take up very little space.[43] Package plants of various types are also available in sizes which can handle the sewage from small towns. These are often cheaper than site-constructed plants and should be considered by small municipalities.

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[42]"In a Metropolitan Area a Series of Lagoons Can Handle All the Sewage," House and Home (October, 1958), p. 84.

[43]Eric H. Nicoll, "Extended Aeration in British Package Plants," Journal of the Water Pollution Control Federation (February, 1971), p. 43.

CHAPTER IV

COMPARATIVE ADVANTAGES OF AVAILABLE DISPOSAL SYSTEMS

The range of available disposal systems for solid and liquid wastes is great and each municipality must choose among these systems for the ones which will serve its needs best. The following matrices are a summation of the material presented in Chapter III. They indicate in table form the advantages, disadvantages, limitations, and costs of these systems and permit a rapid comparison among them.

Solid Waste Matrix

Pollution Danger

This is a measure of the danger of pollution from waste disposal systems as they are usually run. It is possible to cause pollution with any waste disposal system or to run any system except a burning dump without noticeable pollution; however, various systems are more polluting than others based upon average performance, and this is what the terms "high," "low," and "none" are designed to convey. "High" pollution danger systems would not be allowed in areas which have even minimal air and water quality standards. "Low" pollution danger systems would generally be allowed anywhere except where even small amounts of air or water pollution would not be acceptable.

Land Requirements

This is a measure only of the amount of land needed to operate the system in question, not the amount of land needed to dispose of all wastes. For instance a swine feeding station requires only a small amount of land, but since it disposes of only a small fraction of all solid waste, the total land requirements will vary depending upon the system used to dispose of the remaining fractions. "High" refers to systems which do not reduce the solid waste before disposal. These systems may compact it or shred it to reduce its bulk but do not measurably reduce its quantity. They generally require an acre of land each year for each 1,000-2,000 people served. "Moderate" refers to systems which practice some on-site reduction before land burial occurs. Burning dumps are the only system referred to in the matrix which commonly reduce the bulk of refuse before burial. However, a sanitary landfill which included extensive on-site salvage might be able to reduce its land requirements enough to fall within this category. Systems in the "low" category require only enough land to house the disposal equipment. A ten acre incinerator can dispose of the refuse from 100,000 people indefinitely. The ashes which remain must be disposed of in landfill sites, but their quantity and quality is such that they rarely pose severe problems.

Cost Per Ton

This figure represents an average of figures collected from many sources and refers only to the processing costs of the system and amortization of the plant, not the cost of the land or relative collection cost. Thus, a sanitary landfill site can be operated at $1.50 per ton but the real disposal costs may be much higher if land is expensive and the hauling distance is great. All systems which include some salvage should be calculated as cost minus resale. However, since figures for municipal salvage are not available except in a few cases, no general figures for resale can be included. The potential in some areas for salvage resale entirely recouping the processing costs exists, but this potential has not been realized to date.

Design Capacity Limitations

This refers to the limitations of one disposal site to handle given quantities of waste. Although the practical population limit of one sanitary landfill site is probably about 500,000, several such sites could handle the wastes from a large city. Every disposal system has a practical range, except individual home systems such as garbage grinders and home incinerators, and this is what is meant by the term "usual." Garbage grinders and on-site incinerators both have effective individual population ranges between 1 and 1,000. However they must be viewed in the aggregate and as such can handle the wastes from very large populations.

Limitations on Types and Percentages of Wastes Handled

This category refers to the fact that many disposal systems will handle only some portion of the waste of a community. As pointed out before, swine feeding disposes only of the garbage while a sanitary landfill can handle all wastes. Incinerators fall in between as they can handle most wastes, but do not dispose of non-burnables and very large items such as tree trunks.

Heat, Metal, Glass, and Paper Recovery

This set of categories refers to the possibilities for salvage usually realized by various disposal systems. "None" means that salvage is not usually practiced, although in some cases it is possible. For instance, it is possible to salvage some paper and glass at a sanitary landfill site, but this is rarely done. "Hand salvage" means that items of obvious economic value are picked randomly out of the wastes as they are dumped at the disposal site. This method of salvage is widespread but fails to recycle more than 1 or 2 per cent of the solid waste dumped. "Good" means that a large portion of the salvageable material in the waste is recovered. Readers will note that paper and plastic recovery is incompatible with heat recovery. "Excellent" means that almost all of the recoverable material is saved.

Soil Conditioner or Landfill Use

Solid waste has some reuse value as soil conditioner or landfill. Waste which is used as soil conditioner must of course be free of glass, metal, and plastic, and be decomposed to some extent. Ash can be used directly as landfill or mixed with compost to enrich its fertilizer value. Raw garbage can only be used as landfill under circumstances which prevent pollution. This category, then, is designed to express the value and limitations of various waste disposal techniques for landfill and soil conditioning purposes.

Liquid Waste Matrix

Pollution Danger

This category is designed as a measure of the pollution danger resulting from the discharge of effluents from the indicated treatment systems into receiving streams. This is not a measure of what theoretically can be obtained,

SOLID WASTE MATRIX

System	Pollution Danger	Land Requirements	Cost/Ton Processed	Design Capacity	Limitations on Types and Percentages of Wastes Handled	Heat Recovery	Metal Recovery	Glass Recovery	Paper Recovery	Value for Soil Conditioning or Landfill
burning dump	High--air, water, health hazards	Moderate--1 acre per 5,000 pop./year	Low--$1-3/ton	100-100,000 usual: 500-5,000	None	None	hand salvage	None	None	some value as landfill
sanitary landfill	Low--some water pollution possible	High--1 acre/1,000 pop./year	Low--$1-3.50/ton	500-500,000 usual: 5,000-100,000	None	None	hand salvage	None	None	good landfill capabilities
refuse compression with land burial	Low--some water pollution possible	High--1 acre/2,000 pop./year	Moderate--$3-5/ton	5,000-500,000 usual: 20,000-100,000	None	None	hand salvage	None	None	similar to sanitary landfill
composting	None	Low	High--$5-10/ton less resale of compost and salvage material	1,000-500,000 usual: 10,000 100,000	40-50% of waste is compostable remainder is either salvaged or dumped	None	Good	Good	Moderate	compost is excellent soil conditioner-inorganics suitable as landfill
on-site incineration	High--air	Low	Moderate--$3-5/ton	1-5,000 usual: 1-1,000	waste reduced to 1/4 original bulk-ashes must be dumped	None	None	None	None	ashes are suitable for landfill
central incineration-no residue or heat recovery	Low--provided suitable air pollution control devices used	Low	High--$5-10/ton	1,000-500,000 usual: 30,000-100,000	waste reduced to 1/5 original bulk-ashes must be dumped	None	None	None	None	ashes are suitable for landfill
central incineration-residue salvage and heat recovery	Low--provided suitable air pollution control devices used	Low	High--$7-10/ton less resale of heat and salvage material	30,000-500,000 usual: 50,000-100,000	wastes reduced by burning and salvage of metal and glass-remainder must be dumped	Good	Good	Good	None	ashes are suitable for landfill
swine feeding	Low--provided garbage is cooked	Low	usually conducted privately at no cost to city	500-500,000 usual: 5,000-50,000	disposes only of garbage portion--remaining 70-90% must be dumped	None	None	None	None	remaining waste can be used as landfill
garbage grinding	Low--provided sewage treatment facilities are adequate	Low	conducted privately--some sewage sludge increase	1-500,000 usual: 1-500,000	disposes only of garbage portion--remaining 70-90% must be dumped	None	None	None	None	remaining waste can be used as landfill--sewage sludge is good soil conditioner
pyrolisis	None	Low	no plant scale figures available	probably about same as for central incineration	only useable portion is a liquor produced at rate of 100 gallons/ton	Excellent	Good	Good	None	None
oil conversion	None	Low	no plant scale figures available	probably about same as for central incineration	all organics converted to oil-inorganics must be salvaged or dumped	Excellent	Good	Good	None	None
refuse milling with land burial	Low--some water pollution possible	High--1 acre/2,000 pop./year	Moderate--$3-5/ton	5,000-500,000 usual: 20,000-100,000	None	None	hand salvage	None	None	good landfill and land sculpture capabilities

but rather what is the usual result of discharging these effluents. "High" pollution danger indicates that there will be a significant BOD load placed upon the receiving stream as well as COD and inorganic nutrients. "High" pollution danger systems would not be allowed in areas with strict water quality standards. "Moderate" pollution danger indicates that most of the BOD loading has been removed, that the effluent is aerobic (no odor problems), and that the effluent has been treated to kill pathogenic organisms. This level of treatment meets most state water quality standards. "Low" indicates that almost all of the solids and BOD have been removed from the effluent and that the water is neither septic nor represents a health hazard.

Land Requirements

This is a measure of the amount of land needed for the treatment facilities. "Low" indicates that only the amount of land needed to house the tanks and digesters is required as the effluent is discharged to a receiving stream or conducted away for reuse. "Moderate" indicates that the treatment facilities are fairly extensive or that the effluent is discharged onto land. "High" indicates that there are no mechanical facilities and that the sewage is simply held in ponds until it becomes stable.

Cost

The cost figures, like those for solid waste, represent an average from many sources. The cost indicated is for treatment and amortization of the plant, not for the land cost or for any sewage pumping that may have to take place.

Design Capacity Limitations

"Range" is for the service population of one plant. Several plants of one type could serve a much larger population. "Usual" indicates both the economically efficient size and the usual capacity to which various systems are built.

Solids Removal

This is a measure of the degree to which suspended solids are removed from the sewage. Good solids removal indicates that BOD and turbidity, a measure of the lack of clarity of the water, will be low.

BOD Removal

This is a measure of the degree to which the biochemical oxygen demand of the effluent has been lowered.

COD Removal

This is a measure of the degree to which refractory organics have been removed. "Low" indicates that very little of these contaminants have been removed. "Moderate" indicates that some of these contaminants have been removed but that the process cannot be relied upon to complete the job. "Good" indicates that the water which has passed through this treatment process will probably be drinkable.

Inorganics Removal

This is a measure of the degree to which phosphates, nitrates, and other inorganic nutrients are removed from the effluent. "None" indicates that the inorganics in solution pass through untouched. "Low" indicates that while the process is not designed to remove inorganics, some of these nutrients are either utilized by micro-organisms in the treatment process or are trapped in the floc. "Moderate" indicates that the sewage is held long enough for algae to use up much of the inorganic nutrients before the effluent is discharged, or that the effluent is discharged onto land where some of the nutrients are used by land plants. Chemical treatments are specific for certain inorganics and these are indicated on the matrix.

Sludge Production

This category indicates the quantity of sludge which must be disposed of during the treatment processes. "Low" indicates that sludge digestion is very thorough and that only periodic disposal is necessary. "Moderate" indicates that suspended solids are collected without chemical aids and that sludge disposal is an ongoing

LIQUID WASTE MATRIX

System	Pollution Danger	Land Requirements	Cost/1,000 Gallons	Capacity Limitations	Solids Removal	BOD Removal	COD Removal	Inorganics Removal	Sludge Production	Methods of Sludge Disposal	Methods of Water Disposal
PRIMARY											
primary settling	High--BOD, odor, inorganics, COD pathogens	Low--1 sq. ft./ 1,000 gallons/ day	5¢/1,000 gallons	500-150,000 pop. usual: 25,000-50,000	60-90%	40-60%	Low	None	Moderate	digestion--land disposal or incineration	receiving stream or further treatment
primary settling with chlorination, aeration	Moderate--BOD, inorganics, COD	Low--2 sq. ft./ 1,000 gallons/ day	10¢/1,000 gallons	500-150,000 pop. usual: 25,000-50,000	60-90%	40-70%	Low	None	Moderate	digestion--land disposal or incineration	receiving stream
imhoff tank	High--BOD, odor, inorganics, COD, pathogens	Low--1 sq. ft./ 1,000 gallons/ day	10¢/1,000 gallons	350,10,000 usual: 5,000	60-90%	40-60%	Low	None	Moderate	digestion--land disposal or incineration	receiving stream or further treatment
SECONDARY											
chemical precipitation	Low--COD, some inorganics and BOD remain	Low--30 min. retention	16¢/1,000 gallons	500-100,000 usual: 25,000-50,000	70-97%	70-97%	Low	Good phosphate removal	High--hard to digest	dewater--land disposal or incineration	receiving stream or further treatment
primary settling + activated sludge	Low--inorganics COD, some BOD	Low--5 hr. retention	12¢/1,000 gallons	250-60,000 usual: 25,000-50,000	70-97%	70-97%	Low	Low	Moderate	digestion--land disposal or incineration	receiving stream or further treatment
primary settling + rotating bio-stabilizers	Low--inorganics, COD, some BOD	Moderate--stabilizers are used with lagoons or large holding tanks	7¢/1,000 gallons	100-60,000 usual: 500-5,000	70-90%	70-90%	Low	Low	Low	periodic drying and scraping of lagoon or tank	receiving stream
primary settling + trickling filters	Moderage--COD, inorganics, some BOD	Low--1 sq. ft./ 100 gallons/day	12¢/1,000 gallons	350-100,000 usual: 25,000-50,000	70-95%	70-90%	Low	Low	Moderate	digestion--land disposal or incineration	receiving stream or further treatment
primary settling + intermittent sand filters	Low--some COD, inorganics, some BOD	Moderate--1 sq. ft./5 gallons/ day	12¢/1,000 gallons	350-60,000 usual: 500-25,000	90-97%	80-97%	Low	Low	None produced by filter--sludge produced by primary settling	digestion--land disposal or incineration	receiving stream
lagoons	Low--depends upon of number of lagoons and retention time	High--1 acre/ 1,000 people	5¢/1,000 gallons	100-60,000 usual: 500-5,000	70-99%	70-99%	Moderate	Moderate-Good	Low	periodic drying and scraping of lagoon	receiving at stream
primary settling + spray irrigation	Low--depends upon loading and soil characteristics	Moderate variable loading	12¢/1,000 gallons	100-50,000 usual: 200-2,000	80-99%	70-99%	Moderate	Moderate-Good	None produced by irrigation--sludge produced by settling	digestion--land disposal or incineration	percolation--overflow to receiving stream
primary settling + soil mantle filtration	Low--depends upon loading and soil characteristics	Moderate variable loading	10¢/1,000 gallons	100-100,000 usual: 25,000-50,000	90-99%	90-99%	Good	Good	None produced by filtration--sludge produced by primary settling	digestion--land disposal or incineration	percolation
TERTIARY											
chemical precipitation	Low--COD, some inorganics	Low--30 min. retention	10¢/1,000 gallons	250-100,000 usual: 25,000-50,000	90-99%	90-99%	Low	Removes phosphates	Moderate	dewater--land disposal or incineration	receiving stream or reuse
secondary treatment + ammonia stripping	Low--COD, some inorganics, some BOD	Low	2¢/1,000 gallons	undetermined	80-97%	80-97%	Low	Removes nitrates	None produced by stripping--sludge produced by settling	digestion--land disposal or incineration	receiving stream or reuse
secondary treatment + charcoal filtration	Low--some inorganics	Low	4¢/1,000 gallons	undetermined	99%	97-99%	Good	Low	None produced by filtration--sludge produced by settling	digestion--land disposal or incineration	receiving stream or reuse
secondary treatment + ion exchange	Low	Low	30¢/1,000 gallons	undetermined	99%	99%	Good	Good	None produced by exchange--sludge produced by primary settling	digestion--land disposal or incineration	receiving stream or reuse
primary treatment + reverse osmosis	None	Low	30-300/ 1,000 gallons	undetermined	99%	99%	Good	Good	None produced by osmosis--sludge produced by primary settling	digestion--land disposal or incineration	receiving stream or reuse

process. "High" indicates that chemical precipitators are used to encourage settling and that the sludge quantity is therefore large.

Methods of Sludge Disposal

There are dozens of possible methods of sludge disposal, but due to the quantity and quality of the sludge produced during various treatment processes, certain disposal methods are often associated with certain treatment processes. This category indicates the disposal methods usually associated with each treatment process. It also indicates the possibilities for sludge reuse as landfill or soil conditioner.

Methods of Water Disposal

There are likewise dozens of possible methods of disposing of the final effluent from various treatment processes. This category indicates the effluent disposal method usually associated with each treatment process. It also indicates the possibilities for water reuse either for irrigation or as an addition to the water supply.

CHAPTER V

CHOOSING THE SYSTEM

The first part of this paper has dealt with available disposal systems, their costs, limitations, and relative effectiveness. In addition to these inputs, a municipality must calculate many less tangible factors before deciding which waste disposal systems to use. These factors can be divided into three groups for analysis: goals, existing and future situation, and resources, and can best be viewed in a planning framework. All of these factors are dependent upon the general development of the community and should be seen in this context.

Goals

Every community should develop goals concerning waste disposal. If this is not done there is little means of judging whether or not a particular system is doing the job. Recently, goals, in the form of performance standards, have been dictated to many communities guilty of unsanitary or polluting disposal practices. This is much less desirable than internally formed goals because imposed standards may not have the backing of the community. Goal development is a necessary element in comprehensive planning but techniques for accomplishing it are not yet well formed. The following is a suggested goal development procedure for arriving at waste disposal goals. These goals, of course, must mesh with community-wide goals in other facets of planning.

If a municipality has not decided a direction for itself it should look first at short-range goals. For example if there is any hint of unsanitary practices in either the disposal of solid or liquid wastes the first goal should be to correct this. It should be generally accepted that the health of the residents of the community is of paramount importance. If waste disposal service is at a low level or if it is unequally distributed, another short-range goal should be to correct this deficit. The best way to encourage community backing of waste disposal programs is to improve services. If there is gross pollution occuring from any disposal processes or sites, immediate action should be taken to at least temporarily remedy the situation. This should be done for two reasons. First gross pollution may cause health problems either for community residents or for people living downstream. Second, taking immediate action to correct well-known system deficiencies will have public backing and encourage further examination of waste disposal practices. Examples of immediate corrective action might be to close a burning dump or install sewers in an area with bad septic tank problems.

Next the city should look at long-range goals. If land for disposal purposes is becoming scarce the municipality should begin to acquire new land for the future. This should be done within the context of general land use planning so that the sites purchased for waste disposal will be compatible with surrounding uses. If pollution is occuring, long-range plans to install non-polluting disposal systems should be made.

These goals will probably all be accepted by the community, even if they mean more money, because of the awareness present now of the damage which pollution and lack of sanitation can cause. Another goal which might be proposed is to reuse and recycle as much of the waste products as possible. As has been pointed out, salvage can be economically feasible but usually only after a high initial capital investment. Rail-hauling compressed refuse costs about the same as incineration but building an incinerator is much more expensive than buying a compressor. However, with an incinerator a municipality can salvage heat and possibly metal and glass from the residue, whereas with refuse compression there is no chance for salvage. The community goal of increasing the amount of reuse is desirable but it should be explained fully to the people and discussed before being decided upon. The following is a goals check-list which might be used as a guide:

I. Liquid Waste--Short-Range Goals

A. Stop water supply contamination.

B. Make local waterways safe for water recreation.

C. Equalize and extend sewerage service to all parts of the community.

D. Bring facilities into conformance with state and federal standards.

II. Liquid Waste--Long-Range Goals

A. Plan for treatment facility expansion to match population growth.

B. Regulate growth to maintain same high standards community-wide and in the future.

C. Work to reduce pollution from effluent to lowest possible point.

D. Work to find ways to reuse water instead of discharging it to a receiving stream.

III. Solid Waste--Short-Range Goals

A. Close burning dumps or any other sources of gross air, water, or visual pollution.

B. Equalize and extend collection service to all parts of the community.

C. Bring facilities into conformance with state and federal standards.

IV. Solid Waste--Long-Range Goals

A. Plan for disposal facilities to match population growth.

B. Regulate growth to maintain same high standards community-wide and in the future.

C. Work to develop waste disposal systems which reduce pollution to the lowest possible point.

D. Develop systems which reuse and recycle as much of the solid waste as possible. As a corollary, work to develop markets for recycled material which will help reduce recycling costs.

Existing and Future Situation

In addition to goals, a thorough assessment of the existing and future situation of the municipality should be made before a decision is made as to the type of disposal systems to be used. Of first importance is a physical assessment. This should include a soils and hydrology study, a meteorology study, and a land use pattern and population size and density study. The latter studies should also be projected at least twenty years into the future to give an idea of future needs. The soils and hydrology studies will first indicate if any disposal systems cannot be used. Areas of <u>karst</u> topography (land with a limestone base usually laced with underground streams and caverns) for instance and areas with a very high water table are not suitable for sanitary landfill. Land disposal of partially treated effluent is not advisable if the soil is shallow and the underlying rock fissured. Second, these studies will indicate specific sites where disposal facilities should be located.

The meteorology study once again should indicate disposal systems which will not work. Sanitary landfill is very difficult in permafrost areas and sewage lagoons have to be unreasonably large to accommodate a winter's accummulation in areas with a severe climate. A meteorology study may even indicate on which side of the road to build an incinerator. The plume of steam produced by the wet scrubbers in an incinerator can blow across a road, reducing visibility and causing an ice sheet in the winter. Prevailing winds can be used to blow the steam away from the road.

The land use study should help to locate disposal sites where they will not create a nuisance and where any products from the disposal process such as steam or soil conditioner can easily be utilized. Many cities locate their sewage disposal plants next to municipal golf courses and use the water and sludge from the plant to irrigate and fertilize the course. A study of the population size, density, and potential growth will narrow the disposal options considerably. Some disposal systems, as can be seen on the disposal matrices, have larger optimum operating ranges than others and consequently are not suitable for small towns. Small towns can for instance get good results with a simple lagoon system while a lagoon system for a medium-sized city would take up too much land. Projections of rapid growth mean that flexibility and the capacity to expand must be built into the systems. Sanitary landfills are more flexible than incinerators in terms of handling day-to-day load fluctuations but a program of steady increase can be planned into an incinerator plant. Likewise biological sewage treatment systems are less tolerant of day-to-day changes than are chemical systems but can be programed to handle steady increase or decrease. The population-waste disposal situation can also be manipulated in the reverse. Land use and density controls can prevent future problems by limiting, guiding, and timing development to match waste disposal facilities.

Of second importance is an analysis of the social situation, existing and future. A social analysis should include such items as the income and education levels of the citizenry, the amount of civic pride and citizen cooperation in local programs, resident knowledge about sanitation and recycling, and a general picture of wastes in the socio-cultural milieu (refer to Introduction).

Any change in current waste disposal practices in a community will probably result in two changes directly affecting the citizens of that community: first, new disposal systems usually require capital expenditures and this often means increased funding. Any rise in the tax level or any bond issue should be preceded by a comprehensive education campaign which will be easily understood by the residents and is directed towards their general knowledge of waste disposal. Second there may be a change in the waste disposal practices of the people involved. The change may only be switching garbage collection day from Tuesday to Thursday or it may mean separating garbage into types or changing over from a septic tank to a sewer system. A knowledge of the residents' cultural view of waste disposal and their past level of participation in local programs will greatly influence which disposal system should be chosen. For instance an upper middle class suburb with universal home garbage grinders and a past history of excellent community spirit could probably be counted upon to cooperate in a solid waste separation program to aid recycling. The common occurance of home garbage grinders means that the solid waste produced by these homes will be relatively innocuous because the garbage portion will have been flushed into the sewer. Consequently the residents should not object to handling it and possibly storing it if garbage collection of burnables and non-burnables occurs on alternate weeks. This type of program can be explained to well-educated citizens who will cooperate because they agree with the goals behind it. On the other hand, citizens scattered over a semi-rural county with no sense of community can barely be counted upon to deposit their wastes in a county landfill rather than in backyard dumps. They should not be expected to do more than comply with minimum health standards in any realistic waste disposal program.

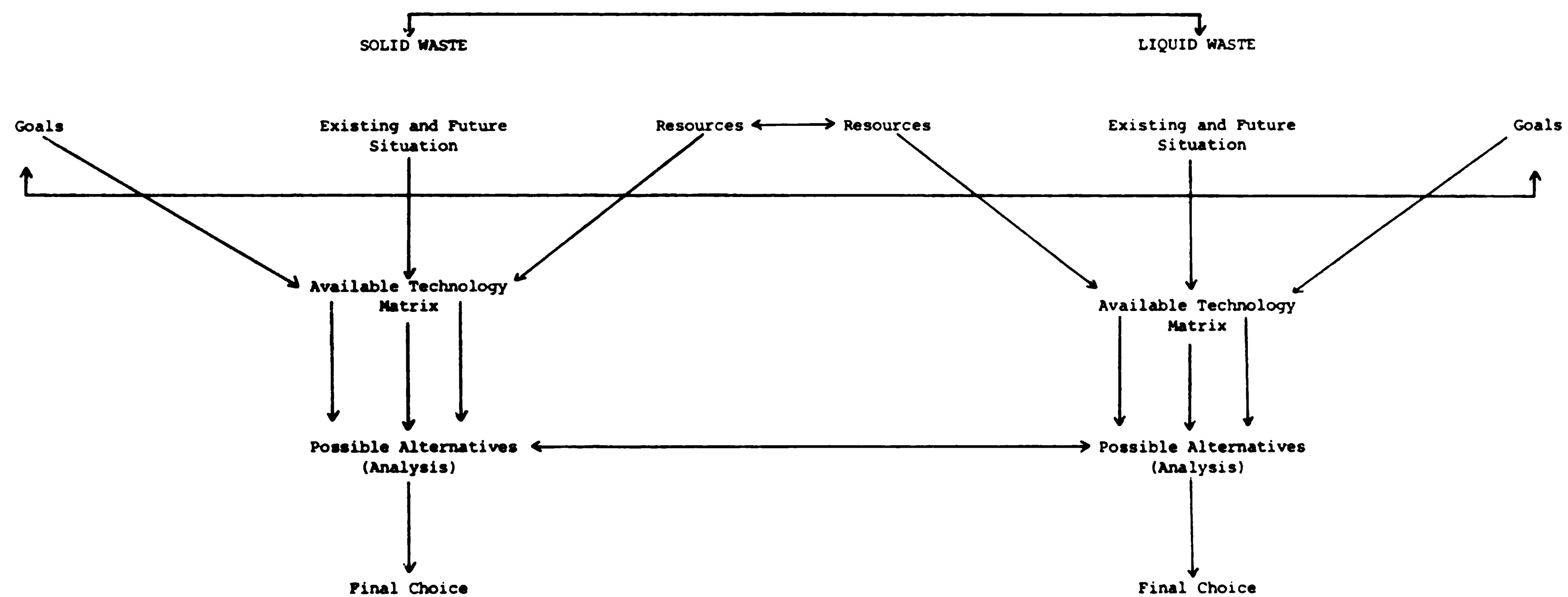
Resources

The last input to any selection of disposal systems is an evaluation of resources. Resources consists of two parts, present physical plant and sources of income, and both should be studied carefully. There are four possible courses of action with regard to the present physical plant of a community, expansion, conversion, abandonment, or rebuilding on the same site. Open dumps can be converted to sanitary landfills, biological treatment plants can be converted to chemical treatment plants, landfill sites can be used to build upon, and so forth. Whatever choice is made, maximum use should be made of the existing plant consistent with the goals of the community and applicable state and federal regulations.

Municipalities usually have several sources of income, taxes, user charges, and bonds. Recently federal funds have become available for capital improvements on a matching basis and in the form of demonstration grants for pilot plants. This last form of funding should be thoroughly investigated before any action is taken. Any one of a combination can be used to finance construction of new plant, while taxes and user charges usually finance operation. Whatever financing system is used it should be adequate to maintain good service to all residents, be equitable, and take full advantage of any revenue products of the disposal process itself. Good results can often be obtained by combining liquid and solid waste authorities. There are a number of areas of overlap between the two kinds of systems which can be taken advantage of to save money. The best compost is produced, for instance, by combining solid waste and sewage sludge. Or sewage sludge can be disposed of in a solid waste incinerator or sanitary landfill. In many communities the two types of plant are located on the same parcel of land to take advantage of these and other economies. Combined authority for all waste disposal can also equalize the funding base for both types of systems.

The following flow chart illustrates the inputs and process that should go into the selection of liquid and solid waste disposal systems for a community. It is designed as a guide to decision-making and, combined with the detailed information on available systems presented earlier, should enable any community to select the disposal

DECISION-MAKING FLOW CHART



systems best suited to its needs. Of course a great deal of engineering data will have to be collected before a community will know exactly what form the plants will take, but the flow chart should lead to a decision about the general design of the plants and what they will be able to achieve. Below is a hypothetical example of a community seeking imaginative answers to its waste disposal problems.

City: Ashbrook, New Jersey, population 50,000 consisting of a small central core and numerous middle class suburbs. The city has a moderate growth rate, fair tax base, and average civic pride among its citizens.

Solid Waste Situation: At present, solid wastes are disposed of in a sanitary landfill located in marsh land on the estuary of the local river. This landfill is destroying marsh land and threatening the river with leacheate pollution. The city decides to reassess its solid waste situation and discovers the following facts: (1) New residential development is taking place away from the river and garbage trucks presently are making some runs of over fifteen miles to the disposal site. (2) The only acceptable new landfill sites are even further from town and would have to be carved out of prime agriculture land. The city notes that its population size is well beyond the threshold needed to support an incinerator and so the decision is made construct a water wall incinerator with electrostatic precipitator pollution control equipment.

A bond is approved by the voters for construction after an extensive publicity campaign and a site is found adjacent to the city's community college. Steam generated by the incineration process is sold to the college, thus reducing operating costs. It is also found that the more central location of the disposal facility means a savings in hauling costs and brings the operating cost of the incinerator almost in line with the costs of the landfill. Next the city applies for and receives federal funds for a pilot incinerator residue recycling plant which further reduces operating costs as the city is able to sell the recycled material for a profit.

Liquid Waste Situation: The city's present waste water treatment plant has a primary settling tank and a chlorination tank. The effluent is discharged into the local river and the city has been cited by the state and federal governments for pollution. When a reassessment of liquid waste disposal takes place the following facts are noted: (1) At present all development within the city limits has sewerage but there is a trend towards large lots with septic tanks outside the city. (2) Soil conditions are such that large-scale use of septic tanks will cause problems in the future. (3) The city has been considering building a golf course near the present treatment plant. (4) Local farmers pump water out of the river during the warm months of the year to irrigate their crops.

As a result the city coordinate with the county government to restrict residential development and prevent the use of septic tanks in subdivisions. Plans are made to go ahead with the golf course and to install a sprinkling system linked to the present sewage treatment facility. Local farmers are contacted about using sewage effluent instead of river water during the warm months of the year. In addition, the city applies for and receives a federal matching grant to expand and modernize its facilities and eliminate pollution. To do this, a chemical secondary treatment facility is added to the present primary treatment facility which brings BOD to within state limits and significantly reduces phosphate levels. During the warm months the chlorinated effluent from the primary treatment facility is used to irrigate the golf course and piped to local farmers. During the cold months when no irrigation water is needed, the secondary chemical treatment facility is used to treat the effluent before it is discharged into the river. Chemical rather than biological secondary treatment is used because it can be started up or shut down within a day's time whereas biological treatment requires up to two weeks to start. The sludge collected during primary settling is digested anaerobically, dried, and distributed for a nominal charge to local farmers. It is also bagged and sold to local residents as soil conditioner. Its popularity has grown due to a publicity campaign and because it is priced lower than commercial preparations.

Of course, solving community waste disposal problems is usually much more difficult than has been indicated above. However this hypothetical example does illustrate some of the factors which should be considered and some of the possibilities for imaginative solution which do exist.

CHAPTER VI

CONCLUSION

Two major questions were asked at the beginning of this discussion about the problems of waste disposal and their technological solutions. The first was "Can wastes be disposed of without causing damaging pollution to the environment." The answer is definitely "yes" with available technology. Properly operated and sited sanitary landfills will cause almost no pollution. More complex solid waste disposal techniques such as composting, incineration, pryolisis, and oil conversion can all be designed with effective anti-pollution controls. Non-polluting liquid waste disposal is more a matter of degree than an absolute. Waste water can be treated successively with finer and finer techniques until the water is essentially pure. All that is needed is sufficient funds to build and operate the treatment facilities and the motivation to do so. Where waste water will not be discharged into a receiving stream, but rather on land, treatment can be less complete with no fear of causing pollution damage. With both liquid and solid wastes, effective, safe, disposal appears to be well within financial reach of most municipalities.

The second question was "Can we begin to reuse some of the resources now being lost through the waste disposal process?" The answer again is "yes" with available technology. Some materials, particularly metal and glass can be easily recovered with present technology. Heat, too, can be salvaged either through the use of waste heat boilers in incinerators or by converting solid wastes into fuels through pryolisis or oil conversion. These last two techniques hold a great deal of promise but will have to be supplemented with further research. Paper and plastics are more difficult to recover from mixed refuse intact but can be salvaged as heat. This is particularly true of plastic which does not presently have a salvage market. Since plastics do not break down in nature it may in fact be a desirable ecological goal to dispose of plastics by incineration, pyrolis, or oil conversion. At present these are the only techniques available for returning the constituent elements of plastics to the environment. The barriers to solid waste reuse appear to be (1) the high capital investment needed for recycling equipment; (2) developing markets for recycled material, and (3) the high expense, relative to present economic return, of operating recycling processes.

Liquid waste reuse appears to be even more promising than solid waste reuse. Waste water can either be treated to the point that it is reusable or it can be partially treated and used for irrigation or aquifer recharge. The solids produced during waste water treatment have proven soil conditioning and fertilizer value. Barriers to waste water reuse appear to be (1) an institutional inertia which inhibits the search for alternatives to pumping waste water into the nearest receiving stream; (2) the high capital investment costs of effective treatment facilities; and (3) the problems associated with dispersing the water and solids back to the land after they have been concentrated by the collection and treatment process.

The third major question, implicit throughout this discussion, is "What can municipalities do now to improve their waste disposal processes?" The answers to this question are not as clear-cut as they were to the preceding two questions. However, the beginnings of answers suggested by Chapter V "Choosing the System" are as follows:

1. Municipalities must reorder priorities to put clean air and water ahead of new residential, industrial, and commercial development and ahead of some other local capital improvement programs.

2. Local governments must reorient their thinking from viewing waste as something which is a nuisance to be disposed of and being to see it as a resource to be reused.

3. Creative techniques for disposing of waste must be developed. This may mean for instance piping waste water out to nearby farms for irrigation or packaging and selling dried sewage sludge for soil conditioner as Milwaukee now does. Or it may mean actively seeking federal demonstration grants for solid waste recycling plants.

4. And finally municipalities must begin to completely reasses all waste disposal programs using a process similar to the previously presented flow diagram. This process should orient waste disposal to a program of land use, transportation, environmental, and social planning and keep in the forefront the goals of reduced environmental impact and resource reuse.

The result, country-wide, will be a whole series of new solutions to the waste disposal problem. Some of these solutions will be only locally applicable but some will have value for many communities. At the present only the federal government and a few state governments are promoting new waste disposal solutions. This will not be sufficient to solve the problems and local governments will have to join in order to make the endeavor successful.

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