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Editorial

Coastal Aquifer Management: Hydrological, Environmental, Economic and Social Challenges in the Context of Global Change

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1. Introduction

Groundwater is limited and its sustainable use is peremptory if we are to preserve dependent ecosystems and human supplies. This resource is especially crucial in densely populated coastal areas with limited surface water sources. The excessive use of groundwater to supply the increasing urban, tourism, industrial, and agricultural demands is adding stress to many coastal aquifers, and the number of cases with alarming signs of groundwater quantity and quality degradation is increasing.

In the current context of climate change, complex interactions between global driving forces (rising sea levels, growing storm frequency, higher evapotranspiration rates, and increasing atmospheric salinity inputs) and human activities (inducing saltwater intrusion, mobilization of brines, chemical pollution, agroindustry contamination, and loss of environmental values) are threatening coastal aquifers. The consequence of this is groundwater salinity exceeding the quality standard required for human health, crop production, industrial activity, and ecosystem survival. Reparative measures and the production of non-conventional water sources to supplement the growing demand may be partial solutions, but the energy price increase is slowing many initiatives down. Thus, understanding these complex interactions is challenging because the equilibrium between sustainable use, economic profit dictated by global markets, environmental protection of dependent ecosystems, and social habits of consumption is subject to the fragile limitations imposed by groundwater salinity.

In the wide "groundwater resource problematic" framework, this Special Issue was established to explore the global driving forces and human activities determining the sustainability of the coastal aquifers, with a special focus on (i) hydrological, geological, geophysical, chemical, and modelling studies aimed at conceptualizing the aquifer functioning and assessing the status of the groundwater resource quantity and quality; (ii) environmental analyses aimed at assessing the factors threatening habitats, including overexploitation, salinity increases, human occupation, pollution, and land degradation; (iii) economic appraisals aimed at linking groundwater use and profit, such as the water–energy–food nexus, water treatment investment, control of international markets, opportunity costs, and energy limitations to generating non-conventional water sources; and (iv) social habits for water consumption and future resilient adaptations, including the effect of water restriction, climate migrants, education, and stakeholder participation.

2. Contributions

Since the call for papers was announced in September 2021, we have received a total of seven manuscripts. After a rigorous review process, five papers have been accepted for

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publication [1–5]. To gain a better insight into the essence of the Special Issue, we offer brief highlights of the published papers below.

The paper entitled "Delimiting Pig Slurry Affected Subsurface Areas by Combining Geophysical and Geochemical Techniques" [1] uses different techniques to evaluate the subsurface conditions of three representative pig slurry ponds under semiarid conditions, presenting results in terms of pH, electrical conductivity, salinity, and nitrate content. The electrical resistivity tomography (ERT) technique was used to study the electrical resistivity of subsurface materials and fluids. Electrical resistivity values and geochemical analyses were compared to establish the pig slurry-affected subsurface area. The ERT-based lower electrical resistivity values were associated with higher salinity and nitrate contents. Spearman's correlation was also used to correlate the electrical resistivity data and physical–chemical properties of soil. The study demonstrates a complete, affordable, and scalable methodology application to livestock residue storage facilities in densely populated coastal aquifers.

The paper entitled "A Python Application for Visualizing the 3D Stratigraphic Architecture of the Onshore Llobregat River Delta in NE Spain" [2] introduces a Python application for use to visualize the 3D stratigraphic architecture of porous sedimentary media. The parameter granulometry deduced from borehole lithological records was used to create three interactive 3D HTML models of essential stratigraphic elements. The first shows the location of the boreholes granulometry. The second includes the main gravel and coarse-sand sedimentary bodies, catalogued as productive aquifers. The third deals with the basement (Pliocene and older rocks) top surface. The modeled stratigraphic elements match well with the sedimentary structures reported in recent scientific publications, thus proving the strong performance of this Python application in visualizing the 3D stratigraphic architecture, which is crucial for groundwater management and governance.

The paper entitled "Estimation of Global Water Quality in Four Municipal Wastewater Treatment Plants over Time Based on Statistical Methods" [3] develops routines to predict temporal changes in water quality by introducing a wastewater quality index (WWQI) for four regional wastewater treatment plants. The application conducted in Murcia in southeast Spain over the period 2019–2021 adopted multivariate statistical analyses to predict the performance of WWQI. Via robust principal components (PCs) analysis of the 16 physicochemical variables of the raw and treated wastewater, 5 main PCs were extracted that explain between 21.39% and 36.79% of the data variability. From the loadings of the PCs, the relationships between the original parameters are analyzed. These techniques provide a comprehensive evaluation framework for monitoring wastewater treatment and possible effects on the environment.

The paper entitled "Calculation of the SPI, SPEI, and GRDI Indices for Historical Climatic Data from Doñana National Park: Forecasting Climatic Series (2030–2059) Using Two Climatic Scenarios RCP 4.5 and RCP 8.5 by IPCC" [4] analyzes three indices to assess drought in the Doñana National Park (DNP) in southern Spain. These are the standardized precipitation index, the standardized precipitation evapotranspiration index, and the groundwater recharge drought index (GRDI), the latter of which was specifically developed to evaluate groundwater drought. The analysis covered the historical period 1985–2015, and made future projections for the period 2030–2060 under climate scenarios RCP 4.5 and 8.5. The findings revealed a 13–14% decrease in precipitation regarding the historical period, whereas wet periods decreased from 25% to 38%. The decreasing recharge rates are attributed to increasing evapotranspiration during the 21st century. The findings will aid administration authorities in formulating integrated water-resource management strategies in the DNP and its surrounding basin.

The paper entitled "A Framework to Assess Natural Chloride Background in Coastal Aquifers Affected by Seawater Intrusion in Eastern Spain" presents a combination of six well-known statistical techniques and the new SITE index in eight groundwater bodies (GWBs) affected by seawater intrusion (SWI) in eastern Spain. The chloride ion was the selected conservative chemical specie used to assess the qualitative status due to variable

SWI affection. The natural chloride background (NCB) obtained from these methodologies at the GWB scale was compared with regional NCB data calculated using the atmospheric chloride mass balance method in continental Spain to segregate atmospherically derived NCB data from chloride contributed by anthropogenic activities and lithology. The atmospheric fraction of NCB is proposed as an external regional criterion to validate the more detailed statistical methodologies applied to define SWI at the GWB scale.

3. Conclusions

The Guest Editors envision that the papers published in this Special Issue will be of interest to researchers and practitioners and help to identify further research routes. We also hope that the readers find the material in this Special Issue both interesting and inspiring when exploring the field of groundwater management in coastal aquifers. The findings and methods presented in this collection of papers will contribute to the growing research fields of the conceptualization of coastal aquifers, the environmental protection of dependent ecosystems, and other crucial economic and social challenges in the context of global change.

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