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THE ECONOMY IN THE TOILET

ENTREPRENEURS ARE FINDING INCOME IN EXCREMENT BY TURNING HUMAN WASTE INTO FERTILIZER, FUEL AND EVEN ANIMAL FOOD.

BY CHELSEA WALD

On the outskirts of Kigali, Rwanda, septic trucks full of human excrement bump and slosh their way up orange dirt roads to their final destination: the Nduba landfill. Until recently, the trucks would spill their contents into giant open pits. But since 2015, workers in green jumpsuits have greeted them outside a row of sheds and plastic-roofed greenhouses, ready to process the faecal sludge into a dry, powdery fuel.

The facility is called Pivot, and its founder is Ashley Muspratt, a sanitation engineer who lived in Ghana, Kenya and Rwanda for more than seven years before moving back to the United States last year. Muspratt insists that Pivot is not a treatment plant. It's a business. Its product powers local industries such as cement and brick plants. "I describe us as dual sanitation and renewable-fuel company," Muspratt says. "Our model really is to build factories."

Muspratt is part of a growing band of entrepreneurs trying to address one of the biggest challenges in public health — poor sanitation — and to turn a profit doing it. According to a report published by the World Health Organization and United Nations children's charity Unicef in July, 2.8 billion people — 38% of the world's population — have no access to sewers and deposit their waste in tanks and pit latrines (see 'Sanitation across nations'). These often overfill or are emptied without regard to safety. By 2030, some estimate that the number of people using tanks and pits will rise to 5 billion, while at the same time international aid for water and sanitation is predicted to shrink. High-profile initiatives such as the Millennium Development Goals have been pretty good at "getting bums on toilet seats or feet on squat pans", says Claire Furlong, an environmental engineer at the IHE Delft Institute for Water

Semi-dried sludge on its way to becoming fuel in Kigali, Rwanda.

SOURCE: WHO/UNICEF

Education in the Netherlands. "But those toilets filled up. What do we do with that?"

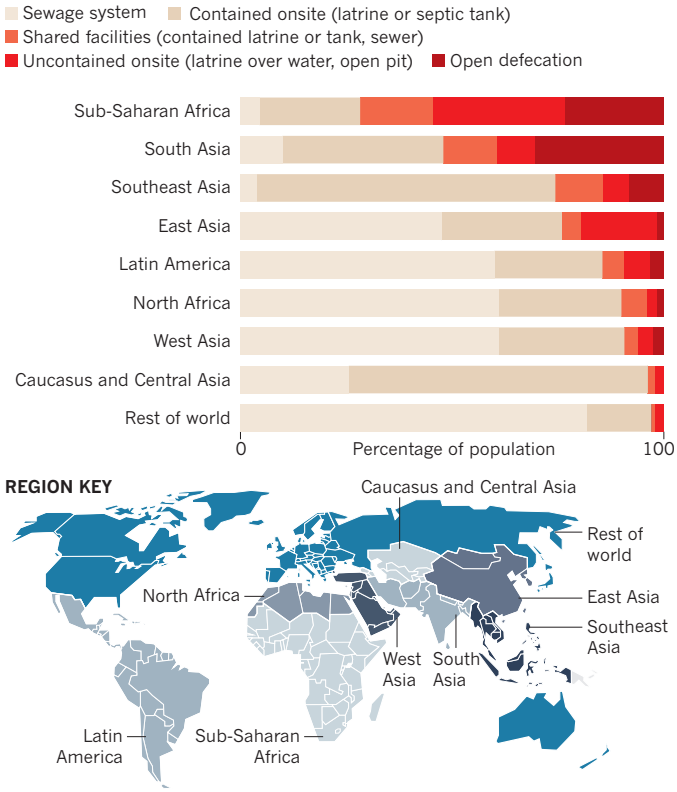
Muspratt and others have a few answers. Making fertilizer or fuel is the most obvious, but researchers and entrepreneurs are exploring other uses. Some are growing plants in drying beds or breeding catfish in the artificial ponds that facilities typically use to treat sludge. Others are drying out sludge and incorporating it into building materials such as cement and bricks. Beyond that, companies are exploring whether certain fatty acids in sludge could provide important components of bioplastics and industrial chemicals. Larvae that feed on faeces are being pressed to make an oil for industrial uses, and in the future they could be used as animal food.

These approaches reflect a rethinking of sludge treatment — with the end product, and not just public health, in mind from the start. The economic model of sanitation is also changing, moving from an entirely public service to one run at least partly by private enterprises that are finding value in excrement, says Doulaye Kone, deputy director of the Water, Sanitation and Hygiene Program at the Bill & Melinda Gates Foundation in Seattle, Washington. Under the old model, he says, "there's no opportunity to sell anything, and then the government has to pay for operational costs. The day the budget dries up, everyone is in trouble." As a result, many treatment plants in developing countries now lie abandoned.

Financing isn't the only reason that waste-to-resource initiatives fall short, warns Furlong. Many promising projects have met with resistance because they failed to address cultural elements, which can affect buy-in, whether from toilet users or national politicians. That could be something as visceral as negative attitudes to human waste, or an unwillingness to use new toilet technologies designed to capture waste in usable form. Muspratt and others instead deal with sludge as it is found in pits and latrines that already exist, to prevent their plants falling into neglect or becoming too expensive to maintain. "The driving force for me was trying to figure a way to not have white elephants all over the continent of Africa."

SANITATION ACROSS NATIONS

Worldwide, 2.3 billion people lack basic, safe ways to dispose of their waste, with 892 million defecating in the open.



HUMAN RESOURCE

Some people need no convincing of the benefits of sludge. In Ghana, some farmers short on fertilizer ask septic-truck drivers to dump their loads onto their fields, where they compost it using traditional methods and spread it onto millet and maize (corn). But this boost of nutrients for the crops poses a risk for those who eat and tend them: the slurry is not safely treated, and increases the chance that the produce will transmit typhoid, cholera, roundworms and various other pathogens that can cause diarrhoea, and lead to anaemia and malnutrition. In young children, repeat exposure can affect both physical and cognitive development.

Even if these farmers weren't using sludge on food crops, disease would still probably be a problem. Less than 5% of people in Ghana have sewers, and there are few treatment facilities for sludge; much of it ends up dumped into ditches or the sea.

Turning sludge into fertilizer is not a big ask, technologically — but it's hard to make a profit because market prices are cheap. Many wastewater treatment plants worldwide, including in the United States, where biosolids are a common by-product of treated sludge, give it away to avoid disposal costs. In Tema, a city east of Ghana's capital Accra, however, a new plant just sold its first few 50-kilogram bags. The operation should turn a profit within three years, says business economist Solomie Gebrezgabher, who works in the Accra office of the International Water Management Institute (IWMI).

The Tema plant uses a process that treats the sludge and composts it simultaneously. Powered by the Ghanaian sun, it consumes much less energy than composting methods that use drying and heating machines. But it takes a lot of space and time, and can be smellier. For about the first ten days, the sludge, which comes from both private homes and public toilets, dries in sand-filled beds, which allow the water to drain out and evaporate away. Then it's mixed with sawdust or food waste and transferred to a covered shed. Workers turn it regularly, and it breaks down over two months, thanks to naturally occurring microbes. During this process, it gets hot enough to destroy pathogens. Then it's spread out to cool and mature. The inexpensive process is appropriate for the conditions in Ghana, Gebrezgabher says. "It doesn't have to be high-tech."

The team approached would-be clients with this bulky soil additive, which improves poor soil's physical qualities — such as its ability to retain water — but doesn't substantially increase the supply of nutrients. When Gebrezgabher spoke to farmers, many weren't interested. So she and her colleagues mixed in ammonium sulfate or urea to add more nutrients, as well as compressing it into easier-to-manage pellets. For farmers who were squeamish about using a product made from sludge, the team got a government safety certification. This time farmers were keen. "They were really excited about it because it has everything that they are looking for," says Gebrezgabher. Another boost came when the government included the product — called Fortifer — in its fertilizer-subsidy programme.

With the product and the potential buyers in hand, the IWMI team partnered with the district government and a private local waste management company called Jekora Ventures, based in Accra. At full capacity, the plant, which opened in April, will process the waste from about 65,000 to 100,000 people every year into 500 tonnes of fertilizer. The company will start splitting profits with the municipality once the plant breaks even. The idea is to use those funds to improve sanitation, Gebrezgabher says. She is working with IMWI teams in other regions to replicate this model, starting with Sri Lanka. "Through not-so-sophisticated technologies, business models can be designed in developing countries that would be commercially viable," she says.

WASTE POWER

There is energy in sludge, too. According to a 2015 report by the United Nations University in Hamilton, Canada, if all the human faeces produced annually were converted into biogas, it would provide electricity to more than 138 million households. The leftover slurry could be dried into a

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Sludge arriving at the Nduba landfill outside Kigali in Rwanda. The waste was once dumped into open pits, but now it is dried and sanitized for use as fuel.

charcoal-like fuel for use by a further 130,000. At Pivot's plant, workers make a solid fuel. They take most of the water out of the sludge by passing it through a microscreen. Then they spread it in greenhouses to dry. Finally, they further desiccate and sanitize it in a thermal dryer that runs on scavenged cardboard. The end result, provided as a powder or in granules, has 20% more energy than other biomass fuels such as sawdust or coffee husks, Muspratt says.

Pivot sells its fuel to cement and brick-making companies, whose ever-glowing furnaces and kilns have a constant need for the kinds of fuel that Pivot makes. The major customers are usually international firms that value sludge as a renewable energy source that they can use in place of coal. Pivot is on track to break even on operating costs, but it still relies on a little outside support. Its spot on the landfill was donated by the municipality, and its infrastructure was paid for with grants. Expecting wild profits from sludge salvage is unrealistic, says Linda Strande, an environmental engineer at the Swiss Federal Institute of Aquatic Science and Technology in Dübendorf. "We would be selling shit here if that was really going to make a huge amount of money," she says. Most projects could expect to recoup 10–20% of annual operating costs, she says. And that's fine, because at least in making some money they reframe sludge as something of value, to be handled with more care.

Ironically, the main barrier Pivot faces is getting enough sludge. In theory, a city of at least one million people such as Kigali should be able to supply it, but nobody was bringing sludge from the hard-to-reach pit latrines in the informal settlements. Here, where two-thirds of the population lives, unlicensed workers were simply shovelling out pit latrines by hand and dumping the contents into nearby ditches or waterways.

So Pivot started a side venture to provide a safe pumping service to the settlements. It has proved popular but, partly because the latrines are unlined and leaky, Muspratt says, "the volumes we are getting out of pits are relatively modest so it hasn't been this, like, windfall of faecal sludge that we'd hoped for". Pivot plans to start grinding up other kinds of combustible waste to blend with its fuel. Like IWMI, Pivot also intends to expand throughout Africa and to India, where millions of people who previously defecated in the open are building latrines thanks to a government initiative. "Our ultimate mission is to be the lowest cost provider of urban faecal-sludge treatment on the market," says Muspratt.

MANNA FROM MANURE

Following a cholera outbreak in 2000, the eThekwini Municipality, which includes Durban, South Africa, installed more than 85,000 urine-diverting dry toilets into rural areas on its outskirts. The diverted urine seeped into the ground, and the authorities asked households to bury the solids on their properties. But burying was a burden on the growing proportion of elderly people, and the increasing population density meant there was less land in which to bury. Even when the faeces was decomposing underground, pathogens survived for much longer than expected. Teddy Gounden and his colleagues at the water and sanitation department wanted to start collecting the waste. "But what do we do to it?" he wondered. More solid than sewage, it would gum up the town's wastewater treatment plants. Lacking urine, it didn't have enough nutrients to make good compost. Disposal at a hazardous-waste site would be expensive.

Then Gounden and his colleagues heard that a certain fly species could make much more valuable products than compost. Flies are normally a health hazard because they feed on both human faeces and food, transmitting pathogens as they flit back and forth. But the black soldier fly (*Hermetia illucens*), which is native to tropical climates, is different: it feeds voraciously in its larval stage, when it stays more or less in one place, and not at all as an adult, making it much less of a health risk.

The fly was put to work on food waste by a Cape Town-based firm, AgriProtein. It developed factories to harness the fly's special habits. The company breeds flies in cages, hatches the eggs in a nursery and then transfers the larvae to the food waste, where they eat their fill. Two weeks after hatching, the larvae naturally migrate off the waste to pupate, making both them and the remaining compost easy to harvest separately. The factories dehydrate the larvae to make an animal feed or extract a fatty oil, which has a range of uses from cosmetics to biodiesel. The leftover organic matter becomes a soil conditioner. Last year, AgriProtein opened the first industrial-scale plant of this type, with a plan for worldwide expansion close behind.

With the food-waste process working well, the company turned to a trickier source material — human waste — under the business name BioCycle. The larvae treated the new food much like the old, says David Wilco Drew, the firm's co-founder and director. In partnership with the eThekwini Municipality, and supported by the Bill & Melinda Gates Foundation, it opened a pilot plant on the premises of a wastewater-treatment works in Durban at the end of 2016.

The material itself has proved tricky because of all the rubbish that toilet users have thrown in, Drew says. He's surprised by the ingenuity of some people, because the toilets aren't exactly open pits. "How can you get an old telephone around a U-bend?" Also conscious of the health risks associated with sludge, BioCycle has adjusted its food-waste process to account for the new input. It tests thoroughly for pathogens and heavy metals. And, instead of making products for agriculture, the plant presses the larvae into oil and the leftover organic matter into solid briquettes, both for use as fuel.

Deliveries from the urine-diverting toilets started in late July this year. At full capacity, the plant will accept 40 tonnes of material from the urine-diversion toilets per day, which it then mixes with food waste. "This is the largest faecal insect site by a mile," Drew says.

With further research, the black soldier flies could treat sewage sludge from the city's sewer system. "There's a lot of potential," Gounden says. Other governments "are all essentially waiting to see what the outcome is".

To make it easier for municipalities everywhere to jump on the sludge bandwagon, Strande's team has developed a booklet and online courses to help local engineers design systems that can churn out marketable products. And to better understand the inputs to such systems, an international team led by researchers at the University of KwaZulu-Natal in Durban is developing standard methods and procedures for characterizing faecal-sludge properties such as moisture, rubbish and pathogen content, and nutrient and calorific values.

Everybody poos, says Drew. One day, he dreams, "every citizen of the world can contribute to our supply chain". ■

Chelsea Wald *is a journalist in The Hague, the Netherlands.*