
self

Efficient Recycling of a scarce resource

Lack of access to clean water is one of the main health problems in many parts of the world. With its research on decentralized water treatment, Eawag could make a significant contribution to the achievement of the Millennium Development Goals. Laboratory and pilot experiments have shown that membrane technology can make it possible to produce safe drinking water even under the most rudimentary conditions.

The "Self" module, which entered field-testing in February 2010, is designed to provide a temporary living space and workplace for two people, independent of external power and water supplies. The two research institutes Empa and Eawag contributed their technical expertise to the development of the module, while Zurich University of the Arts (ZHdK) was responsible for the design. The freight container-sized structure weighs around 5 tonnes and can thus be transported almost anywhere in the world by truck or helicopter. Although it was destroyed by fire at Easter 2010, the project managers plan to fit out a second unit, which was originally intended to serve as an add-on module. "Self" does not need to be connected to a mains power supply, as it has its own power generation system: 1280 solar cells mounted on the roof – with a maximum output of 3750 watts – will provide the electricity required all year round for a module used, for example, as a mobile research station.

Autonomous water supply

Likewise designed to ensure self-sufficiency are the technologies developed by Eawag for preparing drinking water and for recycling most of the wastewater. Rainwater is first collected on the roof, which has a surface area of 26 m^2. Maryna Peter-Varbanets of the Process Engineering department explains: "Although rainwater is relatively clean, it may, depending on the location, be contaminated, for example, by bird droppings, leaves or pollen." To remove these particles and pathogens (bacteria and viruses), "Self" is equipped with a membrane module the size of a shoebox. The pores of the plastic membrane – with a filter surface area of 0.7 m^2 – each measure only a fraction of a micrometre. While water and dissolved

The self-sufficient living module "Self" – here, pitched near Lake Sihl – is a research and demonstration project. As regards water, it is designed to demonstrate the feasibility of obtaining drinking water from treated rainwater and recycling grey water. Decentralized systems could thus represent an alternative to more costly centralized infrastructure – which is not even a realistic option in many parts of the world. Bottom: Sewer repair work. (Photos: Empa, Beat Guyer; Waste Disposal + Recycling Zurich/ERZ) minerals pass through this mechanical treatment step, turbid matter, bacteria, parasites and even viruses are retained. Ultrafiltration thus also functions as a disinfection process, without any need for chemical agents such as chlorine or ozone.

Gravity-driven system

When ultrafiltration is used for large-scale drinking water treatment, as is increasingly the case at centralized waterworks, the process generally involves pumps. These allow raw water to be forced through membrane pores at regular design fluxes of 20 – 100 l per m^2 membrane and hour, so that the system can provide sufficient quantities of treated water within a reasonable time.

In the interests of low-energy and low-maintenance operation, "Self" functions without a pump, relying on gravity alone. The pressure of 100 mbar arising from the roughly 1 m height difference between roof and membrane is enough to permit the preparation of at least 30 l of safe drinking water for daily consumption. In the living area, a display reminds the occupants of how much fresh water they are using. This relatively modest amount (compared to normal domestic drinking water consumption) is sufficient because, in addition, treated grey water is available for applications such as personal hygiene, dish-washing and toilet-flushing.

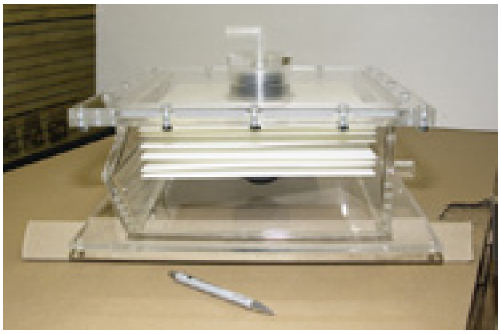
How does the low-pressure process work?

With an expected flux rate of around 5 – 10 l per m^2 membrane and hour, the capacity of the low-pressure filtration system developed by Eawag is considerably lower than that of conventional membrane systems. This, however, is a deliberate design feature, since the operational advantages of the system easily outweigh the higher membrane area required. As laboratory and pilot tests have shown, the permeability of the membrane is preserved for a long period even without the use of chemical cleaning agents. During the initial days of operation, the flux rate declines markedly, as filtration gradually leads to the development of a biofilm on the membrane. However, despite the increased resistance, this process does not result in the formation of an impermeable fouling layer. Instead, the flux rate stabilizes after several days and then remains at a constant level. According to Wouter Pronk, head of the Drinking Water Technology group, laser microscopy confirms that the biological activity leads to the formation of cavities in the biofilm, which combine into channels. As a result, the cake layer becomes porous, and a state of equilibrium is established between the deposition and degradation of organic matter on the membrane, which also stabilizes the flux rate. By contrast, if raw water is disinfected with chemicals such as sodium azide prior to ultrafiltration, membrane permeability declines steadily throughout the period of operation, as the disinfectant also inhibits desired microbiological activity in the layer covering the membrane.

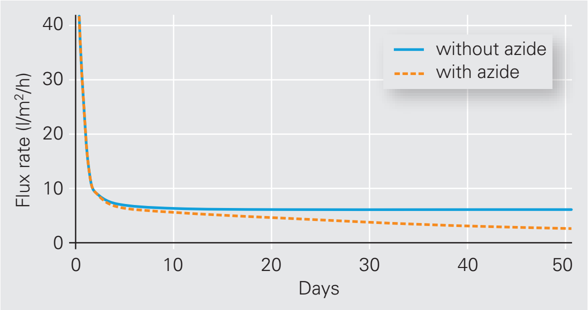
The performance of low-pressure membrane filtration depends in particular on the contaminant load of the raw water to be filtered and on the composition of the natural organic matter: the cleaner the starting product, the greater the flux rate. For example, with a membrane surface area of 1 m^2, approx. 14 l of drinking water per hour can be obtained from river water which has previously passed through a sand filter. However, if diluted wastewater is used, the long-term flux rate is reduced to 3 l/hour.

Variety of advantages for developing countries

Given its simplicity, low-pressure ultrafiltration is especially suitable for decentralized water treatment in developing countries. More than 900 million people currently lack access to safe drinking water – a public health



Left: A compact treatment system is installed above the grey water tank in the equipment compartment of "Self". Centre: Membrane module for preparation of drinking water from roof rainwater. Right: Membrane module for recycling of grey water.



Flux rate for membrane filtration of river water with and without prior disinfection with sodium azide.

problem which also severely impairs productivity. As the costs of membranes have fallen substantially, point-of-use water treatment systems could now be provided for individual homes or small communities for around EUR 1 per person and year, given the economies associated with large-scale production. Another advantage of the low-pressure process is that it does not require an external power supply or chemicals, needs very little maintenance and is both easy to operate and relatively safe. As Wouter Pronk points out, "Faults such as possible clogging of the membrane after prolonged use do not lead to the breakthrough of pathogens, but merely a decline in performance."

As a participant in the European "Techneau" project, launched in 2006, Eawag has not only carried out basic research but also designed a pilot system, which was constructed in cooperation with industrial partners KWB and Opalium (a Veolia Water Systems company). The low-pressure ultrafiltration unit installed in a space half the size of a freight container uses a biosand filter for pretreatment and can supply approx. 5000 l of treated drinking water per day. Following a successful test phase in France, using river water from the Marne, the unit is now (since the end of 2009) being tested in the South African village of Ogunjini near Durban. Maryna Peter-Varbanets explains: "Here, we're particularly interested in how membrane filtration is affected by the sometimes highly turbid raw water."

Decentralized wastewater treatment

In dry regions, where water is a scarce resource, or in remote (e.g. mountainous) areas not connected to supply or disposal systems, decentralized wastewater treatment may also be a viable option. For this reason, the "Self" living module is equipped with a compact wastewater treatment unit in the form of a membrane bioreactor, which is also gravity-driven. The washing machine-sized unit treats the daily kitchen and shower wastewater (grey water) but not the heavily soiled wastewater from the water-saving toilet (black water). The latter is stored in a separate tank and periodically removed from the cycle. Taking into account the recycled grey water, which can be reused for showering, dish-washing and toilet-flushing, Eawag calculates that the occupants of "Self" have at least 100 l of water available per day. This means that – even without rain – two people will have sufficient fresh water to live in the module without any loss of comfort for about 2 weeks. To prevent microbial recontamination during storage, the treated drinking and grey water in the two 200 l tanks is irradiated with a UV lamp at regular intervals.

The field tests will show how effective the grey water treatment process is. Microbiologist Adriano Joss says: "At conventional plants, wastewater treatment via membrane filtration is now running relatively smoothly. The question is whether biological degradation of carbon in the 'Self' project will also work well enough with a lower supply of nutrients. The grey water lacks the abundant nutrients present in urine and faeces, which are used by microbes." At worst, a viscous substance could form, gradually clogging the pores of the membrane.

As costs have come down, point-of-use water treatment with membrane technology has become an attractive option.

However, the idea of repeated use of treated wastewater remains promising. The international "Reclaim Water" project, for example, has investigated technologies for treating wastewater in such a way that it can be used for groundwater recharge. The main objectives are to monitor and reduce the content of pathogens, micropollutants and other contaminants in reclaimed wastewater. In this context, Eawag has studied the effectiveness of a membrane bioreactor combined with nanofiltration on a pilot scale.

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EU project "Technology Enabled Universal Access to Safe Water": www.techneau.org

EU project: "Water Reclamation Technologies for Safe Artificial Groundwater Recharge": www.reclaim-water.org

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