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WHO Collaborating Centre for Health Promoting
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University of Bonn - IHPH Institute for Hygiene and Public Health

WATER & RISK

Dear Reader,
As 2016 is coming to an end, we are preparing for Christmas and would like to conclude the year with our latest edition of the Newsletter on Water&Risk. We hope you have all had a pleasant year with new discoveries in the field of water and risk. While the analysis of E. coli in water is nearly unchanged for more than a century, new methods are continuously being developed in order to increase the specificity of tests, reduce the time needed to retrieve results, and provide more detailed information about the microbial water community. While highly specialized technicians use the latest analytical technologies to figure out differences on molecular levels, we still need robust and cheap methods for laboratory analyses that have to be carried out under basic conditions in low-resource settings. Sometimes equipment is limited, power cuts make incubation at specific temperatures challenging, ants discover agar plates as their food source, dust becomes the biggest enemy, and the ability to improvise is indispensable. Nevertheless, with robust analytical methods we are able to produce reliable results, detecting fecal contamination and revealing potential infectious risks.
These results are integrated into the decision-making supporting not only drinking water safety in low-resource settings, but also regarding recreational water quality and other water usages. The concentrations of fecal indicators in water serve as an indicator for health risks and help establish different guideline values which should not be exceeded depending on the intended use. Nonetheless, we must keep in mind that compliance with guideline values does not result in complete absence of risk. There are pathogens that do not correlate with fecal indicators; the amount of indicators may be influenced by the environment and season; and unique individual susceptibility to disease must be considered.
Finally, we can expect new risks to emerge, including antibiotic resistance and disease transmission through global trade. These are gaining increasing attention as researchers aim to deliver more knowledge about newly discovered risks that are carried via water. Let´s see what 2017 will bring.

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Simple diagnostic solutions for low-resource settings – An illusion?

Since the adoption of the UN Millennium Development Goals (MDGs) in the year 2000, more than two billion people are estimated to have gained access to an improved drinking-water source. Unfortunately, most people living in low-resource settings or economically less-developed countries (LEDC) yet have no drinking-water of sufficient quality for consumption (UNU-INWEH, 2015). Moreover, and as highlighted by the United Nations University Institute for Water, Environment and Health (UNU-INWEH), the metric used for estimating the access to improved drinking-water does not include any data on the quality of access to an improved water source. Inequalities, demography, gender, and economic indicators are not taken into consideration. Consequently, the real number of people having no access to an improved water source would be almost two billion (UNU-INWEH, 2015). Also, water quality deterioration in many parts of the world is estimated to rapidly increase over the next decades, accelerating risks for human health and economic development (WWAP, 2016).

The pre-study for the first-ever and upcoming World Water Quality Assessment highlights that water pollution has become worse since 1990 throughout almost all river systems in Latin America, Africa, and Asia with severe pollution by pathogens already affecting one-third of all river stretches. The report highlights the very low density of water quality monitoring facilities in low-income countries, as well as the significant inconsistency between indicators worldwide and regional knowledge needs (UNEP, 2015).

Additionally, the lack of adequate finances, qualified laboratory technicians, and an uninterrupted supply of energy, as well as limited access to analytical equipment and reagents, or functioning cooling chains, makes it difficult to operate a modern microbiological laboratory. Such conditions consequently create the need for simple, easy-to-operate, and affordable diagnostic solutions which can be applied in remote, low-resource and emergency settings.

Relating to the term 'Global South' often used within this context, it should be highlighted that the lack of access to safe drinking-water is not exclusively shaped by this geographical definition. Remote and Arctic settlements inhabited by mainly indigenous people suffer from very similar problems rarely given any attention, since such places are usually affiliated with high income countries (Arctic Health, 2015 & UNU-INWEH, 2015).

In contrast, and unlike in most low-income or remote areas where poorly treated, semi-protected or open water sources are used, emergency water supply is usually treated, and nearly always chlorinated (Carter, 2015). Supplying treated water for consumption suggests already a lower risk for human health, but does this justify a compromise of diagnostic standards or even a change of paradigm?

Due to the reduced likelihood of microbial cross-contamination and the expected lower numbers of pathogens, a diagnostic test of 'screening' quality should only still be seen as an analytical possibility in the absence of more sophisticated alternatives or even validated methods. Nevertheless, when taking cost and feasibility into consideration, the question of a screening test versus a confirmatory test prevails.

Standard methods and the current state of the art

Testing for microbial indicators such as presumptive thermotolerant coliforms, including E. coli, and for faecal enterococci, by applying either the membrane-filtration method with semi-selective culture media or the most probable number (MPN) method, is still the accepted modus operandi, as outlined by Standard Methods for the Examination of Water and Wastewater (APHA, 2012).

Although new and very specific methods like chromogenic substrates, PCR-analysis, and laser-based methods such as (portable) flow cytometry or matrix-assisted laser desorption/ionization (MALDI) have emerged, these techniques are neither affordable for most low-income places, nor feasible or applicable in most instances, let alone in disaster situations. Moreover, highly qualified laboratory technicians are required to carry out such diagnostic methods and thus reagents need to be readily available. It is for these reasons that UNU-INWEH (2015) calls upon the identification and emphasis of 'high impact and low-cost solutions'.

In any case, and as advised by the WHO Guidelines for Drinking-water Quality, internationally standardised and accepted methods should be evaluated under local circumstances before being applied in the field (WHO, 2011).

Presence/absence tests and the H_2S method – An alternative?

Presence/absence (P/A) tests such as the hydrogen sulphide (H_2S) test may be appropriate for monitoring drinking water of good quality where positive results are rare or in situations where it is impractical to apply more sophisticated laboratory methods (i.e. treated water in remote places or disaster situations) such as the membrane-filter technique. These tests are usually easier to apply and cheaper to procure. However, and as the name suggests, P/A tests are not quantitative: they indicate only the presence or absence of a certain organism – depending on the specificity of the culture medium and the method.

The H_2S test first developed by Manja et al. (1982) in India was and still is regarded as an affordable tool to monitor microbial drinking-water quality in low-resource settings, where standard diagnostic methods are often not feasible. It is a simple P/A test which uses a paper strip, inoculated with a sulphur and iron-containing culture medium, placed in a culture tube which then is filled-up with sample water. The test is read as positive when a black iron precipitation is visible, usually after 18 to 48 hours. When prepared beforehand, no additional equipment (i.e. incubator or UV-lamp) is needed.

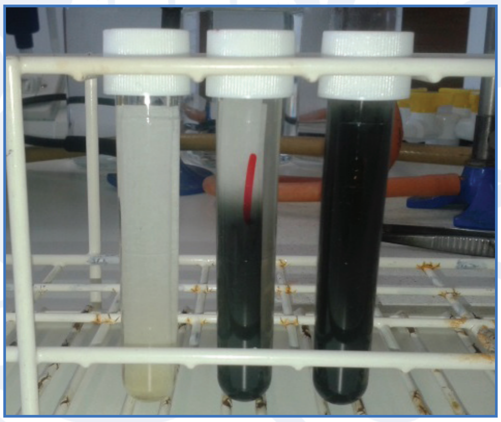


Figure 1: H_2S test reacting positive (black precipitate)
Source: Bastian Schnabel

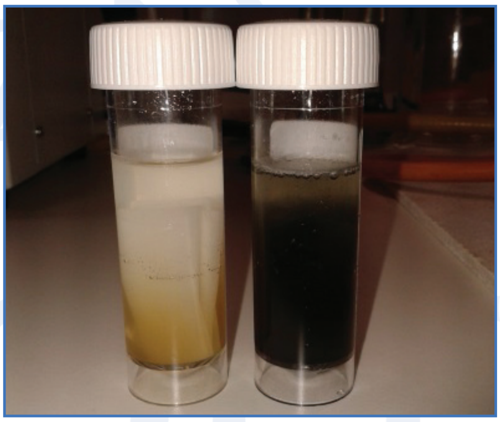
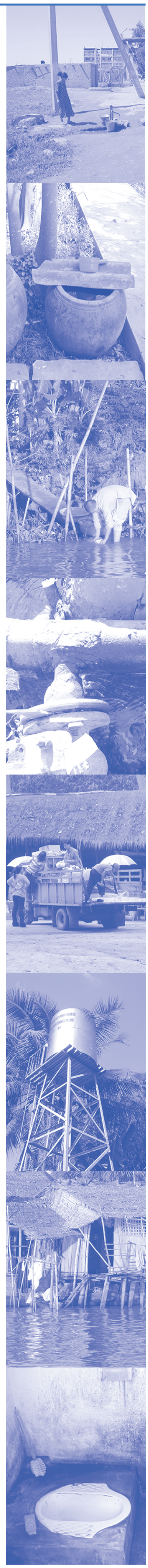


Figure 2: Positive H_2S test (right)
Source: Bastian Schnabel



Unfortunately, little is known about the test's performance, especially in different places or under different environmental/climatic conditions, despite its wide use and popularity. Instead of targeting the acclaimed faecal indicator bacteria (FIB), the original H_2S test targets for sulphate and sulphur-reducing bacteria, which are found commonly in most environments. Yang et al. (2013) highlight that detecting for H_2S producing bacteria can have a comparable quality to established indicators such as E. coli, given an appropriate sample volume.

Further, quality control (QC) aspects have, with regards to the literature published to date, hardly been investigated. Especially when considering that an assessment of quality control in diagnostics consists at least of the following elements: initial demonstration of capability, defining the operational range plus establishing the method detection level, an ongoing-demonstration of capability, followed by a laboratory control standard (APHA, 2012). Also, this procedure should be carried out with a known amount of target organisms, non-target organisms, and organisms closely related to the target organism (ISO, 2014).

Investigating performance and modifications

Due to the H_2S test's popularity and its increasing use, especially in South Asia and sub-Saharan Africa, resulting from its low cost and high feasibility and simplicity, efforts are required to assess its performance and to improve the test's sensitivity and specificity for faecal indicator organisms. Furthermore, an extended investigation into the performance of the H_2S test and its newly created modifications, with comparison to different types of water and sulphate and sulphur-reducing bacteria of faecal and non-faecal origin, is indispensable.

This ongoing research project hence has the aim to close this knowledge gap, to give people and their communities in low-resource settings finally the chance to test their drinking-water (for the still accepted indicator organisms), in fulfilment and support of the new Sustainable Development Goals (SDGs).

Preliminary results from testing modifications of the original H_2S test formula indicate that it is possible to considerably increase the H_2S test's sensitivity for presumptive and thermotolerant faecal coliforms (incl. E. coli). Additionally, preliminary results from testing Manja's et al. (1982) original H_2S test with a broad range of known amounts of isolated bacterial strains suggest that the test reacts positive mainly to Citrobacter freundii ATCC® 8090™, Proteus mirabilis ATCC® 43071™, and Salmonella typhimurium ATCC® 14028™.

The conflict of deciding on the 'right' faecal indicator organism

With regards to the acclaimed and internationally accepted faecal indicator bacteria and the performance of the H_2S test, and without many alternative choices available at the current stage, it is logical to focus on an increased sensitivity and specificity for the already accepted FIB.

Gerba (2000) states that the criteria for an ideal indicator organism are that it should be useful for all types of water; it should be present whenever enteric pathogens are present; it should have a reasonably longer survival time than the hardiest enteric pathogen; it should not grow in water; the testing method should be easy to perform; the density of the indicator organism should have some direct relationship to the degree of faecal pollution; and the organism should be a member of the intestinal microflora of warm-blooded animals.

However, no established indicator so far meets all these criteria outlined above (Gerba, 2000; Gleeson & Gray, 1997), and little is known about the factors influencing and promoting their growth in the environment (Vital et al., 2010). It therefore follows that any diagnostic test should be evaluated under local circumstances, as mentioned earlier.

Nevertheless, the discussion about the 'right' faecal indicator organism remains shaped by compromise, while addressing limitations of knowledge in molecular biology, and the lack of a unified and accepted agreement on what we're actually looking for when analysing the microbial quality of drinking water – regardless if this takes place in low-resource settings or somewhere else.

Surely, and in the absence of globally reliable indicators for faecal contamination, the overall approach has to be made more holistic by including tools such as the water safety plan (WSP) concept or sanitary surveys, and by not leaving out a discussion on intercultural risk perception and risk management. However, any indication for faecal coliforms, faecal enterococci, and/ or faecal H_2S-producing bacteria found in water used for human consumption should be taken with caution. The H_2S test hence is an affordable and feasible alternative for the microbial analysis of drinking water in low-resource settings, and any improvement of its sensitivity and specificity is a step forward to avoid transmission of diarrhoeal diseases.

Acknowledgements

This research is part of a PhD project investigating performance and modifications of the H_2S test through the comparison of the H_2S method with previously validated and established methods. The project is financed by the University of Brighton, UK.

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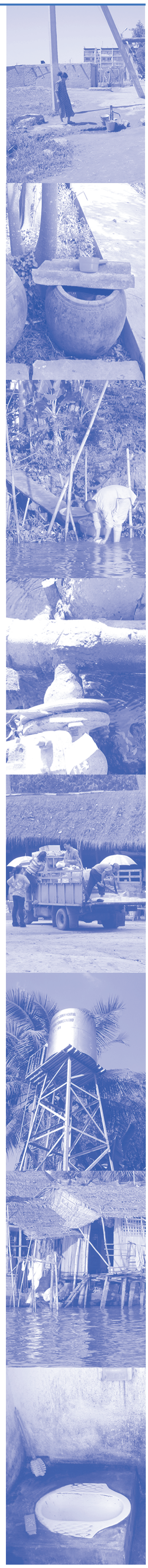

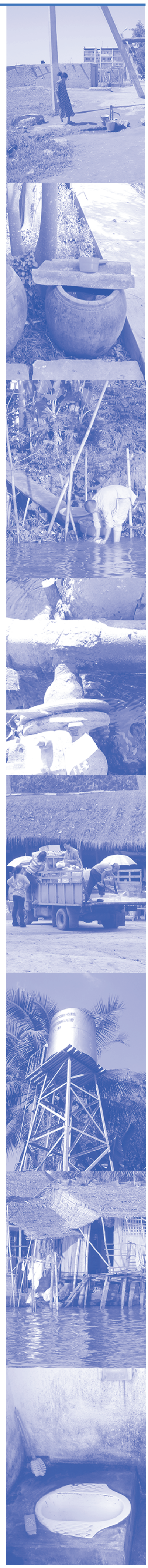

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Health prevention and protection at ports- Insights from an internship at the Hamburg Port Health Center

In times of globalization, ports become more and more important. They are the transition points of increasing flows of goods and (touristic) passenger transport. Here, transmission of biological, chemical and radiological agents as well as communicable diseases can take place. Vehicles, freight, crew members and passengers can serve as vectors and transport health threats over long distances. On an EU level, SHIPSAN ACT plays an important role in the prevention of the spread of diseases across borders and in the protection of the health of passengers and crew members. To ensure this, the initiative aims at strengthening integrated strategies and sustainable mechanisms at the EU level. It consists of 30 partners from 23 European countries and is funded by the European Commission (SHIPSAN 2013). On the national level, port health services are responsible for the surveillance of health impacts. In Germany, Hamburg is the biggest port (Figure 1); the Hamburg Port Health Center (HPHC) takes the lead in terms of health matters at the port and at the airport as well. The HPHC is based at the Institute for Hygiene and Environment Hamburg with three port doctors and six inspectors.

Figure 1: Hamburg harbor, view from the bridge of a ship
Source: Kristina Militzer

In summer 2016, I was doing an internship at the HPHC and gained some insight into different working areas of the HPHC. Ships arriving from foreign ports are required to submit a Maritime Declaration of Health to the HPHC which mainly consist of nine health questions. In case of any anomalies, for example, if an infectious disease has occurred or if someone has died on the voyage, a port doctor will come on board to assess whether or not there is a health risk for crew members, passengers or the harbor. Port doctors can also be consulted by seafarers in the location of the Seaman´s Mission. This anonymous and cost-free service provides seafarers the opportunity to get prompt health advices and medical attention. Additionally, port doctors conduct vaccinations on board and issue medical eligibility examinations for captains. The main everyday functions of the inspectors are to issue ship sanitation certificates (SSC) and to test the water quality on board ships (Figure 2). Both are important measures for the promotion of health and the prevention of diseases of crew members as well as passengers. These are only some examples of the manifold areas of responsibility of the HPHC.

Figure 2: An inspector of the HPHC at work
Source: Kristina Militzer

Ship Sanitation Certificates

Every ship arriving at the port of Hamburg needs a Ship Sanitation Control Exemption Certificate or Ship Sanitation Control Certificate (SSC), which is issued or checked by the inspectors of the HPHC. SSCs have been introduced with the International Health Regulations (IHR) to prevent and control public health risks on board and on international voyages. Since 2007, SSC certification procedures are in place that are more extensive than previously issued Deratting Certificates from 1969 (WHO, IHR 2011). SSCs document the sanitary and health conditions on ships by checking different areas like the sewage and freshwater system, hygienic conditions in the galley and in pantries, the waste disposal system, the equipment of medical facilities (hospital and pharmacy) and the records in the medical logbook. This helps to identify all ship-borne public health risks. This also supports ship owners making it easier for them to determine adequate measures against health threats and to anticipate upcoming risks.

Water on board

Depending on the type of ship, several hundreds of liters of water per day may be needed for daily human consumption as well for working procedures. The quality of potable water is of substantial importance for the health of the crew and passengers. Depending on the flag of the ship, it has to obey different regulations. A ship under German flag is obliged to have the same drinking water quality on board as onshore according to the German drinking water ordinance. Consequently, it has to be free of fecal indicator bacteria like E. coli and pathogens such as Legionella pneumophila, and there have to be regular quality controls by port health services as well (Dirksen-Fischer 2014, p. 101). There are three possible methods of providing potable water on board. One option is that ships produce potable water on their own, which means that seawater is pumped in and treated (desalinated, chlorinated, and mineralized). Assuming a ship is regularly calling at a port; it can also fill water tanks at the harbor and bunker it for the journey. In both cases, contaminations through microorganisms in the storage container and the pipes should be prevented. For instance, flushing rarely used water pipes is recommended in order to prevent stagnating water and the regrowth of bacteria. The third way to provide potable water on board, though it is very cost-intensive and requires more storage space, is to warehouse packed bottles. Besides potable water, there can be another type of fresh water on board ships which is service water. While potable water is used for drinking, cooking and washing, service water is appropriated, among other types of uses, for flushing the toilet. In contrast to potable water, service water may be of lower quality; as a matter of fact, seawater can be used.

Figure 3: Sewage treatment plant on a ship
Source: Kristina Militzer

Sewage water on ships is classified as grey water and black water. Grey water is sewage from the shower and galley. Black water contains among other sources, water from toilets and the hospital. Both types of water are treated in sewage treatment plants on board (Figure 3).

Occupational health and risks on ships

Being on the ocean means living and working under extreme conditions. It is more than likely to encounter a storm on a long journey. Sometimes the freight contains dangerous goods and things have to be fixed while being on the high seas. Ships are always in motion and there is no chance to escape from swell. Accidents may happen which affect the physical health of the crew. Furthermore, there is limited space on ships. Consequently, there are only few places for recreation as well as restricted opportunities to relax which can have an adverse impact on the well-being of the people on the ship. Normally, there is no doctor in accessible proximity. Therefore, seafaring is still considered to be one of the most dangerous occupations worldwide. This underlines the immense importance of maintaining a good state of health for every person on board. To keep the risks of accidents and of falling ill to a minimum, occupational health is central. In order to help ship owners manage occupational risks and implement measures against them, a cooperation effort between SHIPSAN-ACT– Joint Action and the European Agency for Safety and Health at Work (EU-OSHA) is developing an Online Interactive Risk Assessment (OiRA) tool for Maritime Transport. The elimination and reduction of risks and therewith the prevention of accidents is a cornerstone in managing the rough conditions on the high seas.

Mosquito surveillance at the port and airport of Hamburg

During my internship, it was one of my main tasks to organize and conduct a project evaluating the transportation of tropical mosquitoes via ships and airplanes to Hamburg. One of the reason for the surveillance of mosquitoes at the ports of Hamburg was the recent spread of the Zika virus together with clusters of microcephaly and other neurological disorders in Brazil, which the WHO declared as a Public Health Emergency of International Concern. Zika can be transmitted by Aedes albopictus and Aedes aegypti. These mosquito species are already distributed in several African countries and in South-East Asia, and have lately been circulating in the Americas. Aedes albopictus is established in southern Europe as well while isolated cases have been found in southern Germany (ECDC 2015). It is not easy to predict the spread of a mosquito-borne disease. According to the Interim guidance on maritime transport and Zika virus disease by SHIPSAN (2016), it is possible that the virus will spread through ship and air traffic. There are three different ways of spread of the zoonotic disease. One is via the travelling of infected crew members or passengers. Moreover, infected mosquitoes may be transported via ships or planes. In contrast to Anopheles mosquitoes, Aedes is also active during the day and more resistant to changing weather conditions. It is by all means possible that Aedes fly on board ships during loading and unloading and survive the travel to another port in a foreign country or even another continent. Lastly, special types of imported goods like used tires or ornamental plants can contain the eggs of invasive mosquito species. If the eggs, which can resist prolonged desiccation, survive transportation and find suitable conditions at the arrival point they hatch and the mosquitoes may develop. Despite the fact that the likelihood of the spread of Aedes is regarded to be very low, it is good to take all eventualities into consideration.

Figure 4: Mosquito trap with rain cover at the port of Hamburg
Source: Kristina Militzer

In order to monitor whether tropical mosquitoes are being imported to Hamburg, mosquito traps (Figure 4) have been set up at different places at the airport and harbor of Hamburg as well as on a cargo ship which is operating between Hamburg, West Africa and Brazil. At the time of writing, there are no results of the surveillance yet available. But it can be assumed that even if Aedes mosquitoes are found, their establishment in northern Germany is very unlikely due to current climatic conditions. Indeed, in times of climate change the weather conditions might become suitable for Aedes to spread throughout Hamburg. For that reason,

Figure 5: Head of the HPHC Dr. Martin Dirksen-Fischer (right) and trainee Kristina Militzer (left) Source: Kristina Militzer

the HPHC will continue surveilling incoming health threats and proceed with working on the prevention of diseases to protect those on ships, at ports and the general public.

Acknowledgements

I am convinced that the HPHC makes an important contribution to health protection and prevention at the ports in Hamburg. I am grateful for all the new experiences I gained and things I learned within this internship. I especially want to thank Dr. Martin Dirksen-Fischer (Figure 5) who devoted a lot of his time to me while entrusting me with responsibility for numerous tasks. For further information please visit the webpage of the HPHC: *http://www.hamburg.de/hphc/*

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Spread of multidrug-resistant bacteria via wastewater

Antibiotic-resistant intestinal bacteria can enter the environment through toilets and sewage treatment plants. Some multiply or survive in the environment, while others die but their genes persist and can be transferred to other microorganisms. Humans and animals may become colonized with these bacteria if they are exposed to surface water (e.g. via ingestion, recreation, farming). If antibiotic-resistant bacteria cause infections, it is difficult to treat them effectively with antibiotics. In view of the global trend of increasing antibiotic-resistance, it is of public interest to determine whether and how antibiotic-resistant bacteria spread via wastewater and how this can be prevented. The new project HyReKA studies these considerations while trying to answer the question: what impact does the spread of antibiotic-resistant bacteria have on human health?

The project partners within the collaborative project HyReKA "Biological and hygienic–medical relevance and control of antibiotic-resistant pathogens in clinical, agricultural and municipal wastewater and their relevance in raw water" will identify and characterize sources of antibiotic-resistant bacteria, antibiotic resistance genes and antibiotic residues from humans or animals in the environment in a qualitative and quantitative way (source dissemination). Technical procedures to interrupt the environmental transmission via wastewater will be tested and the re-transfer to humans through contact with water or wastewater will be investigated (Microbial Dissemination). The traceability of drug-resistant pathogens and their resistant genes from wastewater back to their point of origin should be evaluated in the sense of Microbial Source Tracking. In contrast to previous projects, HyReKA combines classic hygienic-microbiological methods with modern molecular-biological methods to reveal risk potentials. The risk to human health will be quantified regarding the potential of resistance dissemination or discrimination. The survey also includes whether and how water used directly or indirectly for human consumption (e.g. meat products, drinking water) or resources for their production (e.g. raw water) can be affected by clinically relevant multidrug-resistant bacteria (Figure 1)

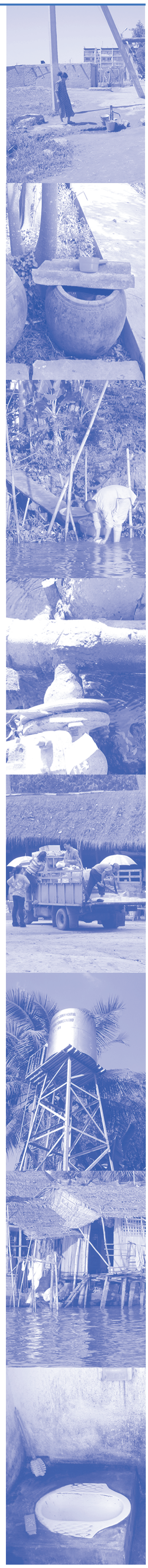


Figure 1: Enterobacteriaceae (intestinal bacteria) on selective agar. Antibiotic-resistant bacteria can spread in the environment via wastewater. Source: Marijo Parčina

Interdisciplinary collaboration

Within the joint project the spread of antibiotic-resistant pathogens from hospitals, agricultural facilities, slaughterhouses and airports via wastewater and sewage water treatment plants into surface waters will be tracked (Figure 2) by an interdisciplinary consortium. This consortium comprises medical, agricultural and biological scientists, two wastewater associations, a wastewater treatment plant and the private company Xylem water solutions, as well as the German Federal Environmental Agency (UBA).

Objectives of the collaborative project

In sum, the HyReKA-network has set the following objectives:

» to examine qualitatively and quantitatively the entry pathways of antibiotic-resistant bacteria, antibiotic resistance genes and antibiotic residues into the environment, including sewage from hospitals, municipal sewage water or sewage water from livestock farms. The aim is to identify stress situations and pathways, and to identify risk potentials;

» to identify the transmission risks from the environment, agriculture or livestock production to humans, arising from contact with contaminated water or food (microbial dissemination);

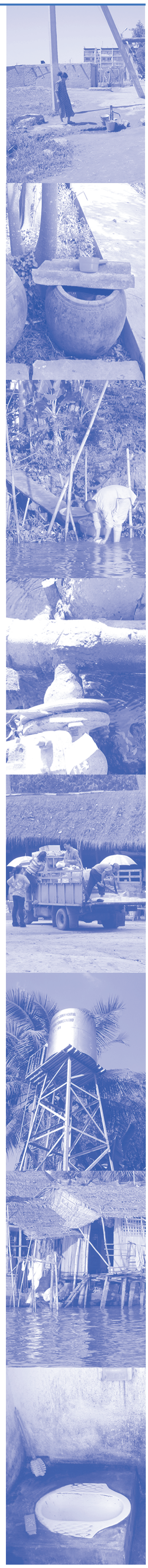
» to examine the traceability of antibiotic-resistant pathogens and resistance genes found in wastewater back to their original sources in the sense of microbial source tracking;

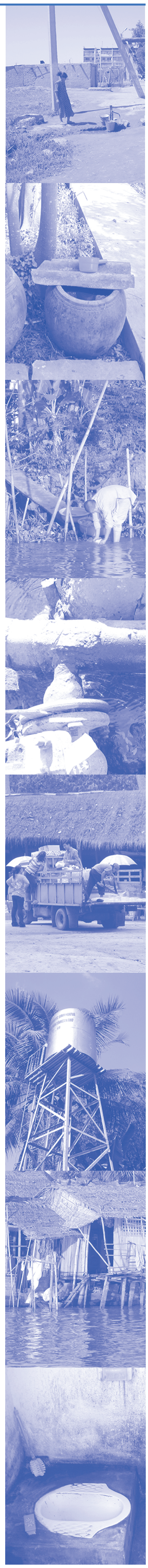
» to examine the effectiveness of innovative technical sewage treatment procedures for interrupting the spread of pathogens;

» to formulate recommendations for action based on the results of the HyReKA joint project as a basis for adapting regulations for the identified risk areas;

» to use results to identify and avoid the risks of multidrug-resistant bacteria dissemination through wastewater: this is also important in light of sustainable risk regulation and the United Nations Sustainable Development Goals.

Figure 2: Possible ways of entry of multidrug-resistant bacteria into the environment.
Source: Thomas Schwartz





Improved health protection

A particular risk is represented by pathogens with a resistance against last resort antibiotics. Curing patients that suffer from an infection with this type of resistant bacteria can be very difficult. The results of the HyReKA project will accordingly help in the development of appropriate measures for interrupting possible transmission pathways within health care facilities. In addition, the emergence of new resistant strains is counteracted, thus protecting the long-term effectiveness of antibiotics.

The long-term goal of HyReKA is to contribute to the improvement of environmental health protection in the area of bacterial infection prevention. The first results are expected in the spring of 2017.

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Rationale and evolution of recreational fresh water quality criteria[1]

For more than 130 years substances that indicate the potential for human infectious disease ("indicators") have been used to monitor drinking water quality. The rationale behind the use of faecal indicator organisms (FIOs) for drinking water quality control has been very clear and straightforward: the objective was to identify any faecal contamination of drinking water. As FIOs such as E. coli and intestinal enterococci are, without exception, part of the normal enteric bacterial flora of warm-blooded creatures, the quality target was easy to determine and to operationalise: only 0 indicator organisms per100 ml water ensure zero faecal contamination of drinking water. For the particular case of drinking water, the indicator principle is a simple Boolean presence/absence decision. It is not required to know anything more about correlations between the concentrations of indicator and pathogenic microorganisms.

The interest for indicator bacteria to assess recreational water quality did not raise until the 1950ties. The challenge to define indicators is obviously much more intricate for recreational water than for drinking water: On the one hand, zero faecal contamination would be an unrealistic quality target for almost every surface water body and, on the other hand, health risks through faecally contaminated water may be expected to be substantially lower through ingesting water during bathing than through drinking water.

Deriving limit values for indicators: systematic problems

The crucial feature of any indicator is the ability to indicate possible a health risk. This can be performed

[1] This article is based on a section of recently published work (Kistemann T, Schmidt, A, Flemming HC, 2016: Post-industrial river water quality – Fit for bathing again? International Journal of Hygiene and Environmental Health 219(7), 629–642).

either directly through conducting epidemiological studies with indicator concentrations as surrogate risk factors, or indirectly via the assessment of pathogen concentrations from indicator concentrations. Although the indirect approach might appear to be simpler and less cost-intensive, in practise this approach is not constructive in the case of recreational water contact for several reasons:

» correlations between FIOs and pathogens are mostly inconsistent;
» no single indicator can reliably predict the presence of all pathogens of interest;
» water analyses required are extensive; in order to embrace the considerable natural variation and detect correlations, both sample sizes and the number of samples positive for pathogens are relevant;
» scientific evidence to define limit values of an indicator for viral pathogens is still weak.

Due to these systematic problems and limitations, limit values of indicator organisms for recreational water (see Table 1) have, without exception, been assessed through the direct method: epidemiological studies by linking FIO concentrations with health outcomes. Cabelli et al. (1983) defined a recreational water quality criterion as a "quantifiable relationship between the density of an indicator in the water and the potential human health risks involved in the water's recreational use." In this respect, the rationale of recreational water quality criteria is not to indicate health-relevant concentrations of pathogenic organisms in the recreational water body, but to indicate a potential health risk beyond a defined 'acceptable' limit. Therefore, in order to install a robust indicator-based water quality system, particularly the following problems and questions need to be addressed:

» Which health risk related to the use of recreational water may be defined as 'acceptable'?
» Which case definition shall be chosen for illness related to use of recreational water bodies?
» Which potential microbiological indicator(s) reliably depict faecal contamination?
» Is there a robust statistical link between the concentrations of indicators and the rate of water-related illnesses for a range of interest?
» By which means can an indicator-based water quality concept, which is based on empirical data of a limited number of investigated settings, be toughened up to account for fluctuating environmental conditions (i.e. for different sites, seasons, weather conditions)?

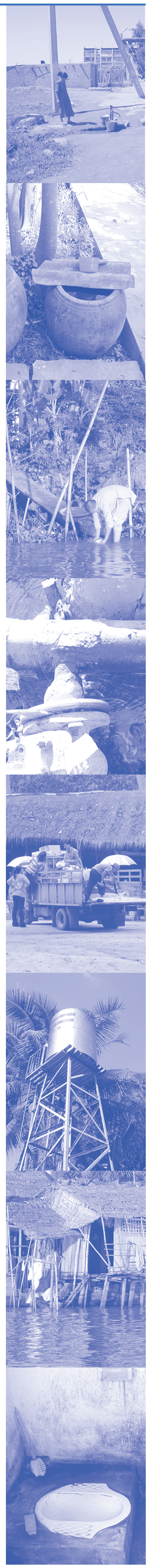
The World Health Organization (WHO), the European Union (EU) and the U.S. Environmental Protection Agency (EPA) have been driving forces in developing rules for safe use of recreational water bodies.

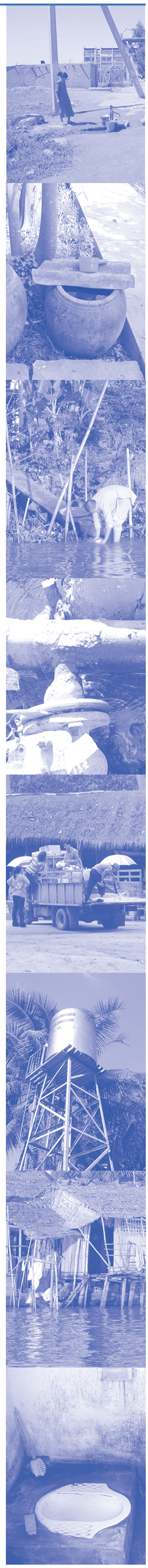
The North American paradigm

In North America, Stevenson was probably the first who published studies on bathing water quality and health outcome in 1953, based upon the results of a series of epidemiological investigations at different U.S. bathing sites (Lake Michigan, Ohio River, Long Island Sound). Swimmers in the Ohio River water, which had a median coliform concentration of 2,700/100ml, turned out to have 32% more gastrointestinal illnesses (GI) than expected – "a significant increase" (Stevenson 1953, p. 538). Similar results – significantly higher GI rate with 2,300/100ml coliform concentration – were found for Lake Michigan, but no associations were detected for the marine bathing beaches.

Based on this fundamental work, the first recreational water quality criteria recommendations were proposed (NTAC 1968). As faecal coliforms were seen to be more faecal specific than coliforms, the coliform concentrations were translated into a faecal coliform index by using the ratio of faecal coliforms to coliforms as measured at the original Ohio River location. To go below detectable risk, one half of the concentration at which a health risk had occurred was proposed as limit value for the log-mean of faecal coliform content of primary contact recreation waters: 200 faecal coliforms per 100 ml. Despite fundamental critique – paucity of epidemiological data; non-consideration of further findings at Lake Michigan; poor definition of 'swimming'; variability in the pollution levels – this criterion was recommended again in 1976 by EPA.

In 1984 Dufour published results of epidemiological fresh water studies conducted on 'barely acceptable' beaches of two U.S. lakes. The evaluation of the data indicated that the limit value being in force would cause an estimated 8 GI cases per 1,000 swimmers (EPA 1986). Using these 'accepted' rates and equations which have empirically been derived by Cabelli et al. (1983) and Dufour (1984), the geometric mean concentrations corresponding to the accepted GI rates were calculated for enterococci (=33 cfu/100ml) and E. coli (=126 cfu/100ml). Additionally, no sample should exceed a confidence limit defined for different types of use, e.g. 75% for designated bathing beaches. In 2012, EPA released its latest recreational water quality criteria recommendations (see Table 1). Related to different models (estimated GI rates 3.6 and 3.2 percent, respectively) the limit values for the geometric mean of the indicators remained nearly unchanged: for enterococci 35 (30) cfu/100ml; and for E. coli (fresh water only) 126(100) cfu/100ml. Echoing the new concepts of WHO (2003) and EU (2006) (see below), confidence limits were replaced by a 'statistical threshold value'. As an additional precautionary tool for making beach notification decisions, EPA (2012) suggested 'Beach Action Values' (BAV). If applied, any single sample above the BAV triggers a beach notification until another sample below BAV is collected.



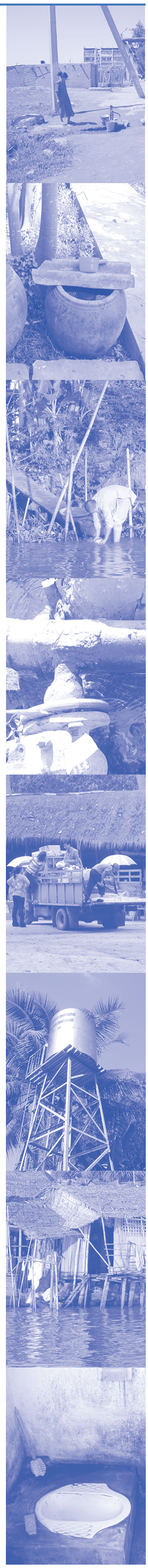


Tab. 1: Quality criteria for recreational fresh water environments

Country / Institution	Year	Indicators	Quality Assessment	CFU/100 ml
Annapolis Protocol / WHO approach				
WHO	2003		**Estimated risk per exposure**	95th percentile
		Intestinal enterococci	A: <1% GI risk, <0.3% AFRI risk	≤ 40
			B: 1-5% GI risk, 0.3-1.9% AFRI risk	≤ 200
			C: 5-10% GI risk, 1.9-3.9% AFRI risk	≤ 500
			D: >10% GI risk, >3.9% AFRI risk	> 500
		+ **Sanitary Inspection Category** (very low – low – moderate – high- very high) » **Classification matrix for faecal pollution of recreational water environments**		
EU / Commission	2006		**Bathing water quality**	95th[1]/90th[2] percentile
		E. coli	Excellent	≤ 500[1]
			Good	≤ 1000[1]
			Sufficient	≤ 900[2]
			Poor	> 900[2]
		Intestinal enterococci	Excellent	≤ 200[1]
			Good	≤ 200[1]
			Sufficient	≤ 330[2]
			Poor	> 330[2]
		+ **bathing water profile** review frequency depending on bathing water quality: every - / 4 / 3 / 2 years		
Australia / NHMRC	2008		**Microbiological Water Quality Assessment Category**	95th percentile
		Intestinal enterococci	A: <1% GI risk, <0.3% AFRI risk	≤ 40
			B: 1-5% GI risk, 0.3-1.9% AFRI risk	≤ 200
			C: 5-10% GI risk, 1.9-3.9% AFRI risk	≤ 500
			D: >10% GI risk, >3.9% AFRI risk	> 500
		+ **Sanitary Inspection Category** / » **Classification matrix for faecal pollution of recreational water environments**		
New Zealand / Ministry for Environment	2003		**Microbiological Assessmant Category**	95th percentile
		E. coli	A: <0.1% risk of campylobacter infection	≤ 130
			B: ≤1.0% risk of campylobacter infection	≤ 260
			C: ≤5.0% risk of campylobacter infection	≤ 550
			D: >5.0% risk of campylobacter infection	> 550
		+ **Sanitary Inspection Category** / » **Suitability for Recreation Grade (SfRG) / SfRG-Matrix**		
		Enterococci should not be used because some can multiply from natural sources		
North American approach				
USA / EPA	2012		**Estimated GI rate: 36[3]/32[4] per 1 000 recreators**	
		E. coli	Beach Action Value	235[3]/190[4]
			Geometric mean concentration	126[3]/100[4]
			Statistical Threshold Value	410[3]/320[4]
		Enterococci	Beach Action Value	70[3]/60[4]
			Geometric mean concentration	35[3]/30[4]
			Statistical Threshold Value	130[3]/110[4]
Canada / Health Canada	2012			Limit value
		E. coli	Geometric mean concentration	≤ 200
			Single sample maximum concentration	≤ 400
		Enterococci	Geometric mean concentration	≤ 35
			Single sample maximum concentration	≤ 70
Other				
Switzerland / BAFU	2013		**Quality class**	Single sample values→ current situation median values→ long-term evaluation
		E. coli	A: health damage not to be expected	< 100
			B: health damage not to be expected	≤ 1000
			C: health damage cannot be excluded	≤1000 or >1000[5]
			D: health damage possible	> 1000
		Intestinal enterococci	A: health damage not to be expected	< 100
			B: health damage not to be expected	< 300
			C: health damage cannot be excluded	> 300 or ≤ 300[5]
			D: health damage possible	> 300

GI = gastrointestinal illness AFRI = acute febrile respiratory illness
[1/2] 95th and 90th percentile respectively to be applied for different limit values as indicated
[3/4] two different models lead to two different limit values, as indicated
[5] for quality class C, at least one indicator (i.e., *E. coli* or intestinal enterococci) must meet the lower indicated limit value

Source: Kistemann et-al. (2016)



The EU and WHO approaches

The European Community published the first Directive addressing the quality of bathing water in 1975 without providing a clear epidemiological rationale (Kay et al., 2004), and installed both guide and mandatory values for three microbiological parameters: total coliforms (500 and 10,000 cfu/100ml, respectively), faecal coliforms (100 and 2,000cfu 000 cfu/ml, respectively), and faecal streptococci (100 cfu/100ml, guide value only).

Prüss (1998) reviewed the entire available body of valid epidemiological studies on health effects from exposure to recreational water between 1953 and 1996. Only 7 studies were identified to address fresh water. Most associations were found between indicators and GI, whereas only few studies reported associations with other symptoms. The review suggested low threshold values for increased risk of GI as well as the existence of dose-response relationships between the bacterial count and symptoms. Enterococci/faecal streptococci turned out to be the indicator organism correlating best with health outcome for both marine and fresh water, E. coli for fresh water only.

Within an extensive epidemiological study in the UK (Kay et. al. 1994) coliforms were shown to have very limited value as indicators of the GI risks. Faecal streptococci showed a dose-response relationship and 33 cfu/100ml turned out to be a robust threshold for increased risk from sewage pollution for marine bathing sites;(Table 1: Quality criteria for recreational fresh water environments page 12) however, these findings were not transferable to fresh water recreation sites. Fleisher et al. (1996) could demonstrate the same for ear infections and the more severe acute febrile respiratory illness (AFRI), both with a higher threshold value than GI. Van Asperen et al. (1998) identified E. coli as being a good predictor of GI risk through bathing in fresh water and recommended it as an indicator with a threshold level of 355 cfu/100ml beyond which increased attack rates were observed. They stated that due to different survival kinetics indicators that correlate best may be different for marine and fresh water.

These new epidemiological insights were important for WHO (2003) and EU (2006) when they conceptualised their new guidelines. WHO defined four categories (A-D) of 95th percentile guideline values for microbial quality of recreational waters (see Table 1) which refer to different estimated GI and AFRI risks per exposure, stretching from <1% GI risk/<0.3% AFRI risk (category A) to >10%/>3.9% risk (category D). Ad-ditionally, and in accordance with the 'Annapolis Protocol' (WHO 1999), the WHO acknowledged the importance of knowledge about relevant conditions in the catchment and recreational areas (sewage discharges, riverine discharges, bather shedding, land use, agriculture, weather conditions etc.) for an improved assessment of health risks. Therefore, the WHO moved away from the exclusive reliance on guide-line or limit values of faecal indicator bacteria, complemented sanitary inspections as a qualitative ranking of susceptibility to faecal influence in recreational water environments and introduced five sanitary inspection categories (very low – low – moderate – high – very high). The result of this two-component approach is a 4x5 classification matrix with six categories of recreational water environments: very good – good – follow-up – fair – poor – very poor (WHO 2003, p. 84). For risk management, WHO (2003) recommended hazard analysis and critical control point (HACCP) as an example of a possible approach. This risk management procedure is to be applied in an iterative manner; it represents a paradigm shift from exclusive product control towards process control in the sense of "Recreational Water Safety Plans". Quality control of the recreational water as the 'product' remains important, but is only one out of a series of critical control points.

The new EU bathing water quality directive (2006) is, albeit incompletely, reflecting this WHO approach (see Table 1): The four categories of indicator organisms (excel-lent – good – sufficient – poor) are defined differently and reflect the proposal that imperative values should limit the health risk; E. coli has been kept as indicator or-ganism; the bathing water classification ('bathing water profile' ≈ WHO sanitary in-spection category), to be reviewed every 2-4 years, comprises only 3 categories: good – sufficient – poor. However, the indicator-based classification and the bathing water profile classification are not merged into a classification matrix, which means that in practice, the bathing water profile classification has still less impact than the microbiological bathing water classification. Most important is, however, that management measures are only mentioned to address poor bathing water quality or exceptional circumstances. Risk management is thus not established as the paradigm of continuously maintaining safe bathing sites.

For a lack of data, WHO (2003) decided to apply the guidelines value derived for coastal waters also to fresh water until review of more specific data would have been undertaken. Later, the first results ever collected in a randomised controlled trial in fresh water were published by Wiedenmann et al. (2006). Depending on the defini-tion of GI, they found relative attributable risks for bathing in fresh waters with indicator concentrations above NOAEL (no observed adverse effect level), ranging from 1.8 to 4.6% and suggested 100 E. coli, 25 intestinal enterococci, 10 somatic coliphages, and/or 10 C. perfringens per 100ml as guide values for recreational fresh water quality. They strongly recommended that standards should be based on rates of compliance with NOAEL, because risks above NOAEL may depend on the unknown susceptibility of the participants. These results were acknowledged by WHO (2009), but specific guideline values for freshwater have not been installed so far. It was recommended, however, that length and frequency of exposure encountered by special interest groups (e.g. swimmers, surfers, canoeists) should be taken into account.

Outlook

The discussion about the most suitable way to define FIO limit values for recreational fresh water bodies is still ongoing. FIOs seem to remain an irreplaceable element of risk management for recreational water bodies. However, multi-dimensional, ecological approaches, equally considering indicator concentrations, current conditions of the recreational site, dynamics over time as well as risk profiles of people searching for recreation seem to be promising for a more realistic prediction and prevention of health risks through water-related recreation.

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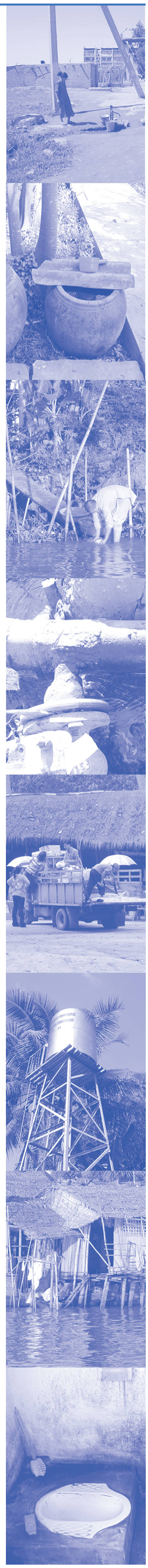

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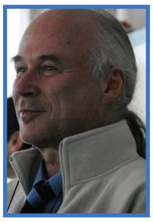

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Watermicro2017

The 19th International Symposium on Health-Related Water Microbiology is organized by the International Water Society (IWA) Specialist Group on Health-Related Water Microbiology (HRWM) biennially. In 2017, the Symposium will run concurrently with the annual Water Microbiology Conference to create a forum for researchers and practitioners focused on microbiology and public health to come together around the intersection of the two. The Conference will be held in Chapel Hill, North Carolina from May 15 – 19, 2017. The Conference will blend interactive workshops with scientific symposia and poster socials, offering participants a variety of opportunities to exchange ideas, debate challenging topics and explore potential collaborations. The focus will be on water microbiology from watershed to human exposure including current concerns in recreational waters, shellfish harvesting waters, emerging technologies and quantitative tools.

Since 2009 the IWA-HRWM Willie Grabow Young Investigator Award is presented biennially in conjunction with the HRWM Symposium. It is made for the purpose of assisting and encouraging young scientists, who are doing outstanding research in the field of health-related water microbiology, specifically in developing countries. The award consists of a stipend for travel, lodging and registration costs for the HRWM Symposium the year of the award (not to exceed US $4,000). In addition, a plaque will be presented to the recipient at the Symposium's Gala dinner. The Award winner will be asked to give a presentation on their work applicable to developing countries during the Symposium.

More information, the call for abstracts, registration and the award can be found here:
http://waterinstitute.unc.edu/conferences/watermicro/
Abstract Submissions, Early-bird Registration Side Events submission are due: January 1, 2017
Willie Grabow Young Investigator Award, application due: January 10, 2017

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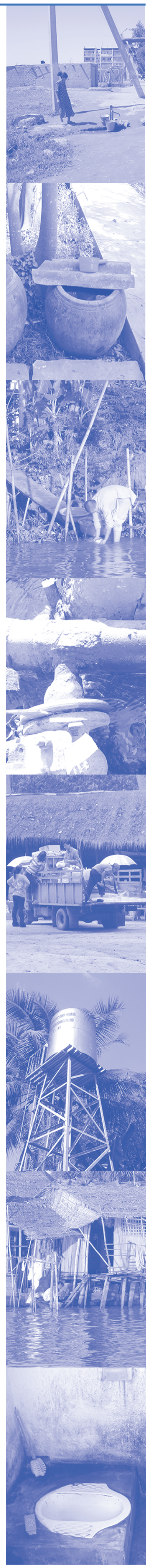

The WHO CC Bonn thanks all readers and contributors for their commitment in 2016 and sends Season's Greetings and best wishes for 2017 !

Events on Water, Health and Risk Communication

January

Tenth Annual Global Water Alliance Conference
4-6 January
Kolkata, India
http://www.globalwateralliance.net/2017-gwa-conference/

February

FSM4 - 4th International Faecal Sludge Management Conference
19 – 22 February
Chennai, India
http://www.susana.org/en/events/calendar/details/146

19th International Conference on Water, Sanitation, Food Security and Waste Management
26 - 27 February
Barcelona, Spain
https://www.waset.org/conference/2017/02/barcelona/ICWSFSWM

March

1st IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery
16 - 17 March
Delft, The Netherlands
http://www.unesco-ihe.org/1st-iwa-conference-algal-technologies-wastewater-treatment-and-resource-recovery

Water Week 2017
19 – 25 March
Washington, DC, USA
http://www.waterweek.us/hello-world/

IWA Regional Symposium on water, wastewater and environment
22 - 24 March
Çesme-Izmir, Turkey
http://www.iwa-ppfw2017.org/

4th Arab Water Week
19 – 23 March
Dead Sea, Jordan
http://www.acwua.org/events/arab-water-week-2017

April

Global Water Summit 2017. Intelligent Synergies
24 – 25 April
Madrid, Spain
http://www.watermeetsmoney.com/

3rd International Conference & Exhibition on Sustainable Water Supply and Sanitation (SWSSC 2017)
23-25 April
Cairo, Egypt
http://www.hcww.com.eg/sustainable-water-supply-sanitation-conference-iii?lang=en

May

19th International Symposium on Health-Related Water Microbiology (Watermicro 2017)
15-19 May
Chapel Hill, USA
http://waterinstitute.unc.edu/conferences/watermicro/

9th IWA Eastern European Young Water Professionals Conference: Uniting Europe for Clean Water: Cross-Border Cooperations of Old, New and Candidate Countries of EU, for identifying problems, finding causes and solutions
24 – 27 May
Budapest, Hungary
http://iwa-ywp.eu/

The 14th IWA Leading Edge Conference on Water and Wastewater Technologies
29 May – 2 June
Florianópolis, Brazil
http://www.let2017.org/

June

4th International Conference on Water & Society
5 - 7 June
Seville, Spain
http://www.wessex.ac.uk/conferences/2017/water-and-society-2017

The 3rd International Conference on Water Resource and Environment
26 – 29 June
Qingdao, China
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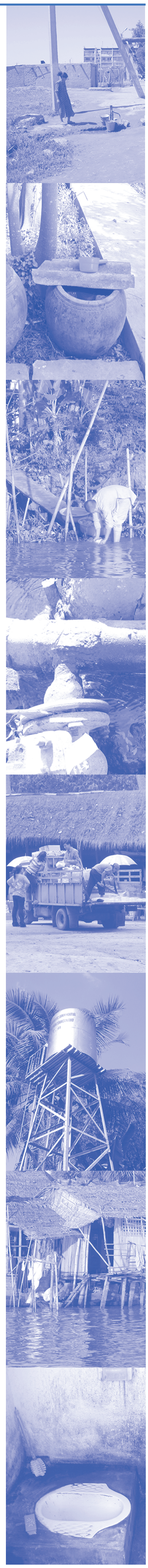

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29 May – 2 June
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http://www.let2017.org/

June

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http://www.wessex.ac.uk/conferences/2017/water-and-society-2017

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WHO Collaborating Centre for Health Promoting Water Management and Risk Communication
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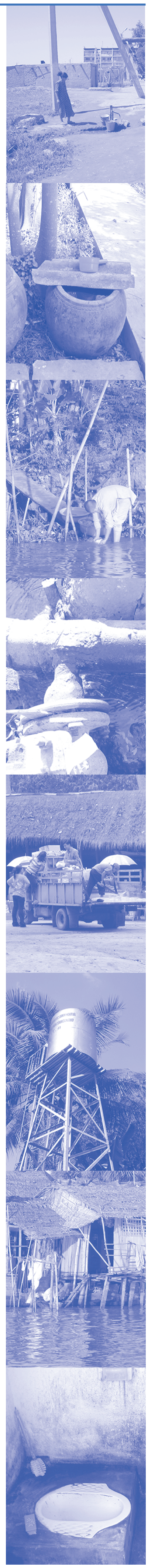

Events on Water, Health and Risk Communication

January

Tenth Annual Global Water Alliance Conference
4-6 January
Kolkata, India
http://www.globalwateralliance.net/2017-gwa-conference/

February

FSM4 - 4th International Faecal Sludge Management Conference
Chennai, India
19 – 22 February
http://www.susana.org/en/events/calendar/details/146

19th International Conference on Water, Sanitation, Food Security and Waste Management
26 - 27 February
Barcelona, Spain
https://www.waset.org/conference/2017/02/barcelona/ICWSFSWM

March

1st IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery
16 - 17 March
Delft, The Netherlands
http://www.unesco-ihe.org/1st-iwa-conference-algal-technologies-wastewater-treatment-and-resource-recovery

Water Week 2017
19 – 25 March
Washington, DC, USA
http://www.waterweek.us/hello-world/

IWA Regional Symposium on water, wastewater and environment
22 - 24 March
Çesme-Izmir, Turkey
http://www.iwa-ppfw2017.org/

4th Arab Water Week
19 – 23 March
Dead Sea, Jordan
http://www.acwua.org/events/arab-water-week-2017

April

Global Water Summit 2017. Intelligent Synergies
24 – 25 April
Madrid, Spain
http://www.watermeetsmoney.com/

3rd International Conference & Exhibition on Sustainable Water Supply and Sanitation (SWSSC 2017)
23-25 April
Cairo, Egypt
http://www.hcww.com.eg/sustainable-water-supply-sanitation-conference-iii?lang=en

May

19th International Symposium on Health-Related Water Microbiology
15-19 May
Chapel Hill, USA
http://waterinstitute.unc.edu/conferences/watermicro/

9th IWA Eastern European Young Water Professionals Conference: Uniting Europe for Clean Water: Cross-Border Cooperations of Old, New and Candidate Countries of EU, for identifying problems, finding causes and solutions
24 – 27 May
Budapest, Hungary
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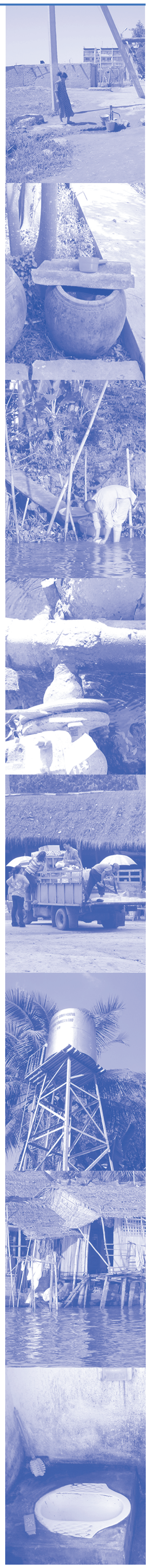

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