Harbour and coastal sediment chemistry and toxicity: a preliminary assessment of dredging activities

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Abstract

In a project to assess the environmental impact of dumping contaminated harbour material in a coastal marine area of the Northern Tyrrhenian Sea, sediments from different sites (harbour, dumping and uncontaminated sites) were sampled in December 1993 and February 1994. In order to evaluate sediment quality, concentrations of heavy metals (Cd, Pb, Cr and Hg) and polycyclic aromatic hydrocarbons (PAHs) were determined and toxicity tests were carried out using the sea urchin *Paracentrotus lividus*. Interstitial water and the sea water overlying sediments (bedded phase and suspended phase) were tested for their effects on fertilization and embryogenesis. Sediment texture was also considered. Metal concentrations, particularly cadmium content, and PAH total concentrations, in harbour sediments were generally higher than in offshore samples. No significant reductions in fertilization were observed. However, effects on the embryonic development were evident and interstitial water toxicity was shown to be greater than either bedded or suspended exposures.

1. Introduction

The Italian legislation governing dredging operations does not indicate, at present, a specific procedure of sampling and analysis for the characterization of dredged materials in order to choose their destination. In fact the permit to discharge into the sea requires a general evaluation of the physical, chemical and microbiological characteristics of the material to be dredged and of the oceanographic conditions of the disposal area. No limits for chemical concentrations are provided and no toxicological assessment is required.

Most sediments are dredged for harbour maintenance and they are disposed at sea in coastal areas. The annual amount of sediments authorized to be dredged and dumped into the sea is quite variable, reaching values of about five million cubic metres (Pagnotta et al., 1990; Pellegrini et al., 1992). This is considerably less than the volumes annually dredged in many Northern European countries in which harbours and channels are at the mouths of rivers.

In 1992 the maintenance dredging of about 500,000 m³ was permitted in the industrial harbour of Livorno (Italy). The disposal site was an area two miles square, near the 40 m bathymetry line, just three miles north of the Meloria Shoals (an interesting ecological area characterized by rich and heterogeneous biocenoses).

In order to evaluate preliminary sediment quality and toxicity, sediment texture, the concentration of heavy metals and polycyclic aromatic hydrocarbons (PAHs) were determined and a bioassay was performed.

Toxicological research generally includes the use of acute and chronic tests with fishes and invertebrates (Burton, 1992). The last two decades have seen the application of sea urchin bioassays to environmental monitoring, and the expansion of this methodology to include multiple exposure pathways and response endpoints such as sperm fertilization bioassay and embryonic development assays (Dinnel et al., 1987). Some important characteristics of the fertilization test are high sensitivity, low cost, world-wide application and
notable rapidity, as the test is performed in minutes instead of hours or days.

For this study, potential toxicity of sediments from harbour dredging sites, a former dumping area and one supposedly uncontaminated offshore site, was measured with the sea urchin Paracentrotus lividus (Lamark) fertilization test. Toxicological endpoints included changes in reproductive success and sediment-induced alterations in embryogenesis following sperm exposure. The echinoid fertilization test is commonly considered a suitable assay for testing the toxicity of waters derived from sediments such as interstitial water and elutriates. Nevertheless, the last few years have seen the application of this assay to whole or solid phase sediments (Pagano & Romana, 1991; Romana et al., 1992; Burgess et al., 1993).

2. Materials and methods

2.1. Sediment collection and storage

Harbour sediment samples were collected in December 1993 with a gravity corer (6-cm diameter; 75-cm high) in three stations (H1, H2 and H3; 11–12 m deep) (Fig. 1).

Offshore sediment samples were collected in February 1994 with a gravity corer and a 50-liter benthic dredge in a former dumping area (O2), in a nearby area (O3) and in a supposedly uncontaminated offshore site (O1) used as reference sediment (Fig. 2).

The sediment samples for bioassay were stored at 4 °C in capped glass vessels from the time of collection until the initiation of the test (about 72 hours); for the others analysis they were immediately frozen in decontaminated vessels.

2.2. Textural and chemical analysis

Samples for grain size analysis were treated with H₂O₂ solution and fractionated by wet sieving. Sand, silt and clay percentages were determined.

The top 8-cm layer from each harbour core and offshore surface sample, collected by dredge and by gravity corer (the top 2-cm layer), were homogenized and from 0.2 to 0.8 g was digested in teflon bombs with a mixture of concentrated hydrochloric, nitric, perchloric and hydrofluoric acids. The digestion was performed by a microwave digester. All samples were digested in duplicate and at least duplicate measurements were performed on each digest. The standard addition method was used for calibration. Cadmium, chromium and lead analysis were performed by graphite furnace atomic absorption spectrometry. Mercury was determined by cold vapour atomic absorption spectrometry after reduction by stannous chloride. The accuracy and the reproducibility of the analytical methods was checked on BCSS-1 certified reference material (National Research Council,