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Enhancing the performance of hazard indexes in assessing hot spots of harbour areas by considering hydrodynamic parameters

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ABSTRACT

The hazard assessment strategies for harbour areas usually rely on tools able to predict environmental threats posed by contaminated sediments, mostly based on biological and chemical parameters and distinctly less on hydrological factors. Although ports are considered semi-enclosed and low-energy systems with scarce capacity to disperse contaminants to the open sea, the hydrological pattern established within the port basin cannot be neglected, especially when the localisation of hot spots is required for clean-up and remediation actions. In the present study we considered both approaches (biological/chemical and hydrological) for assessing hot spots of harbour areas. In particular, the relationship between the sediment hazard assessment c_NWAC (cumulative Normalized and Weighted Average Concentration) index (which is based on chemical and biological data) and a properly selected hydrodynamic parameter (the bottom shear stress) of the port area was investigated. This study demonstrates that marine currents influence significantly the fine-grained fraction distribution of the surficial sediments, and thus, the spatial and temporal variability of contaminant concentration. The evaluation of hydrodynamic parameters enhances the performance of hazard tools in the localization of areas of most concern and thus a detailed knowledge of the hydrodynamic features of the port seabed is advisable before defining a proper characterisation strategy for the harbour area.

1. Introduction

Defining acceptable hazard levels in port sediments is a complex task, because a given quantity of sediment contamination can exert different hazard levels depending on the effects of simultaneous action of meteorological, hydrodynamic, biological and geochemical factors. On the other hand, a complex interaction within and among all these factors results in a transport system with wide variations, both spatial and temporal (NCR, 1997). This variability makes site assessment surveys quite tricky and influences the effectiveness of hazard tools in establishing hot spots within a port basin.

The majority of researchers working at developing assessment strategies for harbors sediments have focused on defining tools able to predict when certain concentrations of contaminants pose a real environmental threat and how to measure the corresponding hazard degree. Chemical and biological data are therefore considered in almost all the hazard assessment strategies reported in literature (Chapman, 1986, 2007; Del Valls et al., 1998; Wenning et al., 2005; Long et al., 2006; Ritter et al., 2008; Piva et al., 2011; Chapman and Smith, 2014; Regoli et al., 2013; Chapman et al., 2013; Gredilla et al., 2014). Less attention has been paid so far to the role that the hydrodynamic circulation could play on spatial and temporal distribution of contaminants in a port basin. Current circulation is of great importance, especially in shallow waters, because it affects tracer mixing and transport of fine sediments, thus promoting several chemical-geological-biological processes such as flocculation, precipitation, adsorption, redissolution, iron oxyhydroxides-driven process, organisms uptake and other biogeochemical cycles. (Rey et al., 2005; Vilas et al., 2005, 2010; Rubio et al., 2011; Mali et al., 2015). In particular, current circulation could be responsible for both suspension and deposition of potentially contaminated sediments. This continuous and reciprocal exchange between water flows and sediments could affect the spatial distribution of con-

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Table 1
Parameters investigated and the relative analytical methods utilized.

Parameters	Details	Description of analytical method	References
Grain size	Gravel, sand, silt, clay separate sands from fine sediments,	Wet sieving through 63 μm mesh to Wet sieving through 63 μm mesh to separate sands from fine sediments, after a pre-treatment with H_2O_2; sieving and laser granulometer.	Romano and Gabellini (2001)
Trace metals	As, Cd, Cu, Cr tot, Fe, Pb, Hg, Mn, Ni, Zn	Total acid (HCl, HNO_3 and HF) microwave-assisted digestion and determination by ICP/MS X Series Thermo Fisher Scientific.	Pellegrini and Lucarotti (2001)
Total petroleum hydrocarbons	C<12; C>12	Solvent extraction and determination by IR spectrometry	US/EPA (1978)
Chlorinated organic compounds	DDD, DDT, DDE, hexachlorobenzene (HCB)	Solvent extraction, purification and determination by GC with ECD detector	Cicero et al. (2000)
Polycyclic aromatic hydrcarbons (PAHs)	16 congeneries: naphthalene, acenaphthene, acenaphthylene, phenanthrene, anthracene, fluoranthene, benz[*a*] anthracene, chrysene, benz[*b*]fluoranthene, benz[*k*]fluoranthene, benzo[*a*]pyrene, benzo[e]pyrene, dibenz[*a,h*]anthracene, fluorine, indeno[1,2,3-cd] pyrene		Ausili (2001)
Polychlorinated biphenyls (PCBs)	17congeners: PCB28, PCB52, PCB77, PCB101, PCB105, PCB114, PCB118, PCB123, PCBB126, PCB128, PCB138, PCB153, PCB156, PCB157, PCB167, PCB180 and PCB189	Extraction in acetone/petroleum solvent and analysis by gas-chromatograph equipped with an Electron Capture Detector.	Cicero et al. (2000)
Total Nitrogen (N_{tot})		CHN analyzer	Nieuwenhuize et al. (1994), Giani (2001)
Total Organic Carbon (TOC)		CHN analyzer	Nieuwenhuize et al. (1994), Giani (2001)
Total Phosporous		Colorimetric titration	Aspila et al. (1976)

taminants adsorbed onto the surficial layers of bottom sediments. In particular, the fine-grain size fraction of the sediments plays a major role because contaminants are preferentially absorbed onto this fraction and because it settles more slowly, thus being potentially transported by marine drifts over long distances (Hakanson and Jansson, 1983; Rubio et al., 2011; De Serio and Mossa, 2013). Marine currents affect the most surficial layer of sea bottom sediments causing differences between the contaminant distributions in these surficial layers with respect to those observed in deeper layers.

Correlations of chemical/biological data with hydrological features were reported by few research groups, (De Pippo et al., 2002; Raffa and Hopkings, 2004; Alyazichi et al., 2015; De Serio and Mossa, 2015, 2016) even if none of these studies dwells on harbor areas.

In the present study, we investigated the correlation between the cumulative hazard assessment index c_NWAC (cumulative Normalized and Weighted Average Concentration) values (Mali et al., 2016) based on purely chemical and biological data and a hydrodynamic parameter properly selected and strictly connected to the sea bottom current velocity, i.e. the bottom shear stress. The aim is to investigate how and to what extent the knowledge of the hydrodynamic features of the seabed could improve the identification of the potential sampling sites useful for the monitoring and hazard identification program.

2. Materials and methods

2.1. Study area

The target study area is the Port of Bari, one of the most important ports of south-east Adriatic coast, located near the urban area of Bari, Italy (Fig. 1). From a geological perspective, the coastal area of Bari is part of the carbonatic plateau of the lithological platform of southern Italy called “Murge” and mainly characterized by sandy sediments, although recently large-scale artificial burying and human interventions heavily modified that coastal tract. Numerous ephemeral watercourses, parallel to each other and perpendicular to the coast, form the peculiar hydrographic network that nourishes the coasts with terrigenous sediments, driving contaminated material to the nearby port tract area.

The Port of Bari is a multipurpose stop-over equipped with docks for handling a range of goods and freight. Water depth in the port reaches a maximum of 15 m, allowing the movement of large ships and vessels. The important commercial activities within the port seriously affect the quality of the port basin and the sea bottom sediments that act as a final sink for all contaminants entering the port within the water column.

2.2. Sediment sampling strategy

Sediment samples were collected in February 2011 from the most significant basins in the port area. The sampling strategy fol-