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WATER & RISK

Dear reader,

I hope you are well. What used to be a polite phrase has gotten more meaning in the light of the Covid-19 pandemic. Suddenly, our regular life got deeply affected and we had to put many things on hold. Of all the effects that this pandemic had on us, to me one of the most difficult was the interruption of social contacts and the forced distancing. Suddenly, visiting my parents was undesirable, our family had to discuss who we would be putting at risk, if we would meet, and how we should behave in this situation. My living room was becoming my workspace and meeting colleagues became a virtual event. We all had to learn that keeping a distance is necessary to protect ourselves and others. And we had to find ways to communicate and stay in contact with those whom we couldn´t meet personally.
With you, our readers, we have always been communicating from a distance and we are upholding this tradition. In issue 30 of the Water&Risk Newsletter, we focus on the One Health concept. Although Covid-19 is a perfect example for an infectious disease that requires a holistic thinking and the One Health concept fits for work related to the SARS-CoV-2, we are happy to present our readers different research projects that address the application of the One Health approach specifically for water-related risks.
We hope you enjoy reading from young scientists about their projects and as usual, we appreciate your feedback,

Stay safe!

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One Health – an integrated approach to health and well-being

It has been well established that health is not merely determined by microbiology, pathology or physical fitness, but a complex web of social, economic and ecological factors. The so-called "social determinants of health" clearly illustrate how social dynamics (i.e. socioeconomic status, education level, risk behaviour, etc.) mediate exposure to pathogens and toxins, access to healthcare and health-promoting factors (e.g. green spaces, healthy diets, etc.) (Dahlgren & Whitehead, 1991). Therefore, when seeking health improvements, the social environment needs to be considered. The social environment has a significant impact on the physical environment, including both the built environment and the natural environment, and vice versa. Physical infrastructure is often less developed in socially-deprived communities (CSDH, 2008), reflected in lower access to healthcare facilities (Butler et al., 2013), food supply (Leite et al., 2019) and green infrastructure (WHO, 2019). At the same time, societal processes, including urbanization, agricultural expansion and industrialization, are impacting the natural environment, giving rise to a multitude of health risks. To analyze and tackle modern health challenges sustainably, it is, therefore, necessary to utilize interdisciplinary, holistic approaches addressing pathophysiological, social and environmental aspects. One such approach, gaining increasing recognition over the past years, is One Health.

The One Health approach

The One Health approach originated from veterinary medicine and entails the interdependence of human health, animal health and environmental health (Evans & Leighton, 2014). In fact, One Health is based on the acceptance of Virchow's statement: "between animal and human medicine there are no dividing lines—nor should there be" (De Giusti et al., 2019:e64). One Health calls for the collaboration between human and animal medicine, along with their associated public health disciplines. While originally focused on the interlinkages of human and animal disease transmission and its control and prevention, modern One Health - as pioneered by Peter Steele and Calvin Schwabe - emphasizes the role of ecology for human and animal health. The importance of the environment for human and animal health was further emphasized in the 12 Manhattan Principles formulated at a conference of the Wildlife Conservation Society in 2004 (Cook et al., 2004). Since then, One Health has experienced increasing momentum, fueled by the avian and swine influenza pandemics in the early 2000s and the high-level endorsements of international organizations. The Tripartite Agreement between the World Health Organization (WHO), the Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE), published in 2010, highlighted the need for intersectoral collaboration to meet the health challenges at the human-animal-environment interface, promoting the adoption of One Health. The most commonly used definition of One Health was coined by the One Health Commission as "the collaborative effort of multiple health science professions, together with their related disciplines and institutions – working locally, nationally, and globally – to attain optimal health for people, domestic animals, wildlife, plants, and our environment" (Gibbs, 2014:87).

Figure 1: Animals feeding on urban waste, Ahmedabad, Indien (Source: T. Falkenberg)

Despite the consensus that the three dimensions of One Health have equal weight, the dominant topics remain zoonotic and vector-borne diseases (Rabinowitz et al., 2018), often neglecting the underlying environmental dynamics. For this reason, there have been recurrent calls for stronger involvement of ecology and social science in One Health to holistically analyze the social-ecological systems influencing the dynamics of the One Health nexus. In the graduate school 'One Health and urban transformation' (Germany), we differentiate between 'Classical One Health', which follows a pathogenic approach and focuses on human-animal interactions within their joint environment (Figure 1), and the 'Extended One Health' approach that addresses underlying structural issues (both environmental and social) as primary intervention points and applies a more salutogenic perspective. The latter covers issues such as land-use changes, water pollution, deforestation and environmental degradation in general.

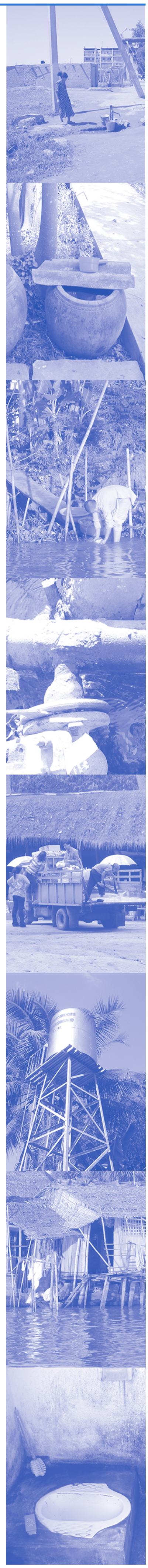
Water Dimensions of One Health

Water forms the foundation for human survival and health. As little as two to three days without adequate water intake lead to severe dehydration and even death. Beyond hydration, water is required for hygiene; it has been demonstrated that low water availability leads to reduced hygiene behaviour (Gilman et al., 1993), which in turn creates health risks. Additionally, water is essential for food production (irrigation), as well as food preparation (cooking). Without sufficient access to water resources, human (as well as animal) health and survival is put in jeopardy. This is reflected in human settlement patterns that have historically occurred along rivers, lakes or any other freshwater sources.

Figure 2: Wastes and water in Accra, Ghana (Source: T. Falkenberg)

From a One Health perspective, water forms an important intersection point, as water effluents from humans and animals are carried into the wider environment to be used again by other human or animal populations. The role of water in disease transmission is well established, with a range of water-borne diseases still threatening health and the WASH (Water, Sanitation, Hygiene) infrastructure lagging behind population growth in many low-and-middle-income countries (Bartram, 2015). As surface water sources are often shared among humans and animals at some point along the watercourse, zoonotic pathogen exchange can be facilitated by water. Not only faecal pathogens can be exchanged via water, but also chemical compounds from agriculture (pesticides and fertilizers) can be flushed into waterways if excessively or inadequately applied; industrial effluents – including organic and chemical toxins and colouring dyes –, as well as pharmaceutical effluents, are commonly released into surface water (Hamilton et al., 2007). As a consequence, water (and surface water in particular) forms a melting-pot of substances released by communities, agriculture, hospitals, industry and animals (Figure 2). Such water contamination can have devastating impacts on aquatic life as well as the self-regulating capacities of water bodies. At the same time, these water resources are utilized for irrigation, hydration and hygiene, consequently exposing populations to a multitude of health risks. Therefore, water is an important component of One Health interactions and serves as a critical control point. Water monitoring should be part of integrated One Health surveillance and safeguarding water quality is essential for achieving optimal health for all.

While ensuring water safety is a prerequisite to minimizing the health risks of the One Health nexus, water also holds salutogenic potential and can thus contribute to health improvements (particularly in the sphere of mental health). The visual and acoustic stimuli of water have inherent properties that contribute to relaxation and mental health improvements that have different levels



of impact depending on individual and physical factors (such as the aesthetic and water quality). Therefore, in the context of One Health, water interventions can create a dual benefit of reducing health risks (through ensuring high water quality) and promoting mental health (through aesthetically pleasing water bodies).

Forschungskolleg 'One Health and urban transformation'

The Forschungskolleg 'One Health and urban transformation' (Figure 3) is a graduate school funded by the Ministry of Culture and Science of the state of North Rhine-Westphalia, Germany, and is jointly operated by the University Bonn, the University of Applied Science Bonn Rhein-Sieg and the United Nations University - Institute for Environment and Human Security. In the graduate school, 13 doctoral students (Figure 4) conduct their research on various One Health topics in the four study sites: Accra, Ghana; Ahmedabad, India; Ruhr Metropolis, Germany; and São Paulo, Brazil. The doctoral students have diverse academic backgrounds, including public health, geography, biology, mathematics, soil science, sociology and nutritional science. The ongoing research projects were developed transdisciplinary through close collaboration with stakeholders from politics, academia, private sector and civil society. As a result, interdisciplinary, action-oriented research projects were conducted to holistically examine the health challenges of the One Health nexus in the context of urban transformation processes.

ONE HEALTH
& URBAN TRANSFORMATION

Figure 3: Logo of the graduate school „One Health and urban transformation"

The research topics were organized in three clusters - water, food and governance - leading to the examination of a wide range of One Health challenges. Within the governance cluster, the analysis was focused on the mechanisms of One Health implementation, including the challenges of developing intersectoral collaborations and the effectiveness of joint interventions. The food cluster focused on the environmental and health impacts of agricultural production and corresponding diets, as well as the specific challenges of urban agriculture. The water cluster examined the central research question: How to promote health through the management of water resources?

In this issue, three research projects of the water cluster will be presented, demonstrating distinct perspectives and approaches. Two projects followed a more pathogenic approach, whilst one analyzed the salutogenic potential of urban blue. The first study examines the spread of antimicrobial resistance via wastewater in Germany, combining sewage monitoring with an analysis of socio-spatial antibiotic usage behaviour. The next study was conducted in Ghana, focusing on the influence of land-use changes on water-borne diseases, with a particular emphasis on schistosomiasis. The third (salutogenic) study was conducted in India and Germany, researching the blue health needs of elderly populations.

Figure 4: Dr. Timo Falkenberg and the doctoral students of the graduate school "One Health and urban transformation", class 2017-2020 (Source: S. Keller)

Call for Applications

The second phase of the Forschungskolleg 'One Health and urban transformation' is due to start in January 2021, with the Call for Applications opening in the coming weeks. Doctoral candidates from all disciplines can apply with their research ideas to address the overarching question: How can One Health contribute to sustainable health improvements and food security? The second phase is organized in two clusters: governance and food systems with six cross-cutting themes: water, antimicrobial resistance, infectious diseases, society, sustainability, and institutions. For further information about the Forschungskolleg and the Call for Applications please refer to our website: *www.zef.de/onehealth.html*.

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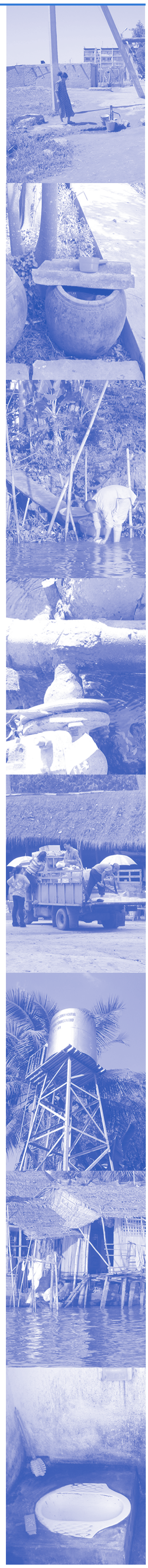

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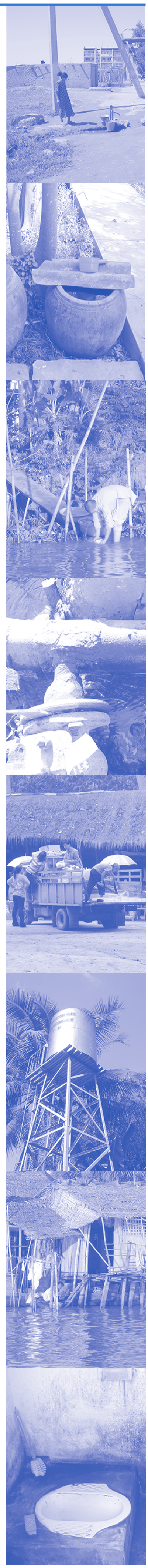
Don't waste water: wastewater surveillance, antimicrobial resistance and One Health

Although the topic of wastewater and sanitation has been long stigmatized in many countries around the world, one thing is indisputable: we all excrete faeces and urine. This process is not limited to human beings but includes other mammals and birds as well. In fact, most anthropogenic activities with water result in the production of some kind of wastewater, which is why it is defined as "used water from any combination of domestic, industrial, commercial or agricultural activities, surface runoff/stormwater, and any sewer inflow/infiltration" (Tilley et al., 2008, p. 175). As such, wastewater is often considered an unusable by-product that needs to be disposed of. In most developed countries, wastewater is discharged and collected in a piped sewer system connected to a centralized wastewater treatment plant with several treatment stages. The treated wastewater is subsequently released to receiving surface waters. However, on a global scale, the vast majority of it is discharged untreated into the environment (WWAP, 2017).

Recently, it has been recognized that wastewater is a rich resource. It contains several valuable substances like organic matter or nutrients such as phosphorus and nitrogen and it can also be used to generate energy or provide a secondary source of water for different sectors (International Bank for Reconstruction and Development / World Bank, 2019). These aspects are particularly interesting in a world that is dominated by population and economic growth, urbanization and urban transformations, as well as climate change, which all create and drive different water-related issues (WWAP, 2017). In this context, the concept of circular economy, especially in relation to the re-use of wastewater, has become more important than ever to recover resources (International Bank for Reconstruction and Development / The World Bank, 2019). Re-using wastewater offers many benefits but comes with numerous risks. Aside from being a valuable resource for nutrients, wastewater is also a vehicle for various pathogens, i.e. virus, bacteria, helminths, and protozoa. Hence, its use can have significant adverse impacts on health. These impacts can be direct, e.g. faecal-oral infections, or indirect in form of sequelae of infections, e.g. stunting, and also with consequences on the broader well-being, e.g. anxiety (WHO, 2018). Adverse health outcomes due to the contact with wastewater are not limited to humans but also occur in animals (Elahi et al., 2017). The discharge of untreated wastewater to the environment can have significant effects on the ambient ecosystems (WWAP, 2017). The interlinkage of these three domains – i.e. humans, animals and the environment – lies at the core of the One Health approach, addressing two main components: institutional collaboration across sectors



and borders, and the intertwined health of the three domains – humans, animals and the environment. A profound change in one of the domains will always have consequences in the other two.

Wastewater surveillance can complement existing mechanisms

Monitoring untreated wastewater can offer insights into the health of the community or its environmental exposures because of its rich content of chemical and biological compounds (Mao et al., 2020). The associated approach of wastewater-based epidemiology (WBE) assumes that the identification and quantification of certain biomarkers mirror the health status of the community living in the respective sewerage catchment (Daughton, 2018). For instance, pathogens are discharged by infected individuals several times during a 24-h course via toilet flushing or hygiene practices (e.g. hand washing), and while cleaning indoor and outdoor facilities into the sewer system of a well-defined geographical sewerage catchment (Sinclair et al., 2008). Such pathogens or other compounds could be considered in wastewater surveillance, which could be used to complement existing epidemiological surveillance systems, contributing to completing the public health picture (Sims & Kasprzyk-Hordern, 2020).

Advantages of wastewater surveillance are numerous. Its analysis tends to be more sensitive than the reporting of diseases or clinical cases, which often only accounts for the most severe cases of an illness in the community; and the detection time can last up to several days from the actual release, due to the retention time of pathogens in the sewer systems (Sinclair et al., 2008). In addition, wastewater surveillance is applied on a population scale, thereby not posing any ethical challenges, and it offers a timelier and more cost-effective approach compared to testing individuals (Sims & Kasprzyk-Hordern, 2020). Thus, wastewater surveillance represents a promising approach for the establishment of monitoring systems for early detection of existing or emerging health issues, of particular relevance in the One Health nexus.

The number of case studies in which wastewater surveillance has been used is constantly increasing. For example, wastewater surveillance has been successfully applied as a key component in WHO's Strategic Plan of the Global Polio Eradication Initiative to detect the introduction and circulation of the poliovirus (Hovi et al., 2012). This approach has further been tested for enterovirus infections (Brinkman et al., 2017) and various pathogenic viruses, including hepatitis A virus and norovirus (Hellmér et al., 2014). Wastewater surveillance may also play a pivotal role in tackling the current coronavirus disease 2019 (COVID-19) pandemic and support global efforts to estimate the true burden of COVID-19 at the population level, revealing the level of viruses excreted from symptomatic and asymptomatic cases alike. So far, SARS-CoV-2 has been identified in wastewater in Australia (Ahmed et al., 2020), different countries in Europe (Lodder & de Roda Husman, 2020; Medema et al., 2020; Wurtzer et al., 2020), and the United States (Wu et al., 2020), among others.

Aside from its use with viruses, wastewater surveillance is also useful for the global monitoring of antimicrobial resistance (AMR). AMR is one of the greatest health challenges of the 21st century. Aarestrup & Woolhouse (2018) highlighted why monitoring of AMR is absolutely crucial and that it can contribute to: "setting national and global priorities, assessing the impacts of interventions, identifying new kinds of resistance, and supporting investigation of (international) outbreaks of resistant pathogens […], [and it] can also inform development of treatment guidelines" (Aarestrup & Woolhouse, 2020, p. 630). Current AMR surveillance systems mainly focus on the inpatient sector and on hospitalized patients who seek treatment for an infection, thereby neglecting the dynamics in the outpatient sector that contribute to the spread of AMR [22]. This makes it hard to estimate the occurrence and distribution of AMR in the wider community as the available data is biased and often relies on rather small sample sizes (Aarestrup & Woolhouse, 2020). Wastewater surveillance has been used to investigate the abundance and diversity of AMR genes and create comprehensive data on a global scale, reflecting both inpatient and outpatient patients, revealing differences between regions and the importance of locally and nationally specific parameters as opposed to variables used at the international level, such as air travel (Hendriksen et al., 2019).

Wastewater surveillance and the importance of the catchment area

Monitoring AMR in wastewater requires comprehensive knowledge of the sewer catchment area and potential sources of AMR elements, such as AMR genes, antibiotics, and resistant bacteria, holistically, based on the One Health approach (see Fig. 1).

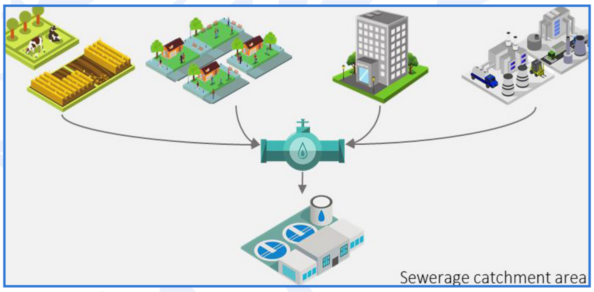


Figure 1: Potential sources of AMR elements in a sewerage catchment area (Source: D. Schmiege; icons from Canva)

Certain types of facilities are considered potential hotspots of releasing AMR elements into wastewater (Picão et al., 2013). Health care facilities such as hospitals (Müller et al., 2018), long-term care facilities as well as (pharmaceutical) industries belong to this group (Larsson et al., 2007). In addition, intensive farming facilities or slaughterhouses also play a role (Savin et al., 2020). Lastly, the presence of biocides or heavy metals can lead to co- and cross-resistance whereby the existence of these substances further selects for resistant bacteria strains via different mechanisms (Finley et al., 2013). So far, research into the role of the community and potential socio-spatial hotspots – i.e. spatial entities like neighbourhoods, in which there are higher antibiotic consumption clusters in comparison to other neighbourhoods in the same catchment area – has been limited. In order to reach such socio-spatial hotspots, it is necessary to identify individuals or groups that tend to have a worse health status and/or handle antibiotics inappropriately. For this, the social determinants of health, defined as "conditions in which people are born, grow, live, work, and age" (CSDH, 2008, p. 1), offer a promising starting point.

This study aimed at exploring this research gap, focusing on Dortmund, a city in the Ruhr Metropolis, Germany, and using a mixed-method approach: systematic literature review, behavioural and social-science survey and wastewater surveillance analysis. To analyse possible driving factors of antibiotic use in the community, we conducted a systematic literature review on determinants of antibiotic use in the community. Through this, we identified more than 590 variables, which were grouped into compositional determinants (characteristics of individuals), contextual determinants (structures in the physical and social environment) and collective determinants (socio-cultural and historical features) (Schmiege et al., 2020). In doing so, we could show that not only variables related to individuals, such as the demographic characteristics (e.g. age, education, employment, income and sex), or the pace of living, but also factors attributable to the broader environment (e.g. deprivation, seasonality and health care services) are of importance.
Based on these results, sampling points for the wastewater surveillance were selected in three socio-spatially different sub-districts in Dortmund where there are no farming activities or pharmaceutical industries of relevance (see Fig. 2). In the same districts, a quantitative household survey was conducted.

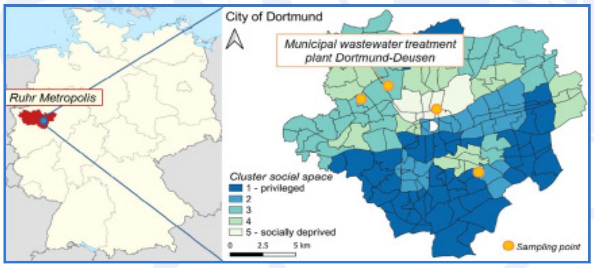


Figure 2: Sampling points in three socio-spatially distinct sub-districts in the city of Dortmund (Source: D. Schmiege; Social space clusters from Stadt Dortmund (2007)).

The aim of the survey was to gather population characteristics and to establish a baseline of knowledge, attitudes and practices (KAP) around antibiotic use and AMR as well as to identify potential risk factors for the colonization with extended-spectrum beta-lactamase (ESBL)- producing *Escherichia coli* (*E. coli*). Previous to this survey, monthly wastewater samples were taken over the course of a whole year between April 2019–March 2020 from those three sub-districts and the inlet of the wastewater treatment plant assessing the levels of AMR elements (see Fig. 3).

The wastewater samples were analysed for the occurrence of ESBL-producing *E. coli* in the laboratory of the Institute of Hygiene and Public Health, University Hospital Bonn, to explore possible differences between the selected sub-districts observable in terms of the occurrence of multidrug-resistant bacteria. The analyses are currently still ongoing. Preliminary findings of the wastewater testing suggest spatial-temporal variations between the considered areas.

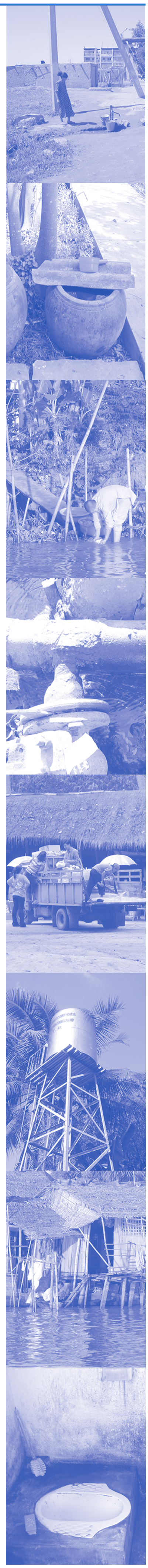
Figure 3: Wastewater samples taken at one of the sampling points within the wastewater system (Source: D. Schmiege)

Wastewater surveillance and the role of social dynamics in the spread of AMR: what's next?

Wastewater surveillance has been successfully applied to various microbiological parameters, thereby providing the opportunity to complement existing surveillance mechanisms and current studies seem promising to start to grasp and increase understanding of the occurrence and distribution of different health risks in the wider community. The study presented here is meant to be a starting point to examine the role of the outpatient community in terms of discharge of multidrug-resistant bacteria into wastewater and to gain a deeper understanding of potential driving factors behind antibiotic use. The results could be used to guide the selection of sampling points within the centralized wastewater system that should be included in a surveillance system to cover different population groups.

Analysing wastewater is not easy, because wastewater itself is a complex environment and the analysis requires advanced equipment and a laboratory with skilled personnel (Sims & Kasprzyk-Hordern, 2020). Dynamic populations, e.g. the presence of tourists and commuters, pose challenges when examining wastewater samples (Sims & Kasprzyk-Hordern, 2020). So far, this surveillance system has mainly been tested and applied in settings with pre-existing piped systems, the usefulness of this approach in low-resource settings and on-site sanitation systems still needs to be examined. The standardization of the sample collection and the methodology of the analytical procedures are other aspects which need to be addressed in order to enable comparability between different settings (Aarestrup & Woolhouse, 2020).

Nevertheless, wastewater surveillance has great potential, particularly when considering the One Health approach and its importance in the global urbanization, which will see more people living in a confined geographical area and using centralised systems.



As of now, most of its applications have looked into risks to human health. In the domain of AMR, animals have also been considered due to the circulation of AMR elements across all three One Health domains: humans, animals, and the environment. The role of the environment, in this case of the water, is often limited to its use as a transmission pathway or vehicle that poses a risk, if contaminated, to humans and animals. Whether or not AMR elements pose a risk is often only assessed in relation to human health in the clinic context, often neglecting the other two One Health domains. Wastewater surveillance for AMR presents an ideal showcase to highlight how considering all three One Health domains, i.e. humans, animals and the environment, jointly is beneficial in order to advance our understanding of a complex health issue that extends beyond human health.

Acknowledgements

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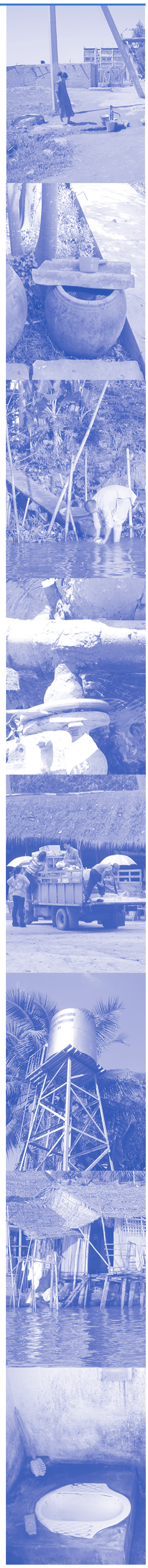

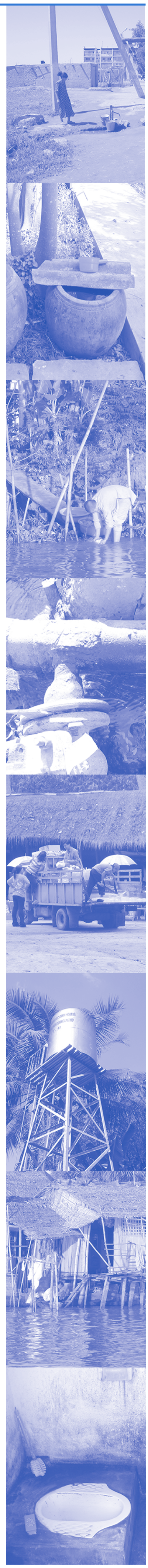

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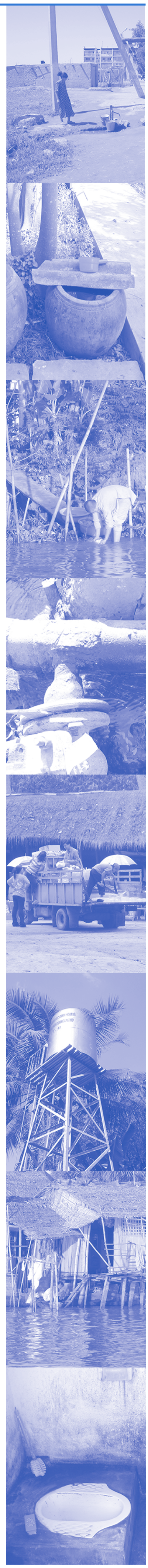
Human-surface water interactions and the transmission of water-related infectious diseases – schistosomiasis in Ghana

Water quality issues are major challenges to humanity, particularly in developing countries, due to high levels of water pollution (Mackinnon et al., 2019). The pollution of water resources is linked to human-water interactions through recreation, land use, and poor waste management, which contribute to the generation of pollutants and the exposure of humans to water-related infectious diseases (WRID). WRID are described as any significant adverse effects on human health caused directly or indirectly through changes in the quantity or quality of water systems that can lead to death, illness, or disorder (UNECE/WHO, 1999). Water is important for the survival of humans, animals, and the functioning of aquatic ecosystems, however, it can serve as the vehicle for infectious disease transmission, given poor conditions of hygiene, sanitation, and health-seeking behaviors (Falkenberg et al., 2018; Mackinnon et al., 2019). A recent global review of the literature on human-surface water interactions revealed complex linkages to human health through interconnected pathways, particularly within urban systems and river catchments (Ntajal et al., 2020). The direct dependence



on surface water systems creates possibilities for interactions between humans and animals within the environment. This can lead to the emergence of WRID such as schistosomiasis, through contacts with polluted water systems (Martel et al., 2019).

Surface water pollution and schistosomiasis transmission nexus

Schistosomiasis is a Neglected Tropical Disease (NTD), which affects the urinary and the intestinal systems of humans and animals through direct contact with polluted water. This is due to the pollution of surface water systems with human and (or) animal excreta containing eggs of *Schistosoma sp.* from an infected host (Kulinkina et al., 2019). The risk of schistosomiasis infections depends on the level of human exposure, water-contact patterns, and the definitive host immunity (Angelo et al., 2018; Kulinkina et al., 2019). The most common symptom of the disease is the observation of blood in urine or stool (Kulinkina et al., 2019; Tchuem-Tchuenté et al., 2017). Besides the environmental factors, which favor the survival and distribution of freshwater snails, humans and animals play major roles in the continuity of the schistosomiasis lifecycle (Figure 1) when they share a common water source (Chadeka et al., 2017). The Schistosomas parasite has a complex life cycle that requires freshwater snails as intermediate hosts in which the parasite undergoes development and the definitive hosts (humans and animals) in which it reaches maturity (Leger & Webster, 2017; McManus et al., 2010).

The cercariae, the parasitic larvae released from the snails, penetrate the skin of humans or animals, transform into schistosomula, enter the bloodstream, develop, pair up and start producing eggs in the bladder or rectum within approximately two weeks (Tchuem-Tchuenté et al., 2017). The interactions between *S. haematobium* (humans) and *S. bovis* (domestic animals) can lead to parasite-host switching, hybridization (emergence of new parasites), and introgression (i.e. gene flow from one species to the gene pool of another species). The consequent challenge is the emergence of new hybrid parasites, which resist the existing treatment and control measures, due to gaps in understanding of the genetic make-up of the new species. Pieces of evidence of hybridization and introgression have been reported across Sub-Saharan Africa, particularly in Senegal and Niger (Huyse et al., 2009; Webster et al., 2013; Webster et al., 2016).

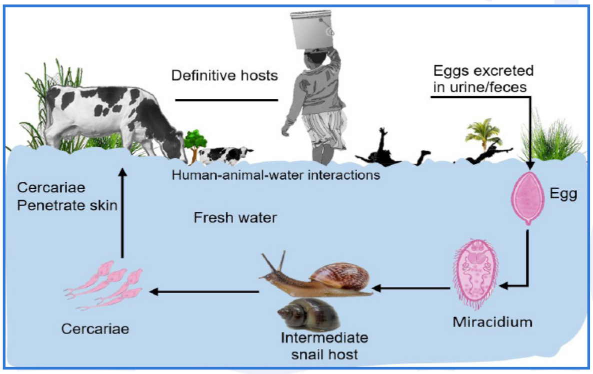


Figure 1: Schistosoma lifecycle. (Source: adapted from Ciddio et al.,2017; and McManus et al., 2010)

Human-water contact patterns and urinary schistosomiasis transmission in Accra, Ghana

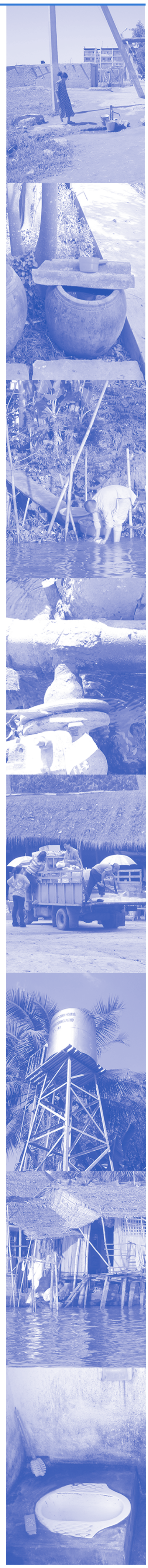
As part of the implementation of the One Health research project, a cross-sectional survey was conducted to understand the influences of human surface-water contact patterns on the transmission of urinary schistosomiasis (*S. haematobium*) in Ghana. The study recruited 336 schoolchildren between the ages of nine and fifteen from six public schools, and distributed in six communities within the Lower Densu River catchment, upon obtaining ethical approval and the required permissions from the health and the education authorities in Ghana. The communities were purposively selected, due to the prevalence of schistosomiasis, and their proximity to surface water bodies and the possibilities of human-water interactions. These communities are located in the peri-urban areas of Accra and are characterized by rapid population growth, limited access to safe drinking water, and limited access to improved hygiene and sanitation (Nyarko et al., 2018).

In addition, the study engaged the disease control officers in the health centers of the various communities and the school staff with interviews on vaccinations and prevention measures. Further, the study conducted on-site observations including the sources of drinking water for the communities and domestic animals. The binary logistic regression analysis was performed to determine the correlation between the dependent (blood in urine) and the independent variables (gender, water-contact frequency, and duration), the odds ratios, using binary data from the survey.

What are the outcomes of the study?

Observed and unreported "blood in urine". The results revealed that 29% of the schoolchildren had experienced blood in their urine in the past six months. The result of the regression analysis revealed that gender was a statistically significant predictor of blood in the urine. Odds ratio analysis shows that male schoolchildren had 4.52 fold odds of being infected by *S. haematobium* compared to female pupils. The study found that males experienced 78% of the cases of blood in urine, which is a reflection of their more frequent engagement in recreational activities such as swimming in the water. It was found that most of these cases of blood in urine were not reported to caretakers, and the few reported cases were not reported in due time. This result is of concern as untreated schistosomiasis cases can destroy the urinary systems and can potentially reinforce the *S. haematobium* transmission cycle, through the release of eggs with urine and fecal matter into surface water.

Limited access to safe drinking water, and improved sanitation and hygiene facilities. The result of the survey revealed that 49% of the children's households depended directly on untreated water from the Densu River and the surrounding streams as the main source of water. Besides the risk of cholera and diarrheal diseases, this water is the habitat of *Bulinus* snails, the intermediate host of *Schistosoma sp.*, which



releases cercariae into the water. When humans enter the water and get into contact with the cercariae they penetrate their skin and enter into the bloodstream. On-site observations revealed a critical factor in the transmission of schistosomiasis, which are cattle that share the same water sources with households in the Densu River catchment. This can facilitate the interactions between *S. bovis* and *S. haematobium*, resulting in the emergence of new hybrid pathogens.

Figure 2: Snails sampled at the community water access point in the Densu River at Kojo Ashong (Source: J. Ntajal)

It was found that Ventilated Improved Pit latrines (VIP) were available and accessible in all of the six schools included in the study. However, 53% of the schoolchildren depended on public toilet facilities at home, which were found in poor conditions and additionally required usage-fees. These conditions were the reason for 33% of the children to practice open defecation. Furthermore, 48% of those children practicing open defecation did so mainly in (and) around the water bodies. The fecal matter and urine of infected humans play a major role in the infection of the *Bulinus* snails, which in turn releases the cercariae that infect humans. As the two hosts meet in a common water body (Figure 2), the schistosomiasis transmission cycle is reinforced, amplifying the incidence and prevalence of the disease.

Surface water-contact activities. The understanding of human water-contact patterns provides a holistic view of the various activities at the community level, which predefine the levels of exposure to the cercariae. The results from the survey of water-contact activities revealed that 53% (34% male, and 19% female) of the schoolchildren were engaged in recreational activities (i.e. swimming), 28% were involved in domestic activities such as washing clothes and fetching water for households use, and 19% were engaged in occupational activities (fishing, irrigation, and crossing streams to reach the school, farms, markets, etc.). The most crucial aspects of the water-contact activities are the frequency and duration of water-contacts. It was found that 39% of the children had water-contacts more than twice per week, and 42% had an average water-contact duration of over 30 minutes. Frequent water-contacts and longer durations increase human exposure to cercariae, thus indicating a higher risk of infection (Figure 3). The result of the regression analysis shows that recreational activity was a significant exposure factor. Children, who were engaged in recreational activity (swimming), had 2.249 times the odds of *S. haematobium* infection. Children who had water-contacts of over 30 minutes per week had double the odds of being infected compared to those with less than 30 minutes of exposure per week.

Are there control and prevention measures?

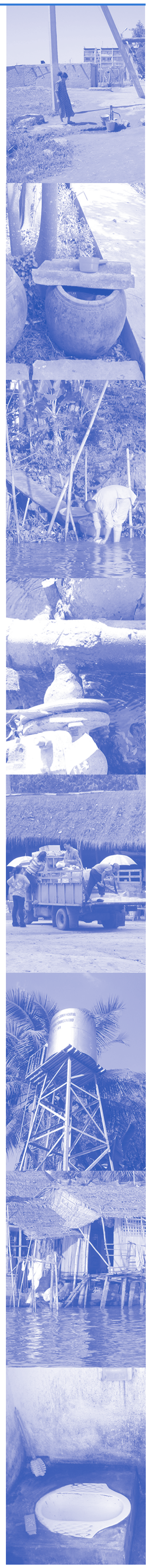
The outcome of the interviews with the disease control officers of the health centers in the various communities and the school staff revealed that there were no schistosomiasis prevention measures established in the communities as well as in most endemic areas in Ghana. As a control measure in the communities, praziquantel was supplied by the government and NGOs during mass drug administration campaigns. In our study, it was found that 46% of the children had received this treatment. However, studies proved that besides the side effects, praziquantel is not the best option as it is not efficient in controlling the schistosomes (Martel et al., 2019; Vale et al., 2017). The disease control officers also mentioned the implementation of sensitization programs to educate the children on the effects and the transmission pathways of the helminthic diseases in the area, but the impacts of such programs on the communities appeared insufficient, due to lack of collaborative efforts among stakeholders.

The way forward – One Health approach?

Schistosomiasis is of considerable medical and veterinary significance, which requires integrated and collaborated solutions for its prevention and eradication. These strategies are part of the holistic One Health approach, which takes into account human interactions with animals (animal definitive host and the intermediate snail host) within the natural and the built-environment. As part of the One Health approach, interdisciplinary and collaborative approaches focusing on human, animal, and environment dimensions can reduce human exposures to *Schistosomas sp.* as well as ensure human and environmental health security. The study highlighted gaps and challenges that still need to be tackled to control and prevent the disease. Considering the transmission cycle of *Schistosomas sp.*, human-water interaction is a key component in the functioning and continuity of its lifecycle.

Figure 3: Community sharing the same water source with livestock in the Weija Lake, Ghana (Source: J. Ntajal)

Therefore, reducing these interactions, through consistent supply of safe drinking water, access to improved sanitation and hygiene free of charge in communities, reducing animals access to the community drinking water sources, corroborated by the implementation of public sensitization programs,



combined with snail population and vegetation control can contribute to the reduction of human exposure and the prevalence of schistosomiasis.

Acknowledgment

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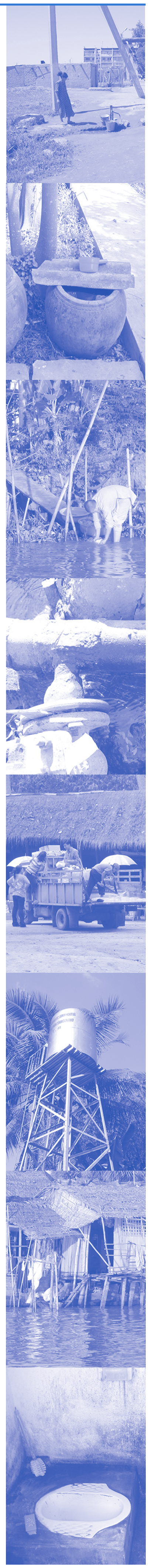
The salutogenic aspects of urban waters: Promoting 'blue health' in cities

Generally, a multitude of pathways links urban waters to health (Rietveld et al., 2016). While research of the urban blue (Kistemann et al., 2010) has focused for a long time on hydrophobic (i.e., harmful) dimensions – e.g. water as a carrier for pathogens and the broader societal impacts of water-associated diseases (Rietveld et al., 2016) – the notion of salutogenic (i.e., health-protecting and health-promoting) aspects for human health has received attention only in recent decades (Foley et al., 2019). This is in so far remarkable as increasing research points to the many ways in which people benefit from blue space exposure beyond the essential provisions for water, sanitation and hygiene (WASH). Four main mechanisms link blue spaces to human health in a broader sense: (I.) provision of (regulating) ecosystem services and improved environmental quality; (II.) increased physical activity; (III.) relaxation and mental wellbeing; and (IV.) enhanced social interactions (White et al., 2018).

In the urban context, blue spaces such as rivers, lakes, ponds, and fountains have shown to offer significant cooling effects on urban heat islands (Völker et al., 2013; Sun & Chen, 2012) and canfurther reduce air and noise pollution (De Coensel et al., 2011; You et al., 2010; Kuttler et al., 2002). As highly attractive destinations, blue spaces motivate urban dwellers to be physically active and to engage with others, e.g., to spend time with family and friends, thus improving the physical and social wellbeing (Vert et al., 2019; White et al., 2018; Bell et al., 2017). By enabling stress relief, restoration and mental health care, blue spaces seem to be a potent instrument against major mental health problems that are significantly associated with urban living (Bell et al., 2017; Gruebner et al., 2017; Nutsford et al., 2016). Given the high land prices of urban blue spaces, urban waters –if carefully planned– provide immense business opportunities with a high return on investment that, in turn, can enhance the health-related quality of life within cities in the long run (e.g., provision of jobs and high-quality housing, attracting cultural industry) (Samant & Brears, 2017; Carta, 2016).

While the diverse health hazards of water must not be neglected, it is, on the other side, fair to say that blue spaces contribute to comfortable living conditions within cities and provide direct health benefits in terms of physical, social and mental wellbeing. Research indicates that blue spaces might be most beneficial for vulnerable populations, such as socio-economically disadvantaged people (Bell et al., 2017). Additionally, 'the blue' can have beneficial effects on the urban ecosystems, for example, providing habitat for urban wildlife, increasing urban biodiversity and helping to mitigate climate change through ecological ('water-sensitive') urban design (Dysom & Yocom 2015). However, compared to green space-health research, considerable knowledge gaps exist on 'blue health' particularly within the urban context (Völker et al., 2018; Völker & Kistemann, 2015; Völker & Kistemann, 2011). For example, little is known on the differences in the "cultural geographies of water" that exist among urban populations in different spatial and cultural contexts (Foley & Kistemann, 2015). Holistic approaches that consider integrated benefits for human, animal and environmental health (One Health) are yet another item on the blue health research agenda (Foley et al., 2019). This article draws on the health potential of urban blue spaces for senior citizens that we have explored in two diverse case study areas: Ahmedabad, India, and Ruhr Metropolis, Germany.

Our work has been guided by the question: how elderly people perceive and use urban blue spaces within their city and what (e.g., which landscape features) constitutes their blue health experiences. Additionally, we wanted to understand the local policies on 'urban blueing and greening' and explore how the supply of blue spaces matches the demand of senior citizens as a vulnerable population mostly overlooked in urban development discourses (Buffel & Phillipson, 2016).



Methodological approach 'Photovoice': Capturing 'blue health' through photography

Given the health potential of blue spaces, these environments can be described as "potentially therapeutic landscapes" (Conradson, 2005) to acknowledge not only the potential adverse effects inherent in water but also the unpredictable manifestation of health outcomes dependent on individual and local circumstances (Figure 1).

Figure 1: Setting up the photo-based choice experiment

A complex set of mediating and moderating factors influences the relationship between blue spaces and health. Consequently, not every blue space visit enhances health and not everywhere are blue spaces good for public health (White et al., 2018). Based on the work of Gesler (1992), Völker & Kistemann (2011, 2015) developed a revised version of the therapeutic landscape model to assess salutogenic health processes in blue spaces. The concept consists of four dimensions of health-related appropriation occurring in a place, defined as the experienced space, symbolic space, social space, and activity space (see fig. 2). These dimensions can be used to guide the research process from data collection to data analysis (e.g. to structure and classify blue health outcomes). In this study, we integrated the model into the methodology photovoice – "a process by which people can identify, represent and enhance their community through a specific photographic technique" (Wang & Burris, 1997: 369). Photovoice has been chosen as the main research approach as it allows capturing individual and group experiences of (blue) spaces, while assessing the perspectives of policymakers and other stakeholders, and, merging the results in the end.

In each case study area, on the demand side, we conducted a baseline survey linked to a one-week participant observation period at a selected urban blue space, followed by individual "photowalks" (i.e., photo-based walking interviews), focus group discussions, and photo-based choice experiments. On the supply side, we conducted key informant and expert interviews with diverse stakeholders involved in urban blue space planning and policy.

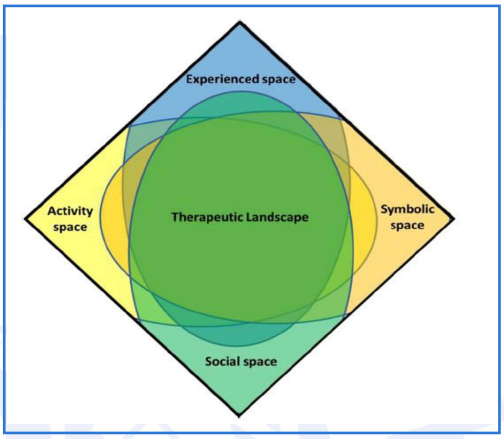


Figure 2: Revised therapeutic landscape model. "Dimensions are not distinctly separated from each other, but can coincide, resulting in a therapeutic landscape" (Völker & Kistemann 2015: 197)

To ensure comparison and a transfer of lessons learned between the two case studies, several eligibility criteria were applied consistently in two areas, including: the selection of comparable blue spaces; inclusion criteria for sampling senior citizens (e.g. aged 65 years plus, permanent and retired residents); and the selection of interview experts with similar professional backgrounds (e.g. landscape architects, urban planners) and fields of expertise (e.g. gerontology, age-friendly city design). Fig. 3 gives an overview of the research design and the multiple case study processes.

For the purpose of this article, as the research is still ongoing, we only refer to the preliminary results of the Indian case study (Figure 4). On the demand side, the participants' observation and the baseline survey revealed that the main visitors of the selected site are mostly young- and middle-old (i.e. younger than 80 years) senior citizens with upper-and-middle-income. Among them, many were Hindu men of affluent neighbourhoods close by. In accordance with the key

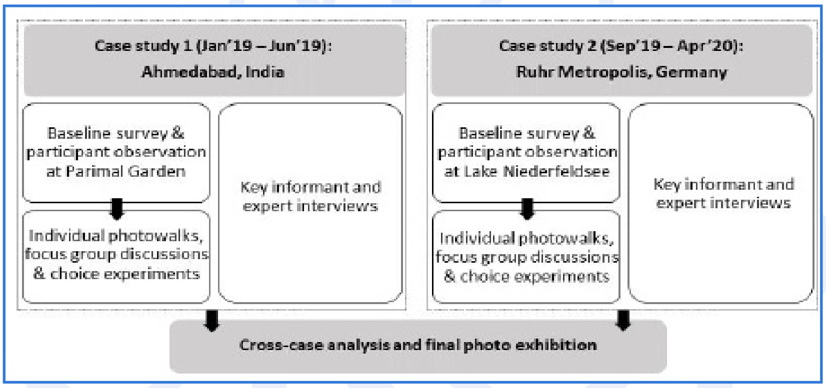
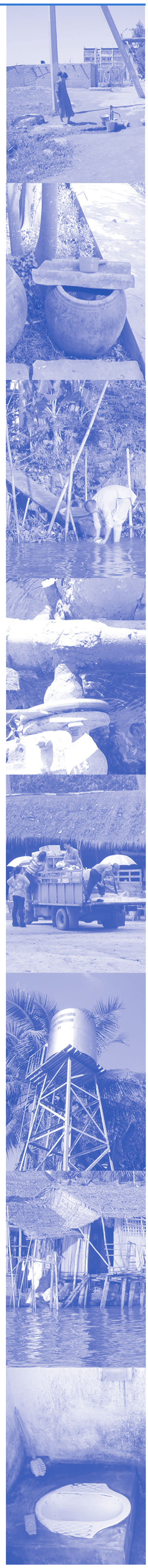


Figure 3: The multiple case-study procedure using the photovoice methodology (Author's compilation)



informant interviews, the results indicate that in Indian states like Gujarat, where a patriarchal caste-class system continues to determine the societal structures, urban blue spaces might be to a significant extent gendered public spaces that display social hierarchies.

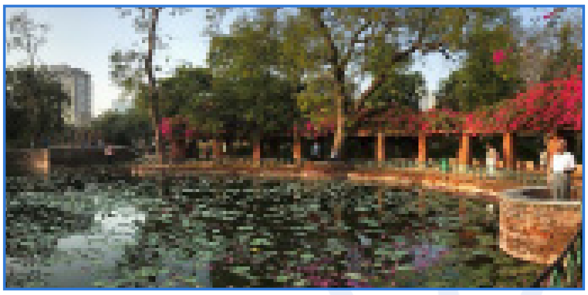


Figure 4: main research site “Parimal Garden”, and the lotus lake within a municipal park in central Ahmedabad, in the state of Gujarat

These results are consistent with other research done in Ahmedabad and in India, showing for example that older women – because of the continuity of traditional gender roles and the lack of economic independence – are still very much restricted to the domestic sphere of their families, thus limiting their possibilities for external support and social interaction (Gangopadhyay & Samanta, 2017). Although urban parks like Parimal Garden are officially accessible for everyone, perceived accessibility limitations and lack of opportunities (e.g. because of family duties or precarious subsistence living conditions) may contribute to excluding certain social groups – such as older women, people of lower castes, as well as religious and ethnical minorities – from using these health resources. Naturally, having blue-green spaces around is a prerequisite to obtaining access to the ‘blue’ and ‘green’. Mobility, in a dense, traffic-congested Indian megacity, was one of the most pressing challenges to access the blue space noted by our photovoice participants, even for those belonging to higher social classes and living in close vicinity. This underlines the importance of considering the special mobility needs of urban seniors in the planning and design of urban blue spaces and the way to reach them (see fig. 5). The lack of public transportation and walkable urban design wasone of the main reasons why the study participants rarely visit other blue spaces in Ahmedabad, making Parimal Garden even more important for them.

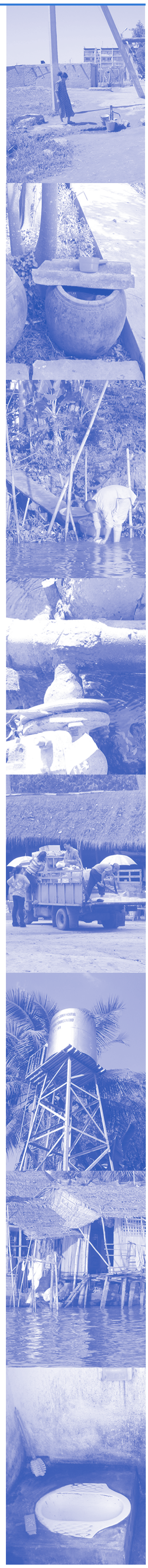
Figure 5: „Photo-walking“ to the Riverfront: The go-along research tool captures barriers such as steps in senior citizens’ blue space access

Blue health experiences of senior citizens in Ahmedabad

The first research step showed that urban seniors make up a large part of the park users and hold a strong relationship to the place. The data confirmed that a blue space is important to facilitate healthy practices, with potential benefits for the health of the senior visitors. Mostly all survey participants (n = 29) reported coming daily to the park for physical activity, participation in socio-cultural and sports groups (e.g. laughing yoga), social interaction and enjoying the contact to nature. For 2/3 of the participants, the Lotus Lake is very important and enhances the amenity value of the park.

In a second step, the individual photowalks (n = 4) allowed for an in-depth examination of elderly people’s urban blue space-health relationship considering their embodied identities, individual living arrangements and changes over the life course, respectively. Major results include the identification of age-friendly therapeutic landscape elements and deeper knowledge of the mechanisms through which ‘the blue’ benefits urban seniors’ health and wellbeing.

Figure 6: Blue health appropriation in Parimal Garden according to the therapeutic landscape model by Kistemann & Völker (2015)



The participants reported on experiences of all four dimensions of health appropriation according to the therapeutic landscape model (see fig. 6). Additionally, the photo-based choice experiments helped to reveal older adult's blue landscape preferences, showing for example that artificial water elements and manmade environments such as the Lotus Lake in Parimal Garden, a fountain, the riverfront walkway and a manmade lake within an entertainment park, belong to the most preferred landscapes, more than natural blue spaces.

Figure 7: The Sabarmati River close to Muslim communities outside the city center

As the sampling in Parimal Garden turned out to be biased towards older Hindu men of higher social classes, we reached out to senior citizens clubs to conduct focus group discussions with elderly people of different backgrounds (e.g. Muslim senior citizens, a traditionally suppressed religious minority in Ahmedabad).

This allowed to shed light into differently blue health experiences and blue space needs among the urban seniors. It became evident that questions regarding access to and design of recreational blue spaces for minority groups are primarily linked to general questions of environmental justice, given the fact that Muslim citizens in Ahmedabad usually live segregated in areas that are deprived of access to any well-maintained public (green, blue, or grey) space (fig. 7 and 8).

Urban blue governance in Ahmedabad:

Figure 8: The Sabarmati Riverfront in the city center

Dried out lakes and waterfront revitalization

On the supply side, results of the key informant and expert interviews (n = 20) confirmed the existing socio-spatial inequities in access to the 'therapeutic blue' within the city. One of the most discussed topics in the city is the regeneration of the Sabarmati Riverfront, a 250 million USD flagship project in ongoing implementation since the late 1990s (AMC, n.y.).

Many interviewees sharply criticized the municipal corporation for clearing the riverfront slum communities and resettling more than 10,000 urban poor families to the city outskirts, far away from the river that provided them livelihood and income opportunities (e.g. work as laundrymen). In contrast to the environmental improvements claimed from the government side, the majority of our interviewees highlighted that the project has further aggravated water scarcity in the region by recharging groundwater and diverting water from the river elsewhere.

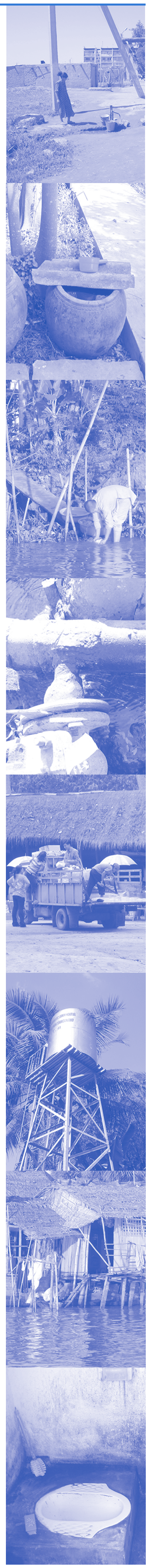
While all attentions lie on upgrading the riverfront, almost nothing seems to be done to conserve the more than 100 historical urban lakes remaining in the city, increasingly deteriorated and almost dried out in consequence of rapid urbanization (Figure 9).

Figure 9: Shut off fountains and degraded lakes - a common picture of Ahmedabad's current urban blue space provision

Yet, local government's plans include large urban greening and 'beautification' initiatives in the next years that shall also benefit the communities currently underserved with recreational spaces. The private business sector is likely to be another important actor in Ahmedabad's future blue-green space development: among other parks, Parimal Garden is currently subject to urban regeneration planning (improving infrastructure and economy) by a local company as part of their investment in corporate social responsibility activities. What remained largely unclear in the interviews is the question: who will advocate for and take action on integrating the concerns and needs of Indian senior citizens into urban development? In times where – also in India – traditional family systems are under pressure and public pension systems do not adequately reach the majority of urban seniors, the third party sector mainly tries to care for the elderly. The reports of a national and locally active NGO highlight that health is an overriding concern for Indian older adults. Challenges arise particularly from dramatically increasing cases of elderly abuse and neglect, high medical cost and the lacking access to basic public healthcare and prevention measures (HelpAge India, 2016). Urban blue spaces are one of many possibilities for taking public health action on ageing Indian population.

Conclusion: The search for the 'blue spatial match' continues

Our study contributes to the little but growing evidence-base on salutogenic aspects of urban waters and health, proving that blue spaces are not only associated with health risks but also entail a huge potential for promoting urban health (Foley et al., 2019; Garrett et al., 2019; Gascon et al., 2017). The increasing group of urban elderly people are likely to particularly benefit from blue space visits. However, this article has exemplarily shown that social inequalities are reflected



in the accessibility and inefficient urban governance of the blue spaces. The urban blue governance is not yet able to fully consider and address the social inequalities in access to blue health; in a way that mostly wealthier and healthier individuals currently tend to have better access to (blue) therapeutic landscapes. Vulnerable populations, e.g. lower-income people, in contrast, usually suffer from higher disease burdens and unhealthy living conditions, while the lacking opportunities to use public health resources, including urban blue spaces. On the other side, studying senior citizens' blue health experiences has revealed that a differentiated view on vulnerable populations is required: ageing occurs very differently, but at the same time, elderly people of all socio-economic backgrounds might face common challenges, such as in terms of mobility or the present urban blue space design.

Particularly in developing countries like India, the weak structure of the civil society – lacking strong community-based organizations with the capacity to bring interests and topics into policymaking – is likely to impede participatory urban planning (UN-Habitat 2009). Thus, it remains questionable who will advocate for vulnerable social groups and the environment itself to ensure environmental justice and ecological health in blue space developments. Although urban planning and policy-making take place in diverse urban contexts, a stable, effective and accountable local government, aswell as a strong civil society is generally essential for urban planning to be effective (UN-Habitat 2009). To reach a socially and environmental inclusive 'spatial match' between health-enabling urban blue space provision and the needs of humans and urban ecosystems, there is still a long way to go –in Ahmedabad and many other cities across the world.

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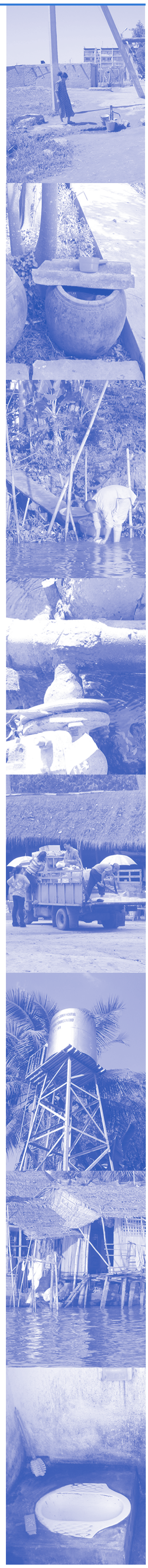

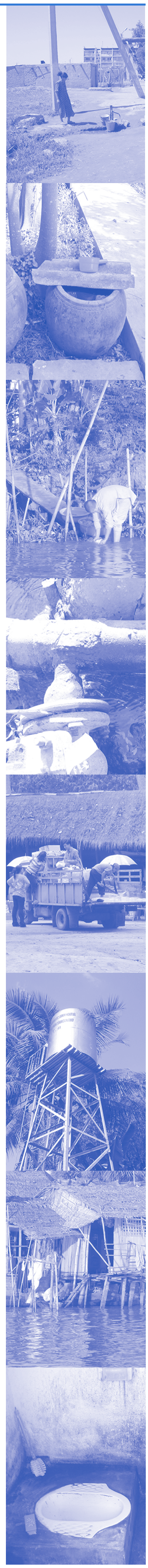

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