Available online at www.sciencedirect.com
ScienceDirect
Applied Geochemistry 21 (2006) 1593–1612
Applied Geochemistry
www.elsevier.com/locate/apgeochem

Trace metals in Antarctic ecosystems: Results from the Larsemann Hills, East Antarctica

Massimo Gasparon [a,*], Jörg Matschullat [b]

[a] *Earth Sciences, The University of Queensland, St. Lucia, Qld. 4072, Australia*
[b] *Interdisciplinary Environmental Research Centre, TU Bergakademie Freiberg, Brennhausgasse 14, D-09599 Freiberg, Germany*

Received 14 November 2005; accepted 28 May 2006
Editorial handling by C. Reimann
Available online 1 August 2006

Abstract

Sediments, mosses and algae, collected from lake catchments of the Larsemann Hills, East Antarctica, were analysed to establish baseline levels of trace metals (Ag, As, Cd, Co, Cr, Cu, Ni, Sb, Pb, Se, V and Zn), and to quantify the extent of trace metal pollution in the area. Both impacted and non-impacted sites were included in the study. Four different leaching solutions (1 M $MgCl_2$, 1 M CH_3COONH_4, 1 M NH_4NO_3, and 0.3 N HCl) were tested on the fine fraction (<63 μm) of the sediments to extract the mobile fraction of trace metals derived from human impact and from weathering of basement lithologies. Results of these tests indicate that dilute HCl partly dissolves primary minerals present in the sediment, thus leading to an overestimate of the mobile trace metal fraction. Concentrations of trace metals released using the other 3 procedures indicate negligible levels of anthropogenic contribution to the trace metal budget. Data derived from this study and a thorough characterisation of the site allowed the authors to define natural baseline levels of trace metals in sediments, mosses and algae, and their spatial variability across the area. The results show that, with a few notable exceptions, human activities at the research stations have contributed negligible levels (lower than natural variability) of trace metals to the Larsemann Hills ecosystem. This study further demonstrates that anthropogenic sources of trace metals can be correctly identified and quantified only if natural baselines, their variability, and processes controlling the mobility of trace metals in the ecosystem, have been fully characterised.

1. Introduction

Trace metal pollution may occur as a result of virtually any industrial and technological activity. Advances in instrumental analysis over the last decade have provided the opportunity to determine ultra-low concentrations (<ng/L levels) of trace elements in a range of environmental matrices, including water, sediment, ice, and biological materials. It is becoming increasingly clear, however, that the degree of temporal and spatial variability within a system usually exceeds analytical uncertainties, often by several orders of magnitude (e.g., Bargagli, 1998; Abollino et al., 2004; Borghini and Bargagli, 2004; Ehrler et al., 2006). Consequently, and as pointed out by Matschullat et al. (2000), the definition of "geochemical backgrounds" and the robustness of geochemical fingerprinting studies based on small selections of samples may need to be reconsidered.

* Corresponding author.
E-mail address: massimo@earth.uq.edu.au (M. Gasparon).

0883-2927/$ - see front matter
doi:10.1016/j.apgeochem.2006.05.007

Although a large number of studies have unequivocally documented the extent of human impact on the Antarctic environment, little attention has been given to the definition of natural baseline levels of trace metals and their spatial and temporal variability. Observations made at heavily impacted sites have often been extended to larger areas, and this might have led to an overestimate of the extent of human impact at a regional scale. Given the role of Antarctica as a gauge of global contamination levels and trends, the definition of natural baseline levels of trace metals in the Antarctic environment has become an important issue for the international scientific community.

The Larsemann Hills (hereafter LH) are located along the Ingrid Christensen Coast of Princess Elizabeth Land, East Antarctica (69°30′ S, 76°20′ E), and comprise a series of N–S oriented, ice-free rocky peninsulas, which extend from beneath the Antarctic ice-cap towards the ocean. The geological basement is a geochemically relatively homogeneous sequence of Mesoproterozoic metasedimentary rocks, intruded by peraluminous granites of Pan-African age (Carson et al., 1995), and free of moraine deposits (Burgess et al., 1994). The area is potentially at high environmental risk, due to the presence of 4 research stations and an ice runway within a few km^2: Law Base (Australia, established in 1986, and regularly visited and resupplied by Australian expeditioners mostly during the summer months), Zhong Shan (People's Republic of China, permanently occupied since 1988), Progress I Station and ice runway (Russian Federation, now abandoned and largely dismantled), and Progress II (Russian Federation, at present not occupied). The area has been occupied only since 1986, and human impact prior to 1986 was virtually nil (Burgess et al., 1992). Activities at research stations, however, are believed to have resulted in some anthropogenic input into at least some of the lake systems (Burgess et al., 1988, 1992; Burgess and Kaup, 1997; Ellis-Evans, 1996, 1997; Gasparon and Burgess, 2000; Goldsworthy et al., 2003).

One of the most striking features of the LH is the presence of more than 150 freshwater lakes. Most of these lakes are small (5000–30,000 m^2) and shallow (less than 5 m), and their water chemistry is primarily influenced by natural processes such as snow melt-water and sea-spray influx, erosion and weathering of the country rock, biological activity, and evaporation (Burgess et al., 1988; Burgess and Kaup, 1997; Gasparon and Burgess, 2000; Gasparon et al., 2002; Gasparon and Matschullat, 2006; Gillieson et al., 1990).

Gasparon and Burgess (2000) concluded that the LH fresh water lakes contain overall extremely low concentrations (ng/L levels) of Pb and other trace metals. The lake water chemistry is dominated by sea-spray and surface water input. No evidence was found for contamination from global air circulation, and it was suggested that trace metal contamination resulting from helicopter, aircraft, vehicle operations and general station activities is negligible. Gasparon and Matschullat (2006) further demonstrated that erosion and weathering of basement rocks can account for the trace metal budget in the LH ecosystem, with the exception of very small, high-impact areas in the vicinity of the stations.

Human impact in the LH has resulted from construction and other activities related to station operations and resupply. Such activities have produced various types of waste, including sewage, domestic and kitchen waste, building material (such as timber, galvanised iron, fibreglass, insulation materials, plastics), workshop waste (machine parts, batteries, gas cylinders, metal and plastic wires and cables, fuel drums), and spills of hydrocarbons (diesel, leaded and unleaded petrol, aviation turbine kerosene) and other liquid chemicals such as antifreeze, lubricants, cleaning agents and laboratory chemicals. Most of this waste is found in the immediate vicinity of station areas and along resupply routes (airstrip, helicopter landing sites, fuel drum stockpiles and fuel resupply areas, and tracks connecting these sites with the stations). Some fragments of timber, paper, plastic, and fuel drums have been scattered around the LH by the strong katabatic winds (Burgess et al., 1992). Other forms of human impact include rock drilling and, more recently, lake sediment coring carried out for scientific purposes. The use of tracked vehicles over the exposed bedrock has dramatically accelerated the rate of mechanical weathering along the vehicular tracks, and the production of fine (sand-size and smaller) particles (Burgess et al., 1992, 1998). Another potential source of contamination is represented by exhaust fumes (burnt hydrocarbons, soot, and trace metals, including Pb) emitted by helicopters during the frequent summer flights (Gasparon, 2001). According to Goldsworthy et al. (2003), hydrocarbon contamination is the most common impact at all LH stations, and in general, high levels of contaminants are found only in the immediate vicinity