Ecotoxicology and Environmental Safety 104 (2014) 132–135

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Bioaccumulation of ^{210}Po in common gastropod and bivalve species from the northern Gulf

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ARTICLE INFO

Article history:
Received 28 December 2013
Received in revised form
24 February 2014
Accepted 26 February 2014
Available online 25 March 2014

Keywords:
Polonium
Circe
Marcia
Fulvia
Stomatella
Cerithium

ABSTRACT

This study sets the baseline for the concentration of the natural-series radionuclide polonium-210 in two species of gastropods and four species of bivalves that are common to the Northern Arabian/Persian Gulf. ^{210}Po is primarily absorbed from water and via ingestion of detrital material by gastropoda and bivalves. This concentrated ^{210}Po can then be passed along to the next trophic level of the marine food web. The lowest ^{210}Po concentration was measured in the gastropod *Stomatella auricular* (10.36–12.39 Bq kg^{-1} dry) and the highest in the bivalve *Marica marmorata* (193.51–215.60 Bq kg^{-1} dry). The measured concentration factor for these molluscs in the northern Gulf varied between 4.8 and 115×10^3, values very similar to the IAEA recommended value for bivalves and gastropods of 2×10^4.

1. Introduction

Polonium-210 is an alpha emitter in the ^{238}U series, with a 138-day half-life. ^{210}Po is present in almost all environmental matrixes, and the main source of ^{210}Po in the environment is ^{222}Rn exhalation from the ground. In addition ^{210}Po is supplied to sea water from atmospheric inputs and river runoff. ^{210}Po is taken up by marine biota via absorption, adsorption and ingestion constituting a large natural radiation dose that is received by marine organisms and human populations consuming seafood (Fowler, 2011; Stewart et al., 2005). In fact natural ^{210}Po is responsible for higher radiation doses to humans consuming marine products than is plutonium and other man-made radionuclides (Pentreath and Allington, 1988). Many marine organisms are capable of concentrating ^{210}Po in their tissues (Bowen and Dymond, 1955; Carvalho and Fowler, 1994; Fowler, 2011; Hameed et al., 1997; Lowman et al., 1971; Pentreath, 1985), leading to bioaccumulation of the radionuclide, resulting in a higher internal radiation dose to the organisms. Mussels being filter feeders ingest phytoplankton and particulate detrital material with a high degree of radionuclide association, and thus can act as an ideal biological indicator of radioactive pollution (Philips, 1980). These organisms often pass on elevated ^{210}Po concentrations to higher trophic levels therefore providing a large fraction of the total radiation exposure experienced by individuals via food chain transfer (Aarkrog et al., 1997; Al-Masri et al., 2000). The objective of this study was to acquire baseline data on the ^{210}Po concentrations in some common gastropods and bivalves, and to determine the bioaccumulation factors for these invertebrates. Six of the most commonly found gastropod and bivalve species in the northwestern Gulf were analyzed for ^{210}Po. Samples of these gastropods and bivalves were collected from six different locations in Kuwait territorial waters within northwestern Gulf during May–July 2013 (Fig. 1).

2. Study area

The study area includes the northwestern part of the Gulf including territorial waters of Kuwait and Saudi Arabia. The gulf is a semi-enclosed water body with limited freshwater inputs from northern rivers (Fig. 1).

3. Materials and methods

3.1. Sample collection and preparation

Fresh gastropod and bivalve samples were collected from six different coastal locations. Upon collection, the gastropod and bivalve samples were immediately transported in seawater to the laboratory. The samples were prepared for analysis in a radionuclide- and trace metal-clean laboratory at the Kuwait Institute for Scientific Research. Standard protocols for sample collection, preparation, and radionuclide determination were adopted from IAEA (1989). The soft tissues to be analyzed were removed from the shell. All of the samples analyzed were

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http://dx.doi.org/10.1016/j.ecoenv.2014.02.023
0147-6513

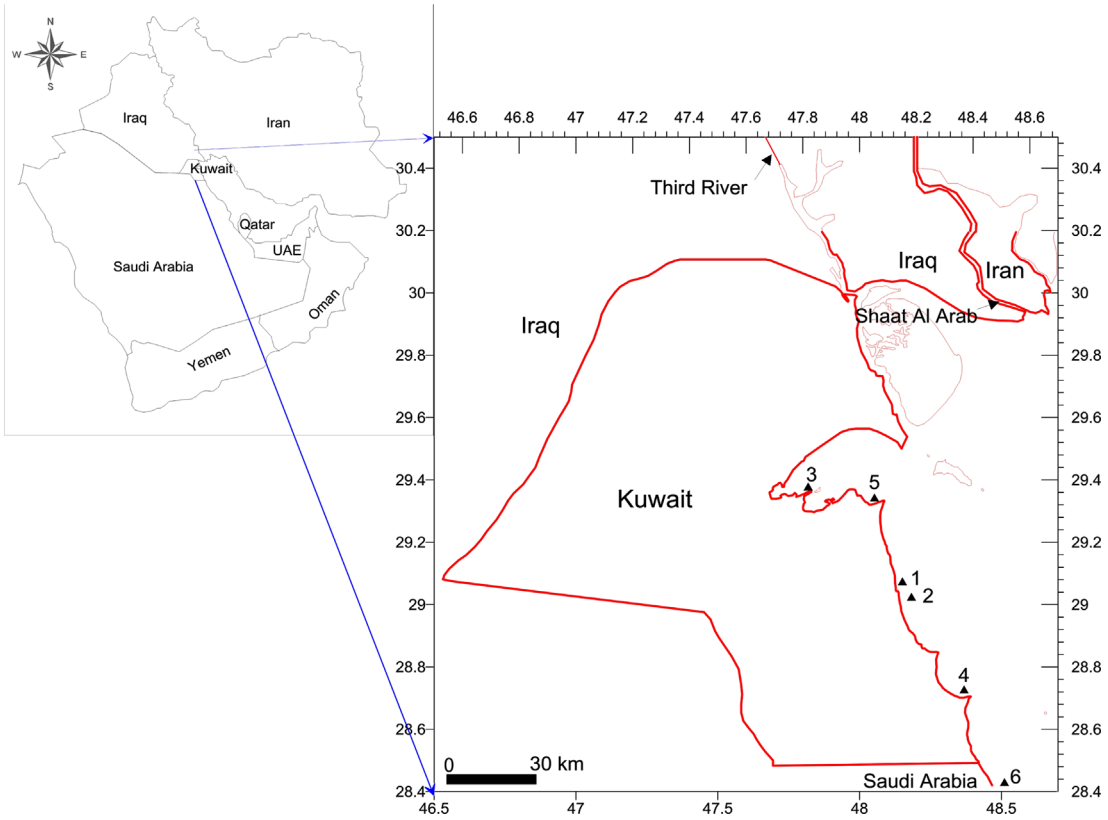

Fig. 1. Location of the six collection sites for gastropod and bivalve samples along the Kuwait–Saudi Arabian coast.

Table 1
Dry weight (%) of the gastropods and bivalves sampled from the northern Gulf.

Sample	Common name	Location[a]	Dry weight (%)
Gastropod			
Stomatella auricular	Snail	1	25.8
Cerithium scabridum	Snail	2	22.2
Bivalve			
Marica marmorata	Clam	3	24.7
Circe intermedia	Clam	4	24.2
Marcia opima	Clam	5	21.8
Fulvia fragile	Cockle	6	23.1

[a] See Fig. 1.

Table 2
^{210}Po concentration in gastropods and bivalves and concentration factors.

Sample	Location[a]	^{210}Po concentration (Bq kg^{-1} dry)	^{210}Po CF ($\times 10^3$)
Stomatella auricular	1	10.36–12.39	4.8–7.2
Cerithium scabridum	2	52.56–60.47	15.3–23.2
Marica marmorata	3	193.51–215.60	76.5–115.0
Circe intermedia	4	58.43–61.57	21.7–24.3
Marcia opima	5	47.29–49.88	14.7–15.9
Fulvia fragile	6	45.42–47.09	16.1–17.5

[a] See Fig. 1.

homogenized composites that had been prepared by bulking similar species of gastropods and bivalves obtained from a single location. The wet weight of the tissue samples were recorded and the samples were then dried at 105 °C, re-weighed, and pulverized. The percent dry weight for each sample species is shown in Table 1.

^{210}Po concentrations were determined using the standard silver disc technique (Flynn, 1968). Each sample was digested using concentrated nitric acid for at least 24 h; hydrogen peroxide was added to help oxidize the organic compounds. A clear solution was made and evaporated to near dryness. The residue obtained was dissolved in 100 ml of 0.5 M HCl. The solution was then heated on a magnetic stirrer to 80 °C, and the ^{210}Po was spontaneously plated onto a 0.64-mm-thick silver disc (1.2 cm dia) after iron reduction with ascorbic acid (Al-Masri et al., 2004; Fisenne, 1997). Reagent blanks were analyzed along with the samples. A Canberra twelve-chamber alpha spectrometry system with a passive ion-implanted silicon detector (active area of 300 mm^2, background count of 2.3 per day, and minimum depletion thickness of 90 μm) was used for the ^{210}Po determination. A 5.305-MeV energy line was used for quantification. The Apex software was used for calibration, QA/QC analyses and radionuclide counting. The samples were spiked with 100 μL of ^{209}Po tracer to ascertain the recovery and efficiency. Together with the gastropod and bivalve samples, the IAEA 414 – Fish Certified Reference Material was analyzed for ^{210}Po, and the massic activity of ^{210}Pb (^{210}Po) was found to vary between 1.86 and 2.21 Bq kg^{-1} with a median value of 2.04 Bq kg^{-1}.

Table 3
^{210}Po concentration in seawater.

Sample	^{210}Po concentration (mBq/L)	
	Location[a]	Concentration
Seawater	1	0.50 ± 0.06
Seawater	2	0.67 ± 0.09
Seawater	3	0.54 ± 0.08
Seawater	4	0.63 ± 0.02
Seawater	5	0.69 ± 0.01
Seawater	6	0.64 ± 0.02

[a] See Fig. 1 (mean concentration 0.62 mBq/L).

The dry-weight concentration of ^{210}Po in molluscs varied between 10.36 and 215.60 Bq kg^{-1} (Table 2). The lowest concentration was found in the gastropod *Stomatella auricular*, a value that is a factor of five lower than found in *Cerithium scabridum*, another common gastropod species in Kuwait waters. The difference in ^{210}Po concentration between these two species is significant ($P \leq 0.001$), a finding