

Biogeochemical cycling of Pb in the coastal marine environment at Terra Nova Bay, Ross Sea

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Abstract: The biogeochemical cycle of lead in the marine coastal environment of Terra Nova Bay has been investigated by determining the lead concentration in a large number of matrices: marine sediments, pack ice, snow, seawater, marine microlayer, aerosol and eight species of marine organisms (the bivalve molluscs *Adamussium colbecki* and *Laternula elliptica*, the seastar *Odontaster validus*, the sea urchin *Sterechinus neumayeri*, the fish *Trematomus bernacchii*, the seaweeds *Iridaea cordata* and *Phyllophora antarctica*, and the nemertine worm *Parborlasia corrugatus*). The study of solid speciation of sediment showed that the site is not influenced by human activity and is hence suitable to examine natural processes. The concentration values found in the suspended particulate matter (SPM) of pack ice core, aerosol, marine microlayer and seawater as well as the particulate morphology, investigated by SEM, seem to support the hypothesis that particulate lead is transferred from the atmosphere to the water column through three different mechanisms: (i) release of SPM from the pack ice during its melting, (ii) input from the continental land through wet deposition, (iii) transport by aerosol and marine microlayer. Concentration data both in the whole organism and in some target organs indicated two suitable biomonitor organisms: the bivalva *Laternula elliptica* (particularly its digestive gland) and the fish *Trematomus bernacchii* (particularly its bones).

Received 4 June 2003, accepted 5 August 2003

Key words: Antarctica, Antarctic Environmental Specimen Bank, biomonitors, lead

Introduction

Antarctica is one of the most pristine areas in the world and it is a privileged observatory for research on global changes. The distance from densely populated areas and its peculiar characteristics make Antarctica a very important area for studying the transport and accumulation of potentially toxic substances. In fact, anthropogenic pollution in Antarctica appears negligible and, with relatively simple food webs, bioaccumulation and biomagnification processes are supposed to be of lower magnitude (de Moreno *et al.* 1997).

Heavy metals are brought into the environment through natural and anthropogenic processes, and they can be considered interesting indicators to assess environmental contamination. When heavy metals enter the environment, they react with both abiotic and biotic components of the ecosystem, and may be tightly bound to both.

Lead is an important heavy metal which is widely distributed throughout the world. It is not essential to metabolism and it is highly toxic for biota, even at very low concentration levels, since it reduces plant photosynthesis and retards the growth of living organisms. In the marine ecosystem, natural contributions of lead come from the activity of submarine volcanoes and hydrothermal sources, which release fluids enriched with metals due to the contact with the surrounding rocks. The anthropogenic sources of lead are historically related to industrial activity and vehicle automotive fuel consumption. Lead can be taken up by

organisms both in inorganic form and as organometallic compound from the sea-water, the sediment, and through the food chain. Although aquatic organisms accumulate metals strongly, toxic effects on the biota are determined by their ability to regulate anomalous concentrations, through various detoxification mechanisms (Bettger & ODell 1981, Ritterhoff 1998).

In Antarctic coastal waters around the Italian station (Terra Nova Bay, Ross Sea) the shallow waters have not seen a marked increase in lead content with respect to the baseline measured in deep waters, showing the absence of significant local lead pollution (Scarponi *et al.* 1998). As a consequence, the site is ideal for investigating the biogeochemical cycle of this element as well as for studying the complex interactions among the various matrices which constitute this particular ecosystem. These include:

- i) the sea-water column, where scavenging processes affect dissolved and particulate metal concentrations,
- ii) the pack ice, which covers the sea surface for a long period of the year and causes the metal to enter the water column during its dissolution,
- iii) the marine microlayer and aerosol that play an important role in transporting the metal from the atmosphere to the sea-water (Grammatika & Zimmerman 2001, Cincinelli *et al.* 2001),

- iv) the marine sediment, which is the principal sink for heavy metals in aquatic environment,
- v) the organisms, which can accumulate toxic elements in specific target organs.

In this work, the biogeochemical cycle of lead in the coastal marine environment of Terra Nova Bay (Ross Sea, Antarctica) was investigated by determining its concentration in several abiotic and biotic matrices. Moreover, in order to take into account the metal bio-availability affecting the metal fraction which enters in the food chain (Cognetti 1992), the solid metal speciation was also investigated. Finally, the information obtained for the biota was discussed with the specific aim of trying to identify some marine organisms that can be used as biomonitors of this unusual ecosystem.

Materials and methods

Sample collection and storage

The samples were collected in Terra Nova Bay from 1988 to 2002 by the Italian Antarctic Research Programme (Fig. 1).

Immediately after collection, all the samples were stored in the freezers and later transferred to the Antarctic Environmental Specimen Bank (Soggia *et al.* 2000, 2001)

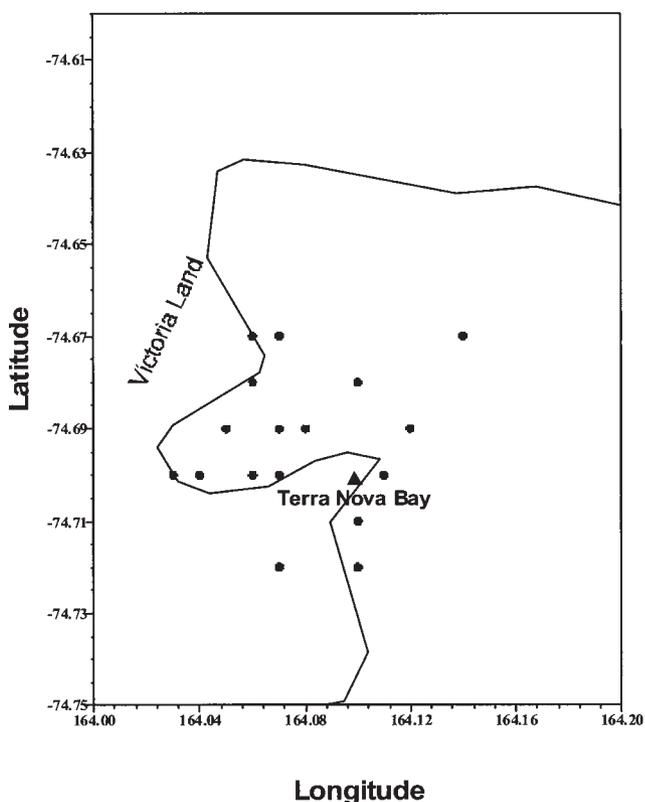


Fig. 1. Sampling sites. Circles show the sampling stations, triangle indicates the Italian station Terra Nova Bay.

in Italy. The storage temperatures were -150°C for the biotic matrices and -30°C or -80°C for the abiotic samples. The storage procedure was tested by Capodaglio *et al.* (1995), by analysing a number of samples directly after collection as well as after storage. The values showed a good agreement, proving the absence of systematic errors due to frozen storage. Moreover, the systematic monitoring of storage quality is an absolute priority of the Specimen Bank (Soggia *et al.* 2000, 2001).

Benthic organisms were collected by SCUBA at a depth ranging from 20 to 35 m. Representative epifaunal organisms collected include the red algae *Iridaea cordata* (Turner) Bory de Saint Vincent and *Phyllophora antarctica* (Rhodophyta) Gepp, the bivalve molluscs *Laternula elliptica* (King & Broderip) and *Adamussium colbecki* Smith, the sea urchin *Sterechinus neumayeri* (Meissner), the sea star *Odontaster validus* (Koehler), and the nemertine worm, *Parborlasia corrugatus* (McIntosh). Fish specimens of *Trematomus bernacchii* Boulenger were caught with a trammel net.

Surface marine sediments were collected by a stainless steel grab, or by SCUBA, and stored in acid clean polycarbonate containers.

In the presence of pack ice, sea-water was collected through a hole drilled by an ice corer (Duncan, UK, Model BTC). When pack ice was absent, the sampling was carried out from aboard an oceanographic vessel. In each case, the sampling bottles were deployed on Kevlar hydroline and tripped by a Teflon messenger. Sea water was collected at different depths using 20 l GO-FLO Teflon bottles (General Oceanics). Immediately after sampling, the bottles were taken to the Class 100 laboratory, where sea-water was filtered under nitrogen pressure using Teflon apparatus. All the containers and materials coming into contact with sea-water were cleaned with 0.1N hydrochloric acid (suprapure grade quality, Merck). Membrane filters were washed with 0.1N hydrochloric acid (suprapure grade quality, Merck), dried under a laminar flux hood and weighed with an accuracy of ± 0.00001 g (Sartorius BP 210 D).

Contamination levels introduced by these appliances were checked by soaking in ultrapure water (Milli-Q water, Millipore) for 12 h and measuring the release of trace metals by inductively coupled plasma mass spectrometry and electrothermal atomization atomic absorption spectrometry (ETAAS). No significant lead contamination was observed. Filters and filtered sea-water were stored at -30°C until analysis.

The pack ice was collected by means of a manually-driven titanium corer, having an inner diameter of 10 cm and stored at -30°C . In order to reduce the contamination, an inner core of about 2 cm in diameter was subsampled by means of a special tool made of a Teflon-covered titanium corer, mounted on the mandrel of a drill. The concentration of lead in the inner part was found to be 3-fold lower than that in the external part. The sub-sampling was performed

under a laminar flux hood. The contamination due to the sub-sampling was evaluated by treating a piece of frozen ultrapure water, similarly. The found value corresponds to a blank value of $0.017 \pm 0.006 \mu\text{g Pb g}^{-1}$ SPM, which is negligible with respect to the whole analytical procedure blank ($1.0 \pm 0.3 \mu\text{g Pb g}^{-1}$ SPM). The amount of lead added during the mechanical decontamination of the core section (23 pg for a sample mass of 224 g) is in good agreement with the data reported by Boutron *et al.* (1994).

Sea MicroLayer (SML) and Sub Surface Layer (SSL) samples were collected simultaneously using a Multiple Use Microlayer Sampler (MUMS) (Cincinelli *et al.* 2001). It collects SML by capillary through a rotating Pyrex glass drum collector. The material adsorbed on the drum surface is removed by a Mylar scraper. The collected liquid is carried to a clean Teflon bottle by a Teflon membrane pump. A probe connected with the onboard MUMS collector was used to collect subsurface water (-0.50 m). The collected samples were filtered in the same conditions as the seawater.

The aerosol was collected on cellulose filters by using a Grasbery-Andersen (PM10) High Volume Sampler, which collects all particles with a diameter of less than 10 μm . The sampler is equipped to control volumetric flow and timing; the air flow rate was $1.13 \text{ m}^3 \text{ min}^{-1}$, with an accuracy of 1%. The sampling periodicity was usually 10–15 days.

Sample preparation

Organisms were thawed, and their body length and weight measured. Whenever possible muscle, liver (or digestive gland), gills, and gonads were removed, weighed and lyophilized, using acid clean stainless steel apparatus. A subsample of homogenized and freeze-dried organisms was solubilized with concentrated nitric acid (suprapure grade quality, Merck), using a microwave digestion system (CEM DS 2000).

Sediment samples were separated into two different granulometric fractions (between 63 and 2000 μm and lower than 63 μm), using a stainless steel sieve; both fractions were dried in oven at 40°C, homogenized and solubilized with concentrated nitric, hydrochloric and fluoridric acids (suprapure grade quality, Merck), using a microwave digestion system (CEM DS 2000). On the other hand, the metal fraction bound to the carbonates and organic labile materials was extracted with acetic acid (0.11 M; pH 2.8), according to the first step of a procedure for metal solid speciation (Ianni *et al.* 2000).

Pack ice cores were melted under a laminar flux hood at room temperature and filtered, according to the same procedure described above.

Suspended particulate matter of microlayer, subsurface layer, aerosol and pack ice were solubilised with concentrated nitric acid (suprapure grade quality, Merck), using a microwave digestion system.

Sample analysis

Determination of lead was carried out using a Varian (Springvale, Australia) SpectrAA 300Z atomic absorption spectrometer equipped with Zeeman-effect background corrector and GTA 96 graphite atomizer. Pyrolytic graphite coated tubes were used. Samples were delivered to the furnace using a Varian PSC 56 programmable sample changer, after storing in acid-washed polypropylene cups.

Scanning electron micrographs were obtained using a Scanning Electron Microscope (LEICA Cambridge Stereoscan 440).

Validation of analytical accuracy

The study of trace metals in remote environments, especially lead, has been fraught with measurement problems arising from inadvertent contamination of samples during sampling collection, handling and analysis. The rigorous control and reduction of any source of contamination is hence of paramount importance. Most of the precautions taken during the sampling and storage steps to avoid or reduce lead contamination have been described above. Briefly, these included accurate choice and cleaning of all the materials coming into contact with samples, care taken by the operators during the sampling and critical evaluation of the blanks. The blank values of the analytical procedures are reported in Table I. The values are low enough to allow the lead to be determined accurately in these samples.

The accuracy of analytical data was further tested by analysing certified reference materials (CRMs). Since several types of matrices were considered, quite a large number of CRMs was used: TORT-2 (Lobster Hepatopancreas Reference Material for Trace Metals, National Research Council, Canada), DORM-2 (Dogfish Muscle and Liver Certified Reference Materials for Trace Metals by National Research Council, Canada), CRM 414 (Plankton Certified Reference Materials for Trace Metals by Community Bureau of Reference, Commission of the European Community), MURST-ISS-A1 (Antarctic Marine Sediment Certified for Trace Elements by PNRA - National Institute of Health, Italy), MESS-2 (Marine Sediment Reference Materials for Trace Elements by National Research Council Canada), CRM 701 (Certified Sediment following a sequential extraction procedure by Community

Table I. Analytical blanks and detection limit.

Matrix	Blank concentration ($\mu\text{g g}^{-1}$)	Detection limit (3σ) ($\mu\text{g g}^{-1}$)
Aerosol	6.1 ± 0.8	2.4
Organisms	0.020 ± 0.004	0.013
Marine sediment (total)	1.2 ± 0.3	0.9
Marine sediment (labile)	0.04 ± 0.02	0.06
Suspended particulate matter	1.0 ± 0.3	0.9

Table II. Precision and accuracy of analytical methods.

Certified reference material	Pb concentration ($\mu\text{g g}^{-1}$)	
	Found	Certified
TORT 2	0.34 ± 0.03	0.35 ± 0.13
DORM 2	0.067 ± 0.014	0.065 ± 0.007
CRM 414	3.53 ± 0.54	3.97 ± 0.19
MESS 2	20.7 ± 2.9	21.9 ± 1.2
MURST-ISS-A1	19.8 ± 2.0	21.9 ± 2.9
CRM 701	3.58 ± 0.3	3.18 ± 0.21

Bureau of Reference, Commission of the European Community). The results are reported in Table II. A satisfactory agreement between the found and certified values may be noted, proving the accuracy of the analytical procedures.

Results

Lead concentration in abiotic and biotic matrices are reported in Tables III & IV, respectively.

The total concentration as well as the metal labile fraction of lead associated with the marine sediment were determined in eight samples, collected in the coastal area inside the Terra Nova Bay, after fractionation into two particle size classes (between 63 and 2000 μm and lower than 63 μm). The mean values were $23.3 \pm 5.3 \mu\text{g g}^{-1}$ and $23.4 \pm 5.7 \mu\text{g g}^{-1}$ for the total concentration and $0.13 \pm 0.06 \mu\text{g g}^{-1}$ and $0.94 \pm 0.32 \mu\text{g g}^{-1}$ for the labile fraction, for the coarser and finer particle size, respectively. The very low mean values of lead in the labile fraction of the

Table III. Lead concentration in abiotic samples collected in Terra Nova Bay.

Sample	SPM (mg l^{-1})	Lead concentration
Aerosol	$16.0 \pm 5.2 \mu\text{g g}^{-1}$	$0.010 \pm 0.003 \text{ ng m}^{-3}$
Pack ice		
0–60 cm	0.89	$23.2 \pm 9.0 \mu\text{g Pb g}^{-1}$ SPM
60–130 cm	1.24	$14.8 \pm 4.8 \mu\text{g Pb g}^{-1}$ SPM
130–170 cm	1.19	$13.6 \pm 3.2 \mu\text{g Pb g}^{-1}$ SPM
170–220 cm	2.25	$11.9 \pm 3.7 \mu\text{g Pb g}^{-1}$ SPM
220–240 cm	22.65	$5.3 \pm 1.9 \mu\text{g Pb g}^{-1}$ SPM
mean value	2.63	$10.0 \pm 3.2 \mu\text{g Pb g}^{-1}$ SPM
Marine sediment		
Total		
2000–63 mm		$23.3 \pm 5.3 \mu\text{g g}^{-1}$
< 63 mm		$23.4 \pm 5.7 \mu\text{g g}^{-1}$
Labile fraction:		
2000–63 mm		$0.13 \pm 0.06 \mu\text{g g}^{-1}$
< 63 mm		$0.94 \pm 0.32 \mu\text{g g}^{-1}$
Marine microlayer 1.11		$18.3 \pm 2.5 \mu\text{g Pb g}^{-1}$ SPM
Sea water		
0.5 m	1.43	$10.0 \pm 2.1 \mu\text{g Pb g}^{-1}$ SPM
0–50 m	1.20	$15.4 \pm 3.5 \mu\text{g Pb g}^{-1}$ SPM
300 m	0.63	$25.8 \pm 5.1 \mu\text{g Pb g}^{-1}$ SPM

Table IV. Lead concentration in pooled organisms collected in Terra Nova Bay (detection limit = $0.013 \mu\text{g g}^{-1}$ dw)

Sample	No.	Organ or tissue	Lead concentration ($\mu\text{g g}^{-1}$ dw)
<i>Iridaea cordata</i>	2	lamina	0.25 ± 0.07
<i>Phyllophora antarctica</i>	1	lamina	< d.l.
<i>Sterechinus neumayeri</i>	10	soft tissue	0.42 ± 0.19
		gonad	0.18 ± 0.16
<i>Adamussium colbecki</i>	20	muscle	0.38 ± 0.42
		gonad	< d.l.
		digestive gland	0.11 ± 0.13
		gills	0.41 ± 0.40
		shell	0.18 ± 0.23
<i>Laternula elliptica</i>	6	muscle	1.56 ± 0.09
		gonad	0.87 ± 0.18
		digestive gland	2.43 ± 1.21
		shell	< d.l.
<i>Parborlasia corrugatus</i>	3	whole	0.25 ± 0.29
<i>Odontaster validus</i>	12	arms	0.27 ± 0.11
		pyloric caeca	0.41 ± 0.17
		gonad	0.33 ± 0.24
<i>Trematomus bernacchii</i>	39	muscle	0.028 ± 0.010
		liver	< d.l.
		spleen	< d.l.
		gonad	0.030 ± 0.006
		bone	0.22 ± 0.06

sediments are in good agreement with those reported for the same area in a previous work (Giordano *et al.* 1999).

Lead associated with the particulate matter included in pack ice was determined in five sections of four cores. Data reported in Table III are expressed as metal concentration both in the SPM (in $\mu\text{g Pb g}^{-1}$ SPM, in order to estimate the SPM composition) and in the corresponding sample volume (in pM, which is more significant to evaluate the metal distribution in the water column). The values found along the pack ice core ranged from 78.0 to 129.5 pM in the section at the interface with sea-water, where the particulate lead concentration is significantly higher due to the elevated SPM amount. These values are higher than the concentrations found in snow and old ice collected in remote areas (4.8–48.3 pM according to Planchon *et al.* 2002 and Boutron & Patterson 1983), highlighting the difference between the continental and marine ice. Indeed, the values are in good agreement with the dissolved lead concentration found in sea-water (24–114 pM, according to

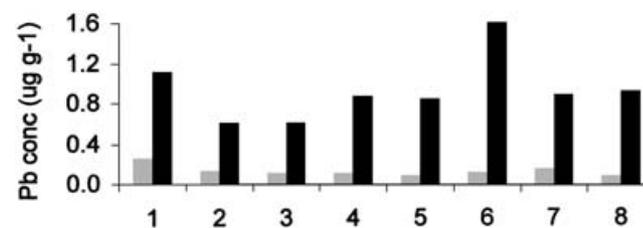


Fig. 2. Lead concentration in the labile fraction of sediments. Particle size: grey = between 63 and 2000 μm , black = lower than 63 μm (mean values with standard deviations of 8–15%).

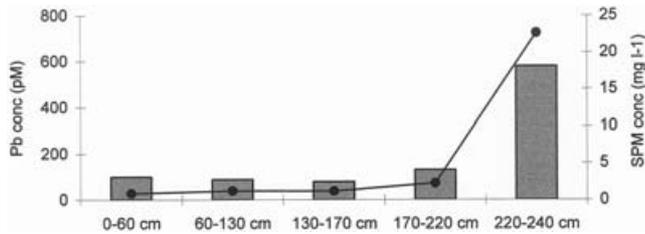


Fig. 3. Concentrations of suspended particulate matter and lead associated with the particulate matter in pack ice core (0–60, 60 cm from the core top, and so on) and underlying sea-water. Grey = Pb [pM], —●— = SPM [mg l⁻¹]

Capodaglio *et al.* 2001) and with the particulate lead mean concentration in the water-column (0–50 m, 89.2 pM).

Lead concentration in the aerosol corresponds to 0.010 ± 0.003 ng m⁻³, in good agreement with the concentration ranges reported for Antarctic areas by Heumann (1993).

Concerning the biotic matrices, the concentrations of the

species investigated, ranged from values below the limit of detection ($0.013 \mu\text{g g}^{-1}$ d.w.) to $2.43 \mu\text{g g}^{-1}$ d.w., with an average of $0.39 \mu\text{g g}^{-1}$ d.w.

Discussion

The very low mean values of lead in the labile fraction would suggest that the area investigated has no human impact from the activity of the Italian research station. In fact, it is known that metals having an anthropogenic origin are mainly obtained in the first sequential-selective extractions (Rubio *et al.* 1991), and in our case the labile fraction represents only 0.6% and 4.0% of the total concentration for the two particle size classes. For example, in industrialized areas like the Mediterranean Sea, the fraction of lead bound to the labile phase is one order of magnitude higher than that found in Terra Nova Bay (Ianni *et al.* 2000). Finally, a preferred association of lead with the finer particles may be noted for the labile fraction of all the

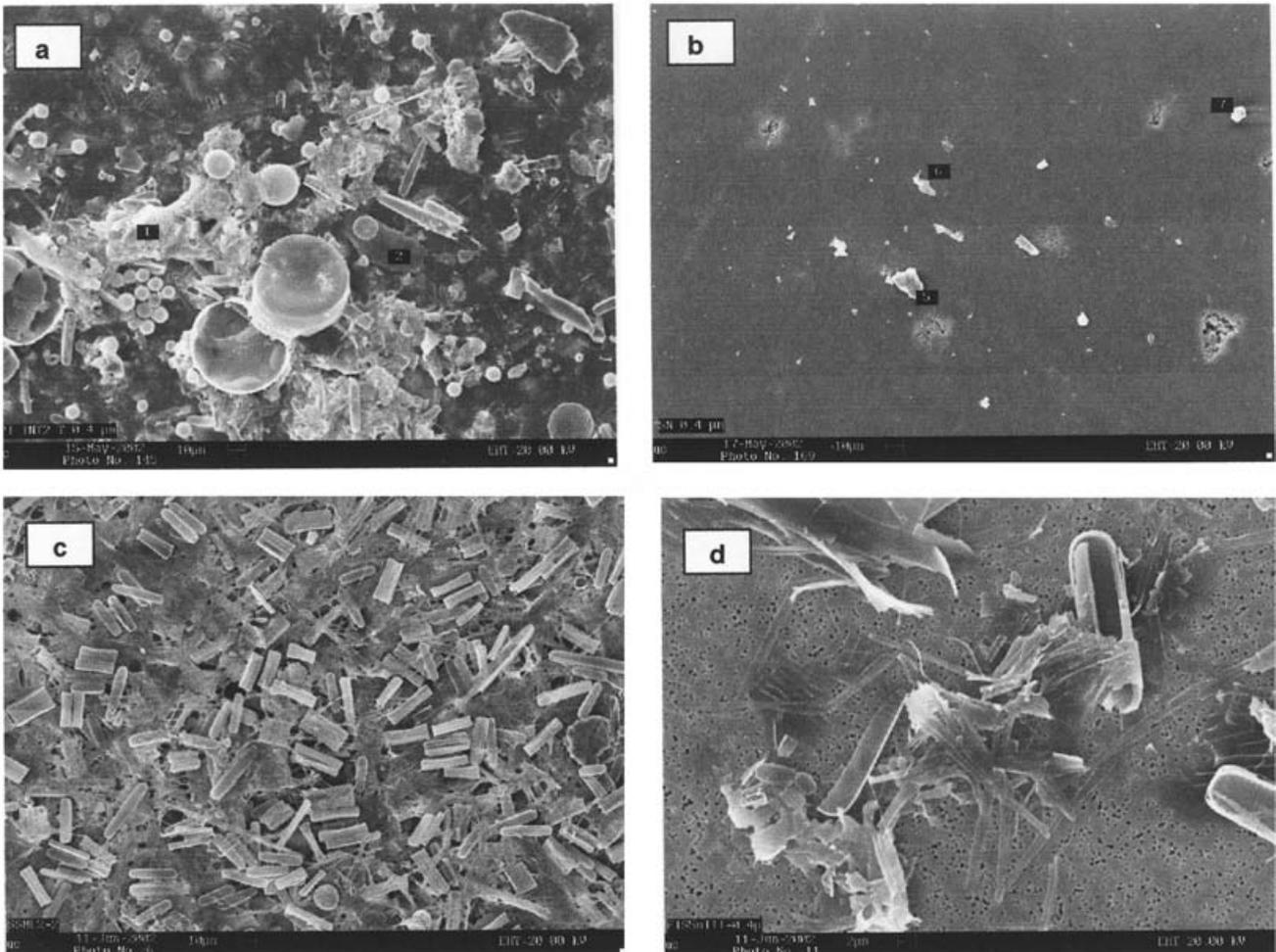


Fig. 4. SEM images at 5000 enlargement of the particulate matter in **a.** pack ice, **b.** recent snow, **c.** marine microlayer, **d.** sea-water. Particulate matter was filtered on a polycarbonate filter with porosity $0.4 \mu\text{m}$; particulate matter in **a,** **c** & **d** is almost characterized by phytoplankton such as diatoms and/or dinoflagellates, instead particulate matter in recent snow (**b**) is composed of terrigenous materials such as quartz.

samples (Fig. 2), while no difference was observed between the total metal concentrations in the particle size classes considered.

The particulate lead concentrations along the pack ice core, which are of the same order of magnitude as in the sea-water, indicate that the release of SPM during ice melting is a significant process by which the metal enters the water column. The result is in agreement with previous investigations on trace metal distribution in the same area (Grotti *et al.* 2001, Frache *et al.* 2001). By analysing the lead distribution along the pack ice core (Fig. 3), quite a homogeneous profile may be noted, except for the section at the sea-water interface, where the SPM concentration is one order of magnitude higher than that in the other core sections.

SEM investigation of SPM included in the pack ice revealed that it is almost entirely composed of biogenic materials, algae and plankton (Fig. 4a). Whereas, the particulate matter included in the snow collected on the pack ice surface is entirely composed of inorganic particles (Fig. 4b), indicating a probable input of lead from the continental land through wet deposition.

The mean particulate lead concentrations in the aerosol and marine microlayer were $16.0 \mu\text{g g}^{-1}$ and $18.3 \mu\text{g Pb g}^{-1}$ SPM, respectively. These values are comparable with the particulate lead mean concentration in sea-water ($10.0\text{--}25.8 \mu\text{g Pb g}^{-1}$ SPM) and marine sediments ($19.3\text{--}29.0 \mu\text{g g}^{-1}$). Therefore, it can be supposed that particulate lead enters the water column through different paths: release from the pack ice during its melting, input from the continental land through the wet deposition and transport by aerosol and marine microlayer.

In the biotic matrices the phytoplankton is often dominated by diatoms and/or dinoflagellates. These same taxa characterise the particulate matter both in pack ice and sea-water microlayer and column (Fig. 4). The analysis of eight species of sea organisms showed similar values (Table IV) for autotrophic organisms, that take in dissolved metals directly from the sea-water, and heterotrophic organisms with different feeding behaviours (filter-feeding, herbivorous, detritivorous and carnivorous) and are situated in upper trophic levels. The bivalve *Laternula elliptica* shows higher values of lead than the other benthic invertebrates considered (Fig. 5). The values in this species are higher in the digestive gland ($2.43 \pm 1.21 \mu\text{g g}^{-1}$) than in

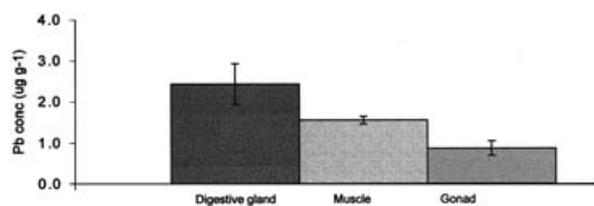


Fig. 5. Mean concentration of Pb ($\mu\text{g g}^{-1}$ d.w.) in organs of *Laternula elliptica*.

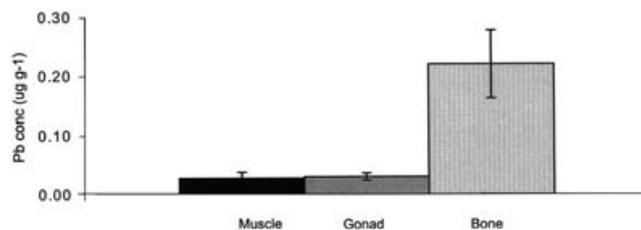


Fig. 6. Mean concentration of Pb ($\mu\text{g g}^{-1}$ d.w.) in organs of *Trematomus bernacchii*.

the other tissues. Data for the fish, *Trematomus bernacchii*, show higher values of Pb in bone ($0.22 \pm 0.06 \mu\text{g g}^{-1}$) than in other organs analysed (Fig. 6), especially if compared with levels of Pb in muscle ($0.028 \pm 0.010 \mu\text{g g}^{-1}$) and gonad ($0.030 \pm 0.006 \mu\text{g g}^{-1}$).

Lead concentration data obtained for biotic matrices were further analysed with the aim of finding useful biological species to be used as biomonitors, in order to establish temporal variations in the bioavailability of heavy metals in this marine environment. Numerous species of bivalves are used all around the world to biomonitor heavy metals in the coastal marine ecosystem. Such biomonitors are able to accumulate and concentrate trace metals in their tissues, with a simple correlation between metal concentration in tissues and average environmental bioavailable metal concentration. Moreover, typical biomonitors are sedentary, abundant, long lived, large and available for sampling throughout the year (Ostapczuk *et al.* 1997). *Laternula elliptica* possesses all these characteristics and the data found in Terra Nova Bay can be considered unaffected by human activities, because no traces of Pb contamination by man-made activities were found in the marine environment. This species of bivalve lives buried in the sediment and its large siphon cannot be fully retracted into its shell. Its metal content is believed to be influenced by the concentration of metal in the surrounding environment. Therefore, we propose developing the use of this bivalve as a biomonitor of lead levels in the marine ecosystem of Terra Nova Bay, using in particular, its digestive gland as the target tissue. Together with this species of mollusc, we have identified another useful biomonitor of this area, in the bone and muscle tissues of the benthic fish *Trematomus bernacchii*. This fish can give us information about Pb present in other compartments of this coastal marine ecosystem because of its feeding behaviour and ecology of fishes. It is known that low levels of lead in fish muscle normally indicate that no artificial contamination has occurred (Zauke *et al.* 1999), so the level of Pb in *Trematomus bernacchii* muscle might be used to biomonitor this metal in the coastal marine environment of Terra Nova Bay. Fish can absorb the bioavailable metal directly from the environment via the gills or the skin or through the ingestion of water and food. Metals in fish are then transported by the bloodstream to the various organs and tissues where it is accumulated, and lead

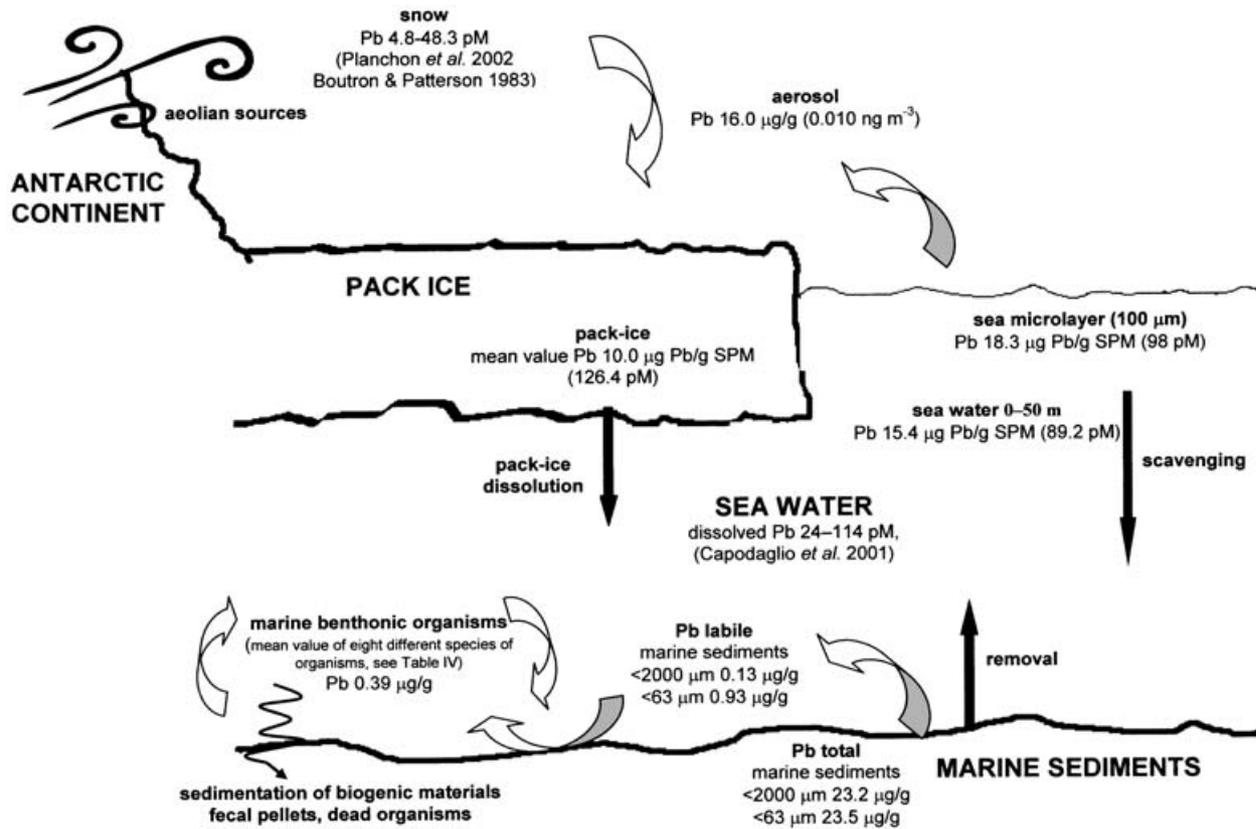


Fig. 7. Proposed model for biogeochemical cycle of Pb in a coastal marine area in Terra Nova Bay (Ross Sea, Antarctica).

is normally accumulated much more in fish bone, liver and gills than in muscle tissue (Gbern 2001). The nototheniid fish, *Trematomus bernacchii*, is a benthos feeder on polychaetes, epibenthic crustaceans, bivalves, echinoderms and lives about ten years. It is widely distributed off the coast of Victoria Land. It is quite sedentary and its feeding habits and biological cycle are well known, making it suitable for monitoring the concentration of Pb in this coastal ecosystem. Moreover, *Trematomus bernacchii* is being used as a bioindicator organism for a biomarker analysis by another research programme operating in Terra Nova Bay (Jimenez *et al.* 1999).

In conclusion, the biogeochemical cycle of lead in the marine coastal environment of Terra Nova Bay has been investigated considering a large number of abiotic and biotic matrices. The results are summarized in Fig. 7. The study of solid speciation of sediment allowed us to establish that this site is not influenced by human activity and is hence suitable to examine natural processes. The concentration values found in the suspended particulate matter of pack ice core, aerosol, marine microlayer and sea-water as well as the SPM morphology, investigated by SEM, seem to support the hypothesis that particulate lead is transferred to the water column through different mechanisms:

- i) release of SPM from the pack ice during its melting,
- ii) input from the continental land through the wet deposition,
- iii) transport by aerosol and marine microlayer.

Concerning the biotic matrices, no specific trend was observed. The analysis of concentration data both in the whole organism and in some target organ allowed us to find two biomonitors organisms for this coastal ecosystem in *Laternula elliptica* (particularly its digestive gland) and in *Trematomus bernacchii* (particularly the bone).

Acknowledgements

This study was performed as part of the Italian “National Program for Research in Antarctica (PNRA: Programma Nazionale di Ricerche in Antartide) and was financially supported by ENEA through a joint research programme. We thank the referees, especially Prof P.S. Rainbow, whose comments helped improve this paper.

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