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Assessment of sediment toxicity in the Lagoon of Venice (Italy) using a multi-species set of bioassays

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ABSTRACT

Within the framework of a Weight of Evidence (WoE) approach, a set of four toxicity bioassays involving the amphipod *Corophium volutator* (10 d lethality test on whole sediment), the sea urchin *Paracentrotus lividus* (fertilization and embryo toxicity tests on elutriate) and the pacific oyster *Crassostrea gigas* (embryo toxicity test on elutriate) was applied to sediments from 10 sampling sites of the Venice Lagoon (Italy). Sediments were collected during three campaigns carried out in May 2004 (spring campaign), October 2004 (autumn campaign) and February 2005 (winter campaign). Toxicity tests were performed on all sediment samples. Sediment grain-size and chemistry were measured during spring and autumn campaigns. This research investigated (i) the ability of toxicity tests in discriminating among sites with different contamination level, (ii) the occurrence of a gradient of effect among sampling sites, (iii) the possible correlation among toxicity tests, sediment chemistry, grain size and organic carbon, and (iv) the possible occurrence of toxicity seasonal variability. Sediment contamination levels were from low to moderate. No acute toxicity toward amphipods was observed, while sea urchin fertilization was affected only in few sites in just a single campaign. Short-term effects on larval development of sea urchin and oyster evidenced a clear spatial trend among sites, with increasing effects along the axis connecting the sea-inlets with the industrial area. The set of bioassays allowed the identification of a spatial gradient of effect, with decreasing toxicity from the industrial area toward the sea-inlets. Multivariate data analysis showed that the malformations of oyster embryos were significantly correlated to the industrial contamination (metals, polynuclear aromatic hydrocarbons, hexachlorobenzene and polychlorinated biphenyls), while sea urchin development to sediment concentrations of As, Cr and organic carbon. Both embryo toxicity tests were significantly affected by high ammonia concentrations found in the elutriates extracted from some mudflat and industrial sediments. No significant temporal variation of the toxicity was observed within the experimental period. Amendments to the set of bioassays, with inclusion of chronic tests, can certainly provide more reliability and consistency to the characterization of the (possible) toxic effects.

1. Introduction

The Weight of Evidence (WoE) approach represents one of the more reliable tools for decision makers supporting the choice of the most suitable intervention strategies on contaminated sediment within an environmental risk assessment (ERA) framework (Burton et al., 2002; Chapman et al., 2002a; Micheletti et al., 2011). The effectiveness of the WoE approach depends largely on the reliability of the methods used for assessing the single Line of Evidence (LoE), including sediment chemistry, benthic community structure analysis, toxicity testing, bioaccumulation and biomarkers (Chapman et al., 2002a, b; Chapman and Anderson, 2005).

Toxicity testing is one of the most critical LoE because it links exposure to contaminated sediment with the effects on the biota. Thus, it is mandatory the use of standardized and reliable methods as well multiple target species (reasonably similar to those living in the site of interest) and endpoints (e.g. survival, reproduction, growth and development) (Reynoldson et al., 2002; Chapman and Anderson, 2005, Carballeira et al., 2012; Aguirre-Martínez et al. 2015).

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In Venice Lagoon (Italy), several monitoring programs were carried out in the past decades investigating the state of the environment through an interdisciplinary approach. In most of the cases, toxicity testing and the other LoE, as water and sediment chemistry, benthic community and biomarkers were individually studied, or just integrated *a posteriori* within a comprehensive framework or partially analysed (Losso and Volpi Ghirardini, 2010). The three-year ICSEL project (Integrazione delle ConoScenze sull'Ecosistema Lagunare, 2003–2006) was the first study at the whole Venice Lagoon scale designed for the development of a WoE approach as screening-level ERA. Data on sediment chemistry, toxicity testing, bioaccumulation and biomarkers data collected in the period 2003–2005 were integrated following a multi-step decision making framework identifying the appropriate and site specific management actions to be adopted for the investigated sites (Chapman and Anderson, 2005).

The aim of this paper was to focus on toxicity testing and sediment chemistry. Sediment toxicity was investigated from May 2004 up to February 2005 (May 2004 (spring campaign), October 2004 (autumn campaign) and February 2005 (winter campaign) considering the following bioassays: i) the 10 d lethality test on whole sediment with the amphipod *Corophium volutator* (Pallas, 1766), ii) the sperm-cell and embryotoxicity tests with the sea urchin *Paracentrotus lividus* (Lamarck, 1816) on elutriates, and the embryotoxicity test with the pacific oyster *Crassostrea gigas* (Thunberg, 1793) on elutriates. International standard guidelines are available for the selected bioassays (USEPA, 2002; ASTM, 2004; ISO, 2005) and specific protocols were previously developed and validated for the application of the water-phase test in Venice Lagoon (Volpi Ghirardini and Arizzi Novelli, 2001, 2002, 2006; Losso et al., 2004; Volpi Ghirardini et al., 2005a). The applicability in Venice Lagoon of the amphipod standard protocol for sediment testing was already verified by Picone (2006) and Picone et al. (2008). Sediment were investigated for the presence of organic carbon (OC), metals, polynuclear aromatic hydrocarbons (PAH), organo-chlorine pesticides (OCP), hexachlorobenzene (HCB), poly-

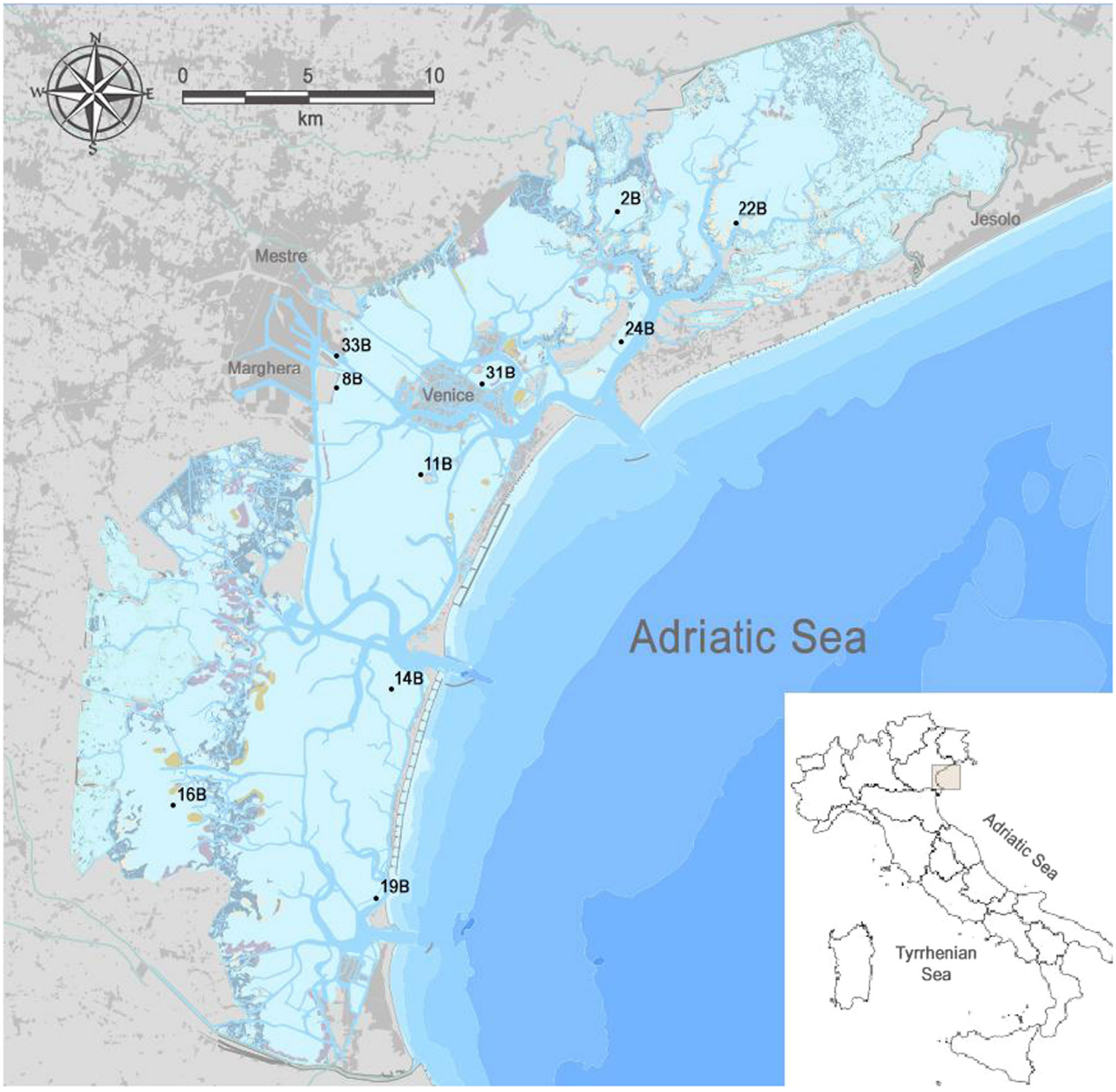

Fig. 1. Sampling sites position in the Lagoon of Venice.