A note from the editors: impact of anthropogenic changes to water on human pathogens

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Water safety is vital, and the quality of water important in terms of public health. One of the objectives of the Water Quality and Health Strategy of the World Health Organization (WHO) for the 2013 to 2020 period, is to obtain ‘the most rigorous and relevant evidence regarding water quality and health’ [1]. In terms of infectious diseases, water can transport pathogens in the environment through different steps of the water cycle [2,3]. In the water, some physical or chemical parameters, e.g. temperature, pH, salinity, organic matter, may affect the survival of the pathogens [4]. Substances intended to control pathogens or insects (antimicrobials, antivirals and pesticides) can occur in water subsequent to their use [5,6] or manufacturing process [7,8]. This may paradoxically induce pathogen or vector resistance to these substances [9-12]. Moreover, water can also bear a number of pathogens with resistance acquired through other pathways [13]. Exposure of people to waterborne pathogens may occur by drinking or swallowing water, inhaling aerosolised droplets and contact with water through bathing and recreation [14,15]. Some pathogens may also be disseminated by water further in the environment (e.g. in the soil and air) potentially allowing human exposure. Consuming foods, grown on/in or irrigated with pathogen-contaminated water may also lead to infection [16,17].

As a number of changes to water, e.g. canalisation, temperature, nutrient enrichment, addition of pest-control or antimicrobial/viral substances, and pathogen contamination, result from human activities, it is relevant to understand their impact on infectious disease epidemiology. To provide some examples relevant for European public health, and to present issues related to the detection and identification of cases of waterborne outbreaks and the proof of anthropogenic change to water as the cause, we issued a call for papers [18]. Subsequent to this, we now publish five articles, through which a number of issues arise and which can be summarised as follows.

The challenges of outbreaks potentially caused by microbial contamination of water are first illustrated in a report from Italy, where an outbreak of monophasic *Salmonella* Typhimurium 1,4 [5],12:i:- with sole resistance to nalidixic acid is described [19]. Attempts to determine the source of this outbreak led to extensive environmental investigations. While its cause could not be ascertained, a number of surface water samples in the outbreak area, including of water used for growing fruit and vegetables, were positive for the outbreak strain. Moreover some water samples from local sewage treatment plants also tested positive, thus leading to the hypothesis that wastewater may have contaminated irrigation water [19]. The epidemiological investigation was complicated and the origin of the outbreak strain and how this strain acquired its resistance to nalidixic acid remain unresolved. The study reinforces the value of detecting waterborne outbreaks early.

Generally, water may become contaminated from a non-point source, such as the runoff of water from manure in agricultural fields, or from a point discharge, such as a hospital wastewater outlet or a sewage treatment plant. The issue of clinical wastewater harbouring microorganisms resistant to antimicrobials, and its subsequent effect on sewage and freshwater is important for public health, particularly if resistant bacteria introduced in the water can not only survive but also grow in wastewater. *Acinetobacter baumannii* for example, is considered a nosocomial pathogen, but its ecology is as of yet not fully understood and the observation of community outbreaks has made environmental niches suspect. A study from Croatia finds multiresistant *A. baumannii* strains in both influent and effluent water to a sewage treatment plant in Zagreb, indicating that such strains can evade the treatment process. The study shows moreover that isolated strains can survive and grow in effluent sewage water up to 50 days, posing a potential risk for further dissemination in the recipient river to the plant [20].

As a risk exists for surface water to become contaminated by wastewater pathogens, there is relevance in fully assessing its safety for further human use. A study from Serbia conducted during the bathing season reveals adenovirus and rotavirus genetic materials in recreational waters of the Danube, along popular public beaches in addition to faecal contamination. As the presence of viruses could not necessarily be predicted by the amount of bacteria measured in the water via routine quality control, the authors conclude that viral indicators may be helpful for further assessing the risks posed by water, in particular in areas where the sewer network is insufficient or inadequate [21].

Which panels of viruses could serve as relevant indicators of water quality in certain circumstances would need further investigations, as this may depend in part on their infectivity doses and persistence in environmental water. Also this might require to know what potential viruses contaminate the water to begin with, possibly first requiring agnostic screening techniques. In this regard, the development and implementation of assays that can be used for the surveillance of the whole population of viruses in water samples can be of interest. In this special issue, a methodology combining tangential flow filtration of sewage combined with deep sequencing, without the need for cell culture, is presented as an agnostic approach to survey viruses in sewage. The use of this methodology is proposed for the surveillance of poliovirus, but broader applications, including creating new viral sequence databases for retrospective analysis of presently unknown human viruses that may be discovered in the future are suggested [22].

Should it be a priori known what viruses likely contaminate water in an area, defining more specific tools to confirm their presence may be considered. Moreover in terms of further risk assessment, and as also discussed in the Serbian study in this issue [21], assays to determine the presence of infectious virus might also be of value.

As illustrated by some of the above studies [19,21], adequate management of wastewater is crucial. Indeed, water contaminated by wastewater can subsequently cumulate in larger water bodies such as lakes or the ocean. There, its impact may be less clear, as not only pathogens, but supportive nutrients may be carried by the wastewater. In combination with meteorological factors such as temperature, this may lead to the sporadic or intermittent occurrence of 'exotic' or 'unusual' pathogens in some areas [4]. An article from the Netherlands describes three cases of *Vibrio cholera* non-O1 serogroup (VCNO) bacteraemia reported in the country. Cases had been prior exposed to fish and/or had contact with surface water. The Dutch study includes a review of the literature to identify sources and risk factors for bacteraemia [23].

In conclusion, this special issue provides some insights into the importance of surveillance of pathogens in the water [19-23] and outbreaks or cases caused by waterborne pathogens [19,21,23]. Wider studies could help further refine criteria for assessing water treatment processes. Through pollution of ground water with antimicrobials and multi-resistant bacteria, waterborne outbreaks of multi-resistant bacteria are likely to become more frequent in the future. The special issue illustrates that addressing the problems due to anthropogenic changes to water on the epidemiology of human pathogens will require a multi-disciplinary approach.

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