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Innovative Toilet Technologies for Smart and Green Cities

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Abstract: For the way to a smart and green urban society, sanitation is an important concern. Currently, using toilets is neither smart nor green. Every flush of common toilets sends about 13 - 16 liters of fresh water to wastewater treatment centers. These processes require 3 – 15 kWh for treating just one cubic meter of wastewater. Another problem is the mixing of urine and feces from the source, necessitating wastewater treatment. This treatment leads to the waste of a high amount of valuable nutrients in the urine, and causes many environmental problems. Also due to common technical water supply problems such as pipe blockage, current toilet systems are not functional in disasters or other emergency situations. However, many of these problems can be solved using smarter designs. In this study, innovative designs have been suggested for toilet systems. These designs use less or no water for reducing water consumption, apply systems such as bi-sloped conveyor belts to separate the urine and feces into two different tanks with biological digestion processes, improve flushing systems using alternative methods to reduce pipe blockage potential, and use special light and handy toilet seats for sanitation in emergency. Following these designs, new products have been made in lab scale to prove that these innovative technologies can reduce water and energy consumption, thereby taking positive steps towards building smarter and greener cities in the future.

Keywords: Green City; Smart Technologies; Sanitation; Source Separation; Emergency; Water Consumption.

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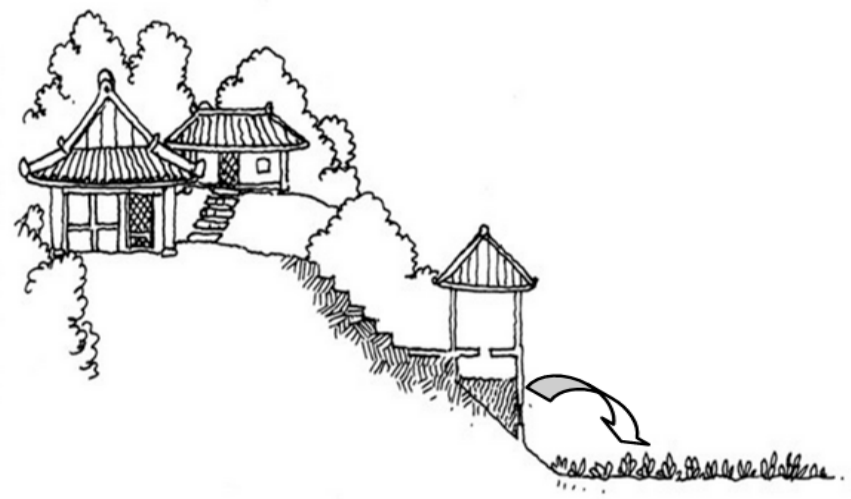
1. Introduction

Sanitation is a natural and essential part of human life, and it is an important concern for sustainable green and smart city planning. However, current sanitation practices are not sustainable.

Due to the many problems that arise from inappropriate practices and management, there are 2.5 billion people who still do not use improved sanitation facilities, and over 1 billion people practice open defecation (UN Human Right to Water and Sanitation, 2012). Therefore, finding sustainable solutions to these problems is an essential concept in modern urbanism.

The practice and management of sustainable sanitation has a very long history, and evidence of ancient sanitation management can be found all over the world (Bracken et al., 2006). In ancient Korean societies, it was well known that urine and feces could enhance land fertility if kept separate from each other and not exposed to water. Following this concept, temple toilets (Haewooso) were designed to deposit the feces into well-ventilated compost chambers. The feces were then removed from the bottom of these chambers and used directly as fertilizer (Figure 1). Additionally, ancient Koreans were familiar with source separation, and they had special instruments for separation and manual transportation of excreta (Figure 2) (Han & Kim 2014).

Figure 1. Temple Toilets Next to Houses and Agriculture Areas



Looking to the past may help to provide solutions to current sanitation problems. By using this historical knowledge, and by applying modern technologies, it might be possible to find sustainable solutions. In this paper, the major problems of current toilet practices in urban areas have been identified, and by following ancient wisdom in sanitation management, solutions have been suggested through innovative smart-design toilets.

2. Major Problems of Current Sanitation Practices

2.1. Using Too Much Water and Energy

Current sanitation practices have high water and energy consumption. A typical toilet consumes between 13 and 15 liters of water per flush. Using this information, a simple calculation shows that about 10,000 m^3 of freshwater is consumed over the 20-year lifespan of only one toilet. Additionally, when

considering the energy consumed to prepare flushing water for toilets through water treatment from dams, desalination, and wastewater treatment, and also taking into account the energy for treatment of the flushed water, about 3 – 15 kWh is needed in order to treat 1 m^3 of flushing water (Han & Kim 2014).

Figure 2. Traditional Manual Transportation of Urine (Left) and Feces (Right)

2.2. Mixing Urine and Feces (Making Black-Water)

Due to the high amount of nutrients in urine, the mixing of urine and feces in sanitation is a wasteful practice. Sending the mixture of urine and feces to wastewater treatment plants not only wastes important nutrients such as nitrogen and phosphorus, but can also lead to algae sludge over-growth in the treatment plants (Hashemi, 2015). Furthermore, releasing black-water back into nature can transfer contaminants such as PPCP, ECD, and micro pollutants into other water resources (Han & Kim 2014).

2.2. Improper Emergency Function and Social Responsibility

Current sanitation practices are not functional during emergencies and disasters, In these situations, water scarcity and damage to the water supply may result due to the higher and more severe demands on the system (Tayler et al. 2003). During disease outbreaks, such as the recent Ebola epidemic, viruses can be easily transmitted through shared toilets (Morella & Foster 2008). Additionally, with improper practices such as open defecation, social problems such as sexual harassment can result due to the lack of privacy (Gatherer 2014).

3. Introducing Innovative Products for Solving Sanitation Problems

This century has seen many tremendous achievements through the innovative use of technology. By following ancient wisdom in the case of sanitation, and by using Hi-Tech, it is possible to solve many of the sanitation problems that plague our cities today. In this case, three lab-scale products are being introduced as follows:

Figure 3. Improved Flushing Mechanism in the 4.5-Liter Water-Saving Toilet

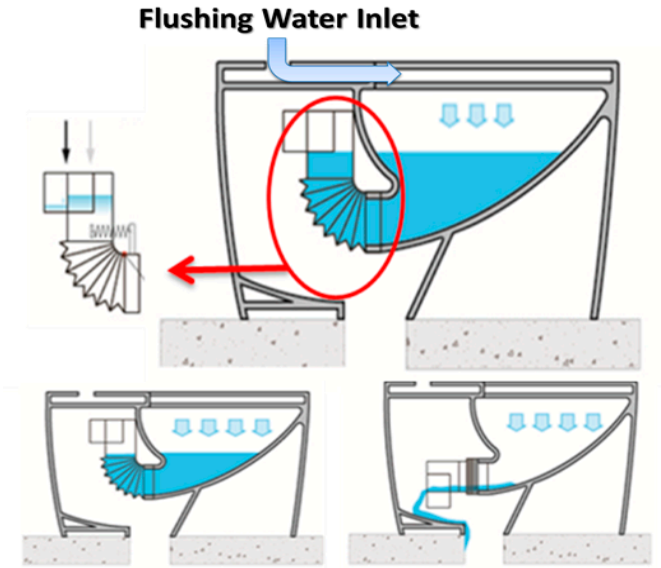
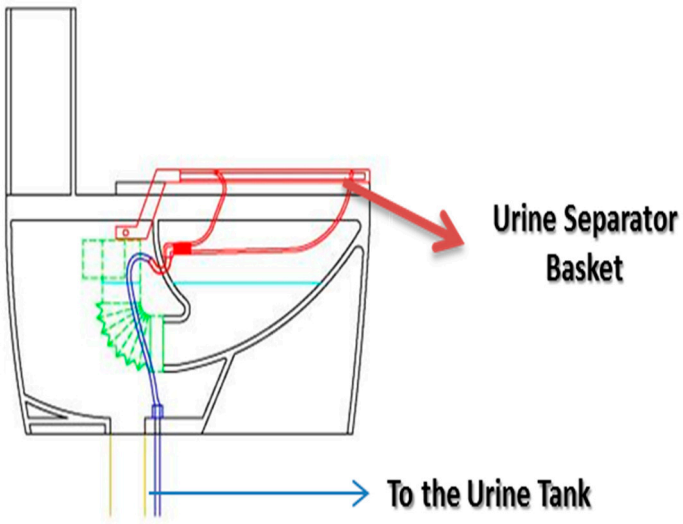


Figure 4. Urine Source Separator Basket for the 4.5-Liter Water-Saving Toilet



3.1. 4.5-Liter Water-Saving Toilet

Siphons are necessary for keeping water inside the pipe and bowl of the toilet in order to prevent odor. However, the use of large amounts of water for flushing results in the improper functioning of these siphons. The poor piping design of siphons is also the main cause of pipe blockage in toilets.

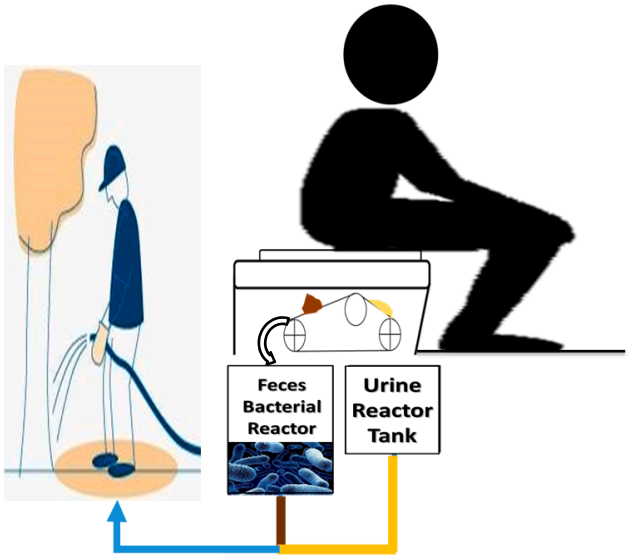
As it is presented in figure 3, in the new water-saving toilet, the siphon system has been redesigned and substituted with a spring. By increasing the height of water the center of gravity shifts to the left when flushing. This pushes the spring down so that the waste will be discharged from the toilet allowing flushing to be done with only 4.5 liters of water. After discharge, the spring comes back and the water will be tapped, preventing the smell.

In addition, a special basket has been designed in order to separate the urine and feces (Figure 4). This basket is also useful for sending urine into a separate reservoir to be utilized for other purposes, such as for fertilizer.

3.2. Bi-Sloped Conveyor Belt Toilet

The Bi-Sloped Conveyor Belt Toilet is waterless. Instead of flushing, the feces and urine are separated from the source using a bi-sloped conveyor belt (Figure 6). The conveyor belt delivers feces to the back where they are deposited in the feces tank. The urine flows down to the front, which leads to the urine tank. The use of additives or microorganism bio-seeds in the urine and feces tanks can create a bio-tank, converting the urine and feces into fertilizers.

Figure 6. Bi-Sloped Conveyor Belt Toilet for Separation and Recycling Purposes



3.3. Emergency Enabled Waterless Portable Private Toilet Kit

This toilet system is actually a package designed for use in emergency situations. The package contains a toilet seat, a waste collecting bag, waste additives, and a tent.

The toilet seat is made of paperboard which can be folded, and which can tolerate up to 300 kg of weight. The waste collecting bag is made from biodegradable materials, and the additives can be added to waste collecting bag in order to reduce the volume of waste. The tent in the package creates a private space for the user and can prevent open defecation, which will help to reduce sexual harassment and other social problems (Figure 7).

This toilet kit is designed for one individual so that it can reduce the potential of virus transmission during outbreaks. Considering the materials, the price of this kit is very low, and it can be used by everyone.

Figure 7. Portable Private Toilet Applicable for Emergency Situations

4. Conclusions

In this paper, we have identified major problems of current toilet practices in urban areas. These problems that exist within urban sanitation systems should be considered and resolved using smart and green urbanism practices.

To solve these problems, this paper suggests several innovative designs for toilet practices. These designs were influenced by ancient Korean wisdom and were realized by applying modern technologies. Through the use of these innovations, future sanitation practices will:

1. Use Less Water
2. Separate Urine and Feces
3. Utilize Waste as Fertilizer
4. Foster Social Responsibility
5. Be Identified as a Technology toward Zero Emission Community.

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Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Bracken, P.; Wachtler, A.; Panesar, A.; and Lange, J. The road not taken - how traditional excreta and greywater management may point the way to a sustainable future. *Wat.Sci.Tech.* **2006**, *7*, 219–227.
2. Gatherer D. The 2014 Ebola virus disease outbreak in West Africa Wachtler, *J Gen Virol,* **2014**, 95, 1619 – 1624.

3. Han M. Y.; Kim, M. K. Revising the Technical and Social Aspects to Wastewater Management in Ancient Korea. In *Evolution of Sanitation and Wastewater Technologies through the Centuries*, Angelakis, A. N., Rose, J. B., Eds.; Publisher: IWA Publishing, UK, 2014; pp. 301-311.
4. Hashemi, Sh. Fate of Nitrogen in Urine Separated Toilet System, M. Sc. Dissertation, Seoul National University, Seoul, 2015.
5. Morella, E.; Foster V.; and Banerjee S. *Climbing the Ladder: The State of Sanitation in Sub-Saharan Africa.* AICD Background Paper 13. World Bank, Washington, DC, 2008.
6. Tayler, K.; Parkinson, J.; and Colin J.; *Urban Sanitation: A Guide to Strategic Planning.* ITDG Publishing, London, UK, 2003.
7. United Nations Office to support the International Decade for Action, Water for Life 2005-2015 / UN-Water Decade Program on Advocacy and Communication (UNW-DPAC); *The Human Right to Water and Sanitation Media Brief*; 2012.