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The essential resource

Photo: Katrin Binner

Prof. Susanne Lackner

Information

Department of Wastewater Management, Institute IWAR
Prof. Dr. Susanne Lackner
Phone: +49 (0) 6151/16–20309
Email: s.lackner@iwar.tu-darmstadt.de
www.iwar.tu-darmstadt.de/abwasserwirtschaft

Professor Susanne Lackner holds the Chair of Wastewater Engineering at the Department of Civil Engineering and Geodesy at the TU Darmstadt. The environmental engineer is an advocate of country-specific solutions – and of more interdisciplinarity.

By Jutta Witte

Professor Lackner, what is it that you find so fascinating about wastewater technology?
I have always been interested in water, not just because I am passionate rower, but above all from an integrated perspective. Water is essential to all life, and with our research we are laying important foundations for protecting this resource. What fascinates me most of all are the microbiological mechanisms that ensure that harmful substances can be removed from wastewater – in treatment plants, but also in nature. I want to discover new things at the interface between process technology and microbiology.

“The focus is shifting to water recycling and resource recovery.“

What demands for research do you see?
I think there is still a tremendous demand for basic research. We still know very little about the microbial populations in treatment plants. Some of them are extremely complex „communities“, and we have only had the technology to measure what organisms even exist for a few years. We still don’t understand exactly what is happening here on a small scale. For instance, we loose the activity of these organisms in some treatment plants, and we still don’t know why.

What do the bacteria do there?
Once the wastewater has been mechanically treated, they are responsible for eliminating organic carbon and nitrogen, plus ammonium and phosphorus. We create the optimum conditions in a treatment plant to encourage a high concentration of bacteria in relatively small volumes to break down these pollutants. In the end, the microbial conversions are the same as in natural waters – just at much higher concentrations.

What options for optimisation do you see?
Even though we have been using biological processes for wastewater treatment for decades, there are still many gaps in our knowledge, and much potential for optimisation. I am interested primarily in the populations that are responsible for nitrogen elimination. We need various groups of organisms here that interact and together catalyse the breakdown process. If they don’t work together properly, it won’t work.

What is the biggest challenge here?
Nitrogen breakdown is a multi-stage process. There are four main groups of bacteria for the various steps that catalyse the various breakdown processes. Each group contains a large number of species with different characteristics. Some processes require oxygen, some are not allowed to have any. It’s an interplay that needs to be controlled properly. We want to understand what type of organisms thrive under which conditions, and then design the process technology accordingly. If we want to continue to optimise wastewater treatment, we need a system that is constantly able to adapt to new conditions.

What other topics are virulent in this country in wastewater treatment?
The elimination of trace elements is becoming more and more relevant in Germany. Phosphorus remains a major issue, and also microplastics are discussed more and more. We already have the necessary process technology, but we don‘t yet know what is best to use where. Resource recovery is also becoming increasingly important, for instance the energetic use of sludge or the recycling of nitrogen as a fertiliser. Here too, though, the technology is not yet fully mature.

A lot of experts talk about a change of paradigm in water management.
I observe this also: the focus is shifting towards water recycling and resource recovery. These are topics that are driven by the fact that in many parts of the world, water is becoming a scarce commodity

before our eyes. This isn't quite such an issue in Germany because we are only rarely affected by the lack of water that so many other countries have to live with.

Are we talking about affluence problems in Germany?

If you look at the global situation, yes. We need to distinguish between what we have here in our country, and what life is like in other parts of the world. We are addressing micro pollutants in the nanogram range which, with regard to the quality of the drinking water, we absolutely need to do. But at the same time, a lot of people in other countries are facing existential problems. Either simply because they don't have enough drinking water, or because their water systems are heavily polluted.

What are the problems in these countries?

Modern infrastructure and clear standards that are self-evident to us, sometimes doesn't exist. In Kathmandu, I have seen how the sewage still runs down the street. This does not mean that we have to do everything the same way we do it here. That's not what is needed. In Nepal, for instance, it would be enough to reduce the carbon and then sanitise the water and use it to directly water the crops.

You are also involved in a research project in Namibia…

For an African country, Namibia has made relatively good progress, which is also due to the good development cooperation that takes place here. The infrastructure is well developed. The small town in the north where we are working, which has a population of more than 7000, has a vacuum canalisation to which almost two-thirds of the households are already connected. The wastewater is treated centrally in treatment ponds. It's low tech, but that doesn't mean the quality is any poorer, and it can be further improved with simple structural measures.

What would be expedient to support regions such as these for the long-term?

I'm in favour of individual solutions. Every case and every system is different, and that's what makes wastewater technology so exciting. We should discuss internationally: for what purpose and at what cost should we actually treat water? Examples like

Photo: Katrin Binner

Clean water is the aim: wastewater treatment plays a key role in making used water usable again.

our project in Namibia also show that we need to co-operate with the people there and work out with them how they will be able to run things themselves in the future. That's why we are working with sociologists there. And it's important to show incentives for secure financing, for instance by taking money for the treated water that is used to water feed crops.

What does such an approach mean for your field?

We need to be far more interdisciplinary in our work, to link the classic engineers and biologists and also bring in other disciplines. This is something I want to make visible to the students, and to train them in that direction. The basic technical sciences are no longer enough to help us move forward with these complex topics.

The author is a science writer and holds a doctorate in History.

EPoNa – upgrading wastewater ponds to generate irrigation water using the Cuvelai-Etosha basin in Namibia as an example

The research association coordinated by the TU Darmstadt wants to upgrade and extend a four-level wastewater pond system in Outapi in northern Namibia so that the treated wastewater can be reused to water feed crops – and the nitrogen and phosphorus compounds that would otherwise be eliminated can be used as fertilisers. Project partners are the Hochschule Geisenheim, IEEM GmbH of Witten/Herdecke University, the Institut für sozial-ökologische Forschung GmbH (ISOE), the Aqseptence Group and H.P. Gauff Engineers, plus the Outapi Town Council, the Namibian government and national training and study facilities. Duration of the project, which is supported by the Federal Government: 1.9.2016 until 31.8.2019.

EiVeN-G – developing innovative methods for nitrogen elimination from highly-polluted digestate

The project deals with the wastewater that is created in the dehydration of agricultural digestate. Nitrogen is to be removed from wastewater using energy-efficient technology before it is then returned to agriculture. The specialists want to develop a robust biological process for this purpose, based on the principle of deammonification, i.e. the transformation of ammonium into gaseous nitrogen and nitrate in treatment plants. TU Darmstadt and the Universidad de Concepcíon in Chile are involved in this project, which is funded by the Federal Research Ministry. Duration: 1.2.2017 until 31.1.2020.

Fewer nitrogen oxi
in exhaust emission

The doctoral candidate Anna Schmidt has created a sensor, that helps to contribute to the development of better diesel catalysts.

Photo: Katrin Binner

M.Sc. Anna Schmidt and Dr. rer. nat. Benjamin Kühnreich in the research laboratory

Information

Research Group High Temperature Process Diagnostics
Dr. rer. nat. Steven Wagner
Otto-Berndt-Str. 3, L1|08-109
Phone: +49 (0) 6151/16–28925
Email:
wagner@rsm.tu-darmstadt.de
www.htpd.tu-darmstadt.de

By Uta Neubauer

Modern catalysts of diesel vehicles are complex systems: incompletely combusted fuel is first oxidised, when, for instance, toxic carbon monoxide turns into carbon dioxide. Then a particle filter separates the harmful soot particles. And then the problem of nitrogen oxides remains to be solved. To this end, a watery urea solution, brand name AdBlue, is injected into the exhaust flow. Urea is a harmless chemical, a relatively small organic molecule that our body produces during the metabolic process and excretes in the urine – hence the name. The automotive industry uses the substance because it releases ammonia. This in turn reacts in the diesel catalyst with harmful nitrogen oxides to produce harmless water and nitrogen, the main component of air.

So much for the theory. In practice, there are a number of flaws in the catalytic process that make it less efficient. This was known to us long before the diesel scandal and fudged nitrogen oxide levels. One of the problems results from the injection of the AdBlue solution, because as Dr. Benjamin Kühnreich, research associate in the UNICO (University Industry Collaborative) High Temperature Process Diagnostics research group in the Department of mechanical engineering explains, „In commercial exhaust after-treatment systems, it has not yet been possible to prevent the urea solution from collecting on the sides of the exhaust pipe“. A thin liquid film develops opposite the injection point. When the water in the AdBlue solution evaporates (the temperature in the exhaust system can reach 500 °C), the urea is left behind and forms solid deposits. „Then you have to run burnout cycles,“ adds Kühnreich.

This in turn costs energy and increases fuel consumption. In the extreme case, if the injection system is incorrectly set, the channels in the catalytic chamber may even become completely clogged. Furthermore, the urea deposit no longer helps to detoxify the nitrogen oxides. „The ideal would be to measure the AdBlue solution so that the film doesn't occur on the wall,“ emphasises Kühnreich. This is quite a challenge, because no one knows yet how and under what conditions the film is created, how thick it is, and what injection technique would help to prevent it. Experts estimate the film to be no more than half a millimetre thick, but no one knows for sure because there has never been any way to measure it.

This gap has now been closed by Kühnreich and his colleague Anna Schmidt. As part of her Master's degree Schmidt, who is now a doctoral candidate in the Department of mechanical engingeering, developed a sensor that, for the first time, can measure the thickness of the films in the exhaust channel. „Although des

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commercial sensors for determining film thicknesses do exist, they are not suitable for this particular case," explains Schmidt. They are not heat-stable, and furthermore need to be applied extremely close to the film. However, they are too big for the narrow exhaust pipe. Schmidt's sensor solves this problem by measuring the film thickness by the absorption of laser light. The laser beam is passed through a small opening in the exhaust pipe to the liquid film, ist guided to the film, and is reflected on the pipe wall. The existing light is bundled and focused onto a photodiode. The film thickness can be deduced from the intensity of the reflected light. In simply terms: thick films absorb more light than thin ones.

„In commercial exhaust after-treatment systems, it has not yet been possible to prevent the urea solution from collecting on the sides of the exhaust pipe."

A certain amount of preliminary work was required for the method to provide reliable information. Scratches on the side of the pipe, for instance, greatly influence the results, because the film layer is thicker around indentations. Likewise, the values can be determined by the temperature and urea concentration, both of which are fluctuating figures. Schmidt initially worked on the light absorption of the AdBlue solution. Her main consideration was: what wavelength does the light have to be to record the thickness of the film without the temperature and other factors influencing the measurement? Her preliminary work showed that light of wavelengths around 1650 and 1440 nanometers was the most suitable. „We were lucky," emphasises Kühnreich. „Light of wavelength 1650 nanometers is used in telecommunications for transmissions in the fibre-optic network, so the corresponding lasers are standard." Although the 1440-nanometer laser is not so widely used, it is available. Using two lasers that transmit different wavelengths makes the new sensor particularly strong.

Once the appropriate lasers had been chosen, Schmidt worked out the most practical sensor construction. The two laser laser beams are combined into a single fibre optic and aimed at the AdBlue film and back again via an optical system that consists of a special lens, a beam diffuser that splits off a reference jet, and mirrors. Photodiodes determine the intensity of the reference laser beam and emitting light. Measuring the film thickness worked extremely well in the model system.

The next step is to test the sensor on a test rig that the researchers are currently constructing. „Determining the film thickness will only become exciting in a larger context, when you also consider the injection cycle and the injection amount of the AdBlue valve, and when you look at the various jets and the resulting films", emphasises Kühnreich. And this is exactly what the automotive industry wants to use the system for. „The key word is ‚pre-development stage'," says Kühnreich. The sensor will not be used directly in the car, but is to help in the development of better catalysts with optimised injection technology. What is really helpful is that only a small hole is required in the exhaust pipe wall for the light to feed through. „The lasers that are connected by glass fibre can be some distance away," says Schmidt. She has not yet tested her sensor in a real catalyst, but Bosch and other companies in the automotive industry that work closely with the TU researchers are very much interested.

There is no doubt that minimising AdBlue films is only one of many options for reducing harmful substances in diesel emissions. Kühnreich says it is typical of science that it concentrates on a single detail to change something. Integration in a joint project and numerous industrial co-operations make sure that the researchers do not lose sight of the big picture, and that ultimately the many pieces of the puzzle are joined together in one solution.

The author is a science writer and holds a doctorate in Chemistry.

Working close to the wall

Processes on the walls of industrial or energy-technical systems such as combustion chambers or exhaust pipes are of key importance in the development of harmful substances. The walls also influence the development of irritating deposits and many catalytic processes. In the light of the increasing reduction of the sizes of engines and systems, close-to-the-wall processes are becoming increasingly significant. This is where Transregio 150, the collaborative research center that was launched three years ago, comes in: researchers at the TU Darmstadt and the Karlsruhe Institute of Technology (KIT) are addressing turbulent, chemically reactive close-to-the-wall multi-phase flows in 17 part-projects. Measurement engineers such as Anna Schmidt and Benjamin Kühnreich are working hand in hand with numerists who design computer models to simulate close-to-the-wall processes.
www.trr150.tu-darmstadt.de

Buttons from a printing machine

The illuminated buttons on bus doors can be difficult for older passengers to see, especially at night. An innovative printing process is being developed at the TU Darmstadt in co-operation with a bus manufacturer for buttons that shine brightly without dazzling.

Photo: Katrin Binner

In the laboratory: flexible printing pads are used to transfer individual layers of the illuminating symbol and the printing image to three-dimensional surfaces.

—— By Boris Hänßler

Speed is of the essence at a bus stop. If you want to board, you need to find the button to open the door quickly. LEDs light up in a circle around the corresponding hand symbol, but at night the diodes can be so bright that it can be difficult to see, especially for older people. Bus manufacturer EvoBus of Mannheim is therefore looking for ways to produce a new kind of button that does not dazzle and yet remains clearly visible in any light conditions. A team under Dr. Hans Martin Sauer of the Institute of Printing Science and Technology (IDD) at the TU Darmstadt, which is run by Professor Edgar Dörsam, has addressed the problem, and is researching an innovative process for printing luminescent materials in the project „Electroluminescence display in capacitive sensor technology (ELSE)“.

The advantage of these materials is that once voltage is applied, they light up gently by themselves – making LEDs superfluous. „What is required is a precise and efficient printing process that allows us to produce any motifs using the minimum amount of materials,“ says Sauer. The project is supported by the Federal Research Ministry in the initiative „KMU-innovativ: Photonik/Optische Technologien“. As well as EvoBus, the partners include the companies Captron Electronic in Olching and Franz Binder in Neckarsulm

The research team opted for the pad printing process. It is used for products with uneven surfaces, such as model railways and PC keyboards. An elastic pad made of silicone rubber takes up the colour from a print form and transfers it to the object. „The pad

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Institute of Printing Science and Technology
Magdalenenstr. 2, 64289 Darmstadt
Phone: +49 (0) 6151/16–22780
Email: office@idd.tu-darmstadt.de
www.idd.tu-darmstadt.de

Part of the research team at the Institute of Printing Science and Technology, Department of mechanical engineering: Christina Bodenstein, research assistant, Professor Edgar Dörsam, director of the institute (centre), and Dr. Hans Martin Sauer, group leader.

Photo: Katrin Binner

printing process is extremely flexible,“ says Sauer. „But because no one has ever combined it with luminescent material, there are no standards.“ These materials are usually applied by screen printing because they are quite coarse grained – seen under a microscope, they look like a cinder track.

The luminescent material need to be applied extremely evenly so that the layer acts as a capacitor. Furthermore, the finished button is to last for ten years on the buses – without the brightness changing greatly during this time. Not an easy task. „We converted a conventional printing press and fitted it with an electric precision drive and measuring probes,“ said Christina Bodenstein, research assistant at the IDD. „This means we can experiment with materials, shapes, patterns and sizes of the printing pads and control every single step by using our own specially developed software.“

„We converted a conventional printing press and fitted it with an electric precision drive and measuring probes.“

The printing process is only one part of the project – another difficulty is accommodating the control electronics for the button in the smallest possible space so it can fit inside the corresponding housing on the buses. Plus it should be contactless. The IDD is therefore collaborating with the Department of Integrated Electronic Systems (IES), Professor Klaus Hofmann. „We are developing a chip that will control the lighting and the sensor,“ said Katrin Hirmer of the IES. „It will also ensure that the electroluminescence and sensors are not affected by interference signals.“ A prototype has already been made. Now it’s down to the finishing touches. As the printing process can print various motifs without adjusting the system, it will also be easy to print the appropriate buttons for instance for hospitals or for machinery and plant engineering. Even Asian symbols would not be a problem, so this innovative technology is most definitely ready for the global market.

The author is a technology journalist.

Demonstrator: A door opening button like this with a printed illuminated hand symbol is to be used on public transport.

Photo: Fa. Franz Binder GmbH & Co.

Stop and Go in the potassium channel

Ion channels control the flow of charged particles into the cell. A surprisingly basic closing mechanism has been discovered for a potassium channel at the TU Darmstadt.

By Hildegard Kaulen

Cells need openings in the cell membrane in order to make exchanges with their environment. However, these openings are not flapping pores, but closable portals in which the signals are transported to and fro in the form of ions. Private lecturer Dr. Indra Schröder from the Department of Membrane Biophysics at the TU Darmstadt, which is run by Professor Gerhard Thiel, is interested in potassium channels. The physicist and head of the junior research group has her very own view of these tiny molecular machines. She is not so much interested in the biological signals that are exchanged via the channels, but in the biophysical closing mechanism. Schröder wants to know what the molecular bolt looks like and how it works.

To that end, the physicist works with very basic potassium channels so as not to make the analysis unnecessarily complicated. She uses two systems with a similar structure but different opening probabilities. One channel is almost always closed, the other almost always open. Both channels originated from algae viruses, but strongly resemble the potassium channels of higher organisms. Schröder works in a cell-free system, and fits the potassium channels into artificial surfaces. „We concentrate solely and exclusively on the closing mechanism, and blend out all the other functions of the potassium channels," says Schröder. „This is legitimate, because the potassium channels are all similar to each other. We are basically working on a prototype, what you could call a model potassium channel."

Schröder and her doctoral student Oliver Rauh have mutated both potassium channels and pushed individual parts of them to and fro like pawns. This enabled them to establish what amino acids are responsible for the low opening probability, and which for the high. The potassium channel with the low opening probability possesses the amino acid serine at a critical point. This amino acid interacts with a remote amino acid, which forces the channel pore to bend. This curve folds another amino acid into the transport route that closes the tunnel.

With the potassium channel with the high opening probability, the amino acid serine was replaced by the amino acid glycine. Glycine does not force the channel pore to bend, which means the tunnel does not close either. „So the closing mechanism of these two viral potassium channels consists only of two amino acids," explains Schröder. „One amino acid closes the channel, the other controls the process. Molecular-dynamic simulations by our co-operation partner Stefan Kast of the TU Dortmund have confirmed this. We had been expecting a far more complicated closing mechanism."

The head of the junior research group assumes that some human potassium channels possess the same bolt as the two viral potassium channels because they both possess the two critical amino acids. Schröder's work is also of relevance to synthetic biology because the potassium channels and their basic closing mechanism can be used in the construction of artificial nano sensors. The noMagic project, in which Schröder is involved, was financed by the European Research Council (ERC), and manipulates living cells with artificially manufactured channels.

The author is a science writer and holds a doctorate in Biology.

Schröder and her colleagues have published their results in the „Journal of the American Chemical Society": Doi: 10.1021/jacs.7b01158

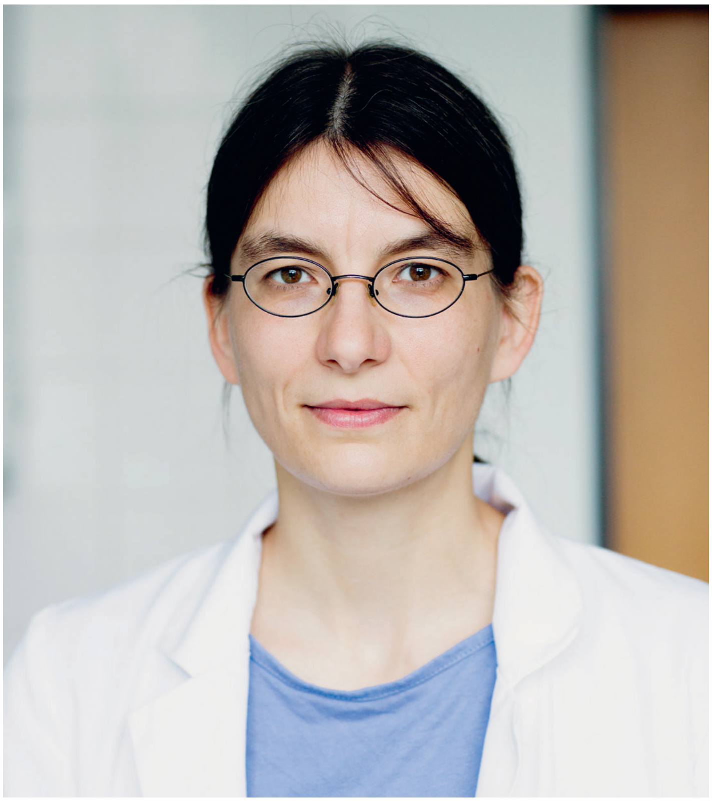

Photo: Katrin Binner

Dr. Indra Schröder

Information

Department of Biology
PD Dr. Indra Schröder
Phone: +49 (0) 6151/16 – 21943
Email: schroeder@bio.tu-darmstadt.de
www.bio.tu-darmstadt.de/ag/professuren/indraschroeder/Schroeder.en.jsp