

Sanitary Landfill Method of Solid Waste Disposal

JOHN M. BELL
Associate Professor
School of Civil Engineering
Purdue University

INTRODUCTION

Reduced to its simplest terms, solid waste collection and disposal consists of the acceptance of the solid waste from processes of human life, the transportation of such material to disposal sites, and the processing and disposal of the material so that nuisances are not created. The entire process must be carried out in such a manner that the public health of the community is protected, that the extent and character of the service is in accord with the desires of the people, and that the operation is conducted effectively and economically.

Surveys have shown that many communities, large and small, do not follow sanitary solid waste practices. There are many reasons why these communities have not taken steps to protect the health and welfare of their citizens from the hazards associated with the inadequate and insanitary collection and disposal of solid wastes. Predominate among the basic causes, however, is the belief that adequate service is too expensive, and a lack of information on how to establish and operate a satisfactory system.

A practical solid waste control program is within the means of any community. In rapidly growing communities a *Master Plan* for the collection and disposal of solid waste, based on a thorough engineering analysis, is vital. The alternative is almost insurmountable future problems. Even the best planned solid waste collection and disposal system will be one of the costliest services provided by a municipality. Few services so directly affect the individual citizen and taxpayer. A poorly planned system is certain to place a continuous, undue burden on financial resources and create ill-will in the community.

THE PROBLEM

The problem of designing the most economical solid waste collection and disposal program for a rural or urban area has become increasingly complex in recent years. The problem mounts each year

because of several trends: population growth, new home construction, increased industrial activity, shortage of disposal sites, and a significant increase in the production of solid waste resulting from modern packaging and consumer consumption.

Population increases have resulted in solid waste problems in communities where previously no service was provided and where there has been little or no recognition of municipal responsibility. Municipalities with established solid waste collection and disposal services have found that community development means new problems. As growth presses to a municipality's borders and vacant land is developed, adequate solid waste disposal sites become less readily available. Frequently, existing methods must be improved or an entirely new system adopted.

Solid waste operations overlap in built-up areas, and municipalities are becoming involved with neighboring communities. The cost and complexity of disposal methods raise the question of municipal cooperation in order to achieve economies. Development of common disposal sites is often indicated as a matter of mutual benefit.

State health authorities have recently established standards for solid waste disposal practice. This added dimension of official state interest is having an impact on prevailing methods of disposal and will affect the decisions of local officials with regard to pending and future policies for solid waste collection and disposal.

DEVELOPMENT OF MASTER PLAN

It goes without saying that the Master Solid Waste Plan of a community must be coordinated with other parts of the total Community Planning Program: such as education, parks and recreation, public health, air pollution control, water pollution control, transportation, etc. Of prime economic importance, for example, is the proper location of disposal facilities in relation to future population concentrations. Sites for these facilities must be designated and acquired either through zoning, leasing, purchase, or condemnation to avoid future hostile public reaction as well as to avoid expensive future acquisition costs.

The first step in the initiation of a solid waste collection and disposal program would be to consult with public health officials for advice on rules and regulations, applicable standards, and suggested procedures. Health departments, local, state, or federal, will give as much assistance as they can and welcome inquiries from local officials. With competent staff and years of experience, these departments can counsel on technical and procedural matters and help local officials avoid pitfalls and simplify their task.

Financial aid is available from several sources. There are existing programs under which advances and grants for municipal public works planning are available.

The planning and design of solid waste collection services and disposal facilities require highly specialized engineering competence, and most municipalities are not staffed to do this work. As a rule, therefore, a consulting engineer is selected. Selection should be based on professional competence and ability to carry out the work within the time limits prescribed. The engineer or consultant is important; this is a poor place to try to economize. The money spent for the services of a competent consulting engineer will bring returns in a final system that is successful and acceptable to the public.

The value and economy of a comprehensive study and report cannot be overemphasized. A comprehensive study should consider all technical aspects of the work, including alternative solutions, the recommended approach, estimates of capital costs, and annual costs for fixed charges and operation, and methods of financing services and facilities.

The consummation of a well-planned project progresses naturally through the phases of the work. Properly conceived, designed, and constructed, the completed solid waste collection and disposal system will be readily operated and maintained, and will meet the standards of the State Board of Health.

SOLID WASTE DISPOSAL BY SANITARY LANDFILL

The term "sanitary landfill" is too often used to refer to a solid waste operation that is little better than an open dump. Actually, sanitary landfill means an installation where a satisfactory, nuisance-free solid waste disposal operation is being carried out in accordance with recognized standard procedures. The operation of a sanitary landfill requires skill and knowledge. It is a scientific method and should be treated as such. Engineering and planning is needed to operate a satisfactory sanitary landfill.

Sanitary Landfill: A method of disposing of solid waste on land without creating nuisances or hazards to public health or safety, by utilizing the principles of engineering to confine the solid waste to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at more frequent intervals as may be necessary.

The following sections of this paper will present the important considerations in acquiring and operating a sanitary landfill.

SITE SELECTION

Selection of a sanitary landfill site depends upon evaluation of the site itself and upon community acceptance of the site for solid waste disposal purposes.

Ordinarily, selection of a site starts with a search for conveniently located waste land or low-value land. Solid waste disposal sites in the state now include borrow pits, ravines, areas adjacent to water courses, and low-lying swampy land. Advantages are relative ease of acquisition and isolation from built-up areas.

Actually, it is possible to use practically any site for a sanitary landfill, although submarginal, rather than potentially valuable land, would ordinarily be selected. Land costs, moreover, are *not* necessarily the controlling factor. The low first costs of waste land may be offset by developmental costs in making the disposal site suitable for landfill operation and in procuring necessary cover material from another location. Long haul to a sanitary landfill may, upon analysis, prove more economical than short hauls to an expensive disposal facility. For large cities, more than one site may be needed for the most economical operation. Counties may operate sanitary landfills at sites that can be utilized by several communities.

Topographic Maps

Clear plans and procedures are essential to the efficient and successful operation of any sanitary landfill. Topographic maps will show to all those involved (planners, legislative bodies, health officials, supervisors, equipment operators, etc.) the existing situation and the sequence of operations planned.

The design of a sanitary landfill should include one or more topographic maps at a scale of not over 200 feet to the inch with five-foot contour intervals. These maps should show: the proposed fill area; any borrow area; access roads; grades for proper drainage of each lift required and a typical cross-section of a lift; special drainage devices, if necessary; fencing; equipment shelter; existing and proposed utilities; employee facilities; and all other pertinent information to clearly indicate the orderly development, operation, and completion of the sanitary landfill.

Geology

The geological characteristics of the proposed site should be determined by on-site testing or from earlier reliable survey data. Geological investigations are one of the most important studies required in select-

ing a site. From such data, it can be determined if cover material of suitable quality is available or whether it will have to be obtained elsewhere. Such investigations also will permit evaluation of geological factors that influence ease of excavation, water pollution, and lateral gas movement.

Site Capacity

Useful life of the sanitary landfill is a major consideration. One of the common difficulties experienced by municipalities is the early exhaustion of disposal sites and the absence of ready alternatives of additional land for solid waste disposal. The useful life of a site comes down to the question of sound planning and good operation, which in combination allow full development of site capacity.

Capacity of a sanitary landfill site is usually expressed on an *area* basis; so many acres per contributory population per year. This approach is sometimes misleading. Actual capacity is determined by the useable disposal *volume* that can be developed at the site. Figure 1 shows volume required as determined by solid waste production and density of fill. Figure 2 shows total solid waste production based on population and per capita generation rate.

As previously noted, landfills are frequently located in abandoned gravel pits, quarries, and ravines as well as on relatively level land.

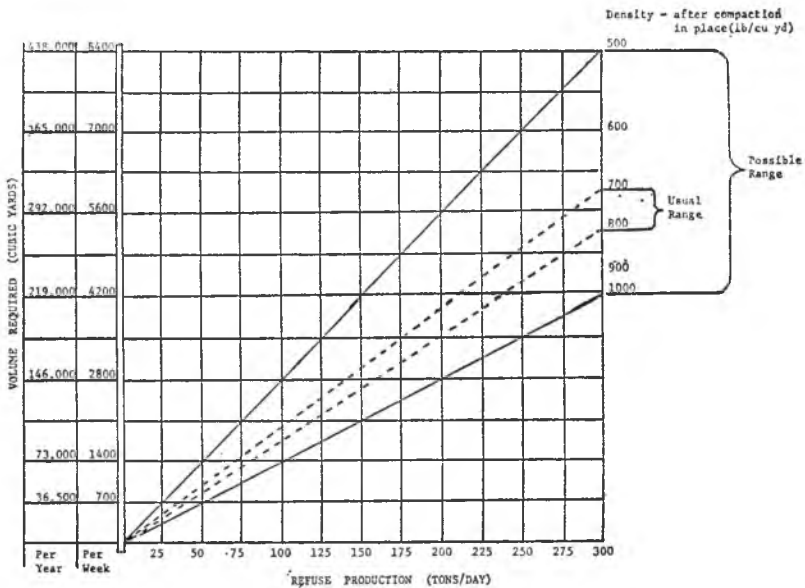


Fig. 1. Sanitary Landfill Volume Requirement.

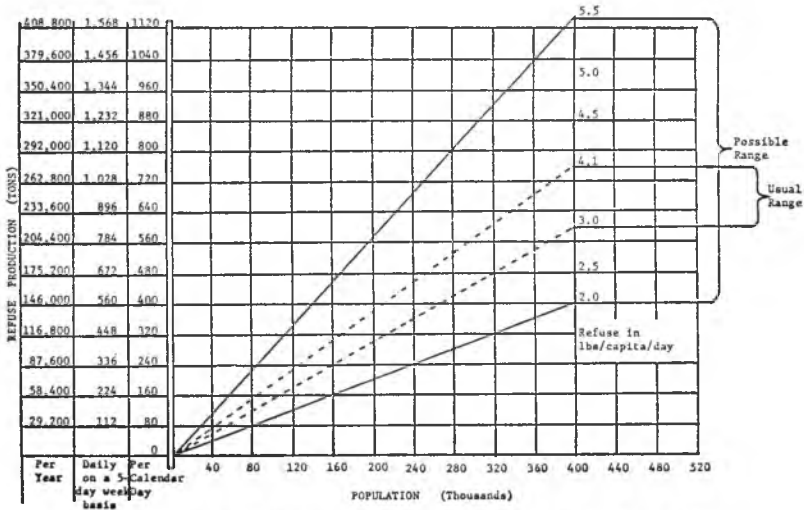


Fig. 2. Refuse Production at Various Per Capita Values.

Consequently, the depth available for fill is as important as the surface area of the site in measuring the capacity. Detailed planning will make it possible to use the total volume of space available.

Assuming a solid waste production of 1,500 pounds per capita per year delivered to the site, with a compaction to 700-750 pounds per cubic yard, annual volume required at a landfill would be approximately 2,000 cubic yards per 1,000 population. Additional capacity of some 15 to 25 percent would have to be provided for cover material if brought from off the site. Sites should be located and acquired that will provide capacity for 20 to 25 years in the future.

Cover material

Cover material is spread over the solid waste and compacted to form a tight seal or cover. This barrier prevents flies from laying eggs on the waste or rodents from invading the fill. It seals in odors, prevents infiltration of rainwater, and minimizes the blowing and scattering of material. It reduces the fire hazard, and helps to produce a dense, stable fill.

An ideal soil for cover material is a combination of approximately 50 percent clay-silt and 50 percent sand. Such a sandy-loam mixture is porous, compacts well, and is not subject to cracking upon drying. Clay, when it becomes dry, will crack, giving rodents and insects an access to the covered solid waste. In addition, when clay becomes wet it is difficult to handle. Soil surveys, published by the Soil Conservation

Service of the U.S. Department of Agriculture, are particularly helpful in locating sanitary landfills with the most suitable soil conditions.

Water Pollution

The possibility of water pollution should be thoroughly investigated when selecting and developing a landfill site. Under certain geological conditions, the burial of solid waste is a real potential for chemical and bacteriological pollution of ground and surface waters. The pollution hazard is increased when disposal is in sand or gravel soil, where the ground water is penetrated, and where wells are located nearby.

In general, landfills should not be located on a site where ground water or surface water will intercept the deposited waste. Provisions can often be made to minimize or prevent pollution from sanitary landfill operations. Some common preventive measures include: 1) locating the site at a safe distance from streams, lakes, wells, and other water sources; 2) avoiding site location above the kind of sub-surface stratification that will lead the leachate from the landfill to water sources; fractured limestone; 3) using an earth cover that is nearly impervious; 4) providing suitable drainage trenches to carry the surface water away from the site; and, 5) diking and de-watering or draining and filling.

Land Reclamation

Part of effective planning and operation is the eventual use of the finished landfill. This should be determined before the operation commences. It will give aim and direction to the whole operation. While land reclamation is one of the advantages of a sanitary landfill, the main object of such an installation is effective solid waste disposal.

Completed landfills have been used for recreational purposes—parks, playgrounds, or golf courses. Parking lots, airports, storage areas, botanical gardens, or agriculture are other final uses. Because of settling and gas problems, construction of buildings on completed landfills generally has been avoided; in several locations, however, one-story buildings have been erected. Multi-story buildings can be built over completed landfills, using steel and concrete pilings, and special engineering design.

Landfill Operation

Detailed engineering planning and control, both prior to and during operation, are necessary to insure efficient operation and maximum site utilization. Careful planning and control will pay dividends

in economy, trouble-free operation, and full capacity utilization of the landfill site.

There are basically two methods of operating a sanitary landfill; the *area* method and the *trench* method. These methods are shown in Figures 3 and 4, respectively. The method selected will depend upon subsurface conditions, drainage, and topography of the land.

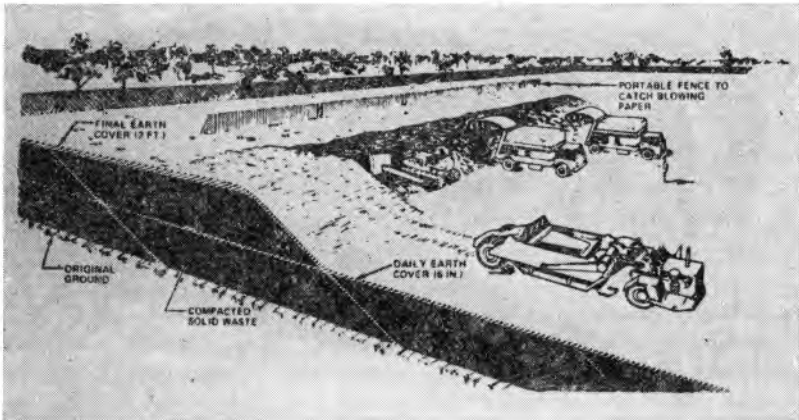


Fig. 3. Area Method—The bulldozer spreads and compacts solid wastes. The scraper (foreground) is used to haul the cover material at the end of the day's operations. Note the portable fence that catches any blowing debris. This is used with any landfill method.

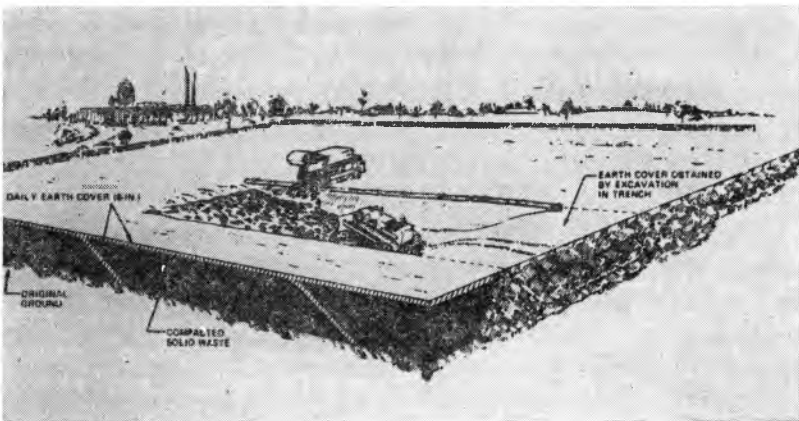


Fig. 4. Trench Method—The waste collection truck deposits its load into the trench where the bulldozer spreads and compacts it. At the end of the day the dragline excavates soil from the future trench; this soil is used as the daily cover material. Trenches can also be excavated with a front-end loader, bulldozer, or scraper.

Area Landfill

The solid waste is placed on the land; a bull-dozer or similar equipment spreads and compacts the waste; then the waste is covered with a layer of earth; and finally the earth cover is compacted. The area method is best suited for flat areas or gently sloping land, and is also used in quarries, ravines, pits, or where other suitable land depressions exist. Normally the earth cover material is hauled in or obtained from adjacent areas.

Trench Landfill

A trench is cut in the ground and the solid waste placed in it. The waste is then spread in thin layers, compacted, and covered with earth excavated from the trench. The trench method of landfilling will consist of any one of the following three methods:

Progressive Excavation: The distinguishing feature of this method is its continuity. Cover material is excavated from the area directly in front of the working face of the landfill and is put over the previously compacted solid waste behind. The cover is excavated as required and the process goes on almost continuously.

Cut and Cover: A cut-and-cover landfill is one in which trench-type excavations are made on the site to hold the solid waste and get cover material. The trenches are usually parallel to each other in order to use the site efficiently. The trenches should be near as possible perpendicular to the prevailing winds to minimize the scattering of loose material. The width of the trench should be approximately twice the width of the tractor used in order to obtain maximum compaction of the material. Unlike the progressive excavation method, solid waste at a cut-and-cover fill is usually discharged at the top of the working face, although in some cases it may be desirable to discharge it at the bottom.

Imported Cover: The imported cover method of operating a landfill is not a single method but rather several, and is used when cover material is obtained from a source outside the site.

The trench method is best suited for flat land where the water table is not near the ground surface. Normally the material excavated can be used for cover with a minimum of hauling. A disadvantage is that more than one piece of equipment may be necessary.

Access Roads

Access roads to the landfill should be regularly maintained under all weather conditions to permit a smooth flow of traffic. Unnecessary delays of collection vehicles are costly and can result in unfinished collection routes. The entrance to the access road should be provided with a gate and lock so that the site may be closed at the end of the day. There

should always be signs showing hours of operation and directing traffic to the designated dumping areas from the access road to the operating face of the landfill.

Operating Face

The operating face in the fill area should be limited to a length which can be easily controlled and worked by the equipment operator. The smaller the face, the less likelihood of difficulties. This requires strict control by personnel at the site over all incoming vehicles.

Spreading and Compacting

A successful sanitary landfill operation depends upon the adequate compaction of the waste. Settlement will be excessive and uneven when the waste is not well compacted. Solid waste should be placed at the top or bottom of the working face, spread in layers about two feet thick, and compacted. If a slope or ramp is used, better compaction will normally result if the waste is spread and compacted from the base upwards. Further compaction is provided by repeated travel of landfill equipment over the layers and, if necessary, by the use of special compacting equipment. Additional compaction is also achieved by routing collection vehicles so that they travel repeatedly over the finished portion of the fill.

The degree of compaction is dependent upon the character of the waste, the weight and type of compacting equipment, and the number of passes the equipment makes over the material. The actual density of the landfill can be determined from operating records and data. The degree of compaction is a useful tool to determine the rate of space usage, the expected life of the landfill, and the overall efficiency of the operation.

Depth of Cells

The total depth of a landfill is governed by the characteristics of the site, the desired elevation of the completed site, and good engineering practice. Eight feet is generally recommended as a maximum single cell depth because deeper cells usually result in fills that have excessive settlement and surface cracking. Fills using lifts shallower than eight feet do not generally make maximum use of available land, but do provide for earlier re-use of the site.

Cover

Daily Cover: A compacted layer of at least six inches of suitable cover material should be placed on all exposed solid waste by the end of each working day. This is to prevent fly and rodent attrac-

tion, blowing of papers, production of odors, fire hazards, etc.

Intermediate Cover: For intermediate cover on lifts which will not have additional lifts placed on them within a year, a minimum of 12 inches of compacted soil is recommended.

Final Cover: A layer of suitable cover material compacted to a minimum thickness of two feet should be placed over the entire surface of each portion of the final lift not later than one week following the placement of waste within that portion. Where trees will be planted on the completed fill, a depth of three feet or more of compacted earth has been found necessary.

Drainage

The surface of the landfill should be carefully graded to permit drainage and prevent ponding of surface water. Standing water may permit mosquito breeding and may interfere with the operation of the landfill. Precautions must be taken to prevent runoff water from eroding the cover material and exposing the waste. Good drainage will usually require periodic regrading of the site, and the use of culverts or grassed waterways. It is recommended that the slope of the completed fill surface be a minimum of one percent. Since the landfill will undergo uneven settlement, it may be necessary to design the original slope for more than one percent to maintain a one percent after settlement. To prevent erosion, however, steep slopes should be avoided.

Fire Prevention

A water supply should be available at the landfill site at all times to prevent and extinguish fires. The water supply may be in the form of a piped supply, tank trucks, well, or auxiliary pumps if the landfill site is located near a source of surface water. Fires can usually be extinguished by smothering with a blanket of earth, but some sort of fire protection should be available in addition to such means; especially if residential or commercial structures are relatively close.

Screening

Where natural screening is not afforded by trees or topography, a permanent perimeter fence and plantings are desirable. This is a must if the useful life of the site is expected to extend over a period of time—more than five years, for instance.

Fencing

Confinement of blowing papers and light solid waste material to the landfill site is best accomplished by use of light, movable fences, such as snow fences. Such fencing is located around the landfill operation to protect surrounding areas. The fence should be regularly

cleaned of litter to prevent unsightliness. Unfortunately, under certain wind conditions paper may blow up and over the fences, so fences do not provide complete control. Prompt compaction and covering and daily pickup of loose paper should be practiced to control windblown paper.

Winter Operation

Certain facilities and procedures are necessary for a successful landfill operation during the winter. These include:

1. Keeping the access road passable for collection vehicles.
2. Providing a heated garage for the motor equipment to facilitate starting in cold weather.
3. Providing shelter for the operator in cold weather.
4. Providing a heated cab on equipment for the operator.
5. Keeping the operating face and surrounding area of the landfill free of snow for equipment mobility.
6. Stockpiling of cover material.

If the trench method is used, the trenches should be excavated before the cold weather. It may be necessary to stockpile cover material and cover it with straw, leaves, or other material to prevent freezing. The material should be piled loosely with a minimum of compaction.

Some landfills might need to use separate winter or wet-weather areas which are more readily accessible from the access road.

Bulky Items

Large bulky items, such as car bodies, refrigerators water heaters, and tree stumps, can be handled routinely with the other solid waste at large landfills that use heavy equipment. At small landfills, special provisions may be necessary to handle bulky items if only light equipment is available.

Hazardous Materials

Although it is not common or recommended practice, hazardous materials, such as sewage sludge, radioactive wastes pathological wastes, explosive wastes, and chemicals, can be disposed of at sanitary landfills under special conditions. The special provisions for handling and disposing of these materials will depend on local conditions. Individual handling and disposal may be necessary using a special area separate from the main operation.

Present disposal methods for hazardous materials are: 1) mixing with soil, 2) evaporation, 3) infiltration, and 4) sanitary landfill. Mixing with soil, sometimes known as "chemical landfill," uses the absorbitive character of the soil, and sometimes achieves biological

degradation of the wastes by soil microorganisms. This method of disposal can be done in essentially two ways: The wastes may be spread over the soil in thin layers and then periodically mixed into it; or placed in a trench or shallow pond (up to three feet deep) followed by the filling of soil into the pond. Some evaporation may take place, especially with the thin spreading techniques.

A thin application to land can be done through shallow furrows, through flood irrigation or by discharge from a moving truck. This method may prove to be more expensive than using the evaporation or infiltration ponds because of the extra time involved in mixing the wastes into the soil. Another disadvantage is the larger surface area needed, and this in turn leads to the possibility of greater production of odors. This method is not recommended for disposal of heavy metal and organic substances that are highly toxic in dust form. The breaking down of toxic wastes through microbial activity in the soil is a help in often permitting the periodic reuse of the area for more waste treatment. Unless the wastes eventually decompose or weather to nonharmful products, however, the entire area will require a final earth cover.

The volume of a waste may be reduced through the evaporation of its water content or the release of some of its volatile constituents. This method is governed by such climatic conditions as temperature, humidity, wind speed, and rainfall. Oil slicks, films, or cakes on ponds can also have a deterrent effect on the rate of evaporation. Certain wastes that emit volatile fumes or vapors, which are toxic air pollutants, should not be handled in this manner. Evaporation in ponds results in an eventual residue of solids being left on the bottom of the dried-out pond, and the filling and drying process can be started again. Periodically the pond bottom can be scraped out and the solids used to heighten the levees or berms and thus increase the volume of the pond. Care must be taken in handling the residues because of the potential dangers from dusts, fumes, or corrosive conditions. In some cases, where several wastes have been mixed, the resulting chemicals may be more hazardous than the original wastes.

Where infiltration of hazardous wastes must be prevented, any proposed evaporation ponds must first receive some form of impervious lining. Materials suitable for this lining may be concrete, asphalt, rubber, plastic, or even a sufficient thickness of impermeable soil such as clay.

Disposal by infiltration can only be considered where there is no danger of ground water pollution. Infiltration is basically a means of allowing the liquid wastes to penetrate into the underlying, porous

sediments of the earth. An advantage of infiltration ponds is that they automatically function with a minimum of supervision and costs. As mentioned before, when the filtration area is dry on top, it is advisable to scrape the caked surface and leave it porous for the next discharge of liquids.

Certain hazardous solid wastes can be landfilled along with ordinary refuse, but these should be carefully placed with the trash and buried with great caution. Containers filled with dangerous liquids are best emptied before the containers are crushed and buried in the landfill. In this way there is no fear of them bursting under pressure of the site equipment and throwing out liquids likely to harm personnel, or cause fumes, fires, or explosions. Extra hazardous materials should be prepackaged in containers such as double drums, and care must be taken not to puncture these during the burial operation.

A landfill containing a large portion of uncompacted refuse—e.g., wood, plaster, concrete—is more suited to liquid wastes disposal than one which has a large proportion of solidly compacted rubbish, because of its more open and absorbent characteristics. Problems of water pollution may be more serious at the general landfill and there is the added disadvantage that often the general public has access to these sites, creating the need for extra supervision. Landfilling is not suitable for certain, extremely toxic wastes which pose hazardous fume or dust emissions, and require greater isolation during the unloading and disposal operation. On no account, should scavenging be allowed on a landfill where toxic wastes are being handled.

The ideal situation for preventing pollution reaching a water source is to have a site where there is a complete clay barrier in the natural topography. To be fully safe the clay should be saucer shaped. When the saucer is filled with percolate, additional liquid overflows the edge of the saucer without passing through the toxics. An alternate to this method is to cover the wastes with clay or other impermeable material; preferably in the shape of an umbrella extending beyond the limits of the toxic waste.

Consideration should be given to disposal sites that rise above the surrounding land levels. The sides of these "hills" should be treated to encourage the quick growth of grass. The addition of a layer of clay or other permanently waterproof substance would prevent any seepage of rain into the hill which, being above ground level, would not suffer any seepage from the sides or from below.

The most positive method of preventing toxic pollution would be to set the waste all in concrete. But the expense of this is justified only in cases of extreme toxicity.

Communication Facilities

Telephone or radio communications should be provided at the landfill. Communications are necessary at the generally remote landfills in cases of emergency. Better administration of both the collection and disposal operation will result with such facilities.

LANDFILL REGULATION

Burning

No burning of solid waste should be practiced at a landfill. Garbage cannot be burned without nuisance except in high-temperature incinerators. Any other method of combustion creates odors, air pollution, and fire and safety hazards. Such burning adversely affects public acceptance of the operation and proper location of future sanitary landfill sites.

Controlled burning of certain combustible materials not readily incorporated in the fill, such as lumber, brush, and tree stumps, may provide a satisfactory means of disposal of these materials at some isolated sites. Such burning, however, must be conducted only at a separate unloading area and with permission of and in accordance with regulations established by the local department of health, air pollution authority, and fire department. The regulations established should specify the hours and meteorological conditions when burning may be permitted; prescribe safety precautions; stipulate the quantity, type, and condition of materials to be burned; and set forth any other necessary limitations.

Dust Control

Excessive dust slows operations, creates accident hazards and aesthetic problems, and may cause eye irritation or other injury to landfill personnel. Dust at the unloading area can be controlled by sprinkling the unloading area and the deposited waste with water. Other dust control measures are the planting of grass or other vegetation on the finished fill and the application of water, road oil, or calcium chloride to the access roads.

Vector Control

Proper operation of a sanitary landfill will reduce insect and rodent problems to a minimum. However, any lapse in proper operating procedures may result in attraction and rapid production of insects and rodents. Supplemental vector control measures may occasionally be necessary to prevent health hazards or nuisances. A vector control

program should be a supplement to, not a substitute for, proper solid waste handling procedures.

Animal Feeding

Hogs should not be allowed to feed on uncooked garbage. Domestic animals should be excluded from the site since they interfere with the operation of equipment and scatter the waste.

Limited Access

If public use of a sanitary landfill is allowed when no attendant is on duty, scavenging and indiscriminate dumping commonly occur. It then becomes necessary to divert men and equipment to policing the area to restore sanitary conditions. Therefore, access to a sanitary landfill should be limited to those times when an attendant is on duty and only to those authorized to use the site for the disposal of solid waste.

Supervision

Successful landfill operation depends upon adequate supervision. The landfill should be under the direction of a qualified individual. The operation of a landfill so that no health, nuisance, or aesthetic problems result is best accomplished when the work is directed by a responsible person who is both able to understand and to implement the plans and specifications.

Salvaging

Nothing should be tolerated that interferes with prompt sanitary disposal of solid waste. Improperly conducted, salvaging delays landfilling operations and creates unsanitary conditions. The accumulation of salvaged material at the disposal site often results in vector problems and unsightliness, which are detrimental to public acceptance of the operation. Scavenging is an unhealthy, aesthetically-objectionable practice that interferes with the orderly and efficient operation of a landfill. All salvaged materials should be removed from the site by the end of the day.

Accident Prevention and Safety

The use of heavy earth-moving equipment, the maneuvering of collection trucks and other vehicles, and the explosive or flammable items that may be in the solid waste create accident-prevention problems at landfills. The remote location of some landfills makes it particularly important that personnel be oriented to accident hazards, trained in first aid, and provided with first-aid supplies. For reasons of safety,

access should be limited to those authorized to use the site for the disposal of solid waste.

At least one person trained in first aid should be on duty during the operating hours. An on-going educational program on safety and first aid should be maintained at all times.

Operating Hours

The hours during which the landfill is open for collection vehicles should be closely phased with the solid waste collection schedule. Since it is necessary to allow time for the equipment operator to compact and cover the final loads of waste, the site should be closed at an hour which enables the operator to finish his daily work.

In scheduling the hours during which the site is open, consideration must be given to individual residents if they are allowed to dump at the site. A good practice is to place detached containers at the gate for use by individuals during hours the landfill is closed.

Inspection and Evaluation

Routine inspections and evaluations of landfill operations should be made by a representative of the state or local health department. A notice of any deficiencies, together with any recommendations for their correction, should be provided to the owner or agent responsible for the use of the land; and the appropriate individual, firm, or governmental agency responsible for the landfill operation.

EQUIPMENT

A wide variety of equipment is on the market today from which to select the proper type and size needed for an efficient operation. Basic needs are a sufficiently large and rugged piece of equipment for use in compaction, excavation, covering, and grading. Each site must be studied before a determination can be made of the exact equipment necessary for preparation of the site, daily operation, and special situations. The terrain, for example, may require extensive provision for drainage, construction of dikes, the use of drag lines through muddy or marshy land, or extra rugged equipment for use in rocky, heavy, or gravelly soil. Cover material at the site requires excavation, transportation, placing, and leveling. If cover material is brought from another location, equipment is required to load and transport such material from its source to the place of use and to handle it at the site.

Types

The most common equipment used on sanitary landfills is the crawler or rubber-tired tractor. The tractor can be used with a dozer

blade, trash blade, or a front-end loader. A tractor is versatile and can normally perform all the operations: spreading, compacting, covering, trenching, and even hauling the cover material. The decision on whether to select a rubber-tired or a crawler-type tractor, and a dozer blade, trash blade, or front-end loader, must be based on the conditions at each individual site.

Other equipment used at sanitary landfills are scrapers, compactors, shovels, backhoes, draglines, and graders. Some of the standard types of equipment are shown in Figure 5.

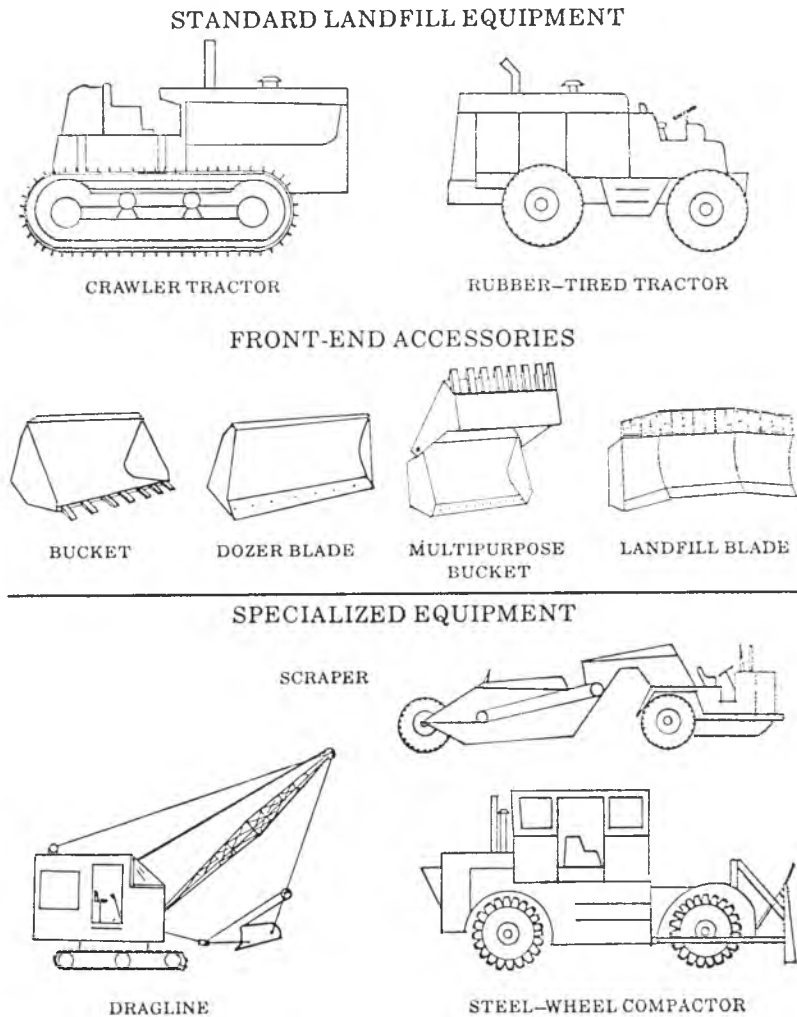


Fig. 5. Standard and Specialized Landfill Equipment.

Maintenance

Equipment breakdowns of a day or more result in the accumulation of solid waste as in an open dump with all the attendant health hazards or nuisances. Systematic, routine maintenance of equipment reduces repair costs, increases life expectancy, and helps to prevent breakdowns that interrupt landfill operations. Prompt repair of equipment and availability of standby equipment insure continuity of operations.

Size and Amount of Equipment

Small sanitary landfills for communities of 15,000 or fewer, or sanitary landfills handling 46 tons of solid waste per day or less, can operate successfully with one tractor of the five- to ten-ton range. Heavier equipment in the 15- to 30-ton range or larger can handle more waste and achieve better compaction. Heavy equipment is recommended for landfills serving more than 15,000 people or handling more than 46 tons per day.

Sanitary landfills servicing 50,000 people or fewer, or handling about 155 tons of solid waste per day or less, normally can manage with one piece of equipment, but provision should be made for standby equipment. At large sanitary landfills serving more than 100,000 people, or handling more than 310 tons of solid waste per day, more than one piece of equipment will usually be required. At such sites, specialized equipment can be utilized to increase efficiency and minimize costs.

Supporting Facilities and Personnel

Supporting facilities are required for efficient landfill operation, including: 1) a heated garage to simplify maintenance, allow easy starting in winter, and extend the useful life of the equipment; 2) shelter for employees to change clothes, keep records, have meals, and secure protection during extreme weather conditions; and 3) toilet facilities, shower, wash basin, and a portable latrine at the site.

Other operating facilities, already mentioned, include fencing for litter control and water supply for fire fighting purposes.

Provision should be made for weighing of all solid waste delivered to the landfill. This provides reliable quantity data, determines trends, and allows estimates of future disposal needs. Scales at a sanitary landfill facilitate control of the operation and may be used in establishing and collecting dumping fees.

Minimum personnel needs are a full-time employee to operate the main piece of equipment and supervise the fill. Depending on the size

of operation, additional personnel may be needed to run equipment, control vehicle traffic, and otherwise assist in operations.

COSTS

The cost of a sanitary landfill consists of the initial investment for land, equipment, and construction features, and the operating costs.

The magnitude of the initial investment depends on the size and sophistication of the landfill. Generally, the major portion of the initial investment is for the purchase of the land and equipment.

The operating cost of a sanitary landfill depends on the cost of labor and equipment, the method of operation, and the efficiency of the operation. Wages ordinarily make up about 40 to 50 percent of the total operating cost. Equipment equals 30 to 40 percent; cover material, administration, overhead, and miscellaneous amount to about 20 percent.

The operating cost of a small operation handling less than 50,000 tons per year varies from \$1.00 to \$5.00 per ton. This wide range is primarily due to the low efficiency of the smaller operations which are usually operated on a part-time basis.

Full-time personnel, full-time use of equipment, specialized equipment, better management, and other factors that lead to high efficiency are possible at large sanitary landfills. The increased efficiency results in lower unit cost of disposal. The unit cost of a large landfill handling more than 50,000 tons per year will generally fall between \$0.75 to \$2.50 per ton.

SUMMARY

Sanitary landfill is the most inexpensive disposal method known today. It is especially suitable for rural areas, mountainous areas, or areas which have an air pollution problem. In communities where land is limited or extremely expensive, this method may not be suitable unless a cooperative agreement can be reached with neighboring jurisdictions. A properly operated sanitary landfill produces no objectionable odors, vector problems, or blight, and is especially suited to the reclamation of marginal land. A sanitary landfill is basic to any other solid waste processing operation, since all produce some material which must be sanitary landfilled.

The conveyance of solid waste from collection to disposal involves people and machinery. It therefore needs *planning*. There is a need for imaginative thinking on the tangled problems of where our cities are headed, where they ought to be a decade or generation from now, and

how to get there. As engineers, public health officials, or just plain citizens, we should insist that all engineering projects, including sanitary landfills, be referred to the *Urban Master Plan*, and when such a plan does not exist, to insist on knowing why it doesn't, and when there will be one.

REFERENCES

1. "Environmental Health Planning Guide," *U.S.P.H.S. Publication #823*, Washington, D.C., 1962.
2. *Refuse Collection Practice*, A.P.W.A., Third Edition, Chicago, Illinois, 1966.
3. *Municipal Refuse Disposal*, A.P.W.A., Third Edition, Chicago, Illinois, 1970.
4. "Manual for Storage, Collection, and Sanitary Landfill Disposal of Refuse," *Special Report*, Indiana State Board of Health, Indianapolis, Indiana, June 1958.
5. *Sanitary Landfill*, A.S.C.E. Manual of Practice No. 39, New York, N.Y., 1960.
6. *Sanitary Landfill Facts*, U.S.P.H.S. Publication No. 1792, Washington, D.C., 1968.
7. "New Methods of Toxic Trash Disposal Are Being Evolved," *Solid Waste Management Journal*, July 1972.
8. "Keep Britain Tidy," *Solid Waste Management Journal*, January 1970.
9. "Dealing With Potentially Lethal Discards," *Solid Waste Management Journal*, May 1971.