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Editorial

Achieving the One Health Goal: Highlighting Groundwater Quality and Public Health

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Abstract: In many regions of the world, groundwater is the main water source for multiple uses, including for drinking, irrigation, and industry. Groundwater quality, therefore, is closely related to human health, and the consumption of contaminated groundwater can induce various waterborne diseases. In the last ten years, the world has witnessed a rapid development in groundwater quality research and the assessment of associated health risks. This editorial introduced the foundation of the current Special Issue, *Groundwater Quality and Public Health*, briefly reviewed recent research advances in groundwater quality and public health research, summarized the main contribution of each published paper, and proposed future research directions that researchers should take into account to achieve the one health goal. It is suggested that groundwater quality protection should be further emphasized to achieve the one health goal and the UN's SDGs. Modern technologies should be continuously developed to remediate and control groundwater pollution, which is a major constrain in the development of a sustainable society.

Keywords: groundwater quality; groundwater pollution; contamination remediation; one health; public health; health risk assessment

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1. Introduction

The United Nations (UN) established the Sustainable Development Goals (SDGs) to guide its member states' agendas and political policies through the next 15 years [1]. Among the 17 goals, SDG-6, *Ensure Access to Water and Sanitation for All*, requires improving water and sanitation management for all people, having urged every nation in the world to take the necessary actions to ensure its people's basic human right: gaining access to safe drinking water. Since the 21st century, with the acceleration of global integration, the population increase, continuous climate change, and rapid development of international trade, some public health events, including sudden infectious and foodborne/waterborne diseases, have occurred frequently, aggravating the complexity of health problems. For example, starting in late 2019, the COVID-19 pandemic has caused over six million deaths worldwide, still affecting daily life to this day. In order to find solutions to these problems, the concept of "One Health" was introduced, practiced, and applied in increasingly more international organizations and countries in the process of health governance [2,3].

Groundwater is one of the most valuable natural resources supporting the survival of human beings and the development of human societies [4–6]. However, serious groundwater pollution can have significant negative impacts on human health [7–11]. Contaminants in groundwater generally have two sources, one being of geogenic origin and the other human activities [12]. To reflect the most recent progress in groundwater quality research and associated public health issues, the Special Issue of the journal *Water,* entitled *Groundwater Quality and Public Health,* was developed. Its aim is to attempt to provide a platform for researchers, policy makers, and engineers to share their latest thoughts and findings on this topic, as well as novel methods dealing with groundwater pollution. The papers published in this Special Issue include the latest research results by world renowned researchers, whose findings could benefit researchers, engineers, policy makers, and government officials in future groundwater quality research and policy making.

2. Recent Research Advances in Groundwater Quality and Public Health

The importance of groundwater quality in maintaining human health has long been recognized [13–17]. As early as the 11th century AD, the Chinese population recognized the impacts of geological conditions on human health [18]; however, modern medical geological disciplines were not established to address the relationships between geoenvironmental elements and the health or occurrence of diseases in the environment until the 1930s, when Russian, Scandinavian and British geochemists established relationships between geochemistry and health in both humans and animals [18,19]. Since the 1980s, a number of books concerning highly interdisciplinary medical geology were edited and published [20–25], summarizing this field's contemporary advances. Among these, the book *Essentials of Medical Geology*, edited by Selinus et al. [20], is an award-winning work used worldwide as both a text and reference book. It involves environmental biological processes of elements, exposure pathways of elements, toxicology and pathology, and the techniques and tools in medical geological studies. Another book, *Introduction to Medical Geology: Focus on Tropical Environments*, edited by Dissanayake and Chandrajith [18], focuses on the impacts of medical geology on the health of millions of people in unique tropical lands. These valuable books provide comprehensive insights into the current developments and future prospects concerning medical geology.

In addition to books, there has been a large number of journal articles published over the past two decades, with the number of journals focusing on geological factors and human health also increasing. Some examples of these journals include *Exposure and Health*, *Human and Ecological Risk Assessment*, and *Environmental Geochemistry and Health*, presenting many papers reporting on the effects of geoenvironmental factors on human health [26–30]. In addition, some water- and geology-related journals also published a number of papers regarding water quality and public health [31–33]. Most recently, Fida et al. [34] reviewed the pollution status of water in Pakistan, where many people do not have access to safe and healthy drinking water, and summarized the significant health problems associated with the low-quality drinking water. Sathe et al. [35] conducted a comprehensive hydrogeochemical investigation in the north-eastern region of India to reveal the relationships between hydrogeological settings and groundwater with high arsenic and fluoride contents, assessing the health risks imposed due to exposure to these elements via drinking water intake. Alfeus et al. [36] assessed the human health risks caused with inhalation exposure to ambient PM2.5 and trace elements in Cape Town, South Africa. All the above studies showed that with the development in social economy, the public is seeking harmony between the rapid economic development and a sustainable environment, paying more attention to the health impacts of environmental pollution.

Particularly in China, on 11 September 2020, the security of public health was proposed to be one of the scientific and technological innovation targets when the Chinese president, Xi Jinping, chaired the symposium for scientists [37]. Since then, increasingly more research has been carried out seeking solutions to basic research questions behind this target. In 2021, the China Geological Survey implemented the Plan of Geological Survey to Support the Healthy China Strategy. The purposes of this were to accelerate the construction of technological systems, organizational structure systems, professional development systems, condition guarantee systems, and coordination and cooperation mechanisms for geological surveys to support the Healthy China Strategic, to systematically understand the status, health risks, and changing trend of major geological problems affecting human health in all of China, especially in key regions such as urban and periurban areas, and to fully reveal the mechanisms and laws behind how these geoenvironmental factors have affected human health. Based on these geological survey projects, medical geology in China is developing at a fast pace. In the past, medical geology mainly focused on the health problems caused by toxic elements and associated processes. However, particular attention has also been paid to the essential elements in the novel geological survey projects. For example, years ago, the main research focus was how toxic elements could cause diseases, such as fluorosis and arsenicosis [38–41], but, now, increasingly more research focuses on the effects of essential elements on human health [42–45]. This shift indicates that people's attitudes to health has changed from knowing how to avoid diseases to knowing how to maintain physical and mental health. This is a big step from traditional medical geology to health geology, and is more supportive towards fulfilling the One Health goal.

3. Papers Published in This Special Issue

The Special Issue *Groundwater Quality and Public Health* in the journal *Water* attracted 23 submissions, and after a rigorous peer review, 11 research papers were published. The topics of these papers ranged from regional groundwater quality and human health to specific elements or pollutants in groundwater (Table 1). Specifically, the 11 published articles could be classified into three topical clusters. The first topical cluster was regional groundwater quality and human health, and included four research articles. The second cluster was nitrate pollution, including two articles; the final cluster centered on trace elements, consisting of five research articles. In addition, as shown in the word cloud map generated using the titles and abstracts of papers in this Special Issue (Figure 1), the most frequently used words or terms in the papers comprising this Special Issue were groundwater, water, risk nitrate, health, hydrochemical, quality, drinking, basin, and HCO_3^-. This indicated that the main research objective among these papers was groundwater, with nitrate being a very common groundwater contaminant. In addition, groundwater quality studies are usually associated with studies on groundwater hydrochemistry represented by major ions such as HCO_3^-, and drinking water intake is the most significant exposure pathway causing human health risks.

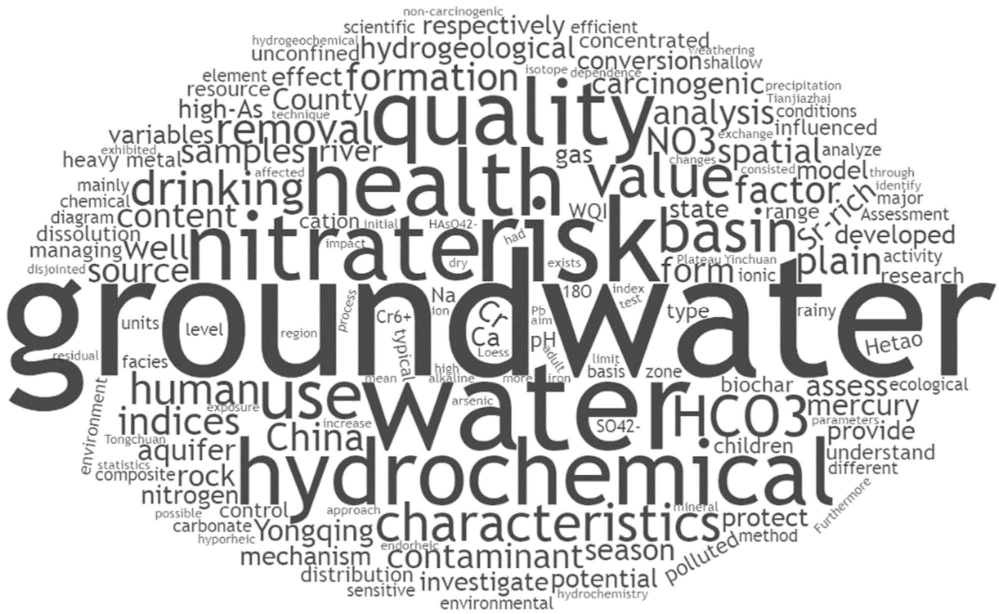

Figure 1. Word cloud generated with titles and abstracts of the Special Issue papers.

Table 1. Information of research papers in the Special Issue.

Topic Clusters	Authors	Titles	DOIs
Regional groundwater quality and human health	Machado et al.	Spatial and seasonal drinking water quality assessment in a sub-Saharan country (Guinea-Bissau)	10.3390/w14131987
	Nsabimana et al.	Health risk of the shallow groundwater and its suitability for drinking purpose in Tongchuan, China	10.3390/w13223256
	Li et al.	Groundwater Quality and Associated Human Health Risk in a Typical Basin of the Eastern Chinese Loess Plateau	10.3390/w14091371
	Bai et al.	Assessment of the hydrochemical characteristics and formation mechanisms of groundwater in a typical alluvial-proluvial plain in China: an example from western Yongqing County	10.3390/w14152395
Nitrate pollution	Jin et al.	Delineation of hydrochemical characteristics and tracing nitrate contamination of groundwater based on hydrochemical methods and isotope techniques in the northern Huangqihai Basin, China	10.3390/w14193168
	Liu et al.	Stimulating nitrate removal with significant conversion to nitrogen gas using biochar-based nanoscale zerovalent iron composites	10.3390/w14182877
Trace elements	Salem et al.	Geospatial assessment of groundwater quality with the distinctive portrayal of heavy metals in the United Arab Emirates	10.3390/w14060879
	Cai et al.	Hydrochemical characteristics of arsenic in shallow groundwater in various unconsolided sediment aquifers: a case study in Hetao Basin in Inner Mongolia, China	10.3390/w14040669
	Liu et al.	Potential toxic impacts of Hg migration in the disjointed hyporheic zone in the gold mining area experiencing river water level changes	10.3390/w14192950
	Liang et al.	Hydrochemical characteristics and formation mechanism of strontium-rich groundwater in Tianjiazhai, Fugu, China	10.3390/w14121874
	Ma et al.	Groundwater health risk assessment based on Monte Carlo model sensitivity analysis of Cr and As—a case study of Yinchuan City	10.3390/w14152419

In the first topical cluster, the research paper by Machado et al. [46] investigated the seasonal and spatial dynamics of drinking water quality across Guinea-Bissau, an endemic cholera sub-Saharan country, to fully understand the impacts of drinking water quality on public health. Serious fecal contamination was discovered in the water resources in this research, and some short-term sustainable measures were proposed for mitigating the associated health risks. To evaluate the quality and potential health risks of groundwater in the Tongchuan area, China, Nsabimana et al. [47] conducted a water quality and health risk assessment. The main contribution of this research was that it combined a carcinogenic risk assessment and noncarcinogenic risk assessment, and proved that traditional water quality assessments must be supplemented with health risk assessments to obtain completeness and comprehensiveness of the assessment. Similarly, Li et al. [48] also assessed the quality and potential health risks associated with the Linfen basin of the eastern Chinese Loess Plateau, and concluded that F^-, Pb, and Cr^{6+} were major contaminants responsible for inducing noncarcinogenic health risks in their study area. Bai et al. [49] focused on interpreting the hydrochemical characteristics and formation mechanisms of unconfined groundwater in a local area in the North China Plain using multiple approaches. This research could provide significant guidance for further groundwater quality protection and management in overexploited groundwater regions.

Worldwide, nitrate is very commonly found in groundwater, especially in agricultural regions [50–53]. The two articles in the second topical cluster reported on research concerning the identification of sources of nitrate and its removal. Specifically, the research by Jin et al. [54] revealed that the hydrochemical evolution of groundwater regulated rock weathering and cation exchange, and adopted stable nitrogen isotopes to trace sources of groundwater nitrate pollution, revealing the main sources of nitrate to be manure, sewage, and NH_4 fertilizers. Liu et al. [55] prepared biochar-based nanoscale zerovalent iron composites for nitrate removal from synthetic groundwater. This experimental research provides the necessary basis for nitrate removal with high efficiency.

The five papers in the third topical cluster involved trace elements, such as arsenic, mercury, strontium, chromium, and other metals. Trace elements in water and soil mainly originated from rock crusts, but also from anthropogenic activities [56,57]. Some are essential for human health when digested in trace amounts, but quickly become toxic when consumed in large quantities [58]. Some trace elements are toxic even in trace amounts [59,60], thus, requiring particular attention from different stakeholders. Salem et al. [61] reported on the spatial variability of heavy metals, such as Al, Ba, Cr, Cu, Pb, Mn, Ni, and Zn, in groundwater in the Liwa area of the United Arab Emirates the using principal component analysis and geographic information systems, while Cai et al. [62] focused on arsenic in shallow groundwater in the Hetao Basin in Inner Mongolia, China. Liu et al. [63] investigated Hg migration via in situ testing in the disjointed hyporheic zone in the gold mining area where river water level changes were detected, and Liang et al. [64] conducted research on the formation mechanisms of Sr-rich groundwater in the Shimachuan River basin, China. Ma et al. [65] assessed the health risk associated with As and Cr in dry and wet seasons using the Monte Carlo model, and quantified the possible ionic forms of As. These articles investigating trace elements could be essential for setting up future groundwater quality monitoring systems and groundwater pollution remediation measures.

4. Future Prospects

Medical geology is truly a multidisciplinary research field, and requires collaboration among researchers, policy makers, and the general public, with groundwater quality research being a fundamental field of this discipline. Hence, for its further promotion, we propose some suggestions that may be fundamental and significant to guiding this discipline:

- Groundwater is influenced by multiple factors, increasing the complexity of groundwater quality research [66,67]. Therefore, continuous research should be promoted, focusing on the mutual interactions among different elements and substances, as well as their effects on the toxicity of newly formed species through their interactions [19]. Particularly, a number of studies [68–70] indicated that land use/land cover, though not capable of altering groundwater quality directly, can significantly alter elemental levels in groundwater, thus, affecting the suitability of groundwater for drinking. Therefore, research on these indirect influencing factors should be highlighted.
- The impacts of human activities on groundwater quality are increasing, and conditions are becoming more complex. Therefore, more monitoring data are required for groundwater quality research. However, obtaining them is not easy, thus, requiring the help of nonprofessional communities. The importance of citizen science in big data accumulation and analysis has been well recognized by the science community [71–73]. However, criticism also exists in the science community, such as concerning the lack of data reliability. Citizen science should, therefore, be further promoted to facilitate groundwater quality and public health research.
- The concept and theoretical basis for medical geology should be further updated. As mentioned previously in this editorial, people's attitude toward health has changed due to the spread of knowledge on how to avoid diseases to knowing how to maintain physical and mental health, which is a broader concept than just knowing how to

avoid diseases. Maintaining health does not only include avoiding diseases, but also keeping healthy via an appropriate intake of necessary essential elements through water, food, and other media. Therefore, the geology of health could be a possible replacement for medical geology in the future.

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