NRL
National Radiation Laboratory

Environmental Radioactivity in New Zealand and Rarotonga

Annual Report

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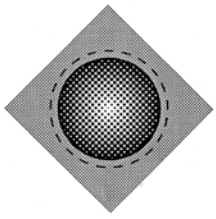
MINISTRY OF HEALTH
MANATŪ HAUORA

Environmental Radioactivity in New Zealand and Rarotonga

Annual Report



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National Radiation Laboratory

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Contents

Summary

During 1997, artificial radioactivity in the environment in New Zealand and Rarotonga continued to be at trace levels only, typical of recent years during which there has been no significant change in the radioactivity status of the environment.

Atmospheric radioactivity was monitored at Kaitaia, Hokitika and Rarotonga; deposited radioactivity was monitored at Hokitika; and milk radioactivity was monitored in the Waikato, Taranaki and Westland regions. Average levels measured were: total beta activity in air, 0.1 mBq/m^3; ^{90}Sr deposition, 0.3 ± 0.2 Bq/m^2; ^{137}Cs in milk, 0.1 Bq/g K; ^{90}Sr in milk, 0.029 Bq/g Ca. Total beta activity deposition at Hokitika was 200 Bq/m^2. Annual total ^{210}Pb and ^{7}Be depositions at Hokitika were 122 and 5320 Bq/m^2 respectively.

No artificial radionuclides were detected by gamma spectroscopic analysis of high-volume air filters during 1997, with weekly sampling periods. The annual-average atmospheric ^{137}Cs concentration in the region, assessed by analysis of yearly air-filter aggregates, was 0.04 μBq/m^3.

Average atmospheric concentrations of natural ^{7}Be and ^{210}Pb were 3.2 mBq/m^3 and 0.07 mBq/m^3 respectively.

1 Introduction

The National Radiation Laboratory (NRL) has monitored environmental radioactivity levels in the New Zealand and South Pacific regions since 1960, as described in earlier reports in this series[1,2]. Monitoring was initially conducted for radioactive fallout from nuclear weapons tests in the Northern Hemisphere, and then for fallout from the French testing programme in the Tuamotu Archipelago. When the French atmospheric testing programme was terminated in 1974, monitoring continued for residues from atmospheric tests, and in order to detect any venting from the underground tests.

By 1985, levels of weapons-test debris in the atmosphere and rainwater had decreased to near the limits of detection for the monitoring techniques then in use, and the extensive monitoring network was scaled down[3] to three monitoring sites, with two in New Zealand and one in the Cook Islands. The sensitivity of atmospheric monitoring at these sites was increased with the installation of high-volume air samplers[4].

The present monitoring programme is intended to provide warning of any influx of radioactivity into the New Zealand and South Pacific regions from any source, to monitor trends in levels, and to facilitate public protection planning in the event of any significant pollution incident. The monitoring programme also provides the basis for certification of the radioactivity content of foodstuffs, both exported and consumed locally. It also serves as the basis of consumer and commercial advisory services concerning radioactivity, and is the basis of comparisons of the environmental radioactivity status of the South Pacific region with that of other regions.

Through its environmental monitoring operations, NRL is involved in international networks which have been set up by the International Atomic Energy Agency (IAEA) and the World Health Organisation (WHO) to improve co-operation and information dissemination, particularly during nuclear emergencies (through the Convention on Early Notification of a Nuclear Accident). The Laboratory is also a member of the WHO/UNEP (United Nations Environment Programme) Global Environmental Radiation Monitoring Programme (GERMON); and it is a WHO Collaborating Centre for environmental radiation measurement. The Laboratory thus acts as an international point of contact for the South Pacific region in all matters pertaining to environmental radioactivity.

Following the signing of the Comprehensive Nuclear Test-Ban Treaty by the United Nations member countries, in September 1996, verification of treaty compliance is now an important international issue, and the NRL monitoring stations at Kaitaia and Rarotonga are to become part of the global verification network. Since late 1996, atmospheric radioactivity data from each of the three NRL monitoring stations has been transmitted, on a weekly basis, to the Prototype International Data Centre (PIDC) in Washington, along with data from many other stations world-wide. Data from all stations may be viewed on the world-wide-web, on the PIDC home page: *http://www.cdidc.org*.

In order to maintain a high standard of capability in radiochemical analysis, NRL takes part in quality assurance programmes run by the WHO, IAEA, and the US Environmental Measurements Laboratory. International analytical inter-comparison exercises are undertaken whenever the opportunity arises.

Although the environmental monitoring programme is designed primarily to detect and monitor levels of artificial radioactivity, measurements include naturally occurring radioactive materials, for comparative and scientific purposes. The atmospheric monitoring therefore includes measurements of concentrations of lead-210 (^{210}Pb), beryllium-7 (^{7}Be) and sodium-22 (^{22}Na) in the atmosphere. Beryllium-7 and ^{22}Na are cosmogenic nuclides (products of spallation reactions of cosmic radiation within the upper atmosphere), while ^{210}Pb is a decay product of gaseous radon-222 (^{222}Rn, which diffuses out of soil). Lead-210 and ^{7}Be depositions are also monitored at one New Zealand site, together with artificial strontium-90 (^{90}Sr) deposition.

The 1993 report[5] provided full discussion of trends in atmospheric caesium-137 (^{137}Cs) levels, radionuclides which contribute to the measured atmospheric beta activity, the age of aerosols collected in the NRL monitoring network, current concentrations of ^{137}Cs in New Zealand soils, and radiation exposure due to fallout (both natural and artificial) in diet.

2 Monitoring programme

The environmental radioactivity monitoring programme comprised the following measurements during 1997.

Atmospheric radioactivity: atmospheric monitoring is regarded as the most important component of the monitoring programme because any radioactive pollution reaching the region will inevitably have been transported in the atmosphere, and the high-sensitivity monitoring would provide early warning of any influx or changing trend in environmental radioactivity levels. Total beta activity (TBA), fission product, ^{7}Be, and ^{210}Pb levels were monitored with weekly collections of particulates from surface air at Kaitaia, Hokitika and Rarotonga. In addition, air filters collected during the year were bulked annually for sensitive measurements of average levels of any other radionuclides which may have been present – for example, ^{137}Cs and ^{22}Na.

The atmospheric monitoring involved the use of centrifugal-fan pumps to draw air through 500 cm^2 filters (Carl Freudenberg, type FA2311) at a flow rate of approximately 3 m^3/min, with a weekly sample volume of approximately 30 000 m^3. The filters were analysed by high-resolution gamma spectroscopy for gamma-emitting artificial and natural radionuclides; by gas-flow proportional counting for TBA; and radiochemically for ^{210}Pb. Annual filter aggregates representing air volumes of approximately 1.6 x 10^6 m^3 were analysed using high-resolution gamma spectroscopy.

The minimum detectable activities for a fission product such as ^{137}Cs in the weekly and annual filter analyses were 0.5 and 0.02 μBq/m^3 (average concentration) respectively.

Radioactive deposition: TBA and ^{90}Sr depositions were monitored at Hokitika with weekly and monthly sample collection respectively. Lead-210 and ^{7}Be deposition was monitored on a weekly basis at Hokitika, using a large-area (1 m^2) rain collector.

Radioactivity in milk: ^{137}Cs concentrations were monitored in dairy milk powders with monthly sample collection from three New Zealand regions: Waikato, Taranaki and Westland. Strontium-90 in milk was monitored in the Westland region only.

Environmental radiation: outdoor environmental gamma radiation levels were monitored continuously in Christchurch as part of the GERMON programme, using both real-time and integrating monitoring methods.

This report summarises results of the above measurements during 1997, and compares them with those reported[6] for 1996. Earlier reports in this series give information

on terms of reference, reference levels and potential health hazard[1,2], and technical information and the design of the programme[3,4]. A review of the history of fallout monitoring in New Zealand is available[7].

3 1997 Monitoring results

Monitoring results for 1997 are summarised in Tables 1, 2 and 3. Results of weekly measurements of atmospheric and deposited radioactivity are given in Table 4.

Radioactivity units used throughout this report are becquerels (Bq), millibecquerels (mBq) and microbecquerels (μBq): 1 Bq = 1 nuclear transformation per second.

3.1 Atmospheric radioactivity

Atmospheric radioactivity monitoring results for 1997 are summarised in Table 1, while results of weekly measurements are given in Table 4. Trends in radioactivity levels during the year are illustrated in Figures 1 - 3.

3.1.1 Artificial radionuclides

No particulate artificial radionuclides were detected by gamma-spectroscopic analysis of the weekly air filters from any monitoring site during 1997.

Caesium-137 was detected at trace levels on the annual filter aggregates from Kaitaia and Hokitika at annual-average levels of 0.04 ± 0.01 μBq/m^3. At Rarotonga, the average ^{137}Cs concentration was 0.03 ± 0.01 μBq/m^3.

3.1.2 Total beta activity

Weekly-average atmospheric TBA levels during 1997 were similar at all 3 monitoring sites, and ranged from 0.04 mBq/m^3 to 0.34 mBq/m^3 (Table 1), with an overall annual-average of 0.1 mBq/m^3, as in 1996[6].

Atmospheric TBA was due mainly to natural radionuclides, as described in the 1993 report[5].

3.1.3 Natural radionuclides

Cosmogenic nuclides

Beryllium-7 continued to be the most significant radionuclide detected on the air filters during 1997, with weekly-average concentrations in the range 0.7 - 6.7 mBq/m^3, and with an overall annual-average concentration of 3.2 mBq/m^3, the same as that recorded in 1996[6].

Sodium-22 was detected on the yearly aggregates of air filters at an overall annual-average concentration of 0.23 μBq/m^3 (Table 1).

Lead-210

Lead-210 was measured on the weekly air filters at levels which were similar at all 3 monitoring sites, as indicated in Table 1. Levels ranged from 0.01 to 0.39 mBq/m^3, with an overall annual-average concentration of 0.07 mBq/m^3.

3.1.4 Trends in radioactivity levels

The annual trend in ^{7}Be levels continued to demonstrate the normal cycles of summer maxima and winter minima in New Zealand (Figures 1 and 2).

Total-beta activity measurements during 1997 followed similar trends to ^{210}Pb, the ^{210}Bi decay product of which is the main contributor of beta activity.

3.2 Radioactive deposition

Results of measurements of TBA, ^{90}Sr and ^{210}Pb deposition at Hokitika are summarised in Table 2.

3.2.1 Total beta activity

The TBA deposition for 1997 at Hokitika was 200 ± 7 Bq/m^2 with 257 cm of rainfall, similar to that recorded in 1996[6]: 175 Bq/m^2 with 333 cm rainfall. The average weekly deposition was 3.9 Bq/m^2, with a range of 0.6 - 14.9 Bq/m^2. The average weekly TBA concentration in rainwater at Hokitika was 0.2 Bq/L, with a range of 0 - 2 Bq/L.

3.2.2 Strontium-90

Strontium-90 deposition was measured in six-monthly aggregates of strontium recovered from the monthly rainwater collections.

Strontium-90 deposition continued to be near the limit of detection at Hokitika during 1997, with an annual total of 0.3 ± 0.2 Bq/m^2 (Table 2), typical of recent years.

3.2.3 Natural radionuclides

Lead-210 and its decay product ^{210}Po are the most significant source of natural dietary radiation exposure due to terrestrial radionuclides (excluding ^{40}K), together contributing over 80% of exposure from this source[8].

The total ^{210}Pb deposition at Hokitika during 1997 was 122 Bq/m^2, representing 61% of the deposited TBA.

Beryllium-7 deposition Hokitika during 1997 totalled 5320 Bq/m^2.

3.3 Radioactivity in milk

Results of milk monitoring during 1997 are summarised below and in Table 3.

3.3.1 Caesium-137

Caesium-137 levels in cows' milk were assessed by gamma spectroscopic analysis of monthly samples of milk powder. Results are summarised as monthly averages in Table 3, with units of Bq per gram of potassium (Bq/g K) and Bq per kilogram of milk powder (Bq/kg).

The 1997 average ^{137}Cs levels were: Waikato 0.09 Bq/g K or 1.2 Bq/kg powder; Taranaki 0.15 Bq/g K or 1.9 Bq/kg powder; Westland 0.05 Bq/g K or 0.7 Bq/kg powder. The three-region mean was 0.10 Bq/g K or 1.3 Bq/kg powder – similar to that reported in 1996[6].

Concentrations of ^{137}Cs in milk continue to be higher in the Taranaki region due to the local effect of volcanic soils.

3.3.2 Strontium-90

Strontium-90 levels in cows' milk were measured by radiochemical analysis of 3-month aggregated samples from Westland. Results are shown in Table 3, with units of Bq per gram of calcium (Bq/g Ca) and Bq/kg powder.

The 1997 average ^{90}Sr level was 0.03 Bq/g Ca or 0.3 Bq/kg powder, as in 1996.

3.4 Environmental radiation

Environmental gamma radiation levels, due to cosmic, atmospheric and terrestrial gamma radiation, were monitored continuously through 1997 using a monitor installed on the Laboratory roof. This monitoring is conducted primarily as part of the WHO/UNEP GERMON programme.

The annual-average environmental radiation dose-rate during 1997 was 80 nanogray per hour, or 0.7 milligray per year, the same as the level reported in 1996[6].

An integrating measurement package comprising thermoluminescent dosemeters and films for 3-month exposure periods, provided by the WHO as part of the GERMON programme, was also used to assess environmental radiation levels. These packages were analysed quarterly by the WHO in France. Results of the integrating measurement and the continuous monitoring were similar during 1996.

4 Summary

Measurements of artificial radioactivity levels in the atmosphere and rainwater in New Zealand and Rarotonga during 1997 indicated that the atmosphere contained only residual traces of global weapons test fallout, with no detectable influx of fresh fission products. Levels of ^{90}Sr and ^{137}Cs in milk continued to be measurable at trace levels only, with levels being virtually the same as those recorded in 1996.

The 1997 average levels of atmospheric, deposited, and milk radioactivity were: TBA in air, 0.1 mBq/m^3; TBA deposition, 201 Bq/m^2 (Hokitika); ^{90}Sr deposition, 0.3 ± 0.2 Bq/m^2 (Hokitika); ^{137}Cs in milk, 0.1 Bq/g K; ^{90}Sr in milk, 0.03 Bq/g Ca.

Overall, the 1997 results were very similar to those reported for 1996[6] as indicated in the comparison of New Zealand site averages below:

	1997	1996
TBA in air, mBq/m^3	0.10	0.10
TBA in rain, Bq/m^2	200	175
^{90}Sr in rain, Bq/m^2	0.3	0.1
^{90}Sr in milk powder, Bq/kg	0.3	0.3
^{137}Cs in milk powder, Bq/kg	1.3	1.1

No artificial radionuclides were detected by gamma-spectroscopic analysis of high-volume air filters during 1997, with weekly sampling periods. Caesium-137 was detected on yearly aggregates of air filters at an overall average level of 0.04 ± 0.01 μBq/m^3.

For naturally occurring radionuclides, the average atmospheric concentrations of ^{7}Be and ^{210}Pb were 3.2 mBq/m^3 and 0.07 mBq/m^3 respectively, while the total annual depositions of the 2 radionuclides at Hokitika were 5320 Bq/m^2 and 122 Bq/m^2 respectively.

5 Other environmental radioactivity work

5.1 Quality assurance

Quality assurance is an essential feature of any measurement laboratory's operations. The National Radiation Laboratory has for many years participated in international analytical intercomparisons performed by agencies in other countries including the WHO, IAEA, and the EPA.

During 1997 the Laboratory participated in one exercise conducted by the USEML, involving analysis of air filters, soil, vegetation and water, for alpha-, beta-, and gamma-emitting radionuclides. Results are shown in Table 5. Overall, results were satisfactory, although there seems to be an upward bias in NRL gamma spectroscopic results which is to be addressed by recalibration of detectors. A problem was also encountered with the vegetation ^{90}Sr analysis, which led to an erroneous result.

5.2 Commercial and advisory services

There was a continuing demand for export certificates and radioactivity tests in 1997. During the year 768 export certificates were issued and 558 commercial analyses performed.

The number of enquiries during 1997 from members of the public and commercial interests regarding radioactivity in consumer products and foodstuffs and environmental issues was normal.

5.3 The Comprehensive Nuclear-Test-Ban Treaty

Dr Matthews continued to assist the Disarmament Division of the Ministry of Foreign Affairs and Trade by giving further technical advice related to the Comprehensive Nuclear Test-Ban Treaty during 1997, including attendance of a Working Group meeting in Vienna in August.

Acknowledgement

The National Radiation Laboratory gratefully acknowledges the assistance of Mr Bruce Buckby of North Weather Ltd in Kaitaia, and Mr Mark Crompton of West Weather Ltd, Hokitika, and their excellent service during 1996. The Laboratory gratefully acknowledges also the continued help of the Rarotonga Meteorological Service with monitoring in the Cook Islands, particularly Mr Nga Rauraa. The Managers of the AnchorProducts Te Rapa Factory (Waikato), Kiwi Co-operative Dairies Ltd (Hawera), Scenicland Milk and Cream (Greymouth) and Westland Co-operative Dairy Co. (Hokitika) are also thanked for their assistance with the milk monitoring programme.

The Laboratory's Environmental Radioactivity Section organised the monitoring and analysed the samples. This report was written by the Section Head, Dr Murray Matthews, who was assisted technically by Ms Mary Jane Okey.

This is the final report in this series compiled by Dr Matthews who resigned from NRL early in 1998 to take up an appointment with the Comprehensive Nuclear-Test-Ban Treaty Organisation in Vienna. Dr Matthews is to be replaced by Dr R (Rick) A Tinker during 1998.

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Table 1: A summary of atmospheric radioactivity levels measured during 1997

Atmospheric radioactivity, weekly measurements

Monitoring site:	KAITAIA	HOKITIKA	RAROTONGA
TBA			
Range, mBq/m^3	0.05 - 0.34	0.04 - 0.27	0.04 - 0.17
Mean, mBq/m^3	0.12	0.10	0.10
Cosmogenic ^{7}Be			
Range, mBq/m^3	1.1 - 5.6	1.1 - 5.8	0.7 - 6.7
Mean, mBq/m^3	3.2	2.7	3.7
Radon decay product ^{210}Pb			
^{210}Pb, range mBq/m^3	0.03 - 0.39	0.02 - 0.34	0.01 - 0.17
mean mBq/m^3	0.08	0.07	0.07

Atmospheric radioactivity, annual measurement: annual average concentration

Fission product ^{137}Cs			
^{137}Cs, $\mu Bq/m^3$	0.04 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
Cosmogenic ^{22}Na			
^{22}Na, $\mu Bq/m^3$	0.24 ± 0.01	0.19 ± 0.01	0.25 ± 0.01

Table 2: A summary of ^{90}Sr, ^{210}Pb and total beta activity deposition measurements at Hokitika during 1997

Deposited radioactivity (Bq/m^2)

	Hokitika
TBA	200 ± 7
^{90}Sr	0.3 ± 0.2
^{210}Pb	122 ± 6
^{7}Be	5320 ± 100
Rainfall, cm	257

Table 3: Caesium-137 and strontium-90 levels in cows' milk during 1997

Results are expressed as Bq ^{137}Cs per gram potassium, Bq ^{90}Sr per gram calcium, and as Bq per kilogram of milk powder. The 95% confidence intervals are of the order of 10% and 20% of the stated results for ^{137}Cs and ^{90}Sr respectively.

Caesium-137

Month	Waikato		Taranaki		Westland	
	Bq/g K	Bq/kg	Bq/g K	Bq/kg	Bq/g K	Bq/kg
1	0.09	1.4	0.23	3.3	0.07	1.1
2	0.17	2.5	0.22	3.3	0.07	1.2
3	0.12	1.6	0.25	3.4	0.05	0.8
4	0.13	1.5	0.16	1.9	0.05	0.8
5	0.09	1.1	0.20	2.2	0.04	0.5
6	< 0.1	< 1	< 0.1	< 1	<0.04	<0.5
7	< 0.1	< 1	< 0.1	< 1	<0.04	<0.5
8	0.05	0.6	0.04	0.4	<0.04	<0.5
9	0.05	0.7	0.08	0.9	0.04	0.6
10	0.05	0.6	0.09	2.0	0.04	0.6
11	0.08	1.1	0.13	1.7	0.04	0.7
12	0.07	0.9	0.15	1.9	0.04	0.7
Mean	0.09	1.2	0.15	1.9	0.05	0.7

Strontium-90

Quarter	Westland	
	Bq/g Ca	Bq/kg
1	0.028	0.28
2	0.033	0.27
3	0.033	0.26
4	0.021	0.30
Mean	0.029	0.28

Table 4: A summary for 1997 of weekly measurements of radioactivity in the atmosphere and precipitation

	Atmospheric concentrations, mBq/m^3									Weekly deposition TBA, Bq/m^2
	KAITAIA			HOKITIKA			RAROTONGA			
Week	Be-7	TBA	Pb-210	Be-7	TBA	Pb-210	Be-7	TBA	Pb-210	Hokitika
1	1.32	0.05	0.05	3.80	0.08	0.09	4.39	0.05	0.06	1.3
2	3.92	0.12	0.09	2.80	0.11	0.11	4.24	0.10	0.06	2.3
3	4.68	0.12	0.05	2.86	0.11	0.04	2.29	0.05	0.04	1.8
4	4.61	0.11	0.06	4.91	0.10	0.04	2.91	0.11	0.07	3.0
5	5.60	0.15	0.07	5.84	0.18	0.13	3.38	0.13	0.10	1.7
6	4.77	0.13	0.07	4.07	0.12	0.07	3.21	0.11	0.04	6.4
7	3.94	0.12	0.04	2.24	0.13	0.05	4.55	0.09	0.06	6.1
8	1.21	0.10	0.05	2.75	0.11	0.12	3.00	0.11	0.05	3.5
9	3.55	0.14	0.08	4.84	0.08	0.04	2.84	0.10	0.06	0.0
10	2.02	0.12	0.05	3.58	0.10	0.05	2.73	0.12	0.02	3.3
11	4.81	0.14	0.05	3.36	0.07	0.03	2.31	0.07	0.03	2.4
12	4.42	0.13	0.05	1.59	0.07	0.03	0.74	0.04	0.01	3.5
13	4.06	0.18	0.06	3.48	0.06	0.06	1.83	0.06	0.02	0.6
14	4.30	0.18	0.12	3.35	0.18	0.13	2.92	0.08	0.04	4.7
15	2.60	0.10	0.05	2.14	0.09	0.05	3.82	0.08	0.05	4.7
16	3.59	0.13	0.06	2.07	0.06	0.04	3.21	0.06	0.04	6.2
17	3.94	0.10	0.04	2.81	0.07	0.03	3.91	0.10	0.03	2.6
18	4.92	0.34	0.39	4.16	0.27	0.28	3.91	0.09	0.06	3.4
19	4.43	0.25	0.22	3.70	0.25	0.34	4.39	0.11	0.06	4.9
20	1.88	0.09	0.03	2.12	0.06	0.04	2.11	0.06	0.04	3.1
21	3.44	0.16	0.07	1.83	0.05	0.04	2.92	0.06	0.03	5.4
22	2.14	0.28	0.06	1.14	0.07	0.06	3.15	0.07	0.05	2.9
23	2.23	0.08	0.05	3.18	0.13	0.13	1.74	0.07	0.03	1.2
24	1.88	0.08	0.05	1.96	0.10	0.10	3.75	0.10	0.05	2.4
25	1.89	0.07	0.04	2.88	0.09	0.07	3.53	0.08	0.05	2.7
26	3.23	0.16	0.09	2.85	0.10	0.10	3.65	0.09	0.06	1.6
27	1.54	0.06	0.03	3.60	0.18	0.16	2.62	0.06	0.03	1.2
28	2.42	0.09	0.05	2.01	0.10	0.06	3.42	0.08	0.04	5.7
29	2.64	0.08	0.03	2.00	0.07	0.04	3.49	0.07	0.05	3.7
30	1.86	0.08	0.05	1.20	0.06	0.03	3.55	0.10	0.05	1.7
31	1.93	0.07	0.05	1.37	0.05	0.06	4.08	0.14	0.13	2.1
32	1.07	0.06	0.04	1.06	0.07	0.09	4.29	0.09	0.05	3.0
33	3.41	0.11	0.07	2.08	0.13	0.10	5.88	0.12	0.08	6.8
34	2.43	0.08	0.04	2.84	0.07	0.07	3.80	0.08	0.07	3.7
35	2.04	0.09	0.05	1.35	0.05	0.05	3.29	0.08	0.06	3.1
36	2.76	0.17	0.17	2.66	0.13	0.10	4.15	0.14	0.13	2.1
37	2.21	0.07	0.05	2.51	0.08	0.05	4.10	0.13	0.08	1.9
38	2.51	0.08	0.07	1.92	0.11	0.09	4.49	0.14	0.09	2.2
39	1.96	0.10	0.07	3.86	0.12	0.09	3.97	0.15	0.12	2.1
40	3.31	0.12	0.06	1.74	0.07	0.05	4.05	0.17	0.08	4.1
41	2.60	0.10	0.05	1.23	0.04	0.03	4.96	0.12	0.09	6.1
42	3.98	0.10	0.05	1.94	0.05	0.02	3.30	0.08	0.08	3.1
43	2.58	0.12	0.05	1.55	0.07	0.03	5.58	0.14	0.14	4.2
44	3.74	0.19	0.22	3.05	0.18	0.15	4.60	0.14	0.10	4.2
45	3.35	0.16	0.18	2.61	0.08	0.03	5.98	0.17	0.11	7.9
46	2.97	0.13	0.14	3.02	0.09	0.03	2.60	0.09	0.07	6.1
47	3.40	0.11	0.08	1.85	0.07	0.06	4.55	0.16	0.17	4.8
48	5.13	0.17	0.12	2.53	0.06	0.05	6.74	0.12	0.12	9.0
49	3.98	0.16	0.12	1.81	0.06	0.06	2.62	0.07	0.06	4.7
50	5.05	0.15	0.09	3.00	0.12	0.05	2.62	0.07	0.06	3.5
51	3.74	0.09	0.07	2.99	0.06	0.05	4.50	0.10	0.07	14.9
52	3.52	0.08	0.08	3.41	0.05	0.05	5.00	0.08	0.09	7.6

Table 5: Intercomparison results

Matrix	Analyte	EML value	Lab median	NRL value
Air filter	**Mn-54**	7.6 ± 0.6	8.3	8.9 ± 0.5
	Co-57	10.8 ± 1.0	11.2	12.9 ± 0.7
	Co-60	5.0 ± 0.3	5.3	5.6 ± 0.3
	Sb-125	12.3 ± 1.0	13.8	15.9 ± 0.8
	Cs-134	10.9 ± 1.0	11.4	11.6 ± 0.6
	Cs-137	8.7 ± 0.8	9.1	10.0 ± 0.5
	Ce-144	15.7 ± 1.0	15.5	17.6 ± 0.9
	Sr-90	1.45 ± 0.15	1.46	1.41 ± 0.03
	Pu-238	0.10 ± 0.01	0.10	0.10 ± 0.01
	Pu-239	0.12 ± 0.01	0.12	0.13 ± 0.02
	U-234	0.10 ± 0.01	0.11	0.11 ± 0.01
	U-238	0.10 ± 0.01	0.11	0.11 ± 0.01
	Gross alpha	0.96 ± 0.05	1.00	0.97 ± 0.04
	Gross beta	0.45 ± 0.03	0.50	0.62 ± 0.03
Soil	**K-40**	334 ± 7	357	387 ± 21
	Co-60	1.1 ± 0.1	1.5	1.9 ± 0.1
	Cs-137	825 ± 14	910	992 ± 50
	Am-241	5.7 ± 0.5	6.1	7.8 ± 1.8
	Sr-90	40.3 ± 0.4	41.8	67.0 ± 3.0
	Pu-238	0.53 ± 0.11	0.56	0.60 ± 0.30
	Pu-239	134 ± 17	133	130 ± 4
	U-234	37.6 ± 2.5	38.7	34.0 ± 2.3
	U-238	42.4 ± 2.5	40.6	39.9 ± 2.3
Vegetation	**K-40**	812 ± 12	915	956 ± 50
	Co-60	12.5 ± 3.2	14.0	13.3 ± 1.2
	Cs-137	189 ± 7	213	221 ± 12
	Sr-90	361 ± 43	380	115 ± 5
	Pu-238	0.18 ± 0.01	0.14	0.20 ± 0.06
	Pu-239	1.94 ± 0.22	1.96	1.85 ± 0.16
Water	**Mn-54**	20.9 ± 0.3	23.4	24.8 ± 1.4
	Co-60	90.9 ± 1.2	97.5	104.0 ± 6.0
	Cs-134	20.6 ± 0.3	22.1	24.5 ± 1.5
	Cs-137	69.8 ± 1.2	78.0	84.0 ± 5.0
	Sr-90	23.2 ± 1.4	23.2	23.0 ± 0.4
	Pu-238	1.29 ± 0.06	1.31	1.30 ± 0.09
	Pu-239	0.85 ± 0.05	0.85	0.83 ± 0.07
	U-234	0.54 ± 0.02	0.60	0.57 ± 0.07
	U-238	0.55 ± 0.02	0.59	0.62 ± 0.07
	Gross alpha	1850 ± 200	1128	898 ± 44
	Gross beta	844 ± 100	551	551 ± 29

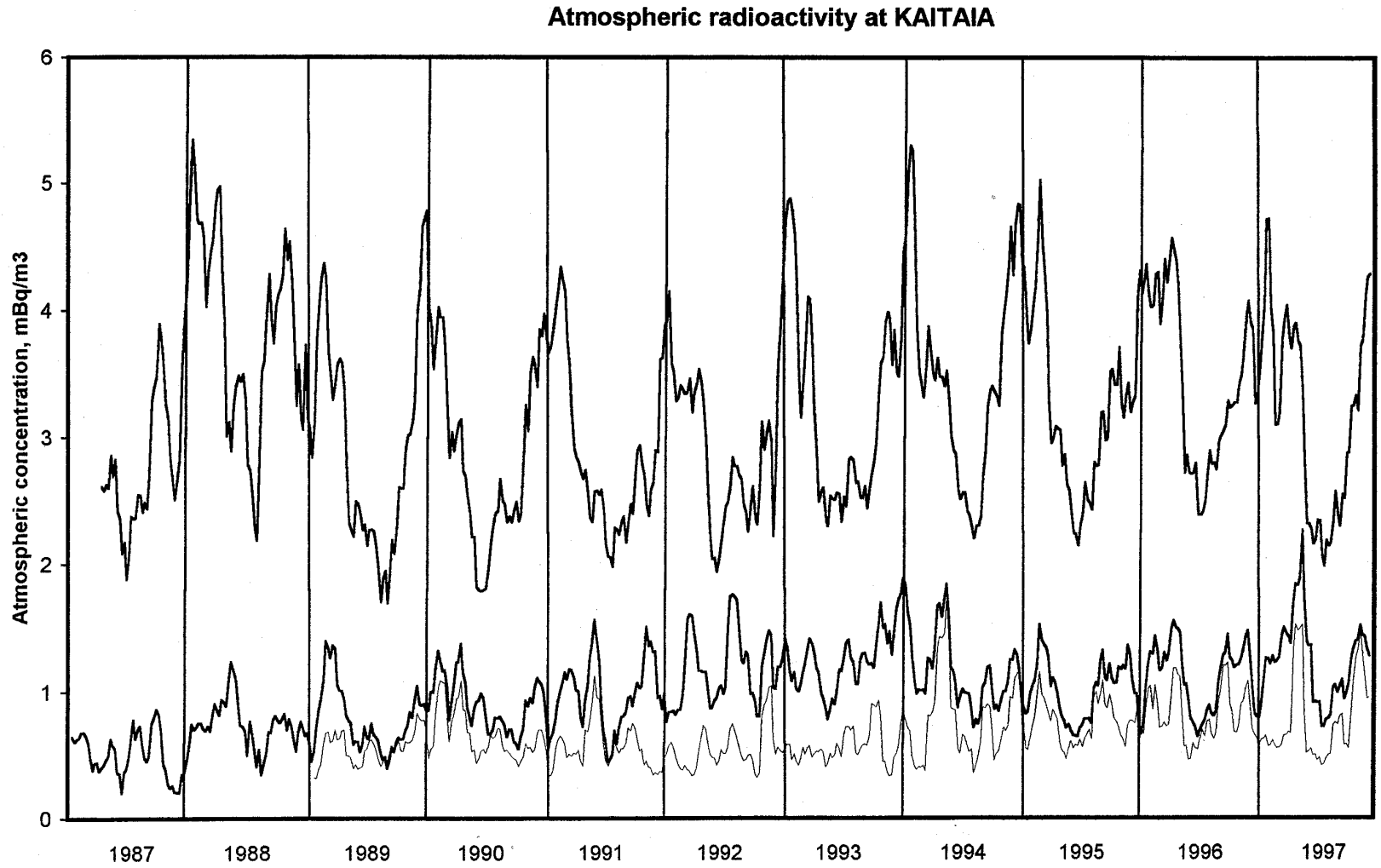

Fig 1 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Kaitaia** during the period 1987 to 1997. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*

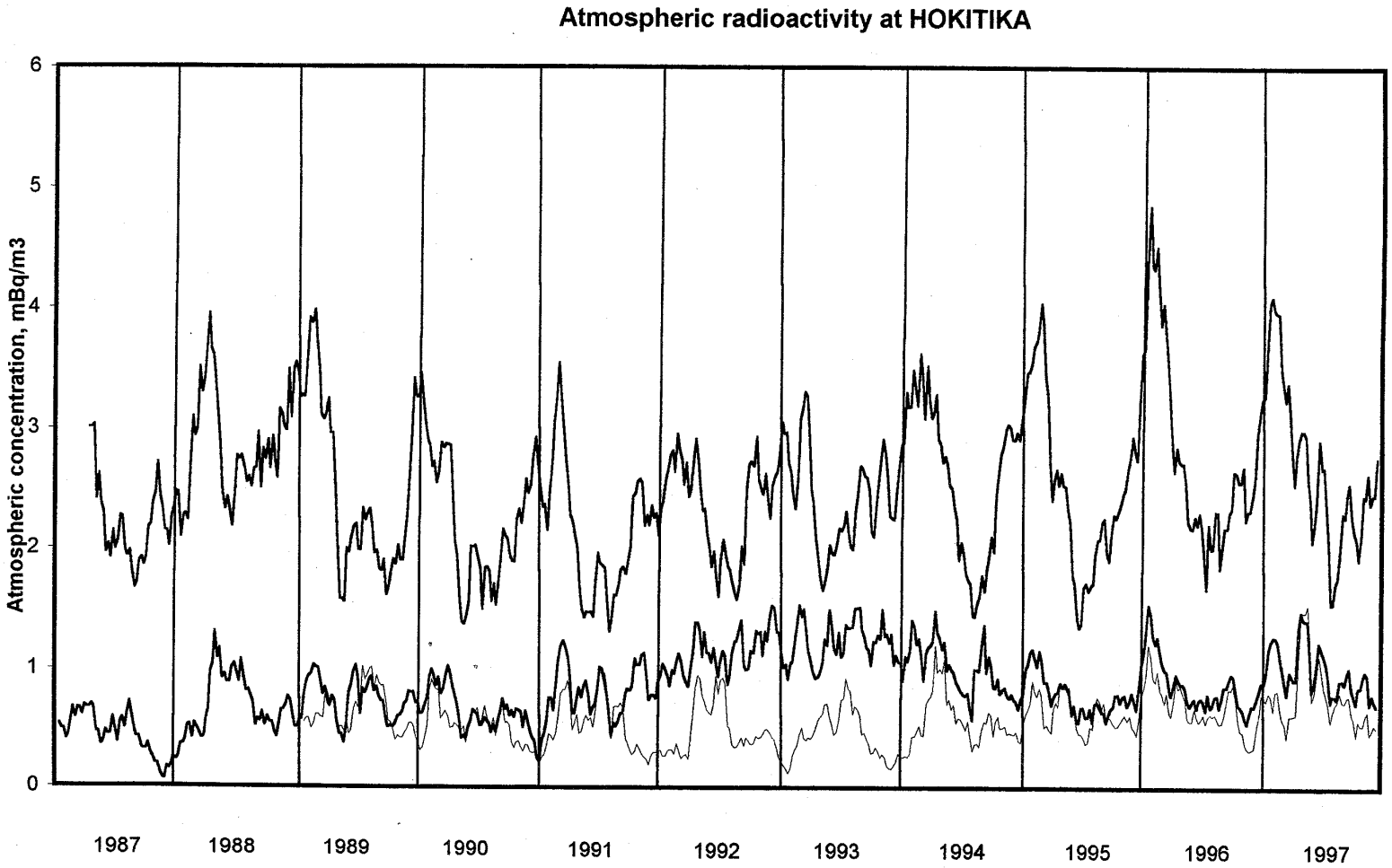

Fig 2 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Hokitika** during the period 1987 to 1997. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*

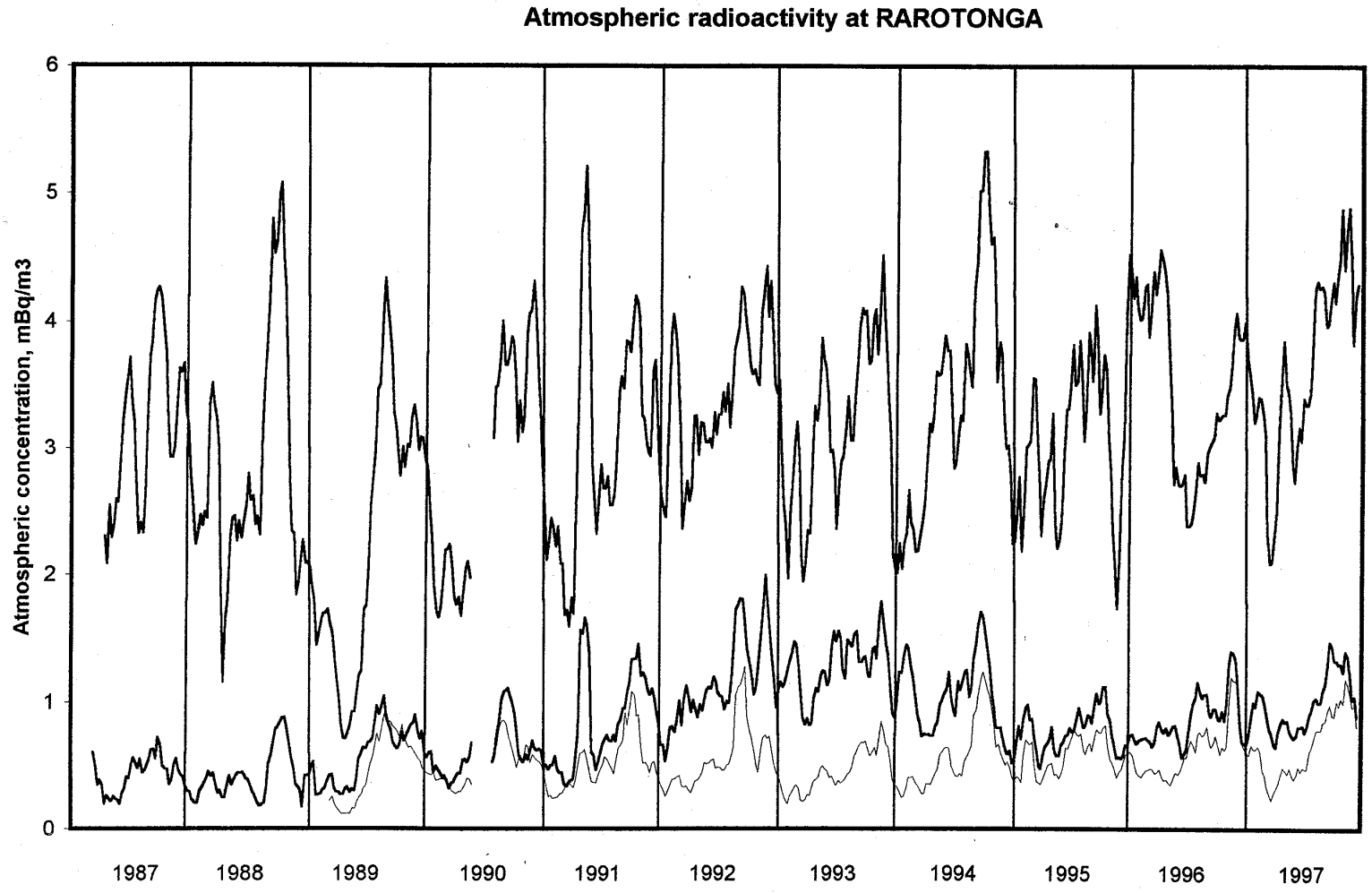

Fig 3 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Rarotonga** during the period 1987 to 1997. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*