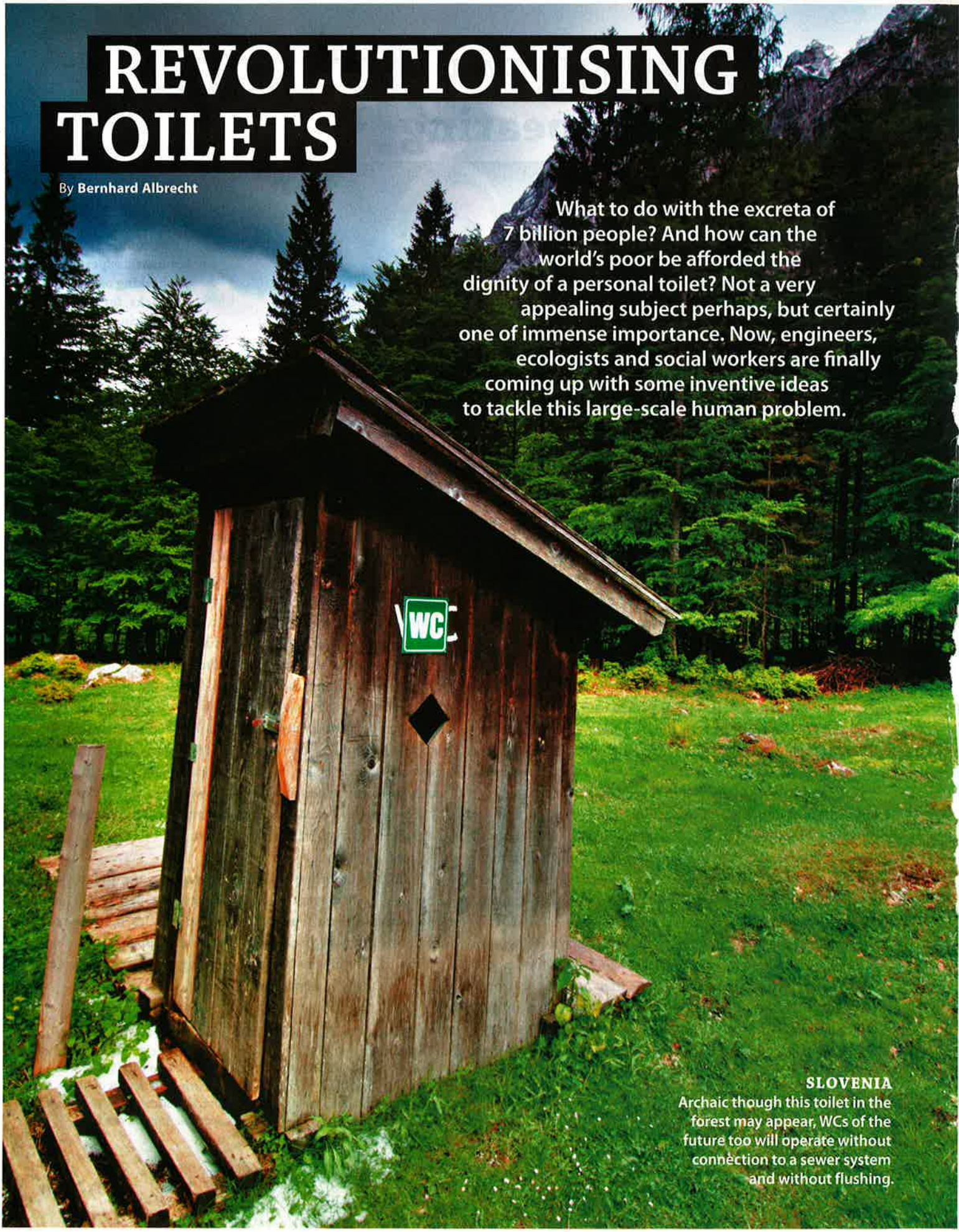
REVOLUTIONISING TOILETS

By **Bernhard Albrecht**

What to do with the excreta of 7 billion people? And how can the world's poor be afforded the dignity of a personal toilet? Not a very appealing subject perhaps, but certainly one of immense importance. Now, engineers, ecologists and social workers are finally coming up with some inventive ideas to tackle this large-scale human problem.



SLOVENIA
Archaic though this toilet in the forest may appear, WCs of the future too will operate without connection to a sewer system and without flushing.

On average, people spend six months of their lives in a place they should have all to themselves

THEY FORM A NETWORK of about 180 organisations across almost 50 countries. They have infiltrated universities, municipalities, even governments. Call them the toilet revolutionaries. Their objective: nothing less than the elimination of sanitation systems in their current form. They believe that the water closet, that embodiment of modern civilisation, has been an undesirable development in industrial history.

The movement started in poor and developing countries, where 2.6 billion people have no access to a toilet and do their highly infectious business out in the open or in buckets, which they then empty out behind their hovels or into the nearest stream or river. Or they defecate into plastic bags, the so-called little airplanes (Rio de Janeiro) and scud missiles or flying toilets (Nairobi), which are tossed up onto the roof—and sometimes also land on someone's head.

However, as part of one of the eight Millennium Development Goals of the United Nations, ratified in 2000, things should have changed by 2015. Access to toilets and clean water is now deemed a basic human right. Unfortunately, little progress has been achieved in this direction.

Some years ago, the Bill & Melinda Gates Foundation challenged 22 universities to 'reinvent the toilet' and promised generous funds from its pool of 265 million US dollars. Proposals for flush toilets and treatment plants along the lines of Western sanitation systems were not accepted since poor countries lack the money, water, energy and sometimes even the subsoil required for high-tech solutions. The toilets of the future were to use no water at all and were to cost no more than three cents per head per day.

But these new toilets could bring about a revolution in wealthy Europe as well—underground, in the sewer system. Europe's water consumption has already fallen by about 12 per cent since 1995. And this frugality brings its own set of problems for water utilities and sanitation networks—in Germany, for instance.

EBB IN THE SEWERS

KIM AUGUSTIN knows the numbers because that's his job: washing machines today consume just 50 litres of water instead of the 150 they used to in 1980. Modern flush systems need 3.5 litres instead of 6; new showerheads have halved the flow required. As head of the department of future technologies of Hamburg Wasser, the city's water supply and wastewater disposal company, Augustin has to look into questions such as when zero-litre

Test case one: in Hamburg's ecological settlement of Allermöhe, solid, liquid and paper from the dry toilet drop into a compost tank in the basement.

washing machines will come into existence or what kind of toilets Hamburg residents will be using in the year 2050—crucial issues for him because the sale of potable water is the company's main source of income. And sales have been going down: since 1990 the daily consumption of water across Germany has declined from 147 litres per head to about 120 litres.

Paradoxically, the decrease in the volume of sewage has been accompanied by an increase in expenses. To prevent the now oversized sewers from clogging, the company has to flush them regularly with potable water at its own cost. And increasing the price of water doesn't make financial sense, for consumers will merely reduce their consumption even further—a vicious cycle.

On the other hand, supply of drinking water and disposal of wastewater call for huge investments. In Hamburg alone these amount to 147 million euros a year. The total investment required across Germany is about 55 billion euros.

Such expenses get squared off only over the course of 100 years or so and calculations have to take into account which areas are likely to see a decrease in population—or an increase, perhaps as a result of immigration. The water business can thus be compared to super-tankers: one must alter course today in order to be at the right place by the year 2050. Quite impossible, really.

Augustin also recently got a foretaste of how quickly consumers could pull the plug on him. This was in Essex, England, where he visited Propelair Limited, a start-up that wants to introduce a high-performance flushing system. The highlight is a pump behind the toilet seat that sprays a mix of air and water at high pressure into the bowl. Instead of 6 litres of water, just 1.5 are required. "Such a system could break the backbone of Hamburg

The first drainage system existed around 2,500 years ago in the Indus Valley Civilisation

Wasser, technologically as well as financially," says Augustin.

Waterless urinals in men's toilets in fast-food chains are already a success: urine flows down the special hardened porcelain like water off lotus leaves. There is also a rumour doing the rounds that NASA scientists are working on a waterless nanotech toilet bowl where faecal matter too slides down on its own.

IT ISN'T MERELY THE REDUCED quantity of sewage that is a problem for the waterworks, but also its composition. Water from toilets—'black water'—gets diluted as it flows to the treatment plant, forming just 1 per cent of the wastewater. Everything else is 'grey water': mildly dirty discharge from showers, rainwater and effluent from factories. "In the treatment plant, we have to go to great lengths to remove this extreme dilution, with high input of energy and very expensive technologies," explains Augustin. Grey water, on the other hand, can be cleaned with economical, simple treatment systems since it contains few dangerous pathogens.

All efforts at purification notwithstanding, residues of pharma products remain—they cannot be filtered out of the water fully. And since treated water is fed, via streams and rivers, into the ocean, the contaminants eventually end up in nature, where hormones can impair fish breeding and antibiotics can make bacteria resistant. Finally, thanks to the food chain, these micropollutants return to the human body. A tiny percentage of germs survive too. The sludge that collects in treatment plants is also polluted. Some of it is incinerated; the rest still finds its way to the fields.

LOOS FOR THE WORLD

PROBLEMS OF PLENTY—or so those 2.6 billion people who have no access to a toilet at all might say. One gram of excreta could have millions of germs teeming in it. Cholera, meningitis, typhoid and other diseases are transmitted through unclean water. Diarrhoeal diseases are the main cause of death among children under the age of five. According to UNICEF, nearly 3,000 children fall victim to these every day.

Test case two: the HTC reactor at the Hamburg Technical University now takes just 3 litres of faeces. Under high pressure this turns into coal, ideal as fuel.

The problem is magnified in the cities. Slums proliferate here, slums that have no sewage systems or drinking water supply. Poor megacities—Nairobi, Lagos, Mumbai, Dhaka—writes American sociologist Mike Davis in his book *Planet of Slums* are "stinking mountains of shit". In Mumbai an estimated 5 million toilet-less residents produce a 'mountain' of 1,000 tonnes of faeces every day.

The Indian government has invested 16 billion US dollars in sanitation and infrastructure programmes. But more than mere latrines are required. For instance, in the 1990s the government constructed 9.45 million toilets of brick or concrete, but most of these were used as additional housing space or even as personal shrines. The poor continued, as before, to answer the call of nature in the open. No one had educated them about the toilets.

Bindeshwar Pathak and his organisation Sulabh International, on the other hand, are focused on awareness building. Since the 1970s this social reformer has also been waging a battle against the practice of manual scavenging by 'lower-caste' Indians, who clean latrines with their bare hands. Pathak proposes a low-cost flush compost toilet, built in accordance with WHO guidelines. He also runs public loos in many cities, including in the pilgrim town of Shirdi, which has 140 Sulabh toilets, visited by 30,000 people every day. His model is probably the simplest among all alternative toilets available: a latrine with two soak pits instead of one. When one is full, the other is used. After about two years the composted excreta from the first pit is used as manure.

But Pathak has his detractors. Pathogens can survive far longer than a year in the moist faecal matter. Worm eggs in particular die only after three years of drying. And ground water can become contaminated if the pits are not leak-proof.

WHEN JUST A BAG WILL DO

AN EVEN SIMPLER SOLUTION could be the 'loo in a bag': a plastic sack, 14 x 38 cm large, stretched over the rim of a small bucket, meant for one-time use. After use the bags are collected and composted, along with their contents, in large containers.

This invention of Swedish architect Anders Wilhelmson is a wonder of modern chemistry, for it is coated on the inside with urea, the enemy of microorganisms—all pathogens in the faeces are killed in a few weeks. The plastic is biodegradable and disintegrates in a few months. The base material of the bag, a synthetic mix with the brand name Ecoflex, is manufactured

by the chemical giant BASF. In fact, Wilhelmson's strategy has always been to involve industry and to develop a business model. He has even created his own firm, Peepoople, for this purpose.

Mass production is set to start this year. The bag will cost three euro cents, with one cent being refunded when it is brought to the collection site. Wilhelmson has much to say about the good reception his 'Peepoo Bag' met during pilot studies conducted in Kenya and Bangladesh. His target: 150 million users per day.

There is arguably no quicker and simple remedy for hygiene distress in crowded slums. Critics, however, point out that Wilhelmson is selling a temporary solution as a permanent one and helping the plastics industry earn big bucks in the bargain. Also, that it will aggravate the dreadful custom of 'flying toilets'. And since the one-time loo is patent-protected and likely to remain beyond the budget of many, they will go back to the conventional plastic bags or use cheaper but ineffective imitations.

Everyone, however, is agreed on the advantages Wilhemson's bag offers in times of natural disasters. According to Peepoople estimates, 50,000 beneficiaries can be reached within three weeks.

SEPARATION IN THE BOWL

PROPONENTS OF THE 'DIVERSION TOILET' offer another solution. "It is for good reason that God has provided us with two orifices," they say, making a case for the separation of liquid from solid within the toilet bowl.

One of the most passionate advocates of excrement segregation is Chris Buckley of KwaZulu-Natal University in Durban, South Africa. After a devastating outbreak of cholera in his province, he fought for the introduction of dry urine-diversion toilets. Over 100,000 of these now exist on the outskirts of Durban.

In this model, a divider runs across a bowl, urine flows through a sieve and seeps into a pit behind the toilet shack. Faeces collects in a compost chamber, is covered with mud and stops stinking in a few hours. For excreta to stink it needs nitrogen, present in urine. The simplest formula for an odourless pit latrine: no urine, no nitrogen, no stink. Infectious bacteria in dry faeces die within a few months. Further composting kills off worm eggs. People with small gardens use the compost as a soil conditioner.

Buckley now wants to persuade the world that urine too is useful—and that there's money to be made from it—because it is rich in phosphorus. But since it pollutes waterways, treatment plants go to great expense to remove it and burn it along with sewage sludge. It then ends up in landfills for hazardous waste—while the world's phosphorus reserves, up to 80 per cent of which is used by the fertiliser industry, are running out. Experts warn that a 'phosphorus crisis' could occur in the next few decades.

Test case three: the dry toilet of a student—one takes a bucket, cuts out one half of the bottom (for solids) and makes an outlet in the other half.

Along with Swiss research centre EAWAG, Buckley plans to construct bio-reactors in Durban that will turn urine into a granulate rich in phosphorus and nitrogen—a high-value fertiliser. One prototype plant is already functional in Switzerland.

Buckley is also working on an improved version of the urine-diversion toilet. He was one of eight candidates to reach the final round of the Bill & Melinda Gates Foundation toilet competition. The teams presented their inventions in Seattle in August 2012. A team from Holland demonstrated how gas can be generated from human waste with the help of microwave plants and used in fuel cells for production of electricity. The Swiss developed a toilet that produced industrial water in situ from urine.

The first prize, though, went to a team from California whose solar-powered toilet generated electricity. Buckley was given a special commendation. Also awarded was a team from England's Loughborough University, whose toilet could extract clean water and minerals from human waste and also use it to produce bio-coal, a subject that this article will return to later.

HAMBURG'S SILENT REVOLUTION

THE FIRST APARTMENTS AND OFFICES not connected to any sanitation system whatsoever are already under construction in Germany. Hamburg stands at the forefront of this revolution. People here are familiar with the deficiencies of the sewage system because the city's drains, built in 1842, are among Europe's oldest. All sewers, many in poor repair, lead to just one treatment plant that has to clean the wastewater of almost 2 million residents.

But since the 1980s the city has also encouraged futuristic projects such as the ecological settlements of Allermöhe

An extra-terrestrial record: the toilet on space shuttle *Endeavour* cost over 19 million US dollars

and Braamwisch with their dry toilet facilities. Excreta from households is collected in huge bins in the basement, composted for about four years and then used as fertiliser in green areas. And now Europe's largest residential estate without connection to the municipal sanitation system is scheduled to come up at Hamburg-Jenfeld, a multi-million-euro project funded by the EU.

The apartments of the 2,000 residents here are to have two pipes for wastewater, one for grey water from kitchen and showers that can be treated on site with minimum energy, and the other for black water: less than a litre per flushing, because of the vacuum toilets similar to those on cruise liners. The pipes can be much narrower than conventional sewers and very little water required to flush them out. Ultimately the Jenfeld black water will flow into a bio-treatment plant and be converted—into energy.

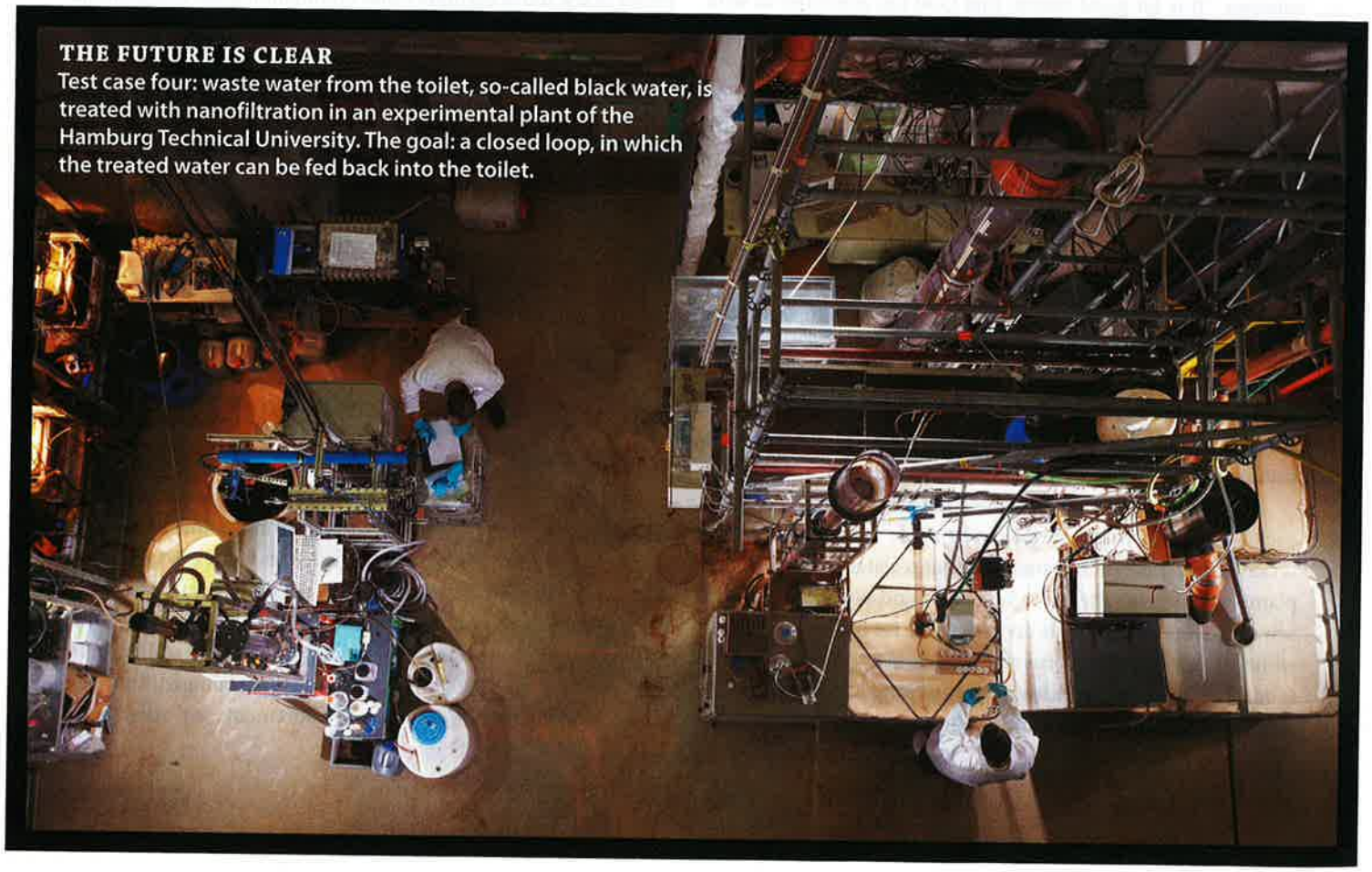
PILOT UNDER THE RAILWAY STATION

AN INNOVATIVE MODEL, but its inventor has already moved on. Ralf Otterpohl, professor of environmental engineering at the Hamburg University of Technology, has set up a pilot plant in a chamber below one of the toilets in Hamburg's railway station. Visitors can see a brown something, interspersed with bits of toilet paper, move slowly through a transparent drainpipe—the faeces of a railway station visitor. This view is blocked after a short while by a steel hopper—and then, on the other side, one sees murky water flowing out. "A grease trap, like those used by restaurant kitchens for their wastewater," explains Otterpohl's colleague Peter-Nils Grönwall. "3,000 euros, a steal!" The separation of solid and liquid: a technology that has the potential to fix the defects of the sewer system. "Brilliant," whispers Otterpohl.

The solid matter ends up in a 60-litre tank; 3,500 toilet-users will fill two of these tanks in a week. The urine from the pilot plant flows into the sewage system, but the professor has a remedy at hand even for this. His combined membrane-nanofilter separates all valuable substances from the urine—and at the same time eliminates pathogens. The filter is part of a toilet facility with a 'closed black water cycle': wastewater is processed to such an extent that it can feed back into the toilet upstairs. What remains is just toilet paper and faeces, rich in substances that should return to the soil. A technology with which Otterpohl and Grönwall hope to achieve the dream of all toilet revolutionaries: closing the loop.

FORMULA OF THE FUTURE

FOR THIS THE TWO ARE RELYING on a long-forgotten magic formula used by aboriginals in the Amazon to create the world's



THE FUTURE IS CLEAR
Test case four: waste water from the toilet, so-called black water, is treated with nanofiltration in an experimental plant of the Hamburg Technical University. The goal: a closed loop, in which the treated water can be fed back into the toilet.

most nutritious land: 'terra preta', black soil or anthropogenic dark earth. Such soil is to be found wherever the inhabitants of that once-flourishing culture dumped their waste: excreta, plant remains, animal and fish bones, ash and charred wood. Even today, 500 years after the decline of the civilisation, papaya trees and corn grow on this mineral-rich land at twice the rate that they do on the nutrition-poor soil of the surrounding rainforest.

Scientists have identified three key factors in the creation of this black soil: 1. Lactic acid bacteria: these residents of human and animal intestines that are excreted cause fermentation in the faeces and kill pathogens. 2. Earthworms: they eat what the bacteria leave behind and their excrement forms the basic component of that wonderful thing, humus. 3. Charcoal: mixed with humus it is a permanent store for those minerals that soils so often lack and that have to be replenished with artificial fertilisers.

But where is Otterpohl's coal to come from?

SCIENTISTS ACROSS THE WORLD have been amazed by the process of 'cold charring', better known as hydrothermal carbonisation (HTC). Many believe that this process, developed a hundred years ago by Nobel laureate for chemistry, Friedrich Bergius of Germany, could even slow down climate change.

Ralf Otterpohl's lab has a small stainless steel reactor for HTC. Regardless of what it is filled with—faeces, pre-treated sewage sludge, kitchen or plant waste—after a few hours at 180 to 300°C and a pressure of 65 bar, you get lumps of coal. One could run power plants and produce energy with this coal. In fact two Swiss sewage treatment companies are already in the process of doing this and are putting up the first industrial HTC reactors.

Otterpohl, however, wants to use this bio-coal to produce black soil. He has asked a member of Kim Augustin's department to study whether hydrothermal carbonisation can be used to remove pharma residues and hormones present in excreta or at least render them harmless. "The process seems to be promising," says Augustin. "It would be a real scoop for the wastewater industry."

Previously, production of bio-coal was primarily considered for use in agriculture: it helps dispose of crop waste elegantly. Today, however, scientists are thinking of applying bio-coal in larger quantities in fields in the hope of binding the carbon dioxide present in the atmosphere with the soil. If a third of all global crop residues could be converted into bio-coal, it would result in a 10 to 20 per cent reduction in greenhouse gas emissions, estimates soil scientist Johannes Lehmann of Cornell University in Ithaca, USA. If faeces too could be treated in the same way, the ecological potential would be far greater.

This is what toilet revolutionaries dream of: that human excrement will enrich the fields, enhance agricultural productivity, create jobs, increase prosperity, control climate change—instead of causing the death of millions of people as it does today. ■

A Big Job: The Complex Business of Sanitation

Why it isn't simply about providing people with toilets. SOPAN JOSHI explains

In his wonderful new book *The Origin of Feces*, Canadian scientist David Waltner-Toews gives the example of the prototype toilets that resulted from the Bill & Melinda Gates Foundation's 2011 challenge to 'Reinvent the Toilet'; but nobody knows when or how these prototypes will be adopted. "It is not simply a matter of 'transferring' technologies, as some naïve development 'experts' used to think. It is a matter of working with people where they live to co-create a narrative within which those technologies make sense."

Sanitation is primarily about communication, not technology. Governments speak a politically correct language that is seldom grounded in local realities. The newfangled 'community-led total sanitation' (CLTS) approach, considered more 'bottom-up', is one acknowledgment of the primacy of communication. But there are big question marks about CLTS; it is sometimes coercive, with vigilante sanitation workers naming and shaming people for open defecation.

Sanitation is not a problem merely for the 2.6 billion people in the world who do not have a toilet. Scientists at the University of North Carolina at Chapel Hill in the US took a closer look at the 4.4 billion people who do have one. They used sewerage data of 2010 from 167 countries, and concluded that 1.5 billion people do have toilets but these are not connected to any sewage treatment system. Which means their excreta is dumped untreated into water bodies. Yet, using the UN definition of sanitation, this 21.4 per cent of human population is on the right side of the Millennium Development Goals.

Now let us look at the 2.8 billion people who actually have toilets connected to treatment systems. Centralised sewage treatment systems are highly complicated and even their strongest advocates acknowledge that their technology is not foolproof. This gets even more complicated with combined sewer systems. Such sewers mix stormwater flow with untreated sewage and discharge it untreated. New York, Washington DC, London and Delhi all have such sewers.

Like climate change, the sanitation problem shows we are all riding on the same spaceship with limited space and more connections than we are capable of understanding. Sanitation is an idea, a value. It should not be confined to a toilet, conventional or reinvented.

Sopan Joshi is a journalist in Delhi and the author of a forthcoming book on sanitation (http://mansampark.in).