

TITLE: HUMANURE SANITATION

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ABSTRACT: Humanure toilets are designed to collect human excreta, including fecal material and urine together without separation, along with a carbon-based cover material, for the purpose of achieving a thermophilic, or heat-producing, organic mass. The thermophilic phase renders the organic material hygienically safe and creates a final product that is suitable for growing food. These toilets are inexpensive and very simple in design and implementation. This study looks at various humanure systems in the United States.

KEYWORDS: compost toilet, humanure, Joseph Jenkins, sanitation, thermophilic

MAIN TEXT:

Introduction: What is "Humanure Sanitation"?

The humanure sanitation system is a compost toilet system designed and intended to promote the thermophilic composting of human excrement. When properly used and managed, it requires virtually no water, produces no waste, creates no environmental pollution, attracts no flies, costs very little, requires no urine diversion, and produces no odor. Instead of waste, the toilet produces humus, a valuable resource that can safely grow food for human beings. It can be constructed for very little money or no money at all if recycled materials are used. The toilet itself can have a small footprint and can therefore be located virtually anywhere outdoors or indoors -- in a bedroom, closet, porch, basement, dormitory, office or apartment. When properly utilized, the toilet produces no unpleasant odor, therefore its presence inside a living area can remain completely unnoticed and discreet. The humanure toilet requires no urine diversion -- all urine, feces, toilet paper and everything that is normally deposited into a flush toilet (not including chemicals) can be deposited into a humanure toilet. The humanure toilet system can also provide the basis for a complete composting system for a home or community, allowing for the recycling of food and other organic materials that are often discarded by people. The humanure toilet requires no pit or hole in the ground, does not allow human excrement to come in contact with soil or water supplies, creates no ground water pollution, and when properly managed, is a pleasant and convenient toilet alternative.

Methods: How does a humanure system work?

The humanure toilet system is based on the concepts and principles of thermophilic composting. There are three basic components required for such a system to successfully operate: 1) the toilet itself; 2) the organic cover material; and 3) the compost bins.

Component #1 - The Toilet: The toilet component is simply a collection receptacle. Its purpose is to collect human excrement, both urine and feces, in a waterproof container or "toilet receptacle." The "toilet material" is collected before it comes into contact with the environment -- human excrement does not contact soil or water. The toilet material is not referred to as "human waste" because nothing that goes into a humanure toilet becomes waste. It is all constructively recycled via thermophilic composting. Hence, the term "humanure" has become popular when referring to human excrement that is recycled through composting systems. The term "waste" is not used, associated with, or appropriate when discussing humanure toilet systems. There is no waste involved in this process.

The size and type of toilet receptacle can vary from place to place, depending on availability and purpose. For example, in the U.S., 5-gallon (20 liter) plastic receptacles are widely available, both new and used. This size receptacle is attractive for a small-scale system because the receptacle can be easily carried by a single person. They are also inexpensive or free, are water proof, have tight lids, and can last a long time. This system is

not to be confused with a "bucket toilet," which is human excrement deposited into a bucket without cover material, then discarded into the environment as waste. Bucket toilets, however, can easily be converted into humanure toilets by adding the other two components of the system.

Larger toilet receptacles can also be utilized in humanure systems. Experimentation is underway with larger toilet receptacles such as 55 gallon (220 liter) containers that can be maneuvered either by two persons or by machinery. Also, direct deposit humanure toilets eliminate the toilet collection device altogether and are instead designed to deposit the humanure directly into the compost pile.

The purpose of the toilet device is to collect toilet material in such a manner as to prevent any contact with the environment. This allows for sanitation without environmental pollution. In addition, the toilet allows for the collection of toilet materials in such a manner that the human excrement is primed for thermophilic composting. The purpose of thermophilic composting is to subject the toilet materials to robust microbial activity which produces heat generated by thermophilic microorganisms. This process has been scientifically proven to destroy human pathogens, rendering the toilet material hygienically safe and achieving the true essence of "sanitation."

Urine diversion is counter-productive to the humanure system. Urine provides essential moisture and nitrogen required for thermophilic composting. When it is removed from the toilet contents, it creates a resultant organic mass that can be deficient in these two necessary ingredients and therefore can retard the extremely important thermophilic reaction. In addition, paper products are encouraged to be added to the toilet contents, such as toilet paper, toilet paper center cardboard rolls, etc. There is no reason to separate these into a trash bin when using a humanure toilet. Feminine hygiene products can also be added to human toilets, although the plastic components of these products will have to be manually screened from the finished compost as they do not microbially decompose.

Humanure toilets can easily be designed for household use indoors, for single person or family use, or for group use where many people gather, such as at music festivals, campgrounds, retreats, refugee camps, villages, etc. They can also be used as backup or emergency toilets when flush toilets are not available due to electricity outages, for example.

Component #2 - The Cover Material -- Without carbon-based cover materials, the humanure toilet will not work. These materials cover the contents inside the toilets as well as the contents of the compost piles. Enough cover material is needed to totally and effectively eliminate odor and/or flies. The correct amount of cover material can be gauged by simply smelling the toilets or the compost piles. If there is any offensive odor, more cover materials must be used. Likewise, if flies can be seen accessing the contents of the toilet or the compost pile, more cover material must be used.

The cover materials must originate from "carbon based" plant cellulose material in order to promote thermophilic composting. One of the most widely used cover materials, for example, is sawdust from trees. Another is peat moss. Rice hulls seem to be popular where available. Cover materials can be any somewhat dry plant material ground into the correct consistency, such as from coco coir, paper products, cardboard, even junk mail. Availability of appropriate cover material is essential to the successful operation of a humanure toilet system. The cover material must not be too coarse. Wood chips, for example, are inappropriate -- even wood shavings are not ideal and can inhibit thermophilic composting due to the inaccessibility of the carbon to the compost microorganisms because the wood particles are too large.

When the cover material is from an appropriate source and of appropriate consistency for use in the toilet, the toilet contents can be covered in such a manner that no odor whatsoever escapes from the toilet. This enables the toilet to be located indoors. However, if

appropriate cover materials are not available or are not utilized, the toilet can emit unpleasant odors. Therefore, it is imperative to understand that the humanure toilet system is not appropriate for all people in all places and situations. In woodland areas or any location where sawdust is available, the toilet works very well. In areas where appropriate organic materials such as from agricultural operations are collected and stockpiled for use with humanure toilets, such a sanitation system can work very well. The agricultural byproducts that may work in a humanure toilet system could include such things as grain chaff, pine needles, coffee grounds, distillery byproducts, cleanings from woolen mills, paper products ground to the right consistency, etc.

A secondary set of cover materials is also required for the successful functioning of a humanure toilet system. These are the cover materials used on the compost pile and they can be much coarser than the toilet cover materials. Compost pile cover materials can include grasses, hay, straw, pine needles, weeds, leaves, or many other organic plant materials that are odor-free and do not attract flies. Such cover materials allow for the collection of large quantities of toilet material in an above-ground compost bin without creating unpleasant odor or attracting flies. They also contribute to the thermophilic microbial reaction, which is aerobic, by creating tiny interstitial air spaces in the compost piles.

If both types of appropriate cover materials are not available, the humanure toilet system is not recommended. If the cover materials are available in limited quantities, then humanure toilets can successfully be used in limited numbers only.

The carbon-based cover materials balance the moisture and nitrogen in human excrement. This creates a desired "carbon to nitrogen ratio" that encourages reproduction of heat-producing microorganisms. By using enough cover material of the correct consistency to prevent odors from escaping the humanure toilet system, the correct balance of carbon to nitrogen can be achieved. In addition, all food scraps and other organic materials that may be available from human activity can be added to the humanure compost system to achieve high-quality compost.

Component #3 - The Compost Bins -- All toilet materials that are collected must be composted in an aerobic, thermophilic manner in order to achieve maximum sanitation. This requires the depositing of the materials into a compost bin of some sort. The purpose of the bin is to allow the piling of the collected material above ground in such a manner that it is not accessible to children, animals or other vermin, or insect vectors. The bins are constructed with a "biological sponge" as the base layer. The sponge consists of plant materials such as straw, hay, weeds, grasses, etc., piled in the bottom of the bin for the purpose of absorbing excess liquids that may collect when the pile is first constructed.

The bins can be constructed on bare soil with the base shaped into a slightly concave configuration, allowing for the pooling of any excess liquid into the center of the bin (preventing leaching out the bottom sides). Bins can also be constructed on concrete or other hard surfaces, although a soil base encourages beneficial soil organisms, such as earth worms, to migrate into the compost pile. Ideally, sufficient material is used in the biological sponge to absorb any excess liquid. Once the thermophilic phase begins, liquid is rapidly absorbed by the extremely robust biological activity, hence the need for urine. Proper management of the compost pile is very important, therefore experience and education are strongly recommended. Composting is as much an art as it is a science.

The compost bin walls may be constructed of wood boards (either new or recycled); masonry materials such as bricks, blocks or concrete; straw or hay bales (which can be reused as cover material after their function as side walls is completed); bamboo; poles or logs; wood shipping pallets turned on their sides, etc. The top of the compost pile is covered with clean cover material at all times of sufficient quantity such that all odor is suppressed. Also, the cover material must be appropriate in consistency so that flies cannot access the contents

of the pile. Straw or hay scattered loosely, but adequately, over the compost pile, for example, works well for this purpose. Very coarse materials such as pond reeds, for example, may not.

Compost operations can be executed in two basic manners: “batch” compost or “continuous” compost. Batch compost occurs when an entire compost bin is filled all at once or in a short period of time – perhaps in a few days or in a week or two. Continuous compost is when a compost bin is added to continuously for a long period of time such as over a year. In either case, after the bin is filled, the compost should be left undisturbed for approximately a year.

How Thermophilic Composting Works -- Thermophilic composting is the aerobic decomposition of organic matter that includes a hot stage dominated by heat producing bacteria. The hot stage may last days, weeks or months, depending on such factors as the organic ingredients, the size of the compost mass, ambient temperatures, geographical location and/or time of year, and moisture content, among others. Thermophilic temperatures are generally in the range of 45 degrees C or hotter.

Much scientific research has been conducted regarding the efficacy of thermophilic compost in destroying such human pathogens as viruses, protozoa, intestinal worms, and bacteria. Research has shown that human pathogens find the thermophilic environment hostile and they will rapidly die off in such an environment. Finished compost that has been subjected to adequate and well-managed thermophilic conditions typically contains “no detectable pathogens,” regardless of the initial pathogen load. When human excrement can be rendered hygienically safe through the elimination of pathogenic organisms, the true essence of sanitation can be achieved. For example, refer to Figure 1 for a list of pathogen thermal death points (excerpted from *The Humanure Handbook*, 3rd edition).

Humanure compost piles will undergo several stages of decomposition in addition to the thermophilic stage. After the hot phase has ended, the organic material will continue the process of biological degradation and transformation into humus aided by non-thermophilic microorganisms, macroorganisms such as earthworms and other insects, and fungi. These additional stages allow for the further decomposition of the organic material to produce a plant-friendly and agriculturally beneficial final product. The composting process therefore incorporates both the element of temperature and the element of time. Combined, they produce an end product that is safe, sanitary, pleasant smelling, stable, can be stored indefinitely and can be used for growing human food. This is the result of a sanitation system that does not depend on water, does not pollute the environment, produces no waste, is inexpensive and, when properly managed, is odor-free, fly-free and pleasant to use.

More information about this system is available on the internet via *The Humanure Handbook*, 3rd edition, which can be read or downloaded in English free at humanurehandbook.com. The same website has a number of instructional video clips showing humanure composting toilets and bins in use, both at a single family scale and on larger scales. Video clips also show humanure toilet receptacles being emptied into a compost bin, humanure compost being used for gardening and for planting trials, etc. There is also a message board open to the public where people from around the world can discuss issues and exchange information regarding humanure toilet systems. The site also has instructions on building a personal humanure toilet.

Results and Discussion -- Case Studies

Household Small-Scale Systems – Much of this data is derived from the author’s experience with his own household humanure sanitation system in Pennsylvania, USA.

Many American humanure toilet systems utilize 20 liter toilet receptacles which are often made from nothing more than simple 5-gallon plastic buckets. The toilet cabinets are built to fit the receptacle. Several receptacles are used, one at a time. As each one fills with

toilet material (fecal material, urine and cover material), they are set aside with lids. The set-aside receptacles, after they're removed from the toilet, can also be used for depositing food scraps. It is not advisable to add food scraps to a humanure toilet in use as it can promote the breeding of fruit flies. When enough receptacles have collected, they are taken to a compost site and the contents deposited into a compost bin.

After emptying, the receptacles are rinsed -- about 2 liters of water are required to clean a 20-liter receptacle. A tiny amount of dish soap and a long-handled toilet brush aid in cleaning the receptacle. The rinse water is added to the compost pile, soap included. In general, one 20-liter toilet receptacle can provide enough toilet capacity to service one adult for one week if the correct cover material is used. Therefore, in a family of four, four 20-liter receptacles may be needed per week. If the compost bin is conveniently close to the toilet and the toilet receptacles are not allowed to freeze, the weekly emptying and cleaning of four receptacles takes about 20 minutes. Alternatively, the toilet receptacles may be filled, set aside with lids, then collected by a humanure recycling service and composted at a central location by trained and experienced composters. Figure 2 shows a typical household humanure toilet.

The author's humanure toilet system has been continually in use in the same location for 30 years. During that time, all household toilet material, along with all kitchen scraps, garden weeds and other organic materials have been recycled through the humanure sanitation system.

Figure 3 shows a typical household compost bin. Household humanure compost bins benefit from a minimum of two chambers, although three are recommended. This is because household compost tends to be "continuous" compost -- organic material is added to the bins on a regular basis over a period of time. It is recommended to collect compost for one year when building a continuous compost pile, then allow that pile to age for one year while a second pile is built -- hence the need for two bin sections. A third, middle section with a roof or covering allows for the storage of dry cover material handy to the active compost bins. Figure 4 shows the author's three section compost bin with cover material being stored in the center bin.

The active compost bins should have four walls or at least be completely surrounded in order to keep out dogs, goats, children, chickens, etc. One wall should be removable to allow for access to the finished compost. A piece of wire fencing laid over the top of the active compost pile will prevent animals from digging into the pile or scratching the cover material off the compost.

Odorous organic materials should never be put "on" a continuous compost pile. They should always be put "into" the pile. This means moving the cover material aside using a compost tool, such as a hay fork, digging a depression into the top center of the pile, then adding the organic material, which may be toilet material or kitchen material. Clean materials such as weeds, leaves, grass, etc., can be used as cover materials. However, any substance that may attract flies or emit odor should always be fed *into* continuous compost piles and should never be deposited on top of the pile. When these simple rules are followed, all food scrap materials can be added to the humanure compost, including all meat, bones, fat, even animal mortalities or entire dead animals. There is absolutely no need to segregate meat or any animal material from a humanure compost system.

Figure 5 shows the author's garden in Pennsylvania, USA -- it has benefited from humanure compost for 30 continuous years. This location receives slightly more than one meter of precipitation per year with seasonal temperatures ranging from a low of -34 degrees C to a high of 40 degrees C. This garden fed a family with six children over three decades. Primary cover materials used in this humanure compost system included local sawdust from sawmills where trees are cut into boards, plus straw, leaves, weeds, and grass. All household

food scraps are included in the compost system, as is all urine, toilet paper, and animal byproducts including small dead animals (ducks, chickens, possums). Temperatures in this compost system, measured by Reotemp compost thermometers, reach 45-55 degrees C and continuously maintain that range, except during cold winter months, as long as fresh material continues to be added to the compost at least weekly.

Austin, Texas, Direct Deposit System -- In July, 2009, the city of Austin, Texas, approved a direct-deposit humanure toilet for residential purposes. This type of humanure toilet has a larger footprint and is not portable because the toilet material is deposited directly into a compost bin underneath the toilet. The double bin system allows one bin to fill for a period of time, then age while the second bin fills up. Again, a carbon-based cover material (in this case, sawdust) is used to balance the nitrogen and the moisture in the toilet. Presumably, thermophilic conditions will develop, although this has yet to be confirmed in this new project. Figure 6 shows the Austin toilet.

New York Pallet Bin System – Humanure sanitation has been utilized in the state of New York, USA, at a natural building conference for the past few years. The collection system utilizes 20-liter plastic receptacles and the compost bins are made from wood shipping pallets turned on their sides. Cover materials include local sawdust in the toilet and local hay in the bins. Thermophilic conditions have been consistently observed in the compost, based on compost thermometer readings. About 100-150 people are served by this system over a period of a week at a time. Figure 7 shows the compost bins used in system.

California Hay Bale System – A group in California, USA, has experimented with humanure sanitation servicing 500 people at a time at a 10-day music festival. This process filled approximately (125) 20-liter toilet receptacles per day, which were collected twice a day and managed by a dedicated team of six people. The toilet materials were manually emptied inside a compost bin made from straw bale walls (Figure 8). All festival food scraps were collected in separate, color-coded containers and added to the compost pile along with the toilet material. Each time the toilet material and food scraps were added to the bin, the bin contents were covered with fresh straw thick enough to eliminate odors and flies. The odor-free and fly-free system was well received by the festival participants who found the humanure toilets to be preferable to the chemical toilets that had previously been used. A 10-minute video clip of the system is available at humanurehandbook.com. The compost pile temperatures were monitored with a 36" Reotemp compost thermometer at 6 locations and two depths inside the pile (45 cm and 91 cm). After 7 ½ weeks, the temperatures were still averaging 62.7 degrees C. After four months, the temperatures were still averaging 57.7 degrees C.

Kentucky "Wheelie Bin" System – Wheelie bins were used to collect humanure at a music festival in 2008 in Kentucky, USA (Figure 9 shows the toilet building). The humanure was collected with sawdust, then simply left to sit inside the wheelie bins for an entire year. The temperature was not monitored, and it is unlikely that thermophilic conditions occurred. After a year, the toilet materials were dumped into a compost pile. Whatever excess moisture (urine) had initially been in the wheelie bins had become absorbed by the sawdust by that time, and odor had largely disappeared. This process was not intentional, but was the result of a lack of planning and little understanding of how compost works. In the end however, there was no waste, no flies, little odor and no pollution. All of the organic material was recycled.

Texas 20-Liter System – A group collected humanure at a building conference in Texas, USA from about 150 people over a week's time. Six humanure toilets were used, each different and all equipped with 20-liter receptacles (Figure 10 shows a bamboo toilet and some of the toilet receptacles). The collected toilet material was trucked to a neighboring farm where it was deposited into compost bins made from pallets. Two bins were filled and compost temperatures in the 55 degree C range were recorded.

Additional Projects – Other humanure projects in a village in Missouri, USA and in Mongolia were also used to collect data and information, but space limitations prevent their review in this paper. More information can be found at humanurehandbook.com.

Problems – Lack of information, training, understanding and knowledge can make humanure sanitation systems problematic. This is compounded by fear of fecal material. People who are not comfortable with alternative sanitation and who do not have a solid understanding of compost should not be managing humanure toilet systems. For example, a village in Missouri, USA, is requiring all members to participate in group humanure sanitation by taking turns collecting and composting the toilet materials. This is a mistake. There should be a dedicated humanure crew who knows what they're doing when collective composting is undertaken.

Correct and adequate cover materials must be used. A Mongolian family moved their humanure toilet outdoors because of bad odor. The simple addition of more cover material in the toilet would have been the correct solution. Some people simply expect toilets to stink and cannot imagine that a toilet can be odor-free – a result easily obtained by humanure toilets when correct cover materials are used in adequate quantities. Cover materials that are too coarse, such as wood shavings, will not mask odor adequately. This causes the user to deposit too much material into the toilet, causing the toilet to fill too quickly and throwing the carbon/nitrogen ratio off balance with too much carbon, thereby making thermophilic composting unlikely. Sawdust works much better than shavings because of smaller particles.

Pond reeds were used as a cover material in a large humanure compost pile in California. The material was too coarse and flies could get through to access the compost. Odor could escape. A switch to straw as a cover material completely eliminated odor and flies. Reeds had been selected as cover material because it was believed that large air spaces were necessary in the compost pile. This is not true. Visible air spaces are not necessary when the compost is piled above ground.

It is important that humanure toilets be kept indoors in a heated area during cold weather; otherwise the contents of the receptacles will freeze and will not be able to be emptied. Frozen receptacles can also crack and leak. A Missouri community refused to keep the full toilet receptacles indoors for fear of odor. However, when a full toilet receptacle is covered with appropriate and adequate cover material, there is no odor. Tight lids on the receptacles allow them to be stacked, requiring little room. The full receptacles were incorrectly placed outdoors where they froze, cracked and were impossible to empty. This constitutes gross mismanagement of a humanure toilet system.

Compost bins can be located too far from the toilet area. This can make the job of emptying toilet receptacles burdensome and unpleasant if the toilet receptacles must be moved manually. There is no reason to situate the compost bins far away. If they are adequately managed and covered, there is no odor. People who fear human excrement assume the compost bins will stink and will put them so far away from the toilet as to be impractical. This is a recipe for failure. The solution is to use enough cover material in the bins to prevent odors from escaping no matter where the bins are located.

The Future of Humanure – Humanure toilets are not for everyone. They are limited to situations where adequate and appropriate cover materials are available. They are a knowledge-based sanitation system and are sometimes referred to as the “thinking person’s toilet.” When properly executed and managed, however, they provide a low-cost, hygienically safe, environmentally friendly, waste-free and pleasant sanitation alternative that produces a wealth of soil fertility.

Figure 1

THERMAL DEATH POINTS FOR COMMON PARASITES AND PATHOGENS

<u>PATHOGEN</u>	<u>THERMAL DEATH</u>
<i>Ascaris lumbricoides</i> eggs	Within 1 hour at temps over 50°C
<i>Brucella abortus</i> or <i>B. suis</i>	Within 1 hour at 55°C
<i>Corynebacterium diptheriae</i>	Within 45 minutes at 55°C
<i>Entamoeba histolytica</i> cysts	Within a few minutes at 45°C
<i>Escherichia coli</i>	One hr at 55°C or 15-20 min. at 60°C
<i>Micrococcus pyogenes</i> var. <i>aureus</i>	Within 10 minutes at 50°C
<i>Mycobacterium tuberculosis</i> var. <i>hominis</i>	Within 15 to 20 minutes at 66°C
<i>Necator americanus</i>	Within 50 minutes at 45°C
<i>Salmonella</i> spp.	Within 1 hr at 55°C; 15-20 min. at 60°C
<i>Salmonella typhosa</i>	No growth past 46°C; death in 30 min. 55°C
<i>Shigella</i> spp.	Within one hour at 55°C
<i>Streptococcus pyogenes</i>	Within 10 minutes at 54°C
<i>Taenia saginata</i>	Within a few minutes at 55°C
<i>Trichinella spiralis</i> larvae	Quickly killed at 55°C

Source: Gotaas, Harold B. (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.81. World Health Organization, Monograph Series Number 31. Geneva.

