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S.I.: DRINKING WATER QUALITY AND PUBLIC HEALTH

Drinking Water Quality and Public Health

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Abstract

Drinking water quality is one of the greatest factors affecting human health. However, drinking water quality in many countries, especially in developing countries is not desirable and poor drinking water quality has induced many waterborne diseases. This special issue of Exposure and Health was edited to gain a better understanding of the impacts of drinking water quality on public health so that proper actions can be taken to improve the drinking water quality conditions in many countries. This editorial introduction reviewed some latest research on drinking water quality and public health, summarized briefly the main points of each contribution in this issue, and then some research fields/directions were proposed to boost further scientific research in drinking water quality and public health. The papers in this issue are interesting and cover many aspects of this research topic, and will be meaningful for the sustainable drinking water quality protection.

Keywords Drinking water quality · Human health · Sustainable development · Water quality management · Drinking water pollution

Introduction

Having access to safe drinking water is a basic human right to all people, regardless of nationality, religion, color, wealth or creed. Contaminated drinking water and poor sanitation are linked to transmission of diseases such as cholera, diarrhea, dysentery, and polio (WHO 2018). Poor drinking water quality is significantly affecting the health of consumers. It was reported that at least 2 billion people globally used a drinking water source contaminated with feces (WHO 2018). In recent years, many developing countries have set reduction of waterborne diseases and development of safe water resources as their major public health goal, and the situation has slightly improved. However, the situation is far from perfect, particularly in rural areas, and this slightly improved situation may even be damaged by the increased demand of water and reduction of water availability due to population growth and economic development (Li and Qian 2018a). Therefore, there still is a long way before gaining the harmony between human, resources and environment (Li et al. 2017a). Fortunately, many scholars are working hard in drinking water studies. In this editorial, three aspects of these studies are briefly reviewed: drinking water quality assessment approaches, drinking water quality factors, and drinking water quality governance policies.

Understanding the status of drinking water quality and associated health risks is the basic to make wise decisions on drinking water quality protection and management. Using a feasible and effective drinking water quality assessment method is critical to achieve reliable results, facilitating wise decision-making. Since the 1960s when the first Water Quality Index (WQI) was developed by Horton, many water quality assessment methods have been proposed (Tian and Wu 2019; Su et al. 2019). The fast development of water quality assessment methods enhances the understanding of water quality either by a simple numerical number or by a more complex interpretation of water quality characteristics. Abtahi et al. (2015, 2016) proposed two drinking water quality indices to understand the general conditions of drinking source water quality in rural communities and the overall drinking water contribution to intakes of dietary elements.

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The two indices are simple, flexible and stable without strong sensitivity to input data. Similarly, Akter et al. (2016) used the weighted arithmetic WQI method to deliver water quality information in rural Bangladesh. These WQIs translate large numbers of variables into a digital number, and are helpful in the understanding of the water quality, making them the most popular water quality assessment methods though with some weaknesses (Abbasi and Abbasi 2012). Most recently, Li et al. (2018a, b) applied matter element extension analysis (MEEA) and entropy TOPSIS in water quality assessment in a wastewater irrigation area and a rapid urbanizing area, respectively. The two approaches are mathematical, but are proved to be reliable to estimate the overall water quality. These water quality assessment approaches, however, depend on water quality standards for water quality classification. Therefore, what really matters is to establish the water quality standards by considering the specific regional/local water quality conditions, the background of water quality indices and the health concern (Gara et al. 2018). Without integrating these concerns into the water quality standards, it would be difficult to gain a true and thorough understanding of the water quality. Whereas the fast development of water quality assessment approaches is indeed quite encouraging.

The assessment of human health risks, unlike the fast development of water quality assessment approaches, relies mainly on the model proposed by the USEPA or revised USEPA models (Adimalla and Wu 2019; He and Wu 2018; He et al. 2018; Li et al. 2016; Wu and Sun 2016; Zhang et al. 2018a, b). For example, Chen et al. (2018) integrated the triangular fuzzy numbers into the health risk assessment model to recognize the uncertainties in the processes of health risk estimation, providing new insight for solving uncertainties in water management. However, the slow development of the assessment model does not hinder the practices of health risk assessment and more and more health risk assessment studies have been carried out in the past three decades, because scholars have gradually recognized the important role of public health risk assessment in sustainable water quality management and protection of consumers from waterborne diseases. For example, Zhang et al. (2018b) and Ali et al. (2018) estimated the non-cancer risks of strontium (Sr) and organophosphate pesticide in drinking water, respectively, using the USEPA model. Particularly, Soldatova et al. (2018) carried out a very comprehensive health risk assessment study by considering the potential toxic impacts of 11 drinking water contaminants including NO_3^-, NH_4^+, Fe, Mn, As, aluminum (Al), NO_2^-, selenium (Se), mercury (Hg), thallium (Tl) and lead (Pb). Joshi et al. (2018) assessed the association of drinking water quality and meteorological factors with the incidence of enteroviral diseases among children in seven metropolitan provinces of Korea, and concluded that the drinking water quality was one of the major determinants on enteroviral diseases. However, the research by Mitra et al. (2018) interestingly found that it was the quantity of water consumed instead of water quality that mattered most in the occurrence of kidney stone disease in West Bengal, India. Deng et al. (2018) investigated the relationships of trace element and mineral levels in drinking water and soil with longevity, and found a good association between slightly alkaline drinking water with enrichment of trace elements and the longevity phenomenon. These practices of exposure and health risk assessment help the development of risk assessment theories and models.

Understanding the factors influencing the drinking water quality is also a necessary step to get wise decisions on drinking water quality protection and management. Typically, the drinking water quality is affected by the quality of source water, the treatment in water treatment plants before distributed, the water distribution system and the containers/tanks used for water storage and the household filters. However, in rural areas and small municipalities the drinking water is usually pumped directly from wells or obtained from rivers/lakes/reservoirs without adequate treatment (Scheili et al. 2015), and therefore, the quality of source water plays a critical role in determining the drinking water quality. Long et al. (2018) investigated the impacts of dry and wet seasons and land use on water quality in a karst system of Mexico, and believed that water–rock interactions, hydrology, and land cover were more important factors on water quality than land use. He and Wu (2019) carried out a similar study on the relationships of groundwater quality and health risks with land use/land cover in a loess area of China. They found that forest and grassland had positive effects on groundwater quality, while loess had negative effects on groundwater quality. Scheili et al. (2016a, b) explored the impacts of raw water quality, climate factors and human operational factors on drinking water quality in small water distribution systems of Canada, which indicated that the drinking water quality was mainly affected by the source water quality and the quality of source water was further influenced by meteorological and climate factors, while the variability of human operational factors was the only factor that could explain the daily scale variability of drinking water quality. There are also many scholars investigating the mechanisms of water quality variation from the point of view of hydrochemistry and geochemistry (Adimalla and Li 2018; Prusty et al. 2018; Wu et al. 2014, 2017; Vishwakarma et al. 2018). These studies show that drinking water quality variation is the results of both natural and anthropogenic factors, and therefore to ensure the stable drinking water quality it is necessary to look after every procedure of the water distribution from the source water protection to the very end when the water is consumed. This involves natural science, social science and management science, and calls for urgent collaboration between natural scientists and social scientists, professionals and general publics, governments and individuals, national institutes and international organizations (Li 2016).

Governance policies are very important to ensure the safety of drinking water supply and establishing sound and effective water governance policies involves participation of governmental officials, professionals and general publics. The governance policies consist of many aspects such as how drinking water should be supplied and distributed through the urban infrastructure, how much water should one consume at normal conditions per day, how and what measures should be taken to guarantee the drinking water quality. All of these need an interdisciplinary political ecology that enables the drinking water supply to satisfy all stakeholders (Rusca et al. 2017). Jabed et al. (2018) reported the people's perception of poor quality water impacts on their health in coastal areas of Bangladesh, and Dey et al. (2018) reported that most of the households in coastal areas of Bangladesh were willing to pay for improving their access to safe drinking water. These community-based studies are helpful to establish effective and efficient drinking water quality improvement programs. There are also some further studies on the governance of drinking water quality from the point of view of what governance conditions contribute to the realization of water quality objectives (Wuijts et al. 2018) and how emerging chemical contaminants governance helps in drinking water improvement (Hartmann et al. 2018). These achievements in drinking water quality management and governance further accelerate the development of drinking water treatment industry and other related fields.

To celebrate the achievements of water quality studies and to promote their further developments, the special issue themed Drinking Water Quality and Public Health is edited and published in Exposure and Health. Twenty one submissions were received for the special issue, and after peer review seven research papers were accepted and published in this special issue. The submissions are mainly from China, India, Iran, France, and Malaysia. High submission rate of this special issue indicates that discussing drinking water and its effects on human health is a very hot research topic. We are sure that the published articles in this issue will be of interest to worldwide readers and contribute a lot to the drinking water science and engineering.

Contribution Summaries

The seven research papers in this issue deal with different topics ranging from basic drinking water quality assessment and health risk assessment to detailed hydrochemical and anthropogenic processes identification. The drinking water sources considered in these papers are also diverse, including groundwater, river water and karst spring water. The contaminants studied range from common ions and physicochemical indices such as SO_4^{2-}, Cl^-, Mg^{2+}, Ca^{2+} and TDS to trace metals (Al and Cr^{6+}), fluoride (F^-) and nitrate (NO_3^-). Figure 1 is a word cloud highlighting the most used terms in the paper titles, abstracts and key words.

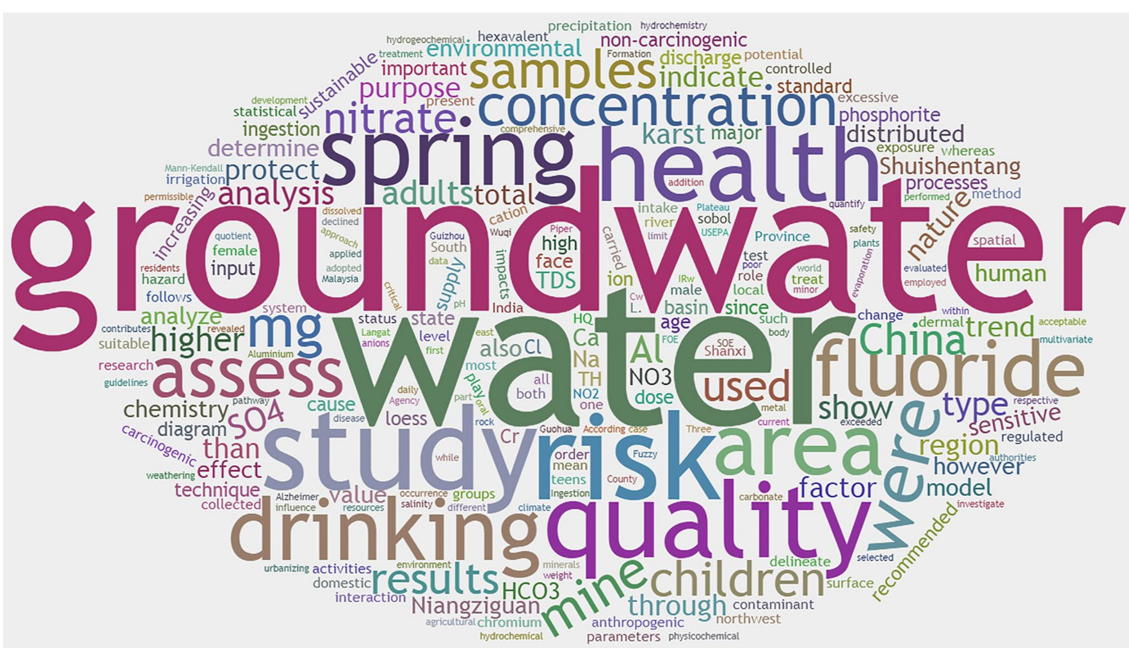

Fig. 1 Word Cloud generated based on the paper titles, abstracts and key words in this special issue at https://wordcloud.timdream.org/

As shown in Fig. 1, the paper topics in this special issue dealt with "water, groundwater, health, risk, quality, drinking, spring…", which indicates that groundwater is the most important part of the water for drinking purpose, and health risk is closely related to the drinking water quality that is determined by many indices such as F^-, NO_3^-, Mg^{2+} and TDS, etc.

Drinking water quality is affected by multiple factors, among which the quality of source water is the most significant one, especially in rural areas where water treatment is usually inadequate (Scheili et al. 2016b). Therefore, understanding the factors affecting the source water quality is useful. Li et al. (2018c) carried out a study on fluoride occurrence and distribution in a loess area of China to determine the geochemical and anthropogenic factors that influence F^- concentration in groundwater. The main contributions of this study are: (1) it identified the natural processes as the main controlling factors of fluoride occurrence, and (2) it offered possibly effective measures for the management of high F^- drinking water based on the health risk assessment results.

Water is important for mine production and domestic consumption in mining areas, while mining activities in turn can have noticeable impacts on water quality (Li et al. 2018d; Njinga and Tshivhase 2017; Wang et al. 2016). Mining activities affect water quality by, on one hand, direct release of chemical carcinogens into water bodies, and on the other hand by altering the hydrodynamics which affect the rates of water–rock interactions and hydrochemical environments where contaminants store and transport (Li 2018; Li et al. 2013). Taking the Guohua phosphorite mine of China as a case study, Li et al. (2018e) studied the processes influencing the solute geochemistry of surface water and groundwater using multivariate statistical techniques and correlation analysis. This study reveals that pyrite oxidation is an important process for the enrichment of SO_4^{2-}, and the results benefit the sustainable water quality management in mining areas.

Gaining a full understanding of the water quality status and the potential impacts on human health is the first step towards sustainable water quality governance (Li and Qian 2018b; Li et al. 2017b). Adimalla (2018) assessed the groundwater quality for drinking and irrigation purposes and estimated the potential negative health impacts of NO_3^- and F^- on consumers in the rapidly urbanizing region of Telangana State, South India. Similarly, He and Wu (2018) performed groundwater quality assessment and health risks assessment of Cr^{6+} and NO_3^- in a loess area of northwest China. Both studies have shown that children are more sensitive to drinking water contaminants, and are therefore, facing higher health threats. The main contribution of the two works is that they provide local authorities with insight into making scientific decisions for sustainable groundwater exploitation and efficient groundwater environmental protection. Kumar et al. (2019) proposed a Sobol sensitivity analysis (SSA) technique to determine the relative importance of inputs of health dose assessment. This technique is useful for uncertainty and sensitivity analysis of input variables of the health risk model.

Apart from groundwater mentioned in the above studies, river water and spring water are also important sources of water for drinking in many parts of the world. In this issue, one paper (He et al. 2019) focus on karst spring water for drinking purpose, and another paper (Ahmed et al. 2019) focus on river water quality. In the study by He et al. (2019), the authors analyzed the time series of karst spring water quality and quantity of two karst springs in China using the Mann–Kendall trend test to delineate the variations of spring water quality and quantity under climate change and human activities. They proved in their study that climate change, particularly the decreasing precipitation was responsible for spring discharge attenuation, while anthropogenic activities such as coal mining and quarrying, agriculture and urbanization were responsible for spring water quality deterioration. In the paper by Ahmed et al. (2019), they examined the health risks of Al ingestion via drinking water in Langat River Basin of Malaysia where rivers provide almost 98% of the raw water for drinking purposes. They compared the concentrations of Al in river water, treated water by the treatment plants, households' tap water, and the filtered water, and believed that reverse osmosis technology could be installed in the water treatment plants to get safe drinking water.

Future Research

The literature review in the first section and the contribution summaries in the second section have indicated that significant achievements have been achieved in drinking water quality studies. However, still many issues remain unaddressed. It is necessary to continue the studies, particularly in the following general aspects.

As the industry further developed, more and more chemicals that have not been considered as contaminants before will be released into the environment such as polycyclic aromatic hydrocarbons, pharmaceuticals and cosmetics. Some of these chemicals could be a potential risk to humans and/or the environment (Gavrilescu et al. 2015). Therefore, the emerging contaminants which are very diverse in terms of toxicity, behavior and remediation techniques should be comprehensively studied in terms of their effects on human health and the mechanisms/exposure pathways of the threat to the public health. More research projects should be funded by organizations and agencies and close collaboration among scientists, governments and general public should be particularly encouraged. Most importantly, the general information such as the spatial distribution and temporal variation of the emerging contaminants should be reported to the government and the public so that necessary measures can be taken effectively and timely (Li et al. 2019).

For the safety of the drinking water supply, conjunctive use of different water sources should be considered (Li et al. 2018f), and it reduces the risks of water shortage and low-quality water consumption, though improved source sometimes does not necessarily mean improved quality (Jessoe 2013). For example, some scholars have proposed rainwater harvesting as a potential water source for fresh drinking water supply in some areas of the world (Adimalla and Wu 2019; Li et al. 2018b). However, more work should be done to testify the feasibility of conjunctive water sources development in specific areas, as it is easier said than done for the sustainable conjunctive development of different water sources. Conditions may vary from one case to another, and thus it calls for a more detailed investigation.

As mentioned previously, drinking water quality studies involves different stakeholders and is affected by many factors. Therefore, large data sets are necessary to understand the processes and mechanisms of drinking water quality variation in the big data era (Li et al. 2017c). More and more scholars have recognized the importance of citizen science in big data accumulation and analysis (Farnham et al. 2017; Jollymore et al. 2017; Li and Qian 2018a, b; McKinley et al. 2017). However, citizen science is associated with criticism such as the data being likely of lower quality (Buytaert et al. 2016). As such, there may still be a long road before the citizen science is readily integrated into drinking water quality studies.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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