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Natural and anthropogenic radionuclide activity concentrations in the New Zealand diet

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ABSTRACT

To support New Zealand's food safety monitoring regime, a survey was undertaken to establish radionuclide activity concentrations across the New Zealand diet. This survey was undertaken to better understand the radioactivity content of the modern diet and also to assess the suitability of the current use of milk as a sentinel for dietary radionuclide trends. Thirteen radionuclides were analysed in 40 common food commodities, including animal products, fruits, vegetables, cereal grains and seafood. Activity was detected for ^{137}Caesium, ^{90}Strontium and ^{131}Iodine. No other anthropogenic radionuclides were detected. Activity concentrations of the three natural radionuclides of Uranium and the daughter radionuclide ^{210}Polonium were detected in the majority of food sampled, with a large variation in magnitude. The maximum activity concentrations were detected in shellfish for all these radionuclides. Based on the established activity concentrations and ranges, the New Zealand diet contains activity concentrations of anthropogenic radionuclides far below the Codex Alimentarius guideline levels. Activity concentrations obtained for milk support its continued use as a sentinel for monitoring fallout radionuclides in terrestrial agriculture. The significant levels of natural and anthropogenic radionuclide activity concentrations detected in finfish and molluscs support undertaking further research to identify a suitable sentinel for New Zealand seafood monitoring.

1. Introduction

Dietary surveys are an invaluable source of data for undertaking risk assessments for public health. Such surveys enable concentrations of contaminants and the impact of reduction programs to be identified over a number of years. In New Zealand, dietary surveys have been undertaken over a number of decades; the most comprehensive is the New Zealand Total Diet Study which has been run seven times from 1974 to the latest in 2009 (Vannoort and Thomson, 2009). These surveys have quantified estimates of health risk for the New Zealand population through exposures to a range of agricultural chemicals and contaminants in the diet.

Assessing radionuclide contamination in the diet is an important consideration in modern food safety. Radionuclides can originate from a variety of sources and processes; either those occurring naturally, such as primordial or cosmogenic formation, or through human activities, such as release from nuclear weapons testing or accidents (UNSCEAR, 2000). Understanding the range of radionuclides in the diet and their respective activity concentrations is necessary to be able to quantify the risk of exposure. Characterising the current background activity of radionuclides in the diet makes it possible to better identify future contamination incidents and emerging long-term trends, and it enables possible mitigation before increasing levels of contamination become a significant health risk.

Radionuclide monitoring in New Zealand foods has focused on determining activity concentrations of ^{137}Caesium (^{137}Cs), and up until 2000, ^{90}Strontium (^{90}Sr) in milk powders (Matthews, 1993). These data have been used to estimate the contribution of nuclear testing fallout radionuclides to the diet. Radionuclide activity concentrations in milk have declined following their peak at an average of 33 Bq/kg ^{137}Cs and 5.5 Bq/kg ^{90}Sr in 1965. The most

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recent study of activity concentrations in milk, in 2010, reported ^{137}Cs levels of 0.4–0.8 Bq/kg dry weight (dw) (Hermanspahn, 2010). However, no comprehensive survey of the radionuclide activity concentrations in other food types in the New Zealand diet has been conducted. It is unknown if milk remains an appropriate sentinel for radionuclide activity concentrations in the New Zealand diet.

Following the Fukushima-Daiichi Nuclear Power Plant accident in March 2011, global awareness has focused on the entry of imported foods with elevated anthropogenic radionuclide activity concentrations into the diet. New Zealand has previously implemented targeted monitoring; for example to determine ^{90}Sr and ^{137}Cs levels in fish from the North Pacific following the marine release from Fukushima-Daiichi (MPI, 2013). This study identified activity ranges for ^{134}Cs of 1.45–2.23 Bq/kg and for ^{137}Cs of 1.93–3.23 Bq/kg in mackerel from Japan, with no detections in tuna from Japan and in mackerel from other North Pacific nations. However results from imported food monitoring have had to be interpreted in isolation as the current ranges of radionuclides in the full New Zealand diet have not been characterised.

The objective of this research was to establish current activity concentrations across a range of food types available to New Zealand consumers for a number of natural and anthropogenic radionuclides. This was a component of a wider programme of research that included examining inputs into the diet and assessing the ingested ionising radiation dose to the New Zealand public. Targeted radionuclides were selected based on several criteria such as those previously identified or suspected to be present in the New Zealand environment, and/or by reference to international regulatory limits established by Codex Alimentarius (CAC, 1993). Additionally where no occurrence data was available for a radionuclide in New Zealand prioritisation was made for inclusion based on the results from overseas dietary monitoring programmes such as the United States Food and Drug Administration total diet survey (US FDA, 2006) and the United Kingdom's Radioactivity in Food and the Environment reports (RIFE, 2013). Interpretation of levels and comparison to results from other countries provides a useful benchmark to establish the current radiological status of the New Zealand diet. Another objective was to assess the appropriateness of the current practice of using milk as a sentinel for radionuclide contamination of the New Zealand diet.

2. Materials and methods

2.1. Sample description

Forty foods were chosen for sampling (Table 1). The majority of foods were domestically produced. Approximately 25% were seasonally imported and exclusively imported foods. Foods were selected based on prominence in the diet as determined from the New Zealand Total Diet Study (Vannoort and Thomson, 2009). Other considerations such as potential for concentrating radionuclides and potential sentinels for specific types of agriculture or aquaculture were taken into account. For example bottled water was selected over tap water due to the potential for higher activity concentrations of naturally occurring radionuclides in bore and artesian sources (EFSA, 2009). The foods tested were classified as fruits, vegetables, cereal grains, animal products, seafood, beverages and other foods.

Samples were obtained from a range of local supermarkets and wholesalers in the Christchurch and Wellington areas of New Zealand, with the exception being wild pork samples, which were sourced from the North Canterbury area of New Zealand. Where possible, food samples were chosen from across important domestic production regions. For example wine samples were selected so as to cover important viticulture regions of New Zealand, and shellfish and salmon obtained from regions with aquaculture. Sampling was undertaken through the year of January 2013 to January 2014. Perishable samples were collected fresh during this period according to seasonal availability. Four samples of each food type were obtained. Pooled samples of fruit and vegetables consisted of 400–600 g of individual pieces. Meat and fish sample sizes were approximately 300 g and liquid samples were approximately 500–1000 ml. Cereal and miscellaneous foods were obtained pre-packed at various weights.

Samples were prepared by removing inedible components, for example peels, hulls, stones and shells. Non-liquid samples were then homogenised, prior to separation of portions for individual radiochemistry assays. Exceptions to this preparation were coffee which was freshly extracted, through an espresso machine, at a ratio of 1 g of beans to 10 ml water; and tea which for the beta and alpha emitter assays was prepared as the brewed drink at a ratio of 1 g of tea leaves to 100 ml water. All liquid samples, with the exception of olive oil, were acidified with 69% nitric acid to 0.1M to prevent sorption losses to container walls.

2.2. Gamma emitters

All food samples were screened for gamma emitting radionuclides using gamma spectroscopy. Samples were prepared in either a 400 ml cylindrical container or a 400–600 ml Marinelli beaker and analysed using CANBERRA high purity germanium (HPGe) semiconductor detectors. Samples were counted for a minimum of 172,000 s. All spectra were analysed using Genie 2000 software to derive activity levels for ^{40}Potassium (^{40}K), ^{131}Iodine (^{131}I), ^{134}Caesium (^{134}Cs) and ^{137}Cs. A proportion of the CANBERRA HPGe detectors were also calibrated to quantify activity levels of ^{60}Cobalt (^{60}Co) and ^{241}Americium (^{241}Am).

Table 1
Sampling regime for dietary survey of radionuclides sorted by food classes.

Fruits	Vegetables	Cereal grains	Animal products	Seafood	Beverages	Other
Apple (D)	Beans (D)	Breakfast cereal (M)	Beef steak(D)	Lemonfish (Rig shark) (D)	Beer (D)	Chocolate (M)
Banana (I)	Broccoli (D)	Flour (M)	Chicken breast(D)	Salmon (D)	Coffee (I)	Olive oil (M)
Kiwifruit(D)	Lettuce(D)	Oats, rolled (M)	Chicken egg(D)	Shellfish (D)	Tea (I)	Peanut (I)
Orange (M)	Mushrooms(D)	Pasta (I)	Honey(D)	Tuna (M)	Water, bottled (D)	Spice mix (I)
Peach (D)	Potato(D)	Rice (I)	Cow's milk (D)			
Strawberry (D)	Pumpkin(D)		Lamb's liver(D)			
Wine (D)	Sweetcorn (D)		Pork chop (D)			
	Tomato(D)		Wild pork(D)			

(D) Samples of New Zealand origin.
(I) Samples of imported origin.
(M) Samples of New Zealand and imported origin.