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Activity concentrations of ^{137}Caesium and ^{210}Polonium in seafood from fishing regions of New Zealand and the dose assessment for seafood consumers

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ABSTRACT

A study was undertaken to determine activity concentrations for ^{134}Caesium, ^{137}Caesium and ^{210}Polonium in New Zealand seafood, and establish if activity concentrations varied with respect to species/ecological niche and coastal region. Thirty seafood samples were obtained from six fishing regions of New Zealand along with a further six samples of two commercially important species (hoki and arrow squid) with well-defined fisheries. ^{134}Caesium was not detected in any sample. ^{137}Caesium was detected in 47% of samples, predominantly in pelagic fish species, with most activities at a trace level. Detections of ^{137}Caesium were evenly distributed across all regions. Activity concentrations were consistent with those expected from the oceanic inventory representing residual fallout from global nuclear testing. ^{210}Polonium was detected above the minimum detectable concentration in 33 (92%) of the analysed samples. Molluscs displayed significantly elevated activity concentrations relative to all other species groups. No significant regional variation in activity concentrations were determined. Two dose assessment models for high seafood consumers were undertaken. Dose contribution from ^{137}Caesium was minimal and far below the dose exemption limit of 1 mSv/year. Exposure to ^{210}Polonium was significant in high seafood consumers at 0.44–0.77 mSv/year (5th–95th percentile). ^{137}Caesium is concluded to be a valuable sentinel radionuclide for monitoring anthropogenic releases, such as global fallout and reactor releases, in the marine environment. ^{210}Polonium is of importance as a natural radionuclide sentinel due to its high contribution to dietary committed dose in seafood consumers.

1. Introduction

With 15,000 km of coastline and a 6.7 million km^2 Exclusive Economic Zone (EEZ), respectively the tenth and sixth largest of any country in the world, the marine environment is a significant and valuable resource to the New Zealand population (Coriolis, 2014). Seafood is collected and harvested on various scales, with a number of quota management systems in place and certain marine species having significant value in terms of trade. Seafood has importance to the New Zealand population as a source of nutrition and is consumed in considerable amounts by some sectors of the community (Tipa et al., 2010; Turner et al., 2005). Chemical contaminants in seafood can therefore lead to significant health burdens to the population and it is an important public health function to identify contaminants of concern and characterise their exposure.

The presence of radionuclides in the environment has been a significant global concern over the last half century. Following the recent accident at the Fukushima Daiichi Nuclear Power Plant, concern has been raised regarding the potential impact of radionuclide release into the Pacific Ocean on seafood, and consequently seafood consumers. Radionuclide monitoring of the marine environment surrounding New Zealand has been limited to date. A much greater focus has been placed on identifying and quantifying terrestrial fallout, through atmospheric dry and wet deposition and through monitoring milk powders from various regions of the country (Matthews, 1993).

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Global release of anthropogenic radionuclides from nuclear weapons testing has also contributed to the levels of radionuclides in the environment. Historically, for the southern hemisphere the most significant contributor to marine anthropogenic radionuclide activities has been nuclear weapons testing. Direct input of global fallout into the South Pacific Ocean (S 30°–60°) has been calculated at 25.8 PBq and 41.3 PBq for ^{90}Strontium (^{90}Sr) and ^{137}Caesium (^{137}Cs) respectively (IAEA, 2005). Oceanic anthropogenic radionuclide activities for four latitudinal boxes of the Pacific and Indian Ocean surrounding New Zealand were estimated for the start of the millennium as being 0.4–0.8 Bq/m^3 for ^{90}Sr and 0.6–1.4 Bq/m^3 for ^{137}Cs (Povinec et al., 2004).

New Zealand is not a nuclear power generating country and its position in the South Pacific places it a considerable distance from nuclear power generating facilities. The closest nuclear reactor is the research reactor (OPAL) at Lucas Heights, Sydney, Australia, approximately 2000 km distant. The closest commercial power reactors are Northern hemisphere plants in Taiwan, Japan and China, all further than 8000 km away, and the closest of the seven Southern hemisphere reactors, in Argentina, is approximately 10,000 km away.

With the input of a significant inventory of radionuclides from the Fukushima-Daiichi nuclear accident into the Northern Pacific, concerns have been raised in many countries surrounding the Pacific as to the potential increase in risks that may result. Modelling of the oceanic distribution suggests that ^{137}Cs from Fukushima-Daiichi will elevate Tasman Sea and South-West Pacific radionuclides by 0.01 Bq/m^3 by 2026, with continuing dispersion through the region over the subsequent 15 years (Nakano and Povinec, 2012).

Certain naturally occurring radioactive materials (NORM) including ^{238}Uranium (^{238}U) and its decay series are present in the marine environment through natural processes, such as terrestrial influx from atmospheric deposition or fluvial transport. As certain minerals can have higher abundances of NORM than are generally present in the crust, the extraction, processing and utilisation of these deposits can lead to concentration of NORM. This technological enhancement of NORM presents a risk for radionuclide entry into the environment from a number of industries which do not involve nuclear technology or nuclear fuel extraction (UNSCEAR, 2000).

A recent survey of radionuclides across the New Zealand diet sampled the muscle tissue of three fish species and three shellfish species for levels of anthropogenic and naturally occurring radionuclides (Pearson et al., in this issue). Of the radionuclides surveyed ^{137}Cs and ^{210}Polonium (^{210}Po) were found mainly in seafood species. ^{137}Cs activity was consistently detected in the higher trophic level fish but was absent in shellfish, while ^{210}Po showed greater variation, with considerably higher levels in shellfish and a roughly hundred-fold difference between tuna and lemonfish. ^{234}Uranium and ^{238}U activities were present in all samples, with significant activities in shellfish, but did not show any elevation in the finfish species over that of terrestrial food sources.

Given the range and magnitude of radionuclides present in seafood it was determined that monitoring of radionuclides in the seafood species may be necessary to provide a complete and accurate portrayal of dietary radionuclide exposure in the New Zealand population. Such an undertaking would complement the current milk monitoring program for terrestrial contamination. To support a seafood monitoring programme, additional research is necessary to better characterise the ranges, and any regional differences, of radionuclides in various New Zealand seafood species including through establishing suitable sentinel radionuclides for monitoring long term trends. The recorded ^{137}Cs and ^{210}Po activities in the analysed seafood samples highlight their suitability as marine monitoring sentinels. ^{137}Cs is a representative anthropogenic radionuclide, with properties such as, significant fission yield, high mobility in the environment and potential for uptake in the marine food chain. ^{210}Po is a marker for NORM sources and also displays the potential for high uptake levels in seafood species. Developing a dataset for ^{137}Cs and ^{210}Po in seafood will also provide a more refined estimate of ionising radiation exposure within seafood diets.

In this paper we detail a monitoring program for ^{137}Cs and ^{210}Po activities in seafood, outlining the sampling from different fishing regions of New Zealand and interpreting the results in the context of the expected behaviour of the radionuclides in the marine environment. Finally the outcome of a dose assessment models for seafood consumers is presented.

2. Materials and methods

2.1. Sampling methodology

The EEZ of New Zealand is divided into ten general fishery management regions (Fig. 1). In order to obtain a wide geographic distribution, the boundaries of these regions were utilised to classify samples as occurring from different sections of the New Zealand coastline. The sampling protocol was designed to capture a range of key seafood species and also analyse for differences between ecological niches.

In addition to targeting niche-specific species in each management region (see sampling protocol in Table 1), two species were specifically targeted as being important commercial catch species for New Zealand. These were the teleost fish, hoki (*Macruronus novaezelandiae*), and the cephalopod mollusc, arrow squid (*Nototodarus* spp. – *Nototodarus gouldi*, *Nototodarus sloanii*). These are deep water species with well-defined fishing stock areas.

All samples specified in the protocol were obtained through

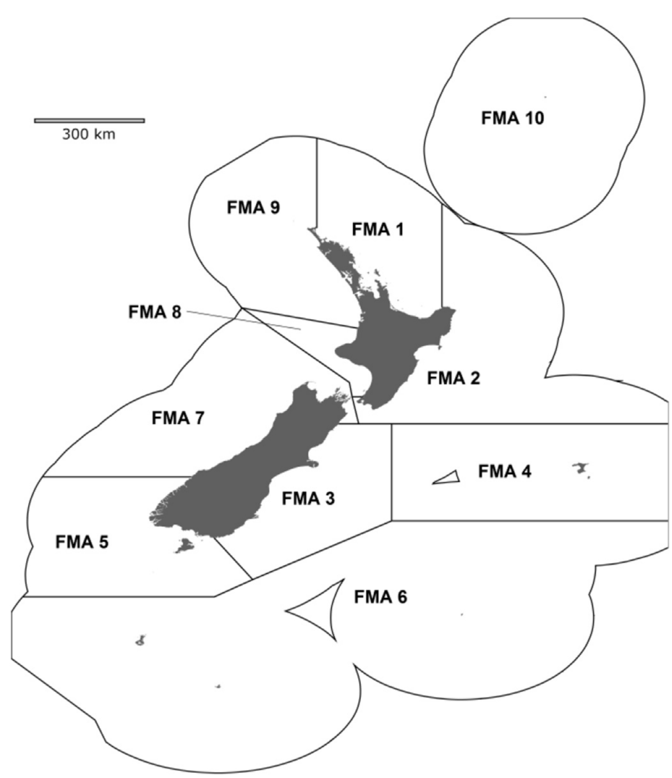

Fig. 1. Outline of New Zealand General Fisheries Management Areas (FMA) *(generated from NABIS (MPI))*.

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