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ENVIRONMENTAL RADIOACTIVITY IN NEW ZEALAND AND RAROTONGA

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CONTENTS

SUMMARY

During 1995 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 and deposited radioactivity was monitored at Kaitaia, Hokitika and Rarotonga, and milk radioactivity was monitored in Auckland, Taranaki and Westland. Average levels measured were: total beta activity in air, 0.09 mBq/m^3; ^{90}Sr deposition, 0.2 ± 0.2 Bq/m^2; ^{137}Cs in milk, 0.08 Bq/g K; ^{90}Sr in milk, 0.03 Bq/g Ca. Total beta activity depositions at Hokitika and Rarotonga were 208 Bq/m^2 and 180 Bq/m^2 respectively. Annual total ^{210}Pb and ^{7}Be depositions at Hokitika were 136 and 6550 Bq/m^2 respectively.

No artificial radionuclides were detected by gamma spectroscopic analysis of high-volume air filters during 1995, with weekly sampling periods. The annual-average atmospheric ^{137}Cs concentration, assessed by analysis of yearly air-filter aggregates, was 0.03 ± 0.01 μBq/m^3 in New Zealand, and < 0.02 μBq/m^3 at Rarotonga.

Average atmospheric concentrations of natural ^{7}Be and ^{210}Pb were 2.9 mBq/m^3 and 0.07 mBq/m^3 respectively.

The report includes data and comment on trends in atmospheric radioactivity levels since 1987.

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 Organization (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 submits monitoring results quarterly to the GERMON headquarters in France; 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.

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 South Pacific Environmental Radioactivity Association (SPERA). Results of recent analytical intercomparisons are included in this report.

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 deposition are also monitored at one New Zealand site, while strontium-90 (^{90}Sr) deposition is monitored at all three.

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.

This report continues the *Annual Report* series under a new title, and is intended to provide an overview of the environmental radioactivity status of the New Zealand and South Pacific (more specifically, Cook Islands) regions, primarily for artificial radioactivity, but also for naturally occurring radioactivity.

2. MONITORING PROGRAMME

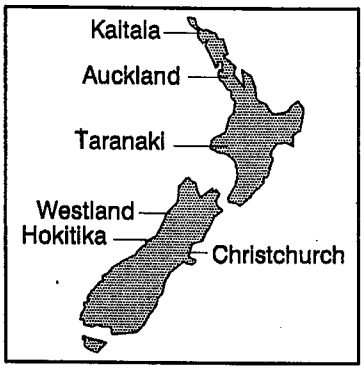
The environmental radioactivity monitoring programme comprised the following measurements during 1995.

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 $\mu Bq/m^3$ (average concentration) respectively.

Radioactive deposition: TBA deposition was monitored at Hokitika and Rarotonga, with weekly sample collection, while ^{90}Sr deposition was monitored with monthly collections at Kaitaia, Hokitika and Rarotonga. Lead-210 and ^{7}Be deposition was monitored on a weekly basis at Hokitika, using a large-area (1 m^2) rain collector (installed in July 1994).



Radioactivity in milk: ^{90}Sr and ^{137}Cs concentrations, together with calcium and potassium levels, were monitored in dairy milk powders with monthly sample collection from 3 New Zealand regions: Auckland, Taranaki and Westland.

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 1995, and compares them with those reported[6] for 1994. 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]. The history of fallout monitoring in New Zealand has recently been reviewed[7].

Proposed changes to the fallout monitoring programme, to take effect during 1996, are described in section 6 of this report.

3. 1995 MONITORING RESULTS

Monitoring results for 1995 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), milli-becquerels (mBq) and microbecquerels (μBq): 1 Bq = 1 nuclear transformation per second.

3.1 Atmospheric radioactivity

Atmospheric radioactivity monitoring results for 1995 are summarised in Table 1, while results of weekly measurements are given in Table 4.

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 1995.

Caesium-137 was detected at trace levels on the annual filter aggregates from Kaitaia and Hokitika at annual-average levels of 0.03 ± 0.01 $\mu Bq/m^3$. It was not detected on the aggregated air filters from Rarotonga (minimum detectable activity 0.02 $\mu Bq/m^3$).

3.1.2 Total beta activity

Weekly-average atmospheric TBA levels during 1994 were similar at all 3 monitoring sites, and ranged from 0.04 mBq/m^3 to 0.23 mBq/m^3 (Table 1), with an overall annual-average of 0.09 mBq/m^3 (after correction for ^7Be as described below), similar to the reported 1994[6] average of 0.13 mBq/m^3 (or 0.10 mBq/m^3 after ^7Be correction).

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

^7Be-correction to TBA values: The greater stability of the new beta counter[6] installed in late 1994, compared with the earlier model, has allowed more precise measurements of factors contributing to measured TBA levels. In particular, the contribution of the ^7Be gamma radiation to the "beta" count rate has been determined to be the equivalent of 0.007 Bq of "TBA" per Bq ^7Be. Although this is a very small contribution, the amount of ^7Be on the air filters is large compared to the TBA, and so the correction is not insignificant. Although this correction was not originally applied to data before 1995, when the old detector was in use, it is reasonable to assume it could have been because detector specifications were similar. All the TBA data since 1987, as shown in Figures 1 - 3, have therefore now been corrected for the small ^7Be contribution. The effect of this has been to lower the TBA levels slightly, without altering any of the annual trends significantly. If the Figures in this report are compared with those presented in 1995[6], a slight downward shift will be noted in TBA levels in years 1987 - 1994.

3.1.3 Natural radionuclides

Cosmogenic nuclides

Beryllium-7 continued to be the most significant radionuclide detected on the air filters during 1995, with weekly-average concentrations in the range 0.3 - 6.2 mBq/m^3, and with an overall annual-average concentration of 2.9 mBq/m^3, similar to that recorded in 1994[6] - 3.1 mBq/m^3. The annual trend in ^7Be levels continued to demonstrate the normal cycles of summer maxima and winter minima in New Zealand (Figures 1 and 2), and a spring maximum at Rarotonga (Figure 3).

Sodium-22 was detected on the yearly aggregates of air filters at an overall annual-average concentration of 0.26 $\mu Bq/m^3$ (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 0.02 to 0.20 mBq/m^3, with an overall annual-average concentration of 0.06 mBq/m^3.

3.1.4 Trends in atmospheric radioactivity

Annual trends in atmospheric concentrations of ^{7}Be, TBA and ^{210}Pb since 1987 are illustrated in Figures 1 - 3 which show 5-week moving-average concentrations.

The TBA data collected at Hokitika since 1987, as plotted in Figure 2, indicate a pronounced "peak" in TBA levels there during the period mid-1991 to mid-1994. This trend was commented upon in the 1993 and 1994 reports, and the 1995 data clearly indicate that there was indeed a peak in activity. Before mid-1991 and during 1995, TBA levels were very similar to the atmospheric ^{210}Pb levels, with any differences presumably being due to cosmogenic radionuclides[5]. The additional radioactivity contributing to the "peak" could not have been due to cosmogenic radionuclides, however, because the trend was not reflected in ^{7}Be levels. It is possible that natural radionuclides, particularly ^{40}K, in stratospheric ash from the Mount Pinatubo eruption of mid-1991, may have been the cause. The peak was also observed at Kaitaia and Rarotonga (Figures 1 and 3), though it was less pronounced there.

Beryllium-7 continued to show the usual trend of spring or summer maxima at all 3 monitoring sites. Data are available from enough years to allow the estimation of mean "mid-peak" dates for each site. On average, atmospheric ^{7}Be levels, and presumably levels of any other stratospheric species, peak at the following times: Rarotonga – late September; Kaitaia – mid January; Hokitika – early March. It is interesting to note that the higher the latitude, the later the peak (in the winter-to-winter cycle), presumably because of a pole-ward shift in the tropopause "fold", or "break", as atmospheric circulation cells shift seasonally.

Annual-average atmospheric ^{210}Pb levels have been relatively static since monitoring began in 1987, as would be expected with a species of purely natural origin.

It has been noted previously[5, 6] that similarities are sometimes apparent among the trends in levels of TBA, ^{210}Pb and ^{7}Be within each year. In Figure 3, for example, periods are evident when the 3 species demonstrate similar trends during the year, suggesting that they are all of high-altitude, or largely stratospheric, origin. The degree of similarity is represented by the correlation coefficient, r, the square of which indicates the amount of variation in one entity which is accounted for by variation in another. For 1995, r^2 values for the 3 sets of variables plotted in Figures 1 - 3 (moving-average ^{210}Pb, ^{7}Be, and TBA levels), as listed in Table 5,

indicate that at Rarotonga and Kaitaia the variations in TBA levels were largely accounted for by variations in ^{210}Pb levels (75% and 59%, respectively). At Rarotonga also, 63% of the variation in ^{210}Pb levels was accounted for by variations in ^{7}Be levels. As ^{7}Be itself is largely of stratospheric origin, it thus seems that both ^{210}Pb and the TBA are also largely of stratospheric origin at Rarotonga. At Kaitaia and Hokitika, 61% and 80% (respectively) of the variation in TBA levels was accounted for by variations in ^{7}Be levels, suggesting a stratospheric source for most of the TBA there too, although the ^{210}Pb was clearly of different origin (r^2 = 0.32 and 0.22 respectively).

3.2 Radioactive deposition

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

3.2.1 Total beta activity

The total TBA deposition for 1995 at Hokitika was 208 ± 6 Bq/m^2 with 355 cm of rainfall, similar to that recorded in 1994[6]: 213 Bq/m^2 with 314 cm rainfall. The average weekly deposition was 4.0 Bq/m^2, with a range of 1 - 9 Bq/m^2. The average weekly TBA concentration in rainwater at Hokitika was 0.55 Bq/L, with a range of 0 - 12 Bq/L.

At Rarotonga, the total deposition was 180 ± 13 Bq/m^2 with 212 cm of rain, which was similar to that recorded in 1994[6]: 246 Bq/m^2 with 174 cm of rain. The average weekly deposition at Rarotonga was 3.5 Bq/m^2, with a range of 0 - 8 Bq/m^2. The average weekly TBA concentration in rainwater at Rarotonga was 1.7 Bq/L, with a range of 0 - 27 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 all monitoring sites during 1994 with annual totals of 0.1 - 0.3 Bq/m^2 (Table 2), typical of recent years.

These ^{90}Sr deposition results may be contrasted with TBA deposition which is of natural origin[5], and with the peak ^{90}Sr deposition recorded in 1964 when the national average was 130 Bq/m^2.

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 1995 was 136 Bq/m^2, representing 65% of the deposited TBA.

Beryllium-7 deposition was also monitored at Hokitika during 1995, and the total annual deposition was 6550 Bq/m^2, with a cumulative equilibrium deposition (corrected for radioactive decay) of 2000 Bq/m^2.

Results of the ^{210}Pb and ^{7}Be measurements made with the large-area rainwater collector since July 1994 are yet to be analysed in detail, and will be the subject of a separate report.

3.3 Radioactivity in milk

The presence of ^{137}Cs and ^{90}Sr in soil, as described in the 1993 report[5], leads to their presence in milk. Results of milk monitoring during 1995 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 1995 average ^{137}Cs levels were: Auckland <0.04 Bq/g K or <0.5 Bq/kg powder; Taranaki 0.16 Bq/g K or 2.0 Bq/kg powder; Westland 0.05 Bq/g K or 0.7 Bq/kg powder. The three-region mean was 0.08 Bq/g K or 1.1 Bq/kg powder – essentially the same as in 1994[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. Results are shown in Table 3, with units of Bq per gram of calcium (Bq/g Ca) and Bq/kg powder.

The 1995 average ^{90}Sr levels were: Auckland 0.021 Bq/g Ca or 0.27 Bq/kg powder; Taranaki 0.029 Bq/g Ca or 0.33 Bq/kg powder; Westland 0.027 Bq/g Ca or 0.32 Bq/kg powder. The three-region mean was 0.026 Bq/g Ca or 0.31 Bq/kg powder – essentially the same as in 1995[6].

3.4 Environmental radiation

Environmental gamma radiation levels, due to cosmic, atmospheric and terrestrial gamma radiation, were monitored continuously through 1995 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 1995 was 80 nanogray per hour, or 0.7 milligray per year, similar to the level reported in 1994[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 1995.

4. SUMMARY

Measurements of artificial radioactivity levels in the atmosphere and rainwater in New Zealand and Rarotonga during 1995 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 1994.

The 1995 average levels of atmospheric, deposited, and milk radioactivity were: TBA in air, 0.09 mBq/m^3; TBA deposition, 208 Bq/m^2 (Hokitika) and 180 Bq/m^2 (Rarotonga); ^{90}Sr deposition, 0.2 ± 0.2 Bq/m^2; ^{137}Cs in milk, 0.08 Bq/g K; ^{90}Sr in milk, 0.03 Bq/g Ca.

Overall, the 1995 results were very similar to those reported for 1994[6] as indicated in the comparison of New Zealand site averages below:

	1995	1994
TBA in air, mBq/m^3 (^{7}Be-corrected)	0.09	0.10
TBA in rain, Bq/m^2	208	213
^{90}Sr in rain, Bq/m^2	0.2 ± 0.2	0.2 ± 0.2
^{90}Sr in milk powder, Bq/kg	0.3	0.3
^{137}Cs in milk powder, Bq/kg	1.1	1.0

No artificial radionuclides were detected by gamma-spectroscopic analysis of high-volume air filters during 1995, with weekly sampling periods. Caesium-137

was detected on yearly aggregates of air filters at Kaitaia and Hokitika at an average level of 0.03 ± 0.01 $\mu Bq/m^3$, but was not detected at Rarotonga.

For naturally occurring radionuclides, the average atmospheric concentrations of ^{7}Be and ^{210}Pb were 2.9 mBq/m^3 and 0.07 mBq/m^3 respectively, while the total annual depositions of the 2 radionuclides at Hokitika were 6550 Bq/m^2 and 136 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.

Unfortunately, during 1994 the EPA announced that it was no longer able to send samples overseas for analysis and that NRL's involvement in the programme, which had run for more than 2 decades, was to end.

The only intercomparison in which NRL took part during the reporting period was the IAEA programme for analysing samples from Mururoa atoll. This involved the analysis of marine organisms and coconut milk for gamma emitting radionuclides, ^{90}Sr and plutonium isotopes. Results of the intercomparison have been published elsewhere[9].

Results were received for intercomparisons conducted in late 1994, and these are presented in Table 6.

Other sources of intercomparison samples will have to be found for future quality assurance, and it is likely that SPERA will play a role in this.

5.2 Commercial and advisory services

There was a continuing demand for export certificates and radioactivity tests in 1995. During the year 876 export certificates were issued (a 33% increase over the previous year) and 860 commercial analyses performed (a 120% increase over 1994).

The number of enquiries during 1995 from members of the public and commercial interests regarding radioactivity in consumer products and foodstuffs and environmental issues was normal. Issues relating to French nuclear-weapon tests at Mururoa dominated environmental interest during the year.

5.3 Test-ban treaty negotiations

Dr Matthews continued to assist the Ministry of Foreign Affairs and Trade by attending two further meetings of experts at the United Nations headquarters in Geneva during 1995. The expert group met to consider technical details of a global atmospheric radioactivity monitoring network for use in verifying compliance with the proposed comprehensive test-ban treaty currently being negotiated.

6. CHANGES TO MONITORING PROGRAMME

The National Radiation Laboratory's environmental radioactivity monitoring programme was last reviewed in 1985 when the large network was scaled down to its present size of 3 monitoring sites only. Since then, radioactivity levels have declined slightly, although the changes are becoming smaller as levels more closely approach limits of detectability. Monitoring results for 1995 were very similar to those of 1994, as indicated in this report. It seems appropriate therefore to again examine the operations, and to maintain a scale of operations consistent with the purposes of the monitoring, as outlined in the Introduction.

During 1996, it is therefore proposed to make the following further reductions in the monitoring programme.

1. Phase out TBA deposition measurements at Rarotonga.

2. Phase out ^{90}Sr deposition measurements at Kaitaia and Rarotonga, as techniques are developed to allow the more sensitive measurement of ^{90}Sr at Hokitika using the large-area rainwater collector.

3. Phase out the measurement of ^{90}Sr in milk at Auckland and Taranaki, maintaining only the Westland site as the high-rainfall indicator of country-wide contamination levels.

As these changes are implemented, the monitoring programme will reduce to:

atmospheric radioactivity monitoring at Kaitaia, Hokitika and Rarotonga

deposition monitoring at Hokitika

milk ^{90}Sr monitoring in Westland

milk ^{137}Cs monitoring in Auckland, Taranaki and Westland.

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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.

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Table 1: A summary of atmospheric radioactivity levels measured during 1995

Atmospheric radioactivity, weekly measurements

Monitoring site:	KAITAIA	HOKITIKA	RAROTONGA
TBA			
Range, mBq/m^3	0.04 - 0.23	0.03 - 0.15	0.02 - 0.16
Mean, mBq/m^3	0.10	0.08	0.08
Cosmogenic ^{7}Be			
Range, mBq/m^3	1.7 - 6.2	0.3 - 4.6	0.6 - 6.0
Mean, mBq/m^3	3.2	2.5	3.1
Radon decay product ^{210}Pb			
^{210}Pb, range mBq/m^3	0.03 - 0.20	0.02 - 0.15	0.02 - 0.12
mean mBq/m^3	0.07	0.06	0.06

Atmospheric radioactivity, annual measurement: annual average concentration

Fission product ^{137}Cs			
^{137}Cs, $\mu Bq/m^3$	0.03 ± 0.01	0.03 ± 0.01	< 0.02
Cosmogenic ^{22}Na			
^{22}Na, $\mu Bq/m^3$	0.32 ± 0.01	0.22 ± 0.01	0.25 ± 0.01

Table 2: A summary of ^{90}Sr, ^{210}Pb and total beta activity deposition measurements at Kaitaia, Hokitika and Rarotonga during 1995

Deposited radioactivity (Bq/m^2)

	Kaitaia	Hokitika	Rarotonga
TBA		208 ± 6	180 ± 13
^{90}Sr	0.2 ± 0.1	0.3 ± 0.2	0.1 ± 0.1
^{210}Pb		136 ± 7	
^{7}Be		6550 ± 130	
Rainfall, cm		355	212

Table 3: Caesium-137 and strontium-90 levels in cows' milk during 1995

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	Auckland		Taranaki		Westland	
	Bq/g K	Bq/kg	Bq/g K	Bq/kg	Bq/g K	Bq/kg
1	0.04	0.73	0.22	2.92	0.07	1.06
2	<0.04	<0.5	0.29	3.70	0.19	2.28
3	<0.04	<0.5	0.17	1.83	0.06	0.95
4	0.04	0.65	0.17	1.67	0.04	0.73
5	<0.04	<0.5	0.28	3.18	0.04	0.50
6	0.05	0.59	0.08	0.96	<0.04	<0.5
7	<0.04	<0.28	0.05	0.66	<0.04	<0.5
8	<0.04	<0.5	0.07	1.00	<0.04	<0.5
9	<0.04	<0.5	0.12	1.50	<0.04	<0.5
10	<0.04	<0.5	0.14	1.96	0.04	0.50
11	0.04	0.67	0.12	1.70	0.05	0.83
12	0.04	0.71	0.18	2.59	0.06	1.01
Mean	<0.04	<0.5	0.16	1.97	0.05	0.74

Strontium-90

Quarter	Auckland		Taranaki		Westland	
	Bq/g Ca	Bq/kg	Bq/g Ca	Bq/kg	Bq/g Ca	Bq/kg
1	0.020	0.25	0.033	0.42	0.029	0.37
2	0.024	0.26	0.028	0.35	0.027	0.29
3	0.027	0.34	0.026	0.30	0.026	0.29
4	0.014	0.24	0.028	0.27	0.024	0.32
Mean	0.021	0.27	0.029	0.33	0.027	0.32

Table 4: A summary for 1995 of weekly measurements of radioactivity in the atmosphere and precipitation

	Atmospheric concentrations, mBq/m^3									TBA deposition	
	KAITAIA			HOKITIKA			RAROTONGA			Bq/m^2	
Week	TBA	Be-7	Pb-210	TBA	Be-7	Pb-210	TBA	Be-7	Pb-210	Hokitika	Rarotonga
1	0.071	4.44	0.069	0.054	2.96	0.031	0.095	3.96	0.048	4.75	7.13
2	0.080	2.92	0.033	0.138	3.85	0.063	0.046	1.59	0.018	1.23	0.49
3	0.087	3.37	0.056	0.105	3.33	0.108	0.053	1.91	0.035	4.14	6.42
4	0.111	4.31	0.064	0.144	4.03	0.076	0.105	3.11	0.055	6.10	2.83
5	0.073	3.64	0.050	0.073	3.19	0.048	0.110	3.32	0.049	4.89	4.73
6	0.142	5.03	0.119	0.107	3.30	0.060	0.045	1.02	0.030	2.73	4.24
7	0.113	3.89	0.084	0.148	4.57	0.153	0.122	3.10	0.121	4.38	3.37
8	0.108	4.06	0.088	0.066	3.51	0.061	0.102	4.51	0.101	2.10	1.52
9	0.171	6.21	0.158	0.112	4.54	0.061	0.114	3.24	0.043	2.49	0.98
10	0.227	5.90	0.130	0.137	4.28	0.084	0.050	3.48	0.041	8.40	3.92
11	0.081	2.52	0.028	0.070	2.32	0.022	0.050	3.48	0.041	3.88	3.05
12	0.098	2.89	0.073	0.055	2.41	0.025	0.051	3.05	0.029	1.62	2.50
13	0.093	2.29	0.057	0.067	2.68	0.072	0.049	2.08	0.034	2.30	4.57
14	0.135	2.89	0.131	0.082	1.99	0.042	0.054	1.89	0.039	3.23	8.32
15	0.113	4.15	0.098	0.071	2.57	0.070	0.034	1.06	0.035	1.90	4.35
16	0.115	2.72	0.071	0.103	3.18	0.124	0.110	4.99	0.064	2.93	5.49
17	0.078	3.37	0.056	0.073	2.84	0.051	0.081	3.58	0.052	1.49	1.69
18	0.055	2.22	0.037	0.073	2.02	0.053	0.061	2.97	0.060	1.98	6.31
19	0.079	2.81	0.042	0.118	2.51	0.141	0.072	2.03	0.045	3.21	3.97
20	0.078	2.75	0.066	0.055	2.08	0.051	0.080	2.83	0.040	2.79	5.60
21	0.098	3.16	0.059	0.117	3.08	0.121	0.018	0.63	0.017	2.79	3.32
22	0.048	2.23	0.033	0.053	1.84	0.044	0.059	2.60	0.057	1.80	2.45
23	0.069	1.94	0.081	0.050	1.52	0.064	0.062	3.29	0.041	3.43	2.56
24	0.060	1.97	0.070	0.029	0.31	0.030	0.111	2.77	0.063	1.78	0.82
25	0.056	1.91	0.036	0.097	1.70	0.064	0.094	5.06	0.069	2.16	2.72
26	0.096	3.12	0.074	0.054	1.78	0.051	0.044	2.82	0.091	5.92	2.28
27	0.043	1.78	0.027	0.043	1.34	0.019	0.061	2.67	0.055	6.12	2.72
28	0.103	2.70	0.108	0.112	1.73	0.062	0.089	4.12	0.065	3.39	3.37
29	0.073	2.53	0.039	0.030	1.78	0.018	0.097	4.44	0.090	3.25	2.18
30	0.080	3.08	0.069	0.055	1.88	0.034	0.102	3.48	0.094	1.11	1.36
31	0.096	2.44	0.092	0.058	1.45	0.061	0.090	2.98	0.071	1.13	0.00
32	0.044	1.67	0.044	0.076	1.54	0.080	0.102	4.25	0.049	4.53	2.99
33	0.085	2.40	0.072	0.057	1.88	0.054	0.059	2.85	0.074	6.40	2.01
34	0.208	4.41	0.203	0.105	2.94	0.113	0.050	1.75	0.028	6.30	3.75
35	0.103	2.91	0.089	0.064	2.50	0.071	0.111	4.79	0.075	7.72	4.13
36	0.082	2.50	0.044	0.037	1.50	0.046	0.130	5.95	0.105	6.06	3.97
37	0.142	3.72	0.088	0.056	2.29	0.047	0.097	3.51	0.057	5.84	2.67
38	0.125	2.45	0.120	0.053	1.99	0.080	0.034	1.66	0.045	5.46	5.60
39	0.103	3.29	0.107	0.064	1.50	0.047	0.118	4.75	0.077	8.08	4.08
40	0.091	3.01	0.076	0.099	2.15	0.078	0.156	3.45	0.112	5.01	3.26
41	0.147	5.09	0.097	0.058	2.70	0.037	0.091	3.00	0.094	4.16	4.57
42	0.090	3.81	0.052	0.067	3.05	0.027	0.114	4.32	0.055	4.46	3.59
43	0.102	1.83	0.064	0.101	1.85	0.068	0.084	3.17	0.065	0.99	2.01
44	0.106	3.31	0.095	0.066	1.78	0.049	0.118	4.15	0.087	3.03	2.72
45	0.152	4.47	0.053	0.063	2.45	0.094	0.051	1.11	0.027	5.45	4.84
46	0.136	2.92	0.062	0.085	3.12	0.054	0.064	1.34	0.041	3.64	4.41
47	0.105	3.22	0.041	0.074	3.28	0.041	0.053	1.99	0.042	2.89	4.30
48	0.088	2.71	0.031	0.053	2.64	0.043	0.050	1.88	0.042	9.03	3.81
49	0.198	3.78	0.182	0.090	2.36	0.071	0.063	2.37	0.053	3.27	2.01
50	0.116	3.33	0.071	0.095	3.24	0.050	0.054	3.05	0.048	9.25	5.98
51	0.038	3.30	0.062	0.049	2.46	0.040	0.060	4.91	0.055	4.08	2.61
52	0.052	3.48	0.032	0.040	2.96	0.018	0.068	3.27	0.069	3.39	1.47

Table 5: Correlations between atmospheric concentrations of TBA, ^{7}Be and ^{210}Pb

The r^2 values are tabulated for each of data pairs indicated. The data are as presented in figures 1 - 3 (5-week moving averages).

r^2	TBA - ^{7}Be	^{210}Pb - ^{7}Be	TBA - ^{210}Pb
Kaitaia	0.61	0.32	0.59
Hokitika	0.80	0.22	0.38
Rarotonga	0.49	0.63	0.75

Table 6: A summary of results of international analytical intercomparisons conducted since late 1994

The Laboratory's analytical result (mean of 3 analyses) is compared with the "known" value as stated by the organiser. Units were varied and are not given in the table. (TAA = total alpha activity, TBA = total beta activity.)

Organiser	Sample	Type	Nuclide	NRL mean	Known
EPA	milk	gamma	^{131}I	82	75
			^{137}Cs	63	59
			K	2.1	1.7
		beta	^{90}Sr	15	15
WHO	water	gamma	^{60}Co	101	103
WHO	water	alpha	U	12	11

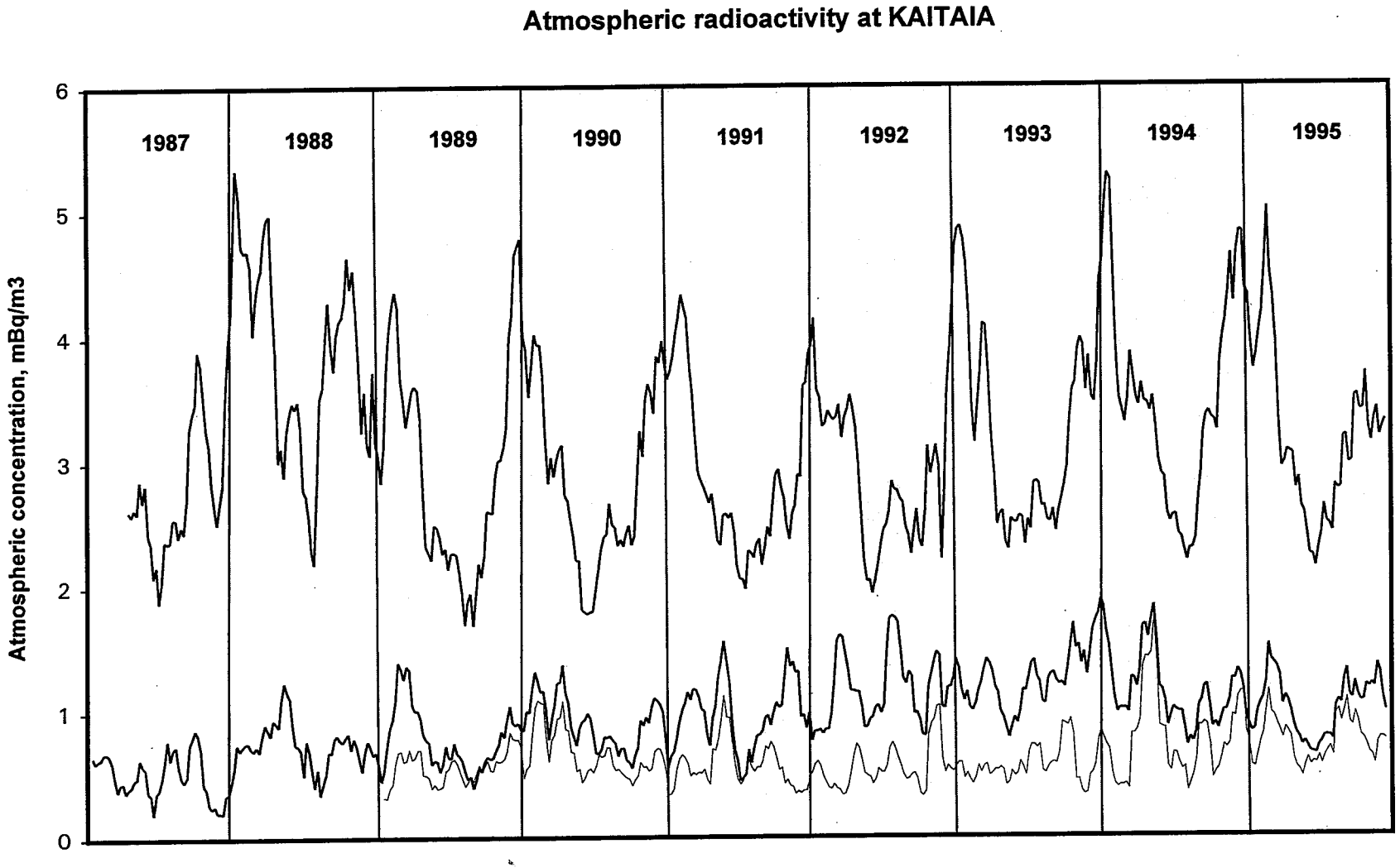

Fig 1 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Kaitaia** during the period 1987 to 1995. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*

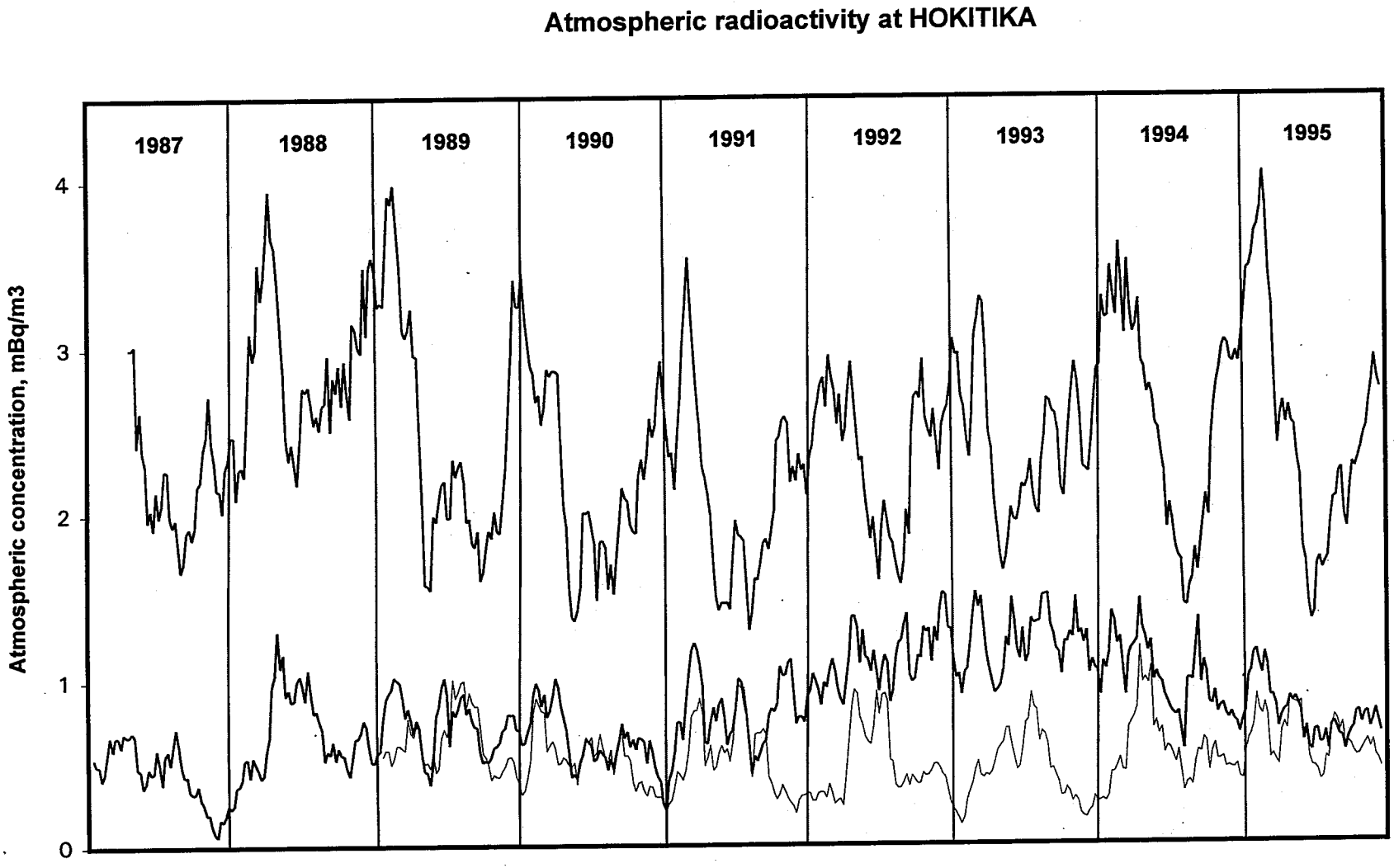

Fig 2 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Hokitika** during the period 1987 to 1995. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*

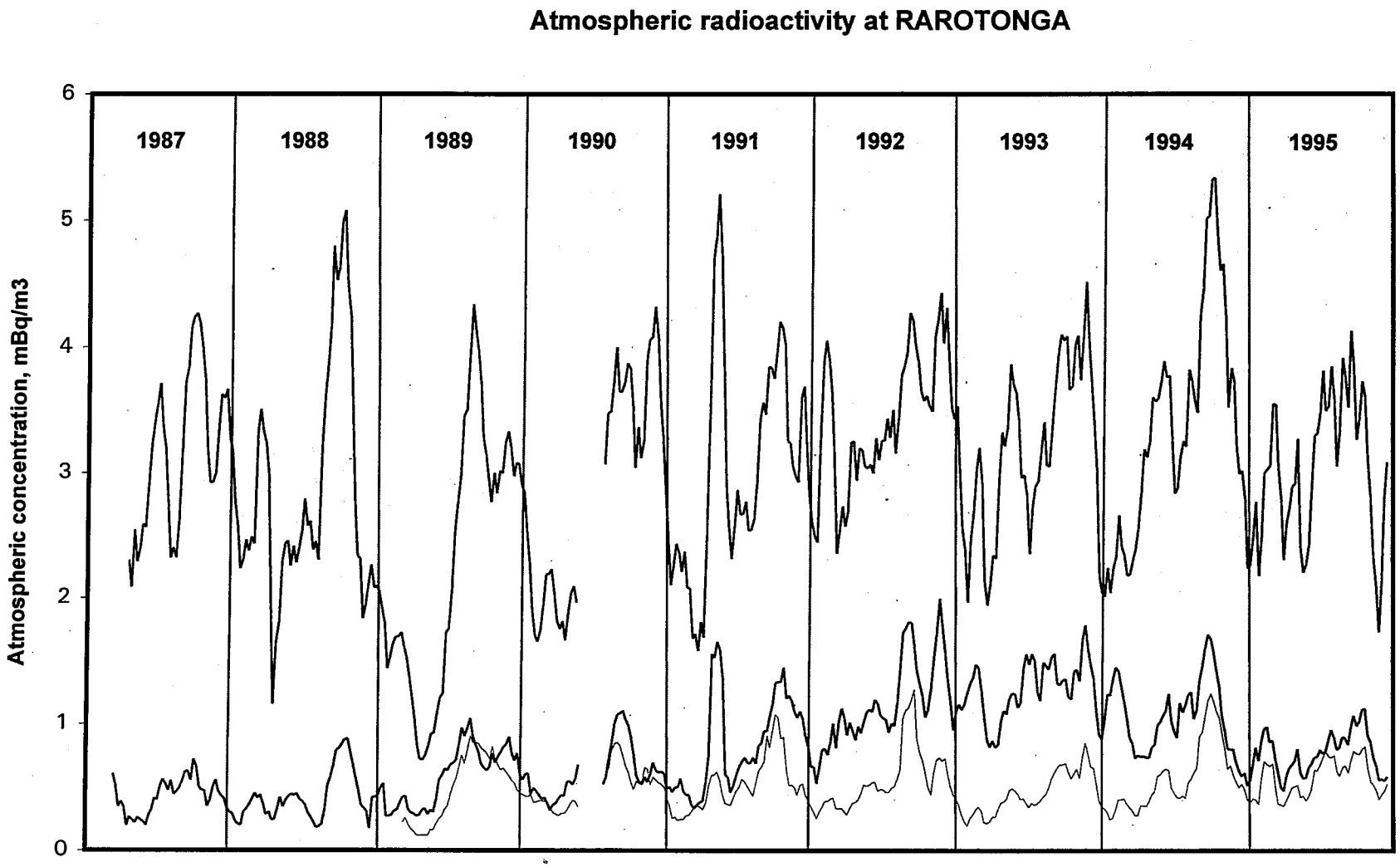

Fig 3 Five-week moving-average atmospheric concentrations of beryllium-7 (upper heavy solid line), total beta activity (middle solid line) and lead-210 (pale line) at **Rarotonga** during the period 1987 to 1995. *A scaling factor of 10 has been applied to ^{210}Pb and TBA levels.*