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

1. Background

the toilet. The initiative of Tantalet is to enhance user with one stone in enhancing the city's sustainability. experience and minimize manpower. According to 2. Methods and results the Agriculture, Fisheries and Conservation Depart- 2.1 Simulation of feces treatment and electricity genment, there are no specific schedules for when they eration ([3]) clean the pit toilets, ADCD staff would only roughly treatment allows human feces to be collected and cussed further in section 3) undergo redox reaction to generate electricity. Thus, reducing excess manpower for other needs as Tan-lows: talet is able to transform a dependent system into a posed of at landfills, which accelerates the exhaus- generated in the process. tion of landfill space and intensifies land pollution. that feces are decomposed in an environmentally sults are as follows: friendly way, which greatly reduces the sludge dis-

posed at landfills, thereby tackling the aggravating In Hong Kong, public toilet facilities are stylish land pollution problem. Moreover, the demand of and creative on the outside, in an attempt to pro-fossil fuels for non-renewable energy generation is mote the development of "smart toilets" [1]. Howev-reduced, alleviating air pollution. Hence, Tantalet's er, there are few applications of technology within innovative electricity generation model kills two birds

A microbial fuel cell is built to simulate the elecestimate the time since last cleaning. Tantalet's feces tricity generation system in pit toilets (to be dis-

The principle of the microbial fuel cell is as fol-

In the left cell (anodic cell), glucose and sludge self-reliant toilet. Overflowing of trash in rubbish bins containing anaerobic bacteria are added. Glucose is is another common problem in public toilets. As oxidized into carbon dioxide and hydrogen ions by most citizens use paper towels to dry off their wet anaerobic bacteria following the equation: C₄H₁,O₆ hands after washing them, causing the creation of a (aq)+6H, $O(1) \rightarrow 6CO$, $(q)+24H^{+}(aq)+24e^{-}$. The hydrogreat deal of trash. Overflowing garbage is a perfect gen ions travel to the right cell via the salt bridge, breeding ground for insects and pests such as ro- which is made of towel strands soaked with saturatdents, they may spread diseases such as fever, ty-ed sodium chloride solution. In the right cell phoid, food poisoning and salmonella which pose a (cathodic cell), air containing oxygen is pumped into serious health issue to humans [2]. Dewatered water to maximize the amount of oxygen dissolved sludge is a major type of special waste in Hong in water. Oxygen is reduced to water following the Kong. At present, most dewatered sludge is dis-equation: $O_{2}(g)+4H^{+}(aq)+4e^{-}\rightarrow 2H_{2}O(I)$. Electricity is

Besides sludge containing anaerobic bacteria, Tantalet's renewable electricity generation system other substances involving a similar chemical reacusing discharged feces from public toilets ensures tion have been added to the left anodic cell. The re-



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 collecventing it from overflowing.

penser and the ultrasound sensor only when a per- manpower required to execute such a process. son locks the toilet door, instead of stand-by mode all the time. Both will be turned off after the person 3. Expectations in large-scale implementation unlocks the toilet door. A further experiment is need- 3.1 Treating human feces ([4]) ed 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 notifi-

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.

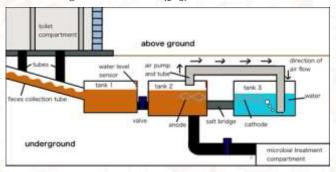
For the automatic toilet paper dispenser, a 360degree servo is used to rotate the toilet paper roll

penser 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 tion and discharge of feces using valves. When the ESP8266, an ultrasonic sensor and the blynk app. water level reaches the water sensor, a motor con- The trending technology Internet of Things (IoT), a trolled by Arduino is activated. The weights are lifted, system of interrelated, internet-connected objects and water flows out through a rubber tubing, pre- able to collect and transfer data over a wireless network, also plaus a major role in making this design The maximum voltage yielded by the sludge with possible. The ultrasonic sensor is installed on the wall anaerobic bacteria is 0.186V. It is about 1/32 and near the top of the rubbish bin. When the ultrasonic 1/28 of the voltage required by an automatic toilet sensor detects an object in front of it, it means that paper dispenser, 6V and an ultrasound sensor, 5V the rubbish bin level is almost full. A signal is sent via respectively. It will be impractical to build and con- the Wi-Fi module to the blynk mobile application nect so many microbial fuel cells to generate big which switches on the virtual LED, alerting cleaners enough and steady voltage. A capacitor or battery, that the rubbish is ready to be emptied. This model therefore, is needed to store the generated electrici- can be installed in multiple rubbish bins, enabling ty. The capacitance will determine how long the au- janitors to determine whether the bins need to be tomatic toilet paper dispenser and the ultrasound emptied with just a quick glance at the app. By using sensor run. One way to make efficient use of the the data of the rubbish bin levels, the bin emptying energy is to turn on the automatic toilet paper dis-process can be optimized, ultimately minimizing the



It is expected that this system will be implementwhich allows toilet paper to be dispensed. An ultra- ed in toilets which are unconnected to the public sonic sensor is used to send signals to turn on or off sewage system, as well as pit toilets in the countrythe servo motor. No paper will be dispensed if the side of Hong Kong to generate electricity for the ultrasonic sensor does not detect any obstacles operation of toilets. Since human feces also contain within the range of 10cm and vice versa. The dis- anaerobic bacteria, they can undergo redox reactions and generate electricity. The feces from the pit Table II. Key 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

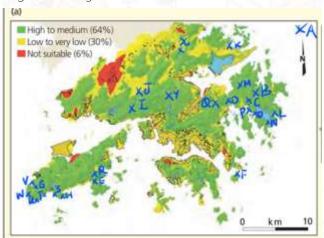
As shown in sections 2.2 and 2.3, alert systems of rubbish bins and toilet paper supplies using the Internet of Things are installed. Thus, janitors only need to maintain the toilets whenever they are alerted. savina manpower and costs.

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

high suitability.



А	Tung Ping Chau Campsite	В	Pak Tam Au Campsite
С	Yee Ting Campsite	D	Shui Long Wo Campsite
Е	Tung Lung Chau Campsite	F	Shap Long Campsite
G	Lo Kei Wan Campsite	I	Man Cheung Po Campsite
T	Ho Pui Campsite	J	Tin Fu Tsai Campsite
К	Long Ke Wan Campsite		Sam A Chung Campsite
М	Pak Lap Campsite	Z	Cheung Sheung Campsite
0	Yuen Ng Fan (Nam Fung Wan)	Ρ	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
Υ	Twisk Campsite		

There are also numerous benefits to placing the The feasibility of constructing the underground structure underground. Wallace (2016) ([7]) used structures at those places is also considered. The Stanley Sewage Treatment Works as an example. figure below ([5], [6]) shows the position of pit toilets Being a "Bad Neighbour" facility with odour and visin Hong Kong on a map showing the suitability of ual impact problems in a rural scenic area with limrock cavern development from the CEDD. It is found ited above-ground space, it has been successful in that most of the pit toilets are located in places with 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/1wScJgnpNErPBWKtzdFF13Flst DMUOi-/view? usp=sharing

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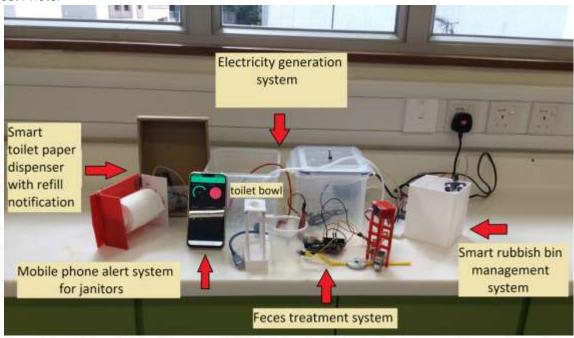
Available:https://gocamping.hk/? unonce=0acafcd030&uformid=179&s=uwpsfsearchtra &taxo%5B0%5D%5Bname%5D=category&taxo% 5B0%5D%5Bopt%5D=1&taxo%5B0%5D%5Bterm% 5D=uwpasftaxoall&taxo%5B1%5D%5Bname% 5D=post tag&taxo%5B1%5D%5Bopt%5D=1&taxo% 5B1%5D%5Bcall%5D=1&taxo%5B1%5D%5Bterm%5D%

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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.

