I BET YOU DIDN'T KNOW...

Toilets in the future may charge your mobile phone!

PSTT College Fellow Dr Rebecca Ellis, links **cutting edge research** with the **principles of primary science**

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There are many things that we take for granted in the developed world. Near the top of this list is being able to flush our toilets.

The flush water washes our waste away in pipes to sewage treatment works. Here, our smelly sewage is safely separated into solids (including all the poo or faeces) and liquids (including the wee or urine).

Following a multi-step treatment process, clean water is released back into rivers and the solids can be used to make fertiliser. For the poorest families of the world, however, the story is very different. They have limited access to clean water and little sanitation.

What do you think might happen if you did not have a toilet linked to a sewage system?

Hand dug pits are frequently the only toilets available for people in the poorest countries and this leads to many health risks. The sewage is not piped away and so it can contaminate the water supply, the land, and crops. Because the toilets are outside, flies can also spread dangerous germs directly from the faeces to the family's food stores.

What are the consequences? Are the people who are without clean, safe toilets more likely to get sick or even die? Yes, they are. One of the most common illnesses caused from inadequate sanitation and hygiene is diarrhoea. Diarrhoeal disease is the second leading cause of death in children under five years old.

What other types of toilets exist?

Composting toilets which turn the faeces and urine into a compost-like material do not need to be connected to water systems or chemical tanks. These could be a better alternative in some rural areas where the waste can be used as fertiliser in farming. However, the composting process may not destroy all the microorganisms which could cause disease (pathogens). Also, this is not a sensible solution in densely populated cities where the number of people means that large amounts of compost will be created and there is nowhere to put it. Another type of toilet that does not need to be plumbed into a water system is a chemical toilet which is built around a tank containing chemicals to minimise smells and reduce the growth of pathogens. These toilets are useful as portable toilets but must be emptied regularly into sewer systems. In poorer countries, this might not be possible.

Is anyone doing anything about this?

The good news is that global leaders want to work towards a fairer world and have set targets for improvement by 2030. Together they decided to set global goals for sustainable development and goal number 6 is providing the whole world with clean water and sanitation.

Scientists have come up with an idea to change the world. Funded by 'The Bill & Melinda Gates Foundation Reinvent the Toilet Challenge', they have redesigned a toilet for those without water and plumbing. It looks like a normal toilet on the outside (Figure 1) but inside there is a lot of clever science at work which the user probably could not imagine (Figure 2)!

Figure 1. Toilet shack fitted with Nano Membrane Toilet in eThekwini municipality, Republic of South Africa.

©Photograph kindly provided by Dr. Kristin Ravndal, Cranfield University.

Figure 2. The Nano Membrane Toilet designed by researchers at Cranfield University, UK.

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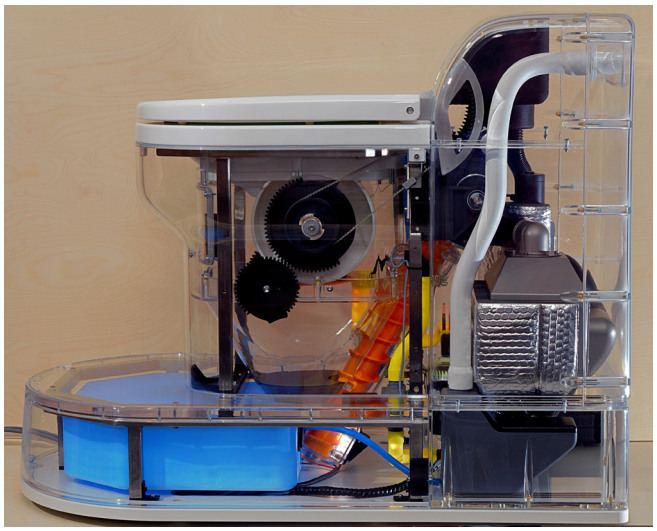


How does the Nano Membrane Toilet work?

Firstly, when the user turns the flush handle, the movement is linked by gears to the toilet bowl itself. When the lid is closed, the bowl swivels down so the waste faeces and urine fall into a holding chamber. This means there are no smells and no flies! Opening the lid turns the toilet bowl back to its starting position and it is ready to be used again.

How is the waste treated inside the toilet?

Well, as the bowl turns down to drop the waste, it is wiped clean by a swiper. The scientists set up field trials where real people used these new toilets and reported on how well they operated. The scientists tested swipers made from different materials in these trials and found that silicon was the best material to use. You could test which materials would make the most efficient swiper by swiping baked beans (a good model for mixed waste-faeces and urine) from a plate with spatulas made from wood, plastic, metal and silicon.

After a settling period in the holding chamber, the faeces sink and are picked up by an Archimedes screw. The faeces are then dried and burnt. Burning (or combustion) blends air with the faeces and turns it into a safe ash which can be used as fertiliser. The best part is that the burning releases heat energy. Some of this heat is used to dry the next lot of faeces, making it easier to be burnt. The toilet design therefore extracts the energy it needs to run efficiently. You could try making Archimedes screws using beads or marbles, cardboard tubes, gardening wire and plastic containers.

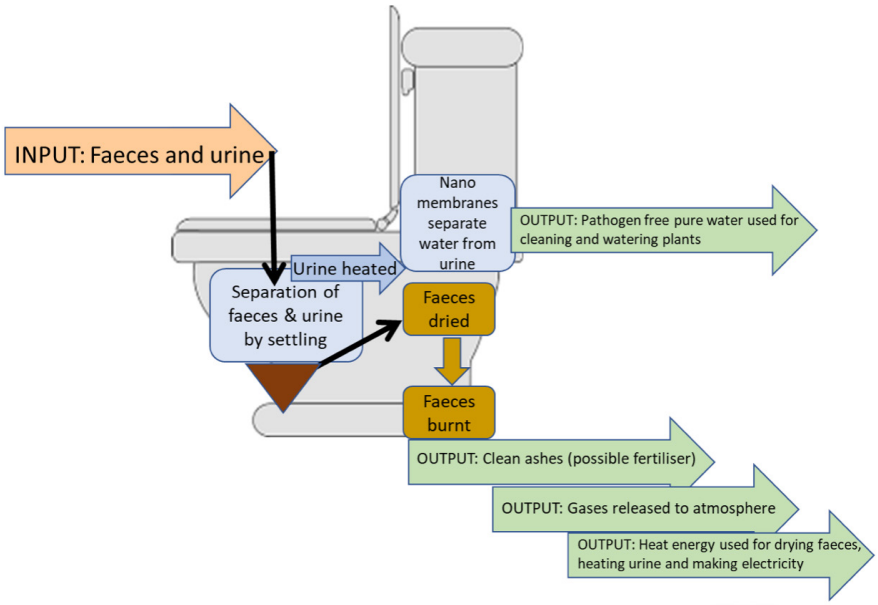
Meanwhile, a weir at the top of the holding chamber takes urine to the next stage of cleaning. A weir in a river is a low dam which can be used to divert water. You have probably created weirs when building sandcastle on the beach!

The urine is taken to the membrane chamber and is heated using more of the energy released from burning the faeces. The membranes are hollow, like straws and only pathogen-free water vapour can pass into them. This water vapour is then condensed, collected and may be suitable for household cleaning or watering plants.

The scientists have found that when the toilet is working at its best there is even some heat energy left over – this could be converted to electricity and used to charge a mobile phone! Heat energy can be converted to electrical energy by heating water to create steam. Steam can turn a turbine which is linked by an axle to the generator. The turning movement is converted to electricity when a conductor moves within a magnetic field.

You could summarise the science inside the toilet using a flow diagram (Figure 3).

Figure 3. Diagram to show how the Nano Membrane Toilet works.



Glossary

Axle	A bar, shaft or rod which connects mechanical machines
Faeces	Waste matter, in solid or semi-solid form, resulting from food that could not be digested in the body (commonly known as poo)
Pathogen	Micro-organisms (bacteria and viruses) that cause diseases
Urine	The liquid by-product of metabolism in animals (commonly known as wee)

The associated **Teacher Guide** provides links to many relevant websites, including a film clip from Cranfield University that explains how the Nano Membrane Toilet works.

The two research papers that generated this work were:

Conceptual energy and water recovery system for self-sustained nano membrane toilet.

By Dawid P. Hanak[1] , Athanasios J. Kolios[2], Tosin Onabanjo[2], Stuart T. Wagland[3] , Kumar Patchigolla[4], Beatriz Fidalgo[3] , Vasilije Manovic[1], Ewan McAdam[5], Alison Parker[5], Leon Williams[6], Sean Tyrrel[5], Elise Cartmell[5]

Energy Conversion and Management 126, 352-361 (2016)

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2. *Offshore Renewable Energy Engineering Centre, Cranfield University, Bedford, Bedfordshire MK43 0AL, UK*
3. *Bioenergy and Resource Management Centre, Cranfield University, Bedford, Bedfordshire MK43 0AL, UK*
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5. *Cranfield Water Sciences Institute, Cranfield University, Bedford, Bedfordshire MK43 0AL, UK*
6. *Competitive Creative Design Centre, Cranfield University, Bedford, Bedfordshire MK43 0AL, UK*

Field testing of a prototype mechanical dry toilet flush.

By Jan Hennig[1], Kristin T. Ravndal[1], Thubelihle Blose[2], Anju Toolarama[1], Rebecca C. Sindall[2], Dani Barrington[1], Matt Collins[1], Bhavin Engineer[1], Athanasios J. Kolios[1], Ewan McAdama[1], Alison Parker[1], Leon Williams[1], Sean Tyrrel[1]

Science of the Total Environment 668, 419–431 (2019)

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