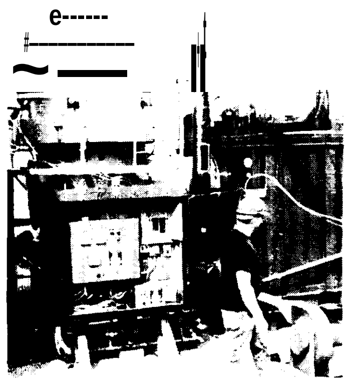
Alternative Sanitation Technologies 5

INTRODUCTION

This chapter discusses a number of new and innovative approaches to providing adequate sanitation systems to Native Alaskan communities. Many approaches have been proposed, but few have been evaluated and tested under realistic conditions. There is, however, a growing need to improve sanitation systems at a realistic cost and with confidence in safe and practical results. For more than three decades, Federal and State efforts to improve waste sanitation among rural Native communities in Alaska have focused on building centralized conventional piped systems. However, these systems have a high initial cost, especially when built in remote regions with harsh cold climates, and because of the environmental extremes, operational maintenance is also difficult and costly. To date, only 72 of the 191 rural Native communities identified by the Indian Health Service have been provided with piped sewerage services. The level of sophistication of waste disposal technologies operating in remote Alaska varies significantly among villages, ranging from complex piped sewerage service with flush toilets to the rudimentary privy and honey bucket systems. Between these two extremes, one finds technologies such as the septic tank and the truck haul approach.

For the most part, the sanitation technologies operating in rural Alaska are merely modifications of approaches designed decades ago for use in more moderate climates. Recently, a modification of the conventional truck haul system tested in the City of Mekuryuk (Nunivak Island, Yukon-Kuskokwim region) is being regarded as a promising alternative to honey buckets. Other systems, such as composting, incinerating, or propane toilets have also been proposed. These alternatives may overcome some of the cold-temperature problems encountered by larger conven-



tional systems and be more effective than honey buckets indisposing of waste and reducing human exposure. The fact that these systems can incorporate low-flush or waterless toilets and eliminate the need for maintaining sewage lagoons is also advantageous. However, because these systems do not require potable water, they defeat, in the view of many, the objective of promoting an ample supply of potable water and thus better sanitation practices in the villages.

Although potentially useful, some of the other innovative technologies discussed in this chapter, such as the National Aeronautic and Space Association (NASA) waste treatment methods, thus far appear either too complex and too expensive for immediate application or are just in their preliminary phase of development. (Current cooperative efforts among Federal and State governments and private organizations to demonstrate NASA's technologies, however, appear to be potentially useful for transferring knowledge and technical experience to remote communities with waste sanitation problems.) Others systems, though already developed, suffer from limited information about their actual full-time performance in treating human waste in areas of harsh climate such as rural Alaska. Finally, an overall mechanism to test and evaluate new systems under actual conditions in these Alaskan villages has yet to be developed. Until this is done, it will be difficult to select a system that is the most cost-effective, safe, and acceptable to the community that must operate it.

FIGURE 5-1: Cowater Sanitation System Showing Water Storage Tank and Toilet Installed Over Indoor Holding Tank

SOURCE Cowater International Inc , Ontario, Canada, Mekoryuk Sewage *Haul System Development Prototype Household Demonstration Final Report,* October 1993

DESCRIPTION OF NEW ADVANCED SYSTEMS CURRENTLY PROPOSED FOR ALASKAN VILLAGES

| Cowater Small-Vehicle Haul System

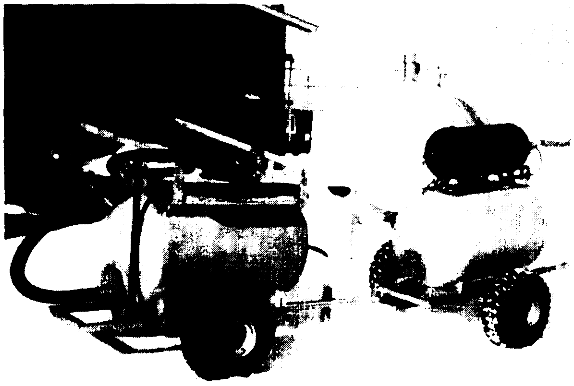
The Cowater small-vehicle haul system, a variation of the larger conventional truck haul system and developed by ***Cowater International*** of Ontario, Canada, is currently being evaluated in the City of Mekuryuk (Nunivak Island, Yukon-Kuskokwim region) as a possible sanitation approach for Alaska (figure 5-1). This technology involves the use of all-terrain vehicles (ATVS; during the summer) and snowmobiles (for winter operations) equipped with a tow trailer and a small vacuum/pressure tank to remove wastewater from house holding tanks (figure 5-2).

Although similar in concept to the truck haul approach, the Cowater system does not require expensive conventional vacuum trucks and is less costly to maintain and operate. In addition, it does not require load-bearing roads and snow removal equipment for its operation. The major elements of this system are: a dual flush toilet, an in-house water storage tank, an outside wastewater holding tank, and a small haul vehicle equipped with a haul tank.

Dual *Flush Toilet*

The dual flush toilet looks like a conventional household toilet, can be connected to a gravity-fed

FIGURE 5–2: Sewage and Water Tanks on Haul Wagons Operated as Part of the Cowater Sanitation System



SOURCE Cowater International Inc Ontario, Canada, *Mekoryuk Sewage Haul System Development Prototype Household Demonstration Flnal Report,* October 1993

water source, and does not require a pressurized water supply. It is designed to control the amount of water consumed, requiring only 1 pint per flush. Sometime in early 1995, one firm expects to begin the large-scale manufacturing of the dual flush toilet (186,1 87,237).

In-House Water Supply System

The in-house system consists of a tank capable of holding up to 150 gallons of potable water. Depending on the desired level of operation, the in-house water supply system can provide water for toilet flushing only; can incorporate a washbasin option in which the water used for hand washing can be recycled as flush water; or can supply water for washing, cooking, and drinking. A small electric pump fitted on the tank provides a constant supply of water whenever needed.

The water stored in the water supply tank is delivered from a small tank mounted on a wagon and drawn by a small haul vehicle. The operator uses the air compressor at the local water treatment plant to draw water from the large storage tanks of the water treatment plant into the haul tank and to fill the small air tank located on the wagon with compressed air. The compressed air is used to force the water from the haul tank into the water supply tank located inside the house.

Wastewater Storage Tanks

Depending on the house's design and the user's needs, the sanitation system may be equipped with either an indoor or an outdoor wastewater holding tank for discharging and storing wastes. Made of a flexible rubber or plastic bladder and aligned by a rigid enclosure, indoor holding tanks can store up to 100 gallons of wastewater. Indoor tanks are evacuated by a blower that pressurizes the tank, pushing the sewage through a pipe into a haul vehicle outside.

Outdoor holding tanks, on the other hand, are heavily insulated and capable of holding larger volumes. These tanks are generally set on skids alongside the house and are connected to the indoor sanitation system by insulated pipes. Outdoor tanks are emptied the same way as indoor tanks. Outdoor holding tanks are preferred to indoor ones because they remove the sewage from the home and eliminate the need to build steps to reach the toilet (120).

Haul Tank and Haul Vehicle

A tank designed for hauling human sewage from the house to the disposal area is made of stainless steel and sized to exceed the capacity of holding tanks.

As shown in figure 5-2, the haul tank can be mounted on a trailer fitted with wheels or skis and hauled by snowmobile, ATV, or a small tractor. With the exception of the pump-evacuated system in which a pump is provided, the system operator is required to use the blower located on the haul vehicle to empty the collected waste into the haul tank. Once the tank is filled, the operator pulls it to the sewage lagoon or disposal area and empties it by gravity. The pump-evacuated system allows the operator to empty the indoor holding tank into the haul vehicle by turning the pump-out switch located on the side of the house.

According to Cowater reports, the field demonstration at Mekuryuk has provided an opportunity for increasing the understanding of the system's engineering and performance, and for successfully working with Native residents in achieving the community's desired level of sanitation and aesthetics (82,1 19,120,1 85).

The "AlasCan" Organic Waste and Wastewater Treatment[1]

The AlasCan is a modular, high-technology, self-contained comporting system designed to handle sanitary and kitchen wastes and greywater(181).[2] The essential components of the AlasCan system are a custom-made comporting tank and a ceramic toilet (consisting of either the fully automatic, computer-operated Nepon Pearl ***foam-flush*** toilet[3] or the pedal-operated ***vacuum*** toilet known as SeaLand VacuFlush). This combination, according to its designers, provides the user the comfort of a flush toilet and the advantage of comporting treatment (97). The AlasCan is also equipped with a kitchen waste disposal system and a greywater treatment tank.[4] To avoid problems experienced with other models in the past (e.g., odor escaping into homes), AlasCan designers built the toilet and compost treatment tank as two separate units (146).

The AlasCan comporting technology has been in use in several facilities in Alaska, Canada, and the lower 48 States. Most of the Alaskan sites, however, are National Guard armories. One particular unit is being used on an oil drilling rig near Prudhoe Bay. Field tests are also being conducted at a few selected locations in the Yukon-Kuskokwim region to evaluate its potential for use in Alaskan Native villages.

Major Components of AlasCan Compost Technology

Comporting Tank

The central component of the AlasCan comporting system is a double-walled "superinsulated" plastic tank containing a fully automated chamber with aerobic bacteria and red worms to decompose sanitary waste or backwater into a safe, fertile humus material similar to garden soil (6,7, 182).5 Wood shavings are added to reduce excess liquid in the tank and to provide the carbon and other minerals needed for effective biodegradation.

The treatment tank is equipped with a series of baffles, air channels, and mixers. A fan is also used to draw warm air into the treatment tank to promote organic decomposition of the waste (figure 5-3). To improve the rate of decomposition, the treatment tank is fitted with two items: automatic churners or agitators capable of mixing the wood shavings, red worms, and waste; and sprinklers, which reincorporate accumulated liquids into the mixture when needed (6,7, 181). The computer-controlled agitators are set to operate for about 20 minutes daily so that recently disposed waste is properly mixed, and the compost pile leveled (6,7). Installation of an auxiliary heating unit may be required in locations where ambient conditions could force the internal temperature of the comporting tank to drop below 60 "F.

The treatment of human waste with the AlasCan comporting technology results in three by-

[1] This technology is commercially known as the AlasCan Model 10 system.

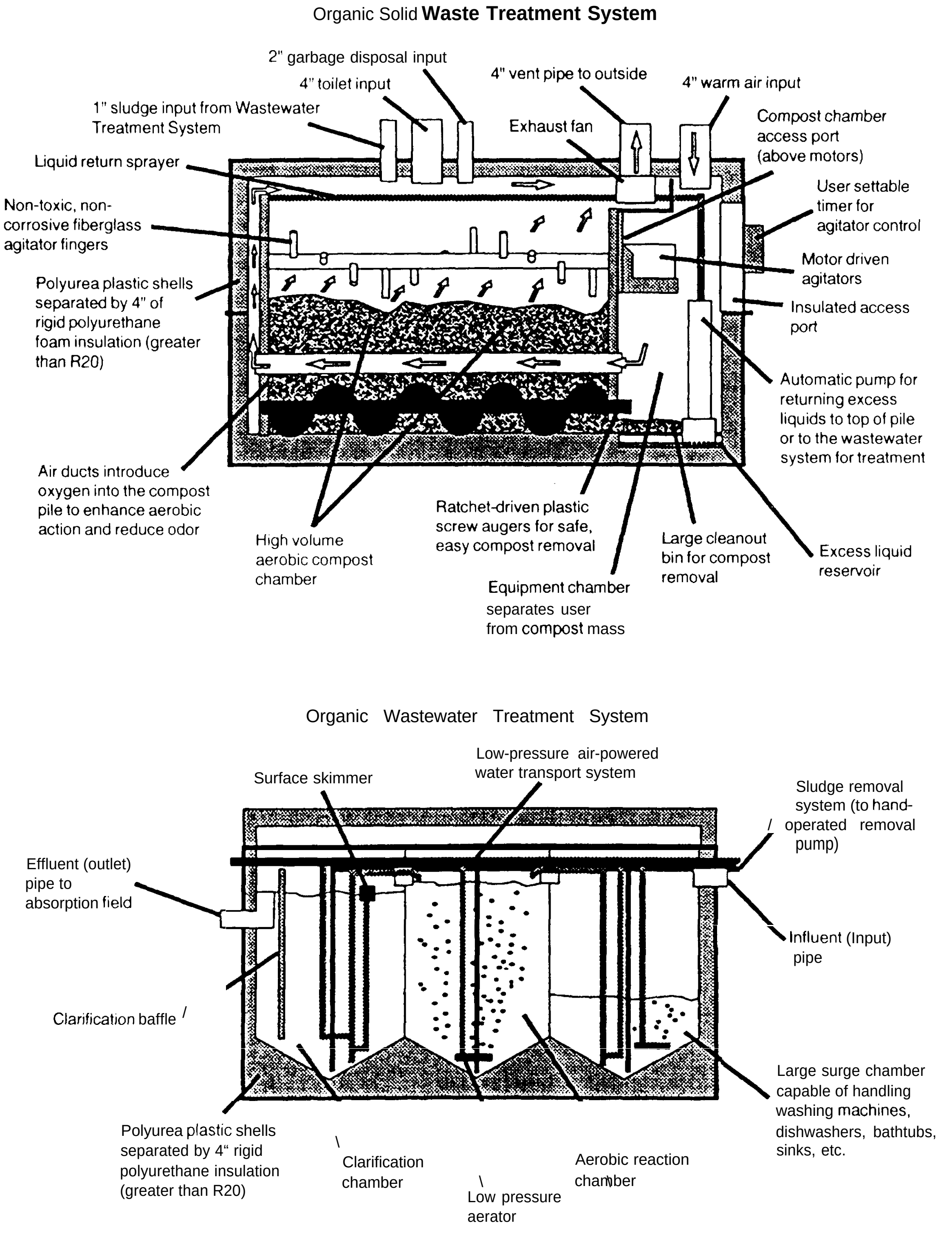
[2] Greywater is household wastewater without toilet waste. It consists primarily of discharged water from bathtubs, showers, sinks, and appliances such as washing machines and dishwashers.

[3] Developed by the Japanese firm Nepon, Inc.

[4] One optional feature offered by the manufacturer of this system is a wall-mounted urinal equipped with the same foam-flush action as the toilet system.

[5] The term backwater refers to the urine, fecal matter, and related debris such as toilet paper deposited in a toilet, as well as the water used to transport these materials

FIGURE 5-3: AlasCan Composting Toilet System



SOURCE Al Geist, Marketing Director AlasCan Inc Fairbanks Alaska, personal communication, Nov 23, 1993 products: water vapor and carbon dioxide, which are released through an insulated vent installed in the home or building, and humus, which collects in a tray in the lower portion of the tank. The aerobic nature of this technology prevents the generation of malodorous methane gas (181).

Its modular design makes the AlasCan system easy to install and maintain. For homes built on slab floors or with limited crawl space, AlasCan uses a special vacuum flush toilet[6] to lift waste up to the comporting tank. Lifting of greywater into the treatment tank is accomplished by a transfer vacuum pump fitted to a small reservoir (6,7,145). For homes without running water, the bathroom toilet is fitted with a small reservoir or water tank.

Ceramic Toilet

The AlasCan system is an improved design over the internationally known Clivus Multrum comporting toilet.[7] Such improvements include, among others, automation of the comporting process; connection of the comporting tank to a modern foam-flush toilet; and addition of a separate greywater treatment tank unit (181). Toilets may be of a "straight drop" waterless or a foam-flush design. The foam-flush toilet design uses a small air pump, which upon flushing, mixes a soaplike substance stored in the tank with water to produce a soapy foam layer inside the bowl that carries the waste down to the treatment tank with minimal splashing. The use of a biodegradable soap is also advantageous because it minimizes the need for toilet cleaning. When the toilet is flushed, waste is discharged to the insulated treatment tank where it is decomposed by organisms (bacteria and red worms) into organic humus (181).

Kitchen Waste Disposal System

The AlasCan system can also be equipped with a small garbage disposal sink fitted with a sprayer. This device is typically located in the vicinity of the kitchen sink. Garbage, placed in the disposal sink for processing, is subsequently piped to the treatment tank where human waste is also treated (181).

Greywater Treatment Tank

In addition to treating black water, the AlasCan comporting technology can be used to treat greywater (figure 5-3). The treatment of greywater is conducted in a three-chambered tank fitted with a series of baffles and filters. After treatment, the treated water is filtered and released into the ground, while the remaining solids are sent to the comporting tank for further decomposition. According to the manufacturer, treated wastewater can be returned safely to the environment because the AlasCan system removes the majority of pollutants found in it, including nitrites, volatile organic compounds, suspended solids, and organic matter (6,7,170).

Phoenix Comporting Toilet

The Phoenix comporting technology has been designed primarily for indoor installation. Its compact shape results in small tank and maintenance areas. The major components of this technology are a toilet, a kitchen waste inlet (optional), and a comporting tank (figure 5-4). Electricity can be supplied by an independent energy source, such as a photovoltaic system or by the small plug-in alternating current (ac) power plug supplied with the unit.

Use of the Phoenix comporting technology in rural communities of Alaska is limited in comparison to areas in the continental United States and Canada. The School of Environmental Engineering of the University of Alaska Anchorage will soon field-test two Phoenix units as part of an ongoing effort to identify potential alternatives to honey buckets in Native communities (196).

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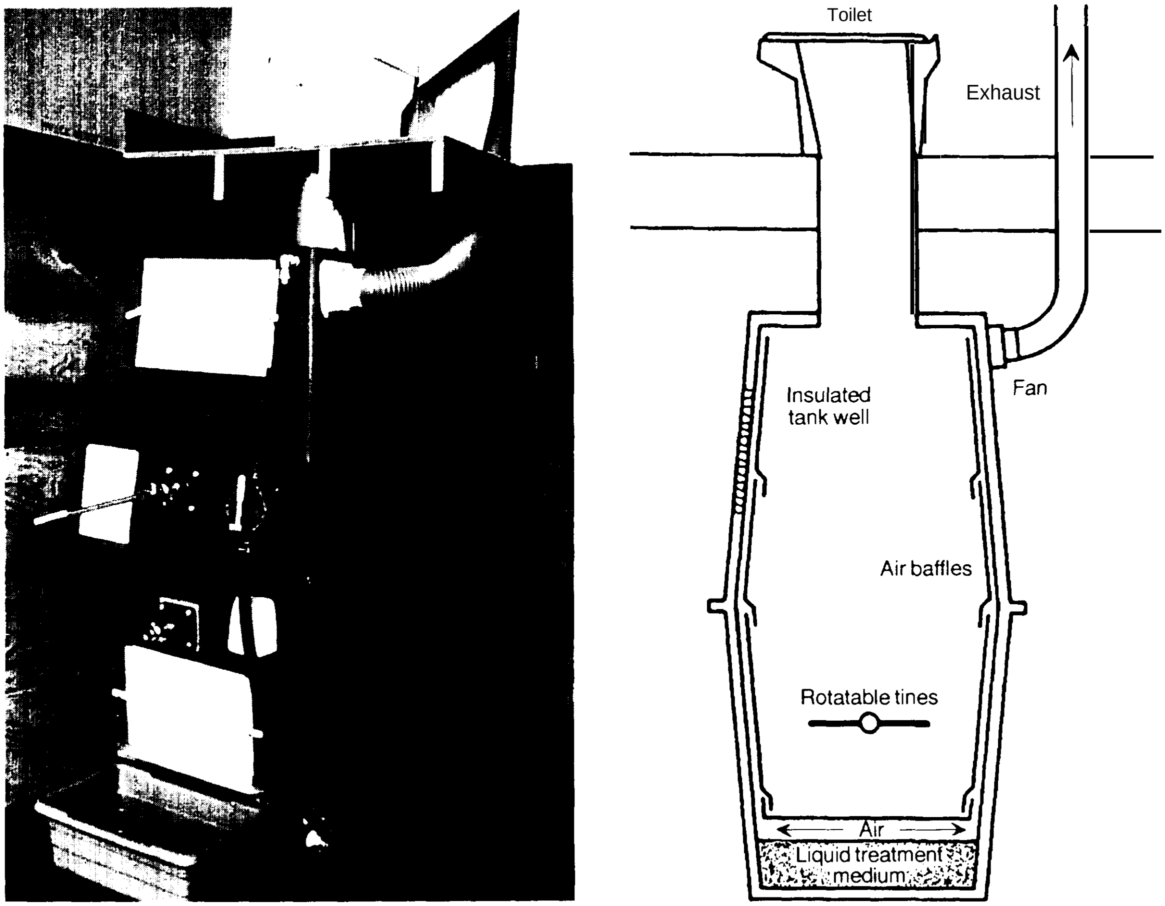
6 Known as the Sealand VacuFlush toilet system

7 The Clivus Multrum system was first developed in Sweden more than 60 years ago with the primary purposes of recycling waste and conserving water and land.

FIGURE 5-4: Phoenix Composting Toilet System



SOURCE Advanced Composting Systems, Whitefish, MT "Testing the Phoenix Composting Toilet," Mar 24, 1991 Advanced Composting Systems, Whitefish MT Evaporation System, " April 1992

Major Components of Phoenix Toilet System

Toilet System

The toilet provided in the Phoenix comporting system is contemporary in design and made of white plastic. The bowl is attached to the composting tank by a chute and secured with a specially designed connector. According to the manufacturer, certain models allow the connection of up to three toilets (3,197).[8]

Kitchen Waste Disposal Inlet

Manufacturers of the Phoenix comporting system have built two types of kitchen waste disposal options. One model consists of a stainless steel rim and bowl fitted with a maple chopping block cover for installation in kitchens with counter tops.

[8] If installation of a urinal is desired, the homeowner needs only to mount it on the toilet room wall and connect it to the composting tank with a vinyl hose. Urinals manufactured for the Phoenix system are generally made of steel or porcelain and are trapless in their design (3).

The other is an aluminum access port that can be installed either on countertops or on vertical surfaces (3).

Comporting Tank

The Phoenix operates much like a garden compost pile, requiring adequate food, air, moisture, and temperature to support the breakdown of sanitary and kitchen wastes into a stable humus-like material. Depending on the model, a Phoenix treatment tank is capable of safely comporting the sanitary and kitchen wastes of four full-time users (Model R200) or eight part-time users (R201). Other Phoenix models, such as the R199, have smaller treatment capacity because they are generally intended for cabin use (two people full-time; more if use is intermittent).

The Phoenix comporting system is ventilated by a multiple speed, 12-volt direct current (de), 4-watt fan.[9] The continuous insulation of the walls of the treatment tank seals the ventilation path and allows the air baffles to perform as heat exchangers; this, in turn, promotes heat retention (up to 80 percent) and increased decomposition rates. Aerobic conditions are maintained by air baffles installed on the side walls of the tank to aerate the compost pile and by rotating tines to keep the compost materials from compacting. Use of coarse wood shavings is required as a bulking agent (2,4,5,196,197) .

Transport of composted material through the tank is facilitated, according to the manufacturer, by the vertical and uncomplicated tank design, and by the incorporation of rotating tines. A built-in hand pump allows accumulated liquids to be sprayed back on the compost pile to maintain proper moisture. The sloped design of the internal tank floor helps separate treated liquids from treated solid byproducts. A liquid evaporator equipped with a small storage tank for peak loading is also used to reduce the amount of treated liquid byproduct that must be drained from the Phoenix system to a holding tank or to the outside environment (small leach field, soil bed, etc.) (197). For conditions in which liquid effluents cannot be discharged, the comporting tank is fitted with a highly specialized system (consisting of a 50- to 100-gallon storage tank, an evaporation tower, a pump, a dc fan or ac blower, and controls and sensors) capable of evaporating between 5 and 13 gallons of liquid effluent per day (2,5).

To ensure proper system operation in areas characterized by subfreezing temperatures, however, it is critical that the Phoenix tank be located in a well-heated area and that all vent pipes be insulated to reduce condensation and freezing (1 11,1 12,197).

Maintenance Requirements

The Phoenix treatment tank (approximately 3 feet wide, 5 feet long, and 8 feet high) requires about 5 feet of additional space in front of the tank, and about 1 foot of clearance above the tank, for proper operation and maintenance. The degree of maintenance required by this technology depends hugely on the frequency of use. The manufacturer recommends that bulking agent be added—about 1 gallon for every 100 uses—and thoroughly mixed into the waste pile. A heavily used system requires more frequent attention and care.

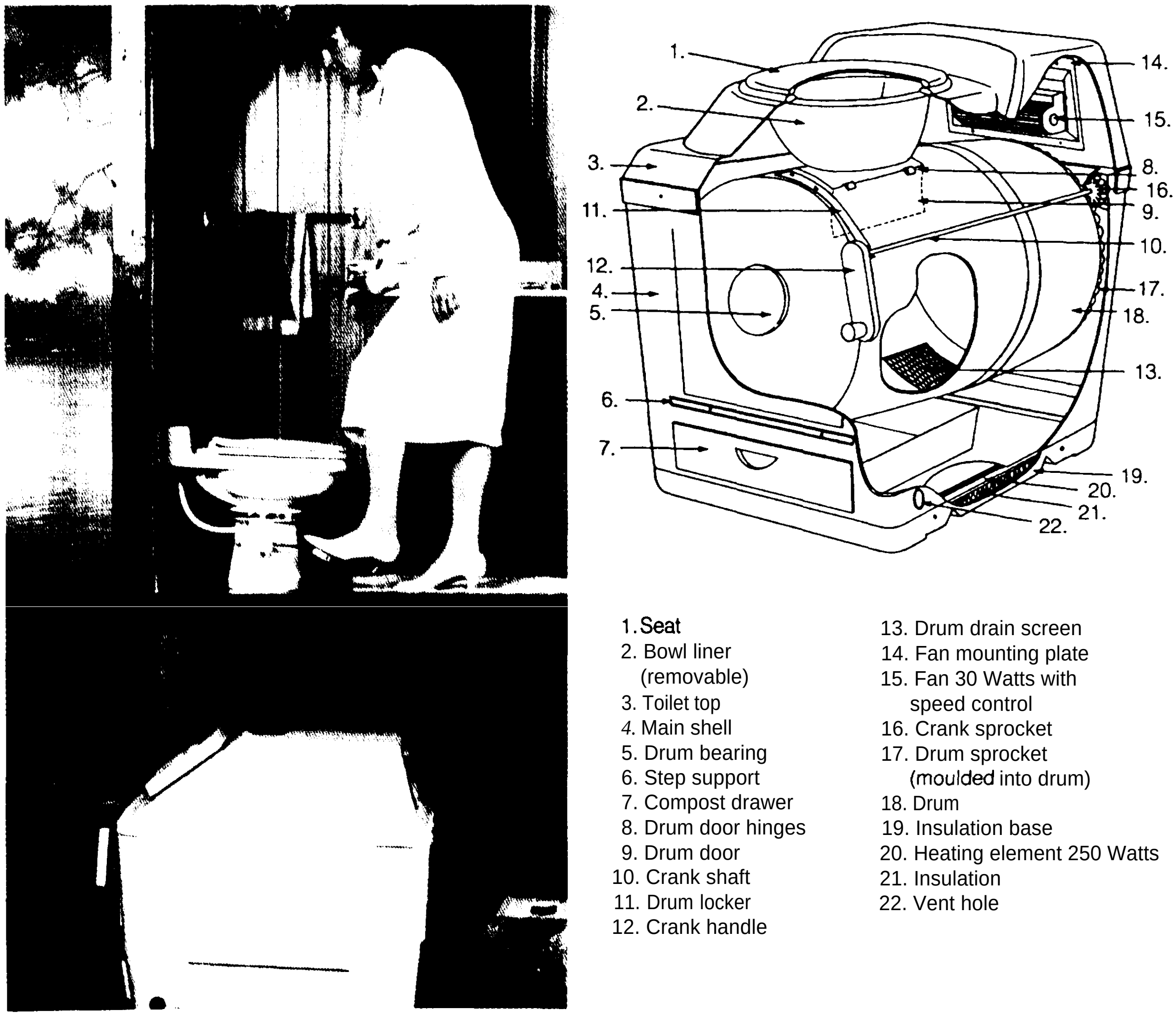
Similarly, the amount and frequency within which by-product materials must be removed depend on the extent of use, the rate of decomposition, and the maintenance of the unit. According to the manufacturer, treated materials should be removed at least once a year, starting after the first year the system has been in operation. It is estimated that about 8 gallons of humus would have to be removed from the tank for every 1,000 uses.

Sun-Mar Comporting Toilets

Sun-Mar Corp. of Ontario, Canada, has developed a series of composting toilets capable of biologically treating human and kitchen wastes, toilet paper, and other organic materials (figure 5-5). Application of the Sun-Mar system in rural

[9] A 24-vtdt dc fan is also available.

FIGURE 5-5: Overview and Schematic Diagram of Sun-Mar Composting Toilet Systems



SOURCE Sun-Mar Corp , Burlington, Canada, “Sun-Mar Cottage Toilets, ” undated

communities of Alaska has been limited in the past. The School of Environmental Engineering of the University of Alaska Anchorage plans to conduct a field test of this technology in an effort to evaluate its feasibility as an alternative to honey buckets (197).

System Characteristics

Sun-Mar comporting toilets are available in electric (ac, dc, solar) and nonelectric designs. During operation, waste is transformed into humus by heat from the compost pile or a heating element, oxygen provided by the ventilation system, and organic material (e.g., peat moss) added to the system by the homeowner (236).

The fiberglass and high-grade stainless steel construction, according to the manufacturer, protects Sun-Mar compost toilets from structural damage at freezing temperature. As with most comporting systems, however, temperatures below 60 'F will adversely affect the rate at which the Sun-Mar system can degrade waste. For this reason, the manufacturer recommends that the 1 l/2-inch vent pipe provided with the system be insulated adequately.

The use of a 30-watt centrifugal blower fan to provide a negative pressure within the treatment unit prevents back-draft and, with it, the formation and release of offensive odors from the toilet system into the home environment. Rotation of the comporting medium with the mixing system, along with the addition of peat moss, helps achieve rapid, odorless treatment of the waste (77,169,236).

The Sun-Mar models considered most likely to be used in rural Alaska are:

Compact and X-L (EXCEL)

The "Compact" model is a self-contained compost toilet system designed to accommodate low-capacity use (1 to2 people for residential use). The X-L model is recommended for larger demand (2 to 4 people). Both models are available in electric and nonelectric versions.

In addition to the toilet, these units contain three separate chambers for waste comporting, compost finishing, and the evaporation of liquid effluents. Comporting is carried out in a unit or chamber called Bio-Drum in which wastes are tumbled to achieve better mixing, aeration, and higher rate of comporting. Liquids are evaporated by means of a 250-watt electric heating unit with a replaceable thermostat installed at the base, and are drawn out of the system through a vent by a small 30-watt fan. The overall weight of these units is about 45 pounds, and their dimensions are 22 1/2 inches wide; 31 inches high, and 32 inches long (194,236).

Centrex and Water Closet Multrum Models

Sun-Mar Corp. has also developed a comporting toilet system consisting of a specially designed low-flush, ceramic toilet[10] connected by a 3-inch pipe to a comporting unit located some distance underneath the floor on which the toilet has been installed. Weighing nearly 60 pounds, the comporting unit of these models is about 33 inches wide, 25 inches deep, and 26 l/2-inches high. These toilets can accommodate the demand of 3 to 5 full-time users and twice as many under part-time use conditions.

Although the toilet does not have a holding tank, the use of water to flush waste into the comporting unit (less than 1 pint of water per flush) requires that the house be connected to a piped water system. Although a septic field is not required, these comporting systems have been fitted with a drain pipe for situations in which complete evaporation of the liquid cannot be accomplished.

Maintenance Requirements

To maintain the Sun-Mar compost technology in good condition, the homeowner must add one cup of peat moss per person per day plus, if available, organic materials or waste such as vegetable cuttings and greens. Adding warm water is also recommended whenever the compost appears to be too dry. The compost must be mixed and aerated every third day; this is easily done by turning the crank handle on the side of the toilet. Removal of the solid byproduct of comporting (humus) is recommended at least once a year for Sun-Mar systems undergoing residential application; less frequent use requires less maintenance (236).

Incinolet Electric Toilet System

INCINOLET toilets have been designed for a variety of applications, including, homes, cabins, barns, shops, boat docks, houseboats, barges, mobile homes, remote work areas, and laboratories. Most systems are about 15 inches wide, 20 inches high, and 24 inches deep (figure 5-6). Depending on the model, INCINOLET toilets can accommodate up to 10 persons (183,184,199,211).

The INCINOLET toilet is designed to use electric heat to reduce human waste—including urine,

10 Manufactured by SeaLand Technology, Inc., of Big Prairie, Ohio.

FIGURE 5-6: Incinolet Electric Toilet System

SOURCE Research Products/Blankenship Dallas TX, 'Incinolet 'hat Electric Toilet - an installation and maintenance manual 1993

Solids, and toilet paper—-to a small amount of ash, which can then be discarded periodically as trash. Installation of INICINOLET systems involves two steps: installing a pipe through the bathroom wall to vent incineration gases to the outside, and plugging the electric cord supplied with the unit into a nearby outlet (21 1).

Placement of a bowl covering or insert made of polyethylene film prior to each use prevents human waste from contacting the bowl surface and reduces the risks of exposure to users. The purpose of the plastic insert is to capture the incoming waste or urine. Once use is completed, the resident can flush the INCINOLET system by stepping on the toilet's foot pedal, which causes the plastic insert and its contents to drop into the incinerator chamber located at the bottom of the toilet.

Although incineration of waste begins immediately after it enters the chamber, home residents can use the toilet even while the incinerator is running, because combustion heat and vapors are vented to the outside to prevent the surface of the bowl from getting hot. INCINOLET can also allow the accumulation of up to four deposits before flushing (i.e., burning).

CombustiOn of waste at 1,400 °F eliminates bacterial growth, while a platinum-based catalyst, similar to those used in automobile exhaust systems, removes offensive odors from the treated waste or ash.

Because electric toilets are appliances, several features have been incorporated into the INCINOLET system to ensure its safe operation (1 83,2 11). These include an operating timer that limits the heating cycle to 1 hour; a temperature controller to limit heater temperature; and a safety thermostat to prevent overheating of the system m case of blower failure. A second thermostat has also been incorporated into the design to eliminate the extremely high temperatures that may occur following failure of the temperature controller. Even though it appears promising, there are few performance data on the use of INCINOLET in rugged, extremely cold environments such as that of rural Alaska.

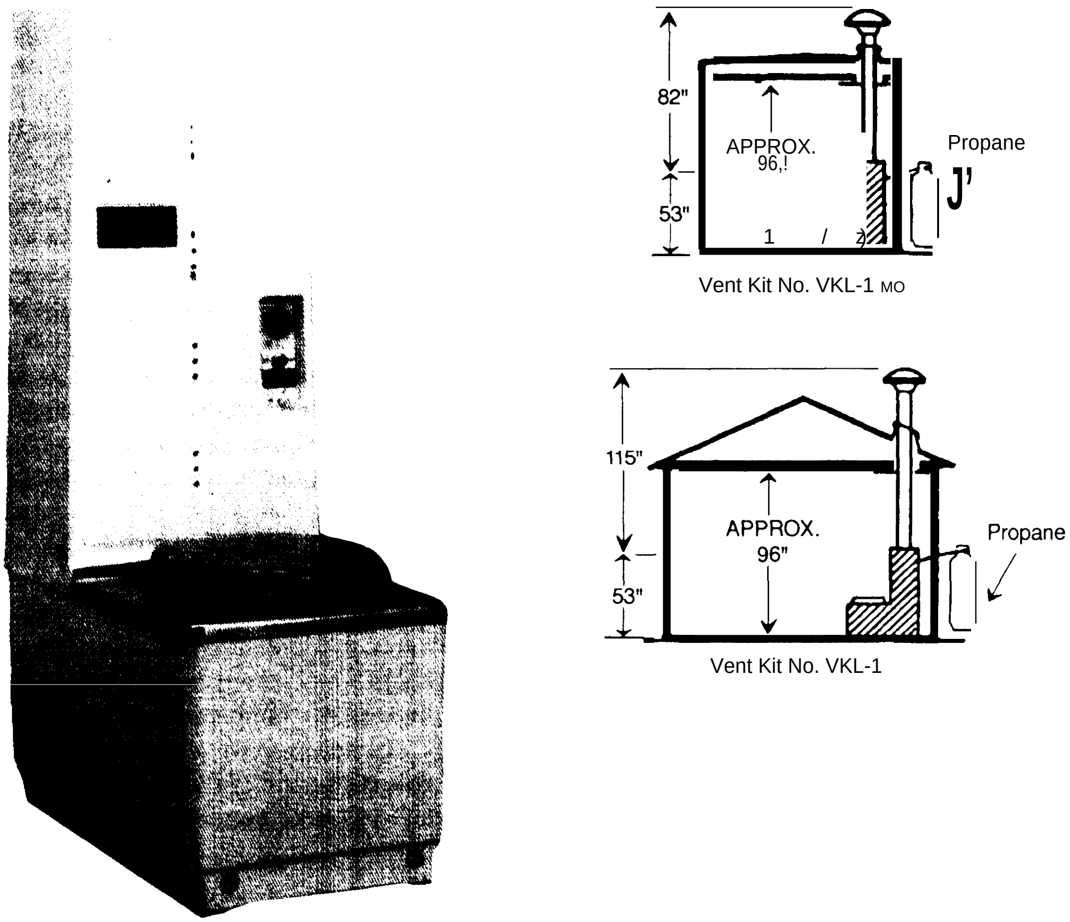
Maintenance Requirements

To ensure proper operation, emptying of the ash is recommended at least twice a week. wiping surfaces with a damp cloth is also suggested for overall cleanliness" The manufacturer advises inspecting the level of the catalyst (white pellets) contained in the incineration chamber every six months (183,21 1).

The Storburn Propane Toilet System

The Storburn technology is a compact, self-contained toilet designed and manufactured by Storbum lntemational, Inc., of Ontario, Canada, to incinerate human waste. Models available can operate with propane or natural gas. Most applications to date are found in cabins, mobile shelter units, and industrial and construction sites. Ac-

FIGURE 5-7: The Self-Contained, Gas-Fired Toilet System Offered by Storburn International



SOURCE Storburn Int , Inc , Ontano, Canada, “Storburn: Pollution-Free Toilet, ” 1993

cording to the manufacturers, about 100 units are already in use in Alaska (144,234).

The Storburn system consists of a toilet made of fiberglass reinforced with plastic material, a stainless steel top deck, and a 3-gallon waste combustion chamber made of cast nickel alloy (figure 5-7). Nearly 4 1/2 feet high and weighing 170 pounds, the entire toilet system covers a floor area of only 18 by 31 inches. A vent and a hookup to a propane or natural gas tank are required for operation.

The Storburn toilet can accommodate between 40 and 60 uses before incineration becomes necessary. Prior to burning of the waste, a chemical powder is added to the toilet system and a special cover is placed on top of the bowl to trip a safety switch, which ignites a pilot light and the burner that heats the combustion chamber. The burner shuts off automatically immediately after all wastes are burned. Depending on the ambient conditions of the area in which it is used, the Storbum toilet system can bum between 10 and 16 maximum-capacity loads (i.e., 600 to 900 uses) with a full 100 pound propane cylinder. The time taken to bum a loaded storage chamber is generally about 4 1/2 hours (234).

According to its manufacturers, the Storburn system is easy to maintain because it has no moving parts and only a few simple electrical controls. The high temperatures reached inside the waste storage chamber sterilize the chamber walls, thus eliminating the generation of foul odors and the need for cleaning the chamber. The only maintenance required is cleaning the burner about once a year (234).

Entech Thermal Oxidation System

Entech, Inc. of Anchorage, Alaska, developed a thermal oxidation process to treat solid waste and sewage from small, remote communities. In addition to incineration treatment of sewage, this technology can be used to treat other wastes and provide some energy as a byproduct.

The Entech thermal treatment system has three basic parts: a primary combustion cell or refractory chamber, where trash and other community wastes are loaded without preprocessing or presorting and are heated—by gas, diesel, or propane torches—to convert them into a combustible gas and other incinerated materials (inert ash, glass, metal, etc.).[11] Removal of treated waste materials from the insulated chamber is required every 6 to 10 cycles.[12] A secondary combustion chamber receives and ignites the gas produced by the primary cell to 2,000 "F to eliminate pollutants and produce a smoke-free, hot air and water vapor emission. According to company literature, "no odor from combustion during the operation of the system is detectable" (134,135,209).

The third major component of this technology is a computerized device called the process logic controller, designed to automatically control the system's operation and reduce the need for hiring highly trained operators. This device monitors the treatment, finishes the cycle, and shuts down the system within a period of 10 to 12 hours after operation was initiated. About 2 or 3 hours after shutdown, the primary cell will be sufficiently cool to allow the next load of waste. Another advantage of the process logic controller is that it permits remote monitoring of performance, and repair diagnosis of the system, by phone from Anchorage to anywhere in the State of Alaska.

Depending on the community's waste disposal needs, schedule of operation, and design preferences, the chambers may vary in size, number, and ability to recycle waste heat. According to its manufacturers, the Entech system can be adapted to operate on a daily, every-other-day, or weekly basis. The configuration of the Entech system can be further designed to collect the radiant heat produced during operation for use in a number of different applications. They may include space heating, water heating, steam production, and refrigerated warehousing—through the use of reverse chillers (135,209).

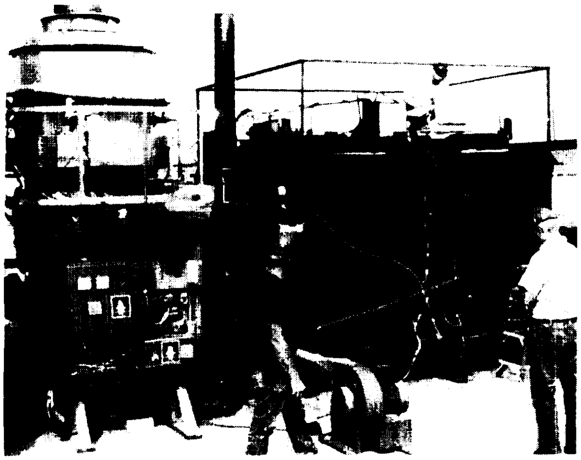
According to company officials, the operation and maintenance (O&M) of the Entech Thermal Oxidation System are relatively simple. An individual who has the capability to read and write at the high-school level, and is familiar with equipment and truck maintenance, is generally qualified to run and service this waste treatment technology. Entech can train operators and supply technical O&M assistance.

Although not specifically designed and built to treat human sewage, the thermal oxidation technology (figure 5-8) could potentially be useful in some communities because it may solve both their honey bucket and their solid waste (trash) disposal problems (208). The initial capital and O&M costs of the Entech technology vary ac -

[11] According to company officials, the Entech system can treat, in addition to trash, a number of waste streams including medical waste, tires (with the rims), wood, construction debris, furniture, oil filters, paint, household cleaning and other chemicals, fish net, absorbent booms and pads, ship wastes, honey bucket waste, used oil, tank bottoms, fish cleaning waste, and oily ship waste (bilge water).

[12] Testing of ash resulting from the treatment of certain hazardous wastes may be required prior to their disposal.

FIGURE 5-8: Entech Thermal Oxidation System



SOURCE Michael G. Pope, President, Entech, Inc., Anchorage, AK, personal communication, Apr. 7, 1994

cording to the size of the community for which it is being considered. High capital and operational costs might make the application of this technology for treating honey bucket waste difficult in communities with few economic resources. However, expanding its application to other waste streams, such as trash, might make it cost-effective overall. The necessary technical and economic studies of the Entech system for treating solid and sanitary wastes in a rural Alaskan village have not been conducted to date.

NASA's Controlled Ecological Life Support System

The Controlled Ecological Life Support System (CELSS) is one of the cooperative applied research programs of NASA that might be useful in solving future sanitation problems in rural areas of Alaska. The major objective of CELSS is to test advanced technologies to support human life in harsh environments such as the moon, Mars, and remote or isolated regions of Earth (96,192). The program focuses on technologies that, 1) produce and recycle food, air, and water in a way that resembles natural processes; and 2) eliminate the need for frequent resupply, and overcome the harsh environmental conditions.[13] Another portion focuses on developing technologies capable of treating human waste and recycling wastewater in a manner that reduces health and environmental risks of exposure. NASA plans to demonstrate technologies relevant to sewage treatment in two programs: the Antarctic Analog Project and the Life Support Research Testbed in Barrow, Alaska. The possibility for commercialization of the technologies employed in these programs will also be explored. It is too early to evaluate whether these systems could be adapted to solve sanitary problems in Native Alaskan villages.

Currently, several advanced waste processing technologies are being tested by Ames Research Center scientists at Moffett Field, California, for possible application in rural Alaska, Antarctica, and space flight (95,96,308,309). Examples of potential candidates include the following:[14]

Incineration—This approach would involve the thermal treatment of concentrated human waste to produce dry, inorganic ash and gases (e.g., water vapor, carbon dioxide). NASA plans testing to evaluate overall system performance, energy consumption requirements, and level of treatment that may be needed after incineration.

13 Based on past Pilot demonstrations of minifarrns and fish ponds conducted at the Ames Research Center, NASA personnel have designed and tested the prototype of a special chamber or mini farm for investigating crop growth in highly enclosed environments. The chamber will be used for testing different types of crops along with certain technological devices (lighting and nutrient del ivery systems; and sensor, monitoring, and control devices). According to NASA, previous attempts with this type of technology have produced "world record yields" (192). Several aquiculture tanks are being operated and tested at Ames Research Center for identifying types of fish (e.g., tilapia) and other aquatic animals that can serve as a food source for human consumption, and as processors of inedible biomass into products useful for crops.

14 Other technologies or engineering concepts that NASA might also consider include the Phase Catalytic Ammonia Removal and the Wiped-Film Rotating Disk Evaporator.

- *Pyrolysis-This* commercially available system uses intense heat to treat hazardous waste in the absence of oxygen. To evaluate its potential in controlled ecological life support strategies, NASA plans to test conventional and more advanced pyrolysis technologies (e.g., pyrolysis technology assisted by microwave radiation) by themselves or in combination with incineration.
- *Wet oxidation-Wet* Oxidation, unlike incineration, which requires wastes to be sufficiently dried prior to treatment, involves the combustion of either a dilute or a concentrated waste slurry at high temperature and pressure. In addition to reducing waste volume, wet oxidation allows the recovery of water and nutrient materials. According to NASA, a small prototype for space application already exists.
- *Supercritical water oxidation-This* technology combines high temperature and pressure to create an environment—supercritical—in which organic and inorganic compounds present in wastes become highly soluble, reducing their complex chemical structure to their most basic forms: carbon dioxide, water, and salts. Studies are needed to evaluate means to prevent possible corrosion and clogging of system components prior to the actual deployment of this technology.
- *Electrochemical oxidation—This* technology is designed to treat organic compounds at ambient temperature and pressure with the assistance of electrochemical- and ultraviolet-generated chemicals, such as ozone. Near term use is not possible because the technology is still in its early phase of development.
- *Plasma-arc incineration-This* treatment process involves the passage of waste materials through a thermal plasma field to reduce their chemical compounds to more basic components such as hydrogen, carbon monoxide, and ash. Because the technology is only in its pilot-scale research stage, additional work is required before it can be applied to NASA's field programs in Alaska and Antarctica.
- *Composting or microbial bioprocessing—This* type of technology employs microorganisms to degrade organic waste under near-ambient conditions and in the presence or absence of oxygen. In addition to volume reduction, composting technologies reduce organic wastes to: 1) carbon dioxide, water, and microbial biomass when oxygen is present; or 2) methane gas and generally smaller microbial biomass in oxygen-starved processes. Application of this technology thus far appears limited because of its inability to break down slurries and solid materials completely.

Life Support Research Testbed in Barrow, Alaska

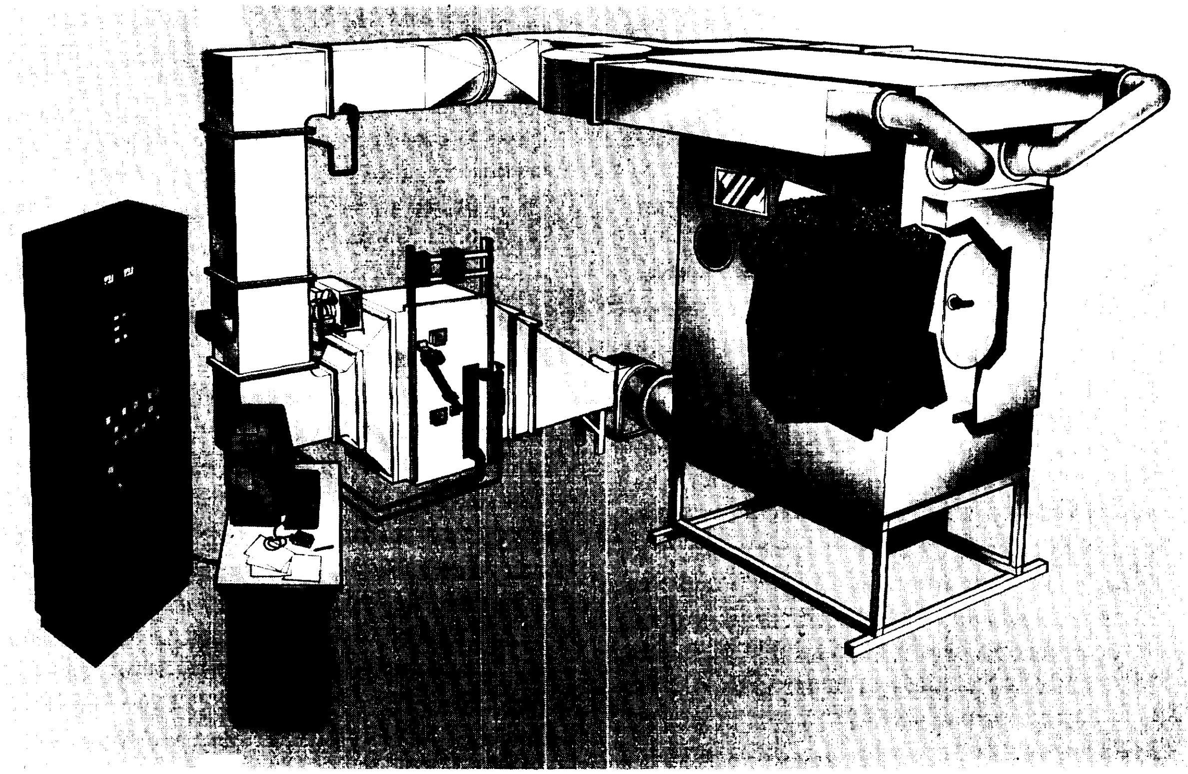
NASA, in cooperation with various Alaskan organizations (i.e., Alaska Science and Technology Foundation, University of Alaska, Native corporations, and the private sector) is planning to test one version of its multi system approach at the National Arctic Research Laboratory in Barrow, Alaska (96,72,196). This test is expected by NASA officials to generate scientific information useful for supporting future use in rural Alaskan villages and other polar regions of the world, as well as for developing an educational outreach program.

Located adjacent to the kitchen of the National Arctic Research Laboratory in Barrow, the testbed is planned to consist of only a modularized crop production chamber equipped with an advanced water recovery system. The capability to process human waste will be added once one of the treatment technologies mentioned above is determined as appropriate for use. Once the entire system is deployed, scientists will have the opportunity to investigate its market potential and adaptability in remote communities where sanitation problems continue to exist.

Antarctica Analog Project

The Antarctica Analog Project is a cooperative effort between NASA and the National Science Foundation to use advanced food production (crop production and aquiculture) systems, water recycling methods, and human waste processing technologies now undergoing development and

FIGURE 5–9: Overview of NASA's Antarctica Analog Project Technology, Which is Being Tested and Scheduled for Deployment at a New South Pole Station by the Year 2,000



SOURCE David Bubenheim, Chief Scientist, CELSS Research and Technology Development, Advanced Life Support Division, NASA Ames Research Center, personal communication, Jan 25, 1994

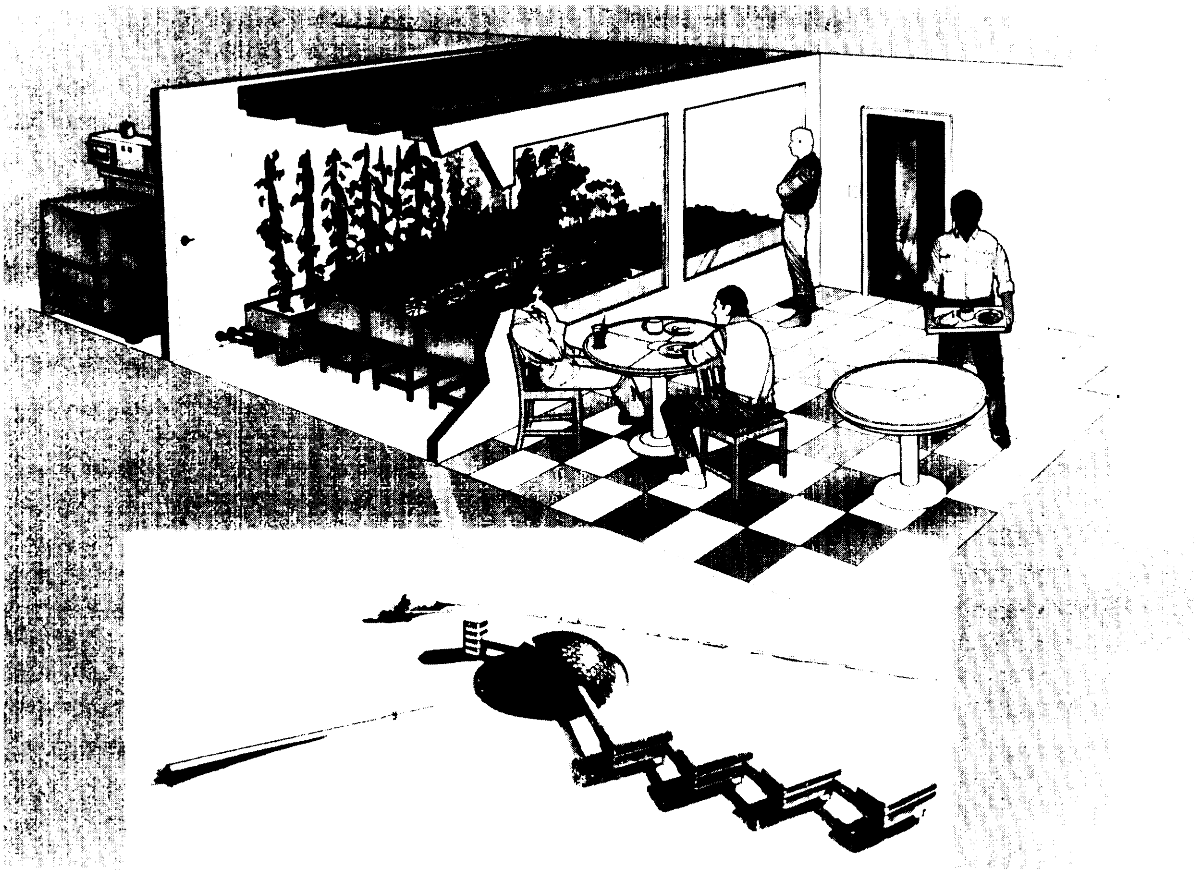
testing. At present, most advanced technologies to support researchers stationed in the South Pole are in their initial stages of project development. NASA researchers are currently identifying all relevant design and performance characteristics associated with crop growth, aquiculture, and waste processing technologies. Evaluation of pilot plant studies is scheduled for sometime in 1995 and 1996 at the South Pole, with deployment of a full-scale system (figure 5-9) by the year 2,000 when construction of a new South Pole station is planned for completion (96,192,235).

When installed, the final Antarctic Analog Project is expected to be fully integrated with the infrastructure of the research station and to consist of a minifarm, a park, a food production system (for growing fish and vegetables), and water recovery and recycling (figure 5-10). Treatment of human waste will be provided by one of the technologies described above once it is successfully demonstrated for use (94, 192, 235). Lessons learned from this research may be applicable in remote areas of Alaska (96,192, 309).

NASA's Space Shuttle Orbiter Waste Management System

The technology used by NASA to collect sanitary waste during space missions is commonly known as the Space Shuttle Orbiter Waste Management System (figure 5-11). The primary purpose of this technology is to safely collect and store urine, hu-

FIGURE 5-10: Artist's Rendition of the Antarctica Analog Project Technology at the Future South Pole Station



SOURCE David Bubenheim, Chief Scientist, CELSS Research and Technology Development, Advanced Life Support Division, NASA Ames Research Center, personal communication, Jan 25, 1994

man waste, and wash water generated during space flight for treatment upon the shuttle's return to earth. The major components of this waste management technology are a urine collection system and a sewage collection-storage system. The system is highly specialized, very costly, and designed for a short-duration, specific mission. Only certain design concepts and unique features may be applicable to the problem of providing adequate sanitation in rural Alaska.

Urine Collection System

To collect urine, air is drawn from the urinal through the piping, and into a fan/pump separator whose rotating and pumping action separates urine from air prior to its storage in a pressurized wastewater tank (90,3 10). Because the lack of gravity prohibits the use of standard urinals, the urinal in the Orbiter waste management system is designed with clear plastic funnels (straight conical design for male use; oval in shape for use by female astronauts) directly connected to the plumbing system (90,3 10).

To avoid the clogging and airflow loss problem caused by drawing debris into the pump/fan separator, which was experienced in early space flights, NASA engineers fitted the base of the urinal with replaceable filtering screens (310). The pumped air used to transport urine through the plumbing is subsequently treated by odor and bacteria filters, and returned to the cabin. Drain water and wash water are stored in a relatively similar fashion (310).

One of the central components of NASA's waste collection and storage technology is the pump/fan separator because it is the system responsible for: 1) providing suction airflow needed for transporting urine and feces; 2) separating wastewater from transport air; and 3) pumping wastewater into the pressurized holding tank.

Sewage Collection/Storage System

NASA's space waste management technology was originally designed to use forced air to push waste into a commode tank where a rotating slinger (a wheel with 10 tines rotating at 1,650 rpm[15]) breaks up and stabilizes the waste before storing it in the commode's tank. After defecation occurs, the user actuates the commode handle to close the slide valve. The fecal material is then stabilized and dried by vacuum action, thus rendering the waste odorless. The air that was used to push waste into the commode tank is filtered by debris, odor, and bacteria filter systems and recirculated to the cabin.

The clogging of filters and loss of airflow caused by fine, dried fecal material experienced during heavy toilet usage in early flights often resulted in poor waste separation, incomplete transport into the storage tank, and inadequate sanitary conditions in the cabin where such fecal particles frequently escaped. The slinger was subsequently removed and replaced with a bag liner that operates like a vacuum cleaner bag: it retains bacteria and waste particles inside it without preventing air from passing through (90).

The rapid filling of the bag liner system with tissue paper as opposed to human waste-caused by the absence of gravity, which, in turn, precludes the separation and dropping of human feces from the body—forced NASA engineers to ultimately replace the bag liner with a feces compactor. By rotating a movable vane located inside the tank, the stretchable fabric material, attached to the movable vane at one end and to a stationary vane on the other, is forced to sweep the interior of the ellipsoidal waste commode and compact the waste. Air drawn through the commode is treated and returned to the cabin. Compaction of waste by this currently used technology is required only every fifth or sixth day of operation.

NASA's Extended Duration Orbiter Waste Management System

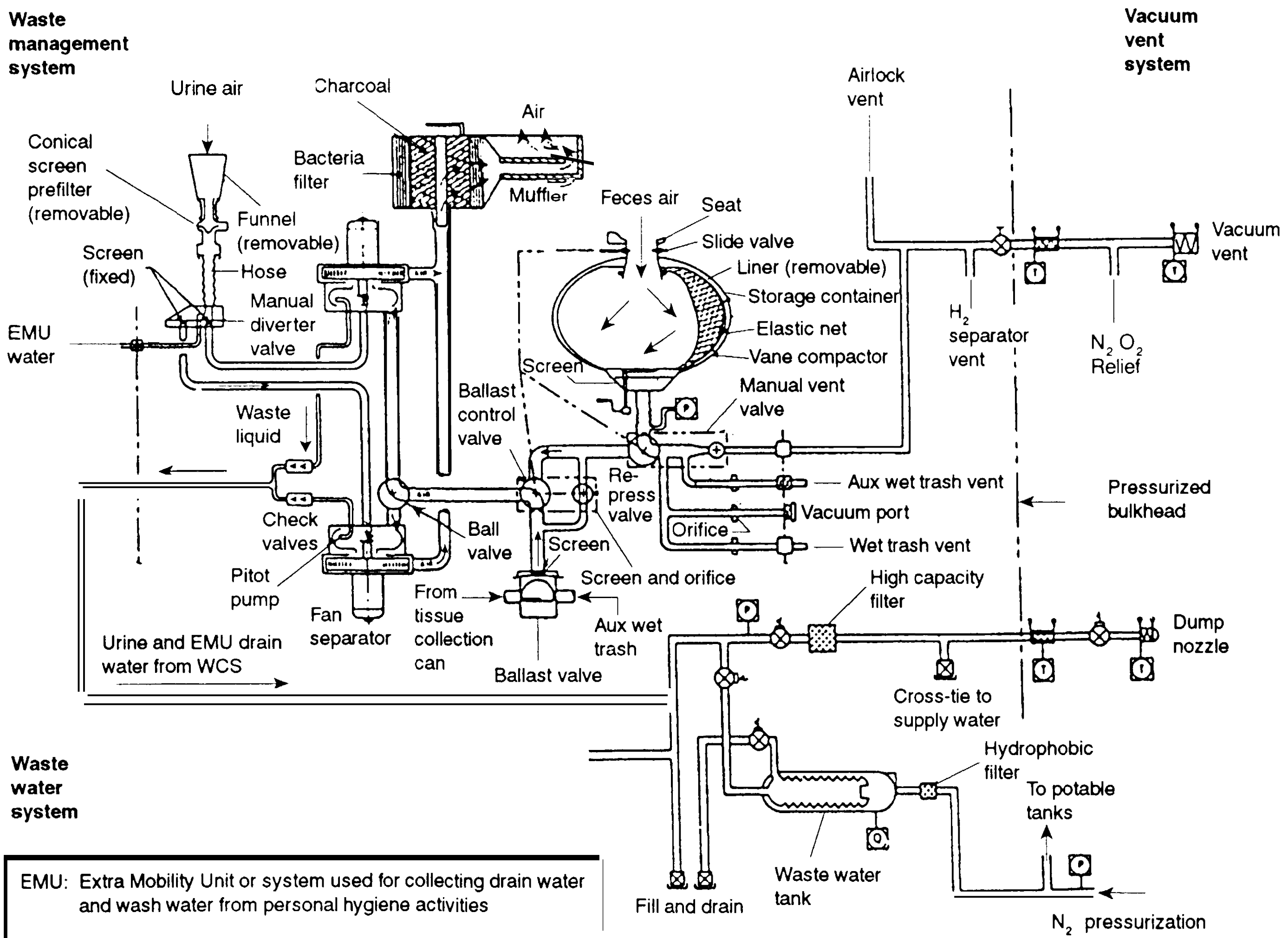
Another very specialized design may be useful for its concepts and unique features. NASA is testing a new waste collection technology known as the Extended Duration Orbiter Waste Management System (figure 5-12) that uses a mechanical piston compactor and disposable bags with plastic lids. Prototypes of this less expensive and easy to maintain waste collection system are being built and scheduled for use in future space flights (90,191 ,239).

The Extended Duration Orbiter waste collection system is designed to be used as a conventional toilet. Its size (12 inches long, 16 inches wide, and 35 inches high), weight (60 pounds), and low power consumption makes this technical approach, according to its developers, one of the most promising for future extended space use (239). One particular advantage of this system over the currently used one is its capability to meet the sanitation needs of up to seven astronauts for a period of 18 to 30 days (90).

During its use, proponents indicate, wastes (including feces, urine, and tissue paper) disposed in the bowl are contained inside a cylindrical bag that permits air to flow through. By applying a load of

15 Revolutions per minute.

FIGURE 5-11: Schematic Diagram of the Sewage Collection/Storage System Installed in NASA's Space Shuttle

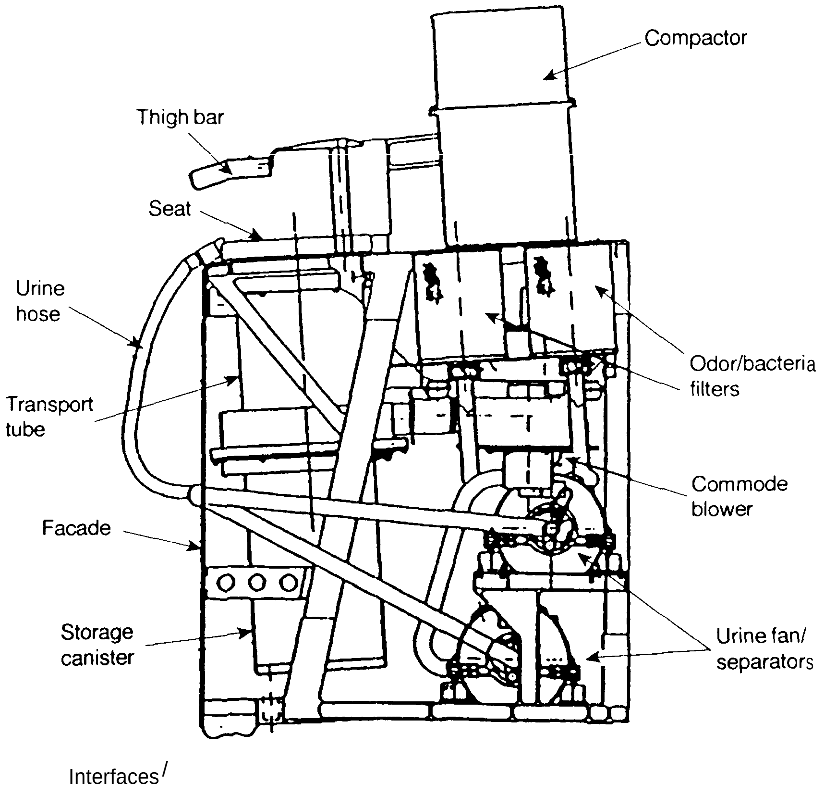


EMU: Extra Mobility Unit or system used for collecting drain water and wash water from personal hygiene activities

WCS: Waste Collection System

SOURCE: H.J. Brasseaux Jr., H.E. Winkler, J.D. North, and S.P. Orlando, "The Extended Duration Orbiter Waste Collection System," *SAE Technical Paper Series*, No. 90 291, 1990.

FIGURE 5–12: Diagram of the Extended Duration Orbiter (EDO) Waste Collection System Planned for Use in NASA's Future Space Flights



SOURCE H J Brasseaux Jr, H E Winkler, J D North, and S P Orlando, "The Extended Duration Orbiter Waste Collection System, " *SAE Technica/ Paper Series*, No 901291, 1990

about 100 pounds, the compactor travels down the transport tube pushing the waste-containing bag and its lid to the bottom of the collection canister where they are compacted. The rigid collar and wiper-like design of the lid are used to scrape any waste that may have adhered to the walls of the transport tube. The bag is then left behind as part of the stored waste material.

Once the piston returns to its original position. the user places a fresh bag in the toilet for the next user before closing the toilet seat and 1 id. Replacement of collection canisters in the proposed Extended Duration Orbiter system is expected to take place only after an average of 30 uses. Test results from recent space flights show the individual bag collection system to be relatively cleaner than the commode system currently in use by the shuttle (21 2).

The "Self-Contained Home" System

According to its designer, the Self-Contained Home technology has been conceived to address in a cost-effective manner the most basic needs of Natives in rural Alaska: housing, heating, and sanitation. As planned, the technology will consist of an insulated house (36 feet by 38 feet) specially designed for the Arctic environment and served with a heat/cook stove, a self-generated water system, and an Arctic toilet system in which human waste is treated with recycled heat. Made of steel, the heat/cook stove-considered the cornerstone of this system-can be operated with wood, coal, or fuel (92,93).

The Self-Contained Home appears to be potentially useful in addressing more than the waste disposal needs of Native communities in rural Alaska, but because this technology is still in its developmental stage, field studies would have to be undertaken to ascertain the actual applicability of this approach.

SUMMARY OF TECHNOLOGY ISSUES AND NEEDS

All of the alternative technologies described above require some degree of development, testing, and evaluation before they could be chosen as a proven system with satisfactory performance ensured. Identifying and developing appropriate technologies, while meeting safety and reliability standards within cost constraints, constitute the major challenge for designers and developers of any sanitary technology in the Arctic. In years past, most Federal and State agencies provided relatively little support for the basic engineering and environmental research required to produce the data necessary to design and implement specific technologies. This deficiency resulted in a shortage of information in several areas, such as hydrology (e.g., snow surveys), soil (e.g., permafrost), ice research, and climate and natural hazards (8). Considerable progress was achieved in these areas during the 1980s, particularly with the construction of the Alaskan oil pipeline and the installation of piped sanitation systems at major oil industry facilities in Pruhdoe Bay. These advanced piped systems cannot be applied in most villages, however, because of high construction, operation, and maintenance costs.

Very few alternative sanitation methods have benefited from field demonstration tests in rural Alaskan communities in the past. Most of the attempted evaluations failed. The failures were largely the result of limited or inadequate guidance provided to Natives by technology developers. With the exception of certain comporting technologies, the Office of Technology Assessment (OTA) found no long-term effort dedicated to the demonstration of alternative sanitation technologies.

Even today, relatively little information exists on the application of alternative sanitation technologies in environments such as that of rural Alaska. Adopting these systems without first exploring the factors that will make their application in Native villages successful is risky and subject to failure. In many Alaskan villages, there are physical, social, and economic conditions not commonly found in other areas of the United States. Such conditions include limited drainage and poor soil conditions caused by discontinuous permafrost, seasonal variations in the quantity and quality of the water available, and high costs of electricity and fuel. Unfortunately, programs to fund field demonstrations of alternative technologies, to coordinate Federal and State technology programs and policies, and to establish a forum for the advancement of innovative sanitation systems do not exist.

Alternative sanitation technologies must be evaluated prior to their actual use among Native communities and must be designed to accommodate the unique Alaskan environment, including factors such as:

- Permafrost—This is of great importance in the engineering and design of structures and systems, particularly in ice-rich, fine-grained soil, where the ground forms an extremely strong and stable foundation material when frozen but an extremely weak foundation when thawed. The location, depth, and extent of permafrost may preclude the selection of certain sanitation systems due to its influence on local soil conditions, groundwater table, and seasonal flooding.
- Availability of water—Adequate availability of water is a key consideration in the selection of flush toilet systems because without it, sewer, septic tank, and truck haul holding tank systems cannot perform properly. (Water is also extremely important for practicing hygiene.) Piped water is normally incorporated into

piped sewerage projects because the two systems are mutually dependent; however, they also lead to increased water consumption, thus creating a need for additional disposal capacity. The interior region of Alaska is generally supplied with water and contains large areas of wet muskeg and lakes, with significant snowmelt runoff and river drainage. In the Arctic region, however, a myriad of shallow lakes disguise the fact that water supplies are actually very limited for supporting sanitation technologies that consume large amounts of water.

- Household size and design—Identifying the number of persons residing in each house for which use of a particular technology might be planned, as well as recognizing the perception they have about that particular technology, is important in estimating in advance the technology's potential for success. Consideration of household size and design is also important in determining waste volumes to be treated or managed, projecting future system expansions, and estimating costs over extended periods of time.
- Technical training—Training Natives in how to operate sanitation technologies has not always been successful. The reasons for such failure have been primarily the use of inappropriate off-the-shelf packaged training programs and the increasing shortage of technical assistance from Federal and State agencies. To avoid these failures, there is a need to develop programs that are culturally sensitive and practical, and that focus on the realities of the particular village in which the technology will be applied. Examples of these include local limitations in management capability, leadership, and fiscal responsibility. Identifying the extent of the external financial and technical assistance that will be needed once the technology is installed will be also useful.
- Native community involvement—Although the intrusion of Western culture has sometimes met with resentment, many Natives continue to believe that the main source of resentment has emerged primarily from being told by outsiders what to do and how to do it, and rarely being included in the development of solutions to local sanitation problems. Encouraging and supporting continued village participation in the selection and implementation process are extremely important for ensuring a strong perception of community ownership over the project-—an element crucial to the successful application of any technology.
- **Local village economy—The** majority of Native communities of rural Alaska rely almost completely on transfer payments and subsidies from Federal and State agencies to operate basic village programs, including sanitation projects. Despite the increasing demand for new sanitation projects, the serious economic difficulties faced by Native villages with existing systems raises the need to avoid installing similar complex technologies in communities with few economic and technical resources to operate them. Consequently, addressing the waste sanitation problem in Alaska's Native communities requires steps that focus on identifying, demonstrating, and adopting more cost-effective alternatives to honey buckets. Selecting technologies that deliver sanitation with little additional adverse impact on the limited or declining local economies is needed.
- Actual costs to Native village residents--In recent years, Federal and State agencies have focused primarily on providing conventional technologies that require high capital costs and a significant degree of advanced engineering. Their efforts to assist Native villages financially with the operation and maintenance of these projects have been rare. This, and the failure to track community expenses for O&M, have limited the information available today for estimating the actual costs of sanitation projects.

Actual cost data for estimating life cycle costs of complete systems in Alaskan Native communities do not exist. Accurate life cycle cost comparisons of alternative and conventional systems are not possible. Not only does this impair the evaluation of each system's cost-effectiveness but it prohibits agency officials from making valid estimates of the overall economic impact of each technology on the community. There are no data on the potential economic savings by communities that might employ alternative technologies rather than conventional ones. Savings associated with the use of alternative sanitation technologies could include, for example, eliminating local expenses associated with building and maintaining a sewage lagoon, reducing the community water and energy consumption, reducing the need for certified facility operators, and reducing equipment repair or replacement costs. Limited data also prohibit the evaluation of the potential impacts of using alternative systems that do not deliver potable water to the home.

Technology selection decisions to date have been based on a capital planning process that takes into consideration the type and size of the sanitation facility to be installed, the financing process to follow, and the methods by which costs will be recovered. This process, however, is largely limited to the construction of conventional technologies and does not allow for a comparison of conventional and alternative approaches based on total life cycle costs. Only minimal attempts have been made to formally incorporate existing alternative sanitation systems into the technology selection process currently in place.

CONCLUSION

Alternative sanitation technologies, such as comporting, electric, and propane toilets, appear to be an improvement over honey buckets because they reduce the possibility of users coming in contact with human waste and they may reduce overall, long-term costs. Not only do these technologies eliminate the need for a sewage lagoon to hold the wastewater for treatment, as in a conventional piped or haul system, they may also yield a by-product that is generally more environmentally safe or easier to handle. These alternative approaches, however, do not provide the potable water that is needed to practice good sanitation.

Certain of the advanced engineering systems or concepts presented in this chapter appear potentially beneficial. Some, as in the case of NASA's life support systems, still require substantial design modifications, adaptation, or testing before they can actually be considered for waste treatment in Native Alaskan villages. Others, like Entech's thermal oxidation system, might be applicable to treating human waste, but they require testing and evaluation.

Conditions in Native villages (i.e., inadequate water supply, poor soil drainage. permafrost, unacceptable topography, high seasonal flooding potential, and weak local economies) appear to favor the application of less costly and complex systems. With the exception of the limited testing conducted on certain comporting methods, most alternative technologies have not been tested for the treatment of human waste in the harsh environmental conditions typical of rural Alaska. Development of a more comprehensive technology evaluation and selection approach capable of supporting demonstration, applied research, and application of innovative technologies is still necessary.