Reinventing the toilet for 2.5 billion in need

High-tech toilets for tackling the growing public health problem of human waste are gaining increasing attention. But, as Gary Humphreys reports, low-tech solutions may be more practical in poor countries.

Professor Karl Linden of the University of Colorado, Boulder, in the United States, is understandably proud of his team's toilet. It looks like a missile tracking system and makes human faeces and urine disappear; or, to be more precise, turns solid waste into biological charcoal, a material known as bio-char that can be safely used as a fuel or fertilizer, while urine-infused bio-char can be used as a nitrogen-rich fertilizer. "Nothing harmful is left over," says Linden. "There are no by-products, no germs, nothing."

The Sol-Char toilet is one of the winners of the Bill & Melinda Gates Foundation's Reinvent The Toilet Challenge, a competition launched in 2011 to encourage the development of technological solutions that will bring safe, affordable sanitation to the 2.5 billion people worldwide estimated to be without it.

In the first three years of the competition, 16 grants were disbursed. One, for example, went to a University of Bristol team, to develop a urinal that transforms human waste into electricity. Another went to Swiss aquatic institute EAWAG for a toilet that stores urine and faeces for energy recovery, and another to RTI International in the USA for a model that disinfects urine, dries and burns waste and converts this into stored electricity.

Recently the Gates Foundation joined forces with India's Biotechnology Industry Research Assistance Council to pick six teams of researchers from India, who are developing several models, including a solar-powered toilet with an in-built waste processing capability and a toilet that uses ultrasound to reduce water wastage.

"The idea of the challenge isn't simply to come up with better toilets, but to invent new ideas and new approaches to dealing with human waste," explains Gates Foundation sanitation expert Jan-Willem Rosenboom, who has 30 years' experience of working on sanitation solutions in the field. Prior to joining Gates, Rosenboom worked for Oxfam and the United Nations Children's Fund (UNICEF).

The Gates Foundation initiative is laudable and addresses a serious problem. According to Bruce Gordon, acting coordinator of the Water, Sanitation, Hygiene and Health unit at the World Health Organization (WHO) in Geneva, the lack of access to safe, clean sanitation currently puts an estimated 2.5 billion people at risk of many diseases including dysentery, cholera, typhoid, schistosomiasis, trachoma and intestinal worms. An estimated 645 000 children under five die every year from diarrhoea – a preventable, sanitation-related disease.

"Progress on the issue has been disappointing," Gordon says, noting that the Millennium Development Goal (MDG) sanitation target to halve the proportion of the global population without access from around 50% in 1990 to 25% in 2015 is unlikely to be met, while the number of people practising open defecation – usually because they have no other option – has fallen by only 21% over the past two decades to around one billion in 2012. "Achieving universal access to basic drinking water sources appears to be in reach, but we will not achieve universal access to basic sanitation without some fundamental change," Gordon says.

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>
> *Jan-Willem Rosenboom*

Is reinventing the toilet the way to achieve that change? Rosenboom thinks so, but has no illusions about the size of the challenge faced, a challenge reflected in the stringent selection criteria of the Reinvent the Toilet Challenge competition.

The winning toilets are supposed to remove germs from waste, recover valuable resources such as energy, clean water and nutrients, without being connected to water, sewer or electrical mains. They should be cheap – less than 5 cents per user per day (US$ 0.05) – and suitable for promoting sustainable and profitable sanitation services and businesses that can operate in poor, urban settings. "It is admittedly a very tall order," Rosenboom says.

It is so tall, in fact, that none of the winners of the Reinvent the Toilet Challenge competition, so far, have managed to tick all of the boxes, though some have come close. Several new toilet models will be field tested this year in Bangladesh, Kenya, India, Senegal and South Africa.

The Bill & Melinda Gates Foundation

At the Re-invent the Toilet Fair in India in 2014, Dr Christopher Elias (right), President of Global Development, and Dr Doulaye Kone (left), Senior Program Officer, both from the Gates Foundation look at Harald Gründl, who is sitting on Eawag's Blue Diversion Toilet

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One problem inventors face is containing costs. The University of Colorado's Sol-Char toilet is a case in point, using expensive fibre optic cable to transfer sunlight captured by an array of parabolic mirrors. Linden was first quoted US$ 20 000 for four metres of cable by a supplier but eventually got the price down to US$ 500.

To get under the US$ 0.05 per user per day price-threshold set by the Gates competition, Linden's team is planning to develop a Phase II household shared toilet suitable for serving 30–40 occupants for 20 years.

Linden himself is fully aware of these cost issues, but argues that the toilet that he and his team built is designed as a proof of concept "taken from a set of scientific theories on paper to a functional unit in less than 16 months". If they receive further Gates funding, the team will work with designers with manufacturing expertise to move closer to a field-ready model in the next phase of development.

Linden and his team are not the only ones wrestling with the issue of price. According to Rosenboom, while the target price of some of the units shown in India was US$ 600, making mass provision prohibitively expensive, "connecting a household to a sewer network usually costs much more than US$ 600". Rosenboom adds: "The investment in sewers, treatment plants, pumping stations – not to mention associated operation and maintenance – represents an enormous outlay for which the household is not asked to pay. Reinvented toilets remove the need for investing in sewers and treatment plants."

Given the vast numbers of people in need, Graham Alabaster, a WHO sanitation expert, agrees, suggests that a unit price of around US$ 40 would be more realistic. "I don't see a lot of use for toilets with a unit price of US$ 600," he says.

Whether or not the Reinvent The Toilet Challenge entries can overcome these problems remains to be seen. In the meantime, sanitation experts point out that perfectly workable toilet technology already exists.

> A properly dug and maintained pit latrine goes a long way to solving many sanitation problems in rural areas
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> *Samuel Godfrey*

"A properly dug and maintained pit latrine goes a long way to solving many sanitation problems in rural areas," says Dr Samuel Godfrey, the head of UNICEF Ethiopia's Water and Environmental Sanitation Programme. Godfrey has 20 years of experience improving water and sanitation and has spent the past 10 years with UNICEF in Africa and Asia. "The challenge is getting communities to dig, maintain and use latrines in remote and difficult to access rural communities," he says. In other words, getting people to change their behaviour.

Encouraging behaviour change, notably through the application of the so-called community-led total sanitation approach is a core focus of UNICEF's sanitation work and has reaped success in several countries, notably Ethiopia. A key aspect of the approach is effectively communicating to communities the risks of open defecation. This includes showing people how flies go from piles of excrement to piles of food and by walking through areas where people defecate. "We get people to change through disgust," Godfrey says.

Behaviour change, however, is not possible without the latrines needed to accommodate it, and here too UNICEF has been active, working in conjunction with the Ethiopian government to engage the private sector by marketing sanitation throughout the country.

The push to upgrade the country's toilets dates back to 2003 in the Southern Nations Nationalities and Peoples Region (SNNPR) of Ethiopia, where it became compulsory for each household to have and use a latrine. Today, the SNNPR reports 75% access to sanitation, the highest of any region in Ethiopia. In the country, as a whole, access to safe sanitation has risen from 7% in 2000 to 60% today.

"Sustainability was an objective from the beginning and no hardware subsidies were provided," says Waltaji Terfa Kutane, an officer with the WHO Ethiopia Country Office, referring to the onus on building sustainable systems with local materials. People built the latrines using locally sourced materials, none of which included fibre optic cables.

Despite the practical approach taken in Ethiopia, UNICEF's Godfrey believes that the Gates Foundation is doing important work. "One of the things we're dealing with in Ethiopia is the urbanization of the population," he says, "a movement which has put tremendous strain on the sanitation capacity of the country's cities".

Godfrey believes that technology focused on turning effluent into something else – which is also the goal of the Sol-Char toilet – has an important role to play. "Even if people are using toilets properly, there's still an accumulation of waste," he adds. "If we can find technological solutions to deal with it, we can make a real difference." ■

University of Colorado

The Sol-Char toilet developed at the University of Colorado, Boulder, USA