Science of the Total Environment 646 (2019) 757–769

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Element concentrations of environmental concern in surface sediment samples from a broad marine area of 25 de Mayo (King George) Island, South Shetland Islands

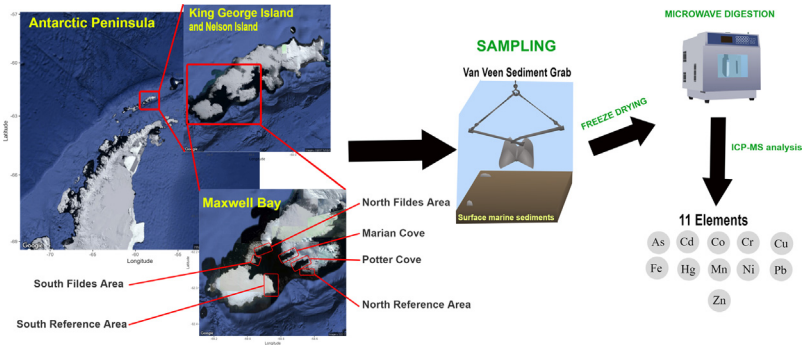
C. Vodopivez [a], A. Curtosi [a], E. Pelletier [b], L.U. Spairani [a], E.A. Hernández [a,c], W.P. Mac Cormack [a,c,*]

[a] Instituto Antártico Argentino, 25 de Mayo 1143, San Martín B1650HMK, Provincia de Buenos Aires, Argentina
[b] Institut des Sciences de la Mer de Rimouski (ISMER), Université du Québec à Rimouski, 310 Allée des Ursulines, Rimouski G5L 3A1, Canada
[c] Universidad de Buenos Aires, Facultad de Farmacia y Bioquímica, Instituto NANOBIOTEC UBA-CONICET, Junín 956 6to piso, CABA, Argentina

HIGHLIGHTS

- Quality of sediments from the region with the greatest human presence in Western Antarctica Peninsula, was evaluated.
- The first data of Hg in marine sediments for the study area are reported.
- Baseline levels are defined for 9 trace elements, Fe and Mn.
- The Igeo/SC tool was used for the first time in many sites of the study area for the evaluation of the sediments quality.
- The possible effect of iceberg scouring, ice-rafting- debris and ice calving on the composition of sediments is discussed.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 9 May 2018
Received in revised form 13 July 2018
Accepted 13 July 2018
Available online xxxx

Editor: Xinbin Feng

Keywords:
Antarctica
Metal pollution
Maxwell Bay sediments
Baselines

ABSTRACT

Western Antarctica (WA) constitutes the area with the highest human presence in the white continent and also the region where the effects of global warming are more evident worldwide. Such human presence represents a potential risk of pollution with both, organic and inorganic contaminants. Global warming also could modify dynamics and transport of the pollutants, increasing summer water runoff, ice melting and iceberg scouring. Under this fast-changing scenario, knowledge about the concentration of contaminants is essential to evaluate the environmental status of this ecologically relevant area. In this work, we performed the first regional-scale monitoring of 9 trace elements (Cr, Co, Ni, Cu, Zn, As, Pb, Cd and Hg), as well as Fe and Mn, in surface sediment from 64 sites comprising six different areas in Maxwell Bay, 25 de Mayo (King George) Island. Target elements were quantified in surface sediment samples (20–30 m depth) obtained during two summer Antarctic expeditions: 2010/11 and 2011/12 by inductively coupled plasma linked to a quadrupole mass spectrometer (ICP-MS). Based on the average values observed for the reference areas, baseline values were defined for the studied region. A regional enrichment in Cu (compared with the global mean upper crust) was observed and related to the widespread mineralization of volcanic rocks. The most anthropized area (South Fildes) mainly showed sediment class 3 (moderately polluted) for Pb, Cd and Hg with a number samples revealing some highly contaminated hot spots. Although elemental contamination in some samples close to scientific stations or sites where logistic operations were evidenced, a pollution pattern was not clearly identified. The present work represents the first regional-

* Corresponding author at: Universidad de Buenos Aires, Facultad de Farmacia y Bioquímica, Instituto NANOBIOTEC UBA-CONICET, Junín 956 (C1113AAZ), 6to piso, CABA, Argentina.
E-mail addresses: emilien_pelletier@uqar.ca (E. Pelletier), uss@mrecic.gov.ar (L.U. Spairani), edy@ffyb.uba.ar (E.A. Hernández), wmac@ffyb.uba.ar (W.P. Mac Cormack).

https://doi.org/10.1016/j.scitotenv.2018.07.174

scale attempt to define the baseline values and the anthropic impacts in this region of the WA and also provides the first data about Hg concentration in surface sediment of the study area.

1. Introduction

Although anthropogenic pollution can reach the polar regions through atmospheric circulation and sea currents, Antarctica is usually included among the few remaining pristine environments on Earth. However, even though this is true for most of the inner zones in continental Antarctica, which remain unexplored, coastal areas being free of ice during summer have received a significant impact of human settlements since the beginning of the 20th century. In this sense, Western Antarctica Peninsula (WAP) and South Shetland Islands constitute the regions of Antarctica with the greatest human presence. With eight stations from different countries operating permanently, the 25 de Mayo (King George) Island exhibits the highest density of human settlements in WAP (Vodopivez et al., 2015).

Chemicals (organic and inorganic) from the stations and their associated logistical activities (airports, fuel tanks, ship operations, power plants) are introduced in coastal marine environment. The occurrence of contamination halos around the stations located in King George Island (KGI) has been reported in several studies (Santos et al., 2005; Curtosi et al., 2007, 2009, 2010; Vodopivez et al., 2015; Trevizani et al., 2016). Trace elements monitoring often give valuable information for evaluating the health of ecosystems and can be useful to identify sources of pollution in terrestrial and coastal marine Antarctic environments (Vodopivez et al., 2001).

It is clear that trace elements input to the Antarctic coastal marine ecosystem results from a combination of two local phenomena: 1) The natural contribution from the coastal rockeries and soils, through surface runoff and subglacial melt-water inputs (Vodopivez et al., 2015) and 2) contribution from local anthropogenic sources associated to logistic and scientific activities (Santos et al., 2005). As marine sediments may contain a substantial proportion of trace elements representing a natural contribution from earth's crust, the task of differentiate the contribution of anthropogenic sources from the natural background is a critical point for a correct evaluation of the human impact on the coastal sediments. Soils and rocks are the terrigenous sources of trace elements for coastal marine sediments and their geochemical characteristics directly affect the composition of such sediments.

Atmospheric warming is believed to influence the distribution and amount of precipitations in Antarctica, and many studies have shown that the Antarctica Peninsula region is experiencing rapid climatic change (Park et al., 1998; Simões et al., 1999; Simões et al., 2004; Thomas et al., 2004). If temperature, water availability and ice coverage are changing, the degree and rate of rock weathering and soil leaching should also be altered. As a result, sedimentation processes in the coastal ocean may also be changed (Khim et al., 2001; Khim and Yoon, 2003).

In addition to the contribution of routine operations during station activities, accidents such as fuel spills, fires, ship sinking or beaching, can be potential sources of pollution.

Available data about trace elements found in marine sediments collected in the surrounding of research stations of KGI is not clear regarding their origin and sources. Some studies reported evidence of metal and metalloid enrichment in surface sediments associated to human activities (Alam and Sadiq, 1993; Santos et al., 2005; Curtosi et al., 2010; Ribeiro et al., 2011; Vodopivez et al., 2015; Trevizani et al., 2016) and in soils close to the coastal line (Amaro et al., 2015; Lu et al., 2012). Other studies suggested that the detected metal concentrations in abiotic and biotic matrixes corresponded to the baseline values (Ahn et al., 1996, 2001; Andrade et al., 2001; Fańas et al., 2002; Abele et al., 2008). All the previous studies were focused on limited areas, comprising only one or a small group of close stations. Due to the large range of the contamination effects, regional-scale studies are necessary for a better understanding of the extension and effects of the contaminants.

Based on the above mentioned evidences and considering the relevance of the trace elements concentration as pollution indicators of the Antarctic sediments, the aim of this study was: (1) to evaluate the concentration of 9 trace elements (Cr, Co, Ni, Cu, Zn, As, Pb, Cd and Hg), as well as Fe and Mn, in surface sediment from six different sites in Maxwell Bay, southeast coast of KGI, as this area comprises nearly 35 km of shoreline and represents the region with the major human presence in the West Antarctica; (2) to define baseline concentration for the nine analyzed trace elements by sampling areas of low human occupation and presumably close to pristine conditions and, (3) to estimate the degree of pollution of these samples by calculating their geoaccumulation indices (Igeo/sediment class). As far as we know, this study represents the first regional-scale contribution to define the baseline values and the anthropic impact in this crowded region of the Western Antarctic Peninsula and also provide the first data about Hg concentration in sediments of the study area.

2. Materials and methods

2.1. Description of the study area

The study area included the southeast sector of the KGI, Maxwell Bay, from Stranger Point (located in Potter Peninsula) to Halfthree Point (Fildes Peninsula), as well as the sector of Nelson Island between O'Cain Point and Duthoid Point (Fig. 1). Six permanent research stations have been operating in the area for >30 years. Also, several refuges and camps are established annually during summer season, all representing an environmental risk for the coastal ecosystem. In addition, in recent years, tourism activity has shown a significant increase in this region.

The geological composition of KGI is dominated by a stratiform sequence of basaltic-andesite lavas and tuffs, and quaternary deposits that include neoglacial moraines and marine sediments (Birkenmajer, 1998a,b). The lithostratigraphic division of KGI has been differently described by several researchers. On one hand, Smellie et al. (1984) suggested two formations: Fildes Formation in the western part of KGI and the Hennequin Formation to the east. On the other hand, Birkenmajer (1983, 1998c) suggested three tectonic blocks divided by large-scale strike-slip faults: the Barton and Weaver peninsulas (Barton Horst) along the central axis of KGI, the Fildes Peninsula (Fildes Block) to the northwest and Potter Peninsula (Warszawa Block) to the southeast. In this work, we based our discussion on this second lithostratigraphic division; so our studied area involves three different tectonic blocks: Barton Horst, Fildes Block and Warszawa Block.

The Barton Horst consists mainly of Paleogene volcanic-sedimentary complex, and is pierced by numerous calc-alkaline Andean intrusions, ranging in composition from quartz-gabbro to granodiorite. Are also present extensive areas of outcrops of the strongly folded and chloritized andesitic lavas, stuffs and agglomerates on the horst (Tokarski, 1988). Inside the Barton Host, the volcanic rocks are commonly folded and altered, whereas the rocks outside the host are mostly unaltered and fresh (Birkenmajer, 1983). The geochemistry of volcanic rocks (basalt, basaltic andesite and andesite) from Barton and Weaver Peninsulas was reported by Yeo et al. (2004). Trace elements in coastal marine sediment would be affected by the leaching of adjacent rock formations.