Marine Pollution Bulletin 112 (2016) 443–451

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Baseline

A multidisciplinary approach for the characterization of the coastal marine ecosystems of Monte Di Procida (Campania, Italy)

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ARTICLE INFO

Article history:
Received 22 April 2016
Received in revised form 5 July 2016
Accepted 6 July 2016
Available online 14 July 2016

Keywords:
Marine pollution
Trophic status
Biological indicators
Environmental geology

ABSTRACT

A multidisciplinary survey was carried out on the quality of water and sediments of a coastal protected marine area, embedded between the inputs from Bagnoli steel plant to the south and a sewage plant, Volturno River and Regi Lagni channel to the north. The study integrated chemical-sedimentological data with biological and ecotoxicological analyses to assess anthropogenic pressures and natural variability. Data reveal marked differences in anthropogenic pollution between southeastern and northwestern zone, with the north affected by both inorganic and organic flows and the south influenced by levels of As, Pb and Zn in the sediments above law limits, deriving from inputs of the Bagnoli brownfield site. Meiobenthic data revealed at south higher relative abundance of sensitive species to pollution and environmental stress to the south, i.e. *Lobatula lobatula* and *Rosalina bradyi*, whereas to the north relative abundance of stress tolerant *Quinqueloculina lata*, *Quinqueloculina pygmaea* and *Cribroelphidium cuvilleri* were determined.

The European seas are affected by intense human activities, which constitute sources of chemical contamination that represents a risk of serious damage in coastal and marine zones (European Environment Agency, 1999). Therefore, it becomes imperative for countries to find out options of environmental protection in a sustainable and environmentally friendly way. A holistic and integrated ecosystem-based approach is needed to manage human activities and to reinforce our understanding of marine ecosystems, and to evaluate what needs to be done to protect them.

In Italy, as in other parts of the world, protected areas and marine parks are established for the main purposes of protecting biodiversity, as well as for the promotion of tourism. The control of sea health status has been mainly performed by the evaluation of chemical contaminants loads in environmental matrices, i.e. water, sediment, and biota. With the publication of the European Marine Strategy Framework Directive (2008/56/EC, hereafter MSFD), the biological components have become important in assessing the ecological status within offshore waters (e.g. plankton and benthos communities) (Borja et al., 2010). The interest of marine ecologists for the bio-assessment of human impact on littoral ecosystems has largely strengthened (Borja, 2005; Borja and Heinrich, 2005; Dauvin, 2005). As a consequence, numerous bio-assessment tools have been developed, or adapted, to the MSFD requirements in recent years. Several reviews have dealt with different components of the systems, spanning from a monofactorial, to an integrative approach, taking into account both environmental typologies and managerial objectives (Simboura and Reizopoulou, 2007; Mangoni et al., 2013).

Up to now, no multi-disciplinary approach exists concerning the environmental characterization of the marine environment facing the promontory of MDP. Thus, with the aim to fill these temporal and spatial gaps, specific studies are indispensable. Based on comparisons of the data of station each other, the chemical data alone were not always reliable indicators (and, therefore, predictors) of biological effects. The importance and usefulness of a multi-disciplinary approach to characterize marine environments, such that of MDP, in this case seems indisputable.

The current work reports physico-chemical and biological parameters of the marine water and sediments at 19 representative stations of Monte di Procida during June 2014 through a combined fieldwork and multidisciplinary approach.

Surface waters were analysed for inorganic nutrients (NO_2, NO_3, NH_4, PO_4, SiO_4), chlorophyll-*a* (Chl*a*) and pigments of the phytoplankton community. Vertical profiles of pH, temperature (°C), salinity (S), dissolved oxygen (DO, mg L^{-1}), percentage of oxygen saturation (%), turbidity (T, nephelometric turbidity units or NTUs) and fluorescence (UF) were also determined. Sediments were analysed for: i) benthic foraminifers (Protista) and ostracods (Crustacea), both parts of

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http://dx.doi.org/10.1016/j.marpolbul.2016.07.008
0025-326X/

meiobenthos, to test the impact of anthropic activities on organisms living in/on bottom sediments; ii) the levels of Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Sn, Sr, Ti, V, Zn; iii) the microbiological quality of sediments by the presence of total coliforms, and of intestinal *Enterococci*, *Fecal coliforms*, *Escherichia coli*. In addition, *Clostridium difficile* was isolated. Grain size analysis and eco-toxicological test in samples with the algal growth inhibition test (GI) with *Phaeodactylum tricornutum* were also performed.

Data collection and analysis consisted of acquiring spatial data and performing statistical analyses between conventional chemical assays, biological and eco-toxicological assessments together with the presence and composition of biological indicators of pollution.

One of the most panoramic sites of the Italian peninsula is represented by the marine environment facing the promontory of Monte di Procida (MDP) in southwestern Italy, capturing stupendous seas views and well-preserved ancient buildings, located in the extended area of the Regional Park of Phlegrean Fields, which was established in 2002 also as a national protected marine area. The area extends for 7350 ha in the suburbs of Naples and, besides MDP, it includes approximately the area of municipalities of Pozzuoli, Bacoli, and the Phlegraean islands (Ischia, Procida, Vivara) as well as the western areas of the municipality of Naples. The territory of Phlegrean Fields represents one of the most important areas in the region for its environmental and historical-archaeological value. MDP represents a beautiful landscape on the tip of the promontory, that plunges into the Gulf of Gaeta and is connected to the islet of San Martino, a squat volcanic island facing a wide bay connected to the mainland by a bridge and a tunnel, which once was a base for tuna fishing and scuba excursions.

In the recent past, several marine ecological emergencies in areas very close to MDP occurred. In particular, environmental crisis hit the northern sector, where the Cuma wastewater treatment plant is located, due to improper treatment of sewage effluents, and the southern side, where the former and dismantling metallurgical plant of ILVA at Bagnoli is present, for improper disposal of toxic industrial wastes.

The Cuma plant has especially experienced several problems of malfunctioning in the last few years. Another serious environmental threat for the MDP area is represented by the network of artificial canals of Regi Lagni, which crosses the Campanian Plain along the provinces of Naples and Caserta, and flowing from the *Ager Nolanus* discharges to the south of Castel Volturno. This drainage system was built as early as the XVII century by the Bourbons and covers a catchment of about 1100 km^2. These channels, together with the Volturno River, have been devastated for a long time by discharges and riverbed overmining, and have greatly affected the enjoyment of the waterscape.

Several bathing places at Napoli, Giugliano and Pozzuoli among which MDP, have been often banned and this fact is a further indication of the potential environmental risk for the studied marine area. In the same way, the Bagnoli industrial plant, which was dismissed in 1991 and actually included in Italian national legislation for environmental reclamation of disused and heavily polluted coastal sites, represents another environmental threat for the marine environment of MDP. Thus, there is a serious risk of marine pollution of MDP from north to south, resulting from the lack of waste water purification and delay of the planned remedial plan.

Water and sediments of the sea facing the MDP promontory, aboard an equipped boat identified as M/B "Oceanix", were collected on June 2014 in 15 sites (Fig. 1 and Table 1), between −0.5 and −9 m depth with a 0.5 m increment. Sediments were sampled by a Van Veen grab.

The individuation of the sampling sites was confirmed by a preliminary ship survey through a serpentine path with real time determinations of the superficial water temperature and salinity to find out any possible anthropic pressure. A peristaltic pump provided water for continuous recording by means Sea-Bird Elec.-SBE 45 and interfaced with a GPS (Garmin Map 78 S). Based on the results of this survey, 6 transects were positioned on an onshore-coast line, perpendicular to the isobaths. Along each transect three stations, 1, 2 and 3 were identified at 100, 200 and 300 m from the coast as much closer to the coast line to detect eventual inputs of pollutants. According to the specific morphobathymetric features of each site: stations A1, A2, A3, B1, B2 B3, C1, C2, C3 were placed along the southeastern sector of the promontory, whereas stations D1, D2, D3, E1, E2, E3, F1, F2, F3 were situated along the northwestern sector of the study area. Sediment samples could not have been taken at B1, B2, C3 because of the presence of bedrock and at C3 due to dense matter of *Posidonia oceanica* prairie. An additional station P was placed inside the port of Acquamorta.

Vertical profiles of pH, temperature (°C), salinity (S), dissolved oxygen (DO, mg L^{-1}), percentage of oxygen saturation (%), turbidity (T, nephelometric turbidity units or NTUs) and fluorescence (UF), from surface to bottom were performed using a Sea Bird Electronic, SBE 19 Plus CTD probe, equipped with a SBE Oxygen sensor and a submersible fluorometer, Scufa Turner Designs Inc. (Sunnyvale, CA).

Surface water samples for the determination of inorganic nutrients (NO_2, NO_3, NH_4, PO_4, SiO4) concentrations were collected in vial of 20 mL from the Niskin bottle and stored at 4 °C until they were analysed, following the procedure described by Hansen and Grasshoff (1983).

Phytoplankton biomass and composition, in terms of larger taxonomical groups, were performed in surface water. Three litres of sea water was then drawn from the Niskin bottle and was filtered on GF/F Whatman filters (47-mm diameter). These were stored in liquid nitrogen until HPLC analyses for pigment spectra determinations according to Vidussi et al. (1996) by a Hewlett Packard (mod. 1100 Series). The photosynthetic pigments analysed were: alloxanthin (AX), β-carotene (β-car), chlorophyll *a* (Chl*a*), chlorophyll *c*2 (Chl*c*2), chlorophyll *c*3 (CC3), diadinoxanthin (Dd), diatoxanthin (Dt), 19′ butanoxyloxyfucoxanthin (BU), fucoxanthin (FU), 19′ hexanoyloxyfucoxanthin (Hex), zeaxanthin (ZX).

The amount of Chl*a* was used to indicate the total phytoplankton biomass. The contribution of the main phytoplankton groups to the total Chl*a* was estimated on the basis of the concentrations of biomarker pigments, using the chemical taxonomy software CHEMTAX (Mackey et al., 1996).

Sediment samples were transported to the laboratory and after careful preparation and washing with vacuum pump, all the samples were dried in an oven at 110 °C for 24 h, then weighed with an analytical balance and subjected to dry sieving through a series of stacked sieves, with 1/4 Φ class interval, up to 31 μm, in a Ro-Tap mechanical sieve shaker for 15′.

The ≤2000 μm fraction was used for analyses of the total pool of Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Sn, Sr, Ti, V, Zn by digesting about 0.5 g of sediment in 12 mL of H_2O_2–HNO_3, in Teflon vessels in an Ethos Plus Microwave Lab Station (Milestone) for 15 min; the obtained solution was taken to a final volume of 100 mL with 5% HCl and then filtered by 0.45 μm (Cicchella et al., 2008). The concentrations of the elements were determined by ICP-AES by a Thermo Electron Corporation IRIS Intrepid II spectrometer.

For the determination of the organic matter (C), samples of 0.5 g of ≤2000 μm sediment were sequentially treated at 105, 180 and 600 °C in a furnace in ceramic vessels up to constant weight for the determination of residual humidity, crystallization water and organic matter (Byers et al., 1978).

Sediments were also analysed for the 16 polycyclic aromatic hydrocarbons (PAHs) indicated by the Environmental Protection Agency (EPA) as important toxicological contaminants. Polycyclic aromatic hydrocarbons (PAHs) analyses were performed by a preliminary extraction and successive purification on silica gel treatment. Successively, the determination of PAHs was carried out by HPLC using a spectrofluorimetric detector (Ausili et al., 1998).

Total hydrocarbons (THCs) were determined by a slightly modified U.S. EPA standard methods (US EPA, 1997).

The marine algal growth of *Phaeodactylum tricornutum* was performed by the International Standard ISO 10253 modified according to Lukavsky (1992).