



Developing A Sustainable, Self-Cleaning, Automatic, And User-Friendly Toilet

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Abstract

Toilets have traditionally been susceptible to lack of regulation, causing them to be blatantly untidy and unhealthy. Foul odour, inadequate sanitization, and improper waste disposal in public toilets lead people to urinate and defecate in open areas or water bodies, causing pollution at different levels (air, water, soil) and a spread of diseases. In an attempt to provide an alternative to the aforementioned issues, this paper will be focusing upon the inculcation of sustainable and hygienic technologies to the making of a self-cleaning, automatic, and user-friendly toilet; another section this paper will be focusing upon are renewable and minimalistic water and energy consumption.

Initial research was done to determine the maximum reduction in water usage and maximum production of electricity through solar panels and filters. This was followed by the incorporation of hygiene-based technologies such as floor jets, water/soap dispensers and air sanitisers. Theoretical analysis was carried out to determine the cost and working of a nano-membrane (or other filters) to separate liquid from waste—followed by composting to convert waste into fertilizer. Lastly, location-based factors (extreme temperature, climate, vandalism, etc.) were taken into account for operation and tackling any setbacks posed by surroundings.

Section 1: Introduction

1.1 Literature Reviews:

1.1.1 Composting techniques

Composting is a natural process in which organic matter is recycled into beneficial fertiliser that aids soil and plant growth. When we need to speed up this process, composting comes into play. It creates an optimal habitat for decaying organisms to conduct their work, resulting in compost, which resembles rich soil. [1] Human faeces, on the other hand, are high in plant-healthy nutrients and may be processed into a soil-nourishing fertiliser. When viruses and pathogens are destroyed at high temperatures, they are quickly killed. The significant nutritional value of human faeces—nitrogen, phosphorus, and potassium—makes it an excellent fertiliser. They also assist to improve soil structure, provide nutrients to plants, and decrease erosion. [2] The best technique to ensure that human faeces are correctly composed is to maintain it at a temperature of 65 degrees Fahrenheit for 20 days. In section 5 of this study, the different types of composters and possible composter architectures are discussed.

1.1.2 Fused Deposition Modelling (FDM)

To extrude thermoplastic material and construct 3D models in FDM, high-temperature nozzles are needed. [3] FDM eliminates the possibility of dimensional mistakes and assures that the print's measurements are correct. This printing method is also cost-effective, making it an excellent alternative for producing floor jets. Section 3.1 goes through the floor jets in great depth.

1.2 Aims and Objectives:

The aim of this project is to research and design a 3D smart washroom that maintains hygiene via air-sanitizers and regular floor cleaning, powers itself through solar panels and separates the water (later recycled) from waste via a nano-membrane that is embedded into a composting and filtrating structure.

The objectives of the project are: (might be reiterated)

- (a) To minimize the need for additional water supply via recycling and filtration.
- (b) Usage of a composter to remove the need of connection to sewer supply and recycle waste.
- (c) Usage of renewable energy and self-powering the SCT via solar panels.
- (d) Assess the application of a water/gas jet nozzle for hygiene and sanitary purposes.

Section 2: Experimental Settings for Solar-Tracking Panels

2.1 General Installation and Process

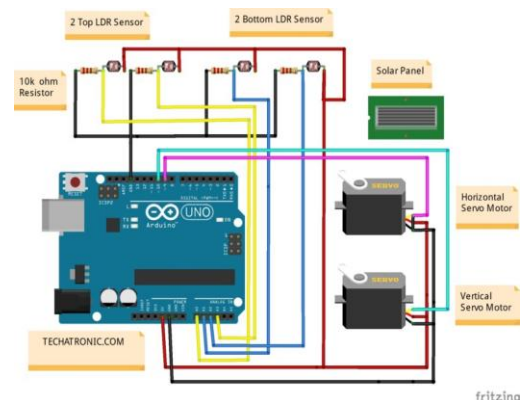
Solar panel is a panel whose PV cells absorb sunlight and turn it into electricity [4]. A solar tracker system enhances a solar panel's method of electricity production, as the sensor in the panel follows the direction of sunlight as it optimizes the angle at which the panel receives the sunrays. When the solar panels are kept under the sunlight, the angle of incidence determines how well the panel will convert light into electricity. [5]

DASTP (Dual Axis Solar Tracking Panels)- To maximize output the solar panels used will have two axis and a sensor. The sensor will be programmed to follow the rays of the sun, giving roughly 14 hours of full electricity production. The reason why DASTP have been used in place of SASTP is to prevent any sunlight loss if the SCT is built at a direction away from sunlight.

The following is a circuit diagram of the dual axis solar tracking panel:

We'll utilize an LDR- (light dependent resistor) whose resistance value will reduce when sunlight strikes it. This implies it simply uses light to modulate resistance. This property of LDR will be used by the dual-axis solar tracking system to change course as the LDR's resistance falls.

Thereafter via two servo motors, the panel will move in all directions. [6]



Electricity Storage- The solar panels will be in a grid-connected photovoltaic system. The electricity produced would be converted into an alternating current after passing through a power inverter. The current will be then guided to the utility grid. This grid will divert the electricity to various components

of the SCT; whilst the excess power will be stored in the grid for later use or generating revenues for SCT's maintenance.

[Note: A model of DASTP on the SCT can be found in section 6.3]

2.2 Calculations and Application (Approximated Values)

8 Solar Panels of 17.6 square feet each will be installed. (The measurements of the SCT can be found in section 6.1 and 6.3)

Length and width of each solar panel = 5.7 feet * 3.1 feet

Amount of electricity produced per panel per hour = 300 Watts

Amount of electricity per panel per day (estimated 14 hours via DASTP) = $300 * 14$
= 4200 Watts-hours = 4.2 KWH

Total Electricity Produced = 33.6 KWH

Section 3: Sanitization and Maintenance

3.1 Floor Jets and Air Sanitizers

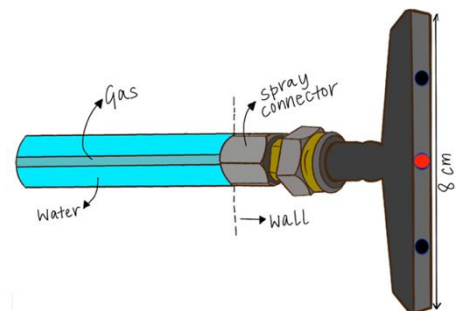
Inspired by Sanitronics Revolving Toilet [7], the SCT features a water (black nozzle) and gas jet nozzle (red nozzle). The nozzle disperses water at high speeds to clean the washroom floor after every use. After the water is drained into the gutter (under the stall door), the air nozzle will gush out air mixed with 0.6 milligrams of Chlorine Dioxide (ClO₂) at high speeds. The pressure of the air will remove any residue water on the stall floor. Chlorine Dioxide will sterilize the facilities and give a germ-free experience to all its users. Every stall will have two jets at each corner (model of the same in section 6.2).

Calculations of ClO₂:

Approved amount per cubic meter = 0.3 milligrams

Volume of washroom door in cubic meter = 2.03881 m³

Final amount of ClO₂ needed = $2.03 * 0.3 = 0.6$ mg



3.2 Automatic Water/Soap Dispensers

The plumbing system of the washroom will comprise of pipes that bring freshwater in, and the other will take the wastewater out. The water that will come into the washroom will be under pressure. It will enter the washroom under enough pressure to allow it to travel up to the sink, around corners or wherever else it's needed. Additionally, the pressure of the water together with the design gradient of floor will remove the need of additional pressure pumps or energy supply. The wastewater after cleaning will be then circulated back to the graphene filter and returned back to the tank. Soap will be dispensed via a dispenser that will be placed to the right of the washbasin. The liquid soap dispenser will be connected to a soap tank that will only need refilling once or twice every month. (estimated via size of tank)

Section 4: Piping, Recycling and Filtration

4.1 Piping with Floor Jets & Air-Sanitizers

Pressure Pumps:

The floor jet system will be connected to a 1 KV water pressure pump installed at the water tank placed on the roof of the SCT. The gas tank will use pressure for gushing out air after the cleaning process. The diameter for the water pipe will be 1-inch, while the diameter of the air will be 0.3 inch. Both the pipes will be separate and have different connections to the nozzle.

It is necessary to ensure that the pipes will be able to withstand the pressure created by the pump. Listed below are some (not all) piping materials evaluated for the same.

Types of Pipes: (Costs- [8])

1. Copper Piping-

On one hand, copper, as a material, is durable, heat resistant and corrosion resistant; it also ensures that no pollutants are absorbed into the water, lowering risk of any contamination. On the other hand, copper pipes are difficult to recycle, and manufacturing them causes pollution. These pipes cost around \$2 to \$4 pf (per foot) (excluding installation cost); the installation of these pipes requires multiple steps such as soldering, bolting etc. making it a costly choice. [9]

A fixing limitation in copper pipes is that they can't be bent easily and risk collapsing if bent without tools; if lead solder gets inside the pipe, it can result in solder poisoning and various other health hazards.

2. PVC (Polyvinyl Chloride) Piping-

Polymerization of vinyl chloride forms PVC which is a type of plastic. PVC can withstand high water pressures, along with resisting rust and corrosion. It is also ergonomic to install and can be molded easily. [8] The material costs about \$0.5 pf making it extremely inexpensive; even with the installation and maintenance costs, the prices only reach up to about \$1 pf. Also, new methods have also made PVC recyclable.

The limitations of PVC piping are:

- They must be installed within walls or hidden from UV rays as UV rays cause it to degrade. [9]
- They can pollute the water at elevated temperatures.

3. CPVC (Chlorinated Polyvinyl Chloride) Piping-

CPVC is a more stable form of PVC, providing all the benefits of PVC and more. The addition of chlorine content in CPVC make it more durable and give it the ability to withstand high temperatures. The material costs about \$0.5 to \$1 pf; however, it might go up to \$2 with metal coating.

The expensive nature of metal-CPVC is not the only problem for its application in SCT as its manufacturing process is highly polluting.

4. PEX (Cross-Linked Polyethylene) Piping-

PEX provides all benefits of PVC with heat-resistance and high flexibility. [9] The biggest advantage of having PEX pipes is that it is compatible with other pipes and does not require any gluing. The only limitation is that it too needs to be hidden from sunrays as it degrades in its presence. The material also costs about \$0.5 to \$1.

PEX and CPVC are also suitable for gas lines.

In summary, PEX will be used for water and gas plumbing as it: can handle water/gas-pressure, can easily be installed, can work with minimum maintenance, can be used with other pipes, and can be bought at low costs.

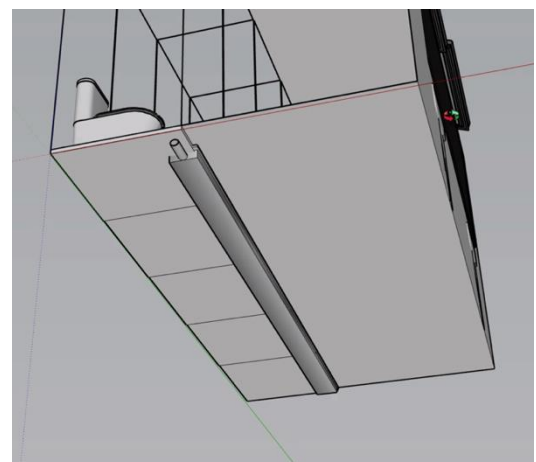
4.2 Sewer Canals and Filtration

The first drain will be placed under the stall door which will clean the water brought in by the water jets. The gutter will be placed at an angle so that the water passes through a graphene filter and returns to the PEX pipe through the 1KW pump that will pull it back to the water tank.

A demonstration of the same can be seen in the diagram:

The pipes concerned with the handwashing will too be connected to this drain to have a centralized process of filtration.

For the maintenance of the graphene filters, refiltration will be required at the end of every alternate week.



Section 5: Composting

5.1 Nano-Membrane Separation

The Nano-Membrane separation will segregate water from human waste. Nanofiltration is done through a filter where the membrane ranges from 1 to 10 nanometers. The water will then be returned to the drain where it would be filtered, whereas the waste will go to the composters. These composters will convert the waste into compost. {Other filters can also be used}

For removing foul odor, the water will be treated with fragrant oils or chemicals.

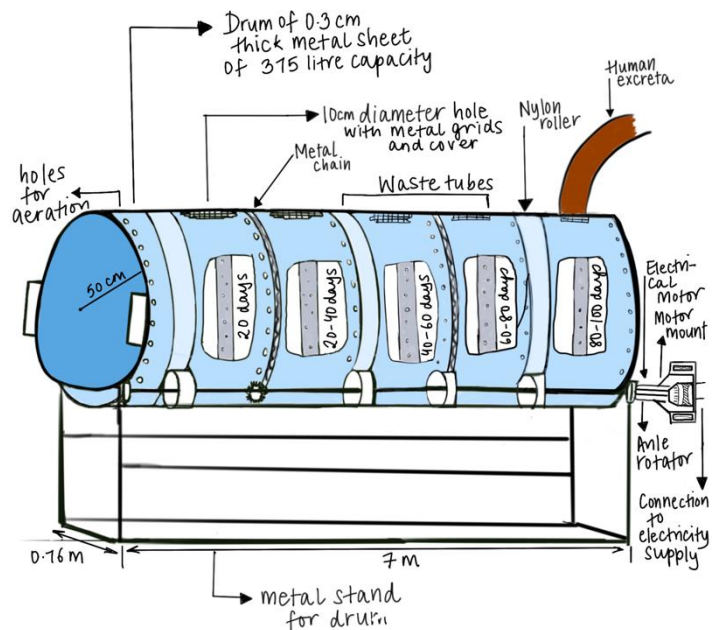
5.2 Types of Composters

The waste segregated from the nano-membrane separation will then be converted into compost via a composter. The types of composters and their possible structures are mentioned below:

Rotary Drum Composter:

A rotary drum composter takes comparatively less time to convert waste into compost- about 2-3 weeks. The compost is rotated on a continuous basis, and the side air vents keep the organic waste in touch with oxygen while the drum maintains heat. [8] The composter will be powered by the utility grid.

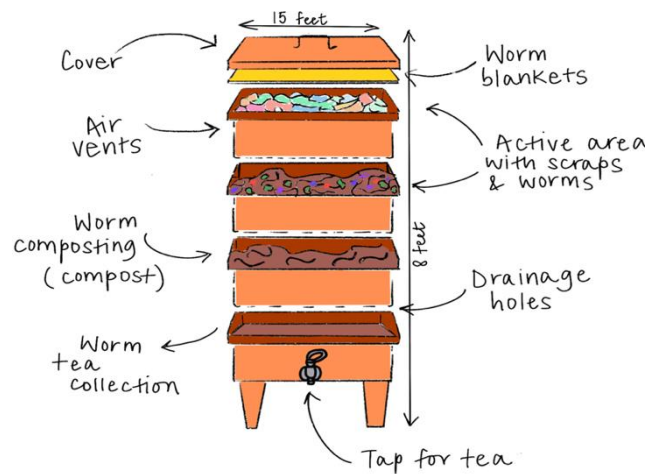
Given is a design of a composter designed specifically for the SCT. The design idea was inspired from [10] [11].



Vermi-Continuous-Composter:

Worm composting is the process of utilizing worms to recycle food scraps and other organic waste into vermicompost, or worm compost, which is a significant soil additive. Worms consume food waste, which decompose as they move through their bodies. Compost is expelled from the worm's tail end. [12] The process usually takes 8 to 9 weeks which is extremely time-consuming.

In summary, the rotary drum composter would be used with a 2KW motor to automatically rotate the drum. The vermicomposter will need to occupy an extremely huge space, or the waste will pile up. The need of an outdoor source will remain constant to collect the fertilizer and feed it to the plants.



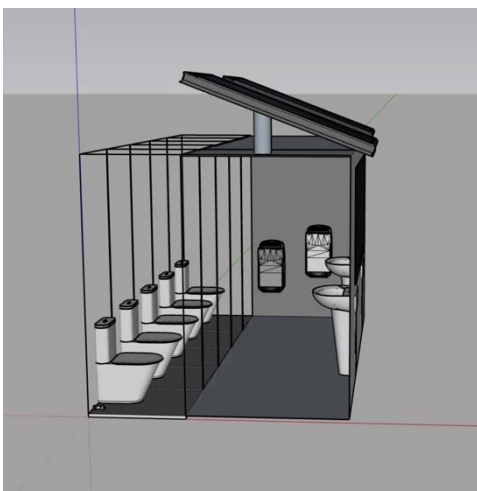
Section 6: SCT Design, Theory and Analysis

6.1 Design Theory- Flooring

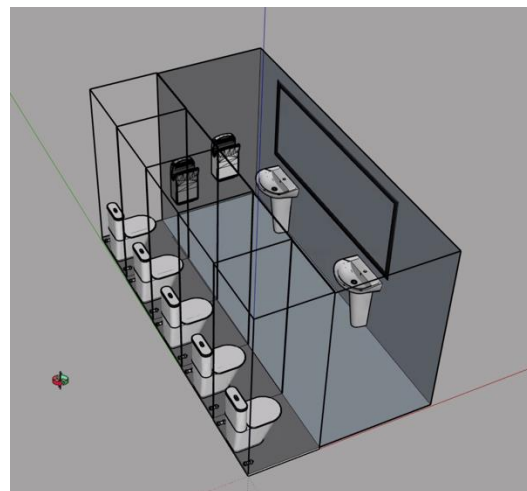
The type of flooring chosen for this project is waterproof vinyl flooring. Vinyl flooring is a stiff product, which combines vinyl's durability, scratch resistance, and waterproof qualities with flooring. Vinyl flooring is inexpensive, resists scratching and is easily available. [13] The flooring for this project will approximately cost 110\$ (150 sq. feet).

6.2 CAD Model

A design of the Solar panel mounted on to the washroom:



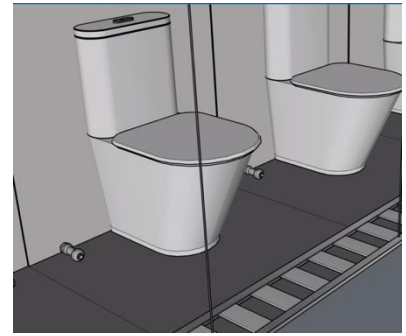
Outline of the basic washroom:



A close-up shot of a stall with the floor jets with the drain:

A sensor will be placed outside every door that will activate the floor jets after every use.

The CAD models do not incorporate the piping structure and water tanks as they may vary from its location.



6.3 Lighting and Windows

One-way mirrors will be used in stalls to forgo the need of artificial lighting in the daytime.

Section 7: Concluding Remarks

7.1 Conclusion

The SCT is a design for a better, more sustainable toilet. It covers all aspects from hygiene to renewable energy making it an eco-friendly and disease-free toilet. The minimalistic requirement of outdoor maintenance also saves costs. Even though the installation costs are high, overtime, the usage of these toilets will reimburse the initial investment.

The test models successfully showcase how the toilet would work. Additionally, this is the first time that sanitization is being performed via air.

7.2 Suggestions for Future Work

Other gases, pipes and composters can be tested to cut down costs and increase efficiency.

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