Designing an Evaluation Protocol for Composting Toilet Systems

An Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute in partial fulfilment of the requirements for the Degree of Bachelor of Science.

By:

Camryn Berry

Zahava Preil

Lena Sophia Thompson

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Report Submitted to:

Professor Seth Tuler and Professor Isa Bar-On

Abstract

Two billion people worldwide lack access to adequate sanitation which ensures hygienic separation of human excreta from human contact. Composting toilets help address this health hazard by containing waste and reducing risk of disease. The goal of our project was to develop a cost-effective, user-friendly and minimally-disruptive protocol to evaluate the function, use and maintenance of composting toilets. This protocol was trialed at Kibbutz Lotan in Israel. We concluded that Lotan's system was effective, though inefficient. The trial allowed us to identify potential improvements to the protocol that can be applied in the future. Our protocol is successful for evaluating the success of a system and how adequately it can address the unnecessary loss of life caused by inadequate sanitation.

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Authorship

Section	Primary Author	Primary Editor
Abstract	Camryn Berry	Lena Thompson
1.0	Camryn Berry	Zahava Preil
2.0	Camryn Berry	Zahava Preil
3.0	Camryn Berry	Lena Thompson
4.0	Zahava Preil	Lena Thompson
4.1	Camryn Berry	Lena Thompson
4.2	Zahava Preil	Camryn Berry
4.2.1	Zahava Preil	Camryn Berry
4.2.2	Zahava Preil	Camryn Berry
4.2.3	Lena Thomspon	Zahava Preil
4.2.4	Zahava Preil	Camryn Berry
4.3	Zahava Preil	Camryn Berry
4.3.1	Zahava Preil	Lena Thompson
4.3.2	Lena Thompson	Zahava Preil
4.3.3	Zahava Preil	Camryn Berry
4.4	Zahava Preil	Camryn Berry
4.4.1	Zahava Preil	Camryn Berry
4.4.2	Lena Thompson	Zahava Preil
4.4.3-4	Zahava Preil	Camryn Berry
5.0-1	Zahava Preil	Camryn Berry
5.2	Lena Thompson	Zahava Preil
5.3	Zahava Preil	Camryn Berry
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1.0 Introduction

Two billion people worldwide lack access to adequate sanitation or "facilities which ensure hygienic separation of human excreta from human contact" (Ritchie & Roser, 2019). This is most prevalent in developing countries where access to water and money for infrastructure is limited (World Health Organization, 2019b). Instead, these affected people must frequently defecate in open areas, including into water bodies. This presents a risk of diseases including cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio, which are all caused by consumption of contaminated water (World Health Organization, 2019a). Inadequate sanitation and its associated diseases are estimated to cause 432,000 diarrheal deaths annually.

Composting toilets can help address The Global Sanitation Crisis by providing adequate containment of waste (Jenkins, 2019). Composting toilets are waterless sanitation systems that do not require energy and decompose human waste via aerobic bacterial respiration into humus (ISO/TC 224, 2016). The general design of a composting toilet includes a toilet seat, a chute, and a collection container, but composting toilet systems can vary in design, use, and maintenance dependent on where and how the toilet is intended to be used.

There are many aspects to consider in a composting toilet system, primarily functionality, use, and maintenance. Functionality comprises the elements that allow the system to turn human waste into compost efficiently and effectively. Use comprises the user experience, including odor, difficulty or ease of use, and attitudes surrounding the system. Maintenance comprises the ease of maintaining the system, the frequency of maintenance required, and the health risk presented to those who maintain the system. All of these variables influence the "success" of a system and should be evaluated.

The goal of this project was to develop a cheap, easy, minimally-disruptive protocol for evaluating composting toilets used in both private and public settings, that collect waste in both small containers above ground that must be emptied daily, and large containers underground that remain in the system until full, respectively. This evaluation assesses functional variables such as the input and output volumes, temperature, pH, moisture, E. coli and total coliforms, microorganism presence, and NPK. The areas of usage the evaluation assesses include use per week, user comfort, preference for composting toilets, first impressions of system, perception of system conditions, differences from flush toilets, community perception, prior experience with a composting toilet system, and recommended improvements, as well as gender, country of origin, age, type of residence to identify a pattern between user demographics and experience. The areas of maintenance the evaluation assesses include frequency of maintenance, difficulty of maintenance, challenges of maintenance, specifics of once a day maintenance, specifics of once a week maintenance, specifics of once a month maintenance, ideal improvements to maintenance, ideal improvements to the design, and the perception of safety.

The developed protocol was applied to three composting toilet systems, on varying public and private levels, at Kibbutz Lotan in Israel. This case study illustrated how the protocol can be applied to existing systems to evaluate their function, use, and maintenance status. The results of the protocol were used to identify both strengths and weaknesses of a composting toilet system, and recommendations for improvements to the system were then made. This case study also illustrated the strengths and weaknesses of the evaluation protocol, and recommendations for improvements to the protocol itself were then made.

The aspirations for this project are that our evaluation protocol can be used to assess different systems and the results can be compared to help identify which composting toilet systems have the greatest ability to alleviate the humanitarian concerns associated with The Global Sanitation Crisis.

2.0 Background

In this chapter, we will discuss the Global Sanitation Crisis and how composting toilets can address it by improving sanitation. We will then describe composting toilet systems, how they work, how they address sanitation and water scarcity, and what aspects of a system are vital to the success of a system and are therefore important to monitor.

2.1 The Global Sanitation Crisis

Two billion people worldwide lack access to basic sanitation facilities, such as a latrine or toilet (World Health Organization, 2019b). Of this population, 673 million people have no alternative but to defecate in the open, including into open bodies of water (World Health Organization, 2019b). This issue has been termed The Global Sanitation Crisis, as lack of adequate water, sanitation, and hygiene presents a significant danger to public health and quality of human life (The last taboo: Opening the door on the global sanitation crisis. 2008). The Global Sanitation Crisis is an issue that disproportionately affects impoverished and developing nations, as shown in figure 1.

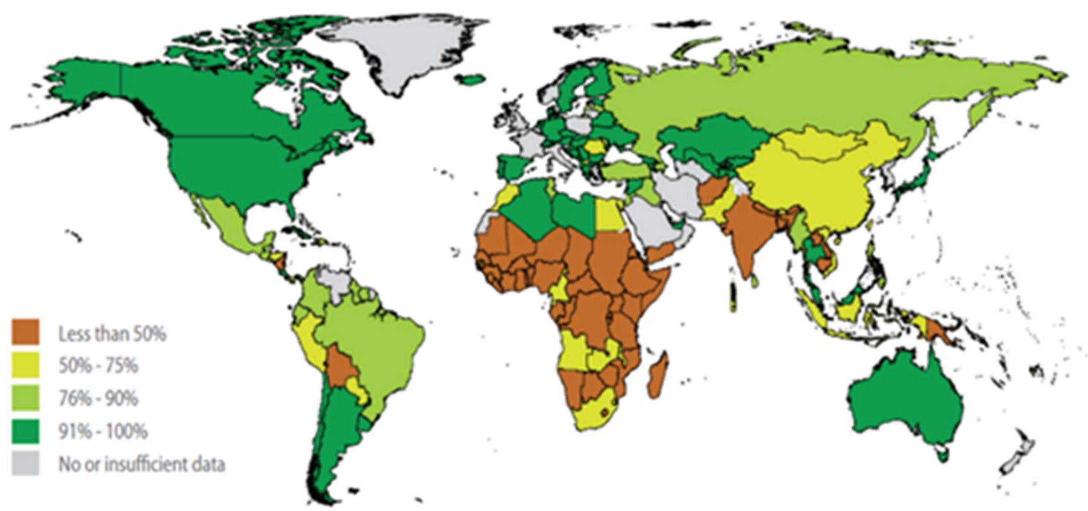

Figure 1: Percentage of Population Using Sanitation Facilities

Source: UNICEF 2014

The danger presented by poor sanitation is primarily that of diseases caused by the consumption of contaminated water. These diseases include cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio (World Health Organization, 2019a). These diseases are caused by exposure to human fecal matter. Globally, at least two billion people use a drinking water source that is contaminated by feces (World Health Organization, 2019a). Of all the illnesses associated with this contamination, cholera, a diarrheal disease that can lead to dehydration and death, is the most prevalent. Researchers estimate that there are 1.3 million to 4.0 million cases of cholera each year (Ali, Mohammad, Nelson, Allyson R., et al., 2015). Inadequate sanitation and its associated diseases are estimated to cause 432,000 diarrheal deaths annually. Poor sanitation also contributes to malnutrition and exacerbates stunting. These health concerns are preventable with the implementation of proper human waste disposal systems.

In addition to presenting a human health crisis, lack of proper sanitation systems reduces individual well-being for many, as there are both social and economic ramifications. These can result from the impacts associated with having to defecate in public areas, such as anxiety and even an increased risk of sexual assault (World Health Organization, 2019b). Lack of adequate waste disposal can also create a loss of educational opportunities, mostly for women, who, as a result of water contamination from human feces, must sometimes walk hours a day carrying large and heavy containers of water to provide their families safe water to drink (Krishnan & Backer, 2019).

Lack of adequate sanitation also affects water scarcity and is affected in turn by water scarcity. Water scarcity is defined as a lack of potable water. Most improved sanitation facilities in the developed world utilize potable water to dispose of human waste (Water sanitation hygiene. 2012). However, in many other areas of the world, the idea of having potable water, or having that water piped directly into the home using electricity, pipes, and other technology, is far out of reach. In many developing countries, human waste is dumped into waterways, such as rivers (Denchak, 2018). In this way, the lack of adequate sanitation facilities also affects water availability. This contaminated water is what contributes to disease, especially diarrheal diseases, as this contaminated water is sometimes, even willingly, consumed (Levy, 2015).

2.2 Composting Toilets: Principle, Design, and Usage

Composting toilet systems have been introduced to help combat the Global Sanitation Crisis by providing containment of human waste. Composting toilets are a subcategory of dry toilets. A dry toilet is defined by The International Organization for Standardization (ISO) as “a toilet which uses no or little water, including composting toilets, urine-diverting toilets, dehydrating dry toilets and other variations” (ISO/TC 224, 2016). The ISO classification of composting toilets can be seen in Table 1. Composting toilets are waterless sanitation systems that do not require energy and decompose human waste via aerobic bacterial respiration into humus. The general design of a composting toilet includes a toilet seat, a chute, and a collection container. An example of this can be seen in Figure 2.

Table 1: ISO Classification of Composting Toilets

Type of Technology	Water required	Energy required	Recycling/ reuse	Advantages	Disadvantages	Outputs
Composting Toilet	No	No	Yes, after treatment	Does not require a constant source of water. Can be built and repaired with locally available materials. Low capital and operating costs. Suitable for all types of users (sitters, squatters, washers, wipers).	Odors can occur if the vent pipe is not operating properly or if the pile is not covered after use with litter or bedding material. The excreta pile is visible except where a deep pit is used. Vectors such as flies are hard to control unless fly traps and appropriate covers for the pile are used.	Humans excreta and urine together, or in diverting models separately.

Source: (ISO/TC 224, 2016)

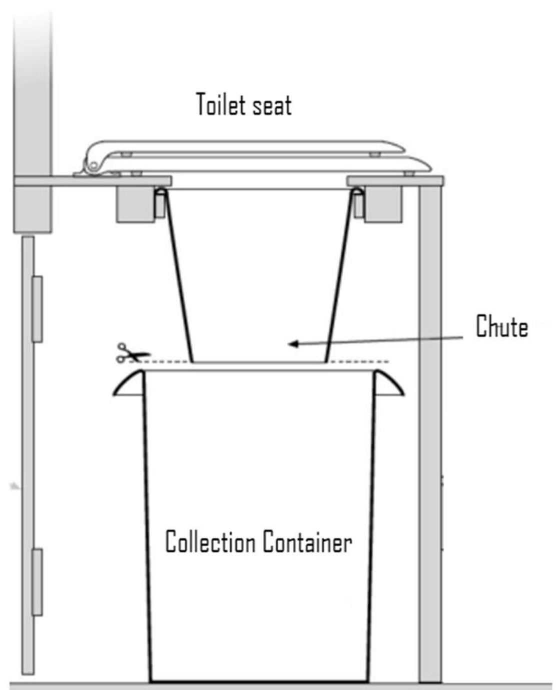

Figure 2: General Schematic of a Simple Composting Toilet

Source: Alex Cicelsky 2020

From the user perspective, the mechanics of using a composting toilet is similar to that of a flush toilet. Solid, liquid, and paper waste can all be put into the system. This waste is then collected in a plastic or metal container or drum. These collection containers remain beneath the toilet until they are full and are then removed and replaced. The frequency of removal depends on the size of the container and the frequency of use. The full collection container is moved to compost elsewhere. The time it takes the waste material to decompose into workable compost is dependent on the conditions of the system that affect the efficiency of composting. This finished compost can then be used to fertilize plants and assist in agriculture. Composting toilets eliminate the need for water and energy for safe waste management, making the system more achievable for under-resourced communities. In addition, these systems contain the waste in collection containers while decomposition occurs. This keeps fecal matter out of public spaces and water supplies.

The design of a composting toilet varies based on how it combats oversaturation from liquid waste, which is necessary due to the reliance of the composting process on oxygen. For the purpose of this project, we are ignoring systems in which liquid is diverted before entering the collection containers. Composting toilets reduce oversaturation either in their design or in their use. Composting toilets designed for this problem utilize a spacer at the bottom of the collection container. Liquid, called leachate, drains to the bottom of the container through a mesh that keeps out solid waste. The container then has a spout at the bottom from which the leachate can be drained once the spout is opened (Jenkins, 2019). Composting toilets that mitigate oversaturation by their use ask users to refrain from urinating in the toilet, requiring adaptability from the user, presenting an inconvenience (Arianto, 2010). Oversaturation can also be avoided by asking users to add dry materials to the toilet after use. These dry materials are typically sawdust, hay, or other organic material that provides absorption of liquid (Ecoflo Wastewater Management, 2015).

In addition, composting toilets can vary in their design in accordance with the intended portability and number of users of a system (Madhavan, 2014). Some composting toilet designs include the collection container in the base of the toilet and allow the entire toilet to be moved easily and quickly. The container is smaller and has to be emptied more often and is, therefore, more equipped for private use within a household (Lewis, 2014). Other composting toilet designs are comprised of a typical flush toilet bowl, but the bottom empties directly into the collection container that is underneath the level of the floor. This design allows more room for a larger collection container and is, therefore, more equipped to handle public use (Jenkins, 2019). Different variations of composting toilet systems can be seen in Figures 3 and 4.

Figure 3: Nature's Head Personal Composting Toilet

Source: Nature's Head

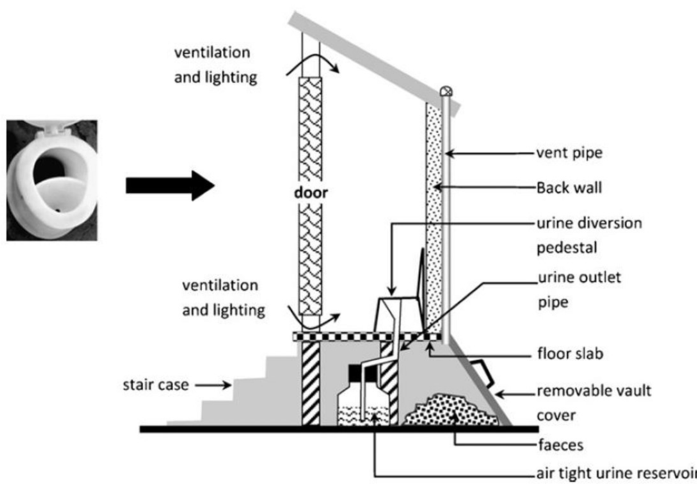

Figure 4: Permanent Composting Toilet

Source: ResearchGate

Different adaptations can be made to a composting toilet system to suit different environments. For the purpose of this project we will consider composting toilets used both privately and publicly, that collect waste in both small containers above ground that must be emptied daily, and large containers underground that remain in the system until full.

2.2.1 Composting Toilets: Chemistry and Biology

Aerobic bacterial respiration is the process that turns human waste in a composting toilet into usable humus. The basic equation for aerobic bacterial respiration is $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$. $C_6H_{12}O_6$ is the chemical formula for the carbohydrates that compose human excreta. In combination with oxygen (O_2), these reactants are converted to carbon dioxide (CO_2) and water (H_2O) by microbiology that is naturally occurring in human waste (Riley, 2014).

The microbiology in the system is dominated by the presence of a mixed population of bacteria and fungi. The prevalence of these microorganisms is directly related to the environmental conditions of the collection tank. These conditions include temperature, pH, moisture, and time.

As the microorganisms grow, heat is generated by the energy released during aerobic respiration. The temperature of the organic matter is important because the enzymatic function of the bacterium is most efficient when warm and bacterial growth rate is increased considerably. Temperature is also vital for the destruction of pathogens, such as E. coli. Pathogens are any bacterium, virus, or microorganism that causes disease. When dealing with human waste, E. coli presents the most concern (World Health Organization, 2018). The temperature of a system should be approximately 60℃ to increase bacterial productivity and eliminate this pathogen (Lopez, Zavala, et al. 2004). Ideally, E. coli will be entirely absent from the system before use in agriculture.

The bacteria present in composting toilet systems grow best around neutral pH values. In composting toilet systems, pH should remain approximately neutral, though the pH will initially drop as organic acids are formed. The pH restabilizes around 7.0 with the assistance of other biochemical processes. In general, the optimum pH is between 6.5 and 7.5 (Cornell Waste Management Institute, 1996).

Moisture enables microorganisms to hydrolyze complex organic compounds into simpler ones before metabolisis. However, oversaturation can eliminate the oxygen from the composting toilet system, suffocating the bacteria. Moisture levels should remain within the range of 40% to 70% moisture content, with the optimum value being 60% (Environmental Protection Agency, 1999). Moisture content is the amount of moisture in the sample measured as a percentage of the sample's original weight.

Time is vital to the destruction of pathogens, but also to the aerobic respiration that creates usable humus. In a system with perfect conditions (suitable temperature, pH, and moisture) the total volume should decrease to 30% of the original volume in three to six months (Jenkins, 2019).

2.2.2 Composting Toilets: Maintenance

In addition to proper chemical and biological conditions, the success of a system depends on how well it is maintained. The maintenance of a composting system depends on its design, use, and function. The maintenance of the specific composting toilet systems we are considering involves mandatory maintenance, discretionary maintenance, and general oversight.

Mandatory maintenance includes the removal and replacement of the collection container and the draining of leachate (Solomon, Casey, Mackne, & Lake, 1998). The frequency of the removal and replacement of the collection container is dependent on the size of the container and the frequency of which the toilet is used. The removal and replacement of these containers is required to ensure that a container does not overflow. The frequency of the draining of leachate is dependent on the moisture content in a collection container, which can be influenced by whether or not users are allowed to urinate into a system. The draining of leachate is required to ensure that the bacteria in the container are being exposed to oxygen and the respiration is kept aerobic (Jenkins, 2019).

Maintenance also includes discretionary activities such as adding extra dry material, adding compost from food waste, and using chemical treatments to mitigate odors from the collection containers. Adding extra dry material helps combat oversaturation by absorbing excess moisture (Ecoflo Wastewater Management, 2015). Adding compost from food waste can introduce more bacteria to the system to increase the efficiency of composting. Adding chemical treatments for odor can help improve the experience of the toilet user. These activities are not mandatory for the toilets to function but can improve the conditions of the system (Cicelsky, 2017).

Maintenance also includes the general oversight of the system, such as fixing cracks in the collection containers, removing blockages from the toilet to the container, and keeping the facilities clean (Greywater Action, 2015). General oversight consists of reactionary maintenance, where a problem has occurred with the ability to use the toilets and is then resolved.

Any form of maintenance of a composting system presents a risk of exposure to E. coli, which is always present in raw waste material (ISO/TC 224, 2016). The level of risk, determined by the E. coli concentration, and when the risk is eliminated from the system, determined by when in the composting process E. coli is eradicated, should be evaluated to make suggestions about what safety precautions are appropriate to take when maintaining a system.

2.2.3 Composting Toilets: Evaluating a System

There are many aspects to consider in a composting toilet system, such as functionality, use, and maintenance. These aspects include different variables that influence the "success" of a system and should be evaluated.

An evaluation protocol that exists, but is not publicly available, is through the National Sanitation Foundation International, or NSF International (NSF International, 2020). This process requires the following:

1. Application and information submission
2. Product evaluation
3. Product testing in lab
4. Manufacturing facility inspection, production confirmation, and product sampling
5. Test results review and acceptance
6. Contract signed and products listed
7. Annual plant inspection and retesting (NSF International, 2020)

NSF certification costs from $1,500 USD to $2,500 USD (BPI, 2012). This evaluation is expensive and time-consuming and eliminates the ability to use the toilet system while it is being tested in laboratory conditions. From these limitations, we decided that there is a need for an evaluation protocol that prioritizes minimizing the cost and time spent on assessing the system, as well as being able to keep the toilets in use during the evaluation process.

3.0 Methodology

The goal of this project was to develop an inexpensive, user-friendly, minimally-disruptive protocol for evaluating composting toilets used in both private and public settings, that collect waste in both small containers above ground that must be emptied daily, and large containers underground that remain in the system until full, respectively. To achieve this goal, we completed the following objectives:

1. Identify the functional, usage, and maintenance variables that influence the success of the system.
2. Develop an evaluation protocol to assess these variables.
3. Trial the evaluation protocol on the composting toilets at Kibbutz Lotan.
4. Identify areas of improvement within the protocol and make recommendations to future evaluators.

3.1 Functional Variables

The functional variables that must be evaluated are the factors that influence the efficacy and efficiency of the composting process. These factors were decided based on research involving literature pertaining to how composting toilets create compost materials, conversations, and interviews with developers of composting toilet systems, the standards set by the United States Environmental Protection Agency and the standards used to govern the minimum performance of composting toilet systems for National Sanitation Foundation certification: the NSF International Standard ANSI/NSF 41-1998: NonLiquid Saturated Treatment Systems. This standard is not an evaluation protocol but can be used for comparing a system to the ideal conditions. The variables that were identified through this research are input and output volumes, microorganism presence, temperature, pH, moisture, NPK, E. coli concentration, and time.

When deciding the method of evaluating each variable, priority was placed on the accessibility of measurement tools, cost of measurement tools, and whether or not the measurement could be conducted while the system is continuing to be used. The variables, importance, ideal measurement, and the tools used to measure them are summarized in the table below.

Table 2: Functional Variables of a Composting Toilet System

Variable	What is its importance?	What is the ideal measurement?	What is the measurement tool?
Input/Output volumes	Measures bacterial efficiency	The output is 30% of input	Meter stick
Microorganism presence	Measures bacterial presence	N/A, dependent on the size of the system	Culture Counting
Temperature	Measures system conditions	60℃	Thermometer
pH	Measures system conditions	6.5 to 7.5	pH meter
Moisture	Measures system conditions	40% to 70% moisture concentration	Moisture meter
NPK	Measures benefit of compost	N/A, dependent on the desired use of compost	NPK test kit
E. coli	Measures health risk	0	Compartment Bag Test by Aquagenex
Time	Measures bacterial efficiency	N/A	Clock and calendar

3.2 Usage Variables

The areas of usage the evaluation assesses include user satisfaction, comfort, and frequency of use. In order to evaluate these areas, we created a survey as part of the protocol, which details what questions should be asked to users of the system to gain insight into their experience. These surveys ask users about their patterns of use, attitudes regarding the composting toilets, community perception of the composting toilets, and opinions of the conditions of the system to attain a greater understanding of how comfort and convenience would influence a user to utilize a composting toilet system.

While we were devising questions for the survey, we did our best to word the questions so that they would be understood by non-native English speakers. The survey is intended to be anonymous as participants would likely be more honest with their answers. When we were drafting questions for the survey, we discussed asking questions about demographics such as gender, what type of environment the participant grew up in, and country of origin to analyze if there is a correlation or trend between demographic and use.

Table 3: User Variables of a Composting Toilet System

Variable	Type of response	Importance
Gender	Short answer	Demographic information
Country of origin	Short answer	Demographic information
Age	Number	Demographic information
Type of residence	Short answer	Demographic information
Use per week	Number	How frequently they use the composting toilet
User comfort	Y/N	Whether or not they feel comfortable using the composting toilets
Preference for composting toilets	Y/N	Do they prefer to use the composting toilets over flush ones
First impressions of the system	Long answer	How the user felt using the composting toilet system for the first time
Perception of system conditions	Long answer	How they feel the conditions of the composting toilets are
Differences from flush toilets	Long answer	Differences from flush toilets
Community perception	Long answer	How does their community perceive composting toilets
Prior experience with a composting toilet system	Long answer	Other places they have used a composting toilet system and what their experience was like there
Recommended improvements	Long answer	Things they think could be improved

3.3 Maintenance Variables

The areas of maintenance the evaluation assesses include ease of maintenance, frequency of maintenance, and safety risks presented to those who maintain the system. In order to evaluate these areas, we included an interview section of the protocol, which details what questions should be asked to those who maintain the system to gain insight into their experience. The variables we considered, and their importance is summarized below.

Table 4: Maintenance Variables of a Composting Toilet System

Variable	Importance
Frequency of maintenance	How well the system is looked after
Difficulty of maintenance	The burden on those doing maintenance
Challenges of maintenance	Potential problems, room for change
Specifics of once a day maintenance	Most important or sensitive components
Specifics of once a week maintenance	Secondarily important or sensitive components
Specifics of once a month maintenance	Tertiarily important or sensitive components
Ideal improvements to maintenance	Areas long-term personal found unsatisfactory in work being done
Ideal improvements to the design	Areas long-term personal found unsatisfactory in problems or required labor
Perception of safety	Comfort and willingness to perform maintenance

3.4 The Evaluation Protocol

This section includes the evaluation protocol in its entirety. It is written as an instructional procedure.

Evaluating the Function, Use, and Maintenance of a Composting Toilet System

Written by:
Camryn D. Berry
Zahava C. Preil
Lena S. Thompson

Overview

This protocol was specifically developed for the evaluation of composting toilets used in both private and public settings, that collect waste in both small containers above ground that must be emptied daily, and large containers underground that remain in the system until full, respectively. By following this protocol, you will be able to evaluate a composting toilet system by means which are cheap and practical, while allowing the system to remain in use. The protocol addresses functional variables, usage variables, and maintenance variables. The functional results of the protocol can be compared to ideal standards to determine the success of a system. The usage results provide insight into how well the system is working for the users. The maintenance results indicate what part(s) of the system are working well or need to be improved.

Terminology and Definitions

Collection container – the mechanism in which the waste is stored
Escherichia coli (E. coli) – a pathogen that can cause severe abdominal cramps, bloody diarrhea, and vomiting
Chute – the mechanism by which the waste is funneled into the collection container
Active containers – collection containers that are still receiving inputs of human waste
Inactive containers – collection containers that are no longer receiving input and are only in the composting process

Safety

In order to evaluate the functional variables of a composting toilet, contact must be made with human waste. Due to the risk of E. coli exposure, it is important you wear long gloves, safety glasses, and a face mask. A plastic apron to cover the torso is recommended.

Method of Data Analysis

All results should be recorded in spreadsheets. By using a program such as Excel, statistical analysis can be easily performed. It is recommended that functional data be organized using a separate spreadsheet to correspond to a separate collection container. An example of a spreadsheet used to collect functional data is shown below.

	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/2020 9:00	68.5	80.5	74.5			15.8			11
3	1/24/2020 9:00	74.5	79.5	77			15.1			13
4	1/26/2020 9:00	70	82	76			12.8			8
5	1/27/2020 9:00	71.5	80.5	76			12.6			9
6	1/28/2020 15:00	70	83.3	76.65	10.9	12.7	11.8	10	6.9	12
7	1/29/20 9:00	71	81.9	76.45	14.9	14.9	14.9	10	7.1	19
8	1/30/20 9:00	70	81.5	75.75	12	14.4	13.2	10	7	16
12	2/1/20 11:00	69.7	79	74.35	13.1	16.1	14.6	10	6.9	17
13	2/2/20 9:00	70	81.5	75.75	13.8	15.4	14.6	10	7.1	15.5
14	2/3/20 10:00	71	80.5	75.75	14.1	15.8	14.95	10	7	18
15	2/4/20 10:00	72.3	80	76.15	15.5	16.8	16.15	10	6.9	17
16	2/5/20 17:30	74	78	76	20.7	18.5	19.6	10	7	18
17	2/6/20 11:00	71	75	73	16.5	17.8	17.15	10	7	16
18	2/10/20 9:30	70.8	82	76.4	13.6	17.3	15.45	10	7.5	15.3
19	2/11/20 9:30	71.9	79.2	75.55	14.5	16.3	15.4	10	7	15
20	2/12/20 9:30	70	77.5	73.75	15.6	16.8	16.2	10	7	17.5
21	2/13/20 9:15	70.8	78	74.4	13.9	17.2	15.55	10	7.2	18.5
22	2/18/20 10:00	69.5	80	74.75	18.2	20.5	19.35	10	7.1	20.5
23	2/21/20 10:00	69.4	79.4	74.4	15.5	19.6	17.55	10	7	20.2

Bin 8 | Bin 10 | Bin A Four Times Collection | Bin A | Bin C | Bin D | Bin E | Bin F | Bin G | Bin J

For the analysis of usage procedure results and maintenance procedure results, which use surveys and interviews, it is recommended to use a codebook where a number corresponds to each common response. A codebook assigns a number to a common response. For example, “difficult to use” could be assigned to the number “3”. Each time a synonym or the words “difficult to use” appears in the results, the number “3” is assigned to that data.

Evaluation of Functional Variables

The variables this functional procedure will evaluate are volume, temperature, pH, moisture, E. coli and total coliforms, microorganism presence, and NPK.

Volume of Collected Solids

Materials:

- Meter stick

Procedure:

1. Measure the length, width, and height of the collection container if the volume is unknown.
2. Uncover the collection container. This may require the container to be removed from beneath the chute.
3. Identify an area of relative minimum height. Place the end of the meter stick at this location without inserting it into the waste and hold the meter stick perpendicular to the ground.
4. Measure the height from the top of the collection container to the relative minimum.
5. Identify an area of relative maximum height. Place the end of the meter stick at this location without inserting it into the waste and hold the meter stick perpendicular to the ground.
6. Measure the height from the top of the collection container to the relative maximum.
7. Replace and recover the collection container to its original position.

8. Subtract the measured values from the full height of the collection container for the actual minimum and maximum heights of collected solids.
9. Average the actual minimum and maximum height values and then multiply by the length and width to calculate the average volume in the collection container.

This procedure should be repeated once daily for active containers. For inactive containers, this procedure should be repeated once a week.

<u>Temperature of Collected Solids</u>
Materials:
- Thermometer

Procedure:
1. Uncover the collection container.
2. Insert the thermometer approximately 40cm deep into the material close to the edge of the collection container. Be sure that the thermometer is not touching the side of the container.
3. Record the temperature with the thermometer still inserted into the material.
4. Insert the thermometer approximately 40cm deep into the material in the center of the collection container.
5. Record the temperature with the thermometer still inserted into the material.
6. Replace and recover the collection container to its original position.
7. Record ambient temperature to identify any patterns that may occur between the temperature of the container and the ambient temperature.
8. Average the bin temperature by adding the temperature recorded at the edge of the bin and the temperature recorded at the center of the bin. This data is now comparable to the ambient temperature.

This procedure should be repeated once daily for active and inactive containers.

<u>pH of Collected Solids</u>
Materials:
- pH meter

Procedure:
1. Uncover the collection container.
2. Insert the pH meter approximately 40cm deep into the material in the center of the collection container.
3. Record the pH with the meter still inserted into the material.
4. Replace and recover the collection container to its original position.

This procedure should be repeated once a week for active and inactive containers.

Moisture Levels of Collected Solids

Materials:

- Moisture meter

Procedure:

1. Uncover the collection container.
2. Insert the moisture meter approximately 40cm deep into the material in the center of the collection container.
3. Record the moisture with the meter still inserted into the material.
4. Replace and recover the collection container to its original position.

This procedure should be repeated once a week for active and inactive containers.

Presence of E. Coli and Total Coliforms

Materials:

- Aquagenx compartment bag test

Procedure:

1. Obtain a 50 mL sample from the collection container from approximately 40 cm deep.
2. Dilute the sample with 1 L of distilled water and gently swirl to mix.
3. Pour 100 mL of this dilution into Whirl-Pak Thio-Bag.
4. Add Aquagenx EC and TC growth medium to sample in Whirl-Pak Thio-Bag and gently swirl to mix.
5. Pour sample with dissolved medium from Whirl-Pak Thio-Bag to Aquagenx Compartment Bag and seal.
6. Allow the sample to incubate for 20-48 hours in any temperature between 25℃ - 44.5℃.
7. After 20-48 hours, score E. coli results in ambient light. Yellow/yellow-brown means it is negative for E. coli. Blue/blue-green means it is positive for E. coli. Compare to the Aquagenx MPN table.
8. After 20-48 hours, score total coliform results in ambient light. If it fluoresces it is positive for total coliforms. If it does not fluoresce, it is negative for total coliforms. Compare to the Aquagenx MPN table.
9. Decontaminate samples with bleach and dispose.

This procedure should be conducted once per collection container.

Microorganism Presence

Materials:

- Petri dish or streak plate
- Growth medium

Procedure:

1. Obtain a 50 mL sample from the collection container from approximately 40 cm deep.
2. Dilute the sample with 1 L of distilled water and gently swirl to mix.
3. Add growth medium to this dilution and pour a known volume into a petri dish.
4. If the cells are distributed on the plate properly, it can generally be assumed that each cell will give rise to a single colony. Count each colony with the naked eye.
5. Based on the known volume, calculate the bacterial concentration.

This procedure should be conducted once per collection container.

<u>Nitrogen, Phosphorous, and Potassium of Humus</u>
Materials:

- Milwaukee MT 6003 NPK Test Kit which includes:
    - MT 5015 Extraction Solution, 3 bottles (100 mL)
    - MT 5009-0 Nitrogen Reagent, 25 packets
    - MT 5010-0 Phosphorus Reagent, 25 packets
    - MT 5002-0 Potassium Reagent, 25 packets
    - Three 1 mL plastic pipette
    - Five test tubes
    - One tube-stand
    - One spoon
    - One brush
    - Three color cards
    - One graduated card
    - Operating manual

Procedure as defined by the Milwaukee MT 6003 NPK Test Kit manual ((Milwaukee Instruments, 2013):
Nitrogen Testing

1. Use the included pipette to transfer 2.5 mL of the clear general extract to a clean test tube.
2. Add the content of one packet of MT 5009-0 NITROGEN reagent. Replace the cap on the test tube and shake vigorously for 30 seconds to dissolve the reagent.
3. Allow the tube to stand for 30 seconds. Match the pink color with the N color card as described above and note the N reading.

Phosphorus Testing

1. Use the pipette to transfer 2.5 mL of the clear general extract to a clean test tube.
2. Add the content of one packet of MT 5010-0 PHOSPHORUS reagent. Replace the cap on the test tube and shake vigorously for 30 seconds to dissolve the reagent.
3. Allow the tube to stand for 30 seconds. Match the blue color with the P color card as described above and note the P reading.

Potassium Testing

1. Use the pipette to transfer 0.5 mL of the clear general extract to a clean test tube.
2. Fill the tube to the lower graduation mark (2.5 mL) with the MT 5015 Extraction Solution.
3. Add the content of one packet of MT 5002-0 POTASSIUM reagent. Replace the cap on the test tube and shake vigorously for 30 seconds to dissolve the reagent.
4. Allow the tube to stand for 30 seconds. Following test tube reading instructions as described above in the “Reading the Color Card” section and note the K reading.

Evaluation of Usage Variables

The variables this usage procedure will evaluate are use per week, user comfort, preference for composting toilets, first impressions of system, perception of system conditions, differences from flush toilets, community perception, prior experience with a composting toilet system, and recommended improvements, as well as gender, country of origin, age, type of residence to identify a pattern between user demographics and experience.

Surveying Users of the Composting Toilet System

Procedure:

1. Identify a group of users of the composting toilets and ask for their participation in your evaluation.
2. Administer the survey below to willing participants using a method that stores participant's responses, such as Google Sheets.
3. Identify patterns and results based on common responses.

Usage Component Survey

This survey is used to evaluate the success of a composting toilet system based on user experience.

Gender

Your answer

Country of Origin

Your answer

Age (numerical)

Your answer

What type of residence do you live in at your country of origin?

- ○ Urban
- ○ Suburban
- ○ Rural
- ○ Other:

How often per week do you use the composting toilets (best numerical guess)?

Your answer

Do you feel comfortable using the composting toilets?

- ○ Yes
- ○ No

Do you ever prefer to use the composting toilets over flush toilets?

- ○ Yes
- ○ No

Why or why not?

Your answer

What was your first impression of the composting toilet system?

Your answer

How do you feel about the conditions of the system?

Your answer

Is there anything in particular that you notice about your experience with a composting toilet that is different than a flush toilet?

Your answer

What is your perception of how composting toilets are perceived in the community in your country of origin?

Your answer

Have you ever used composting toilets anywhere else? If yes, where? What was your experience?

Your answer

What do you think could be improved?

Your answer

Submit

Evaluation of Maintenance Variables

The variables this maintenance procedure will evaluate are frequency of maintenance, difficulty of maintenance, challenges of maintenance, specifics of once a day maintenance, specifics of once a week maintenance, specifics of once a month maintenance, ideal improvements to maintenance, ideal improvements to the design, and the perception of safety.
Procedure:

1. Identify individuals who maintain the composting toilets and ask for their participation in your evaluation.
2. Ask the below to willing participants and take an audio recording of the interview.
3. Transcribe the responses and identify patterns and results based on common responses.

- How often do you do maintenance?
- What does that entail?
- Why do you think that these haven't been implemented more outside of Lotan?
- What do you think are the biggest challenges of implementing them?
- What is the biggest challenge in maintenance right now?
- What are the benefits of the use of composting toilets?
- What could be improved? Right now? Idealistically?
- What is your ideal in five years?
- How safe do you feel working with them?
- What do you do once a day, once a week, once a month? What type of work does this system need to succeed?
- Why do you think that these haven't been implemented more outside of Lotan?
- Why hasn't there been an evaluation of the systems?
- Which system do you think works best? Why?

4.0 Case Study

In order to assess the cost, ease, and time duration of our evaluation, we tested our developed protocol at Kibbutz Lotan in Israel on their three systems of composting toilets. This location was of particular interest and value, as Lotan uses both public and private systems. This provided us with the opportunity to collect a variety of data in terms of the composting process, user experiences, and required maintenance.

4.1 How We Applied the Protocol to Evaluate the Lotan Systems

At Lotan, there are three different locations of composting toilet systems. These composting toilets were designed by Alex Cicelsky, a founding member of Kibbutz Lotan as well as the co-founder of the Center for Creative Ecology. The composting toilets vary in their design, use, and maintenance.

4.1.1 EcoKef Public Toilets

The EcoKef is a communal area consisting of gardens, a playground for children, and a place for tourists to learn about the systems present at Kibbutz Lotan. The composting toilet system there is comprised of four toilets in one bathroom that are intended for public use. Each toilet has the same design, which is similar to a traditional flush toilet bowl that connects to a chute that funnels the waste through the floor into each collection container, which is a reused municipal trash bin. However, there are concrete cylinders that replace the traditional ceramic toilet bowl.

Once a user enters the bathroom, a solar-powered fan is switched on in order to divert unpleasant odors. A user can then excrete both solid and liquid waste into the system, as well as placing their paper waste into the toilet. The user must then pour dry material, in this case straw that has been filtered out of cow feces, into the toilet. The lid to the toilet must then be closed to prevent odor from escaping and insects from interacting with the compost. This is to eliminate the possibility that insects carrying pathogens would spread said pathogens throughout the community.

The layout of the system is depicted in Figure 5 and allows for mandatory maintenance to be conducted on the posterior side of the bathroom building approximately four meters below ground level. This area is lined with concrete and houses the four collection bins in use, as well as 4-5 additional bins that are in the composting process. This area also contains a hole where leachate can be drained into. This hole leads to the constructed wetland where leachate can be filtered.

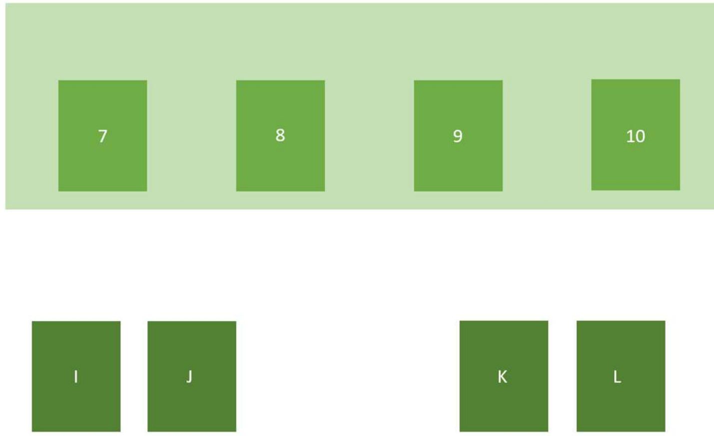

Figure 5: Layout of Collection Containers at EcoKef

4.1.2 EcoCampus Public Toilets

The EcoCampus is a living area within Kibbutz Lotan with a focus on permaculture, including mud homes and solar stove. The composting toilet system there is comprised of four toilets in two bathroom buildings (two in each) that are intended for public use, though used mostly by residents of the EcoCampus. Each toilet has the same concept for the design, which is similar to the EcoKef toilets: a traditional flush toilet seat connects to a chute that funnels the waste through the floor into municipal trash bins. However, two of the toilets are in wooden stages, one is a standalone mud cylinder, and one is a mud stage with a cut out where a person's leg would fit as they sit on the seat.

The user experience of the EcoCampus varies from the EcoKef toilets in two important ways. Firstly, there is no fan system to decrease the presence of unpleasant odors. Secondly, men are encouraged to urinate into urinals that are separate from the composting toilets system. This partially helps alleviate concerns of oversaturation within the collection bins, by reducing the amount of liquid waste and by consequence, the amount of leachate.

The layout of the system is depicted in Figure 6 and allows for mandatory maintenance to be conducted on the posterior side of the bathroom building approximately two meters below ground level. This area, unlike the EcoKef, is not walled off and is exposed to the surrounding environment, allowing for greater sun exposure as well as insect and animal presence. This area houses the four collection bins in use as well as any additional bins in the composting process. A solution of vinegar, lactic acid, and essential oils is added to the collection containers in this system to combat unpleasant odors. This area also contains a hole where leachate can be drained into.

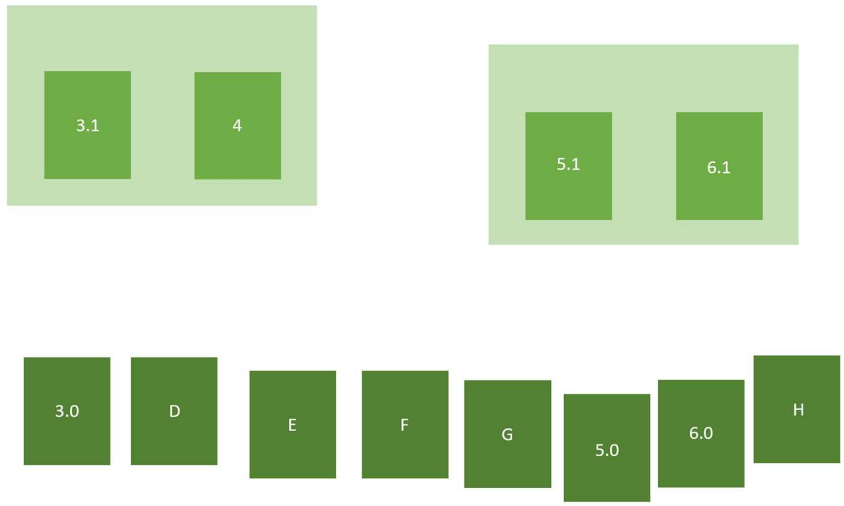

Figure 6: Layout of Collection Containers at EcoCampus

4.1.3 Square Dome Personal Toilets

The square domes are two of the living units within the EcoCampus, specifically housing their own composting toilet bathroom in each. This system consists of two toilets in two separate bathrooms, one in each dome, that are intended for private use by the residents of each square dome. Both toilets have the same design. A toilet seat connects directly to a temporary collection container. This temporary container is emptied each day by the residents into their own municipal trash bin behind the square domes. The temporary container is then hosed down and placed back into the resident's bathroom.

Users can still excrete both solid and liquid waste into the system as well as dispose of their paper waste, and the user must still pour the dry material into the temporary collection container. This system has no ventilation to mitigate odors. The system also places an additional responsibility on the user to transfer their waste into a separate bin each day.

The layout of the system is depicted in Figure 7 and allows for mandatory maintenance to be conducted above ground in the area behind the square domes. This area is not walled off and is exposed to greater sun exposure as well as insect and animal presence. This area houses the two municipal waste bins in use as well as any additional bins in the composting process. This area also contains a hole where leachate can be drained into and hoses with which to rinse out the waste containers.

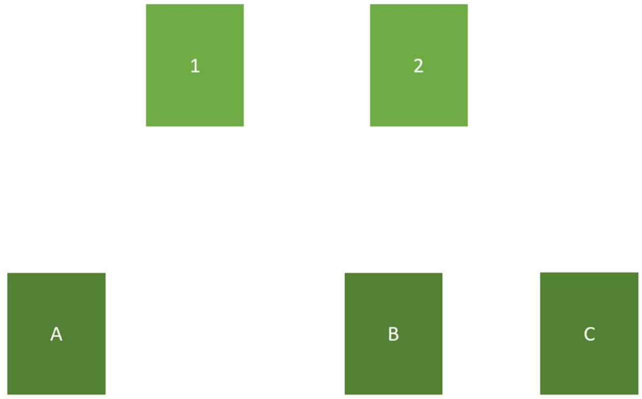

Figure 7: Layout of Collection Containers at Square Domes

4.2 Methodology of Evaluating Composting Toilets at Kibbutz Lotan

The following section describes the methodology used for evaluating the three composting toilet systems at Kibbutz Lotan, as a combination field test and case study of our developed protocol.

4.2.1 Safety and Researcher Roles

Before any contact with the waste was made, one researcher would don a plastic smock (constructed from a basic garbage bag), lab safety goggles, a pair of cow insemination gloves, and a pair of latex gloves to keep the longer, less fitted cow insemination gloves in place. These long gloves would be taped to the shoulders of the smock to prevent them from rolling down in the process of testing. Any hair long enough to hang in a researcher's face was tied back. Altogether these provided reasonable protection from potential contamination. A second researcher would be present to record data. This was done by writing values and observations in a laboratory notebook to be analyzed using Microsoft Excel.

Pictured below in Figure 8 is an example of two researchers performing daily measurements. As a note, the image is from the first day of testing, before we realized a smock should be added to avoid clothing contamination. This need was made evident in the photo by the contact researcher Preil's contaminated glove made with her clothing.

Figure 8: Researchers Berry and Preil Performing Height Measurements

4.2.2 Application and Evaluation of the Functional Variables at Lotan

There were a number of variables we had to consider evaluating the functionality of each composting toilet system. Together they comprise an account of if and how fast microorganisms grew, material decomposed, and pathogens were eliminated.

The height of the solid waste in a collection bin was used to monitor the volume of material that was either being added to an active toilet bin or the volume that was being decomposed by microorganisms in an inactive bin. The height was measured using a straight wooden stick hand-marked with lines to indicate centimeters. The stick was placed in the bin at the relative minimum height and the relative maximum height of the solid waste. These max and min heights were used to calculate an average height of collected solid waste. These height measurements were conducted once daily.

The temperature of the solid waste was used to evaluate whether or not the conditions of the system were suitable to efficiently decompose waste and effectively eradicate E. coli. The temperature was measured using a thermometer indicating temperature to the tenth of a degree Celsius. The thermometer was placed into the top of the material at both the edge and core of the bin. The pH and moisture of a composting toilet system were both used to evaluate the environmental conditions that determine whether or not the conditions of the system were suitable for bacterial respiration and growth. They were measured using a combination pH/moisture meter intended for use in plant soil. The pH/moisture meter was placed into the material at the core of the bin. Each of these three variables was measured once daily.

The E. coli concentration of a composting toilet system was used to evaluate the health risk presented by interaction with the system and use of the compost in agriculture. The E. coli concentration was measured using the Aquagenx Compartment Bag Test E. coli and Total Coliform (CBT EC + TC) kit, provided to us graciously by Clive Lipchin of the Arava Institute.

The content from the bins was diluted to a ratio of 18.1mL of waste to 500mL of water. 100mL of this dilution was transferred into a collection bag, and a powder growth medium was added. The sample was then poured into a compartment bag that separated the sample into 10mL, 30mL, 56mL, 3mL, and 1mL. The top of the compartment bag was rolled down, sealed, and left to incubate for 48 hours. After 48 hours, the E. coli test results were scored under ambient light based on each compartment's color: yellow, yellow-brown, blue, or blue-green. Each compartment bag was then scored under UV light in a dark environment based on whether or not a compartment fluoresces blue. The scores were compared to the CBT kit's Most Probable Number (MPN) Table, which is based on the World Health Organization ``Guidelines for Drinking Water Quality," 4th Edition, indicating the E. coli concentration and WHO Health Risk assigned to that concentration.

4.2.3 Application of the Survey and Interview Evaluation at Lotan

While at Lotan, we drafted specific survey and interview questions to gain an understanding of the users' experiences with each of the composting toilet systems available. We contacted the people we wanted to interview and administer the survey to through text. This was to have a written record of our interaction, and it had the added benefit of being a casual, low pressure way to interact with the students. We did not want to stigmatize using the composting toilets, so to avoid this possible discomfort, we conducted the surveys and interviews in informal settings. This relaxed atmosphere, providing a safe space for a conversation to start regarding composting toilets, gave us more data and insight into their personal opinions of the systems. This also provided us with an opportunity to collect information that answered questions that we did not think of, provided unprompted by the participants. Some of the surveys were administered while the participants were preparing for dinner, while others were done in a common social area. We also administered some of the surveys verbally, reading the questions aloud and writing down the responses. The reasoning for this was to see if there was a difference in the types of responses; in some situations, written survey answers result in less content. Contrast this with verbal surveys, which can elicit more information, as surveyors can ask follow up questions based on the responses received. However, in our particular case, the only question where administering the survey verbally produced a noticeable difference in results was the prompt for improvement ideas.

The interviews were all given in the common social area, keeping each participant out of earshot of the next. This was important, on account of topics such as bowel movements being potentially sensitive to some people, and we did not want to allow the respondents to unintentionally influence one another.

As a result of the limited population from which to sample, we were required to perform some subjective analysis to determine the efficacy of the questions in the survey. For example, in the surveys, we initially asked how frequently per week people used the composting toilets. We wanted a numerical answer instead of a written one but failed to specify this in the survey itself. In some cases, this resulted in answers for which we needed to use our best judgement to interpret quantitatively, such as "every day." We thus discovered the need to specify directions such as 'write a numerical answer'.

We surveyed a total of fourteen students, nine from the Green Apprenticeship group, and five from the Netzer group. The Green Apprenticeship students were a collective of young adults learning about permaculture at Kibbutz Lotan. The Netzer group consisted of young British students who had signed up to be in this program to learn more about their Jewish roots. The former group of students were surveyed due to their use of the EcoCampus system, detailed in 4.1.2, throughout their stay at Kibbutz Lotan. The latter group were surveyed due to their use of the personal composting toilet system, detailed in 4.1.3, for their three week residency.

4.2.4 Application and Evaluation of the Maintenance Variables at Lotan

In accordance with the developed protocol, we interviewed the two people who care for the systems at Kibbutz Lotan. Mike Kaplin, a co-founder of the Center for Creative Ecology, performs his own regular checks on cleanliness and operation of the toilets. Core Center faculty member Eran Meiri is responsible for draining the leachate and monitoring the bin capacity status for each unit. The purpose of these interviews with them was to gain insight into how much care and maintenance each system needs to run smoothly, and where need still exists when compared to our findings. We were able to learn more about the challenges and benefits associated with each of the systems, as well as the safety concerns felt by those running the project for longer.

Observational data was also recorded in the lab notebook each day during the process of our measurements regarding the state of the bins. Cracks could occur from age, intense sunlight, overfilling, intense pressure, or mistreatment, leading to leakage. Leakage could also occur if the leachate drainage valves at the bottoms of the bins were damaged or improperly sealed. Either way, leakage of leachate from the bins or gaps leading into the bins would compromise the integrity and safety of the composting toilet system. The developed protocol did not include recording observational data and a recommendation was made to add it.

4.3 Results of the Kibbutz Lotan Evaluation

The following sections discuss the results of our evaluation field test at Kibbutz Lotan. This covers the functionality, use, and maintenance of its three composting toilet systems using the methodologies detailed previously in this chapter.

4.3.1 Data Gathered from Evaluating Bin Functionality and Results

Below are the results of our collection of data assessing the functionality of the three composting toilet systems. These include measurements of average height, average temperature, and pH as daily measurements and measurement of E. coli as a single time test.

Moisture was not included in these graphs because every moisture reading exceeded the maximum reading of 10 on the pH/moisture meter used, due to improper calibration.

In graphs depicting height, circular points indicate where the authors of this paper were the researchers taking measurements and square markers indicate another team performed this function due to our absence.

Active bins are referred to by numbers and inactive bins are referred to as letters, in accordance with the maps provided in figures x through x. Exceptions to this rule are bins 3.0, 5.0, and 6.0, which changed from active to inactive bins after our evaluation began.

Bin 1 was an active use repository for one of the two personal toilets, described in 4.1.3. Because this was a continuously active toilet for the month of January, the height trends overall strongly upwards, with small changes where we took measurements from different points, to ensure a representative spread of data points. After the square domes were vacated on February 7th, we can see the heights beginning to trend slightly downwards, as the composting process continues and nothing new is added. Overall bin 1 gained 10cm while active and showed a net gain of 8.3cm.

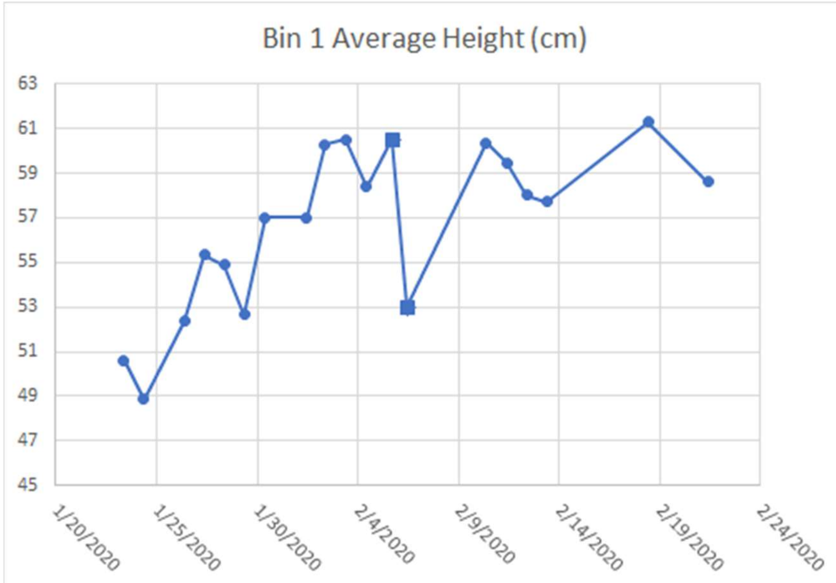

Figure 9: Bin 1 Height

In terms of temperature, bin 1 shows some responsiveness to outdoor temperature, generally if not exactly following its trends. One notable exception is the large spike to 46.2°C on February 5th. This was very near the end of the Netzer program participants' stay, close to the fullest bin 1 would become. The average overall temperature for this bin was 30.4°C, and it never fell below 20°C. pH ranged from 6.5 at its most acidic to 8 at its most alkaline, staying mostly within the ideal conditions of 6.5-7.5.

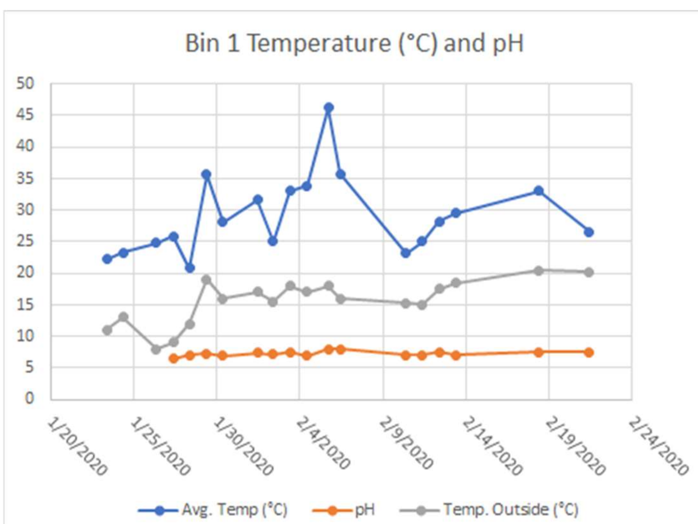

Figure 10: Bin 1 Temp & pH

Bin 2 was the other active square dome personal toilet. Likewise, it rose in height while the room was occupied, and began to fall when vacated. While active, it gained 13.1cm, which fell to 10.1cm by the end of our data collection as decomposition occurred.

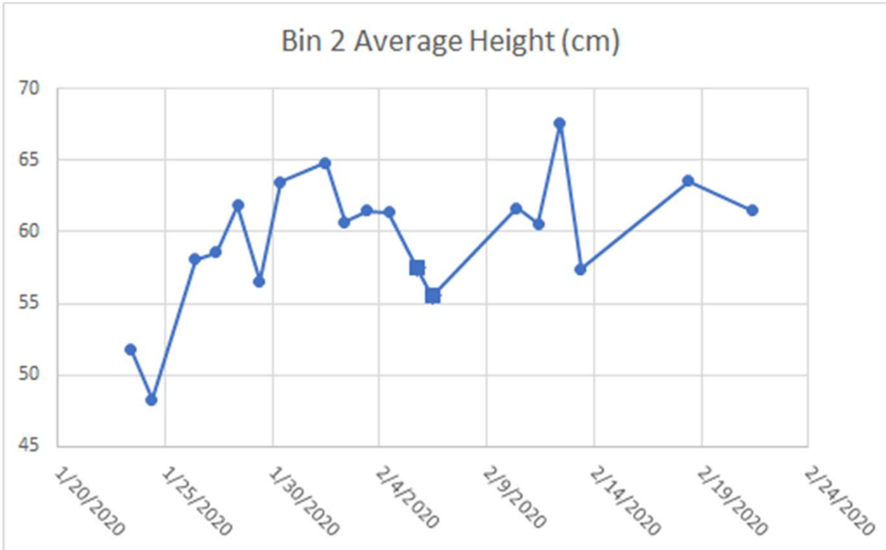

Figure 11: Bin 2 Height

Temperature-wise, while bin 2 did show some responsiveness to air temperature, though less than bin 1. While active, bin 2 was vastly more prone to sharp, erratic spikes, with the temperature rising and falling from day to day and leveled out to more steady readings after new material was no longer being added. The average temperature of bin 2 was 34.47°C, with a maximum of 45.1°C and a minimum of 22.95°C, trending warmer than its counterpart bin 1, even if its peak was slightly cooler. Like bin 1, bin 2 had a pH that largely adhered to the ideal range.

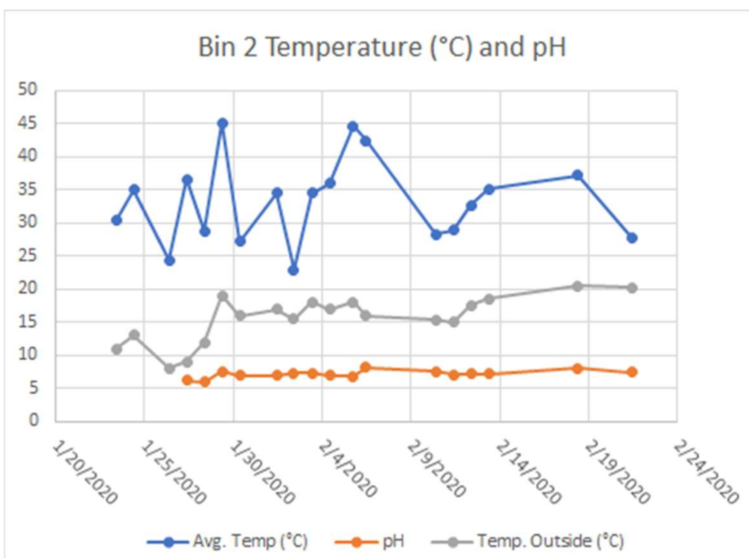

Figure 12: Bin 2 Temperature & pH

Bin A is one of the two inactive bins for the square dome personal system. It displays a gradual but fairly clear downward trend, with a few small variances where we took data from different sites to ensure an accurate data spread. There's a rather sharp drop in correspondence with the days another team was taking the data, so it's possible they made a mistake such as pushing the stick down into the compost. Including their data, the average height of bin A was 66.52cm.

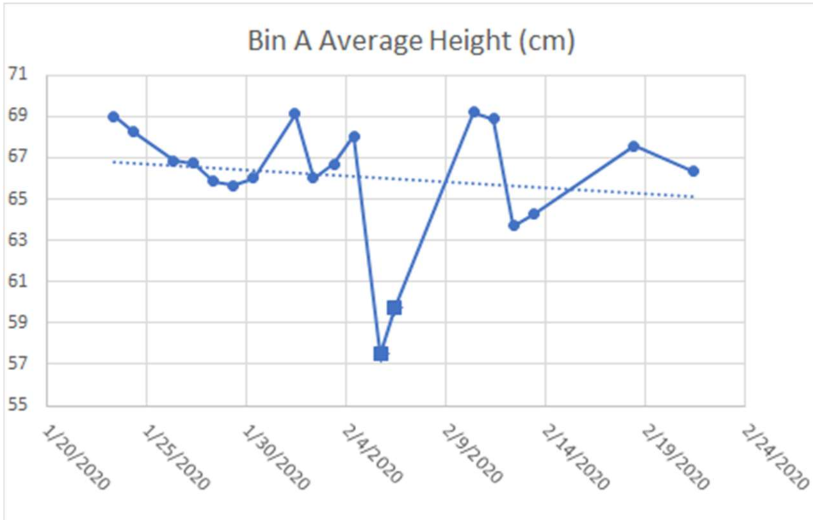

Figure 13: Bin A Height

Bin A's average temperature correlated very closely to the outside temperature, possibly indicating a strong impact of the weather on the composting at this site. As bins A, B, and C all sat in full exposure to the sun, this is perhaps not a surprise. With an average temperature of 21.42°C and a maximum of 23.45°C, this inactive bin is clearly cooler than its active counterparts. The average pH of bin A was 7.2, and overall it stayed mostly in the ideal range, but fluctuated a fair amount.

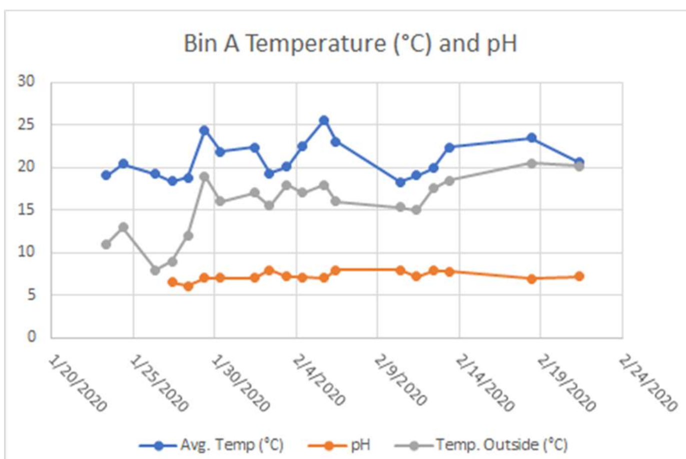

Figure 14: Bin A Temperature & pH

Bin C was the second of the inactive square dome bins from which we took measurements. Three months is considered to be the minimum time for the material to compost in its inactive state, no new material being added before it could be used in agriculture. Thus, we took that as the maximum time back from our starting point to perform testing. If a bin had been moved to inactive composting in August, as bin B was, it was "done" when we started testing in January. C, like A, trended gradually and clearly downwards over the course of our testing, and exhibits the same extreme drop by the temporary research team's measurements. The average overall height was 68.26cm.

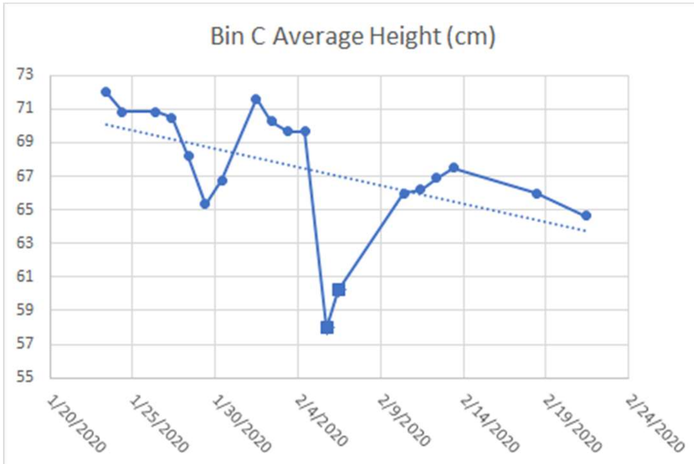

Figure 15: Bin C Height

Bin C adhered very closely in temperature to the air temperature. Its average overall was slightly lower than that of bin A at 19.25°C, and likewise a lower maximum at 20.95°C. It tended toward the most alkaline edge of the ideal pH range, averaging 7.5, but going over the ideal 6.5-7.5 range frequently.

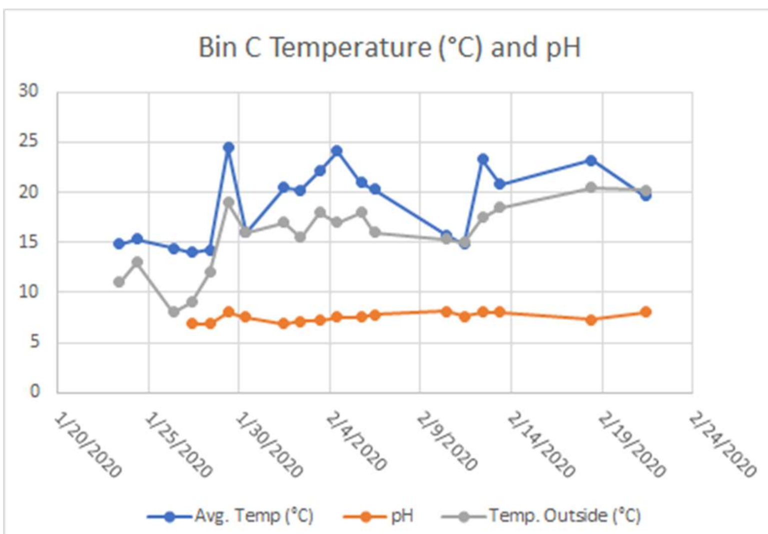

Figure 16: Bin C Temperature & pH

Bin 7 was the first of the active use bins in the EcoKef public bathroom. All of the active EcoKef toilets presented a slight challenge in terms of acquiring height measurement on account of the bins being attached via tubing and lid structures to the toilet above. These were not entirely removable, and thus height was gathered with a tape measure rather than our usual straight, marked stick. This made measurement slightly more susceptible to inaccuracy. In addition, this setup made it more difficult to see, to judge from where in the bin measurement of height should occur. Because waste was deposited into these toilets via the overhead chute, there was a sharp pyramid shape that occasionally needed to be leveled out with a stick, creating such changes as seen on February 12th, when the average height was 66.6cm, compared to the 10th, when it was 71.45cm. The average height of the material overall was 71.77cm.

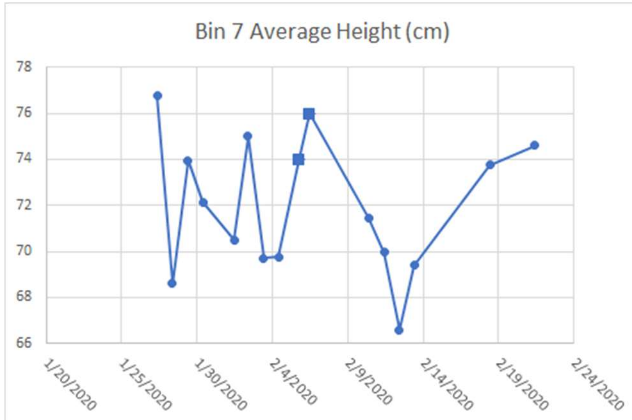

Figure 17: Bin 7 Height

Bins in the EcoKef, unlike those in the two Eco Campus systems, were in a below-ground enclosure with an awning overhead, sheltered from direct sunlight. There is still a correlation evident with air temperature, but these bins tended to be cooler overall, with bin 7 averaging 17.58°C. In addition, this bin dropped to a minimum temperature of 15°C, and never surpassed 21.25°C. The pH of bin 7 also tended to be more acidic, never going above 7.1, though staying within the ideal 6.5-7.5 range.

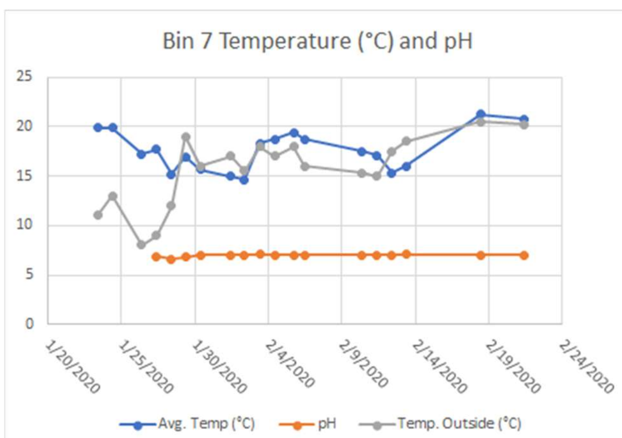

Figure 18: Bin 7 Temperature & pH

Like its counterpart, bin 7, bin 8 was one of the three active EcoKef bins we measured. It seems to have been used slightly less, being one of the toilets in the center of the room rather than at either edge, where people may have felt more comfortable. Its average overall height was only 56.37cm. It does exhibit the same drop in height mid-February when the material was manually leveled.

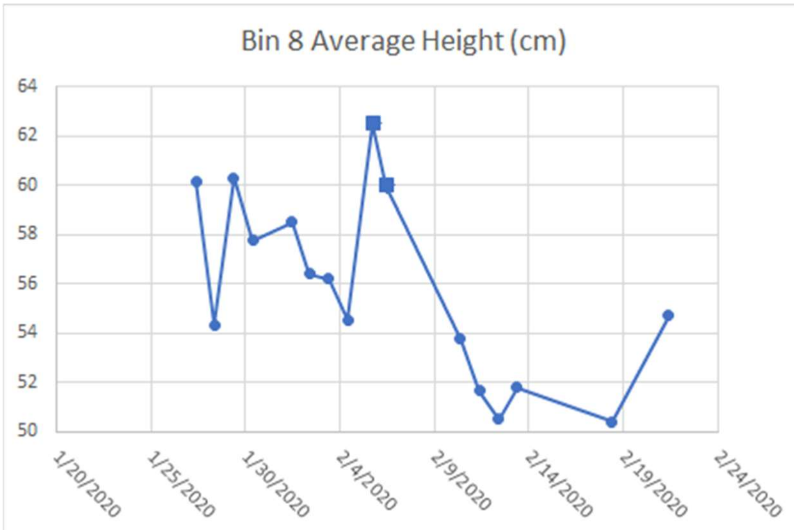

Figure 19: Bin 8 Height

Bin 8 trended slightly warmer than bin 7, at an average temperature of 21.27°C and maximum of 24.95°C, and overall tended toward temperatures above the air temperature. It did show a similar pH to bin 7, firmly within, and tending towards the acidic end of, the ideal range.

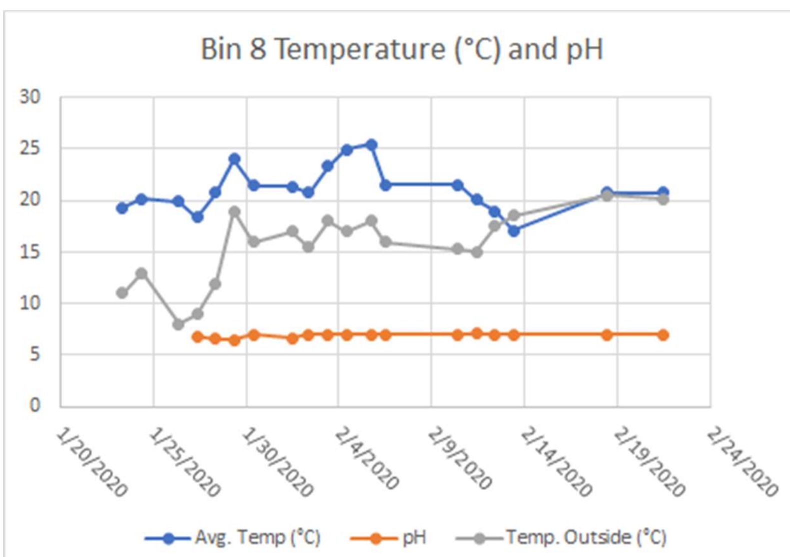

Figure 20: Bin 8 Temperature & pH

Bin 10 was the final of the three active EcoKef toilets measured, being at the opposite edge of the bathroom from bin 7. We did not take data from bin 9, as it had been emptied entirely the day before we began testing and was not used enough in our time to provide valuable data. Bin 10 was relatively low, with an overall average height of 50.13cm. This made taking measurements of its height slightly easier, as it gave more room to navigate the measuring tape under the lid. This is reflected in the relatively steadier height measurements for this bin seen below. It did still trend upwards overall in material more steadily than bin 8, indicating that people were depositing material into the bin more rapidly than it was decomposing.

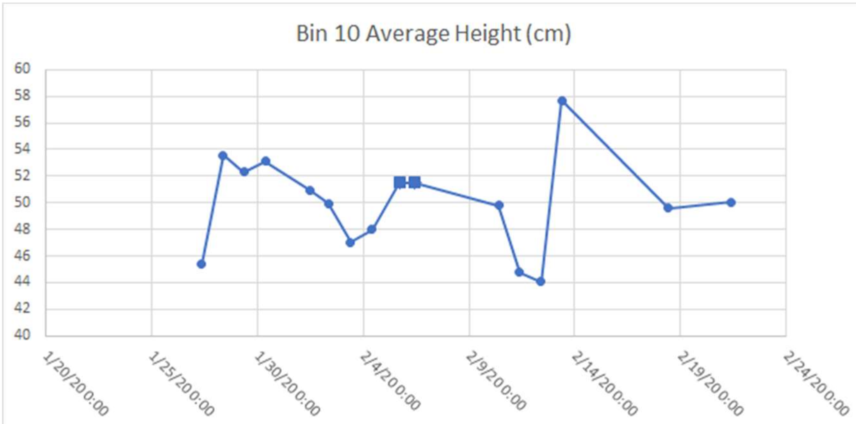

Figure 21: Bin 10 Height

Bin 10's temperature behaved somewhat between 7 and 8; it correlated quite closely to the air temperature but remained above at all points. It averaged the highest of its group, at 24.47°C, and in addition had the highest minimum temperature of its group, 19.95°C. The pH exhibited slightly more variation and tended toward more alkaline values but stayed primarily within the ideal range.

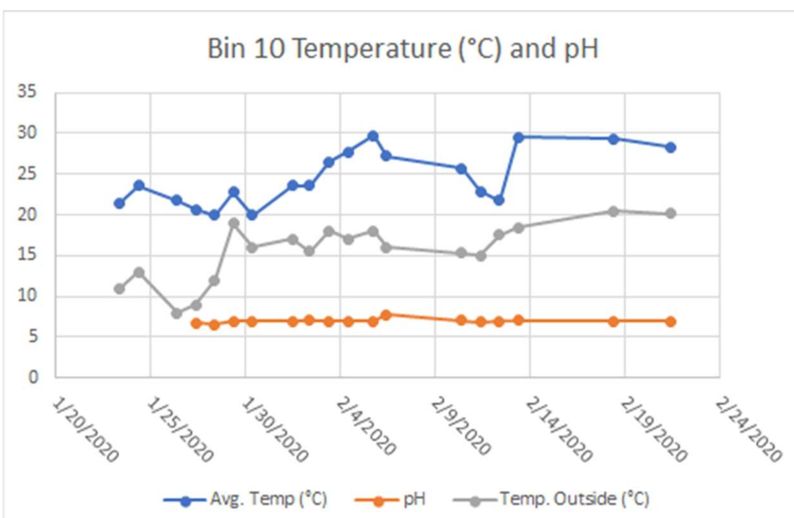

Figure 22: Bin 10 Temperature & pH

Bin J was the first of the EcoKef's inactive compost bins. There are small peaks and drops where we took data from different areas of the material, but it nonetheless exhibits the desired clear downward trend.

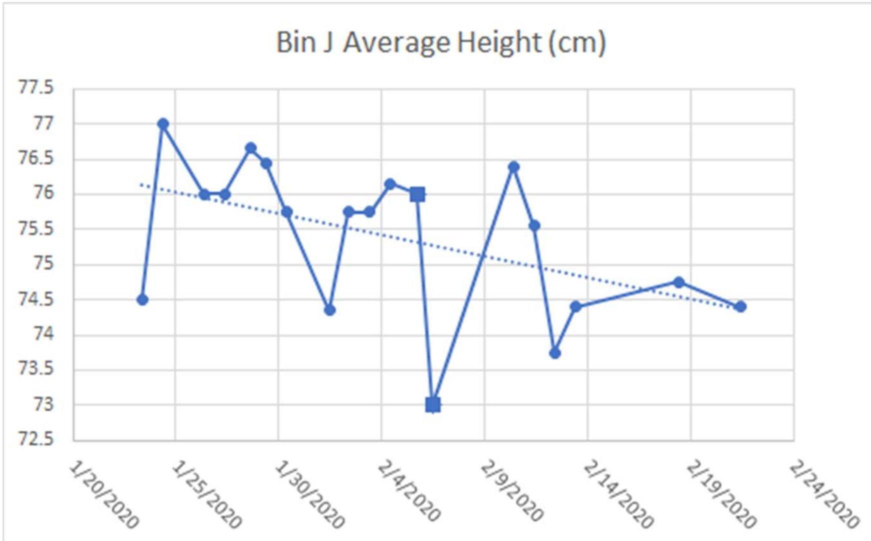

Figure 23: Bin J Height

In terms of temperature, J reflects the air temperature in its measurements and was often at or below that level. It had a minimum temperature of 12.6°C, an average of 15.45°C, and a maximum of 19.6°C, overall fairly cool. This bin was moved to inactive status in November, upwards of a month from our starting point, so this data makes sense. The pH stayed fairly steady, reading just around the middle of the ideal range the entire time.

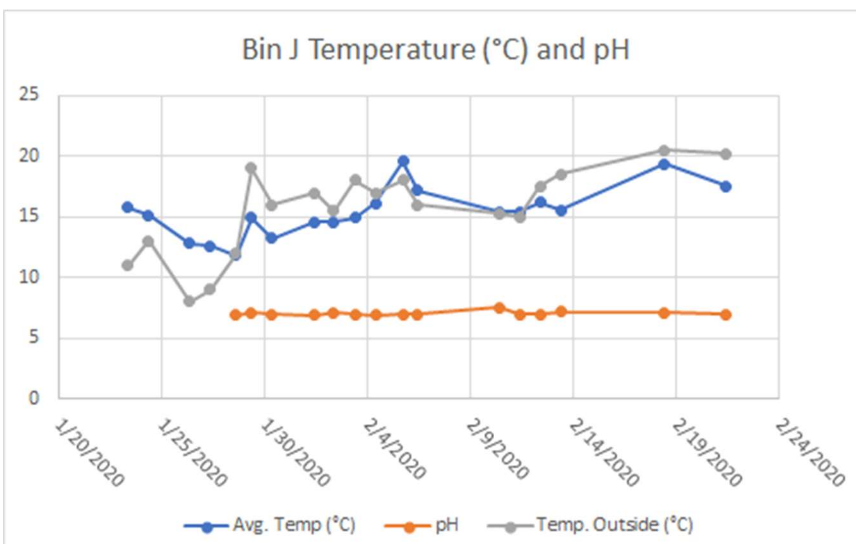

Figure 24: Bin J Temperature & pH

Bin K followed the pattern of irregular heights that do overall trend downwards. Its average height was 72.08cm.

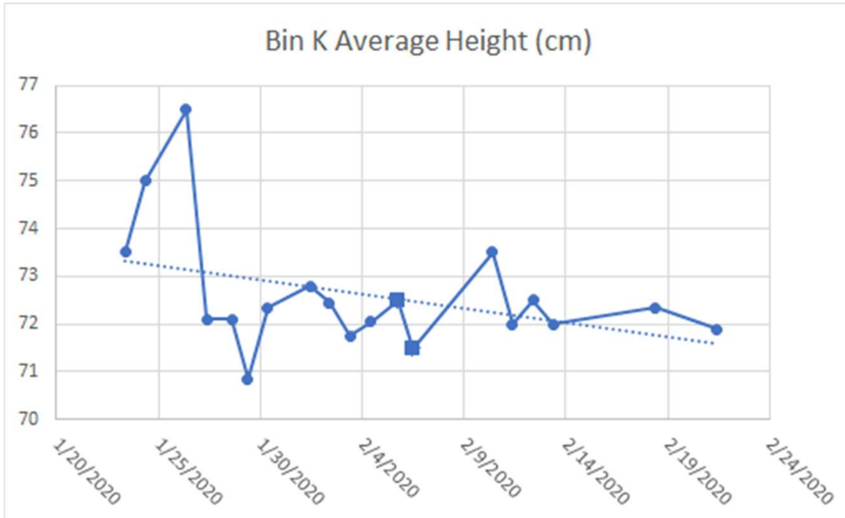

Figure 25: Bin K Height

K, like J, was from November and exhibited bin temperatures very close to the air temperatures. Bin K, in fact, tended towards being slightly cooler. Its lowest temperature was 12°C, average 12.59°C, and the highest 17.75°C. pH readings overall stuck very close to 7.

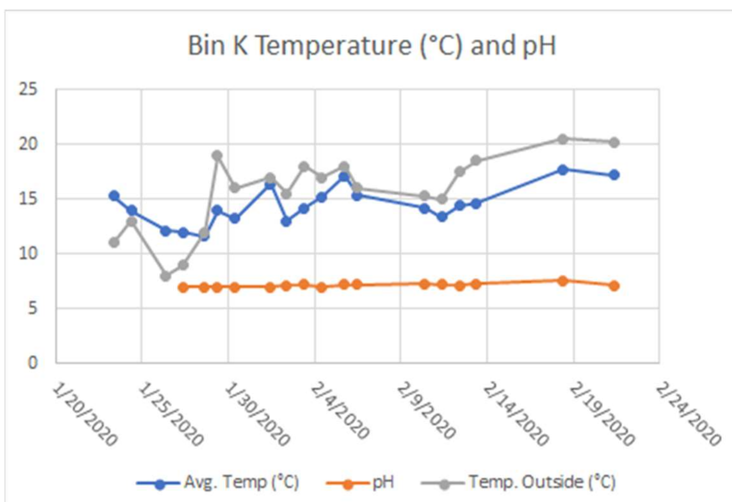

Figure 26: Bin K Temperature & pH

Bin L was the newest of the EcoKef inactive bins, having been moved to inactive composting just days before we began our testing. It displays by far the clearest and most regular downward trend, losing a total of 8.35cm from our first few days to the last. There is a spike one the first day the temporary team took measurements, a curious contrast to their usual pattern of unusually low height readings; since average heights are calculated from a relative minimum and maximum point, it's possible didn't record an adequate low, throwing off their calculation. Even with this discrepancy included, the data for bin L indicates a steady and relatively speedy decomposition process.

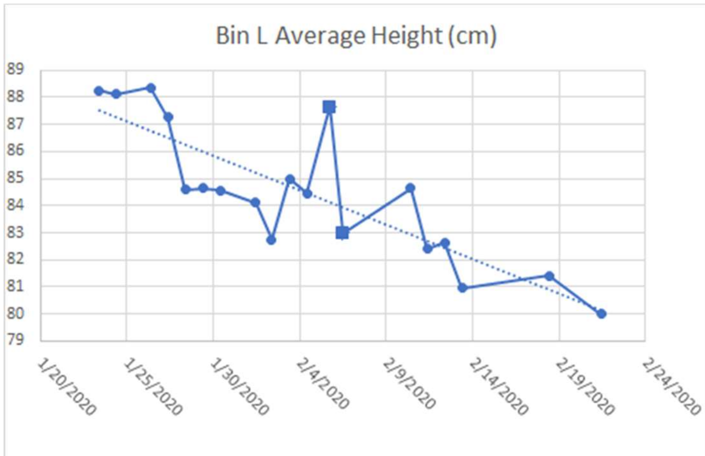

Figure 27: Bin L Height

Bin L's temperatures do show some responsiveness to the outside temperature, but are always higher, unlike its older counterparts in inactive EcoKef bins where the composting process would have been further along, closer to completion. At 21.37°C, it's the only one of the three with an average temperature higher than 20°C. In fact, its minimum temperature, 19.7°C, is higher than the maximums of J or K. L's pH is fairly regular, generally within the ideal 6.5-7.5 range.

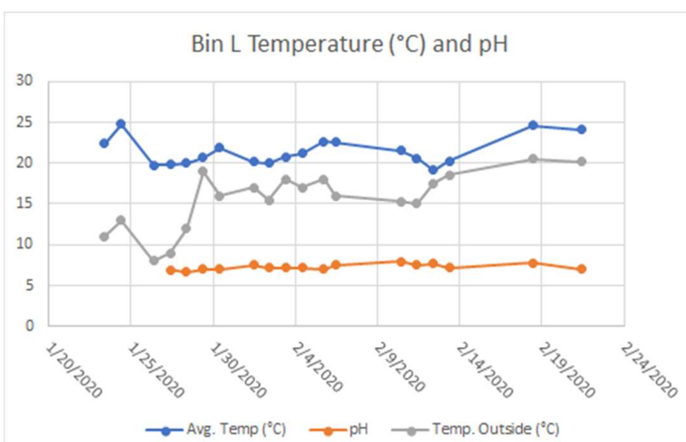

Figure 28: Bin L Temperature & pH

Bin D was the first of the inactive EcoCampus public toilets. The setup of the EcoCampus active bins includes a gate and heavy covering, making access extraordinarily difficult. Consequently, we did not gather data from the four active units. Like bin L in the EcoKef, D was moved to inactive status in January. It too displays a mostly smooth trend downward, dropping 7.35cm from the first days to the last.

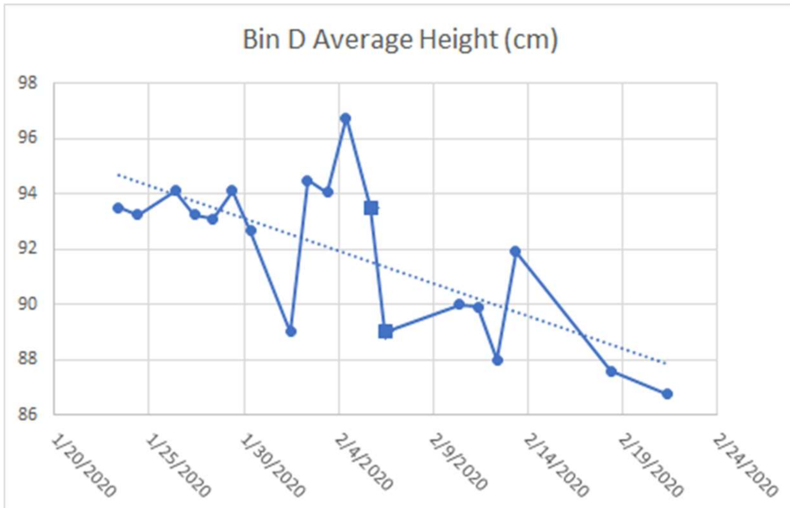

Figure 29: Bin D Height

The temperature for bin D stuck remarkably close to that of the outside, remaining above it for the entirety. Like those of the personal toilet system, the inactive EcoCampus public bins were stored outdoors and exposed, potentially making them more sensitive to weather. The average temperature overall was 22.7°C. The average pH was 7.4, approaching the upper limit of the ideal range.

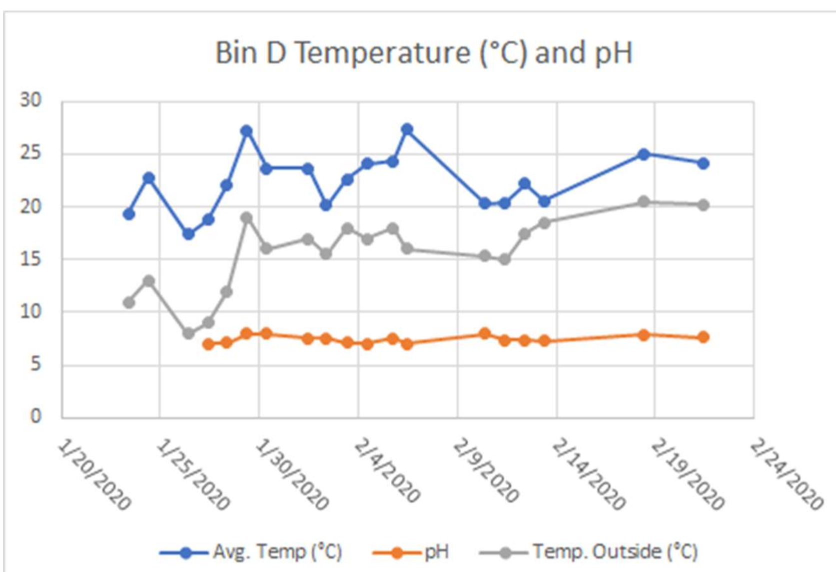

Figure 30: Bin D Temperature & pH

Bin E was among the older bins tested, having been moved to inactivity in November. It did trend downwards, but very slightly, losing about 4cm from its early height to its later recordings.

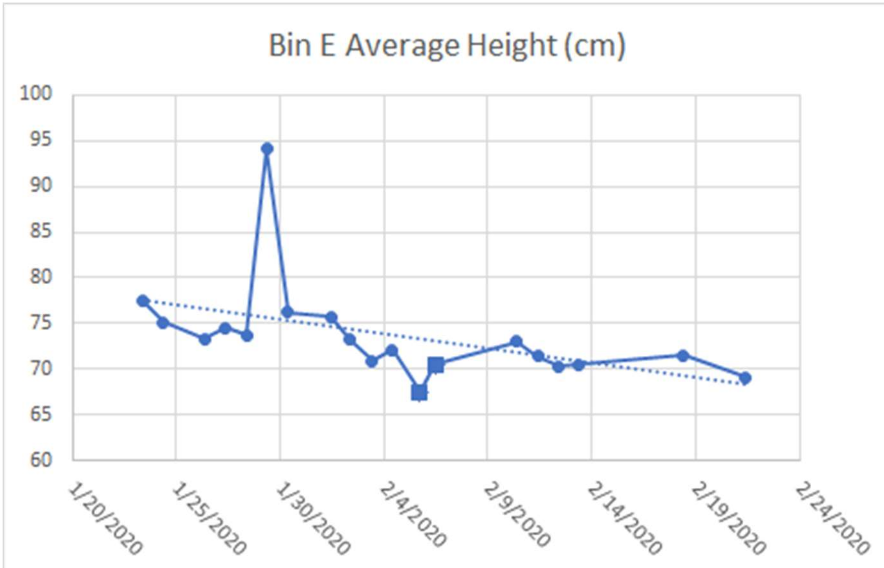

Figure 31: Bin E Height

Bin E was cooler than D, sticking very closely not only to the patterns but to the values or the outside temperature. It did reach a maximum of 22.9°C, but it also fell to a minimum of 12.85°C. The pH had the same average as that of D, 7.4.

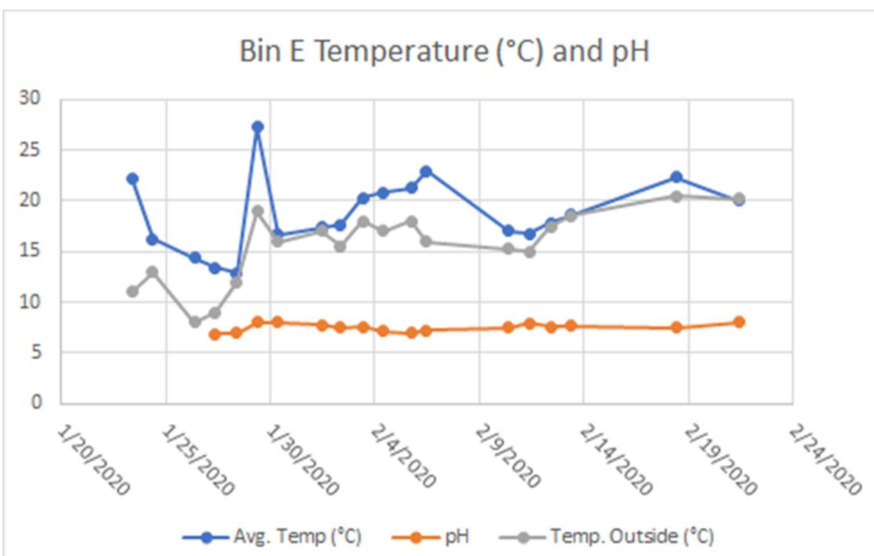

Figure 32: Bin E Temperature & pH

Bin F was moved to inactive status in December, putting it in the middle of our test subjects' ages. Being roughly just under two months old when we commenced our testing, it still seemed to have entered its slowing down phase by then, dropping in height about 3cm from its early to late averages.

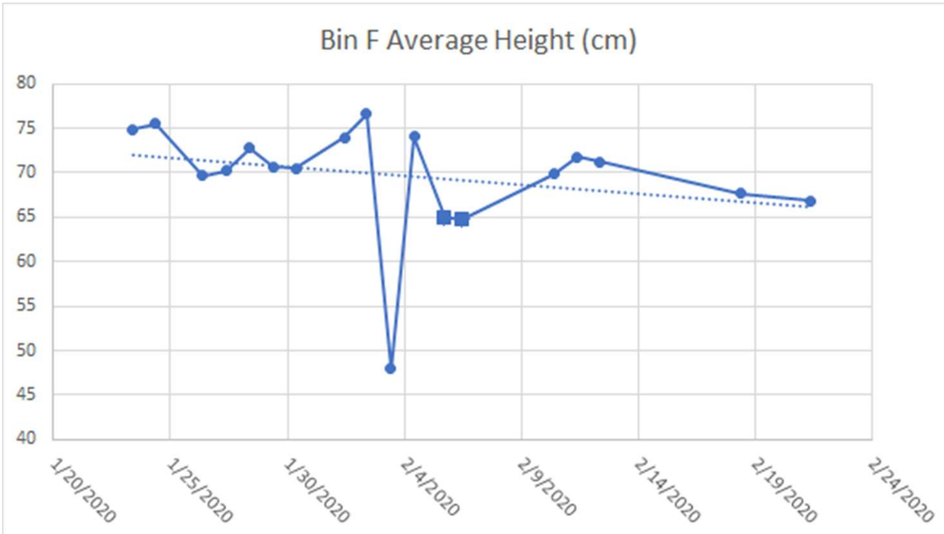

Figure 33: Bin F Height

Bin F, as its previously analyzed counterparts, stays above and reflects the outside temperatures from its testing times. Its maximum temperature was 30.15°C, average 22.64°C, and minimum 16.3°C, showing a wide range. pH likewise ranged from 6.9 to 8.3.

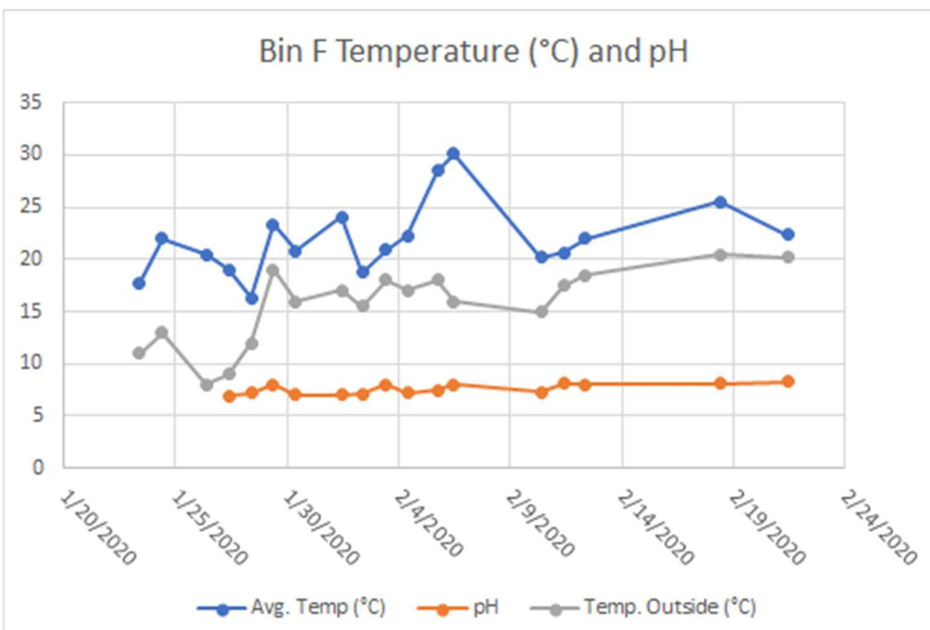

Figure 34: Bin F Temperature & pH

Bin 6.0 was moved to inactive status during our first days, giving us data from the beginning of its decomposition process. It took some time for the height to drop below the rim of the bin, in some places even sticking out above the edge, allowed by the bowed nature of the lid. Once it did, the height continued to drop swiftly and steadily, going from an initial 102cm of compost to a final 93.25cm.

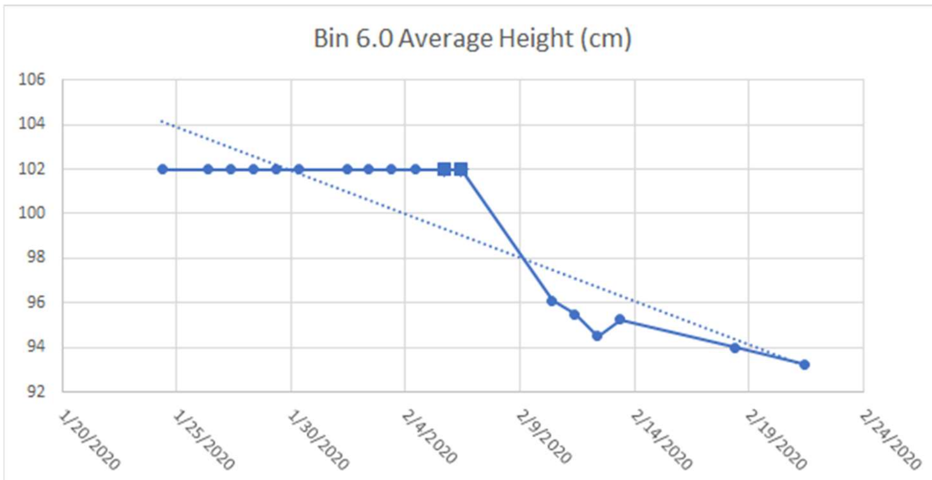

Figure 35: Bin 6.0 Height

As seen with other fresh or active bins, 6.0 reflects the outside temperature but stays well above it. The temperature readings started off high and gradually began to decline, still adhering to the aforementioned pattern, perhaps as the compost grew older and began transitioning to the slower nature seen in bins even a month its senior. It had one of the higher maximum temperatures we observed, at 38.5°C. Even its minimum was 23.05°C.

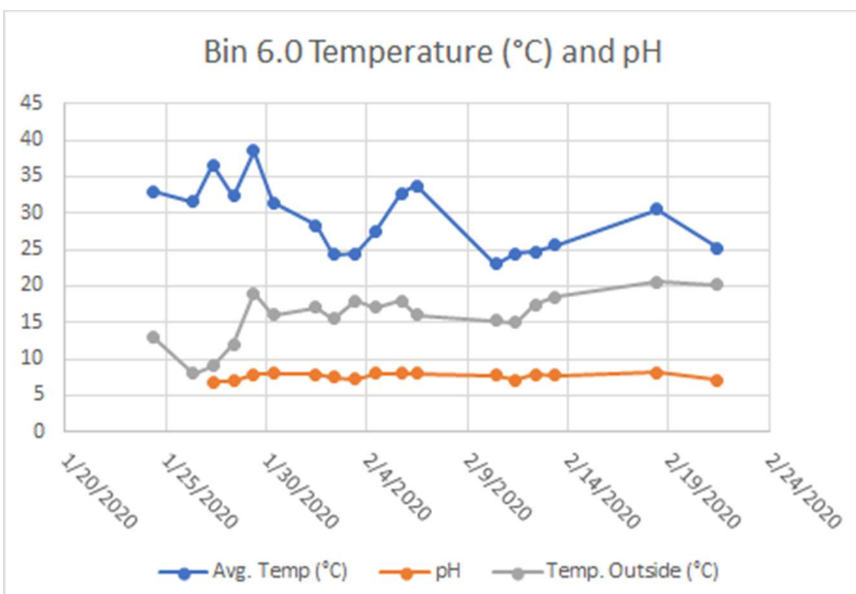

Figure 36: Bin 6.0 Temperature & pH

Like bin F, bin G was another that had been moved to inactivity in December, but likely later in the month, as shown by its greater overall drop in height in the same time we did testing. From its early days to its last, it dropped a full 9.85cm

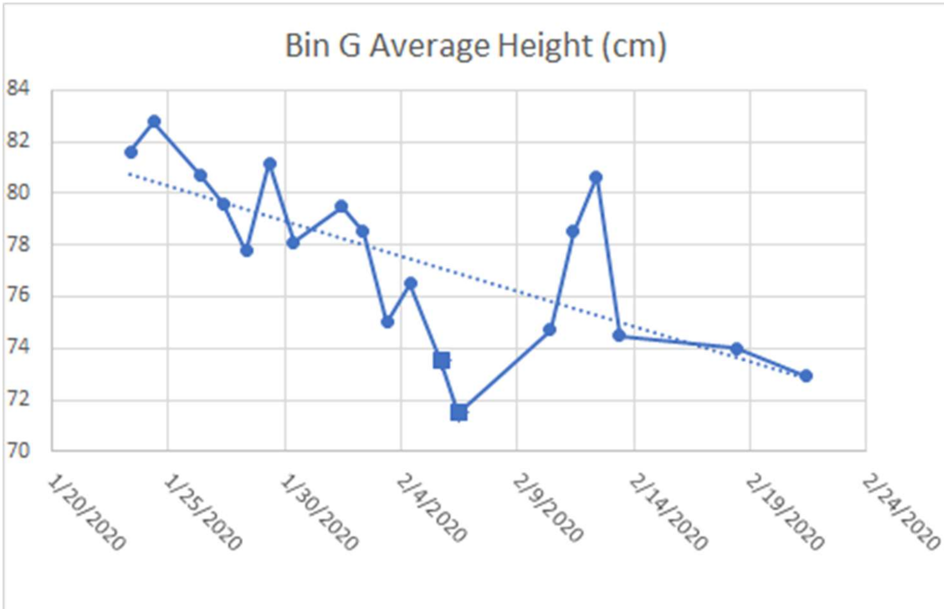

Figure 37: Bin G Height

Bin G followed typical temperature patterns for a bin its age. Its highest temperature was 26.05°C, lowest 15°C, and average 20.5°C.

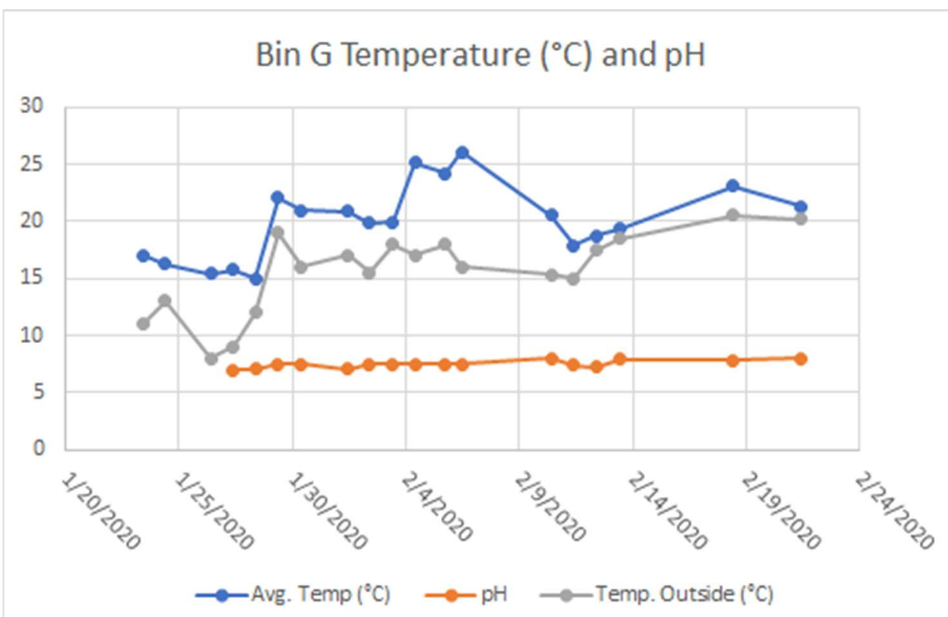

Figure 38: Bin G Temperature & pH

Bin I, from the EcoKef, was the oldest bin we tested for E. coli. It was moved to inactive status in June, over six months before we arrived. It tested entirely negative for E. coli.

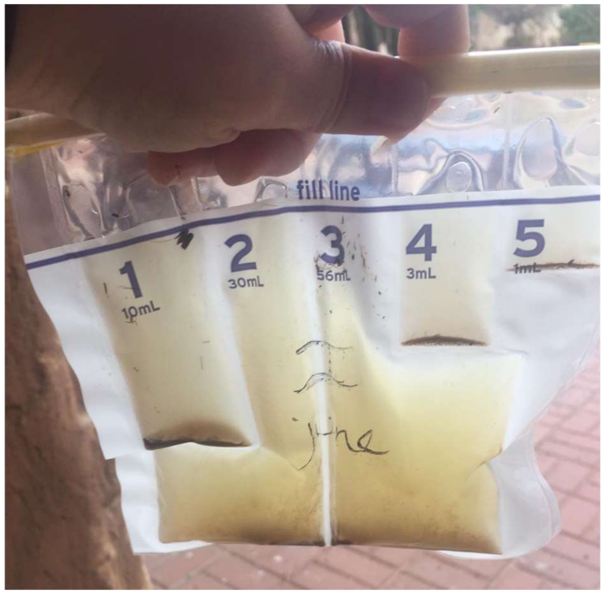

Figure 39: Bag Test of Bin I (June)

Next was the bin moved out in August (none were done in July), bin H from the EcoCampus public toilets. It too tested negative for E. coli.

Figure 40: Bag Test of Bin H (August)

Bin E, of the EcoCampus public system, was moved to inactive status in November (none were moved in the intervening months). About three months before we tested it, the agreed minimum for humanure compost, it tested negative for E. coli.

Figure 41: Bag Test of Bin E (November)

Bin F, an EcoCampus public toilet bin moved to inactivity in December, also tested no for E. coli.

Figure 42: Bag Test of Bin F (December)

Bin 6.0 was moved to inactivity from use in the EcoCampus public systems less than two months before we performed the E. coli testing, and it too came back negative.

Figure 43: Bag Test of Bin 6.0 (January)

Bin 5.0 was moved from active use in the EcoCampus public toilets during our time performing this evaluation, so we knew it was less than one month old when we tested it for E. coli in February. It came back positive, the first inactive of our tests to do so.

Figure 44: Bag Test of Bin 5.0 (February)

Bin 10 was for one of the toilets in active use in the EcoKef system. It came back extraordinarily positive for E. coli, as expected for fresh material.

Figure 45: Bag Test of Bin 10 (Active)

Once the material had passed its three-month minimum time composting inactively, it could be moved from the bins to long term storage, from which it could then be used in agriculture as the need arose. There is one such long term storage pile of compost in the EcoKef, and another for the EcoCampus. The EcoKef pile, despite the promising results of the EcoKef bin tests, came back positive for E. coli.

Figure 46: Bag Test of EcoKef Pile

The pile for the EcoCampus systems was sufficiently large and spread out that different regions could be identified as being older or newer compost. This test, of its older area, came back negative for E. coli.

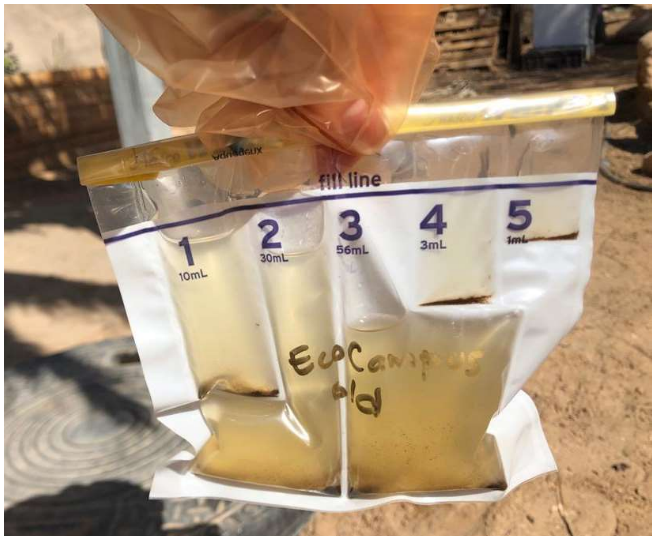

Figure 47: Bag Test of Eco Campus Pile (Older)

The newer section of the EcoCampus pile, on the other side, came back positive for E. coli.

Figure 48: Bag Test of Eco Campus Pile (Newer)

In addition to testing for E. coli, this particular kit has the capacity to test for total coliforms, which are largely harmless but can serve as an indicator of potential environmental contamination, from things like animals (Coliform bacteria: 5 things you should know | culligan nation. 2016). Where the bag cells fluoresced under UV light, it indicated a positive result for total coliforms, as seen below in Figures 49 and 50 with example tests 6.0 and the EcoCampus pile.

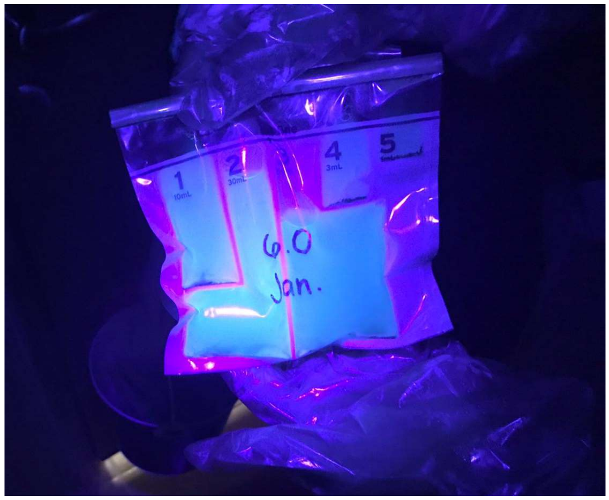

Figure 49: Bag Test of Bin 6.0 Under UV Light

Figure 50: Bag Test of Eco Campus Pile Under UV Light

4.3.1.1 Experimental Repeated Daily Measurement

The question arose of how much air temperature at the time of testing impacted our measurements, especially those of bin temperature. To examine this, we took a single day and repeated the data collection process four times, at 9:00 AM, 12:00 PM, 3:00 PM, and 6:00 PM. While many of these added tests revealed nothing of interest, the most useful selections from the results of the data collected through this experiment are detailed and analyzed below.

Bin 1 had a much higher average height during our first test, and stayed more level throughout the day, indicating we used a much higher point. This is unlikely to have been a result of temperature.

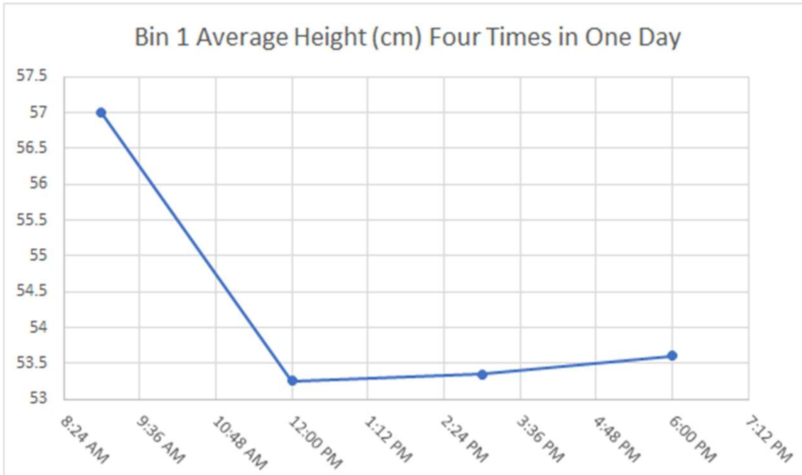

Figure 51: Experimental Bin 1 Height

The temperature of bin 1 did rise through the day as the air temperature did, though curiously it continued to rise even after the sun had set and the air temperature slightly decreased. pH fell by a fair amount through the day, from 8, outside the ideal range, in the morning, to 7 in the evening.

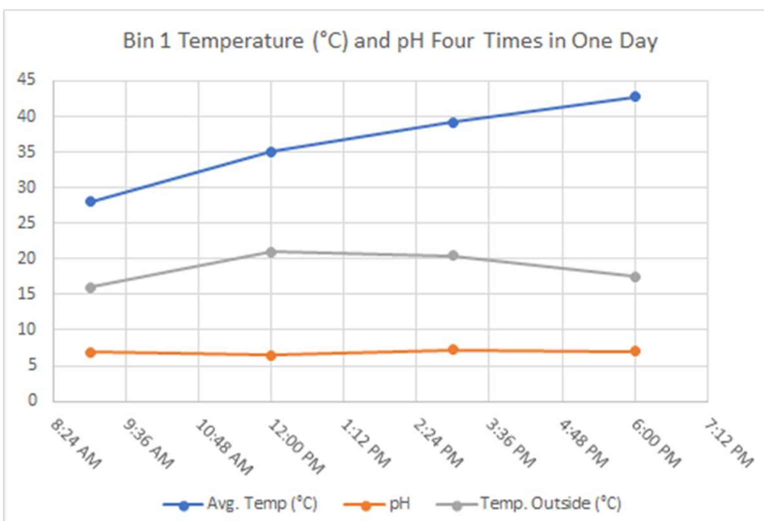

Figure 52: Experimental Bin 1 Temperature & pH

Bin A, an inactive bin, displayed some rise and fall throughout the day; again, likely the result of different measurement sites.

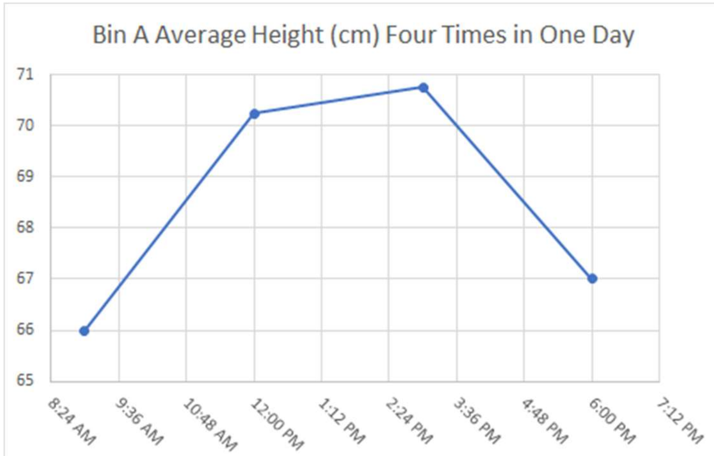

Figure 53: Experimental Bin A Height

The temperature of bin A rose along with the air temperature, though like its counterpart bin 1, it stayed on the upward trend even as air temperature fell again for the night. pH remained unchanged.

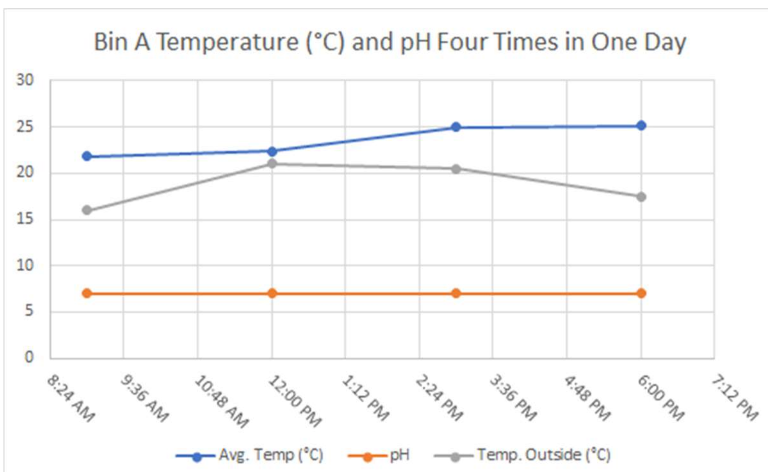

Figure 54: Experimental Bin A Temperature & pH

Bin 7 lost height more steadily through the day, though not by a large enough amount to be more than variation in sample location.

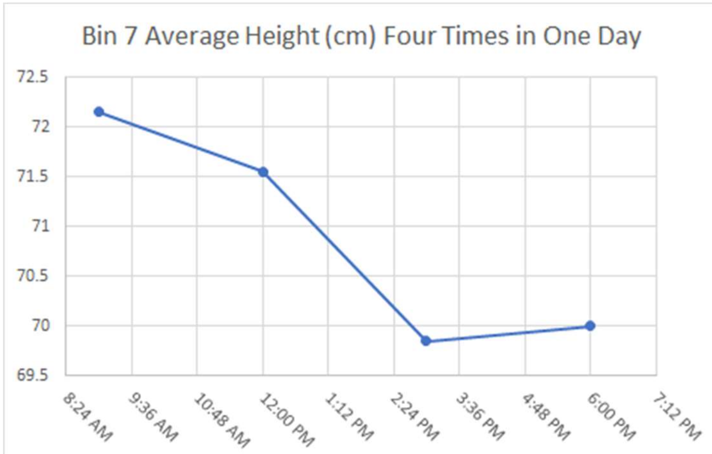

Figure 55: Experimental Bin 7 Height

In terms of temperature, bin 7 stayed very steadily at or below the air temperature, rising less than 2°C. Unlike bin 1, in full sun exposure, bin 7 is in the EcoKef enclosure, and thus more sheltered from effects of weather and sunlight. pH also stayed flat in the center of the ideal range, 7, no matter the environmental changes beyond.

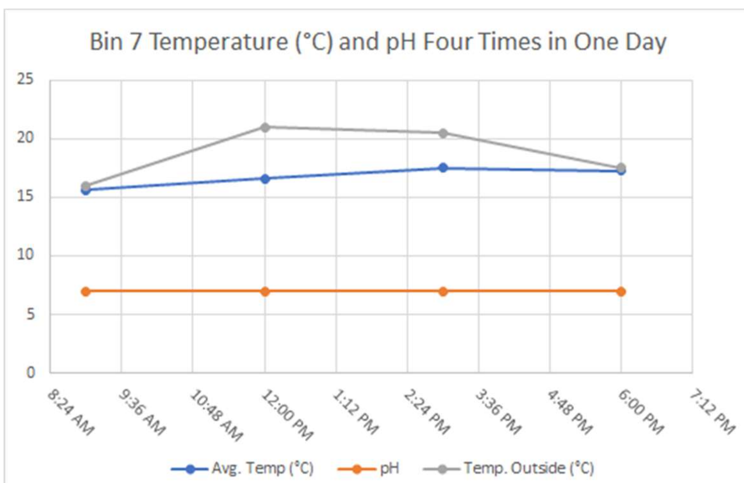

Figure 56: Experimental Bin 7 Temperature & pH

Bin L fell in height about 2cm steadily over the day, a small enough to figure to easily dismiss as normal variance.

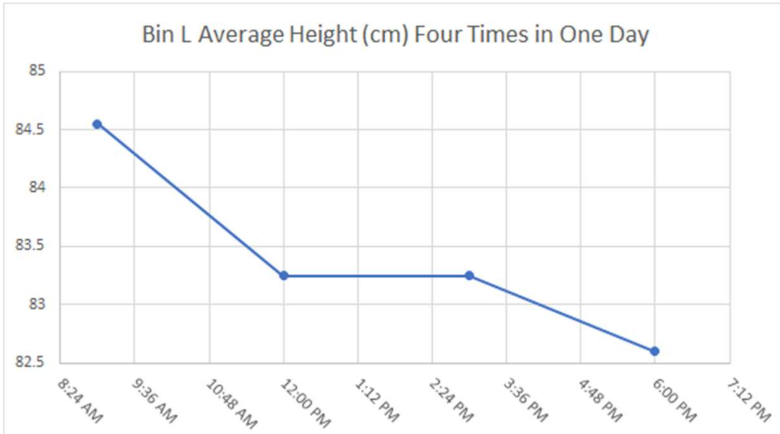

Figure 57: Experimental Bin L Height

The temperature of bin L, a bin both sheltered and inactive, varied by less than 1.5 degrees over the course of the day, and its pH stayed within a range of 0.3.

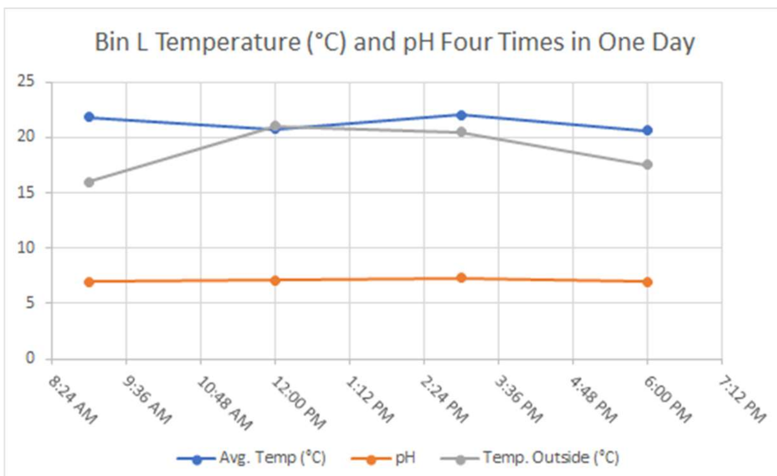

Figure 58: Experimental Bin L Temperature & pH

The height of bin 6.0, which was quite fresh and incredibly full at this time, stayed very steady.

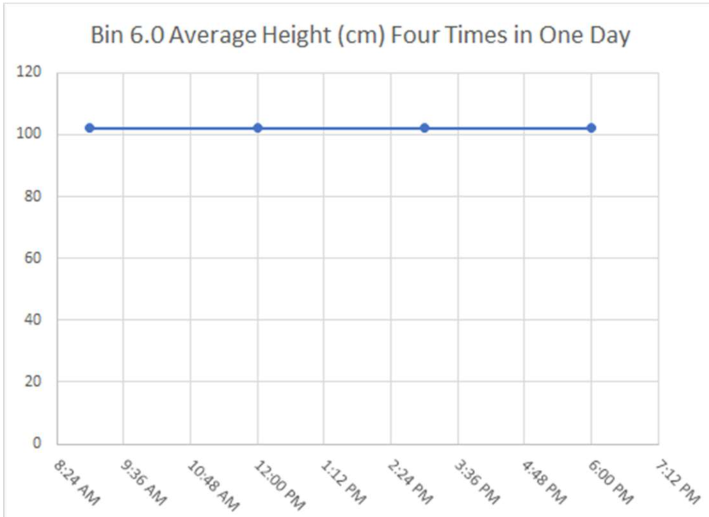

Figure 59: Experimental Bin 6 Height

The temperature of bin 6.0 did rise steadily, if not greatly, throughout the day. Keeping in line with the other bins that did so, it also rose even after sunset. pH followed the exact pattern of changes shown in bin 1 (8 at 9:00, 7.5 at 12:00 and 15:00, 7 at 18:00).

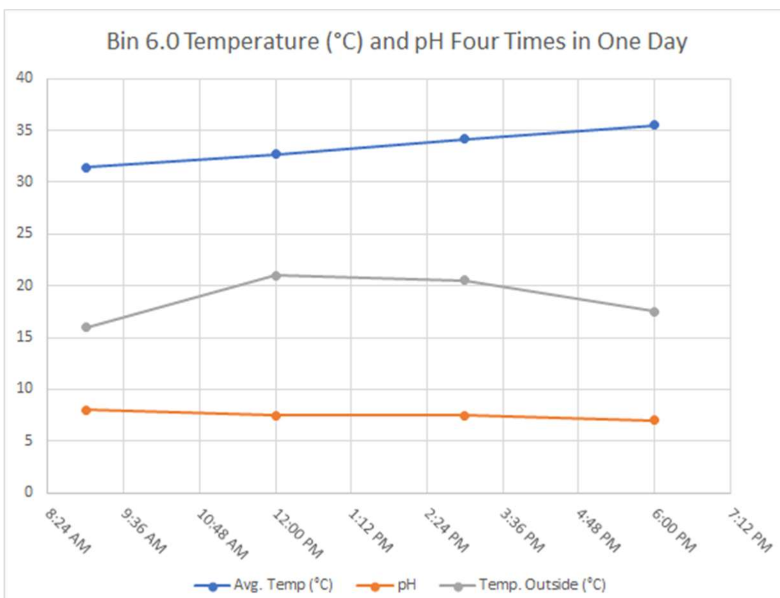

Figure 60: Experimental Bin 6 Temperature & pH

4.3.2 Data Analysis of the Use of Composting Toilets at Kibbutz Lotan

Due to the lack of the quantity of data, the data is treated as anecdotal. We have analyzed the sentiment of the data as it is difficult to draw conclusions with only fourteen responses to the survey. Additionally, the data is location specific. The data that was collected from the surveys were analyzed manually using a code book for varied responses and standard deviation in terms of analyzing frequency. A code book is when variables are assigned to a number that corresponds with a common, specific response. For example, if a common response to the question of, “What is your country of origin?” was “United Kingdom”, the number assigned to this response would be 1. If the next most common response to the same question was “United States”, it would be coded as 2. This allows for an easier analysis of data as software is used to tally up the results without the analyst going through and counting the responses at the end. If there were multiple data answers that could be taken from a single response, both responses would be coded and the “n” value increases. The “n” value corresponds to the number of responses. It is recorded as a separate, new response even though it is from the same survey participant. This is so that no data is lost but also ensures that the number of responses is proportionately recorded. This is noted in the graphs and tables as “n = x” which corresponds to how many responses were recorded. If there is not an “n = x” in the heading of the table or graph, assume the number of responses is fourteen.

Gender, country of origin, and type of residence was data that was recorded in order to see if there was a possible correlation between any of these demographics and subsequently collected data. Below are pie charts that detail the breakdown of the demographics of the survey participants.

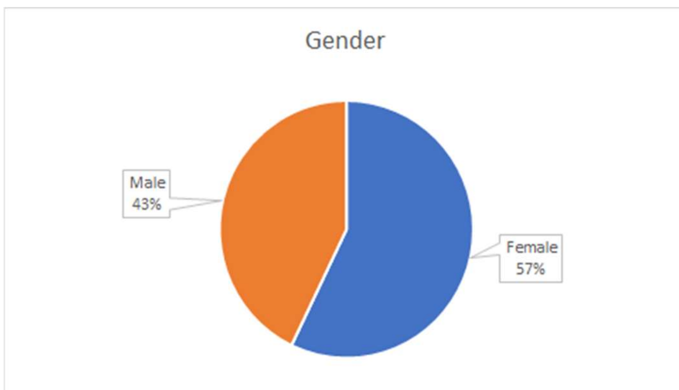

Figure 61: Gender Data

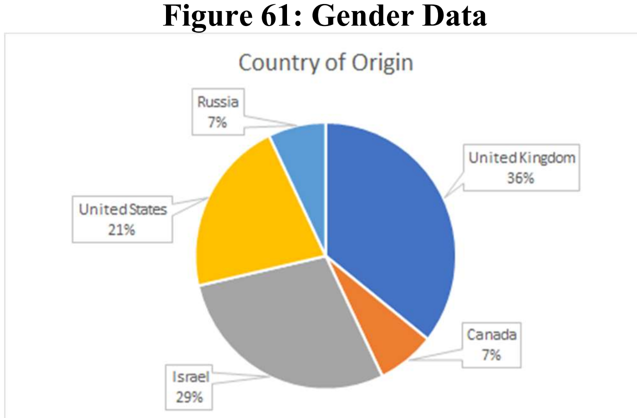

Figure 62: Country of Origin Data

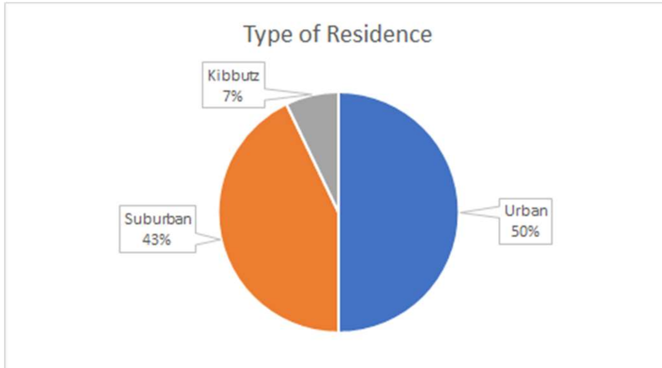

Figure 63: Type of Residence Data

We asked what type of residence the survey participant grew up in to see if this would have an influence on their perceptions of composting toilets. We decided to keep kibbutz as a separate category as we were analyzing data from survey participants that were living on a kibbutz and we wanted to see if living on a kibbutz would make a difference in the way the person answered the survey questions. However, there were no trends that appeared when the data was analyzed by comparing responses from urban residents and suburban residents.

Preference to use composting toilets and comfort both tie into the user's emotional experience with the composting toilets. The differences from flush toilets and conditions of composting toilets are related to the user's experience but are less about how they feel.

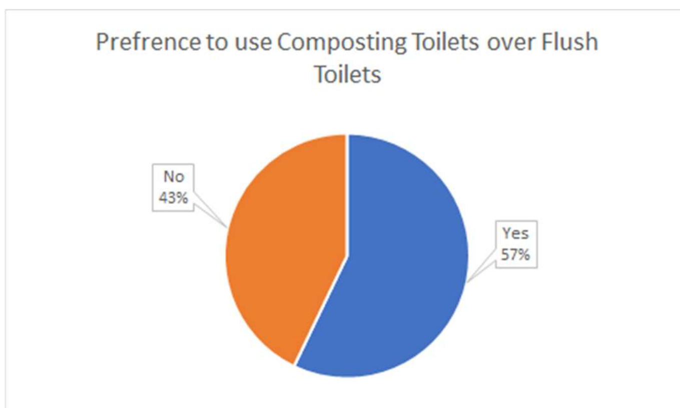

Figure 64: Preference Data

Most of the survey participants were willing to use the composting toilets over the flushing toilets. Both the questions about preference and comfort were asked as "yes" or "no" questions as a way to test what type of questions would give responses that would be easy to analyze and also give enough information.

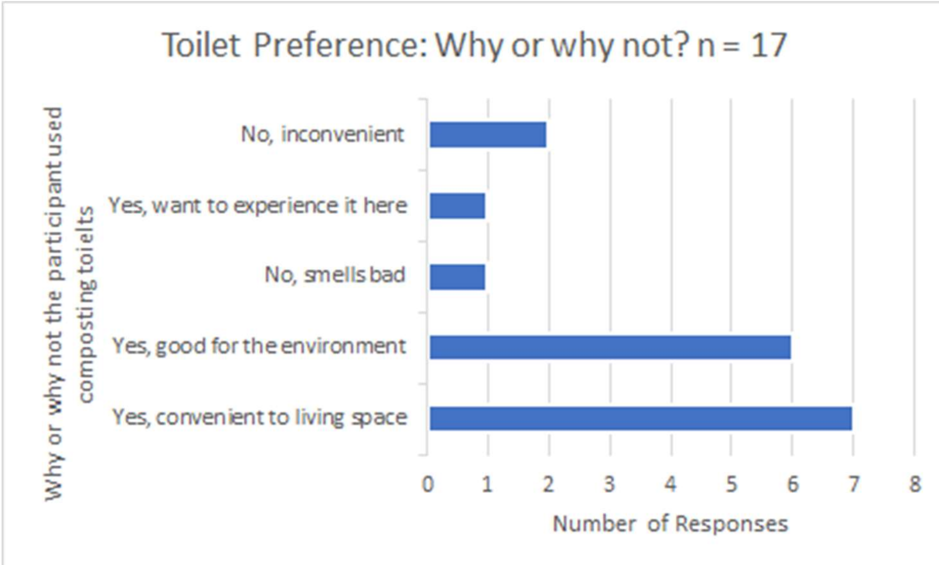

Figure 65: The Why Behind Preference Data

To provide a space for an expanded answer as to why or why not the survey participant preferred using composting toilets or not, we followed up the "yes" or "no" question with asking them "why or why not" they said yes or no to their preference. In our data sample, we can conclude that people would use the composting toilets if they were in close proximity rather than a flushing toilet. The people who took the survey were also ecologically conscious as they cared about the impact flushing toilets had upon the environment. This is important when considering where to build a composting toilet system as people on the kibbutz if it is convenient to their immediate location.

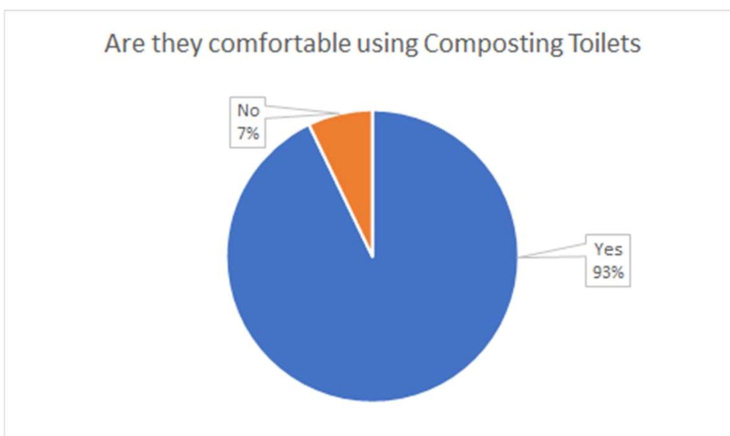

Figure 66: User Comfort Data

After using the composting toilets for about three weeks, most of the survey participants were comfortable using the composting toilets.

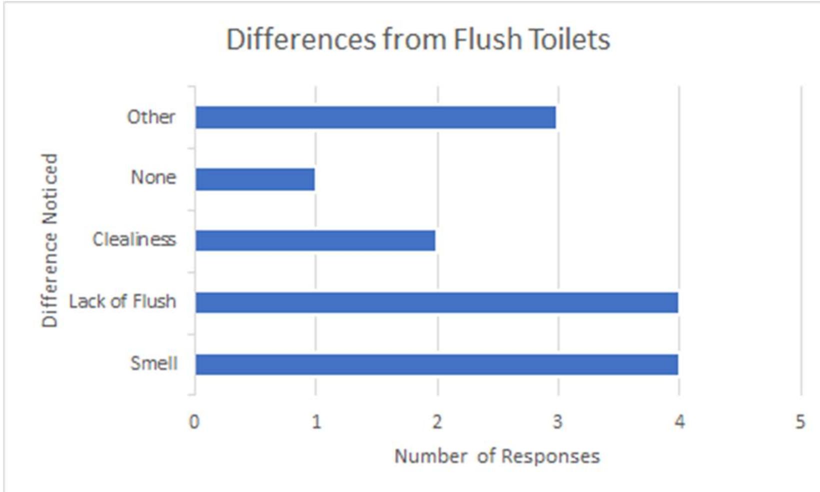

Figure 67: Differences from Flush Toilet Data

The specific question that was asked to get these responses was, “Was there anything in particular that struck you about using the composting toilets for the first time?” This was to attempt to have the survey participant think back to the first time they used the composting toilets at Lotan. First impressions can give insight into how the user feels due to what they notice first. One trend that can be concluded from this data is that the one thing that people noticed immediately about the composting toilet system was that there was a different smell. This is where the survey questions we asked began to form this trend involving smell. Additionally, the lack of flush was an immediately noticed difference between toilets that use water. The lack of flush causes a change in routine that some survey participants noted took some time getting used to. There was also a concern about how clean the composting toilets were as human excrement contains E. coli.

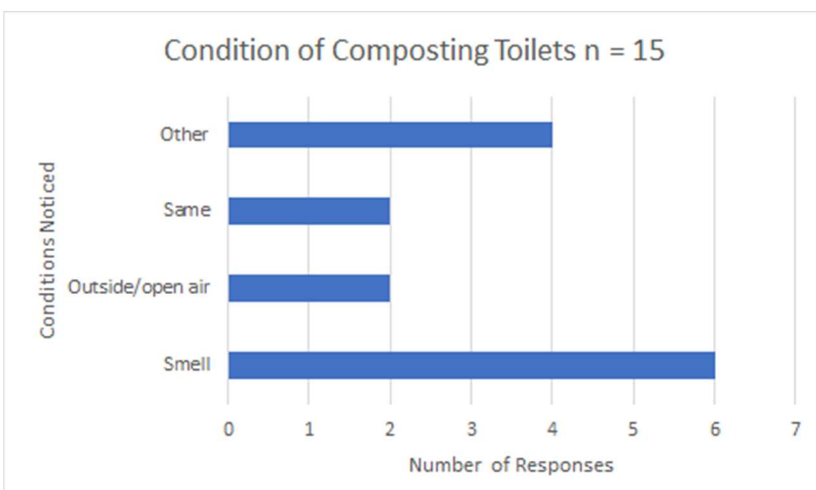

Figure 68: Conditions of System Data

The difference between asking what the condition of the composting toilets and what the survey participant noticed first was that conditions were constant over time and not a first impression of the system. The trend of smell being a noticeable difference from flushing toilets can be seen here. Also, the fact that the composting toilets were outside was particularly noticeable to some participants whereas others said that the conditions were the same as flushing toilets. The “other” variable refers to responses that did not fall into the other categories and would require their own specific category that would only apply to one response.

Community perception relates to how the participant believes the community they grew up in would feel about composting toilets. We also wanted to get the participant’s perception of how the Lotan community uses the composting toilets. This was to evaluate the engagement level people think there is with the community that the composting toilets were built for.

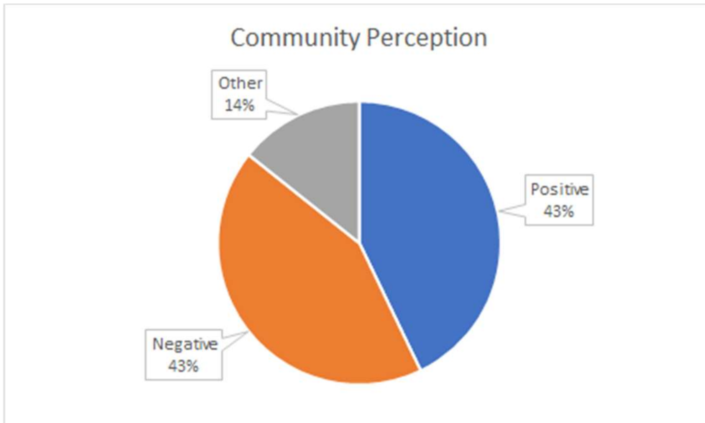

Figure 69: Community Perception Data

In this case, the participants that responded with “other” had responses that did not answer the question.

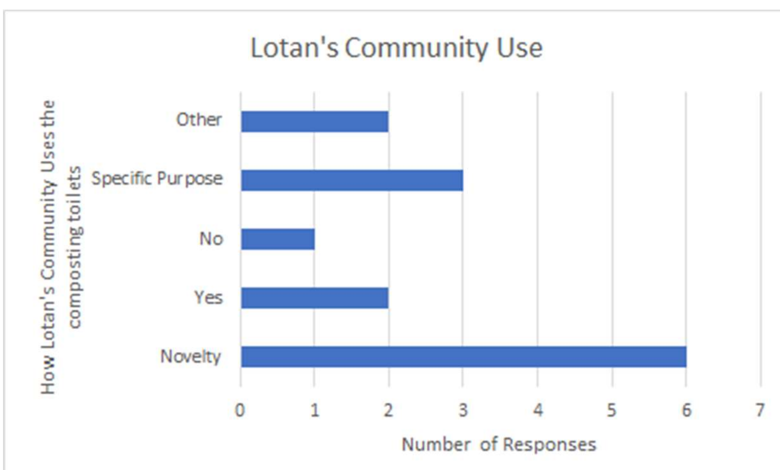

Figure 70: Community Use Data

In this case, the participants that responded with “other” had responses that did not answer the question or were not categorizable due to the vagueness of the response.

We ask about if the participant had used composting toilets in other places to see if this was their first experience with composting toilets or not. This was to see if the responses would provide some insight into whether their experience was better or worse and ties into their recommended improvements.

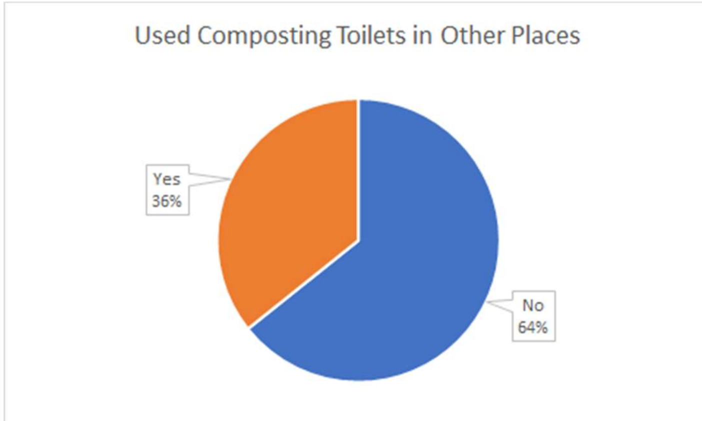

Figure 71: Use Elsewhere Data

The survey participants that responded “yes” had used them in rural areas such as the desert or mountains or in developing areas of Ecuador and South-Central America.

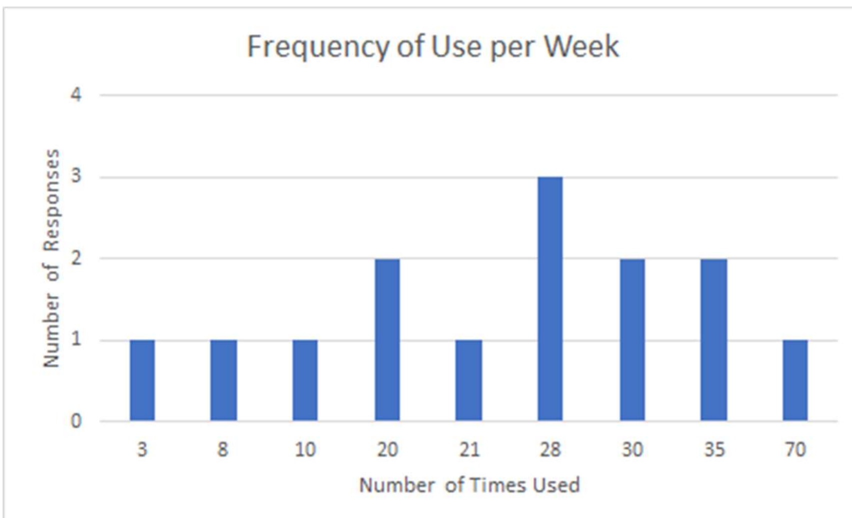

Figure 72: Frequency of Use Data

A frequency table involving standard deviation was used to analyze the frequency data. Since we did not survey all the potential people at Lotan, we surveyed a sample of the population. Therefore, sample standard deviation was used to analyze this data, not the population standard deviation. On average, from our survey data, people used the composting toilets twenty six times per a week with a standard deviation of seventeen. This means that it is difficult to draw conclusions about how many times a person uses a composting toilet per week because it varies largely among our data sample.

4.3.3 Data and Information Regarding Maintenance of Lotan Systems

From our own experiences working with an on the three Lotan composting toilet systems over the duration of this project, we were able to gather a fair deal of information regarding the maintenance. On day one of testing, a mishap experimenting with collecting temperature samples near the bottom of the bin, where the process was less active, led to the immediate realization that certain bins had not been drained, period. That process is meant to occur every two weeks minimum, to avoid the exact scenario we encountered: a high volume of liquid leachate suffocating the compost. This prompted a full system check from Kaplin and Meiri, which uncovered that that had not been the only bin overlooked. Leachate draining was supposed to occur every two weeks; in reality this was closer to once per month, if that. Toilets and their areas within the bathrooms were given a cleaning once per day, and at that time checked for routine concerns such as excessive smell, presence of insects, or bins being full and requiring replacement. Replacement may be the most difficult aspect of maintenance physically; a full or even mostly full compost bin is remarkably heavy and difficult to move, regardless of the bins having wheels. Nonetheless this happened as needed, which was four times during our testing, and per bin reported as every one-six months depending on use. Generally, the impression for both our research team and the Lotan personnel was that the system was safe enough to interact with for maintenance, provided certain common sense safety precautions were taken, such as protective gear or washing. One of the bins leaked regularly from its drainage valve. Many of the bins had damaged lids, being cracked or difficult to align properly for a good seal. During the time we were performing our evaluation, Meiri implemented a new preventative measure; for the bins sitting out in full exposure to sunlight in the EcoCampus systems, he added thick mesh covers to stave off sun damage. Kaplin and Meiri both reported not being able to do maintenance as frequently as they'd like or consider ideal on account of other responsibilities, and though the systems were all working fairly well, it was clear as we worked there was room for improvement in the upkeep.

4.4 Discussion of Results and Recommendations for the Kibbutz Lotan Composting Toilet Systems

In this section, we will discuss our findings regarding the results of our evaluation of the Kibbutz Lotan composting toilet systems and recommendations formed based upon them. This discussion is split into sections regarding the compost product itself, maintenance of the collection and composting systems, the experiences of system users, and plans moving forward.

4.4.1 Issues and Improvements Regarding System Functionality

The primary concern our evaluation turned up regarding the functionality of the composting toilet systems at Kibbutz Lotan is temperature. The optimal temperature for growth of beneficial microorganisms and pathogen elimination is 60°C; the highest temperature we recorded on any bin at any time was 45.1°C, and that was a bin in active use, not composting longer-term, with average temperatures per bin ranging from 17.58°C to 34.48°C. It should be noted that our research took place during the winter. It meant that our data did not cover periods of the year wherein the air temperature is warmer and sunlight is more abundant. All of the data in section 4.3.1 indicates strongly that air temperature directly affects bin temperature, especially for inactive bins. It could therefore easily be the case that during warmer times, the compost does reach its optimal 60°C.

Steps could be taken to increase compost temperature, including insulation, storage in a warm environment, or the addition of bacteria or fuel. Any of these would make the system faster and more concretely effective. However, in addition to temperature, E. coli elimination is also a function of time. Even though the compost does not reach the ideal heat standards, every E. coli test we ran on bins two months inactive or longer came back free of E. coli. We actually ran the January test twice to make sure it wasn't a mistaken result, and it came back entirely negative each time. This means that even a bin moved to inactive status in the winter could be clear of pathogens within the minimum time.

The only serious flaw, being one presenting a danger if unchanged rather than merely being suboptimal, is that two of the three tests we ran on the ready-for-agriculture piles turned up positive for E. coli. Every test was positive for total coliforms, which are not in themselves a danger. When found in water it can indicate the presence of soil; this is compost. But certain strains of E. coli constitute life-threatening pathogens. The presence of these bacteria in the piles, specifically the EcoKef pile and the newer section of the EcoCampus pile, could be explained by them being outside. Even during our testing, we witnessed local wildlife, such as cats and dogs, relieving themselves on the EcoCampus pile. The newer section was less covered and would be more vulnerable to this sort of contamination. Likewise, the EcoKef pile was covered with a tarp, which would not have been an insurmountable deterrent. It's also possible some compost was added to the pile before it had finished eliminating E. coli, and thus introduced it to the larger environment.

We strongly recommend two things to avoid this contamination, which would render the compost unusable. First, store it in more covered conditions to protect it from wildlife. Merely some kind of sealed shelter, like a shed, would be sufficient. Second, test the bins for E. coli before adding them on. There are too many variables to know exactly when a bin has completed its cycle; it would be safer and more certain to perform the simple E. coli bag test and know months or more of work hasn't been compromised.

4.4.2 Issues and Improvements Regarding System Usage

Part of our evaluation was to see what needed to be improved about the system regarding use, and what users would like to see improved. When we analyzed the survey data, it was apparent that smell was a large issue for users. Below in Figure 73 is a bar chart showing what the survey participants reported as areas they believed would benefit from change.

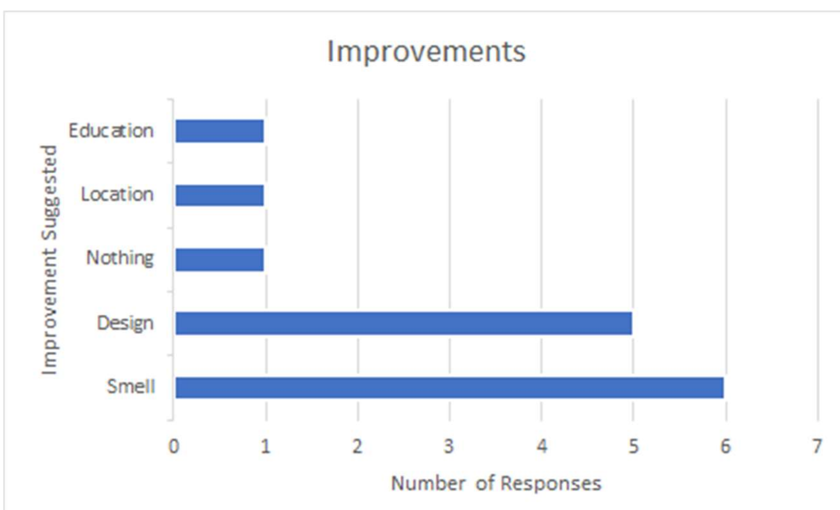

Figure 73: Recommended Improvements Data

Improvement of education was described as the user wanting to have more of an understanding of how the toilets compost the waste, what the compost can be used for, and how to maintain the system. While not specifically about the user experience of composting toilets, one survey participant responded that they would like to see more composting toilets placed around the campus. This was due to the inconvenience they expressed at having to return to a specific location if they wanted to use a composting toilet specifically. At Lotan, there are four composting toilet units located in the EcoCampus living area, two at the personal system, and four at the EcoKef. There are no composting toilets in the main campus of the kibbutz, only traditional flushing ones. One takeaway from this data is that perhaps if there were composting toilets in the main areas, people would use them, as they don't use water and are better for the environment. However, as this conclusion is being drawn from a sample size of fourteen people, this conclusion may be anecdotal.

Design improvement suggestions ranged from lowering the toilet seat, to allowing more space leg space in the stalls, to implementing some sort of system where instead of flushing water, there would be a box full of the dry material that would "flush" and refill automatically. This would help normalize the composting toilets by making the usage process closer to that of a flushing toilet, making it more comfortable and routine.

Additionally, one respondent reported that the communal composting toilet system was better than the personal composting toilet system, as there was less interaction with the waste. The personal composting toilets systems have more variation in the care that they receive as the users must take the waste out every day and rinse out the bucket that the waste is in. This adds water to the system that will have to filter out and become leachate. As the personal system uses some water, it loses some of the environmental benefit. When we interviewed the personal composting toilet system users, both midway through their stay and at the close, there was still a discomfort for some regarding emptying their toilets daily. Most said that it became part of their normal routine, but that they would be happy to not have to do this daily chore when they returned to their homes elsewhere. The ease of use is important to a user because if the system is difficult to use, people are less likely to use it. This conclusion is reflected in the desire to have composting toilets at more convenient locations; if it is convenient, people will use it.

One solution that was being implemented at Kibbutz Lotan in order to address smell, the most popular improvement note, was to apply a Korean Natural Farming spray solution of essential oils, lactic acid, and vinegar on the waste. While this did not eliminate odor, it changed the smell of the compost from a powerful unpleasant waste odor to a more slight and sweeter fragrance. As there is not a lot of research on whether this spray alters the efficiency of composting, we cannot recommend this as a permanent solution. Additionally, all the toilets that the survey participants were using had this spray implemented as part of the daily maintenance, and they still reported smell as an issue. Another solution to smell, implemented at the EcoKef composting toilet systems, was a solar chimney-fan system. These fans drew the air away from the toilet and user, eliminating the smell.

4.4.3 Issues and Improvements Regarding System Maintenance

The system at Lotan was not being maintained as well as would have been liked. It was functional, sure, but it had issues that could be addressed to make the system run more smoothly and safely, as well as easier to continue maintaining in the future. Leachate should be drained much more frequently, weekly if not daily. Lowering this buildup would limit the risks associated with potential leaks, a reality we observed occurring, as well as take pressure off the bins, lessening wear. Discussions were already in progress regarding this issue, primarily focusing on automating the process through a continuously active pump. This way human effort would not have to be a factor anymore, eliminating gaps in maintenance from issues such as if the people working it lacked time, or found it deeply unpleasant.

Besides pressure from built up leachate, a major source of strain on the compost bins is the weight and volume of the composting material. While in theory the compost process took it down to 30% of its original volume, material was added to each bin continually until it filled up. So, while we did see it decrease in its inactive phase, it was far less than a 70% drop. Overstuffing the bins like this not only leads to cracking but can also negatively impact the composting process through its pressure. To keep the same total volume, it would be ideal to use wider, shorter bins. There may be another option that wouldn't require the purchase or construction of new bins: transfer the compost to the long term storage more often. If our tests showed that the compost was E. coli free easily by the three month mark, the material doesn't need to be sitting in its bins for six months and beyond, as we saw. If bins were tested at the three month mark and found affirmatively E. coli free at that point and were then immediately moved to the long term storage of the piles, the bins would be free to use again. By not allowing the bins to become as full before moving them to short term composting, they would have to be replaced more often, but it would save the bins from wearing out, allowing them to be used for more time overall without necessitating new purchases.

The system is clean, people enjoy using it because it is environmentally beneficial, and it works. These maintenance recommendations primarily aim to keep it that way, and to make it easier and more sustainable moving forward.

4.4.4 Moving Forward

One point that has surfaced throughout this process is that ultimately, we had less than two months in which to evaluate this system. We recommend that Kibbutz Lotan continue to carry out our protocol, switching the measurements we performed once daily to once weekly, and those we performed a single time in our evaluation to once per month. It should be noted that the testing kit we used for E. coli, specified in 4.1.3, is $680 USD for a set of 100, so if this cost is an issue, the E. coli testing can be at a lower frequency provided compost at different stages is still checked. Future participants in our evaluation protocol should also be aware that the E. coli test requires an incubation period between 20 and 48 hours.

5.0 Results of our Evaluation

In the sections below, we discuss the results of performing the functional, usage, and maintenance aspects of our evaluation.

5.1 Ease of Functional Evaluation

There were really two main difficulties this field test of our evaluation faced. First, in places the composting system design made it difficult for us to access the bins. Sometimes this could be circumvented by constructing or buying different equipment; others, it prevented us from testing those variables entirely. Perhaps with more time a solution could be found for addressing these cases. The second difficulty is the physical discomfort of wearing the protective gear for an hour in the heat. It was a sealed casing of plastic from fingers to collar to waist; if the air temperature exceeded about 12°C, with the sun, sweat built up quickly and uncomfortably. Unfortunately, safety gear was necessary. If extreme care were taken, it would be possible, if not advisable, to do away with the smock, but gloves must be worn for contact with human waste.

By and large, our evaluation went efficiently and effectively for the field conditions. Most of the delays came from lack of information, and most of that was the result of our team making assumptions about what would be readily available. There was a thermometer ready, which we used to take temperature measurements, but nothing to measure height. It was fairly easy for us to construct a meter-stick from a straight gardening stick, a ruler, and a marker. Later we additionally managed to purchase a tape measure, to accommodate the systems with unremovable lids, along with the pH/moisture meter used to assess the environmental conditions of the bins. We were given a set of E. coli test kits from a previous researcher. In the end the only test we did not end up running was NPK, which would have informed what type of agriculture the end compost was ideally suited to assist: not a safety or effectiveness concern. Along with the gloves and containers for taking samples, we had to spend just under ₪130 NIS, less than $40 USD. A future team may not start with the same equipment and have higher, or lower, costs; for example, the Aquagenx CBT kit we used is $680 USD for 100 kits.

5.2 Ease of Use and Data Analysis Regarding Use

Once we established communication between the survey participants through text, we set up a time to administer the survey. This was the most difficult part of surveying, as it was challenging to find time to meet with each individual between their classes. Two researchers administered the surveys in a low pressure setting, specifically the EcoCampus common area. Either a laptop or phone with the survey ready was provided to the survey participant, or when the survey participant had their hands occupied, the survey was administered verbally. Interestingly there was not much difference in length or quality of responses between methods, except the question of possible improvements; for this alone it seems the atmosphere of conversation rather than just asking a question and receiving an answer prompted more creative and thoughtful answers. In both methods of surveying, the process took around fifteen minutes.

Some of the survey participants were somewhat uncomfortable taking the survey, as there were questions about their habits of excretion. Most considered it at least a bit strange that we wanted to know about their frequency and usage habits regarding the composting toilet system, but largely felt they understood the purpose of our surveys when they heard the nature and scope of our project.

The small sample pool of participants made usage data was a bit difficult to analyze. There were not many trends, and there were often answers that were entirely unique. This proved difficult to code using a codebook due to the difficulty it caused in grouping answers. When there is a larger pool of data, unique responses can be categorized as "other," but we had so few answers that we wanted to actually see what the meaning or intent was behind the responses was, more conclusive data rather than a blank grouping of a bunch of unknown answers.

5.3 Ease of Evaluating System Maintenance

In order to evaluate the maintenance, in terms of variables such as frequency, difficulty, feasibility, and room for improvement, we took two approaches: performing checks ourselves, and interviewing those on the Kibbutz who had responsibility for maintenance. For the former, this was folded into the time we spent testing functional properties, taking no extra time and only additional effort in terms of focus and observation. For the latter, it was primarily a matter of identifying with whom we needed to speak and finding time to do so. We had worked and spoken with both Kaplan and Meiri previously, which made approaching them with this request easier, and they responded amicably. Each interview took approximately half an hour, a time restricted by both of them having responsibilities limiting their availability. Occasionally they gave nonspecific responses or spoke at length on topics that were more ideological than relevant to maintenance. That said, both Kaplin and Meiri were open about their thoughts on the system, what was working and what needed change, as well as willing to point out areas where they themselves could be doing more to maintain the system, giving us a fair volume of useful information.

6.0 Recommendations for the Evaluation

In this section, we evaluate our evaluation and in order to provide recommendations for what could be done better in the future. These recommendations are based upon the results we collected from the case study at Lotan.

6.1 What Can be Changed to Improve the Evaluation of Function

For future conductors of our evaluation protocol, we recommend a number of adjustments to improve the quality and ease of assessing system functionality. First, measurements do not strictly need to be taken daily. It would be useful to do so at the beginning of the testing process, as well as to take measurements at different times of the day, to obtain a sense of how much readings fluctuate. This will give researchers a baseline idea of how sensitive and quick their systems are, and therefore what appropriate frequencies and times of day would be at their sites. For example, we concluded at our site that for the speed of the Kibbutz Lotan systems, 1-3 times a week was sufficient for measuring the “daily” variables. We also found that the compost bins, in particular the older ones, were somewhat susceptible to changes in heat based on the air temperature. Therefore, it made sense to measure mid-morning, when the ambient temperature would be neither extremely cold nor extremely warm for the compost.

We recommend as much as possible to use equipment that either can be calibrated or has a wide enough range on its own. If we had needed millimeter measurements, we could have added them to our meter-stick. The thermometer was sufficiently sensitive for the range of temperatures tested. The moisture meter used was unhelpful, since every measurement we took with it exceeded its maximum and there was no way to readjust it to “zero.” Our collection containers were not incredibly wide, but we still discovered it was valuable to take a temperature reading from the center and the edge, since they would often be different. For a system whose compost is stored more horizontally, researchers would be advised to test at a number of intervals along the length. In addition, try to be entirely clear on the setup of the composting toilet system before beginning the field evaluation. It will assist with speed and quality of testing to come in understanding not just, for instance, that tests will have to be done on temperature; it should also be understood if and how to the composting waste can be accessed in order to be tested at all.

Finally, we have recommendations in terms of safety gear. Gloves are a necessity. They do not have to be the shoulder length cow insemination gloves, though those provide the ideal level of coverage, particularly in systems like those at Lotan. When dealing with bins that could not be opened all the way due to space limitations, one researcher had to keep them propped open using her upper arms while her hands were occupied with the testing instruments. In order to prevent contamination of her clothing, these long gloves were worn to protect her. A smock is also not strictly required if future researchers are comfortable taking extreme, precise caution each time, but is nonetheless strongly recommended. The safety goggles served little function and could be done without, but we would recommend wearing a face mask to prevent risk of inhalation or ingestion.

6.2 What Can be Changed to Improve the Evaluation of Use

Some recommendations that we have after implementing our survey at Kibbutz Lotan are to survey more participants, ask more specific questions to elicit further details about participants' experiences, and to change the wording of some questions to minimize misunderstanding.

As there were only fourteen responses to the survey, there was not a lot of data to analyze, and thus the conclusions that were drawn from the data are only site specific. A larger sample size would provide more conclusive evidence. Another consideration is to survey people who before they used the composting toilets for the first time here on their tour, as this could give insight as to how their opinions of composting toilets changed after their experiences with the Lotan system. We did not interview children, nor did we interview people with handicaps. These demographics, with their different needs, could provide valuable information as to how they perceive the system and what type of recommendations for improvements they would have. Also, we did not ask about the ethnicity of the survey participants. This is an axis of identity that could have influenced their responses, as people with different ethnicities may grow up with different cultural perceptions. For our surveys, it was imperative that we were present as the participants frequently asked questions about the survey. This was due to lack of clarity of the question in some cases, but this sometimes created unintentional pressure on the survey participant.

The point of the surveys was to get users' input and opinions about their experiences with the composting toilets. We identified one of the key indicators of a successful composting toilet system to be if people were consistently using them. As such, it is valuable to consider their opinions as to what they would like to see improved or what is not working with the system. We recommend adding more specific questions to help the survey participant organize their thoughts. Anecdotally, we recognized that participants might sometimes have a recommendation, but might not think it important or relevant to share. This helps the evaluator understand the difference between a survey participant forgetting to add something without a direction question and not having the data at all because the survey participant thinks that it is not important.

Some of the wording of the questions may have been difficult for non-native English speakers to understand, such as in the question, "Was there anything in particular that struck you about using the composting toilets for the first time?" The word "struck" in this context may be difficult to understand. A recommendation we have is to translate the survey into the native language of the survey participants, as this would help prevent misunderstandings. To avoid differing or flawed translations, we recommend partnering with bilingual, native speakers to translate the survey.

When designing our study, we asked a variety of types of questions to identify which formats would provide the most consistently useful responses from participants. For example, we asked, "Do you ever prefer to use the composting toilets over normal flush toilets?" as a "yes" or "no" question in order to get an easily analyzable response. However, this question did not identify why or why not the survey participant had that particular preference, so a simple, "Why or why not?" was added as a follow up, intended to be a short answer. We often found that we needed to add these sorts of follow up questions, so we recommend adding these secondary questions to the survey to formalize the methodology and produce more consistent results.

When performing the Lotan case study there was an expressed interest from survey participants in getting a better education on what happens with the maintenance of the composting toilet system and how to use the compost from the system. More information on these recommendations can be found in Section 4.4.2. We recommend asking questions about what prior knowledge the survey participants have about the system they are using. These responses can then be used, for example, to create instructional signs or placards in the composting toilet stalls to rid users of common misconceptions and provide them with additional information.

In the responses to "why or why not" the survey participants preferred to use the composting toilets, there were six out of seventeen answers saying that they chose to use the composting toilets over flush ones because it was good for the environment. This was based on their awareness of the fact that the composting toilets are a dry system. The survey participants did not necessarily know how the composting of the waste worked, just that it happened. It could be possible that having more of an education about the system would continue to motivate more people to use the composting toilets.

6.3 What Can be Changed to Improve the Evaluation of Maintenance

We made checking in on system maintenance a part of our other daily checks, for ease and brevity. For future use, we recommend making a formal checklist, rather than relying on observation while in the area. Questions on such a checklist should include but are not limited to, per bin: is it leaking, is it cracked, is it full or overfull, has it been otherwise damaged or tampered with, and has it been drained sufficiently recently. If there is a person or group of people responsible for maintaining the system, definitely speak with them. An interview rather than a simple survey is advised if time is available, to benefit as much as possible from the information and perspective of the people who know the system. Interview questions can be devised after the research team has spent time evaluating the composting process themselves to best assess what they need to know about their specific system. In general, they should ask about what maintenance looks like in practice, what its custodians would like maintenance to look like, how difficult it is mentally and physically, how frequent associated tasks are, and how time consuming they are, as starting points. In addition, our maintenance evaluation focused heavily on maintenance of the functional aspects, primarily the composting bins, with only some attention dedicated to usage-related maintenance, such as cleanliness of the bathrooms themselves. In a future implementation of our protocol, we recommend expanding the concept of maintenance for the system, to include aspects like the bathroom facilities; everything that goes into keeping the system running and usable, not just the end elements.

7.0 Conclusion

The goal of this project was to develop a cheap, easy, minimally-disruptive protocol for evaluating composting toilets used in both private and public settings, that collect waste in both small containers above ground that must be emptied daily, and large containers underground that remain in the system until full, respectively. By identifying the functional, usage, and maintenance variables that influence the success of the system, we were able to develop an evaluation protocol that was then field tested at Kibbutz Lotan in Israel. We acknowledge that the limitations to our project are that these recommendations are only applicable to the specific composting toilet system of Kibbutz Lotan as the data that was collected and analyzed for this evaluation was from this particular site.

The protocol identified areas of strength and weakness in the composting toilet systems' function, use, and maintenance. Our results showed that the composting process is taking place effectively, though not at peak efficiency. This dearth of efficiency will likely be resolved once the ambient temperature increases. During our evaluation, our results showed that the active bins tested positive for E. coli, as did some of the composting piles. While this is reasonable for active bins, where waste is still being added, the composting piles are more unexplained. We speculate that the piles may have had a bin that was not finished composting deposited too early. In addition, we observed animals defecating into one pile. If this was a regular occurrence, it could have reintroduced E. coli. Due to the presence of E. coli, regardless of cause, this humus is not fit for agricultural applications at this time. However, the bins that we tested that came back negative for E. coli proved that the system eliminates pathogens after roughly six weeks of inactive composting, so it does work.

Results also showed that users of the composting toilets wanted to see improvement in odor control. The most successful way unpleasant odors associated with composting toilets was being addressed was through the implementation of an automatic fan system, such as in the EcoKef system. When analyzing the survey data, we noticed that in the communities where our survey participants grew up, they often reported stigma surrounding the use of composting toilets. Composting toilets were viewed as unsanitary and smelly, but given the chance, the survey participants had had their minds changed by their experiences at Kibbutz Lotan. Some of the survey responses indicated that their experience was normalized after using the composting toilets for a period of time around three weeks, or through making some adjustments to the system. One suggestion was to engineer a small box that would serve as a "flushing" mechanism. This box would deposit the dry material onto the waste in a measured fashion and would refill automatically. An additional recommendation was to create more locations of composting toilets that would increase the accessibility and proximity of the toilets for users. Many of the survey responses indicated that they would use the composting toilets over flush toilets if this were the case, as they are better for the environment. These recommendations would benefit the composting toilet system as they could potentially increase use.

In terms of recommendations for maintenance, we advise that bins should be considered full before they reach the top, as this would decrease wear from too much pressure on the bins from the weight of the compost, humus, and leachate. In addition, inactive bins that have passed the three month minimum should be tested for E. coli, and if they are negative, the compost should be vacated from the bins into the piles. This would lower the time each bin is out of use in the active parts of the system, and make considering them full earlier more feasible by avoiding bin shortage. Finally, we recommend that drainage happen more often. This is necessary to prevent the system from becoming anaerobic and suffocating the bacteria that perform the composting process.

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Appendix A: Data from Daily Measurements of Compost Bins

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	46.5	54.7	50.6			22.2			11
3	1/24/20 9:00	42	55.7	48.85			23.3			13
4	1/26/20 9:00	47	57.7	52.35			24.8			8
5	1/27/20 9:00	49.2	61.5	55.35			25.9	10	6.5	9
6	1/28/20 9:00	45.3	64.5	54.9	16.4	25.3	20.85	10	7	12
7	1/29/20 9:00	41.8	63.5	52.65	35.7	35.6	35.65	10	7.3	19
8	1/30/20 9:00	42	72	57	25.4	30.7	28.05	10	6.9	16
12	2/1/20 11:00	44	70	57	29.1	34.2	31.65	10	7.4	17
13	2/2/20 9:00	42.8	77.8	60.3	22.9	27.1	25	10	7.2	15.5
14	2/3/20 10:00	44.5	76.5	60.5	29.4	36.7	33.05	10	7.5	18
15	2/4/20 10:00	42.4	74.4	58.4	31.9	35.9	33.9	10	6.9	17
16	2/5/20 17:30	48	73	60.5	44.2	48.2	46.2	10	8	18
17	2/6/20 11:00	39	67	53	32.2	39.2	35.7	10	8	16
18	2/10/20 9:30	47.5	73.2	60.35	20.5	25.8	23.15	10	7.1	15.3
19	2/11/20 9:30	48.5	70.4	59.45	21.9	28.1	25	10	7.1	15
20	2/12/20 9:30	46.5	69.5	58	24.2	32.3	28.25	10	7.5	17.5
21	2/13/20 9:15	46.5	68.9	57.7	25	34	29.5	10	7.1	18.5
22	2/18/2020 10:00	48.1	74.5	61.3	28.1	37.9	33	10	7.5	20.5
23	2/21/20 10:00	48	69.2	58.6	23.4	29.8	26.6	10	7.5	20.2

Figure 74: Bin 1 Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	46	57.5	51.75			30.4			11
3	1/24/20 9:00	44	52.5	48.25			35			13
4	1/26/20 9:00	52.7	63.5	58.1			24.4			8
5	1/27/20 9:00	46.5	70.6	58.55			36.6	10	6.2	9
6	1/28/20 9:00	55.2	68.5	61.85	27.6	30	28.8	10	6	12
7	1/29/20 9:00	49.3	63.8	56.55	44.1	46.1	45.1	10	7.6	19
8	1/30/20 9:00	56.5	70.5	63.5	25.2	29.2	27.2	10	7	16
12	2/1/20 11:00	54	75.7	64.85	32.1	37	34.55	10	7	17
13	2/2/20 9:00	51	70.4	60.7	17.8	28.1	22.95	10	7.3	15.5
14	2/3/20 10:00	50.5	72.5	61.5	30	39	34.5	10	7.3	18
15	2/4/20 10:00	52.5	70.2	61.35	30.9	41.1	36	10	7	17
16	2/5/20 17:30	48	67	57.5	42.8	46.5	44.65	10	6.8	18
17	2/6/20 11:00	47	64	55.5	39.5	45.3	42.4	10	8.2	16
18	2/10/20 9:30	55.4	67.9	61.65	21.8	34.7	28.25	10	7.5	15.3
19	2/11/20 9:30	55	66.1	60.55	23.1	34.6	28.85	10	7.1	15
20	2/12/20 9:30	69.2	66.1	67.65	25.6	39.7	32.65	10	7.2	17.5
21	2/13/20 9:15	50	64.8	57.4	27.6	42.7	35.15	10	7.2	18.5
22	2/18/2020 10:00	53	74.1	63.55	31.3	43	37.15	10	8	20.5
23	2/21/20 10:00	52.5	70.5	61.5	24.9	30.7	27.8	10	7.4	20.2

Figure 75: Bin 2 Data

	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/24/20 9:00	102	102	102			32.9			13
3	1/26/20 9:00	102	102	102			31.5			8
4	1/27/20 9:00	102	102	102			36.6	10	6.9	9
5	1/28/20 9:00	102	102	102	25.3	39.3	32.3	10	7	12
6	1/29/20 9:00	102	102	102	36.5	40.5	38.5	10	7.9	19
7	1/30/20 9:00	102	102	102	25.6	37.3	31.45	10	8	16
11	2/1/20 11:00	102	102	102	23.7	32.8	28.25	10	7.9	17
12	2/2/20 9:00	102	102	102	20.4	28.2	24.3	10	7.5	15.5
13	2/3/20 10:00	102	102	102	22.1	26.8	24.45	10	7.2	18
14	2/4/20 10:00	102	102	102	23.3	31.5	27.4	10	8	17
15	2/5/20 17:30	102	102	102	31.7	33.7	32.7	10	8	18
16	2/6/20 11:00	102	102	102	33.5	34	33.75	10	8	16
17	2/10/20 9:30	90.2	102	96.1	17.7	28.4	23.05	10	7.7	15.3
18	2/11/20 9:30	102	89	95.5	19	29.8	24.4	10	7.1	15
19	2/12/20 9:30	87	102	94.5	21.1	28.3	24.7	10	7.9	17.5
20	2/13/20 9:15	88.5	102	95.25	19.4	31.7	25.55	10	7.8	18.5
21	2/18/20 10:00	86	102	94	27	34	30.5	10	8.2	20.5
22	2/21/20 10:00	84.5	102	93.25	20.5	29.8	25.15	10	7.1	20.2

Figure 76: Bin 6 Data

	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00						19.9			11
3	1/24/20 9:00						19.9			13
4	1/26/20 9:00						17.2			8
5	1/27/20 9:00	61.5	92	76.75			17.7	10	6.9	9
6	1/28/20 9:00	57	80.2	68.6	13.8	16.6	15.2	10	6.6	12
7	1/29/20 9:00	62	85.9	73.95	16	17.9	16.95	10	6.8	19
8	1/30/20 9:00	59.8	84.5	72.15	13.2	18.1	15.65	10	7	16
12	2/1/20 11:00	59	82	70.5	12	18	15	10	7	17
13	2/2/20 9:00	66.5	83.5	75	14.8	14.5	14.65	10	7	15.5
14	2/3/20 10:00	57.4	82	69.7	17.5	19.1	18.3	10	7.1	18
15	2/4/20 10:00	59	80.5	69.75	17.6	19.9	18.75	10	7	17
16	2/5/20 17:30	63	85	74	17.8	21	19.4	10	7	18
17	2/6/20 11:00	60	92	76	14.9	22.6	18.75	10	7	16
18	2/10/20 9:30	62	80.9	71.45	15.1	19.9	17.5	10	7	15.3
19	2/11/20 9:30	66.4	73.5	69.95	15	19.2	17.1	10	7	15
20	2/12/20 9:30	63	70.2	66.6	14.2	16.5	15.35	10	7	17.5
21	2/13/20 9:15	65	73.8	69.4	15.1	16.9	16	10	7.1	18.5
22	2/18/20 10:00	70.5	77	73.75	17.9	24.6	21.25	10	7	20.5
23	2/21/20 10:00	69.2	80	74.6	18.8	22.7	20.75	10	7	20.2

Figure 77: Bin 7 Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00						19.3			11
3	1/24/20 9:00						20.2			13
4	1/26/20 9:00						19.9			8
5	1/27/20 9:00	46.3	74	60.15			18.4	10	6.8	9
6	1/28/20 9:00	45.2	63.5	54.35	18.9	22.6	20.75	10	6.6	12
7	1/29/20 9:00	51.6	69	60.3	24.6	23.5	24.05	10	6.5	19
8	1/30/20 9:00	49	66.5	57.75	19.5	23.4	21.45	10	7	16
12	2/1/20 11:00	46.5	70.5	58.5	17.1	25.7	21.4	10	6.7	17
13	2/2/20 9:00	48	64.8	56.4	16.5	25	20.75	10	7	15.5
14	2/3/20 10:00	48	64.4	56.2	20.9	25.8	23.35	10	7	18
15	2/4/20 10:00	46.1	63	54.55	23.5	26.4	24.95	10	7	17
16	2/5/20 17:30	53	72	62.5	26.8	24.2	25.5	10	7	18
17	2/6/20 11:00	54	66	60	20.5	22.6	21.55	10	7	16
18	2/10/20 9:30	46.5	61	53.75	18	25	21.5	10	7	15.3
19	2/11/20 9:30	51.5	51.8	51.65	17	23.1	20.05	10	7.1	15
20	2/12/20 9:30	49.3	51.7	50.5	18.3	19.6	18.95	10	7	17.5
21	2/13/20 9:15	51.1	52.5	51.8	15.7	18.5	17.1	10	7	18.5
22	2/18/20 10:00	40.3	60.5	50.4	16.4	25.1	20.75	10	7	20.5
23	2/21/20 10:00	52.5	56.9	54.7	18.8	22.7	20.75	10	7	20.2

Figure 78: Bin 8 Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00						21.5			11
3	1/24/20 9:00						23.6			13
4	1/26/20 9:00						21.8			8
5	1/27/20 9:00	23.8	67	45.4			20.7	10	6.8	9
6	1/28/20 9:00	44.1	63	53.55	17.2	22.7	19.95	10	6.5	12
7	1/29/20 9:00	42.6	62	52.3	20	25.6	22.8	10	7	19
8	1/30/20 9:00	42.3	63.9	53.1	17.9	22	19.95	10	7	16
12	2/1/20 11:00	37.2	64.7	50.95	20.8	26.4	23.6	10	7	17
13	2/2/20 9:00	40.9	59	49.95	19.1	28	23.55	10	7.1	15.5
14	2/3/20 10:00	38	56.1	47.05	20.7	32.3	26.5	10	7	18
15	2/4/20 10:00	41	55	48	19.6	35.8	27.7	10	7	17
16	2/5/20 17:30	46	57	51.5	24.8	34.6	29.7	10	7	18
17	2/6/20 11:00	42	61	51.5	22.9	31.6	27.25	10	7.8	16
18	2/10/20 9:30	43.1	56.5	49.8	16.6	34.8	25.7	10	7.1	15.3
19	2/11/20 9:30	43.5	46	44.75	16	29.8	22.9	10	6.9	15
20	2/12/20 9:30	39.5	48.6	44.05	18.3	25.2	21.75	10	7	17.5
21	2/13/20 9:15	46.5	68.9	57.7	25	34	29.5	10	7.1	18.5
22	2/18/20 10:00	45	54.2	49.6	23.7	35	29.35	10	7	20.5
23	2/21/20 10:00	41	59.1	50.05	20.2	36.4	28.3	10	7	20.2

Figure 79: Bin 10 Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	64	74	69			19.1			11
3	1/24/20 9:00	63.5	73	68.25			20.4			13
4	1/26/20 9:00	61	72.7	66.85			19.2			8
5	1/27/20 9:00	60.5	73	66.75			18.4	10	6.5	9
6	1/28/20 9:00	58.5	73.2	65.85	15.7	21.9	18.8	10	6.1	12
7	1/29/20 9:00	57.9	73.4	65.65	25.1	23.7	24.4	10	7	19
8	1/30/20 9:00	60.5	71.5	66	20.3	23.4	21.85	10	7	16
12	2/1/20 11:00	63.5	74.7	69.1	19.6	25.1	22.35	10	7	17
13	2/2/20 9:00	57.5	74.5	66	16.5	22.2	19.35	10	8	15.5
14	2/3/20 10:00	62.2	71.2	66.7	16.5	23.6	20.05	10	7.2	18
15	2/4/20 10:00	62.7	73.4	68.05	20.6	24.5	22.55	10	7.1	17
16	2/5/20 17:30	56	59	57.5	25.6	25.6	25.6	10	7	18
17	2/6/20 11:00	58	61.5	59.75	21.1	25	23.05	10	8	16
18	2/10/20 9:30	65.5	72.9	69.2	17.7	18.9	18.3	10	8	15.3
19	2/11/20 9:30	65	72.8	68.9	17.3	20.9	19.1	10	7.2	15
20	2/12/20 9:30	57.5	69.9	63.7	17.7	22.2	19.95	10	7.9	17.5
21	2/13/20 9:15	59.5	69	64.25	20.6	24.2	22.4	10	7.8	18.5
22	2/18/20 10:00	65.6	69.5	67.55	21.2	25.7	23.45	10	6.9	20.5
23	2/21/20 10:00	63.5	69.2	66.35	18.7	22.5	20.6	10	7.2	20.2

Figure 80: Bin A Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	68.5	75.5	72			14.8			11
3	1/24/20 9:00	68.2	73.5	70.85			15.3			13
4	1/26/20 9:00	67.2	74.5	70.85			14.4			8
5	1/27/20 9:00	67	74	70.5			14	10	6.9	9
6	1/28/20 9:00	62.4	74	68.2	13.4	15.1	14.25	10	6.9	12
7	1/29/20 9:00	57.1	73.6	65.35	25.1	23.7	24.4	10	8	19
8	1/30/20 9:00	59.5	74	66.75	14.9	17	15.95	10	7.5	16
12	2/1/20 11:00	68.2	75	71.6	25.7	15.2	20.45	10	6.9	17
13	2/2/20 9:00	65.5	75	70.25	22.6	17.8	20.2	10	7.1	15.5
14	2/3/20 10:00	66.7	72.6	69.65	26.4	17.8	22.1	10	7.2	18
15	2/4/20 10:00	64.7	74.6	69.65	21.9	26.3	24.1	10	7.5	17
16	2/5/20 17:30	57	59	58	21.5	20.4	20.95	10	7.5	18
17	2/6/20 11:00	59	61.5	60.25	23.6	17	20.3	5	7.8	16
18	2/10/20 9:30	59.4	72.6	66	16.9	14.5	15.7	10	8.1	15.3
19	2/11/20 9:30	60	72.4	66.2	14.4	15.3	14.85	10	7.6	15
20	2/12/20 9:30	61	72.8	66.9	28.1	18.5	23.3	10	8	17.5
21	2/13/20 9:15	62	73	67.5	22.3	19.3	20.8	10	8	18.5
22	2/18/20 10:00	59.9	72.1	66	23.9	22.5	23.2	10	7.3	20.5
23	2/21/20 10:00	58.3	71	64.65	19.5	19.7	19.6	10	8	20.2

Figure 81: Bin C Data

	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	85	102	93.5			19.4			11
3	1/24/20 9:00	84.5	102	93.25			22.8			13
4	1/26/20 9:00	86.2	102	94.1			17.4			8
5	1/27/20 9:00	84.5	102	93.25			18.8	10	7	9
6	1/28/20 9:00	84.2	102	93.1	17.5	26.7	22.1	10	7.1	12
7	1/29/20 9:00	86.2	102	94.1	26.7	27.8	27.25	10	8	19
8	1/30/20 9:00	83.3	102	92.65	21.2	26.1	23.65	10	8	16
12	2/1/20 11:00	88	90	89	25	22.3	23.65	10	7.5	17
13	2/2/20 9:00	87	102	94.5	18.9	21.3	20.1	10	7.5	15.5
14	2/3/20 10:00	86.1	102	94.05	20.7	24.6	22.65	10	7.1	18
15	2/4/20 10:00	95.5	98	96.75	21.9	26.3	24.1	10	7	17
16	2/5/20 17:30	85	102	93.5	23.1	25.5	24.3	10	7.5	18
17	2/6/20 11:00	83	95	89	28.2	26.5	27.35	10	7	16
18	2/10/20 9:30	84	96	90	18.3	22.3	20.3	10	8	15.3
19	2/11/20 9:30	85.8	94	89.9	18.7	22	20.35	10	7.4	15
20	2/12/20 9:30	83.5	92.5	88	20.7	23.6	22.15	10	7.4	17.5
21	2/13/20 9:15	89	94.8	91.9	18.2	23	20.6	10	7.3	18.5
22	2/18/20 10:00	83.2	92	87.6	19.4	30.7	25.05	10	7.9	20.5
23	2/21/20 10:00	84	89.5	86.75	23.1	25.3	24.2	10	7.6	20.2

Figure 82: Bin D Data

	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	70.5	84.5	77.5			22.2			11
3	1/24/20 9:00	66.2	84	75.1			16.2			13
4	1/26/20 9:00	66.7	80	73.35			14.4			8
5	1/27/20 9:00	68.7	80.4	74.55			13.4	10	6.9	9
6	1/28/20 9:00	66.9	80.5	73.7	11.1	14.6	12.85	10	7	12
7	1/29/20 9:00	86.2	102	94.1	26.7	27.8	27.25	10	8	19
8	1/30/20 9:00	72	80.5	76.25	16.5	16.8	16.65	10	8	16
12	2/1/20 11:00	72	79.5	75.75	15	19.7	17.35	10	7.8	17
13	2/2/20 9:00	68.5	78	73.25	16.6	18.7	17.65	10	7.5	15.5
14	2/3/20 10:00	63.8	78	70.9	21.1	19.4	20.25	10	7.6	18
15	2/4/20 10:00	66.7	77.5	72.1	20.9	20.8	20.85	10	7.1	17
16	2/5/20 17:30	67	68	67.5	21	21.6	21.3	10	7	18
17	2/6/20 11:00	68.5	72.5	70.5	24	21.8	22.9	10	7.2	16
18	2/10/20 9:30	67.2	78.9	73.05	15.3	18.8	17.05	10	7.5	15.3
19	2/11/20 9:30	66.3	76.5	71.4	15.5	18.1	16.8	10	7.9	15
20	2/12/20 9:30	64.9	75.8	70.35	17.3	18.3	17.8	10	7.6	17.5
21	2/13/20 9:15	65.5	75.5	70.5	17.7	19.6	18.65	10	7.7	18.5
22	2/18/20 10:00	67	76	71.5	20.9	23.7	22.3	10	7.5	20.5
23	2/21/20 10:00	63	75.3	69.15	18.7	21.3	20	10	8	20.2

Figure 83: Bin E Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	70	79.7	74.85			17.8			11
3	1/24/20 9:00	72.5	78.5	75.5			22			13
4	1/26/20 9:00	64.2	75.2	69.7			20.5			8
5	1/27/20 9:00	62.5	78	70.25			19	10	6.9	9
6	1/28/20 9:00	65.2	80.4	72.8	12.6	20	16.3	10	7.2	12
7	1/29/20 9:00	64.4	76.9	70.65	23.2	23.6	23.4	10	8	19
8	1/30/20 9:00	64.5	76.5	70.5	17.8	23.9	20.85	10	7	16
12	2/1/20 11:00	70	78	74	21.1	27.1	24.1	10	7	17
13	2/2/20 9:00	74.5	78.7	76.6	15.8	21.8	18.8	10	7.1	15.5
14	2/3/20 10:00	69.8	26	47.9	19.4	22.5	20.95	10	8	18
15	2/4/20 10:00	70.8	77.3	74.05	20.7	23.9	22.3	10	7.2	17
16	2/5/20 17:30	62	68	65	28.2	28.8	28.5	10	7.5	18
17	2/6/20 11:00	61	68.5	64.75	31.6	28.7	30.15	10	8	16
18	2/10/20 9:30	62.7	77	69.85	17.8	22.6	20.2	10	7.3	15
19	2/11/20 9:30	69.5	74.1	71.8	17.8	23.5	20.65	10	8.1	17.5
20	2/12/20 9:15	68.2	74.2	71.2	18.2	25.8	22	10	8	18.5
21	2/18/20 10:00	62	73.4	67.7	22.4	28.6	25.5	10	8.1	20.5
22	2/21/20 10:00	61.7	72	66.85	20.1	24.6	22.35	10	8.3	20.2

Figure 84: Bin F Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	76.5	86.7	81.6			17			11
3	1/24/20 9:00	76	89.5	82.75			16.3			13
4	1/26/20 9:00	74.2	87.2	80.7			15.4			8
5	1/27/20 9:00	74.2	85	79.6			15.8	4.1	7	9
6	1/28/20 9:00	71	84.5	77.75	14.4	15.6	15	10	7.1	12
7	1/29/20 9:00	86.3	76	81.15	23.5	20.6	22.05	10	7.5	19
8	1/30/20 9:00	71.9	84.3	78.1	21.4	20.6	21	10	7.5	16
12	2/1/20 11:00	72	87	79.5	21	20.7	20.85	10	7.1	17
13	2/2/20 9:00	70.5	86.5	78.5	19	20.7	19.85	10	7.5	15.5
14	2/3/20 10:00	63.7	86.3	75	20.4	19.5	19.95	10	7.5	18
15	2/4/20 10:00	67.4	85.6	76.5	29.1	21.1	25.1	10	7.5	17
16	2/5/20 17:30	64	83	73.5	23	25.4	24.2	10	7.5	18
17	2/6/20 11:00	63.5	79.5	71.5	26.5	25.6	26.05	10	7.5	16
18	2/10/20 9:30	66.2	83.2	74.7	23.5	17.5	20.5	10	8	15.3
19	2/11/20 9:30	72	85	78.5	17	18.7	17.85	10	7.4	15
20	2/12/20 9:30	74.5	86.8	80.65	17.9	19.6	18.75	10	7.2	17.5
21	2/13/20 9:30	65.2	83.8	74.5	17.3	21.3	19.3	10	7.9	18.5
22	2/18/20 10:00	64	84	74	21.5	24.7	23.1	10	7.8	20.5
23	2/21/20 10:00	62.8	83	72.9	19.5	23.1	21.3	10	8	20.2

Figure 85: Bin G Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/2020 9:00	68.5	80.5	74.5			15.8			11
3	1/24/2020 9:00	74.5	79.5	77			15.1			13
4	1/26/2020 9:00	70	82	76			12.8			8
5	1/27/2020 9:00	71.5	80.5	76			12.6			9
6	1/28/2020 15:00	70	83.3	76.65	10.9	12.7	11.8	10	6.9	12
7	1/29/20 9:00	71	81.9	76.45	14.9	14.9	14.9	10	7.1	19
8	1/30/20 9:00	70	81.5	75.75	12	14.4	13.2	10	7	16
12	2/1/20 11:00	69.7	79	74.35	13.1	16.1	14.6	10	6.9	17
13	2/2/20 9:00	70	81.5	75.75	13.8	15.4	14.6	10	7.1	15.5
14	2/3/20 10:00	71	80.5	75.75	14.1	15.8	14.95	10	7	18
15	2/4/20 10:00	72.3	80	76.15	15.5	16.8	16.15	10	6.9	17
16	2/5/20 17:30	74	78	76	20.7	18.5	19.6	10	7	18
17	2/6/20 11:00	71	75	73	16.5	17.8	17.15	10	7	16
18	2/10/20 9:30	70.8	82	76.4	13.6	17.3	15.45	10	7.5	15.3
19	2/11/20 9:30	71.9	79.2	75.55	14.5	16.3	15.4	10	7	15
20	2/12/20 9:30	70	77.5	73.75	15.6	16.8	16.2	10	7	17.5
21	2/13/20 9:15	70.8	78	74.4	13.9	17.2	15.55	10	7.2	18.5
22	2/18/20 10:00	69.5	80	74.75	18.2	20.5	19.35	10	7.1	20.5
23	2/21/20 10:00	69.4	79.4	74.4	15.5	19.6	17.55	10	7	20.2

Figure 86: Bin J Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/2020 9:00	69.5	77.5	73.5			15.3			11
3	1/24/2020 9:00	72.5	77.5	75			14			13
4	1/26/2020 9:00	76	77	76.5			12.1			8
5	1/27/2020 9:00	69.2	75	72.1			12	10	7	9
6	1/28/2020 15:00	69.5	74.7	72.1	10.8	12.4	11.6	10	7	12
7	1/29/20 9:00	68.2	73.5	70.85	13.8	14.1	13.95	10	7	19
8	1/30/20 9:00	69.2	75.5	72.35	12.7	13.8	13.25	10	7	16
12	2/1/20 11:00	71.8	73.8	72.8	17.9	14.9	16.4	10	7	17
13	2/2/20 9:00	69.7	75.2	72.45	11.9	14.1	13	10	7.1	15.5
14	2/3/20 10:00	69.7	73.8	71.75	13.4	14.9	14.15	10	7.2	18
15	2/4/20 10:00	70.1	74	72.05	14.7	15.8	15.25	10	7	17
16	2/5/20 17:30	72	73	72.5	16.8	17.5	17.15	10	7.2	18
17	2/6/20 11:00	70	73	71.5	14.4	16.3	15.35	10	7.2	16
18	2/10/20 9:30	69.9	77.1	73.5	12.3	16	14.15	10	7.3	15.3
19	2/11/20 9:30	70.5	73.5	72	11.5	15.2	13.35	10	7.2	15
20	2/12/20 9:30	70.5	74.5	72.5	13.5	15.3	14.4	10	7.1	17.5
21	2/13/20 9:15	70.5	73.5	72	13.5	15.8	14.65	10	7.3	18.5
22	2/18/20 10:00	72	72.7	72.35	16	19.5	17.75	10	7.6	20.5
23	2/21/20 10:00	70.8	73	71.9	16.1	18.3	17.2	10	7.1	20.2

Figure 87: Bin K Data

	A	B	C	D	E	F	G	H	I	J
1	Date	Low Point (cm)	High Point (cm)	Average Height (cm)	Corner Temp (°C)	Core Temp (°C)	Avg. Temp (°C)	Moisture	pH	Temp. Outside (°C)
2	1/23/20 9:00	84	92.5	88.25			22.4			11
3	1/24/20 9:00	83.2	93	88.1			24.8			13
4	1/26/20 9:00	83.5	93.2	88.35			19.7			8
5	1/27/20 9:00	82	92.5	87.25			19.8	10	6.9	9
6	1/28/20 9:00	79.2	90	84.6	16.7	23.3	20	10	6.7	12
7	1/29/20 9:00	90.3	79	84.65	17.3	24	20.65	10	7	19
8	1/30/20 9:00	79.3	89.8	84.55	19.3	24.4	21.85	10	7	16
12	2/1/20 11:00	78.7	89.5	84.1	15.8	24.6	20.2	10	7.5	17
13	2/2/20 9:00	76	89.5	82.75	16.9	23	19.95	10	7.2	15.5
14	2/3/20 10:00	81	89	85	18.3	23.2	20.75	10	7.2	18
15	2/4/20 10:00	79.7	89.2	84.45	18.7	23.6	21.15	10	7.2	17
16	2/5/20 17:30	81	94.3	87.65	20.9	24.4	22.65	10	7	18
17	2/6/20 11:00	80	86	83	19.3	25.8	22.55	10	7.5	16
18	2/10/20 9:30	80.4	88.9	84.65	18.1	25	21.55	10	7.9	15.3
19	2/11/20 9:30	78	86.8	82.4	18	23.1	20.55	10	7.5	15
20	2/12/20 9:30	77.8	87.5	82.65	15.9	22.4	19.15	10	7.7	17.5
21	2/13/20 9:15	75.1	86.8	80.95	16.1	24.4	20.25	10	7.2	18.5
22	2/18/20 10:00	77.5	85.3	81.4	20.6	28.6	24.6	10	7.8	20.5
23	2/21/20 10:00	75	85	80	20.3	27.9	24.1	10	7	20.2

Figure 88: Bin L Data

Appendix B: Survey Data

ID	Timestamp	Gender	gender	Country of Origin	countryorigin	Age (numerical)	What kind of residence do you live in at home (country of origin)?	residencetype	How often per week do you use the composting toilets (best numerical guess)?	frequencyofuse	Do you ever prefer to use the composting toilets over normal flush toilets?	toiletpreference	Why or why not?	preferencewhy1
1	1/21/2020 9:	Female	1	Scotland	1	18	Urban	1	Everyday	28	No	2	Yes as it is close by to us	1
2	1/21/2020 9:	Female	1	England	1	19	Urban	1	Everyday	28	No	2	If it's closest I will use it	1
3	1/21/2020 9:	Male	2	United Kingdo	1	19	Suburban	2	30	30	No	2	Yes because the composting toilets are by where we live	1
4	1/21/2020 9:	male	2	UK	1	18	Urban	1	30	30	No	2	No. I'll use them if they're closer but often if you use them too much or pee a lot in the compost, they smell quite bad.	3
5	1/21/2020 9:	Male	2	United Kingdo	1	18	Suburban	2	10	10	Yes	1	Yes because it's closer (generally) and more convenient	1
6	1/27/2020 17	Female	1	Canada	4	23	Urban	1	35 times - 5x	35	Yes	1	Yes! I walk to the bustan to use the composting toilets because I like to reduce my waste	1
7	1/27/2020 17	female	1	israel	3	24	Urban	1	70	70	Yes	1	yes. beacuse i live here now and want to experience that	4
8	1/27/2020 17	Female	1	America	2	19	Suburban	2	21	21	Yes	1	No because when you gotta go you gotta go	5
9	1/27/2020 17	Female	1	USA	2	18	Suburban	2	8 times	8	Yes	1	Yes, better for the environment	2
10	1/27/2020 18	Male	2	United States	2	23	Suburban	2	3	3	Yes	1	While he's here, 100%, tough to use a normal toilet (because he sees how much potable water is being wasted)	2
11	1/27/2020 18	Male	2	Russia	5	24	Suburban	2	Every day	28	Yes	1	Yes. Because it's better for the environment on many levels.	2
12	1/27/2020 18	Female	1	Israel	3	25	Kibbutz	2	20	20	No	2	No, it depends on life	5
13	1/27/2020 18	Male	2	Israel	3	25	Urban	1	20	20	Yes	1	yes because they are closer in the neighborhood, yes because of the positive ecological ramifications	1
14	1/27/2020 18	Female	1	Israel	3	25	Urban	1	35	35	No	2	Yes, when it's the closest. I don't go specially to the moadon to use, but if I'm there	1

preferencewhy2	Do you feel comfortable using the composting toilets?	comfort	Was there anything in particular that struck you about using the composting toilets for the first time?	difference	How do you feel about the conditions? Is there anything in particular that you notice about your experience with a composting toilet that is different than a traditional toilet?	condition	condition2	What is your perception of how composting toilets are perceived in the community in your country of origin?	communityperception	Do you think other people use composting toilets here at Lotan? Do you think that they use it regularly or just as a novelty?
	Yes	1	No	4	The smell	1		They are a good idea	1	Just as a novelty
	Yes	1	The smell	1	The smell	1		Some are more welcoming to it then others	1	If they're very eco will use it regularly
	Yes	1	Getting used to the process of putting in fibre etc	2	It smells more, but this depends on how much fibre has been put in by the previous person.	1		They are a bit 'eco-freako' but good.	1	On Lotan the composting toilets are a novelty for visitors, and for residents, but perhaps regular for people who work on the eco-kef site.
	Yes	1	There's no flush	2	You need to think a lot more about how you use the toilets - if you don't maintain them properly every day they get pretty unhygienic.	4		Probably not especially well in the wider community - people worried about smell.	2	I think people do but it's rare and only for a specific purpose - e.g someone trying to be as eco-friendly as possible.
	Yes	1	It was weird not having to flush and there being an extra step before washing hands.	2	The smell is generally worse and you have to clear it out daily	1		I think they're generally accepted but not the preferred type of toilet	1	Others use it regularly because of convenience
2	Yes	1	No water waste!!	5	Outside- have to leave comfort of room to use in middle of night, can be cold and damp	2		Dirty, gross, unsanitary	2	Just as a novelty
	Yes	1	whether its clean	3	dust	4		not that thrill to use	2	no
	Yes	1	They felt cleaner than I expected	3	No	3		I think people think they're grosser than try are	2	I think it's a novelty in general society
	Yes	1	It didn't smell bad	1	It feels exactly the same	3		I think we all like that we are helping the environment in such a simple way	1	Some people do, probably regularly
	Yes	1	No smell (smelled not bad, did not smell like normal backed up toilets), instantly felt comfortable (first time all good), didn't know what he was putting on top of it (learned later [within the first week]), liked the brush to clean it (made it homey), simple process, smells like a nice barn, seat wasn't cold	1	Less rushed, more relaxed, when you finish no flush (awkward)	4		Gated community, upscale, would be perceived poorly (perhaps would view those toilets as lower level), grew up in upper-middle-class (house grew up in, difficult with pre-existing toilet, outside installation may be a barrier)	2	Here: running water systems in their houses, he makes an effort to use them (enjoyable experience)
	Yes	1	That it's possible to turn waste into something valuable (like fertilizer for growing food)	5	At first it could be unsual, but with more time it becomes as comfortable as any toilet	4		Maybe weird or ancient way to deal with this issue, although outside of western countries they are used frequently	2	Yes, I know people who use them all the time, I hope more people do
	No	2	Smell	1	It's good, if it could be flush that would be amazing. Then it would feel like a western toilet without being in a western toilet	4		I think they're fine with it here	3	Yeah they're good with the compost toilets here in this community
2	Yes	1	Used them since childhood, school trips (14 years old, sleep in the desert mobile ones)	5	Much more open to air, prefer that way (natural), no flushing, smell (good and bad)	1	2	Weird, prefer to not do it (smell, convenience, dry material), lots of people would use it given the chance	3	Lots of people would use it given the chance, because of the benefits of the compost, Not necessarily as it is not convenient
2	Yes	1	After you go, it's just silence. But I like it, it's not weird	2	Smell, but your doesn't bother me	1		They are well appreciated, they love it, it's cool	1	Yes, like a novelty

lotanuse	Have you ever used composting toilets anywhere else? If yes, where? What was your experience?	places	What do you think could be improved?	improvement
1	No	1	The smell	1
4	Nope	1	The smell	1
1	No	1	The process of emptying the composting toilets in the square domes - the bin based composting toilets are better.	2
4	No I haven't.	1	Not too sure - maybe something to do with the smell or a system that means you don't need to empty it as frequently.	1
4	No	1	The seat could be lower down.	2
1	First time	1	More vanity options, mirror, lights, smell?	1
3	no	1	good looking and smell	1
1	Yes in the white mountains. Those are far less well kept	2	Nothing	3
5	Yes, in Ecuador, it felt the same and also didn't smell	2	If they were closer	4
5	May have been in Israel, hiking in desert, another time, but didn't understand what it was	2	Better education of why the toilets are used --> how one can personally benefit from their, making your own system in a home (city, suburb, etc.) --> applications when he leaves	
2	Yes, In many places I've traveled composting toilets are used(south-central america)	2	Smell management is important to make it comfortable to many people who would be thrown off by this concept	1
2	No	1	If it could be a hole that I could just stand over and poop, like I used to in India	2
1	School trips (14 years old, sleep in the desert mobile ones)	2	He specifically doesn't have a problem, but if he were to design it, make it less interaction with the waste (dumping, visuals, smell) --> box with dry material that would replace the flush	2
1	No	1	Maybe put a small chair so I can put my leg on it.	2

Appendix C: Codebook of Survey Response

Current Var Name	**New Var Name**	**Var Label**	**Var Value Labels**	**Instructions**
ID	--	Variable ID		Leave as is for now
Gender	gender	Gender of surveyee	1 = female 2 = male	Leave as is for now
Age	--		numerical	Leave as is for now
Country of Origin	countryorigin	Where the surveyee is from	1 = United Kingdom 2 = United States 3 = Israel 4 = Canada 5 = Russia	
Residence type of country of origin	residencetype	What type of environment the surveyee lives in where they're from	1 = urban 2 = suburban	
Frequency of use	frenquencyofuse	How often they use it weekly	numerical	
Toilet preference	toiletpreference	Do they prefer to use the composting toilets over flush ones	1= yes 2 = no	
Why or why not?	preferencewhy	Why or why not they prefer to use the composting toilets	1 = yes, proximity to living space 2 = yes, good for environment 3 = no, smells bad 4 = yes, want to experience it here 5 = no, inconvenient	
Comfort	comfort	Do they feel comfortable using the composting toilets	1 = yes 2 = no	
Noticeable differences	difference	Differences from flush toilets	1 = smell 2 = lack of flush 3 = cleanliness 4 = none 5 = other	
Conditions	condition	How they feel the conditions of the composting toilets are	1 = smell 2 = outside/open air 3 = same 4 = other	

Community perception	communityperception	How does their community perceive composting toilets	1 = positive 2 = negative 3 = other	
Lotan use	lotanuse	Do they think people at Lotan use the composting toilets	1 = novelty 2 = yes 3 = no 4 = specific purpose 5 = other	
Other places they've used composting toilets	places	--	1 = no 2 = yes	
Improvements	improvement	Things they think could be improved	1 = smell 2 = design 3 = nothing 4 = location 5 = education	