



Hydrogeoethics in sustainable water resources management facing water scarcity in Mediterranean and surrounding regions

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The Mediterranean region and surrounding areas comprise the semi-enclosed sea, which shares a coastline of over 46,000 km, between the southern borders of mainland Europe (namely, Iberian, Italian, Balkan Peninsulas and France), Anatolian Peninsula, western Middle East region and northern Africa. The narrow Strait of Gibraltar connects the Mediterranean Sea to the Atlantic Ocean. It is also the crossroad over 480 million inhabitants living within three continents: Africa, Asia, and Europe. Nearly one-third of the Mediterranean population is concentrated along its coastal regions. In addition, about 250 million people live in coastal hydrological basins, increasing environmental pressures (EEA 2015; Allam et al. 2020). In addition, groundwater resources are the main source of water supply in several

Mediterranean countries and are subject to anthropogenic pressures resulting from unequal distribution, uneven accessibility and quality issues (García-Ruiz et al. 2011; Calvache et al. 2018; Fader et al. 2020).

The Mediterranean and surrounding areas are considered a biogeographic region directly impacted by climate change and associated hydrological hazards and other human-induced environmental risks (e.g., Döll 2009; García-Ruiz et al. 2011; Milano et al. 2013; Leduc et al. 2017; Calvache et al. 2018; Cramer et al. 2018; Allam et al. 2020; Schilling et al. 2020, and references therein). Furthermore, according to UN-Water (2021), climate change is expected to increase seasonal variability, creating a more erratic and uncertain water supply. This will worsen problems in already water-stressed areas, potentially enlarging the geographical extent of water stress-prone areas. In addition, the effects of climate variability led to the increase of water stress levels because the water demand grew. Datta (2005) states that a critical issue is an imbalance between water demand and availability, and management approaches face various ethical issues and dilemmas. Consequently, a new approach is imperative to embrace ethics, eco-responsibility, and sound hydrological sense (Groenfeldt 2021).

In the context of the United Nations' 2030 sustainability Agenda, an action plan to strengthen sustainable water development was adopted. The plan addresses several sustainable development goals (SDGs), contains targets and adopts an interlinkages approach. However, the strong relationship between water and ethics is challenging to recognise the groundwater value in resource management. The current trends on the valuation of water are based on five interlinkage perspectives (UN-Water 2021): (i) valuing water sources in the environment (in situ water resources and ecosystems); (ii) valuing water infrastructure (water storage, use, reuse or supply augmentation); (iii) valuing water services (mainly drinking water, sanitation and related human health aspects); (iv) valuing water as an input to production and

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socio-economic activity (food and agriculture, energy and industry, business and employment); (v) sociocultural values of water (recreational, cultural and spiritual attributes).

Currently, society demands a balanced groundwater footprint in sustainable resources management, eco-responsibility, and water ethics (e.g., Leopold 1990; Custodio 2000; Llamas 2004; Datta 2005; Llamas et al. 2009; Groenfeldt and Schmidt 2013; Ziegler and Groenfeldt 2017; Groenfeldt 2019, 2021). Therefore, protecting and valuing water is a shared societal responsibility (UN-Water 2021). In addition, the dissemination of geological information with the public shall be straightforward within a geoethical framework (Di Capua et al. 2021). Thus, sustainable water resources management, water conservation and water services encompass technical-scientific aspects and issues of social equity and intra- and intergenerational justice (Di Capua 2021). Hence, it is crucial to recall the powerful thought of Custodio (2021): “ethics is not a guide with rules and recommendations for action but a set of supporting concepts and principles for human behaviour.”. Because of that, water ethics depend on applying the precautionary and subsidiarity principles, as well as the understanding of the functioning and uncertainties of hydrological systems (Custodio 2021; Stewart et al. 2021).

Hydrogeoethics is an emergent transdisciplinary field in geosciences focused on ethical research and best practices related to responsible groundwater science and engineering, creating conditions for sustainable water resources management while respecting human needs and environmental dynamics (Abrunhosa et al. 2021). Also, it is grounded on the principle of responsibility (Jonas 1976, 1984), the ethical criterion that should guide any human action on socio-ecological systems (Peppoloni et al. 2019; Di Capua 2021). Moreover, like geoethics, it can be defined through the same characteristics (Peppoloni and Di Capua 2021a, b,c): geoscience knowledge-based, contextualised in time and space, human agent-centric, and shaped as virtue-ethics. Currently, the boundary of geoethical analysis has expanded to include the global issues of modern societies, above all anthropogenic and environmental changes, which redefine the possibilities and expectations of human life on the planet (Peppoloni and Di Capua 2021b, c). Therefore, its studying objects are related to transdisciplinary fields in geosciences, anthropological and social sciences, dealing with the relationship between humans and the water cycle, including cultural, aesthetic, and historic traditions linked to water uses, legal frameworks, best practices and governance, groundwater management-society-policy interface (Di Capua 2021). Or, straightforwardly, as stated by Groenfeldt (2019), “the ethical basis for our decisions about nature, development, and water is constantly evolving”. On the other hand, Custodio (2021) points out an impressive thought interrelated between the water ethics and moral principles

must be highlighted in the availability and the preservation of water resources to maintain a healthy relationship with nature, the environment and all components that affect society in terms of values and practices (e.g., economy, health, energy, land use, employment, quality of life, cultural, spiritual and religious values).

The themed issue on “Hydrogeoethics in Sustainable Water Resources Management Facing Water Scarcity in Mediterranean and Surrounding Regions” includes selected contributions in hydrogeology, urban groundwater, rural hydrogeology, groundwater harvesting agroecosystems, environmental law, water resources, and water-related research and practice. The published article set is an impressive coherent sample of further investigation first presented mainly during the thematic sessions at the 1st Congress “Geoethics & Groundwater Management” that took place in Porto city (Portugal) in May 2020 (details in Abrunhosa et al. 2021). The main scope of the then proposed thematic sessions was the debate on integrating all aspects of geoethics in sustainable groundwater management theory and practice. As a result, the emergent scientific field called hydrogeoethics is found soundly grounded in hydrogeology and geoethical principles and values, including the engineering, socio-economic, legal, environmental, arts, and cultural dimensions. It is also considering a shift in the centrality of liquid freshwater from its already highlighted 1% surface water, to 99% groundwater, as a leitmotif to give visibility to groundwater, which is currently mostly invisible (Abrunhosa et al. 2021; Cherry 2021). The special issue presents interesting studies in model regions underlining sustainable groundwater resources management and geoethical dimensions. The articles published in this volume also illustrate hydrological systems under climate crisis, environmental and societal pressure. The urgent need for an ethos for long-term environmental sustainability, socio- and eco-responsibility, to live following geoethical principles and values is emphasised.

The themed issue highlights key emerging research topics that reshape the current disciplinary boundaries in hydrogeology, groundwater science and engineering, environmental law, social sciences to support a balanced, sustainable water resources management under a geoethical perspective. This is one of the methods in hydrogeoethics. Additionally, it offers in-depth insights from comprehensive studies that address several SDGs and interrelated targets in the scope of the UN ‘2030 goals and beyond. Currently, society has become aware and more demanding in the environmental practices of water resources management and actions. In fact, the fundamental issue centred on water quality as a human right and, in a broader overview, as vital to all ecosystems and nature (e.g., Gleick 1998; Falkenmark 2003; Llamas and Martínez-Cortina 2009; Groenfeldt and Schmidt 2013; Tortajada and Biswas 2017; Gleeson et al. 2020).

Thus, nature-based solutions for water are water management strategies inspired and supported by nature and mimic natural processes (Kabisch et al. 2017; UN-Water 2018). According to Ribeiro (2021), “to live in an ethically responsible society, we need to modify water planning and management in order to achieve fairer access to drinking water, as well as providing effective social responses to public health concerns without jeopardising ecosystems.”. Furthermore, the design with natural solutions is a keen example of synergy between human beings and the Earth and environmental systems. Last but not least, hydrogeoethics addresses a conceptual and practical framework for a reliable people-centric approach in dialogue with ecocentric perspectives, underlining the connectivity, interlinkages, and interdependency of groundwater resources management, water conservation, environment, social and cultural activities.

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