The Sanitary Landfill in the Subarctic

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ABSTRACT: A field study of two and a half years was conducted into the application of the sanitary landfill to the Subarctic. Temperatures and gas concentrations were observed in an experimental cell and groundwater quality measured on the periphery. Carbon dioxide concentrations peaked during the warmer periods corresponding to minimum oxygen concentrations. No methane was ever detected nor were significant changes in groundwater quality observed. After the study period the cell was opened for examination and showed that little decomposition had occurred. This indicates that serious consideration must be given to the use and location of landfills in cold climates.

RÉSUMÉ. *Les comblements sanitaires dans le Subarctique.* On a mené pendant deux ans et demi une étude appliquée de comblements sanitaires dans le Subarctique. On a observé les températures et les concentrations de gaz dans une cellule expérimentale, et la qualité de l'eau du sol à la périphérie de cette cellule. Les concentrations de bioxide de carbone atteignirent un sommet pendant les périodes plus chaudes correspondant aux concentrations minimales en oxygène. On n'a détecté aucune trace de méthane et on n'a observé aucun changement significatif de la qualité de l'eau du sol. A la fin de la période d'étude, on a ouvert la cellule pour examen, et découvert qu'il n'y avait eu que très peu de décomposition. Ceci indique qu'il faut apporter beaucoup de soin à l'emploi et à la localisation des comblements en climat froid.

РЕЗЮМЕ. *Метод естественной переработки бытовых отходов в субарктике.* В течение двух с половиной лет проводилось исследование применения земляных камер для естественной переработки бытовых отходов в условиях субарктики. Измерялись температура и концентрация газов в экспериментальной камере, а также количество грунтовых вод на её периферии. Максимум концентрации двуокиси углерода и соответственно минимум концентрации кислорода наблюдался в теплые периоды года. Ни метана, ни изменения количества грунтовых вод обнаружено не было. По окончании периода исследований камера была вскрыта для обследования, которое обнаружило малые следы разложения. Это указывает, что вопрос об использовании и размещении земляных камер, предназначенных для естественной переработки бытовых отходов, в условиях холодного климата требует серьёзного рассмотрения.

INTRODUCTION

The acceptability of sanitary landfills for the disposal of solid wastes in cold climates depends a great deal on the criteria used in making this judgement. If the sole requirement is to minimize costs of sanitary disposal, the sanitary landfill would probably be applicable wherever suitable cover material is available throughout the Arctic and Subarctic. When consideration is given to the possible effects of this operation on the soil, this method of disposal requires second thoughts since the initial disturbance of the permafrost may have far-reaching consequences. For this reason the Alaska Department of Health and Welfare has discouraged the use of sanitary landfills in permafrost areas.

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The possibility that solid waste placed in sanitary landfills may remain unchanged for posterity gives rise to certain political and philosophical questions outside the realm of engineering. For example, will future population growth require subsequent removal of the fill? Who would bear the cost of known alternative — but more expensive — methods of disposal when some even consider landfills an unnecessary cost? Are these other methods any more acceptable in terms of long-range considerations? As the public becomes more aware of the problems associated with the disposal of solid wastes, and as regulations against existing, unsatisfactory practices are strengthened and enforced, questions such as these will require answers. Until that time, and where suitable cover material is available, the sanitary landfill method of disposal is far superior to the general practice of open burning, which pollutes the atmosphere and subsequently harbours vectors of disease.

In 1967 the Alaskan Air Command, U.S. Air Force, asked the Environmental Sciences Branch of the Arctic Health Research Center to investigate the feasibility of the sanitary landfill for Air Force installations in subarctic Alaska. The request was prompted by Executive Order 11282 and the standards issued in compliance thereof. These forbid the burning of more than 25 lbs. of refuse at a single site during a 24-hour period, and required that refuse be incinerated only in a facility specially designed for that purpose. These further required that refuse not be left in open dumps, and that sanitary landfills be operated in accordance with certain prescribed procedures (Code of Federal Regulations 1969).

A most comprehensive study of the sanitary landfill in cold climates was completed by Weaver and Keagy twenty years ago (1952). This study, based on the operation of a landfill for 2 years at Mandan, North Dakota, described nearly all the techniques in use today in the cold weather operation of sanitary landfills. During its operation, Mandan experienced its coldest January on record to that date. The low for that month was −44°F., and the average temperature was −10.2°F. Over 72 inches of snow fell during one of those winters.

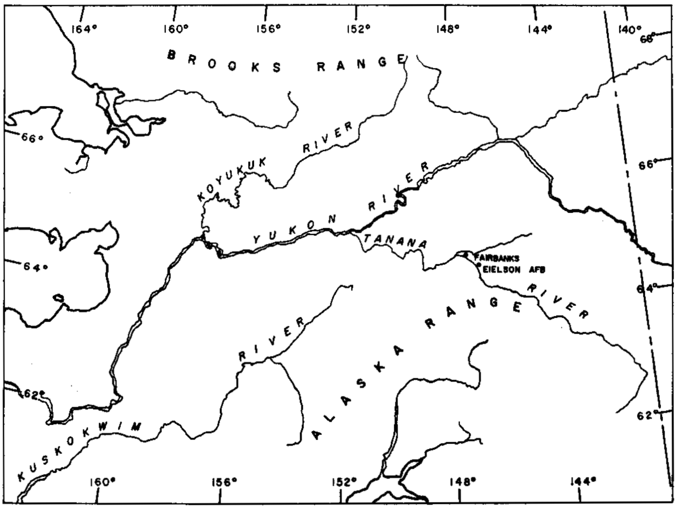

FIG. 1. Location Map.

The investigators found that after a 2-year period considerable waste decomposition had occurred but that a great deal more was required. Cells filled during the summer and autumn held their temperatures throughout the winter whereas cells started in freezing weather did not begin to decompose until temperatures were high enough to permit bacterial action. One of the primary reasons for their successful winter operation was the sandy soil for cover available at the site. The soil was 64 per cent sand, 14 per cent silt, and 22 per cent clay.

Subarctic Alaska lies generally between the Alaska and Brooks Ranges and consists of broad, flat river valleys and rolling highlands (Fig. 1). The climate is very dry with long, warm, summer days, and very cold winters. Temperature extremes range from −75°F. to +100°F. The river valleys are characterized by high groundwater tables, generally underlain by permafrost, and by a soil of silt and gravel. Nearly all the population in the area centres in the major river valleys such as the Yukon, Tanana and Kuskokwim rivers.

In Alaska, as in most northern climates, attempts to operate refuse-dumping areas as sanitary landfills rapidly degenerate to open dumping. Obtaining workable cover material during extended cold periods is extremely difficult in interior Alaska since the cover most frequently available is frozen silt. However, with planning and certain precautions, suitable cover material could be obtained over most of the year.

The better refuse disposal practices in interior Alaska have been at large military installations, Eielson Air Force Base and Fort Jonathan Wainwright. At these installations, the refuse is dumped on the ground and covered every working day with 2 to 3 feet of ashes from the power plant. The face of the fill is left open. Once each year a soil cover is placed over the top.

THE EXPERIMENTAL REFUSE CELL

To determine the effect of cold ground temperatures on the decomposition of refuse, and the effect of any decomposition on the nearby groundwater, an experimental refuse cell was filled over a 3-week period at Eielson Air Force Base and observed for 2½ years. Located 23 miles southeast of Fairbanks on the

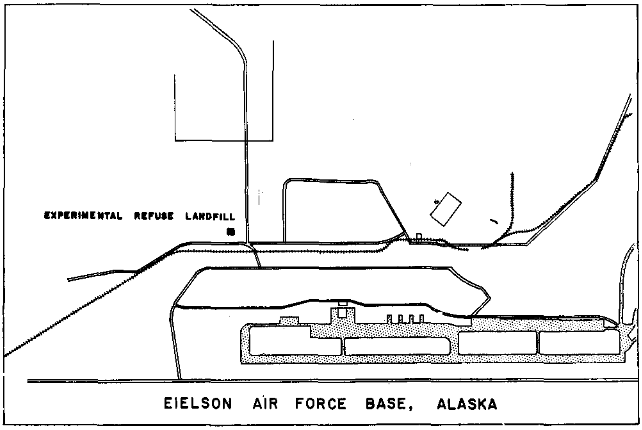

FIG. 2. Map of Eielson Air Force Base.

Tanana River floodplain, Eielson has a mean annual temperature of 24°F. and an average annual precipitation of 14 inches. The cell (Fig. 2) is in a gravel-fill area that is being considered for refuse disposal.

Late in September 1967, a pit approximately 60 feet by 110 feet was cleared for the cell and an access ramp, and to provide room for a bulldozer to operate. The bottom of the pit was approximately 4 feet below the prevailing ground surface and 1 foot above groundwater level. Collection vehicles entered the pit to deposit their loads, and the bulldozer pushed the refuse to the back of the pit and compacted it.

Refuse entering the landfill was from the residential and industrial areas of the base, but no demolition or construction wastes were permitted. Problems were encountered with the collection vehicles because of their age and condition, resulting in many lost man-hours of collection time.

The weight of refuse deposited was determined by weighing the trucks as they entered and again as they left the cell. Weights were taken to the nearest 10 pounds using portable wheel scales. An average of 20,500 pounds of refuse was deposited daily. Over the 3-week period required to fill the cell, 184 tons of refuse were deposited. The completed cell, measuring approximately 60 feet square with a maximum depth of 5 feet at the centre, was covered with 2 feet of earth.

The volume of the compacted refuse was 454 cubic yards, and the density 820 pounds per cubic yard. A somewhat lower density would have been achieved had the refuse been covered daily. Assuming that 150 cubic feet of cover per working day are required for a normal landfill operation as opposed to a single experimental cell, the density would have been reduced to about 700 pounds of refuse per cubic yard.

While the cell was being filled, 4 sampling probes were installed at approximate depths of 0, 2, 3, and 5 feet from the surface. The probes consisted of ½-inch plastic tubing encasing copper-constantan thermocouples for temperature measurement, and ¼-inch tubing for gas sampling. Holes were drilled in the tubes to ensure adequate gas entry.

When the landfill was completed, 8 well points were driven near the cell to monitor quality of the groundwater (Fig. 3). All wells were 8 feet deep except

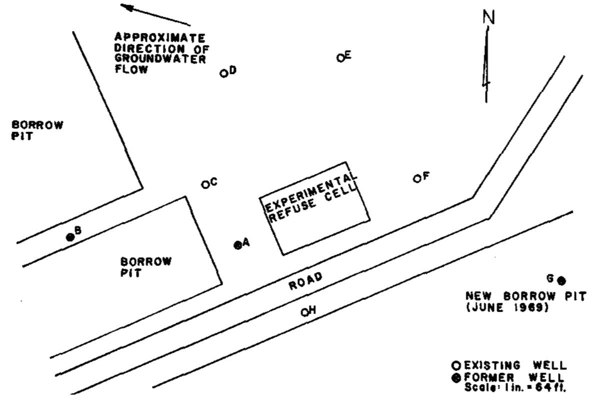

FIG. 3. Layout of experimental cell and wells.

well A, which was 3 feet deep. Located in a low area, which was being recharged by groundwater, well point A was removed in July 1968. During housing construction on base, a borrow pit was opened south of the experimental cell in June 1969, destroying well point G. The operation of heavy equipment in excavating the pit resulted in the loss of well point B also, and two temperature probes.

SAMPLING PROCEDURES

Samples of gases in the cell, and water samples from the wells were taken each month. Temperatures in the cell were determined at the same time, with a portable potentiometer.

Gas samples were drawn into gas sampling tubes with a portable hand pump. A gas partitioner was used to separate the carbon dioxide, oxygen, nitrogen, carbon monoxide and methane, and to measure their concentrations to the nearest percentage.

Water samples, collected in vacuum flasks and transferred to plastic bottles, were tested as follows:

Parameter	*Method*
pH	
Specific conductivity	
Total hardness	EDTA titration
Calcium hardness	EDTA titration (1967-1969); atomic absorption spectrophotometry (1969-1970)
Alkalinity	Phenolphthalein Indicator
Chlorides	Colorimetry
Sulphates	Turbidimetry
Iron	Atomic absorption spectrophotometry
Sodium	Flame spectrophotometry (1967-1968); atomic absorption spectrophotometry (1968-1970)

Owing to the iron in the well points, the iron content in the water samples was found to increase with the length of time the water lay in the well. To eliminate this problem, the wells were pumped just before the samples were drawn.

RESULTS

Temperatures in the upper part of the cell varied according to the season. A low of 20°F. was reached during the first winter, and a low of 14°F. during the second, colder winter. During the third winter, which was warmer but with little snowfall to serve as insulation, the temperature of the cell dropped to 10°F. High temperatures for the two summers were 70°F. and 80°F.

Temperatures deeper in the cell varied little at different depths and were more closely grouped and less affected by season than were temperatures in the upper part of the cell. Low temperature deep in the cell was 31°F. the first winter, 28°F. the second, and 25°F. the third. The high for the first summer was 65°F., and for the second summer it was 58°F.

The carbon dioxide and oxygen contents of the cell also varied according to season. Maximum CO_2 content was reached during the warmest outdoor temperatures, and minimum concentrations were observed during the winter. Oxygen content followed an inverse pattern. Carbon dioxide reached a level of 34 per cent of all the gases in the cell during the first summer, and 30 per cent in the second summer. Deep in the cell, carbon dioxide comprised 19 per cent of the gases the first winter, 8 per cent the second, and 10 per cent the third. At the upper part of the cell, the carbon dioxide content varied from 26 per cent to 4 per cent of the gases present.

Oxygen comprised from 0 per cent to 12 per cent of the gases deep in the cell, and from 2 per cent to 20 per cent of the gases at the top of the cell. No methane and no hydrogen sulphide were ever detected.

TABLE 1. Average water quality from wells in vicinity of experimental landfill, November 1967 - April 1970

Well	pH	Specific Conductance umho/cm	Alkalinity mg./l.$CaCO_3$	Hardness mg./l.$CaCO_3$	Calcium mg./l.$CaCO_3$	Iron mg./l.	Sodium mg./l.	Chloride mg./l.	Sulphate mg./l.
A	6.8	1610	352	278	130	22	14	26	3.9
B	7.0	370	84	82	52	2.0	3.6	1.6	6.6
C	7.2	450	108	105	67	13	4.6	3.8	2.3
D	7.1	450	111	112	75	5.6	4.2	1.3	4.8
E	7.2	370	93	95	60	3.1	3.3	1.1	3.0
F	7.0	570	134	146	101	3.7	4.3	1.3	11.5
G	7.0	490	117	122	77	1.0	3.8	0.8	9.7
H	7.1	410	104	103	61	5.5	3.2	1.7	4.0

Temperatures and gas contents are shown in Figs. 4 and 5. Analyses of the well waters, summarized in Table 1, show seasonal variations in water quality, as is usually the case in shallow wells. In shallow wells, hardness, alkalinity, and conductance are lowered substantially by the spring melt. A discontinuity in water quality data was caused by some wells going dry during the winter months, and to the freezing of others. Among the wells, there were no significant differences in water quality.

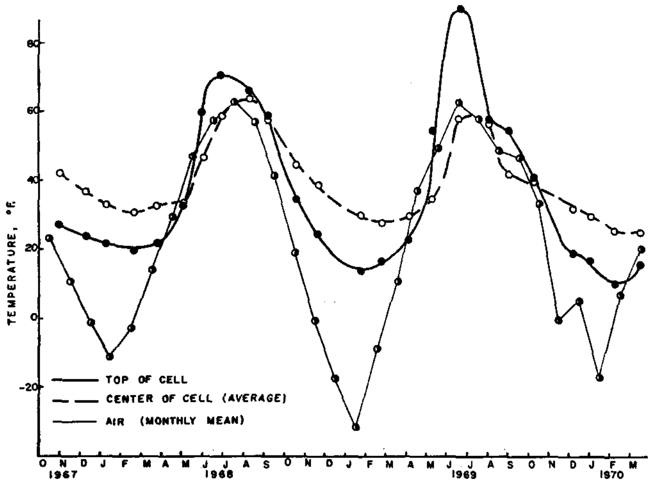

FIG. 4. Temperatures observed in cell compared to air temperatures during study.

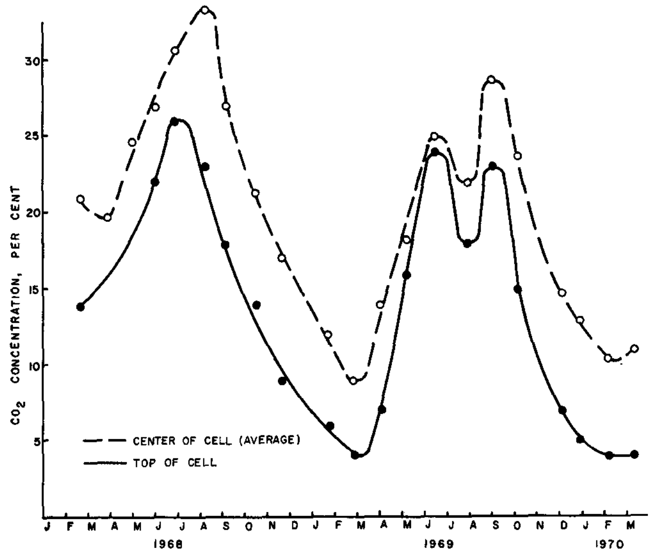

FIG. 5. Concentration of carbon dioxide measured in experimental cell during study.

When part of the cell was opened at the end of 2½ years, 6 inches were found to be moist, odoriferous and covered with mould. Below this level, the refuse was dry and there was no evidence of decomposition of paper and cardboard, which comprised the bulk of the waste. The pH values ran from 7.5 to 8.0 at the top to 5.5 to 6.0 within the cell.

DISCUSSION

External air temperatures and solar radiation strongly affected temperatures within the cell. With the melting of the snow cover, and with the advent of long hours of sunlight, temperatures in the cell rose markedly, peaking in midsummer. By early winter they had returned to ground temperature. The amount of snow cover and external air temperatures accounted for the small changes in the minimum temperatures observed each winter. The gradual reduction in bacterial action, as certain of the wastes were assimilated, may have been another factor contributing to the gradual lowering of the high and low temperature extremes within the cell.

It was evident from the changes in carbon dioxide content that decomposition was occurring within the cell, and that the rate of decomposition was highly dependent on cell temperature. Since temperatures and carbon dioxide values were lower than those found in studies made elsewhere, a slower rate of decomposition was to be expected. Two sampling periods excepted, the presence of oxygen within the cell indicated that the decomposition was aerobic. Methane, a product of anaerobic decomposition, was not detected, even when the oxygen was depleted.

A quantitative evaluation of gas changes was not possible since it is not feasible to measure the various parameters governing carbon dioxide levels, such as: changes in gas volumes and vapour pressure due to temperature changes in the cell; changes in gas volumes due to the stoichiometry of the oxidation reaction; changes in groundwater level; and diffusion through the soil. Visual examination, however, indicated that except for the area at the top of the cell, the amount of decomposition that had occurred was negligible. The better results obtained at the top of the cell are attributed to the higher oxygen content, the presence of more moisture, and warmer summer temperatures. For all practical purposes the lower portion of the cell, which holds the bulk of the refuse, can be expected to remain in its original condition for an indefinite period.

SUMMARY

The opening of the borrow pit adjacent to the experimental cell precluded the possibility of collecting additional reliable data, and this particular project in the study of sanitary landfills was terminated. It is doubtful however that additional data would have added significantly to those already collected. Significant findings of the study were:

a) Refuse deposited averaged 20,500 pounds per day, or about 2.2 pounds per capita per day.

b) Using a bulldozer, refuse compacted to a density of 820 pounds per cubic yard.

c) Decomposition below the top 6 inches of the cell was negligible, and the bulk of the refuse could be expected to remain as it was when placed in the cell.

d) Carbon dioxide and other gases of decomposition were present but no methane was detected.

e) Ambient air temperature, itself affected by season and radiation from the sun, affected the rate at which the refuse decomposed.

As a result of these findings, and from observation of other landfill operations in Alaska, several conclusions regarding the operation of sanitary landfills in the Subarctic may be drawn:

1) Since the decomposition of the bulk of the refuse is minimal, landfilling should not be considered for ultimate disposal in locations where future growth might encompass the landfill site. The exceptions to this would be those cases where sites are programmed for future use as parks, recreational areas or green belts.

2) Ash is acceptable as a winter cover material in the Subarctic, provided that the face of the fill is covered daily. Soil should be used during the months it can be moved. A 6-inch layer of ash over the top and the face, and a 6-inch soil cover would suffice until the final lift, which should provide 2 feet of soil cover.

3) One possibility for speeding up the rate of decomposition is the addition of moisture into the system and pumping air through the landfill during the summer months. It would not be difficult to test this method in a field trial.

Should power plants in the Tanana Valley convert to fuel oil, their ash would not be available for cover, and plans should be made for adequate refuse disposal before this occurs. If cover material cannot be obtained on a daily basis, other methods must be considered, such as incineration, milling of refuse and disposal on the land, or composting.

Incineration requires little land for final disposal of the ash, and some of the waste heat can be salvaged. Its disadvantages are high capital cost, high operation and maintenance costs, and its potential for polluting the air. In the Tanana Valley, with its known potential for air quality problems, serious consideration should be given to a form of disposal that would not contribute to air pollution.

The milling of refuse with disposal on the land is a new technique now being tested in Madison, Wisconsin. The refuse is milled in a plant into small fragments, then placed in a landfill area for disposal. It appears that milled refuse requires no soil cover, compacts into less bulk, and degrades more readily. These characteristics would extend the life of a landfill and eliminate a major problem in providing cover in the winter. Decomposition would probably not be complete, however, with the soil temperatures encountered in subarctic Alaska. Costs appear to be at least competitive with those of incineration.

Composting goes a step beyond milling by promoting the major part of the degradation process in the compost plant before final disposal. In the subarctic climate, mechanical digestors would also be required to achieve degradation. As a result, capital, operations and maintenance costs are high but might still compete with the costs of incineration. The end product of composting would be usable as cover material or soil conditioner.

The milling of refuse in particular appears to have great promise for subarctic conditions where nearby final disposal sites are readily available. A thorough investigation of the several alternative methods outlined is recommended in preparation for future changes in local power plant operations.

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