A vacuum toilet at the NIOO in Wageningen. The contents are vacuumed out under pressure, after which the toilet is rinsed with 1 litre of water.

GRIETJE ZEEMAN,
personal professor of New Public Sanitation at Wageningen University

'Nutrients can be extracted from our wastewater. And there is every reason to do so.'

NEW PUBLIC SANITATION BLAZES A TRAIL

Shame to waste it

Extracting energy and minerals from the waste flushed down the toilet is both necessary and possible. Professor Grietje Zeeman wants to make the techniques for doing this broadly useable. The days of old-fashioned flush toilets are numbered.

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'They come in porcelain and in stainless steel, in standing and wall-mounted versions, and from different makers.' Like an experienced salesperson, Grietje Zeeman (1951) of the Environmental Technology department at Wageningen University, part of Wageningen UR, outlines 'her' range of vacuum toilets. 'When you press the button everything is sucked away under pressure. Only when the valve shuts again does a litre of water flow in, to keep the toilet clean.'
In the Technotron building on the Wageningen campus there are various urinals without a flush and separation toilets with a receptacle at the front of the pot for urine. By using this toilet you not only save water but also contribute to research. The waste matter is piped to Zeeman's lab for further processing and purification. Zeeman (1951) gave her inaugural lecture as personal professor of New Public Sanitation mid-September. 'It's all about the collection, transportation and treatment of household waste water,' says Zeeman. 'What is 'new' about it is that I am adding extraction and reuse to the process.'
Zeeman consistently refers to urine and faeces as 'resources', referring to nutrients such as nitrogen and phosphate compounds, and to organic matter which can be used to make biogas. These resources disappear into the sewer every day along with tens of litres of >

drinking water from each toilet. Zeeman wants to call a halt to this waste of water and of resources. To this end she has developed a sanitation method based on separating black water (from the toilet) from grey water (from the bath, shower, washing machine and kitchen), followed by anaerobic purification – i.e. using bacteria that do not need any oxygen. The UASB (Upflow anaerobic sludge bed) reactor used for this is a typical Wageningen product, developed by ex-professor Gatze Lettinga.

MASSIVELY DILUTED

Not only is biogas produced by this anaerobic purification, but nutrients can also be extracted for reuse in agriculture. It is almost impossible to apply this method in traditional sanitation systems. 'The bacteria that are responsible for the anaerobic digestion process function better in warm conditions. In order to purify conventionally collected household waste water anaerobically, all that water would have to be heated. That would take too much energy.'

So sewage treatment plants traditionally rely on aerobic purification. The bacteria that do this work can function well in cold conditions. The disadvantage is that oxygen has to be added to the water, which costs energy. 'What is more, those bacteria convert organic matter into CO_2 instead of into biogas that you can use as a source of energy.'

Zeeman has set herself the goal of making the 'new sanitation' broadly utilizable. First and foremost, that entails separating black and grey water. 'You treat the grey water from the shower, bath, washing machine and kitchen separately. After a fairly simple level of purification, that water can be reused in the household, for irrigation or for soil infiltration,' Zeeman explains. 'A second important step is to reduce the amount of water used in the toilet itself. For this we have opted for a vacuum toilet: these are the only ones at present that meet our demands for minimal water use and optimal comfort. Conventional toilets use about six to eight litres of water per flush; vacuum toilets just one litre. It is also a fully developed system, designed for aeroplanes and cruise ships, which we can simply copy-paste.' The black water from the toilet is treated on the spot. This is no longer only done in the Wageningen lab, but also in various real-life situations.

Since 2006, for example, vacuum toilets have been installed in 32 new houses in Sneek in the northern Dutch province of Friesland. These toilets are linked with a treatment plant in situ, but because it was just a trial, the sewage system was kept as a backup.

'Wageningen University wanted to set up a pilot project for decentralized waste water processing using anaerobic digestion. Then we stuck our necks out,' says Henk Heikema van der Kloet, director/ manager of the De Wieren Housing Association in Sneek. 'If you want to get sustainable, innovative techniques onto the market, you need experiments. That is the only way you will get innovations in newly built homes.'

CHLORINE-FREE

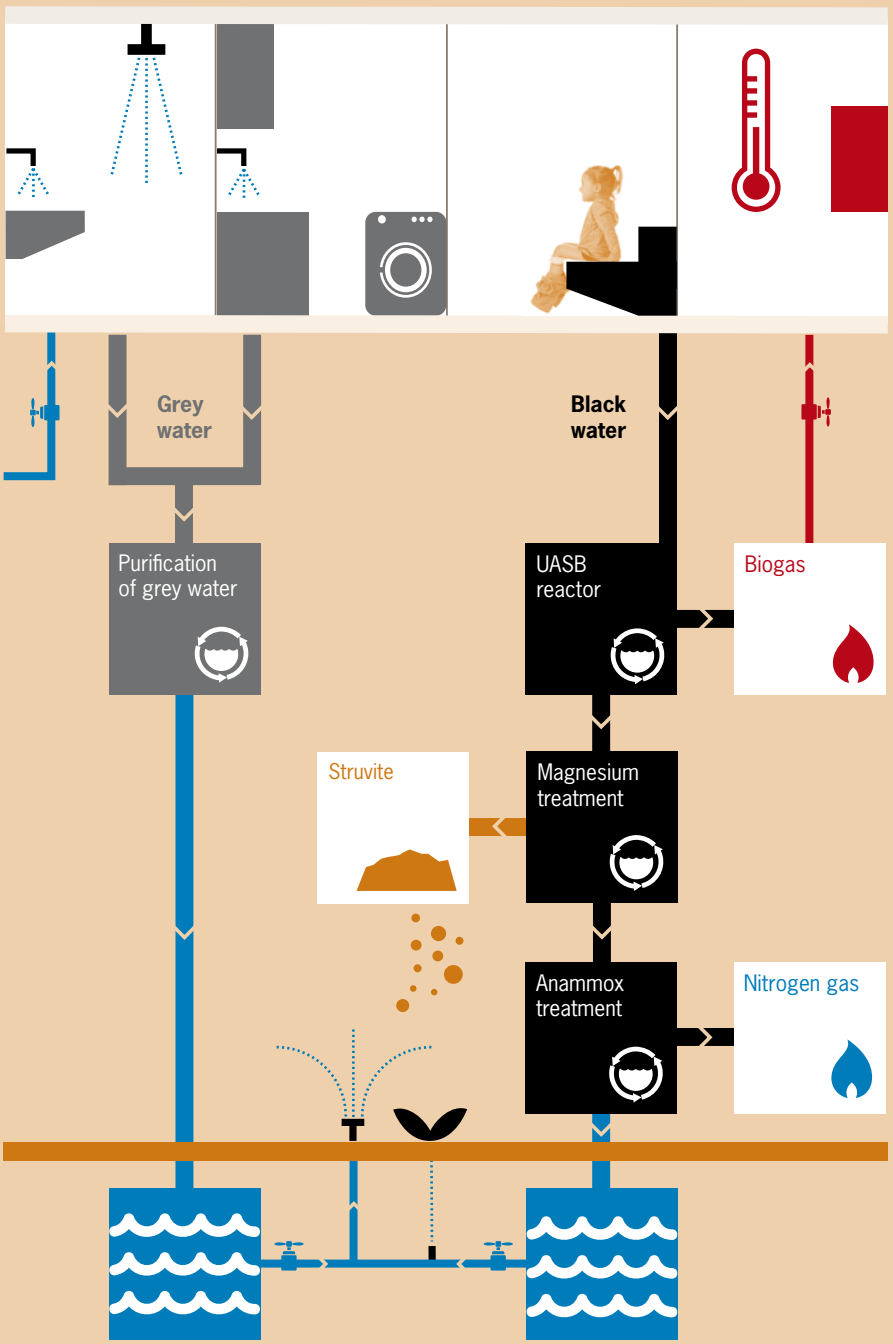
The study showed that the project partners, De Wieren and Patrimonium housing associations and Sneek municipal council, were satisfied with the system, as were the residents themselves. 'Only the noise made by the vacuum toilet caused some complaints at first. So a sort of silencer was fitted onto it,' says Zeeman.

Zeeman's principle is now being applied by the DeSaH company, which commercialized the concept, in the newly built Noorderhoek housing estate of more than 200 houses. Confidence in the system is now so high that the traditional sewage system is being abandoned. 'Here we are going to use the biogas produced to fuel a seasonal thermal storage system which will provide heating.'

Nutrients are extracted in Sneek as well. 'In traditional water purification, most of the phosphate ends up in >

'It is our duty not to waste phosphate'

NEW PUBLIC SANITATION



'New public sanitation' stands for the collection, transportation and treatment of household waste water so that minerals can be extracted from it. The first step in the method is to separate black water (from the toilet) from grey water (from the bath, shower and kitchen).

After a relatively simple purification process, the grey water can be reused in the household and for irrigation.

The black water – which contains the most minerals – is purified by anaerobic bacteria in a UASB reactor which produces biogas, mainly methane.

Treatment with magnesium leads to precipitation of phosphate and some of the nitrogen compounds in the form of struvite.

The remaining nitrogen compounds are converted into nitrogen gas with the Anammox technology.

Anaerobic digester for purifying 'black water' and producing biogas, at the NIOO in Wageningen.

the sludge, which is then burned. And nitrogen compounds are converted by bacteria into nitrogen gas, which disappears into the air,' says Zeeman. In anaerobic purification most of the nutrients are in the watery effluent. 'That is sometimes seen as a minus point: the water cannot simply be discharged. But the flip side of that is that there is a considerable advantage: the nutrients can be extracted.' And there is every reason to do so, Zeeman stresses. 'Phosphate is a finite resource. We are already getting warnings of scarcity. It is actually our duty not to waste it.' In Sneek this is being done by treating the anaerobic effluent with magnesium so that the phosphate and some of the nitrogen compounds sink to the bottom in the form of struvite. 'Currently that is just being collected but we are hoping to get struvite approved as a fertilizer for use in agriculture. That way we can close the cycle and the nutrients that get into our food through agricultural crops go back to the fields.'

PRODUCTION OF FERTILIZER

In Sneek, the nitrogen compounds that are still in the effluent at this point are converted into nitrogen gas by anaerobic bacteria. Nitrogen is not a finite resource – the air is full of it. Nevertheless, it is worth extracting from the waste matter. 'One percent of worldwide energy consumption goes into producing artificial fertilizer by extracting nitrogen from the air. So extracting nitrogen is really a way of saving energy,' states Zeeman. 'However, the effluent is still too

> ‘To apply this on a large scale you need new infrastructure’

diluted for it to be possible to extract nitrogen in an energy-efficient fashion with the existing technology. We use PhD research projects to work on alternatives such as using ammonia to generate electricity in a microbial fuel cell.’

Zeeman is also hoping to see innovations in the sanitation branch. ‘I am no toilet designer but I think it should be possible to design a separation toilet in which you only use one litre of water for the faeces, while collecting the urine. In that case you can not only extract the nitrogen more efficiently, but you can also carry out the anaerobic purification at higher temperatures. By using thermophilic digestion at 50 to 70°C, for example, whereby biogas production is linked with disinfection. My future research will concentrate on this anaerobic disinfection. We shall also look at ways of cleaning up the micro-pollution such as traces of drugs and hormones.’

ALGAE AS HARVEST

Meanwhile, Zeeman’s approach has reached other places too. The Villa Flora at the Floriade horticultural expo in Venlo, for example, is equipped with a vacuum toilet and a digester. Closer to home, her principles can also be seen in action at the Dutch Institute for Ecology (NIOO), which moved into a new building for about 250 employees in Wageningen early in 2011. ‘The construction was based on the cradle-to-cradle principle, in which cycles are closed,’ explains Louise Vet, director of the institute. ‘Before building started, I asked Environmental Technology: what is the state of the art and how can NIOO take things a step further? That is how we ended up with the idea of the vacuum toilet and anaerobic digestion, but that was not enough for us. We want to use the effluent coming out of the digester for something useful such as feed for growing algae. We are working on that with Grietje Zeeman now.’ NIOO and Environmental Technology are studying whether an algae reactor can provide a method of extracting phosphate and nitrogen compounds. The algae grow – still in the lab at present – on the water that comes out of the digester. The ‘harvest’ can be processed into fertilizer, fish feed, bioplastic or fuel. ‘Our building is an engine for new research. That is a great adventure,’ says Vet.

LARGE-SCALE USES

Zeeman’s appointment as professor reflects her role as a trailblazer. And yet the predominance of old-fashioned water purification has not been challenged yet. ‘In 2001, we started with three homemade cubicles in a testing centre. Ten years on, a few projects have been carried out. I am certainly satisfied; this is a long-term ambition,’ says Zeeman. ‘To apply it on a large scale you need new infrastructure. Sewers last at least 50 years, so you cannot just dig up all that investment tomorrow. That is why we need to set out a strategy for a transition from old to new infrastructure. Water boards often tell me: we would really like to introduce new sanitation systems but we have just installed a new sewer. Or: we have overcapacity in water purification. I want to develop modules that can be installed when part of the system is up for renewal.’

Little by little, then, our old-fashioned toilets will have to make way for the new. ‘It is definitely easiest on a new housing estate or in a renovation project,’ says Zeeman. And when residents are highly motivated. Like Zeeman herself: she lives in an old house in Wageningen that is currently under renovation. A vacuum toilet is being installed on every floor, linked to an anaerobic digester. ‘No, it is not profitable. Normal people would certainly never do it, but I want to practice what I preach.’ ■