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COVID-19 Lockdown Effects on a Highly Contaminated Coastal Site: The Mar Piccolo Basin of Taranto

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Abstract: The COVID-19 pandemic has had a dramatic socio-economic impact on mankind; however, the COVID-19 lockdown brought a drastic reduction of anthropic impacts on the environment worldwide, including the marine–coastal system. This study is concentrated on the Mar Piccolo basin of Taranto, a complex marine ecosystem model that is important in terms of ecological, social, and economic activities. Although many numerical studies have been conducted to investigate the features of the water fluxes in the Mar Piccolo basin, this is the first study conducted in order to link meteo-oceanographic conditions, water quality, and potential reduction of anthropic inputs. In particular, we used the model results in order to study the response of the Mar Piccolo basin to a drastic reduction in the leakage of heavy metal IPAs from industrial discharges during the two months of the mandated nationwide lockdown. The results show the different behavior of the two sub-basins of Mar Piccolo, showing the different times necessary for a reduction in the concentrations of heavy metals even after a total stop in the leakage of heavy metal IPAs. The results highlight the high sensitivity of the basin to environmental problems and the different times necessary for the renewal of the water in both sub-basins.

Keywords: COVID-19 lockdown; coastal marine environment; semi-enclosed basin; monitoring stations; numerical model

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1. Introduction

The COVID-19 pandemic imposed strict lockdowns in many countries around the world at various stages, a fact that represented the unique and unforeseen experience of drastically reducing anthropogenic environmental impacts.

Many studies have reported that the effect of COVID-19 lockdowns promoted a reduction in pollution. It is still not apparent if its effect is short-term or long-term [1–3].

The aim to end this global pandemic has attracted researchers' attention in a wide range of domains, such as medicine, biology, the environment, socioeconomics, and tourism (e.g., [4–9]).

During the COVID-19 pandemic, even breathing fresh air in a park carried a risk of contagion. In fact, physical and numerical studies by [4–6] showed the importance of droplet mobility during human respiratory activities in the spread of infectious respiratory diseases. Research carried out by [6] showed numerical results in order to obtain an understanding of the nature of respiratory clouds and the necessary distance from an infected person to minimize respiratory transmission.

Moreover, several studies indicated that SARS-CoV-2 was spread from wastewater treatment facilities to natural water bodies, particularly in developing nations with subpar waste treatment infrastructure [7–9]. Therefore, the environmental damage caused by the COVID-19 epidemic posed a serious threat to human health and aquatic food security.

The stringent regulations that prevented commerce and travel for two months have provided a once-in-a-lifetime chance to monitor the effects of human activities on the sea on a global scale. In fact, the aquatic ecosystems had a chance to regenerate, thanks to less pollution and human activities [9–13], although masks, gloves, and hand sanitizer bottles were increasingly discovered in the sea, showing COVID-19's negative repercussions.

The reader can refer to [14] for a comprehensive review of the positive and negative impacts of the COVID-19 pandemic on water bodies on a global scale.

The study [13] highlighted that the positive COVID-19 impacts could be summarized as follows: (i) a reduction in the exposure of community infections, thanks to the continued monitoring of wastewaters; (ii) lower pollution levels caused by domestic and industrial wastewater discharge into water bodies all over the world.

In contrast, the negative COVID-19 impacts can be summarized as follows: (i) SARS-CoV-2 presence in wastewater; great amounts of plastic, drugs/chemicals, and biological pollution in wastewaters; (ii) greater amounts of municipal and medical waste in water bodies.

Taranto, like the rest of Italy, was in a lockdown starting in March 2020, which reduced human activities, resulting in the absence of activity with regard to fishing and, above all, industrial activity, which is the main source of human stress on the ecosystem of the Mar Piccolo basin (Ionian Sea, southern Italy). Due to the existence of the naval station, the largest refinery in Europe, Taranto is one of the most significant Italian harbors.

In the last years, many samplings of the sediments have been conducted in the Gulf of Taranto, one of the most polluted marine areas in Europe and also declared a site of national interest (SIN) (Italian Law, 1998) because of the serious contamination of marine sediments [15–17]. In fact, the massive industrialization of the Taranto area has resulted in the sediment being contaminated over time by various organic compounds and heavy metals.

However, the presence of several submarine springs, called "citri", refills the basins with freshwater, favoring very high biodiversity and mussel farming [18,19].

In recent years, the "Special Commissioner for the urgent measures of reclamation, environmental improvements, and redevelopment of Taranto" has authorized multidisciplinary research in order to obtain a geo-environmental characterization of the Taranto coastal basins.

Various chemical characterizations of marine and coastal areas in SIN_07 Taranto were carried out [20,21]. However, during the July 2009–May 2010 period, ISPRA carried out the first activities for the preliminary characterization of marine and coastal areas in SIN_07 Taranto, excluding, however, the southernmost sector of the First Bay in the Mar Piccolo basin (known as "Area 170 ha").

Through about 2000 sediment samples, the spatial distribution of each parameter showed that the sediments in the Mar Grande were silty sands, sandy silts, and sands, while in the Mar Piccolo basin, the sediments were mostly silt and sandy silt.

Moreover, the first meter of sediment in the Mar Grande basin was contaminated by metals (Cd, Cu, Hg, Pb, Sn, and Zn); in contrast, a high concentration of both inorganic and organic compounds was identified in the Mar Piccolo basin with special reference to the First Bay of the basin, exceeding national limits. Finally, organic pollutants (IPAs—polycyclic aromatic hydrocarbons) exceeded the site-specific threshold in the First Bay, also in the deeper layers.

Contaminated-site management has always been a hot topic that has attracted both academic and public attention; the studies focus on the risk assessment of heavy metals that have adverse effects on the ecological environment. The negative effects on the environment have not yet been fully understood, and in recent years, there has been a growing need to understand how new technologies and methods can be applied in the management of contaminated sites.

In the last few years, many remediation techniques, such soil replacement, electrokinetic (EK) remediation, and soil flushing, have been widely applied to clean up Pb-contaminated sites [22,23].

Microbial-induced carbonate precipitation (MICP) technology has recently gained popularity because the resultant amount of carbonate precipitation and the immobilization efficiency are, in general, higher [24,25].

However, in circumstances where the solution can be worse than the disease, “no action” may be the preferred option. An eventual removal of these contaminated sediments from the Mar Piccolo basin through dredging activities could cause harmful changes in this vulnerable environment [26].

Therefore, as previous studies have shown [27–30], these heavily anthropized coastal basins require continuous monitoring activity.

Furthermore, numerical models are preferred for this scope; they allow us to reproduce and predict marine physical phenomena in a relatively short time, with moderate costs.

Our goal is to assess the environmental effects of this unprecedented change in anthropic activities during the COVID-19 lockdown by the synergic use of monitoring activity and numerical modeling.

Until now, no study has been conducted in the Mar Piccolo basin of Taranto without considering the continuous leakage of heavy metal IPAs from the industrial discharges outside the Mar Grande. Therefore, the dramatic COVID-19 pandemic suggested that we conduct this study, showing the unique and unexpected experience of a drastic reduction in anthropogenic environmental impacts.

Therefore, this is the first study conducted in order to link meteo-oceanographic conditions, water quality, and the potential reduction of anthropic inputs.

The paper is structured in the following way. Section 2 describes the area studied, the monitoring activity, and the numerical modeling. Section 3 shows the validation of the model outputs with field data, the main features of the water fluxes in Mar Grande and Mar Piccolo, and the response of the basin to a drastic reduction in the leakage of heavy metal IPAs from industrial discharges during the two months of mandated nationwide lockdown.

2. Materials and Methods

The domain under investigation in the present work is a quasi-closed sea region called Mar Piccolo, located in the northeastern area of the Ionian Sea in southern Italy, within the Gulf of Taranto. It is composed of two bays with a total surface area of about 20.72 km^2 and an average depth of about 7.0 m. The Mar Piccolo basin is connected to an external basin named Mar Grande by means of two channels, i.e., the Navigable Channel and the Porta Napoli Channel (Figure 1).

Figure 1. Target area: location of the industrial discharges and monitoring station.

It is a complex marine ecosystem with typical lagoon features, characterized to continue the release and diffusion of contaminants by human activities. The lagoon features of the Mar Piccolo basin are mainly due to the presence of 34 submarine freshwater springs (locally called "citri"), of which 20 are in the first inlet and 14 in the second inlet. Therefore, it is important to test potential strategies for the management of coastal areas to mitigate human impact [31–33].

2.1. In Situ Data

Data of hourly current velocity for the studied coastal area were obtained from the meteo-oceanographic station installed in the Mar Grande basin during December 2013, in the frame of the Flagship Project RITMARE; it is located at the geographical coordinates 40°27.6′ N and 17°12.9′ E, as shown in Figure 1. The station is provided with a weather station and a CTD (Sea-Bird SBE 37-SIP-ODO with sensors for conductivity, temperature, salinity, pressure, and dissolved oxygen), a bottom-mounted acoustic Doppler current profiler (ADCP), and a multidirectional wave array.

The dataset has been processed with quality-control procedures following SeaDataNet protocols:

- Twice-yearly instrument maintenance and calibration in specialized labs;
- Visual examination of the data time series;
- Correlation between related parameters (e.g., salinity and temperature).

Further details on the MG station can be found in [34].

2.2. Numerical Modeling

The hydrodynamic (HD) and transport (AD) of MIKE 3 FM, produced by the Danish Hydraulic Institute [35], were used to evaluate how hydrodynamic parameters affect the possible transport, dispersion, and decay of dissolved or suspended substances typically present in industrial discharges outside Mar Grande (ENI, ILVA1, ILVA2) in order to identify and characterize the area in the basin most sensitive to environmental problems.

Furthermore, the Particle module (PT) was added to the main MIKE 3 FM HD code to carry out particle tracking applications in order to study the main features of the water fluxes in Mar Grande and Mar Piccolo.

The MIKE 3 FM HD model is based on the numerical solution of three-dimensional incompressible Reynolds-averaged Navier–Stokes equations, subject to the assumptions of Boussinesq and of hydrostatic pressure. The Transport module simulates the spreading and fate of dissolved or suspended substances in an aquatic environment under the influence of fluid transport and associated dispersion processes.

The Particle Tracking module (PT) uses a Lagrangian discrete-parcel method. The mathematical concept behind particle tracking is to transport particles according to a drift regime and add dispersion by introducing a random walk term. The peculiar features of the PT method used to obtain the present results are described in detail in [36].

Input and Boundary Conditions for Hydrodynamic Runs

The bathymetry of the basin was carried out, interpolating on a numerical mesh with 7235 elements and ten vertical layers (Figure 2). More details about the different data sets used to obtain the mesh can be found in [19].

The annual simulation was performed with reference to the year 2020. The hydrodynamic simulation was carried out using a baroclinic model coupled with k–ε, a turbulent model [37,38].

At the open boundary of the domain, the model is forced by the temperature, salinity, and u and v components of sea current vertical profiles extracted by the Mediterranean Sea Physics Reanalysis model [39].

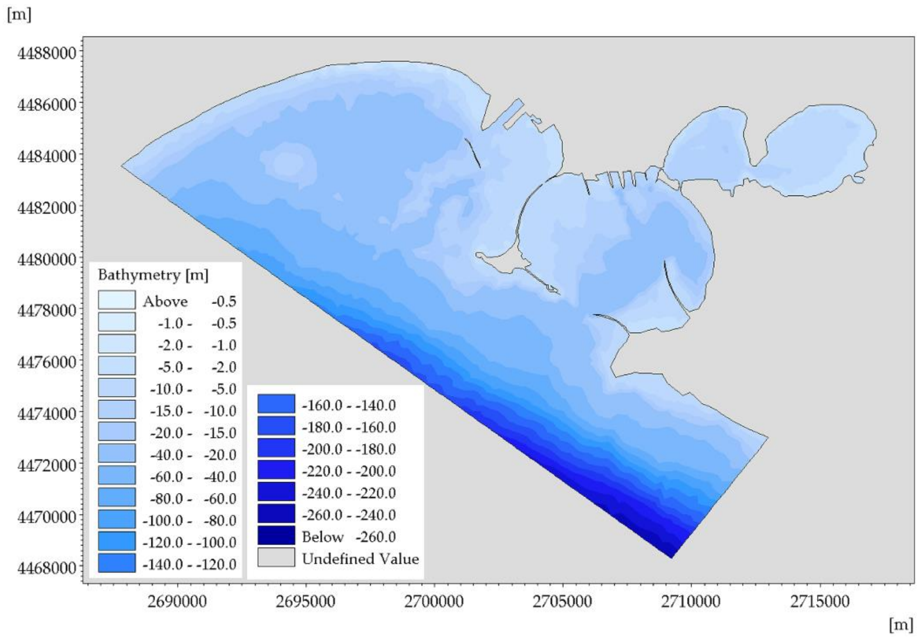


Figure 2. Bathymetry of the simulated domain and computation mesh.

At the surface, the atmospheric data (u and v components of wind, atmosphere pressure, total cloud cover, solar radiation, and air temperature) are used as boundary conditions. These data were taken from the ERA-Interim developed through the Copernicus Climate Change Service [40,41]. The reader can refer to [28] for further detail on the peculiar features of the method used.

The HD model is coupled with a transport (AD) module in order to analyze the spreading of a contaminant. Two runs (AD1 and AD2) were carried out in order to better understand the impact of the COVID-19 pandemic lockdown on water quality and, therefore, to assess the different ways in which the contaminant is transported in this area during this period. For the AD1 test, the spill is modeled as a continuous leakage of heavy metal IPAs from industrial discharges outside Mar Grande (ENI, ILVA 1, ILVA 2) over the whole year (Figure 1). The concentrations (mg/L) were provided by the measurements carried out in 2009 by ARPA Puglia. In particular, for the winter condition, an average concentration value is equal to 1.28, 1.57, and 2.035 mg/L for the ILVA 1, ILVA 2, and ENI discharges, respectively.

For the summer condition, an average concentration value is equal to 2.58, 0.43, and 2.040 mg/L for the ILVA 1, ILVA 2, and ENI discharges, respectively.

For the AD2 test, the continuous spill is interrupted during the period of lockdown (March 2020–April 2020).

Finally, the Particle module (PT) is added to the main MIKE 3 FM HD code to carry out particle tracking applications in order to study the main features of the water fluxes in Mar Grande and Mar Piccolo. Each floating particle is subjected to transport by the modeled currents as well as a randomly fluctuating velocity (in both direction and magnitude) derived from the random walk model. Five simulations (PT1–PT5) are carried out in order to have statistical robustness for the computed trajectories. For each simulation, about 100 passive particles are released on 1 March 2020 inside the Mar Grande and Mar Piccolo basins into different sources (Figure 3). In particular, for the PT1 test, the particles are released inside the Mar Grande basin at station point MG1; for the PT2 test, the particles are released inside the Mar Grande basin at station point MG2; for the PT3 test, the particles are released inside the Mar Grande basin at station point MG3; for the PT4 test, the particles are released inside the Mar Piccolo basin at station point MPI; for the PT5 test, the particles are released inside the Mar Piccolo basin at station point MPII. Each simulation is repeated, releasing the particles in both the surface and bottom layers.

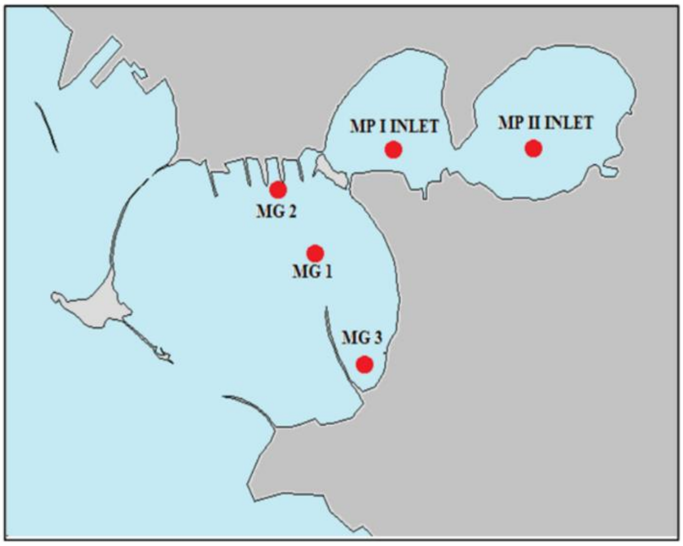


Figure 3. Location of the station points where particles are released in the Particle module (PT).

3. Results and Discussion

3.1. Meteo-Oceanographic Conditions

The wind and wave data from March 2020 are processed. Figure 4a,b display the polar plots of the wind and waves, and the directions of propagation are shown.

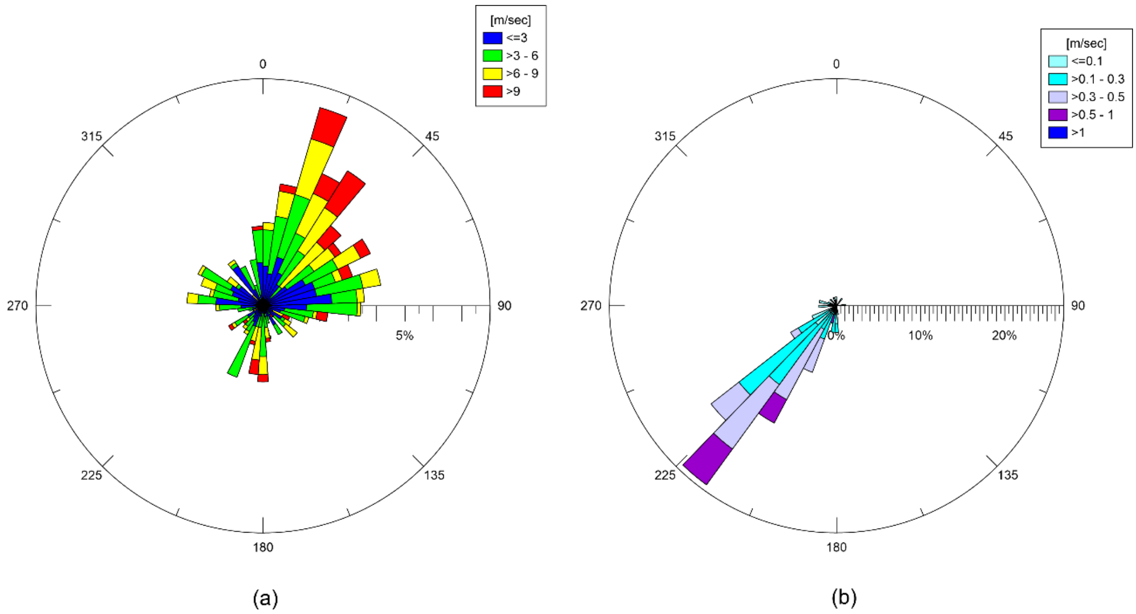


Figure 4. Polar plot of measured (**a**) wind and (**b**) waves in March 2020.

The month of March is characterized by winds that mainly come from S-SO, with peak intensities of >10 m/s.

In this month, a well-defined and evident path can be recognized, with high waves that came from N-NE and peak intensities in a high range of 0.5–1 m.

As shown by [42], it can also be stated that in this case, it was not possible to find a close correspondence between the wind distribution and the significant wave distribution.

Figure 5 displays a similar trend for the water temperature (°C) and conductivity (S/m) in March, which show mean values equal to 13.86 °C and 4.52 S/m, respectively.

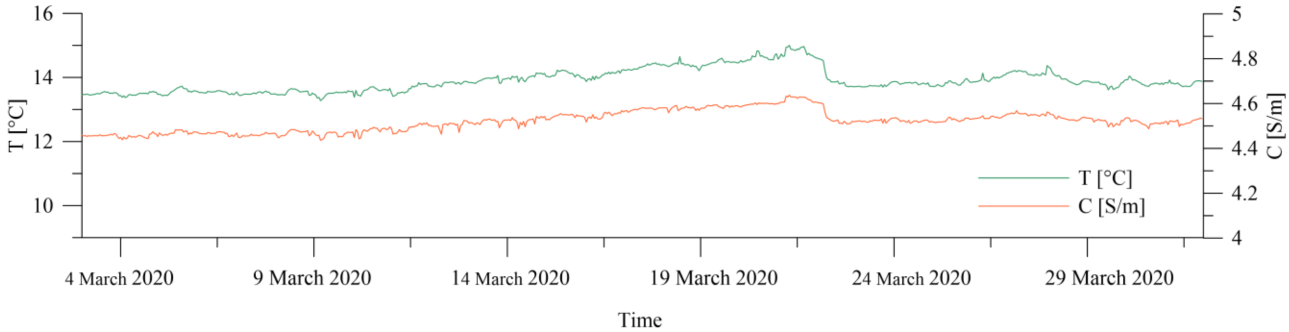


Figure 5. Time series of measured water temperature [°C] and conductivity [S/m] in March 2020. Time is local time.

3.2. Model Validation: Model Results versus Monitoring Data

The MIKE 3 FM model current velocity outputs were compared with the data measured at the MG station at z = −5 m during March 2020.

Figure 6 shows the time series of the computed and observed current intensities. A good agreement between the modeled and measured currents is shown. A global assessment of the model performances is made using a statistical index, I_W, as proposed by [43].

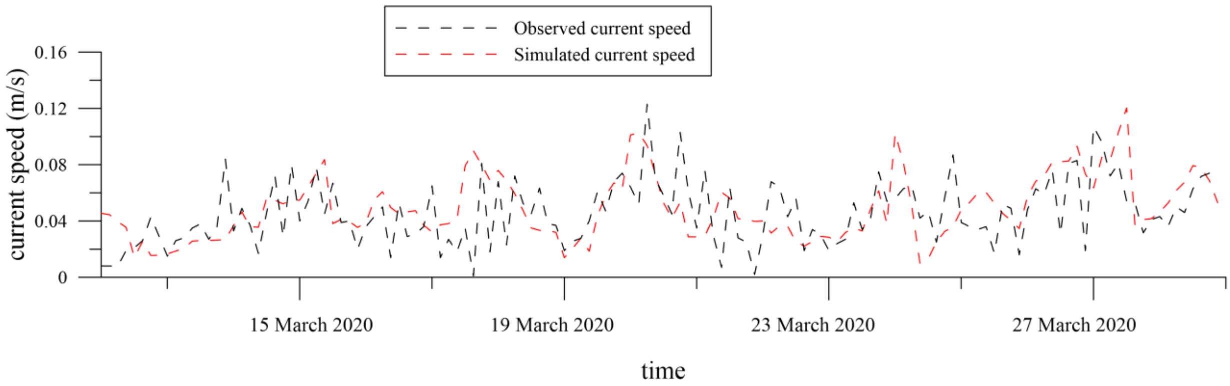


Figure 6. Comparison between the time series of the measured (in the MG station) and the modeled current velocities (MIKE 3 FM HD) at z = −5 m.

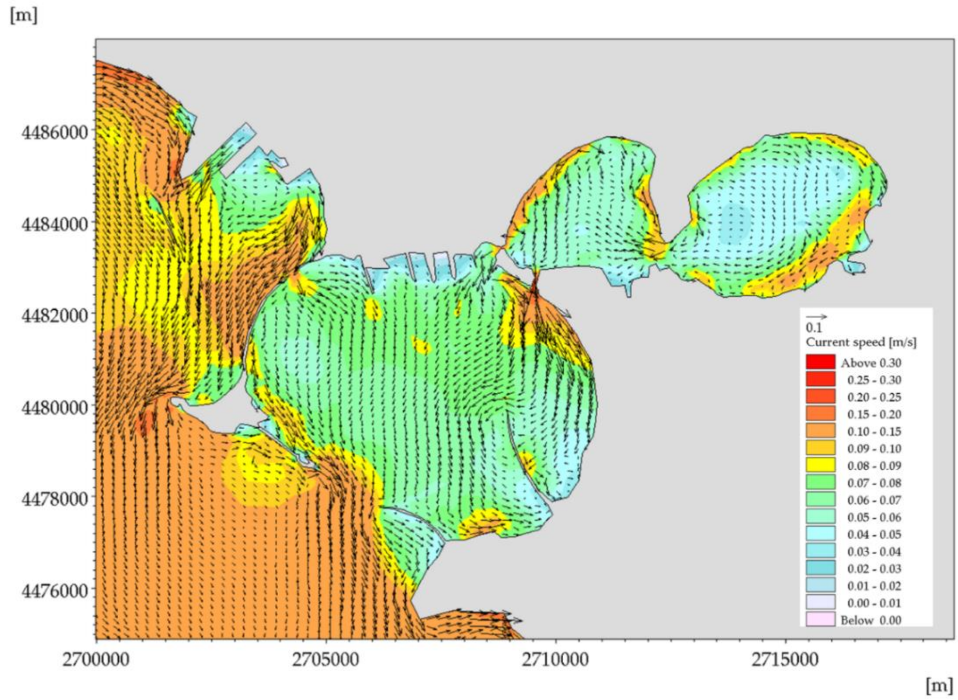
I_W, in terms of magnitude and velocity directions, takes a value of 0.75 and 0.7, respectively, which is a good result, especially considering the simplifications that are necessarily applied in modeling to reproduce a very complex phenomenon.

3.3. Current and Transport Module

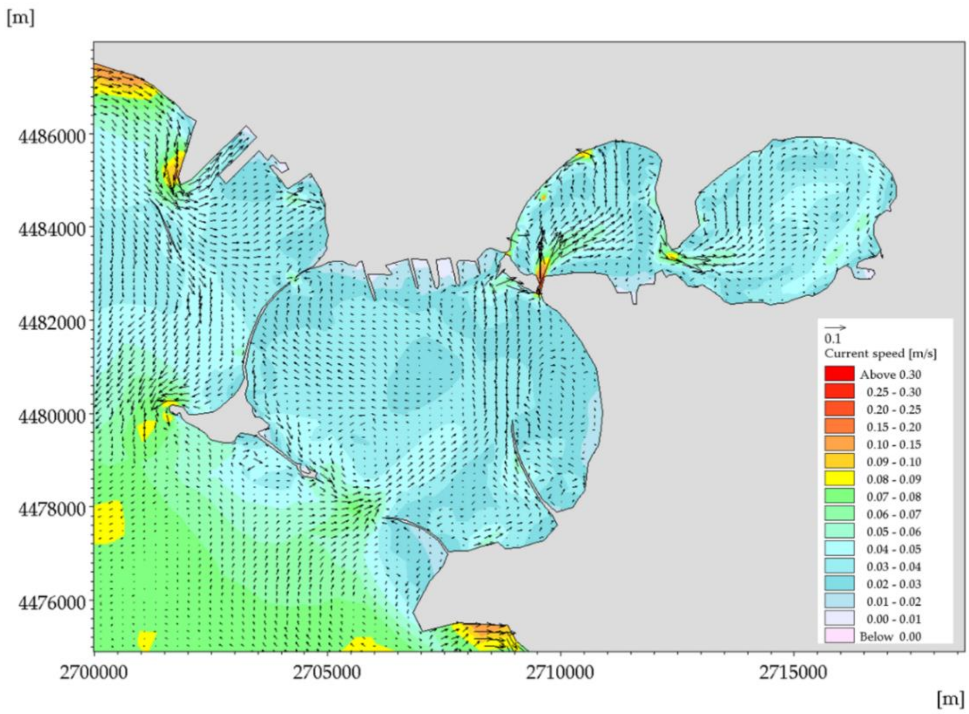
The calibrated MIKE 3 FM model has reproduced the main characteristics of the basin circulation from the year 2020 (Figure 7a,b), showing a structure very similar to that reproduced for the years 2013–2015 [19].

The general circulation consists of a double mechanism of the water–mass exchange between Mar Grande and Mar Piccolo: (i) the salty and cold water entering the system at the bottom layer (Figure 7b) and (ii) the less salty and warmer water outwardly directed to the surface (Figure 7a).

Furthermore, the bottom current is inflowing towards the second inlet of the Mar Piccolo basin, while there is an opposite behavior at the surface. The reproduced velocity values show a peak (0.3 m/s) along the navigable channel of the Mar Piccolo basin.



(**a**)

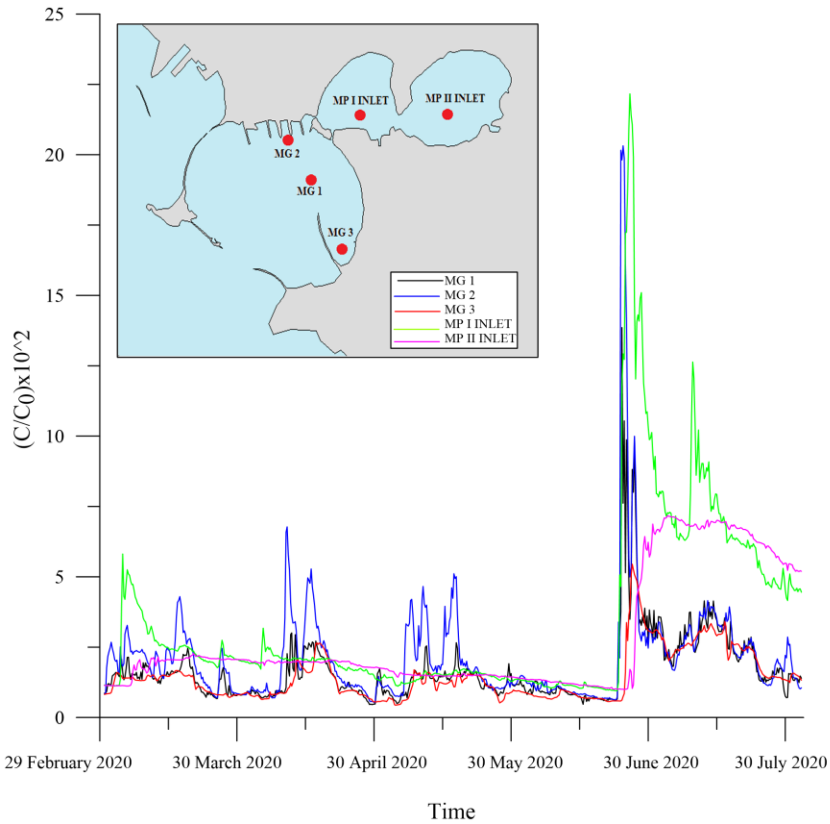


(**b**)

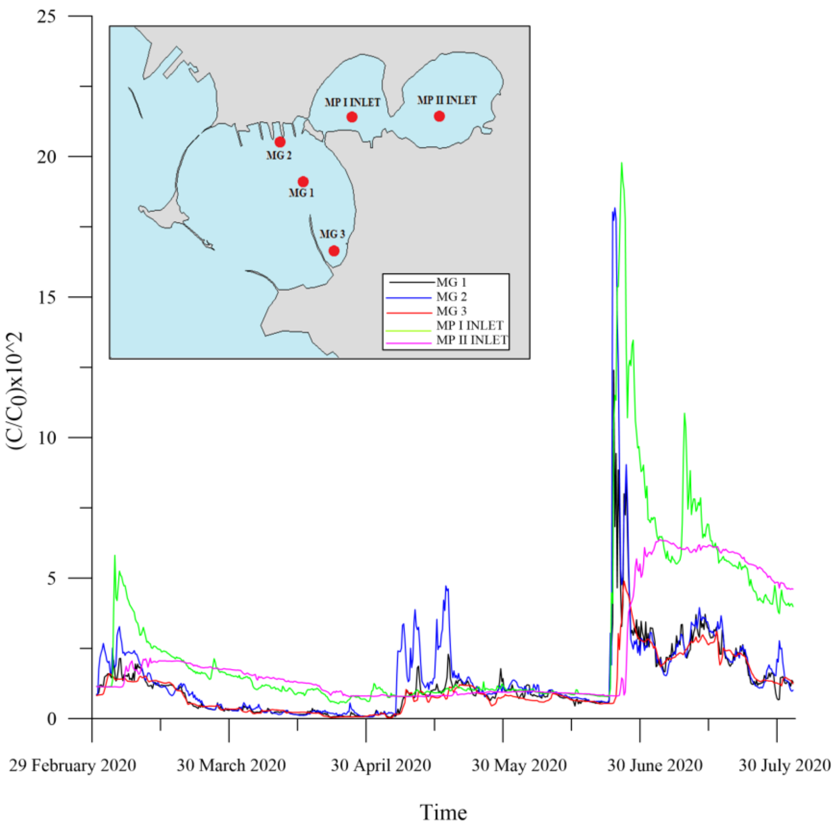
Figure 7. Computational maps of the annual-averaged currents (**a**) at the surface and (**b**) at the bottom.

In order to evaluate the environmental effects of the COVID-19 pandemic lockdown on the coastal area, the time series of the computed heavy metal concentrations at each stationing point have been analyzed for both tests (AD1 and AD2).

The results (Figure 8a,b) highlight the different behavior of the two sub-basins (i.e., Mar Grande and Mar Piccolo).



(**a**)



(**b**)

Figure 8. Time series of heavy metal concentrations (IPAs) at stationing points (**a**) AD1; (**b**) AD2.

In particular, the reduced or stopped leakage of heavy metal IPAs from industrial discharges during the two months of mandated nationwide lockdown (AD1) quickly decreases the heavy metal concentrations by 90–95% in the Mar Grande basin (Figure 9).

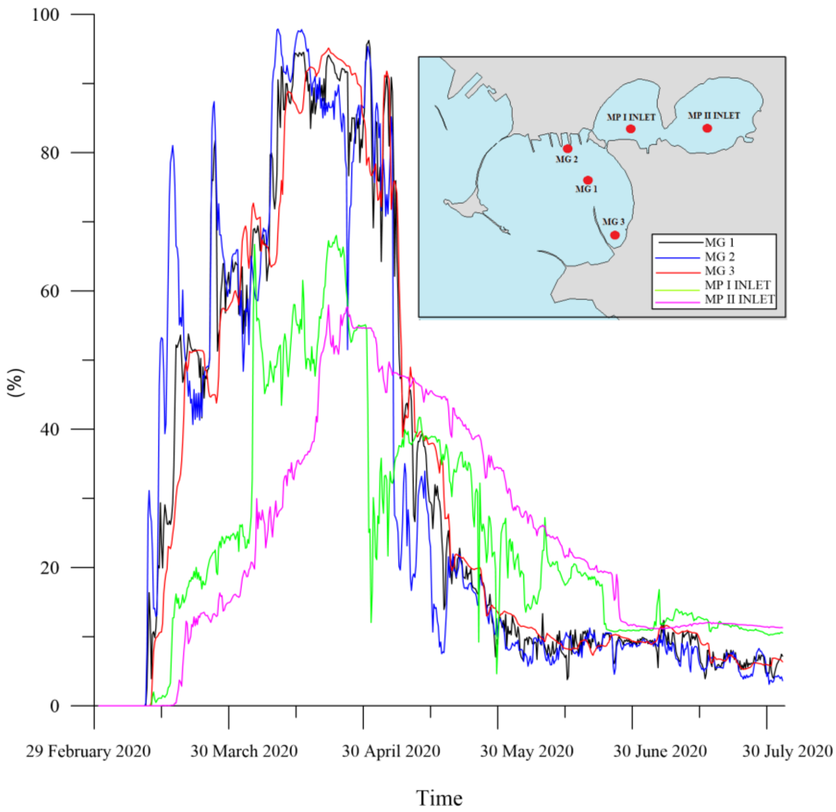


Figure 9. Percentage of heavy metal concentration reduction during the COVID-19 pandemic lockdown.

In contrast, in the Mar Piccolo basin, a slower and lesser reduction in heavy metal concentrations can be observed during the lockdown. In fact, only after 30 days of lockdown, the heavy metal concentrations begin to reduce (Figure 9).

This result highlights that the heavy metals remain trapped in Mar Piccolo, and the water exchange between the two sub-basins is poor. Instead, the Mar Grande basin, positively affected by the exchange flows with the open sea, is less exposed to possible retention of heavy metal pollution.

These numerical results confirm the results of different sediment sampling [20,21], which showed that higher concentrations of both inorganic and organic compounds were identified in the Mar Piccolo basin than in the Mar Grande basin.

3.4. Lagrangian Drift Model

As the vigorous water exchange between a semi-enclosed basin and the open sea can provide some protection from pollution, in this section, the peculiar features of the water fluxes in the Mar Grande and Mar Piccolo basins are analyzed.

Analyzing the results of the PT1 test, with a release of particles at MG1 (Figures 10 and 11), we observed that the surface Lagrangian transport directed outside the Mar Grande domain is much faster than the bottom one, with a remarkable time difference (30 days), due to outflow occurring through the southeastern gap connecting the Mar Grande basin to the open sea.

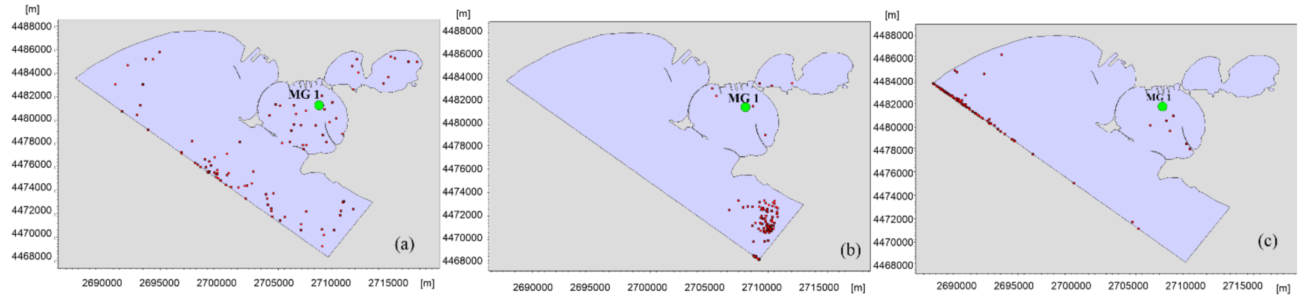


Figure 10. Percentage PT1 (MG1)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 30 days after release at surface layer.

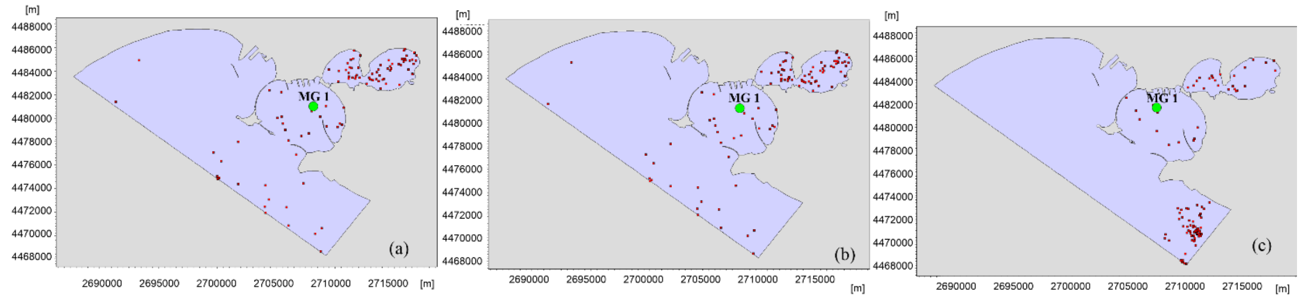


Figure 11. Percentage PT1 (MG1)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at bottom layer.

Furthermore, the particles are transported and directed into the Mar Piccolo basin by the current at the bottom layer (Figure 11).

The numerical results highlight that the surface Lagrangian transport directed outside the Mar Grande domain is much faster, with a release of particles at the MG2 (PT2 test) and MG3 (PT3 test) station points (Figures 12–15).

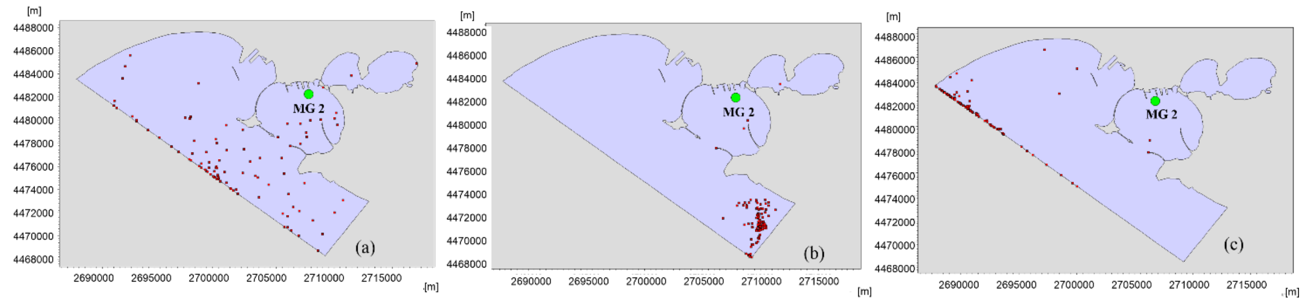


Figure 12. Percentage PT2 (MG2)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at surface layer.

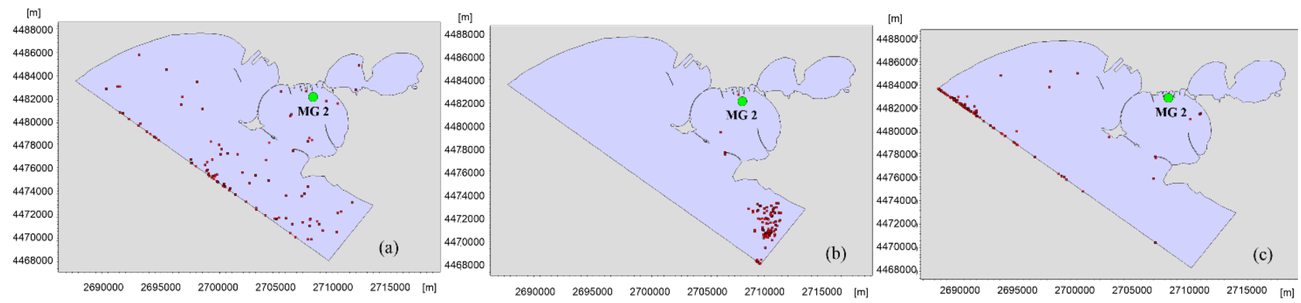


Figure 13. Percentage PT2 (MG2)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at bottom layer.

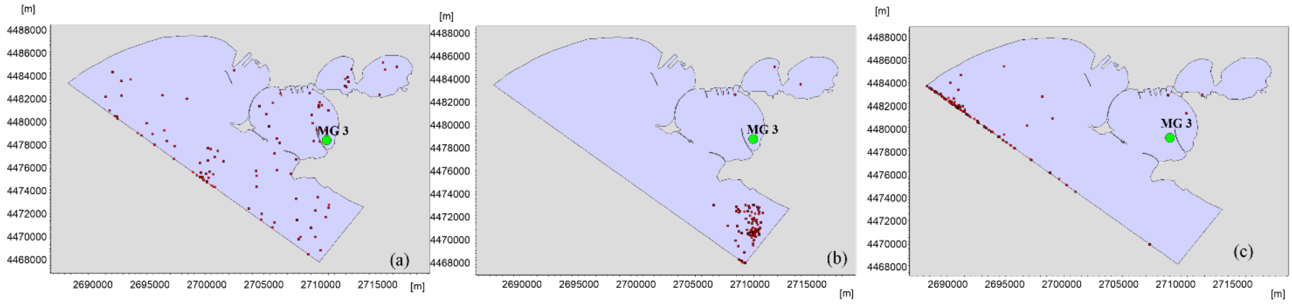


Figure 14. Percentage PT3 (MG3)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at surface layer.

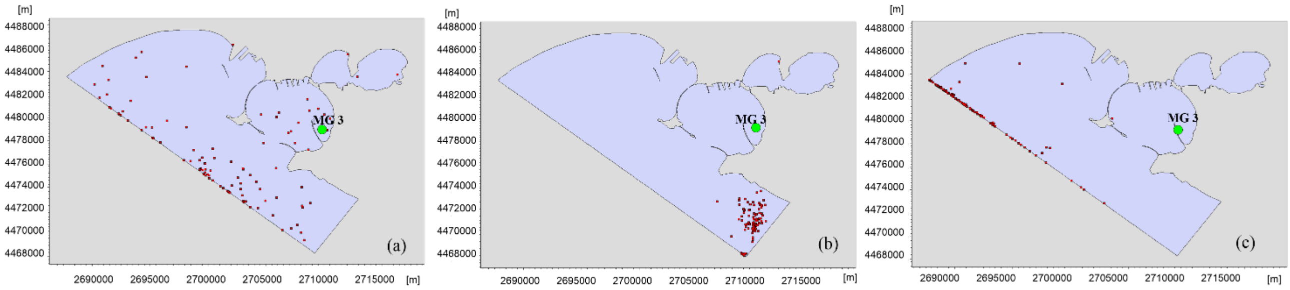


Figure 15. Percentage PT3 (MG3)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at bottom layer.

In contrast to the Mar Piccolo basin (PT4 and PT5 tests), the results (Figures 16–19) show slower surface and bottom Lagrangian transport directed outside the domain, with a remarkable time difference (more than 30 days) due to a low water exchange between the semi-enclosed basin and the open sea.

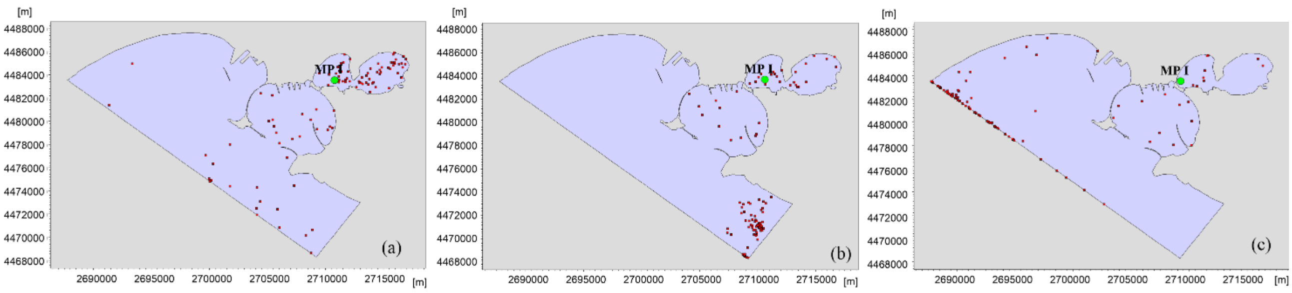


Figure 16. Percentage PT4 (MPI)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at surface layer.

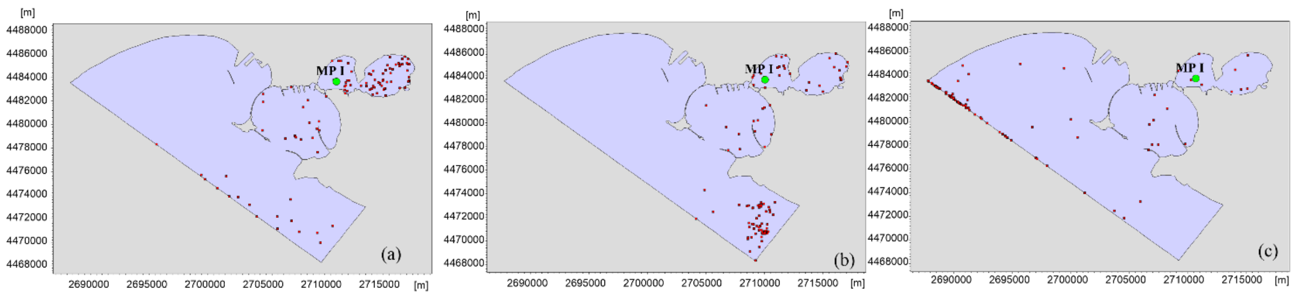


Figure 17. Percentage PT4 (MPI)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at bottom layer.

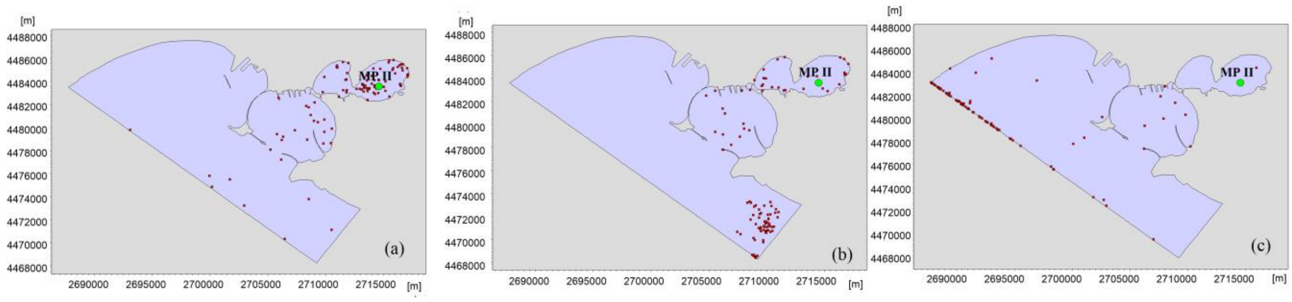


Figure 18. Percentage PT5 (MP II)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at surface layer.

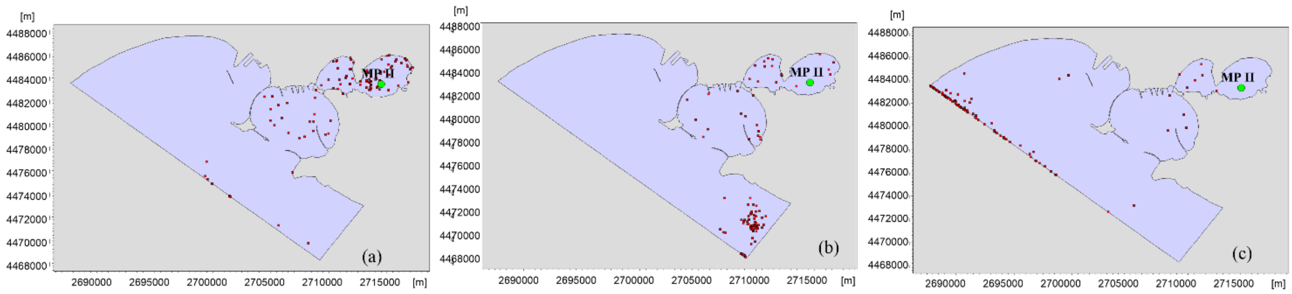


Figure 19. Percentage PT5 (MP II)—the cloud of particles: (**a**) 30 days after release; (**b**) 60 days after release; (**c**) 90 days after release at bottom layer.

Therefore, confirming the results related to flow exchanges by [19], the Mar Piccolo basin is more sensitive to environmental problems than the Mar Grande basin. The results highlight the Mar Piccolo basin's ability to retain water as well as the different times necessary for water renewal in both the top and bottom layers. The exchange of water and mass plays an important role in regulating the biodynamics of the ecosystem in this area.

4. Conclusions

The present work analyzes a possible positive SARS-CoV-2 impact on the status and quality of the Mar Piccolo coastal marine environment. The stringent regulations that prevented commerce and travel for two months have provided a once-in-a-lifetime chance to monitor the effects of human activities on the sea on a global scale.

Taranto, like the rest of Italy, was under lockdown from March 2020, which reduced human activities, resulting in the absence of activity with regard to fishing and, above all, industrial activity, which is the main source of human stress on the ecosystem of the Mar Piccolo basin (Ionian Sea, southern Italy).

Due to the existence of the naval station, the largest refinery in Europe, Taranto is one of the most significant Italian harbors. At the same time, the presence of several submarine springs, called "citri", refills the basins with freshwater, favoring very high biodiversity and mussel farming.

Contaminated-site management has always been a hot topic that has attracted both academic and public attention; the studies focus on the risk assessment of heavy metals that have adverse effects on the ecological environment. These heavily anthropized coastal basins require continuous monitoring activity. Furthermore, numerical models are preferred for this scope; they allow us to reproduce and predict marine physical phenomena in a relatively short time, with moderate costs.

The numerical model MIKE 3D FM AD was implemented to evaluate the response of the Mar Piccolo basin, a complex marine ecosystem with typical lagoon features, to a drastic reduction in the leakage of heavy metal IPAs from industrial discharges during the two months of mandated nationwide lockdown. To reproduce the sea circulation structure in the target area, the MIKE 3 FM model current velocity outputs were compared with data measured at the MG station.

Therefore, two simulation runs, denoted as AD1 and AD2, were carried out with the aim of comparing the effects due to the COVID-19 pandemic lockdown on water quality and, therefore, assessing the different ways in which the contaminant has been transported in this area during this period. For the AD1 test, the spill was modeled as a continuous leakage of heavy metal IPAs from industrial discharges outside the Mar Grande basin (ENI, ILVA 1, ILVA 2) over the whole year.

For the AD2 test, the continuous spill was interrupted during the period of lockdown (March 2020–April 2020).

The results highlight the different behavior of the two sub-basins (i.e., Mar Grande and Mar Piccolo).

In particular, the reduced or stopped leakage of heavy metal IPAs from industrial discharges during the two months of mandated nationwide lockdown (AD1) quickly decrease the heavy metal concentrations by 90–95% in the Mar Grande basin. In contrast, in the Mar Piccolo basin, a slower and lesser reduction in heavy metal concentrations can be observed during the lockdown. In fact, only after 30 days of lockdown, the heavy metal concentrations begin to reduce. This result highlights that the heavy metals remain trapped in Mar Piccolo, and the water exchange between the two sub-basins is poor. Instead, the Mar Grande basin, which is positively affected by the exchange flows with the open sea, is less exposed to the possible retention of heavy metal pollution.

As the vigorous water exchange between a semi-enclosed basin and the open sea can provide some protection from pollution, the main features of the water fluxes in the Mar Grande and Mar Piccolo basins were studied using the Particle module (PT).

Analyzing the results, we observed that the surface Lagrangian transport directed outside the Mar Grande domain is much faster than the bottom one, with a remarkable time difference (30 days) due to outflow occurring through the southeastern gap connecting the Mar Grande basin to the open sea.

Furthermore, the particles are transported and directed into the Mar Piccolo basin by the current at the bottom layer.

In contrast, in the Mar Piccolo basin, the results show a slower surface and bottom Lagrangian transport directed outside the domain, with a remarkable time difference (more than 30 days) due to a low water exchange between the semi-enclosed basin and the open sea.

Therefore, confirming the results related to flow exchanges by [19], the Mar Piccolo basin is more sensitive to environmental problems than the Mar Grande basin. The results highlight the Mar Piccolo basin's ability to retain water as well as the different times necessary for water renewal in both the top and bottom layers. The exchange of water and mass plays an important role in regulating the biodynamics of the ecosystem in this area.

A possible future extension of the research may be aimed at a deeper understanding of the mechanical and chemical behavior of contaminated sediments, with the synergic use of monitoring activity, numerical modeling, and sediment sampling in the Mar Piccolo basin of Taranto.

Moreover, an index-based approach can be used in order to identify the possible hot-spot areas, i.e., the areas where industrial discharges can have a stronger impact on the contamination of marine sediments, which is useful for important environmental management strategies in order to reclaim this complex marine ecosystem.

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