Microchemical Journal 110 (2013) 21–27

Contents lists available at SciVerse ScienceDirect

Microchemical Journal

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

Post-fire study of the Brazilian Scientific Antarctic Station: Toxic element contamination and potential mobility on the surrounding environment

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ARTICLE INFO

Article history:
Received 29 October 2012
Received in revised form 21 January 2013
Accepted 21 January 2013
Available online 5 February 2013

Keywords:
Soil pollution
PCA
Antarctica
Fire
X-Ray Fluorescence

ABSTRACT

We evaluated the new on site soil conditions and their potential risks immediately after a fire that completely destroyed the Brazilian Antarctic Station, on February 2012. The investigated variables were the concentration of potentially toxic elements (Cd, Cr, Cu, Mn, Ni, Pb, V and Zn) in soil samples collected close to the station and inside the burnt station's ruins. Soil samples collected 4 years before the fire were used as reference samples for comparative purposes. Principal Component Analysis (PCA) and μ-X-Ray Fluorescence were used as preliminary tools to provide fast and reliable qualitative information about soil pollution. Inductively Coupled Plasma Optical Emission Spectrometry (ICP OES) was chosen for the quantitative determination of the chemical elements under study. A Toxicity Characteristic Leaching Procedure was applied to access the potential mobility of the chemical elements in the environment. We found high pseudototal concentrations of Cu, Pb and Zn in soils collected within the station's ruins reaching the alarming levels of $34{,}000 \pm 4{,}000$, $13{,}700 \pm 500$ and $42{,}200 \pm 1{,}700$ mg kg^{-1}, respectively. A point that deserves a close and special attention is the possible contamination of nearby lakes that supply the station with water, due to the high leachable Pb and Zn concentrations of the contaminated soil. Also, attention should be given to the possible development of melting channels carrying contaminated water to the coastal marine ecosystem. Due to its high risk of contamination, a complete clean-up procedure ought to be carried out, with barriers to avoid leaching/washing, removal of all debris and underlying soil, and careful disposal of the contaminated material, followed by remediation.

1. Introduction

The Antarctic continent is 98% covered by ice, being the remaining 2% ice free areas vegetated by sparse moss and lichen fields and most rarely by a grass specie. Then, the occurrence of natural fires in this environment is not a common event due to the lack of native combustible material [1,2]. All reported fire incidents at Antarctica are related to human habitations, since there are over 53 scientific bases in operation within the Antarctic territory [3]. In these stations, according to the reported fire history, electric fault is the main cause of burning [2]. Moreover, intrinsic characteristics of Antarctica such as dry climate and frequent wind storms contribute strongly to aggravate this dramatic fire scenario. Also, the low availability of water in liquid state (due to the common below freezing temperatures) hampers the fire fighting procedures in an emergency situation [2].

On February 25th, 2012, a major fire devastated the only permanent Brazilian research base in Antarctica, the Comandante Ferraz Station, located at the King George Island, Maritime Antarctica. According to official reports, giant flames rapidly spread into the station's buildings devouring constructions' insulations, batteries, motorcycles, fuels, and all laboratory and maintenance supplies. This tragic event also took away the lives of two brave militaries, and served as a catalyst for political discussions about strategies for human occupation in Antarctica in a safe and environmental-friendly way. It was an unfortunate occurrence, given the good record for environmental monitoring and protection exhibited by the Brazilian station since its installation in 1984.

In order to recognize Antarctica as a place fully dedicated to peace and science and also to prevent damages to its pristine condition, the Antarctic Treaty was reinforced. The Protocol on Environmental Protection to Antarctica (the Madrid Protocol) imposed strict rules for environmental management and impact assessment derived from human presence on that special place [4]. International scientific programs installed at Antarctic stations are aware about risk assessment and environmental quality evaluation [5–9]. Their studies focus on several contaminants such as toxic metals [8,10–15], hexavalent

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0026-265X/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.microc.2013.01.007

chromium [16], persistent organic chloride compounds [17], brominated diphenyl ethers [18,19], among others [14,20–22].

Environmental assessment studies regarding evaluation of fire consequences to the Antarctic ecosystem was already subject of investigation by some researches either by determination of inorganic or organic compounds' concentrations. Braga Bueno Guerra et al. [8] investigated the soil contamination degree of samples from Hope Bay, Antarctic Peninsula. In this region, a British station burnt down in 1948. This accident dispersed a thick mantle of debris that was subjected to chemical and physical changes under polar climate conditions for over half a century. In this study, the pseudototal concentrations of eight potentially toxic metals were determined in superficial soil samples collected at the impacted points. Strong contamination pattern was evidenced reaching high-level contents of Cd, Cu, Pb and Zn: 50 ± 10, 2,100 ± 100, 19,380 ± 120 and 5,200 ± 200 mg kg^{-1}, respectively for the most disturbed sites. Until now, no effective clean-up was performed at Hope Bay.

On September 28th, 2001, a fire destroyed a laboratory nearby the Rothera station located at the Adelaide Island, Antarctic Peninsula. Dickhut et al. [19] measured brominated diphenyl ethers in air, snow and sea ice samples collected at Western Antarctica between 2001 and 2007. In this study, they found a correlation between the fire and high concentrations of decabromodiphenyl ether (BDE 209). This compound is a flame retardant which is added in protective coatings commonly used in plastic and polymeric materials of electrical and electronic devices.

On this subject, this is the first study aiming to evaluate the impact of the fire that burned down about 70% of all permanent Brazilian settlement at Antarctica, in February 2012. For this aim, soil samples collected by our group in the same studied area (4 years before the fire) were used as reference samples for comparative purposes with the supposedly contaminated soil samples collected after that tragedy. The hypothesis to be tested in this study is that the fire led to a concentration of a myriad of chemical elements in the studied environment, mainly due to the disintegration of metallic alloys, solders and batteries (potential sources of Cu, Mn, Ni, Pb and Zn), paint pigments (potential source of Cd, Cr and Pb) and by diesel burning (potential source of V). Principal Component Analysis (PCA) and μ-X-Ray Fluorescence (μ-XRF) were used as preliminary tools to provide qualitative information about soil pollution. Inductively Coupled Plasma Optical Emission Spectrometry (ICP OES) was chosen for the quantitative determination of the metals Cd, Cr, Cu, Mn, Ni, Pb, V and Zn in the leachable and in the pseudototal fractions of the soil samples.

2. Experimental section

2.1. Sample collection and preliminary treatments

Our research group performed two sampling campaigns: one before the fire (on February 2008) and the second after it (on March 2012). In both campaigns the same sampling protocol was adopted in order to avoid soil sample contamination and to ensure comparability between the 2 groups of samples. The samples were collected and stored in clean plastic bags that were kept refrigerated until they were processed in the laboratory. All samples were dried at 60 °C until constant weight, sieved to obtain particle size smaller than 212 μm, which were stored in previously decontaminated polyethylene pots. Fig. 1 provides detailed information about the sampling points.

In the first campaign, 7 soil samples (S1–S7) were collected from 4 different sites, one reference unaffected by the station's oil tanks (control sample) and the remaining at the neighborhood of the station's diesel tanks. More information about these samples can be found in the study of Guerra et al. [23]. In the second Antarctic collection, 34 samples (at 0–10 cm depth) were collected, being 9 of them located inside the Comandante Ferraz's ruins (S33–S41) and the remaining (S8–S32) around the station (see Fig. 1). Before sampling, a military team had preliminary removed the coarse waste material

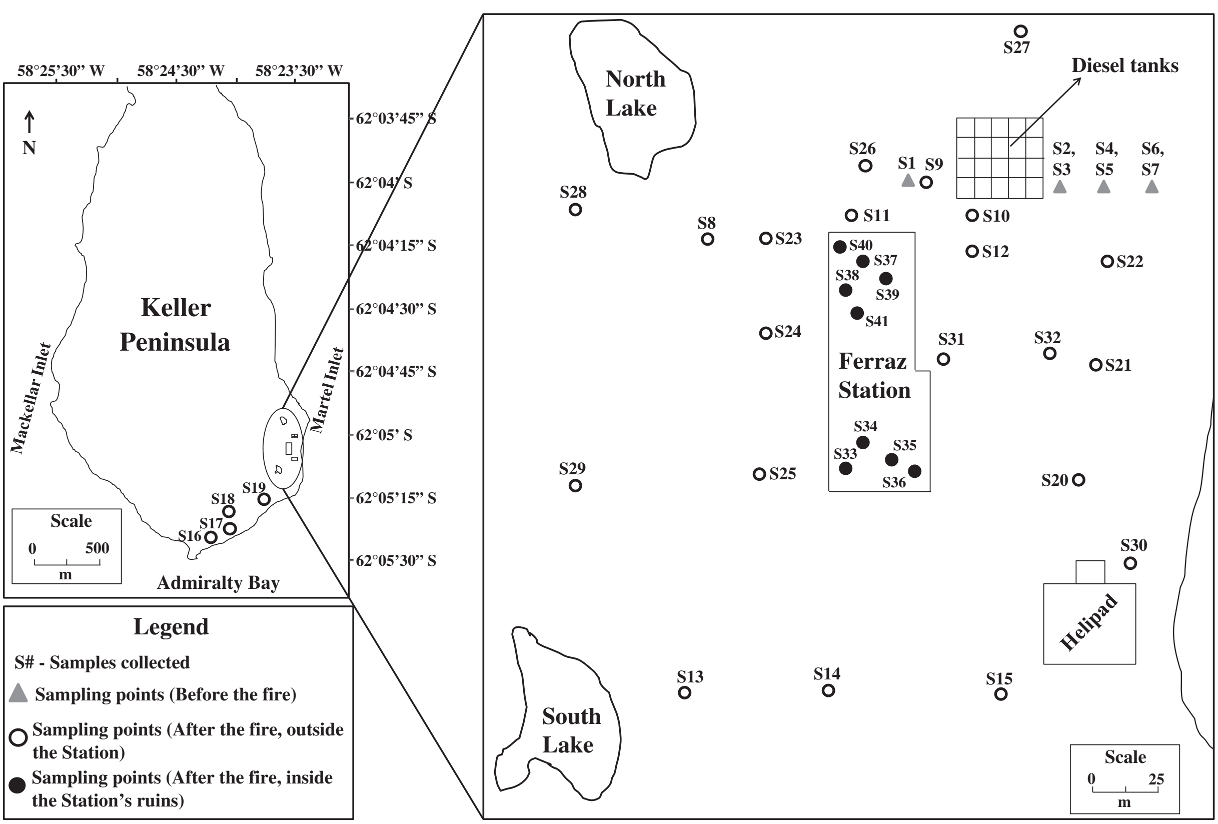

Fig. 1. Sampling points in the Keller Peninsula, around the Comandante Ferraz Station and inside the station's ruins.