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Editorial

Advances in Urban Groundwater and Sustainable Water Resources Management and Planning: Insights for Improved Designs with Nature, Hazards, and Society

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1. Scope

"It appears therefore that, in early times, Man's interference with the natural flow of water consisted mainly in taking water from rivers and springs, and that this water would find its way back, in a polluted condition, into the rivers, having suffered some reduction in quantity by evaporation. The size of streams would, therefore, not be markedly interfered with, although the water would be greatly polluted. We have to remember, in this connection, that the population was considerably less, and the quantity of water used per head very much less in early times than is now the case (. . .)." R.L. Sherlock (1922, p. 272)

In nature, urban groundwater results in several processes, including climatic, geological, geomorphological, geochemical, ecotoxicological, and hydraulic processes and sanitation, sustaining several ecological services. Urban development profoundly impacts hydrological systems, particularly in the invisible component of the water cycle: groundwater (e.g., [1–3]). That impact was noticed a long time ago and focused on societal roles in the development of urbanisation and the consequent contamination and pollution of hydrosystems (e.g., [4–7]). Additional issues in sustainable water resource management and hydrological cycle comprehension are added by urbanisation [8–10]. In addition, climate analysis is taking on an increasingly central role in the life of humanity. Climate greatly impacts many environmental issues and requires reliable, as well as complete, data [11,12].

An intricate network of pipes constitutes the anatomy of the urban underground, including, namely, conduits, channels, galleries, storm sewers, and other structures that alter the hydraulic conductivity of geomaterials (e.g., [9,13–18]). Consequently, these urban buried features act as favourable pathways for the fluid flow of urban-sourced contaminants into groundwater resources. In addition, the ground's surface is generally covered by several structures, such as buildings, asphalt, concrete, and bricks, that are perceived as effectively impervious. In addition, the increasing environmental pressures, such as overexploitation, contamination and/or pollution issues, and climate variability, affect urban groundwater systems (e.g., [1,19–21]).

The release of contaminants from urban infrastructures alters the chemistry of the surrounding environment and affects water quality. Urban streams (some also channelled and shallowly buried) receive dissolved and particulate chemical loadings from runoff, sewer connections, direct discharge from other waterways, and interactions with groundwater. The chemistry of urban runoff tends to be dominated by materials associated with or accumulated on impervious surfaces, such as heavy metals and deicing salt from

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roadways. Sewage treatment plants are typically designed to remove some but not all human-produced compounds and suspended material from water (e.g., [22,23]).

Source controls, i.e., pollution prevention, represent fundamental steps towards minimising the presence of pollutants in urban stormwater and the concomitant potentially adverse effects in receiving water bodies. Moreover, source control policies are the most cost-effective management tool for dealing with low-level diffuse pollution. Therefore, there is a strong need to advance this pollution control tool [24]. However, frequently, the opportunities for preventing pollution sources are limited or hard to achieve. Then, it may be more feasible to control the release activities rather than primary sources, such as atmospheric deposition, drainage surfaces, anthropogenic activities, and urban drainage systems [25].

Currently, more than half (54%) of the population lives in urban areas (ca. 4 billion people) at locations generally close to coastal areas, and it is projected that this proportion will grow to 68% by 2050 [26]. Urban groundwater is a relatively recent field of hydrological sciences (e.g., [3,15,19,27–30]). However, attention is focused on the relationship between urban development and water resource management that started in the 1950s–1960s, when the accelerated growth after World War II, especially in Europe and North America, started to create a wide range of hydrological problems. Most of these issues were related to urban runoff and flooding, so within a short period, urban hydrology was decisively established (e.g., [29,31,32]). Urban development impacted surface water resources, but the effects have also started on groundwater, hence the emergence of the urban groundwater concept (e.g., [9,19,30,31]). La Vigna [3] proposed a groundwater city classification that reflects geographical aspects, climate contexts, and hydrogeological settings, with a clear connection to groundwater dynamics with several categories: (i) coastal, lagoon, and delta groundwater cities (CGC-LDGC); (ii) volcanic groundwater cities (VGC); (iii) hard-rock and karst groundwater cities (HRGC-KGC); (iv) alluvial groundwater cities (AGC); (v) cold climate groundwater cities (CCGC); (vi) arid climate groundwater cities (ACGC).

A paradigm shift based on holistic management is required to design sustainable water systems. Thus, an urban water framework must be based on sustainable technical–scientific studies and embrace socioeconomic, cultural, heritage, and ethical dimensions [33]. Therefore, the solutions to be promoted should be planned and organised in an environmental balance and harmony with the natural environment (e.g., [6,21,34,35]) within a spirit of comprehensive studies and societal practices, eco-responsibility, and geoethics [36].

Lastly, researchers should continue identifying, mapping, and quantifying the contributing potential contamination and pollution sources and developing control strategies and treatment technologies in collaboration with the industry, local authorities and representatives of citizen groups. Furthermore, it is urgent to tackle innovative programs and actions visible in primary, secondary, and higher education about the crucial role of groundwater in society, geosystems, and ecosystems, particularly in urban areas (e.g., [2,37]). Moreover, enhanced public awareness of groundwater will inspire citizens and stakeholders to take advised, local action on water issues [38].

2. Articles

This Special Issue (SI) highlights the presentation and discussion of model urban studies, methodological approaches, and reflections that describe the current state-of-the-art methods on challenges and emerging fields related to the mapping, characterisation, assessment, mitigation, and protection of sustainable groundwater systems in peri-urban and urban areas.

The contributions unfold two major dimensions: (1) groundwater protection studies in urban areas and implications for sustainable groundwater resources management; (2) groundwater contamination investigations in model urban and peri-urban areas. The paper set includes model urban areas in Europe (Italy and Portugal, including the Azores), Asia (China, India, and Thailand), South America (Brazil), and Africa (Egypt, Kenya, and Zambia). The SI comprises 11 papers involving over 64 authors, all dealing with several groundwater methodologies and tools. In addition, the papers include six feature papers and one editor's choice paper.

Articles here shape many interesting approaches, such as the following:

(i) The feature paper from Foster et al. [39] analyses sustainable management drivers and policy demands related to urban self-supply from groundwater. In the last decades, the use of private water wells in developing cities increased enormously but in a chaotic manner. The authors outline this sensitive question based on ten globally selected urban cities from three continents. This insightful contribution highlights the following impressive thought: "it is thus very important that urban self-supply from groundwater must not be ignored by the public authorities and should be systematically included in city-wide surveys and monitoring of water-supply provisions. Policies need to be introduced that encourage municipal water utilities and local government offices to provide services to private water well users in return for formal water well registration and payment of a modest resource fee." [39].

(ii) The articles by Cai et al. [40], Andrei et al. [41], and Valente et al. [42] highlight groundwater hazard concerns in distinctive hydrogeological media, geological settings, and geoenvironmental issues. Cai et al. [40] point out a detailed study in Limin village, Nantong City, Jiangsu Province (SE China), regarding the analysis of the water level (pumping/recovery tests) forecast of groundwater sources using numerical modelling and the contamination impacts on the nearby environment. Andrei et al. [41] present an isotopic hydrology study for tracing municipal solid waste landfill contamination of groundwater in two urban areas, in Cagliari province, Sardinia (SW Italy), and Umbria region, Perugia province (Central Italy). The findings of two model regions confirm that the δ^2H isotope enrichment is a useful tracer for detecting contamination processes between leachate from municipal solid waste landfills and groundwater [41]. Finally, Valente et al. [42] describe an exploratory geo-hazard investigation in assessing the impact of volcanic eruptions on a groundwater-fed water supply system in the Ponta Delgada urban area, São Miguel Island (Azores, Portugal). This study offers key guidelines for other municipalities in the Azores or comparable volcanic islands, where the water supply issues during and after a volcanic event are similarly critical.

(iii) The papers of Afonso et al. [43], Mansilha et al. [44,45], and Zeferino et al. [46] report case studies in Portugal related to GIS mapping for environmental hydrogeology, hydrogeochemistry, and hydrodynamics assessment in peri-urban and urban areas. Afonso et al. [43] assessed the major urban hydrogeological processes and their dynamics, as well as anthropogenic interactions in groundwater systems in fissured media of the Porto city urban area (NW Portugal). Mansilha et al. [44] outline a study that identifies major effects of a large forest wildfire on groundwater quality from springs linked to a small supply system in a peri-urban forest area in Braga city's (NW Portugal) vicinities. In addition, the investigation concludes that an interlinkage between groundwater depletion and devastating wildfires might seem questionable, but the parametric drinking water values demonstrate the groundwater system's vulnerability to wildfires. Mansilha et al. [45] describe an environmental hydrogeology study on drained effluents from the abandoned colliery mine of São Pedro da Cova, located in the Porto peri-urban area (NW Portugal), examining their suitability for irrigation purposes. The results suggest a cost-effective methodology, minimising the pollution of natural streams and soils and increasing the potential use of effluents. Zeferino et al. [46] present a study to delineate the effectiveness of well-head protection areas after long-term applications on public supplies with continuous pumping located in a densely populated urban area of Montijo municipality (SW Portugal).

(iv) A set of papers [47–49] underlining several case studies on numerical analysis and modelling of groundwater resources management. Liu et al. [47] describe a model for analysing the development pattern of water resource's carrying capacity by examining the water conservancy in Jilin Province (NE China). The lessons learned could be applied to other regions. Krishan et al. [48] present a comprehensive study of hydrogeochemistry processes in the groundwater system salinity of the Mewat region, Haryana province (NW India). The outcomes of this study will be useful in managing and remedying groundwater systems. Finally, Abdelfattah et al. [49] outline a study on the coastal aquifer in the western area of Port Said (NE Egypt). The findings emphasise optimum withdrawing scenarios with sufficient groundwater but a smaller salinity.

3. Outlook

The urban water cycle provides a conceptual and unifying basis for a correct assessment of groundwater systems and leads to the foundation of studies on the sustainability of water resources. The role of climate, geology, geomorphology, land use and land cover, hydrogeochemistry, hydraulics, and human activities is important for an integrated assessment of water resources in urban areas. In addition, remote sensing provides valuable and up-to-date spatial information on terrain and natural resources. Recently a new focus has emerged, addressing questions on Geographic Information Systems (GIS) studies integrated into urban water supply systems, notably in historic cities. Sustainable urban groundwater systems are considered increasingly significant in global development issues such as management, protection, distribution, safety, and services (e.g., [2,3,19,27,29,39,50]). In addition, urban population growth and improved living patterns lead to increased water use and demand. While climate and environmental change raise several issues related to the accessibility of urban water resources, such an approach concerning all ecosystem characteristics in peri-urban and urban environments necessarily requires a transdisciplinary methodology that encompasses socioeconomic and cultural perspectives and technical-scientific solutions based on compatible designs with nature, and that is attentive to societal dynamics (e.g., [20,21,33]).

New challenges are emerging, and they are related to mapping, assessing, abstraction, and modelling the urban water cycle. The development of GIS-based inventories in urban areas is a challenge that is vital for planning and managing water resources, assessing water supply security, and defining asset strategies. Furthermore, the urban water cycle concept in urban environments should be highlighted, emphasising holistic and integrated sustainable management related to climatic, physiographic, hydraulic, environmental, and socio-cultural conditions. Indeed, the role of sustainability should be carried out by conducting a consistent analysis of the interlinkages between urban groundwater and the sustainable development goals, as highlighted, for example, by the UNESCO 2030 Agenda. Water issues will continue to be on the agenda of all societies as they cut across the balance of communities, ecosystems, energy transition and climate emergency, heritage, and societal issues and will mark the agenda of any society permanently. However, a correct understanding of the urban water cycle should be based on the sustainable protection and management of the resource, territorial planning, eco-responsibility, hydrogeoethics, and good practices.

In the current year, 2022, World Water Day was dedicated to groundwater, making the invisible visible. This SI offers a set of papers that promote reflections, methodologies, and learned studies on the importance of fresh water in urban areas.

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