WATER & RISK

Dear reader,

Have you ever had a "gut feeling"? The role of our largest sensory organ – the gut – has been overlooked by science for a long time. Only recently we understood that there is a gastrointestinal-nervous system circuit. Potentially, also gut microbes can interact through gut cells with our nervous system. Research is looking into microbiota and how the microbiome can provide information on the biodiversity of the microbiota in a certain habitat, and also spatio-temporal changes. Our microbiome has become intensively analyzed and the more we discover the less we know, instead more questions appear. Nowadays, it is common knowledge that antibiotics affect the gut microbiota, but what about other substances that we are exposed to regularly? How do they affect our microbiota? Could there be larger impacts on health than we think?

If our gut microbiota is affected, our nutrient uptake might be affected, too. Diarrhea, helminth infections and environmental enteropathy affect the nutritional status. Increasing the access to WASH for all is helping to reduce these diseases and by this improving the nutritional status. Like the diversity of microbiota proofs to be beneficial for health, a diversity of methods and approaches are benefical for upscaling WASH. From data acquisition in the field to the development of policies, transdisciplinary action is taken and we are pleased to be able to share with you some aspects of this tremendous work. This year we could also celebrate the 20th anniversary of the adoption of the Protocol on Water and Health. A number of publications in this newsletter that have been launched this year, and are proud to have contributed to some.

We don´t know what 2020 will bring, but we should consider to trust our gut more often, because billions of organisms in it might know better than a single human brain.

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Microbiomes: An Undervalued Impact of Water Treatment on Human Gut Health?

Physical and chemical treatment is essential to keep drinking water free from disease-causing microorganisms. But what if there was another impact of treated drinking water on our health, one which has yet to be adequately considered? Given recent developments in microbiology, the question is now beginning to be asked: to what extent is treated water playing a role in gut health?

The field of microbiology is increasingly taking a more holistic approach to the analysis of microorganisms accounting for all the microbes present in a particular environment, otherwise known as a "microbiome". These organisms include bacteria, archaea, viruses, fungi, and other single-celled lifeforms. Conceptually, this shifts the focus from single organisms to instead thinking about how microbial life interacts not just with one another but also with their natural environment. All niches that have their own microbial populations can be considered to have microbiomes, including the ocean, air, soil, and even treated drinking water.

Traditionally, bacteria have been cultured (i.e. grown) in the laboratory, a method that has been used as the foundation for our knowledge of the species present in a microbiome. We now know that <1% of all microbial life can be cultured (Staley and Konopka, 1985), meaning that, until recently, the majority of microbial life has been hidden from us. We are fortunate that, in relation to human health, many of the relevant pathogenic species are readily culturable, allowing us to monitor and control their numbers in water sources and collection and distribution systems. However, there are many more microorganisms in water than just Escherichia coli and Vibrio cholerae.

How do we know this? Whole microbial community analysis has only recently become possible with the advent of new technology: DNA sequencing. This technique is independent of culturing, and relies instead on extracting all the DNA from a given sample (e.g. water), followed by sequencing of the DNA. This technology enables scientists to decode and read the genes which are present, providing a detailed and more complete profile of the microbial species present in that sample. DNA sequencing has been nothing short of a

revolution for microbiologists, leading to the realization that microbial communities are far more complex than previously thought.

The Drinking Water Microbiome

Some small-scale studies have investigated the drinking water microbiome and found that water samples are diverse, exhibit high spatio-temporal heterogeneity, and will be affected by everything from raw water source to pipeline materials. Despite these previous studies, no definition has been established for what constitutes a core set of microbes in the treated water microbiome. The task to identify a core water microbiome is a difficult one. For example, in the US alone there are tens of thousands of water systems; to sample even a representative number would be challenging. To address the key gaps in our knowledge of global drinking water microbiomes, there has recently been a call for a large-scale drinking water microbiome project (Hull et al., 2019), the results of which would ultimately be used to:

- improve water policy,
- facilitate accurate predictions for how the water microbial population may affect the nitrification and corrosion of infrastructure,
- respond to extreme weather events caused by a changing climate.

Filling some of these knowledge gaps, a recent study conducted over a one-year period found i) compositional similarities across the four drinking water distribution systems of Paris, and ii) alterations to the bacterial community composition caused by a flooding event that increased undesirable populations of Escherichia and Legionella (Perrin et al., 2019). Microbiome research is still in its infancy, but we are at the point where we can now ask how all the organisms, and not just common pathogens which survive in the drinking water microbiome, may impact the consumer.

The Human Gut Microbiome

To understand the effects organisms in water might have on our health, we first need to become familiar with another microbiome — one that humans host within their bodies. Beginning with the oral cavity and ending with the rectum, microbes colonize the entire length of the gastrointestinal (GI) tract. Most of these are concentrated in the large intestine where they are housed at approximately 1011 cells per gram (Sender et al., 2016). Known as the human gut microbiome (HGM), this is the most important microbiome relating to human health. The HGM may contain anywhere between 500 and 1,000 bacterial species at a ratio of approximately 1.3 microbial cells for every human cell (Xu and Gordon, 2003, Sender et al., 2016). The microbiome is responsible for the breakdown of complex food molecules, thereby providing energy and important metabolites to host cells. The HGM also includes viruses and eukaryotes (e.g. fungi and protozoa), which when taken together, represent one of the richest microbial ecosystems on earth. It is now clear that the trillions of microbes in our gut not only have a direct effect on host metabolism,

behaviour, immunology, and physiology, but that this delicate relationship has been fine-tuned over millennia of co-evolution. However, it has only been over the last two decades that research into the HGM has revealed the profound impact it has on our health; especially the bacterial component, which is so significant that it has been likened to the discovery of a new organ. Between 2013 and 2017, there were almost 13,000 publications on the gut microbiome alone — a figure that increases every year (Cani, 2018).

Maintenance of the gut microbiome is essential for optimal health, but microbiologists are still struggling to decipher which organisms are responsible for positive and negative impacts on the gut. It is understood, however, that an imbalance in the microbiome composition (termed "dysbiosis"), can result in chronic disease states, including irritable bowel disease, irritable bowel syndrome, and metabolic diseases such as Type II diabetes, obesity and metabolic syndrome.

How is it that these vast numbers of bacteria have come to colonize us? A number of factors influence the HGM composition, including the host's general health status, genetics, lifestyle, antibiotic use, mode of birth, breast-feeding, and particularly, diet. In addition to these, a number of other factors may be grouped together as "environmental exposure", to which drinking water belongs.

Drinking Water as a Potential Source of Microbial Gut Diversity

With our current water treatment methods, it is not possible to completely eliminate bacteria from water (Helbling and Vanbriesen, 2008). Bacterial concentrations in drinking water are estimated to be around 106 -108 cells/litre (Hammes et al., 2008). This is the equivalent of up to 100 million bacterial cells per litre. In terms of microbial density, this is not an outrageous number; however, water is consumed so regularly by so many individuals, it would be surprising if this did not represent a significant exposure for the host gut microbiome to external microbial influence. Indeed, top microbiome scientists are now alluding to this fact (Dominguez-Bello et al., 2019, Sonnenburg and Sonnenburg, 2019). It is known that there are species regularly identified in drinking water (such as Bacteroidetes and Proteobacteria) which are also found in the human GI tract (Vaz-Moreira et al., 2014). This indicates that there is potential for microbial overlap, especially if a system becomes contaminated with wastewater, but this has yet to be studied in detail. If it seems strange that the microbes in drinking water might impact a human GI tract and the organisms residing there, consider that species found in water that are also capable of surviving in (and infecting) humans are the very reason for water treatment. Moreover, it is estimated that up to 60% of gut bacteria have the ability to form spores (Browne et al., 2016), which are dormant but extremely resilient cells capable of surviving in adverse conditions, yet can regenerate when circumstances are favourable (such as reintroduction to a GI environment). Furthermore, a
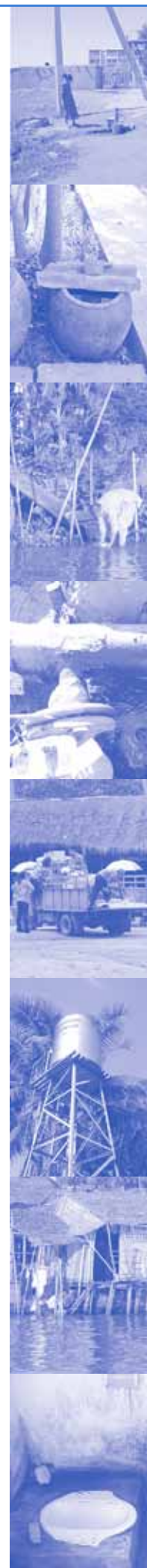
weakened or compromised gut ecosystem, for example following a course of antibiotics, may be more amenable to colonization from waterborne species.

A reason the influence of drinking water has not been reported in humans could simply be due to the fact that the impact of water on the gut microbiome has been overshadowed and is difficult to distinguish from other influencers of HGM, such as diet. To uncover statistically meaningful results of water on HGM composition would require a very large dataset to overcome the major confounding factors of microbiome variability. A controlled, longitudinal experiment taking detailed environmental samples (water, hand swabs, etc.) as well as human microbiome samples (i.e. faeces) for parallel sequencing is the best approach to improve our understanding for how the water microbiome affects the HGM.

The Urbanized World and Microbiome Diversity

Many of us now live in urbanized, industrialized societies, in which conditions are remarkably different from how our ancestors would have lived. For the first time in human history, we are exposed to hygiene and chemical products, pollution, medicines and more. Also for the first time, we consume processed, sterile foods, as well as a sanitized supply of water. An interesting question to pose is whether raw water has historically acted as an environmental source for enrichment of microbial gut populations, particularly in infancy and early childhood before the microbial populations within the HGM have stabilized. How different would our microbiomes be if we did not change to our industrialized lifestyles? Did this transition happen too quickly for our microbiomes to adapt?

Lower gut bacterial diversity is consistently correlated with impaired gut health and is a hallmark of the "industrialized" microbiome. For example, it is known that pre-industrialized societies harbour a greater HGM diversity than those living in developed and industrialized societies, and are also less likely to suffer from chronic intestinal diseases, suggesting the rapid diversion from our ancestral lifestyles as the likely culprit (Segata, 2015). The evidence points to this most likely being due to changes in diet, environment and lifestyle, of which the consumption of disinfected water could be playing a role.

Interesting data is emerging that compares the microbiomes of numerous traditional tribes (i.e. individuals living a pre-industrialization lifestyle) which consume water from different environmental sources. The Hadza are a hunter-gatherer tribe based in Tanzania and provide a window into the pre-agricultural microbiome. The source of drinking water, whether from either a spring or stream, was shown to exert a significant difference on the composition of the HGM communities of tribe members. Similarly, significant differences were observed between Himalayan populations consuming underground water compared to those drinking water from rivers and streams (Jha et al., 2018).
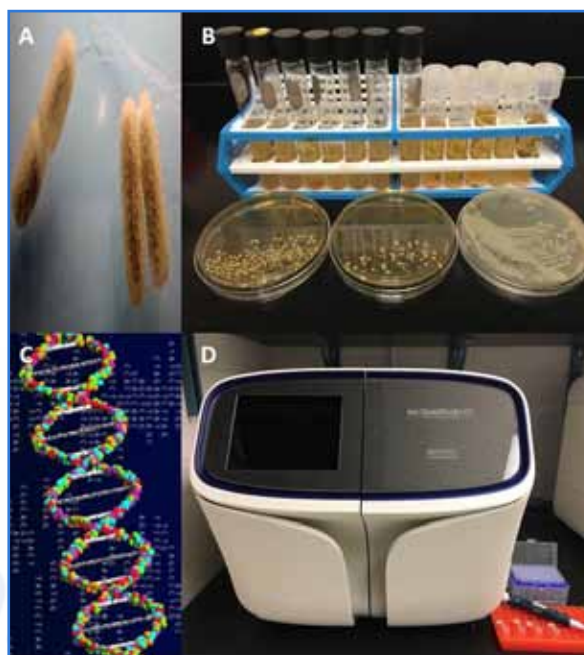

Figure 1: Traditional vs Molecular Techniques for Analyzing Bacterial Communities. Working with live bacterial cells (A) to grow bacteria in liquid form and on agar plates (B) vs working with bacterial DNA (C) to run on a DNA sequencer (D), which will produce genetic information to be read on a computer. (Source: A. Marsh)

The greater microbial density of untreated water sources may mean that water-induced changes in HGM composition are easier to detect. As part of a larger microbiome analysis, these findings were incidental; a study with adequate controls specifically to assess changes in human gut microbiome in relation to water source has yet to be carried out. Of particular interest would be to compare the microbiomes of populations consuming treated vs. untreated water in an environment where other lifestyle and dietary factors are highly similar to control for variation. How exactly would these microbiomes differ in composition and diversity; would differences be more noticeable in young than old? Only once we identify such changes can we begin to make inferences about the effects of drinking water on gut health.

Chemical-Induced Disruption of HGM?

The human gut microbiome is sensitive to perturbation. These range from major disturbances, such as antibiotic treatment, to more minor effects, such as artificial sweeteners or dietary emulsifiers. In fact, almost anything that passes through the gut is likely to have some impact on the microbiome.

Therefore, it is worth asking: are residual disinfectants in the water supply a concern for the host microbiome? Chemicals, like antibiotics, are indiscriminate and will not only target undesirable microbes but also will have a widespread impact on the gut population. Even if chlorine concentrations are low at <5mg/L (WHO, 2017), it is plausible that persistent, long-term exposure of chlorine — or perhaps more likely, chlorine by-products such as trihalomethanes (THMs) — could influence gut bacterial populations. While toxicity studies have shown that these do not negatively affect
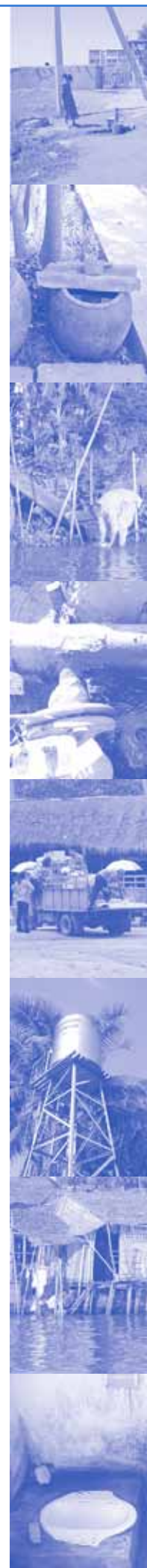
human physiology, their effects on the HGM have not been directly studied in humans.

However, there is some precedent for this. In mice, the animal model most frequently used as a proxy for human GI tract in microbiome experiments, intestinal populations were shown to be affected by the source of water. In fact, tap water resulted in increased numbers of clinically relevant species and antibiotic resistance-associated bacteria in the mouse gut microbiome compared to sterilized water (Dias et al., 2018). Similarly, associations were identified between domestic water sources and microbial profiles in infants (Baumann-Dudenhoeffer et al., 2018). Further research is required to fully elucidate which communities are affected, and whether there are negative impacts for human health. An outline for how such a study might be conducted was recently proposed by Martino (2019), who makes the point that microbiome alterations are most likely to be observed in infants given that their gut microbiomes are still developing, and are therefore most susceptible to environmental influences.

Of course, disinfection of drinking water has saved countless lives, and the suggestion is not to alter sanitization methods but rather to see whether and to what extent there is collateral damage to the microbiome as a result of regular consumption of treated drinking water. If proven, it would be advantageous to know what these might be in order to develop strategies to allow for the replacement of important missing microbes.

Outlook

The drinking water microbiome is understudied compared to other microbiomes. The tools now exist to characterize the microbial life in these environments and by doing so we can now learn more about these microbial populations to understand the impact they are having on our health. There are several points which need to be addressed:

- what exactly constitutes a drinking water microbiome?
- how/if does this microflora – even independently of undesirable species – impact the human gut microbiome?
- are the ways in which water is treated having a residual impact on the host microbiome?

Detailed understanding of the water microbiome will enable those working in the water sector, including engineers, microbiologists and policy makers, among others, to implement appropriate interventions in response to changes or disturbances in water microbial populations. Such changes are likely to include contamination of drinking water and response to climate change-related extreme weather events which will increasingly impact drinking water infrastructure and quality.

It is important to bear in mind that microbiome research is still in its early days. Scientists are continuing to decipher which bacterial species are key to stable, robust gut ecosystems and long-term gut health, and conversely, which bacteria are associated with chronic disease. The water microbiome is even less well understood; despite some tantalizing evidence, it remains an open question as to how, or if, treated drinking water impacts our gut microbiome, beyond reducing the risk of infection from pathogens. While this complex subject has many unknowns, one thing seems likely: we can expect to hear more about this topic in the years to come.

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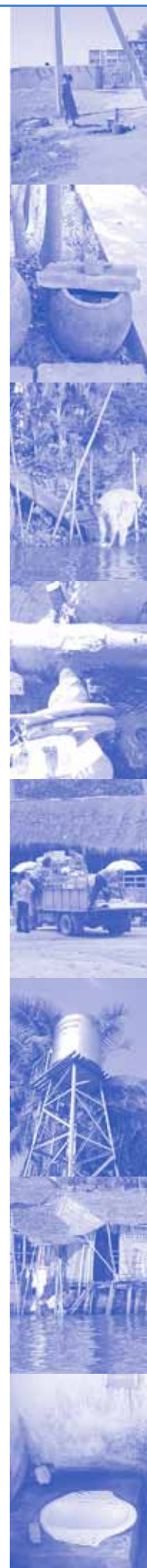
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Impact of open defecation practice and community drinking water quality: A case study of Siaya County, Kenya

Preventing contamination of drinking water sources and improving its quality is one way of preserving public health and ensuring better cognitive development of children. Poor sanitation and human activities have been found to be a major source of water contaminants. Subsequently, inadequate management of industrial and domestic wastes, as well as agricultural activities contaminate the drinking water sources and expose millions of people to disease-causing pathogens and chemicals. Indeed it has been found that human activities such as agriculture, manufacturing and production as well as practices such as open defecation in the fields, can lead to serious contamination of community water sources. It has been estimated that poor water quality as a result of inadequate sanitation and hygiene account for nearly half a million deaths annually mainly through infectious diarrhoea (WHO, 2019). Nine out of ten such deaths are in children and virtually all of the deaths are in developing countries (Ashbolt, 2004).

In many rural areas in developing countries, communities rely on small scale water supplies as well as surface water sources such as rivers, lakes, ponds, and earth pans that collect runoff water. Most of these sources are prone and exposed to both bacteriological and chemical contamination. In Kenya, especially in rural areas, the danger of being exposed to such contaminants is higher in both urban and rural setups. This trend has been observed in Siaya County too, where more than half of the population use unimproved water sources and more than 20 % of the population use unimproved sanitary facilities while 16 % practice open defecation (KNBS, 2013). The county lacks sewerage systems in its peri-urban areas and just like in many other parts of Kenya, industrial wastes as well as domestic wastes and agriculture play a major role in polluting water sources.

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhoea, dysentery, hepatitis A, typhoid and polio among other infections (WHO, 2019). However, efforts have been made to improve on the same through the promotion of point of use water treatment technologies, community total sanitation approaches such as community-led total sanitation (CLTS) and regulations, water safety planning promotion and effective water quality monitoring among other approaches to ensure water quality for use.

Surface water sources have been cited as an important environmental transmission route of diarrhoea causing pathogens (Vermeulen, 2016). This is due to human excreta being exposed to the environment through poor sanitation unimproved latrines or outright open defecation in the bushes. CLTS intervention has been used as an approach to improve on latrine accessibility and avoid open defecation, thus positively impacting on health outcomes. It has been reported that where CLTS is practised, there is reduced communal water source contamination with human excreta (Okullo, Moturi, & Ogendi, 2017).

CLTS Approach

CLTS is a participatory approach developed by Kamal Kar in 1999 in Bangladesh, where it was first tested with mixed success or outcome (Engel & Susilo, 2014). It is based on the principle that communities must be empowered to stop open defecation (OD), and to build and use latrines without the support of any external hardware subsidy (Brown, 2010). This has seen UNICEF change its corporate commitments and programming from direct implementation through provision of subsidies to community approaches to total sanitation (UNICEF, 2014), that is, sanitation provision without 'outside' help or assistance. As a participatory development programme the key aim of CLTS is to

reduce disease and facilitate a change in attitude and behaviour regarding defecation and sanitation based on internal, community-led projects (Brown, 2010). Brown (2009) observes that various tools such as 'shame and disgust' are used in order to 'trigger' collective actions of the communities to make their localities totally free from open defecation. Brown further reports that when successful, CLTS leads to intense local community action, and clean and open defecation-free (ODF) villages. Although CLTS has been lauded as a 'silver bullet' to sanitation provision in communities that have poor access to sanitation services, critics point out that it is tantamount to coercive approaches used in colonial public health programmes and that it prejudices individual's or human right at the expense of common good (Bartram, et al., 2012).

CLTS Implementation in Siaya County

CLTS was first introduced in Siaya County in the year 2010 by the Ministry of Public Health and Sanitation. The implementation targeted all the 1982 villages in the six sub-counties namely Rarieda, Ugunja, Ugenya, Bondo, Gem and Alego Usonga. By 2015, only 29 % of the villages had been declared open defecation free (ODF) and the county was off-target to achieving ODF status (Singh & Balfour, 2015a). It was also observed that more than half of the villages which had been declared ODF were reverting back to open defecation (OD) status (Singh & Balfour, 2015b). This prompted the Ministry of Health (successor to the Ministry of Public Health and Sanitation) with technical assistance from UNICEF to adapt and pilot test micro-planning to CLTS implementation (Singh & Balfour, 2015a). Micro-planning is a tool that has been used in the context of decentralisation to guide decisions and to monitor the achievement of objectives in regard to CLTS implementation (Singh & Balfour, 2015a). The tool has been used successfully in immunization and education programmes. However, the county was not able to achieve ODF until April 2018. CLTS and ODF is not an end by itself but require progression to improved latrines. Improved latrine definition is linked with principles of construction and maintenance of the sanitation facility to ensure disease transmission and prevention is controlled. Latrine construction is one of the major steps towards preventing surface water contamination. In this regard, it means management of faecal or excreta at the household level for the achievement of public health and prevention of disease

Water Quality in Siaya County

Siaya County which is found in the western part of Kenya is bordered by Lake Victoria, a resource which is shared between several other counties. It is surrounded by Busia County to the North West, Vihiga and Kakamega Counties to the North East, Kisumu County to the South East and Homa Bay County (SCIDP, 2013). The County experiences a bi-modal rainfall, with long rains falling between March and June while short rains fall between September and December with relief and altitude influencing its distribution and amount. The

rainfall ranges between 800mm to 2,000mm in the highlands while the lower areas receive rainfall ranging between 800 to 1,600mm. Although it can be argued that the county receives enough rainfall (Figure 1), Siaya County is drier in the western part towards Bondo and Rarieda sub-counties but wetter towards the higher altitudes in the eastern part particularly Gem, Ugunja and Ugenya sub-counties (SCIDP, 2013).
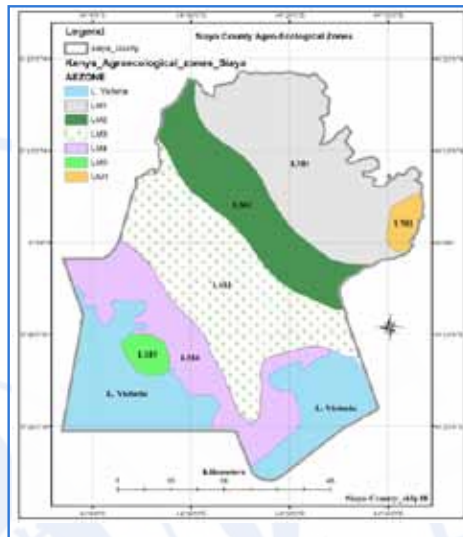

Figure 1: Map of Siaya County agro-ecological zones (Source: SCIDP, 2018)

Siaya County has five agro-ecological zones (LM1 to LM5). Alego Usoga Sub-County is under low-midland zones (LM2 and LM3) which are sub-humid and humid zones with reliable rainfall. Parts of Rarieda and Bondo Sub-Counties fall under semi-humid, semi-dry lower midland zones (LM4 and LM5). However, the upper parts of the two Sub-Counties (Rarieda and Bondo) are classified under the mid-land zone of LM3. Ugunja and Gem Sub-Counties are classified under zone LM1, with reliable rainfall. The County is divided into six administrative sub-counties of Gem, Ugunja, Ugenya, Alego-Usonga, Bondo and Rarieda. Alego-Usonga Sub-County is the largest, covering an area of 605.8 km^2 and has the most locations.

Figure 2: A communal water pan (Source: J. Wasonga)

The Sub Counties are further divided into 30 wards and several villages (SCIDP, 2013). The majority of the population, over 50 % rely on surface water (see figures 2-4) for their domestic water supplies. In most of the villages, there is low usage of latrines particularly among the poor households.

Figure 3: A communal water kiosk (Source: J. Wasonga)

It is estimated that only 34 % of the population in Siaya County use improved sanitation while 16 % of them have no sanitation facilities and resort to open defecation. Only 3 % of the population have handwashing facilities near designated areas. This lack of improved sanitation and contaminated communal water sources coupled with other factors has contributed to negative health indicators such as high child mortality standing at 167 deaths per 1000 live births in the county (KNBS, 2013).

Figure 4: A communal water pond (Source: J. Wasonga)

Water samples were collected from fourteen major communal water sources across the county which included surfaces sources such as Kosewe earth pan, Migowa earth pan, Kogwang water tank, Lusi earth pan, Koyoko earth pan, Kotonda earth pan, Nyaira water kiosk, Kotieno earth pan, Kothacha pond, Kolang'o pond, Kawino earth pan, Garage earth pan, Ochilo earth pan and River Yala. Chemical and bacteriological water analyses were conducted to determine the extent of pollution on these water sources (Figures 5 and 6).
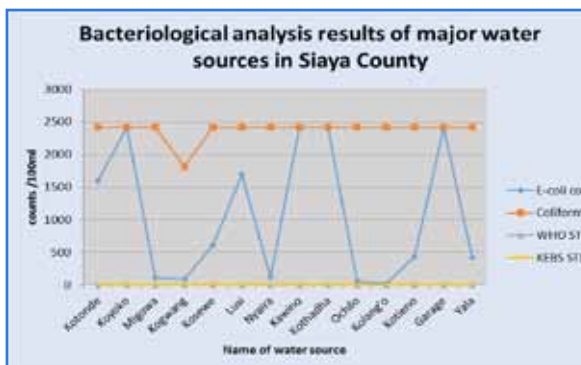

Figure 5: Bacterial levels in Siaya water sources (Source: J. Wasonga)

The bacteriological test results showed that *E. coli* was present in all the water sources above the recommended levels by World Health Organization and Kenya Bureau of Standards. However, the most contaminated communal sources were found to be earth pans and water kiosk (Koyoko, Nyayiera, Kowino, Kothacha, Ochilo and garage) sources which had counts above 2,000/100ml. All the water sources that samples were taken from had total coliform and *E. coli* count above 2,000/100ml. Only one source, Kogwang water tank had a total coliform and *E. coli* count of around 92.1/100ml and 1,800/100ml respectively, while two (Kogalo and Ochilo earth pans) had *E. coli* count of 24.8/100ml and 53.4/100ml respectively but total coliforms count above 2,000/100ml, which was still exceeding the recommendations by the World Health Organization (WHO, 2017) and the Kenya Bureau of Standards/Water Regulatory Services Board (WASREB, 2008). Samples with lower *E. coli* were collected mostly but not exclusively from a water kiosk, a tank and ponds, nevertheless they still showed high levels of total coliforms.

For chemical analysis, all the sources met the World Health Organization and Kenya Bureau of Standards recommendations except Kothacha earth pan, Kotieno, Koyoko and Lusi ponds where high nitrate and nitrite were detected. Turbidity was high in all the water sources.
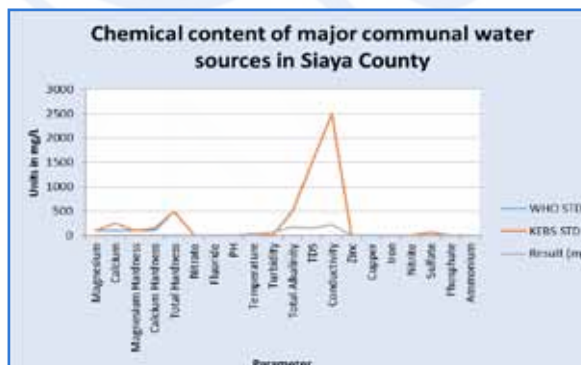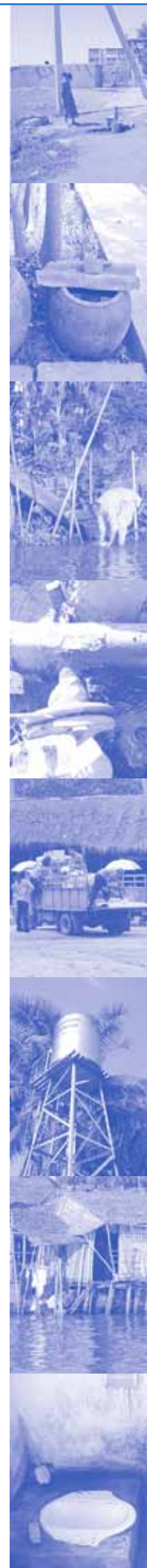

Figure 6: Chemical analysis results for all sampled major water sources sites in Siaya County (Source: J. Wasonga)

Multimodal approaches are needed to improve DW Quality

Communal water sources in Siaya County are heavily contaminated with faecal content as has been shown in this study. This is in line with other studies which have shown that most surface water sources in sub-Sahara Africa, Kenya included, are contaminated with faecal content (Kumpel, Peletz, Bonham, & Khush, 2016). The presence of E. coli in drinking water indicated recent faecal contamination as well as the presence of coliforms. The presence of these two indicator bacteria showed that there is a greater risk that pathogens are present in the drinking water, thus rendering the source not safe for human consumption. The presence of these bacteria could also be interpreted as a failure of CLTS as an approach to prevent water sources contamination with excreta. Thus, CLTS intervention should be combined with hygiene promotion and education on point of use water treatment among other approaches. In as much as the promotion of CLTS is pegged on achieving open defecation free villages and improvement of health outcomes such as lower reported cases of diarrhoea, some studies have found the contrary (Khale & Dyalchand, 2010). Furthermore, it has been reported that where CLTS has been implemented, there is a higher risk of groundwater sources contamination (Khan, Baig, Nawab, Mahmood, & Nyborg, 2016). Indeed, CLTS as an intervention of improving public health should be combined with other approaches to make it more effective and impactful.

Incorporating approaches such as water safety planning, safe animal waste handling alongside CLTS will dramatically improve the health of populations. Water safety planning is adaptable to any water sources and can be applied in any socioeconomic setting. Domestic animal faeces have been found to contribute substantially to faecal contamination of water sources causing enteropathogenic infections (Barnes, et al., 2018; Ercumen et al., 2017) . Thus, combining these interventions alongside CLTS has the potential of ensuring improved water quality from the sources to the point of use.

Chemical contamination of drinking water sources, if present, poses a major challenge in rural water supplies. However, based on the analysed chemical parameters, all the water sources met both the World Health Organization and Kenya Bureau of Standards recommendation for drinking water. The presence of nitrite and nitrate was observed in six out of the fourteen sources sampled way above the recommended standards, which could be indicative of agricultural activities or animal wastes. Drinking water sources should not contain harmful chemicals such as nitrite or nitrate. These chemicals at elevated levels cause diseases which may lead to development challenges in children as well as cancer among the general population

Conclusion

Contamination of communal water sources is a serious challenge especially in developing countries where water sampling, monitoring and testing is not common. However, bacteriological contaminants can be dealt with through promotion of point of use technologies that aim at improving drinking water quality at the household level. Governments and other CLTS practitioners can ensure the improvement of the health of the population through adopting and implementing multi-faceted approaches to improved public health. CLTS as a stand-alone intervention has its limitation and if combined with other interventions, can dramatically improve not only the environmental sanitation of a population, but also the water quality used for domestic purposes.

Acknowledgement

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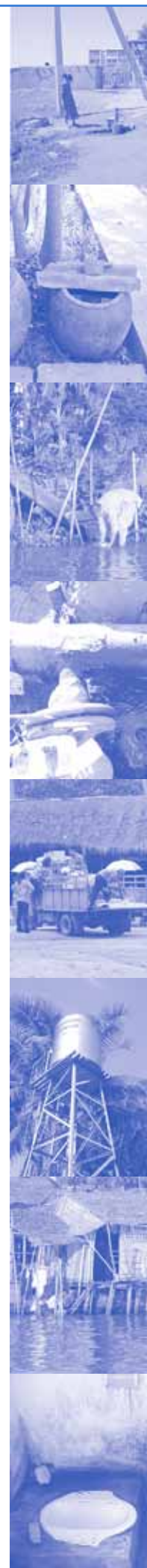
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Water and Health Research, Policy and Practice:
Holistic, interdisciplinary, mixed methods approaches

Water - the most precious resource of all - is the core of sustainable development, and serves as a crucial link between societies and the environment (UN-Water 2017, UN 2010). Worldwide, populations keep growing and with them the demand for food, thus the pressure on water resources is increasing, and fragile ecosystems are tapped to meet the water needs. Especially in communities in low- and middle-income countries, safe drinking water is often scarce with water being polluted past the point of consumption, exposing populations to infectious diseases and environmental health risks (Anthonj and Falkenberg 2019). The interaction between water and health is closely linked to geographical development research and underlies spatiotemporal dynamics. This interaction differs in different locations – between urban and rural areas, with socio-economic disparities –, in different cultural contexts – with different levels of health-related knowledge, risk perceptions and behaviour (Gatrell and Elliott, 2015).

Under the Agenda for Sustainable Development, which entails 17 Sustainable Development Goals (SDG) (Figure 1), water is mainly addressed under SDG 6. This goal outlines how different targets contribute to the overall ambition to "ensure availability and sustainable management of water and sanitation for all".

As for the link with water and health, water matters intrinsically cross-cut with different sectors and are closely interlinked with other goals and targets across the 2030 Agenda (UN General Assembly, 2015; UN-Water 2017).

Figure 1: The Sustainable Development Goals (Source: United Nations)

This article explores the use of medical geography as one of the most suitable disciplines to address complex and context-specific water-related global health challenges, as it offers various holistic and interdisciplinary approaches. Medical geography entails disease ecology or geographic epidemiology; it investigates causes of relationships between the environment, health and diseases in space and time;

and it applies geographical concepts and methods to understand health-related problems. A growing focus is set on interdisciplinary approaches, drawing on social, political and economic theories and building on the understanding of ecological principals and processes. Traditional mapping and quantitative approaches are complemented by additional research methods, including mixed methods, making use of more qualitative and participatory research. This enables the assessment of subjective feelings towards places, health-related perceptions and beliefs and health-related behavior in the cultural context of health (Gatrell and Elliott 2015, Kistemann and Schweikart 2010, Meade and Earickson 2005).

In the past years, I have worked on several projects in Sub-Saharan Africa, South America, Southeast Asia and the South Pacific, where the application of toolboxes that involved mixed methods and interdisciplinary perspectives has proved their usefulness and added value for water and health research, policy and practice. Here, I am presenting the approaches used in two studies.

Using holistic approaches for improved health-related wetland management

Across Sub-Saharan Africa, wetlands often constitute the only accessible water resources in otherwise uninhabitable landscapes, which is why they are being used extensively for domestic and agricultural purposes (Horwitz et al. 2012). The resulting degradation and contamination of water have the potential to spread disease-causing microorganisms and provide increased breeding habitats for disease vectors (Derne et al. 2015), adding up to the growing pressure on the water availability. So far, there have been several knowledge gaps about whether and how different kinds of wetland use influence the exposure to health risks and transmission of infectious diseases.

To fill these gaps, a study on water-related infectious disease exposure in a wetland was conducted in semiarid Kenya between 2013 and 2017. The study was part of the project GlobE Wetlands in East Africa – Reconciling future food production with environmental protection, funded by the German Federal Ministry of Education and Research, at the GeoHealth Centre at the Institute for Hygiene and Public Health at the University of Bonn, Germany. It aimed at:

- Identifying health risks and the prevalence of water-related infectious diseases that may be present in wetlands.
- Assessing the association between wetland use and health risks, and wetland users' health-related behavior.
- Estimating health risk perceptions of the wetland users concerning the identified and assessed health risks and prevailing diseases.

This study involved different disciplines, such as medical geography, epidemiology, public health, behavioural and social science, water resources management, environmental sciences and others. A mix of quantitative and qualitative empirical research

was conducted with different respondent groups that represented differing cultural contexts and different perspectives, including a community perspective and a service provider perspective. Specific examples of methods that were used are highlighted in Italics in the section below.

Triangulation was a key concept that this study followed. It describes a method that serves to analyze a phenomenon by combining data from different sources and levels on the same research topic; applying different methods; applying different theories or hypotheses; and employing different people for the collection and analysis of the data.

Information on water-related diseases previously associated with wetland use was retrieved through an extensive literature review. The information was used to develop the data collection tools, both quantitative and qualitative, for the empirical part of this study which involved different user groups observed in the wetland environment: farmers, nomadic pastoralists, and service sector workers. A syndromic surveillance approach and an observational spot check were used for the quantitative assessment of health risks arising from wetland use in the surveyed population of the Kenyan wetland. Health risk perceptions related to wetland use were captured through in-depth interviews with representatives of all user groups in the wetland. Moreover, expert interviews with representatives from the health, water, education sectors and others were included to add a service provider perspective on top of the community perspective (Figure 2).
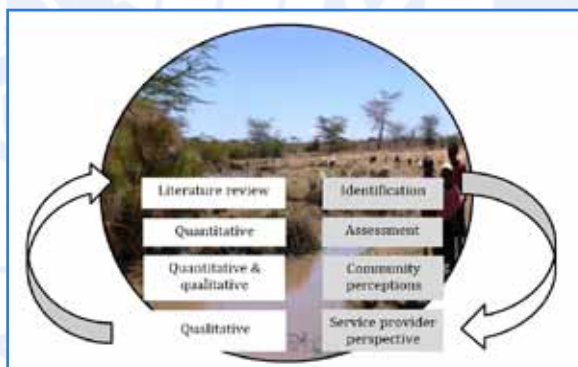

Figure 2: Health risk assessments for health-promoting wetland management (Source: C. Anthonj)

The mix of interdisciplinary approaches and their triangulation resulted in an in-depth understanding of the situation in the considered environment. This allowed to comprehensively map challenges faced by the population in this particular setting and to identify high-risk groups.

The study revealed that the literature base available on use-related disease exposure does not reflect real risks the community is facing. These real risks differ between different user groups, and are perceived differently in different cultural contexts and with varying prevailing health beliefs. The study demonstrated that local risk perceptions reflect real risks, and that risk perceptions determine health-related (protective and risk) behaviour. This study underpinned the vital role of wetland users as key informants and demonstrated that risk perception studies and resulting recommendations
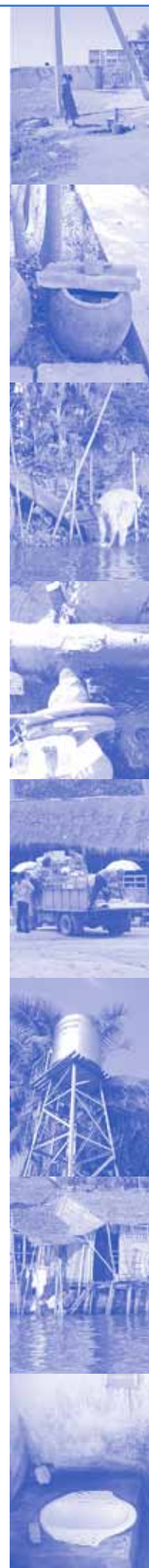
from the grassroots level serve as helpful supportive tools for health-promoting wetland management which requires a sensitive, integrative approach that takes into consideration any and all of the humans, ecology, and animals affected.

The resulting recommendations for wetland and health managers, included:

- Improving the provision of safe drinking water
- Upscaling of sanitation coverage
- Implementing measures to drive change in hygiene behaviour
- Establishing a waste management system
- Adopting simple environmental options
- Reducing occupational health risks during farming
- Targeting nomadic pastoralists
- Strengthening the role of community health workers in health management and information dissemination
- Improving collaboration to achieve a health-promoting wetland management.

These recommended actions entail detailed practical measures to adopt at the policy and implementation level for an improved, locally-informed and health-promoting wetland management. They are relevant at a national as well as at an international level for global policy-making and for achieving progress towards the SDGs (Anthonj, Diekkrüger et al. 2019).

Using data to strengthen national WASH and health systems

The ability of Small Island Developing States in the Pacific to effectively manage WASH and waste management is constrained by their small size, geographical isolation and expansion, environmental fragility, small and predominantly rural but rapidly urbanizing populations, and limited human and financial resources. WASH research, monitoring and global action are still lagging behind the necessary efforts to achieve health-promoting sustainable development. Fiji, Kiribati and the Solomon Islands, like other Pacific Island Countries, are often not able to provide adequate WASH services to their populations (Hadwen et al. 2015, WHO & UNICEF 2019). Besides, these countries are facing significant challenges from a changing climate, and the effect of extreme weather events such as tropical storms, drought, heavy rainfall, and flooding, as well as hardships related to rising sea levels. Located at the Ring of Fire, Pacific Island Countries are also prone to earthquakes, volcanic eruptions, and tsunamis.

The Water, Sanitation and Hygiene Sector Monitoring project in Pacific Island Countries (2016-2019), funded by the UNICEF Pacific, implemented in close collaboration with the Governments and Ministries of Health of Fiji, Kiribati and the Solomon Islands, aimed at:

- Assessing the WaSH situation through analysis of baseline and census data from rural and urban households, schools and health care facilities.
- Strengthening national WaSH systems (including monitoring) in Fiji, Kiribati, and the Solomon Islands.

Quantitative baseline and census data of WASH and waste management services in households, schools and health care facilities were collected. The data were analyzed and mapped with a focus on uncovering service coverage inequalities and discussed with WaSH sector stakeholders at the national and international level (i.e. government bodies and international and UN organizations working on WASH). The results were then contextualized with rainfall data and extreme weather events (Figure 3).

Figure 3: Strengthening national water, sanitation, hygiene and health systemsmanagement (Source: C. Anthonj)

Inequalities in terms of access to adequate WASH and waste management were a dominant finding of this project, and included urban-rural inequalities of WASH in households, domestic inequalities across different provinces (Anthonj, Tracy et al. 2019), inequalities in WASH across different school types (i.e. primary schools, high schools) in the Solomon Islands, and inequalities in WASH across different types of health care facilities (i.e. nursing stations, health centres) in Fiji and Kiribati.

Weather- and climate-related results showed that domestic sanitation infrastructure is highly vulnerable, and little adaptable, under extreme rainfall scenarios - flooding and drought - both of which are predicted to increase in frequency and intensity in future, and this entails increased human health risks (Fleming et al. 2019). An analysis of disaster preparedness and response in the context of the 2016 Tropical Cyclone Winston – the most severe storm to make landfall in the Southern Hemisphere to date – showed that health care facilities in Fiji are very vulnerable, and not sufficiently prepared to respond to a potentially increased burden of disease during and/or after extreme weather events.

The situation assessment integrated aspects related to WASH, health, education, emergency management, climate change, urban planning and infrastructure. This resulted in comprehensive, evidenced-based and contextualized recommendations (e.g rural and urban sanitation infrastructure adapted to extreme weather events), particularly relevant to SDG 6 implementation. This work was conducted jointly with governmental and non-governmental stakeholders (i.e. Ministry of Health, Ministry of Lands, Ministry of Education, UN-Habitat and UNICEF). The results inform national and global public health programmes, and will facilitate planning for the implementation of national and international strategies and policies towards the achievement of the SDGs (WHO & UNICEF 2019).

Holistic, interdisciplinary, mixed methods approaches to progress towards sustainable development of water matters

The presented studies addressed different water-related global health challenges. They were conducted in very diverse geographical, climatological and sociocultural settings and had different objectives. Nevertheless, similar approaches were used that allowed to consider the setting, on one hand the wetlands in semi-arid Kenya, and Small Island Developing States in the Pacific on the other, as a complex system in its entirety. Research, policy and practice adopted holistic and interdisciplinary approaches (combinations of risk assessments, syndromic surveillance, behavioural studies, perception studies), making use of mixed methods (literature review, grounded theory, quantitative survey, observational spot checks, qualitative interviews, focus group discussions, stakeholder meetings), considering different perspectives within and outside of the community (different sociocultural groups, stakeholders, and community versus health care providers), at different implementation and geographical levels (local, regional, national, international).

In the presented studies, the use of a single method or assessment would have been insufficient to draw a comprehensive picture and thus to create an understanding of the situation and its policy-relevant implications. The studies set a major focus on triangulation of the results, which allowed to fully display the context and complexity by using and discussing results from different data sources against each other.

The world does not operate in simple, linear, cause-and-effect relationships but is dynamic and context-specific. Diverse actors see water-related health challenges from different perspectives and have different priorities. It is therefore vital to look at water-related global health challenges from different angles and from a holistic system's perspective. As the case studies from a wetland in Sub-Saharan Africa and from Small Island Developing States showed, interdisciplinary, mixed methods toolboxes, used in medical geography have several benefits:

- They embrace the complexity and help understand and solve challenges related to water and global health;

- They have the potential to bring together stakeholders from different sectors for programming at different levels to facilitate discussions;

- They form detailed evidenced-based contextualized recommendations on realistic measures how policy makers, different actors and donors can improve health-promotion for target populations and make locally-informed interventions efficient, effective and sustainable in the context of the Sustainable Development Goals.

Acknowledgements

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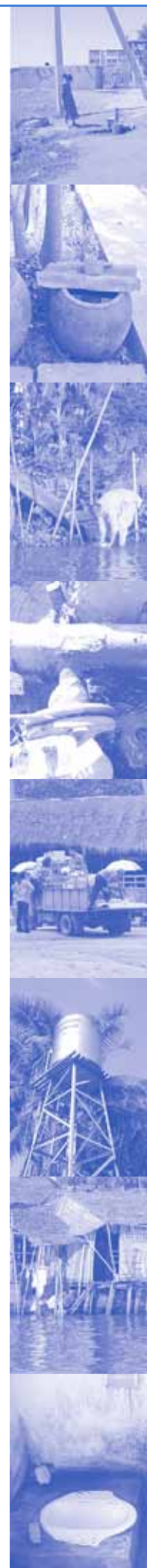
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Managing drinking water risks takes time

Four years after moving from California to North Carolina to do water research, I have a story to tell. It starts even before I started, when Professor Jamie Bartram, a veteran of water and sanitation programs at the World Health Organization (WHO), asked me what kind of projects I wanted to take on for my doctoral studies. I scribbled down a few notes on the various ideas we ran through, and one rose to the top of the page.

Years earlier, Prof. Bartram led a lengthy, stakeholder inclusive process to develop a new drinking water safety intervention, called a Water Safety Plan (WSP), similar to preventive approaches used to avoid contamination in meat, dairy, and other types of packaged food production (Bartram et al., 2009). After re-entering academia to initiate the Water Institute at UNC Chapel Hill, he still held a keen interest in seeing how the programs played out in practice. As public health professionals, we often hear, "global is local" and "think globally, act locally." Earlier efforts to examine WSP feasibility in the US and North Carolina (Amjad et al., 2016; Baum et al., 2015) provided foundational understanding, but little policy or practice activity to build upon. Meanwhile in Iceland, drinking water risk management had been legislatively enforced since 1995, and a pioneering observational effectiveness study showed a dramatic 14% drop in diarrheal disease rates following WSP implementation (Gunnarsdottir et al., 2012b).

Dr. Jean-François Loret, a researcher for a water supplier based in France (Suez) proposed doing some quantitative evaluation work on their drinking water risk management programming, as a follow up to an earlier survey study on the costs, benefits, challenges, and facilitating factors to WSPs in 21 systems in five countries (Loret et al., 2016). They sought an eager graduate student to dive in right away. As a bonus, they gathered not only extensive water quality data, but also several years' worth of rare high-resolution health data from a prescription-based surveillance program that the national public health agency started in France in 2010 (Bounoure et al., 2011). While population health outcomes are not the only measure of risk management success (Gelting et al., 2012), we were able to replicate a finding of health improvement (lower acute gastroenteritis rates) in a high-resource

setting with drinking water disinfection (Setty et al., 2017). This demonstrated both the potential for incremental improvement in all water supply systems and the likelihood of even greater gains in low-resource settings.

We similarly observed a number of improvements in water quality and rates of compliance with regulatory and other management thresholds (Setty et al., 2017). Interestingly, the findings (and the WSPs themselves) varied quite a bit from location to location. This reflects adaptation of an off-the-shelf intervention to the local needs and implementation context (Setty, 2019). Rather than the common approach of measuring compliance with a standard set of water quality thresholds created at the national or international level, WSPs offer practitioners much more flexibility to target their own, often more stringent, site-specific operational controls. WSPs advise that controls should address the highest-priority risks identified for the location, based on the product of likelihood multiplied by consequences. Knowing a risk factor is outside the desired limits allows operators to respond quickly, while water production is still in progress, to correct the issue and avoid major consequences.

Finding some positive outcomes was exciting; yet, it begged the question of whether the changes made via the WSP related logically and causally to the changes in water quality and health. To address this, I resolved to look at the data again through a new lens. This required matching water quality and health records on a daily or monthly basis, not as large chunks of pre- and post-intervention, but as an ongoing time series of discrete events. Such an approach can be tricky since a waterborne pathogen must pass several checkpoints before manifesting as disease: introduction into water, resistance to treatment, distribution to a consumer's tap, consumption, incubation, symptom development, reporting, and diagnosis or treatment. To make it more complicated, gastroenteritis is largely underreported, and more often results from person-to-person and foodborne exposures. Screening out the background noise involved several statistical controls that recognize human behavior patterns, such as when we are more likely to seek healthcare, as well as our relationship to environmental fluctuations.

In the end, the research bore fruit, as we found significant links between exposures and health risks at all locations studied (Setty et al., 2018a). The most risk stemmed from elevated turbidity, which can be a site-specific real-time risk indicator, and what I dubbed "flush" events – a dry period when contaminants build up on land surfaces, followed by enough liquid precipitation to transport it into waterways. While we cannot eliminate either of these risks, both can be actively tracked and managed using a WSP.

Figure 1: Participating in a panel discussion at a project report-out meeting in Spain (Source: K. Setty)

Next came an opportunity to better understand precisely how operators and managers interact with their water system to achieve performance improvement. One of the utilities we studied had carefully collected data over several years on 24 different operational performance measures, which they identified independently as important goals for their system. Triangulating quantitative high-resolution sensor data with performance assessments, alarm logs, complaint records, and other qualitative reports from managers, we reconstructed how WSP inputs drove changes in operational performance, which led to better control of water quality risks (Setty et al., 2018b). This report emerged in parallel with a larger WHO-sponsored overview of WSPs implemented in the Asia-Pacific region (Kumpel et al., 2018), which largely agreed with the indicators the Suez system successfully trialed in France. The WHO and International Water Association (IWA) followed up the same year by publishing a collection of diverse case examples to illustrate how closely operations and maintenance process improvements intertwine with WSPs (WHO and IWA, 2018).

Eventually, like most research programs, mine circled back home to see whether additional steps could be taken to make possible proactive risk management programs in the United States (US). While we might think of the US as a high-resource setting, contextual factors such as a substantial existing regulatory burden and perceptions of inadequate time and resources have made this a rather troublesome location for WSP implementation (Amjad et al., 2016; Setty et al., 2019; WHO and IWA, 2017). We partnered with the Water Research Foundation (WRF), Corona Environmental, and four large US utilities to (a) examine applicable risk management guidance, (b) tailor guidance for surface water sources in the US, (c) pilot-test a risk management program for the first time, and (d) evaluate the pilot. The preliminary literature review and workshop showed that WSP guidance met many of the criteria needed to enable risk management programming, but was more likely to be effective if transcribed into or hybridized

with national regulatory or voluntary guidance (in this case, we recommended voluntary standards developed by the American National Standards Institute and American Water Works Association) (Setty et al., 2019). The evaluation work is described in detail in a forthcoming project report (WRF 4748). I can safely say the approach holds promise, but faces many challenges that demand implementation support (Setty, 2019).

With fortuitous timing, Dr. Giuliana Ferrero of the IHE Delft Institute for Water Education this past year led and included me in a comprehensive review of capacity building and training approaches for enabling WSP implementation (Ferrero et al., 2019). We recognized the many steps that need to be taken between development of guidance and successful program outcomes, including stepwise introduction, practice, and reinforcement along the lines of educational theory and tailoring the approach and messaging to the provider, audience, and delivery format to address specific needs and stages of program scale-up. Teaming up again with Shannan George, a training specialist at the Water Institute, I similarly gained hands-on experience teaching introductory WSP content to a virtual class of about 25 international learners, many of whom seek to apply WSPs in practice.

Wrapping all of these experiences into my dissertation felt a bit like piecing a puzzle together, but thanks to some good advice from my dissertation committee, I recognized the strong role context and complexity played in each case. This led me to identify five crosscutting themes (described below) that generate recommendations for ongoing WSP science, policy, and practice (Setty, 2019).

For starters, complex interventions cannot be evaluated in the same way as simple interventions, because they involve multiple actors making many types of changes at different scales (e.g., individual, organizational, community). Public health research in general has often taken cues from controlled clinical trials, although we face entirely different challenges in scaling water, sanitation, and hygiene programming. That is, context is a critical factor that cannot and should not always be "controlled" in applied research. Success must be measured differently, using tailored study designs, and researchers must keep this in mind when synthesizing evidence.

Along the same lines, tailoring is an embedded expectation in complex interventions such as WSPs, and these adaptations to context and site-specific risks must be documented to understand which changes helped, did not effect, or hurt the effort. Knowledge of where adaptations differ from the original guidance can help to identify critical factors (aka core components) that should be preserved faithfully to avoid losing effectiveness (Proctor et al., 2011). Documenting adaptations also helps one understand what has been done so far, and therefore could be adjusted, which leads to the next point...

The third theme of quality improvement means that WSPs are living programs not done once but implemented consistently over time. Using short plan-do-check-act cycles has been proposed (Bereskie et al.,
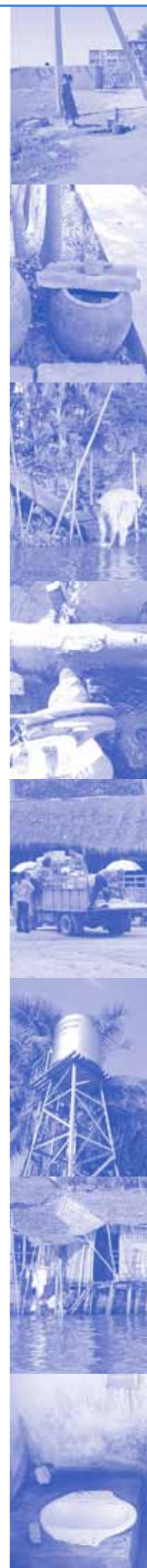
2017) as a way to nudge outcomes in the direction of WSP goals by repeatedly trialing an approach, evaluating results, and adjusting course. This sets the bar not as a single demonstrable improvement, but as maintaining stability and incremental improvement over time. It also prevents programs from growing stale, by setting time expectations for auditing and updating.

Figure 2: Water "taste test" at a WSP-compliant treatment plant (Source: K. Setty)

WSPs are human-centered interventions because they rely on people picking up the guidance, interpreting it, and taking some action. Buy-in from all stakeholders, from politicians to managers to operators to contractors to residents, has been shown as a critical factor in WSP success (Gunnarsdottir et al., 2012a; Kayser et al., n.d.; Summerill et al., 2010). The best way to make WSPs sustainable is to understand human limitations and tendencies, and make it easy for people to do the right thing (Bartram et al., 2009). In much the same way, we might recognize that we need an alarm clock to avoid oversleeping, or a workout pal to minimize our risk of skipping exercise. If an intervention becomes overly difficult or burdensome, it simply will not render gains in the long term. Lastly, while WSPs have quickly permeated a number of countries (WHO and IWA, 2017), meeting the Sustainable Development Goal of universal safely managed water (UN Water, 2018) will require active dissemination and implementation efforts to bridge the gap between science, policy, and practice. Some keen adopters may not require much of a push. For instance, Australia has already integrated WSPs into their national regulations, partly owing to a Cryptosporidium scare (Baum and Bartram, 2018). Implementation science frameworks, models, theories, and strategies might help to address climates more resistant to risk management, where greater contextual barriers often exist (Setty, 2019).

Although few people read dissertations these days, I find this research substantially more valuable if it jumps off from the pages of scientific libraries into the way people carry out their work. WSPs represent a preventive lifestyle. If your work focuses on drinking water provision or wastewater safety, you might consider whether WSPs or their counterpart sanitation safety plans (Jackson et al., 2015) could be doing more for your system. Alternatively, if you are planning a project, event, or goal as another part of your professional or personal life, you can always broadly apply the concept of risk management to identifying, ranking, and ensuring your biggest risks are under control (ISO, 2018). My advice? Keep calm, take measured risks, and keep trying!

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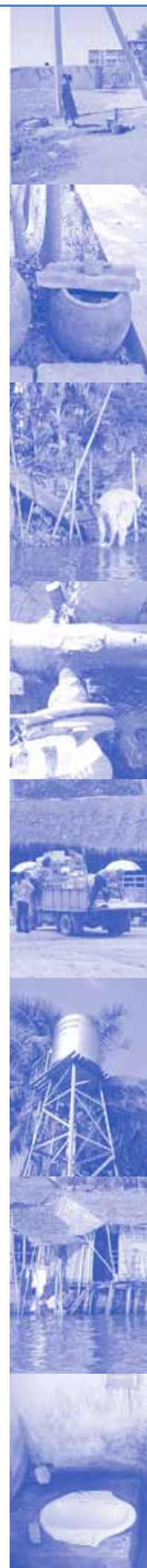
Protocol on Water and Health - Publications

The 5th Meeting of the Parties on the European Water and Health Protocol brought together 250 participants from the pan-European Region to discuss progress in implementing health and rights based approaches to improve drinking water and sanitation in communities, schools and health care facilities. At the meeting, six new publications on water and health have been launched.

We think they are worth reading!

Strengthening drinking-water surveillance using risk-based approaches (2019)

The framework for safe drinking-water recommended by WHO promotes a risk-based preventive management approach to ensure safety of drinking-water. Independent drinking-water surveillance is one of the core components of this framework and is an essential public health function.

The document available in English and Russian at: http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2019/strengthening-drinking-water-surveillance-using-risk-based-approaches-2019

Improving health and learning through better water, sanitation and hygiene in schools. An information package for school staff (2019)

Access to safe and reliable water, sanitation and hygiene (WASH) is a critical precondition for providing a safe school environment that supports equal opportunities for high-quality education and healthy development of children. This package of tools offers practical support for school staff on how to address common WASH problems and deliver improvements. It will help schools strengthen health

education and implement whole-school policies that promote the health, well-being and dignity of pupils and school staff.

The document is available in English and will be soon available in Russian at: http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2019/improving-health-and-learning-through-better-water,-sanitation-and-hygiene-in-schools.-an-information-package-for-school-staff-2019

Surveillance and outbreak management water-related infectious diseases associated with water-supply systems (2019)

Despite high access rates to improved water supplies, drinking-water supply systems are among the most important sources of water-related infectious diseases (WRID) posing a threat to public health in the pan-European region. This publication addresses surveillance and outbreak management of WRID associated with drinking-water supply systems, building on existing guidelines for infectious disease surveillance and outbreak response. It aims to help countries to build on and strengthen their systems by providing

The document is available in English and Russian at: http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2019/surveillance-and-outbreak-management-of-water-related-infectious-diseases-associated-with-water-supply-systems-2019

Surveillance of water, sanitation and hygiene in schools : A practical tool (2019)

Accsess to WASH in schools in the pan-European region presents many and diverse challenges. A key step to improve the situation, bringing better educational and health outcomes, is high-quality surveillance to raise awareness and drive progress. This publication provides a practical tool to support countries in strengthening surveillance of WASH in schools. The findings will inform the development of supportive regulations and improvement planning to safeguard children's health, well-being, dignity and cognitive performance. The tool also enables countries to use the data collected to facilitate policy dialogue and inform international

reporting, including on progress towards achieving the Sustainable Development Goal targets related to WASH in schools.

The document is available in English and Russian at: http://www.euro.who.int/en/health-topics/environment-and-health/water-and-sanitation/publications/2019/surveillance-of-water,-sanitation-and-hygiene-in-schools.-a-practical-tool-2019

The Human Rights to Water and Sanitation in Practice: Findings and lessons learned from the work on equitable access to water and sanitation under the Protocol on Water and Health in the pan-European region

This publication capitalizes on the findings and lessons learned from the work on equitable access to water and sanitation under the Protocol since 2011. It features the experiences of eleven countries from the pan-European region that have established baseline measures of their situation with regard to equitable access to water and sanitation.

Protocol on Water and Health and the 2030 Agenda: A Practical Guide for Joint Implementation

The Protocol on Water and Health is a legally binding instrument aimed at achieving safe drinking water and sanitation for everyone and effectively protecting water resources in the pan-European region. The Protocol provides a sound approach, valuable experience and a successful regional platform to implement the Sustainable Development Goals pertinent to water, sanitation and health.

The brochure is available in English and Russian at: http://www.unece.org/index.php?id=52057

WATER, SANITATION, HYGIENE & HEALTH NEWSLETTER

To stay up-to-date with the latest WASH news by WHO, events and publications, send an email to LISTSERV@who.int with the text "subscribe WATERSANITATION" in the body of your email.

The WHO CC Bonn thanks all readers and contributors for their commitment in 2019 and sends Season's Greetings and best wishes for 2020 !
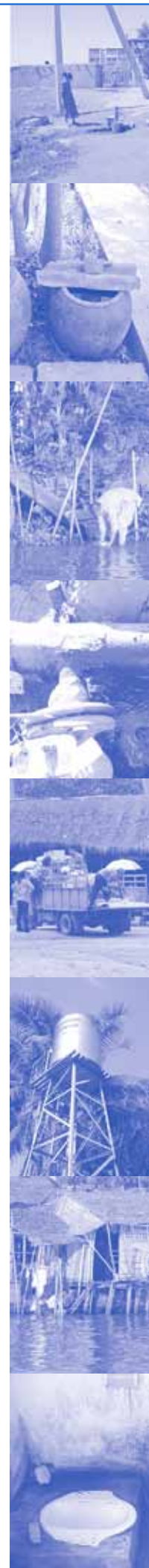
Events on Water, Health and Risk Communication

January

Water Management in Cold Climate 2020
12 - 14 January 2020
Harbin, China
www.wmcc2020.net

February

2nd IWA Polish Young Water Professionals Conference
12 - 14 February 2020
Warsaw, Poland
www.iwa-ywp.pl

6th IWA young water professionals conference of the BeNeLux
12 - 14 February 2020
Luxembourg, Luxembourg
www.ywpbenelux.org

20th AfWA International Congress and Exhibition
24 - 27 February 2020
Kampala, Uganda
www.afwa2020.org

March

AWA/IWA Australia-New Zealand Young Water Professionals Conference 2020
12 - 14 March 2020
Brisbane, Australia
www.awa.asn.au

World Water Day
22 March 2020
Edinburgh, United Kingdom
www.worldwaterday.org

Global Water Summit 2020
28 - 30 March 2020
Madrid, Spain
www.watermeetsmoney.com

April

Protocol on Water and Health - Global workshop on transboundary agreements
1 - 2 April 2020
Geneva, Switzerland
www.unece.org

May

12th Eastern European Young Water Professionals Conference: Water Research and Innovations in a Digital Era
20 - 23 May 2020
Riga, Latvia
www.iwa-ywp.eu

XVII IWRA World Water Congress
11 - 15 May 2020
Daegu, Republic of Korea
www.worldwatercongress.com

June

LET2020 - The 17th IWA Leading Edge Conference on Water and Wastewater Technologies
1 - 5 June 2020
Reno, USA
www.iwa-let.org

5th International Conference on Ecotechnologies for Wastewater Treatment (ecoSTP2020) „impacting the enviroment with innovation in wastewater treatment"
22 - 26 June 2020
Milano, Italy
www.ecostp2020.polimi.it