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Challenges for Safe and Healthy Drinking Water in China

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Abstract

Purpose of Review Rapid economic growth and its huge population are putting tremendous pressure on water sustainability in China. Ensuring clean drinking water is a great challenge for public health due to water shortage and pollution. This article reviews current scientific findings on health-related issues on drinking water and discusses the challenges for safe and healthy drinking water in China.

Recent Findings From literature published since 2010, a variety of emerging contaminants were detected in drinking water, including disinfection byproducts (DBPs), pharmaceuticals and personal care products (PPCPs), endocrine-disrupting compounds (EDCs), antibiotic resistance genes, and pathogens. Arsenic and fluoride are still the two major contaminants in groundwater. Microcystins, toxins produced by cyanobacteria, were also frequently detected in surface water for drinking. Health effects of exposure to arsenic, fluoride, nitrates, DBPs, and noroviruses in drinking water have been reported in several epidemiological studies. According to literature, water scarcity is still a severe ongoing issue, and regional disparity affects the access to safe and healthy drinking water. In addition, urbanization and climate change have strong influences on drinking water quality and water quantity.

Summary Multiple classes of contaminants of emerging concern have been detected in drinking water, while epidemiological studies on their health effects are still inadequate. Water scarcity, regional disparity, urbanization, and climate change are the major challenges for safe and healthy drinking water in China.

Keywords Emerging contaminants · Water sustainability · Water scarcity · Epidemiology · Public health

Introduction

Safe and healthy drinking water is essential for public health. Inadequate water supply and poor water quality have been linked to numerous health outcomes, e.g., diarrheal diseases [1•, 2]. It was estimated that water pollution, including unsafe water sources, unsafe sanitation, and inadequate handwashing, was responsible for 1.8 million deaths worldwide in 2015. Among these deaths, 1.3 million deaths were attributable to unsafe water sources [3••]. In China, the expansion of its population and economic growth in past decades inevitably led to many environmental problems, particularly in relation to water. It was estimated that there were 40 billion tons of water shortage per year on average in China [4]. Water pollution is pervasive, nearly 80% of lakes in China suffer from eutrophication, over 40% of its rivers are heavily polluted [5••], and groundwater is ubiquitously contaminated in both shallow and deep aquifers [6•]. According to the Blue City Water Quality Index (BCWQI) developed by the Institute of Public and Environmental Affairs (IPE) in 2019 (Fig. 1), many cities (regions) located mainly in Northern China (e.g., Hebei and Shanxi provinces) have relatively poor to poor water quality, while a few cities located in the South or Southwest of China (e.g., Guizhou province) have good to excellent water quality.

The connection between water pollution and adverse health effects is well established in China. Water pollution in rivers and lakes has contributed to the increasing rate of cancer mortality, such as liver cancer and digestive tract cancers [4, 7]. To date, papers have discussed the challenges of water issues in China from the aspects of water resources, pollutions, and policies [4, 5••, 8•], while understanding the current

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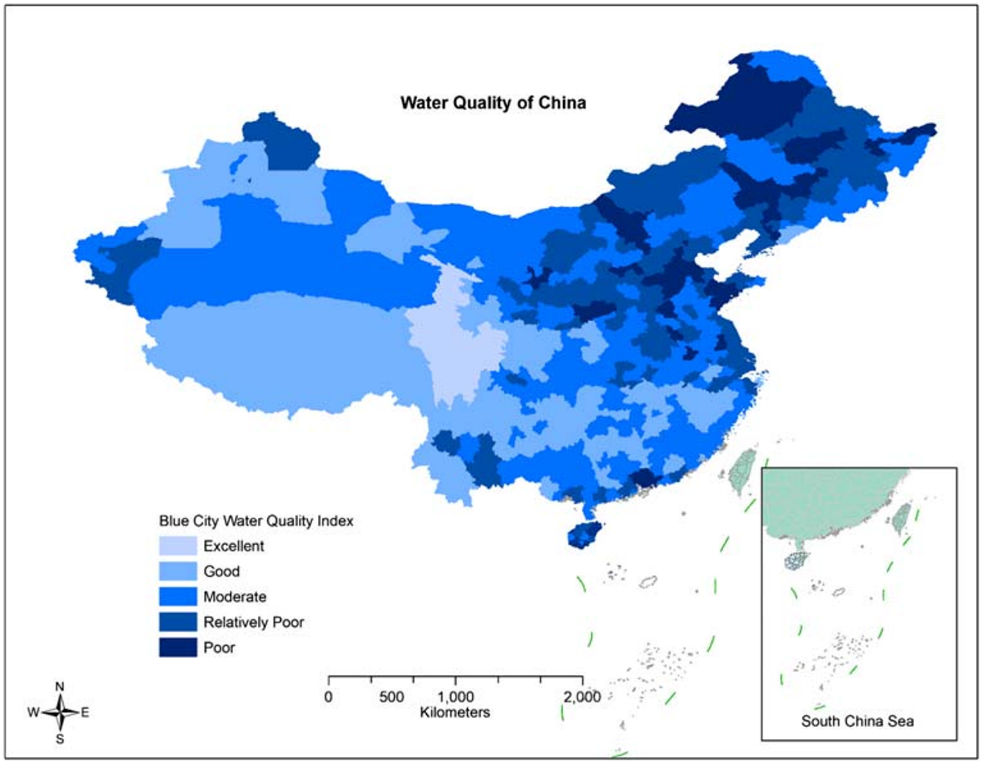

Fig. 1 Overall water quality classified by the Blue City Water Quality Index (BCWQI) in mainland China. BCWQI was developed by the Institute of Public and Environmental Affairs (IPE) in 2019, which is the weighted index based on the quality scores for surface water (50%), drinking water (30%), and groundwater (20%). The data were obtained from IPE (2019): Blue City Water Quality Index report (http://www.chinawaterrisk.org/opinions/blue-city-water-quality-index/)

challenges for safe drinking from a health aspect is still needed, such as emerging contaminants in drinking water, health effects of these contaminants as well as factors influencing safe and healthy drinking water.

In this review, literature related to drinking water in China was selected from Google Scholar and PubMed databases published in English or Chinese from 2010 to 2019. First, the emerging contaminants in drinking water were reviewed. Second, epidemiological studies on the health effects of contaminants in drinking water were summarized. Finally, the challenges faced in China concerning safe and healthy drinking water were discussed.

Contaminants of Emerging Concern

Though a range of microbial and chemical contaminants are known to potentially contaminate drinking water supplies, emerging contaminants are of particular concern because they may pose a high risk to human and ecological health. Their occurrence, effects, and approaches to its management and treatment are not yet fully understood. Generally, they are referred to as the contaminants found in drinking water recently [9]. However, in a broader context, contaminants detected in drinking water many years ago are also thought as emerging contaminants or contaminants of emerging concern (CECs) if they still raise significant concern, such as arsenic [9].

Contaminants in drinking water are listed in Table 1. For each contaminant, its study location and water type are provided. Based on its characteristics, drinking water is simply classified into three types. Type 1 is treated water, including tap water, finished water, and bottle water. Type 2 is groundwater or well water. Type 3 is surface water for drinking (untreated water), such as water from reservoirs, rivers and lakes, or rainwater. Disinfection byproducts (DBPs), pharmaceuticals and personal care products (PPCPs), and endocrine-disrupting compounds (EDCs) are the three major groups of CECs in type 1 water. Arsenic and fluoride are major contaminants in type 2 water. Antibiotic resistance genes, pathogens, and algal toxins are mainly found in type 3 water.

DBPs are widely present in treated drinking water during the water disinfection process, such as chlorination, chloramination, and ozonation. Epidemiological studies have shown that long-term exposure to certain DBPs in drinking water have been associated with many adverse health effects such as bladder, colon, and rectal cancers [10]. Currently, over hundreds of types of DBPs have been detected in drinking water. The major DBPs detected in drinking water in China are haloacetic acids (HAAs), trihalomethanes (THMs), nitrosamines, N-nitrosodimethylamine, adsorbable organic halides, and iodinated DBPs [11–25].

PPCPs are a large and diverse group of products used for personal health or for promoting the growth and health of livestock and agriculture, including antibiotics, hormones, pharmaceutical drugs, and personal care products [26•].

Table 1 Contaminants of concern in drinking water reported in literature since 2010

Category	Contaminants	Location	Water type	Literature
Disinfection byproducts	Haloacetic acids and trihalomethanes	Taiwan	1	Chang et al., 2010 [11]
	Nitrosamines	Thirty cities	1, 3	Wang et al., 2016 [17]
	Trihalomethanes and haloacetic acids	Thirty-five major cities	1	Pan et al., 2014 [15]
	Disinfection byproducts	Jinhua [Zhejiang]	1	Zhou et al., 2019 [24]
	Disinfection byproducts	Jiangsu, Zhejiang, and Shanghai	1	Yu et al., 2019 [21]
	Disinfection byproducts	Beijing	1, 3	Wei et al., 2010 [25]
	Trihalomethanes and adsorbable organic halides	Shandong	1, 3	Yao et al., 2019 [19]
	N-nitrosamines	Shanghai	1, 3	Chen et al., 2019 [12]
	Trihalomethanes	Xi'an [Shaanxi]	1, 2	Zhang et al., 2018 [22]
	Nitrosamines	Shaoxing [Zhejiang]	1, 3	Yin et al., 2019 [20]
	Nitrosamines	Beijing, Shanghai, Xuzhou [Jiangsu]	1	Luo et al., 2012 [14]
	Iodinated disinfection byproducts	Shanghai	1	Wei et al., 2013 [18]
	Disinfection byproducts	Jinhua [Zhejiang]	1	Zhou et al., 2019 [24]
	N-nitrosodimethylamine	Thirty-five cities	1	Sang et al., 2019 [16]
	Nitrogenous and carbonaceous disinfection byproducts	Shenzhen [Guangdong]	1	Huang et al., 2017 [13]
Pharmaceuticals and personal care products (PPCPs)	Pharmaceuticals and personal care products	Changzhou [Jiangsu]	1, 3	Jiang et al., 2019 [29]
	Pharmaceuticals	Beijing	1	Cai et al., 2015 [27]
	Pharmaceuticals	Fifteen cities	1, 3	Lv et al., 2019 [33]
	Pharmaceuticals	Thirteen cities	1	Leung et al., 2013 [30]
	Veterinary antibiotics	Hong Kong	1	Li et al., 2017 [31]
	Fibrates	Shanghai and Zhejiang	1, 3	Ido et al., 2017 [36]
	Phthalate esters and pharmaceuticals	Taiwan	1	Yang et al., 2014 [35]
	Pharmaceuticals, hormones, and perfluorinated compounds	Taiwan	2	Lin et al. 2015 [32]
	PPCPs	Shanghai	1, 3	Xu et al., 2018 [28]
	Sulfonamides	Huixian [Guizhou]	2	Qin et al., 2019 [34]
	Pharmaceuticals	Shanghai	3	Wen et al., 2014 [37]
	Antibiotics	Shanghai	1	Wang et al., 2016 [38]
Endocrine-disrupting compounds (EDCs)	Bisphenol analogues	Twenty water treatment plants	1, 3	Zhang et al. 2019 [45]
	Endocrine-disrupting pesticides	Yangtze River Delta	3	Feng et al., 2016 [41]
	Phenol endocrine-disrupting compounds	Suzhou [Jiangsu]	1, 3	Li et al., 2018 [42]
	Perfluorooctane sulfonate	Jiangsu	1, 2	Yu et al., 2015 [50]
	Perfluoroalkyl acids	Seventy-nine cities	1	Li et al., 2019 [43]
	Nonylphenol, octylphenol and bisphenol-A	Taiwan	1	Chen et al., 2013 [40]
	Polycyclic aromatic hydrocarbons	Seventy-eight cities	1	Zhang et al., 2019 [46]
	Polycyclic aromatic hydrocarbons	Jiangsu	2	Pan et al., 2015 [44]
Flame retardants	Organophosphate esters	Seventy-nine cities	1	Li et al., 2019 [47]
	Organophosphorus flame retardants	Nanjing [Jiangsu]	1, 3	Liu et al., 2019 [48]
	Organophosphate flame retardants	Eight cities	1	Li et al., 2014 [49]
Antibiotic resistance genes	Antibiotic resistance genes	Shanghai	3	Jiang et al., 2013 [54]
	Antibiotic resistance genes	Taihu Lake	3	Stange et al., 2019 [57]
	Antibiotic resistome	Hong Kong	1	Ma et al., 2019 [56]

Table 1 (continued)

Category	Contaminants	Location	Water type	Literature
	Antibiotic resistance genes	Guangzhou [Guangdong]	1, 3	Su et al., 2018 [51]
	Antibiotic resistance genes	Shanghai	3	Li et al., 2020 [52]
	Antibiotic resistance genes	Hangzhou [Zhejiang]	1, 3	Xu et al., 2016 [58]
	Antibiotic resistome	Nationwide	1	Ma et al., 2017 [55]
	Sulfonamide and tetracycline resistance genes	Zhejiang, Jiangsu, and shanghai	1, 3	Guo et al., 2014 [53]
Pathogens	Cryptosporidium	Thirty-three cities	1, 3	Xiao et al., 2012 [64]
	Antibiotic-resistant *E. coli*	Hangzhou [Zhejiang]	3	Chen et al., 2017 [59]
	Pseudomonas aeruginosa	Guangdong	1, 3	Wu et al., 2016 [62]
	E. coli O157:H7	Changchuan [Jilin]	2	Ding et al., 2018 [60]
	Salmonella typhimurium	Changchuan [Jilin]	2	Li et al., 2018 [61]
	Cryptosporidium	Three Gorges Reservoir	3	Xiao et al., 2013 [63]
	Giardia	Three Gorges Reservoir	3	Xiao et al., 2013 [63]
Algal toxins	Microcystins	Taihu Lake	3	Qin et al., 2010 [65]
	Microcystins	Poyang Lake	3	Zhang et al., 2018 [67]
	Microcystins	Lake Erhai [Yunnan]	3	Yu et al., 2014 [66]
Inorganic chemicals	Arsenic	Nationwide	2	Rodriguez-Laado et al., 2013 [69]
	Arsenic	Nationwide	2, 3	He and Charlet 2013 [70]
	Arsenic	Taiwan	2	Guo et al., 2014 [84]
	Arsenic	Xi'an [Shaanxi]	1	Zhang et al., 2018 [22]
	Fluoride	Zhongning [Ningxia]	2	Chen et al., 2017 [77]
	Nitrate	Zhongning [Ningxia]	2	Chen et al., 2017 [77]
Others	Pesticides	Shanghai	1, 3	Xu et al., 2018 [28]
	Perchlorate	Multiple locations	1, 2, 3	Wu et al., 2010 [80]
	Volatile organic contaminants	East China	2	Bi et al., 2011 [81]
	Methyl tertiary-butyl ether	Nanning [Guangxi]	1	Zhang et al., 2016 [82]
	Neonicotinoid insecticides	Hangzhou [Zhejiang]	1, 3	Lu et al., 2020 [79]
	Asbestos fibers	Dayao [Yunnan]	2, 3	Wei et al., 2013 [83]

Water type: (1) treated water, including tap water, finished water, and bottle water; (2) groundwater or well water; and (3) surface water for drinking

PPCPs have been identified as contaminants of emerging concern because they are ubiquitous in the aquatic environment, but their impacts on the environment and human health are little known. PPCPs have been frequently detected in drinking water in China in recent years, including pharmaceuticals, veterinary antibiotics, fibrates, hormones, and perfluorinated compounds, sulfonamides, and antibiotics [27–38].

EDCs are a group of chemicals that can interfere with hormones biosynthesis and metabolism or disturb normal homeostatic reproduction or control [39]. Though their health effects are yet not fully understood, studies suggested that EDCs have been linked to but not limited to diseases such as cancer, altered nervous system function, alterations in sperm quality and fertility, diabetes, obesity, cardiovascular problems, neurological disease, and learning disabilities [39]. Common EDCs include bisphenol A (BPA), phthalates, phenol, polychlorinated biphenyls (PCBs), dioxins, phthalates, etc. Some of them are also grouped into PPCPs. Currently, EDCs detected in drinking water include bisphenol analogues, endocrine-disrupting pesticides, phenol endocrine-disrupting compounds, perfluorooctane sulfonate, perfluoroalkyl acids, nonylphenol, octylphenol and bisphenol, polycyclic aromatic hydrocarbons, etc. [40–46]. Some flame retardants acting as EDCs, such as organophosphate esters and organophosphorus flame retardants, were also detected in drinking water [47–50].

Extensive use of antibiotics in human, livestock, and agriculture leads to the prevalence of antibiotic resistance bacteria

(ARBs) and antibiotic resistance genes (ARGs) in the environment. They can be transferred to drinking water sources and contaminate drinking water [51]. ARGs are of great concern because they can cause many vital antibiotics to lose their effectiveness and cause infectious diseases to become difficult to control [52]. Several studies reported that ARGs have existed in both surface water and treated water in China [51–58].

Microbial contamination in drinking water is a public health problem in rural China where treated drinking water is not accessible. Exposure to pathogens in water can cause infectious diseases such as diarrheal diseases. In China, people generally boil water before drinking it, which can largely deactivate pathogens and prevent infections. Some pathogens have been reported in drinking water (mainly in surface water), such as *Cryptosporidium*, *Giardia*, antibiotic-resistant *E. coli*, *E. coli* O157:H7, *Salmonella typhimurium*, and *Pseudomonas aeruginosa* [59–64]. Toxic cyanobacteria in drinking water pose a global threat to human health because they can produce toxins, particularly microcystins. Cyanobacterial blooms in Taihu Lake have resulted in a water crisis in local areas in 2007 [65]. Recently, microcystins were frequently detected in surface water, e.g., Erhai Lake, Taihu Lake, and Poyang Lake [65–67], but microcystins have been rarely detected in treated water.

Arsenic is a poisonous metalloid and has been detected in groundwater in many areas in China [68, 69]. In Northern China, a high concentration of arsenic in water was attributable to geogenic processes. In Southern China, on the other hand, a high concentration of arsenic in water was a result from human activities [70]. Exposure to arsenic in groundwater has been linked to many types of acute diseases and chronic diseases [70–76]. Besides arsenic, fluoride and nitrate are also a concern in groundwater [77]. High concentration of fluoride in groundwater was widely detected in Northern China, especially in Inner Mongolia and Ningxia, two autonomous regions [78].

Other contaminants of concern to drinking water include pesticides [28], neonicotinoid insecticides [79], perchlorate [80], volatile organic contaminants [81], methyl tertiary-butyl ether [82], and asbestos fibers [83].

Drinking Water and Health

It is well known that water pollution has resulted in many human health problems. However, epidemiological studies on the health effects of contaminants in drinking are still inadequate (Table 2). Arsenic in drinking water has been widely investigated. In Taiwan, arsenic in groundwater was linked to end-stage renal disease, chronic kidney disease, liver cancer, skin cancer, cerebrovascular disease, urinary tract cancer, and lung cancer [71–74, 76, 85–87]. In Inner Mongolia, exposure to arsenic in primary surface water was associated with cardiovascular disease [75], and exposure to arsenic in tap water was linked to skin lesions [88]. Fluoride is another contaminant of concern in groundwater. Excess fluoride intake in groundwater was associated with hypertension and carotid artery atherosclerosis in Zhaozhou, Heilongjiang province [89, 90]. Fluoride in drinking water was also associated with both dental and skeletal fluorosis nationwide in China [91]. Two studies examined the effects of exposure to nitrates in drinking water in Taiwan. The results showed that exposure to nitrates in drinking water was connected with a higher risk of brain tumors in childhood [92] except for non-Hodgkin lymphoma [93]. It was also found that nitrogen compounds in groundwater and surface water were associated with esophageal squamous cell carcinoma in Shexian, Hebei province [94].

Several studies examined the associations between disinfection byproducts in drinking water and health outcomes. Among them, three studies were conducted in Wuhan, Hebei province, which found that exposure to drinking water DBPs, particularly total trihalomethanes, might have contributed to decreased semen quality in humans [95, 96], and exposure to trihalomethanes in drinking water in late pregancy might adversely affect fetal growth [97]. In mainland China, the National Standards for Drinking Water Qualities from 2006 (GB5749–2006) regulated all trihalomethanes and 13 individual DBPs [98]. Given the health risks of these chemicals, they need to be monitored routinely in drinking water.

Exposure to pathogens in drinking water can cause outbreaks of infectious diseases. Three studies have reported that noroviruses in drinking water were responsible for gastroenteritis illness outbreaks in Jiaxing (Zhejiang province), Shenzhen, and another city in Guangdong province, respectively [99–101]. In one study, the outbreak of acute hepatitis in Zhejiang was likely caused by hepatitis E virus in tap water [102].

Though exposure to PPCPs, EDCs, and other contaminants in drinking water can cause multiple health effects, little is known about their associations with human health outcomes based on epidemiological studies.

Challenges for Safe and Healthy Drinking Water

Great changes have taken place in China in the past decade, both environmentally and economically. China's gross domestic product (GDP) per capita has exceeded $10,000 USD in 2019, and the urbanization progress continues with the urbanization rate near 60% by 2020. Meantime, water shortage and pollution have become a prominent public health issue. The Chinese government has made clean water a priority and made plans to mitigate the water crisis. However,

Table 2 Health effects of contaminants in drinking water from epidemiological studies reported during 2010–2019

Contaminants	Health outcomes	Location	Water type	Literature
Arsenic	Skin lesions	Wuyuan [Inner Mongolia]	1	Wei et al., 2019 [88]
Arsenic	Cardiovascular disease	Inner Mongolia	3	Wade et al., 2015 [75]
Arsenic	End-stage renal disease	Taiwan	2	Cheng et al., 2018 [73]
Arsenic	Chronic kidney disease	Taiwan	2	Hsu et al., 2017 [86]
Arsenic	Chronic kidney disease	Taiwan	2	Cheng et al., 2017 [74]
Arsenic	Liver cancer	Taiwan	2	Lin et al., 2013 [87]
Arsenic	Skin cancers	Taiwan	2	Cheng et al., 2016 [71]
Arsenic	Urinary tract cancer	Taiwan	2	Chen et al., 2010 [85]
Arsenic	Cerebrovascular disease	Taiwan	2	Cheng et al., 2010 [72]
Arsenic	Lung cancer	Taiwan	2	Chung et al., 2013 [76]
Fluoride	Hypertension	Zhaozhou [Heilongjiang]	2	Sun et al., 2013 [90]
Fluoride	Carotid artery atherosclerosis	Zhaozhou [Heilongjiang]	2	Liu et al., 2014 [89]
Fluoride	Fluorosis	Nationwide	1	Wang et al., 2012 [91]
Iodine	Goiter	Hebei	1, 2	Lv et al., 2012 [103]
Nitrates	Childhood brain tumors	Taiwan	1	Weng et al., 2011 [92]
Nitrates	Non-Hodgkin lymphoma	Taiwan	1	Chang et al., 2010 [93]
Nitrogen compounds	Esophageal squamous cell carcinoma	Shexian [Hebei]	2, 3	Zhang et al., 2012 [94]
N-nitrosamines	Esophageal cancer	Huai'an [Jiangsu]	1	Zhao et al., 2019 [23]
Disinfection by-products	Semen quality	Wuhan [Hubei]	1	Zeng et al. 2014 [96]
Trihalomethanes	Fetal growth	Wuhan [Hubei]	1	Cao et al. 2016 [97]
Trihalomethanes	Semen quality	*Wuhan [Hubei]	1	Zeng et al., 2014 [95]
Norovirus	Acute gastroenteritis	Jiaxing [Zhejiang]	1	Shang et al., 2017 [100]
Norovirus	Gastroenteritis	Shenzhen [Guangdong]	1	He et al., 2010 [99]
Norovirus	Gastroenteritis	Southern China	1	Yang et al., 2011 [101]
Hepatitis E virus	Acute hepatitis	Zhejiang	1	Chen et al., 2016 [102]

Water type: (1) treated water, including tap water, finished water, and bottle water; (2) groundwater or well water; and (3) surface water for drinking

*Participants who visited the hospital in Wuhan

many factors influence the sustainability of safe and healthy drinking water. Among them, water shortage, regional disparity, urbanization, and climate change are likely the major challenges.

Water Scarcity China has about 20% of the world population, while its freshwater resources only account for 7% of the world's resources. As a result, drinking water access per capita is very low. Given increasing demands for water usage, uneven distribution of water resources, and pervasive water pollution, water scarcity has become a major challenge for the sustainability of drinking water in China [8•]. There are two major types of water scarcity: quantity-related water scarcity and quality-related water scarcity. Quantity-related water scarcity is a result from the shortage of water resources and the high demand of water usage. For example, Northern China has access to only 20% of the total freshwater resources but this amount needs to support over half of the total population [104]. In contrast, 80% of freshwater resources is available to Southern China, but the demand for water usage is very high due to the rapid development of industry and the economy [104]. Quality-related water scarcity is when water is unsuitable as a source of drinking water or other uses due to its poor quality. In China, water pollution has been reported everywhere from surface water to groundwater and from freshwater to seawater [6•, 104]. Insufficient water supply is directly associated with adverse health outcomes such as gastrointestinal infections and diarrheal diseases [105].

Regional Disparity In China, water resources are unevenly distributed throughout different regions. Water resources are concentrated in the south and far west regions, which is inconsistent with the distribution of the population. Besides water resources, regional disparity is also embodied in water supply, economy, technology, and information. Water supply in China is very different between urban and rural communities. In urban areas, water treatment facilities are concerned about the presence of organic matters, ammonia, algae, and chemical spills in water, while rural areas are concerned about microbes, arsenic, fluoride, and ammonia in their drinking water. Urban areas have advanced water treatment technology, thanks to a large amount of investments, whereas rural communities cannot afford the same [106]. In addition, detection of emerging contaminants was mostly carried out in large cities such as Beijing, Shanghai, Hangzhou, and Shenzhen. There is little information about these contaminants in smaller cities and rural areas.

Urbanization By 2020, there is now about 60% of the population living in cities. The rapid urbanization is likely to put more pressure on an already severe water problem. As more people move into cities, water supply and infrastructure cannot keep pace with the population growth in many regions. In addition, changes in lifestyle in urban areas increase the demand of water usage. The increase of water demand may push municipal suppliers to use water sources with poor quality, which is of concern to public health [107•]. Urbanization is closely related to industrialization in China. With growing industrialization and urbanization, numerous pollutants have been discharged into aquatic environments without appropriate treatment, which deteriorates water quality and leads to severe health consequences such as a high rate of cancer [108]. For example, Shijiazhuang was originally a rural area, and its main urbanization began after 1953 when it became the capital of Hebei province. During this time, many industries were developing in that area such as textile plants and pharmaceutical factories. As a result, water quality deteriorated. In parallel with socioeconomic development and urbanization, the occurrence of colorectal cancer has been rising [109].

Climate Change Climate change is expected to have significant influences on both water quantity and water quality by shifting precipitation patterns, melting snow and glaciers, raising temperature, and increasing the frequency of extreme events. Extreme weather events, (e.g., floods) can spread harmful pollutants such as chemicals, fuel, bacteria, and others into drinking water, thus affecting human health. Heavy rainfalls not only impact surface water quality but also can lead to fecal contamination of groundwater [110]. Drinking water in China is particularly vulnerable to climate change. For example, over 300,000 people in Yunnan province had difficulties getting access to drinking water due to a severe drought in May 2019. Besides Yunnan, other regions such as Jilin, Inner Mongolia, has also suffered from severe droughts in recent years. Rising water temperature is likely to promote the growth of microorganisms in water. It also leads to the proliferation of toxic cyanobacteria. One example is the water crisis caused by cyanobacterial blooms in Taihu Lake in 2007, which was likely to have been driven by climate variabilities [65].

Besides challenges mentioned above, the lack of transparency about water quality also threats public health. Currently, the quality of drinking water has been monitored by local and central government environmental agencies as well as research institutes. However, detailed information about contaminants in drinking water is rarely released to the public, which discourages efforts from individuals or private sectors to improve public health.

Conclusion

China has faced serious drinking water problems over the past 10 years. A variety of emerging contaminants have been detected in drinking water. Among them, DBPs, PPCPs, and EDCs are the major types of contaminants in tap and treated water. Arsenic and fluoride were widely detected in groundwater. ARGs, microcystins, and pathogens (particularly noroviruses) were frequently detected in surface water. These contaminants in drinking water pose a great threat to public health. However, only limited epidemiological studies have been conducted to investigate their health effects with the exception of arsenic. There have been a few studies that examined the health outcomes of fluoride, DBPs, and noroviruses in drinking water. It is still very rare to find epidemiological studies on the health effects of PPCPs, EDCs, and ARGs in drinking water.

To ensure safe and healthy drinking water, both water quantity and quality are important. Water scarcity, regional disparity, urbanization, and climate change are the major challenges to achieving this goal. China has committed itself to tackling the water crisis and made ambitious plans to ensure clean drinking water is available to the public, such as through water transfer projects [5••] and regulations to control water pollution [6•, 111]. Additionally, advanced water treatment technology has been developed, and portal water treatment devices have been widely applied. These measures are likely to alleviate the drinking water crisis and improve public health in China.

Compliance with Ethical Standards

Conflict of Interest The author declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the authors.

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