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Case Studies of Municipal Waste Disposal Systems

By H. W. Sheffer, E. C. Baker, and G. C. Evans

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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ILLUSTRATIONS

CASE STUDIES OF MUNICIPAL WASTE DISPOSAL SYSTEMS

by

H. W. Sheffer,[1] E. C. Baker,[2] and G. C. Evans[3]

ABSTRACT

Technical and economic aspects of community refuse disposal systems and their effects on the environment are identified and described. Seven landfills and two incineration systems, located throughout the United States, are reviewed.

INTRODUCTION

Nearly 190 million tons of throwaway material, including 48 billion cans, 26 billion bottles, 100 million tires, and 8 million old cars, is discarded by Americans each year (4).[4] By 1980 the heap will consist of 340 million tons per year of garbage, trash, and junk, which will strain to the limit traditional methods of disposal. Congress, by the Solid Waste Disposal Act of 1965, delegated to the Bureau of Mines responsibility for conducting research on solid waste problems. The present investigation reviews some existing methods of municipal refuse disposal in an attempt to identify potential problems associated with them. Case studies were made of sanitary landfills and incineration systems throughout the United States; ocean disposal, though of potential major importance, is not included in the present survey. Particular emphasis is placed on construction and operation of sanitary landfills in abandoned strip mines.

In choosing the cases, no effort was made to include all alternative systems and proposals for refuse disposal and utilization. Instead, emphasis was placed on projects incorporating features that could be applied widely and on projects utilizing novel equipment or applying standard equipment in novel ways.

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[1] Supervisory physical scientist.
[2] Industry economist.
[3] Geologist.
The authors are with the Eastern Field Operation Center, Bureau of Mines, Pittsburgh, Pa.
[4] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

Information and illustrations presented in the report were obtained on visits to the case-study sites and in discussions with representatives of industry, Government, and educational institutions. Many of the case studies were conducted under grants obtained from the Public Health Service, U.S. Department of Health, Education, and Welfare (19).

The term "sanitary landfill" is used to denote the disposal of refuse in excavated land, whether it be ordinary land areas or abandoned strip mines. "Incineration" denotes the controlled burning of refuse in some form of containment.

SANITARY LANDFILLS

The sanitary landfill is the most widely used method of refuse disposal in the United States. Refuse deposited in a sanitary landfill is compacted and covered to prevent odors, fires, rodents, insects, and other nuisances usually associated with open dumping. Careful planning and control result in the efficient disposal of all components of refuse.

Experiments in Landfill Hydrology

Pollutional leachate is always generated by landfills in the humid climate of the Eastern United States (6-7). The leachate is high in bacteriological oxygen demand (BOD), chemical oxygen demand (COD), iron, sulfate, and chloride. The leachate can be renovated either naturally or by collection and treatment. In natural renovation the pollutants in the leachate are removed as it moves through the earth surrounding the landfill. Collection and treatment depend upon the leachate's being interecepted by an engineered collection system before it enters the ground water system. Most research work on landfills has been done in arid areas. Only a little information is available concerning the quantity and quality of leachate produced from landfills in the East.

The Pennsylvania Department of Health, in conjunction with Drexel University, set up a project to study the leachate and the hydrology of landfills. Dr. A. A. Fungaroli of Drexel University built a lysimeter, 6 feet square and 14 feet tall, that simulates the center of an 8-foot-thick sanitary landfill (8). Environmental conditions were controlled to duplicate those in southeastern Pennsylvania; temperature was automatically recorded at intervals; and gas and leachate samples were collected and analyzed. The refuse was selected so that it was similar to Kaiser's chemical analysis of refuse components (11). The refuse was sized and compacted to approximately 327 pounds per cubic yard before it was placed in the lysimeter. A 2-foot-thick layer of soil was placed over the compacted refuse. Graded Ottawa sand beneath the refuse permitted effluent to be collected from the bottom of the lysimeter.

Minor amounts of leachate came from the lysimeter within 1 month of its construction. Part of this leachate had been squeezed from organic components of the refuse and part was simulated rainwater which had been channeled through the refuse to the bottom of the lysimeter. The field capacity of the refuse was reached 1 year after the lysimeter was constructed, as indicated by the volume of leachate approximately equaling the volume of "rainwater."

Leachate COD was very high during the first month, and then it leveled off around 25 X 10^3 mg/ml after 7 months. By the time field capacity had been reached, COD was declining. Iron concentration peaked and fell about 7 months after construction and then leveled off around 8 X 10^2 mg/ml. Chloride concentration peaked about 8 months after construction and fell rapidly as field capacity was reached.

A field project was developed in the second phase of the Drexel laboratory lysimeter research (9). The project site is in southeastern Pennsylvania in conditions which are thought to be ideal: deep, well-drained soil, derived from underlying deeply weathered granite gneiss, and a water table 20 feet below the surface. The landfill is 50 feet square and 10 feet deep, and it is instrumented via tubes radiating from a 4-foot-diameter pipe in the center of the fill. Test holes were drilled in and adjacent to the fill to monitor temperatures and collect gas and water samples. Data are just starting to accumulate at the site, which was constructed in April 1969.

Pennsylvania State University, in cooperation with the Pennsylvania Department of Health, set up a project to trace leachate in soil derived from carbonate rock (13). It is located at State College in central Pennsylvania. The water table is usually 100 to 200 feet below the surface at this location. The soil is sandy, varies from 5 to 50 feet thick, and has relatively high vertical permeability. The underlying bedrock is deeply weathered and has many fracture zones, which have been enlarged by solution.

A 30-foot-square trench was lined with plastic so that the leachate would drain at one end through a spreader pipe. Test holes were drilled up to 40 feet deep, and suction lysimeters were installed in them. Refuse was emplaced in October 1967, and water was added to the surface to bring the landfill to field capacity in a short period of time. The leachate, which was detected 12 feet below the surface 6 months after emplacement of the refuse, was analyzed for BOD, chloride, and iron.

Each of the two preceding projects is continuing to date. Further, the Pennsylvania Department of Health has drilled test holes in and around old landfills to test for leachate. It appears from observations of some old landfills that leachate does not pollute ground water, but does pollute surface water. Sometimes, because the porosity of the refuse is higher than that of the surrounding earth, leachate flows out of the refuse at the surface. Under these conditions, natural renovation of the leachate is impossible, and it should be collected and treated.

The Illinois State Geological Survey, in cooperation with the University of Illinois, examined the hydrology of solid waste disposal sites in northeastern Illinois near Chicago (10). The age of four sanitary landfills ranged from 2 to 20 years. The landfills are all in glacial deposits ranging in texture from clay till to course sand and gravel. Three of the landfills penetrate the water table. Test holes were drilled in and around the landfills.

Water samples were collected from these holes, in which piezometers had been installed. The samples indicated that organic acids and COD are renovated by adsorption, ion exchange, and filtration. Total solids, chlorides, hardness, and iron are renovated by the glacial deposits more slowly than organic acids and COD. A ground water mound formed in the landfill as the water table rose from its normal depth of 2 to 5 feet to conform with the landfill topography. Therefore, rain falling on the landfill flowed away from the landfill in all directions and often formed springs along the side in the direction of the predominant flow.

Because of the population explosion and its concentration in urban areas, the demand for land and unpolluted water is increasing along with the quantity of solid waste. These factors point to the urgent need for methods of disposal that require less land area and result in less or even no pollution. Cost is an important factor in the efficient design and management of a disposal technique. Leachate is produced in landfills in humid climates and will pollute the natural drainage or ground water. Moving waste material away from population centers to allow for natural renovation is sometimes politically and economically not feasible. The studies on landfill hydrology indicate that the better way of solving the problem is to design landfills so that leachate can be collected and renovated before it reenters the hydrologic system. There is an urgent need to design an economical system to handle the landfill leachate. Because leachate is produced for many years after the landfill is in place, the treating system should have some other purpose as well, such as treating sewage from a nearby population center.

Disposal of Refuse in Strip Coal Mines

The use of abandoned strip coal mines for sanitary landfills should improve the environment. The mines can be more aesthetically appealing after they have been filled. They need not pollute water or air. The land can, and should, be reclaimed and become useful.

It is easier to use filled land for recreational parks without structures because the land is unstable for many years after filling. Sanitary landfills have been used for agriculture, and residences, parking lots, airfields, and several-storied structures have been built on them when careful attention has been paid to special engineering problems created by drainage, uneven settling, and the generation of foul-smelling explosive gas. Uneven settling and bearing capacity can be somewhat improved by separating the types of refuse during construction of the landfill.

Selecting an abandoned strip coal mine for a sanitary landfill is a complicated process in which many factors must be considered. The site should be located as close to the collection area as possible. Haulage costs from the point of household pickup to a landfill constitute 80 percent of disposal costs. About 1 acre of land is required for each 10,000 persons for 1 year of operation if the depth of the refuse is compacted in 7-foot lifts. Consideration should be given to location so that prevailing winds will not blow toward the community served.

Earth cover material should be evaluated for quality and quantity. Large quantities of earth and broken rock are normally available as a byproduct of strip mines, but this material may not be suitable as daily cover for landfill refuse. Sandy loam free of rocks larger than 6 inches is recommended as cover material (2). Experience with strip mines indicates earth containing less than 35 percent coarse fragments is satisfactory. The material after compaction must preclude ponding of water. It must prevent vectors and small animals exiting or entering the refuse. A minimum of 6 inches of material is required for daily cover. Each 7-foot lift should be covered by at least another foot of earth. The final cover for the landfill should be over 2 feet thick.

The prevention of ground water pollution should be considered in the selection of a site. Pollution of ground water will occur (1) when the site is over or adjacent to an aquifer; or (2) when the water in the fill from precipitation, from decomposition, or from an artificial source saturates the refuse to above field capacity so that (3) leached fluids are produced, and the leachate is capable of entering an aquifer. In a humid climate it will be almost impossible to prevent the first two conditions, and therefore, in site selection and site preparation the third condition must be alleviated. A foot of undisturbed earth should be left between the landfill and the water table for each foot of fill depth.

In the eastern half of the United States, where strip mines are located near areas of dense population, the climate is humid, and leachate may be expected to form. Gas and water samples collected from drilled test holes in and near old landfills can be used to determine the extent of pollutional leachate formation. Local topography and drainage patterns can be used to estimate the quantity of water expected to flow through the refuse. The geology will determine if the leachate will enter the rocks forming the boundaries of the landfill.

It is important to know the geology of the surface mining area. Leachate should filter through soil before reaching bedrock, a condition that is precluded if the refuse contacts bedrock. The chemical activity, structure, and fracture patterns of the rocks need to be examined. If the structure is too complex it may be impossible to determine the direction of leachate flow. When the chemical activity of the rocks is high, the leachate may enlarge fractures by solution and thus develop channels to aquifers. After the channels are developed there will be little renovation of the leachate enroute to the aquifers.

Strip mines are often in the vicinity of underground mines working the same or underlying coal seams. The leachate should not be allowed to enter underground workings, active or inactive. The foul odors and unhealthful aspects of the leachate would make working conditions intolerable in an active mine. Leachate in inactive underground mines could stray into unknown aquifers, perhaps miles from the landfill.

The following steps are recommended in preparing a landfill site (2):

1. Make a study to permit accurate planning for access roads, drainage, lift heights, diversion channels, dikes, or levees; to determine soil characteristics; and to estimate the life of the site.

2. Build a semipermanent, all-weather road on the site and a vehicle turnaround if needed.

3. Build an all-weather access road to the site.

4. Take measures to prevent paper from being windblown.

5. Build appurtenances, such as an earth berm or solid fence, around the site to screen the activity for aesthetic reasons.

6. Provide suitable facilities for storing and servicing equipment.

7. Provide facilities for workmen.

8. Install scales to weigh refuse to help determine costs and to improve management practices.

9. Contour the surface of the fill to provide for immediate water runoff in order to eliminate ponding or washout.

10. Place 6 feet of cover material (sandy loam with less than 35 percent coarse fragments) between the refuse and bare rock to prevent their coming in contact. Clay should be used to cover coal seams.

11. In cases where the leachate enters the ground water, install a drainage and collection system before the landfill is constructed. The bottom of the landfill should be covered with an impermeable barrier and then covered with permeable earth material, such as gravel, which will drain via pipes to a collection and treatment system. Since the refuse may produce leachate for over 20 years, the treatment system should be designed for long operation.

The ramp method of operating a landfill in a strip mine is generally applied. The ramp-type operation is especially desirable because the heavy moving equipment is continuously driven over the face of the fill working area. A ramp having a maximum slope of 30° from the horizontal is made from high ground to low ground. The refuse may be dumped at the top or the bottom of the ramp. It is then spread and compacted in about 2-foot layers, after which it is covered with at least 6 inches of earth. These cells are built up to form a lift about 7 feet high. Each lift is covered with at least a foot of earth before another lift is built on top of it. The final lift should be covered with at least 2 feet of earth and immediately seeded to prevent erosion. Better compaction is achieved when the refuse is dumped at the bottom of the lift and spread upwards to form a cell.

Adequate earthmoving equipment should be provided for the excavating of drainage systems, moving and compacting the refuse, placing and compacting the earth cover material over the refuse, and finishing to maintain the desired grade and contour of the fill. The type and size of the dozers and scrapers depends on the method of operation and characteristics of the site. A 35,000-pound crawler tractor with a dozer blade can dispose of some 300 tons of refuse in an 8-hour working day by using the ramp method.

Inspection for and control of rodents should be maintained on a continuous basis. All ponded surface water should be drained and the depression filled with nonputrefying material. During fill operations, an insect spray should be applied when necessary. All voids on fill banks and surface should be filled and compacted.

Monitoring the activity of the landfill may be accomplished in several ways. Gas generated within the refuse may be bled off with vertical pipes spaced throughout the fill. Often sufficient gas is evolved to flare. As the rate of decomposition decreases, the quantity of gas should decrease. An increase in moisture in the refuse tends to increase the rate of decomposition. The settling rate of the fill may be measured by surveying bench marks around the fill and installing observation markers in the fill during construction. Generally most of the settling occurs during the first 2 years after construction. Settling and decomposition will vary according to the content of the fill.

Ground water pollution from the fill can be monitored by drilling test holes into the water table and aquifers to obtain water samples. Lysimeters should be installed beneath landfills to determine if the landfill seal is adequate and permanent. Surface water drainage should also be sampled. The samples should be analyzed for chemical and biological pollution. Chemical (chlorine) contamination has been detected over 1,000 feet from fills.

Allegheny County, Pa.: System Approach

In 1968 the Allegheny County Health Department surveyed and evaluated 21 of the 29 operating landfill sites in the area. Sixteen of these had leaching and drainage problems; all but two were unsightly, and most of them had dust, rodent, and odor problems.

Two of the 21 privately operated sites were maintained and operated in compliance with county environmental standards (<u>1</u>). One of these currently handles all (700 to 800 tons per day) of the refuse generated daily in Pittsburgh. This refuse disposal site (fig. 1), located at an active strip coal mine, is part of a privately owned refuse disposal system that incorporates a transfer station, modern moving and hauling equipment, and good housekeeping practices. It is well managed and warrants the name "sanitary landfill."

The transfer station is a two-level enclosed structure with concrete approaches and exits (fig. 2). City and private haulers bring the refuse to the station and dump it on the concrete floor at the top level. Hi Lifts push it into hoppers. The hoppers dump into a hydraulic ram compartment.

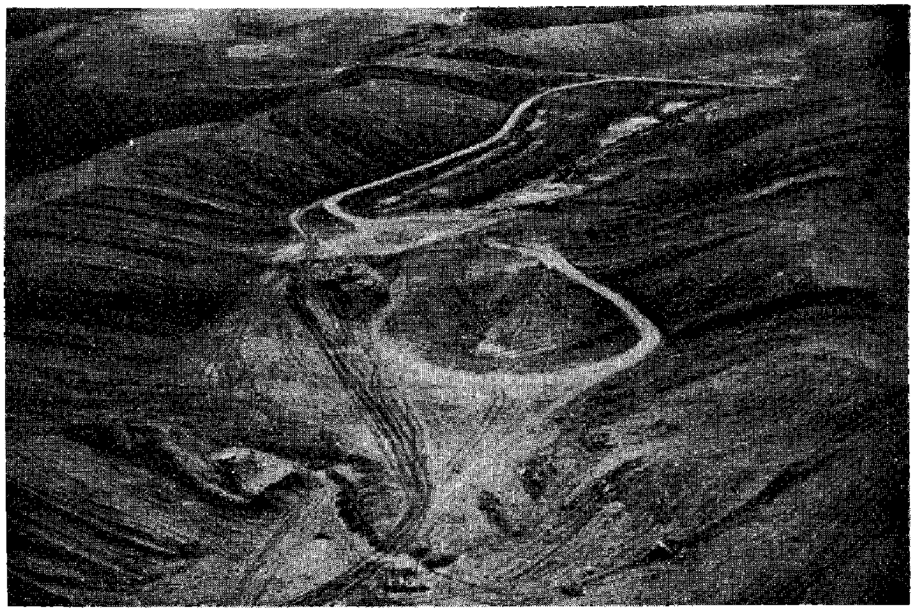
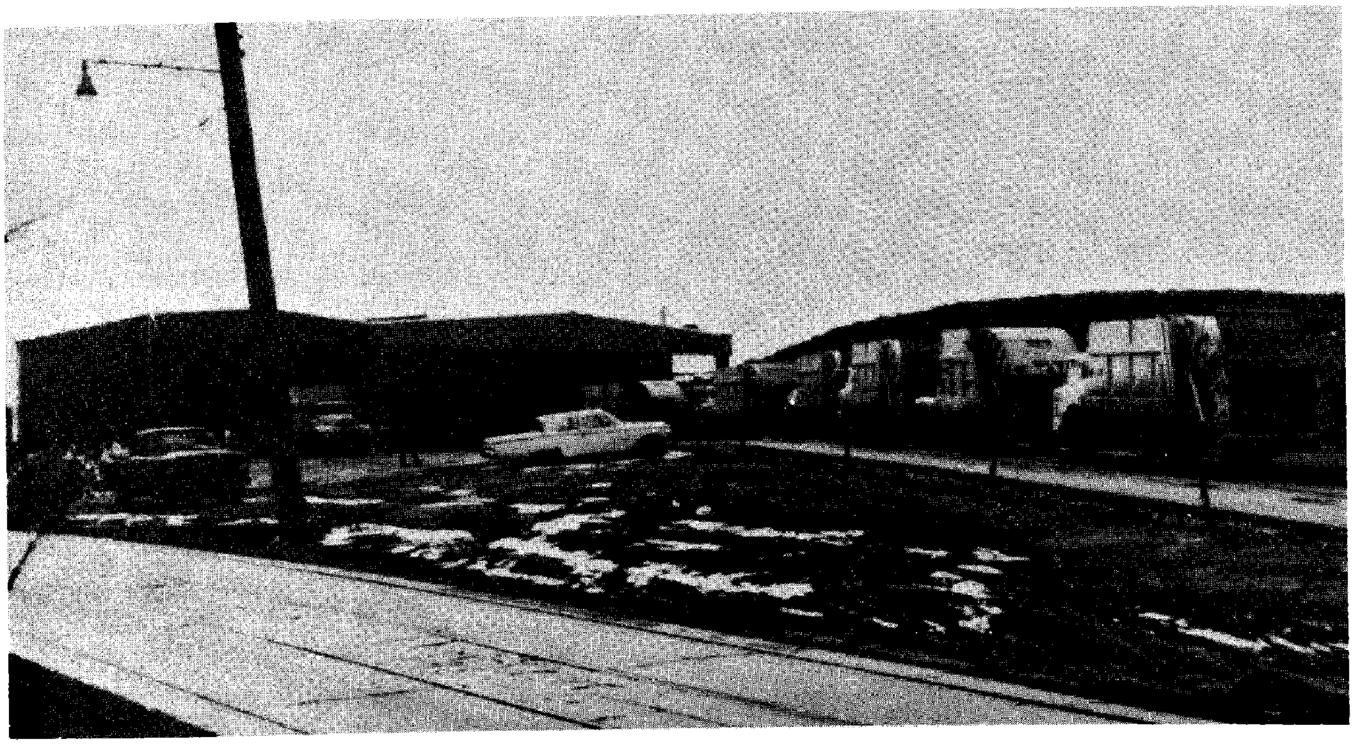


FIGURE 1. - Refuse Disposal Site in Strip Coal Mine, Allegheny County, Pa. Refuse is placed in a channel created by strip coal mining.

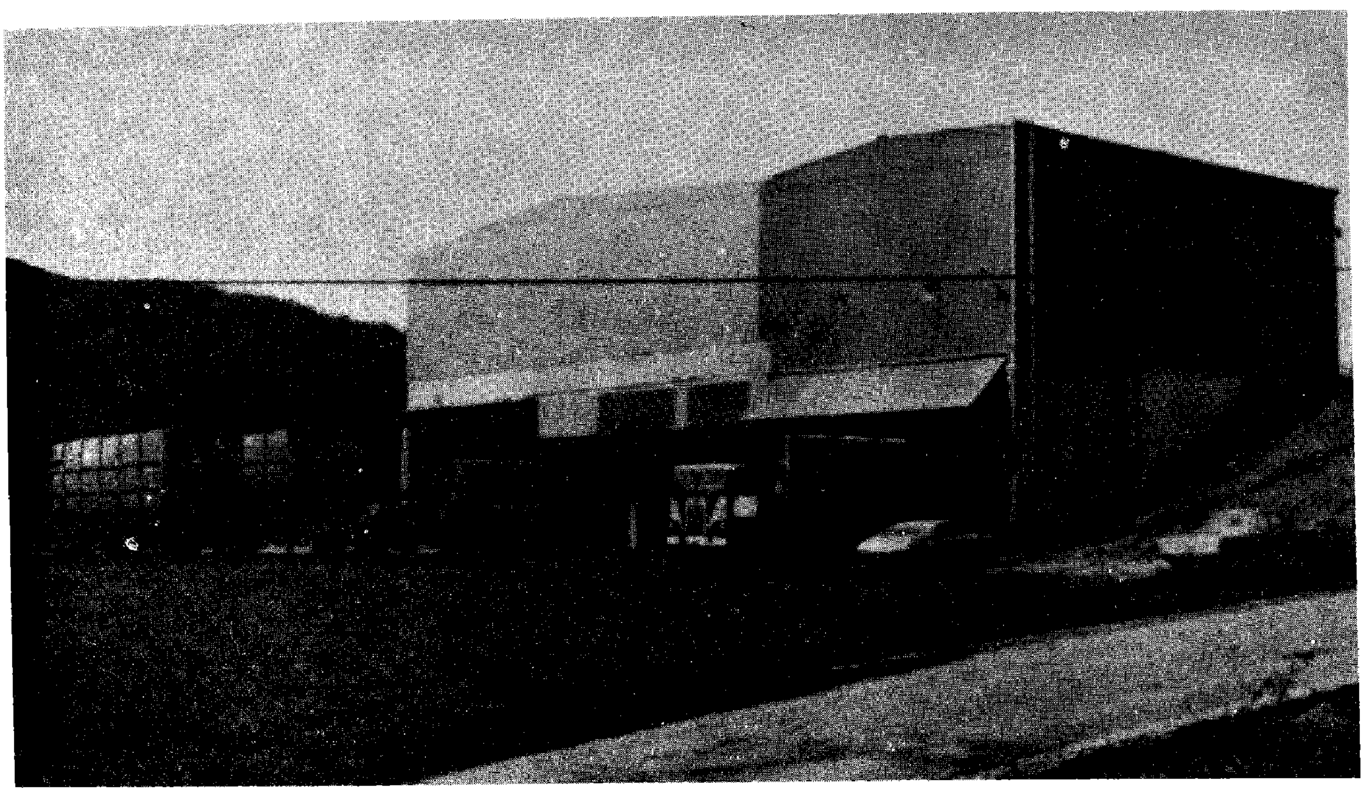
Twenty-ton enclosed trailer trucks are backed into the ram compartment outlet on the lower level. About 17 tons of trash are pressured into the truck body. The trucks are driven 12 miles to the strip coal mine landfill site where they are dumped (fig. 3). A bulldozer spreads and compacts the refuse to a depth of 8 feet. The refuse then is covered with 1 foot of soil. This procedure is employed until a specific area of the strip mine is filled. Some of the pits are filled to a depth of 160 feet. At this location 3,600 acres are to be mined in the future, and all have potential for landfill use.

Together, the transfer station and landfill operation employ about 10 men. Prior to disposing of all of the city's trash in this landfill, the city operated incinerators that required the services of 75 to 90 men. The capacity of refuse pickup trucks in Pittsburgh is about 5 tons. Without the benefit of the privately operated transfer station, the city would be required to operate about 14 trucks, in addition to the six trucks used currently, to haul 800 tons of refuse per day to the landfill site. This privately owned refuse disposal system has been in operation for more than 4 years. The owners claim that it could handle all refuse from Allegheny County.

In 1967 the Allegheny County Health Department applied for a Federal grant to construct and operate an 800-ton-per-day refuse disposal facility that would demonstrate the capabilities of, and incorporate, the following major components: a transfer station to receive all collected household refuse; a shredder capable of disintegrating tires, steel drums, appliances, and lumber; an air separation unit to salvage marketable materials; a high-pressure compaction unit that would feed the refuse into 20-ton transfer trailer assemblies; a pollution and noise control device; a centralized washing facility for cleaning; collection and transfer trucks; and a sanitary landfill located in a bituminous strip coal mine. The project was planned as the initial step in the development of a county-wide system. Based on the availability of worked-out strip coal mines in Allegheny County, and on the economies and favorable environmental effects associated with the operation of the existing privately operated transfer station system, it is reasonable to assume that the integrated system proposed by the county would also be technically and economically beneficial.

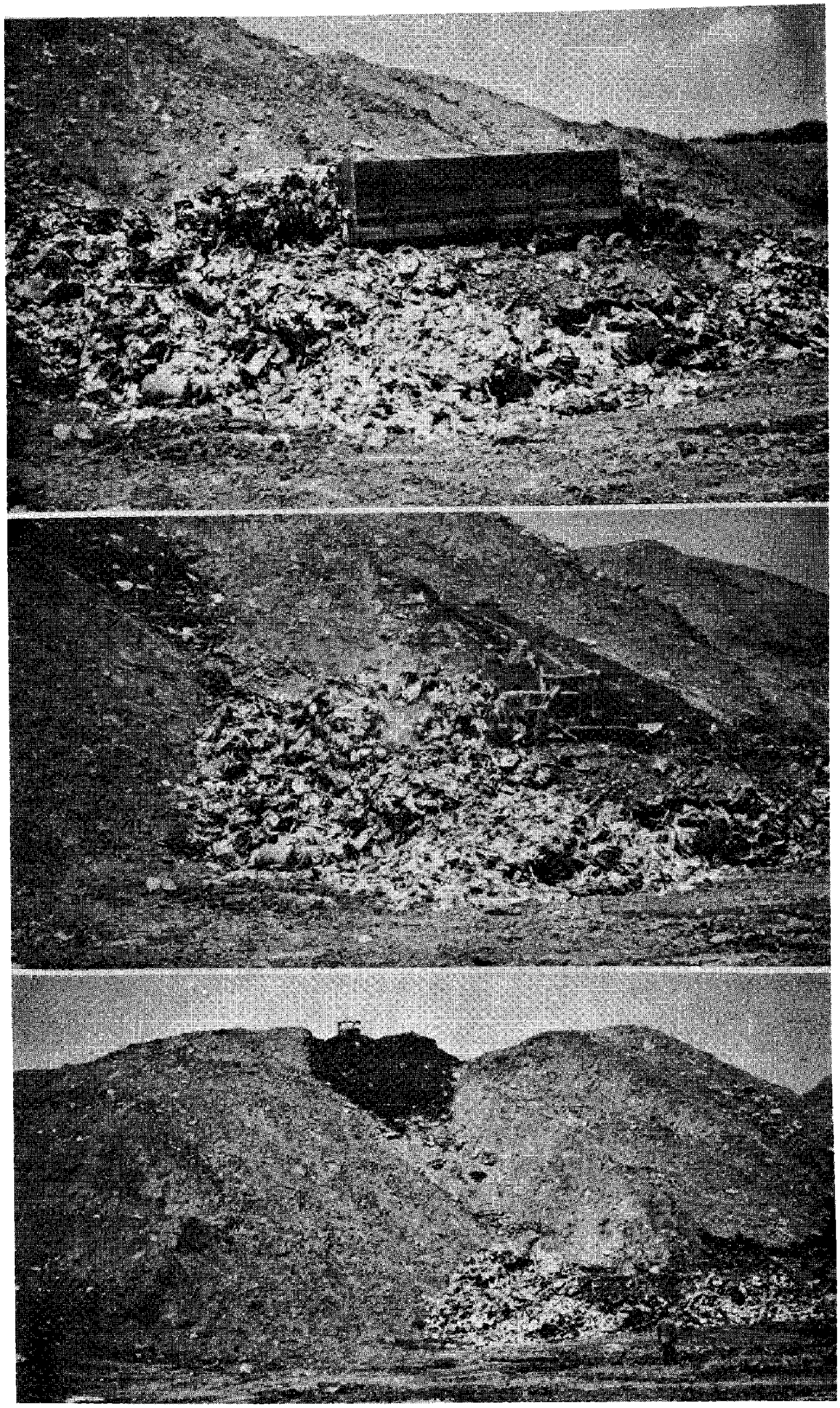


Upper side of station where refuse is discharged into transfer hoppers.



Lower side of station where compactor trailers receive refuse.

FIGURE 2. - Refuse Transfer Station, Allegheny County, Pa.



Refuse is pushed from trailer by a hydraulic ram.

A bulldozer spreads and compacts refuse after discharge from transfer trailers.

Bulldozer covers compacted refuse with soil bank material left over from strip mining.

FIGURE 3. - Landfill Operation in Strip Coal Mine, Allegheny County, Pa.

Frostburg, Md.: Abandoned Strip Mine

An abandoned strip coal mine pit, 1,900 feet long, 110 feet wide at the bottom and 500 feet wide at the top, and from 35 to 50 feet deep, was prepared to receive refuse on April 1, 1967 (14, 19). The refuse is accumulated from the city of Frostburg, Md. (population 16,000). The purpose of the landfill operation is to eventually eliminate haphazard and illegal dumping in 87 roadside dumps surrounding the city (fig. 4). After 1 year of operation, 24 of these dumps had been eliminated. Refuse is not collected by governmental agencies in many of the rural areas around Frostburg. People living in these areas usually haul their trash to the landfill. A receiving station is provided 24 hours a day to accommodate these individual haulers. Refuse received at the landfill is compacted and covered with earth at the end of each day's operation.

Three nearby wells were sampled for 8 months to test for pollutional effects of the landfill. Seepage from the toe of the fill and pollution of ground water were not detected during this period.

Estimates indicate that operational costs are $1.40 per person served and that 50 percent more refuse could be handled without increasing the unit cost. This would allow serving 24,000 people in place of the 16,000 now being served. About 9 acre-feet of land per year are utilized for each 10,000 people served.

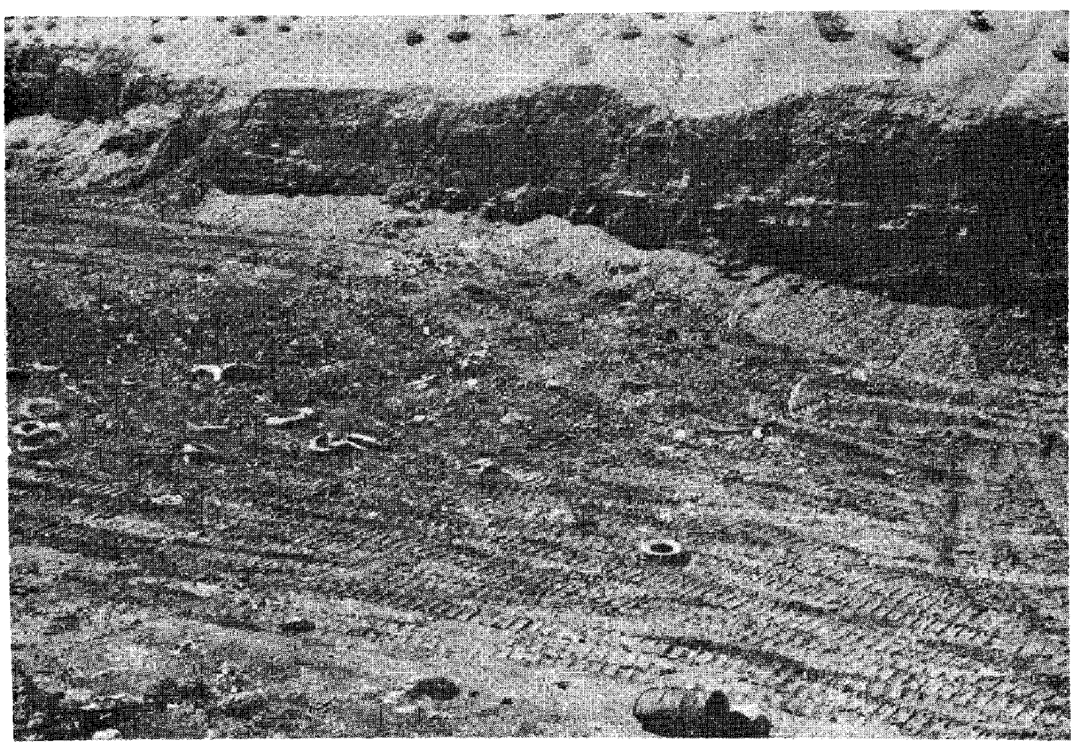
This project is not unique. However, it is clean and well managed. It appears to be operating without pollutional side effects and could well be expanded to handle the refuse from nearby Cumberland, which is operating an open-burning dump.

Westernport, Md.: Mine-Acid Test Cells

In June 1969, approximately 3 miles from Westernport, Md., a miniature landfill and testing system 100 feet long, 16 feet wide, and 6 feet deep was constructed to simulate an abandoned strip coal mine. The test system is adjacent to a stream of acid mine water having a pH of 3.4. The purpose of this project was to determine if acid mine water could be neutralized by community refuse placed in abandoned strip mines. Test cells (fig. 5) were filled with garbage, ashes, paper, plastics, sewage wastes, demolition waste, combustibles, and noncombustibles and compacted to 1,000 pounds per cubic yard. The system was designed to divert a portion of the 3.4-pH mine water over and through the test cells and to collect the effluent leaving the cells.

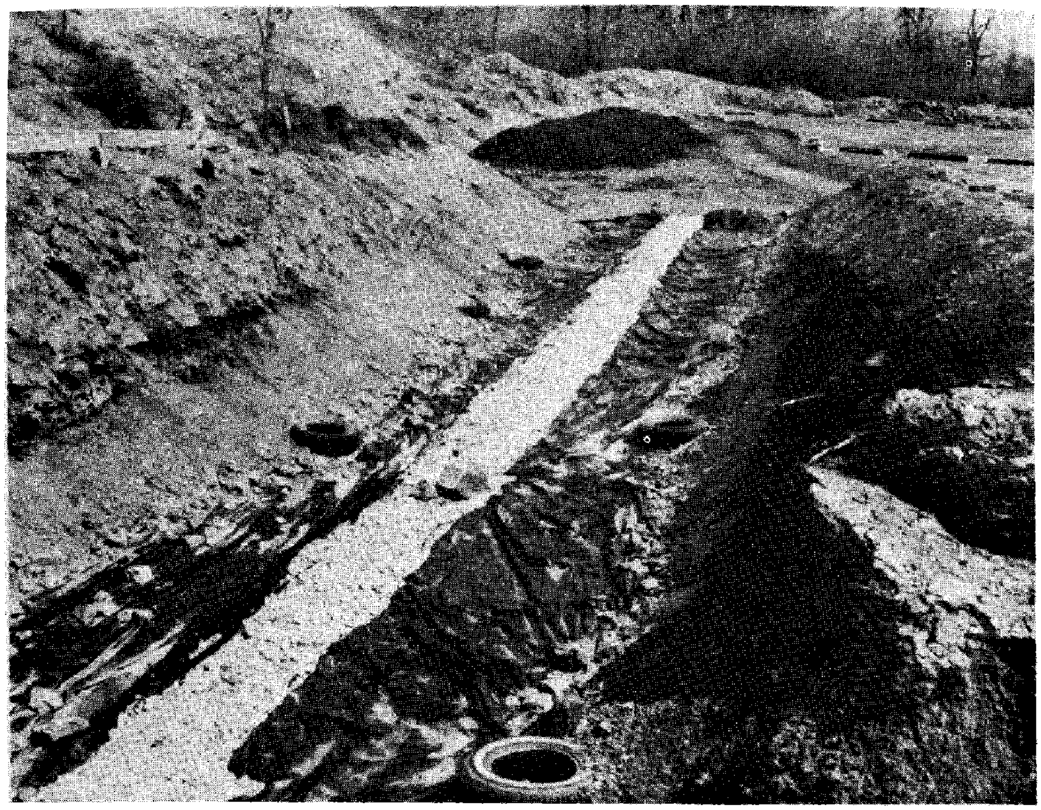
The program was discontinued after 3 months. The effect of raising the pH was very successful. (See fig. 6.) However, the adverse biological and biochemical effects that resulted from this treatment far outweighed the benefit of neutralizing the acid mine water. The biological and biochemical effects are reflected in figure 7, which shows that the 3.4-pH acidity of the stream increased to 5.8 after passing through the test cell. But, total solids increased from 3,586 to 12,032 ppm, turbidity increased from 78 to 1,500 ppm, oxygen content of the effluent was zero, and the BOD increased from 3 to 8,618 ppm.

Refuse is discharged from trucks into former strip mine.



Refuse is covered daily with fill material. Air trapped in tires causes them to work to the surface.

FIGURE 4. - Landfill Operation in Abandoned Strip Coal Mine Near Frostburg, Md.



Crushed stone was placed around a perforated pipe in the bottom of the test cell.

Acid mine water was introduced above refuse in test cell by a perforated pipe.

FIGURE 5. - Mine-Acid Test Cell Near Westernport, Md.

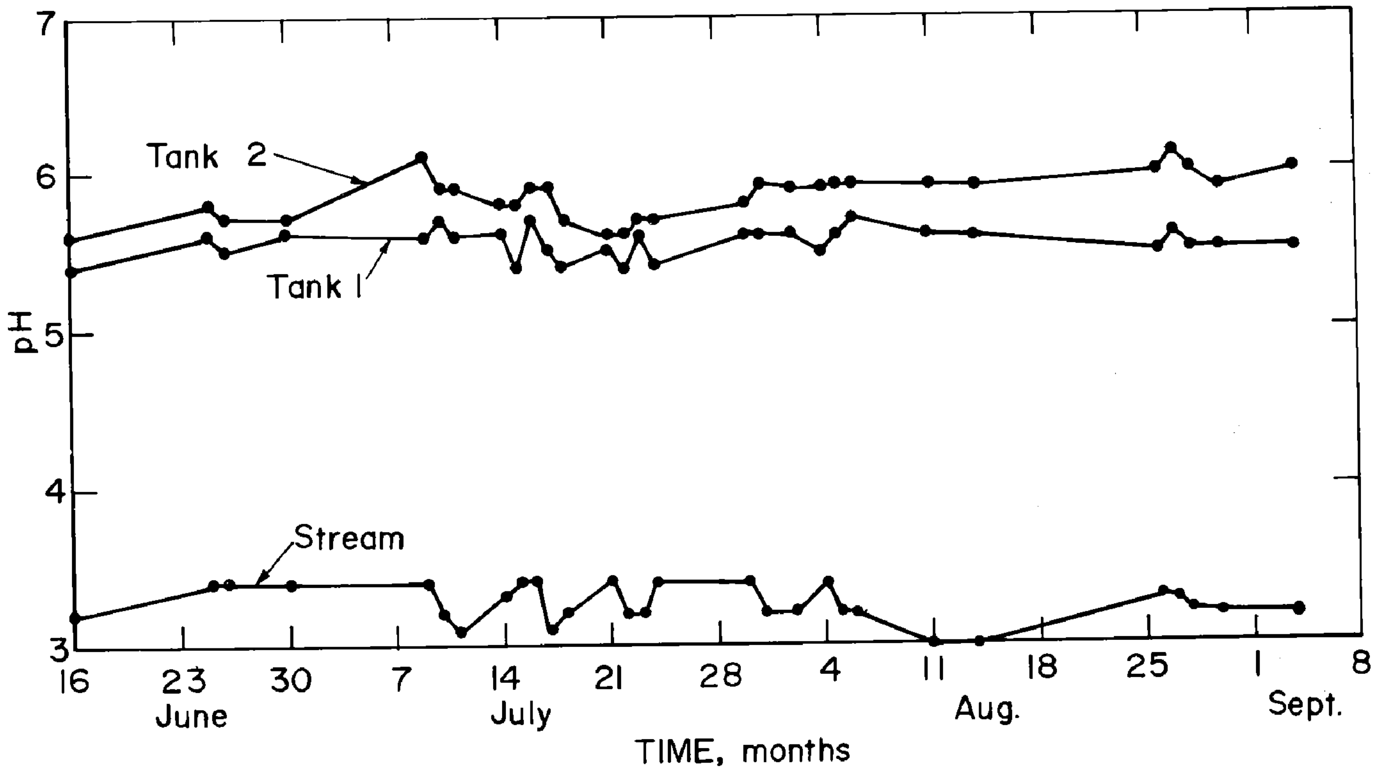


FIGURE 6. - Results of pH Test. Percolating acid mine water through household refuse significantly raised pH of the water, but adverse biological and biochemical effects offset the advantages of neutralization.

STATE OF MARYLAND

DEPARTMENT OF WATER RESOURCES

LABORATORY ANALYSIS REPORT

FILE TITLE: *Westernport Landfill*

COUNTY OR CITY: *Allegany*

DATE: *9 / 19 / 69*

Item	Sample		Time	Temp	pH	Code
1	*T369*	*Stream*				
2	*K 417*	*Filter Bed Effluent*				
3						
4						
5						

Analyses and Notations: *DO—BOD—pH—Min. Acid—Tot. Acid—Tot. Alk,—Sulfates ——Manganese—Hardness—Turbidity—Solids (SS, DS, TS)——*
Iron- HCl (glass bottle fixed with HCl)

Item	Suspended solids, ppm	Dissolved solids, ppm	Total solids, ppm	Turbidity, ppm	Dissolved oxygen, ppm	Biochemical oxygen demand 5 days/20°C, ppm	Color ppm	Laboratory pH	Mineral acidity, mg/l as $CaCO_3$	Total acidity, mg/l as $CaCO_3$	Total alkalinity, mg/l as $CaCO_3$	Sulfates, mg/l as SO_4	Manganese, mg/l as Mn	Iron, mg/l total Fe	Aluminum, mg/l Al	Hardness, mg/l as $CaCO_3$
1	22	3,564	3,586	78	1.40	3.0		3.40	54	523	0	2,000	23.2	50	16	2,100
2	229	11,803	12,032	1,500	0	8,618		5.80	0	1,600	5,400	225	0	40	34	5,100
3																
4																

FIGURE 7. - Comparative Analyses of Stream and Effluent Solutions.

King County, Wash.: In-Place Compactor

A landfill operation (fig. 8) at Cedar Hill, King County, Wash., is operated by the county (19) and was designed by Johnson-Campanella-Murkami and Company.[5] The company designed the transfer stations, the trailers for hauling refuse from the transfer stations to the landfill site, and the compactor used to emplace the refuse in predug trenches.

Refuse collected by the municipality and other contractors is hauled to one of seven transfer stations. Sixteen refuse trucks can be unloaded simultaneously at each transfer station. At the station the refuse is discharged into specially designed containers mounted on a 40-foot-long trailer. A modified backhoe machine is used to compact the refuse in the container prior to haulage to the landfill site.

The trailer was designed to carry two containers and is pulled by a tractor truck. The weight of material loaded into the containers varies with the type of material being loaded and amount of compaction effected by the backhoe. The normal load per container averages about 10 tons. Truck haulage from the transfer stations to the landfill ranges from 11 to 30 miles.

At the landfill site a modified Koehring shovel raises the containers from the trailer body. The shovel rotates through an arc of 180° and locates the container above a hopper in a high-density, in-place compacting machine known as "the mole." The trash is dumped into the hopper in the mole. After one load or more has been placed in the hopper, a large piston in the mole is activated which compacts and extrudes the trash through the rear end of the mole. A telescoping cover follows the movement of the piston.

The mole operates in a predug trench. It is pushed forward by the pressure exerted by the piston against the backwall of the trench; that is, as the compacted material is extruded by the piston, the mole is moved forward in the trench. A bulldozer is used to push loose fill dirt over the trash that has been extruded.

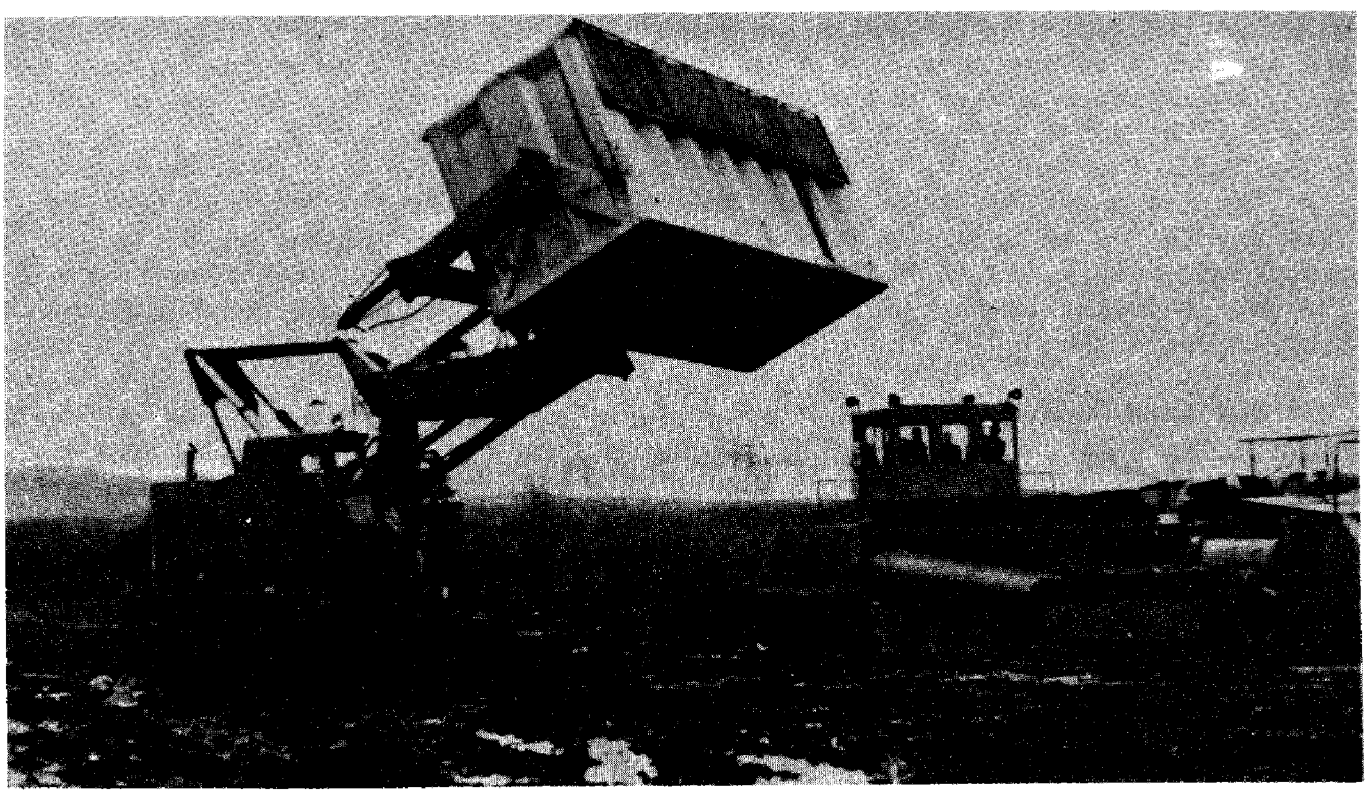
The trash containers hauled by the trailer measure 8 by 8-1/2 by 19 feet, and the trash is compacted during extrusion into a 7-foot square. Average compression ratios were given as approximately 10 to 1. The cost of the mole was estimated at $500,000 to $700,000. The main advantages of the King County operation are the use of well-designed transfer stations that do not disturb the metropolitan environment and extended use of available land because of the high degree of compaction of the refuse.

San Francisco, Calif.: Comparative Proposals

Efficient and effective refuse disposal in and around San Francisco is achieved by cooperation between private contractors and city and county

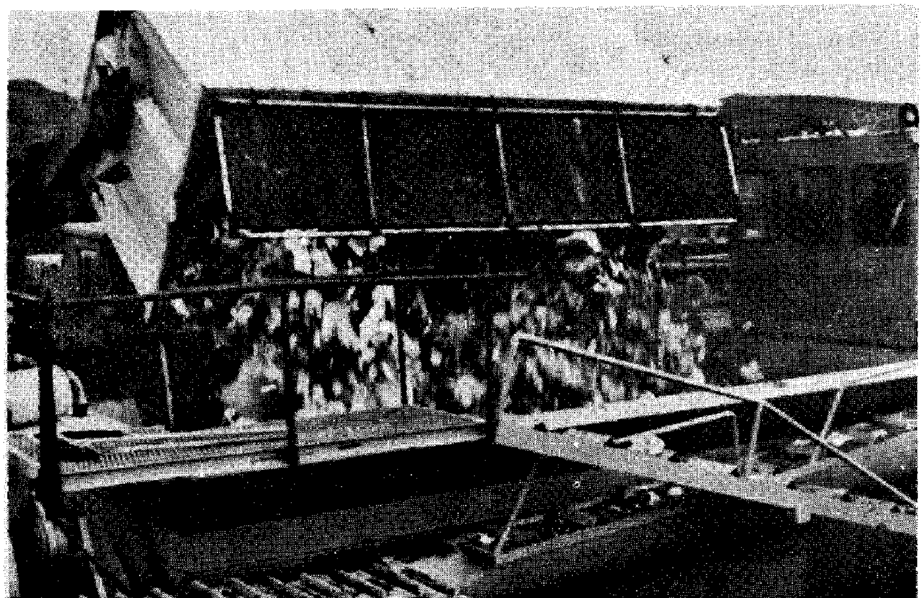
[5]Reference to specific companies, services, and products is made for identification only and does not imply endorsement by the Bureau of Mines.

Special trailer hauls two refuse containers from transfer station to landfill site. Modified power shovel removes containers from trailer.

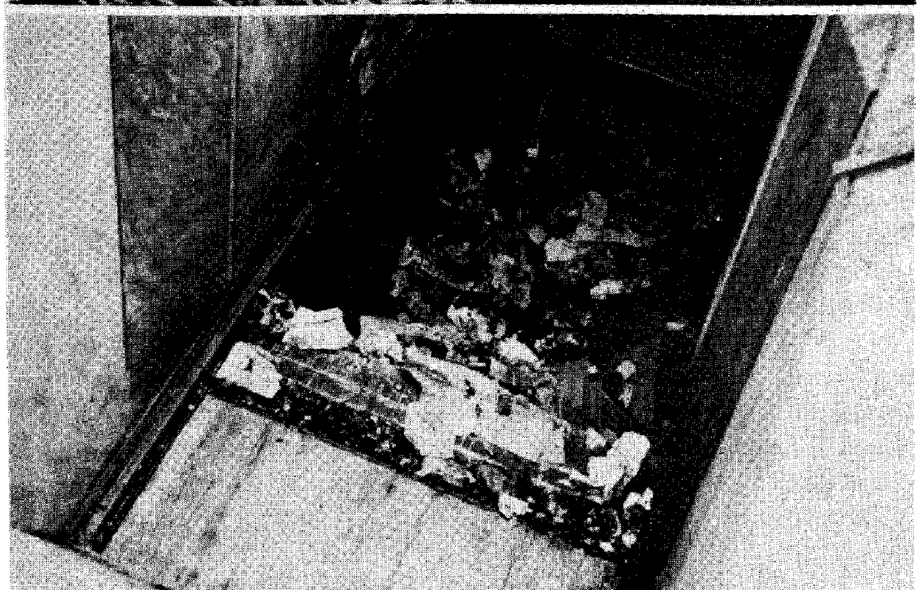


Refuse container is moved into position above hopper of compacting machine known as "the mole."

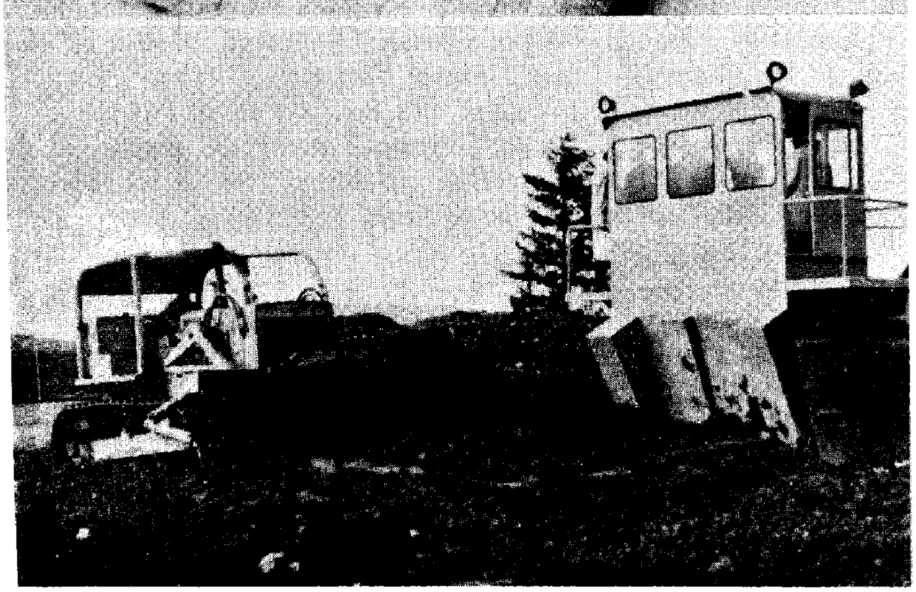
FIGURE 8. - Operation of Landfill Site, King County, Wash.



Refuse is discharged into hopper of compactor; cover prevents paper from being windblown.



A piston compresses refuse in the bottom of the hopper. A telescoping cover follows the piston.



A bulldozer pushes loose fill dirt over compacted refuse that has been extruded from the rear of the in-place compactor.

FIGURE 8. - Operation of Landfill Site, King County, Wash.—Continued.

governments. The San Francisco area has a Scavenger Rate Control Board to regulate service and rates.

In 1959, according to Leonard Stefanelli testifying before a subcommittee of the U.S. Senate Public Works Committee on March 31, 1970, private landfill contractors advised the city that existing landfill areas serving the high population density areas in San Francisco County would be filled by 1966. Subsequently, as a result of city and contractor planning and cooperation, some $2 million was invested by the contractor to build roadways, dikes, subfloors, and landfill facilities on 105 acres of tidelands situated in the city of Brisbane, just south of San Francisco. Beginning in 1966, 2,000 tons of refuse per day was transported in 700 loads to the Brisbane site, which serves five contiguous cities. The site is situated adjacent to a main freeway. It is landscaped, pollution controlled, seagull controlled, and all haulage routes and trucks are screened from traffic on the freeway.

An operating cost of $3.50 per ton was realized for all refuse delivered to the site. This cost is relatively low because it is a mass-production operation. There are economies of scale in disposing of refuse from five cities in one landfill site.

When this site began operation, the city of Brisbane applied for, and won, a court judgment against the landfill contractor to stop operations in 1972. Subsequently the contractor undertook studies to recommend alternate systems to handle the area's refuse after 1972.

First, a 2,000-ton-per-day, $16 million incinerator system was recommended. This system incorporates heat recovery units for steam production, which could be sold to a utility company. Support facilities prepare demolition waste and incinerator residue for burial at sea. The cost of operating this system would be $6.50 per ton.

The second proposal was to transport all refuse 375 miles by railroad to a desert in northeastern California. The railroad company planned to build a transfer, receiving, processing, and loading station in their San Francisco yards to handle all the refuse generated in the city and county of San Francisco. In 1969 the railroad presented a final proposal calling for a 10-year contract at about $10 per ton. This estimate was based on amortizing an investment of $6.5 million, borrowed at about 8 percent interest, in 10 years.

The third proposal was to construct and operate a transfer station-landfill project to handle the 2,500 tons per day of refuse from the city and county. The landfill was 32 miles from the city where 544 acres of lowlands would be filled and reclaimed as a park and golf course. Investment costs for this system would be about $2.5 million. The contractor would charge $6.50 per ton of refuse handled. The charge for this service would result in increasing the household refuse disposal rate from $1.85 to $2 per month. In conjunction with this operation full-scale metal-recovery facilities would be constructed.

It appears that the three systems are technically and economically feasible. There is no "best" system because each has its advantages and disadvantages.

The incinerator system would be relatively inexpensive at $6.50 per ton; volume reduction to less than 10 percent would eliminate hundreds of truck hauls per day. But, the feasibility of building an air pollution control system capable of meeting the county clean air standards at a reasonable cost is questionable.

The rail haulage system entails a large investment and operating cost, but it would provide landfill area to take care of the city and county refuse for a century or more with insignificant air and water pollution.

The transfer station-landfill system appears to be a reasonable investment. A $2 million facility cost would insure economical refuse disposal for the next century. Because of knowledge gained from the operation of the existing landfill project, the startup of the new system could be accomplished with minimum difficulty.

Santa Clara, Calif.: Accelerated Stabilization

In 1966 Ralph Stone & Company, Inc., of Los Angeles, Calif., initiated work on a project for the city of Santa Clara to determine the effects of accelerated decomposition on stabilization and volume decrease of community refuse in a landfill (18-19).

During 1967 refuse from an existing sanitary landfill was excavated and transferred to a newly constructed anaerobic cell. The refuse was compacted after each 1- to 2-foot layer was added. The cell was filled to a depth of 7 feet then covered with 2 feet of earth. The volume of refuse excavated from the existing sanitary landfill was 530 cubic yards. The volume of the compacted refuse in the new cell was 667 cubic yards, an expansion of 25.6 percent. Subsequently, an aerobic (oxidation) test cell and a residue test cell were constructed. The aerobic cell was then filled with collected househole refuse and compacted. Air was distributed through it for 90 days. The oxidized refuse was transferred to the residue cell where it was recompacted and covered. The volume reduction achieved following the 90-day aeration, transferal, and recompaction process averaged 25 percent more than the reduction achieved with the original 530-cubic-yard volume excavated from the existing sanitary landfill. The aerobic and residue cells and their operational sequence are illustrated in figure 9. Figure 10 schematically shows the aeration system, including an access manway for observing and measuring internal environment and collecting landfill samples. The illustration also shows the location of the test equipment for measuring temperature, humidity, moisture content, and settlement and for collecting gas and leach samples from the refuse. Laboratory tests showed that longer periods of aeration and the addition of water to the refuse would increase oxidation and compaction. However, it was necessary to control aeration so as to maintain an oxidizing temperature below 200° F, because one fire in the cell was started when temperatures reached 219° F. As a result of aeration most of the methane and carbon

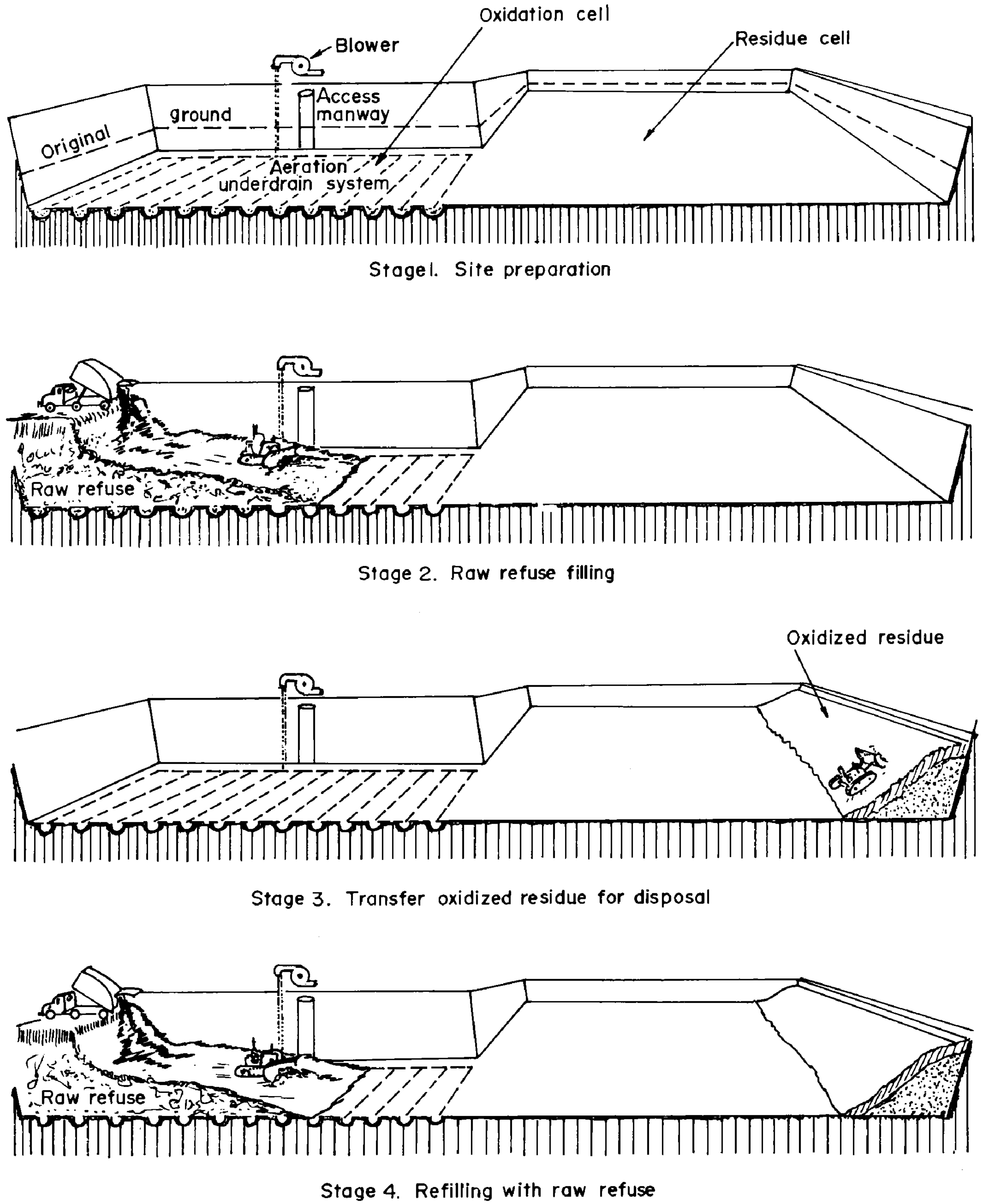


FIGURE 9. - Operational Sequence of Test Cells, Santa Clara, Calif.

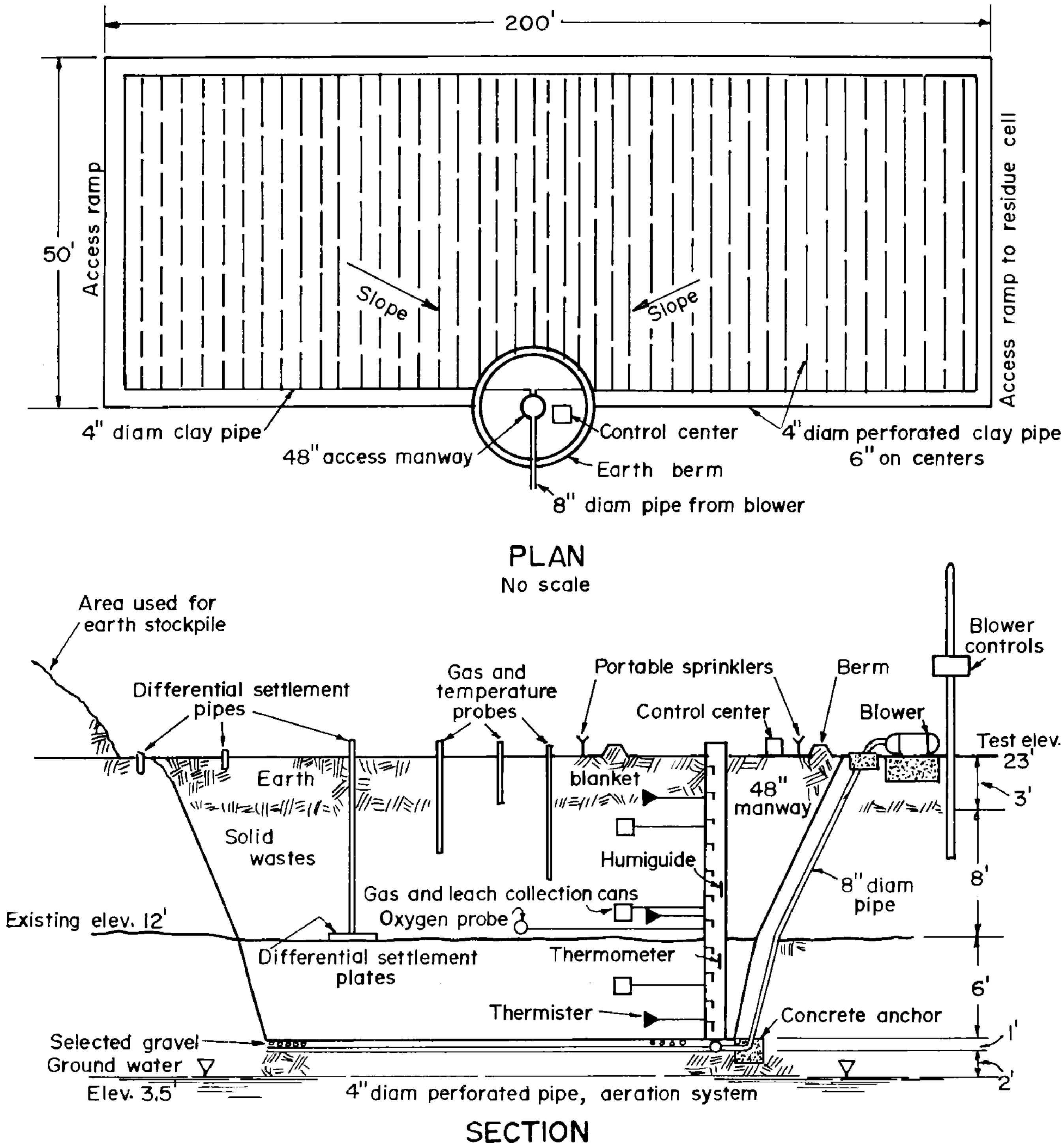
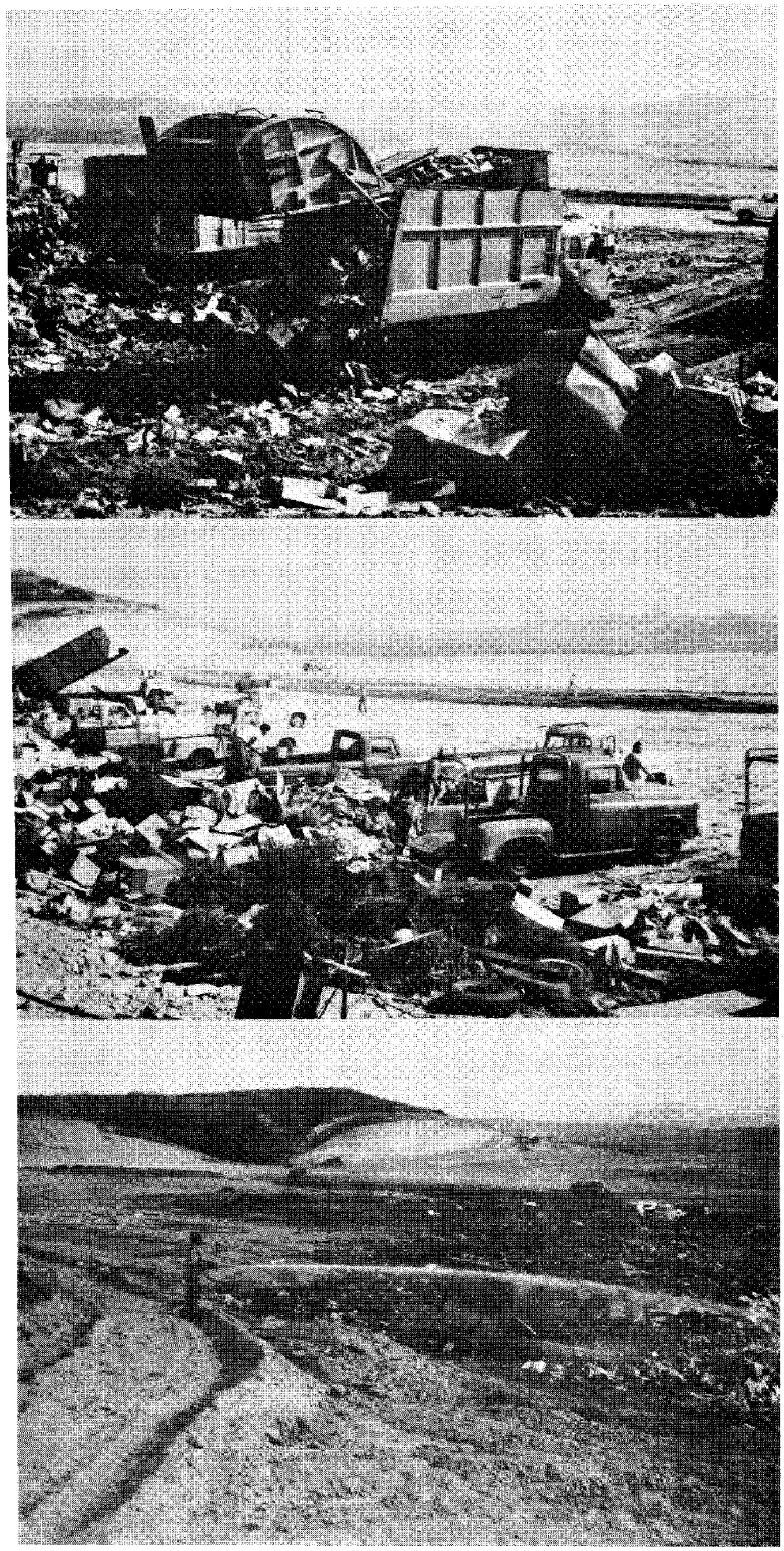


FIGURE 10. - Schematic Drawing of Aerated Test Cell, Santa Clara, Calif.

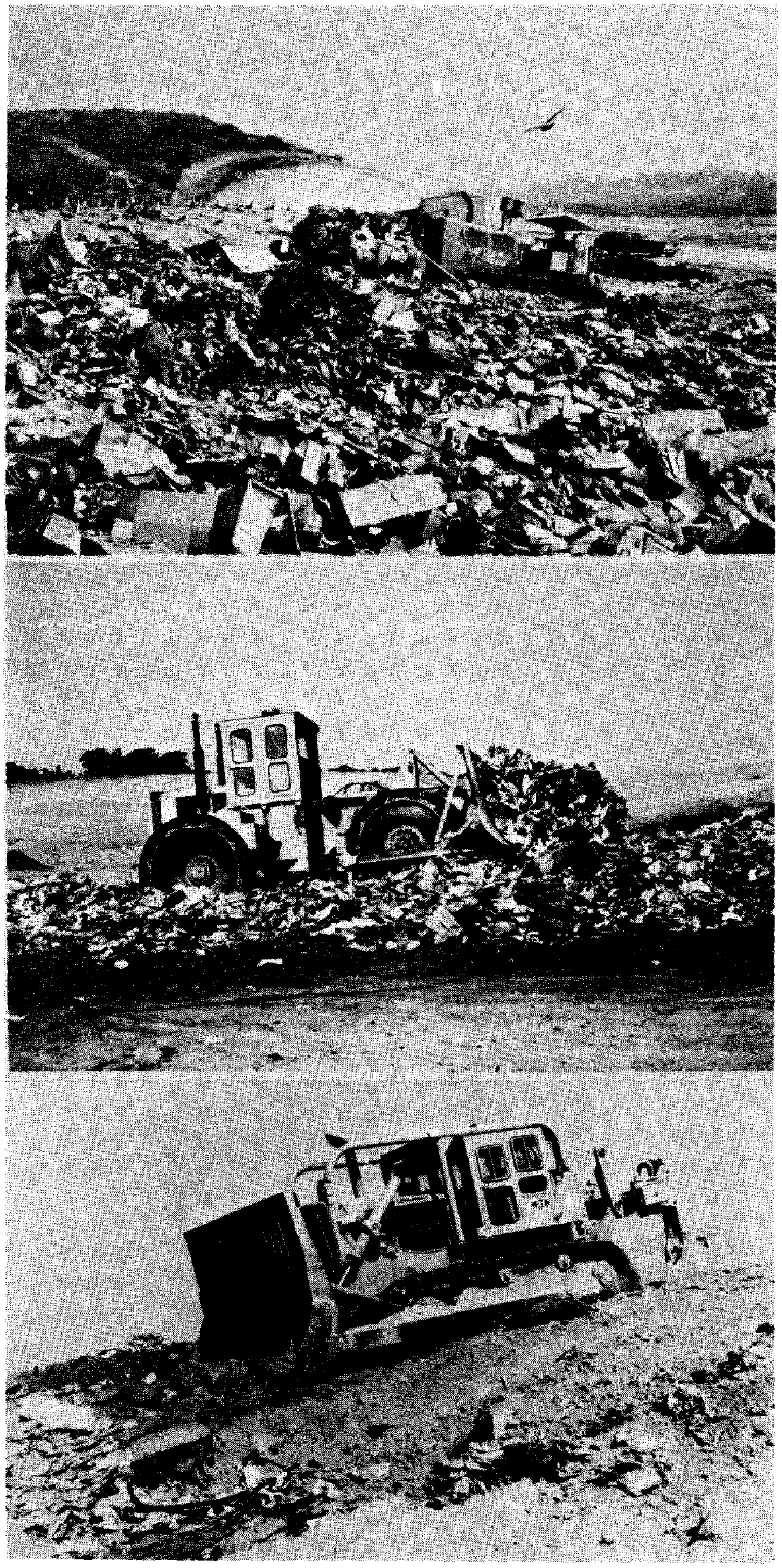


In San Diego, city packer trucks bring in about 40 percent of the refuse.

The remaining 60 percent is brought in by private citizens and commercial contractors.

Water is applied to the refuse to keep down dust and to increase compaction.

FIGURE 11. - Conventional Landfill Operation, San Diego, Calif.

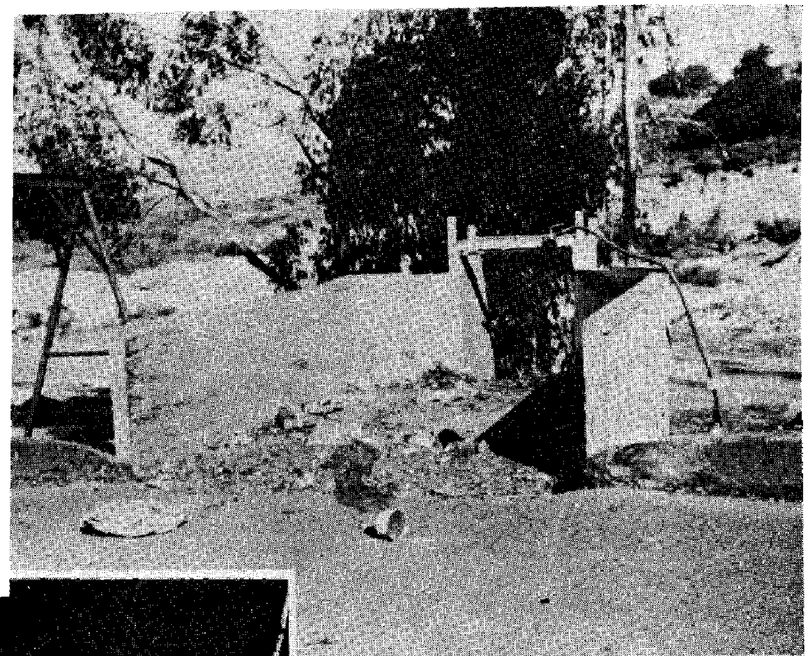


The refuse is spread and compacted by bulldozers . . .

. . . or by heavy compactors like this one.

The compacted refuse is covered with earth at the close of the day.

FIGURE 11. - Conventional Landfill Operation, San Diego, Calif.—Continued.

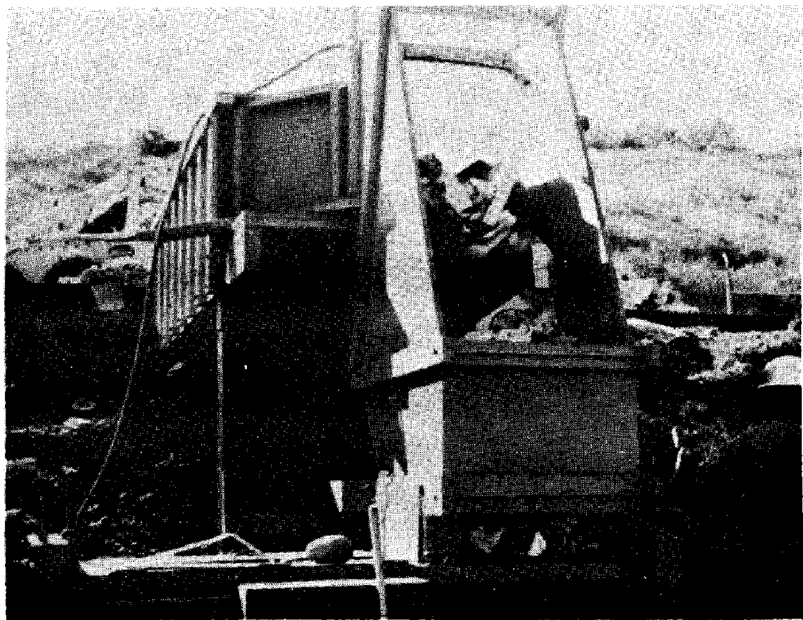


End view of upper ramp leading to baler hopper.

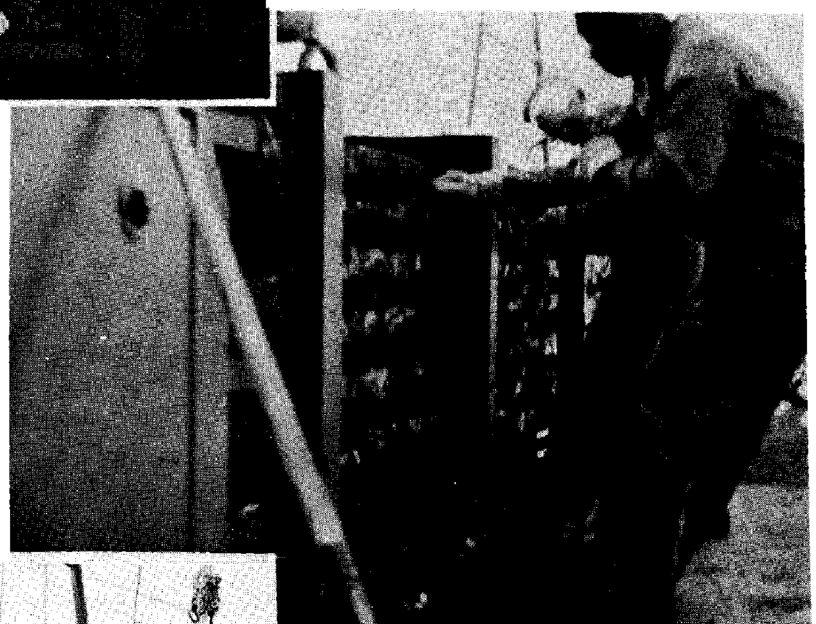
Refuse "bridging" at throat of chute has to be manually dislodged.

Water is applied to refuse as it enters chute.

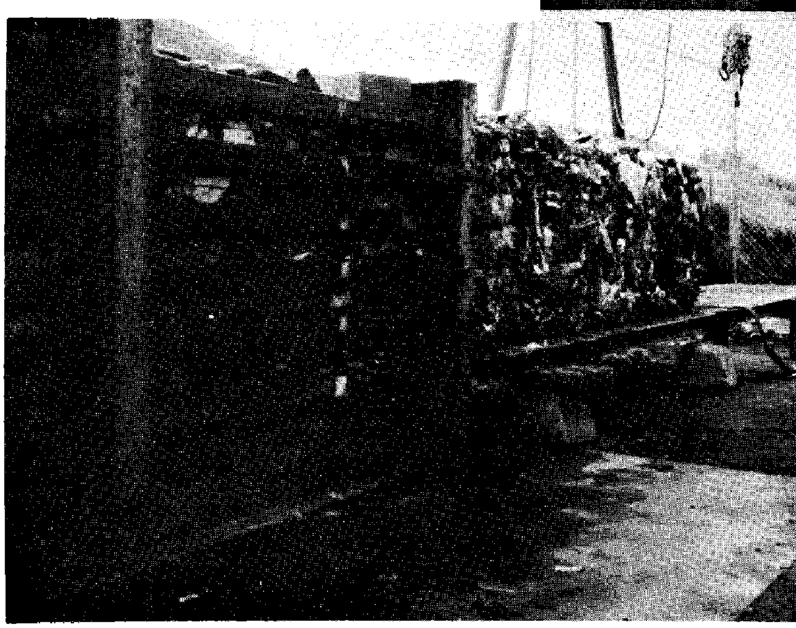
FIGURE 12. - Light-Duty Refuse Baler, San Diego, Calif.



Refuse descending chute into baler chamber.



Baling wires are tied manually.



Bales emerging from extension of baler chamber.

FIGURE 12. - Light-Duty Refuse Baler, San Diego, Calif.—Continued.

monoxide formed during decomposition was converted to carbon dioxide and water. Vermin and bacteria were eliminated by the high temperature in the cell and by oxidation of the putrescible waste components. It required about 6 weeks of oxidation to degrade cellulose by microbial activity. Noxious odors did not emanate from the aerobic residue during its transfer to the residue cell. The average organic content of the oxidized aerobic residue was about 20 percent less than that of raw refuse. Settlement of well-compacted anaerobic and aerobic residue cells was about the same--1 to 2 percent of their depth for the first year.

The total unit costs for disposal of solid wastes for the two systems are estimated as follows:

Landfill	Cost, dollars per ton
Aerated, well-compacted...........	2.46
Anaerobic, well-compacted..........	2.24

It appears that for an additional 22 cents per ton, the aerobic landfill system affords many social and environmental benefits, such as conservation of landfill space and elimination of water and air pollution.

San Diego, Calif.: Compacting and Baling of Refuse

San Diego's fleet of 72 packer trucks of closed-box design with rear-loading hoppers and two- and three-man work crews collects and disposes of about 0.5 million tons of household refuse per year at a cost of about $10.30 per ton, or $2.5 million per year. Disposal sites are located in natural canyons, and a conventional landfill method is employed--specifically, refuse is disposed at the base of the working face (fig. 11). Refuse is compacted by a bulldozer and a steel-lugged compactor. Water is added to the refuse to improve compaction. The bulldozer compacts the refuse to 1,231 pounds per cubic yard; the compactor compresses it to 1,383 pounds per cubic yard. The refuse is covered with earth at the close of the day.

Household refuse in San Diego for collection and disposal will increase 100 percent by 1985 to 1.0 million tons per year (15). Assuming a continuation of present practices and conditions, by 1985 the existing landfill sites and two other sites that are set aside for use will be filled. It is estimated that the costs of refuse collection and disposal will then be twice those of today.

Refuse baling by a light-duty baler and stacking at the site of a landfill are shown in figures 12 and 13. The baling test at the landfill site was conducted during January 1968 to determine the feasibility of baling raw refuse as it was received from the collection trucks (15-19). About 49 tons of city-collected refuse was processed into 140 bales with average densities of about 700 pounds per cubic yard. Each bale was tied manually with wire strands. Sixty-four of these bales were stacked three-high in a hillside shelf dug out for this purpose; then they were covered with earth.

A test with a heavy-duty baler, manufactured by the American Baler Company, was conducted at the company's plant in Bellevue, Ohio. Refuse from the city of Bellevue was shredded and baled into six bales having densities of about 1,500 pounds per cubic yard.

Densities obtained by the light-duty baler were not competitive with the compaction and volume reduction produced by the bulldozer and steel-lugged compactor presently used in the landfill operation. The densities of the bales obtained by the heavy-duty baler, compared with the compaction obtained using the bulldozer and steel-lugged compactor, appear to justify the investment in shredding and compacting equipment. The conservation in landfill space would be appreciable.

In an attempt to conserve landfill space, the city made studies of systems incorporating a conventional transfer station and a baling-transfer station. In the conventional transfer system the refuse is collected, hauled to a transfer station, and compacted in other trucks for hauling to the landfill. In the baling-transfer system the refuse would be taken to a transfer and baling station after pickup, baled, and then hauled to the landfill.

On the basis of landfill operating costs, San Diego's present method of watering, spreading, and compacting is $0.84 per ton. The estimated cost for the baling-transfer system would be $0.45 per ton. The difference in cost is due to a lower transportation and handling cost, a saving of about $35,500 a year, which could pay for the investment cost of the baling-transfer station in about 9 years.

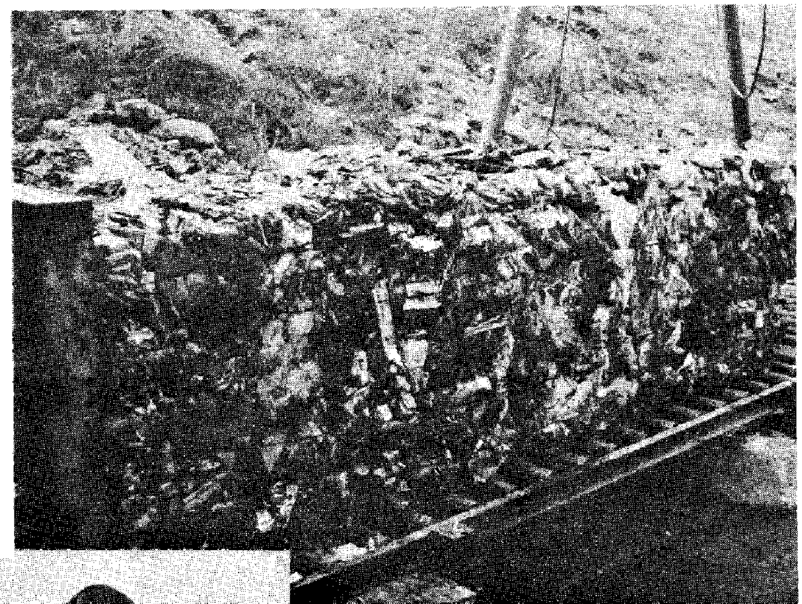
INCINERATION

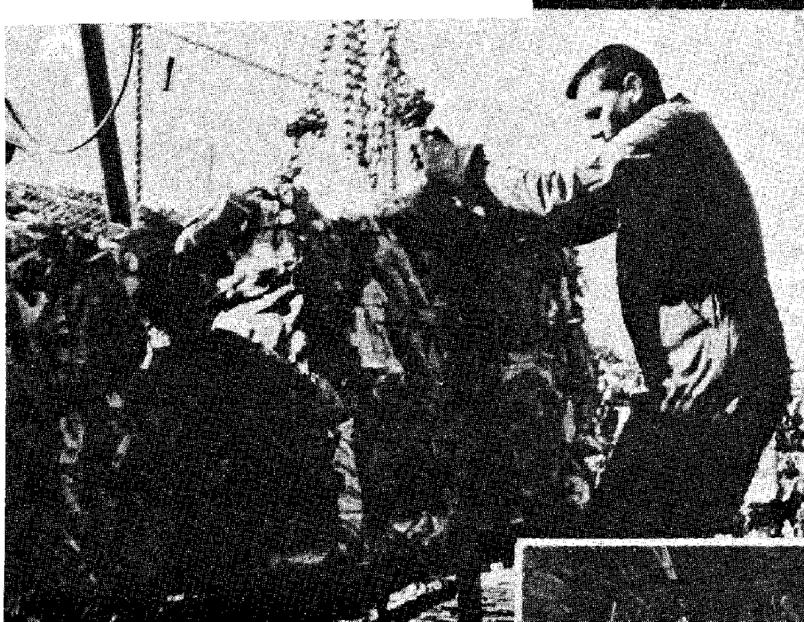
Incineration is the basic method for the reduction of municipal refuse to a minimum volume for disposal in landfills. The increased generation of per capita refuse and the decreasing land areas for burial of wastes favor the process. New principles and devices are being developed to improve incinerator art so as to reduce emissions of dust, odor, smoke, and water contaminants and to obtain sterile residue of minimum volume. It is generally accepted that the capital and operating costs of constructing and operating a sanitary landfill are much less than those incurred in the disposal of community wastes by incineration. However, since 1960 some cities, including New York, Baltimore, and New Orleans, have curtailed sanitary landfill refuse disposal in favor of incineration because of the unavailability of suitable land within economical haulage distances from collection points.

New Orleans, La.: Incineration Versus Landfill

A study prepared for the city of New Orleans in 1969 (17) by the firms of Albert Switzer & Associates, Inc., Baton Rouge, La., and Greenleaf/Telesca Engineers, Miami, Fla., compares sanitary landfill and incineration economics. The system that existed in the metropolitan area of New Orleans in 1968 prior to the study included five incinerators and two sanitary landfills. The purpose of the study was to determine if the addition of a sanitary landfill or

Bales are pushed along roller conveyor.





Hoisting bale from conveyor.

Bales are placed in dump truck for transportation to the fill.

FIGURE 13. - Handling and Disposal of Baled Refuse, San Diego, Calif.

Other bales are transferred directly from the truck to the fork lift.

Fork lift stacks the bales in the simulated fill.

Stacked bales are covered with earth.

FIGURE 13. - Handling and Disposal of Baled Refuse, San Diego, Calif.—Continued.

the enlargement of two existing incinerators would be the most efficient and economical method of increasing the refuse disposal capacity that would be required by 1973.

A land site capable of accepting 600 tons of refuse per day for 10 years and located within 11 miles of the five incinerators was selected as a basis for the landfill evaluation. Haulage costs were from the incinerators to the landfill. Collection costs were not considered.

Available land in this area is low and swampy. Construction of a landfill would require diking, draining, and pumping to maintain it in a dry condition acceptable for waste. The site would have to be maintained watertight after filling with waste to prevent leachate pollution.

The site preparation, spreading and compacting the waste, and compacting the cover material would cost 88 cents per ton of refuse handled. The cost of cover material using river bottom sand would be $1.70 per ton. Total cost of constructing and maintaining this modern sanitary landfill would be $2.58 per ton of refuse. Also, the system would require one transfer station at an operating cost of $1 per ton of refuse, and the haulage cost from the incinerators and transfer station would average $1.67 per ton handled. In sum, the addition of 600 tons per day of landfill capacity would result in a total disposal cost of $5.25 per ton.

Two incinerators were to be enlarged by 1973, with a combined additional capacity of 600 tons of refuse per day. Noncombustible waste would amount to 60 tons; the residue from incineration would be 97 tons. This would necessitate the hauling of 157 tons of residue and noncombustibles to the landfill. The cost of operating a transfer station and hauling 443 tons of refuse to the landfill would be eliminated.

The comparative costs of disposing of 600 tons of refuse in a landfill alone versus incineration plus landfill are shown in the following table:

	Landfill		Incineration	
	Tons	Total cost	Tons	Total cost
Transfer station	600	$600	-	-
Haulage from transfer station to landfill.	600	1,002	60 noncombustible 97 residue	$262
Landfill operation:				
Site preparation	600	228	60 noncombustible 97 residue	60
Spread and compact waste	600	180	60 noncombustible 97 residue	47
Spread and compact cover material	600	120	-	-
Cover material	600	1,020	-	-
Incinerator operation	600	-	540	1,890
Total	-	3,150	-	2,259

In this specific refuse disposal situation, a network of incinerators strategically placed in districts with high population densities would result in substantial savings. Total disposal costs for the landfill system would be $5.25 per ton compared to $3.75 per ton for the incineration plus landfill system.

Santa Clara, Calif.: Underground Incineration

One prospect for future waste disposal is the underground incineration of municipal and industrial solid wastes. A project conducted by Ralph Stone & Company, Inc., Los Angeles, Calif., involved the construction of a 65-foot-square, 8-foot-high incineration cell having an internal waste capacity of 118 cubic yards. The walls of the cell consist of a mixture of sandy loam and rubble in the shape of truncated pyramids. The cell is charged with refuse, which is then covered with 1 foot of earth. A flexible air-supported canvass cover is anchored over the cell (fig. 14). Air is supplied to the cell in amounts to support and control burning. The refuse is ignited by charcoal placed in pits in the refuse. The burning is maintained because the heat value of household refuse is about 5,000 Btu per pound, which is sufficient to support combustion. The process was tested twice between November 1969 and February 1970. Each burning cycle lasted about 20 days, and nearly 90-percent reduction in the volume of refuse was realized.

The gases that passed through and were filtered by the berm walls were not contaminated with carbon monoxide and carbon dioxide. Nitrogen and sulfur oxides were negligible. Odors were minimal, and no smoke emissions were observed. The residue consisted of fused metal and glass, and ash. The ash was inert, nontoxic, and almost completely soluble in water.

According to the designer, the capability of this process to handle all types of bulky and noncombustible wastes without prior processing at a cost of less than $3.28 per ton makes it a very attractive system. The construction of and equipment for a facility to incinerate about 100,000 tons of household refuse per year would be about $323,000.

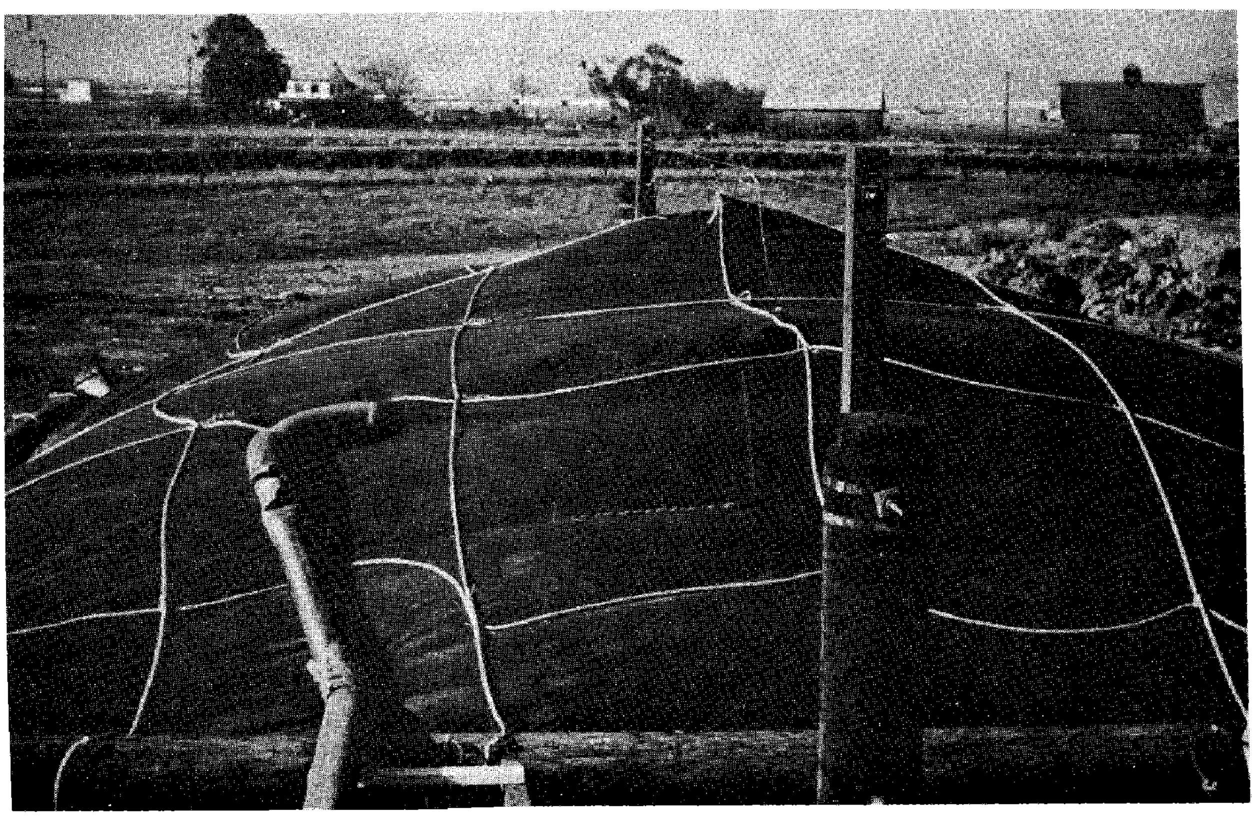
Resource Recovery

A major research effort of the Bureau of Mines is directed at the recovery and utilization of byproducts from community refuse and incinerator residues (3, 5, 12, 16). One investigation (3) was limited to the recovery of metals and minerals contained in the incinerator residues of six cities having historical and current salvage operations.

About 7 million tons of steel annually is converted to metal packaging material, and about 28 percent of household waste is made up of tinned containers on a dry-weight basis. However, except in the mining industry, market outlets for the ferrous metal contained in incinerator residue are nonexistent.

Glass comprises about 44 percent of incinerator residue by weight. The demand for cullet (broken and waste glass), which is added to new material to facilitate melting in the making of glass, exceeds the supply because the

Test cell is covered with canvass that is tied down to wooden planks around the top edge of the cell.



Flexible hose from airblower to test cell delivers enough air to support and control burning.

FIGURE 14. - Underground Incineration Test Cell, Santa Clara, Calif.

collecting and processing by cullet dealers is not too profitable. There are few suppliers, and until a more economical process for cullet recovery is designed, the glass industry will be in short supply.

Atlanta, Ga., one of the six cities studied, has a refuse incineration capacity of 1,450 tons per day. Tin cans recovered and processed from incineration amounted to about 5,900 tons in 1968. The remaining residue, including fly ash and grit recovered from spray chambers and quenching water, is used for cover material on sanitary landfills. The direct operating cost to process and prepare 1 ton of tin cans for shipment was about $8; the capital amortization costs were about $3. The product selling price is about $11.50. The $0.50 appreciation makes the operation unattractive.

In Baltimore, Cincinnati, Los Angeles, Milwaukee, and New Orleans, the other five cities studied, no marketable items are presently salvaged from refuse or incinerator residue. In all but one of these cities, the recovery and sale of tin and glass cullet has been conducted, but the trend away from salvage has been influenced by economic considerations and the absence of market outlets. In three of these cities, there is a marked trend in favor of mixing household refuse for reasons of convenience and collection economy. The greatest single problem related to incinerator residue salvage is the absence of sufficient outlets for items of ferrous metal and glass. These items are estimated to account for about 75 to 80 percent by weight of the average incinerator residue.

SUMMARY

A privately owned refuse disposal system incorporating a transfer station, refuse hauling equipment, and disposal in an abandoned strip coal mine currently handles 700 to 800 tons per day of refuse collected in the city of Pittsburgh, Pa. A similar disposal system is currently under consideration for all of Allegheny County, Pa., as a result of the economies and the favorable environmental effects associated with the existing system, coupled with the availability of numerous abandoned strip mines in the county.

The operation of an abandoned strip coal mine in Frostburg, Md., resulted in the elimination of 24 of 87 open dumps in 1 year. This project is an example of a sanitary landfill operated without high user cost and adverse environmental effects.

Acid mine water percolated through household refuse in test cells simulating abandoned strip coal mines increased the pH of the water from 3.4 to 5.8. However, accompanying adverse biological and biochemical effects offset the advantages of the neutralization of the acid mine water.

A landfill operation at Cedar Hill, King County, Wash., features a high-density compacting machine that compacts and extrudes refuse into a predug trench. This disposal system minimizes truck hauls and handling and covering time at the landfill site, conserves land use, and minimizes pollution from refuse as a result of high-density compaction.

Three alternate systems to dispose of refuse collected in San Francisco and vicinity appear to be technically and economically feasible. An incineration system would reduce land use requirements; however, although it would be relatively inexpensive to operate, the capability of meeting county clean air standards at a reasonable cost is questionable. A 375-mile rail haulage system would require a larger investment and operating cost. Landfill area for disposal of refuse without significant air and water pollution would be available for a long period of time. A transfer station-landfill system would insure economical refuse disposal for the next century and could be accomplished with minimum difficulty.

A solid wastes landfill stabilization project conducted by Ralph Stone & Company, Inc., engineers for the city of Santa Clara, Calif., proved that aeration of sanitary landfills provides more rapid stabilization, greater refuse density following compaction, the conservation of landfill space, and elimination of vermin and bacteria by high-temperature oxidation.

Densities obtained by the city of San Diego, Calif., in testing a light-duty refuse baler were not as great as those obtained during compaction of refuse by bulldozers and other wheeled compactors. However, densities obtained by using a heavy-duty baler were substantially greater and appear to justify the investment in shredding and compacting equipment required for the baling of refuse.

A study prepared for the city of New Orleans showed that the addition of incinerator capacity in lieu of the construction and operation of sanitary landfill capacity would be the most efficient and least costly method of disposing of the accumulation of refuse.

An underground incineration project conducted by Ralph Stone & Company, Inc., for the city of Santa Clara, Calif., proved that a 90-percent reduction in the volume of refuse and elimination of noxious gases could be effected.

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