Sanitary Landfills in Northern States

— *A Report on the Mandan, North Dakota, Project* —

By RALPH J. VAN DERWERKER, B.S.

Of 135 North Dakota municipalities surveyed in 1947–48, only three used incinerators for refuse disposal, and three others relied on the open-face dump type of sanitary landfill. The open dump was the only answer to the problem in 129 communities.

Seeking a sanitary solution to the refuse disposal problem, the North Dakota State Department of Health invited the Public Health Service to participate in a study of the use of landfill techniques for small cities and towns in cold climates. The city of Mandan, which has a population of 7,298 (1950 census) and where winter temperatures of $-30°$ to $-35°$ F. are not uncommon, was selected for an experimental landfill project. In the spring of 1949 the project got under way.

By agreement, the city paid for an equipment operator and other costs, in addition to providing the site. The State was responsible for office and travel expenses. The Public Health Service obtained the necessary heavy equipment and assigned a sanitary engineer to take charge of the project.

Mr. Van Derwerker is the chief of the municipal and rural branch of the division of sanitation, Bureau of State Services, Public Health Service. This paper, a review of the operation of the Mandan project, is based on progress reports made by the project engineers, Leo Weaver and Donald M. Keagy, division of sanitation, Public Health Service. A detailed technical report of the experiment is being prepared for publication.

When the official participation of the Public Health Service ended with completion of the first year of operation, sufficient data had been accumulated to show that the sanitary landfill satisfactorily and economically could solve the problem of refuse disposal for northern communities. However, at the beginning of the second year, another Public Health Service sanitary engineer was assigned to the project to continue gathering data for another year.

Site Selection

The choice of landfill sites narrowed down to two: One included some 20 acres of land located a little over 1 mile from the main street; the other was an open-face dump operated by the city on low, submarginal land which filling would make usable. The latter, however, was close to the center of town, and because of the experimental nature of the project the city commissioners favored the out-of-town site. The Public Health Service engineer approved of the out-of-town site because it was particularly well-suited for the trench-type of landfill and thus would have more demonstration value for other communities.

The selected site was elevated considerably above the surrounding terrain, well exposed to the high winds prevailing in the area. It had a 2.5 percent slope at the southern end, rising gradually to 6 percent at the north. There was a shallow ravine in the east-central portion,

and a deep coulee on the northeastern end. Excellent drainage existed. Soil analysis showed 64.2 percent sand, 13.5 percent silt, and 22.3 percent clay.

It was decided to construct the fill in the form of a wide **U** so that refuse could always be dumped with, instead of into, the wind. A topographical map facilitated accurate planning with respect to grades, size of fill site, and other work. The fill when completed would be a uniformly sloping field with excellent drainage.

Operation

The first trench was excavated in June 1949. The original trench width of 1½ times the width of the tractor was increased later to 2½ times (or about 17 feet) to permit more maneuverability for backing the collection truck into the trench in order to protect the refuse from high winds. Experience shows that too wide a trench, however, reduces efficient operation, since too much cover material is required each evening.

The usually recommended trench depth for a sanitary landfill is about 3 feet for a one-level fill. The average depth at Mandan, however, was 6 feet in order to provide extra protection from the high winds and additional dirt for a two-level fill. The extra depth encouraged careful dumping by individuals, after hours, since they seem to prefer to throw refuse into an excavation rather than on the surface.

The two-level operation proceeded as follows: First, the refuse was placed in the trench and compacted to 5 or 6 feet (fig. 1). Then,

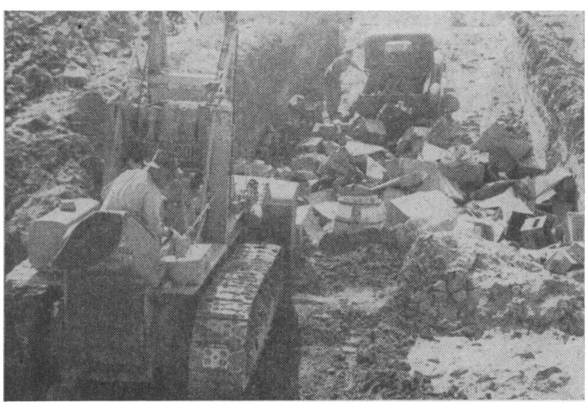

Figure 1. Construction of first level of fill.

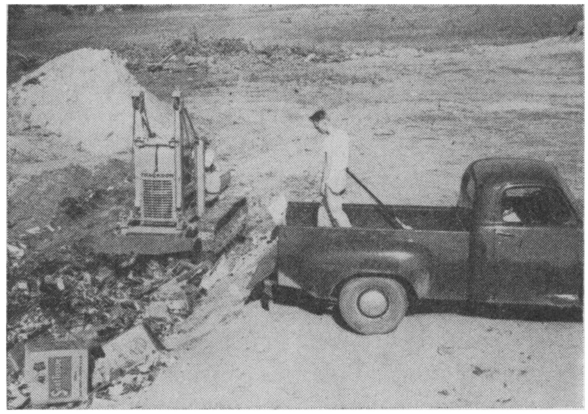

Figure 2. Construction of second level of fill.

it was covered with 9 to 12 inches of dirt. When enough area on the first level had been built up to permit free operation of the tractor and dumping vehicles, the second level was started (fig. 2). This type of operation made it possible to use the lower level when strong winds were blowing, and the upper level during periods of calm. Cover material for the upper layer was obtained by excavating the next trench to be used at the lower level.

Experimentation with various depths of cover material indicated that 2 feet of cover under average conditions will result in not less than 1 foot at all points, which is sufficient for sanitary purposes. Approximately 5,518 cubic yards of earth were dug and used for cover during the first year of operation. This gives a volume rate of 4.7 acre feet per 10,000 population, as against a generally accepted rate of 6 acre feet per 10,000. The reasons for the lower rate at Mandan were, probably, that the quantity of domestic ashes was small, due to the extensive use of natural gas, and that Mandan does not produce the large amounts of solid, industrial wastes common to many other towns.

It was essential to guard against mixing too much dirt with the refuse. Otherwise, the available cover material is too rapidly depleted, and the trench becomes deeper than is desirable.

Controls Necessary

Operations were impaired at first by the absence of regulations establishing daily hours for dumping. The fill was left each evening in neat and orderly condition, and the records

show that no fires ever started in completed cells. However, material dumped indiscriminately during nights and week ends caused fires and created public health and nuisance hazards, which made it necessary to establish and enforce strict dumping hours.

The city collected refuse from the residential areas on a fee basis, but business establishments either hauled their own or contracted with private haulers. Some difficulty was encountered in trying to get the latter to dump at specified points. This was overcome gradually through the encouragement of community support by means of an active public relations program, principally by means of articles in the local newspapers. The operator-foreman was very helpful, also, in patiently explaining the operation to all visitors.

Paper and Fire

Windblown paper constituted a serious nuisance, even though the problem had been anticipated. The erection of a windrow, the two-level design, the depth of trenches, and the U-shape of the fill, all had been planned to counteract the effect of high winds. In addition, a 4-foot chicken-wire fence was erected, but it was not particularly effective in overcoming the problem. Subsequently, the problem was solved by the use of snow fences.

The paper collected from the residential areas was well mixed with garbage, and was not much affected by the wind, but refuse from the business district was mostly paper and created a greater problem.

Fires seldom, if ever, occur in properly compacted and covered refuse, but they may occur in material deposited during the day or when the operator is off duty. Hot ashes may smoulder unnoticed, and suddenly burst into flame; refuse compacted in a truck may blaze suddenly when dumped and exposed to air. Daytime fires can be extinguished quickly by covering and compacting. Trucks carrying smouldering material were also unloaded at the unused end of the trench, or in another trench.

Vermin

Daily compaction and covering of the refuse seemed to eliminate any fly-breeding or rat-breeding problem. Flies, however, followed each truck during hot weather and were drawn to bits of garbage adhering to the tractor, necessitating the spraying of the tractor with DDT in order to protect the operator. On larger projects, it may be necessary to make scheduled use of insecticides on the truck bodies and over the site.

Preparation for Winter

Original plans called for the preparation of a trench 300 feet long, 6 feet deep, and 22 feet wide, to be prepared and placed in reserve for winter operations. However, because of the limited data available on volume of refuse, it was later decided to dig a second reserve trench, which measured 100 feet in length, 25 feet in width, and 6 feet in depth.

The second reserve trench actually had to be put in use early in March 1950. The continuance of winter operations was insured by this foresightedness. Refuse delivered to the fill in February averaged 69 yards per working day, or a total of 1,656 yards. Experience showed that a reduction of 65 to 75 percent could be obtained through compaction.

To provide cover material for the time when it would be too cold to dig, about 700 cubic yards of dirt from trenches dug in the fall was stockpiled as close to the working area as possible. The practical distance for a stockpile seems to be up to 100 feet from a trench. Probably a limit of 50 feet should be set when a crawler tractor is used.

The stockpiles were built with their axes parallel to the prevailing northwest winds to keep them comparatively free of snow, and their sides were sloped steeply to shed rain. With a moisture content at excavation time of 9.2 percent, and of 4.9 percent when sampled from the stockpile in January, lumping never became a serious problem when moving earth from the pile for cover.

Winter Operation

Over 72 inches of snow fell up to April 1—more than ever before recorded; and more fell during April. On recommendation of the State highway department, however, snow

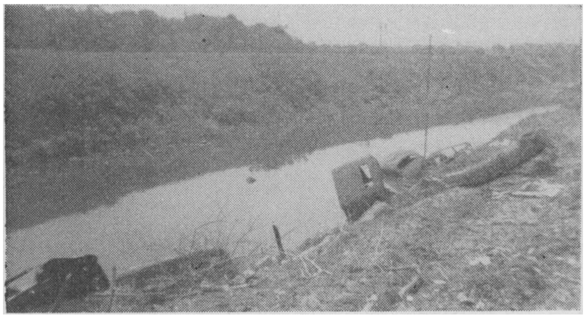

Figure 3. Old dump area prior to landfill operations.

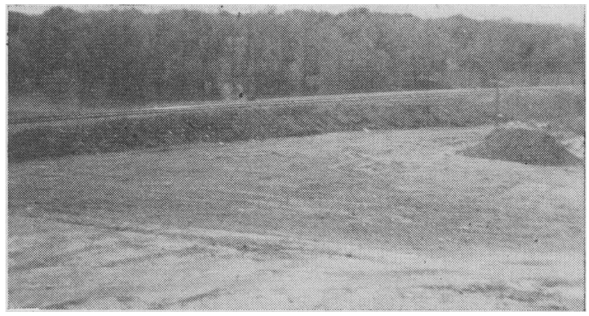

Figure 4. Dump site after landfill operations.

fences had been built at the landfill site. Drifting, therefore, caused no difficulties, and snow did not accumulate in large quantities in the trenches.

The temperature in January 1950 averaged −10.2° F.—a new record for the month—with a minimum recorded temperature of −44° F. The entire winter was severe, as indicated by the fact that the Missouri River ice break-up did not occur until April 15, later than ever before. But equipment problems were surprisingly few. The daily starting of the diesel-driven tractor was made possible through the building of a garage at the site, in which an oil stove, burning continuously, kept the temperature at a constant 20° to 30° F. A well-constructed, heated cab in the tractor is essential. Also, the tractor was equipped with grousers for use on ice or hard-packed snow.

Other Experiences

Experience at places other than Mandan indicate that winter landfill operations may be facilitated by one of the following procedures:

1. Plow or scarify the area to be excavated before the frost arrives and place insulating material (leaves, hay, etc.) to a depth of at least 3 feet, replacing the insulating material over the working area as the trench is excavated.

2. Excavate the required number of trenches in advance, and stockpile the cover material. Work the stockpile, if wet, to insure drying, and protect it with leaves, placed in the form of cells, with each cell being opened as cover material is needed. Leaves should also be mixed into the pile.

When spring floods cut off the approach road to the trench landfill site, in March 1950, operations were moved to the vicinity of the former open-face dump, where an area type of landfill was started (figs. 3 and 4). The speed and ease with which the move was made indicate the versatility of the landfill method of disposal.

In the new area, water from the spring runoff stood 3 feet deep, making it impossible to obtain cover material by trenching. Cover material was obtained from various places—from the upper layers of the old dump, from a nearby hill, etc.

The depth of the new fill was from 12 to 15 feet. Therefore, refuse was deposited in two layers, for the same reasons which dictated this type of operation at the original site.

The rat population at this dump, of course, had been eliminated when dumping was discontinued. Otherwise, the rats would have migrated to new food sources, with consequences which could have been tragic to the residents of the community. Under supervision of the United States Fish and Wildlife Service, poisoning operations were carried out by employees of the city street department.

Cell Temperatures

High temperatures in a closed cell result from anaerobic bacterial activity and digestion of organic material. The degree of heat and its duration are excellent measures of the bacterial action. The following temperature data are presented from the experiment conducted at Mandan.

Temperature graphs were maintained on three test cells, identified as C_1, C_2, and C_3, from

January 1950 through June 1951. The first two cells were located on the original landfill site, and the last on the new site at the former city dump. These graphs were combined with a graph of the daily atmospheric temperatures to show the relationship between air temperature and temperatures in the cells (fig. 5).

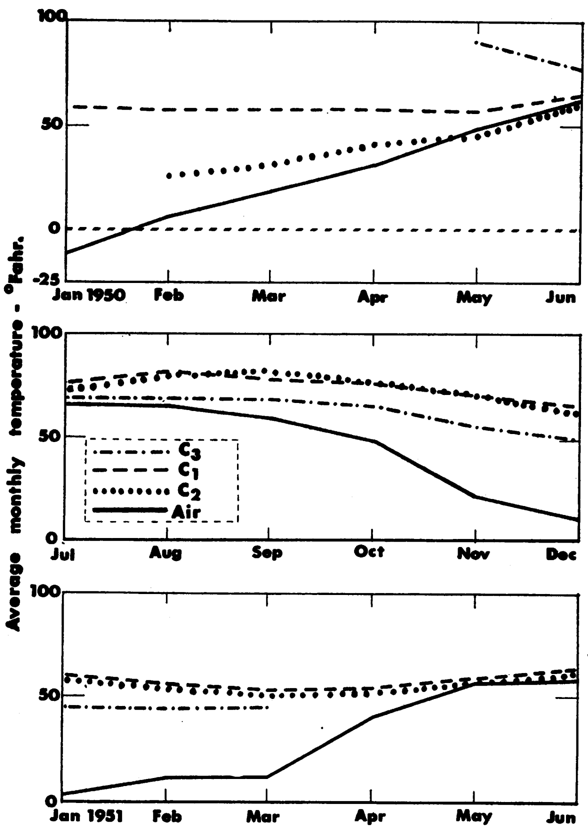

Figure 5. Comparison of monthly averages of cell and atmospheric temperatures, Mandan landfill project.

Refuse was deposited in cell C_1 in November 1949 and the cell was closed, but temperature-recording equipment was not available until January 1950. From then through May 1950, the graph shows that a stable temperature was held, apparently independent of atmospheric conditions, including the winter period.

Cell C_2 was completed in January 1950. The conclusion reached from the temperature graph for this cell is that refuse placed, compacted, and covered in freezing weather generates little or no heat from decomposition until atmospheric temperature rises high enough to permit bacterial activity.

Cell C_3 was started and completed in warm weather. The internal temperature of the cell rose to a peak of 93° and fell to 83° F. within a single 2-week period. The rise to only 93° F. indicates a high content of inorganic material in the refuse.

The temperature data also show that the temperature peaks in the three cells were considerably lower than the 140° to 180° F. frequently mentioned in literature on similar studies. Probably the reason for the slow decomposition of the refuse was the high paper and cardboard content which did not provide optimum environment for bacteria. It may be necessary, in similar operations, to provide a catalyst in order to promote complete bacterial reaction within a reasonable time.

The equipment used for temperature-recording was not expensive, and should be within the reach of any community. It was comprised, basically, of a maximum-registering thermometer, which is familiar to all milk sanitarians, and a prepared 6-foot length of pipe. The thermometer mentioned cannot be used when atmospheric temperature is greater than cell temperature. For a complete year-long record, a dial-type thermometer is needed.

Refuse Analysis

The laboratories at the Environmental Health Center, Public Health Service, in Cincinnati, Ohio, performed monthly chemical analyses of raw-refuse samples from Mandan through the year 1950, with the exception of November. They also made analyses in July 1950 and July 1951 of samples of refuse which had been buried in July 1949.

Probably the most significant indication of bacterial action already accomplished and remaining to be accomplished was the BOD (biological oxygen demand) results. The BOD dropped from an average of 77,050 ppm for the fresh garbage and refuse, to 30,000 ppm for that buried for 1 year, to 23,500 ppm for that buried for 2 years. These figures appear to follow an asymptotic curve, as would be expected. However, it appears that even after 2 years of burial, a considerable amount of bacteriological decomposition remains to be accomplished under the climatic conditions of the North.

Settlement and Soil Analysis

Data compiled concerning the percentage and time of settlement showed that (1) the minimum percentage of settlement over a 24-month period was zero, (2) the maximum over a 17-month period was 18 percent, (3) the lowest percentage of settlement occurred in the first cells, which were constructed during the summer, and (4) the highest percentage occurred in the cells constructed during the winter.

The rate of settlement, however, is affected by many variable factors: the skill of the operator in placing, compacting, and covering the refuse; the percentage of garbage in the refuse; the percentage of dirt mixed with the refuse; the amount of travel over completed cells by tractors and trucks; the depth of individual cells; and weather conditions at the time refuse is deposited. The last factor includes the probability that the operator will do a less thorough job of compacting at 20° below zero than at 60° above, and the fact that frozen refuse is less compactable. Therefore, it is difficult to predict accurately the percentage of settlement that a sanitary landfill in a cold climate will show.

Adequate standards which will enable an engineer to submit a soil sample from a proposed landfill to a soil laboratory and receive sound information on all the problems he may encounter remain to be developed.

In the meantime, H. W. R. Larson, of the Bureau of Reclamation Soils Laboratory, Bismarck, N. Dak., has suggested that all soils be submitted for mechanical analysis. In the case of heavy soils, Dr. Larson recommends determination of the sulfate ion as a test for gypsum content, and determination of the lime content as a test of porosity. These would indicate how easily the soil could be handled. Also, for heavy soils, Dr. Larson states that determination of exchangeable sodium will tell whether or not the soil will work in lumps.

Weight and Volume

Weighing of the Mandan refuse was begun in February 1950 and continued through May. Of course, for reasonably accurate weight and volume data, a full year's figures are desirable. However, two interesting facts were uncovered from the 4-month experience: (1) an average weight of 3 pounds of refuse per capita per day; and (2) an almost equal division between refuse from the business district and that from the residential areas.

For purposes of comparison of one community's experience with that of another, weight records are much more reliable than volume estimates. The Mandan experience indicates the unreliability of cubic yardage figures. Loads on the 12-yard packer truck varied from 60 to 80 percent of capacity, depending on the truck's mechanical condition. Therefore, an assumption that 50 loads totaled 600 yards could be up to 40 percent erroneous. Also, yardage from a nonpacker truck obviously cannot be considered the same as that from a packer truck.

Costs

The average monthly cost of operating the sanitary landfill at Mandan, based on a 10-month study, was $432.98. This figure includes the pay of the equipment operator ($235.91 for an 8-hour day and a 6-day week); $27.73 for fuel, grease, repairs, and other operating costs; $22.34 for general expenses, such as fencing, land, etc.; and $147.00 for tractor amortization ($8,000 at 4 percent over a 5-year period).

The average amount of refuse deposited monthly (February through May 1950) was 327.55 tons. Applying this 4-month weight average to the 10-month cost average shows a disposal cost of $1.32 per ton. This means an increase in the monthly disposal cost of $282.98, or of 86 cents per ton, since Mandan had previously paid a dump attendant $150 a month.

The 10-month period included 255 working days, during which the tractor and operator worked a total of 536 hours, or 2.1 hours per working day. Assuming that they were used on other municipal projects for only one-half of the possible working time, a reasonable cost estimate for the operation of the landfill could be worked out as follows:

Wages (4-hour day, 6-day week)	$117.50
Operating costs	30.00
General expenses	25.00
Amortization	73.00

On the basis of 327.55 tons of refuse per month, this computation brings the cost per ton to 75 cents.

Repair costs over a 5-year period will, as a rule, be larger than those shown in the Mandan experience, but they may be offset somewhat by salvaging used equipment, by careful operation and maintenance of equipment, and by judicious use of municipal repair facilities and labor.

Note that these estimates include amortization of equipment, which few communities consider in their cost tables. Eliminating the amortization figure reduces the cost per ton to 53 cents, which is comparable to the unit cost commonly reported for a sanitary landfill.

In final analysis, actual landfill costs will depend on what a community charges to operation, and on planning and efficiency.

Conclusions

The primary purpose of the Mandan experimental sanitary landfill project was to determine if this method of refuse disposal would be practical in the colder portions of the United States. The winter operation in Mandan has answered this question affirmatively.

With proper planning and efficient operation, a community of 5,000 population should be able to manage a sanitary landfill. On a project of this size, the tractor is required for only 2 or 3 hours a day, and is available the rest of the day for gravel loading, snow removal, street excavation, or other municipal requirements. Such an arangement, of course, would make it essential to regulate dumping hours at the fill strictly, to prevent the scattering of refuse during evenings and week ends.

Communities smaller than 5,000 population might modify the landfill method with a form of sanitary trenching. In this, of course, it would be necessary to clean up the site before digging the trench. Usually, the accumulation on small dumps can be moved only by heavy equipment; thus, the trench may have to be dug by county or rented equipment. In this form of operation, the refuse should be compacted and covered at least twice weekly in warm weather, and as often as practicable in the winter.

A small road scraper or bulldozer can be used if heavy equipment cannot be obtained. Large items, such as tree limbs, car fenders, barrels, etc., would have to be removed by hand.

The steps in the operation of a sanitary trenching area by a small community can be itemized as follows:

1. Clean up the old dump and exterminate rats.
2. Build an all-weather road to the site.
3. Dig a trench, storing dirt at the ends or on the sides.
4. Designate a specific area for large objects.
5. Work over the refuse in the trench, and cover the top and face with at least 2 feet of dirt.
6. Each spring, incorporate the large objects into the fill, burn the accumulated brush, and dig a new trench.

Sanitary trenching is not as good a method of disposal as a sanitary landfill, but it is a vast improvement over the usual open dump.

Coming in Public Health Reports

Next month's issue will include the first of a number of reports and papers on world health developments: *international health assistance programs* described in maps, text, and pictures, with "case reports" of current projects . . . a *symposium* from the 3d National Conference of the U. S. National Commission for UNESCO, with contributions by Gaylord W. Anderson, Joseph W. Mountin, Albert W. Dent, and Frank G. Boudreau, and an introduction by C.-E. A. Winslow . . . *The WHO and Environmental Health*, by Herbert Bosch . . . and a review of the work of *WHO Expert Committees* written by American members.