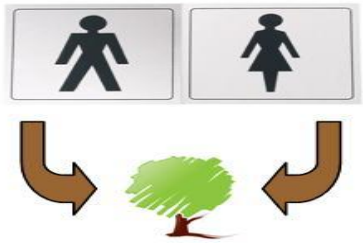
Duchamp de Loo

A composting toilet

The Composting Loo's



Ian McBride
Megan Gerdes
Ramin Moazzami
Jessica Jewett

Introduction to Design, Engr. 215
Spring 2009

Table of Contents

Table of Figures

Table of Tables

1 Problem Formation

1.1 Introduction

Section 1 of the design project is intended to present an objective statement for the team design. Along with the objective statement, there is a black box model of our design, portraying in simplest terms what the world is like before our design is implemented (input) and what the worlds is like after our design is finished (output). A project called WaterPod is allowing us to design a project for their team. WaterPod is a group of artists that are going to live on a self-sustaining barge for six months.

1.2 Objective

The WaterPod project will be traveling on a barge throughout the New York waterways. They will be educating the public about many different ways you can help the environment that would be affordable and be easy to maintain. The team has to come up with an environmentally friendly way to get rid of or use the WaterPod group member's excreta. This black box model, Figure 1 below, portrays our task for this project. We need to develop a way to achieve the requests of our client and make sure the design does not exceed the requirements of the project.

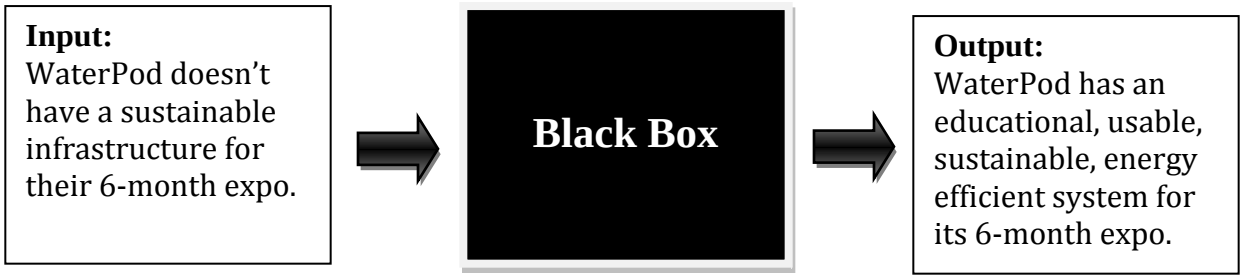


Figure 1 Black Box Model

2 Problem Analysis and Literature Review

2.1 Problem Analysis

A problem analysis is used to break down a system into its different components. The problem analysis below includes input variables, output variables and solution variables with their corresponding constraints and restrictions. These variables and their constraints are included and considered in the final design of the project.

2.1.1 Input:

WaterPod's crew of six does not have a sustainable toileting system to use while on board.

Input Variables:	**Constraints:**
Visitors to the barge ----------	Some interest in environmental sustainability
Human excrement of crew ----------	Only 1 person can use at a time.
Organic dry material ----------	1-2 cups added each use. High carbon content. Small particle in the range of .5mm-20mm diameter.

2.1.2 Output:

WaterPod has a toilet that is educational and environmentally sustainable.

Output Variables:	**Constraints:**
Visitors to the Barge ----------	Educated about sustainable human waste management.
Soil ----------	Time to compost – Minimum of 6 months

2.1.3 Solution

Create a composting toilet.

Variables:	**Restrictions:**
Building materials ----------	Fewer than 400 dollars in price, durable – won't decompose. Must support weight of person.
Size ----------	Must fit in WaterPod's restroom building
Time ----------	Minimum of 6 months of composting
Methods of heating ----------	Must go through thermophilic heat phase to kill potential human pathogens.
Technique ----------	Separates urine from feces. (based on client's request) Not flushed with water.

2.1.4 Criteria

Criteria for the design project.

Criteria:	**Constraints:**
Effectiveness----------	Makes compost, doesn't smell.
Ease of Use ----------	Is simple to operate.
Smell----------	Minimal odor.
Safety----------	Eliminates pathogens. Sustains supports of average human weight during excreta process.
Shippability----------	Must fit in shipping crate with other projects.
Cost----------	Must cost $300 or less.
Durability----------	Must last 6 months.
Safety----------	Eliminates pathogens. Sustains supports of.
Aesthetics----------	Comparable to flush toilets. Fresh and clean.

Educational Value---------- Must show composting toilet system.

2.1.5 Usage

The toilet will be used numerous (1-10) times a day by each of six crewmembers aboard WaterPod.

2.1.6 Production Volume

One composting toilet system will be constructed.

2.2 Literature Review

The literature review is a collection of research topics that are considered and referred to during the design process. Topics are relevant to the design and implementation of a composting toilet. Our research topics include: Client Criteria, Compost, Composting with Human Manure, Composting Toilets, and Components of Compost Toilet System.

2.2.1 Client Criteria

The main specifications from the client, for this project, are that the solids be separated from the liquids in the toilet. This insures the excrement will be fully composted; the compost will aerate more quickly which will allow you to use the compost more quickly. The client also wanted the unit to be mobile or movable if necessary, which will be accomplished within the constraints of the shipping criteria.

2.2.2 Liquids Composting Tank

One of the client's criteria is for the urine to be separated from the feces. The urine from there can be combined with water to then go straight into a garden which easily absorbs the nitrogen from the urine.

2.2.3 Solids Composting Tank

The solid fecal matter needs to be separated from the urine because it needs to be processed before it can go into a garden. The solids tank will be directly below the toilet, which will be connected with a chute that will direct it into the tank. The tank will be sealed except for a vent, which will allow air to enter to allow the aerobic process to occur, and the chute connected to the toilet.

2.2.4 Compost

Composting is a process that over time transforms organic material into usable, nutrient rich soil. Composting has many components to consider because conditions must right for the cultivation of microorganisms, which are essential to the process. For compost to be successful the following must be considered and managed: moister levels, oxygen availability, temperature, the nitrogen/carbon ratio and availability of nutrients.

2.2.4.1 Compost Organisms

A compost pile is an intricate environment. Ideally, compost contains a multitude of interacting organisms that recycle organic waste material. Dead, decomposed bodies of soil organisms make up one third of a compost pile. Compost organisms are commonly divided into three groups or levels; primary consumers, secondary consumers, and tertiary consumers. Though varying in size and quantity each member of the compost food web has an essential role in the transforming of waste into nutrient rich soil.

Primary consumers are the most abundant organisms in a compost piles and initiate the compost cycle. Primary consumers are herbivores. They are the organisms that break down the organic matter and the micro organisms that eat the broken down organic residues. This group includes bacteria, actinomycetes, fungi, nematodes, snails, mites, slugs, earthworms, millipedes, sow bugs and worms. Bacteria generate the heat and are the reason most of the decomposition occurs in compost. With these important jobs bacteria cultivation is vital to the composting process. Fortunately bacteria are present on all organic matter and they reproduces incredibly rapidly. Secondary consumers are the organisms that eat primary consumers. They include both herbivores and carnivores: nematodes, protozoa, rotifers, soil flatworms, springtails, some types of mites, and feather-winged beetles. Tertiary consumers are the third group of organisms and they eat secondary consumers. Tertiary consumers are carnivores; some tertiary consumers are centipedes, predatory mites, rove beetles, ants, spiders, pseudo scorpions, and earwigs. This group contains mainly larger independently mobile insects, visible by humans. These insects are usually not present during the high heat portion of the composting process. Most insects prefer to be in the compost pile so the worry of unwanted insects migrating to your garden is minimal.

2.2.4.2 Moisture

Moisture content of a compost pile is a very important component of composting. Quality moisture content for compost would be a 50-60%. This means that if you grasp a handful of composting material and squeeze it a drop or two of water should come out. Proper moister balance will insure the health of your composting food web. If compost is kept too wet the system will become anaerobic (without air) and many of the organisms in the pile will not be able to do their job. This would result in a slow decomposition process, the pile would begin to smell, and nutrients may leach. Too little water in your compost is also undesirable and will result in inhibited bacterial activity. Covering and adding dry materials or adding water with a hose, may be necessary to maintain proper moisture balance.

2.2.4.3 Oxygen

Proper aeration of the compost pile is an important element of composting. Aerobic microorganisms need oxygen for their metabolism and respiration. The organic materials within the compost need to be aerated as well, with a minimum concentration of 5% for aerobic microbes' survival. If processes proceed anaerobic (lacking oxygen) the pile will not heat up properly, it will decompose more slowly and may have an odor. It is important to

consider aeration when designing your compost bin. Adding dry materials, covering the pile during heavy rain, and turning the pile manually also is necessary to insure proper aeration.

2.2.4.4 Temperature and the Decomposing Process

The process of microorganisms breaking down organic matter can be described in three phases: 1) the mesophilic, or moderate-temperature phase, which lasts for a couple of days, 2) the thermophilic, or high-temperature phase, which can last from a few days to several months, and finally, 3) a several-month cooling and maturation phase (Walker, Dr. Larry).

The mesophillic phase or medium heat phase involves organisms, which quickly break down available organic material. As these decompositions continue the compost pile begins to heat up. When the temperature of the compost pile raises above 40°C the mesophilic microorganisms are replaced by the heat loving thermophilic microorganisms. Many microorganisms that are human or plant pathogens are destroyed at temperatures of 55°C and above (Walker, Dr. Larry). The thermophilic phase is essential to the sanitation of the soil. High temperatures accelerate the breakdown of fats, proteins, and other major structural components of plants. As the availability of high-energy materials decreases, the compost begins to gradually cool down, and tertiary consumers return to the pile.

2.2.4.5 Nitrogen/Carbon Ratio and Nutrient Availability

Nitrogen in a compost pile usually comes from green material such as grass, yard trimmings and also from manure. Carbon in a compost pile usually comes from dried materials such as dried leaves, twigs, sawdust or hay. The best carbon to nitrogen ratio is about 30:1, or 30 parts carbon for each part nitrogen by weight (Walker, Dr. Larry).

If the nitrogen/carbon ratio is out of balance the microorganisms in the pile will be drastically affected. There must be sufficient nitrogen for organism growth but in excess nitrogen may cause chemical processes that produce bad odors. If microorganisms are not well populated the pile will not heat up properly and ultimately will not decompose properly.

Adequate phosphorus, potassium, and trace minerals such as calcium, iron, boron, copper, etc. are essential to microbial metabolism. These nutrients are not limited because they are heavily generated in the compost source materials (Walker, Dr. Larry).

2.2.5 Composting With Human Manure

There are many things to consider when composting with human manure. Compost derived from human manure may lack the normal diversity of materials found in conventional yard composts, and may be very high in nitrogen. This can have many repercussions including a good nitrogen/carbon balance. Human manure compost may also have excess wetness causing lowered aeration, and slowed degradation. Other considerations include odor, pathogens, flies, and uses for the soil produced.

If the compost pile is mainly comprised of human waste it is important to add sawdust or other organic material that is dry and will aid in providing aeration in the pile. Adding these materials

should also reduce the odor of the pile. Many people may also worry about the presence of numerous flies, especially in the early phase of the composting process. Mixing in other materials and covering the pile may help combat flies. Flies though annoying, can be considered ultimately beneficial because they transport or fly in many of the vital decomposer bacteria. Pathogens that may be present in human feces are also an important concern. The compost pile needs to properly advance thru the heating cycle. The destruction of pathogens develops if the pile has an adequate thermophilic heating period. A longer waiting time is recommended for human compost and is not recommended for use on edible plants because some pathogens may remain.

The composting process takes anywhere from a few months to a few years to complete. There are a lot of factors that play a role in how long it takes for the waste to decompose. This process can be sped up by different methods such as: supplying lots of air, turning or mixing the waste periodically, adding worms, monitoring the temperature and microorganism activates.

2.2.6 Compost Bin Design

The facility will accommodate everyone, be easy to maintain and keep clean and hygienic. To be able to accommodate everyone you need to understand how much waste will be produced. Each adult produces about 2.5lb of excreta (urine + feces) per day, of which two lb is urine and half of a pound is feces (Beckmann, Curt). Human waste is composed of mostly water; about 75% of feces and 94% of urine is water. If the urine were kept separate two adults would fill two thirds of a five-gallon bucket in about 10 days. This is taking into consideration toilet paper and some cover material that is mixed in.

Composting bins are used as a storage container for compost. These containers are often made out of plastic, but can also come in steel or other metals, and organic material. The containers are cylinder in shape to correspond with the toilet seat design. The bins are simple in design; one can be made out of four pieces of material, as long as it holds waste.

Composting bins range from a number or sizes: 15 gallon, 20 gallon, 30 gallon, 50 gallon, and 55 gallons. The bins have a hatch door that is removable so the finished waste can be extracted easily. The material can be accumulated so that it can all be used as compost and easily accessible. The bins can be stored outside.

The bins are made so that the material in the container can easily be maneuvered. The material in the bin needs to be turned occasionally to make them aerobic. The aerobic process occurs within the piles and allows the waste to compost. Without turning of the material the aerobic process will not work within the bins; containing the material in the bins makes the process work more quickly and efficiently.

2.2.6.1 Plastic

Plastic is an organic material that is cost efficient. It contains a high molecular weight that means it contains materials that improve its performance. Plastic is malleable and can be formed in to almost any shape. The flexibility of plastic makes it an ideal material for

composting bins. It holds liquids too to insure no mess. The most common type of plastic made for small items and liquid containers. Plastic will not rust or mold or get destroyed by water or bugs. Its strength will allow you to use the same bin for your toilet for many years.

2.2.6.2 Wood

Wood comes from trees and shrubs that contain water and nutrients to help the plants grow. It is an organic material that is cheaper than all the other materials. It can be easily recycled and reused. Water and bugs damage wood; this shows that wood can be broken down much faster than the other materials. This could be a good or bad thing; bins may need to be replaced more often but the bin decomposes with the compost to make even the toilet compost. There are many different types of wood and each depends on the tree it is coming from. Trees contain different nutrients from the environment they are growing in. The different nutrients establish how strong the wood will become. Wood is cheap and breaks down with the compost making it a great choice to make a bin out of.

2.2.6.3 Metal

Metal is strong and can with stand most weather and bugs. There are a lot of different types of metal that can be used. Metal is malleable when heated and can be transformed into almost any shape. You can make or order a bin to fit your design. Its strength helps you make sure the compost and process won't be interfered with. Metal is a good material to use when electricity or solar power is involved because conducts heat and electricity well. Metal is lightweight and can be formed into many shapes. It will not break down for years and years so your bins would not have to be replaced for a long time.

2.2.7 Composting Toilets

The purpose of the composting toilet is to dispose of human waste and create compost that will be used to fertilize plants. Human waste is organic and contains elements like nitrogen, carbon, phosphorus and potassium, which are all important nutrients for plant growth. For a good fertilizer peat moss, wood chips, sawdust, chopped leaves or grass clippings are added to raise the carbon levels. It is good practice to keep this material close to the toilet and add some every time a deposit has been made. This makes for excellent compost and aids with the decomposition process.

The design of the composting toilet can be very simple or as technical as one would want. It all depends on how much time and money you want to spend making the toilet and what kinds of materials you have access to. The final location of the toilet should also to be taken into consideration when designing.

2.2.7.1 Owner Built

Most composting toilets out there are owner built. They require little maintenance and don't require transferring of material to a separate composting site if they aren't simply collection toilets. Home built systems tend to use low-temperature composting. Threw the addition of carbon based bulking agents after each use of toilet such as sawdust, hay, straw, weeds or most types of yard waste composting can be accomplished effectively and with little hassle.

2.2.7.2 Collection Toilet

The simplest type of composting toilet is a collection toilet and it is also the cheapest option. This is simply at toilet that empties into a tray, that you empty into a separate compost pile. This system is best for someone who doesn't mind emptying his or her toilet out every day and has a large area for compost pile. This is the most hands and needs to be watched over and properly maintained to reduce smell and insure proper composting.

2.2.7.3 Commercial Toilets

Commercial toilets tend to very expensive but effective. They can either use water or be waterless. Can use electricity or use none. Commercial composting toilets are ideal for urban homes that may not have a large area for a composting system. Moreover commercial toilets are good for people who have an environmental conscience but wish to "flush it and forget it".

2.2.8 Components of Composting Toilet System

The toilet hatch, compost chambers, and ventilation are the three main components that need to be considered when making a composting toilet.

2.2.8.1 Toilet Hatch

The first stage of a compost system is the toilet hatch. This is where the material is introduced to the chambers. Prior to it traveling to the chambers, the urine and feces has to be separated. A release hatch of some sort to separate to the two substances can do this. Moreover many designs include a funnel that re-directs the urine to a separate tank where it is processed separately.

2.2.8.2 Reason for different Chambers

Composting toilets systems work best when they include two chambers. The point of this is you fill up one chamber and then switch to use the other chamber while the first sits and composts. This results in shorter composting time due to smaller amount of volume and allows.

2.2.8.3 Ventilation

Ventilation is needed for two main reasons. Firstly air is needed in order for composting to occur due to it being an aerobic reaction. Without this the bacteria inside that are required for the process to matter would die. The second reason is to prevent a buildup of methane.

3 Search for Alternative Solutions

3.1 Introduction

In this section we brainstormed design possibilities for the composting toilet system. Then we researched and developed alternative designs and components of the toileting system, based on our brainstorming ideas.

3.2 Brainstorming

As a group we thought and talked about design possibilities. We found it much easier to discuss when we broke the toileting system into components we hoped to incorporate. See Figure 2 below.

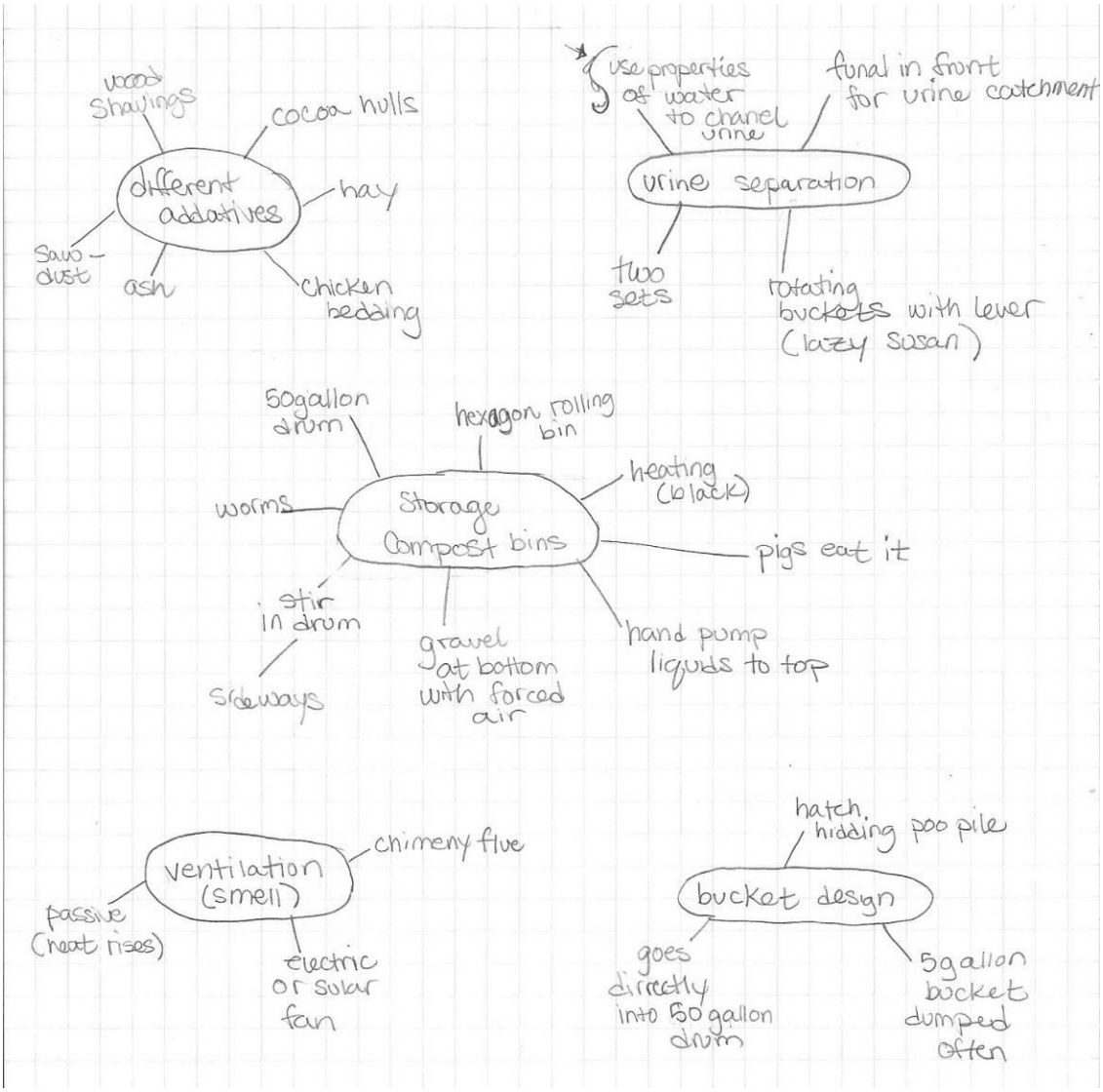


Figure 2 Brainstorming notes.

3.3 Alternative Solution - Design Components

The designs have been broken into components to provide a clearer explanation of alternative solutions for the composting toilet system. The components discussed in this section are methods for: Urine Separation, Compost Storage and Bin Designs, Additives, Ventilation, and Toilet Bowl Alternatives. Each design has a definition, and design criteria are addressed when applicable.

3.3.1 Urine Separation

Urine separation is a specified request of the client. Separating urine from feces is very beneficial in the process of composting humane manure. Urine, when diluted with water, can be applied directly to non-food plants. Removing urine leaves the remaining excreta drier, allowing remaining compostable material to be more aerated and reduces smell. Separating urine will also lowers volume of human manure to be dealt with, and the space needed for compost storage. (Joseph Jenkins & Wikipedia. "Composting toilet.")

3.3.1.1 Oil Sealant

The oil sealant can be used to help prevent excess smell of urine from the holding tank. Oil is less dense than urine so it sits on top of urine. Systems are designed to have urine pass through an oil barrier that sits on top of urine. Then the system uses gravity and the density properties of oil and urine to push the urine through the oil barrier and piping into the holding tank.

3.3.1.2 Toilet bowl with lip urine drain:

Regular toilet with inside toilet bowl containing raised lip around large hatch used to catch feces. Urine flows down curved slope, through a drain into a tube attached to a storage bucket.
Size: Toilet is shaped and looks like a regular toilet. The only additional size would be a small urine-holding tank located either behind the toilet or will be piped off to some different location.
Durability: The durability of the design depends on the material that the toilet is made of. Porcelain will be extremely durable and will have a very long life. Plastic will hold up, but will not last as long as porcelain. When cleaned regularly the tube connecting from the drain to the urine tank will last six months.
Ease of use: Is as easy to use as a toilet. It uses the existing idea and normal toilet concept. Females would only have to sit a little bit further on the seat to make sure the drain would collect the majority of the urine. Males will have to seat down to urinate to allow the urine to be separated.
Effectiveness: For best results regular cleaning is necessary.
Aesthetics: Looks like a regular toilet seat, with an added feature inside.
Smell: With regular cleaning and proper ventilation there should be no odor.
Safety: It is safe and user friendly because it works just like a toilet.
Educational Value: This design shows that composting toilets can be conventional looking and easy to use.

3.3.1.3 Two different systems, one for urine and one for feces:

This design uses two different toilets to separate urine more easily. One is used for feces collection and the other will be used solely for urine collection. The urine toilet will be a regular bowl but with a funnel at the bottom connecting to piping which flows into a holding container.
Size: The size of the design will almost double because there will be two toilet systems. The toilets will either be separated and free standing or will be connect and adjacent to each other on the same platform.
Durability: This system is very durable but can get clogged if not cleaned.

Ease of use: Having two toilets is a change in the way we use the bathroom but is only a few steps more than regular toileting systems. All that is involved is urinating in one system and dropping excreta into the other. The separation of the systems allows the urine to be diluted and then used in the garden right away. The feces cannot be used right away, it takes a year to compost and become safe compost to use in a garden. Having two toilets is more work than we are used to when it comes to using the bathroom; this design takes more care and restraint then regular toilets.
Effectiveness: Very effective if used and cleaned properly.
Aesthetics: This takes up more room than one toilet and you have to remember which toilet to use when.
Smell: Smell can very easily be removed by keeping some oil in the piping to insure block the urine smell coming back through the piping and toilet.
Safety: This system is completely safe with the toilet seats closed.
Educational Value: A very simple design, but makes composting toilets look large and bulky.

3.3.1.4 Andy Warren's urine separator:

The design that was constructed by Andy Warren uses a curved metal plate that uses the property of liquid's natural tendency to follow the contours of the surface that it's on. This empties into a tube, which is attached to a collection tank.
Size: The system cannot be installed below the surface of the ground; this system will have to be lifted up a little bit off the ground. To allow gravity to transfer into the drain that flows into the urine box.
Durability: So long as the metal plate is cleaned and corrosion is not allowed to happen this system will work until gravity stops working.
Ease of use: This design is as simple as a regular toilet. Sit down regularly and urinate and the metal plate works on its own. The only issue is men will have to sit down in order for it to work.
Effectiveness: The metal plate is very effective and drains urine naturally threw gravity.
Aesthetics: The outside of the system looks just like a regular toileting system. The only difference is the metal plate underneath the user.
Smell: Smell of urine can be present but can be reduced with cleaning.
Safety: With toilet seat lid down the system is completely safe.
Educational Value: This is a non-conventional design of separating urine, which uses a very clever process. Would educate on non-conventional ways to separate urine.

3.3.1.5 Water less Urinal (for men)

With the urinal design men would not have to sit down to urinate. The urinal works by having the urinal drain down into piping. From there it passes threw a sealing barrier of oil. The sealing barrier works because urine is denser than oil so the urine passes through the oil and the oil stays in the drain to prevent smell. Urine then goes through more piping into a holding tank.
Size: Having an additional toilet in the bathroom with increase the size of the system. The urinal can be mounted on a wall, which would reduce total floor space taken up.
Durability: With proper maintenance the urinal will not break and last six months.
Ease of use: The urinal will make it really easy for men to urinate and allow them to stand up and not have to sit down. They would still have to sit on the toilet to drop some excreta.

Effectiveness: The urinal helps with the separation and will allows less urine to possibly fall into the compost. This design allows the composting process to occur more quickly.
Aesthetics: Having a urinal in your bathroom may not be beautiful but they are extremely functional and men using the bathroom with enjoy using it more than sitting down to urinate.
Smell: The oil sealant keeps out all smell.
Safety: The urinal is safe, if someone falls in you would only have to shower after. Nothing harmful would happen to that person.
Educational Value: This design shows that waterless toilet can be as easy to use with only a little more clean up than a regular toilet.

3.3.1.6 Lever activated dual bucket rolling platform:

This design uses one toilet seat but two buckets underneath the toilet system to separate the urine. There will be a lever attached to a platform, underneath where the buckets are stored. The platform works like a lazy-susan, a round platter that can be rotated easily in a 360 degree circle. Pushing the lever in one direction would move the fecal bucket underneath you and pushing it the other way would move the urine bucket underneath you. The buckets would be positioned onto a moving platform located a foot beneath the toilet seat platform. The buckets would be regularly emptied threw a hatch on the side of the toilet platform. Figure 3, below, shows how the system would work.
Size: The size of this system would be large. The toilet seat would have to be mounted on top of a raised platform with enough room to house buckets on a moving platform
Durability: There are many components to this design that affect the entire system. If one little component breaks the whole design could stop working. To fix the system it would have to be totally taken apart because of its location underneath the platform.
Ease of use: This system would be easy to use but would involve more steps than the user would probably want to take in order to go to the restroom. Moreover the rolling platform underneath the toilet platform would be solely moved through the use of the lever which could be hard for some to use if the buckets were full underneath the user.
Effectiveness: This process would completely separate the urine from the feces. Making the composting process occur rapidly.
Aesthetics: It would be appealing to the eye because there is only one toilet. Though the raised large platform that one must sit on might seem like an eyesore, there would have to be steps to allow the user to comfortable sit on the toilet.
Smell: Smell would be very present due to the inside hull of the platform being exposed to air. With proper coverage, regular cleaning and good ventilation the smell could be reduced.
Safety: There are many problems that could occur making the system unsafe, the lever could get stuck and the buckets could become so heavy the lever would be hard to pull or push.
Educational Value: This is a very interesting design that would spark interest in people do to having to engage a lever.

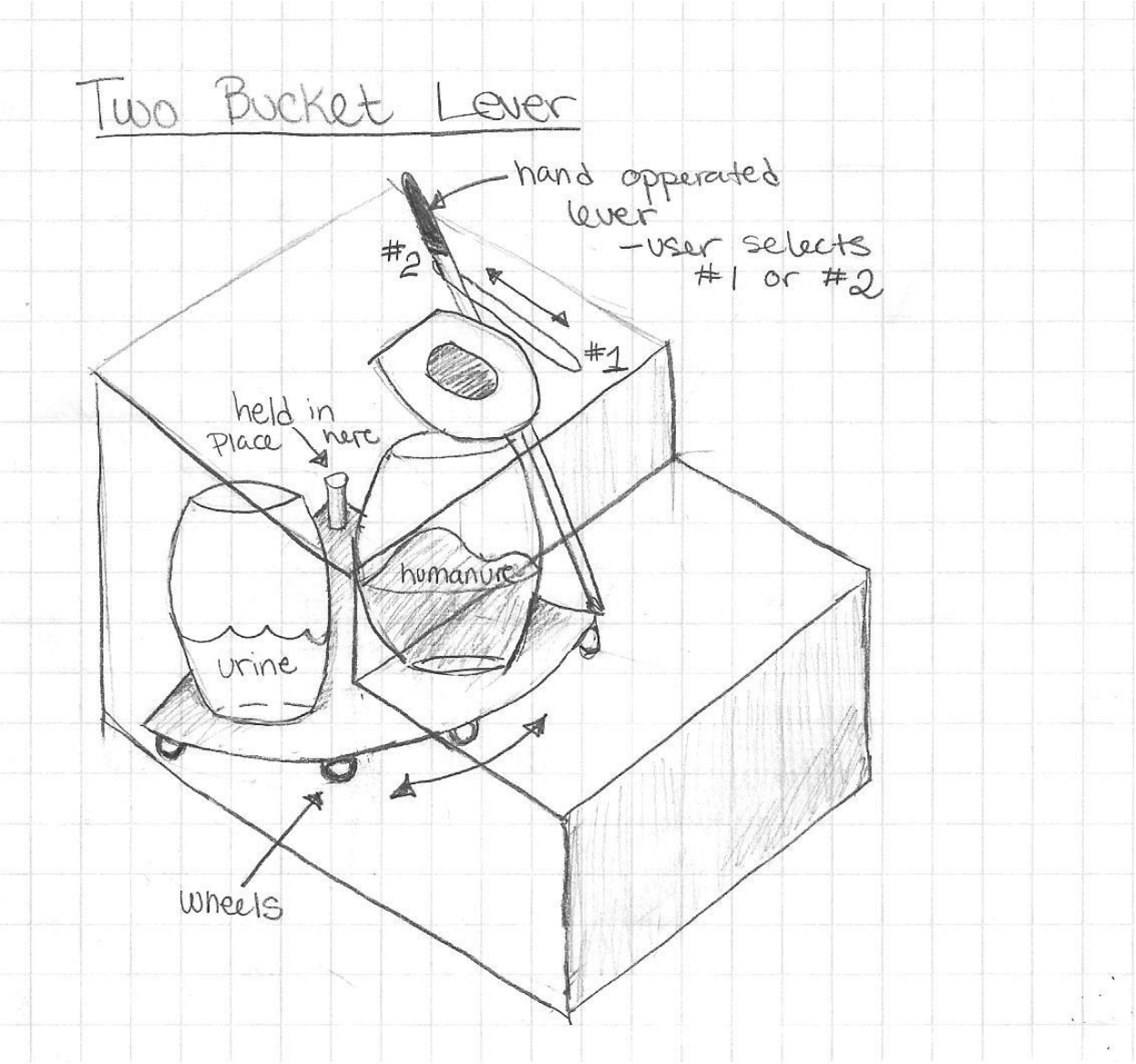


Figure 3 Two-barrel lever toilet system design. **Drawn by Jessica Jewett.**

3.3.2 Compost Storage and Bin Designs

Storage is a key design factor in the composting toilet system. The storage bins must be able to make compost within a year and with little maintenance costs. . Special concerns for these storage bins arise because they will be kept on a barge. The situation raises a concern with the leakage problem when composting in storage bins. On this barge the bins will not be able to be dug into the ground, which soaks up any leaks and liquids. The bins must be able to hold the amount of compost that accumulates in 6 months. (Helvi Heinonen-Tanski/ Christine Van Wijk-Sijbesma & David Omick)

3.3.2.1 Heating: Black painted barrels

The bins will be painted black to capture heat from the sun as a natural radiation. This radiation helps the compost get hot enough for the pathogens and some bacteria that are formed within humanure.
Cost: The barrels would need a cost or two of black spray paint. This could be purchased at any art or hardware supply store of $10 a can. Three to four barrels could be painted with one can.
Durability: The paint will last 5-6 years. It is waterproof and will last through rain, snow, and sunshine.
Ease of use: The paint is applied once before use in the toileting system. One to two coats will last five to six years. The paint will also withstand many harmful weather conditions: rain, snow, sunshine.
Effectiveness: The paint helps the composting process occur. The paint makes sure the bins get enough heat to allow the feces to become compost.
Aesthetics: The dark color makes the barrels hide well in the garden and/ or bushes. They allow you to have many barrels around and
Smell: The paint does not smell after it dries.
Safety: The paint does not harm any plants or animals.
Educational Value: The black paint is clearly visible to show spectators how the heat is sustained and captured from the sun.

3.3.2.2 Heating: Heated Floor

A floor built with heating panels across the whole thing. All the composting barrels will be heated from the bottom and this evaporates the liquid without drying the compost out. Uses a battery or power source.
Size: 6’ by 4’
Durability: Will last more than a year, unless some component gets broken or disconnected. The floor cannot withstand water or any kind of harsh weather. Needs to be taken care of and looked after, to make sure everything is working properly.
Ease of use: Runs all the time, the barrels just need to be placed on the flooring.
Effectiveness: The heating from the floor makes the composting process occur more rapidly. The heater makes the compost temperature rise without drying it out.
Aesthetics: The barrels would cover the flooring and the barrels would be painted black. The floor would have to be inside somewhere because of the weather and electrical components.
Smell: There should be no smell.
Safety: The electrical parts could be hazardous if they get wet or disconnected.
Educational Value: This would allow you to see the heat factor and how the heat affects the system. One barrel could be set off of it and that would allow you to see the difference between the two composting barrels.

3.3.2.3 55-gallon drum:

In this design a 55-gallon drum is used to store the feces for composting. The drums are painted black on the inside and outside this helps them retain more heat, which will aid in the composting. The drums are kept somewhere with good ventilation and since they will be heavy

when filled it is best to designate them an area. To prevent flies from getting into the barrel it is covered with netting, a bungee rope around the top of the barrel secures the netting down. To stop any rain water from getting into the barrel it is covered with a piece of corrugated plastic (Ex. Polycarbonate). This is easy to find and cheap they are usually used make a cover over decks. The reason for using the corrugated plastic instead of just putting a lid on the barrel is that air can flow in and out. The panels are secured down by placing any heavy object on them such as a brick. To help with the composting we will need to mix the contents of the barrel every few days. This can be done using a compost crank. The compost crank works like a screw when the handle is turned it digs into the pile then u lift without turning this brings up the wetter material from the bottom. This is repeated 3 or 4 times around each barrel. The crank will have a sleeve that it will slide in after use so no cleaning is involved. Figure4, below, is an example of what this design would look like.

Size: For the six-month period, there will be 6-8 55-gallon drums needed. A 55gallon drum is about 4 feet tall and 2 feet wide.

Durability: The drums are very durable.

Ease of use: This is a simple design and easy to use just dump the feces into the barrel, mix the material and cover.

Aesthetics: The barrels are not that nice to look at but can easily be disguised.

Smell: If the barrels are mixed regularly and kept well aerated it will not smell.

Safety: It is safe and user friendly.

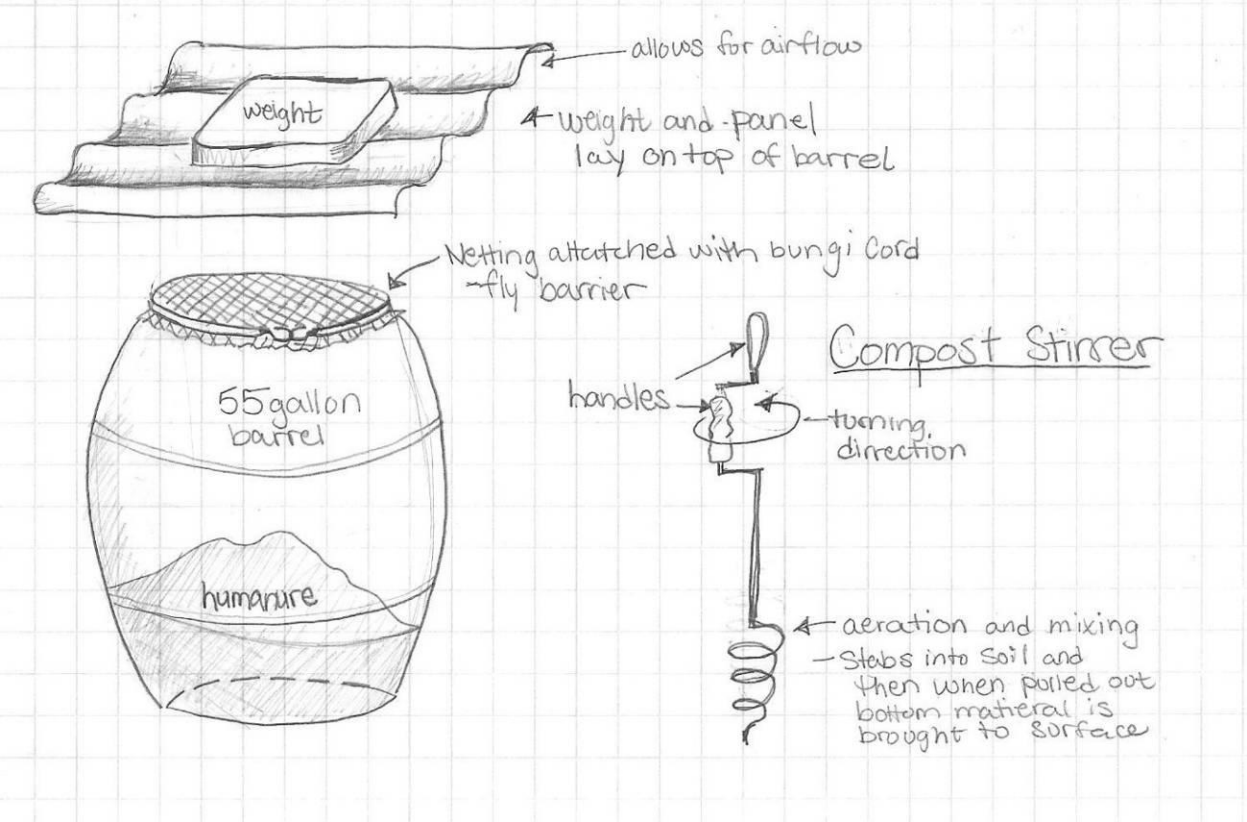


Figure 4 55-gallon barrel with aeration design, including stirring stick. **Drawn by Jessica Jewett.**

3.3.2.4 Hexagon Rolling Bin:

A rolling compost bin can be rolled around barge for easy mixing and aeration of the pile. The hexagon shape allows the bin to stay in place or be shifted on alternating sides.
Size: About 55gallons
Durability: Prefabricated tested and very durable.
Cost: From distributor would cost around $100-$200 each and would need at least 5 bins.
Ease of use: When full can become very difficult to roll
Effectiveness: Compost is mixed and aerated relatively easily and effectively. Tiny holes in the bin, for airflow, can be covered with screen but may allow liquid to leak onto the barge.
Aesthetics: Hexagon shape is interesting and the rolling design is innovative.
Smell: Low smell, contents are contained in bin.

3.3.2.5 Worm Bin:

Vermicomposting (worm composting) is a method of composting which does not require the thermophilic heat phase. There are two types of worms suited for composting; red worms (Eisenia foetida) and Lumbricus rubellus, (note nether of these species are dew-worms, large garden worms). To construct a worm bin hardware cloth (heavy metal mesh) is joined in a cylinder shape with wood supports along the sides. Hardware cloth will allow for good aeration while containing the contents inside. Worm bins should be kept in the shade, especially when composting humanure. Since the bin does not need to be heated, keeping it cool will reduce smell and the ideal temperature for worms is 40 – 80 degrees Fahrenheit, they also like damp bedding. The bottom 1/2ft – 1ft of the bin has a layer of dry material that allows for drainage (leaves, sticks woodchips, etc.) and worm breading. The sides of the bin are lined with sticks to insure good aeration and to hide contents of the bin. For the WaterPod worm bin design the bottom of the bin has a box lined with pond liner and filled with gravel. This is to insure proper drainage and to prevent liquid seepage onto the barge (normally a little excess liquid could letch into the ground.) This can also be supplemented with a hand pump to bring liquids back to the top. Included in the worm bin design is a lift able lid to prevent outside insects, reduce smell and to allow for easy bucket dumping.
Size: A worm bin for WaterPod would be rather large (volume = 153ft^3) with a radius of about 3.5ft and a height of 4ft, see worm bin figure bellow.
Durability: This design would be quite durable. The only concern would be when the bin was near full; the strength of the mesh and supports may be taxed.
Cost: The cost of the worm bin would be more than our budget, but hopefully many of the materials could be donated. Gravel and pond liner would be around $50, wood for supports and base $100, and the hardware cloth (need about 90ft^2) would be around $650.
Ease of use: This design requires some initial building and set up, but once constructed it would be very easy to use. Lift lid and dump. Figure 5, below, shows what this design would look like.
Effectiveness: This is a very natural and effective was to compost. The worms will transform the humanure into rich nutrient soil in 1 – 2 years. A concern may be the illumination of human pathogens. Since the compost does not go thru the extreme heat phase some pathogens may remain (for the most part the worms will take care of them). Due to this concern the worm bin might be left alone a longer period of time.

Aesthetics: The worm bin design would be very interesting visually. The lid can be lifted easily to view the compost in process. The design is symmetrical, large and contains all of the humanure in one pill.
Smell: This bin is dependent on having proper aeration; this can increase the possibility of smelling. The airflow thru the system may also help dilute the smell of the pill. The amount of humanize should be balanced by dry materials. Not allowing the system to get too hot will also help eliminate smell.
Safety: The only safety concern would be that all the pathogens might not be eliminated without extreme heat.
Educational Value: This is a very visually inviting design, which will attract attention and interest. The process and materials are easily viewed. Vericomposting can also be used for regular compost that may attract more people who are just interested in composting.

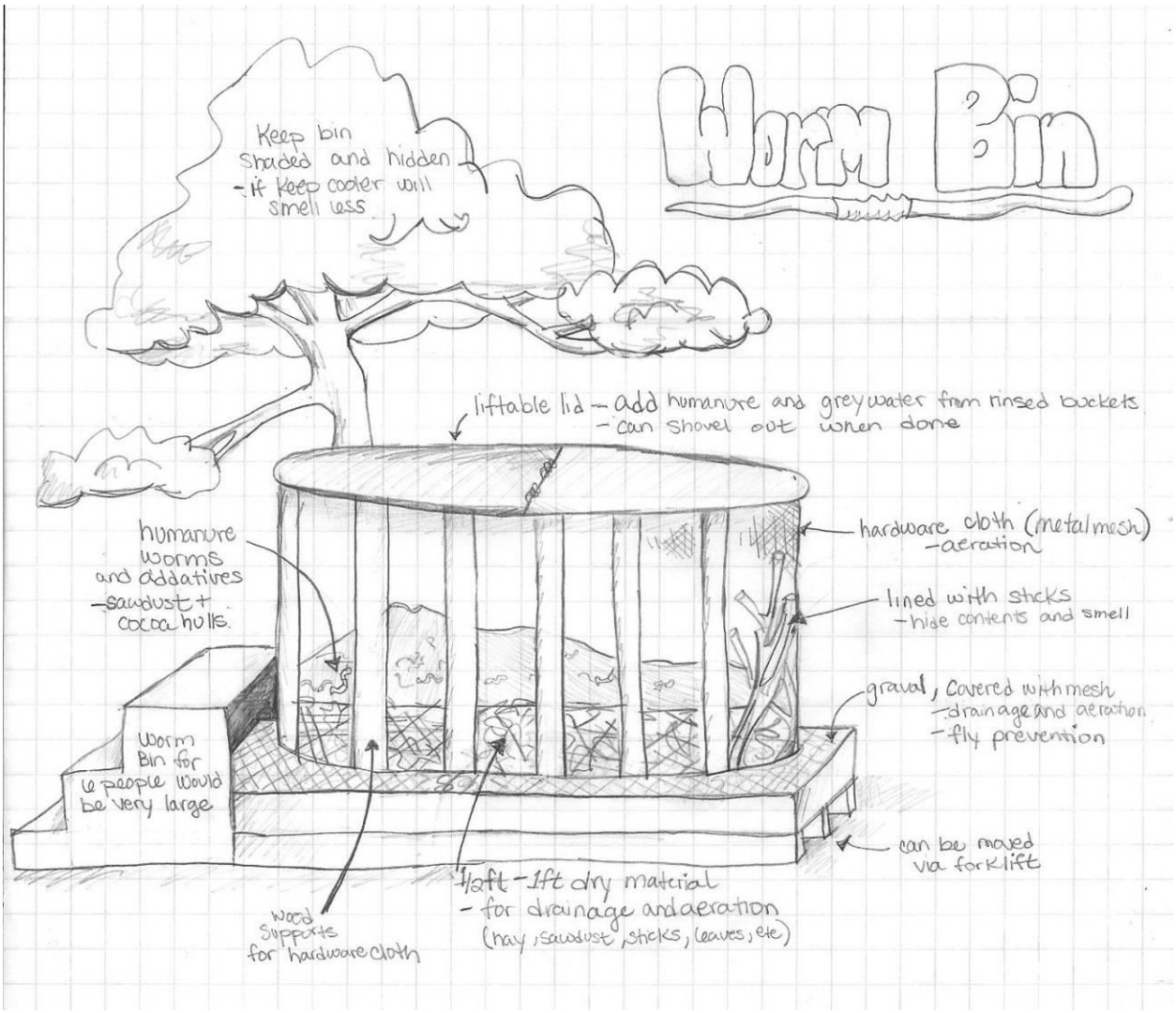


Figure 5 Composting **with worms, bin design. Drawn by Jessica Jewett**

3.3.3 Additives

After using the toilet a scope of dry material should be added. Additives provide aeration, aid in reducing smell, provide carbon, absorb water and are essential for the composting process. Most additives are the most effective when mixed with other additives because of the balance between absorption and aeration ("Home Composting", N.L Schouw/ S. Danteravanich/ H. Mosbaek/ J.C Tjell, & Joseph Jenkins).

3.3.3.1 Cocoa Hulls:

Cocoa hulls are the shell of the cocoa bean.
Size: Relatively large, woodchip like pieces.
Cost: Hopefully donated, put may be pricier than other options if not found in the area.
Effectiveness: Cocoa hulls decompose slowly and are favored by worms. Water flows thru the hulls easily. If mixed with sawdust the texture and water retention of the hulls can be increased
Aesthetics: Ruff shredded texture.
Smell: Chocolaty aroma ideal for covering humanure.

3.3.3.2 Sawdust:

Sawdust is a very fine grade byproduct of wood production. The dust produced after cutting wood with a saw.
Cost: Hopefully donated
Ease of use: Soft and easily scooped into or out of any container.
Effectiveness: Sawdust is so fine it may absorb and retain too much water not allowing for adequate aeration. Ideally sawdust would be mixed with a larger material.
Aesthetics:
Smell: Very absorptive and can efficiently cover excreta reducing smell. On the other hand it may reduce aeration that will cause the pill to smell later.

3.3.3.3 Hay:

Long tuberous thin sticks, used as bedding and feed in farming industry.
Cost: Hopefully donated, very cheep and easy to find otherwise.
Ease of use: Since hay comes in bails and is long fibers it would have to be broken down into smaller pieces to be effectively used as a scooped additive (if used by chickens first they may do this for you).
Effectiveness: Very good for aeration but not very absorbent.
Smell: Hay has a very distinct smell, which will add in reducing humanure sent.

3.3.3.4 Ash:

The byproduct of burning fibrous carbon based material.
Size: Very fine particles.
Cost: Hopefully donated, or ash from outdoor stove.
Ease of use: Particles are so fine they may become airborne and create unwanted dust. Easily scooped and forms to whatever container it's put in.

Effectiveness: High in minerals and very beneficial for composting.
Safety: Airborne particles can inter nose and mouth causing irritation.
Educational Value: Using recycled materials from outer design projects reinforces recycling awareness.

3.3.3.5 Chicken Bedding

Chicken bedding from the chicken pin on board. The bedding will probably consist of some ratio of sawdust, woodchips and newspaper.
Size: The variety of materials will vary in size
Cost: Donated and reused after chickens
Effectiveness: Chicken bedding may be damp and not be an effective dry cover for the humanure. It can also add more nutrient variety to the compost, and there is a possibility of adding unknown chicken pathogens.
Smell: There is some concern that the chicken bedding may smell like chickens and might not efficiently cover humanure smell.
Educational Value: Using waste materials from other group projects would be very educationally supportive of the recycling process.

3.3.4 Ventilation

A good ventilation system removes bad odors. Ventilation is important in speeding up the composting process. Having a good source of air means aerobic organisms will be breaking down the matter as suppose to the anaerobic organisms that will release gasses responsible for the bad odor. We are going to consider 3 different methods of ventilation for our design (Joseph Jenkins, Paul Calvert, Wikipedia “Composting Toilet” & Larry Walker).

3.3.4.1 Passive ventilation

There will be a ventilation pipe that starts in the area where the feces will be dropped; from there it goes straight up and out of the outhouse. Depending on the surrounding area and climate the pipe will either exit straight through the top otherwise angled out the sides or the back. The heat generated from the brake down of the feces will force the air to flow out of the vent pipe
Size: A 3-4 inch hole for the vent pipe to exit the outhouse and a 3-4 inch vent pipe that will be attached to one of the back corners.
Durability: As long as the workmanship is good and the materials purchased are durable this system will last for a long time.
Effectiveness: The drawback with passive venting is that we will be relying solely on the heat aspect to force the air out.
Aesthetics: This will not affect the aesthetics much; the only visible components will be the vent pipe.
Smell: This type of venting should have more than sufficient amount of airflow for there will not to be any bad odors.
Safety: It is safe and user friendly.

3.3.4.2 Electrical Fan

A fan that needs a power source would allow the ventilation to work better. The fan pulls the odor and hot air out of the bathroom. The fan needs a power source which would use more energy.
Size: A small fan, one that would be sufficient for this system will be around a 5Watt fan, a fan such as this can run on almost any electrical source such as batteries or a solar panel.
Durability: This design might be slightly less durable, since there will be electrical components.
Cost: This system can cost anywhere from $50 for a battery operated fan to $300 for a good solar panel operated fan.
Effectiveness: Electric fans are probably the most effective. They will work around the clock, independent of temperature or climate. They will allow for the most amount of air to flow through the system over a long period of time.
Aesthetics: This will not affect the aesthetics much, the only visible components will be the vent pipe and that could get covered if needed. If a solar panel is used it can make the system more educational.
Smell: This type of venting should have more than sufficient amount of airflow for there will not to be any bad odors.
Safety: It is safe and user friendly.
Educational Value: If solar panels are used to.

3.3.4.3 Chimney flue or cowl

A chimney flue or cowl is an attachment that is installed on top of a vent pipe. The purpose of the cowl is to divert any rainwater away from the vent pipe and it also aids in the flow of air out of the pipe. There are many different types of flues or cowls but for our purpose the best would be a rotating cowl.
Size: The same as the passive system with an additional of the cowl on top.
Durability: As long as the workmanship is good and the materials purchased are durable this system will last for a long time.
Cost: The price for these cowls varies but for our purposes one would cost $15 to $25.
Effectiveness: This is an effective method the spinning cowl will also spot rodents and insects from entering.
Smell: This type of venting should have more than sufficient amount of airflow for there will not to be any bad odors.
Safety: It is safe and user friendly.

3.3.5 Storage and Pump

Storage of the compost starts with the depositing of the excreta. It will be located under the toilet seat and the matter will be dropped inside along with the additives. The storage and composting will either take place in what it is dropped into, or will occur in a separate location (Joseph Jenkins, “The Compost Crank” & “Home Composting”).

3.3.5.1 5-gallon bucket

These small bins holding excreta and additives and start composting once full. Can either be added to a larger barrel or just start composting in the barrel.
Size: 5-gallon bin
Cost: $10 each bin. You need about 2 or 3 so they can be inter-changed. Plus about $20 to paint them black.
Durability: The material used would not break down. The barrels could be used for 3-5 years. They can withstand rain, sleet, and snow; the weather would not affect the barrel and the compost inside.
Ease of use: Once barrel is full, about a day or two, it needs to be moved to a 55-gallon drum or you will need many small barrels. Can be transported by just rolling it or carrying it to the 55-gallon barrel. Needs to be cleaned every couple weeks. Or whenever you feel is necessary. Doesn't need to be in a huge room, just accessible to be extracted.
Effectiveness: Works well, the additives and excrement at this point are composting. This could allow you to start composting but would need to be turned frequently.
Aesthetics: The barrels can be placed under the toilet and hidden by the frame. The black barrels will be easily hidden within the garden.
Smell: There should be no smell, once composting
Safety: Unless leakage occurs the bin should be completely safe.
Educational Value: You can show the process of the excrement before it starts composting. Allow you to see more processes to the composting system.

3.3.5.2 55-gallon barrel (drum)

The 55-gallon barrel would sit directly beneath the toilet. The barrel would sit there until it got full and needed to move after about a month.
Size: 23" in diameter and 35" in height
Cost: $20-30 for each barrel need about 6- 7. To paint all the barrels the price would be $30.
Durability: The material used would not break down. The barrels could be used for 3-5 years. They can withstand rain, sleet, and snow; the weather would not affect the barrel and the compost inside.
Ease of use: The barrel could be kept in one placed in the garden and just have additions every couple days. Needs to be looked at every time something is added, to make sure composting process is occurring.
Effectiveness: Allows the compost to work within itself without much interacting form the people. Works well, has a great surface area to volume ratio. Compost should be ready in one year.
Aesthetics: The barrels can be placed under the toilet and hidden by the frame. The black barrels will be easily hidden within the garden.
Smell: There should be no smell, once composting
Safety: There is no safety hazard.

Educational Value: Can explain the process well, but is harder to see the steps between the excreta and the compost since all of it is in one bin.

3.3.5.3 Hand pump:

A hand pump can be used with a barrel or a drum to siphon the liquids that will collect on the bottom and transfer it to the top. There will be a shelf on the bottom of the drum so that the material will sit on and any liquids will drain below the shelf. The pump will remove this liquid and dispense it over the top of the pile. This assists in the evaporation of the liquids and helps with the composting process. The pump will reduce the amount of odor by increasing the amount of oxygen that can get to the bottom of the pile.
Durability: The pumps are very durable.
Cost: The pumps can be purchased for about $35 from most hardware stores and even from eBay. The installation might me tough since it has to be removable without making a mess.
Ease of use: The use is easy but installation might be a little hard.
Effectiveness: The pump will be very effective it will help with aeration and helps evaporate excess liquid.
Smell: This will help in the reduction of odor.
Safety: It is safe and user friendly.

3.4 Alternative Solutions

This section describes eight alternative solutions for the design project. For reference to solution components see page numbers to far right.

3.4.1 Duchamp de Loo:

This design uses a platform system that the toilet seat is on and that is covering the entire system. This design looks and feels like a conventional toilet. The system uses a urine separator that will be located under the front half of the toilet seat. The bucket is located under the toilet seat and the urine diverter. This system is using the ash and chicken bedding for the additives. A cup of additives must be stirred into the composting bucket after every use. The urine diverter should be washed out every couple of days. This process is used like a conventional toilet except for the stirring and additives; these steps only take a few minutes of effort and are very simple to do. The design components are further discussed on the following pages and whole design is drawn in Figure 6 below.

Urine Separation	Urine separator with oil sealant	15, 16
Storage	20 gallon drums	19
Additives	Ash and chicken bedding	22, 23
Ventilation	Rotating Cowl	23
Bucket	20 gallon bucket	19

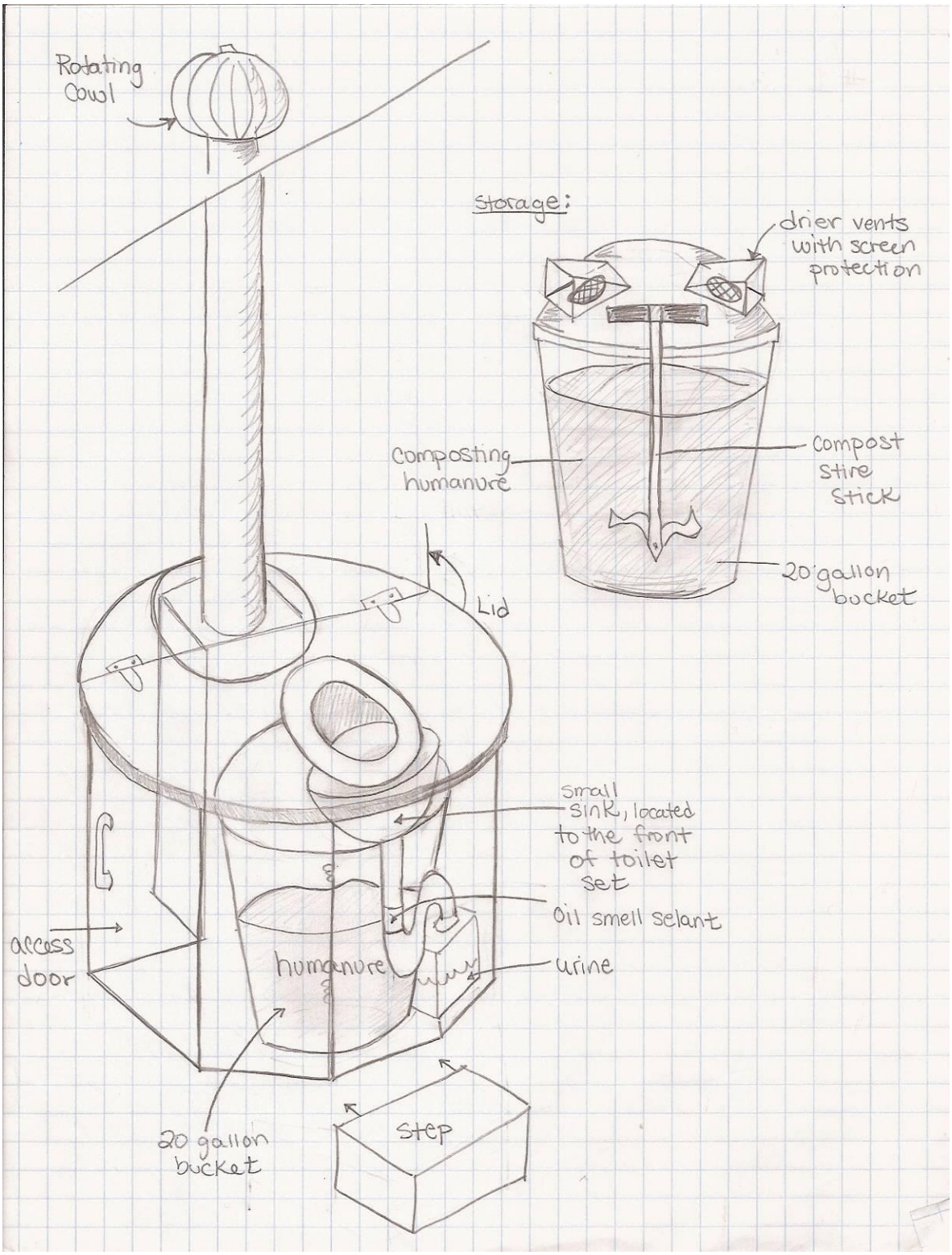


Figure 6 Duchamp de Loo Drawn by Jessica Jewett.

3.4.2 Down it goes:

This solution uses a frame to hide the whole composting and urine separation process. The frame allows the system to look and feel like a regular toilet. The solution uses a urine separator and a bucketing system. This allows the product to be use like a regular toileting system. The system only takes a few minutes longer to use that a regular toilet. The extra minutes come from putting the additives in and stirring the compost. The compost needs to be stirred occasionally, every few uses. The components of the design are discussed further on the following pages and whole design is drawn in Figure 7 below.

Urine Separation	Funnel	15, 16
Storage	55 gallon drum with pump	19
Additives	Ash and chicken Bedding	22, 23
Ventilation	Rotating cowl	23
Bucket	55 gallon bucket	19

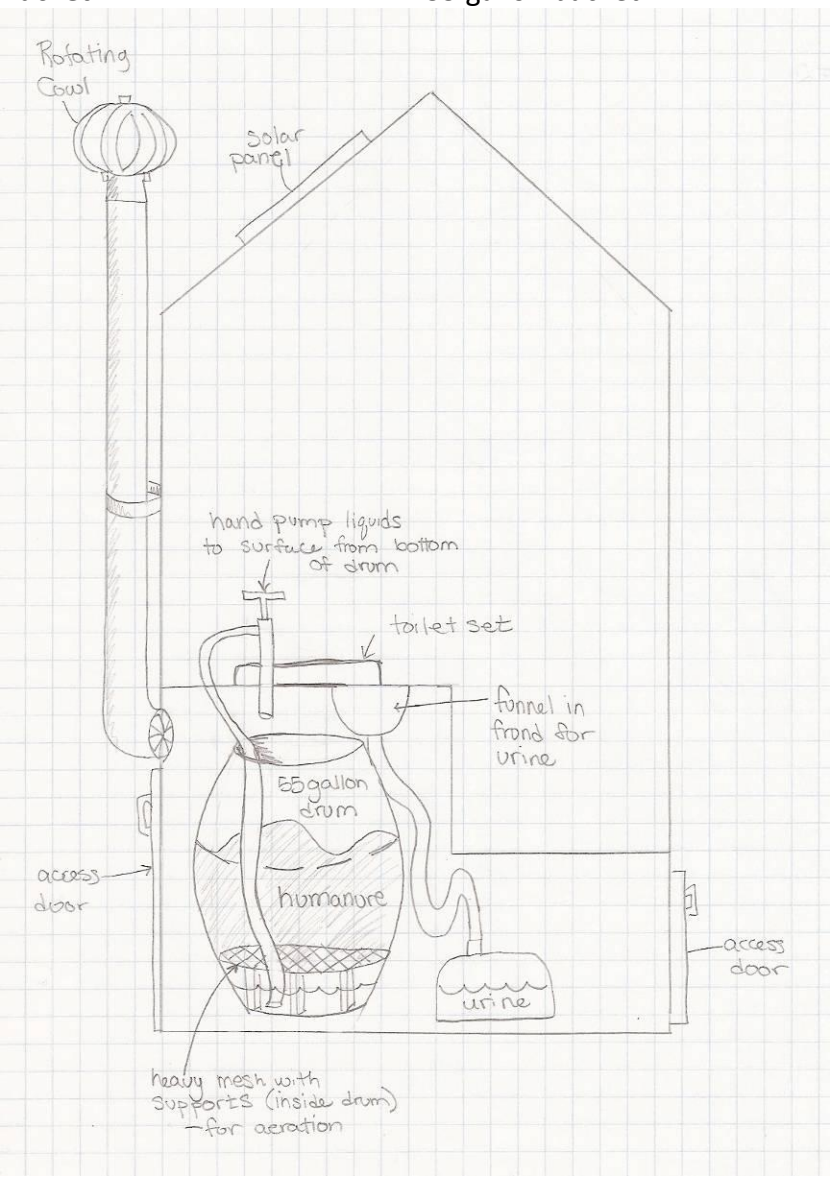


Figure 7 Down it goes, Drawn by Jessica Jewett.

3.4.3 Bowel Bowls:

This system uses a non-conventional urine separation system. This design would have two toilet seats next to each other. One toilet seat would be used for unloading excrement and the other would be used to urinate in. This would be a more difficult to use that any regular toilet. This system involves moving when you are still in the process of emptying your bowels. This design would take up more room because of the extra seat and the extra storage underneath. It would be bulky and have more maintenance issues. There would be more cleaning necessary and the dumping and storage of the buckets would be harder to deal with. The other components to this design are further discussed on the following pages and whole design is drawn in Figure 8 below.

Urine Separation	Two different toilets	15, 16
Storage	55 Gallon Drum	19
Additives	Hay and ash	22, 23
Ventilation	Passive	23
Bucket	2 x 5 gallon buckets	19

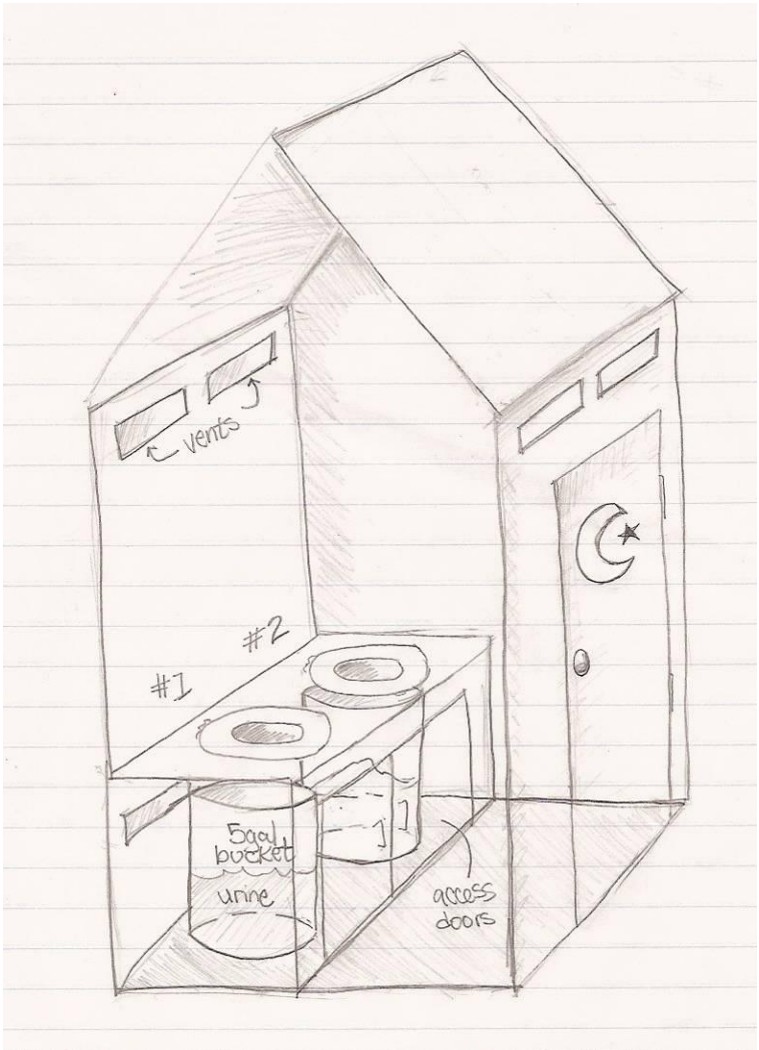


Figure 8 Bowel Bowls Drawn by Jessica Jewett.

3.4.4 Ashurnal:

This design uses a funnel and a urinal to separate the urine. The funnel is located underneath the toilet seat and above the composting bucket. This allows the men to be more comfortable when using this system. The design uses all the components to make sure the excreta will safely and easily turn into compost. The components of the design are described in greater detail on the following pages and whole design is drawn in Figure 9 below.

Urine Separation	Funnel and urinal	15, 16
Storage	55 Gallon Drum	19
Additives	Ash and Chicken Bedding	22, 23
Ventilation	Rotating Cowl	23
Bucket	5 gallon bucket	19

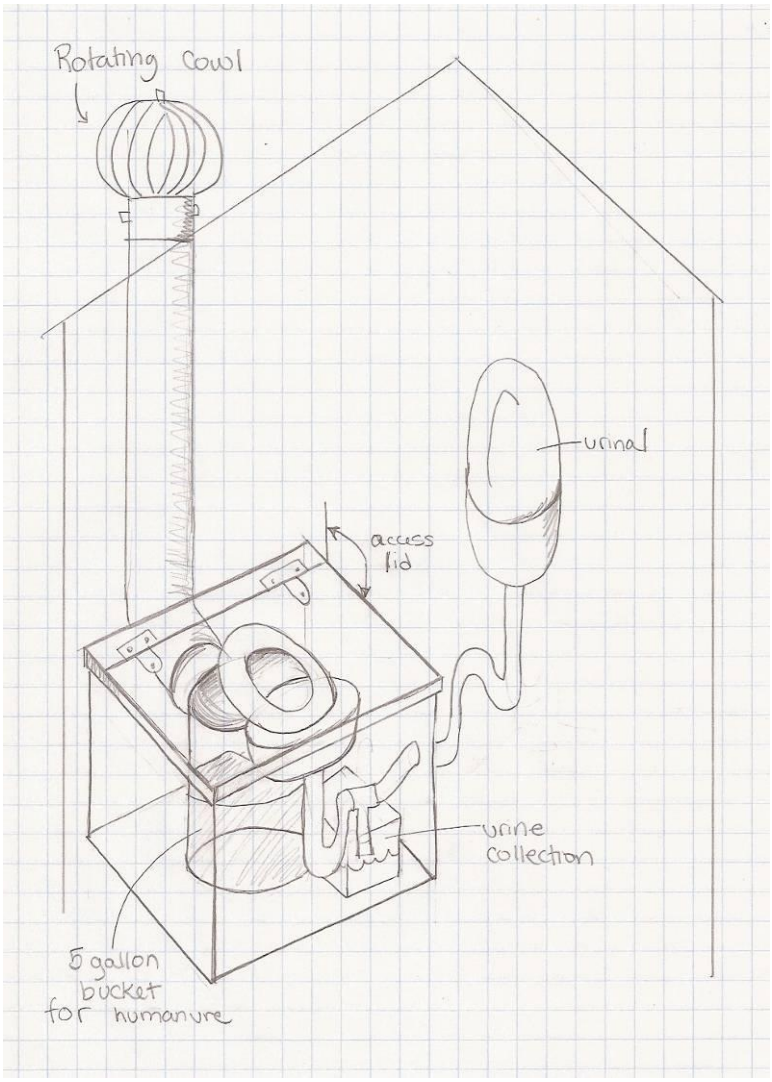


Figure 9 Ashurnal Drawn by Jessica Jewett.

3.4.5 Fountaine:

In the Fountaine system will have an Andy Warren style urine diverter and urinal for the men to use. The excreta will be dropped along with the additives into a 5 gallon bucket and will then be transferred to a 55 gallon drum where it will be composted. A rotating cowl will be put on top of the air vent and will be used to help assist the ventilation. For additives we will be using ash and the Chicken Coop Bedding. Components of design are discussed in the following pages and whole design is drawn in Figure 10 below.

Urine Separation	Andy Warren and urinal	15, 16
Storage	5 Gallon Drum	19
Additives	Ash and Chicken Bedding	22, 23
Ventilation	Rotating Cowl	23
Bucket	55 gallon bucket	19

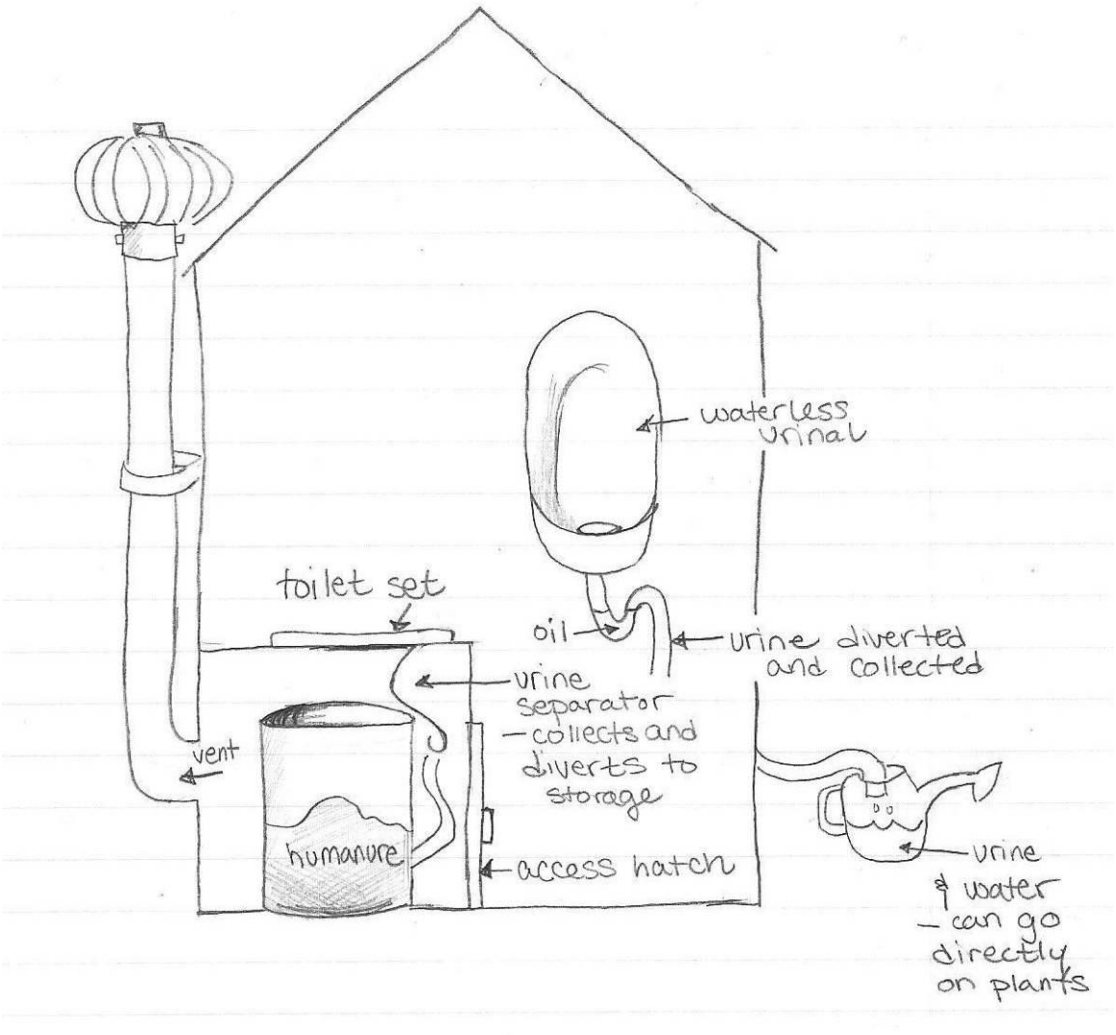


Figure 10 Fountaine Drawn by Jessica Jewett.

3.4.6 Roll Around Brown

The Roll Around Brown system will have for the urine separation, rotating buckets that use a hand powered lever to rotate the buckets into position. The excreta will be deposited into a 5 gallon bucket and then transferred into a Hexagon Storage bin. Located below the Hexagon Bin will be an Electric Floor Mat that will speed up the composting inside the bin. Ventilation will simply be passive threw the air vent and the additives will be Hay and the Chicken Coop bedding. Components of design are discussed in the following pages and whole design is drawn in Figure 11 below.

Urine Separation	Rotating Buckets, hand powered with lever	15, 16
Storage	Hexagon Bin	19
Additives	Hay and Chicken Bedding	22, 23
Ventilation	Passive	23
Bucket	5 gallon bucket	19
Additional heating	Electric floor mat	

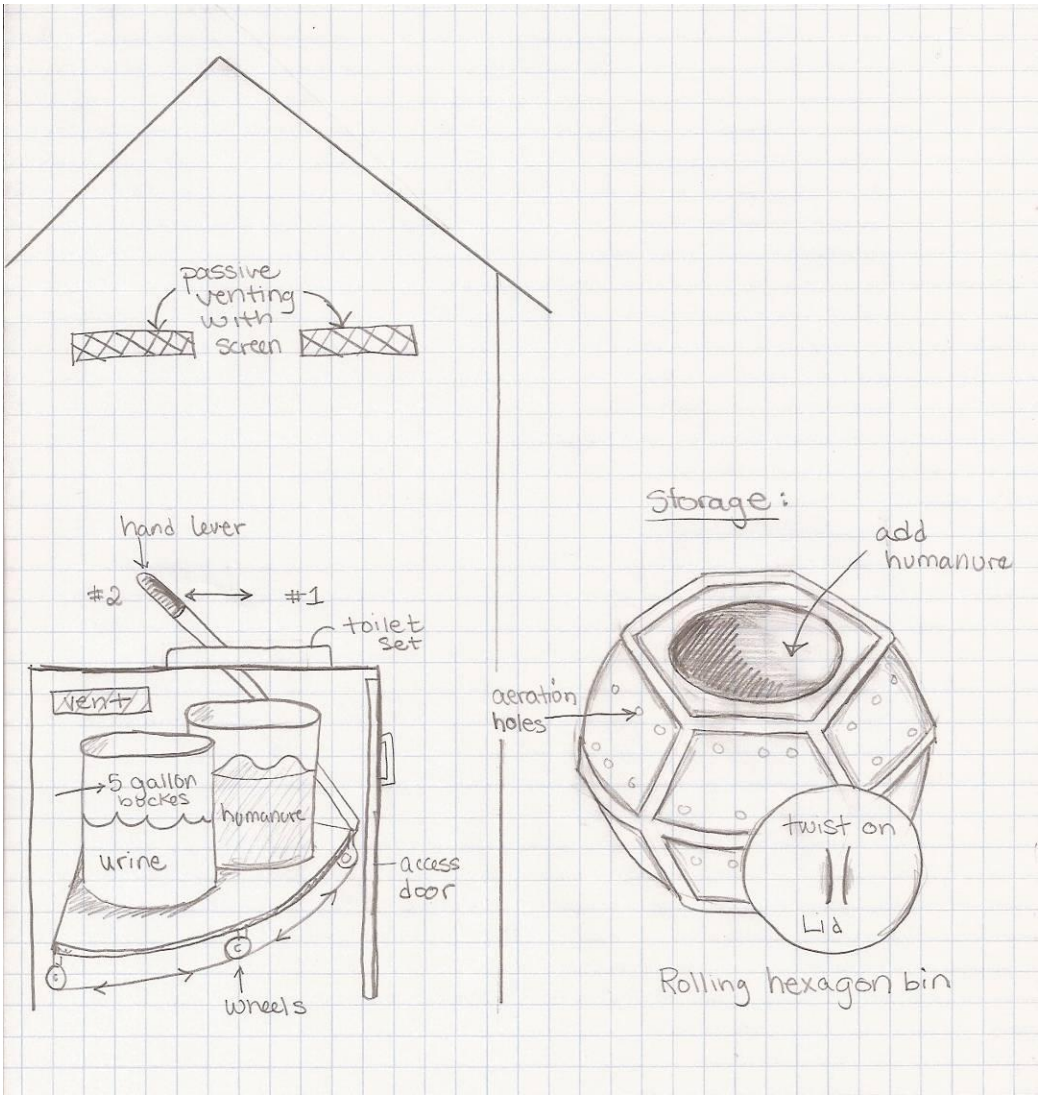


Figure 11 Roll Around Brown Drawn by Jessica Jewett.

3.4.7 Brown Apple:

The Brown Apple system uses for the urine separation a funnel located in front of the toilet seat to divert urine and it also incorporates a urinal for the men to use. The excreta will be deposited into a 5 gallon bucket and will then be moved to a Worm Bin which is where the composting will occur. The ventilation system will include both a solar fan to move most of the air threw and will also have a Turbine located on the top of the vent to help even more with the ventilation. Cocoa and Wood Shavings will be used as additives in this system. Components of design are discussed in the following pages and whole design is drawn in Figure 12 below.

Urine Separation	Funnel and Urinal	15, 16
Storage	Worm Bin	19
Additives	Cocoa and wood shavings	22, 23
Ventilation	Solar fan with wind directional vent cap	23
Bucket	5 gallon bucket	19

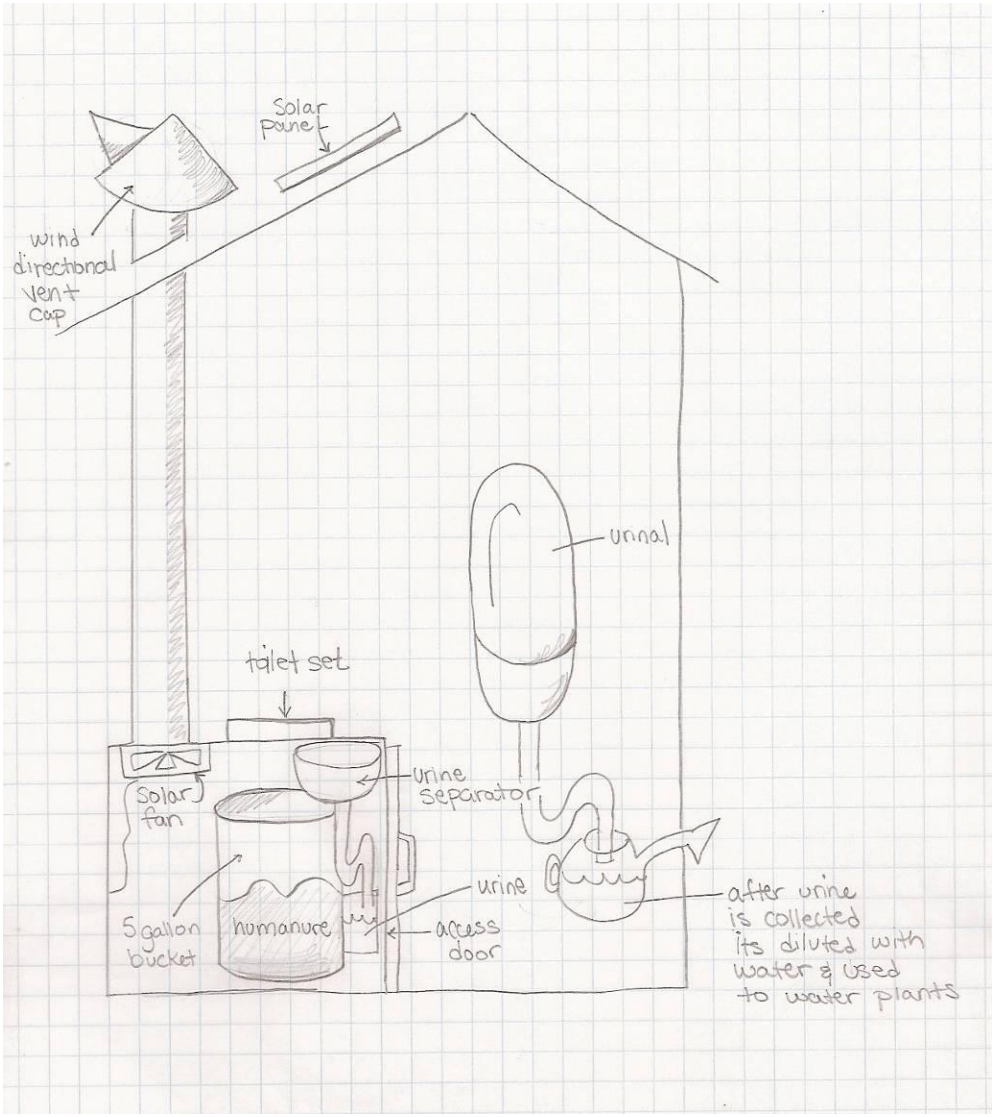


Figure 12 Brown Apple Drawn by Jessica Jewett.

3.4.8 Gotta Go:

In this system we used an Andy Warren design urine catchment system as well as a urinal for the men to use. The 55 gallon drum will be used as both the collection bin and the storage/ composting container. There will be a solar powered fan to help with the ventilation and the additives that will be used will be Cocoa and the Chicken Coop Bedding. Components of design are discussed in the following pages and whole design is drawn in Figure 13 below.

Urine Separation	Andy Warren and urinal	15, 16
Storage	55 gallon drum	19
Additives	Cocoa and Chicken	22, 23
Ventilation	Rotating cowl	23
Bucket	55 gallon drum	19

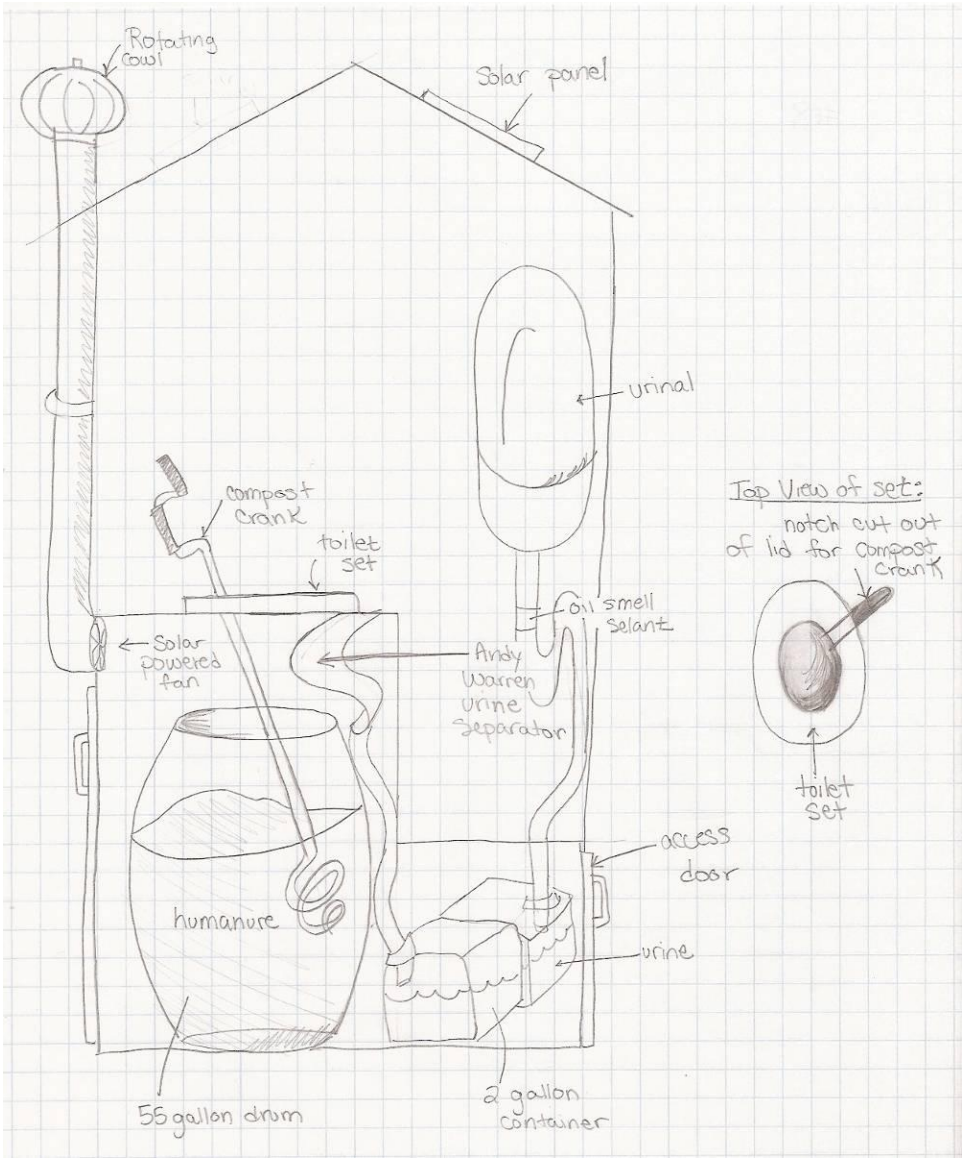


Figure 13 Gotta Go Drawn by Jessica Jewett.

4 Decision Phase

This section defines in detail the project criteria, lists the possible design solutions, describes the decision process, shows a Delphi box weighing all the criteria against the alternative solutions and presents the final design decision justification.

4.1 Criteria Definition

The criteria we used to decide which design to use is defined here. The criteria are based on client's needs, a toileting system's needs, and our budget. The design we chose best fit the criteria that we came up with.

4.1.1 Lowest Cost:

The cost of the final design is limited to $75 per team member, bring it to a $300 total. If the cost of the project exceeds this amount the client must be willing to provide for the difference. Ideally the client should not need to contribute to the project cost.

4.1.2 Shippability:

The entire Engr. 215 projects had a weight restraint of all projects weighing just under 200 lbs. This made it a huge factor to make the system as light as possible.

4.1.3 Durability:

The entire composting toilet system must have a life span that will exceed the length of the WaterPod voyage. As a group we will design a system that will much exceed the lifespan of the WaterPod.

4.1.4 Usability:

The ease of the client using the system will either make or break the system. The client should with ease, use the system and be able to clean the system with simple intuition.

4.1.5 Effectiveness:

How the system produces compost defines how good the system works. The toilet must work with little repairing and fulfills standards it states. The design that will be chosen will meet the WaterPod's request for urine separation to be used in watering plants.

4.1.6 Smell:

The smell of the system will determine whether the system is working or not. If the composting system is working properly smell should be very minimal. The amount and quality of additives will also affect the overall smell.

4.1.7 Aesthetics:

The system as a whole must look, feel and work well in order to receive public approval. People will not use a toilet that is not clean or looks clean and is also safe to use.

4.1.8 Safety:

The toilet design will dispose of potentially hazardous human pathogens. The toileting system will make sure no pathogens are spread when in use. The structure must also support the weight of the people using it. Moreover there will be no risk of users falling inside the toilet.

4.1.9 Educational value:

When the public views this toilet, they should be able to easily and quickly learn how the system works and why you should use it.

4.2 Solutions

Below are the eight alternative designs under consideration for the final design, as is described in Section III:

- Duchamp de Loo
- Down it goes
- Bowel Bowls
- Ashurnal
- Fountaine
- Roll Around Brown
- Brown Apple
- Gotta Go

4.3 Decision Process

To decide which design we would choose we each decided what we thought was most important in our criteria. The criteria allowed us to judge each design on how well all the components would work together. We all weighed the criteria on a 1 to 10 scale, 10 being the most important. Table 1 shows which criteria we thought were most important to the success

of our project. We based some things on availability because some components in our designs we could not obtain.

Criteria:	Ian	Jessica	Ramin	Megan	Average
Effectiveness	9	8	9	10	9
Ease of Use	8	9	8	7	8
Smell	7	8	7	10	8
Safety	8	9	9	6	8
Shipability	7	7	7	5	7
Cost	5	8	8	6	7
Durability	7	4	6	8	6
Aesthetics	5	5	4	7	5
Educational Value	6	5	5	4	5

Table 1 Criteria evaluation, made in Excel by Ramin Moazzami.

4.4 Final Decision Justification

The decision phase was based on the criteria the team found to be most important. This Delphi box, Table 2, allows us to weigh each criteria and then weight the entire criteria based upon those criteria. Each design criteria is based in a scale the team came up with. Each alternative solution is then compared with all the other designs using the criteria. Table 2, below, shows how each design weighed against the criteria. All the designs had different aspects that they weighed better against but in the end the Duchamp de Loo best fulfilled the criteria.

Criteria:	Weight	Ducha-mp de Loo	Down it goes	Bowel Bowls	Ashu-ral	Fountaine	Roll around Brown	Brown Apple	Gotta Go
Efficitveness	9	35 / 298	36 / 306	30 / 255	28 / 238	27 / 230	28 / 238	20 / 170	28 / 238
Ease of Use	8	37 / 296	38 / 304	30 / 240	30 / 240	28 / 224	32 / 256	28 / 224	28 / 224
Smell	8	33 / 264	34 / 272	27 / 216	26 / 208	25 / 200	27 / 216	24 / 192	32 / 256
Safety	8	38 / 285	38 / 285	35 / 263	36 / 270	38 / 285	38 / 285	33 / 248	32 / 240
Shipability	7	33 / 215	32 / 208	28 / 182	32 / 208	28 / 182	26 / 169	30 / 195	28 / 182
Cost	7	36 / 234	26 / 169	30 / 195	28 / 182	30 / 195	28 / 182	26 / 169	27 / 176
Durability	6	32 / 176	34 / 187	34 / 187	28 / 154	30 / 165	29 / 160	30 / 165	34 / 187
Aesthetics	5	36 / 180	36 / 180	34 / 170	30 / 150	34 / 170	28 / 140	28 / 140	30 / 150
Educational Value	5	37 / 185	35 / 175	31 / 155	30 / 150	32 / 160	34 / 170	32 / 160	30 / 150
Total		990	919	889	844	872	821	829	845

Table 2 Delphi Matrix Justification for final solution, made in Excel by Ramin Moazzami.

5 Specification of Solution

Section 5 describes all the components of the final design. View Figures 14-17 for multiple specifications of the design. Figure 18 depicts the components of the final design with labels describing where each component connects to the next. The cost of the design is divided into three parts. Design cost shows how much time the group spent on this design. Implementation cost describes all the materials used when constructing and designing. Maintenance cost states how much money will need to go into the design in the future. Section 5 also includes instructions on how to assemble and install the design.

Figure 14 Front view of toilet.
Taken by Ian McBride

Figure 15 Back view of frame with lid open
Taken by Ian McBride

Figure 16 Urine separation view from above.
Taken by Ian McBride

Figure 17 Composting humanure storage bin.
Taken by Ian McBride

5.1 Solution Description

Duchamp de Loo, is a composting toilet system that can be used and can educate people about environmental ways to get rid of human waste. The many features of the design include: the toilet seat, a urine catcher along with urine storage, the human manure bin, an additives bucket, a stirring stick, a ventilation system and access doors to allow you to retrieve your compost

The design is constructed to be as simple as possible but still be effective. Multiple different processes are involved when using the toilet system. There is the urine catchment system, the fecal matter catchment, the ventilation system and the composting system. The toilet part of the system is depicted below in Figure 18.

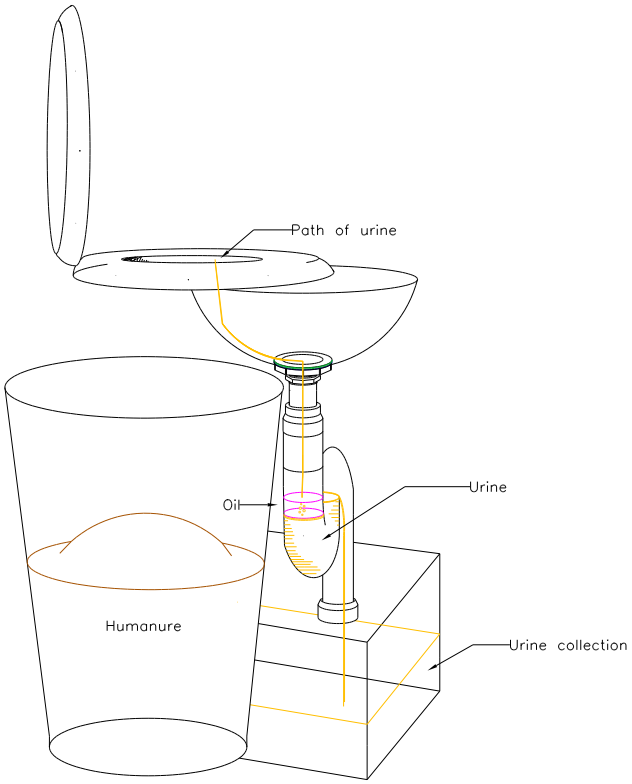


Figure 18 Final Design, made in AutoCAD by Jessica Jewett.

The urine catchment bowl is located towards the front of the seat to collect urine. Urine directed into the bowl where it flows down the piping. From there the urine passes through an oil barrier. The oil barrier works as a sealant keeping the smell of the urine trapped below the oil due to it being less dense than urine. The urine then travels into a urine storage tank. From there it can be diluted with water ratio of 10:1 and can be used as fertilizer for plants.

The fecal matter catchment is a composting bin that is located directly under the toilet seat. The composting bin will be filled with fecal matter and the dry additives that will added after every use. The dry additives that will be used will be the ash from the rocket stove, the Chicken Coop Bedding from the Chicken Coops and dry woodchips or sawdust that the barge may create. Once the composting bin is filled with material (which should take about 3 weeks) the composting bin will be removed from under the toilet and a new one will be put in its place. From there the bin will have the top of it installed and will be set in its designated location. The bins will need to sit for about 1 year in order for composting to be finished. Every three days

the composting storage bins will need to be stirred with the stir rod and the bin located under the toilet seat will need to be stirred every day

The ventilation system is a simple vent connecting to the storage area located under the toilet seat. The vent will start at the top of the toilet platform and will go straight up to the roof. At the top of the vent (located above the roof level) there will be a rotating cowl to provide moving air flow. At the bottom of the vent the client will have an option of installing a solar fan to further prevent smell if rotating cowl doesn't provide enough ventilation power.

5.2 Cost

The cost of this project is divided into three categories: design, implementation and maintenance cost.

5.2.1 Design Cost

Figure 19 is the total number of hours spent on each phase of the Design Project for the entire design team. Overall 133 hours were been spent on the project.

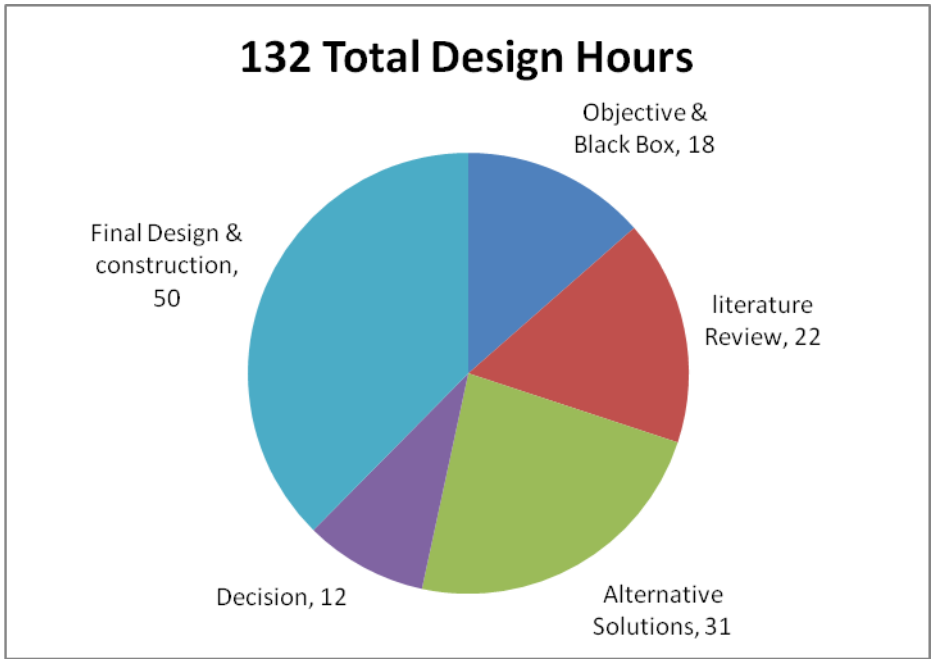


Figure 19 Design Hours Pie Chart, made in Excel by Ramin Moazzami.

5.2.2 Implementation Cost

The estimated total cost for the project is about $146-158. Below is Table 3 of the average cost per item and what we got donated.

Materials	Use	Amount	Cost
8'x6' Ply Wood	Frame for toilet set	2	$15.00
2x4 Wood	Frame for toilet set	4	$20.00
Toilet seat	To sit on	1	Donated
funnel	Urine separator	1	$3.00
Wood stain/Clear coat (1/2 gallon can)	To water seal ply wood	1	$5.00
Air vent	To vent odors	6	$35.00
6 inch Ventilation pipe	To vent compost to roof	6 feet	$5.00
Rubbermaid tube 20-gallon	To hold feces while composting	1	$8.00-$20.00
5 gallon bucket	To hold additives	1	$5.00
2 gallon plastic gas can	To hold urine	1	Donated
Drain catch	To minimize odor of urine on urinal	1	Donated
Drain	To drain urinal	1	$6.00
PVC pipe	For urine diversion from urinal and urine separator	10 feet	Donated
Pipe cement primer	To prep pvc pipe	1	$3.00
Pipe cement	To bond pvc pipe	1	$3.00
PVC joints	For urine diversion	5	$3.00
Miscellaneous plumbing supplies	For urinal hock-up		$20.00
Compost crank	Aeration and mixing of Humanure.	1	$5.00
Screen	To prevent bugs from entering for storage lid and vents	8 feet	$10.00
Total Cost			$146-158

Table 3 Cost of materials, made in excel by Ramin Moazzami.

5.2.3 Maintenance cost

The maintenance cost is very low. All that is required is diluting the urine with water before you use it as a fertilizer and the cost of the cover material. Water will be obtained from the barges excess water supply. The cover material can be obtained at relatively no cost and will utilize the chicken coop bedding waste and the ash from the rocket stove.

5.3 Implementation Instruction

Maintaining and building a composting toilet requires a series of different but easy tasks. They go as followed.

1. Building the Duchamp de Loo
2. Going to the restroom
3. Adding additives

4. Stirring the bins
5. Removing Bins
6. Maintaining the system
7. Cleaning the system
8. Checking compost at the end

These instructions are discussed in detail in Appendix II, Section 6.2: Duchamp de Loo Instructions.

5.4 Prototype Performance

Final construction on Duchamp de Loo was completed on May 3, 2009. Tested components of Duchamp de Loo, include; the frame, the urine catchment system and the oil sealant smell prevention feature. The composting process of humanure could not be tested due to project time constraints. The frame of the toilet easily supports the weight of 250plus lbs. The lid and side access door function correctly as well, moving easily on their hinges. The urine catchment system, which requires the user to sit slightly forward on the toilet during urination, covers approximately 1/3 of the front of the toilet set hole. This placement is based on averaging personal team member urination path streams, using toilet set covers. The oil sealant smell prevention feature of the toileting system was the last component to be tested. When oil is placed in the drain catch as specified, when a moderate flow of water (from the tap) is added it passes thru the oil and out the other end, oil free, as desired. Oil does not cross over to the outflow side of the drain catch unless water is added to the system at a much faster and higher pressure than would ever be produced by urination. Smell prevention was tested by substituting a strong smelling tea instead of water, in this case the smell of the tea was significantly reduced when blocked by oil

6 Appendices

6.1 Appendix I

Abrahamsson, Flemming. Mikroben: The composting toilet an ecologically responsible solution. Renewable Energy, (1997). http://www.deatech.com/natural/waste/toilet.html (Feb 24, 2009).

"Appalachia - Science in the Public Interest." ASPI Publications, (1990). http://www.a-spi.org/tp/tp2.htm, (Feb. 23, 2009)

Beckmann, Curt. "Composting Toilets." (2008). http://www.appropedia.org/Composting_toilets (Feb 23, 2009)

Calvert, Paul. "Compost toilet." (2007). www.practicalaction.org/docs/technical_information_service/compost_toilets.pdf (Feb. 23, 2009).

"Campus Greening with 17 million students." Bio Cycle 49.1 (2008): 10-12.

"The compost crank." Lotech Products. (2001). www.lotechproducts.com (Feb. 23, 2009).

Heinonen-Tanski, Helvi. Van Wijk-Sijbesma, Christine. "Human excreta for plan production." Bioresource Technology 1.96 (2005): 403-411.

"Home Composting."California Integrated Waste Management Board. (1995). http://www.ciwmb.ca.gov/organics/Homecompost/(Feb 23, 2009).

Jenkins , Joseph. The Humanure Handbook: A Guide to Composting Human Manure. (2005).
Polprasert , Chongrak . Organic Waste Recycling Technology and Management. John Wiley and Sons. West Sussex, England. (1996): 17-67.

Schouw, N.L., Danteravanich, S., Mosbaek, H., & Tjell, J.C.. "Composition of human excreta-a case study from South Thailand." The Science of the Total Environment 1.286 (2002): 155-166.

Obeng, Letita A., and Wright, Frederick W.. The Co-composting of Domestic Solid and Human Waste. The World Bank. Washition D.C., (1987): 1-24.

Omick, David. "Living Outside the Box: Composting Toilets." (2007). http://www.omick.net/composting_toilets/composting_toilets.htm(Feb. 23, 2009).

Polprasert, & Chongrak. "Organic Waste Recycling Technology and management." John Wiley & Sons Ltd. Sussex, England. (1197).http://www.compostingtoilet.org/ (Feb 23, 2009).

Walker, Dr. Larry. “The Science and Engineering of Composting.”Cornell Waste Management. (1997). Institute,http://compost.css.cornell.edu/science.html(Feb 23, 2009).

Wikipedia. “Composting toilet.” (2007). http://en.wikipedia.org/wiki/Composting_toilet (Feb 24, 2009).

Zavala, Miguel Angel Lopez., Funamizu ,Naoyuki., & Takakuwa, Testsuo.”Modeling of aerobic biodegration of feces using sawdust as a matrix.” Water Research 1.38 (2004): 1327-1339.

6.2 Appendix II

Duchamp de Loo Instructions

These instructions will show you how to construct use and maintain the Duchamp de Loo. We have split the instructions into sections to allow you to be able to use this design as quickly and easily as possible.

6.2.1 Building the Composting Toilet System

Instructions on how to assemble the frame, oil sealant, and compost storage lid.

6.2.1.1 Frame assembly

Instructions on how to assemble frame of Duchamp de Loo.

- Place the larger back piece labeled a vertically.
- Bolt piece marked B to the indicated back piece holes.
- Bolt the other side(the right side) of piece B to Piece C.
- Bolt part D to part C (left side of D to the Right side of C)
- Once frame bolts are fully tightened attach hinges of piece E to piece A.
- Attach small metal bracket (labeled left and right in relation to standing facing the front of the frame, bend go inward) to the notched space on the back side of piece D, line up bolt holes.
- Place bin inside frame, centered and back.
- After frame is placed in desired position, drop sink bolts into drilled holes in metal bracket at front of frame
- Twist on the drain catch part labeled F to the sink pipe.
- Secure piping end to gas can located on desired side (recommended placement on opposite side of access door).
- Clip splash guard to bin and position around sink.
- Attach hinges of lid to drilled holes in piece A
- Place smaller circle piece G, with vent in empty circle area. Pencil marks specify proper alignment. When lined up attach with provided white topped screws in predrilled holes.
- Attach ventilation system to roof.

6.2.1.2 Oil sealant set up

Instructions on how to set up urine oil sealant feature.

- Poor water into urine catchment sink until it starts to come out into the collection can.
- Add 2/3 cup of vegetable oil and a few drops of a strong scented essential oil if desired. Note: when oil is added more water should drain into collection can.

Oil should not need to be added again unless; cleaning whole system, the smell is not being blocked anymore, or to refresh essential oil scent. If water is dumped into the drain catch too rapidly (not normal urination speed) the oil system may be disrupted and need to be redone.

6.2.1.3 Compost storage lid assembly

Instructions on how to assemble/make compost storage bin lid.

- Acquire two drier vents and a 20 gallon Rubbermaid bin.
- Remove top part of vent and discard (recycle) the rest
- Cut two holes in the lid as seen on shipped example bin
- Glue screen over the holes on the vent (using liquid nails for example)
- Drill small holes for bolts in the sides of the vent and around drilled holes on the bin lid.
  Attach vent with bolts and glue if desired (using liquid nails for example)

See shipped example bin lid for clarification. To prevent flies and other insects from entering the bin it is important to seal the vent as airtight as possible,

6.2.2 Going to the Restroom

Using the restroom with the Duchamp de Loo is almost the same to using a conventional toilet.

- Sit down.
- If you are urinating you should sit a little closer to the front of the system. The urine collection bowl is located underneath the front half of the toilet seat.
- If you are excreting feces you should sit a little farther back to make sure no feces falls into the urine collection bowl. The compost bucket is located underneath the toilet seat and the urine collection bowl.
- After going to the bathroom you will wipe and clean yourself normally. Toilet paper can go into the system.
- Add a cup of cover material to the bin; the bucket should have even amount of feces and cover material.
- Shut toilet seat when finished. This minimizes the odor because it can't travel back up through the toileting system.
- Wash hands.

6.2.3 Adding Additives

Mae sure to keep the bucket containing the cover material (Additives) is normally full. This is important because the cover material helps to dry out the excreta, adds carbon. This cover material keeps the smell from rising back up the system.

- Add a cup after each use; the compost should be equal parts dry matter to fecal matter.
- Scoop matter and dump on top of fecal matter.

The additives that can be used include the ash from the rocket stove and the old chicken coop bedding from the chicken coops. Wood chips or sawdust if located or donated to WaterPod can be used as an additional additive for the system.

6.2.4 Stirring the Compost Bin

Stirring the bins must be done frequently:

- The bin located under the toilet seat must be stirred every day. The stirring stick
- The composting bins that are waiting to turn into compost must be stirred every 3 days.

6.2.5 Removing Bins

Once the collection bins have filled up you need to remove them and store them.

6.2.5.1 Urine bin

Below are the steps for emptying out the urine collection bin, this must be done daily.

- Open up access door or top lid.
- Locate tank to the side of compost bin.
- Un-hook piping from collection tank.
- Screw on nozzle to tank.
- Dilute urine with 10-1 ratio of water to urine.
- Mixture is ready to be used as fertilizer for plants.

6.2.5.2 Compost Bin

Below are steps to removing the composting bin, this will become full every 3 to 4 weeks.

- Remove the bin threw the access door or the top lid door.
- Replace the full compost bin with an empty bin to re-connect system.
- Position full bin in desired composting zone, and place the lid on the bin.
    - The lid has two dryer vents installed on top of the lid.
    - They have screens installed to prevent bugs from getting inside.

- Screens located on top vents should be closed when it is raining and left open when it is not.

6.2.6 Maintaining

In order to keep Duchamp de Loo functioning properly; all parts of the system must be properly maintained. The system will take up to 15 minutes each day to properly maintain it.

- Stirring the compost collection bucket located under the toilet seat. The stirring stick will be located on the side of the toilet. Just stab the stick into the compost and turn it a few times, this allows aeration in the pile which speeds up the composting process.
- Rinsing out the urine catchment bowl with water, a quick rinse to remove urine residue and excess smell. The water must be poured like slowly into it, as if you were urinating. The oil would have to be replaced if the water is dumped down the pipes too quickly.
- Diluting the urine bin, this will be done daily. The urine must be diluted with a 10 to 1 ratio of water to urine for it to be safe as a fertilizer for many plants.
- Cleaning of fecal spray guard (laminate shield located around bin to prevent fecal spray from coating inside of the system shell). This may involve scrubbing guard with bio-degradable soap and with minimal water.

6.2.7 Cleaning

The system can be cleaned to the user's liking but we suggest you clean it daily for optimal cleanliness.

- The toilet top needs to be wiped off.
- The toilet seat should be wiped off.
- The fecal spray guard could be wiped off.
- The urine bin should be diluted and emptied on to non-food plants.

6.2.8 Checking Compost at the End

With proper aeration, drying and mixing compost can take between 10-12 months to be complete. The compost should be dark and rich, it should smell earthy.