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Characterization of a former dump site in the Lagoon of Venice contaminated by municipal solid waste incinerator bottom ash, and estimation of possible environmental risk

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ABSTRACT

Bottom ash from a municipal solid waste incinerator on a former contaminated site, the island of Sacca San Biagio (Lagoon of Venice), was examined in order to evaluate levels of pollutants and their potential mobility and availability. Heavy metal concentrations were determined and the actual contamination of the site was compared with national legislation on polluted sites. The site was mainly contaminated by zinc, copper and lead. Physico-chemical characterization of bottom ash was carried out by SEM (Scanning Electron Microscopy) with micro-analysis by EDS (Energy Dispersive X-ray Spectroscopy) and XRD (X-ray Diffractometry), for information on newly formed minerals. SEM-EDS analysis revealed the presence of particles, compounds and clusters containing heavy metals and, in particular, the presence of barium sulfate, which was assumed to be a site-specific compound. Similarities between bottom ash and atmospheric PM10 collected on the adjacent island of Sacca Fisola were studied and a risk of aerodispersion of the fine fraction of ash was assumed. Lastly, in order to evaluate the potentially available fraction of metals (non-residual fraction) and the directly exchangeable fraction, two single extraction procedures with HCl and citric acid were carried out, respectively. Results showed a relatively low concentration of readily phyto-available metals, as well as the high concentrations found for some heavy metals (Cu, Pb, Zn) in the potentially mobilizable fraction.

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1. Introduction

Former disposal sites of hazardous materials may represent a long-term source of environmental contamination, since pollutants can be directly propagated to surface and ground waters and air. In particular, bottom and fly ashes, which are the main residues of MSWI (Municipal Solid Waste Incinerator) activity, contain high concentrations of potentially hazardous elements (such as heavy metals) (Chandler et al., 1997; Zevenbergen et al., 1998; Huang et al., 2006). There is evidence that bottom ash is unstable in atmospheric conditions, since weathering changes the mineralogical characteristics of bottom ash, mainly by reducing its chemical reactivity by carbonation and trapping of heavy metals in newly formed minerals (Piantone et al., 2004).

Although several studies have investigated weathered and unweathered MSWI bottom ash, to our knowledge there are no published data about bottom ash more than 12 years old (Zevenbergen et al., 1998; Meima and Comans, 1999). It is therefore of interest to study the 35-year-old MSWI bottom ash of a former disposal site located in the Lagoon of Venice.

In this study we examine the environmental risk related to ash stored on the island of Sacca San Biagio (SB in Fig. 1), near the city centre of Venice, over a period of about 10 years, during incinerating activity which started in 1973.

This paper provides data on metal contamination and the main mineralogical characteristics of MSWI bottom ash stored on the site. Mineralogical neoformations due to weathering processes are discussed with reference to data on younger bottom ash (Zevenbergen et al., 1998, 1999; Meima and Comans, 1999; Piantone et al., 2004). Comparisons of airborne particle collected from the nearby island of Sacca Fisola (SF in Fig. 1) is also discussed. Lastly, two single extractions with cold HCl and citric acid were carried out, to evaluate the potentially mobilizable and the directly exchangeable metal fractions, respectively, and to gain information on the risk associated with the diffusion of contaminants through the trophic chain.

1.1. Study area

The island of the former incinerator, called Sacca San Biagio (SB), is located in the middle of the Lagoon of Venice, at the western end of the island of Giudecca. The site covers about

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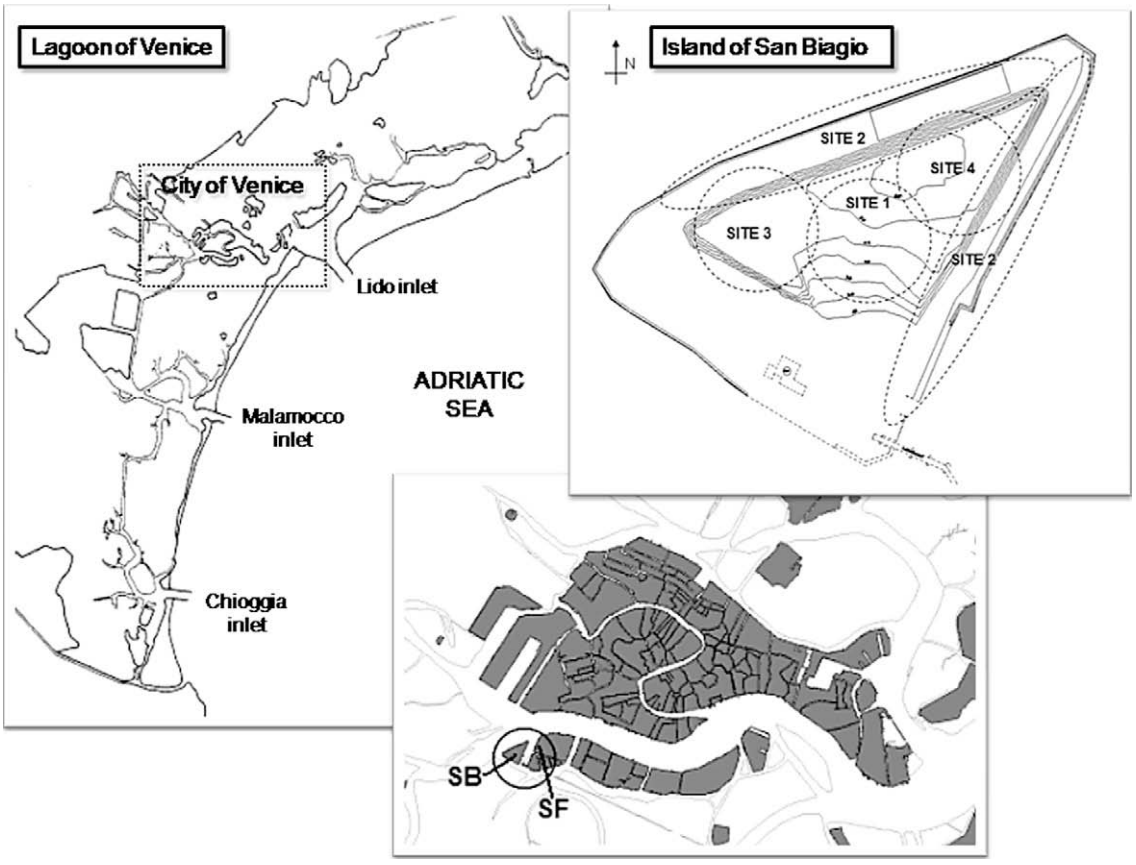

Fig. 1. On the left: map of Lagoon of Venice. Down: map of Venice; SB: island of Sacca San Biagio; SF: island of Sacca Fisola. On the right: map of Sacca San Biagio, showing four sampling sites.

45,000 m^2 (Fig. 1). It was originally a natural deposit of sediments emerging at low tide, filled with inert materials and rubble in the post-war period. In 1970, a municipal solid waste incinerator was built, and operated from 1973 to 1984. During this time, approximately 60,000 m^3 of bottom ash were collected and dumped on the site.

In 1994, the island was secured against erosion with walling made of reinforced concrete sheet piles, but total impermeabilization was not guaranteed.

The incinerator was demolished in summer 2003. Currently, the island is used as a temporary waste dump and is almost completely covered with spontaneous mainly herbaceous, pioneer vegetation.

2. Materials and methods

2.1. Sampling and pre-treatment of bottom ash

Bottom ash samples were collected from various sub-areas of SB. In particular, as shown in Fig. 1, the island was divided into four sites, each containing three sampling points. A total of 12 samples was collected, from reciprocally distant points on the island for optimal representativity of the site itself. Samples were collected after a period of 72 h without rain. Primary samples (1 kg per sample) were collected between depths of 0 and 30 cm and were stored in polyethylene bags for transport and storage. The samples were then stored at −20 °C until pre-treatment for analysis.

Bottom ash primary samples were dried for 72 h at 60 °C. The ash was then sieved through stainless steel sieves and separated into size fractions for the following analyses. Chemical analyses were carried out on the fraction passing through a 2-mm sieve. For chemical analysis, portions of the samples (300 g) were ground in a mechanical agate grinder until fine particles were obtained. SEM-EDS and XRD analyses were performed on size fractions <63 μm and between 15 and 5 μm. In particular, bottom ash fraction between 15 and 5 μm was selected in order to obtain a range of particles with size suitable for comparison with PM10 airborne particle.

2.2. Sampling of atmospheric particle

In order to investigate possible aerodispersion of dumped ash, atmospheric PM10 was collected from the western side of the nearby island of Sacca Fisola (SF in Fig. 1) on a Sentinel PM Tecora sampler. Atmospheric particle was collected on filter membranes (MCE, 0.45 μm pore size) by daily exposure for 24 h, in various meteorological conditions and 15 filter samples were analyzed by SEM.

2.3. Determination of pH values of bottom ash

The pH of ash was determined potentiometrically in a slurry system using an electronic pH meter (Basic 20, Crison). Determination of the pH was carried out according to the European standard EN 13037 (1999) at a solid to liquid (S/L) ratio of 1:2.5 (v/v) on each sample of bottom ash.

2.4. Determination of total metal concentrations in ash samples

A careful microscopic examination of bottom ash showed the presence of very small fragments of glass (probably added to ash to improve its physical resistance to the wind and rain action).To prevent the dissolution of glass fragments not connected with

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