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Editorial

The Impact of Treated Urban Wastewaters and Flood Discharge on the Quality of Bathing Water

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1. Introduction

What do we know about the Adriatic Sea and the state of its health? Are purification plants enriching it with nutrients or with chemical and microbiological pollutants? Are we triggering any gene alterations with this biomass? Do we have laws specific and focused enough to guarantee the protection of the marine environment considering its local peculiarity?

Water is a fundamental component of daily life, from recreational to domestic needs, as well as for industrial and agricultural use. Sustainable water management is a popular topic in a multiplicity of scientific, social and political programs around the world. Nevertheless, the healthiness and hygienic quality of hydric resources are increasingly threatened, and ultimately, their availability is affected.

In general, this problem concerns all water bodies, not just hydric resources intended for human consumption. In fact, even the surface waters of rivers, lakes and seas increasingly show the alteration of their physicochemical and health characteristics, induced by ongoing climatic change and by growing human pressure. The modification the physicochemical profile of freshwater and marine environments, threatened by chemical pollution, microbial pollution, plastic and microplastic and noise, induces consequent alterations in their ecology. In fact, the changes in macro-variables (such as temperature, turbidity and salinity) affect the equilibria that regulate the distribution, and therefore, the availability, of nutrients upon which the plant and animal populations depend. The holistic approach is now an asset of the EU Marine Strategy; we believe that this concept should be adopted by all regulations with "water" as a topic. National governments transpose EU directives by adapting them to local governance organizations; however, there is often a delay between the adoption of these regulations and their effective implementation. Moreover, in some cases, these regulations seem to be improperly tailored to local peculiarities. Therefore, the level of sensitivity toward the importance of environmental protection and the actions implemented to pursue this objective are not homogeneous among territories, despite their geographic proximity. Consequently, comparing knowledge and sharing the implementation of actions may be an effective way to boost the efficacy of the interventions. The water

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quality of the Adriatic Sea is proven to range from good to excellent, although it can be very heterogeneous (e.g., there are unbalanced nutrient ratios in some areas [1]). From EU Directive 91/271/EEC to date, the 10th report, published in September 2020, highlights significant progress in the area of wastewater treatment, with ever-higher levels of compliance. However, in the sectors of sewage and wastewater treatment, many challenges remain.

Pathogens, nutrients, suspended solids, salts and emerging contaminants (e.g., antibiotics, drugs, flame-retardants, etc.) or so-called oxygen-consuming materials (i.e., microbes and decaying organic waste) are among the components present in domestic or urban discharged water; these are mainly collected by purification plants, where they are treated before reaching their final destination of marine waters. The key role of wastewater treatment (WWT) is to contribute to the protection of receptor bodies and their associated environments, coupled with the need for an evolution in attitudes toward WWT management. Microbiological characterizations and chemical analyses, using both instrumental approaches and purposely developed new molecular and analytical devices (i.e., optimized biosensors) were conducted simultaneously on wastewater and seawater in the discharging areas.

This Special Issue, which consists of 11 manuscripts, explores several goals related to environmental protection through cross-cutting technological solutions: to treat wastewater, to control chemical and microbiological pollution, to manage wastewater with a cross-border vision, and to share knowledge with the aim of protecting the Adriatic Sea, introducing a methodological approach in this field of environmental protection. Finally, we want to underline the importance and spread awareness of this topic among young people as an investment in boosting future protection of the marine environment.

The articles presented in this Special Issue can be categorized into the following themes:

(1) The spread of fecal pollutants and antibiotic resistance in the aquatic environment as a major public health concern. Curran et al. [2] conducted a study in the city of Venice (Italy) on microbial pollution sources, including domestic wastewaters, due to the lack of sewage treatment infrastructure. The authors conducted metagenomic analyses of DNA extracted from sediment samples to characterize the microbial community composition; the presence of fecal microbes as well as other non-enteric pathogens; and the content of genes related to antibiotic and heavy-metal resistance and virulence. Their results suggested the existence of widespread microbial pollution of the sediment in the canals of Venice; this was coupled with the prevalence of antibiotic resistance genes (ARGs) resistant to antibiotics frequently used by humans, as well as of genes resistant to toxic heavy metals that still persist in the lagoon.

Similarly, Fonti et al. [3] pointed out how wastewater treatment plants represented continuous sources of ARGs and of microbial pollution for marine coastal waters. The authors used a combination of molecular tools to provide evidence that the sole use of primary treatments in urban wastewater management results in pronounced inputs of microbial pollution into marine coastal waters. At the same time, the use of conventional treatments does not fully eliminate ARGs in treated wastewater. The complementary use of molecular techniques could successfully improve the evaluation of depuration efficiency and help develop novel solutions for the treatment of urban wastewater.

(2) A study on dissolved potentially toxic element (PTE) levels was carried out by Girolametti et al. [4] to assess the impact of treated urban wastewaters on the quality of bathing waters in the Adriatic Sea. Their results demonstrated the efficiency of the investigated depuration plants, underlining the importance of wastewater treatment for the protection of the Adriatic Sea.

(3) Intense rainfall can affect bathing water quality, especially in areas with poorly developed sewage systems or combined sewer overflows (CSOs). The aim of the studies conducted by Ordulj et al. [5] and Manini et al. [6] were to assess the impact of precipitation on coastal bathing water quality in the areas of Split and Kaštela (eastern Adriatic Sea) and in the area of Fano (western Adriatic Sea), respectively. Ordulj et al. reported that the quality of bathing waters in the Kaštela area was significantly worse

than in the Split area, due to the low efficiency of the sewage system in these areas. It was also revealed that bathing water quality depends on the timing of the sampling and on the indicator against which it is assessed. *Escherichia coli* proved to be a better indicator for early-morning sampling, while intestinal enterococci were better for late-morning sampling.

The results of [6] highlighted that fecal microbial contamination was related to rainy events with a high flow of wastewater, with recovery times for the microbiological indicators varying between 24 and 72 h and influenced by a dynamic dispersion. The positive correlation between ammonium and fecal bacteria in the Arzilla River and the consequences in seawater can provide a theoretical basis for controlling ammonium levels in rivers as a proxy for monitoring the potential risk of pathogen pollution in bathing waters.

Finally, Ferrarin et al. [7] developed a relocatable modeling system able to describe the microbial contamination that affects the quality of coastal bathing waters. Pollution events are mainly triggered by urban sewer outflows during massive rainy events, with relevant negative consequences on the marine environment and tourism and on the related activities of coastal towns. A finite-element hydrodynamic model was applied to five study areas in the Adriatic Sea which differ in their urban, oceanographic and morphological conditions. The authors concluded that the modeling suite can be used as a beach management tool for improving the protection of public health, as required by the EU Bathing Water Directive.

(4) Combined sewer overflows (CSOs) close to water bodies are a cause for grave environmental concern. In the past few decades, major storm events have become increasingly common in some regions, and meteorological scenarios predict a further increase in their frequency. Consequently, CSO control and treatment according to best practices, the adoption of innovative treatment solutions, and careful sewer system management are urgently needed. The construction of an innovative detention reservoir along the Arzilla River (Fano, Italy) to store diluted CSO wastewater was presented by Romei et al. [8]. Their preliminary results suggested that the detention tank exerted beneficial environmental effects on bathing water by lowering the microbial load.

(5) The spatial and temporal occurrences of chlorophyll profiles provide a good representation of changes in the marine environment. The study by Kvesić et al. [9] aimed to characterize chlorophyll's vertical distribution, and described its variability based on the stratification conditions and the presence of a wastewater effluent plume using modern fluorescence techniques. Along with chlorophyll, macronutrient (nitrogen—N; phosphorus—P; silicon—Si) concentrations play a crucial role in the evaluation of the trophic status of a water body and of eutrophication phenomena. The entry of nutrient loads into the sea is mainly represented by river runoff and depuration plant (DP) outflows. Fanelli et al. [10] provided important information on the distribution of nutrients in seawater related to the activity of depuration plants. The study was focused on the influence of treated wastewater plants on open-sea nutrient contents. The results showed that the considered depuration plants have a negligible impact on the marine ecosystem as the nutrients present in the treated wastewater undergo strong dilution once they reach the marine basin.

(6) Communication and knowledge transfer from science and research to the general public is a paramount step in raising people's awareness of environmental issues. The paper by Baldrighi et al. [11] aimed to present the successful communication initiatives developed during two Interreg projects, AdSWiM and WATERCARE, with schools and educational organizations at a local and national level in Italy and Croatia.

(7) The activities developed during the AdSWiM project period are presented by Susmel et al. [12] in a project report paper; the paper aimed to highlight the results of the heterogeneous activities carried out during the project, but also to emphasize how bodies with different institutional set-ups, roles and methods of working were able to interact, with the aim of ensuring cross-border protection of the Adriatic sea.

All of these papers and this Special Issue aim to focus the readers' attention on the Adriatic Sea and its peculiarities, and to suggest the need for particular investigations for each aquatic environment; generalizations are not any more meaningful, and we need to zoom in on each area to better describe them and, thus, to activate effective strategies for both prediction and protection.

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References

1. Cozzi, S.; Giani, M. River water and nutrient discharges in the Northern Adriatic Sea: Current importance and long term changes. *Cont. Shelf Res.* **2011**, *31*, 1881–1893. [CrossRef]
2. Curran, J.F.; Zaggia, L.; Quero, G.M. Metagenomic Characterization of Microbial Pollutants and Antibiotic- and Metal-Resistance Genes in Sediments from the Canals of Venice. *Water* **2022**, *14*, 1161. [CrossRef]
3. Fonti, V.; Di Cesare, A.; Šangulin, J.; Del Negro, P.; Celussi, M. Antibiotic Resistance Genes and Potentially Pathogenic Bacteria in the Central Adriatic Sea: Are They Connected to Urban Wastewater Inputs? *Water* **2021**, *13*, 3335. [CrossRef]
4. Girolametti, F.; Fanelli, M.; Ajdini, B.; Truzzi, C.; Illuminati, S.; Susmel, S.; Celussi, M.; Šangulin, J.; Annibaldi, A. Dissolved Potentially Toxic Elements (PTEs) in Relation to Depuration Plant Outflows in Adriatic Coastal Waters: A Two Year Monitoring Survey. *Water* **2022**, *14*, 569. [CrossRef]
5. Ordulj, M.; Jozić, S.; Baranović, M.; Krželj, M. The Effect of Precipitation on the Microbiological Quality of Bathing Water in Areas under Anthropogenic Impact. *Water* **2022**, *14*, 527. [CrossRef]
6. Manini, E.; Baldrighi, E.; Ricci, F.; Grilli, F.; Giovannelli, D.; Intoccia, M.; Casabianca, S.; Capellacci, S.; Marinchel, N.; Penna, P.; et al. Assessment of Spatio-Temporal Variability of Faecal Pollution along Coastal Waters during and after Rainfall Events. *Water* **2022**, *14*, 502. [CrossRef]
7. Ferrarin, C.; Penna, P.; Penna, A.; Spada, V.; Ricci, F.; Bilić, J.; Krzelj, M.; Ordulj, M.; Šikoronja, M.; Đuračić, I.; et al. Modelling the Quality of Bathing Waters in the Adriatic Sea. *Water* **2021**, *13*, 1525. [CrossRef]
8. Romei, M.; Lucertini, M.; Esposito Renzoni, E.; Baldrighi, E.; Grilli, F.; Manini, E.; Marini, M.; Iagnemma, L. A Detention Reservoir Reduced Combined Sewer Overflows and Bathing Water Contamination Due to Intense Rainfall. *Water* **2021**, *13*, 3425. [CrossRef]
9. Kvesić, M.; Vojković, M.; Kekez, T.; Maravić, A.; Andričević, R. Spatial and Temporal Vertical Distribution of Chlorophyll in Relation to Submarine Wastewater Effluent Discharges. *Water* **2021**, *13*, 2016. [CrossRef]
10. Fanelli, M.; Girolametti, F.; Truzzi, C.; Illuminati, S.; Ajdini, B.; Susmel, S.; Celussi, M.; Šangulin, J.; Annibaldi, A. Impact of Depuration Plants on Nutrient Levels in the North Adriatic Sea. *Water* **2022**, *14*, 1930. [CrossRef]
11. Baldrighi, E.; Muzlovic, P.; Annibaldi, A.; Penna, A.; Manini, E.; Rosetti, E.; Renzoni, E.E.; Grilli, F.; Giacomini, G.; Kristovic, I.; et al. ADSWIM and WATERCARE Projects Meet Kids and Youth: The Challenge of Bringing the World of Research to School to Merge Research, Education and Communication. *Water* **2022**, *14*, 1843. [CrossRef]
12. Susmel, S.; Girolametti, F.; Fonti, V.; Figueredo, F.; Scognamiglio, V.; Antonacci, A.; Manna, V.; Bilic, J.; Soljan, V.; De Bortoli, N.; et al. The Interreg project AdSWiM: Managed use of treated wastewater for the quality of the Adriatic Sea. *Water* **2022**, *14*, 2460. [CrossRef]