Tantalet: A Smart Toilet System

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Abstract

Tantelet is a vision of a smart and sustainable toilet, comprising a feces treatment and electricity generation model, a smart tissue dispenser, as well as a smart rubbish bin management system. A microbial fuel cell is built to simulate the electricity generation system in pit toilets. Different substances are tested to simulate the electricity generation of faeces in toilets featuring anaerobic bacteria, where the maximum voltage generated ranged from 0.019V to 0.186V. Not only is the electricity generated renewable, but the feces are also decomposed in an environmentally friendly way. As such, sustainability is enhanced. A smart tissue dispenser is designed to control the amount of tissue paper grabbed by each user and to detect the level of tissue paper remaining, alerting janitors to refill the tissue rolls when necessary. Similarly, a smart rubbish bin management system is devised which detects whether a rubbish bin has been filled, notifying janitors to empty it. It is envisioned that this system will be generally implemented in toilets unconnected to the public sewage system to generate electricity for self-sufficiency.

Contents

Table I. Results of electricity generation

Substances present in the left cell	Maximum voltage recorded (V)
Yeast and sugar solution	0.019
Sludge with anaerobic bacteria	0.186
Anaerobic bacteria bought from stores	0.161

A second model is made to simulate the collection and discharge of feces using valves. When the water level reaches the water sensor, a motor controlled by Arduino is activated. The weights are lifted, and water flows out through a rubber tubing, preventing it from overflowing.

The maximum voltage yielded by the sludge with anaerobic bacteria is 0.186V. It is about 1/32 and 1/28 of the voltage required by an automatic toilet paper dispenser, 6V and an ultrasound sensor, 5V respectively. It will be impractical to build and connect so many microbial fuel cells to generate big enough and steady voltage. A capacitor or battery, therefore, is needed to store the generated electricity. The capacitance will determine how long the automatic toilet paper dispenser and the ultrasound sensor run. One way to make efficient use of the energy is to turn on the automatic toilet paper dispenser and the ultrasound sensor only when a person locks the toilet door, instead of stand-by mode all the time. Both will be turned off after the person unlocks the toilet door. A further experiment is needed to measure the energy consumption for each toilet use. In addition, the maximum number of toilet users has to be estimated for the subsequent total capacitance estimation.

2.2 Automatic toilet paper dispenser with refill notification

The dispenser is constructed to dictate the amount of toilet paper that is dispensed each time, preventing heavy-handed users from withdrawing an excess amount of paper.

For the automatic toilet paper dispenser, a 360-degree servo is used to rotate the toilet paper roll which allows toilet paper to be dispensed. An ultrasonic sensor is used to send signals to turn on or off the servo motor. No paper will be dispensed if the ultrasonic sensor does not detect any obstacles within the range of 10cm and vice versa. The dispenser will automatically turn off after 10 seconds to prevent any undesired paper being dispensed.

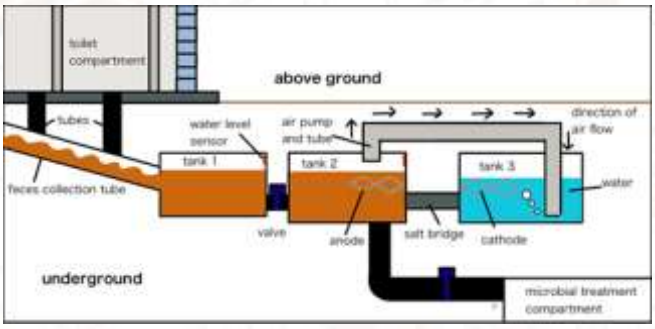
For the toilet paper refill notification system, a light sensor is used to detect the amount of toilet paper remaining. When the light intensity sensed by the light sensor exceeds 600cd, that is when approximately 10 pieces of paper are left, a signal will be sent via the Wi-Fi module to the blynk mobile application. The virtual LED in the app will be switched on, reminding users to refill toilet paper soon.

2.3 Smart rubbish bin management system

This design involves the Arduino Wi-Fi module ESP8266, an ultrasonic sensor and the blynk app. The trending technology Internet of Things (IoT), a system of interrelated, internet-connected objects able to collect and transfer data over a wireless network, also plays a major role in making this design possible. The ultrasonic sensor is installed on the wall near the top of the rubbish bin. When the ultrasonic sensor detects an object in front of it, it means that the rubbish bin level is almost full. A signal is sent via the Wi-Fi module to the blynk mobile application which switches on the virtual LED, alerting cleaners that the rubbish is ready to be emptied. This model can be installed in multiple rubbish bins, enabling janitors to determine whether the bins need to be emptied with just a quick glance at the app. By using the data of the rubbish bin levels, the bin emptying process can be optimized, ultimately minimizing the manpower required to execute such a process.

3. Expectations in large-scale implementation

3.1 Treating human feces ([4])



It is expected that this system will be implemented in toilets which are unconnected to the public sewage system, as well as pit toilets in the countryside of Hong Kong to generate electricity for the operation of toilets. Since human feces also contain anaerobic bacteria, they can undergo redox reac-

tions and generate electricity. The feces from the pit toilets are collected and flow into tank 1 through feces collection tubes, where they are temporarily stored. When the feces reach a certain level, the water level sensor is activated, cueing the valve to open and the feces flow into tank 2. Air is regularly pumped out of tank 2 to prevent the exposure of oxygen to anaerobic bacteria. The air is then pumped into the water tank for oxygen supply. Redox reaction is carried out in tank 2 and 3, generating electricity in the process. The feces then flow into another compartment, in which they undergo microbial treatment.

3.2 Benefits of the smart technology

As shown in sections 2.2 and 2.3, alert systems of rubbish bins and toilet paper supplies using the Internet of Things are installed. Thus, janitors only need to maintain the toilets whenever they are alerted, saving manpower and costs.

3.3 Concerns over land use

Although the toilet system occupies a certain space, their effects on the land supply of Hong Kong are insignificant because they are designed to be located at the country parks of Hong Kong where the sewage system cannot reach. Those places have little residential or commercial land uses competing with the smart toilets.

3.4 Feasibility of construction

The feasibility of constructing the underground structures at those places is also considered. The figure below ([5], [6]) shows the position of pit toilets in Hong Kong on a map showing the suitability of rock cavern development from the CEDD. It is found that most of the pit toilets are located in places with high suitability.

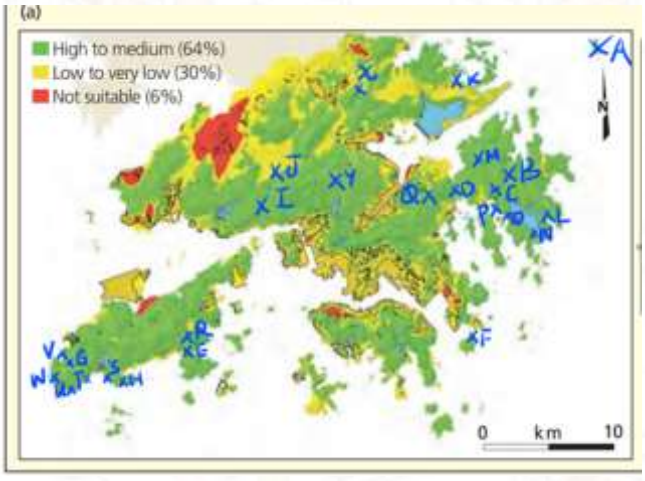


Table II. Key

A	Tung Ping Chau Campsite	B	Pak Tam Au Campsite
C	Yee Ting Campsite	D	Shui Long Wo Campsite
E	Tung Lung Chau Campsite	F	Shap Long Campsite
G	Lo Kei Wan Campsite	H	Man Cheung Po Campsite
I	Ho Pui Campsite	J	Tin Fu Tsai Campsite
K	Long Ke Wan Campsite	L	Sam A Chung Campsite
M	Pak Lap Campsite	N	Cheung Sheung Campsite
O	Yuen Ng Fan (Nam Fung Wan)	P	Po Kwu Wan Campsite
Q	Ngong Ping Campsite (Ma On Shan)	R	Pak Fu Tin Campsite
S	Shek Lam Chau	T	Tai Long Wan Campsite
U	Kau Ling Chung Campsite	V	Nga Ying Kok Campsite
W	Tsin Yue Wan Campsite	X	Lau Shui Heung Campsite
Y	Twisk Campsite		

There are also numerous benefits to placing the structure underground. Wallace (2016) ([7]) used Stanley Sewage Treatment Works as an example. Being a “Bad Neighbour” facility with odour and visual impact problems in a rural scenic area with limited above-ground space, it has been successful in minimising the impact on the local community through odour control and visual impact and effectively shielding the sewage treatment works from public views.

4. Video Link

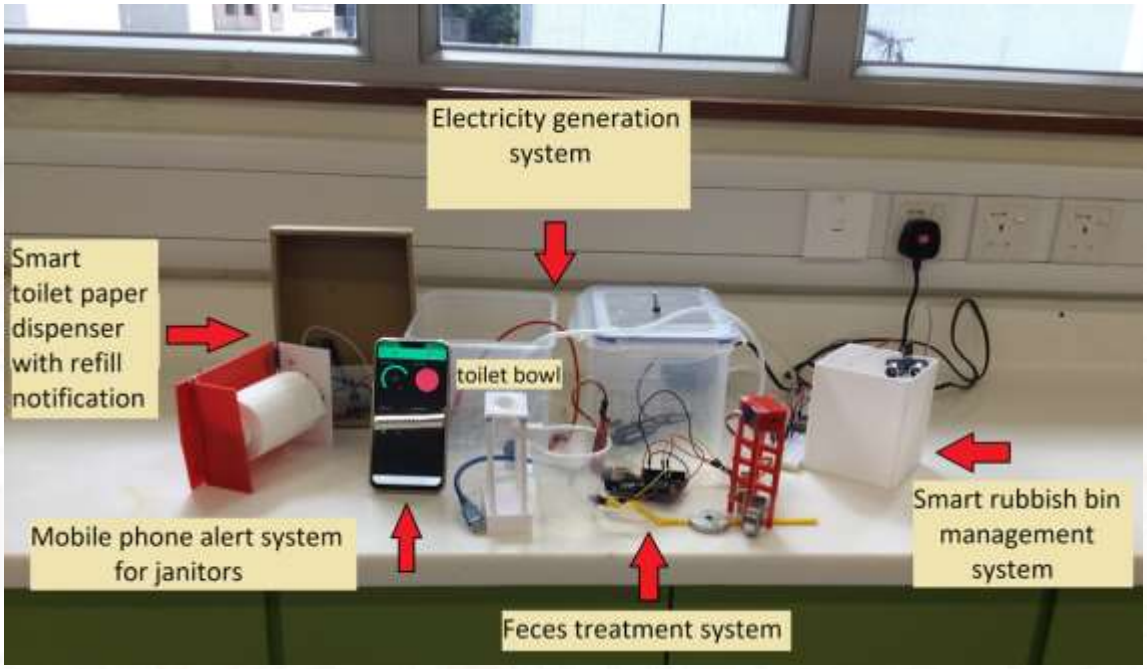
https://drive.google.com/file/d/1wScJqnpNErPBWKtzdFF13Flst_DMUOi-/view?usp=sharing

5. References

[1] Legislative Council of Hong Kong Special Administrative Region - Measures to improve public toilet facilities and services, Nov. 2019. Available: https://www.legco.gov.hk/research-publications/english/essentials-1920ise04-measures-to-improve-public-toilet-facilities-and-services.htm

[2] Compactor Management Company, "Overflowing Garbage Bins: Serious Threats and Prevention Tips", July. 2020. Available: https://www.norcalcompactors.net/overflowing-garbage-bins-serious-threats-and-prevention-tips/
[3] Paultnylund, Instructables, "DIY Microbial Fuel Cell! EASY!" Oct. 2017. Available: https://www.instructables.com/DIY-Microbial-Fuel-Cell-easy/
[4] 頭條日報 Headline Daily, "新·潮--鄉下化糞池", May. 2020. Avaliable: https://hd.stheadline.com/news/columns/765/20200502/851373/%E5%B0%88%E6%AC%84-%E6%96%B0%E2%80%A7%E6%BD%AE-%E9%84%89%E4%B8%8B%E5%8C%96%E7%B3%9E%E6%B1%A0
[5] Long-term Strategy For Cavern Development, Suitability of Cavern Development, 12 August 2020 Avaliable:https://www.cavern.gov.hk/suitability.htm
[6] Go Camping, Search results for "地區 所有, 設施 旱廁", 2017.
Available:https://gocamping.hk/?unonce=0acafcd030&uformid=179&s=uwpsfsearchtrg&taxo%5B0%5D%5Bname%5D=category&taxo%5B0%5D%5Bopt%5D=1&taxo%5B0%5D%5Bterm%5D=uwpqsftaxoall&taxo%5B1%5D%5Bname%5D=post_tag&taxo%5B1%5D%5Bopt%5D=1&taxo%5B1%5D%5Bcall%5D=1&taxo%5B1%5D%5Bterm%5D%5B%5D=glamping&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e5%2585%2583%25e6%259c%2597&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e5%25a4%25a7%25e5%259f%2594&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e5%25a4%25a7%25e5%25b6%25bc%25e5%25b1%25b1&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e7%25b2%2589%25e5%25b6%25ba&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e8%258d%2583%25e7%2581%25a3&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e8%25a5%25bf%25e8%25b2%25a2&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e9%258c%25a6%25e7%2594%25b0&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e9%259b%25a2%25e5%25b3%25b6&taxo%5B1%5D%5Bterm%5D%5B%5D=%25e9%25a6%25ac%25e9%259e%258d%25e5%25b1%25b1&taxo%5B2%5D%5Bname%5D=post_tag&taxo%5B2%5D%5Bopt%5D=1&taxo%5B2%5D%5Bterm%5D%5B%5D=%25e6%2597%25b1%25e5%25bb%2581&skeyword=
[7] Wallace, M. I., & Ng, K. C.. Development and application of underground space use in Hong Kong. Tunnelling and Underground Space Technology, 2016, January 6
Available: https://www.sciencedirect.com/science/article/pii/S0886779815302649.

Project Photo:



Postlude

Creative Experience: Originally inclined to design a Smart home in hopes of incorporating technology into peoples' lives, we finally settled on building a Smart toilet as we believe public toilets are one of the least concerned facility by Hong Kong people while being as important as other facilities such as buildings, and cars. We decided to improve rubbish bins and toilet paper dispensers in public toilets since most of them do not include any Smart or IoT technology, whereas toilets and sinks are continuously improving. Moreover, the concern of Hong Kong's sustainability gave us an idea to further excel the system by setting up a feces treatment and electricity generator. Finally, Tantalet, the name of the system is a word created by us which means tantalizing toilets. It is envisioned that the system will be generally implemented in public toilets, to generate electricity for self-sufficiency while enhancing user experience and minimizing manpower.

Photo of Group Members::

From left to right: Chow Chung Yan, Wong Sum Yin Kennice, and Hon Chung Yan

Editors' Comments on the Submission: The project proposes a smart toilet system, "Tantelet", to increase the sustainability of the toilet's electricity, paper, fecal disposal and garbage disposal. This is a very novel idea, its concept can be extended to various aspects. This is a comprehensive project: all the methods and results are illustrated clearly, the logic is strong, and the data is accurate. The video covers multiple experiments which very attractive and lively. It is a project worthy of further research and development.