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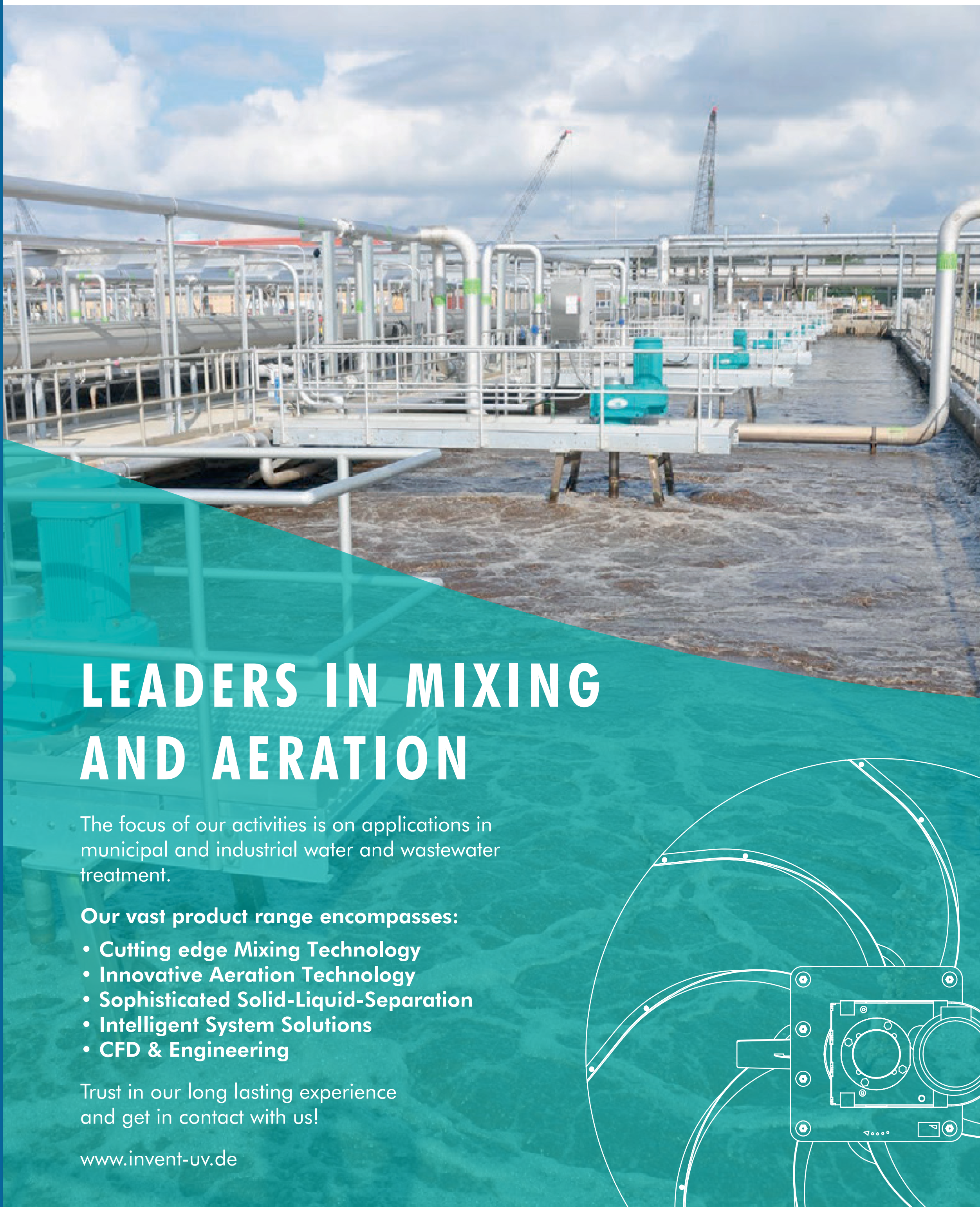
Water Management
Wastewater Treatment

DWA
Clear Concepts. Clean Environment.

International Special Edition 2018/19



Contents

Editorial

DWA

Municipal Wastewater Treatment

Water Management

Training

Products and Services

KA Korrespondenz Abwasser, Abfall
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Science, Education and Training Fight Water Crises

2.1 billion people lack access to safely managed drinking water services. By 2050, the world's population will have grown by an estimated two billion people and global water demand could be up to 30 % higher than today. This information comes from the *United Nations World Water Development Report 2018: Nature-based solutions for water*. Agriculture currently accounts for 70 % of global water withdrawals, mostly for irrigation – a figure which rises in areas of high water stress and population density. Industry takes 20 % of the total, dominated by energy and manufacturing. The remaining 10 % goes to domestic use – the proportion used for drinking water is much less than 1 %, as stated by UNESCO in the just-mentioned report.

For people based in northern Europe, water is an abundant resource being available in ample quantity and excellent quality. But not far away the situation looks quite different. In the summer of 2017, several provinces in Italy were facing serious droughts. In parts of Campania, no rain has fallen for 18 months. In 2018, Cape Town in South Africa is waiting for or fearing Day Zero, when water will be turned off for millions of homes. Droughts also hit the United States of America, e. g. in California. Experts at the World Resources Institute in Washington, D. C. (USA) estimate the risk of water shortages in Spain and Greece to be "extremely high". The Organization for Economic Co-operation and Development (OECD) has forecast that by 2030, almost 50 percent of the world's population will live in high-stress areas, that is, regions where more water is needed than is available. Today, some 1.9 billion people live in potentially severely water-scarce areas. By 2050, this could increase to around 3 billion people. Environmental damage, together with climate change, is driving the water-related crises we see around the world. Floods, drought and water pollution are all made worse by degraded vegetation, soil, rivers and lakes.

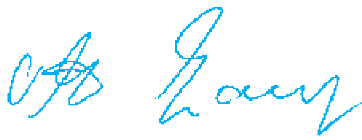
Is this a bleak outlook for the earth's future? Not necessarily. Education, responsible conduct, science and technology can help. Water can be re-used, i.e. wastewater can be purified to an extent that allows it to be used for irrigation. World Water Day 2018 suggests, that by using the solutions we already find in nature, we can reduce floods, droughts and water pollution.

Those of us who are looking for conventional high-tech might visit trade shows and exhibitions where they will find plenty of everything and stimulation for solutions they have perhaps not yet thought of. The world's leading trade fair for water, sewage, waste and raw materials management is IFAT, biennial in Munich, Germany, and at now five locations worldwide. Here are more than 3000 companies as exhibitors and some 140,000 visitors. A treasury of environmental technology and a must-visit for experts worldwide and of all levels of qualification. IFAT emanated from an initiative of the German Association for Water Management, Wastewater and Waste (DWA) in the 1960s and DWA has since then been a conceptual partner of IFAT. Every two years DWA is present in Munich with a variety of events and booths as meeting points and with conference programs and professional competitions at other locations.

Some good examples what water management can achieve are highlighted in articles in this issue. Sewage treatment plants are an effective and important means in this respect. Some top experts from Germany give information for the dimensioning of activated sludge plants for different climate zones. A report by the researchers will be published in English some stage in 2018. The annual "Performance Comparison of Municipal Wastewater Treatment Plants in Germany" shows how things can be if wastewater treatment plants are operated by highly qualified and trained people. This is supplemented by the short article "Training of Skilled Persons for the Wastewater Sector in Vietnam".

An example for integrated water resources management in an arid region is highlighted in the article "Bringing an IWRM Concept into Practice – A Case Study: the Zayandeh Rud River Basin/Iran". Interesting also "The Fight Against Climate Change as an Opportunity in Germany? Current Developments and Further Needs Where Water is in Excess".

All this shows: Water problems are not confined to southern countries, but can also happen in the northern hemisphere. We need highly qualified personnel to operate plants and other facilities. Science, research and education are essential. Sometimes, more rationality is required at the side of consumers. Given all this, I am sure we have the potential to overcome water crises of the world and are not facing a bleak future.



Bauass. Dipl.-Ing. Otto Schaaf
President of the German Association for Water Management, Wastewater and Waste (DWA)

		Publication	Euro
☐ Standard DWA-A 161E	New	**Static Calculation of Jacking Pipes** May 2018 (German edition March 2014), 99 pages, A4, ISBN 978-3-88721-245-2, the content of the Standard DWA-A 161 and the DVGW code of practice GW 312 is identical This Standard applies to the structural calculation of pipes with a circular cross-section which are installed according to the pipe jacking method in a straight or bending direction in non-cohesive or cohesive soils (loose soils as per DIN 18319) with static force in accordance with Standard DWA-A 125.	83,00 *
☐ Standard DWA-A 131E	New	**Dimensioning of Single-stage Activated Sludge Plants** May 2018 (German edition June 2016), 69 pages, A4, ISBN Print: 978-3-88721-643-6, ISBN E-Book: 978-3-88721-644-3 In contrast to earlier editions, in which the dimensioning procedure for nitrifying and denitrifying activated sludge plants was based on the measured BOD_5 load, the design is now based exclusively on the COD load. This Standard deals not only with the description of the process, the design procedure and the design bases, but also with the calculation of the mass of the sludge and the design of the secondary treatment and sludge activation.	81,50 *
☐ Software	New	**Activated Sludge Expert 3.0** After translation of the new Standard DWA-A 131 the next version 3.0 will be published (expected for winter 2018)	in preparation
☐ Standard DWA-A 216E	New	**Energy Check and Energy Analysis – Instruments to Optimise the Energy Usage of Wastewater Systems** December 2017 (German edition December 2015), 64 pages, A4, ISBN Print: 978-3-88721-570-5, ISBN E-Book: 978-3-88721-571-2 This Standard provides planners, operators and competent authorities with a practice-oriented and scientifically sound working aid for the procedural and energetic optimisation of wastewater systems and a consistent methodology.	80,00 *
☐ Standard DWA-A 262E	New	**Principles for Dimensioning, Construction and Operation of Wastewater Treatment Plants with Planted and Unplanted Filters for Treatment of Domestic and Municipal Wastewater** May 2018 (German edition November 2017), 68 pages, A4, ISBN Print: 978-3-88721-641-2, ISBN E-Book: 978-3-88721-642-9 This Standard provides you with a uniform basis for the design, construction and operation of soil filters for the biological treatment of municipal wastewater. Newer test results for primary treatment in multicompartment septic tanks were taken into account and new types of soil filters were added.	83,50 *
☐ Standard DWA-A 272E	New	**Principles for the Planning and Implementation of New Alternative Sanitation Systems (NASS)** in preparation 2018 (German edition June 2014), 34 pages, A4, ISBN Print: 978-3-88721-645-0, ISBN E-Book: 978-3-88721-646-7 This Standard provides you with important information on the main features of new alternative sanitation systems as well as a comprehensive overview of the current state of the art. Besides the boundary conditions, under which the use of new alternative sanitation systems can be particularly advantageous, you are equipped with basic procedures for conceptualization and planning.	43,50 *
☐ Guideline DWA-M 277E	New	**Information on Design of Systems for the Treatment and Reuse of Greywater and Greywater Partial Flows** in preparation 2018 (German edition October 2017), 34 pages, A4, ISBN Print: 978-3-88721-647-4, ISBN E-Book: 978-3-88721-648-1 This Guideline provides information and assistance for the planning, design, construction, operation and maintenance of greywater treatment and reuse systems for different applications, or for the purpose of discharge into a receiving water body. Systems which do not treat the generated greywater are not covered in this document.	46,50 *

		Publication	Euro
☐ DWA-Topics	New	**Design of Wastewater Treatment Plants in Hot and Cold Climatic Zones** in preparation 2018 (German edition October 2016), 308 pages, A4, ISBN Print: 978-3-88721-615-3, ISBN E-Book: 978-3-88721-616-0 This topic has been compiled with the purpose of amending the DWA Set of Rules which is applicable in Germany by design approaches for a broad range of international application. The focus is on municipal wastewater treatment processes that are commonly used throughout the world, e.g. activated sludge processes, trickling filter systems, anaerobic processes and wastewater ponds.	
☐ CD-ROM	New	**DWA Set of Rules – English Version on CD-ROM** Edition April 2018, ISBN 978-3-88721-632-0 – English translations of significant publications of the DWA Set of Rules, 49 DWA-Standards and Guidelines, 4 DWA-Topics and various brochures in pdf format (single user)	298,00 *
☐ Brochure	New	**Plain talking** **Water: facts and figures** 1st edition 2018, 22 pages, 20 x 20 cm	1,50
☐ Brochure	New	**Plain talking** **Wastewater concerns everyone: Origin, discharge and treatment** 2nd edition 2018, 21 pages, 20 x 20 cm	1,50
☐ Brainyoo Flashcard and eLearning Suite	New	**Pumps and pumping stations** More than 200 questions and answers to pumps, maintenance of pumps, pumping stations and operational, health and safety in pumping stations. Brainyoo is a learning software compatible for PC, Mac, Android, iOS and synchronizes learning content across all devices. For order visit www.brainyoo.de	22,90

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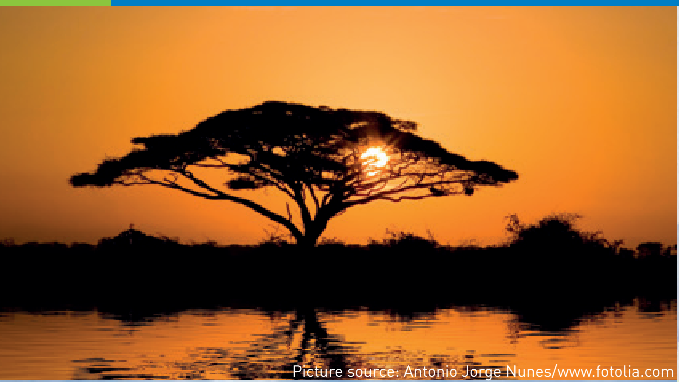
DWA participates in IFAT trade fairs worldwide with a diverse program. Firstly, expert lectures within the Technical Scientific Conference. Secondly, Products in Practice (PiP) sessions, which provide a perfect mix of theoretical knowledge and on-site live demonstrations by different companies. Furthermore, in order to



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IFAT Africa

IFAT Africa takes place every two years in Johannesburg

It was first launched in 2015 and will next take place in 2019

www.dwa.de/ifat-africa

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IFAT Eurasia

IFAT Eurasia takes place every two years in Istanbul

It was first launched in 2015 in Ankara/ Turkey and will next take place in 2019

www.dwa.de/ifat-eurasia

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Coming soon: IFAT Brazil

Messe München plans on rolling out a local IFAT edition in Brazil.

The expected debut fair takes place in 2019

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en.dwa.de

or reach out to Roland Knitschky at knitschky@dwa.de support the international engineers of tomorrow, DWA implemented the UNIVERSITY CHALLENGES and WATER SKILLS. Lastly, DWA helps represent the German water sector on behalf of the Federal Ministry for Economic Affairs and Energy at the German Pavilion.

IE expo China

IE expo China takes place every year in Shanghai

It was first launched in 2004 and will next take place in 2019

www.dwa.de/ie-expo

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IFAT Munich

IFAT Munich takes place every two years in Munich

It was first launched in 1966 and will next take place in 2020

www.dwa.de/ifat-en

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IFAT India

IFAT India takes place every year in Mumbai

It was first launched in 2013 and will next take place in 2018

www.dwa.de/ifat-india

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DWA and IFAT international

In 2017, DWA participated in four different local IFAT editions in Istanbul/Turkey, Shanghai/China, Johannesburg/South Africa and Mumbai/India

IFAT Eurasia benefited from its change of venue from Ankara to Istanbul, even though some exhibitors and visitors likely shied to attend due to the political situation. The appreciation from Turkey towards the German engagement was great and the brand IFAT manages to assert over competitors among national and international exhibitors with its program for their local visitors. Next to the participation in the German Pavilion and the Technical Scientific Conference, DWA implemented the University Challenge. A competition, in which teams of three students prove their skills and knowledge in developing strategies for a sustainable usage of the resource water. Four teams participated in the debut event, which was a success and laid the foundation for future University Challenges to come.

The IE expo in Shanghai was able to position itself very strongly within the market, which resulted in numerous new exhibitors and visitors. China puts a great effort into improving the environmental protection. DWA too – participating in the conference program and by having executed three University Challenges in total by now, contributed in the increasing success of the fair.

Messe München decided to execute IFAT Africa without the construction machinery fair. Their strategy worked out. 152 exhibitors, numerous visitors and many young talents seized the opportunity to inform themselves about new environmental technologies, increased their network and exchanged their knowledge and experiences. Within the sessions, the full range from basic sanitary provisions up to high-tech solutions was covered. Furthermore, the University Challenge launched at IFAT Africa. Three teams attended, were extremely engaged and well-prepared and put a lot of effort and fun into their work. Additionally, DWA contributed in the Young Professionals Forum, a meeting point for young talents, which aimed to provide career information. The program was very well received, the room was packed with people and the discussions were lively, which resulted in many new contacts between young talents, companies and start-ups.

In 2018, IFAT India celebrates its 5th anniversary and, according to the Messe München, the fair is more successful than ever before. The increase of visitors – a growth of 30 percent – can be traced to the pressing environmental issues, which the population currently faces, states Bhupinder Singh, CEO of the Messe München India. Besides the Technical Scientific Conference and the University Challenge India, DWA organizes the Active Learning Center (ALC), which gains on importance continuously. The ALC is a platform for live demonstrations and is placed in the center of the exhibition hall. Both, the Products in Practice (PiP), as well as the University Challenge India (UCI) were able to attract a lot of audience and contributors. The ALC is a format, which is going surely to establish even more in the future. Particularly the PiP is not only relevant for companies, which can demonstrate their products on-site, but also for visitors, who profit from a combination of learning in theory and trying their products out on-site.

Further information or to stay updated on upcoming dates:

www.dwa.de/international KA

Get to know the German Water Sector

The German water sector is very progressive and its current state of research and learnings can well be adapted to the water industry worldwide. In order to help experts to get a full understanding of its setup, with all its complexity in structure, laws, facts and figures, stakeholders, as well as the administrative setup, the German Association for Water, Wastewater and Waste (DWA) implemented the seminar "Introduction to the German Water Sector – Learn from Experience". Within three days, participants experience a balanced mix of theoretical knowledge, practical experience and group work, rounded up by an excursion. In order to address the specific needs of the target audience, the seminar takes place twice per year. Next to the overall information on the German water sector, one seminar focuses on river basin management, whereas the other one deals with wastewater treatment in particular. The basics, being covered in both appointments, are the standards and rules in Germany, including the importance of the Technical Safety Management (TSM), the role and meaning of the Technical Vocational Education and Training (TVET), being a solid foundation of knowledge, the integration of policies, decisions, participation processes and costs across sectoral interests, including involvement of industry, agriculture, urban development, navigation, fisheries management and more. Relevant case studies round up the lecture. The seminar focusing on river basin management additionally deals with basic principles of river basin management, including visions for living rivers. Experts, who are interested in wastewater treatment on the other hand, are going to learn about new concepts for a resource saving water management.

Participants can provide a project factsheet prior to the seminar, so the lecturers can touch upon practice-oriented topics. Attendees are also able to address concrete questions related to their working area on-site. The seminar is held in English and the target audiences are all people, working in the international water sector.

Further information or to stay updated on upcoming dates:

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Dimensioning of Wastewater Treatment Plants in Hot and Cold Climates

Holger Scheer, Tim Fuhrmann and Peter Wulf (Essen/Germany)

Deviating wastewater temperatures and salinity levels or specific discharge requirements in other countries regularly challenge export-oriented suppliers of wastewater technology and engineering know-how. The dimensioning of sewage and sludge treatment plants for the special conditions in other countries therefore required the existing DWA regulations to be amended. For this purpose, internationally applicable dimensioning approaches were developed in the five-year EXPOVAL joint research project funded by the German Ministry for Education and Research (BMBF). These were presented at an event in Essen/Germany. The dimensioning approaches have been added to the new DWA Topic T4/2016, which was presented for the first time at the event.

Without state funding for the 16 German universities and industrial companies involved, the development and validation of the extended dimensioning approaches for world-wide application would not have been possible. As a representative of the Federal Ministry of Education and Research (BMBF), Undersecretary Dr *Ulrich Katenkamp* accordingly highlighted in his welcome address the contribution of the EXPOVAL joint project (Transfer-Oriented Research and Development in the Field of Wastewater – Validation to Technical Installations) which apart from supporting the know-how transfer to foreign regions also should help German companies to achieve success in the face of international competition.

Constraints and conditions for international projects

The particular constraints and conditions for foreign projects were emphatically addressed by several speakers. Dr. *Fritz Holzwarth* (formerly in the Federal Ministry of the Environment and still active for internationally oriented organizations) and *Volker Karl* (formerly KfW Development Bank) set out the range of challenges for the use of German wastewater technology and design approaches abroad. These were illustrated by Prof. *Holger Scheer* of Emscher Wassertechnik GmbH who co-ordinated and led the EXPOVAL project, based on the example of discharge requirements and monitoring regulations in the international market which differ from those in Germany. He pointed out that the monitoring practice with daily composite samples, which is not common outside Germany, has a major impact on dimensioning.

Accounts of experiences from export companies were provided for lively discussion. Dr. *Uwe Moshage,* representative of an international consulting firm (Dahlem Beratende Ingenieure GmbH & Co. Wasserwirtschaft KG), *Christian Schulmerich*, plant engineer, (Passavant Energy & Environment GmbH) and Dr. *Ralf Schröder,* managing director of a planning and operating company (WTE Wassertechnik GmbH), described the challenges of insufficient basic data and emphasised the need for internationally applicable, more competitive dimensioning approaches. The advantages of the new dimensioning approaches will be ultimately evident in better adapted designs.

The contribution of research projects such as the EXPOVAL project for the export of wastewater management knowledge and technology was presented by Dr. Ing. *Gerd Sagawe* (EnviroChemie GmbH and board member of German Water Partnership) with further project examples.

The speakers as well as the participants expressed the wish for a better availability of the new dimensioning approaches in the new DWA Topic T4/2016 and favoured its translation at least into English, without which international acceptance would not be achievable.

Modification of DWA dimensioning rules

The DWA dimensioning rules used for wastewater plants so far are aimed at the conditions prevailing in Germany. Application in different climates, for example, is possible only with appropriate adjustment. Correspondingly modified dimensioning approaches were presented for municipal wastewater treatment methods such as activated sludge systems, trickling filter, anaerobic and wastewater ponds.

Besides extending to, in particular, lower and higher wastewater temperatures (5–30 °C), the dimensioning approaches presented were throughout adapted to the internationally widespread monitoring practice using daily average values. For carbon decomposition, COD is used as a design parameter throughout. In addition, it was investigated and shown that, with appropriate adaptation of the biomass, permanently increased salt contents of up to 10 g/l have no negative influence on the rating of the C and N treatment performance.

New approaches to wastewater treatment

The extended and new design approaches were briefly explained by the project participants. The start was the activated sludge process, for which Prof. *Marc Wichern* (Ruhr-University Bochum) presented the recommendations in addition to the dimensioning rules described in the standard DWA-A 131. This relates, for example, to the aerobic sludge age which is adjusted based on temperature and which has a major influence on the dimensioning of the basin but also on the adjustment of the process factor to the monitoring practice. In addition, Prof. *Martin Wagner* (Technical University of Darmstadt) spoke about the required pressure or surface aeration systems, the consideration of increased temperatures and salinity and altitude in dimensioning among others according to DWA-M 229-1.

As the DWA standards for the increasingly less-used trickling filter and wastewater pond methods in Germany did not yet provide adaptions to wastewater temperature changes, new empirical dimensioning algorithms were developed for this purpose: Dr. *Christian-D. Henrich* (Enexio Water Technologies GmbH) presented the algorithms for carbon decomposing and nitrifying trickling filters based on modified approaches according to Velz respectively Gujer and Boller. *Sebastian Weil* (IEEM gGmbH – Institute of Environmental Engineering and Management at the University of Witten/Herdecke) explained the dimensioning algorithms for anaerobic and non-aerated ponds, further developed on the basis of internationally accepted approaches by Mara, as well as specifications for aerated ponds. Prof. *Uwe Neis* (Ultrawaves Wasser- und Umwelttechnologien GmbH) presented large scale studies into the use of pond-like systems with symbiotic algae-bacterial biomass, which were carried out for the first time in the course of the EXPOVAL project.

Anaerobic reactors are not used in Central Europe because of too low wastewater temperatures in the municipal applications. They can be practical in hot climates however, assuming the climate-friendly collection of the biogas produced. The corresponding dimensioning was presented by Prof. *Karl-Heinz Rosenwinkel* (Leibniz University of Hannover) and *Klaus Nelting* (DiMeR GmbH) using the example of UASB reactors.

In the field of wastewater disinfection, which has become increasingly important on an international scale, the elimination of helminth eggs had so far lacked both uniform analysis methods and reliable dimensioning principles for micro-screening. As presented by Prof. *Peter Cornel* (Technical University of Darmstadt), this gap was closed as a result of the EXPOVAL research.

New approaches for sludge treatment

Prof. *Norbert Dichtl* (Technical University of Braunschweig) presented add-ons for anaerobic sludge treatment under special climatic conditions: The design temperature range for digesters according to DWA-M 368 has been expanded to include the low-mesophilic interval of 20–34 °C. It has also been verified that, under certain conditions, digesters can be economically dimensioned at average daily air temperatures from 20 °C without thermal insulation.

A new, manufacturer-independent dimensioning method was presented for solar sludge drying based on a modification of Wendling's modified hydrometeorological model according to Penman. Operating recommendations were also offered which make solar drying of sewage sludge conceivable even in moderate climates.

At the end, Prof. *Norbert Dichtl* presented the results of a conveyor screw for thermal sewage sludge disinfection developed in collaboration with Huber SE.

New DWA Topic T4/2016

All of the above dimensioning approaches have been included in an application-orientated form into the new DWA Topic T4/2016 "Design of wastewater treatment plants in hot and cold climates". This was presented by Prof. *Holger Scheer* and Dr. *Tim Fuhrmann* . The report complements the DWA Set of Rules with globally applicable dimensioning approaches for activated sludge, trickling filter and wastewater pond systems, UASB reactors, systems for anaerobic sludge stabilization and solar sewage sludge drying as well as for aeration systems and the elimination of helminth eggs. The dimensioning approaches are supplemented in each case by practical calculation examples. An English translation will be published in May 2018.

www.expoval.de/en/dwa-topic

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Guidelines for the Dimensioning of Activated Sludge Plants Outside Germany Based on Standard DWA-A 131

Marc Wichern, Daniel Herzer, Manfred Lübken (Bochum/Germany), Peter Wulf, Holger Scheer (Essen/Germany), Karl-Heinz Rosenwinkel and Maike Beier (Hannover/Germany)

Summary

In the context of the project "Transfer-orientated research and development in the wastewater sector, validation of dimensioning and operating guidelines for activated sludge plants – EXPOVAL", sponsored by the German Federal Ministry of Education and Research (BMBF), complementary guidelines for the dimensioning of activated sludge plants in other climatic zones have been developed in accordance with the internationally well-known DWA Standard DWA-A 131 (2016). Relevant data was used from large scale wastewater treatment plants, laboratory tests and mathematical simulations. Excerpts thereof are presented here with special emphasis on the dimensioning of the aerobic sludge age and the required process factor value. Recommendations are given on how to proceed in when the design is not based on qualified random sampling but average values. References are also given on the dimensioning of simultaneous aerobic sludge stabilization, the expected surplus sludge production and on denitrification. The results of the joint EXPOVAL project, which has focused on activated sludge plants as well as on many other methods of wastewater and sludge treatment, have been published in DWA Topic T4/2016 [2], which is released as English version in 2018.

Key words: wastewater treatment, municipal, activated sludge plant, design, DWA-A 131, international, climatic zone, hot, cold, sludge treatment, excess sludge, biological nitrogen removal

1 Introduction

Municipal activated sludge plants in Germany are usually designed in accordance with DWA Standard DWA-A 131 [1]. This worksheet also receives high acceptance abroad. This steady state dimensioning approach for activated sludge plants also facilitates dimensioning of the aeration tank volume and of the secondary clarifier. In addition, many detailed operation-relevant values can be calculated, including the surplus sludge production and oxygen demand. It is recommended that the dimensioning approach is applied at temperatures found in moderate climatic zones (8–20 °C). With the following recommendations, an expanded temperature range of 5–30 °C is covered [2].

The underlying safety concept of DWA-A 131 [1] is based on monitoring the discharge concentrations using qualified random samples, this being typical for Germany. Outside Germany however the requirement is often only to meet average values (dayly, monthly) respectively an annual maximum load or an annual elimination value is defined. If DWA-A 131 [1] is used for the dimensioning of activated sludge plants outside Germany, its application involves the question of how to deal with other process requirements abroad, or to what extent, for example, design volumes can be reduced if dimension is based on daily average values.

Fig. 1: Secondary Clarifier of the wastewater treatment plant of Fujairah, United Arab Emirates (UAE) (Photo: EW)

2 Dimensioning guidelines

To make it easier to apply the following design references to high and low temperatures, all recommendations are based on the newly published DWA-A 131 [1]. The underlying calculation process (Figure 2) has not changed from DWA-A 131. The following dimensioning recommendations refer primarily to the modification of individual parameters or equations.

2.1 Input data

As per the new DWA-A 131, the chemical oxygen demand replaces the biochemical oxygen demand. When planning for other climatic zones, particular attention must be paid to the inflow characteristic and input data of the plant. These can vary both in terms of dynamics and with respect to the prevailing substances (concentrations, ratios, etc.) from catchment area to catchment area and thus from plant to plant. As countries in other climatic zones often have very different dietary habits

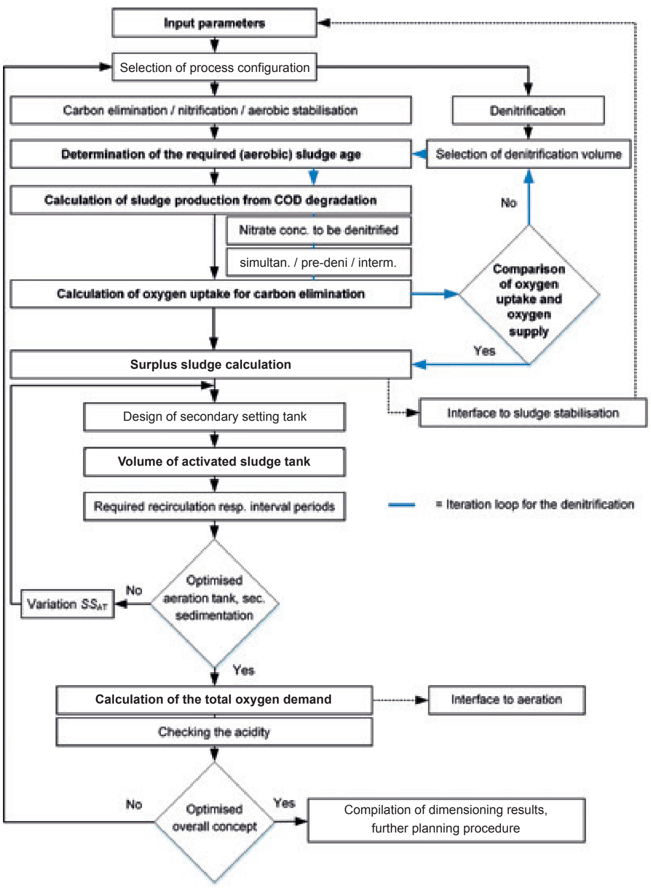

Fig. 2: Design process for an activated sludge plant (according to DWA-A 131 [1])

compared to Central Europe or North America, it is extremely important to conduct investigations of local wastewater composition.

2.2 Dimensioning criterion – aerobic minimum sludge age

Scientific investigations have shown that apart from *Nitrosomonas* and *Nitrobacter,* nitrification also involves other groups of organisms such as *Nitrospira*. DWA-A 131 applies typical nitrification kinetics which identify *Nitrosomonas* as a key nitrification organism in the temperature range between 8 and 20 °C. We recommend applying the same specification for the temperature ranges of 5–8 °C and 20–30 °C.

Wastewater temperature T_W [°C]	Recommended sludge age $t_{SS,design}$ [d]
< 10	4
10 to 20	3
> 20*)	(2) 3 including anoxic volumes or phases

*) At temperatures above 20 °C, plant design including nitrification and at least partial denitrification is recommended.

Table 1: Design sludge age for plants with carbon elimination (without nitrification)

$S_{NH4, EST, dM}$	f_N					
	1.4	**1.6**	**1.8**	**2.0**	**2.2**	**2.4**
1.0 mg/l	1.5	1.6	1.8	2.0	2.2	2.4
2.0 mg/l	1.2	1.2	1.2	1.3	1.4	1.6
2.5 mg/l	1.2	1.2	1.2	1.2	1.3	1.5

Table 2: Process factor PF depending on the KN inflow fluctuations f_N and the secondary clarifier effluent concentration $S_{NH4, EST, dM}$ (5–30 °C)

$S_{NH4,EST,dM}$	Design temperature T [°C]					
	5	**10**	**15**	**20**	**25**	**30**
1.0 mg/l	21.8	13.3	8.2	5.0	3.1	2.0
2.0 mg/l	14.5	8.9	5.4	3.1	2.0	2.0
2.5 mg/l	13.6	8.3	5.1	3.1	2.0	2.0

Table 3: Aerobic sludge age [d] for plant sizes of up to 20,000 I depending on the temperature and the ammonium nitrogen concentrations in the secondary clarifier effluent

$S_{NH4,EST,dM}$	Design temperature T [°C]					
	5	**10**	**15**	**20**	**25**	**30**
1.0 mg/l	13.6	8.3	5.1	3.1	2.0	2.0
2.0 mg/l	10.9	6.7	4.1	2.5	2.0	2.0
2.5 mg/l	10.9	6.7	4.1	2.5	2.0	2.0

Table 4: Aerobic sludge age [d] for plant sizes of up to 100,000 I depending on the temperature and the ammonium nitrogen concentrations in the secondary clarifier effluent

$$t_{SS,aerob,design} = PF \cdot 1{,}6 \cdot \frac{1}{\mu_{A,max}} \cdot 1.103^{(15-T)} =$$

$$PF \cdot 1.6 \cdot \frac{1}{0.47} \cdot 1.103^{(15-T)} \quad [d] \; (1)$$

Although nitrite oxidizing bacteria can limit nitrification performance at higher temperatures, the effect of correspondingly altered kinetics on the aerobic sludge age in the 27–30 °C range is minimal. For the sake of a simplified, practical design no explicit equation is introduced for the nitrite-oxidizing bacterial group.

Plants targeting carbon elimination (without targeted nitrification)

According to DWA-A 131 (2016), activated sludge plants targeting exclusively carbon elimination should be dimensioned for a sludge age of 4 d ($B_{d,COD,InAT}$ > 12,000 kg/d) to 5 d ($B_{d,COD,InAT}$ < 2,400 kg/d). In the case of permanently high wastewater temperatures, it is recommended to reduce the design sludge age for the sole purpose of carbon elimination according to Table 1. It is not necessary to differentiate for different plant sizes when monitoring daily average values of discharge concentrations.

It is to be expected that plants will also nitrify at temperatures above 20 °C and at an aerobic sludge age of 2 d. Therefore, it is necessary to take this un-targeted nitrification into consideration when dimensioning the aeration system and operating the clarifier. For this reason, an additional anoxic basin or non-aerated denitrification phases should be included in the design. Thus, the oxygen consumption can be reduced and acid capacity improved in case nitrification occurs. At temperatures above 20 °C therefore, a system design including nitrification and denitrification is recommended.

From around 27 °C, the actual growth rate (and hence the turnover rate) of the ammonium oxidizing bacteria may exceed that of the nitrite oxidizing bacteria. In municipal activated sludge plants with relatively low loads, fully mixed tanks and with a limited minimum aerobic sludge age, however, the effects are negligible up to 30 °C. However, it can have a significant effect in the design of Sequencing Batch Reactor (SBR) plants or high-load plants, especially at high wastewater temperatures (> 27 °C). If necessary, it should be taken into account and verified separately.

Plants targeting nitrification

The prevailing monitoring practice in Germany is based on a qualified random sample (2 h composite sample). This strict practice is special by international standards, as in other countries mainly 24-hour composite samples or annual loads are used. One of the consequences of this is that safety factors included in the dimensioning with A131 may be reduced.

DWA-A 131 (2016) includes a "Process Factor" (PF) which, amongst other things, takes into account the fluctuations of Kjeldahl nitrogen (KN) inflow load via the peak factor f_N. Normally f_N decreases as the size of the catchment area increases. For the 5-30 °C temperature range, the process factor was calculated by dynamic simulation. The values given in Table 2 can be used for calculation irrespective of temperature. Intermediate values may be interpolated.

If there is no information on fluctuations of the KN inflow load in case of new designs outside Germany, Tables 3 and 4 can be used for the sake of simplicity. The aerobic sludge age should not be less than two days or must be verified separately, for example, by experiment or dynamic simulation.

Plants with simultaneous aerobic sludge stabilization

Based on investigations in the research project it is suggested that the design sludge age for simultaneous aerobic sludge digestion with nitrification and denitrification should be determined as per DWA-A 131 (2016) for the extended temperature range:

$$t_{SS,design} \geq 25 \cdot 1.072^{(12-T)} \qquad [d] \ (2)$$

For simultaneous aerobic sludge digestion with nitrification applies analogical:

$$t_{SS,design} \geq 20 \cdot 1.072^{(12-T)} \qquad [d] \ (3)$$

In addition, a criterion is presented below defining when sludge is sufficiently stabilized. The degree of stabilization is determined based on how much of the heterotrophic gross biomass produced in the process being oxidized aerobically/anoxically in the same period of time. The following equation applies:

$$f_B \cdot Y \cdot C_{COD,degr} = Y \cdot C_{COD,degr} \cdot \left((1 - f_i) \cdot b_{H,T} \cdot \frac{t_{TS}}{(1 + b_{H,T} \cdot t_{TS})} \right) \qquad [mg/l] \ (4)$$

Resolved according to the sludge age and taking into account the temperature-dependent decay coefficient for the heterotrophic biomass $b_{H,T} = b_{H,15°C} \cdot 1.072^{(T-15)}$:

$$t_{SS} = \frac{f_B}{b_{H,15°C} \cdot 1.072^{(T-15)} (1 - f_B - f_i)} \qquad [d] \ (5)$$

With a decay coefficient of $b_H = 0.17\ d^{-1}$ at 15 °C, an inert fraction of $f_i = 20$ % and $f_B = 62$ %, a stabilization period of 25 d results for T = 12 °C, which corresponds to the value according to DWA-A 131 (2016) for simultaneous aerobic sludge stabilization with nitrification and denitrification. The percentage of 62 % for f_B means that 62 % of the active gross heterotrophic biomass produced is oxidized simultaneously during the same period.

The values of the design sludge age required for simultaneous aerobic stabilization are given depending on process (nitrification with/without denitrification) in Figure 3 and are in accordance with the recommendations of DWA-M 368 [3].

A long stabilization time is required at low temperatures. At a required design sludge age of more than 30 d plants with si-

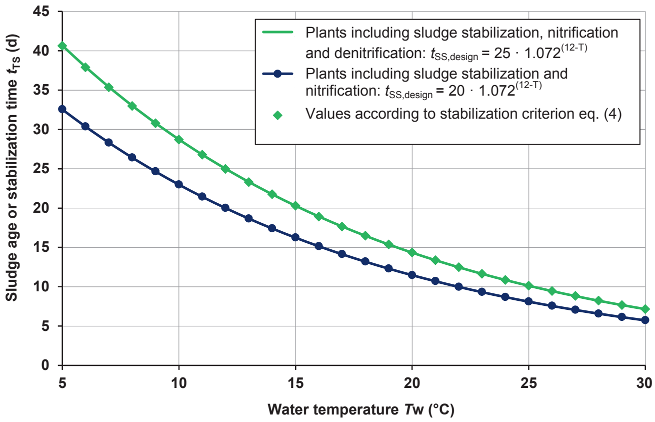

Fig. 3: Required design sludge age based on wastewater temperature for simultaneous aerobic sludge stabilization

multaneous aerobic sludge stabilization must be assessed for economic efficiency. Separate stabilization processes might be more economical: i.e. separate aerobic stabilization with thickening, composting after dewatering or the addition of lime. Separate anaerobic sludge stabilization is worthwhile in larger plants.

2.3 Denitrification

The non-aerated activated sludge tank volume required for denitrification is calculated with DWA-A 131 by comparing the oxygen equivalents from the nitrogen load to be denitrified versus the proportional chemical oxygen demand available in the denitrification tank. Accordingly, in the case of pre-denitrification, the COD in the plant inflow and the hydrolysis of the non readily biodegradable COD plays a decisive role for the question of how much nitrate can be eliminated.

In other climatic zones, a different composition of the wastewater as well as in many cases a greater degree of pre-degradation in the sewer system and different process rates can be found.

Different process rates due to temperature can be taken into consideration for pre-denitrification by adjusting the exponent α_{DB} (Equation 6).

$$OU_{C,D,pre} = 0.75 \cdot \left(OU_{C,la,pre} + \left(OU_C - OU_{C,la,pre} \right) \cdot \left(\frac{V_{D,pre}}{V_{AT}} \right)^{\alpha DB} \right) \quad [mg/l] \qquad (6)$$

Table 5 displays the relationship between α_{DB} and the temperature in the activated sludge tank and allows equation 3 to be applied for temperature ranges outside DWA-A 131 (2016).

There are no changes for intermittent and simultaneous denitrification processes.

2.4 Surplus sludge production

The required volume of the activated sludge tank is determined from the calculated surplus sludge production together with

Type of process	T [°C]			
	5–8	8–20*)	20–25	25–30
Plants with primary settling tank	0.64	0.68	0.75	0.76

*) Temperature range 8–20 °C according to DWA-A 131 [1]

Table 5: α_{DB} depending on temperature in the activated sludge tank

Glossary of abbreviations

Abbreviation	Unit	Description
α_{DB}	–	Exponent considering the proportional oxygen consumption with pre-denitrification
$B_{d,COD,InAT}$	kg/d	Daily total COD load at the inflow of the aeration tank
$b_{H,T}$	d^{-1}	Temperature-dependent decay rate of the heterotrophic biomass
$C_{COD,deg}$	mg/l	Concentration of biodegradable COD in the homogenized sample
f_B	–	Proportion of biomass being oxidized aerobically/anoxically per gross active heterotrophic biomass produced
f_i	–	Inert proportion of the decayed biomass
f_N	–	Peak factor of the nitrogen load
I		Inhabitants
KN		Total Kjehldahl nitrogen (KN = org. N + NH_4-N)
OU_C	mg/l	Oxygen uptake for carbon elimination in relation to the wastewater inflow
$OU_{C,D,pre}$	mg/l	Oxygen uptake equivalent for carbon removal at the pre-denitrification
$OU_{C,ed,pre}$	mg/l	Oxygen uptake from easily degradable COD and externally added carbon with pre-denitrification
PF	–	Process factor for nitrification
$S_{NH4,EST,dM}$	mg/l	Concentration of ammonium nitrogen in the effluent of secondary sedimentation tank as daily mean
$t_{SS,aeob}$	d	Aerobic design sludge age
$t_{SS,design}$	d	Total sludge age upon which dimensioning is based
T_W	°C	Wastewater temperature
V_{AT}	m^3	Volume of the total activated sludge tank from nitrification and denitrification
V_D	m^3	Volume of the tank used for denitrification
$V_{D,pre}$	m^3	Volume used for pre-denitrification
V_N	m^3	Volume of tank used for nitrification
X_{BM}	mg/l	Concentration of biomass
$X_{inert,InAT}$	mg/l	Concentration of the inert particulate COD at the inflow of the activated sludge tank
$X_{P,BioP}$	mg/l	Concentration of phosphorus incorporated into the biomass
Y	g/g	Yield factor (gram of produced biomass (COD) per gram of biodegradable COD)
$\mu_{A,max}$	d^{-1}	Maximum gross growth rate of autotrophic organisms biomass at 15 °C

the total suspended solids resulting from secondary clarifier dimensioning. In addition, the amount and composition of the primary and secondary sludges determine the further design of the sludge treatment section.

The research project compared the surplus sludge production measured at large-scale plants abroad with calculated sludge production. The data from the large-scale plants showed that in reality the surplus sludge quantities at 30 °C are often greater than those resulting from steady-state plant design. Among others, this is due to the difference in wastewater composition compared to German wastewater. It is therefore strongly recommended to measure at least the mineral dry matter and the inert particulate COD in the inflow of the activated sludge tank or wastewater treatment plant. If measurements are not possible, it is to be expected that at temperatures above 25 °C, the proportion of mineral dry matter in the total dry matter of the inflow of the wastewater treatment plant is between 30 % (pre-treated wastewater) and 40 % (raw sewage). The proportion of inert particulate COD ($X_{COD,\ inert}$) to the total particulate COD (X_{COD}) can be assumed to be between 30 and 40 % in the activated sludge tank inflow.

2.5 Composition of sludge masses – phosphorus balance

As design according to DWA-A 131 (2016) and the recommendations presented here cover a temperature range of 5–30 °C, it seems reasonable to link phosphor incorporation, similar to the nitrogen incorporation, to the sludge age. According to findings, which for example have been used in the EAWAG BioP module [4, 5], phosphorus incorporation can be assumed as follows:

$$X_{P,BioP} = 0.014 \cdot X_{BM} + 0.005 \cdot X_{inert,InAT+BM} \quad [mg/l] \qquad (7)$$

2.6 Oxygen demand

It is recommended to calculate the oxygen demand required for the microbial conversion of organic compounds according to DWA-A 131 [1]. Further information on dimensioning of aeration systems can be found in DWA Topic T4/2016 [2] in chapter 7 "Aeration systems".

2.7 Planning and operational guidelines

High wastewater temperatures result in lower required sludge ages and thus in reduced activated sludge tank volumes. As a result of shorter hydraulic retention times, peak loads in the inflow result more quickly to corresponding peak concentrations in the effluent. If peak concentrations are relevant for monitoring, this should be taken into account in the design process. Dynamic simulation [6, 7] can also be used for the design.

Furthermore, the solubility of oxygen decreases at high wastewater temperatures. A higher air supply is required due to the oxygen consumption for carbon degradation and nitrification. At the same time, high wastewater temperatures lead to lower sludge ages and thus to low activated sludge tank volumes. In the case of pressure aeration the base area of the aeration tank may not be large enough to allow the installation of the necessary number of aeration elements. Then a tank layout with a larger base area but a lower depth has to be taken into account. For international applications, especially in developing, emerging and transition countries, the use of surface ventilation systems should be considered as an alternative to pressure aeration, depending on local conditions. Advantages of the latter include operational safety and longer service life. The main disadvantage may be less efficiency, depending on the application.

High temperatures in wastewater systems can cause possible odors as a result of the decomposition processes. Pumping stations, mechanical treatment stages and sludge storage tanks should considered to be covered or include air collection and treatment.

In very hot climates, appropriate operating temperature ranges must be ensured by ventilation and air conditioning of the mechanical aggregates and electrics. In very cold temperatures, the design of the plant must guarantee adequate protection against frost (including enclosures, frost monitors in buildings and shafts with dry pumps, auxiliary heating of intermittently used pipes, heating of the scraper ways).

Aeration dimensioning for different temperature load cases is required if there is substantial fluctuation of the wastewater temperature throughout the year. This results in correspondingly different required biomass volumes. In the interests of energy efficiency and conservation of resources, with major fluctuations, it is not recommended to maintain the biomass volume for the worst-case low-temperature load all year round. Endogenous respiration and the energy required to mix the biomass would result in an inefficient system and increased energy consumption. In the case of substantial temperature fluctuations in larger plants it is recommended at the planning stage to consider a multi-line design or subdivision of the activated sludge tank volume with decommissioning of individual lines or partial volumes at high temperatures. In medium and large plants, two or more lines are generally recommended, not least from the perspective of operational reliability. Sufficient oxygen input must be ensured in all cases via the aeration installation of the operated tanks. As an alternative to take tank volumes out of order, the solids content can be reduced to adjust the required biomass.

3 Prospects

The design recommendations supplementary to DWA-A 131 given above and other calculation approaches of the EXPOVAL project are summarized in DWA Topic T4/2016 [2], which is available in English since 2018.

Acknowledgement

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29th Performance Comparison of Municipal Wastewater Treatment Plants in Germany

DWA Working Group BIZ-1.1 “Wastewater Treatment Plant Neighbourhoods”

Summary

A representative picture of the wastewater treatment plants in Germany is shown by the countrywide DWA performance comparison of municipal wastewater treatment plants. Overall, in the 2016 reporting year, the requirements of the EU Urban Wastewater Directive were met or significantly exceeded in the countrywide average. While there are no large differences in the various capacity classes for the COD and Tot N degree of degradation, the wastewater treatment plants with a design capacity of less than 10,000 I clearly performed less well with phosphorus removal. In the federal state of Baden-Württemberg, with predominantly wastewater discharge using combined water flows, it is apparent that in practice most of the wastewater treatment plants were supplied with combined wastewater inflows which, in part, lay far above the recommendations of the DWA. In the coming years a general further need for action in wastewater treatment plants could be triggered, through legal requirements, for the construction of a fourth treatment stage for the removal of micro-pollutants from the wastewater.

Key words: wastewater treatment, municipal, German, wastewater treatment plant, performance comparison, combined system

1 Aims, principles and limits of the federal performance comparison

The DWA performance comparison presents the quality of wastewater treatment and the electricity consumption used for

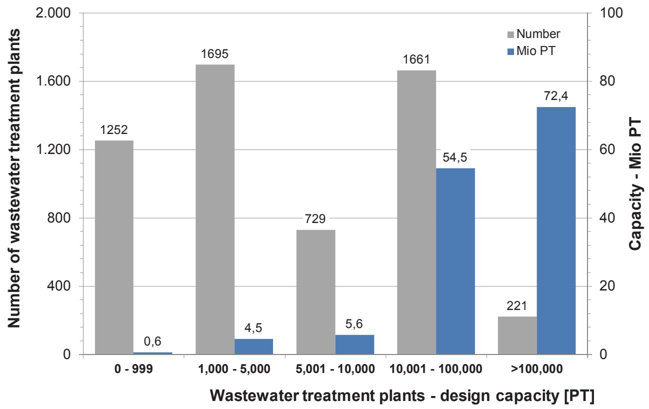

Fig. 1: Wastewater treatment plants involved in the 2016 DWA performance comparison

the purpose. The performance comparison reflects the qualified work of operating personnel, who should be appropriately acknowledged here. The benchmarking data was collected and evaluated by the DWA state associations and the Austrian Water and Waste Management Association (ÖWAV) in the context of the joint DWA working group BIZ-1.1 “Wastewater Treatment Plant Neighbourhoods”.

According to the Federal Statistical Office, the proportion of the population connected to municipal wastewater treatment plants was 95.3 %. Of the total of 9307 municipal wastewater treatment plants in Germany with a design capacity of 151.8 million residents, 5558 wastewater treatment plants with a design capacity of 137.6 million residents participated in the 29th DWA performance comparison. With a participation rate of

DWA Federal State Association	Baden-Wuerttemberg	Bavaria	Hesse/Rhineland Palatinate/Saarland	North	North East	North Rhine-Westphalia	Saxony/Thuringia	DWA	ÖWAV
wastewater treatment plants [number]	917	1451	1387	524	277	502	500	5558	850
annual sewage amount [millions of m^3]	1678	1475	1486	848	486	2301	454	8728	1123
installed volume [million residents]	21.6	23.7	18.0	21.8	13.1	31.6	7.8	137.6	22.0
mean p. e. loading [million residents]	16.8	18.0	15.4	16.7	11.6	22.2	5.9	106.7	15.2
installed p. e./mean p. e. loading	1.29	1.32	1.16	1.30	1.13	1.42	1.31	1.29	1.45
specific resultant wastewater [m^3/(p. e. × a)]	100	82	96	51	42	104	76	82	74
specific energy consumption [kWh/(p . e. × a)]	31.6	30.1	31.8	31.3	29.8	34.5	36.9	31.9	27.9
COD inflow [mg/L] discharge [mg/L] elimination [%]	 438 19 95.6	 537 26 95.1	 453 22 95.1	 867 38 95.6	 983 45 95.4	 425 25 94.2	 575 27 95.3	 547 27 95.1	 594 28 95.2
Total nitrogen*) inflow [mg/L] discharge [mg/L] elimination [%]	 41.2 9.1 77.9	 49.9 9.5 81.0	 44.5 8.2 81.7	72.2 8.8 87.8 	 84.7 11.6 86.3	 40.5 7.2 82.2	 56.4 9.4 83.3	 50.3 8.7 82.7	 47.2 8.7 81.5
P_{tot} inflow [mg/L] discharge [mg/L] elimination [%]	 6.1 0.48 92.1	 6.5 0.84 8.0	 6.5 0.84 87.0	 11.3 0.56 95.0	 12.4 0.66 94.7	 5.9 0.41 93.1	 8.4 0.87 89.6	 7.5 0.62 91.7	 6.7 0.63 90.6
NH_4-N discharge [mg/L]	 0.65	 1.38	 1.55	 1.14	 1.17	 1.04	 1.11	 1.13	 1.29
NO_3-N discharge [mg/L]	 7.2	 6.4	 5.0	 6.0	 8.4	 4.9	 6.8	 6.1	 5.9
N_{inorg} discharge [mg/L]	 7.8	 7.8	 6.6	 7.1	 9.6	 5.9	 7.9	 7.2	 7.2

*) Total Nitrogen = $N_{inorganic} + N_{organic}$

Table 1: Mean feed and discharge values, degrees of elimination and other parameters

90.6 %, the results for 2016 can be considered representative for Germany. The more than 3.6 million spot measurements taken by operating personnel in the context of self-monitoring, and which are incorporated in the evaluation as mean annual values, provide the foundation.

As in the past, the evaluation is grouped by DWA federal state associations and size range (SR) of the wastewater treatment plants. The distribution of wastewater treatment plants with respect to installed size and number is shown in Figure 1. While only 4 % of the wastewater treatment plants have a design capacity greater than 100,000 p. e. (SR 5), these plants represent 53 % of the total design capacity.

2 Results

The results of the inflow and discharge measurements (load-weighted average values), the eliminations, further characteristics and information about participants are compiled in Table 1. As in the previous year, the results of the Austrian Water and Waste Management Association (ÖWAV) performance comparison of wastewater treatment plants for the installations in Austria and South Tyrol are also shown.

Compared to the previous year, there are only minor changes to the inflow and discharge concentrations in the national average. The degree of decomposition is fairly constantly high.

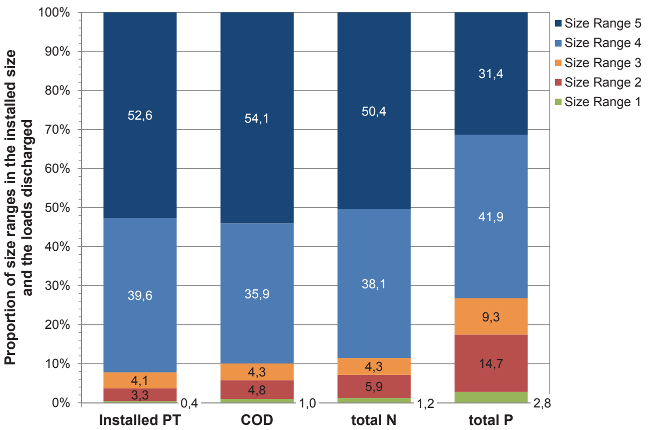

Fig. 2: Percentages of sizes and load discharged by treatment plant size classes

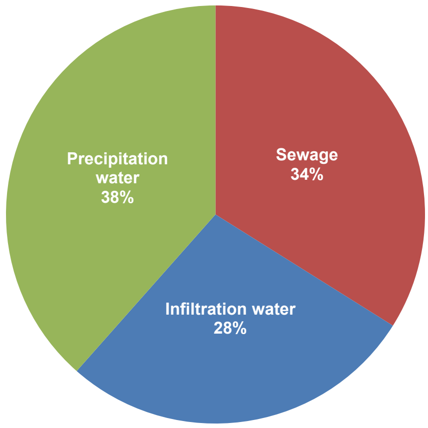

Fig. 3: Composition of the inflow treated in the wastewater treatment plants (915 wastewater treatment plants in the Baden-Wuerttemberg Federal State Association)

It is worth noticing the higher rate of N and P elimination in the North and North-East federal state associations compared to the results of the other state associations. This is due to the significantly higher concentrations in the inflow. The separate systems, which are more widespread in these federal states, may be amongst the reasons for this.

On the whole, as a federal average, it was possible to meet or significantly exceed the requirements of the EU Urban Waste Water Treatment Directive, again in 2016. It is still nevertheless necessary for some installations (sewer network and wastewater treatment plants) to be brought up to the present state of the art.

The reference value used to determine the specific wastewater input and the specific electricity consumption was the average plant load in relation to number of residents from the average COD inflow load. A specific COD load of 120 g/(p. e. × d) was assumed here.

The specific resultant wastewater is 82 m^3/(p. e. × a) in the national average. In the North and North East federal state associations, the specific resultant wastewater was significantly lower due to the widespread separate system. In the other federal state associations, dewatering takes place primarily in the combined system and so wastewater treatment plants are subjected to significantly higher specific resultant wastewater.

Also, the respective electricity consumption was gathered in all federal state associations. The specific electricity consumption (kWh/(p. e.) was calculated for 5033 wastewater treatment plants. There are only slight variations in the specific electricity consumptions between the federal state associations. The lowest values are found in Austria/South Tyrol and in the North-East federal state association. The highest values can be found in the North Rhine-Westphalia and Saxony/Thuringia federal state associations.

The COD and total nitrogen loads introduced into the bodies of water correspond largely to the respective proportions of the installed sizes, grouped into size ranges (Figure 2). Plants in size ranges 1 to 3, however, have an above-proportional share of phosphorus at about 27 %, although, taking their installed size into account, these plants only represent a proportion of 8 %. The reason for the high share in plants of size ranges 1 to 3 is that, due to an absence of statutory requirements, some of these do not have to carry out any specific measures for phosphorus elimination. Particularly in water bodies with low regimen wastewater treatment plant discharges loaded with phosphor can lead to a higher phosphorus concentration in the water than is acceptable for a healthy ecology.

3 Wastewater flow in combined systems

Due to the rainwater, urban areas dewatering in combined instead of separate systems produce far higher water volumes that must be treated at the treatment plants. This can be seen

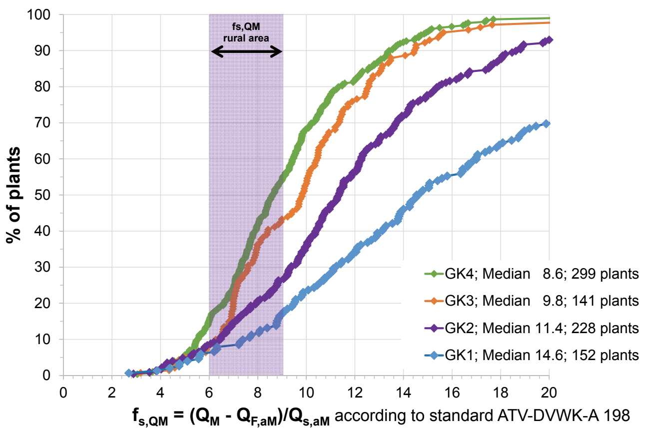

Fig. 4: Sum frequency of the factors for the sewage flow in combined systems in plant sizes 1 to 4 (wastewater treatment plants in the Baden-Wuerttemberg Federal State Association)

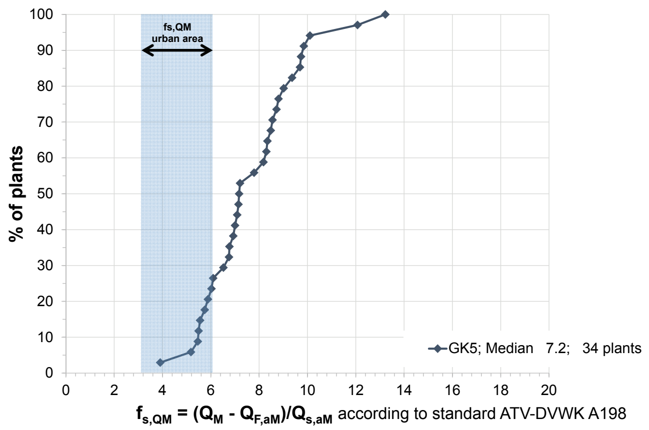

Fig. 5: Sum frequency of the factors for the sewage flow in combined systems in plant sizes 5 (wastewater treatment plants in the Baden-Wuerttemberg Federal State Association)

from the specific resultant wastewater listed in Table 1, which is far lower in the regions where the separate system is more widespread, such as in the North East federal state association.

In Baden-Württemberg, wastewater is mostly drained in combined systems. The proportion of infiltration water calculated using the moving-minimum method [1] provides nationwide approximate information about the inflow of sewage, infiltration water and precipitation water also treated in the wastewater treatment plants. Figure 3 shows the composition of the wastewater treated at the treatment plants in 2016. The relatively high proportion precipitation water at 38 % is surprising. Depending on the weather and the location of the catchment area, approx. 100 days per year are affected by mixed water inflows (precipitation events and subsequent rainwater run-off) in average conditions.

The sewer system and wastewater treatment plant are linked in terms of dimensioning by the maximum flow to the treatment plant Q_M (m³/h), which is stated in the water permit. $Q_M = f_{Sp,S} \times Q_{S,aM} + Q_{F,pM}$ are defined in ATV-DVWK-A 198 [2], wherein $Q_{S,aM}$ is the average annual domestic and industrial wastewater flow (wastewater on which a fee is charged) and $Q_{F,pM}$ is the average value of the infiltration water flow over a specified period and/or the annual average value. The bandwidth of the factor $f_{Sp,S}$ is stated in ATV-DVWK-A 198 depending on design capacity. For wastewater treatment plants for more than 100,000 residents (urban area) it is between 3 to 6 and for plants below 100,000 residents (rural area) it is between 6 to 9.

From the cumulative frequency curves of the different size classes, it can be seen that in practice the factor increases in wastewater treatment plants with smaller connected loads and in many cases exceeds the range specified in the German DWA standards. For example, the factor is greater than 11 in 20 % of the size 4 wastewater treatment plants and greater than 12 in size category 3. Only in a few cases is the factor less than 6 (Figure 4). 75 % of plants for over 100,000 residents exceed the recommended maximum factor of 6 (Figure 5).

Since the infiltration water occurrence is subject to seasonal fluctuations, the factors for the domestic and industrial wastewater flow in the combined system during individual precipitation events may be significantly higher.

With increasing mixed water inflows comes the risk of increasing sludge build-up in the clarifier, possibly associated with sludge floatation and an increase in the emissions related to particulate matter. Furthermore, the impact load at the beginning of a combined water inflow can lead to nitrification overload. Over several hours this can result in increased NH_4-N concentrations in the biology stage and in the plant discharge . This issue is of particular relevance when monitoring on the basis of qualified random samples or 2-hour composite samples. Guidelines for minimizing the effects of increased combined wastewater inflows can be found in the DWA publication "Technical Measures for the Treatment of Increased Combined Wastewater Outflows in Wastewater Treatment Plant" [3]. However, the potential technical and operational influences on the wastewater treatment plants are limited and performance losses with increased combined wastewater inflows cannot always be avoided or kept to a reasonable level. Where this is not acceptable, operators should reduce the throttled flow to the wastewater treatment plant and adjust the combined wastewater treatment in the sewer system accordingly.

4 Summary

It was possible to participate in the Germany-wide DWA performance comparison at a high level in 2016 again. We would like to offer our sincerest thanks to the operating personnel at the municipal wastewater treatment plants. The results provide a representative picture of the cleaning performance of wastewater treatment plants in Germany. 5558 wastewater treatment plants with a design capacity of 137.6 million residents participated in 2016. As in the previous year, the corresponding data of ÖWAV for Austria including South Tyrol was presented for comparison. The results correspond largely to the data for German wastewater treatment plants.

On the whole, as a federal average, it was possible to meet or significantly exceed the requirements of the EU Urban Waste Water Treatment Directive, again in 2016. Whereas there are no great differences between the various size ranges in respect of the COD and the total nitrogen degradation degree, the phosphorus elimination of wastewater treatment plants whose

installed size is less than 10,000 p. e. was significantly inferior. These wastewater treatment plants represent a proportion of about 8 % of the total design capacity, but are responsible for about 27 % of the phosphorus load introduced into the bodies of water. Causes lie with those plants which, due to an absence of statutory requirements, do not have to carry out any specific measures for phosphorus elimination.

In Baden-Württemberg, with wastewater collection primarily in combined system, it can be seen that in practice most wastewater treatment plants are subject to combined wastewater inflows, some of which are far above the recommendations in ATV-DVWK-A 198 [2]. This represents a major challenge for the operators of wastewater treatment plant, since the cleaning performance, for example can be negatively affected by sludge floatation from the clarifier and increasing NH_4-N discharge concentrations. For the purposes of protecting water bodies, the discharge from the combined-water treatment plants and the cleaning performances of the wastewater treatment plants for mixed-water inflows must be considered together. Because of the interdependency, the choked outflows from the stormwater tanks with overflow and the maximum flow of combined wastewater to the wastewater treatment plant must be reconciled.

The aim of wastewater treatment is to achieve the highest possible level of purity with the minimum expenditure of primary energy. It is therefore obvious that the wastewater treatment sector is no exception to the need not to waste energy. By means of an energy check and an energy analysis, it should in future be possible to evaluate the electricity consumption for wastewater treatment correctly, to identify unnecessary excess consumption, and to introduce measures to achieve energy-efficient operation.

A further, general need for action in respect of wastewater treatment plants may be triggered in coming years as a result of statutory requirements for the construction of a fourth purification stage to remove trace substances from the waste water. Extensive research is at present being undertaken in this field.

Acknowledgement

The working group DWA BIZ-1.1 Wastewater Treatment Plant Neighbourhoods, would like to thank all the participants, lecturers and representatives of the Wastewater Treatment Plant Neighbourhoods for their support in the collection and evaluation of the data, without which this Germany-wide performance comparison would not be possible. The 29th performance comparison – based on the data for 2016 – is also available from the DWA website *(www.dwa.de)* free of charge by selecting “Events – Neighbourhoods – Further information” from the menu.

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Head loss in Fine-Screen Systems

Experimental and numerical Analysis of various Fine-Screen Designs

Michael Kuhn (Höpfingen/Germany), Marco Tassone, Gerhard Braun and Klaus Kimmerle (Saarbrücken/Germany)

Summary

Current methods for calculating head loss with fine screens yield data which differ considerably from practical experience. This issue was the motivation for modeling in detail the hydrodynamic properties of an unblocked fine screen. A total of 395 experiments involving varying unblocked fine-screen designs were carried out at the laboratory flume of the University of Applied Sciences in Saarbrücken, Germany. The changes in head loss due to the variation of flow-related parameters such as flow rate, bar spacing, screen installation angle, bar shape and impounding of the downstream water line and framework geometry were measured. Using the OpenFOAM® open-source software program, a numerical simulation was carried out and the results contrasted and compared with the experimentally determined head losses and its potential for facilitating screen design discussed.

Key words: fine screen, head loss, bar spacing, bar shape, installation angle, OpenFOAM®

Introduction

Current methods for calculating head loss with fine screens yield data which differ considerably from practical experience [1]. The purpose of the study was to model the flow dynamics of fine screens which are currently in use in municipal wastewater treatment plants. In addition, the effects of these screens on flow with varying design parameters were to be determined. These are necessary for describing the system and calculating mathematical relationships, and make it possible to describe head losses more precisely. The head loss ($h_1 – h_2$) results from the difference between the water level before the screen h_1 (intake level) and the water level after the screen h_2 (discharge level). On the basis of the relevant research literature [2, 3], characteristic parameters such as bar shape f, bar spacing, bar width, installation angle, flow rate and weir height h_w (i. e., the upper edge of the dam weir) were selected for the investigation of the fine-screen system. In addition, the hydrodynamics of fine screens are decisively influenced by frame geometry. In order to be able to investigate the influence of the frame more exactly, this parameter was included in the trials.

Methodology and Measurement Procedures

An S6 tilting flume laboratory water channel made by the Armsfield company (Figure 1) was used in the experiments. The laboratory flume has a 7.5 m flow channel which is 300 mm wide and 500 mm deep. The water level in the weir h_2 can be varied by altering the angle of a flap located on the outflow (weir height h_E). The position of the fine screen is sufficiently far from the inflow that a stable flow can be established in front of the fine screen. The tilt angle of the laboratory flume can be adjusted using a mechanical adjusting unit.

In addition to optical assessment of the flow by means of photographic methods, two ultrasonic sensors (HLS 528-5-1300, Hydac International) were installed for determining head loss. A magnetic-inductive flow meter (Aquaflux IFC 010 k, Krohne Messtechnik) was used to determine the effective flow rate. Measurement data were recorded automatically using LabVIEW.

The hydrodynamic characteristics of various fine screens were investigated without any screenings or gradient. Our industrial partner Kuhn GmbH constructed the model screens for this purpose. The schematic construction of the fine screens and the shape of the bars used can be seen in Figure 2. To ensure the most constant screen bar spacing (4) possible, a separate base plate (5) and screen comb (3) was built for each bar spacing investigated. It was possible to vary the angle of the screen bars using the comb fixture (2) and the angular bracket (1).

All measurements were recorded at intervals of 0.1 seconds in order to be able to register wave movements in the water. Arithmetic means were subsequently calculated for all individ-

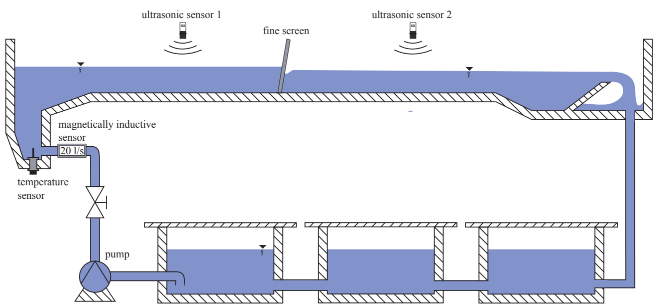

Fig. 1: Schematic presentation of the laboratory flume at the University of Applied Sciences in Saarbrücken, Germany (S6 Tilting Flume)

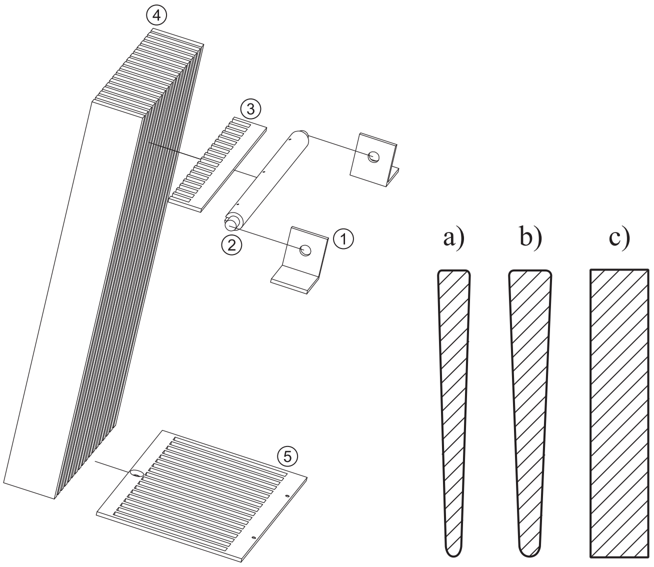

Fig. 2: Explosion view of a fine screen used in the study including flat bars and the bar profile L × W: trapezoidal profile 40 × 6 (a), trapezoidal profile 40 × 8 (b) and flat bar 70 × 10 (c)

ual measurements made in the experiment. Each trial lasted 60 seconds. Thus, the results presented here involve the mean values of approximately 600 individual measurements. At the beginning of recording measurements, flow conditions were always stationary. In this way it was ensured that starting and shutdown processes of the pump and possibly resulting hydraulic jumps did not affect the experiments.

The Experiments

Before each experiment the relevant parameters of bar shape f, bar spacing s, angle of installation α, weir height h_W as well as flow rate $\dot{Q}$ and frame width b_R were selected and adjusted for the respective fine-screen variant. Two trapezoidal sections with a leading-edge width of 6 mm (a) and 8 mm (b) as well as a bar depth of 40 mm each and a rectangular shape with a leading edge of 10 mm (c) and a bar depth of 70 mm were investigated. In addition to the bar sections, two perforated metal plates with perforations of 3 mm and 6 mm and hole pitch of 5 mm and 9 mm were assessed to determine their hydrodynamic properties.

All experiments were carried out in a laboratory flow channel with a fixed width of 300 mm and a constant slope of 0°. The selection made resulted in the experimental schedule summarized in Table 1. The frame width was set at 20 mm and 30 mm. These widths correspond to a flow channel surface proportion of 13.3% and 20%, respectively. Table 1 summarizes the experiments and their parameters.

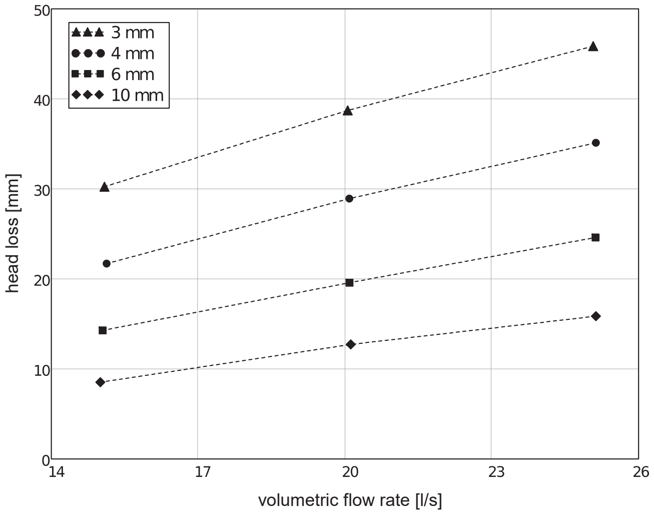

Fig. 3: Depiction of head loss [mm] as a function of flow rate [l/s] and various bar spacing for the bar shape (a), at a constant installation angle of 80° and a constant weir height of 30 mm

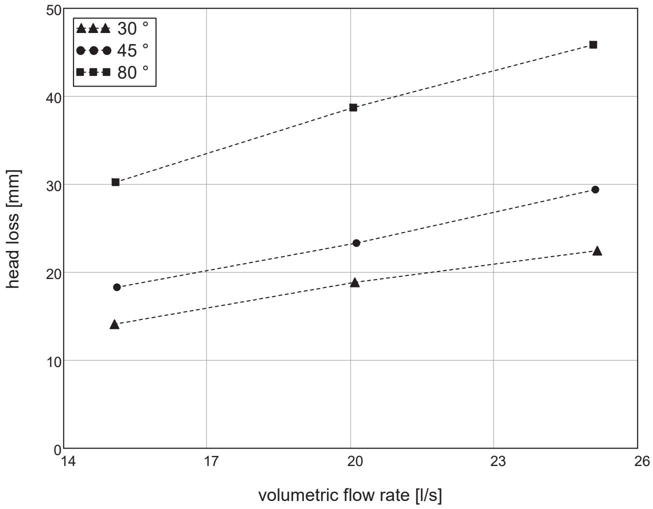

Fig. 4: Depiction of head loss [mm] as a function of flow rate [l/s] and various installation angles for the bar shape (a), at a constant bar spacing of 3 mm and a constant weir height of 30 mm

Simulation

In addition to the experimental investigation of the hydrodynamic characteristics of the fine screens described above, a computer-assisted streaming simulation was carried out using the OpenFOAM open-source software program. The simulations consisted essentially of these steps: geometry creation, spatial discretization, physical description of the flow physics, calculations, visualization and evaluation of the results of the simulation. The objective was to test whether the simulation in the area of screen optimization and reconfiguration could be beneficially employed.

The procedural steps outlined up to and including the description of the flow physics can be summarized as involving the main stage of "pre-processing." Initially, a 3D diagram of the flow area to be investigated was created. The spatial discretization of the geometry was carried out on the basis of the regularly recurring characteristics of fine screens using the blockMesh generation utility, which is part of the OpenFOAM program library. The resulting calculation network consisted of about 3.3 million hexahedral cells. After this, geometrical or numerical boundary conditions were assigned to the boundaries of the geometry. Among other things, the measured flow rate of each particular experiment was specified as the initial constraint. The following criteria were selected, calculated and evaluated for the simulation: The bar shape (c) with a constant bar spacing of 10 mm and a weir height of 0 mm. An installation angle of 90° and a flow rate of 20 l/s were specified.

In order to make it possible to calculate the flow through the fine screen, the existing phases of water and air in the simulation had to be taken into account. The multiphase equation solver interFoam was used. This applies the volume of fluid method to calculating the phase boundary interface. Calculations are carried out on a fixed grid which covers the areas on both sides of the free upper surface, meaning the free upper surface is not defined as the boundary of the area to be solved [4]. The viscosity of the two phases and their sheer stress were calculated from the measured water temperature and entered into the equation solver. The Reynolds-averaged Navier–Stokes equation (RANS) models were used to describe the characteristics of a turbulent flow. Additional physical models for turbulence modeling were added to the continuity and Navier-Stokes equations. Both the standard *k-e* and the *k-w*-SST turbulence models were investigated. The calculations were carried out on 36 processor cores.

After this, visualization of the results of the simulation was carried out. The ParaView open-source software was used for this step.

Results

Several results of the experimental research are shown in Table 2. The results of the numerical flow simulation are also presented after that.

In Figure 3, the head losses of the bar shape (a) are presented as a function of flow rate and bar spacing with a constant

Trials	1	2	3
bar shape [–]	a	a; b; c; d	a; b; c; d
bar spacing [mm]	6	3; 4; 6; 10	3; 10
bore diameter [mm]		3; 6	3; 6
weir height [mm]	70	30; 50	30
installation angle [°]	30; 40; 50; 60; 70; 80; 90	30; 45; 80	30; 45; 80
flow rate [l/s]	15; 17.5; 20; 22.5; 25	15; 20; 25	15; 25
frame [mm]	–	–	20; 30

Table 1: Overview of the experiments carried out with various parameters

installation angle of 80° and a constant weir height h_w of 30 mm. With a reduction of bar spacing from 10 mm to 3 mm, the head loss with a constant flow rate of 15 l/s increases from 8.5 mm to 30.2 mm. This is the equivalent of a 355% increase in head loss. At a flow rate of 25 l/s, there is a 307% increase in head loss. With closely spaced bars, an increase in flow rate has a stronger effect because of the smaller cross-section available for flow and the increased turbulence.

In addition to bar spacing, the installation angle also has a decisive influence on head loss in fine screens. The effects of the angle can be seen, for example, in Figure 4 for a constant bar spacing of 3 mm and a weir height of 30 mm for bar shape (a). At a flow rate of 25 l/s, the head loss increases from 22.5 mm at an angle of 30° to 48.9 mm at an angle of 80°. This is equivalent to an increase in head loss of 117 %.

In addition to the two variables just mentioned, bar spacing and installation angle, screen geometry is also of decisive significance in the calculation of head loss.

The dependency of head loss on bar and sieve geometry can be seen in the following Figure 5, which shows head loss in mm as a function of flow rate for various bar and sieve geometries with a constant bar spacing of 3 mm and a constant perforation diameter of 3 mm as well as a constant installation angle of 80° and constant weir height of 30 mm. At a flow rate of 15 l/s, the head loss ranged from 30.2 mm for bar shape (a) to 80.2 mm for bar shape (c), or from 45.9 mm to 123.0 mm when the flow rate was 25 l/s. As can be seen in Figure 5, the head losses of the perforated metal sheet with a perforation diameter of 3 mm are higher than those for the trapezoidal shapes (a) and (b) and lower than those for the flat bars (c).

Figure 6 shows the influence of the weir height when all other conditions remain unchanged. For the bar shapes investigated, weir height dependence on head loss was evident at a bar spacing of 6 mm. For the flat bar (c) at 15 l/s, the head loss decreases from 40.8 mm at a weir height of 30 mm to 31.4 mm at a weir height h_W of 50 mm. This represents a 23 % reduction in head loss. For the trapezoidal profile (a) the head loss was reduced by 59 % by increasing the weir height from 30 mm to 50 mm for the flow rate investigated.

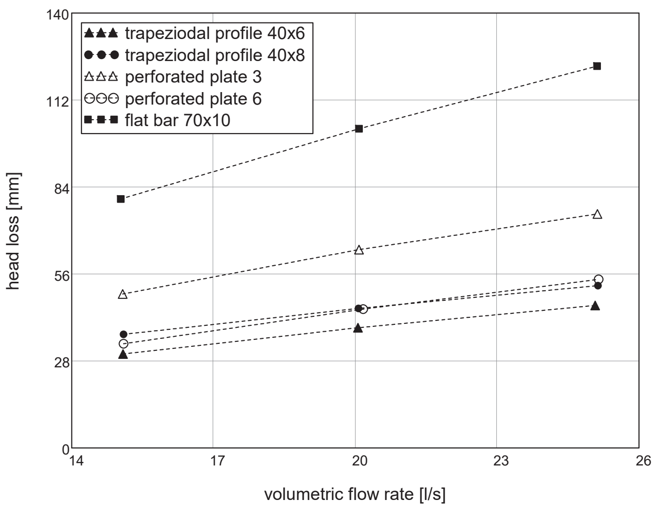

Fig. 5: Depiction of head loss [mm] as a function of flow rate [l/s] for various bar and sieve shapes, at a constant installation angle of 80° and a constant bar spacing of 3 mm and a weir height of 30 mm

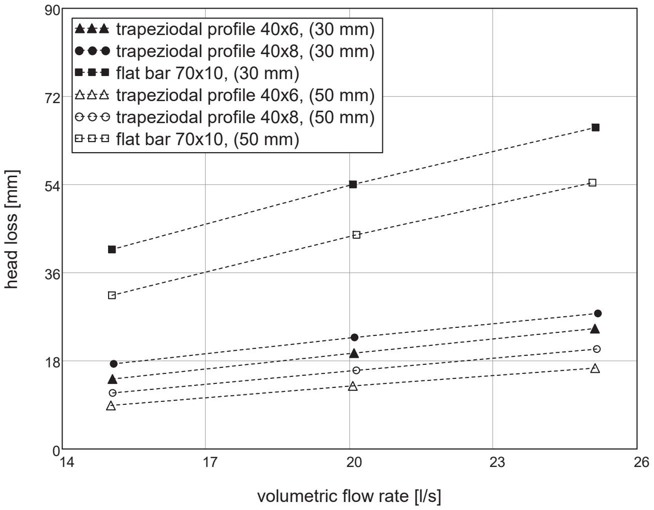

Fig. 6: Depiction of head loss [mm] as a function of flow rate [l/s] with various weir heights for the bar shapes (a), (b) and (c) at a constant installation angle of 80° and a constant bar spacing of 6 mm

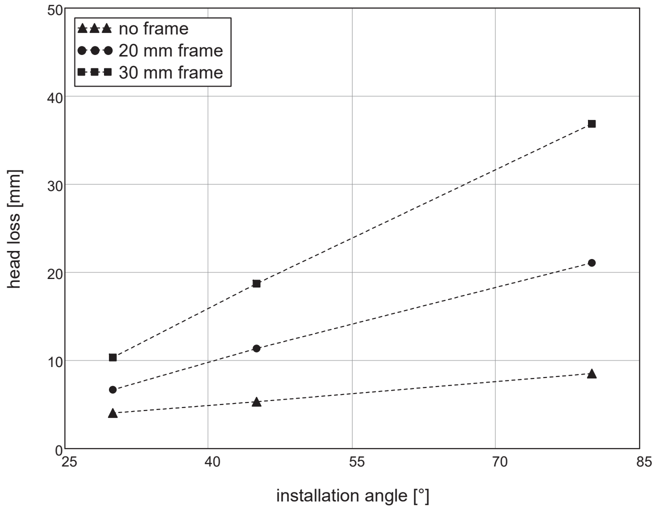

Fig. 7: Depiction of head loss [mm] as a function of the installation angle at varying frame geometries for the bar shapes (a) at a constant flow rate of 15 l/s and a constant bar spacing of 10 mm and constant weir height of 30 mm

The influence of a specific frame design increases as the installation angle increases (Figure 7). Thus, the head loss at 15 l/s with a constant installation angle of 30° and a constant bar spacing of 10 mm increases from 4 mm without a frame to 6.7 mm with a 20 mm wide frame and to 10.3 mm with a 30 mm wide frame. This corresponds to an increase in head loss of about 230 %. For a 20 % blockage of the flow surface, the head loss at 15 l/s increases by more than 400 % from 8.5 mm without a frame to 36.9 mm with a 30 mm frame.

Simulation with OpenFOAM®

The results of the simulation for the case in Table 2 are presented below. The simulation time amounted to about 12 hours for the standard-*k-e* turbulence model and about 1 hour less for the *k-w*-SST turbulence model.

Of special interest for head loss is measuring the headwater and tailwater levels and the flow rate through the fine-screen geometry. The agreement of the water levels between the turbulence models employed is $\leq +7.4$ %. The simulated head loss deviates by ≤ 10 % from the experimentally determined head loss. In Table 2 the experimentally determined headwater and tailwater levels and the resulting head loss are compared with the results of the simulation. It can be seen that there are no significant differences between the turbulence models employed in connection with water level.

If the velocities are checked at, for example, 0.4 m and 0.3 m in front of the screen, no significant differences in velocity can be detected. The average velocity measured here was 0.39 m/s. The simulated flow velocity deviates from the experimentally measured flow velocity of 0.44 m/s by about 13 %. Directly in front of the fine screen the simulated average flow velocity increases to 0.42 m/s. This is explained by the increase in velocity of the flow through the fine screen. Comparison of the velocity fields of both turbulence models immediately after the fine screen reveals a significant difference.

In both models the speed between the screen bars was about 1.3 m/s. In the case of the standard- *k-e* turbulence model, flow through the fine screen is in a straight line and there is no disruption of the flow caused by the screen geometry. The *k-w*-SST turbulence model, on the other hand, assumes a regular oscillating eddying motion when flow passes through the screen geometry.

In the experiment, the flow was photographed immediately after passing through the screen structure. To make a visual comparison of the results of the simulation with the real flow, the simulation results were prepared so they had the same identical detail view. Figure 9 shows the real flow when passing through the fine screen (left) compared directly with the results of the simulation (right). The agreement between the experiment and the numerical flow simulation suggests that the simulation can be validly employed.

Conclusions

The hydrodynamics of fine screens depend on numerous factors, which make the design of such systems difficult. For three bar shapes currently in use, two trapezoidal shapes (a) and (b) and a flat bar (c), the parameters of bar shape f, bar spacing s, installation angle α, weir height h_w as well as flow rate $\dot{Q}$ and frame width b_R were closely investigated, documented and

	Experiment [mm]			Simulation [mm]			Deviation [%]		
	h_1	h_2	Δh	h_1	h_2	Δh	h_1	h_2	Δh
Standard-*k-e*	159	49	110	171	50	120	+7.4	+2.0	+9.0
k-w-SST				171	51	121	+7.4	+4.0	+10.0

Table 2: Comparison of experimentally measured and simulated head losses

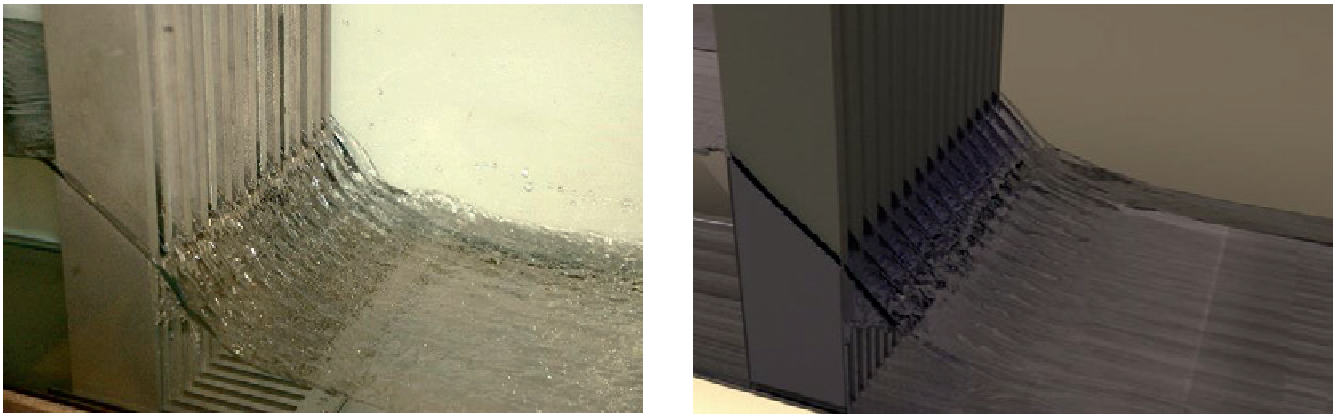

Fig. 8: Comparison of screen outflow as a detailed view of the experiment (left) with the processed simulation results (right)

evaluated, using a laboratory flume. To supplement the experimental investigation, a numerical flow simulation was carried out with OpenFOAM® with an error level of less than 10 %. It will thus be possible to reliably calculate the head loss from unblocked fine-screen systems in the future. The numerical simulation can be applied to the designing and optimizing of screens. In more extensive studies the model could be extended in order to calculate anticipated head losses in real-world applications, taking account of the blinding of the screen.

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Bringing an IWRM Concept into Practice

A Case Study from the Zayandeh Rud River Basin/Iran

Shahrooz Mohajeri, Lena Horlemann (Berlin/Germany), Mohammad Ali Torfeh (Isfahan/Iran) and Ali Asghar Besalatpour (Berlin/Germany)

1 The Zayandeh Rud River Basin

The catchment of the Zayandeh Rud, with an area of about 26 900 km² (located between 31 to 34 degrees north latitude and 49 to 53 degrees east longitude, Figure 1), is one of the most diverse regions in Iran: from the snow-covered Zagros Mountains, through wide floodplains and desert regions to the Gavkhuni wetland, the catchment is a special habitat. For centuries the river has attracted people and the entire region is host to a uniquely diverse ecology. During the last 60 years, the population in the catchment has grown from less than a million to almost four million. Today, more than 1 million people live from the land; producing wheat and other staple food. Important steel, oil and cement industries have settled along the river, which along with numerous smaller enterprises employ more than 300 000 people.

The steady growth of the region, coupled with the onset of climate change, have taken their respective tolls, leading to increasing water management challenges. While water demand rises, the Zayandeh Rud's water resources decrease and with them the livelihood of people and important ecosystems dwindle. Temperatures have been rising constantly, while annual rainfall (average: 265 mm year^{-1}) has been declining. As the gap between water availability and water demand grows, the different water users increasingly compete for the scarce resource.

Fig. 2: Empty river: People welcoming the water after the seasonal dam opening (© inter 3 GmbH)

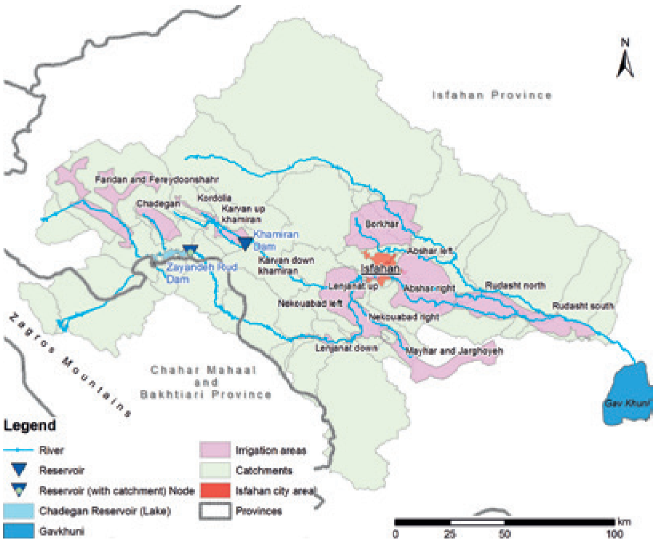

Fig. 1: Location of the Zayandeh Rud river basin (© Technical University Berlin)

The Zayandeh Rud river basin is now experiencing a serious water crisis reflected by drying rivers and wetlands, declining groundwater resources, land subsidence, deteriorating water quality, agricultural losses and ecosystem damages. The Zayandeh Rud River, the backbone of human development in central Iran, dries up seasonally (Figure 2, the Gav Khuni wetland dries up completely), imposing extensive pressure on agriculture, industries and urban populations. Sustainable and integrated water management is therefore vital in the Zayandeh Rud catchment.

2 The IWRM Zayandeh Rud Project

Since 2010 the "IWRM Zayandeh Rud" project, funded by the German Federal Ministry of Education and Research (BMBF), has been carried out by Iranian and German partners. The overarching aim of the project is to present options for integrated water management for the Zayandeh Rud river basin as an

Fig. 3: Networking: WATEX fair visit with the former Iranian Minister of Energy, Hamid Chitchian (© German Water Partnership e. V.)

example for the entire region. The German consortium involves seven scientific institutes and companies specialised in the water sector and the Iranian consortium consists of 15 governmental bodies, research and consulting institutions (Figure 3).

A necessary precondition for integrated water resources management (IWRM) is that the relevant actors of the affected provinces, sectors and national institutions become aware that they do not only sit in one boat but also have to row in the same direction. IWRM requires cooperation, discussion and agreement on the measures to be taken in order to reach a common goal. To this end, the project team developed an IWRM concept in close cooperation with stakeholders (e. g., urban and rural water companies, agriculture, industry and environment) and based on this, outlined an IWRM process (Figure 4).

At the beginning of the project, the fact that decision making was split and there existed a lack of sectoral cooperation, implementing IWRM was a very challenging undertaking. It required the coordination between administrative units that stretched across the catchment. Thus, at a stakeholder workshop and during several meetings the lack of a catchment related organisation was discussed and a local IWRM commission was founded. In addition, to serve decision makers on issues concerning water management operations and strategies

Fig. 4: IWRM process for the Zayandeh Rud river basin (© inter 3 GmbH/boeing gestaltung, Berlin)

Fig. 5: Participation: Agricultural transformation strategy workshop with farmers in Isfahan (© inter 3 GmbH)

Fig. 6: Training: Presentation of an Alphaliner for sewer rehabilitation in Isfahan (© inter 3 GmbH)

by summarising, merging, and visualising relevant information, the development of a water management tool (WMT) as Decision Support System (DSS) was adopted. One of the main challenges was now to gather the data necessary for the computer models.

Agriculture is the main water user in the Zayandeh Rud catchment with more than 80 percent of water consumption, but the project team faced a lack of agricultural data and knowledge at basin level. By carrying out a comprehensive study, a database on relevant agricultural parameters was set up. In addition, using a mix of participatory methods, tentative application of innovative technologies and computer models, options and measures were developed for a forward-looking strategy and sustainable agricultural transformation in the catchment (Figure 5).

Moreover, the Isfahan province is one of the most important industrial regions in Iran, and its water demand is rising. Nevertheless, limited precise data and knowledge about current and future industrial water use were available at basin level. After setting up a database for industrial parameters, some practical measures were developed. For two steel companies and one gas-fired power plant in Isfahan, the potential for developing alternative water resources has been estimated. For an industrial settlement the adaptation of the 'Eco-Industrial Park' Concept – resourcee-optimized, cross-linked development – is envisaged.

High water consumption and malfunctioning water and wastewater treatment plants (WWTP) in the Zayandeh Rud river basin were the other critical issues. Therefore, some recommendations for water use and WWTP operation and monitoring as well as some strategies and measures for wastewater reuse were developed in the project.

For a better implementation of the IWRM concept, comprehensive knowledge of all people involved in introducing innovative approaches and measures of sustainable water management is required. Expanding skills for IWRM implementation as well as facilitating knowledge and technology transfers are considered in the form of capacity development in the basin. For this, training is carried out within the pilot projects and a German-Iranian Training Center is in its set-up stage to establish technology and knowledge exchange on a permanent basis (Figure 6).

3 Challenges for IWRM Implementation

Some of the results and measures developed within the IWRM project need to be put into practice by individual sectors or companies, whereas others concern different water using sectors and therefore require joint efforts. While the implementation of sectoral measures –like the optimization of a wastewater treatment plant's process technology– is usually a managerial decision at company level, cross-sectoral measures need to be jointly agreed upon and implemented in an elaborate process. Irrespective of these categories, two essential preconditions need to be fulfilled when it comes to implementing measures: willingness (at political and/or company level) and financial feasibility.

Political decision-making in the Zayandeh Rud catchment is characterized by the political rivalry of the three riparian provinces. While the river originates in the economically less developed Chaharmahal-va-Bakhtiary province, the main stream flows through the province and city of Isfahan, an industrial center and a cultural site with a considerable international reputation. The third province, Yazd, is of less significance in terms of land area but receives most of its drinking water from the Zayandeh Rud.

Vastly challenging cooperation processes between the provinces are even further complicated by interventions of the central authorities in Tehran; the centralized organization of the Iranian state also claims its prevalence in water resources management (Figure 7). This claim is embodied particularly in the form of decisions on investments and permissions by the Ministry of Energy.

The general issue of financial constraints adds to this complicated political mélange between the individual provinces and between the provinces and the central government. Many projects initiated or already under implementation demand investment into new projects and financial compensation obligations but meet empty public purses which eventually impede aspired developments.

4 Strategies for IWRM Institutional Design

One of the internationally most common approaches for overcoming such coordination and cooperation problems described

Fig. 7: Knowledge exchange: RBO conference in Tehran in 2016 (© inter 3 GmbH)

is the establishment of a River Basin Organization (RBO) (Figure 7). At its 16th session, the Supreme Water Council, as the highest decision-making body, enacted the establishment of RBOs in accordance with the government's IWRM goals. The first RBO was established in 2013 for the Zayandeh Rud catchment as a pilot when the IWRM project was in its second project stage. The official guidelines determined eleven objectives for RBOs that include participation and enhanced cooperation of the main water-related authorities and sectors (agriculture, industry, drinking water and the environment), the establishment of balanced water consumption and use across the basin and among the different water users, or the protection of water resources.

The RBO Zayandeh Rud mainly consists of high-ranking officials. The Minister of Energy is the head of the organization, as his department is the main authority responsible for water resources management. The Deputy Minister for Water and Wastewater Affairs is also a member of the RBO. Other national government bodies represented are the Ministries of Agriculture, of Industry, Mines and Trade, of the Interior, of the Environment, the Planning and Budgeting Organization and the Iranian Water Resources Management Organization. From the regional level, the governors of the provinces that share the catchment and representatives of farmers' associations are represented. The RBO composition in general is, however, not limited to these people and other authorities can be invited. Even though the RBO is still in its infancy and organization, potential and capacities cannot yet be compared to well-established RBOs in Germany or Europe, its creation can be regarded as an important step towards the implementation of IWRM.

Seeing that the RBO mainly acts at the national level and is supposed to harmonize the interests of the different water using sectors and provinces, the Headquarters for the Rehabilitation of the Zayandeh Rud was founded by the Governor of Isfahan Province as a counterpart at provincial level in late 2017. The main responsibilities of the Headquarters are the establishment of a platform for the exchange of information and ideas for the relevant stakeholders within the Zayandeh Rud catchment. Necessary strategies and activities shall be developed in cooperation with the neighboring provinces. The Headquarters will also act as an intermediary between the provincial stakeholders and the national level, i.e. the RBO, in advocating local political-administrative and financial demands.

These recent developments show that the concept of IWRM is unfolding in political decisions that pave the way for more subsidiarity in the form of provincial or local involvement in strategy design and decision-making. The future will reveal the extent to which national-local coordination will lead to more efficient water management in the catchment. For now, it is important that political ambitions exist to solve the water management problems by involving relevant stakeholders from all levels and sectors in the sense of IWRM.

For more information visit:

www.iwrm-zayandehrud.com

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The Fight Against Climate Change as an Opportunity in Germany?

Current Developments and Further Needs where Water is in Excess

Flérida Regueira Cortizo, Annika Förster, Michael Schnabel and Daniela Vaziri (Berlin/Germany)

It is uncommon for northern European cities to feel like tropical countries in early summer. Berlin in June 2017 presented one of these rare exceptions. There would be no cause for serious concern had the city not been deluged by more than four times the average monthly rainfall, flooding several areas in the city. Similar extreme weather events occurred across Germany and Europe.

In August 2017, 30 European partners published the results of a study funded by the European Research Council in the journal *Science*. Using a new international river flow dataset of unparalleled scale and diversity, the researchers provide an explanation for the link between climate change and floods.

Germans say *es ist fünf vor zwölf* – meaning it's five to twelve – to express that time is running out. The impact of climate change has created a need for improved monitoring of water resources and aquatic systems as well as extreme weather events. New flood prediction and prevention methods, tools, and technologies are needed more than ever before.

With the clock ticking, challenges need to be addressed promptly. A solid framework for this is essential. The German Strategy for Adaptation to Climate Change aims to reduce vulnerability and improve adaptive capacity to climate change. The strategy specifies the consequences of climate change for 13 sectors in Germany and presents mitigation measures. The strategy is integrated into an international framework of climate change measures.

Active involvement in international scientific networks and strategic partnerships between institutions and companies are essential parts of climate research. German cities in particular are supporting the development and application of technologies that offer new solutions to climate change challenges. According to the Federal Environment Agency (UBA), more than 90 percent of all major German cities (76 cities with more than 100 000 inhabitants) are actively developing concepts and strategies to adapt to climate change. The primary instruments include specific local and regional adaptation measures, planning parameters, and structural measures.

Considering that extreme events such as water shortages or heavy rainfall and the resulting floods will occur more often in the future, efficient water use, flood and sea protection, and the related infrastructure must be improved. Awareness needs to be raised about the risks and information should be provided to prevent damage to property and persons.

What can be done where water is in excess?

Climate modeling instruments can help highlight regions where water is in excess. In Germany, more than 50 research institutions share findings from climate and adaptation research on the Klimanavigator platform. The resulting modeling systems have a high spatial resolution, which enables small-scale structures, such as those in mountainous regions, to be described. The models offer a higher level of detail about the distribution of temperature and precipitation. Additionally, the system is able to produce simulations of weather extremes such as intensive convective precipitation or storms.

Particular attention needs to be paid to the way drainage systems are planned. Reservoirs and water treatment plants need to be equipped to handle larger volumes to prevent combined sewer systems from flooding. Furthermore, customized area management needs to restrict the sealing of surfaces – especially in highly populated areas – to ensure rainwater can soak away in case of heavy rain events. The so-called "sponge city" concept calls for urban areas to be adapted to collect rain water on green roofs or in public places, and even to allow these areas to flood for a short time when there is water in excess. This concept is already being implemented in the city of Hamburg through its green roof strategy.

Last but not least, flood retention areas need to be created. The European Water Framework Directive (WFD – Directive 2000/60/EC) and the EU Flood Risk Management Directive (FRMD – Directive 2007/60/EC) already stipulate an integrated management of river basins with coordinated protection and usage requirements. In Germany the federal government and the states have identified priority measures for the rivers Elbe, Danube, Rhine, Weser and Oder under the National Flood Protection Program. More than 20 000 hectares of wetland will be restored throughout Germany, creating more than 1.2 million cubic meters of additional containment volume as assessable polder. The program includes 32 interregional projects for dike relocation, 59 projects for controlled flood retention, and 16 projects covering vulnerabilities.

However, implementing these measures requires the public and private sector to work hand in hand. New technologies from innovative companies are needed to ensure that Germany reaches its ambitious goals for adaptation to climate change. This is why strong support is available to foreign firms considering an investment in the field of climate change adaptation in Germany.

Financing and incentive instruments

Enterprises in the climate change adaptation sector that are planning to establish a facility in the promising German market can take advantage of a wide range of financing and incentive instruments.

Direct grants and other funding instruments, e. g. public promotional loans, public guarantees, and equity capital, can reduce investment costs significantly in designated support areas.

Visit *www.gtai.de/incentives* for a wide range of information on the available incentives and funding. Here is a quick overview of a small selection of relevant R&D financing and incentive instruments.

NaWaM supports R&D in the field of sustainable water management

The Federal Ministry of Education and Research (BMBF) promotes the development of innovative technologies, processes, and systemic solutions for sustainable water management through the "Sustainable Water Management" (NaWaM) funding program. The aim is to develop key technologies in cooperation with industry, adapt them to changing basic conditions, and disseminate them internationally.

The BMBF calls for the participation of industrial enterprises, in particular small and medium-sized enterprises, in collaborative projects. Through this program the ministry aims to strengthen Germany's leading international position in the water technology sector.

www.fona.de

Franco-German Fellowship Programme

Germany and France are jointly promoting R&D in the areas of climate change, renewable energy, and ecosystems. The countries are inviting researchers from all over the world to cooperate with German and French partners to advance research under the motto "Make our planet great again".

The calls for proposals have already been published. Further information:

www.fona.de

Promoting adaptation to climate change: Attractive funding

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) funds measures to adapt to climate change. Funding priorities include the establishment of concepts for adaptation to climate change within enterprises. The aim is to strengthen the adaptability of different actors locally as well as regionally. Funding is provided in the form of grants, up to a maximum of EUR 300 000.

Further information:

www.foerderdatenbank.de

Services of Germany Trade & Invest

Germany Trade & Invest (GTAI) is the economic development and investment promotion agency of the Federal Republic of Germany. With more than 300 employees worldwide, it offers companies comprehensive and tailored information for trade and investment projects.

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www.gtai.de/umwelttechnik
http://www.gtai.de/GTAI/Navigation/EN/Invest/Industries/environmental-technologies.html
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Capacity Building Initiative TCC Danubius for Danube Region

Heike Burghard (Ulm/Germany)

In large part of the Danube region the water sector still suffers from obsolete infrastructure and the waste water sector even lacks in essential infrastructure, the waste water treatment plants. The reason for this bad state is an enormous investment delay caused by the transition process, in the territory of Ex-Yugoslavia additionally by the Homeland War, aggravated in 2009 by the financial crises with slow recovery in the recent years. The EU accession (recently realised or still planned) or membership of the countries in the Danube region requires modernisation and upgrading of the infrastructure mainly in the waste water sector in order to fulfil the Acquis communeautaire and to reach EU standards. New plants and equipment however need to be maintained and operated by skilled and qualified staff. Therefore most of the utilities in the region need intensive training for adapting to the new challenges.

TCC Danubius is offering on basis of DWA (German Association for Water Management, Wastewater and Waste) training materials and adapted to the local conditions several training modules. The set of magnetic cards for training purposes in the waste water sector has also been translated into Croatian language and is used on regular basis in the TCC-courses. Most visited is the WWTP Manager course for staff working on the waste water treatment plants, whether as Head of plant, as electrical or mechanical service staff or as laboratory staff. This six-weeks modular training devided in six units of each one week with ten different subjects is an essence of the DWA waste water technician qualification. This training is specially designed for staff with basic professional qualification, e. g. electrician with experience in the sector. The practice oriented approach with exercises and group works is possible in small groups of maximum 15 persons and in the local language. For offering the training in local language the pre-condition is the availability of trainers in the country. Respectively TCC Danubius realised with support and involvement of DWA and after a selection process based on criteria as professional experience, communication skills and volunteer engagement several train-the-trainer workshops. Some of those previously qualified trainers, also recruited from utilities, are now active on a regular basis in these trainings for utility staff.

Team work

Hands-on training

TCC Danubius is always in close contact with DWA, even now after several years of activity. Every two years DWA realises an audit, which is a guarantee for keeping the standards high and at the same time for detecting potential for optimisation and improvement. Furthermore the trainers receive on regular basis refreshing and up-grading of their trainer skills by DWA. On basis of this net cooperation the National Croatian Water Agency “Hrvatske Vode” entered into negotiation with DWA for translating all DWA rules and standards.

TCC Danubius is satisfied with the developments since 2014, which was the year of foundation of this non-profit organisation and looks with optimism into the future according the motto “Progressing together”.

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Training and Further Training of Specialists for the Wastewater Sector in Vietnam

Hoang Mai Phan (Vietnam) and Norbert Lucke (Dresden/Germany)

Initial situation

The rapid development of the Vietnamese economy within the last two decades admittedly provides for a continuous boom in the whole country, it leads, however, also to massive environmental problems. Thereby, particularly in the wastewater sector, there is a lot of catching-up to be done. Thus, currently, only ca. 60 % of the municipal households are connected to the public sewer system and at the same time only ca. 10 % of this collected wastewater is treated in a wastewater treatment plant.

In Vietnam there are over 800 urban regions, however, only 37 central wastewater treatment plants with a total capacity of 890,000 m^3/d (December 2016)[*]. The Vietnamese government has decided in the medium term to increase the level of connection to 80 % and to treat 60 % of the municipal wastewater in accordance with the valid standards. In addition to that, according to the Ministry of Housing and Urban Development, some 36,000 km of sewer network, 116 municipal wastewater treatment plants and 150 industrial wastewater treatment and pre-treatment facilities are required. An estimation implies that for their operation ca. 8,000 specialists are required who, currently, are not available.

Up until now in Vietnam there has been no vocational training for the water sector and no efficient programmes, and self-supporting structures for training and further training of the personnel employed in the wastewater treatment plants. A survey carried out in 2016 in Vietnamese wastewater facilities resulted in the following qualification status of the technical personnel employed there (Table 1).

Furthermore, both the academic as well as the professional training in Vietnam have a low relatedness to practical experience. Likewise, the cooperation between educational establishments and businesses, in our case these are the water and wastewater organisations, is inadequate.

[*] Ministry of Construction, Agency of Technical Infrastructure (2016): oral communication

Programme for the training of specialists in Vietnam's wastewater sector

Within the framework of the programme "Reform of the professional training in Vietnam", which is being carried out by the German Society for International Cooperation (GIZ) on behalf of the Federal German Ministry for Economic Cooperation and Development (BMZ), one has succeeded in initiating the build-up of a deliberate and sustained vocational training and further training for the wastewater sector in Vietnam and to establishing the new profession of specialist for wastewater engineering for Vietnam. In addition to that, since the start of the project at the end of 2013, from the German side a consortium made up from the consulting companies GOPA and PLANCO as well as the Stadtentwässerung Dresden GmbH as Specialist Corporation under the direction of the GIZ have cooperated closely with the Vietnamese partners.

A requirement and practice oriented training ensures the later employment of those trained as they are the prerequisite for their practical employment in the wastewater establishments. In order to guarantee this, a cooperative approach is followed, which is based on a close collaboration with later employment operations. At the same time it is the explicit wish of the Vietnamese partners that the level of the training and the requirements placed on the trainees are equivalent to the applicable standard in Germany.

While up until now the professional training in Vietnam has taken place exclusively via vocational schools, in this project, for the first time, a vocational training institute (the Ho Chi Minh Vocational College of Technology), local companies (the drainage operations in Ho Chi Minh City, Binh Duong, Khanh Hoa, Can Tho and Vung Tau) as well as a specialist association (Vietnam Water-Supply & Sewerage Association) are working closely together in order, together with the German partners, to develop and implement a practice-oriented training programme matched to the conditions in Vietnam, as well as an authoritative professional standard for the whole country.

Qualification status	Overall	of these water/environment
university degree or equivalent	1,635	709
college/vocational school, secondary school leaving certificate	1429	641
without professional qualification	2,065	–

Table 1: Qualification status of the technical personnel employed in Vietnamese wastewater facilities

In the autumn of 2014 a start was made to carry out continuation and further training of in total 23 Vietnamese specialists as future instructors and vocational trainers for the professional training of the specialists for wastewater engineering. These were recruited from the teachers of the Ho Chi Minh College of Technology II (HVCT) as well as from specialists of the already named wastewater companies in South Vietnam.

In October 2017, all participants in this qualification programme successfully passed the final examination for specialist for wastewater engineering in accordance with the requirements with regard to the examiner, examination procedure and tasks as well as the training quality of the Chamber of Industry and Commerce (IHK) Dresden. All of them were certified by the Vietnam Water-Supply & Sewerage Association (VWSA) as instructors and 9 were confirmed as examiners.

Parallel to their own continuation and further training, since the autumn of 2015, these Vietnamese specialist colleagues themselves have been training independently 22 Vietnamese school-leavers as specialists for wastewater engineering. These trainees will take their examination in the autumn of 2018.

It is thanks to the great engagement of all those involved in the project that since April 2017 in Vietnam the profession of specialist for wastewater engineering is officially recognized and certified.

Programme for the further training of specialists who are already employed in the wastewater sector

While the vocational training to specialist for wastewater engineering is conceived primarily as initial training for young persons, this course offer is aimed especially at specialists of other technical professions (mechanic, electrician, skilled building worker), who already work in the sewer network and/or wastewater treatment plant or are to operate in these in the future, and also to engineers who are employed in the wastewater sector.

That an urgent requirement for such a further training programme exists was confirmed through the already named survey of 42 Vietnamese wastewater operations carried out at the beginning of 2016.

Aim of this further training is, in the first instance, to procure knowledge for the operation of the drainage networks and the wastewater treatment plants respectively to deepen the already existing specialist knowledge of the processes of wastewater and sludge treatment. A particular core theme with this is formed by the mastery of unusual operating situations in wastewater treatment facilities.

The technical basis for this course programme is formed from the courses developed by the German Association for Water, Wastewater and Waste (DWA) for the operational personnel of wastewater treatment plants, which have proved themselves over many years in Germany.

Overall control with the establishment and implementation of this further training programme, which started in autumn 2016, lies with the Vietnam Water Supply & Sewerage Association (VWSA). For this, in total 13 specialists from Vietnamese wastewater operations were specially trained. Naturally these courses have been adapted, together with the Vietnamese technical colleagues, to the specific conditions in Vietnam.

Up until now the wastewater treatment plant technician basic course as well as the advanced training courses “Nitrogen and phosphorus removal” and “Malfunctions and proceedings in wastewater treatment plants” have been run as pilot schemes and have already been successfully carried out by the Vietnamese colleagues. A sewer technician basic course will have its pilot run in 2018.

Conclusions and outlook

From the previous experiences with the pilot runs and establishment of the cooperative training “Specialist for wastewater engineering” it can be derived that a holistic approach, which takes into account all important aspects of the training for this industrial sector, is particularly promising. With this, the economy is to play an important role with the elaboration of the professional standard and of the curriculum as well as the examination requirements and the certification, in order that the requirements and needs of the employment market find the necessary consideration. This leads to a broad recognition of the training and thus to the improvement of the employment opportunities of the trained specialists. In the case of the wastewater sector the cooperation with the economy is institutionalised through the organization Vietnam Water Supply and Sewerage Association (VWSA), which has been anchored in a Memorandum of Understanding between the VWSA and the programme “Reform of the professional training in Vietnam” (GIZ).

For the establishment of the job description as well as the new training it is important that all actors, in the first instance these are the professional training institute, the state authorities, the specialist association VWSA as well as the companies, can find a functioning cooperation mechanism and through this jointly make the important decisions as well as jointly shape and carry out the essential processes. This applies naturally also for the evaluation and the dissemination of the pilot training “Specialist for wastewater engineering”. Following the conclusion of the first training course the VWSA and the programme “Reform of the professional training in Vietnam” (GIZ) are working closely together, in order to evaluate the previous experiences and to develop further improvement potential. Building on this, from both sides, recommendations for action are being elaborated for the optimisation and the multiplication of the training.

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WorldSkills Abu Dhabi 2017

Second rank for Patrick Gundert at the vocational competition "Water Technology"

In October 2017, the German team, which consisted of 42 men and women, attended the 44th WorldSkills of professions in Abu Dhabi. In 37 competitions and the demonstrations-skill "Water Technology", the attendees proved their skills, partly in teams, partly individually, against their most talented colleagues worldwide. A total of 1,300 young talents from 59 different countries and regions proved their knowledge and abilities in 51 disciplines. Patrick Gundert from Neuwied in Germany achieved the second rank in the "Water Technology" demonstrations-skill. The winner of the competition was the attendee from Iran.

Abu Dhabi, October 18th 2017. At 5.30 pm local time, Dr. Nader Imani (Festo Didactic), and Rüdiger Heidebrecht (Head of Department Education and International Cooperation), announced the winners of the demonstrations-skill "Water Technology". Four busy days lay behind the five candidates, who all did a great job. Mohammad Hossein from Iran achieved the first rank, followed by Patrick Gundert from Germany and Dmitrii Ponomarev from Russia.

All participants were coached by their local experts prior to the competition. Hilmar Tetsch from Stuttgart is the "Chief Expert" of the competition and did a great job. Not only did he train the 19-year-old Patrick Gundert, but he was also respon-

Patrick Gundert taking part in the WorldSkills competition in Abu Dhabi (© WorldSkills)

sible for the assignments, evaluation and for providing the required materials. Since many years, he is involved in the DWA-sub-committee BIZ-13 “Berufswettbewerbe”(professional competitions). He is very experienced and has a great international network.

“We have extremely engaged experts for our national competitions for our skilled workers and Universities at IFAT and now also for the high-level competition at the WorldSkills”, says Rüdiger Heidebrecht, and is proud that Germany managed to support the implementation of the new challenge so dispositive. “Without the voluntary helpers and the active support of the DWA-member Festo, this would not have been possible”, he adds. The collaboration between DWA and Festo has its origins with the WorldSkills Leipzig in 2013. Back then, German trainees from various cities introduced the profession “Water Supply Engineering Technician” and “Sewage Engineering Technician” to the WorldSkills community. On an international level, these professions merged into the competition “Water Technology”. Festo also participated in the WorldSkills 2015 in Brazil.

Patrick Gundert and his parents, who came with him to Abu Dhabi, cheered for him and were very pleased with his result. In total, 360 supporters and family members traveled to Abu Dhabi. The German national team consisted of 42 members who represented 37 professions. In total, 1,300 competitors from 59 countries proved their skills in 51 professions. The event is the biggest of its kind and meeting point for educational experts around the world. Patroness of the German team is the Federal Chancellor Dr. Angela Merkel. The Federal Ministry of Education and Research, sector associations und chambers support the event.

Patrick Gundert is in his third apprenticeship year at a wastewater treatment plant in Neuwied and was trained by his educator Andreas Brubach. The “Servicebetriebe Neuwied” provide a great education and are, to a large extend, responsible for the great result of their trainee. The vocational training varies a lot within the different countries worldwide. WorldSkills participants are younger than 23 years, and study at Universities, polytechnic schools or vocational schools. The dual education, as is being executed in Germany, does not exist in other countries. Therefore, Patrick competed against science students, among others. He succeeded due to his good practical education and his determination. Nevertheless, he couldn’t hide his nervousness, when being watched by people and cameras.

Every participant, expert and visitor collected unforgettable impressions and experiences to take back home. The keywords “international understanding”, “defining educational standards”, “making new friends”, “location determination” and “networking” only insufficiently describe the event and spirit on-site.

DWA significantly helped implement the competition “Water Technology” at the WorldSkills International. Along with Festo and new partners, the commitment is supposed to increase even more in the future. It is planned that during the upcoming WorldSkills, which take place in 2019 in Kazan/ Russia, twelve countries participate in the competition. 29 countries joined in the competition of installers (building service engineering), which took place right next to “Water Technology” – a number one should remember.

The competitor, who is going to attend for Germany in Kazan in 2019, is going to be determined at the next IFAT Munich 2018. There, the WaterSkills Germany are going to take place. Teams of trainees and experts are going to compete against each other and prove their skills. KA

Patrick Gundert (centre) with Rüdiger Heidebrecht (left) and Hilmar Tetsch (right)

Products and Services

Compact Stainless-Steel Diamond Filter – High-Tech for Tertiary Wastewater Treatment

The global reuse of water directly after it has been treated in a wastewater treatment plant is increasingly gaining in importance, be it for reasons of environmentalism or efficiency. This increases demands on the treatment of wastewater and requires additional treatment phases. A fundamental part of tertiary wastewater treatment is the added filtration. It is the basis for further steps of conditioning, such as a fourth treatment stage, separation of microplastics, retention of phosphorus, or disinfection.

Invent Umwelt- und Verfahrenstechnik AG made use of their long-standing experience in the sector of water and wastewater treatment as well as their expertise in the fields of fluid mechanics, hydraulics and component design to develop the iFILT-diamond filter. It was constructed especially for the separation of solids from fluids as the next treatment phase after secondary sedimentation. It removes the smallest suspended solids that are still present in wastewater, for example activated sludge flakes, microplastics, precipitation flakes after phosphorus reduction or powdered activated carbon.

Industrial enterprises are also greatly interested in the energy-efficient and ecological use of their processing water. The iFILT-diamond filter can be applied in many areas, such as in the general reuse of processing water in the paper and textile industries, water treatment in fisheries or the treatment of flush water in the beverage industry.

The iFILT-diamond filter consists of one or more filter wheels, backwash unit, enclosure and tray. The filter discs are directly mechanically connected without the additional usage of a central pipe. They are equipped with high-quality, stainless steel, high-performance filter cloth with pore sizes varying between 10 and 100 μm.

The iFILT-diamond filter is charged directly into the rotor center via a fluid-mechanically optimized distributor, which eliminates the usage of a gasket in the feed area. This rules out any unnoticed leakages and filtrate contamination due to worn-out gaskets. Via the distributor wastewater runs through the filter wheels from the inside towards the outside. The increasing loads of solids on the filter material slowly leads to a rise of the hydraulic resistance, which eventually leads to a rise of the water level within the filter wheels. When a predetermined water level within the filter wheels has been reached a backwash of the filter cloth is triggered. The periodic backwash or removal of retained solids from the filter cloth is performed with the help of splash water, which is applied to the filter cloth from the outside. The splash water pump is charged with filtrate and thus does not require an external water supply. By way of rotor rotation and cleaning action of the spray nozzles the removed solids are flushed into an internal collecting flume and are drained off the machine separate to the filtrate. The solids are usually reintroduced to the wastewater treatment plant's influent.

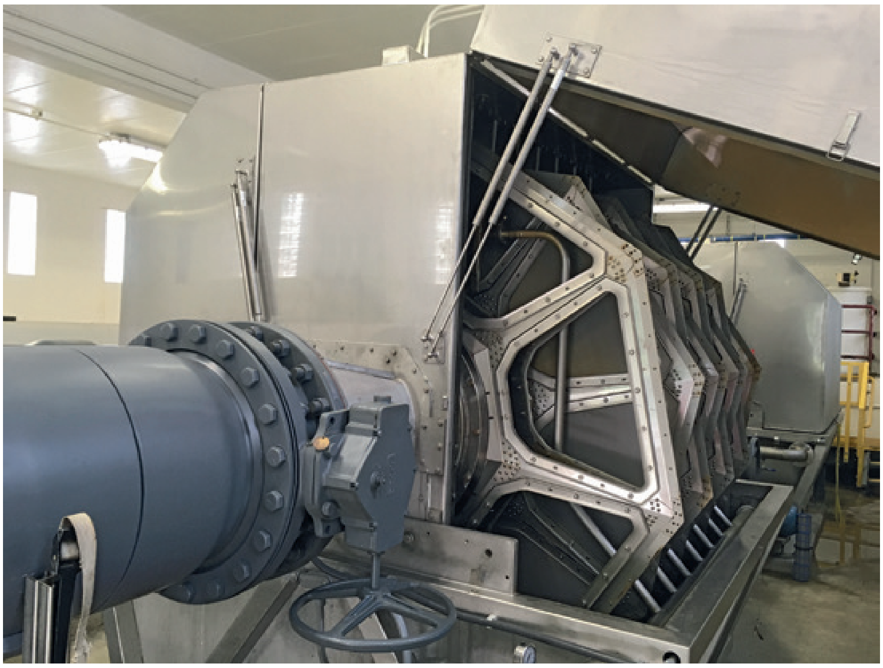
The iFILT-diamond filter uses a well-thought-out fluid-mechanical overall concept. Depending on the individual case this concept enhances hydraulic performance by up to 100 percent. This is achieved by using a holistic fluid-mechanical optimization approach that is based on the principle of cross-flow-filtration.

The continuous rotation of the disc, the very high rotational speed and the thus initiated effect of a tangential-dynamic filtration limit the built-up of a surface layer to a minimum and enable an optimal hydraulic discharge. A small number of rotating filter discs already achieve high throughputs. This means low spatial requirements: the iFILT-diamond filter can be put into operation even under restricted circumstances with regard to space.

Apart from the hydraulic efficiency and the resulting high economic efficiency the iFILT-diamond filter offers additional advantages for the operator. The fact that no large-scale gasket neither in the rotor's feed nor the discharge area is required makes the machine virtually maintenance-free. Leakage and therefore unnoticed deterioration of the filtrate's quality will not happen. As the filter disc is in constant rotation the energy-intensive backwashing cycles are reduced to a minimum and the overall energy consumption of the filter is extremely low.

All components of the iFILT-diamond filter are made of high-quality stainless steel, therefore by far exceeding all requirements of modern wastewater treatment with regard to durability and longevity. The applied material meets the highest demands on robustness and me-

The Invent iFILT-diamond filter at a municipal wastewater treatment plant (source: Invent)



Interior view: the rotating filter discs are mechanically directly connected. They are equipped with high-quality stainless steel filter cloth (source: Invent)

chanical stability even under the most adverse conditions.

Additionally, being an Invent complete solution, the diamond filter is particularly easy to install. During assembly it will only be attached to the supply and drainage pipes and electrically connected.

The iFILT-diamond filter is available in a container version or a concrete tank version, which makes it easy to adjust it to any given conditions.

Up to now the processing steps of filtration or micro-sieving have been connected with high investment costs, a fact that has a deterring effect on many municipalities and industrial enterprises. However, public pressure to tackle this subject in order to protect the environment is mounting. The newly developed and fluid-mechanically optimized iFILT-diamond filter meets all demands on continuative treatment steps in communal and industrial water treatment. Invent therefore makes sure that tertiary treatment steps can be realized in a more economic and largescale way.

Invent Umwelt- und Verfahrenstechnik AG
www.invent-uv.de

Spectrophotometer *NANOCOLOR® VIS* II

The spectrophotometer *NANOCOLOR® VIS* II by Macherey-Nagel combines high-tech instruments with outstanding usability. With it's intuitive, icon-based menu guidance, this photometer can be used like a smartphone or tablet. The high-resolution touch screen display is clearly arranged.

On the technical side, the *NANOCOLOR® VIS* II features the well-known and proven barcode technology for a rapid measurement of *NANOCOLOR®* tube tests, while measuring *NANOCOLOR®* standard tests or pre-programmed methods is easily done as well.

The entirely new scan menu allows to scan in real time at different resolutions, but also to perform in depth analyses of the scans. The customer can highlight peaks and valleys, add and subtract scans and generate high quality images with no additional software or complex programming.

As a unique aspect of all Macherey-Nagel spectrophotometers, the *NANOCOLOR® VIS* II also features an integrated nephelometric turbidity (NTU) measurement function; however, it has been significantly enhanced in this instrument. An automation of this measurement is the integrated NTU-Check function, allowing the detection of interfering turbidities with every tube test measurement – a huge safety aspect for the customers' measurement results.

To make laboratory work even more easy and comfortable, Macherey-Nagel launched the new sipper module *NANOCOLOR®* FP-200, which is directly operated via the spectrophotometer *NANOCOLOR® VIS* II and even allows for the analysis of aggressive samples.

Dealing with large sample numbers in photometric analysis often requires a lot of time and resources due to the preparation of the samples in different cuvettes and the frequent changes of the cell in the photometers. The combination of the *NANOCOLOR® VIS* II with the sipper module *NANOCOLOR®* FP-200 and a flow cell (2 mm, 10 mm or 50 mm) reduces the work effort drastically and comfortable when a high number of samples is analyzed.

With this peristaltic pump, a constant amount of liquid is pumped through a flow cell and the measurement is started automatically in the photometer. Besides conservation of resources, the *NANOCOLOR®* FP-200 can also increase the measuring accuracy. One reason for that are the same optical conditions for zero and sample measurement. Errors due to optical differences between different cuvettes are avoided, because all solutions to be analyzed flow through the same cuvette.

Unwanted contact with chemicals is effectively avoided with the sipper module, because there is no need to pour samples into the cuvette. The hoses and the sipper module itself are highly resistant against organic solvents and aggressive liquids. Special tubes for extremely aggressive chemicals are commercially available.

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