Purifying water with

wetlands

Salinization and drought are increasingly causing shortages of freshwater in coastal regions. In the Zeeuws-Vlaanderen district on the southern Dutch coast, a Wageningen solution is being tested: the purification of sewage and wastewater from industrial processes in wetlands. This could provide a buffer supply that the entire district can draw on in the summer months.

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> ‘Plants contain enzymes that break down substances such as ibuprofen’

That salinization of freshwater in the coastal provinces of the Netherlands would become an ever more serious problem was something Huub Rijnaarts already knew 10 years ago. ‘In the deltas of China, Vietnam and Bangladesh, we could already see problems, with an insufficient influx of freshwater from the hinterland combined with the increasing infiltration of salty seawater due to rising sea levels,’ says the professor of Environmental Technology. In recent years, the message has got through in the Netherlands too that an adequate supply of freshwater to households, farms and industry can no longer be taken for granted. The dry summer of 2018 caused particularly serious problems, with lower agricultural yields, shortages of irrigation, cooling and drinking water, and shipping brought to a standstill.

The Rhine and the Maas rivers supply water to almost all of the Netherlands through a smart system of channels and pipelines. The province of Zeeland is the exception. It is not directly connected with this ingenious main water system and depends for its freshwater on a 120-kilometre-long pipeline from the storage basins in the Biesbosch wetlands nature reserve. ‘Particularly in dry summer periods, people and industry in Zeeuws-Vlaanderen are very dependent on the scant supply of freshwater from this pipeline. And during a long and severe drought, an adequate supply is not guaranteed,’ says Rijnaarts.

WETLAND

Since 2015, he has been doing research in the WaterNexus project on the potential to collect used freshwater and brackish water and to purify and reuse it, starting in Zeeland. He is doing this with 24 partners: universities, research institutes, consultancy firms, technology suppliers, water boards and water companies. A total of 15 PhD students and two postdocs are doing research on different aspects of the topic. At the heart of the project is something called a helophyte filter, now on a small scale, but potentially several hectares in size. The filter is a natural basin – which Rijnaarts calls a ‘constructed wetland’ – that provides natural purification. ‘The wetland removes organic matter and micro-pollutants that pose problems for the reuse of the water in agriculture and nature, or for the desalinization of the water.’

The first applied tests by WaterNexus are taking place at Dow Benelux, which has the biggest chemical plant in Western Europe in Terneuzen. The plant needs 20 million cubic metres of cooling and processing water a year. ‘This company’s main production resource is under pressure. In times of scarcity, industry is the first to be cut off from the pipeline. That hasn’t happened yet in the Netherlands, but in an emergency, drinking water and water for sensitive nature get priority,’ says Rijnaarts. The farmers, who increasingly need water to irrigate both their arable fields and their greenhouse crops in the summer months, are not at the top of the priority list of water consumers either. And given the salinization of surface water, they cannot just pump water out of the ditches to water their fields.

CONDENSING STEAM

Dow Benelux, which is encountering a freshwater scarcity not just in Zeeland but at many delta locations around the world, can reuse about half the water used in its plants. ‘By condensing the steam from the production process into water, for instance,’ explains water specialist Niels Groot, professor and water technologist at Zeeland University of Applied Sciences. Dow obtains the other half of the water it needs from Evides water company. ‘Some of that water comes from the pipeline from the Biesbosch, but in order to be less dependent on river water, especially in the summer, we get some of it from purified domestic wastewater from the municipal wastewater treatment installation run by the water board in Terneuzen,’ says Groot. The cooling processes, which take six million cubic metres, are the biggest water guzzlers for Dow. ‘We try to go on reusing that cooling water as long as possible. To protect our pipes we have to add anti-corrosive materials, as well as chemicals to control legionella bacteria. Because a lot of this processed cooling water evaporates during cooling after hot processes, the residue that remains gets more and more concentrated and salty,’ explains Groot. Dow discharges this water in the Westerschelde estuary, to the tune of about 1.5 million cubic metres a year.

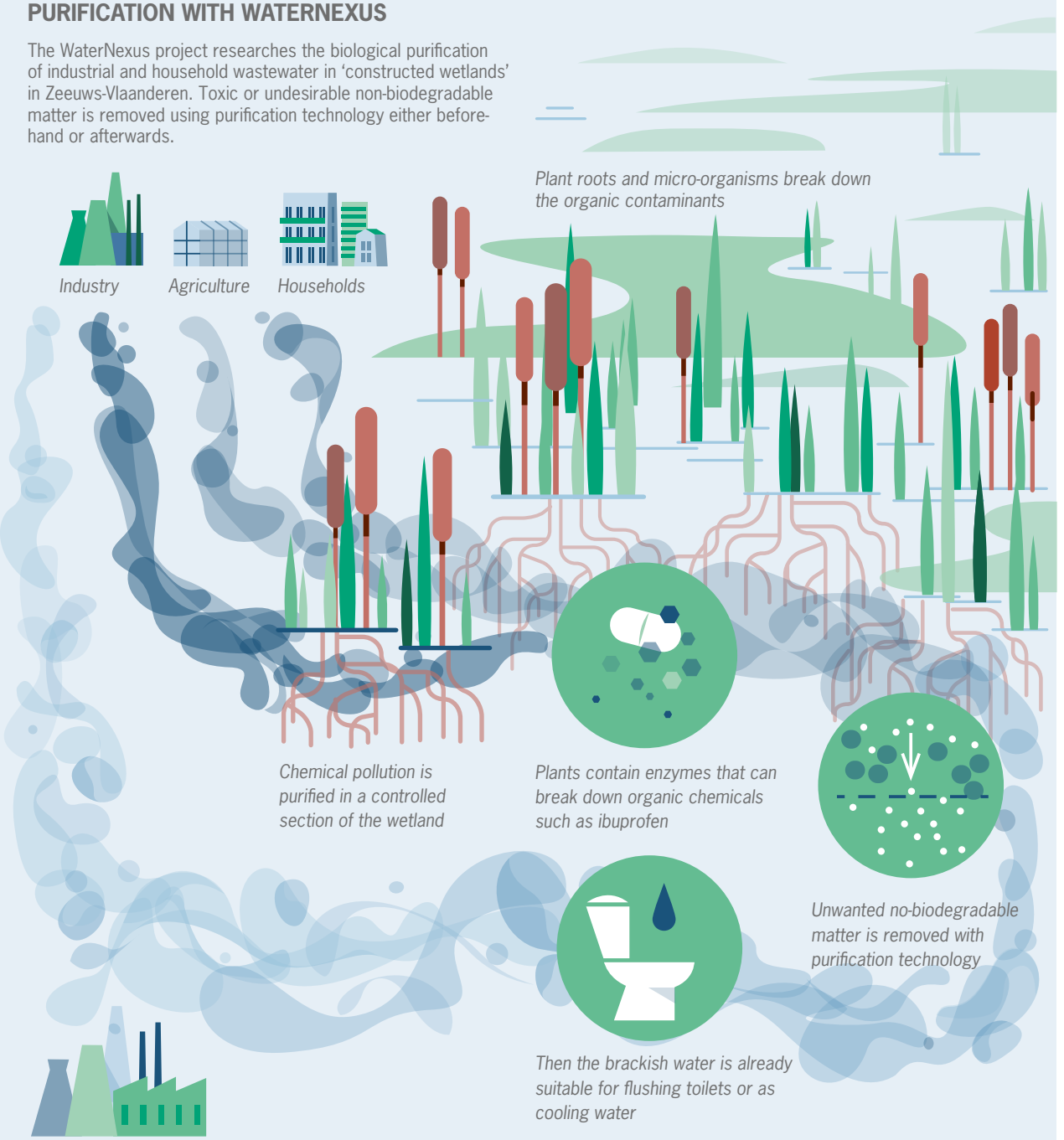
This wastewater can be treated in WaterNexus’s helophyte filter to make it fit for reuse, say Groot and Rijnaarts. The wetlands are not in contact with ground- and surface water. And the biological purification in such wetlands can break down much more chemical pollution than a lot of people imagine, says Rijnaarts. Industrial process chemicals that Dow adds to the cooling towers could be broken down in the scaled-up wetlands of the future. That is WaterNexus’s ambition. ‘The chemicals could be broken down in a small, controlled area of the wetland, after which the water flows through to the main area for storage,’ says Rijnaarts. There humus hydrocarbons are also removed that are naturally present in water and become concentrated due to the evaporation of water in cooling towers. ‘The whole process creates a supply of good quality water for getting through the dry season.’

EIGHT BASINS OF REEDS

On a small trial plot in Wageningen, PhD student Thomas Wagner demonstrates what this gentle, biological purification process in a wetland looks like. Eight basins containing algae and reeds are irrigated with ‘cooling water’. ‘It is not the real saline cooling water from Dow; I replicated that water in the cellar of our lab,’ says Wagner. ‘The basins contain sand to which humus particles stick, and the plant roots absorb disinfection and anti-corrosion substances, which the micro-organisms on the roots then break down further.’ A number of the basins contain >

PURIFICATION WITH WATERNEXUS

The WaterNexus project researches the biological purification of industrial and household wastewater in 'constructed wetlands' in Zeeuws-Vlaanderen. Toxic or undesirable non-biodegradable matter is removed using purification technology either beforehand or afterwards.

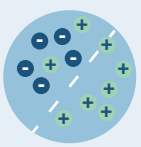


Desalinization

The surface water in Zeeuws-Vlaaderen, like many other parts of the world, is plagued by salinization. For some forms of reuse, the water is desalinized afterwards. New energy-saving techniques are used for this, which were developed in Wageningen.

Capacitative deionization
Porous electrodes attract and absorb salt ions

Electrodialysis
Ion-selective membranes selectively let positive or negative ions through



> ‘We can design an alternative water network for the whole of Zeeuws-Vlaanderen’

strikingly few plants. ‘In those we have looked at the breakdown of the same substances by sunlight,’ says Wagner, who received his PhD for this study at the end of February.
One of the things he studied was how to achieve optimal aeration of the roots and the micro-organisms by letting the water flow through the basins both horizontally and vertically, and varying the speed of the flow. He also studied the optimal order for the basins. ‘The main lesson is that we shouldn’t aim to break down as many pollutants as possible in a single basin,’ says Wagner. ‘Every time, you should leave just enough pollution for the reeds in the next basin to have something to do as well, so they can grow and break down the contaminants.’ He adds: ‘We want to work with these kinds of compartments in the real-life situation too, in what we call engineered or constructed wetlands.’ At first he succeeded in breaking down 40 per cent of the anti-corrosion materials, and now he has reached an elimination rate of 100 per cent. ‘The micro-organisms need to be given time to evolve and to adapt to the pollution.’

UPSCALING QUICKLY

Meanwhile, similar basins have been installed on the site of Evides water company next-door to the Dow plant in Terneuzen, where the optimal configuration figured out in Wageningen will be tested on real cooling water. Wagner does not expect problems. ‘I hope that after this test, Dow can quickly upscale to the demonstration scale of several hundred square metres with larger quantities of cooling water than the 150 litres a day I test here. Eventually we’ll need a few hectares.’
And that is not all, says Rijnaarts. ‘Plants have enzymes at their disposal that work in the same way the human liver works to break down waste products. The cytochrome P450 enzyme system, for example, can break down organic chemicals such as the medicine ibuprofen in wastewater.’ Making use of these plants would mean that domestic wastewater in Zeeland towns doesn’t have to be discharged into the sea but can be purified in a wetland and saved for reuse. That is a good method for all domestic wastewater in the Netherlands, which is full of pharmaceutical residues. It might also be feasible to purify water left over from the cultivation of bell peppers and aubergines in the greenhouses of Terneuzen in the basin. ‘And farmers from the surrounding area could store their surplus water from the fields in the winter in this kind of wetland,’ adds Johan Elshof of the farmers’ branch organization ZLTO. ‘In times of drought in the summer, they could pump it back to water their outdoor crops.’

TOXIC CHEMICALS

WaterNexus does not focus exclusively on gentle, biological techniques, though. ‘For a few substances, such as non-biodegradable chemicals, we use hard chemical decontamination technology to extract them from the water,’ says Rijnaarts. ‘Before the wetland treatment for toxic substances for the plants or organisms in the wetland, or afterwards if they are problematic for reusing the water.’
For some applications it is necessary to desalinate the water too. With desalinization techniques, the researchers want to be able to reduce the salinity of the wetland water to any level required. ‘Some crops or nature areas can cope with a bit of salt water, and toilets in houses and business premises can be flushed with brackish water too,’ says the technologist. If the water for industrial or agricultural purposes needs to be less salty, then WaterNexus wants to use the most energy-saving desalinization techniques. So not only using reverse osmosis, a widely used technique, pushing saltwater through

WATERNEXUS

WaterNexus is a project in which partners collaborate on new solutions for the water supply in coastal zones facing shortages of freshwater. It is financed by the Dutch Research Council (NWO) through the ministry of Infrastructure and Water Management and supported by 24 partners. Besides Wageningen University & Research, they include six other universities (the University of Amsterdam, VU University Amsterdam, Utrecht University, and the Technical Universities of Delft, Eindhoven and Twente), research institutes such as Deltares, KWR, TNO, and STOWA, consultancy firms (Witteveen+Bos, RH-DHV and Fugo), technology suppliers, water boards and the water companies Evides, Oasen and WLN. WaterNexus is coordinated by Professor Huub Rijnaarts of the Wageningen Environmental Technology group.

a membrane so that the salt stays behind on the membrane filter. That uses a lot of energy for pumping and for cleaning the membrane. WaterNexus is considering two energy-saving techniques developed in Wageningen: electrodialysis and capacitive deionization (see illustration).
If the purification process in the trial basins is upscaled to the level of large natural reed filters used in combination with these more heavyweight techniques, Rijnaarts thinks it can produce a sizeable buffer of water that the whole district can draw on in the summer months. WaterNexus therefore wants to create models that calculate the supply of and demand for water of different qualities, with a view to honing the management of the 'second-hand water'. Rijnaarts: 'We can soon develop an alternative network of this kind for the whole of Zeeuws-Vlaanderen, reducing its dependence on the Biesbosch pipeline. This design could be in place in 10 years.'

FISH IN THE DESERT

Shell is involved in WaterNexus too. Environment manager Albert Janssen: 'The project is interesting because it researches integral solutions for the real world.' Shell needs cooling and processing water too, but also ends up with water that is discharged when fossil fuels are extracted from deep layers of rock at all its oil and gas extraction locations around the world. 'This production water can contain a wide variety of salts. So we are very interested in how the wetlands can improve the quality of this water and which plants can grow in it,' says Janssen, who studied in Wageningen and has been a part-time professor in the Environmental Technology group for several years. In the Gulf state of Oman, Shell's partner Petroleum Development Oman has created a wetland on the edge of the desert. 'We are exchanging experiences with WaterNexus on that. There are now all sorts of birds and fish in a place where there used to be nothing but desert.'

The valuable flora and fauna that the wetlands foster is an important aspect for the Netherlands too, says Rijnaarts. It means cycling and walking routes can be part of the landscape. So WaterNexus has invited the nature conservation organization Natuurmonumenten, the nature management agency Staatsbosbeheer and some environmental organizations to collaborate on a follow-up project aiming to strengthen the green dimension of the concept. 'You see,' says Huub Rijnaarts, 'whether there is a WaterNexus project or not, nature is going to be faced with salinization due to rising sea levels. Salt can have negative effects, but we can also create unusual nature areas out of freshwater-saltwater transition zones. And don't forget that these wetlands don't just purify water; they also absorb the greenhouse gas CO_2, thus contributing to climate mitigation.'

WATER IN AMSTERDAM

What can be done in Zeeland can also be done in other coastal provinces, reckons Rijnaarts. In Amsterdam, for instance, the supply of freshwater in dry summers is dwindling due to the diminishing influx from the Rhine and the IJsselmeer. At the same time, more and more saltwater is seeping into the soil from the polders and through the big new locks in the North Sea Canal at IJmuiden. Reusing water purified in wetlands could be part of the solution to this. 'Just like all big cities, Amsterdam needs to create more green infrastructure to cope with overheating in the city and make it more liveable,' says Rijnaarts. 'What is more, cities can combine green water purification with rainwater harvesting from extreme rainfall, helping to prevent flooding of the sewerage system.'
Together with the Institute for Advanced Metropolitan Solutions and the water board Waternet, Rijnaarts is studying various options for improving the Amsterdam water system. There is also potential for exporting this way of thinking about freshwater and salinization to other deltas. Several twinning projects are already part of the WaterNexus project. In the city of Khulna in Bangladesh, a proposal is being drawn up to purify urban wastewater instead of discharging it into the river. Rijnaarts: 'Once treated, that urban water supplies clean fresh water that can be used for agricultural purposes.' In Ho Chi Minh City in Vietnam, the Saigon and the Mekong rivers converge in the Mekong delta. 'There are enormous industrial estates there with hundreds of companies that cannot get any more processing water from the rivers because seawater has infiltrated beyond the factories' intake points,' explains Rijnaarts. Three PhD students, two of them Vietnamese, are researching the possibility of using a wetland in combination with hard technologies for the reuse and storage of water, and for purifying industrial wastewater. But in other countries such as China, Qatar, Oman and Saudi Arabia too, a combination of wetlands and desalinization technology could contribute to an extensive reuse of water, says Rijnaarts. 'There too, WaterNexus wetlands have a lot to offer.' ■

http://waternexus.nl/

HUUB RIJNAARTS
professor of Environmental Technology:

'Cities can combine green water purification with harvesting rainwater from extreme rainfall'