

DESIGN AND OPERATIONAL CHALLENGES AND SOLUTIONS FOR SOLID  
WASTE MANAGEMENT IN NORTHERN ALASKA

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WASTE MANAGEMENT IN NORTHERN ALASKA

A

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## **ABSTRACT**

This paper examined the challenges of designing, constructing, operating, and maintaining an effective solid waste management system in northern Alaska. Northern Alaska presents unique challenges for developing an effective solid waste management plan. The communities in the region are not connected to the road system and the main strategy for disposing of solid waste is by developing aboveground landfills. This strategy has been used for many years, but as communities are increasing in size and the effects of climate change are becoming apparent, an adjustment in this strategy may be required.

This research examined the current solid waste practices in northern Alaskan, reviews the regulatory requirements, isolates difficulties in current solid waste practices, identifies the unique challenges of working in the region, and anticipates operational practices that may create problems in the future. A main topic of study was the effect of the heat generated by exposed and decomposing waste in landfills and how this could affect the stability of the permafrost below and around the landfill.

After accounting for all of the aspects identified, design and operational recommendations and strategies for solid waste management in northern Alaska were outlined. This paper considered solutions not only for current problems facing northern Alaska, but tried to anticipate what problems may occur decades or centuries in the future when conditions may be vastly different than they are today. An effective solid waste management strategy was found to be essential for a healthy community for current and future generations.

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## LIST OF ABBREVIATIONS

<u>ABBREVIATION</u>	<u>NAME</u>
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ARL	Anchorage Regional Landfill
ATV	All-Terrain Vehicle
C	Celsius
DCCED	Department of Commerce, Community, and Economic Development
EPA	Environmental Protection Agency
F	Fahrenheit
ft	Foot
GSHP	Ground Source Heat Pump
IGAP	Indian Environmental General Assistance Program
m	Meter
MSW	Municipal Solid Waste
MSWLF	Municipal Solid Waste Landfill
O&M	Operation and Maintenance
US	United States
USDA	United States Department of Agriculture
USGA	United States Geological Survey

## INTRODUCTION

Solid waste management in northern Alaskan communities is a growing public health concern. Villages and agencies tend to focus on installing or maintaining water and wastewater systems in rural Alaska and less attention is given to the landfill problem that is becoming an increasingly important problem now that warming temperatures observed in the region are causing permafrost to thaw. Permafrost degradation due to thawing leads to a host of problems such from sinking landfills to an increased rate of shore erosion. In some communities, mounds of waste containing items like batteries, computers, and hazardous waste are tumbling into rivers and oceans as the land erodes away. This provides a direct path for pollutants to leach into waters used for subsistence activities (DeMarban, 2012).

The Environmental Protection Agency (EPA) has granted an exemption for landfills rural Alaskan communities. This means that a lot of the smaller landfills do not have liners underneath the waste and have little monitoring requirements to protect against contaminates in the waste from seeping into the environment. This type of landfill is allowed in part because the permafrost in the region serves as a natural barrier to prevent the contaminants from spreading. With the continued warming of the permafrost in the northern regions, this protective permafrost barrier may become thin or disappear.

Thawing permafrost is not the only reason why landfills in northern Alaska are becoming an increasing danger to public health. An inadequate solid waste management program poses a public health hazard to the community as well. The lack of an effective solid waste management program is often due to shortage of funding or education in the

community on the proper practices of disposing solid waste. Without continuous monitoring over the landfill, disposal of objects like car batteries, chemicals, human waste, animal carcasses, and hazardous waste are more likely to be dumped or burned in the landfill than a properly monitored landfill. Not only can pollutants from these items harm the environment, but they can also be transported back into the community on the vehicle tires and shoes where humans and animals can come into contact with them. Improper burning in the landfills can cause thick black smoke full of pollutants and dioxins that travel back into the town or settle onto nearby berry bushes used for food.

This paper will examine how solid waste management in northern Alaska can improve public health in communities through a combination of design practices, operation and maintenance practices, and changes that the community can implement. The benefits from making enhancements to the solid waste management program will not only affect the health of the current residents, but will also have a direct impact on the future generations living in the region. A quote often used to put this in perspective is: “Landfills are where we pay for the disposal of our waste. Dumps are where our grandchildren pay for the disposal of our wastes.”

## **CURRENT SOLID WASTE PRACTICES**

The climate, geology, and remote location of northern Alaska present many unique challenges in developing a municipal solid waste (MSW) strategy for many communities. For years, landfills in northern Alaska were built and operated similar to conventional landfills used in subarctic regions without accounting for factors like permafrost or erosion due to the thawing of the soils. These landfills have degraded or washed away by eroding river banks over the years raising many environmental concerns.

There is an increased awareness about these factors affecting landfills and as a result the new landfills developed in the region tend to be built on thaw-stable ground or on raised pads above undisturbed tundra. Most communities in Alaska have their own landfill where residents can deposit solid waste. Many existing landfills are located in or close to the town. New landfills are now sited as far as practical outside of town. Fill aggregate for constructing above grade landfills and the access roads to them are often hard to find in the region and construction costs are typically high. Funding in these communities is often allocated to water and waste water projects before solid waste projects. As a result of high costs and low funding, every effort is made to reduce the size and cost of the landfills needed. Burn boxes or incinerators are widely used in the region to reduce the amount of waste placed in the landfill. Recycling and re-use programs are used to further reduce the size of landfill needed. Some communities that do not allow the excess material brought in for construction to be deposited at their landfill and the contractor must backhaul all construction waste.

Depending on the community, MSW is hauled to the landfill by both individuals and by paid services that haul waste to the landfill. Only the larger communities have garbage or dump trucks like you would see in larger Alaskan cities. Instead, waste is often hauled to the landfill on an ATV or snow machine trailer over gravel roads or boardwalks. Once at the landfill, waste is either placed in the landfill or burn box. The condition of the landfill varies from community to community. Some landfills are well organized and have defined places to dump waste; other communities may just have piles of waste placed where it is most convenient for the people to dump. The Figures 1 & 2 show examples of both scenarios. Nome has a well-run and funded landfill that employs a landfill operator while Buckland does not have the funding to maintain their landfill and a result, waste is scattered throughout the site.



Figure 1: Nome Beam Road Landfill. Photo courtesy City of Nome



Figure 2: Buckland Landfill.

## LANDFILL TYPES

There are three main types of landfills seen in northern Alaska: aboveground, excavation, and depression, (Magee, 2002). Aboveground landfills are built by constructing a raised gravel pad and perimeter berms on the existing ground. Aboveground landfills are more costly to construct due to the large amounts of fill needed, but often are necessary because of high groundwater conditions and soil that is unsuitable for excavation. Excavation landfills are constructed by creating an excavation to place MSW in and will use the excavated material as a daily or final cover over the waste. Excavation landfills are the preferred options but depend on suitable soils, low groundwater depth, and not disturbing the permafrost regime. Depression landfills are similar to excavation landfills, but take advantage of topographical features such as canyons, ravines, borrow pits, and quarries to be used for landfills.

Most of the lands in northern Alaska are wet, poorly drained and underlain by ice-rich permafrost. Aboveground landfills are often the only choice available for communities in northern Alaska. Aboveground landfills maintain an adequate separation from groundwater while also delaying the heat transfer to the permafrost located below it. The next section on MSW regulations will further discuss the criteria for placing a landfill in these conditions.

Another subset of landfill types are wet and dry landfills. Wet landfills are where liquid is purposely added to the landfill to encourage rapid decomposition of the organic components. Dry landfills try to keep the waste as dry as possible by shedding rain and snowmelt away from the site and installing final cover immediately after the waste is



placed. The importance of wet or dry is in the difference in heat produced by the decomposing waste in them. This will be further expanded upon in the heat generation section.

### **Alaska Department of Environmental Conservation (ADEC) Classifications**

ADEC has three classes of landfills for the State of Alaska: Class I, Class II, and Class III. Municipal Solid Waste Landfills (MSWLF) is split into these classes by the amount of waste they receive on an annual daily basis as well the remoteness of the landfill. The current ADEC (2103) solid waste regulations, 18 Alaska Administrative Code 60.300 defines these by:

- Class I
  - Accepts, for incineration or disposal, 20 tons or more of MSW and other solid wastes daily, based on annual average; or
  - Does not qualify as a Class II or Class III MSWLF.
- Class II
  - Accepts, for incineration or disposal less than 20 tons daily of MSW or other solid wastes based on annual average; or
  - Is located on a site where there is no evidence of groundwater pollution caused or contributed to by the landfill;
  - Is not connected by road to a Class I MSWLF or, if connected by road, is located more than 50 miles from a Class I MSWLF; and
  - Serves a community

- That experiences for at least three months each year, an interruption in access to surface transportation, preventing access to a Class I MSWLF; or
  - With no practicable waste management alternative, with a landfill located in an area that annually receives 25 inches or less of precipitation.
- Class III
  - Is a landfill that is not connected by road to a Class I MSWLF or, if connected by road, is located more than 50 miles from a Class I MSWLF, and accepts for disposal;
  - Ash from incinerated municipal waste in quantities less than one ton daily on an annual average; or
  - Less than five tons daily of MSW, based on annual average.

There are 9 Class I landfills, 14 Class II landfills and 187 Class III landfills in Alaska. The Oxbow Landfill near Prudhoe Bay is the only Class I landfill in northern Alaska. Landfills in Barrow and Kotzebue are Class II landfills. All other landfills above the Arctic Circle are Class III landfills<sup>1</sup>.

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<sup>1</sup> Jacobson Ted, (2014) Rural Alaska Landfill Operator Training. Developed by: The Alaska Chapter of the Solid Waste Association of North America and Alaska Department of Environmental Conservation

## **SOLID WASTE REGULATIONS**

The regulations governing Solid Waste Management in Alaska is 18 Alaska Administrative Code 18 AAC 60 (ADEC, 2013). These regulations aim to ensure that landfills are designed, constructed, and operated to minimize health and safety threats, pollution and nuisances. Each type of solid waste that is disposed of in a landfill must be placed only in a landfill that meets the standards for that type of waste. These regulations can be used to develop a list of constraints used when locating and designing a new landfill. A summary of the regulations applicable to the design of a new landfill are listed below:

### **Groundwater Separation Distance**

A new unlined landfill or a lateral expansion of a landfill may not be located closer than 10 feet above the highest measured level of an aquifer of resource value unless the landfill is constructed two feet or more above the natural ground surface (18 AAC 60.217).

### **Access Requirements**

The owner or operator should be able to control public access to the landfill with natural barriers, artificial barriers or a combination of both. Access control should be integrated into the design of the landfill. The public salvage area should be designed so

that it does not hinder facility operations, create a safety hazard, or cause pollution (18 AAC 60.220).

### **Permafrost**

The ADEC will not approve the construction of a landfill on permafrost unless it can be demonstrated that a practical alternative to the site chosen does not exist. Landfills on permafrost must be designed and operated so that the permafrost remains frozen to the greatest extent practical and water does not pool anywhere on the site. If the permafrost under a landfill begins to settle so that water is pooling on the site, the owner or operator shall take corrective actions to eliminate all pooling water within 90 days after the pooling began (18 AAC 60.227).

The ADEC will not require the installation of a liner, groundwater monitoring, or methane gas monitoring for a landfill located in permafrost regions if the landfill is designed, developed and operated to prevent permafrost degradation and to ensure all of the waste will freeze with the permafrost and remain frozen. A sufficient number of temperature sensing devices will need to be installed and monitored to detect any thawing in the waste. Waste that will not freeze or that could hinder freezing should not be placed in the landfill (18 AAC 60.228).

### **Disease Vector, Wildlife, and Domestic Animal Control**

The design of a landfill shall incorporate elements to minimize wildlife and domestic animal from being harmed by contact with the waste or becoming a nuisance (18 AAC 60.230).

### **Floodplains**

A landfill shall be located out of the 100-year flood plain unless it can be designed to not restrict the flow of the 100-year flood, reduce the temporary water storage capacity of the flood plain, or result in the washout of solid waste that would pose a hazard to public health (18 AAC 60.310).

### **Wetlands**

A new MSW landfill cannot be located in wetlands unless it meets the requirements of ADEC, the Clean Water Act (Sections 307 & 404), the Endangered Species Act of 1973, and the Marine Protection Research and Sanctuaries Act of 1972. New landfill sites located in wetlands and the additional permitting would add time, cost and complexity to the project.

### **Other**

The design of a landfill should be so the layout and positioning of the new landfill should minimize dust, odor, noise and traffic. Effects from the operation of the facility

should not become a nuisance or a hazard to public health, safety, or welfare. ADEC regulations require a minimum setback of 50 feet between the waste management area and the property line of the facility (18 AAC 60.233).

The operator of the landfill is required to apply an intermediate cover to any inactive portion of the landfill within seven days. Intermediate cover is typically a soil material at least 12 inches thick. An inactive portion is defined as an area that does not receive waste for a period of 90 days or more (18 AAC 60.243). For active areas, 6 inches of cover material or an alternative material is to be placed over solid waste to control vectors, fire, odor, blowing litter and scavenging (18 AAC 60.345). If possible, the landfill should be located near a readily available source of cover material.

Other regulations given in 18 AAC 60 are tailored to the operation, record keeping, financial, closure and post-closure requirements for a landfill. These regulations are not pertinent to this report and may be noted, but not discussed in detail in this paper.

The U.S. Environmental Protection Agency (EPA) also has regulations for solid waste management. Subtitle D of the Resource Conservation and Recovery Act, established standards for the location and design of solid waste landfills in the United States. Subtitle D focuses on state and local governments as the primary planning, regulating, and implementing entities for the management of non-hazardous solid waste. EPA provides state and local agencies with information, guidance, policy, and regulations. The standards established in Subtitle D are incorporated in 18 AAC 60, which is administered by ADEC.

## PERMAFROST AND LANDFILLS

Permafrost is defined as soil or rock having temperatures below 0° C (32° F) during at least two consecutive winters and the intervening summer. (Andersland and Ladanyi, 2004). Permafrost ranges from relatively dry gravel to almost pure ice.

Permafrost is continuous in northern Alaska approximately north of the Seward Peninsula. For most of central and southern Alaska, permafrost is discontinuous, see Figure 3. For permafrost to form, generally the average annual air and ground surface temperatures must be below 0° C (32° F) . The thermal properties of the soil, geothermal gradient of the earth, vegetation layer, snow cover, slope, surface water, and ground water all are factors that affect the formation and thickness of permafrost at a particular site.

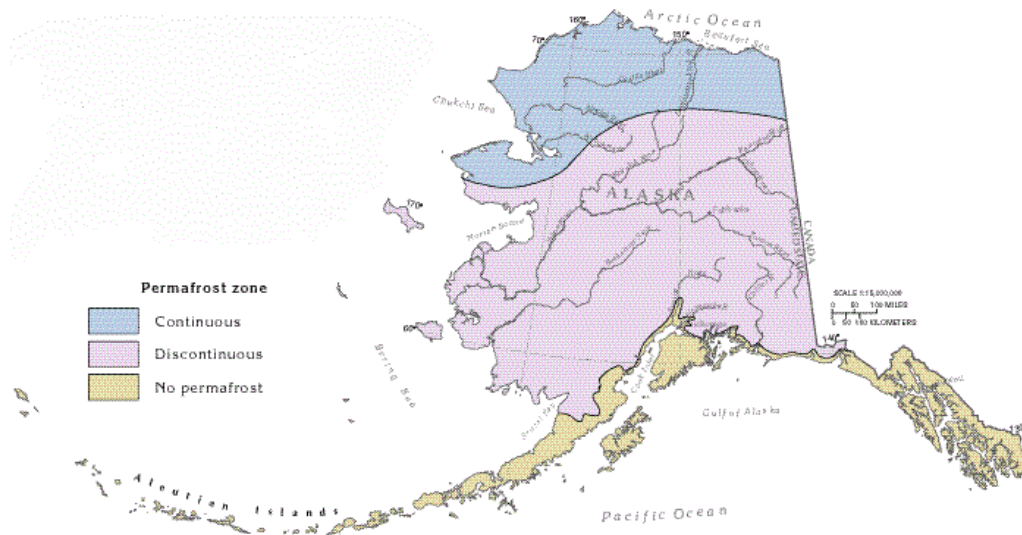


Figure 3: Continuous Permafrost in Alaska, Source: USGS (1999)

Constructing landfills above permafrost is unavoidable in some regions of northern Alaska. The ADEC regulation allow for landfills to be constructed above permafrost with

some exemptions and exemptions as described in the section on regulations. The concern with constructing landfills over permafrost is the increased potential for the landfill to thaw the permafrost below it. In some cases where the landfill is located over frozen dry gravel, there would be no significant structural impact to the landfill if the permafrost entirely thawed. Whereas if there was a substantial amount of ice in the permafrost soil, the thawing of this ice could result in settlement from the solid ice turning into liquid water and the subsequent consolidation. For example, a geotechnical investigation of potential landfill sites done in Buckland, Alaska found ice lens of approximately 10 feet in thickness overlain by 12 to 24 inches of silty material and organic mat (see Figure 4).





Figure 4: Test Pit at Potential Landfill Site in Buckland, Alaska.

In the aforementioned Buckland, a thawing of the 10 plus feet of frozen ice under the landfill would render the landfill unusable. Even when there is no significant structural danger caused by thawing permafrost, the potential for contaminants to leach through the now unfrozen ground must be considered.

When locating a potential landfill site in northern Alaska there are many items to consider minimizing the danger of permafrost. Removing tundra or the organic mat and its insulating properties usually causes the permafrost to thaw in the summer. It is

preferred if the landfill designed where a geotextile is used to allow the placement of fill directly on tundra. Southern facing slopes are less likely contains permafrost because of the additional solar energy these slopes receive. Streams, rivers, and other water bodies have a warming effect on adjacent area and permafrost may be thin or non-existent.

The top layer of soil that thaws during the summer and freezes again during the winter is called the active layer. This layer is susceptible to damage if disturbed during the summer when it is thawed. Disturbing the active layer in the summer has been shown to cause settlement from thawing permafrost to be 10 to 25 percent of the original active layer depth within 2 years (Magee, 2002). It may take years for the permafrost to re-stabilize from disturbances. During that time, the terrain can change dramatically.

## **HEAT GENERATION FROM MUNICIPAL SOLID WASTE**

Heat generation occurs in MSW landfills due to decomposition of the organic fraction of the waste mass. Heat is a primary byproduct of MSW landfills similar to leachate and gas. The heat generated results in long-term elevated waste temperatures with respect to local air and ground temperatures (Hanson et al., 2013). The heat generated by decomposition of waste can produce high temperatures in landfills that are not negligible when considering thawing permafrost. Data indicates that landfill liner temperatures can be expected to reach 30-45° C (86-113° F) under normal landfill operation. However higher temperatures of 55-60° C (131-140° F) have been observed (Hanson et al., 2013). Landfills that have a significant leachate mound may have had temperatures up to 70° C (158° F) (Bouazza et al., 2011).

Much research has been done to monitor in situ temperature in organic waste landfills. Bouazza (2011) aimed to capture the temporal evolution of temperature at various locations within the landfill over a 20 month period. The results indicated that the temperatures increased within the first few weeks, then decreased to a stable value of 53-57° C (127-135° F) after several months. However, this study was done in a warm climate in a large landfill and the temperatures, while noteworthy, may not be applicable to northern Alaska. An additional fact noted in this study was that a temperature drop was observed in the first lift after two months. It was hypothesized this drop was caused by the reduction in oxygen available because of the addition of the second lift over the first.

## **Thermal Analysis**

To prevent the premature thawing of permafrost below a landfill, a thermal analysis should be done during the design of the landfill. The thermal analysis would give the working thickness of the floor of the landfill that would keep the new thaw depth within the original active layer zone. The thermal analysis should also be able to give a final cover thickness needed to keep the waste permanently frozen if desired. This information is needed to qualify as a freeze back landfill by the ADEC requirements.

Many thermal models for landfills have been developed and papers written on the subject (Bonany et al., 2013, Hanson et al., 2006, Zambra et al., 2013). These range from one-dimensional analysis to three-dimensional models. To be able accurately model temperature in landfills, the modeling requires transient, nonlinear analysis to account for complex boundary conditions and temporal trends. Heat generation rate function of variable complexity need to be developed empirically that provide temporal trends in heat generation of wastes due to biological decomposition including: step function (aerobic/anaerobic), exponential growth/decay function, temperature-dependent exponential growth/decay function, and energy-expended-based function (Hanson et al., 2013). This complexity of modeling required would be outside the scope of rural Alaskan landfills. Currently, ADEC does not have any specific requirements for thermal modeling (ADEC, 2016).

## Properties of Waste

For a thermal analysis of landfills to be modeled, the unit weight, thermal conductivity, and heat capacity are required for the subgrade, waste, and cover materials. Hanson et al. (2013) developed a list of waste properties to be used to create a model for predicting heat generation and temperature in MSW landfills. These properties are listed in Tables 1 and 2.

Table 1: Waste Composition (Hanson et al., 2013).

Waste Composition	Percent of total weight (%)	Mass heat capacity (J/kg K)
Paper	27.1	1260
Glass	4.1	1160
Ferrous metal	4.5	630
Aluminum	1.1	880
Nonferrous metal	0.5	934
Plastics	8.7	1800
Rubber and leather	2.2	1590
Textiles	3.5	1310
Wood	4.5	1360
Food wastes	9.0	1715
Yard trimmings	9.3	1360
Inorganic waste	1.2	1842
Other	1.4	850
Water	23.1	4190

Table 2: Material properties for analysis (Hanson et al., 2013).

Property	Value
Unit Weight of waste	9.8 (kN/m <sup>3</sup> )
Thermal conductivity of waste	1.0 (W/m K)
Volumetric heat capacity of waste	2000 (kJ/m <sup>3</sup> K)
Thermal diffusivity of waste	5.0x10 <sup>-7</sup> (m <sup>2</sup> /s)

## **Temperature Comparison of Wet and Dry Landfills**

A landfill can be developed as a wet or a dry landfill. A dry landfill keeps incoming waste as dry as possible by shedding rain and storm water away from the landfill and by placing final cover as soon as possible. A landfill is the reverse of the dry landfill where liquid is purposely added to the waste. Leachate from these landfills are sometimes collected and re-injected into the landfill. The purpose of the wet landfill is to promote active degradation of the organic elements contained in the waste. Wet landfills typically have a liner system to prevent leachate from draining out of the cell and into groundwater. No Alaskan landfills north of the Arctic Circle have liners. Instead the permafrost forms an impermeable layer that acts as a liner thereby protecting the groundwater from contamination.

A study was done at a landfill north of Philadelphia, Pennsylvania (Koerner, 2004) that investigated the in situ temperature of geomembrane liners at two different cells in the same MSW landfill where the liquids management practices differed significantly. One cell is a dry landfill where liquids are purposely minimized. The other cell is an anaerobic bioreactor with the waste at a high moisture content or wet landfill. Over 10.5 years, the study found that the temperature at geomembrane below the dry cell was an average of 20° C (68° F) for 5.5 years when it abruptly increased to an average of 30° C (86° F) where it rose slightly thereafter. In the wet cell, the temperature started at 25° C (77° F) and gradually rose to 41-46° C (106-115° F) over 3.7 years and continued to rise. Temperature recordings from the cover of both cells recorded normal seasonal

temperature swings from freezing to 30° C (86° F) showing that the ambient conditions did not affect the geomembrane temperatures (Koerner, 2004).

The data indicates that preventing excess water into the landfill will increase the temperatures generated during the decomposition of organic mater in the landfill. As the temperature was monitored below the lower liner in the study, it could be said that this is the temperature that could be experienced against the permafrost if a similar large wet landfill were constructed in northern Alaska.

### **Effect of Placement Conditions for MSW Temperatures in Cold Regions**

Temperatures in landfills can reach high temperatures based on the level of decomposition that takes place inside of them. The previous study was done in warmer climates than Alaska. A study done by Hanson et al. (2006) at the Anchorage Regional Landfill (ARL) from 2002 to 2006 looked at the waste temperatures in a colder climate and studied the how the placement of waste in winter or summer affected the long term temperature in the landfill.

For the study thermistor probes were placed at various locations including below the liner, within the liner, in the waste mass, in the interim cover, and in the subgrade outside the perimeter of the landfill. It was found that the waste temperatures generally increased upon placement in the landfill. Temperature readings at depth remained steady while temperature readings near the surface showed wide variations. The highest stable temperature readings came in waste that was placed during warm summer months. It was also found that the center of a 7m thick lift of waste placed during the winter remained

frozen 2 years after placement. Steady temperatures in the landfill ranged between -1 to 35° C (30 to 95° F) were recorded. Anaerobic decomposition conditions were found to start within 3 to 4 years of waste placed during summer and barely any decomposition was found in the frozen waste. Heat content of the waste are directly related to initial waste temperature. Peak heat content was also found to be a function of precipitation. The peak heat content increased with precipitation up to a value of 0.1 inch/day (2.3 mm/day) then decreased with additional precipitation.

Discussions with the Engineering Manager<sup>2</sup> at the Anchorage Regional Landfill indicated that temperature readings are still done as of 2016 at the landfill and that the frozen waste recorded in the study has long since thawed. The waste that is frozen in the winter eventually thaws and then raises to the temperatures that were seen in waste placed during the summer.

A later study at the Sainte-Sophie landfill in Quebec, Canada (Bonany et al. 2013) took the work done at the Anchorage Regional Landfill in 2006 and built on it to further understand the waste stabilization process in northern climates. Instrument bundles were placed in the landfill to monitor temperature, oxygen, moisture content, settlement total load, mounding of leachate and electrical conductivity. The data from this monitoring was used to develop a finite element model to simulate the heat fluxes to and from the waste and the heat generated by anaerobic and aerobic process in the waste.

The analysis of the data of the Quebec landfill indicated that most of the aerobic activity occurs in the upper portion of the waste that is exposed to the atmosphere. The

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<sup>2</sup> Mark Madden, January 2016.



heat transfer within the waste is primarily through conduction. The heat generation that occurs in the waste is from the ambient air via convection and radiation, the subsurface soil in the form of conduction, the adjacent waste lifts via conduction, and biodegradation of the organic waste.

The Quebec landfill data showed that even with ambient conditions in the summer being above 30° C (86° F), the waste in the center 6m of waste was still frozen. This indicates that waste has a relatively low thermal conductivity and the liquid in frozen waste takes a significant amount of heat to thaw. By the time this waste thawed, an additional 7m of frozen waste had been placed on top of it. This would indicate that the heat from the base of the landfill thawed the waste rather than the high temperatures of the ambient summer air. The data also gave evidence that the majority of heat generation is from aerobic activity occurring in the top 1m of waste (Bonany, 2013).

The research done at the landfills in Anchorage and Quebec shows that the sequencing of waste placement is an important consideration for landfills in arctic climates. Both studies show that when thick or multiple lifts are placed in the winter, it takes months to years to thaw. This long frozen duration is due to the low thermal conductivity of waste and that there is insufficient initial heat to initiate or sustain microbial activity. The thawing of the waste is from the flux of heat above and below the frozen waste lift and not from solar radiation or ambient air convection during summer months.

## **Harnessing the Heat Generated by Solid Waste Landfills**

Existing ground-source heat pump (GSHP) technology could be adapted to harness the heat generated by solid waste landfills and reduce the heat going into the ground. GSHP could also produce electricity or heat homes by using the elevated temperatures produced from the decomposition of organic material.

As previously discussed, MSW landfills will sustain temperatures of up to 35° C (95° C) higher than the surrounding subsurface because of the exothermic decomposition of the organic materials in the waste. Using the similar technology as is currently used in landfills to collect and transmit leachate and landfill gas, piping could be used for installing heat exchange piping in the landfill or leachate lagoons. A closed loop GSHP systems using a closed-loop of heat exchangers in the landfill, a heat pump using a low boiling point refrigerant could be used to heat nearby buildings with a heat distribution network (Coccia et al., 2013). Such systems already found on the shelf that could be used with only slight modifications. The major modifications needed would be to protect the components placed in the waste from the corrosive and clogging environment found there as well as keeping the piping from breaking when waste settlement occurs. Studies done in the on the subject have concluded that landfills are a suitable resource for geothermal heat exchange.

The process of extracting heat from the landfill to use to produce heat or electricity for other uses could also be used to keep the permafrost below the landfill frozen and to freeze warm wasted placed in the summer time. This technology already

exists as well and is commonly used in the arctic. The problem with using this technology is that the length of time that the landfill would need it, it would far outlast the systems.

### Effect of Waste Age on Heat Content

An important factor to consider is how long a landfill will produce heat from decomposing waste. Coccia et al. (2013) summarizes several studies have been done effect of the age of waste on the heat generation. These studies separated the heat generated in waste due to decomposition from the heat associated with climate fluctuations by using the heat content. Heat content is defined as the area between the temperature time series for ambient temperatures expected at that same depth due to heat flow from seasonal climatic boundary condition. The studies found that there was a rapid increase in temperature of young waste to a peak temperature after two to seven years which lead to a gradual decrease in temperatures for the next 25 or more years (Coccia et al., 2013). (See Figure 5)

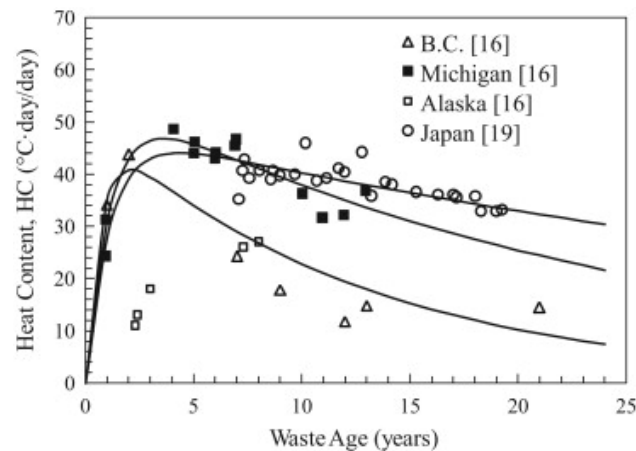


Figure 5: Heat content vs waste age graph (Coccia et al., 2013)

## **DESIGN CHALLENGES AND SOLUTIONS**

Every potential new solid waste disposal site in northern Alaska will be different from any site and different solutions will be required for every site. There is no one single answer to the problem of what to do with solid waste. There are several factors that need to be considered when designing a new solid waste landfill.

### **Landfill Location**

Location is often times constrained by the ADEC requirements for the distance from a new landfill or lateral expansion of an existing landfill. ADEC requires 10,000 feet separation from runways used by turbojet aircraft and 5,000 feet from runways used only by piston type aircraft. The Federal Aviation Administration also needs to be notified if the landfill is within a 5-mile radius of the runway. The purpose of this is to minimize the possibility of bird strikes to airplanes. Landfills attract birds that scavenge waste found in landfills. Daily cover material placed on the waste reduces the amount of scavengers, but does not totally eliminate it.

It is important to also solicit and consider local input into landfill location. Local stakeholders are very knowledgeable about the land and can give information that will help find the best new landfill location. Examples of information gained from stakeholder interviews include: caribou migration routes, favorite berry picking spots, and the direction that snow drifts. These are all important design factors that need to be considered in the landfill design and solid waste management plan.

## **Waste Reduction**

Construction of landfills in northern Alaska can be prohibitively expensive due to its inaccessibility, high costs of commodities, lack of good fill material in addition to all the challenges of constructing on permafrost that we have covered. To reduce the amount of waste going into a landfill, there are two options that are largely used in Alaska. They are burning and backhauling. These two methods are further discussed in the following section on landfill operational considerations.

## **Landfill Waste Volumes**

The size of a new landfill should be determined during the design phase based on the desired life of the landfill. The design life of the landfill may vary from community to community, but due to the high mobilization and demobilization costs in northern Alaska, the design life should be as long as practical. Typically landfill design lives of landfills are in the range of 10 to 30 years in northern Alaska.

The design life is calculated by first establishing annual waste volumes going into a particular landfill. This can be done by several methods. Conducting an annual survey of the landfill and calculating the year over year volume change is the most accurate method but due to cost, it is only done by the larger landfills in Alaska. Another popular method is to weigh the waste coming into the landfill. The weighing method is popular because it establishes a way to be able to charge for dumping but is not an accurate method of establishing a volume entering the landfill because it needs to be converted based on the level of compaction the waste experiences. Waste densities range from 200

lbs/cy for compacted residential waste to 750-1,250 lbs./cy for MSW compacted at municipal landfills (MDEQ, 2007). This large range of density for waste makes it hard to establish an accurate conversion factor. Another reason why measuring waste as it enters the landfill is not accurate is settlement. Waste in landfills settles substantially over time, which could extend the life of the landfill several years over the design life. Other factor like burning waste also complicates the estimate of yearly waste disposal.

A common method to calculated waste per year in smaller northern Alaskan communities would be to calculated the waste in the current landfill and divide that by its operational life. The design volume of the landfill is calculated by multiplying the annual waste volume by the design life and adjusting for population changes.

It is common practice to design a landfill that is broken into individual cells. These cells can construct one at a time, several at a time, or all at once. There are several benefits from breaking a landfill in to cells. One benefit is being able to contain the waste deposited at the landfill in one location at a time and minimizes the amount of exposed waste. The other benefit is to manage construction costs. If not enough funding is available to construct a landfill, it can be constructed one cell at a time. It should be noted that due to mobilization/demobilization costs and economies of scale, this method would cost more in the long term. New landfill sites should be chosen with the thought of future expansion nearby.

## **Heat Generation**

The heat generated in MSW landfills was discussed in depth in the previous section. This section will focus on the challenges resulting from the heat generated in landfills and provide several solutions to the problems. As stated previously, heat generation from MSW is only a problem if the landfill is located over thaw unstable permafrost. A geotechnical investigation should be performed at any new landfill site prior to the design of the landfill.

The most practical solution to prevent the excess heat generation from decomposing waste from warming any thaw unstable permafrost is install a thick gravel fill pad with rigid board insulation. Using the waste characteristic identified in this paper, the soil properties identified in the geotechnical report, and the local climate data from the site, a series of heat flow calculations should be performed. A minimum depth of gravel fill and a thickness of rigid board insulation should be calculated that will keep the heat generated from the waste from penetrating past the active layer of the soil. A cost analysis should also be performed on several combinations of gravel and insulation thicknesses to find the optimal combination.

## **Effects of Changing Climate on Landfills**

Landfills are typically designed to be in operation for dozens of years and when they are finally closed, ADEC regulations require monitoring and maintenance for 5 to 30 years and possibly longer. After that, landfills can still pose a significant health and safety risk hundreds of years into the future. It is important to account for this extreme time

frame when working with landfills. An important consideration is what the currently warming climate trend could have on the landfill. Average annual temperatures in Alaska have increased by 1.7 C since 1949 with climate models indicating continued warming in northern latitudes. Permafrost temperatures have also increased in Alaska in the 1960's (Hong, 2013). Permafrost degradation from climate change poses a serious threat to landfills in the form of thaw settlement, erosion and the disappearance of the once impermeable soil.

Thaw settlement poses only a minor maintenance issues to unlined landfills. As northern Alaska populations increase or if there is a tightening of regulations, a lined landfill may be required. Thaw settlement will then be a major design issue as current landfill lining technology is susceptible to differential settlement (the geomembrane may rupture). Alaska has been mapped to identify regions at risk from thaw settlement due to climate change. Research shows that there is an increase in the risk of thaw settlement in northern Alaska in 2050 with the greatest risk located in parts of northwest Alaska. (Hong et al., 2013).

Other complications due to climate change are erosion and sea level rise. There are numerous cases of Alaskan villages needing to be relocated due to coasts and rivers closing in on populated areas. There are ongoing efforts to relocate the communities to safer locations, but not much thought is given to what will happen when the erosion hits existing or old landfills and dump sites. The northern coast of Alaska is fairly low lying, if sea levels increase dramatically due to climate change, landfills along the coast of Alaska could be potentially covered by the sea.



## **LANDFILL OPERATIONAL CONSIDERATIONS AND SOLUTIONS**

### **Sequencing and Lift Thickness**

As discussed in the previous section on heat generation in landfills, waste has a low thermal conductivity and can take years to thaw or freeze if placed in thick lifts. Depending on the goal of the landfill, a sequencing plan in determining, where, when and how thick waste will be placed in the landfill can help achieve these goals. If the goal is to have the landfill be continuously frozen, a landfill operator may choose to place thin lifts of waste when the weather is above freezing over a wider area and then in winter months when the thin layers are frozen, place thicker frozen lifts of waste to provide year round frozen waste. This will vary from landfill to landfill depending on the shape and volume remaining.

### **Burning**

Burning is commonly used to reduce in rural Alaska communities. Burning can reduce the volume of waste by up to 90%. Burning not only reduces volume of the waste in a landfill it, also reduces the amount of leachate that the landfill generates. The problem with burning waste is that when there is fire, there is also smoke. Smoke from burning waste can contain many pollutants such as dioxins, lead, and mercury depending on what is allowed to be burned. Depending on the location of the landfill, the wind speed and direction, the smoke can adversely affect the health of the community. The key to reducing the amount of pollutants released into the air from burning waste is a

combination of proper sorting and high temperatures. Only clean wood, paper, cardboard and food waste should be burned at a landfill. Other items like plastic, batteries, and e-waste should not be burned. To produce the high temperatures needed to completely burn waste, a burn box is often used. This combines a structure with proper ventilation to ensure high temperatures. Summit and Tok are two Alaskan companies that make burn boxes often seen in northern Alaska. Incinerators use a mechanical method to add fuel and air flow to produce an even higher temperature. Incinerators require additional maintenance and fuel to operate and are not recommended for smaller communities that do not have the resources to operate them.

### **Backhauling**

Backhaul is when transportation companies haul old material out of a community after delivery new material. The tendency in northern Alaska communities is to import most resources but send out very little. What is left in the community usually ends up at the landfill. Backhauling solid waste protects communities against pollution and also reduces the cost of local waste management. Backhauled materials usually consist of recyclables and hazardous waste. Recyclables that are typically backhauled consist of aluminum cans, cars, and whitegoods. Hazardous wastes backhauled are usually car batteries and e-waste. Most communities are served by barges or by air but few are on the road system which makes backhauling expensive. Other issues with backhauling are covered in the next section dealing with the remote location and logistic challenges faced in northern Alaska.

### **Thawing Permafrost and Subsidence**

All effort should be made to prevent or minimize permafrost beneath landfills from thawing. This can be done at existing landfills by preventing water from ponding on the site and prevent ground disturbances adjacent to the landfills. Depending on the soil conditions below the landfill, when permafrost thaws, there could be substantial subsidence of the ground. If this happens, all low areas should be filled in and graded to prevent the ponding of water that could increase the rate of permafrost thaw. If the thawing of permafrost is significant, an analysis of the landfill should be completed to see if there is potential for contamination of groundwater or nearby surface water that the permafrost was previously preventing.

## COMMUNITY CHALLENGES AND SOLUTIONS

### **Funding for Solid Waste Management**

Like all utilities, operating a solid waste management program requires money to operate. Landfills are usually an expensive upfront cost to build, but there is an ongoing operations and maintenance (O&M) cost associated with it as well. Funding for solid waste is problematic for a lot of communities in northern Alaska. Lack of funding leads to a lack of maintenance and upkeep at the landfill which in turn affects the health and wellness of the community. It takes hundreds of thousands of dollars to millions of dollars to design, permit, and construct a new landfill. Rarely, any communities can afford to pay for new landfills out of pocket. Without funds to construct a new landfill an existing landfill risks being over filled or the kept in operation in an unsafe location or manner.

To operate a solid waste program, money must be available to pay the operators, purchase daily cover material, fuel for equipment needed to pick up and deposit the waste. Funding to operate the solid waste management program in a community can come from the community itself. A fee for the service of using the landfill can be charged. This is a common practice in larger cities but in small cities this is often not implemented due to complex political and socioeconomic factors. Some communities charge business only, some charge residents only and some communities only charge a nominal fee. Of these fees charged, they often go unpaid with little recourse. The EPA has compiled data from exemption requests from 81 communities and analyzed the

information given. They have found that 62 percent of communities receive fees but are between 0 and 90 percent successful in collecting them.

A solution that some communities have found that works well is to bundle all of the utilities into a single fee and to terminate service when a payment not made. A resident is much more likely to pay outstanding solid waste service fees if their water and cable TV are turned off. A case study in this is the community of Nondalton, Alaska. Nondalton, connected solid waste fees to other services like water and sewer. It was difficult for the community to accept this for the first three years, but now it is accepted and an expected service. They found that their collection rate went up to 96 percent after this was implemented. For residents not able to pay the fee, community service work in lieu of fee could be implemented. The Rural Utility Business Advisor (RUBA) Program offered through the State of Alaska's Department of Commerce, Community and Economic Development (DCCED) can offer assistance in setting up a fee structure and implementing it.

There are many government funding sources available to construct or operate a landfill in Alaska. The United States Department of Agriculture (USDA) Water and Waste Grant is for communities looking to fund large solid waste infrastructure such as heavy equipment and facilities or new landfills. The USDA Preplanning Grant can be used to prepare planning documents for new landfills. The Indian Environmental General Assistance Program (IGAP) is available for tribes to implement solid and hazardous waste activities. The IGAP is an annual fund that is useful for operation costs and backhaul of solid waste but will be discontinued for O&M in the year 2020. There are

many other funding sources available for solid waste management from government and private sources.

Most government funding sources are for grants which are one time funds and should be used towards large improvement projects. Some government funds are also awarded on a competitive basis and may not be reliably counted on. A sustainable funding source is needed to cover the costs of annual O&M costs. The fee structure mentioned previously is one method of providing this funding source. If fees are not enough to cover the costs other solutions would be to make money from recycling, charge contractors coming into town a fee or get them to clean up the landfill as cost for disposing waste there, and other simple methods like bake sales or bingo have also been used in Alaskan communities to raise funds.

### **Remote Location/Logistics**

Only a few communities in northern Alaska are connected to the road systems. Access to the communities is by air or barge. The remote access adds additional costs to everything from groceries, gas, and construction. If a community is accessible by river, barge costs are much lower than shipping by air. However, barges typically only come a couple times a year in the summer. This makes planning and logistics critical for bringing supplies and equipment or hauling waste out of a community.

Some common issues with the remote location are shipping material out of the community. Barges have a tight schedule to keep and depending on tides, may only have a few hours to load or unload material. It is critical to have all the material or waste that is

to be placed on the barge staged and ready to go when the barge arrives. The barge will not wait for waste to be collected or packaged for shipping.

When shipping hazardous waste, it is necessary to make sure that it is packaged correctly. Transporters have to follow federal regulations for shipping hazardous material. Proper packaging is the responsibility of the shipper and large fines can be levied against communities for improper shipping. It is also important to realize that there are different regulations for different types of transportation methods. Barges, roads, cargo airlines, and passenger airlines all follow different regulations. It has been the case where hazardous waste has been packaged and sent by air to hub communities where it was to be barged out only to realize that it was not properly packaged for barge travel and had to sit at the docks until the hub community was forced to deal with waste that they did not generate.

The solution to these problems is proper planning and communication. If communities plan ahead and be ready, they can anticipate problems. Communication between shippers and transporters is also necessary to anticipate problems and changes in schedules. It is recommended that pictures be taken of waste after it has been packaged and those pictures to be reviewed by the transporters to look for problems.

### **Resource Recovery**

Efforts need to be made to recover as much resources in the waste as possible before disposing of them in the landfill. This will reduce volume of waste in the landfill, minimize health, safety, and environmental risk. Additionally, pre-cycling can be done to

minimize the amount of waste entering into the communities. Pre-cycling is the practice of reducing waste by attempting to avoid bringing items into the home or community which will generate waste. For rural Alaskan communities, this can be done by buying in bulk, buying materials in recyclable containers, consolidating shipments to villages, and removing packaging material prior to bringing personal goods into the community.

Re-use of items, repurposing items and salvaging are other ways to recover resources from the waste before disposal into the landfill. These actions need support from both the community and the local government to be truly effective. Re-use centers need to be set up where residents can drop off partially used items such as partially used paints, weed killer, solvents, and other items that should not be placed into a landfill. Other community members can “shop” in this re-use center for items they need. Salvage areas at the landfill where old snowmachines, ATV, building materials, and appliances are placed so that others can salvage them for parts.

### **Hazardous Waste**

Hazardous waste can be a confusing topic when dealing with waste entering the landfill. The topic is very complicated with many factors to consider. Education is key for a successful hazardous waste management program. Residents of the community need to be taught what waste is safe to dispose of in the landfill or burn in the burn box and what waste needs to have special treatment because it is hazardous. Signs and flyers around the landfill and community go a long way with education. Educating the children in schools so that they grow up understanding the importance of properly disposing waste is one of the most effective ways to educate the community as they will bring these lessons home.



Properly labeled and organized landfills are essential to getting residents to properly dispose of recyclables and hazardous waste. A landfill with a container that has a large sign saying “waste oil” or “batteries” will have a significantly higher chance of those items being properly disposed of versus a landfill that does not have clearly marked or easily accessible places to recycle. Sign making material can easily be salvaged from the landfill.

### **Qualified Workforce**

The ADEC regularly visits and inspects landfills in the state of Alaska. The ADEC scores each landfill based on a list of criteria. They have found the one thing that all the top ranked landfills in Alaska have in common is a landfill operator. The operator makes sure the landfill is organized, with the proper material going to its proper place that waste is covered daily, and does general upkeep. Alaska has an established system for training landfill operators to know what is required to have a well maintained landfill.

There are noted cases where it is difficult for rural Alaskan communities to fund the position of landfill operator and high turnover rates for the position present additional problems. While no great solution has been found for the problem of qualified operators, it has been found that having a buy-in from the community on what needs to be accomplished for the solid waste program can help<sup>3</sup>.

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<sup>3</sup> Solid Waste Alaskan Taskforce conference, January 2016.

## **Coordination between City and Village**

There are occasional conflicts between local government entities when it comes to solid waste management. In rural Alaska, there are often both city and village councils that decided what happen in the same community. Typically, the city owns, permits, and operates the solid waste program for the community. However, the village council can receive funding from sources not available to the city. A conflict can arise if there it difference of opinions between the two entities. The typical solution for this is for a Memorandum of Understanding (MOU) to be drafted that clarifies the roles and responsibilities of the different entities.

## **LANDFILL CLOSURE AND POST-CLOSURE CONSIDERATIONS**

Once a landfill has reached its final elevation, a final cover should promptly be placed over the waste. ADEC regulations require final cover to be placed within 90 days of the final waste being placed (18 AAC 60.245). The requirements for closure of a landfill will vary depending on its Class. A Class III requires 24 inches of soil be placed over the waste and be graded to promote drainage without erosion (18 AAC 60.390). Class I and II landfills require that the cover system have a permeability less than or equal to the permeability of any bottom liner or natural subsoils. The cover placed over the landfill at a minimum should be 18 inches of earthen material with permeability no greater than  $1 \times 10^{-5}$  centimeters per second (18 AAC 60.395).

Storm water management will be the primary consideration once a landfill is closed. Storm water should be managed so that the minimal amount of water will reach the waste and create leachate. The top of the final cap should be sloped so that any precipitation that lands on it will flow off instead of soaking through. Settlement of waste over time should be considered and the slope of the final cap should account for large differential settlements that may occur. A large landfill such as the Anchorage Regional Landfill sees waste settlement of 1 to 3 feet a year. Side slopes that were 3H:1V at ARL are now 5H:1V. If the large slopes are needed to account for settlement, shallow slopes can be used, but may require annual grading to keep storm water from ponding. The initial design of the landfill should have created drainage features to prevent surface water from entering the landfill. These features may need to be modified or maintained after closure.

## CONCLUSION

In conclusion, managing a solid waste program in northern Alaska can offer a unique but solvable set of challenges. The key strategy is to be able to anticipate the problems that can occur, such as thawing permafrost, extreme temperatures, poor funding, remote locations, and differing cultures. Problems with solid waste management often do not occur overnight and likewise, they are never solved overnight.

Location should be the primary design consideration of new landfill. Positioning potentially harmful waste away from the community, permafrost, runways, waterways, and subsistence areas will minimize the impact the waste has on the community. If this is not possible, the landfill should be designed to accommodate for these factors. The design of the landfill must also consider problems that can occur in the distant future.

Operations and maintenance of the landfill is critical for public health. It has been shown that a having a capable landfill operator can make the difference between a marginal and exceptional landfill. Developing isolated areas for recycling and hazardous waste keeps unnecessary and dangerous waste out of the landfill. Proper burning of waste maintains air quality and minimizes waste entering the landfill. Maintaining drainage away from the waste prevents stormwater from entering the waste and becoming harmful leachate.

A successful solid waste management program must also develop community wide buy-in to the program. A community that understands that benefits of a strong solid waste management program will be more likely to fund the program and encourage proper disposal habits. Educating the community about the dangers of an ineffective solid

waste management plan is a key factor in developing community buy-in. Another effective solution is to have a solid waste “champion” in the community to encourage good disposal habits and advocate for increased funding for the program.

Well designed, operated, maintained, and closed landfills are where the communities pay for the disposal of their own wastes. Poorly designed, operated, maintained, or closed “dumps” are where the future generations will pay to dispose of current generations wastes. The financial costs as well as the costs to the environment and community health will always increase the longer the problems are deferred.

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