EVALUATION AND DESIGN OF A DECENTRALIZED ALTERNATIVE TO CONVENTIONAL WASTEWATER INFRASTRUCTURE IN CUBA

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INTRODUCTION

Water is essential to all known forms of life. It is fundamental as a solvent for all the major components of cells, is essential to metabolic processes, and is required for photosynthesis. The importance of water however, is often overlooked. As Rachel Carson wrote in her 1962 work, *Silent Spring*, "In an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of his indifference." Water thus, the solvent of proteins and DNA in our bodies, also functions as the modern-day solution to domestic waste, serving as solvent and transporter to such wastes.

The use of water as a conveyor of domestic waste dates back to antiquity. The great Roman sewer was constructed to drain the Roman Forum. Though its function was largely to carry away stormwater, the sewer also flushed away waste from public toilets, bathhouses, and other public buildings. Up until the middle of the nineteenth century little changed in the handling of domestic waste. Sewers were largely used for handling stormwater and pit toilets for collecting human excrement (Fair and Geyer 1954). Three worldwide cholera outbreaks served as the impetus for change and the launch of sanitary engineering. Cholera outbreaks in London and Newcastle killed over 10,000 people in 1853 alone. It was not until 1883 that Pasteur and Cook discovered the causative organism of cholera, establishing the link between fecal contamination of water due to poor sanitation and cholera (Hoffbuhr 2006). The technological shift was the discharge of domestic waste into combined sewers, which conveyed domestic waste and stormwater away from dense population centers to nearby waterways. This system relied largely on dilution of contaminants and improved drinking water treatment technologies of filtration and chlorination. The innovation proved successful at dramatically decreasing the death toll associated with waterborne diseases (Viessman and Hammer 2005).

As the science surrounding wastewater continued to advance, new contaminants periodically emerged. But subsequent advances regarding the management of domestic waste was always built on the late-19th century solution of using water to carry pollutants away. Initially sewers simply discharged their flows downstream, untreated, until the public health and environmental evidence against such practices surfaced. By the 1960s treatment of wastewaters prior to discharge became

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more prevalent. Plants were first designed to deal with biochemical oxygen demand and suspended solids. Later pathogens, followed by nutrients such as nitrogen and phosphorus were found to be problematic for public health and the environment, spurring on expansion of existing wastewater treatment plants. Most recently, pharmaceuticals and endocrine-disrupting compounds have taken on the label of emerging contaminants (Viessman and Hammer 2005). Thus, the modern day approach of handling domestic waste has followed a reactionary approach. This paper subscribes to a new approach which removes water from the equation. If the water is never contaminated, then contaminants need never be removed from water through costly treatment processes. This paper presents compost toilets as an advantageous and cost-effective solution that is especially suitable for Cuba, where studies have shown that the wastewater infrastructure requires significant investments.

CURRENT STATE OF CUBA'S WASTEWATER INFRASTRUCTURE

Of Cuba's 11.2 million inhabitants, 94% are reported to have access to wastewater collection systems. However, as of 2007 it was estimated that only 4% of the wastewater collected received any sort of treatment (Cueto and De Leon 2010). Untreated wastewater discharge is a major public health and environmental issue, not only in Cuba, but in the rest of the Caribbean, where over 70% of domestic wastewater is discharged untreated into the sea. This issue is recognized by the Cuban government, which in 2009 collaborated with the United Nations Environment Programme to host wastewater experts and discuss plans for reducing pollution attributed to untreated wastewater discharge (Corbin 2009).

Cuba's wastewater treatment deficiencies stem from a lack of infrastructure maintenance and investment. Many of the wastewater systems in operation today were designed for a much smaller population. The City of Havana's central network was constructed over 80 years ago with plans of servicing 600,000 people. Currently, this system services approximately 950,000 residents. Because of the inability to efficiently process wastewater, several bodies of water have been contaminated, including Havana Bay, one of the most contaminated bays in the Caribbean (Solo-Gabriel and Perez 2008).

The extent of this problem is severe. In 2010, Cueto and De Leon estimated the cost of providing adequate collection and secondary wastewater treatment for the 15 largest cities in Cuba, encompassing 48% of the island's population, at $2.2 Billion U.S. in restoration and construction of wastewater treatment plants, pump stations, and wastewater networks. Ignoring economies of scale, wastewater infrastructure costs to cover the entire island would total $4.6 Billion U.S., plus an additional 4% annually in operation and maintenance costs (Murphy 1979).

PROPOSED DECENTRALIZED SOLUTION

The limited wastewater treatment infrastructure in Cuba leads to a unique scenario. Cuba can follow the traditional steps of large, expensive, yet effective wastewater treatment facilities, or they can avoid the negative effects many countries have experienced with wastewater treatment disposal by eliminating water contamination. Instead of using potable water as a means of transporting fecal matter and urine to a facility, domestic waste can be kept in its concentrated form and treated locally. This leads to the concept of desiccation or decomposition as forms of treatment for domestic waste.

Both desiccation and decomposition have been shown to effectively treat domestic waste, though each provides distinct advantages and disadvantages (Esrey at al. 1998). The technology of desiccation dehydrates the waste in a processing vault to levels below 25% as quickly as possible. This is accomplished through heat, ventilation, and the addition of dry bulking materials. At this level of humidity there is "rapid pathogen destruction, no smell, and no fly breeding" (Esrey at al. 1998). The device in which this occurs works by either separating the urine or combining urine with fecal matter and evaporating excess liquids. One of the limitations of this technique for use in Cuba is the high relative humidity at an average of 78% (ONE 2011). Another hindrance is that this system does not yield compost as it does not decompose, but rather turns into mulch that is rich in nutrients, carbon, and fibrous material. In addition, other materials such as toilet paper, kitchen scraps, and bulking agents also do not decompose, possibly requiring separate or additional treatment and disposal.

The sanitation system of decomposition can be an effective method for use in Cuba due to the inherent climate, economical limits, and useful benefits of composting toilets. With decomposition, human excreta along with additional bulking agents such as vegetable scraps, sawdust, dry sugarcane byproducts, or leaves are placed into a processing chamber, where a variety of micro-organisms breakdown the material into compost. This compost is much smaller than the original input volume of feces and urine since CO2 is produced and escapes through a vent pipe, moisture is evaporated away, and less bulking agents are needed as compared to desiccation. To optimize the process, conditions such as temperature, airflow, bulking agents, and moisture are controlled. Pathogens are destroyed due to the exothermic reaction of decomposition (leading to temperatures above 60°C) and competition from better adapted micro-organisms (Vinneras et al. 2003). Composting toilets require sufficient oxygen to maintain aerobic conditions, a moisture content of 50-60%, a carbon-to-nitrogen ratio within the range of 15:1 to 30:1, and temperatures well above 15°C (Esrey at al. 1998). These conditions lead to odorless pathogen-free compost that is efficiently processed within a matter of a few months or even weeks.

The limitations of the decomposing process are mainly focused on controlling the many conditions needed to optimize decomposition. The system needs to be tailored to the characteristics of the surrounding environment. It is relatively simple to control humidity since urine is always provided to the system in even the driest locations. However, composting efficiency increases where there are high average temperatures such as Cuba, which has an annual average of 25°C, making composting the preferred mechanism for decentralized domestic waste treatment (ONE 2011).

There are also additional considerations regarding the implementation of compost toilets as a domestic waste treatment alternative. Site-specific strategies must be evaluated to determine how the public is to dispose of the compost. Rural areas will likely have nearby uses to provide nutrients to the soil. However, urban dwellers often lack sufficient space to utilize the compost, so it will have to be transported to areas where it is needed, likely requiring additional infrastructure based on collection and distribution, similar to that of municipal solid waste (MSW). The need for such transport is reduced in Cuba, given the prevalence of urban agricultural farms which were fostered following the agricultural crisis of the 1980's. Before the crisis, Cuba imported 94% of its fertilizer from the Soviet Union at subsidized prices. Since then, Cuba has explored options to reduce the demand for chemical fertilizers, including composting of organics in MSW which make up 60% of the stream, which could also be treated in a compost toilet along with fecal matter and urine (Korner et al. 2008).

Additionally, whether the general Cuban population will accept the composting toilet is left to further research. Common complaints include fears of having to sit above composting feces and apprehension of creating a favorable environment for insects. Also, traditional flush toilets require little maintenance and operation from the user, whereas even the most automated compost toilet systems require greater attention. These issues deem it necessary for the system to be designed so that it is ergonomic and simple to use, while meeting certain health and dimension standards.

PUBLIC AND ENVIRONMENTAL EFFECTS

Public Health

The presence of pathogenic bacteria, viruses, and parasites in human feces poses a considerable threat of infection to the human population; more so than animal fecal matter for the simple reason that not all animal pathogens are compatible with the human anatomy (Jones et al. 2003). Improperly treated compost can be a health hazard and lead to infection through contaminated foods or water. The target pathogens that have been specifically identified in Cuba are presented in Table 1 (Index Mundi 2012).

Table 1. Target Pathogens for Domestic Waste Treatment in Cuba

Bacteria	Viruses	Parasites
Campylobacter	Hepatitis A	Ascaris Lumbicodines
Escherichia Coli	Hepatitis E	Cryptosporidium
Salmonella	Rotavirus	Entamoeba Histolytica
Yersinia Enterocolitica		Giardia Lamblia
		Hookworm
		Toxoplasma Gondii
		Trichuris Trichiria

Source: (Index Mundi 2012).

With the known linkage between pathogenic contamination of water supplies and pit toilets, it is understandable for people to have reservations regarding the use of compost toilets. What few people realize, however, is that the modern-day compost toilet is its own isolated, economical, and ecologically-friendly sanitation station, with the potential to increase the accountability of the contemporary treatment of feces. Because of the collective nature of sewage systems, pinpointing the source of contaminants is difficult. In Cuba, where only about 4% of sewage water receives any sort of treatment, the threat of pathogenic infections is an irrefutable reality (Cueto and De Leon 2010).

Regularly, new contaminants are found that need to be dealt with at treatment facilities. Instead of engineering new forms of treatment, the compost toilet is a proactive approach which sequesters domestic waste from the high quality potable water supply, ensuring that contaminants are less mobile in the environment. This in turn facilitates treatment of any current or future contaminants, since they are undiluted and safely sequestered. Moreover, the overall sanitation capabilities of this technology are effective, utilizing the simple mechanisms of heat and desiccation. The recommended temperatures and time lapses necessary for the effective elimination of the pathogens mentioned are provided in Table 2 (Esprey et al. 1998).

Environmental and Ecosystem Health

The environmental and ecosystem health effects associated with wastewater are matters of water quality and quantity. In terms of pollutant loads, nutrients such as nitrogen and phosphorus are the greatest pollutants of concern. High levels of nutrients in wastewater plant effluent can lead to algal blooms, oxygen depletion, and fish kills. Secondary wastewater treatment only provides modest nutrient removal capacities of 30% or less (Viessman and Hammer 2005). Studies have shown that the majority of nutrients in water are associated with toilet flushing, at 78% of total nitrogen and 59% of total phosphorus, see Figure 1 (USEPA 2002). Thus, by removing toilets from the domestic wastewater stream, the nutrient loads to water ecosystems will be considerably reduced while also diminishing traditional wastewater treatment costs.

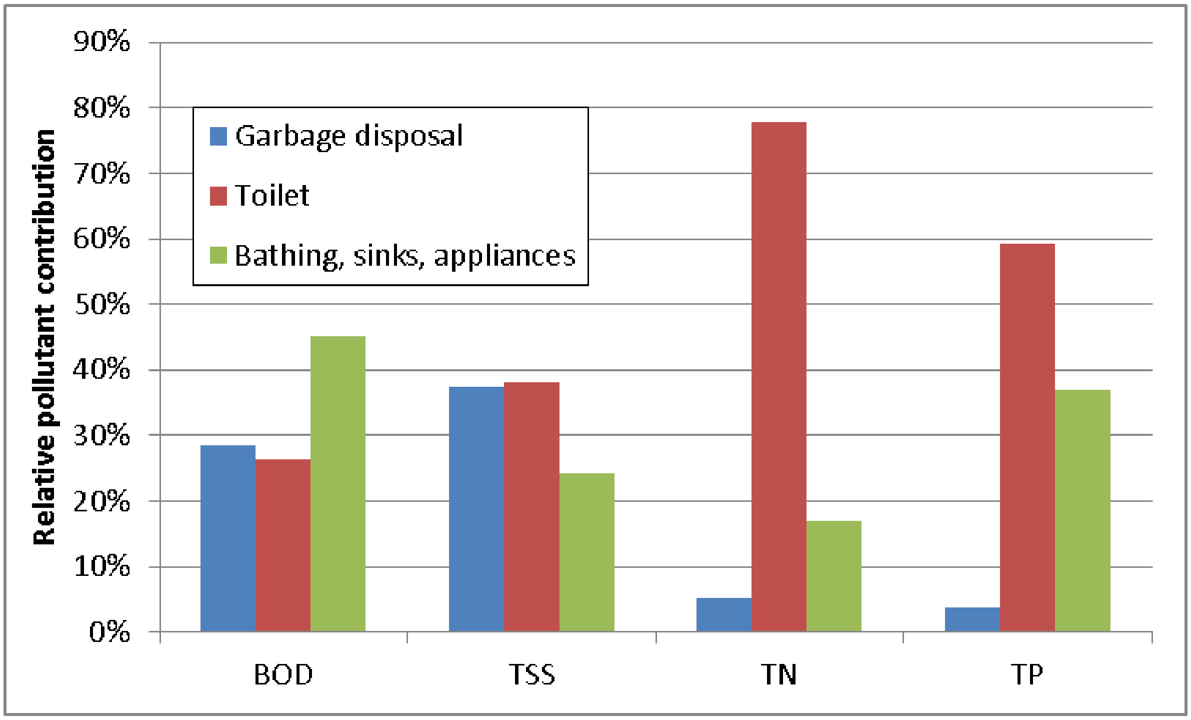
In addition to nutrients, there are emerging contaminants of concern which represent a broad range of pollutants found in water systems, including endocrine-disrupting chemicals, pharmaceuticals, and personal care products. These contaminants largely originate from the feces and urine of humans and go untreated in water treatment facilities since they are not designed to remove these constituents. Though the effects of these pollutants are unclear, preliminary studies have shown some negative environmental and public health effects, for example endocrine-disrupting chemicals have been linked to reproductive problems in aquatic life (Guillette et al., 1994). Though the ability of compost toilets to treat these emerging contaminants is also unclear, the technology successfully sequesters these pollutants so that they can be handled more effectively. By making the compost toilet a major item in the infrastructure of a city, large pollutant effluent discharges in major waterways and bays can be avoided. Take for example Havana Bay, one of the busiest, dirtiest ports in the Caribbean. The bay, fed by a total of 106 sources of pollution, including three major rivers, has received major attention from the Cuban government (GIWA 2004).

Table 2. Recommended Temperature and Time Lapses for the Effective Elimination of Pathogens of Concern in Cuba

Pathogen	Heat Applied (°C)	Time Required
Ascaris Lumbicoides	55	60 min
Campylobacter	57-71	2-3 days
Cryptosporidium	57-71	2-3 days
Entamoeba Histolytica	55	1 sec
Escherichia Coli	55	60 min
Giardia Lamblia	57-71	2-3 days
Hepatitis A	57-71	2-3 days
Hepatitis E	57-71	2-3 days
Hookworm	50	50 min
Rotavirus	57-71	2-3 days
Salmonella	60	30 min
Toxoplasma Gondii	57-71	2-3 days
Trichuris Trichiria	57-71	2-3 days
Yersinia Enterocolitica	57-71	2-3 days

Source: (Esprey et al. 1998).

Figure 1. Relative Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) Contribution to Residential Wastewater by Source



Source: (USEPA 2002)

Besides the water quality issues, compost toilets also have an impact on the quantity of water used. According to Mayer et al. (1999), toilets are the single largest user at 27% of total residential indoor water use. One person produces 1–2.5L of urine and uses 6-15 times that amount of potable water to flush it away (Anand and Apul 2011). Hence, removing the toilet as a potable water user will significantly reduce demands. Meaning less groundwater needs to be pumped from the aquifers, treated, and pumped to the customer. This reduced potable water use ensures a more sustainable handling of the island's water resources, while prolonging the need to add costly water treatment infrastructure.

Economic Impacts

The term eco-tourism is used to describe the practice of traveling the world with an ecologically responsible frame of mind. It can be added that those destinations who have adapted to accommodate this mentality also uphold and practice eco-tourism. Cuba's economy, 30% of which is tourism, would benefit from the implementation of composting toilets in future touristic projects, not only because it will attract tourists concerned with making their environment just a little greener, but mostly because composting systems help save money in the long run (GIWA 2004).

A composting system is an investment with long-term savings in water treatment and distribution. In addition, the by-product of installing these fertilizer generators can be used to strengthen another sector of the Cuban economy, agriculture. Together with hunting and fishing, sugarcane and tobacco agriculture makes up 17% of the island's economy, or $3.16 billion U.S. (GIWA 2004). If optimized and produced in high enough yields, the idea of using human fertilizer as a substitute for synthetic or animal fertilizers holds great appeal in terms of savings, and has the potential to become an economic sector of its own.

With the right mentality and the desire to take initiative, human fertilizer production can stir up the job market in a variety of ways. In the urban sector, the decreased need for plumbing can increase the flexibility of residential planning, and with new compost toilets installed in metropolitan sectors, there will be a necessity to collect the waste. A system of compost pick-ups can take shape, similar to the infrastructure currently in place for picking up trash from homes. This will require processing plants, truck drivers, and ingenuity. It may even become an aggregate function of the MSW system already in place, except this waste can be put to good use and help the nation's economy.

The toilet manufacturing industry will definitely be subject to change, and as more input goes into making these commodes, the better the designs of the future will be. With greater designs, comes greater export potential and eventually, what you have is more than a household commodity, but a thriving industry that forms an integral part of people's lives.

COMPOST DESIGN

As previously mentioned, the state of Cuba's wastewater treatment infrastructure is unique and would require a high level of capital if updated through traditional means. The proposed solution is that of the implementation of composting toilets. However, there are still many issues remaining regarding the feasibility of these systems on a large scale. Like other decentralized approaches, composting works best within certain parameters. This paper presents one decentralized option for the treatment of domestic waste, but the compost toilet is not a one-size-fits-all solution for all of Cuba, but rather, we believe, one part of the puzzle.

The Cuban population can be categorized into rural, suburban, and urban living. Compost toilet designs can be optimized for the varying requirements of these environments. This paper focuses on a design fit for the urban setting, since these are the areas with largest population. Given the current housing infrastructure, the design must fit within the space allotted to a traditional flush toilet. Additionally, there is the need for easy removal and relocation of compost to farm areas. Ease of use also plays a crucial role, with a population accustomed to the flush toilet. However, there needs to be a balance between ease of use, afforded by automation, and cost and reliability. More automation requires more parts, particularly electronic, which increases the likelihood of failure. Additional parts also increase initial manufacturing costs, maintenance, and operating costs associated with energy. The use of electrical components is also an issue given Cuba's frequent electrical blackouts.

With these requirements in mind the University of Florida designed a compost toilet to appeal to Cuba's urban environment. Composting was chosen over desiccation as the primary mechanism for treatment so as to produce organic fertilizer and increase treatment capacity, given composting's ability to substantially reduce the volume of wastes, meaning less frequent removal of compost and reduced solid waste transporting costs. Aerobic composting was chosen because it produces CO2, which is odorless and easier to handle than the more environmentally harmful methane gas produced in an anaerobic process. Therefore a mixer was designed to rotate within a drum so that all areas of the pile where well aerated.

High temperatures due to the exothermic process of composting would kill pathogens and help evaporate excess moisture. In addition, a fan (located inside the ventilation pipe) and heating element will be installed to prevent possible foul odors from escaping and to evaporate any excess liquids, although Cuba's climate and the natural air flow of the toilet should aid this process considerably. The drum has drainage holes that lead to an evaporation pan beneath which the heating element is located. The heating element is connected to a moisture sensor and thus only operates when deemed necessary. Both the fan and heating element require electricity from the power supply. Given the unreliability of this supply, a battery was also incorporated into the design to ensure continued operation through blackouts.

The structural components of the compost toilet including the body, drum, and mixers were designed to be constructed of acrylonitrile butadiene styrene (ABS) plastic. ABS's flexibility in design, properties, recyclability, and low cost of production make it ideal as the material of choice. ABS is known to resists chemical attacks from several components that are found in human feces. Since it is a thermoplastic, mold injection is proposed for mass production. The expected lifetime of the polymer for the current application is over 50 years. The expected loads on the structure will not be sufficient to cause any deformity in the polymer. Typical operating temperatures for this polymer are between -20°C and 80°C (Lu et al. 2000).

After composting, it is necessary to implement a method for the removal of the final product. For removal, a desiccation drawer was designed to attach under the drum to collect the compost. The desiccation further ensures the destruction of pathogens, and isolates the final product from fresh contamination. In order to achieve desiccation, the drawer has a large tilt, many holes, and is close to the heating element. Every few weeks the user would use a handle to turn the drum and align the output holes of the drum and body so that compost would fall into the drawer. The user would then empty the drawer after a couple of weeks when it is safe to apply to the soil. In an urban area, the user would likely empty the compost into a bin for MSW-like collection. For schematics of the proposed compost toilet design, see Drawings 1-7.

ECONOMIC ANALYSIS OF COMPOST TOILETS

Initial Cost

An estimate for the total cost of the toilet has been calculated. Typical prices for the components that are found on the market were used to figure the cost of the toilet. For the main structural ABS components of the toilet, the total cost is estimated at $100 U.S. The electronic components such as the fans, microcontrollers, and battery are estimated at $60 U.S. The cost for assembly of the toilet is highly dependent on the economic status of the island since these costs are highly dependent on employee wages, unlike the raw materials. It is expected that the largest cost for production will come from the initial capital that would have to be generated to start the mold injection plant that would manufacture the plastic components. Considering these factors the approximate manufacturing cost of the toilet including raw components is $380 U.S. The estimated cost for installation is no more than $100 U.S. The expected total cost to implement the composting toilet infrastructure to serve Cuba's 11.2 million population would be $1.7 Billion U.S., assuming one toilet per residence and 2.5 people per home (ONE 2011). Compared to the cost of restoring and adding capabilities to the standard methods of processing wastewater the compost toilet infrastructure - a completely new system - would be 80% more cost effective.

Annual Maintenance and Operations Cost

Once the composting toilet is in operation, maintenance and service must be considered. A conservative lifetime for the toilet is 35 years (Anand and Apul 2011). The plastic components are not expected to fail during this lifetime. If any plastic components fail, their replacement will be very low cost. The main components that are expected to fail are the electronic and the electro-mechanical components such as the fans, heating elements, and sensors. These components are modularized to keep replacement and labor costs low. The estimated maintenance cost based on individual component service lives is $13 U.S. per year.

Service costs for the removal of compost will be dependent on the associated costs of transportation, storage, and market value of the compost. Fertilizer market value is expected to continue to rise due to the increasing scarcity and cost of petroleum-based fertilizers, which might eventually offset the cost of collection (Langergraber 2005). Venezuela is used as a model for calculating the cost of MSW collection and disposal at $5 U.S. per person per year. Cuba produces 4.7 million tons of MSW per year which is 1.4 kg per person per day (UNEP 2002). A person produces, on average, 260 grams of feces per day, which accounts for 20% of the MSW (Anand and Apul 2011). Therefore, it is expected that the total cost of compost collection for the island will be approximately $11.2 Million U.S. per year.

The energy costs for running the toilet are minimal. The cost is associated with the heating requirement to maintain the proper temperature and moisture for efficient composting, as well as powering the fan. Humans produce approximately 1,500 mL of urine per day (Anand and Apul 2011). The urine that is produced must be evaporated out of the compost at a rate that makes composting most efficient. The temperatures that have been proposed are 44 and 60°C. A basic calculation was carried out to determine the amount of time a 250 Watt heating element would have to remain on to attain the desired temperature. The calorimetric heat capacity equation was used to determine the amount of energy that would be required to heat the organic matter to the desired temperature (Equation 1). Since it was assumed that the majority of the matter's mass was due to water, water's heat capacity value was used in the calculations. Heat loss due to thermal conduction out of the system was not considered in detail.

$$q = mC\Delta T \qquad (1)$$

Where: *m* = mass, C = specific heat capacity, and ΔT = temperature rise

Using a 250-Watt heating element, the time required to raise the temperature of the matter to 60°C is approximately two hours, whereas 44°C would require approximately one hour. Knowing the time that the heating element must be on allows us to determine approximately how much energy the composting toilet will consume. Assuming the temperature in the toilet system will be maintained at 44°C, we can use Equation 2 to find the daily kilowatt-hour energy consumption

$$\text{Daily Kilowatt-Hour (kWh)} = (\text{Wattage} \times \text{Hours Used Per Day}) / 1000 \quad (2)$$

With wattage of 250 and an hour of usage, the daily kilowatt-hour consumption for the heating element is estimated to be 0.25kWh. For the fan, which will create negative pressure in the composting chamber, a 30-watt power consumption was assumed. Using Equation 2 and assuming the fan will need to be on 24 hours a day, the fan is estimated to consume 0.72kWh. The same procedure can be done for other electronic devices such as sensors and controls. The daily kilowatt-hour consumption for these miscellaneous components is estimated to be 0.24kWh. Assuming $0.11 U.S. per kilowatt-hour, the estimate operational energy cost for the whole system is $50 U.S. per year. This takes into account all the energy consumption of all components in the system.

The total costs for the proposed compost toilet design are summarized in Table 3. The initial investment and annual operation and maintenance costs of the conventional wastewater treatment proposed by Cueto and De Leon (2010) are compared to the compost toilet design costs outlined in this paper (Table 4). Service lives of 50 and 35 years, for the conventional and compost toilet designs were assumed, respectively. In order to account for the time value of money, net present worth calculations were carried out using various discount factors and a least-common-multiple project life of 350 years (Table 5). The results of this work show that with discount factors of 3% or greater, compost toilets are a more cost-effective solution to Cuba's wastewater problem over conventional secondary treatment. It is important to note that many added benefits were not included in this analysis such as the value of the compost as a fertilizer, the reduced nutrient and other pollutant load on the aquatic environment, and the reduced potable water demand and associated costs of treatment and transport. Also not included in the analysis was the cost or possible benefit of the bulking material, since this could be derived from the MSW stream (benefit) or shipped from an outside source (cost).

Table 3. Compost Toilet Costs for Proposed Design both per Residence and for the Entire Island of Cuba

Category	Cost per Residence ($ U.S.)	Cost for Nation ($ Millions U.S.)
Production	$380	$1,406
Installation	$100	$370
Annual Maintenance	$13	$49
Annual Collection Service	$10	$36
Annual Energy Costs	$50	$185

Source: Authors' calculations.

Table 4. Initial and Annual Operation and Maintenance Cost for the Conventional Wastewater Alternative (Cueto and De Leon 2010) and Proposed Compost Toilet Design, and Assumed Service Lives

Category	Conventional Wastewater Design	Compost Toilet Design
Initial Investment ($ Billion U.S.)	4.6	1.8
Annual O&M ($ Billion U.S.)	0.2	0.3
Service Life (years)	50	35

Source: (Cueto and De Leon 2010) and authors' calculations.

Table 5. Net Present Cost for the Conventional Wastewater Alternative and Proposed Compost Toilet Design for Various Discount Factors and a Project Life of 350 Years

Discount Factor	Conventional	Compost Toilets	Compost Toilets / Conventional
0%	96.6	112	116%
2%	16.5	17	103%
3%	12.1	11.7	97%
4%	10	9.1	91%
6%	7.9	6.5	82%
8%	7	5.3	76%
10%	6.5	4.5	69%
12%	6.1	4.1	67%

Source: Authors' calculations.

Conclusion

A quick glance into the overall framework of Cuban infrastructure reveals an ample degree of opportunity for innovation. The compost toilet is an idea tailored to and focused on the need for cost-efficient solutions to a major wastewater treatment problem. It is not, however, the only remedy. Our initiative as a team is to provoke creativity through engineering, and thus pave the road for the continuation of the creative process. With room for improvement in the sectors of power generation, transportation, solid waste management, telecommunications, civil infrastructure, and others, Cuba offers engineers the chance to think outside the box, to learn from generations of trial and error, and update a nation by skipping decades of technological evolution.

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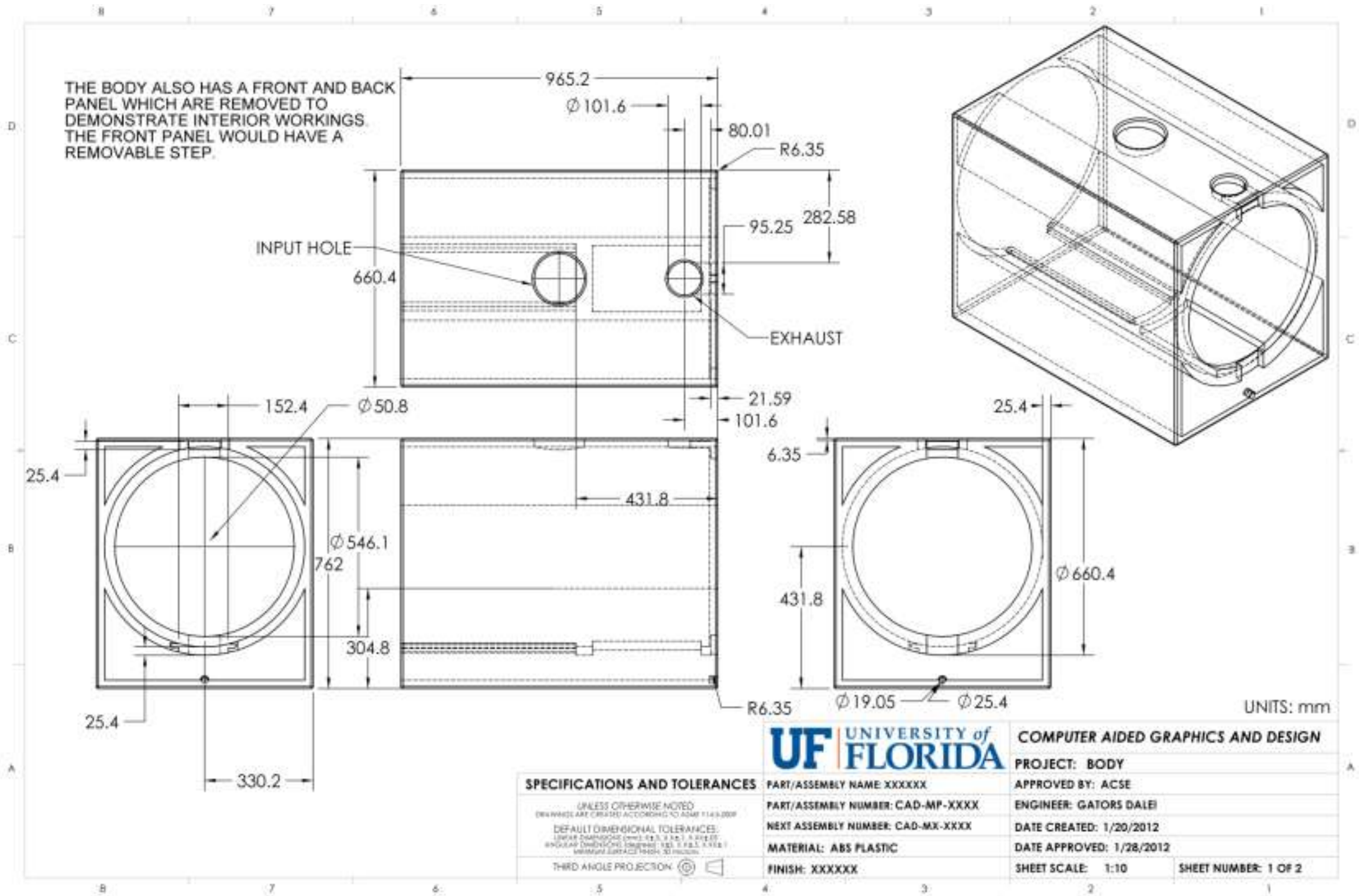
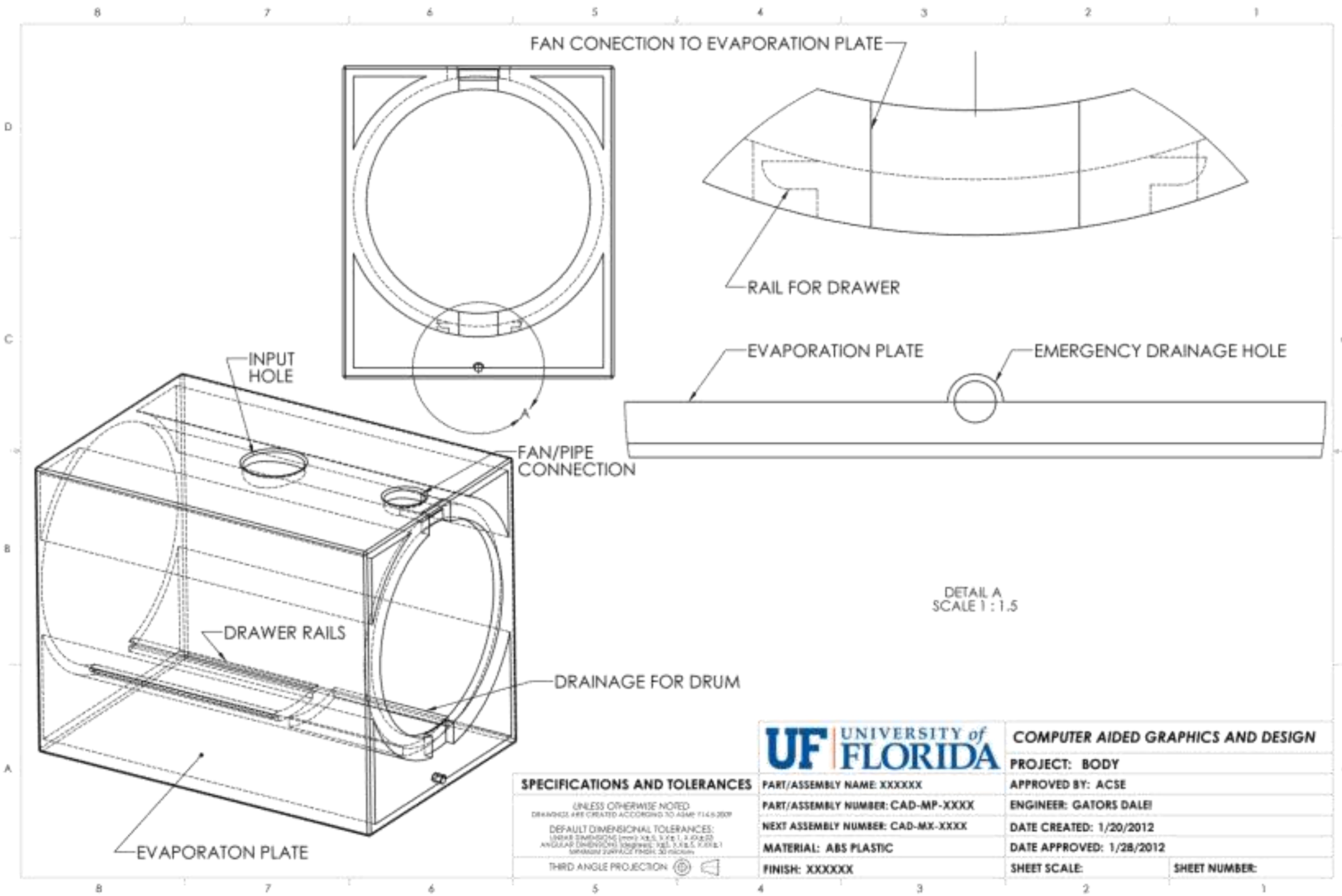
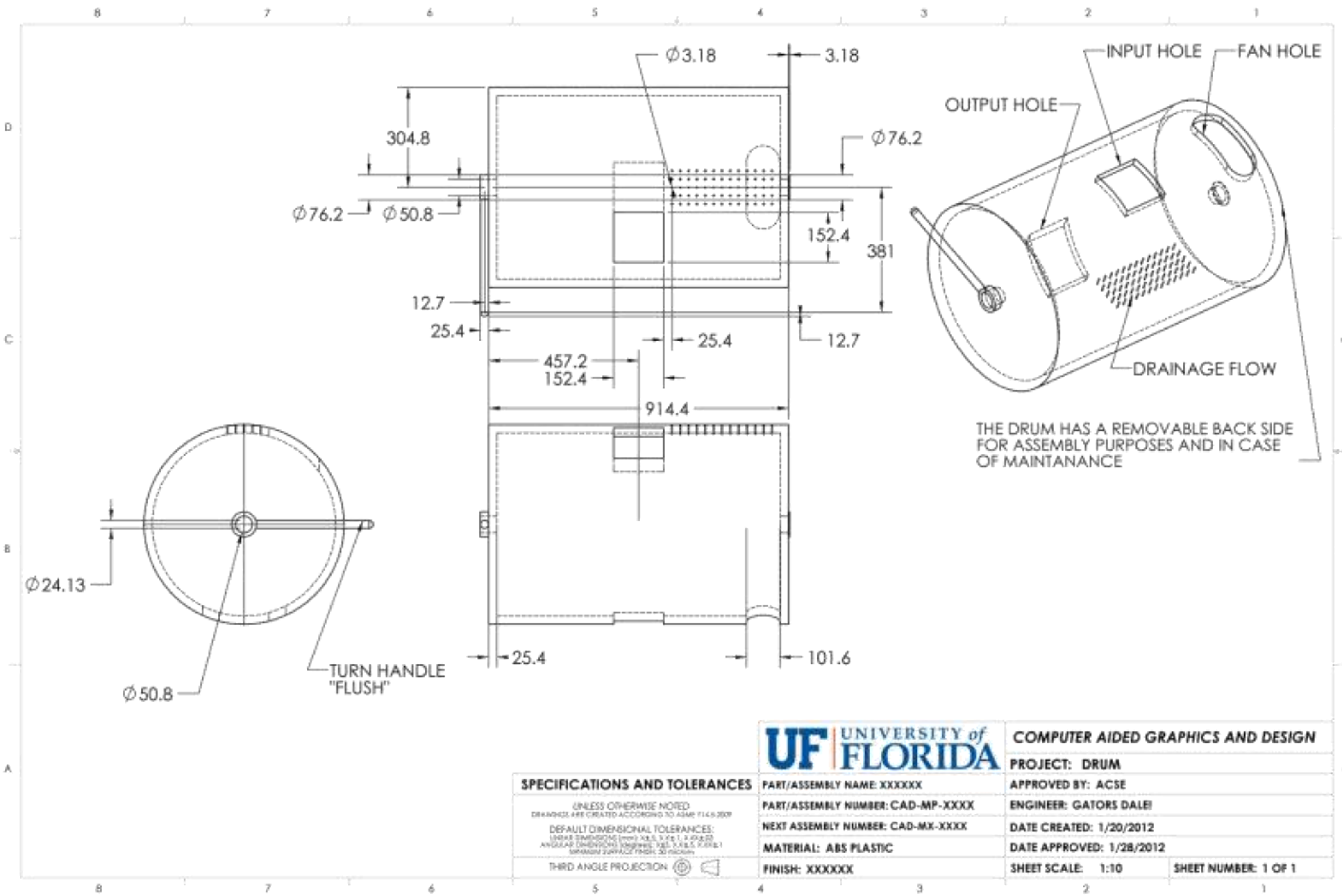
Drawing 1. Body of proposed compost toilet design, whose purpose is to contain all the interior components along with handling most of the load.



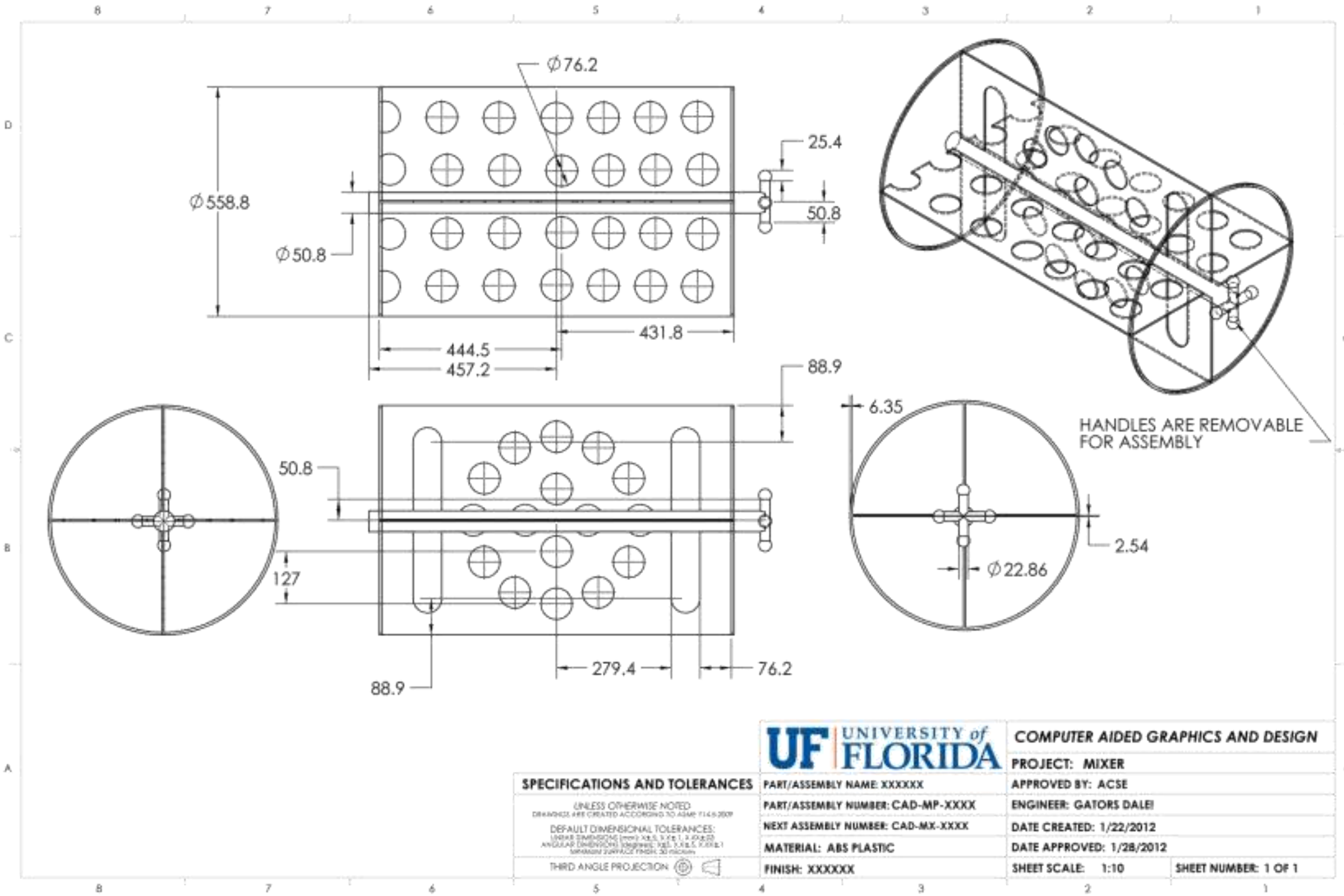
Drawing 2. Detailed view of subcomponents of the body including labels for major structures.



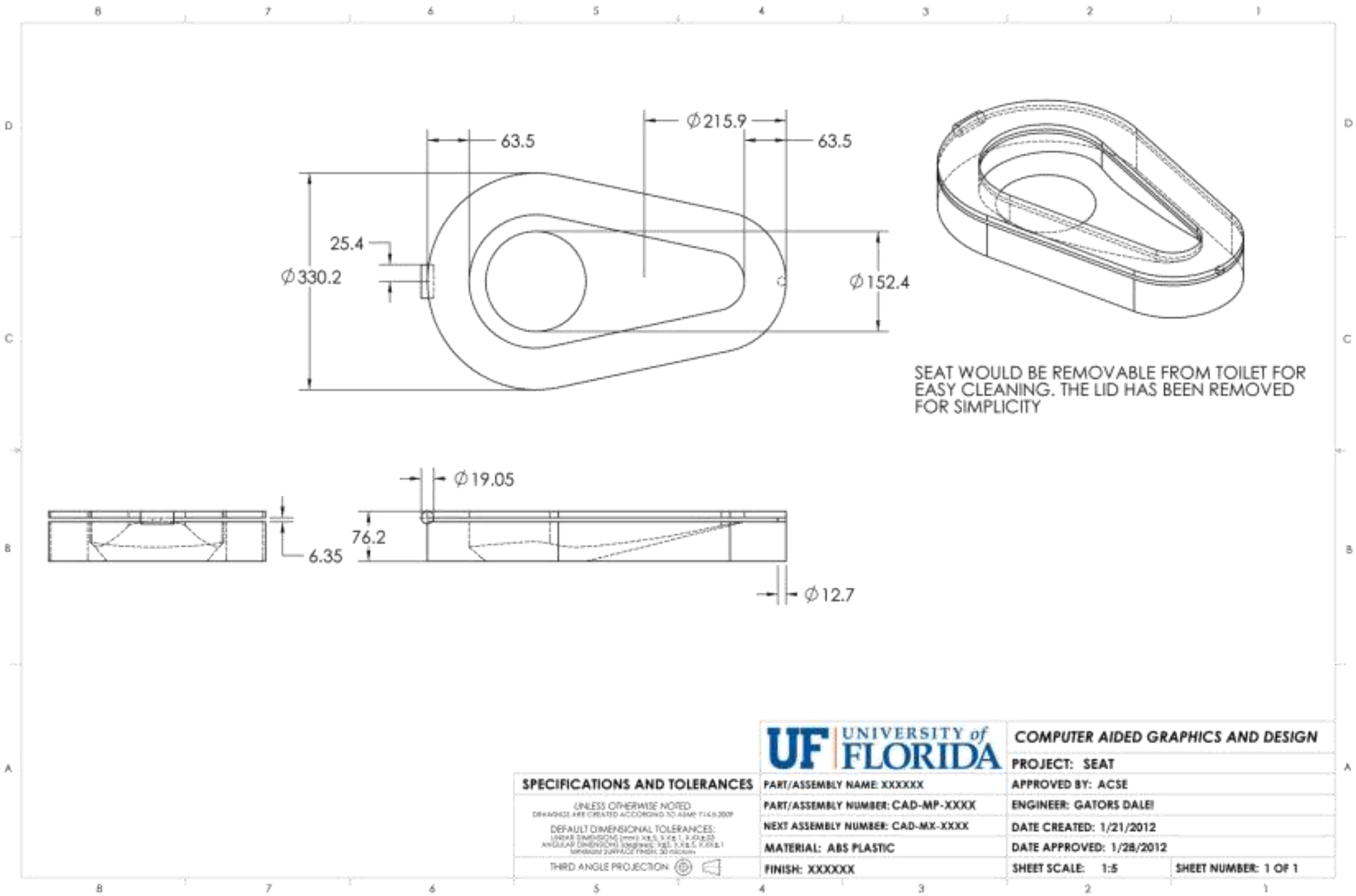
Drawing 3. Drum along with its design components. The drum is the main compartment in which decomposition of fecal matter occurs. It has a input and output hole along with an array of small holes for the purpose of draining excess moisture due mostly to urine.



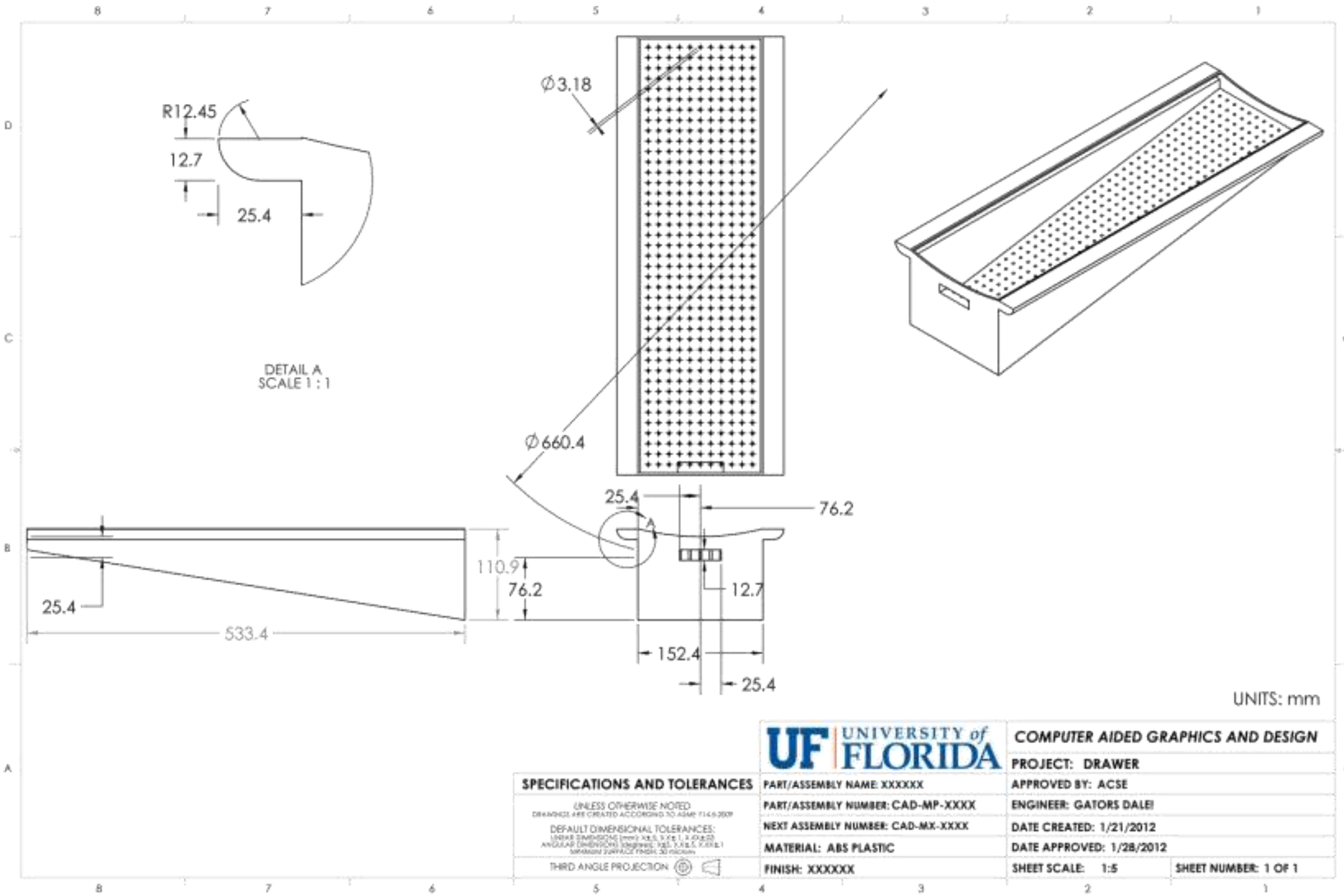
Drawing 4. Mixer depiction. It was designed to aerate the fecal matter to provide enough oxygen for complete aerobic decomposition.



Drawing 5. This is the toilet seat. It acts almost like a normal toilet bowl since it serves as the input into the body and drum of the toilet. It is missing the lid for simplicity and will be removable from toilet for easy cleaning.



Drawing 6. Desiccation drawer, designed for removal of fully composted product.



Drawing 7. Assembly of compost toilet components. Bright colors were used for distinction of components, although the general material of choice is ABS plastic. Front and back panels along with a step and toilet lid have been removed for simplicity.