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Editorial

Water Quality Modelling, Monitoring, and Mitigation

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Abstract: In the modern era, water quality indices and models have received attention from environmentalists, policymakers, governments, stakeholders, water resource planners, and managers for their ability to evaluate the water quality of freshwater bodies. Due to their wide applicability, models are generally developed based on site-specific guidelines and are not generic; therefore, predicted/calculated values are reported to be highly uncertain. Thus, model and/or index formulation are still challenging and represent a current research hotspot in the scientific community. The inspiration for this Special Issue came from our desire to provide a platform for sharing results and informing young minds around the world to develop suitable models to understand water quality so that mitigation measures can be taken in advance to make water fit for drinking and for life-supporting activities.

Keywords: water quality; monitoring; modeling; mitigations; water quality indexing

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1. Introduction

Due to the rapid increase in anthropogenic activity in catchments, further adverse changes in access to water resources are expected in the future [1] Under these conditions, water quality (WQ) plays an important role that determines its economic utility, including in the potable or drinking water supply, recreation, and agriculture. In the modern era, the study of and commitment to monitoring, modeling, and mitigation have become important and meaningful aspects of the environmental impact assessment process [2]. Under various circumstances, the potentially adverse impacts on ecological flora and fauna can be mitigated through the strategic design and implementation of appropriate models, tools, or techniques to diminish the severity of the effects [3,4]. Different types of nutrients, contaminants (heavy/trace metals), micropollutants, nanoparticles, microplastics, microbes, etc., disturb the ecological life in freshwater bodies [5,6]. Therefore, evidence-based pollution control is urgently needed to focus on the elementary level of water governance, known as "monitoring, modeling, and mitigation". Monitoring sets the empirical basis by providing spatio-temporal information on substance (contaminants and WQ parameters such as dissolved oxygen, biochemical oxygen demand, chemical oxygen and demand, and nutrients) loads as well as the driving boundary conditions for evaluating WQ trends and statuses and for further providing useful information to mitigate contamination and to balance ecological life [7]. Thus, modeling helps to provide long-/medium- and long-term information for times and locations where monitoring is not at all possible [8,9].

The proposed Special Issue will explore cross-disciplinary approaches, modeling, and methods and will discuss water quality risks as well as solutions for the implications for environmental sustainability and for the further conservation of ecological life. The interconnectedness of this critical problem cannot be assessed with traditional approaches; instead, inter- and trans-disciplinary approaches are urgently required worldwide to deal with water resource problems and environmental sustainability challenges.

2. Overview of Water Quality Indexing Models

In general, water quality index (WQI) models are frequently used to evaluate the WQ of freshwater bodies (e.g., lakes, rivers, and reservoirs) [10,11]. These models use aggregation techniques to convert extensive WQ datasets into a single representative value. Since the 1990s, WQI models have been extensively used to evaluate the WQ of surface water and groundwater [12] based on local criteria because they are easy to handle and free (Figure 1). The literature has reported that more than 30 WQI models have been created and introduced worldwide to evaluate the WQ of freshwater bodies [13–15]. WQI models are generally completed in four consecutive stages: (i) the selection of WQ parameters, (ii) sub-indices generation for individual parameters, (iii) the calculation of the weighting values of each parameter, and (iv) the sum of all sub-indices values to evaluate the WQI. The literature has reported a range of applications of WQI models to evaluate the WQ of freshwater systems [10,14–16]. However, most of the models that have been developed are based on site-specific guidelines and are not generic; therefore, the large uncertainty in the predictions and/or estimations made by these WQI models is coming into the picture and creating a hindrance in strategic mitigation measures for WQ control for sustainable ecological life and human use.

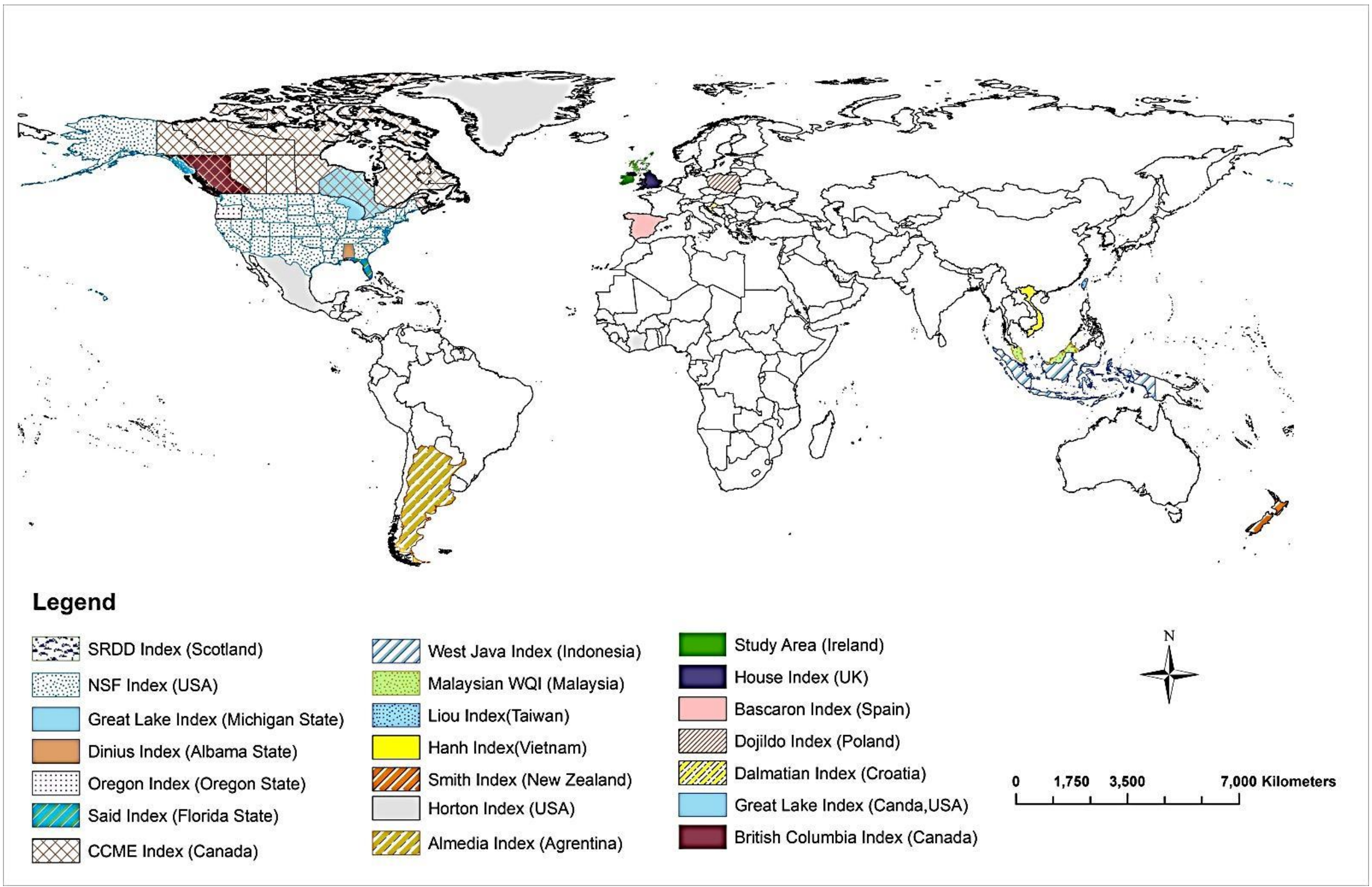

Figure 1. Commonly used WQI models worldwide [15].

3. Water Quality Models, Challenges, and Limitations

Water quality modeling (WQM) is an important tool that aids environmentalists, policymakers, water resource planners, and managers in strategic water resource management.

However, WQM represents a challenge in the scientific community due to several constraints and limitations. In general, WQ models are classified based on the types of receiving water, the complexity of the models, and the WQ parameters (e.g., nutrients, dissolved oxygen, biological oxygen demand, etc.) that the model can predict. Thus, WQM requires proper standardization, pollution hotspots, the identification of common features, and policy-relevant models. These models save labor costs, materials, and time [16] and help in effective pollution mitigation for the watershed. In the recent era, numerous models have been frequently used to simulate the water quality of freshwater bodies (streams, rivers, reservoirs, and lakes), estuaries, coastal waters, and marine ecosystems [17]. However, due to the different theories and algorithms applied in the models, their corresponding outputs are different and create huge differences in the results; thus, models could be useful and produce fruitful results when applied to solve particular environmental problems [18].

Water quality (WQ) models are generally categorized into two categories: (i) physical and (ii) mathematical models [19]. Furthermore, they can be categorized according to the complexity of model simulation, i.e., 1D, 2D, and 3D; type of approach (conceptual, physical, or empirical); data requirements; types of pollutants; area of application (groundwater, catchment, lake, river, coastal waters, etc.); nature (stochastic or deterministic); and spatial analysis [20]. In recent decades, WQ models such as ANSWERS-2000, AquaChem, MIKE SHE, AGWA, GLEAMS/CREAMS, AQUATOX, APEX, EFDC, EPD-RIV1, BASINS, HSPF, KINEROS2, LSPC, NLEAP, PRMS, QUAL2K, QUAL2E, SWMM, SWAT, WARMF, WAM, WCS, and WASP7 have been frequently used to predict WQ worldwide [21]. Because of data requirements and availability as well as types of catchment problems, the simplest reliable models are dominant over complex models [22].

WQ modeling is still challenging in the scientific domain due to the lack of expert handling of user, site, and/or regionally specific and parameter-specific information as well as inadequacies in model calibration and errors in data reporting. The uncertainty in WQM comes from various sources of errors, such as (i) parametric uncertainty, (ii) structural errors, and (iii) errors in the measurements of the input values and response uncertainty [23]. In developing countries (e.g., India and China), a uniform model standardization system has not been recognized, which limits the extensive utilization of those models for ecological and water management as a result of the lack of benchmarks and comparisons between different modeling outcomes [9,10,16]. Spatial variability is reported as a serious problem in catchment-scale WQM that generally acquires catchment behavior, representative site selection, and the integration of nonlinear biogeochemistry [24]. However, the complexity of models, the inadequate availability of data, and poor WQ data are other important limiting factors for WQM.

4. Water Quality Mitigation Measures

Water quality mitigation measures or strategies are generally intended to inform and assist communities in identifying potential alternatives to minimize the adverse impacts of pollutants on WQ and to ensure that water is safe for community use [25]. Ultimately, mitigation measures help to protect, restore, preserve, and improve the WQ of receiving water bodies. WQ protection refers to adequately treating runoff to protect downstream resources from WQ degradation [26]. Restoration comes into action if the protection strategies are not sufficient to maintain WQ standards as per the permissible limits. Stakeholders from different fields working together to achieve WQ restoration goals [27]. Water quality preservation necessitates a decision-support framework that can be used to evaluate, monitor, and optimize the effects of different drivers on WQ [28]. Furthermore, WQ improvements can be accomplished by identifying the highest priorities for WQ conditions and implementing mitigation strategies to address ongoing issues in a study area (Figure 2) [29,30]. Sometimes, the study areas do not follow the jurisdictional boundaries; therefore, several stakeholders need to work together to achieve local/regional/national WQ goals.

Figure 2. Implementation steps for strategies to mitigate WQ problems [2].

Water quality standards can be mitigated through regulation, remediation, and watershed management [31]. Water regulation in a specific area can control the free discharge of waste from industry or sewage treatment plants by setting standards for each pollutant released into surface waters [31]. Remediation acts, such as biological, chemical, and physical acts, help in cleaning the water contamination; (i) biological remediation is a cost-efficient method and is also called "bioremediation", which involves the use of naturally occurring organisms such as plants, bacteria, and fungi to remove or neutralize water pollutants and to breakdown hazardous substances into less toxic or nontoxic substances. Human sewage and agricultural chemicals that leach from the soil into the groundwater are generally treated by bioremediation [32,33]. (ii) Chemical remediation methods use chemicals to react with the water contaminants to remove or make them less harmful, and (iii) physical remediation includes the removal of water contamination by treating it with filtration or disposing of it. Overall, all these three remediation methods are somehow complex, expensive, and difficult to adapt.

Watershed management strategies consist of reducing the chemicals applied to land, making them more effective for nonpoint source pollution than setting pollution standards [3]. In a watershed, riparian areas promote WQ and limit pollution; therefore, their maintenance and restoration are crucial. Vegetation surrounded by a water body absorbs nutrients and provides shade to keep water cool and increase its capacity to hold dissolved oxygen (DO). Additionally, vegetation reduces runoff, promotes infiltration, and lowers soil erosion. Hence, vegetation plays a key role in the effective management of WQ through watershed management. Watershed practices that are beneficial for maintaining WQ standards include (i) regional infiltration basins; (ii) neighborhood-scale practices such as rain gardens, bioretention, and permeable pavement; (iii) stream restoration, including pooling and meandering to enhance infiltration; (iv) floodplain restoration, including floodplain benching; (v) stream (riparian) buffers; (vi) using park green space and fields to store and infiltrate water; (vii) stormwater-friendly post-construction design; and (viii) protecting and resting natural and human-made wetlands. Some important actions can be taken to get rid of polluted water before pollution ever happens and to mitigate WQ standards:

- Avoid dumping waste in and around water bodies—dumping waste in water bodies leads to water pollution over a short period time.
- Septic systems need proper maintenance and cleaning from time-to-time—leakage from septic tanks can cause groundwater pollution.
- Stakeholders and industries need to follow WQ regulations and laws—breaking local government rules can put water at a high risk of contamination due to anthropogenic activities.
- All chemicals and pesticides need to be disposed of properly—pouring these hazards into nearby drains, sinks, grass yards, or water closets can lead to them entering local water sources and water supply networks.
- Do not pour kitchen leftovers, such as cooking oils and fat substances, into the sink—pouring these substances can seriously clog sink drains as well as spread illness into utilizable water.

- Try not to use any bleaching substances for washing at home—using bleach can trigger poisoning and maybe internal burning and can eventually damage local environmental sources.
- Schedule cleanings for yards and nearby areas with your neighborhood—dirty surroundings may cause water pollution and put human health at risk.

Overall, we need to work on mitigating water quality and educating friends, family, neighborhoods, and relatives about the necessary actions for water safety.

Most WQ mitigation measures aim to prohibit illicit discharge, control erosion, reduce pollutants, and control excessive flows. Additionally, strategies consisting of implementing outreach, education, and other activities that promote infiltration, flood reduction, and stable drainage channels could be beneficial for WQ management [34]. Stormwater flow management, floodplain restoration, channel stabilization, and green infrastructure installations are the main strategies to prevent pollutant discharge into surface waters from stormwater, including wastewater. Wetland protection, rehabilitation, and restoration activities improve WQ and quantity and support the maintenance of floodplains in their natural state [35]. The protection of riparian areas and floodplains and keeping hazardous materials from source water areas can directly safeguard drinking WQ and can indirectly protect public health. Sometimes, financial resources limit the application of these mitigation strategies, so the prioritization of mitigation strategies can focus on important WQ issues that are necessary to complete in a short period of time. To overcome this, the provision of grants/funding is also essential to encourage vegetation planting and maintenance over time.

5. Conclusions

Water quality (WQ) tools and models are described and selected based on their applicability, site- or regional-specific qualities, weaknesses, strengths, and whether or not they are intended for commercial or industrial use. The outputs of models and WQ indexing are different based on the input requirements and data availability and therefore have large levels of uncertainty, are not freely available for commercial use, and require skilled model users. Model selection is a robust task in the scientific domain; therefore, when selecting suitable models for pollution control in freshwater bodies, catchments, or a specific site, there are requirements to consider, such as the availability of datasets, the complexity of the models, and the type of freshwater bodies, and the intended objectives should be modeled so that mitigation strategies can be implemented in fruitful ways.

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