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^{210}Polonium and ^{210}lead content of marine birds from Southeastern Brazil

José Marcus Godoy [a,b,*], Salvatore Siciliano [c], Zenildo Lara de Carvalho [b], Davi C. Tavares [d], Jaílson Fulgencio de Moura [c], Maria Luiza D.P. Godoy [b]

[a] Instituto de Radioproteção e Dosimetria (IRD), Caixa Postal 37750, Barra da Tijuca, 22642-970 Rio de Janeiro, Brazil
[b] Departamento de Química, Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), Rua Marquês de São Vicente 225, 22453-900 Rio de Janeiro, Brazil
[c] Escola Nacional de Saúde Pública, FIOCRUZ, Dept° de Endemias, Grupo de Estudos de Mamíferos Marinhos da Região dos Lagos (GEMM-Lagos), Rua Leopoldo Bulhões, 1480–6° andar, Manguinhos, Rio de Janeiro, RJ 21410-210, Brazil
[d] Universidade Estadual do Norte Fluminense-UENF, CBB, Laboratório de Ciências Ambientais, Campos dos Goytacazes, RJ 28013-602, Brazil

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ABSTRACT

In this study, we report the ^{210}Po and ^{210}Pb concentrations of bone, muscle and liver samples that were obtained from twelve different marine bird species stranded on beaches in the central–north region of Rio de Janeiro State. Both radionuclides were highly concentrated in the liver samples; however, the lowest mean ^{210}Po/^{210}Pb activity ratio (1.3) was observed in bones compared with liver and muscle (16.8 and 13.8, respectively). Among the species that were studied, *Fregata magnificens*, with a diet based exclusively on fish, had the lowest ^{210}Pb and ^{210}Po concentrations and the lowest ^{210}Po/^{210}Pb activity ratio. The ^{210}Po concentrations in *Puffinus* spp. liver samples followed a log-normal distribution, with a geometric mean of 300 Bq kg$^{-1}{}_{wet\ weight}$. Only two references pertaining to ^{210}Po in marine birds were found in a Web of Science search of the literature, and each study reported a different concentration value. The values determined in this experiment are consistent with those in one of the previous studies, which also included one of the species studied in this work. No values for ^{210}Pb in marine birds have been published previously.

1. Introduction

The 'Grupo de Estudos de Mamíferos Marinhos da Região dos Lagos' (GEMM-Lagos; the 'Lagos Region Study Group on Marine Mammals') regularly patrols approximately 250 km of the central-northern region of the Rio de Janeiro State coast (between 21°18′S and 23°S) in search of strandings. Since March 1999, the GEMM-Lagos has maintained a regional reporting network and database of marine animal strandings, which includes information on dead beach-cast marine birds. In response to the strandings, post-mortem examinations and scientific sampling are performed on a regular basis. The stranding date, location, gender, total body length and possible cause of death are recorded (Siciliano et al., 2011).

Basic information about the species studied during this work is presented in Table 1 (Carboneras, 1992; Onley and Scofield, 2007; Sick, 1997; Shirihai, 2008). The set of analyzed samples includes information about small birds, such as *Pterodroma mollis mollis*, and larger birds, such as *Fregata magnificens*; birds living in the coastal zone and in the pelagic region; and both migratory and non-migratory species.

Although marine birds are considered top predators, data on the ^{210}Po concentrations in marine birds are very scarce. In fact, only two references were found in a search of the Web of Science database (Noshkin et al., 1994; Skwarzec and Fabisiak, 2007). Additional data on ^{210}Po in seabirds were obtained from Gwynn et al. (2010), published in a Nordic Nuclear Safety Research report.

Skwarzec and Fabisiak (2007) reported that ^{210}Po was found primarily in skeleton, feathers and liver. As observed for other heavy metals (Scheuhammer, 1987), ^{210}Po in feathers is predominantly found to be adsorbed rather than having been built into the feather structure. Similar difficulties in describing ^{210}Po in feathers were reported by Gwynn et al. (2010), who observed no clear relationship between ^{210}Po concentrations in muscle and feathers. Additionally, 40–60% of the polonium content was removed after treatment with acetone, leading to the conclusion that a potential association exists between this radionuclide and preen oil. According to Skwarzec and Fabisiak (2007), a detailed study of the measurements of ^{210}Po in feathers of two species of seabirds

* Corresponding author. Instituto de Radioproteção e Dosimetria (IRD), Caixa Postal 37750, Barra da Tijuca, 22642-970 Rio de Janeiro, Brazil.
E-mail address: jmgodoy@puc-rio.br (J.M. Godoy).

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Table 1
General information about the studied species.

Taxon	Common name	Total length (cm)	Food habits	Migratory status	Habitat
Sphenisciformes Sharpe, 1891					
Spheniscidae Bonaparte, 1831					
Spheniscus magellanicus	*Magellanic Penguin*	66–73	Fish (anchovy; sardine) and cephalopods	South Hemisphere	Coastal
Procellariiformes Fürbringer, 1888					
Diomedeidae Gray, 1840					
Thalassarche melanophris	*Black-browed Albatross*	80–96	Fish and krill. Eventually also eats cephalopods and jellyfish	South Hemisphere	Pelagic
Procellariidae Leach, 1820					
Pterodroma mollis mollis	*Soft-plumaged Petrel*	32–37	Cephalopods, crustaceans and fish caught at the sea surface	South Hemisphere	Pelagic
Procellaria aequinoctialis	*White-chinned Petrel*	51–58	Cephalopods, crustaceans and fish caught below 13 m	South Hemisphere	Pelagic
Calonectris borealis	*Cory's Shearwater*	44–46		North Hemisphere	Coastal/Pelagic
Puffinus gravis	*Greater Shearwater*	46–51	Cephalopods, crustaceans and fishes caught at the sea surface	South Hemisphere	Pelagic
Puffinus griseus	*Sooty Shearwater*	41–46	Cephalopods, crustaceans and small fishes	North Hemisphere	Pelagic
Puffinus puffinus	*Manx Shearwater*	30–35	Cephalopods, crustaceans and fish	North Hemisphere	Pelagic
Suliformes Sharpe, 1891					
Fregatidae Degland & Gerbe, 1867					
Fregata magnificens	*Magnificent Frigatebird*	92–96	Fish caught at the sea surface	Resident	Coastal
Sulidae Reichenbach, 1849					
Sula leucogaster	*Brown Booby*	69–83	Fish and cephalopods	Resident	Coastal
Charadriiformes					
Laridae Rafinesque, 1815					
Larus dominicanus	*Kelp Gull*	56–59	Onivorous (mainly fishes)	Resident	Coastal
Sternidae Vigors, 1825					
Sterna hirundo	*Common Tern*	28–34	Fish (also catches food in rivers and lagoons).	North Hemisphere	Coastal

showed that over 63% of polonium is connected with adsorbed forms of the element. They supposed that this part of polonium comes from the air. Only approximately 37% of polonium in feathers was built into their structure. These results lead to the conclusion that marine birds are an important link for polonium circulation in the environment. However, for use in pollution studies, feathers must be collected from the breasts of nesting birds (Burger, 2013); because fledglings are not able to fly very far (e.g., only within nearby vegetation), they exhibit contaminants that are acquired locally from food gathered by their parents (Burger, 1993).

The polonium content in muscle in seabirds depends on the birds' food habits; those eating fishes have lower ^{210}Po concentration in muscle than do those with a diet that includes items such as mollusks and crustaceans. According to Carvalho (2011), if fewer trophic links exist in the food chain, the ^{210}Po concentration will be higher in the top predator tissues.

Therefore, because the present study involved only adult birds, feathers were not included; only bone, liver and muscle samples were analyzed. In addition to ^{210}Po, ^{210}Pb was determined to calculate the decay corrected ^{210}Po concentration at the sampling collection time and the ^{210}Po/^{210}Pb ratio. These values were, in turn, used to determine the fraction of ^{210}Po directly incorporated by the animals and the fraction generated by the ^{210}Pb decay.

2. Materials and methods

Tissue samples from twelve different marine birds species were analyzed (Table 1). Fig. 1 shows the sampling collection region along the Rio de Janeiro coastal area. Based on the samples available, the present work was limited to muscle, liver and bone samples. The stage of decomposition was determined based on the Geraci and Lounsbury (2005) scale, where stage 1 represents a fresh sample and stage 5 indicates advanced decomposition. It is also possible to estimate a time of death based on the Geraci and Lounsbury (2005) scale: stage 1 $<$ 0.5 day, stage 2 $\approx$ 1.5 day, stage 3 $\approx$ 5 days and stage 4 $\approx$ 7 days. This application represents an adaptation of the Geraci and Lounsbury (2005) scale, which was originally developed for stranded marine mammals.

To correct for the chemical yield and enable an accurate ^{210}Po determination, approximately 74 mBq/sample ^{208}Po spike was added to 1 g of liver and 5 g of muscle tissue or bone, and the sample was dissolved in *aqua regia* (3 HCl:1 HNO_3). The ^{208}Po spikes used are traceable to BIPM and were diluted according to the Radionuclides Metrology Section of the Institute for Radioprotection and Dosimetry (SEMRA/IRD). The resulting solution was slowly evaporated to dryness, and the residue was dissolved in 0.5 mol L^{-1} HCl. Polonium was spontaneously deposited onto silver discs in the presence of 0.50 g of hydroxylamine hydrochloride. The ^{210}Po and ^{208}Po alpha emissions were measured using a 450-mm^2 Ortec alpha spectrometer with a counting time of 1000 min. The accuracy and precision of the radiochemical method were evaluated using IAEA reference materials (IAEA-437, Mussel from Mediterranean Sea, and IAEA-384, Fangataufa Sediment) and estimated to be within 10%. The polonium yield in the analyzed samples of seabirds ranged from 53 to 94%, with a typical yield of 70–80%. The ^{210}Po concentration values are given with one standard deviation (SD). The detailed method and its validation were described by Godoy (1980).

The ^{210}Po values were decay-corrected to the sample collection day, which was well defined, and the correction for the assumed time of death amounted to only 2.5% for stage 3 samples and 3.4% for stage 4 samples. The ^{210}Po concentration on the sampling day was calculated using Equations (1) and (2) and represents the excess of ^{210}Po relative to ^{210}Pb. Based on this equation, when ^{210}Po$(t = 0)$ is zero, ^{210}Po and ^{210}Pb are in secular equilibrium:

$$^{210}\mathrm{Po} = \frac{I(^{210}\mathrm{Po})}{I(^{208}\mathrm{Po})}\cdot A(^{208}\mathrm{Po})\cdot e^{-0.000655\cdot t1}\cdot e^{0.0050\cdot t2} \quad (1)$$

$$^{210}\mathrm{Po}(t=0) = \left(^{210}\mathrm{Po} - {}^{210}\mathrm{Pb}*\left(1-e^{-0.0050\cdot t3}\right)\right)*e^{0.0050\cdot t3} \quad (2)$$