FEASIBILITY STUDY:
Sanitation Options for Ger Communities in Mongolia
Focusing on Humanure Compost Toilet Systems, or "Bio-Toilets"

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Abstract: A two-phased feasibility study was conducted over a four week period in Mongolia from late February, 2006 to mid-May, 2006. The purpose of the study was to determine whether "humanure compost toilet systems" according to a design developed by Joseph Jenkins, author of the Humanure Handbook, which describes the system in detail, could provide a successful alternative to the pit latrines currently in wide-spread use in Mongolia. Graywater disposal and reuse systems were also explored. The study determined that the necessary components for implementation of the "bio-toilet" system (as it was translated) are available, including social acceptance of the concept. A pilot program was established that included a training component utilizing an instructional DVD and a printed instructional manual, both created specifically for this project. Twelve families volunteered to take part in the pilot program, six in Ulaanbaatar, the nation's capital, and six in Erdenet, the nation's 3rd largest city, Each was provided with a bio-toilet and each constructed a compost bin. This bio-toilet feasibility study ended just as the two-year pilot project began. No further data on the pilot project is available at the time of this writing. Regarding graywater disposal and reuse in ger areas of Mongolia, potential systems depend upon whether the households are producing graywater or blackwater, and whether they carry their water by hand or have on-site piped water. The quantity and quality of household effluent determines what sort of graywater disposal/reuse system can be recommended. Such systems range from the commonly used soakhole, to standard septic systems, small-scale septic systems, graywater ponds, soilbeds, and standard wastewater treatment via a centralized wastewater treatment plant.

This bio-toilet feasibility study developed in two separate stages. The first took place in late February and early March of 2006. The second took place in the first half of May, 2006. Both phases had a duration of approximately two weeks.

PHASE ONE:
Public Presentations, Surveys, Organic Material Assessment, Environmental Issues

The purpose of phase one was to introduce a compost toilet system to the government and people of Mongolia based on the work of Joseph Jenkins as described in his book, the Humanure Handbook. The word "humanure" is a contraction of the words *human* and *manure*. The system would typically be described as a "*humanure compost toilet system*," because the composting does not take place in the toilet itself (that would be a "*composting* toilet"). The humanure compost toilet system requires three elements in order to be successful. They are 1) the toilet, which is a simple, inexpensive collection device; 2) a compost bin approximately 1.3 to 1.5 meters square and 1.2 meters high, where the actual composting takes place, typically outdoors; and 3) carbon-based (cellulose* based) compost additives, referred to as "cover materials." These additives cover the compost ingredients that may have offensive odors, such as the toilet materials, thereby masking the odors as well as balancing the nitrogen and excess liquid typical of human excrement. All three of these components are essential for the successful operation of the humanure compost toilet system. If all three components are available, such a system can be established for very low cost, can be used comfortably indoors without unpleasant odors, can be continued indefinitely, and will produce a valuable humus on an annual basis which can be used for food production.

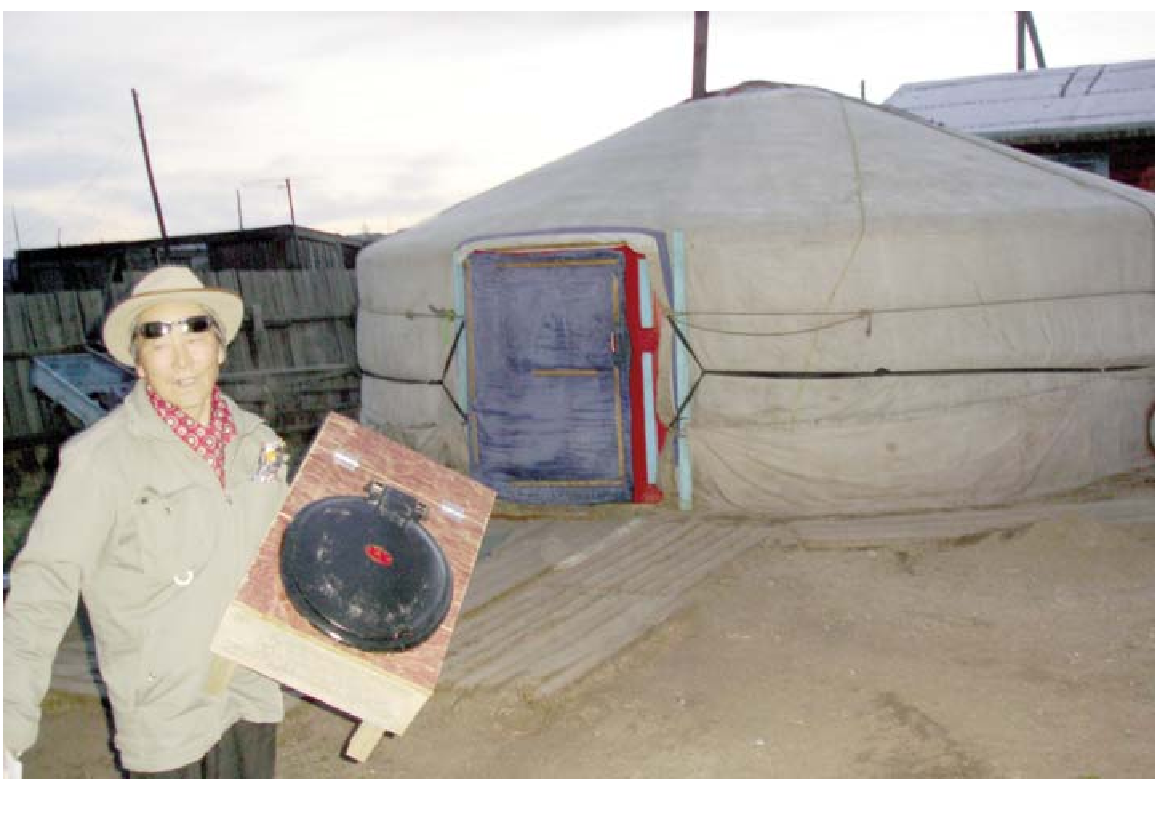
Due to the limitations of language, "humanure compost toilet system" was translated into "bio-toilet" when the concept was presented to the Mongolians. Consequently, we will use the terms “bio-toilet” and “humanure compost toilet system” interchangeably in this report.

Public Presentations

In order to present the bio-toilet concepts to the Mongolian people, a Powerpoint presentation was prepared by Jenkins at his home office in Pennsylvania in early February of 2006 and sent to Mongolia at that time to be translated by PADCO (see attached PDF - *Human Excrement Recycling for Ger Housing Areas*). The translated presentation provided the basis for introducing the Mongolian people to the bio-toilet. This presentation was shown to the Ministry of Construction and Urban Affairs in Ulaanbaatar (UB) in late February, 2006, with government representatives, members of NGOs, and other interested persons attending. The presentation was then shown to larger groups of community members, *bag* (neighborhood) leaders and *ger* (traditional round felt dwelling) area inhabitants, both in UB and Erdenet, Mongolia, as well as to government representatives in Erdenet. In addition, the presentation received coverage on national and local TV and radio. Jenkins also conducted a press conference with national TV about the bio-toilet issue, which was also broadcast. Finally, two bio-toilets were constructed by ger inhabitants in early March, 2006, and this was also recorded and broadcast by a TV crew.

The purpose of presenting the bio-toilet idea to the Mongolian people was to determine what interest or feasibility, if any, there might be in establishing these toilets in ger areas. The compost concept proved to be new to the general population, as did the entire bio-toilet idea. However, the reaction to the presentations was surprisingly positive. In fact, numerous ger inhabitants expressed a desire to immediately begin using these bio-toilets.

This is not surprising considering the fact the virtually all of the ger inhabitants were using pit latrines. The latrines consist of a small outdoor shelter removed from the dwelling, with minimal pri-



Press conference, Ulaanbaatar, February 28, 2006 (above)
Public presentation, ger neighborhood, March 5th, 2006 (below)

vacy in many cases, and a space in the flooring boards over which one squats when relieving him or herself into an open hole in the soil. The floor boards are often covered in urine and perhaps fecal material, frozen during the winter months and therefore slippery. The prospect of an indoor toilet without odors that would not pollute the environment, but which would produce soil fertility, was attractive to many people. For example, immediately after one of the first public bio-toilet presentations, a retired lady approached the presenter with a note, written in Mongolian, asking for help in improving the soil fertility on her plot, stating “I have just wanted to make my plot just like yours.” At another public venue, a group of about 20 ger inhabitants who had attended the Powerpoint presentation waited outdoors in the cold for quite some time just to tell the presenter how grateful they were to have this information and how they would “work so hard” to be successful at using a bio-toilet. One elderly man at a public presentation, during the question and answer period at the end, suggested they begin using the toilet systems immediately and they have a competition to see who can make the best compost.

In short, the reaction to the idea of establishing bio-toilets in ger communities was positive.

Typical pit latrine

Social Survey

A survey was conducted by the PADCO team in March/April of 2006 to glean further information about the social attitudes of ger inhabitants. According to the survey data taken from 250 randomly selected ger households in seven towns, every household uses a pit latrine. These take 1-5 years to fill for 27% of the population, 5-10 years to fill for 38% of the households, and 36% of respondents say their pit latrines take at least 10 years to fill. When full, most households (87%) dig a new latrine, although 10% add chemicals and 1% empty the existing hole and have the contents trucked away. Most of the respondents (74%) stated that their pit latrines do not produce unpleasant odors during the summer months, although 19% said they did produce unpleasant odors and 5% didn't know. Most of the households (88%) continue to use the pit latrine during cold winter nights, while 10% use a chamber pot or bedpan and 1% just go outside on the soil. 63% of the people stated a desire to have an indoor toilet in a heated area, while 10% said they would not prefer an indoor toilet; 27% didn't know.

Most of the respondents had a garden plot. Few had never had any garden. Of those who had a garden and now do not, a significant reason for no longer gardening was poor soil. Most of the respondents would prefer a big garden. Preferred vegetables include root crops such as potatoes, carrots, turnips, onions and garlic.

The survey indicated that a significant portion of the household waste material consists of potentially compostable organic material. The majority of the respondents simply discard the organic material along with the general waste. There seemed to be little, if any, knowledge or understanding of compost among the households surveyed.

These data suggest that an indoor compost toilet system may appeal to a significant number of households, but not to all of them. Finished compost would be useable by most households for gardening or horticultural purposes. However, composting is a new concept to which the inhabitants have had little, if any, exposure. A simple compost toilet system that is based on biological organic material management rather than technology, such as the humanure compost toilet system, would require training of any households who would elect to employ such a system. Furthermore, pilot systems would require monitoring for a number of years until acceptable compost has been produced and the bugs have been worked out of the system. At that point in time, individual community members who have become adept at composting will be able to share their knowledge and act as defacto educators within the community.

Potential Benefits of the Bio-Toilet System

The primary benefits of the humanure compost toilet system in this cultural venue include 1) low cost, 2) decentralization, 3) positive environmental impact, 4) enhanced food production capabilities.

Costs

Costs are minimal. Little advanced technology is required for the operation and long term usage of such a system. The costs for constructing both the needed toilets and the compost bins are low (see itemized costs, Appendix 1). The primary costs lies in the production and transportation of organic cover materials. However, when the cover materials consist of recycled refuse materials from such activities as the milling of lumber or the production of crops or food byproducts, the use of these materials may not constitute a financial expenditure other than to transport the materials to ger communities. On the contrary, in some cases a business may pay to have the materials removed from the business site, thereby offsetting the transportation costs. For example, the Erdenet carpet factory currently pays about $30 U.S. per day to have 9 cubic meters of waste wool transported to a landfill. Our meeting with the factory manager on March 3rd, 2006, indicated that they would be willing to pay to have the material taken instead to a compost recycling project.

Decentralization

The bio-toilet compost systems can either be centralized or decentralized. Decentralized, or “on-plot” systems, when the compost is confined to the individual household plot, can be created and maintained by individual households without the need for long-term government control, oversight, or expense. Centralized compost systems, on the other hand, involve a scenario where the household toilet containers, when full, would be routinely collected and removed to a centralized composting facility by an outside service. Such a service-oriented system may require some degree of government oversight and regulation.

Positive Environmental Impact and Enhanced Food Production

These toilet systems, when properly utilized, can completely recycle most or all of the household recyclable organic materials without contributing to ground water pollution or soil pollution. The recycled organic material can be utilized for food production and soil improvement. If the toilet materials are properly co-composted with a mix of other household organic materials along with imported plant-based cover materials, then allowed to sufficiently age, the finished compost will be hygienically safe, pleasant smelling, and valuable as a soil amendment.

Cover Materials

“Cover materials” are “carbon-based” materials, typically cellulose*-based plant byproducts such as sawdust, hay, straw, grass, leaves, paper products, garden weeds, grain hulls, etc. Human manure is a high-nitrogen material that also contains a high amount of liquid primarily in the form of urine. It will not support the growth of compost organisms alone. However, by combining it with the cover materials, the nitrogen is balanced by the carbon, thereby creating a carbon:nitrogen ratio that will promote the growth of compost organisms. The excess liquid is also absorbed by the cover material. Once compost organisms begin to proliferate in the compost, the temperature of the mass will rise and the quantity of liquid will be diminished by the composting process. Furthermore, the cover materials prevent odors from being released by the organic materials that are being covered. The amount of cover material needed is gauged by the presence of odor. If odor is present, more cover material is added until the odor is gone. The system, therefore, is simple and easily understood by common people.

There are two types of cover material needed for the bio-toilet system. The first is a finer material that is used in the toilet itself. This is often sawdust, but can also consist of such materials as rice hulls, shredded paper, leaves, peat moss, grain chaff, etc. In the outdoor compost bin, a courser material is preferred in order for better management of the compost pile, air entrapment inside the compost mass, for providing an insulating layer of material around the outside edges of the compost mass, etc. The courser material may consist of hay, straw, weeds, grasses, leaves, perhaps wool waste, other animal manures mixed with bedding, etc.

In an effort to gauge the nature and quantity of organic materials that may be available for use in a Mongolian bio-toilet system, sources of such materials were sought out in the Erdenet area during Phase One. The local rug factory was visited, as were the paper factory, abandoned lumber mills and the government agricultural department. In UB, local sawmills were visited during Phase Two. Significant quantities of sawdust were located in both areas. Large amounts of waste wool are also available. Due to time constraints, only a fraction of possible sources of cover materials were explored.

Sawdust is produced in both Ulaanbaatar and Erdenet, which is ideal for making compost when combined with human manure and urine, but the full extent to which this material is available has not been determined. The sawdust is being produced as a byproduct of the local lumber industry. All of the ger area household plots are encircled by wooden fencing. In addition, many of the household dwellings are constructed of wood, which is harvested locally. The sawdust from this wood could be used in humanure toilet systems if it can be made available free of charge or at low cost to the households which elect to use such toilets. The sawmills in UB allow the sawdust to be taken free of charge, whereas large sawdust piles in Erdenet appear to have been abandoned. An additional logistical issue involves transporting the sawdust to the ger areas so that it can be utilized by the households that are using the bio-toilets. Another concern involves the sustainable production of the sawdust material. Ger households that utilize humanure toilet systems must be provided with a reliable source of cover materials in order for their toilet systems to function properly in an uninterrupted manner.

An additional potential source of cellulose based compostable organic material lies in paper products. Paper products such as cardboard, newspaper and waste paper, if ground or finely shredded, may work well in humanure compost toilet systems. No sources of paper products were located, although a comprehensive search was not undertaken due to time limitations. In addition, such organic materials as waste wool, grain chaff, and fermentation byproducts could potentially be utilized as cover materials in compost bins.

When large quantities of cover materials are needed for large numbers of village composters, a comprehensive survey of available compostable cover materials should be conducted before the compost toilet systems are adopted on a large scale. This survey would include local businesses, such as manufacturing operations where organic materials are used (wool, wood, paper, food, etc.), logging and lumber operations, and agricultural operations such as wheat, oats and barley growing as well as associated industries such as the beer-making and vodka-making industries. It is likely that significant quantities of compostable materials are going to waste or are being landfilled that could instead be diverted into a compost recycling stream that could include human manure. Available materials must be located, assessed for composting suitability, and made available to either the village areas where humanure compost toilets are to be utilized, or to centralized composting operations where the collected bio-toilet material is taken to be composted. This approach would not only provide cover materials that would enable the continued use of safe and constructive biological toilets, but it would also help to eliminate waste in the local manufacturing community. The Erdenet carpet factory wool waste is collected when the incoming natural wool is pre-cleaned prior to entering factory production. It contains quantities of both manure and dirt, which makes it attractive as a composting feedstock.

In order for bio-toilets to become successfully employed in ger areas in Mongolia, such compostable

Compostable cover materials may be available in large quantities. Sawdust (above, in Erdenet), and wool waste (below, at Erdenet carpet factory) are immediately available. Expanses of cultivated fields between Ulaanbaatar and Erdenet indicate the potential availability of agricultural byproducts (bottom).

additives will have to be made reliably available to those ger households that employ such toilet systems. Considering the potential for environmental pollution by the widespread use of pit latrines, it seems that the promotion of bio-toilet compost systems would be advisable and that efforts should be undertaken to acquire and supply compostable cover materials to those residents who are willing to take the initiative to utilize such toilets.

Environmental Issues Associated with Pit Latrines

Environmental issues associated with pit latrines are significant. According to an interview conducted in Ulaanbaatar with sewage engineer Guillaume Hibou on March 10, 2006, Ulaanbaatar's wastewater treatment plant has a daily capacity of 230,000 cubic meters per day and is now at almost 75% capacity, treating 170,000 cubic meters of wastewater per day. Ninety-eight percent of the water consumed in Ulaanbaatar is consumed by only 40% of the population— people living in the central part of the city in apartments and other permanent housing that is connected to the municipal water supply. The remaining 60% of the population, those who live in the ger areas, consisting of approximately 590,000 people, consume only 2% of the city's water supply. If the ger area population were to be connected to the municipal water sources and their wastewater were subsequently drained into the municipal sewage system, the existing wastewater treatment plant would soon become overloaded.

In Ulaanbaatar, the municipal drinking water supply originates from ground water sources, some of which are located near or underneath the city and may be as shallow as four meters or even two meters in some locations. Precipitation measures only about 250 mm annually, or about ten inches, which is not a significant amount for ground water recharging. Furthermore, with nearly 600,000 people using pit latrines in the area immediately surrounding Ulaanbaatar, the situation is like an environmental time bomb. The approximately 120,000 pit latrines, most dug to a depth of about two meters, are constantly filling with human fecal material which will inevitably work its way into the underground water tables. Once the ground water becomes polluted, there is little that can be done to reverse the pollution other than to remove the sources of pollution and allow nature to run its course.

In short, the potential for fecal contamination of the drinking water supplies in the Ulaanbaatar area is significant if the issues of fecal contamination of the environment are not addressed. Bio-toilets can remove that source of contamination depending on to what extent the toilet systems are employed.

Wastewater

Ger households that currently carry their water from a kiosk utilize simple soak holes in the ground as a means of disposing of their graywater. The reuse of this water for seasonal gardening purposes does not seem to be an established practice. When a household uses a minimum amount of water, which is the inevitable consequence of having to carry water, such simple soak holes can continue to provide an adequate means of disposing of excess graywater. However, graywater recycling systems should also be developed for gardening purposes. These could consist of soil beds with underground perforated drainage pipes, or simply small soakholes in the soil strategically located near plant growing areas. It should be a goal at all times when improvising ger area water or sanitation systems to minimize expense and maximize cost effectiveness. As such, there is no blanket system that will work for all ger households. Some households may have piped water, some may have flush

Typical water kiosk

Typical water carriage system

toilets, some may have no money to spend, others may have lots of money. Some may produce a lot of wastewater, while others may produce a minimal amount. Graywater disposal or reuse systems, therefore must be tailored to meet the needs of each individual household.

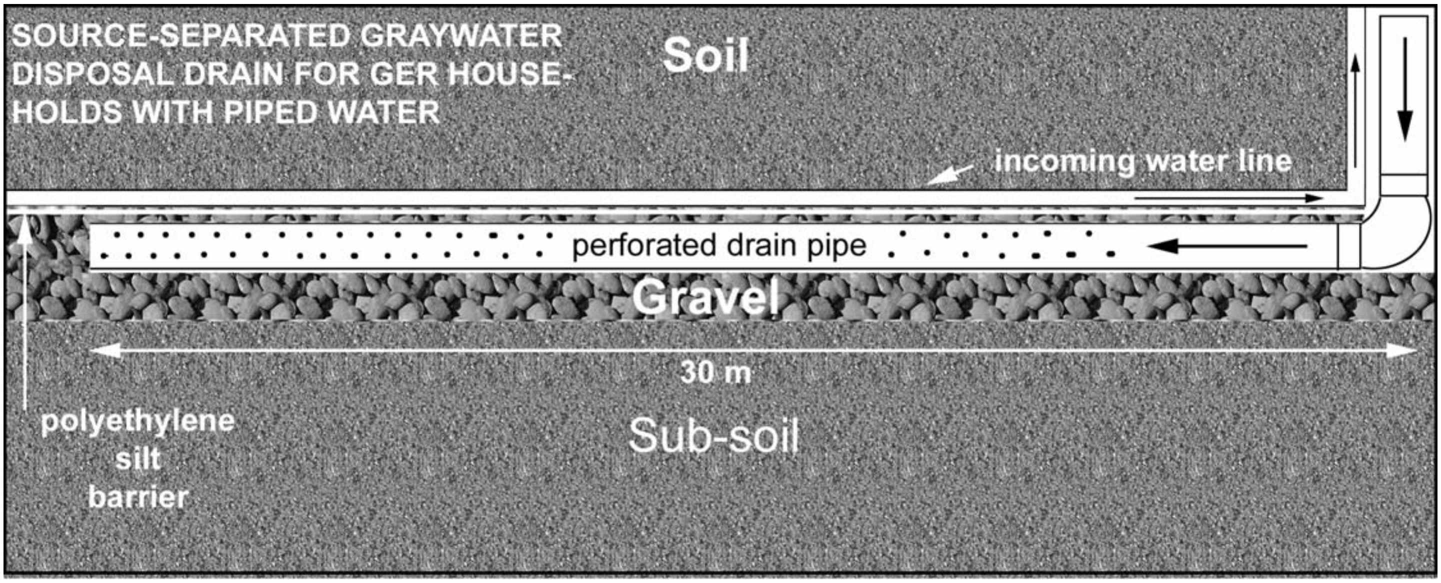
If ger area households were to become connected to municipal water sources, i.e. piped water, then it will be necessary to develop means for the disposal or recycling of the wastewater. Disposal or recycling of household wastewater presents a significant problem when the wastewater contains toilet wastes and/or garbage disposal organic materials. However, if the wastewater is “source-separated,” meaning such organic materials are not allowed to enter the wastewater effluent, then the problem of dealing with the waste water is not as serious. Households produce source-separated wastewater when they divert their discarded organic materials away from a waterborne waste disposal system and instead into a composting system. A household composting system can recycle toilet materials, food discards, and liquids that may typically be dumped down a drain (such as stale beer, sour milk, etc.).

Source-separated gray water has an environmental water quality roughly equivalent to treated wastewater that is discharged from a wastewater treatment plant directly into the environment, although the graywater contains much less nitrogen. Therefore, direct discharge of the graywater into a soakhole, small septic tank, or, seasonally, into soil beds located individually in household garden plots, may provide a suitable solution for source-separated graywater disposal or recycling. Also, above ground graywater ponds that employ aquatic vegetation for purification of the water and which collect the source-separated graywater drainage from numerous households may prove to be useful alternatives to conventional wastewater treatment plants.

If ger households are connected to a direct water supply, the incoming water line will have to be buried to a depth of 3 meters or more. At the time the trench is being dug for the incoming water line, a perforated drain pipe approximately 10-15 cm in diameter and at least 10 meters long, placed underneath the incoming water line in a bed of gravel and covered with a sediment barrier, such as sheet plastic, could suffice as a year round graywater disposal drain system for source separated graywater (see illustration, next page). Wastewater disposed of in a drainage system such as this would have to be filtered prior to disposal to prevent the drain pipe from becoming clogged with sediment.

Wastewater that is not source-separated may be disposed of via a standard wastewater treatment plant. An alternative would be to install large, on-plot septic systems that a number of households could tap into, or to install smaller, individual septic systems and leach fields in each plot. Wastewater lagoons could also provide a disposal solution for a large quantity of wastewater that is sure to be generated if large numbers of ger families tap directly into the municipal water supply. It seems likely that different households may opt for different systems based on their ability to pay. In any case, ger area graywater recycling or disposal requires additional research when considering the wastewater generated by directly connected households.

Where there is no direct connection to piped water, water usage in the ger areas is minimal because the water is carried by hand to the household. In such cases, no black water is produced and the quantity of graywater is more easily manageable. A family of two, for example, may only utilize 240 liters of water per week. Some of that graywater could be used in a compost system for washing compost buckets, for example, and for watering the compost when necessary. During the growing season, if gardens are established, household graywater can be used to provide water for the gar-



dens, shrubs and trees. It's likely that all graywater can be utilized in this manner during the growing season by households that carry their water. Graywater in such households could be disposed of down a soakhole during the winter months similar to the hole utilized in the pit latrines. The graywater should not be disposed of in pit latrine holes because this will increase the likelihood of ground water pollution by the fecal material already in the hole. When a compost toilet is used, a pit latrine is not necessary. A graywater soak hole can be dug separate from the pit latrine hole. The dirt taken from the graywater hole can be used to cover the pit latrine contents, thereby minimizing the leaching of fecal material into the ground water while masking unpleasant odors.

PHASE TWO:
Educational Materials, Training, Implementation and Monitoring of Pilot Project

Education and Training

A 50 minute bio-toilet instructional DVD was produced by Jenkins for training purposes (a copy of which has been provided to PADCO). It proved to be very helpful. It was filmed in Pennsylvania in late April, 2006, at the Jenkins home where a humanure compost toilet system has been functioning continuously for the past 27 years. The footage was voiced-over in Mongolian by Otgonbayar Galbadrakh of the Urban Development Resource Center. The film explains the nuances of using such a compost toilet system, including management of the toilet, use of cover materials, and management of the compost bins. The film also demonstrates various bio-toilets, including a household toilet, a small-business toilet, a private office toilet, and a camp toilet.

In addition, a short instruction manual was produced by Jenkins that explains in writing, with illustrations, the operation of a bio-toilet system (see attached PDFs). The manual was also translated by Otgonbayar Galbadrakh into Mongolian.

Families who want to establish compost toilet systems on their plots as part of the pilot project in UB and Erdenet are required to participate in the training program. The training includes watching the 50 minute instructional DVD and reading and reviewing the instruction manual during a workshop scheduled for that purpose. Volunteers who successfully complete the training are then provided with a bio-toilet and are further instructed on the construction of a compost bin and acquisition of cover materials. After they construct their compost bins, the bins are inspected. The pilot groups agreed to coordinate their activities so the group members could communicate with each other more easily and work together in a somewhat unified manner. They also agree to allow their systems to be monitored by the local health department, agricultural department, student monitors, or other researchers. They further agreed to a two-year commitment to the project and to assume whatever expense may be required in maintaining sufficient cover materials for successful operation of the bio-toilet system during the project period.

Implementing the Pilot Project

Due to time constraints and the physical distance between the two pilot project cities (approximately 7 hours by car) it was decided to limit the pilot project groups to six families per city, or twelve families total. The two cities selected were the capital of Mongolia, Ulaanbaatar, population about one million, with about 60% living in ger communities, and Erdenet, Mongolia's 3rd largest city with a population of about 87,000. Mongolia's 2nd largest city, Darkhan, with a population of about 95,000, was also considered for a pilot project group. The introductory Powerpoint presentation had been shown during Phase One at Darkhan, with considerable interest from the local community leaders, but the limited time allotted for the establishing of these pilot projects did not allow the addition of a third city.

In UB, the six pilot project families were all socially connected in some manner and to some degree — either by relation, or by friendship, allowing for a group that could easily communicate with each other should the need arise. In Erdenet, the pilot project families were all located in ger neighborhoods on the west side of the city. They agreed to work together as participants in the pilot project with one of the volunteers, a retired agronomist by the name of Gonchig Khisigdavaa, agreeing to oversee and coordinate the group. All project participants were given a copy of the instruction manual. Each group was provided a copy of the instructional DVD for review at their convenience.

The original intention was to have each pilot project family build their own toilet. It was soon realized that this was impractical due to logistical reasons. Instead, we constructed the 12 toilets ourselves in an afternoon and provided them to the families free of charge. The cost was about $11.00 U.S. per toilet, including labor and overhead. We had also considered building a compost bin for each family, but soon realized the impracticality of this approach due to time constraints. Instead, we purchased materials and built one compost bin as a demonstration project in UB, then had the UB participants each build their own bins. In Erdenet, the group was shown the photos of the UB compost building workshop, which provided enough information for them to build their own bins. The demonstration compost bin in UB cost $13.00 using new materials. Most participants used salvaged or scrounged materials to build their bins.

Monitoring the Pilot Project

Government representatives indicated strong support for the compost toilet system project. Our meetings with the Governor, Deputy Governor, and Cabinet in Erdenet, for example, indicated positive support for the development of bio-toilet alternatives. A meeting was held at the Erdenet government building with the director of the Department of Agriculture, including the area agronomist and a representative from the Department of Health. This group expressed a scientific understanding of composting and were aware of the proven validity of the process with respect to pathogen reduction. They also concurred that human manure must be recycled for agricultural purposes sooner or later and that the soil amendments traditionally available in Mongolia are diminishing due to the reduction in the number of herd animals and animal manure. This loss of soil fertility could be offset by the recycling of human manure. They also indicated that human manure could become valuable enough to buy and sell, thereby creating an economic market heretofore unavailable. They further recommended the establishment of a permanent laboratory for the purpose of analyzing finished compost from bio-toilet systems in order to monitor potential human pathogens and to assess the agricultural quality of the compost.

Due to the pioneering nature of the ger area compost toilet project, such a project should be overseen and monitored by representatives of the Departments of Health and Agriculture. It is recommended that university students become involved to help monitor the project. This would make an excellent research project for graduate students, for example, who could monitor the temperature of compost piles on a regular basis, make observations regarding odors, leachates, cover materials, graywater usage on compost, practical difficulties encountered by the compost practitioners, etc. Such collected data would constitute a wealth of information that would enable the project to advance based upon rational analyses of sound scientific data.

Our meeting with Chuluunbat, Director of the National Agriculture University in Erdenet, on May 9th, 2006, indicated support for a monitoring program involving students from the university. We put him in contact with the pilot project group in Erdenet with the expectation that he would follow up and help establish a monitoring system for that group. The data that should be monitored from the pilot project should include social and practical data as well as laboratory analyses of finished compost. The social and practical data can be collected on a regular basis (once a month is recommended) by students. The student or researcher monitoring the project families should arrive at the project family's location with a questionnaire to be filled out by the researcher. Questions to be asked of the pilot project participants should include, but not necessarily be limited to:

1. Is the toilet system, including the toilet and the compost bin, producing any unpleasant odor?
2. Is the compost bin attracting flies, dogs, or other vermin?
3. Are the participants able to provide themselves with adequate cover materials in a timely manner?
4. What cover materials are they using? What quantities (e.g. bales of hay or straw/month or volume of sawdust/month)?
5. Are they composting their food materials as well as toilet materials?
6. Are they adding other materials to the compost such as weeds. leaves, grasses, other animal manures, etc.? List.
7. Is there any resistance to the use of the toilet by any family members? If so, why?
8. Has the toilet been set up in a private location? Indoors or out?
9. Is there any visible indication of leachate draining from the bottom of the compost bin?
10. What is the temperature of the compost mass when measured in the center of the compost pile at a depth of 50 cm? What is the ambient air temperature?
11. Do the participants have any complaints, comments or suggestions?
12. If the compost is frozen, how long has it been frozen? When did it thaw out?
13. Have friends or neighbors shown interest in the compost toilet system? Positive or negative?
14. Have the participants used their pit latrines when they could instead have used the compost toilet?

15. Have they been including all of their urine in the compost?
16. Is the compost too dry? Have they been watering it with graywater? How much graywater have they used to wet their compost (e.g. liters/week)?
17. Have they been meeting with the other pilot project participants to compare their experiences?
18. Have guests used the toilet? Feedback from them?

The researcher should also record his or her own observations regarding the bio-toilet, compost bin and cover materials. The problems that are most likely to occur include a) the compost being too dry and therefore not heating up; b) the compost being frozen for a long period and the compost bin therefore becoming too full or the compost pile too tall (i.e. not flattened); c) insufficient cover materials being used, which will be indicated by odor or leachate; d) dogs or other animals getting into the compost (indicating a need for a better compost bin barrier); e) flies on the compost pile (indicating a need for more cover material); f) irregular use of the toilet system not allowing for sufficient mass to accumulate in the compost pile; and g) improper cover materials such as wood chips, bark or other larger wood chunks, or wood ashes or coal ashes.

Laboratory analyses of the finished compost should include pathogen analyses. Such analyses would test the compost for indicator pathogens such as *E. coli* and *Ascaris* and any other tests deemed appropriate by the local health department. The compost should also be tested for agricultural quality. Such testing should measure pH, nitrogen, phosphorous and potassium and any other tests determined to be necessary by the local agricultural department.

The bio-toilet compost system requires approximately a year of collection of the compostable materials followed by another year (or more) of curing during which the compost is left undisturbed to allow for the materials to finish composting. As such, there is a minimum time period of approximately two years before the first finished compost will be available for analysis. Finished compost will therefore not become available until the spring of 2008, at the earliest, so there is plenty of time to organize the laboratory analysis phase of this project. In the meantime, regular monitoring of the participants is strongly recommended in order to identify and rectify any problems that might occur and to collect data. It is further recommended that funding be obtained that will allow for this monitoring. It is also recommended that the monitoring be conducted primarily by Mongolians.

Additional Options for On-Site Sanitation in Ger Areas

In addition to the bio-toilet compost system, other options may be considered for on-site sanitation in ger areas depending on whether the household has directly piped water, or not.

Option 1. Pit latrines with water-proof vaults:

This option would continue the use of pit latrines, except that fecal material and urine would be deposited into an aboveground or underground waterproof vault. Such a vault can be constructed of concrete, possibly pre-fabricated, or other material such as plastic or fiberglass. The advantages of such a vault system would be that the fecal material would not come into contact with the environment. The disadvantage include the fact that the vaults would have to be pumped out on a regular basis; unpleasant odors would persist; the vaults could allow for the breeding of flies and mosquitoes; and the latrine would probably remain separate from the living area, thereby being inconvenient and uncomfortable, especially during the winter months. Waterproof vaults are also more expensive than a standard pit latrine. Such a vault system is used in the U.S., as required by law, by Old Order Amish communities who live without electricity.

A vault system would require a pumping service that would probably consist of pump trucks that would suck the contents out of the vault and transport them to a disposal area, probably a wastewater treatment plant (as is done in the U.S.). Alternatively, if the vault material were covered with sawdust or other suitable cover material on a regular basis, in order to prevent odor, and if the vaults were removable and replaceable, then the filled vaults could be collected and the contents composted at a central facility. Either scenario would require specialized equipment and facilities that may be currently unavailable.

Option 2: Ventilated pit latrines:

A variation of the vault system is the “ventilated pit latrine,” which is a pit latrine that has an underground collection hole lined with boards, stones or other materials intended to impede the diffusion of fecal material into the soil. This variation does not require pumping or removal of the toilet material, which is collected in the latrine until full. A new, lined hole is then provided. After a sufficient aging period, the abandoned latrine contents can be removed by shovel and employed for agricultural purposes. The disadvantage of this system is potential ground water pollution, odors, flies, mosquitoes, lack of aerobic composting and therefore potentially unsanitary material, loss of soil nutrients due to the drainage of urine into the soil, and the inconvenience of using an outdoor toilet. The advantage of using this system is that it is relatively low-cost and entirely on-site with no need for pump trucks or other high-tech equipment or machinery.

Option 3: Commercially available composting toilets:

Commercial composting toilets are manufactured units made of plastic or fiberglass, some of which require electricity, some of which do not. These toilets are designed primarily to be dehydration devices rather than true composting devices. Depending on the design, urine may exit through a drainage system and the remaining solids may be dehydrated using a low wattage heating device. The dehydrated solids accumulate in a tray underneath the toilet and must be occasionally emptied and either composted, disposed of, or used directly as a soil amendment. Advantages include on-site, self-contained management. Disadvantages include expense, loss of soil nutrients due to the urine loss through drainage, and potentially unsanitary finished material due to the lack of aerobic composting. Such toilet contents are required by law in the U.S. to be disposed of in a manner similar to sewage because of the persistence of indicator pathogens in the “compost.” There are many types and models of available commercial composting toilets ranging widely in price. A low-end composting toilet in the U.S.costs around $1,000.00 U.S. The costs associated with the use of commercial composting toilets may be prohibitive in Mongolia.

Option 4: Urine separation toilets:

Urine separation toilets are similar to the waterproof vault system, except that the urine is diverted during defecation or urination into a holding tank. The urine is then diluted with water and utilized directly for gardening purposes. The remaining solids can be covered with sawdust or other cover material to prevent odor, then occasionally shoveled out of the vault and employed as a soil amendment. The advantage of this system is that it can be kept on-site without the need for the transporting of toilet materials off-site. Such a system also requires a smaller amount of cover material due to the diversion of urine, which allows for a drier toilet material. The primary disadvantages are that the solids are unlikely to compost properly with the urine removed. The remaining solid mass, therefore, may not be hygienically safe for direct gardening purposes. The separation of urine may require the purchase of toilets designed for that purpose, the costs of which are variable and may be prohibitive. Also, the diversion of urine during defecation may be an undesirable toilet practice for some.

Option 5: On-plot septic systems:

Standard, on-site septic systems could provide another option for sanitation in ger areas where directly piped water is available. Such systems generally consist of an underground settling tank (septic tank), which is designed to settle out the solids in the effluent and then to drain the remaining effluent into a sub-soil, on-plot leach field. Such as system in the U.S. typically costs between $5,000.00 and $15,000.00 U.S., with an average cost around $10,000.00. In Mongolia, the costs should be considerably less. The primary advantage is that such systems allow the use of flush toilets. The disadvantages include potential ground water pollution, loss of soil nutrients, excessive water usage, need for regular pumping to clean out the settling tank, and considerable installation expense.

Septic systems can also be designed and constructed to collect the wastewater from several households at once by using larger tanks and larger leach fields. This may be an option that could help reduce costs in some ger areas.

Summary

Bio-toilets seem to be a feasible option in Mongolian ger communities for a limited number of inhabitants, particularly those who do not have piped water connections, nor are likely to have piped water in the near future. Bio-toilets can also be utilized by those households that do have piped water in order to eliminate the need for flush toilets and the resulting production of blackwater effluent. However, bio-toilets require the availability of organic cover materials to function properly. The extent to which such materials are available has not been fully determined. Limitations on such materials will establish a limit on the number of people who can employ bio-toilets in their households. In the meantime, there is sufficient organic material immediately available to allow for a considerable number of household bio-toilets to become utilized. However, due to the pioneering nature of this project, we are starting with a pilot project consisting of only twelve volunteer households. A preliminary training program has been established for these households. If the pilot project is adequately monitored and the progress of the project is determined to be successful, additional households may be added to the pilot project. The data collected from the project will enable rational decision-making concerning the future expansion of bio-toilets in ger areas. In addition to the research involved with the monitoring of the pilot projects, further research is needed to determine 1) the full extent to which compostable organic materials are available for use in bio-toilets, and 2) proper means of recycling or disposing of graywater in ger areas.

Appendix 1: Toilet and compost bin construction costs

The cost to set up one compost toilet and compost bin, using new materials, is about $24.00 U.S. per system, not including cover materials except one bale of hay at $1.50 U.S. each. Sawdust from the local lumber mills is free.

These are actual costs determined by buying the materials listed below in Ulaanbaatar at the construction markets. The toilet receptacles and cleaning brushes were purchased at the Black Market. These costs can be significantly reduced by using salvaged materials.Although we built a demonstration compost bin in the UB area out of new wood, the pilot project participants built their own bins out of the materials they had on hand, for little or no cost. The toilets can also be constructed out of recycled materials, although ideally the toilets will be mass-produced so as to make sure the details are correct [for example, toilet receptacles must exactly fit the toilet top hole; the hole for the receptacle must be set back about 3.8 cm (1.5”) from the front of the toilet; the height of toilet box must be correct; the toilet top should be one piece, etc.].

The wire cover on the compost bin can be eliminated if the composter can prevent dogs or other animals from accessing the compost using a different technique (such as a board barrier, for example). This would eliminate $1.50 U.S. in cost.

In addition, an individual humanure compost toilet system should utilize more than one toilet receptacle. Four is recommended for convenient use of the toilet (i.e. the toilet can continue to be used even after a receptacle or three are filled because the filled ones can be set aside, with lids, and emptied into the compost bin at the convenience of the user without interrupting the use of the toilet). In our pilot project, we supplied each family with a toilet and one receptacle, asking them to provide the additional receptacles at their own expense. We designed the toilets to utilize commonly available receptacles.

The labor estimate was based on the actual labor pay rate for Habitat for Humanity carpenters (5,000 tugrits.day). We built 12 toilets, including three coats of shellac finish, in about 6 hours, with two carpenters and two helpers. This was a relatively slow process due to the carpenters’ lack of experience in building these toilets, and a lack of proper tools. Based on this experience, with proper tools and an established shop location, these toilets could easily be produced at the rate of 6 per day, or more, by a single worker.

Costs below are based on 1,200 Mongolian tugrits/U.S. dollar. Costs have generally been rounded up to allow for unforeseen expenses.

OVERALL COSTS

$11.00 U.S. Construction Costs per Toilet: Materials: $7.18, Labor: $1.00, Overhead: $2.00, or roughly rounded up to about $11.00/toilet.

$13.00 U.S. for a single compost bin made from entirely new wood materials, including one bale of hay for “biological sponge” to be spread on bottom of bin before toilet materials are added.

TOILETS (cost per toilet)

1. **$1.07 U.S./toilet for a plywood top**: Plywood top, 4'x8' sheet or 122 cm x 244 cm (enough for 12 tops) = 13,000 tug. or about $1.07/toilet
2. **$2.00 U.S. for a toilet seat**: Toilet seat = 2,400 tug. or about $2.00
3. **16 cents U.S. for a pair of hinges**: Pair of hinges = 200 tug. or about 16 cents
4. **4 cents U.S./toilet for screws**: Screws for hinges = about 4 cents per toilet (1,200 tug. or $1.00 for a bag of screws)
5. **8 cents U.S./toilet for nails**: 1,100 tug./kilo or about 8 cents/toilet
6. **$1.00 U.S./toilet for side boards and legs**: side boards are 1"x6"x76" (2.5cm x 15cm x 193cm) [lumber is 55,000 tug. or $46.00 U.S. for a cubic meter of rough-sawn pine/larch]. A cubic meter of 2.5 cm (1") boards would consist of 1m (39") x 1m (39") = 1521 square inches x 1m (39") = 59,319 square inches total, or 411 square feet (or approximately 40 square meters, or about $1.13 U.S./square meter). Each toilet requires a minimum of 3.2 square feet. At $46.00 U.S. for 411 square feet, the cost is eleven cents/square foot, or about 36 cents U.S. per toilet for the side boards. The leg boards would be approximately the same, for a total of about $1.00 U.S./toilet for the side boards and legs.
7. **24 cents U.S./toilet for wood finish**: Shellac for 24 toilets = 7,000 tug or $5.85 U.S., or 24 cents U.S./toilet. Add one paint brush at 500 tug. or about one cent U.S. per toilet.
8. **$1.50 U.S./ new plastic receptacle** (18-20 liter capacity) with lid

LABOR

Labor (estimated) at $1.00 U.S./toilet: Estimated at 5,000 tug./day for a carpenter who can make about 6 toilets in a day minimum, or about 833 tug/toilet (67 cents U.S./toilet)

OVERHEAD COSTS

Overhead: $2.00 U.S./toilet (estimated): Gasoline for hauling vehicle, other truck or vehicle expense, tools, etc., estimated at $2.00 U.S./toilet

COMPOST BINS

Compost bins: $13.00 U.S. each if built entirely out of new wood (rounded to $13.00 U.S.)

One bin requires 6.76 square meters of 2.5cm (1") lumber, for the side boards, if built of wood, or $7.64 U.S./bin @ $1.13 U.S./square meter.

Posts are about 50 cents U.S. each (2"x3" lumber), or $2.00 U.S.

Wire mesh to cover compost is about $1.50 U.S./bin

Long-handled toilet brushes for cleaning receptacles are about 40 cents U.S. each.

A bale of starter hay is about $1.50 U.S.

***Cellulose**

Cellulose, ($C_6H_{10}O_5$), is a long-chain polymeric polysaccharide carbohydrate of beta-glucose — the most abundant naturally occurring organic substance, being found as the principal component of cell walls in higher plants where it provides the main structural feature. Cotton is almost pure cellulose at 98%; flax is 80%, and wood is 40-50%. The primary cell wall of green plants is made primarily of cellulose; the secondary wall contains cellulose with variable amounts of lignin. Lignin and cellulose, considered together, are termed lignocellulose, which (as wood) is the most common biopolymer on Earth. Cellulose is the most abundant form of living terrestrial biomass (R.L. Crawford 1981). Cellulose is the major constituent of paper. Cellulose fibers make up a significant portion of the dry weight of most plants. Cellulose is also the main constituent of animal feeds such as hay.

Material	% Cellulose
Cotton	98
Ramie	86
Hemp	65
Jute	58
Deciduous woods	41-42
Coniferous woods	41-44
Corn stalks	43
Wheat straw	42

Pilot group training in Erdenet (top) and in UB (center).
Pilot group bio-toilet pickup, UB (bottom).

18 liter capacity toilet receptacles with lids are abundantly available at the Black Market (top). Toilets are being mass produced for the pilot project group (center). One of the group's toilets already customized by the new owner (bottom).

The bio-toilet itself is a simple, inexpensive collection device.

Compost bins were built by the pilot project participants.

Pilot project participant and compost bin in Erdenet (above). Demonstration compost bin in UB (below).