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University of Bonn - IHPH Institute for Hygiene and Public Health

WATER & RISK

Dear reader,

This year´s World Water Day was themed "Leaving no one behind". Today billions of people are still living without access to safe water. And the increasing demand for water fuels numerous conflicts: Agricultural versus domestic use; water resources shared between countries; industrial bottled water production affecting local drinking water availability are just a few of them. The UN calls this year the International Year of Moderation aiming to raise awareness that moderation promotes peace, security and development. We need to choose negotiation over confrontation and promote dialogue, tolerance, understanding and cooperation. We have to communicate in one or more of the world´s many languages. While the UN has five official languages there are more than 7,000 languages spoken around the globe. And more than one third is at risk of being lost. Through language we define our identity, express our culture, preserve customs and traditions and participate in all aspects of society. Language is pivotal in the areas of human rights protection, good governance, peace building, reconciliation, and sustainable development. This year is also the International Year of the Periodic Table which should enhance global awareness of, and increase education in the basic sciences with special attention to the countries of the developing world. Science can improve the quality of everyday life and support that no one is left behind. Science can support understanding and identifying and reducing conflicts. It can also help us to find a common language for discussions, which is indispensable for the aim of leaving no one behind.
Whoever you are, wherever you are, water is your human right.

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Clinical wastewater as a hotspot for the occurrence of antibiotic residues in the aquatic environment

The treatment of bacterial infections caused by multidrug resistant organisms represents one of the big challenges of modern medicine. 90 years after the discovery of penicillin by Alexander Fleming (1929), antibiotics are still one of the most frequently used pharmaceutics. But Fleming already recognized how quickly resistances can be developed in bacteria, even in bacteria in the human body, and alerted us about the danger that the time "may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant" (Fleming, 1945). As Fleming predicted, in the last decades, the development of new antibiotics and their clinical application were accompanied with the development of new antibiotic resistances (Saga & Yamaguchi, 2009).

The latest statistics of fatalities associated with infections by drug resistant bacteria in the US (U.S. Department of Health and Human Services - Centers for Disease Control and Prevention, 23.04.2013) and the European Economic Area (Cassini et al., 2018) show the increased weight of infections with antibiotic resistant bacteria for the global health system and underline the importance of ensuring the effectiveness of antibacterial agents. The situation is aggravated by a decreasing number of newly developed agents, especially antibiotics with gram-negative spectrum (Walsh, 2010).

Meanwhile, recent studies showed that sub-lethal environmental concentrations (concentrations under therapeutic dose) of antibiotic residues may exert a selection pressure in favor of resistant bacteria, promoting their spread (Bengtsson-Palme & Larsson, 2016; Jutkina et al., 2018) To control the spread and further development of antibiotic resistances, different approaches have been implemented, such as the reduction of the total antibiotic consumption through a more restrictive prescription of antibiotics in intensive livestock farming (Bundesierärztekammer (BTK), 2015); the prohibition of antibiotics as growth promoters (VO(EG) Nr. 1831/2003, 30.12.2005); more restrictive prescription practices and a better information of the patients (Kümmerer, 2003) as well as advanced hygiene procedures in the human medical sectors (Westphal-Settele et al., 2018).

Therefore, it should be noted that antibiotics are not completely metabolized in patients (or treated animal) – with a metabolization rate between 10 % and 90 %, related to the respective substance – and certain amounts of the administered antibiotics are released unchanged into the sewage system via urine or feces (Kümmerer, 2009). At the end of the wastewater pathway, published studies have shown that antibiotic residues (Kümmerer, 2009) as well as resistance genes (Rizzo et al., 2013) and antibiotic-resistant bacteria (Müller et al., 2018), especially observed in hospital wastewater, are incompletely eliminated by the sewage treatment plants and eventually end up in the environment. However, it is still necessary to consider a number of degradation mechanisms (outside the patient or treated animal) such as light induced degradation, thermal degradation, hydrolysis, enzymatic degradation, adsorption to organic material or chelation to calcium or magnesium ions, which lead to a further reduction of the excreted antibiotic residues in the sewage treatment plants as well as in the environment (Kümmerer, 2009).

The diversity of clinical wastewater in terms of identified antibiotic residues and their concentrations depends on several factors, such as medical specialties, sampling sites and times or consumption patterns. For example, Diwan et al. (2010) detected significant differences in the residue concentrations in the wastewater and the subsequent drains from an Indian hospital at different times during the day (10:00 and 16:00). Furthermore, the concentration of detected residues varies according to the type of department in the hospital and the geographical location of the hospital, depending on different prescription practices (BVL & Paul-Ehrlich-Gesellschaft für Chemotherapie e.V., 2016).

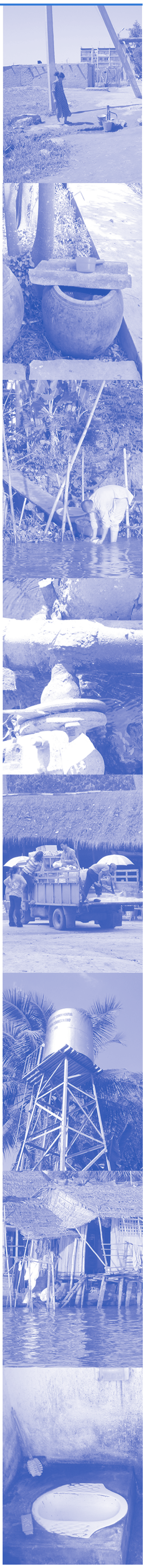
In this study, the first clinical wastewater defined as the wastewater in the toilet, sink syphons and shower drains of patients restrooms – has been examined for possible antibiotic residues by means of high performance liquid chromatography coupled with a tandem mass spectrometry (HPLC-MSMS) (Voigt, A. et al., 2019). This aimed at further characterizing clinical wastewater streams and identifying potential hotspots of high antibiotic residues that could exert increased selection pressure in the immediate area of vulnerable patients. For this purpose, different clinical departments of several German hospitals characterized by different antibiotic prescription praxis have been examined. A total number of twenty rooms have been examined in an oncological clinic (high consumption), six rooms in a psychosomatic clinic (clinical wastewater with antibiotic prescription), one room in a dermatological clinic (comparatively low and irregular prescription) and five rooms in a neurological rehabilitation clinic (as another clinical department with high consumption). In addition, sanitary units in five private households have been analyzed as a control sample (Voigt, A. et al., 2019).

Figure 1 provides an overview of the theoretical wastewater streams: the streams contaminated with antibiotic residues (e.g. wastewater from the oncology clinic) and antibiotic-free (e.g. wastewater from psychosomatic) as well as the path of entry of antibiotic residues with clinical origin into the environment (Voigt, A. et al., 2019). Further sampling spots, such as from sewage treatment plants (influents and effluents) or surface water were not part of the work presented here and will be dealt with in further studies.

During sample collection, a status quo sample was taken first, which was defined in the presented work as a random grab sample without any prior knowledge about the room occupancy, the last cleaning or use of sanitary units or the current medication administrated to the respective patient. Afterwards, the syphons were flushed and a sample was taken, which was defined as the start of stagnation. At regular intervals (approx. 2h, 4h, up to 24h), further stagnation samples were collected analogously. Figure 2 illustrates the sampling procedure.

According to the results of the study, at least one antibiotic has been detected in 71 out of 94 (76 %) examined clinical sanitary units. In accordance with the lack of antibiotic consumption, no antibiotic residues have been found in the six psychosomatic patient rooms considered in the study and in the examined private households (where household members reported no antibiotic intake). The highest antibiotic residue concentrations (up to 79,000 μg/l) and the most frequent detection of antibiotics have been observed in the patient rooms of the oncological clinic and the neurological rehabilitation clinic. In the oncology clinic, sulfamethoxazole (shower: 100%, wash basin: 95%, toilet: 70%), its metabolite N4 acetylsulfamethoxazole (shower: 84%, wash basin: 60%, toilet: 70%) and trimethoprim (shower: 95%, wash basin: 90%, toilet: 65%) have been detected most frequently. The frequency of detection of these two antibiotics is plausible due to the prophylactic prescription practice of cotrimoxazole (a preparation of sulfamethoxazole and trimethoprim, 5:1) (Voigt, A. et al., 2019).

These results have shown that the detection of antibiotic residues is related to the amount of antibiotics administered. Even in clinics with a tendency to lower antibiotic consumption (such as dermatology), antibiotic residues (ceftazidim, ciprofloxacin, clindamycin, piperacillin, dehydratoerythromycin) could also be detected. In case of the examined dermatology patient rooms, similarly to oncology and the neurological rehabilitation clinic, several antibiotics have been detected which were not part of the patient's current medication. This has been attributed to a possible accumulation of antibiotics in the biofilm matrix, which is spread throughout the water supply network. Further results showed that after sufficient flushing of the sanitary units, the residue concentrations (status quo sample) could be significantly reduced. Nevertheless, reappearance and



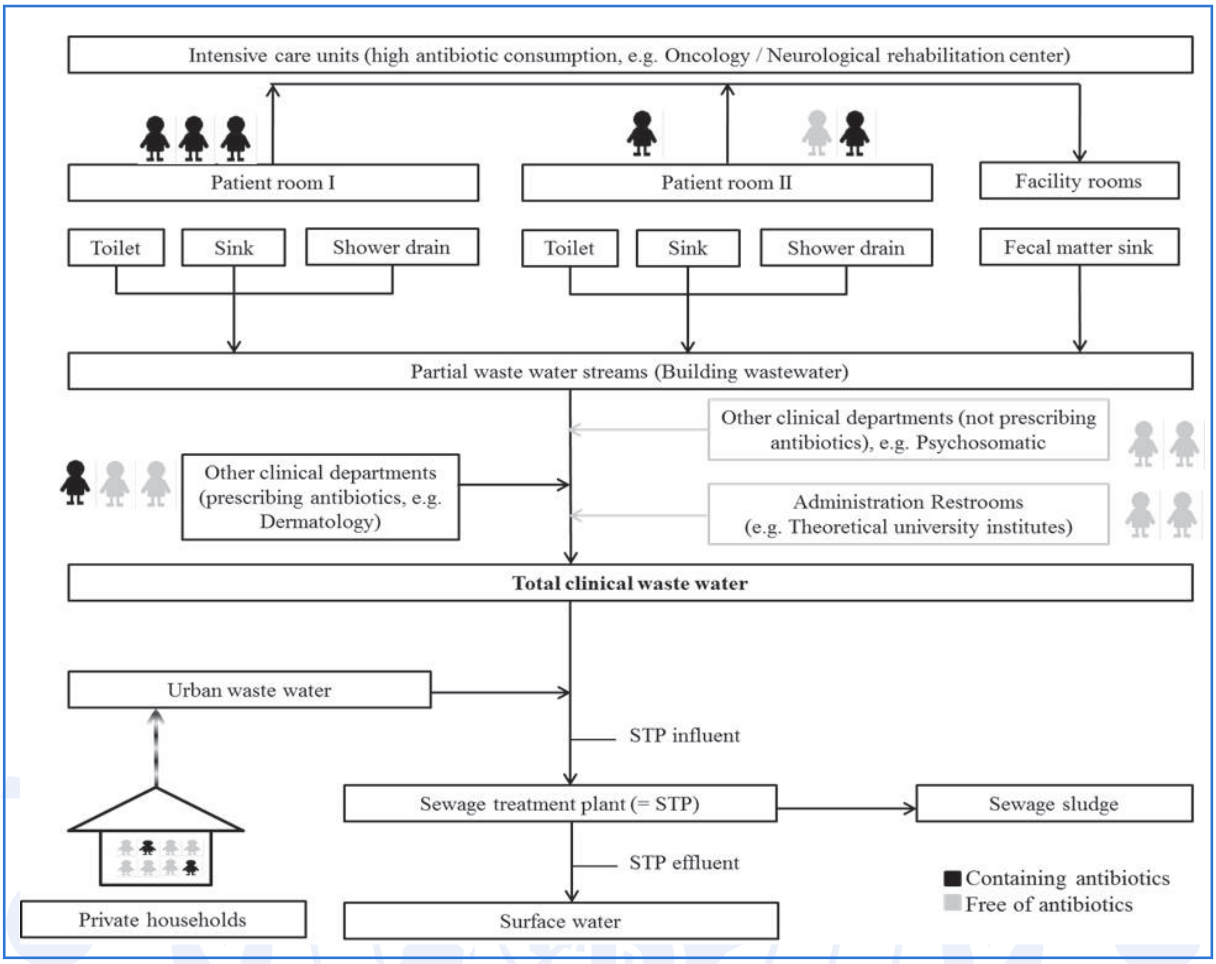


Figure 1: Schematic overview of clinical wastewater streams (from patient's room into surface water). Wastewater stream, antibiotic-free (= grey) and contaminated with antibiotic residues (= black) (Voigt, A. et al., 2019).

an increase of the antibiotic residue concentration could be detected during temporal stagnation of the aqueous phase. This phenomenon has been explained by a possible penetration of the antibiotics into the biofilm, their subsequent accumulation in the biofilm and a back diffusion into the aqueous phase after rinsing of the system (Voigt, A. et al., 2019).

The presented study is part of a PhD-Thesis which is also focused on the complexity and the importance of clinical wastewater as well as the development of a fast and simple screening method for a high number of antibiotics in different aquatic matrices. The study shows that wastewater systems of hospitals represent a potential reservoir for antibiotic residues in areas of direct exposure for vulnerable patients, especially for clinics with high antibiotic consumption. To the best of our knowledge, the occurrence of high antibiotic residue concentrations in clinical sanitary facilities is neglected in the current regulatory guidelines (e.g. cleaning plan). Therefore, there is a need for further research on the possible influence of such high concentrations on the respective microbiome as well as operational research for the development of possible solutions for the reduction of antibiotic residues in clinical sanitary units to inform future guidelines and respond to this major challenge.

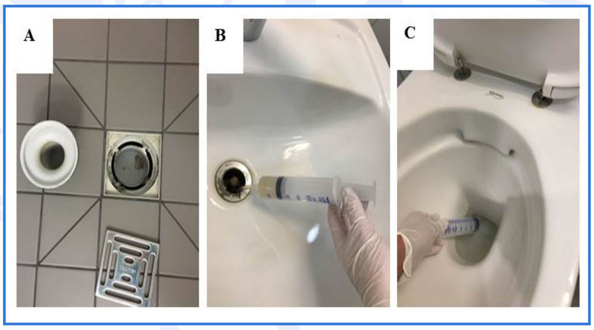


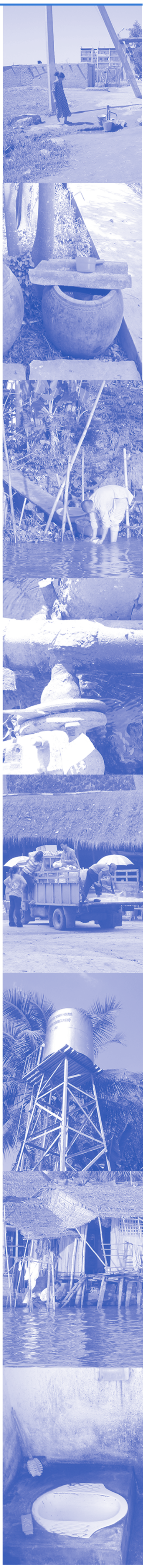
Figure 2: Sampling spots (exemplary): A) shower drainage B) sink and C) toilet (Voigt, A. et al., 2019)

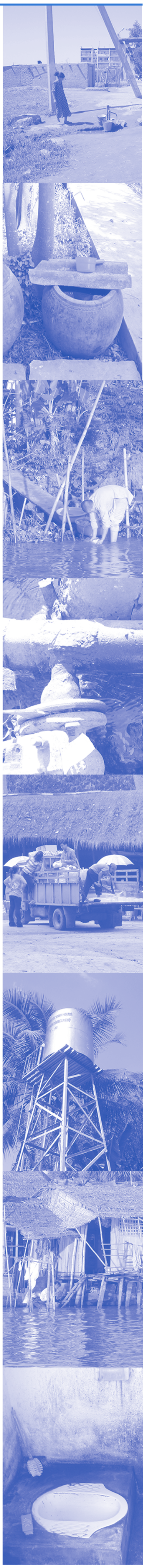
References

Bengtsson-Palme, J., Larsson, D. G. J., 2016. Concentrations of antibiotics predicted to select for resistant bacteria: Proposed limits for environmental regulation. Environment International 86, 140–149.

Bundestierärztekammer (BTK), 2015. Leitlinien für den sorgfältigen Umgang mit antibakteriell wirksamen Tierarzneimitteln. Deutschen Tierärzteblatt , 1–24.

BVL,Paul-Ehrlich-Gesellschaft für Chemotherapie e.V., 2016. Germap 2015 Antiinfectives Intelligence, Rheinbach.





Cassini, A., Högberg, L. D., Plachouras, D., Quattrocchi, A., Hoxha, A., et al., 2018. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015 - A population-level modelling analysis. The Lancet Infectious Diseases , 1–11.

Diwan, V., Tamhankar, A. J., Khandal, R. K., Sen, S., Aggarwal, M., et al., 2010. Antibiotics and antibiotic-resistant bacteria in waters associated with a hospital in Ujjain, India. BMC Public Health , 414–421.

Europäisches Parlament, Rat der Europäischen Union. Verordnung (EG) Nr. 1831/2003 des Europäischen Parlamentes und des Rates vom 22. September 2003 über Zusatzstoffe zur Verwendung in der Tierernährung 30.12.2005.

Feuerpfeil, I., López-Pila, J., Schmidt, R., Schneider, E., Szewzyk, R., 1999. Antibiotikaresistente Bakterien und Antibiotika in der Umwelt. 42, 37–50.

Fleming, A., 1945. Sir Alexander Fleming - Nobel Lecture. URL: https://www.nobelprize.org/prizes/medicine/1945/fleming/lecture [accessed: 21.11.2018].

Jutkina, J., Marathe, N. P., Flach, C.-F.,Larsson, D. G. J., 2018. Antibiotics and common antibacterial biocides stimulate horizontal transfer of resistance at low concentrations. Science of the Total Environment 616-617, 172–178.

Kümmerer, K., 2003. Significance of antibiotics in the environment. The Journal of Antimicrobial Chemotherapy 52, 5–7.

Kümmerer, K., 2009. Antibiotics in the aquatic environment - a review - part I. Chemosphere 75, 417–434.

Müller, H., Sib, E., Gajdiss, M., Klanke, U., Lenz-Plet, F., et al., 2018. Dissemination of multi-resistant Gram-negative bacteria into German wastewater and surface waters. FEMS Microbiol. Ecology 94, 1–11.

Rizzo, L., Manaia, C., Merlin, C., Schwartz, T., Dagot, C., et al., 2013. Urban wastewater treatment plants as hotspots for antibiotic resistant bacteria and genes spread into the environment: a review. Science of the Total Environment 447, 345–360.

Saga, T., Yamaguchi, K., 2009. History of Antimicrobial Agents and Resistant Bacteria. Japan Medical Association Journal 52, 103–108.

U.S. Centers for Disease Control and Prevention, 2013. Antibiotic Resistance Threats in the United States, 2013. Atlanta.

Voigt, A., Färber, H., Wilbring, G., Skutlarek, D., Felder, C. et al., 2019. The occurrence of antimicrobial substances in toilet, sink and shower drainpipes of clinical units: A neglected source of antibiotic residues. International Journal of Hygiene and Enviromental Health. DOI: 10.1016/j.ijheh.2018.12.013.

Walsh, T. R., 2010. Emerging carbapenemases: a global perspective. International Journal of Antimicrobial Agents 36, 8–14.

Westphal-Settele, K., Konradi, S., Balzer, F., Schönfeld, J., Schmithausen, R., 2018. Die Umwelt als Reservoir für Antibiotikaresistenzen. Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz 61, 533–542.

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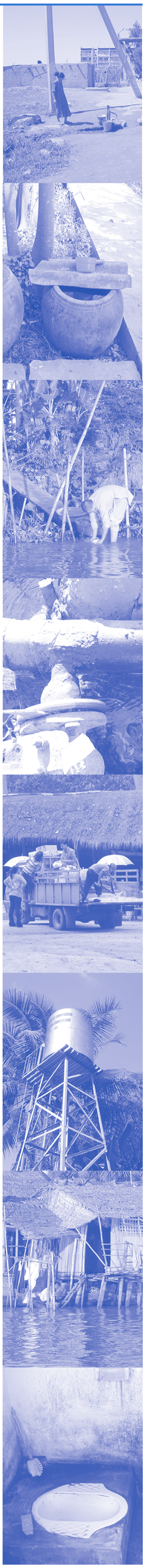
Addressing the FUTURE of WATER – showcase of an interdisciplinary and applied PhD program enabling international exchange

An interdisciplinary programme to shape the water researchers of tomorrow

Ever increasing water demand and changing dynamics within the aquatic environment due to climate change require novel ways to address questions around safe and sustainable water use and reuse. Large-scale technological methods to minimize the anthropogenic effects on the water cycle are challenging to develop, expensive and energy consuming. Thus, interdisciplinary and cross-sector approaches to Water, Sanitation and Health (WASH) can help to manage and minimize water associated risks to society.

In 2013, the state government of North Rhine Westphalia, in Germany, launched the strategy “Progress NRW” (Fortschritt NRW) to strengthen the local research for sustainable development and promote interdisciplinary and solution-oriented approaches. In the first phase, 12 structured PhD programs received funding covering a multitude of topics, ranging from research about the opportunities and challenges brought



by the global refugee migration to the health care in Germany, to gerontological research about well-being.

FUTURE WATER (http://www.nrw-futurewater.de/index.php/home.html) is one of these PhD programs and it kicked off in November 2015. The first cohort consisted of 12 implemented projects and 2 associated projects focusing on sustainable solutions for the challenges of the water sector. The program brought together PhD students with different backgrounds, such as environmental engineering, water chemistry, microbiology and – more exotic but in line with its interdisciplinary focus – philosophy and business economics, to position themselves and their work at the juncture of academia, society and policymaking. Thanks to the trans- and interdisciplinary nature of the program, requiring the students to work closely with each other as well as with mentors, the PhD projects strongly focussed on current and future water challenges in the urban context.

Figure 1: First cohort of PhD Students under the program FUTURE WATER (2015) (Source: Leifels)

As one of the PhD students in the first cohort, I worked on the project "Application of molecular methods for the detection and evaluation of enteric human-pathogenic viruses in complex water matrices" at the Department of Hygiene, Social and Environmental Medicine at the Ruhr-University Bochum under the supervision and guidance of Prof. Michael Wilhelm. The project aimed at investigating the environmental microbiological aspects of WASH with a multi-disciplinary approach to evaluate the occurrence of waterborne human virus pathogens and their interaction with their immediate aquatic environment. While the focus of my work was to develop a culture-independent molecular method to determine virus infectivity, working at the Medical Faculty allowed me to have a broader view on the issues related to water and health.

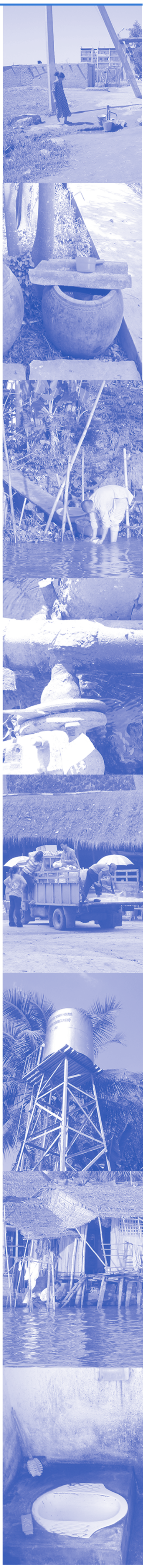
A framework for international collaborations across research fields

In the very early stages of their theses, all FUTURE WATER doctoral candidates attended the 7th International Young Water Professional (YWP) Conference of the International Water Association (IWA) held in December 2014 in Taipei, Taiwan. During the event, I had the chance to meet Dr. Petros Muchesa and Prof. Tobias G. Barnard, both from the University of Johannesburg and the South African National Institute for Occupational Health, whose work concerned the assessment of the co-occurrence of free-living Amoeba (FLA) and amoeba-resistant bacteria (ARB) in the drinking water distribution system as well as the investigation of drinking water biofilms in several hospitals in Johannesburg, South Africa (Muchesa et al., 2016). Independently and on their own capacity both, FLAs such as *Naegleria fowleri* and several Acanthamoeba species and their associated bacteria (e.g. *Serratia marcescens* or *Stenotrophomonas maltophilia*) are of some public health concern. Their presence in premise plumbing and taps of sensitive areas in hospitals add another dimension to their relevance in the environmental health context, as demonstrated by the studies of Dr. Muchesa on the microbial occurrence in drinking water distribution systems (Muchesa et al., 2016; Muchesa et al., 2017).

A second encounter at the 2015 YWP conference, gave life to a collaboration between the University of Johannesburg and the Ruhr University Bochum, which led to a follow-up study to investigate the occurrence of additional amoeba-associated bacteria, in particular Legionella, in the water distribution systems of three hospitals in Johannesburg (Muchesa et al., 2018). Utilizing DIN-ISO/TS approved molecular protocols, it could be shown that up to 380 genomic copies of *L. pneumophila* were present inside *Vermamoeba vermiformis* originating from taps in the Intensive Care Unit, Neonatal wards or operating theatres. The proximity of such health-care associated respiratory pathogens to presumably immunocompromised patients poses a public health risk.

Close to the end of my thesis work, I got the opportunity to conduct a six-week research visit to the Water Institute at the Gillings School of Global Public Health, University of North Carolina in Chapel Hill, NC, USA. The brief stay at this very innovative institution allowed me to gain insights into interdisciplinary areas of global sustainable water management, health and human development as well as universal access to safe water, sanitation and hygiene for all. These research fields were intrinsically linked with previous projects I conducted on the microbiological risks in water basins, going beyond the molecular level and addressing the human role in managing and controlling the environmental risks.

One project I contributed to was aimed at collecting information about the management of WASH services in 72 countries. The analysis of the semi-structured surveys conducted with WASH practitioners, within the initiative "Safe Water for All" and under the lead of Dr. Karen Setty and Prof. Jamie Bartram, revealed that among the targets of Sustainable Development Goal (SDG) 6, the areas of wastewater and sewage sludge emerged as top priorities. To achieve these targets, survey participants recommended putting a focus on capacity building and knowledge generation (Setty et al., 2018).



Another project, in collaboration with Dr Emanuele Sozzi and Prof. Mark Sobsey, had the aim of understanding how to address questions associated with the emergence of relatively high persistence of non-enveloped enteric viruses, such as Ebola, in faecal waste. Recent outbreak events in the Democratic Republic of Congo revealed the lack of protocols and reagents for a fast and reliable physico-chemical inactivation of bulk volumes of potentially hazardous human faecal waste during the outbreak. The assessment of benzalkonium chloride as a disinfection method of highly complex organic matrices, such as faeces, showed promising properties of the reagent and led to the recommendation to include it in guidelines for the inactivation of high-risk waste (Sozzi et al., 2018).

The direct implementation of the research endeavour into concrete projects

In parallel to the collaboration with Dr Muchesa and Prof. Barnard in Johannesburg, the original thesis work on the development of a culture-independent method to distinguish virus infectivity in the aquatic environment made progress and found a practical application. An initial laboratory-based evaluation of the two intercalating reagents propidium monoazide (PMA) and ethidium monoazide (EMA) showed promising results and allowed for a successful removal of false-positive signals of several enteric viruses after inactivation with chlorine and high temperatures (Leifels et al., 2015). The ethidium and propidium monoazide (EMA/PMA) based assay was then adapted to be used on surface water samples in the context of the SAFE RUHR project (Leifels et al., 2016). The research endeavour of the project, which was funded by the German Ministry for Research and Education (BMBF), brought together a wide variety of disciplines to determine whether it is safe to use the Ruhr River in Essen, Germany, as a recreational bathing side.

According to the European and German regulations, declaring a river safe for bathing requires a long-term risk assessment. Considering the occurrence of enteric viruses such as human adenovirus (HAdV), members of the family Enterovirus and Rotavirus, which have been identified as the main hazards, leading to the highest burden of disease (Strathmann et al., 2016). Previous European projects evaluating similar river systems showed that all methods currently employed to determine the viral load of a water body like the Ruhr River have their own inherent disadvantages. While molecular detection is quick and cheap, it does not allow for the distinction of virus infectivity. Culture-based methods, on the other hand, detect every infectious virus particle in the sample but take up to 14 days before results can be obtained. The application of the adapted version of the EMA/PMA based molecular assay showed that the pre-treatment with the reagents successfully removes non-infectious virus particles from the reaction and thus allows for a more precise quantitative microbial risk assessment (Leifels et al., 2016).

Through the synergy between FUTURE WATER and SAFE RUHR and with the collaboration of Dr Martin Mackowiak at the Biofilm Centre at the University Duisburg-Essen, it was decided to investigate river sediments and (epilithic) biofilms on the surface of river rocks – both neglected environmental reservoirs for faecal indicator bacteria (FIB), faecal derived coliphages as well as human pathogenic viruses – in comparison to the aquatic environment (Mackowiak et al., 2018). While the nature of both sample matrices did not allow for a quantification of human viruses, qualitative analysis using the EMA/PMA based molecular methods showed a relatively high abundance of HAdV across the samples, specifically in 54% of the biofilm samples and 50% of the sediment samples.

Figure 2: Ready for field work, collecting river sediments in Germany (Source: Leifels)

The more traditional faecal indicator Escherichia coli and the intensely discussed somatic coliphages could be detected in higher numbers in both reservoirs– both regarding colony forming units for E. coli or plaque forming units for coliphages obtained by culture methods as well as genomic copies per litre quantified by qPCR (quantitative real-time Polymerase Chain Reaction). It is therefore advised, that future studies evaluating the role of faecal originating enteric pathogens in marine and freshwater environments for public health should consider including sediments and biofilms into their sampling campaign to ensure that those reservoirs are accounted for.

The importance of an interdisciplinary approach to takle the complexity of relevant public health questions related to WaSH

Even though all the individual projects I contributed to are apparently concerned with very different topics, they all had a connecting factor, namely that interdisciplinary approaches were key to assess matters related to WASH. Regardless of the issue under investigation, whether it was drinking water biofilms in South African hospitals, sediments and biofilms as reservoirs for enteric waterborne pathogens in the urban river in Germany, infection control and prevention regarding high hazard faecal waste under outbreak conditions or the proper access to online learning resources for WASH professionals, single disciplines showed incapable of tackling the problem as a whole. Furthermore, the very nature of the water cycle ("what goes around comes around") means that issues such as virus / bacteria carrying amoeba in hospital environments or microbial pathogens enriching in sediments calls for holistic approaches.

With the help of the experiences and knowledge acquired in the interdisciplinary PhD program FUTURE WATER and the financial help of the Gateway Fellowship of the Research School at the Ruhr-University Bochum, I got the chance to work with Prof. Nicholas J. Ashbolt at the School of Public Health, University of Alberta in Edmonton, Canada, on a new study about several WASH related questions associated with the co-existence of FLA and enteric viruses.

Figure 3: Presenting with Lydia Abebe at the UN in Bonn, Germany (2017)

Prof. Ashbolt's group was just recently able to demonstrate that Vermamoeba species isolated from taps are able to harbour clinically relevant Coxsackievirus B5 (CVB5, a member of the Enterovirus family responsible for hand foot and mouth disease in children) for extended periods (Atanasova et al., 2018). Unlike the previous assumptions, CVB5 not only avoided being digested by its amoeba vehicle but also maintained infectivity for over 12 months.

If this behaviour can be shown for other enteric viruses with an even higher public health relevance, the implications for disinfection requirements might have to be adapted accordingly. Examples for viruses which might use protozoa to increase their environmental persistence are HAdV 40/41, the number one global cause of gastrointestinal disease in children under the age of five after the success of Rotavirus vaccination campaigns or Norovirus GII – which, according to the US CDC and the Robert-Koch Institute, is of concern to the public and causes outbreaks in hospitals, educational facilities and cruise ships resulting in high burden of disease and loss of income every year.

Furthermore, considering the dimension of environmental health, the putative ability of FLA to host viral contagions has potential implications on the reuse of treated wastewater, an issue discussed in regions with high water demand worldwide and for which the European Commission proposed a new set of rules to stimulate and facilitate its application in May 2018 (http://ec.europa.eu/environment/water/reuse.htm). Since the direct or indirect contact of the public with reclaimed water can never be avoided, the putative increase of virus resistance to disinfection using UV and Ozone due to its incorporation into FLA means that higher doses of these inactivation agents are required than for virions alone. Current regulations do not account for that, but future studies like the one currently under preparation at the School of Public Health, University of Alberta, could help in pro-actively addressing the issue using interdisciplinary approaches to tackle its different dimensions to improve understanding and identify methods to reduce the risk to the public.

References

Atanasova, N.D., Dey, R., Scott, C., Li, Q., Pang, X.L., Ashbolt, N.J., 2018. Persistence of infectious Enterovirus within free-living amoebae - A novel waterborne risk pathway? Water Res 144, 204-214.

Leifels, M., Hamza, I.A., Krieger, M., Wilhelm, M., Mackowiak, M., Jurzik, L., 2016. From Lab to Lake - Evaluation of Current Molecular Methods for the Detection of Infectious Enteric Viruses in Complex Water Matrices in an Urban Area. PLoS One 11, e0167105.

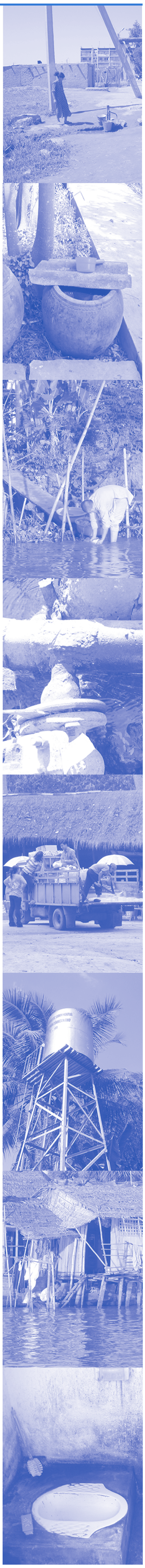
Leifels, M., Jurzik, L., Wilhelm, M., Hamza, I.A., 2015. Use of ethidium monoazide and propidium monoazide to determine viral infectivity upon inactivation by heat, UV- exposure and chlorine. Int J Hyg Envir Heal 218, 686-693.

Mackowiak, M., Leifels, M., Hamza, I.A., Jurzik, L., Wingender, J., 2018. Distribution of Escherichia coli, coliphages and enteric viruses in water, epilithic biofilms and sediments of an urban river in Germany. Sci Total Environ 626, 650-659.

Muchesa, P., Leifels, M., Jurzik, L., Barnard, T.G., Bartie, C., 2016. Free-living amoebae isolated from a hospital water system in South Africa: a potential source of nosocomial and occupational infection. Water Sci Tech-W Sup 16, 70-78.

Muchesa, P., Leifels, M., Jurzik, L., Barnard, T.G., Bartie, C., 2018. Detection of amoeba-associated Legionella pneumophila in hospital water networks of Johannesburg. Southern African Journal of Infectious Diseases 33, 72-75.

Muchesa, P., Leifels, M., Jurzik, L., Hoorzook, K.B., Barnard, T.G., Bartie, C., 2017. Coexistence of free-living amoebae and bacteria in selected South African



hospital water distribution systems. Parasitol Res 116, 155-165.

Sozzi, E., Baloch, M., Strasser, J., Fisher, M.B., Leifels, M., Camacho, J., Mishal, N., Elmes, S.F., Allen, G., Gadai, G., Valenti, L., Sobsey, M.D., 2018. A bioassay-based protocol for chemical neutralization of human faecal wastes treated by physico-chemical disinfection processes: A case study on benzalkonium chloride. Int J Hyg Environ Health.

Strathmann, M., Horstkott, M., Koch, C., Gayer, U., Wingender, J., 2016. The River Ruhr - an urban river under particular interest for recreational use and as a raw water source for drinking water: The collaborative research project "Safe Ruhr" - microbiological aspects. Int J Hyg Environ Health 219, 643-661.

Setty, K, Jiménez, A., Willetts, J., Leifels, M., Bartram, J., 2018. Global Water, Sanitation, and Hygiene Research Priorities and Learning Challenges under Sustainable Development Goal 6. Dev Policy Rev (in press)

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A joint research project: Review of innovative measures to reduce trace elements and microorganisms in surface water (ReSMo)

The environmental quality standards for surface waters have been significantly expanded in the recent amendment of the German Ordinance on the Protection of Surface Waters (OGewV, 2016). The added substances are mainly anthropogenic trace elements. In the current regulations, limitation values for microbiological parameters are established only for water intended for specific uses, such as agricultural irrigation (AGA, 1991) or recreational use (BadeGewVO, 2007; EU-BadegewRL, 2006). Nevertheless, it can often be observed that waters not explicitly intended for one of the mentioned uses are used for activities for which hygiene-relevant characteristics are important (e.g. water sports or playing children).

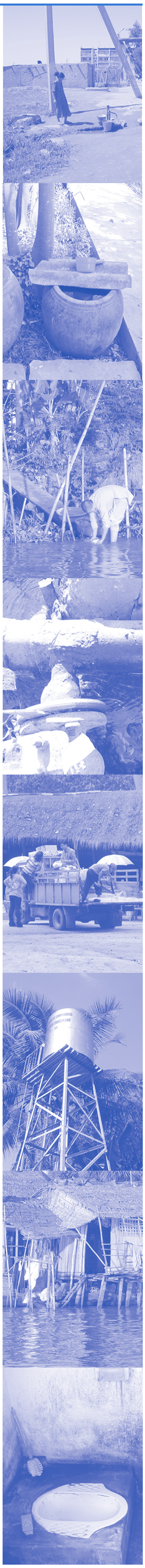
In the course of climate change, it is assumed that precipitation may change in terms of quantity, incidence and frequency. As a result, longer periods of dry weather are likely, which can lead to extreme low water flows in the watercourses made up of high amounts of purified wastewater. On the other hand, there are also more and more severe precipitation events, which can lead to a more frequent load and discharge of stormwater as well as to higher discharges through diffuse pollution from the landscape water balance.

For nearly two decades, a series of multidisciplinary research projects addressing hygienic–microbiological and physicochemical surface water contamination has been conducted by the Institute of Hygiene and Public Health, University of Bonn (IHPH) and the Erftverband, Bergheim. The studies took place in the river Swist catchment area (289 km^2, 108–330 m NHN) located in the federal state of North Rhine-Westphalia, south-west of the cities of Cologne and Bonn, in the western part of Germany.

The pollutants burden arising from sources such as sewage, combined sewer, and stormwater discharges have been already documented in various publications and research projects (Rechenburg and Kistemann, 2009; Rechenburg et al., 2006; SWIST I 2001; SWIST II 2004; SWIST III 2007; SWIST IV 2012). Additional burdens affecting contaminations with micropollutants have been identified from diffuse pollution or the run-off over drained areas (Mertens et al., 2017; Schreiber et al., 2016).

Figure 1: Retention soil filter (Source: Erftverband)

The Ministry for Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia commissioned the Erftverband and the IHPH with the research and development project "Review of innovative measures to reduce trace elements and microorganisms in surface water" (ReSMo - Überprüfung innovativer Maßnahmen zur Reduzierung von Spurenstoffen und Mikroorganismen in Fließgewässern). As part of this project, various emission



sources responsible for the burden of surface waters by micropollutants (trace elements and microorganisms) have been further verified or systematically investigated for the first time. Based on the findings of the emission sources, measures to reduce the pollution burden on receiving water bodies have been developed and evaluated for their effectiveness.

Figure 2: RSF test facility to investigate the effectiveness of RSF as an additional purification stage for WWTPs (Source: IHPH)

The pollution of the watercourses with trace elements from wastewater treatment plants (WWTP), as well as their retention, is a strong focus of water research and the optimization of water management. Among others, a particular interest is the improvement of the cleaning performance of WWTP. The discussed processes are mainly UV disinfection, activated carbon filtration or adsorption, ozonation and the use of membrane bioreactors. Another recent option is the use of retention soil filters (RSF). In order to investigate their effectiveness as an additional purification stage for WWTPs, a RSF test facility (R&D project TAPES, 2016) was set up at a WWTP and monitored during the years 2013-2016.

The aim of the ReSMo project was to expand the available data set and strengthen the statistical validation of large-scale RSF performance for treating combined sewage overflow (first validated in the project “Swist IV”) and the application of RSF as a fourth purification stage in WWTPs. Additionally, the amounts of stormwater pollution from separate sewer systems as part of the total emission balance have been verified. Last but not least, objective of the investigations was the development and evaluation of measures to reduce water pollution from drainage systems.

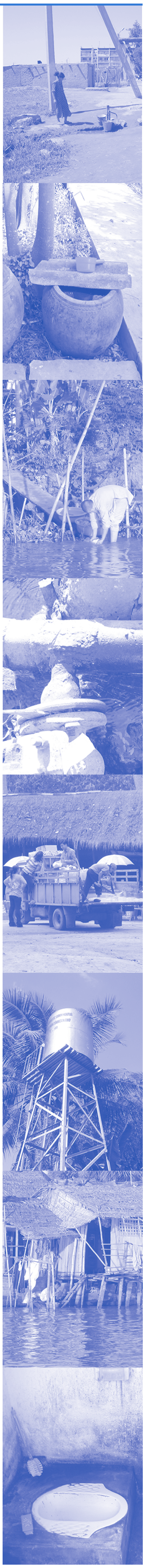
The investigated hygienic–microbiological parameters consisted of: 12 different bacteria, phages and parasites, such as the bacteria *Campylobacter* spp., *Clostridium* spp. (and *C. perfringens*), *Escherichia coli* and coliform bacteria, intestinal enterococci, *Salmonella* spp., Heterotrophic bacteria (22 °C and 36 °C); the viral indicator somatic coliphages; and zoonotic parasites such as *Giardia lamblia* and *Cryptosporidium* spp.. In addition to these hygienic–microbial parameters, chemical analyses have been undertaken by the Erftverband. Thirty chemical parameters, such as nutrients and heavy metals, and 144 micropollutants, such as pesticides, pharmaceuticals and industrial chemical compounds, have been investigated by gravimetrical, electrometrical or acidimetric methods, by HPLC–MSMS or GC–MSMS.

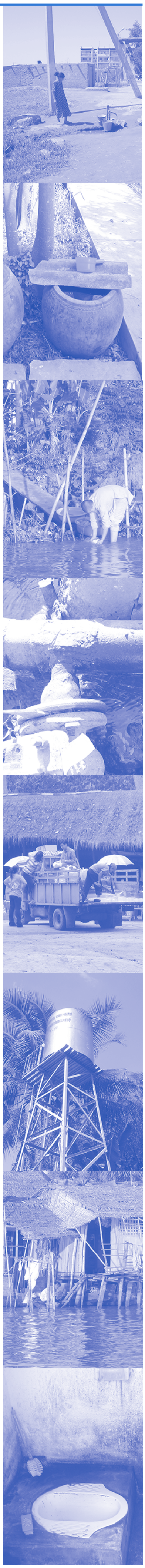
In the event of heavy precipitation, an extensive treatment of the combined sewage overflow is sometimes carried out by means of RSF in order to reduce the microbial load on rivers in Germany. The results of the RSF site monitored in this project confirmed that both microorganisms and trace elements can be effectively retained through this system. The reduction rates of the hygienic-microbiological parameters were comparable with the values mentioned in various pieces of literature (Petroski & Grobe, 2010; Scheurer et al., 2015; Uhl et al., 2008); But they were consistently lower than the values of previous studies conducted by the research partners at another RSF site (SWIST IV). Similar observations could be made in regard to the examined chemical parameters. Since the structure of the two filters is identical, the observed differences could be explained by the different operational filter speed. A lower filter speed leads to higher retention time and thus to a higher reduction rate.

Figure 3: Sampling point for the analysis of stormwater discharge from a separation sewer system at the outlet of a rainwater retention basin (Source: Erftverband)

In addition to the large-scale RSF facilities, an RSF test facility, as a forth purification stage for WWTPs, was examined for the same hygienic-microbiological and chemical parameters. For most of the hygienic-microbiological parameters, an additional reduction of the parameter levels of approximately 1 to 2 log steps could be observed compared to the reduction within the WWTP; some of the monitored parameters were below detection limit after the water had passed through the RSF. Thus, the process achieves similar or even higher reduction rates in comparison to processes most commonly discussed as fourth purification step for WWTPs.

The hygienic-microbiological and chemical investigations showed that discharges of considered clean stormwater also contribute to the load of the receiving waters. The revised German Ordinance on the Protection of Surface Waters (OGewV 2016) contains limit values for five of the investigated chemical parameters. The theoretically calculated concentrations, after dilution of the stormwater within





a potentially non-polluted water body, fall well below the values mentioned in the OGewV 2016. But since the discharges from separate sewer systems represent only one of many pathways for pollution, the entries from separate sewer systems contribute to critical total pollution of the receiving water bodies. Since the OGewV 2016 does not give values for microbiological parameters, the evaluation of these parameters was conducted in reference to the German regulation on bathing waters which is based on the bathing water directive of the European Union (BadeGewVO, 2007; EU-BadegewRL, 2006). For example, the burden of the faecal indicators E. coli and faecal enterococci fell well above the levels allowed for bathing waters. The source of these pollutions is known to be mainly the run-off from sealed surfaces (e.g. leaves, soil, dog droppings, etc.). Due to the high level of microorganism concentrations observed, false connections within the sewage system seem also to play a role.

To reduce the river pollution by agricultural drainages, a drainage filter has been developed, which is particularly suitable for many small decentral drainage systems in the project area. The filter can be installed in existing systems without major structural changes. In laboratory tests with various filter materials, the effectiveness of the retention for microorganisms and trace substances was tested and significant reduction for all tested microorganisms could be detected. The trace substances sulfadiazine and 2-methyl-4-chlorophenoxyacetic acid (MCPA) could be retained by the filter to over 99%. Thus, the newly developed drainage filter offers great potential to significantly reduce the pollution of surface waters caused by drainage discharges. The practical suitability of the method will be examined in future research projects.

References

BadeGewVO (2007): Verordnung über die Qualität und die Bewirtschaftung der Badegewässer (Badegewässerverordnung) vom 11. Dezember 2007.

EU-BadegewRL (2006): Richtlinie 2006/7/EG des europäischen Parlaments und des Rates vom 15. Februar 2006 über die Qualität der Badegewässer und deren Bewirtschaftung und zur Aufhebung der Richtlinie 76/160/EWG.

Mertens, F.M., Brunsch, A.F., Wunderlich-Pfeiffer, J., Christoffels, E., Kistemann, T. und Schreiber, C. (2017): Mikroschadstoffe im eingeleiteten Wasser aus einem Regenwasserkanal im Einzugsgebiet der Swist. Korrespondenz Wasserwirtschaft 10(3), 145 - 150.

OGewV (2016): Oberflächengewässerverordnung vom 18. März 2016 (BGBl. I S. 1429).

Petroski, K. und Grobe, S. (2010): Bewertung der Leistungsfähigkeit von vier Retentionsbodenfiltern hinsichtlich der Rückhaltung hygienisch relevanter Mikroorganismen. , IWW Rheinisch-Westfälisches Institut für Wasser. 91 Seiten, Mühlheim an der Ruhr.

Rechenburg, A. und Kistemann, T. (2009): Sewage effluent as a source of Campylobacter sp. in a surface water catchment. International journal of Environmental Health Research 19(4), 239-249.

Rechenburg, A., Koch, C., Claßen, T. und Kistemann, T. (2006): Impact of sewage treatment plants and combined sewer overflow basins on the microbiological quality of surface water. Water Science and Technology 54(3), 95-99.

Scheurer, M., Heß, S., Lüddeke, F., Sacher, F., Güde, H., Löffler, H. und Gallert, C. (2015): Removal of micropollutants, facultative pathogenic and antibiotic resistant bacteria in a full-scale retention soil filter receiving combined sewer overflow. Environmental Sciences: Processes and Impacts 17(1), 186-196.

Schreiber, C., Rechenburg, A., Koch, C., Christoffels, E., Claßen, T., Willkomm, M., Mertens, F.M., Brunsch, A., Herbst, S., Rind, E. und Kistemann, T. (2016): Two decades of system-based hygienic–microbiological research in Swist river catchment (Germany). Environmental Earth Sciences 75(21), 1393.

SWIST I (2001): Untersuchungen zur mikrobiellen Fließgewässerbelastung durch Kläranlagen. Institut für Hygiene und Öffentliche Gesundheit der Universität Bonn. 126 Seiten, Bonn.

SWISTII (2004): Untersuchungen zur mikrobiellen Fließgewässerbelastung durch Regenentlastungen der Mischkanalisation am Beispiel der Swist. Institut für Hygiene und Öffentliche Gesundheit der Universität Bonn / Erftverband. 197 Seiten, Bonn / Bergheim.

SWIST III (2007): Mikrobielle Belastung der Fließgewässer aus diffusen Eintragspfaden am Beispiel der Swist. Institut für Hygiene und Öffentliche Gesundheit der Universität Bonn / Erftverband. 124 Seiten, Bonn / Bergheim.

SWIST IV (2012): Überprüfung und Bewertung von Maßnahmen zur Reduzierung der chemisch-physikalischen und hygienisch-mikrobiologischen Belastungen von Fließgewässern am Beispiel der Swist. Erftverband, and Institut für Hygiene und Öffentliche Gesundheit der Universität Bonn im Auftrag des MKULNV NRW. 113 Seiten, Bergheim / Bonn.

TAPES (2016): Transnational Action Program On Emerging Sunstances - Final Project Report. 209 Pages.

Uhl, M., Mang, J., Maus, C. und Grotehusmann, D. (2008): Untersuchungen zur Reinigungsleistung von Retentionsbodenfiltern. 11. Regenwassertage (DWA), 1/24 - 23/24.

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Events on Water, Health and Risk Communication

April

1st Intermittent Water Supply conference
7 - 9 April 2019
Kampala, Uganda
www.iws2019.org

Waste Water Management 2019
8 - 9 April 2019
Kyiv, Ukraine
http://wwm-expo.com/event/venue

International Symposium on Waterborne Pathogens
29 - 30 April 2019
Tampa, Florida, United States
https://www.awwa.org/Events-Education/Waterborne-Pathogens

May

10th International Conference on Sustainable Water Resources Management
7 - 9 May 2019
https://www.wessex.ac.uk/conferences/2019/water-resources-management-2019

10th International conference on river basin management including all aspects of hydrology, ecology, environmental management, flood plains and wetlands
8 - 10 May 2019
Alicante, Spain
https://www.wessex.ac.uk/conferences/2019/river-basin-management-2019

UNESCO International Water Conference: Leveraging intersectorality for sustainable water security and peace
13 - 14 May 2019
Paris, France
13 May 2019 to 14 May 2019
https://en.unesco.org/waterconference

Water Microbiology Conference
14 - 16 May 2019
Chapel Hill, United States
https://waterinstitute.unc.edu/conferences/watermicro2019/

June

LET2019- The 16th IWA Leading Edge Conference on Water and Wastewater Technologies
10 - 14 June 2019
Edinburgh, United Kingdom
iwa-let.org

12th IWA International Conference on Water Reclamation and Reuse
16 - 20 June 2019
Berlin, Germany
iwareuse2019.org

10th IWA International Symposium on Waste Management Problems in Agro–Industries
19 - 21 June 2019
Rhodes, Greece
agro2019.itu.edu.tr

Asia Sewage Sludge Treatment Congress 2019
26 June 2019
Shenzhen, China

International Young Water Professionals Conference
23 - 27 June 2019
Toronto, Canada
iwa-youngwaterprofessionals.org

August/September

World Water Week: „Water for society – Including all“
25 - 30 August 2019
Stockholm, Sweden

20th International Symposium on Health Related Water Microbiology
15 - 20 September 2019
Vienna, Austria
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