UBC Farm Urine-separating Vermi-composting Toilet: Its operation and the stability, maturity and safety of the end-products

Larisa McNeil

University of British Columbia

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Larisa McNeil (Work-Study student)
Susan Baldwin (Faculty Member)

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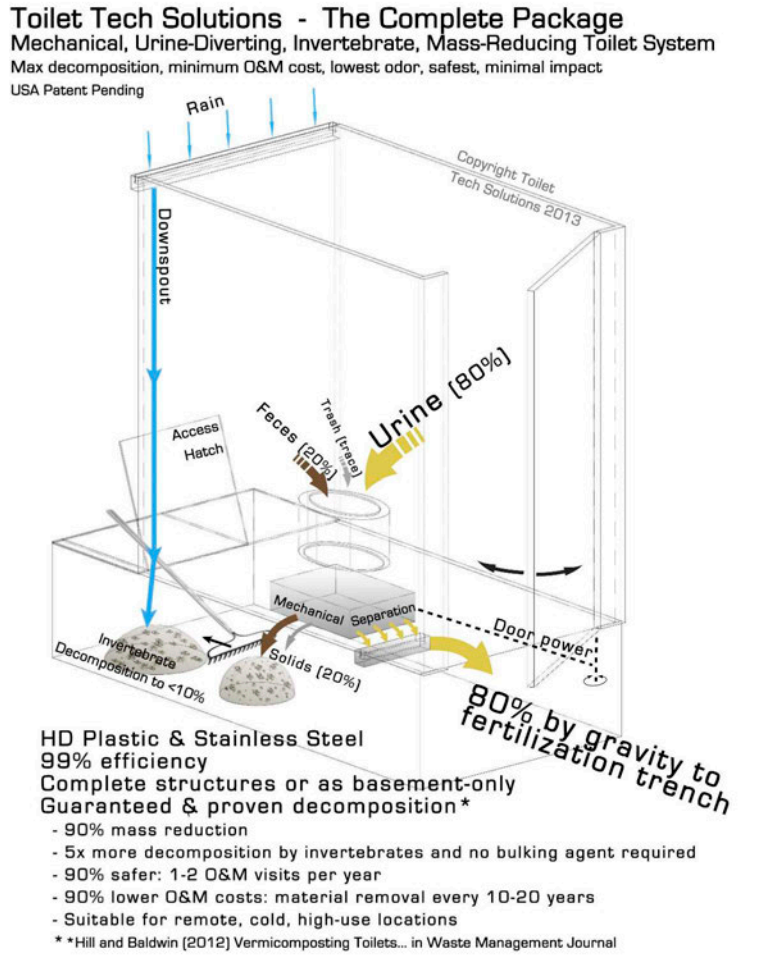
Introduction

The UBC Farm toilet is a novel sustainable and portable composting outhouse designed by Geoff Hill who recently graduated from UBC with a PhD in Geography. The waterless toilet, using a patented lever mechanism, is able to efficiently separate the fecal matter, which falls on to a sloped flat plate, from the urine, which runs off into a trough and is then collected in a separate holding container. Upon closing and opening of the door, the lever sweeps across the flat surface, pushing the feces into a collection bin underneath the structure.



The urine, which contains nutrients like phosphorus and nitrogen and very few pathogens is then able to be processed further in order to create a renewable fertilizer. Unlike current phosphorus fertilizers, which are acquired through mining and therefore not sustainable, this process is completely sustainable and renewable. Through the addition of salts of magnesium, the urine can be made into struvite, a fertilizer. Struvite can then be used on the crops, with out fear of pathogen contamination from fecal matter. Previous "composting" toilets, which did not separate fecal matter and urine, suffered from high levels of pathogenic contamination as well as incompletely degraded fecal matter, due to the fact that the moisture and high ammonia content of urine prohibited proper degradation of waste. When composting occurs, the degradable organic matter in the feces is

consumed by harmless microbes, which reduce the overall volume of the material. Microbes also oxidize the ammonia to nitrate, and possibly reduce the nitrate to nitrogen gas. These processes are inhibited in conventional human waste composting toilets.

At the farm toilet, the fecal matter is dealt with using a technique called vermicomposting. Vermicomposting is a process in which worms break down the fecal matter and leave it as stable, easily disposed of product. By using worms, which greatly speed up the degradation of organic matter, it is possible to obtain mature compost in a much shorter period of time that conventional composting. Furthermore, the volume of waste is very much reduced due to the exclusion of urine and rapid vermicomposting, and the stable end-product can be easily transported to a safe disposal location, should that be necessary. The composted material is stable if there is no more biodegradation taking place, which can be determined by measuring the evolution of CO_2, a byproduct of biodegradation. In future work we will determine the time required to produce stable end-product. The composted feces may still contain pathogens that are not destroyed during the composting process, and that is why it must be transported to a waste treatment facility. But, the much reduced volume and mass of the final end-product makes this more feasible than transporting un-decomposed feces and urine. Eventually, we hope to produce a safe end-product by testing modifications to the vermicomposting process so that the final material can be used as a fertilizer on-site.

The farm vermicomposting toilet structure uses red wiggler worms, which live in the collection bin and gradually consume the fecal matter and produce high quality, mature compost.

Methods

The toilet end-products must be tested to ensure that urine is pathogen free, and the compost is stable and mature. In order to do this, simple testing kits can be used to determine the number of pathogenic bacteria present in the collected urine, as well as levels of ammonia and carbon dioxide in the composted fecal matter.

Compost stability was measured using a Solvita® compost quality test. A simple test that can be performed without training, the kit is able to determine levels of carbon dioxide and ammonia in final product. Using an incubation for four hours at room temperature, of a compost sample with a pre determined moisture range, the gel paddle is inserted into the compost, one for each ammonia and carbon dioxide and then the lid is sealed. The gel paddle detects evolution of carbon dioxide and ammonia gas and change color proportionately. A reading of 5 on the ammonia evolution test, indicating 0.02 mg or less of ammonia is indicative of mature compost. Lower ranks of ammonia (i.e. 1, 2, 3, or 4) indicate that ammonia is still being produced, with the lower number indicating more ammonia production. A reading of 8 on the carbon dioxide evolution test, indicating ambient levels of carbon dioxide are indicative of stable compost. Similarly, lower readings (less than 8) mean that CO_2 is being evolved and composing is still going on. Ammonia and carbon dioxide are the most common gasses given off during the composting process. High levels of carbon dioxide may be indicative of oxygen depletion and therefore anaerobic degradation, as well as potential odor. High levels of ammonia are caused by an imbalance of the carbon nitrogen ratio involved in the microbial metabolization of these elements. If there is an imbalance, nitrogen may break down faster than carbon, resulting in partially degraded compost. Ammonia also creates an unpleasant smell, which may disturb people in proximity to the toilet.

As for the urine, in order for it to be applied to crops as a fertilizer, it must be completely clear of pathogens, in order to not contaminate the soils and subsequently cause harm to humans or animals, which may consume those crops. Having come into contact with the fecal matter on the sweeping plate mechanism, it is important to determine that the urine has not become contaminated.

A common measure of bacterial contamination, is measuring coliform growth. Coliforms are part of the bacterial family, *Enterobacteriaceae*, which commonly colonize the guts of mammals, specifically *E.coli* is capable of causing diseases in humans and livestock. These gram negative, rod bacteria ferment lactose and other complex sugars and are often indicative of fecal contamination in water sources and other places. Using Coliscan Easygel®, the number of these bacteria present can be assessed by growing up a diluted sample of urine and counting each colony that forms. Under the assumption that each colony started out as one bacterium, the number of colonies on the plate represents the number of individual cells in the diluted sample. Using this number, it can then be calculated, the number of viable cells that were present in the urine per milliliter. Coliform bacteria produce an enzyme with which they break down the lactose that they use as an energy source. Testing uses a special dye, which is analogous to lactose, that when cleaved by the enzyme that breaks down lactose, turns blue. By including this dye in the growth media, colonies of cells that produce this enzyme will be blue. However, many bacteria contain this lactose degrading enzyme, so in order to differentiate the coliform *E.coli* from the other harmless bacteria, the presence of the enzyme glucuronidase is also tested. A dye is also added to the media, which is cleaved by glucuronidase, producing a red color. Because only coliform *E.coli* produce both of these enzymes, it is then possible to differentiate similar looking bacterial colonies in order to identify just the ones that pose a risk to humans and livestock. Any coliform *E.coli* would therefore produce both enzymes and the resultant colonies would be purple instead of just blue or red.

Results

The farm vermicomposting toilet was used during the summer of 2013. A door open/close counter indicated that there were 3131 uses of the toilet. The urine separation system worked successfully as there was no evidence of feces in the urine or urine in the feces container. The surface of the urine separating plate was clean.

Upon testing using the Solvita® kit, of compost that had been maturing for about 4 months, the ammonia read at 5, and the carbon dioxide read at 8. This indicated that the toilet has successfully, separated, and with the help of the worms, broken down the fecal matter into mature and stable compost.

Inoculation of diluted urine samples collected from the barrel that accumulated urine over 4 months on the Coliscan Easygel® medium resulted in the growth of only white colonies and no purple, red, or blue colonies. This indicates that there are culture-able bacteria present (showing that growth is possible on the medium, and the test is working) but no bacteria that produced either enzyme were present and therefore no coliform bacteria were found to be viable in the urine, and it is presumably safe for downstream processing.

In summary, testing of the toilet at the UBC farm over the summer of 2013 demonstrated that the urine separating mechanism worked successfully. Solids were collected in their own container. At the end of the summer the composted feces were stable and mature after. Urine accumulated in a barrel where aging occurred. No *E. coli* were detected in the urine, and its pH was 9, with an ammonia concentration of 2.25g/L.

Proposed Future Research

To develop this system into a stand-alone unit, more research and testing are needed to 1) determine the actual time needed for feces to vermicompost to final maturity and stability, and 2) design and test a process for treating the urine so that it can be disposed of without harm to the

natural environment while also extracting the nutrients for reuse.

For this work, the farm toilet can remain in its current location and Masters students in the Chemical and Biological Engineering Department will take responsibility for feces and urine management. The work is planned to take place in the Summer of 2014. During the winter it is unlikely that the toilet will receive much use, and the temperatures may be too cold for composting to be rapid. Therefore we recommend locking the toilet to prevent its use during the winter.

A brief scope of work is given for each of the proposed projects:

1) A previous survey of composting toilets[1] found that vermicomposting produced mature and stable end-product. The final material is reduced in mass and relatively inexpensive to transport to a point of disposal. Insufficient pathogen destruction may prevent usage of the final product on agricultural or forest land[2]. It is proposed to determine the time required to produce mature and stable material by collecting feces in staged batches. Over the summer of 2013 no time course sampling took place and so it is not known how long it takes the feces to reach maturity and stability. The Solvita test will be used to determine the stability and maturity as a function of batch age. This will also enable the calculation of mass of solids produced per usage and provide a guide as to how frequently end-product needs to be removed. A method is being devised for determining this.

2) Urine is much more voluminous and would be expensive to transport to a disposal location. We found that aged urine contained no *E. coli*, but more tests need to be performed to fully screen the urine for all microorganisms present, so as to fully evaluate its safety. Of most concern is the amount of nitrogen in the urine, and uncontrolled release of this into the environment likely would be harmful. To address this, we propose to develop a nutrient recovery system based on sequential adsorptive and reactive media. Research will involve selection and testing of suitable materials together with characterization of the geochemical and microbiological fundamentals. The outcome will be a design for a unit that can be attached to the toilet for processing urine, that will operate passively and require very little maintenance, and produce an organic fertilizer product.

These projects are expected to take place over two years, as is typical for Masters degrees in Chemical and Biological Engineering.

[1] Hill and Baldwin (2012) "Vermicomposting toilets, an alternative to latrine style microbial composting toilets, prove far superior in mass reduction, pathogen destruction, compost quality, and operational cost", Waste Management Volume 32, Issue 10, October 2012, Pages 1811–1820

[2] Hill, GB, Lalander, C, Baldwin, SA (2013) "The Effectiveness and Safety of Vermi-Versus Conventional composting of Human Feces with Ascaris suum Ova as Model Helminthic Parasites", Journal of Sustainable Development; Vol. 6, No. 4; 2013

Susan A. Baldwin
Professor
Chemical and Biological Engineering
University of British Columbia
[redacted]

Larisa McNeil
Undergraduate Student
Microbiology and Immunology
University of British Columbia
[redacted]

Appendix

Figure 1: The Farm urine separating vermicomposting toilet.

Figure 2: The toilet was used 3,131 times during the summer of 2013.

Figure 3: The urine is collected in a barrel.

Figure 4: The feces are collected in a container with worms.