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Effects of anthropogenic activities in a Mediterranean coastland: the case study of the Falerno-Domitio littoral in Campania, Tyrrhenian Sea (southern Italy)

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ABSTRACT

The environmental status of the Falerno-Domitio littoral, a sector of the Italian south coast (Campania region) locally affected by an extensive anthropic pressure and pollution, was assessed by a multi-disciplinary approach, consisting of geological vs. biological studies. Geochemical abundance of potentially hazardous trace metals in beach sands is mainly constrained by the nature of the source rocks. Geochemical data of marine sediment quality with regards to possible heavy metal pollution and the enrichment factors of selected potentially toxic metals show that Cr and V values are higher in marine samples than in natural sources, suggesting that they are, at least in part, of anthropic derivation. A relationship between meiobenthos and heavy metals (Cr, Co, and V) has been also observed, providing a valuable biological marker to human-deriving chemical pollution. Ecotoxicological analyses confirm a relationship between enrichment in selected metals and moderate toxicity of some sea-bottom sediments closer to the coastline.

1. Introduction

In the Mediterranean ecoregion, Italian marine coastal environments are areas of invaluable naturalistic relevance, even if locally modified by the anthropogenic pressure/impact effects to various extent. National and European Commission directives have established, mainly starting from the last two decades, strategies for protection and/or improvement/re-establishing of the natural equilibrium status of these areas, trying to balance both socio-economic growth and environmental protection in order to achieve sustainable development (European Commission, 2000, 2008). The European requirements challenge researchers to a) check the ecological status and b) find methods to measure it (Paganelli et al., 2011). Within the politics of landscape safeguard, the shoreline areas represent a sort of natural laboratories, where to test a key interconnection between preservation of natural habitats and anthropogenic activity. In order to fully characterize and monitor the quality and health status of coastal environments, the knowledge of different biotic vs. abiotic factors of sediments, which can be a reservoir for anthropogenic pollutants (Burton, 2002), has a key importance. In particular, sediment pollution by trace metals in estuaries and around coastal areas is an international environmental issue (Alyazichi et al., 2014 and reference therein). The effects and responses of resident benthos and other aquatic organisms to sediment-bound pollutants depend on a synergy of different parameters, mainly related to the geochemical nature of sediments and to the presence of multiple classes of environmental pollutants. The analysis of benthic foraminifers (Protista) and ostracods (Crustacea), organisms able to secrete calcareous shells that persist in the sea-bottom sediments, allows to obtain data on meiofaunal subrecent assemblages and their interaction with the environmental evolution linked to anthropic activities and to the long-duration consequences related to the presence of pollutants in sea-bottom sediments (Schafer et al., 1975; Samir, 2000; Pascual et al., 2002; Triantaphyllou et al., 2003; Vilela et al., 2003; Bergin et al., 2006; Ruiz et al., 2003, 2005, 2008, 2013; Romano et al., 2008, 2009; Frontalini and Coccioni, 2008, 2011; Frontalini et al., 2009; Armynot du Châtelet and Debenay, 2010; Barras et al., 2014). As the sediment is a complex and heterogeneous matrix, the exposure on solid and elutriate phases was assessed by using a multitrophic battery of ecotoxicity tests to evaluate the impact on the aquatic biota. The ecotoxicological effects can be tested by some biological models such as *Vibrio fischeri* (bioluminescence inhibition), *Phaeodactylum tricornutum* (growth inhibition), and *Brachionus plicatilis* (mortality), to evaluate the impact on the aquatic biota. To outline the factors which influence the main sediment littoral drift as well as the coastal physiography and the morphological variability also related anthropic action (i.e. erosion and recession phenomena, etc.), the geomorphological/sedimentological approach to the littoral deposits is of crucial importance. Environmental

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components of the littoral prism, with a particular attention to the submerged beach, have to be evaluated in detail, because they influence the littoral drift of marine sediments deriving from watercourses and the sedimentary balance of the various costal physiographic units. Besides, the abiotic features of marine and beach sediments can be thoroughly characterized by means of integrated mineralogical, geochemical and petrographic investigations; provenance studies related to major elements and REE concentrations and mineralogical-petrographic composition of beach sediments can indicate their source areas and the geological settings of sedimentary basins, and also identify the main factors in controlling the composition of the beach sands, i.e. rivers and/or longshore currents (Armstrong-Altrin et al., 2012; Papadopoulos et al., 2014).

The northern sector of the Campania region littoral (southern Italy) is an area with heterogeneous natural environments and wildlife habitats, with sand dunes and beaches, watercourse mouths, lakes, coastal ponds, marshlands, etc. This area is also well known for its archaeological heritage, represented by many Graeco-Roman sites, such as the *Cumae* excavation (together with Ischia island, the oldest Greek colonies on the mainland of Italy) southward, and the *Sinuessa* site northward. Since the second half of the 1950s the Falerno-Domitio coastline, as other areas of the Campania coastline, was affected by an extensive and uncontrolled anthropic pressure, which caused severe land degradation (De Pippo et al., 2008); for instance, its central area called the Domitia coast, due to strong urban and industrial pollution, was classified as one of four sites of national interest (SIN) in the Campania Region to be remediated and reassessed by governmental actions (Verde et al., 2013). A few detailed investigations exist on the Falerno-Domitio littoral under a comprehensive geological-biological-environmental perspective. Previous studies focused on hydrologic, sedimentological and macrobenthic analyses of some areas of the Campania and Latium regions, as Gaeta Gulf - Volturno river mouth area (Ferretti and Setti, 1989), and Circeo cape - Ischia island area (Zurlini and Damiani, 1989). An exhaustive sedimentological, microphytobenthic (diatoms), geochemical, and biological study was carried out by Verde et al. (2013) on both sediments and waters samples coming from a sector of the Falerno-Domitio littoral falling in the Caserta Province (the so-called *Litorale Domitio*), extending from the Agnena canal to the Patria lake. Moreover, a thorough review study on literature data of chemical contaminants in both waters and sediments mainly in the Gulf of Naples and some nearby coastal areas was carried out by Tornero and Ribera d'Alcalà (2014), with the aim of extracting recommendation for mitigating pollution sources and risks for the Campania region; this work also includes geochemical data (SiDiMar 2001-2004) of some heavy metals related to the Volturno river mouth.

The present work describes the results of an interdisciplinary research (FARO 2012 project, Università di Napoli Federico II) focused on the assessment of the environmental quality of the Falerno-Domitio littoral, through the definition of physical and biological aspects of sediments collected from both marine and beach selected sites. Sedimentological and geomorphological survey of the shoreline, analyses on benthic foraminifers/ostracods and ecotoxicological assays on seabed sediments, as well as mineralogical, petrographic and geochemical analyses on both beach and seabed sediments were cross-checked to thoroughly characterize the geological nature and distribution of sediments sampled in this part of the Mediterranean coastal area. The final aim is to update the knowledge of the ecological status of the Falerno-Domitio littoral with new data about biotic and abiotic features on such impacted areas.

2. Materials and methods

2.1. Study area

The Falerno-Domitio littoral (hereafter FDL) is a wide shoreline of the Tyrrenhyan Sea (western Mediterranean area), extending for about 50 km in the northern sector of the Campania region, from Torregaveta (west of Naples) to the mouth of the Garigliano river, which is the natural limit between the Campania and Latium regions (Fig. 1). During the Quaternary, a strong subsidence of this plain was controlled by NW-SE and NE-SW normal faults and accompanied by high sedimentation rate. Hence, the Campanian Plain is filled by thick layers of alluvial deposits of the Garigliano and Volturno rivers, whose supplying areas are the Mesozoic-Tertiary sedimentary carbonates and subordinate Miocene terrigenous deposits of the southern Apennine chain, and volcanic products of Phlegrean Fields, Roccamonfina and Somma-Vesuvius. In the northern sector, the FDL is limited by the Mesozoic carbonates (Massico and Aurunci mounts), and by the Roccamonfina volcano. During upper Pliocene and Quaternary an intense vertical tectonics led to the formation of horst and graben bordered by normal faults; to this phase is also related the formation of the Campania Plain. Roccamonfina is a stratovolcano active between ca. 550 and 150 kyr (Rouchon et al., 2008). The volcanic products belong to the potassic and ultrapotassic series (from shoshonitic basalts to trachytes and from leucite basanites and tephrites to phonolites; Conticelli et al., 2011 and references therein). The growth of the Roccamonfina volcano within the Garigliano and Volturno rivers basins caused the deviation of the two watercourses and was one of the most relevant geomorphological events of the coastal area between Campania and Latium during the Pleistocene. The central-southern part of the FDL (Torregaveta, Cuma and Licola) is within the Phlegraean Fields *s.l.* volcanic area, and characterized by a Quaternary, highly explosive magmatism of potassic series (from shoshonitic basalts to trachyphonolites). The most important volcanic products are those related to the eruption of the Campanian Ignimbrite (~39 kyr BP; De Vivo et al., 2001) and the Neapolitan Yellow Tuff (~15 kyr BP; Deino et al., 2004; Fedele et al., 2011). At approximately 20 km to the east of the FDL lies the Somma-Vesuvius complex, which activity started about 25 kyr BP and with magmatic products belonging to the ultrapotassic series (potassic basalts and tephrites, trachytes and phonolites; Santacroce et al., 2008).

From the geomorphological point of view, the FDL is characterized by various transition environments that can be observed from the north to Cuma and Torregaveta; these are represented by a sandy beach with a discontinue parallel-to-the-shoreline dune belt (located in the areas of Garigliano river mouth-Mondragone and Ischitella-Cuma-Torregaveta), the Garigliano and Volturno river mouths, and the Patria and Fusaro lagoons (De Pippo et al., 2004). The FDL is a very important naturalistic site and at least in part still preserves untouched natural areas. As a matter of fact, it partly belongs to the Natural Reserve of the Volturno river mouth - Licola coast, and to the Regional Park of Phlegraean Fields; wide areas colonized by Mediterranean maquis are still present, together with backdune secular pinewood and the *Silva Gallinara* relict wood, known since the Graeco-Roman Period. As already stated, the FDL is worldwide famous for its archaeological heritage dated from the Graeco-Roman period onward (Balassone et al., 2013; Morra et al., 2013). Ruins of Roman *villae* and roads and other remains widely occur from the southern FDL seashore named *Spiaggia Romana* until the Garigliano river. Some remarkable examples are the road named *Via Domitiana*, the Servilio Vatia *Villa Maritima* (Caputo, 1995), lying underwater for 3 m below sea level (m bsl), and the Medieval coastal towers of Capodiferro and Patria. On the other side, growing anthropic pressure in the FDL led to a strong erosion of the shoreline, with successive, often tardive, recovery actions (Pennetta et al., 2011). The coastal dynamics, the morpho-sedimentary features, biocenosis and ecology of emerged and submerged beach were modified, triggering an environmental degrade and allochthonous organisms proliferation. The FDL was included in the above mentioned SIN in 1998, due to the long-term contamination mainly related to inputs from the Volturno river, the chronic malfunction of the wastewater treatment plant of Cuma, and some minor outfalls discharging untreated wastewaters. According to Lima et al. (2012), the main contamination sources are