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Baseline

Plutonium and cesium baseline concentrations in seawater from northern Arabian Gulf

S. Uddin*, A. Aba, M. Behbehani, A.N. Al-Ghadban, W. Al-Zekri, H. Al-Shammari

Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, Kuwait

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ABSTRACT

The Arabian Gulf is a semi-enclosed water body that has witnessed accelerated anthropogenic activity, in terms of commissioning of nuclear power plants, desalination facilities, oil refineries and extensive coastal development. Furthermore, three wars during the past three decades is a potential worry. This study presents the first plutonium baseline in seawater from the Northern Arabian Gulf. The $^{239+240}$Pu concentrations in seawater vary, between 2.9 and 4.9 mBq m^{-3}, a range that is comparable to other water masses at this latitude. The ^{238}Pu ranged between 0.04 and 0.05 mBq m^{-3} and the ^{137}Cs concentration between 1.04 and 1.18 Bq m^{-3}. The ratio of ^{238}Pu/$^{239+240}$Pu at all eight sampling stations was 0.01, while the ratio of $^{239+240}$Pu/^{137}Cs varied between 0.01 and 0.02. The presence of ^{137}Cs and $^{239+240}$Pu in seawater from this region can mainly be attributed to the global atmospheric deposition and fluvial transport. The seawater concentration of $^{239+240}$Pu is five order of magnitude lower than bottom sediments in the area.

The Arabian/Persian Gulf area is a semi-enclosed marine water body, which is an extension of the Indian Ocean. There is paucity of data on anthropogenic radionuclides from the Indian Ocean region in general (IAEA, 2005) and from Gulf in particular. The commissioning of the Bushehr Nuclear Power Plant (BNPP) across the Gulf and others being built in the United Arab Emirates (UAE) and Saudi Arabia along the Arabian Gulf catchment, to meet the increasing energy requirements, necessitates the establishment of the baseline levels of anthropogenic radionuclides in seawater to assess marine radionuclide concentration due to normal and fugitive wastewater release and accidental releases, if any. The data regarding the concentrations of anthropogenic radionuclides ^{137}Cs, ^{238}Pu, and $^{239+240}$Pu are important for assessing radiological contamination in the marine environment due to the substantial inventories and the ecological risk they may pose. The plutonium isotopes have a very long half-lives of 24,110 years for ^{239}Pu, 6561 years for ^{240}Pu and 87.7 years for ^{238}Pu and on the other hand half-life of ^{137}Cs is 30.17 years.

In order to undertake comprehensive assessment of the radionuclide concentration in the marine environment, a reliable baseline concentration is required, against which future changes in levels can be assessed. Previous studies showed that most of the Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs) are low in concentration (Uddin et al., 2015). This low concentration provides an opportunity to use them as indicators for detecting any systematic or accidental release into the marine environment.

The marine environment of the Gulf is critical for power and desalination, food stocks, and sea transportation. Kuwait's geographic location makes it vulnerable to receiving a wide variety of pollutants from around the Gulf due to the counterclockwise water circulation in this area (Al Ghadban et al., 2008). This paper presents 2016 levels of cesium and the first plutonium isotope concentrations in northern Arabian Gulf water's, filling in a data gap on plutonium concentration in seawater in this region. The concentrations of $^{239+240}$Pu and ^{137}Cs are compared with similar published information from other regions globally to see if there are any spatial variation in concentrations.

The seawater samples were collected from eight stations, that were selected based on a multi-criteria evaluation (Uddin et al., 2009) considering bathymetric conditions, hydrodynamic flow regimes, sediment transport, and accessibility (Fig. 1). The area is drained via the Shatt Al-Arab River, Euphrates and the Third River, that brings limited freshwater along with significant quantities of sediments (Uddin et al., 2011).

Water samples were collected at a depth of 1 m below the sea surface using 5-l Niskin bottles. The water samplers were manually lowered to the sampling depth and then opened. Once full, the samplers were raised and the seawater transferred into appropriate containers, acidified, and stored. From each location 100 l of seawater were transferred into four containers of 25 l each. The containers were labeled with date and time, the Global Positioning System (GPS) locations and sample IDs were noted. Then the containers were sealed.

* Corresponding author.
E-mail address: sdin@kisr.edu.kw (S. Uddin).

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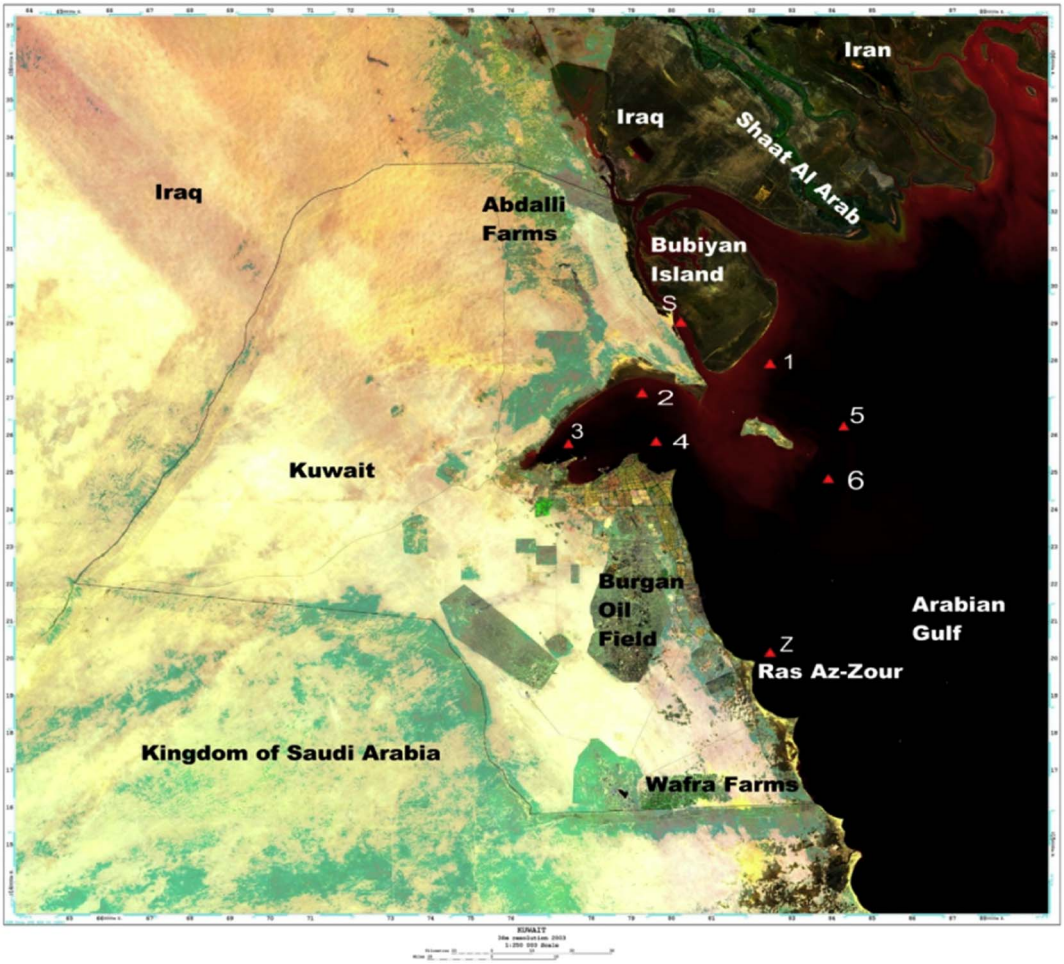

Fig. 1. Location of fixed monitoring stations.

Putonium samples were prepared using an anion exchange resin. Analytical grade Dowex 1 × 4 with 200-mesh bead size was used. Plutonium alpha sources were prepared by filtration on micro pore filters. Filters were counted for $4.5 * 10^5$ s using alpha spectrometry system equipped with large size Passivated Implanted Planar Silicon (PIPS) detector (450 mm^2). Each sample was spiked with 100 µl (47.66 mBq) of ^{236}Pu to assess the recovery. Blank and spiked samples were prepared and analyzed along with the test sample for quality control purposes.

The ^{137}Cs was determined using ammonium molybdophosphate (AMP) method (Aarkrog et al., 1983; Jefferies and Steele, 1989; Molero et al., 1993) from 100 l seawater sample. The recovery ranged between 93 and 100%. The solid precipitate of AMP weighs between 15.8 and 25 g. These samples were put in an appropriate calibrated geometry and counted on an ultra-low background gamma spectrometry system. The system was calibrated for each weight and geometry. The detection limit for a 20 g sample for 100,000 s counting was 2 mBq L^{-1}.

The freshwater needs of the Gulf region are largely meet by desalination of seawater. There are large desalination facilities installed along the western Gulf coast, with a cumulative desalination capacity exceeding $11 * 10^6$ m^3 d^{-1} (Lattemann and Höpner, 2008; Uddin et al., 2010). The concentrations of ^{137}Cs, ^{238}Pu and $^{239+240}Pu$ in seawater samples in the northern Arabian Gulf (NAG) along with a ratio of $^{238}Pu/^{239+240}Pu$ and $^{239+240}Pu/^{137}Cs$ are presented in Table 1. The $^{239+240}Pu$ concentration in Kuwait waters was in range of 2.9–4.9 mBq m^{-3} whereas the ^{238}Pu range was between 0.04 and 0.05 mBq m^{-3}. There are no datasets available for $^{239+240}Pu$ in the Gulf region. The last reported values of $^{239+240}Pu$ were part of

Table 1
^{137}Cs and $^{239+240}Pu$ concentrations in seawater (July 2016).

[a]Station	^{137}Cs (mBq m^{-3})	^{238}Pu (mBq m^{-3})	$^{239+240}Pu$ (mBq m^{-3})	$^{238}Pu/^{239+240}Pu$	$^{239+240}Pu/^{137}Cs$
1	1040 ± 80	0.05 ± 0.02	3.9 ± 0.6	0.01	0.01
2	1120 ± 90	0.05 ± 0.03	4.2 ± 0.5	0.01	0.01
3	1180 ± 80	0.05 ± 0.01	4.9 ± 0.3	0.01	0.02
4	1160 ± 90	0.05 ± 0.03	3.8 ± 0.5	0.01	0.02
5	1180 ± 80	0.04 ± 0.02	3.7 ± 0.5	0.01	0.01
6	1070 ± 80	0.04 ± 0.01	3.2 ± 0.4	0.01	0.02
S	1110 ± 80	0.05 ± 0.02	3.8 ± 0.6	0.01	0.01
Z	1050 ± 80	0.04 ± 0.01	2.9 ± 0.4	0.01	0.01
Range	1040–1180	0.04–0.05	2.9–4.9		

[a] See Fig. 1.