NRL - F/54

DEPARTMENT OF HEALTH
NEW ZEALAND

ENVIRONMENTAL RADIOACTIVITY ANNUAL REPORT

1974

NATIONAL RADIATION LABORATORY
P. O. BOX 25-099, CHRISTCHURCH
NEW ZEALAND

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TERMS OF REFERENCE AND ACKNOWLEDGEMENT

In September 1957 the New Zealand Department of Health was charged, under a Cabinet directive, with the responsibility for monitoring environmental radioactive contamination in New Zealand and also in any Pacific areas with which New Zealand was associated.

The Department delegated this responsibility to its National Radiation Laboratory at Christchurch where the measurement of radioactive fallout became a natural extension of the work of the Laboratory in the fields of radiation protection - the control of radioactive pollution and the safe use of ionizing radiations in medicine, education, research and industry.

The National Radiation Laboratory therefore undertook responsibility for sample collection, analysis, and interpretation of data on environmental levels of radioactivity. The network of collecting stations shown in Fig. 1 was subsequently established. In addition to the New Zealand sampling, monthly collections of rainwater have also been provided from Fiji and Rarotonga. Within New Zealand, collections were made, and samples were provided, by officers of this and other Government Departments (particularly the staff of the New Zealand Meteorological Service), by pathologists, and by the managers of milk processing plants. Their continued co-operation is gratefully acknowledged as it has made possible the Laboratory's routine monitoring programme.

The Environmental Radioactivity Section of the Laboratory was responsible for the organisation of the monitoring operations, sample analyses, and reporting and interpretation of results:

L. P. Gregory	Officer in Charge, Monitoring Operations, Radiochemistry, Editorial Work.
T. Baltakmens	Professional Officer, Radiochemistry.
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The assistance of the mechanical and electronic workshops, the draughting and clerical sections of the Laboratory is gratefully acknowledged.

H. J. YEABSLEY
DIRECTOR

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SUMMARY

During 1974 the country-wide average deposition of strontium-90 on New Zealand was the lowest since measurements commenced in 1960.

A maximum country-wide average level of 3.6 millicuries per square kilometre was deposited in 1964 following the large scale U.S.S.R. and U.S.A. nuclear tests in 1961 and 1962. Annual deposits thereafter decreased to a minimum of 0.8 mCi/km^2 in 1968. Smaller increases reaching a maximum annual deposit of 1.4 mCi/km^2 occurred in the next few years as a result of French nuclear tests in the South Pacific. During 1973 and 1974, however, the country-wide average annual deposit decreased to 0.3 mCi/km^2, less than one-tenth the 1964 maximum. It is estimated that at the end of 1974 about 22% of the total strontium-90 deposition on New Zealand had come from French tests in the South Pacific.

The concentrations of strontium-90 and caesium-137 in milk reflect the changes in fallout deposition. The average levels during 1974 were the lowest since measurements commenced.

Results for the extended monitoring programme covering the seven low to intermediate power nuclear tests in the 1974 French test series were published in the previous report (NRL-F/53, November 1974). It is expected that future deposition of long-lived material from the 1974 series will be less than that from several of the earlier French test series.

During 1974 the levels of radioactive contamination were small percentages of the reference levels. It is considered, therefore, for the reasons discussed under "Reference Levels" p. 3, that these levels do not constitute a public health hazard.

In addition the radiation dose resulting from the long-term average levels, since measurements commenced, is small compared not only with natural background but also with common variations in natural background.

CONTENTS

INTRODUCTION

This report continues the series of annual reports concerned mainly with long-term levels of environmental radioactivity in New Zealand and at Fiji and Rarotonga. Sample collecting stations in New Zealand are shown in Fig. 1. The present report should be read in conjunction with the previous re-designed annual reports (1) especially the first of these which summarised all the earlier reports, and discussed global fallout and specific radionuclides of potential health significance.

From June to September 1974 France conducted her eighth series of nuclear weapon tests in the South Pacific. The results of the extended programme monitoring short-term levels of fallout from these tests were recently published and compared with levels monitored during earlier French test series (2).

The 1974 nuclear test series was reported to be the last to be conducted by France in the atmosphere, and future testing in the South Pacific is to be conducted underground. At the time of going to press news reports stated that such underground testing at the Mururoa and Fangataufa atolls in French Polynesia was imminent. The Laboratory's routine monitoring programme has therefore been extended on a permanent basis to include six Pacific Island monitoring stations. The monitoring programme is designed to detect any venting of fission products to the atmosphere. Results will be included in the routine annual reports of this series.

The unit of radioactivity (the Curie) and the sub-units used in practical measurements are defined on the inside back cover. Units used for expressing the deposition of radioactive fallout, and the concentration of specific radioactive substances in various environmental media are included.

POTENTIAL HEALTH HAZARD AND REFERENCE LEVELS

There are no internationally accepted "permissible levels" for the exposure of people to fallout from nuclear weapons testing. Most of the measurements recorded in this report concern such contamination and it is considered necessary in the public interest to provide some guide by which the significance of the values may be appreciated.

Development of Reference Levels

The simplest procedure is to compare measured values with those which would give the annual "Dose Limits" suggested by the International Commission on Radiological Protection (3). The I.C.R.P. dose limits were established for individual members of the public so that the risks from controllable radiation sources should be no greater than other risks

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(1) "Environmental Radioactivity":
Annual Report 1971, Report No. NRL-F/48, June 1972
Annual Report 1972, Report No. NRL-F/50, April 1973
Annual Report 1973, Report No. NRL-F/52, June 1974

(2) "Environmental Radioactivity. Fallout From Nuclear Weapons Tests Conducted by France in the South Pacific From June to September 1974, and comparisons with previous test series".
Report No. NRL-F/53, November 1974.

(3) Recommendations of the International Commission on Radiological Protection: ICRP Publication 9. Pergamon Press, 1966.

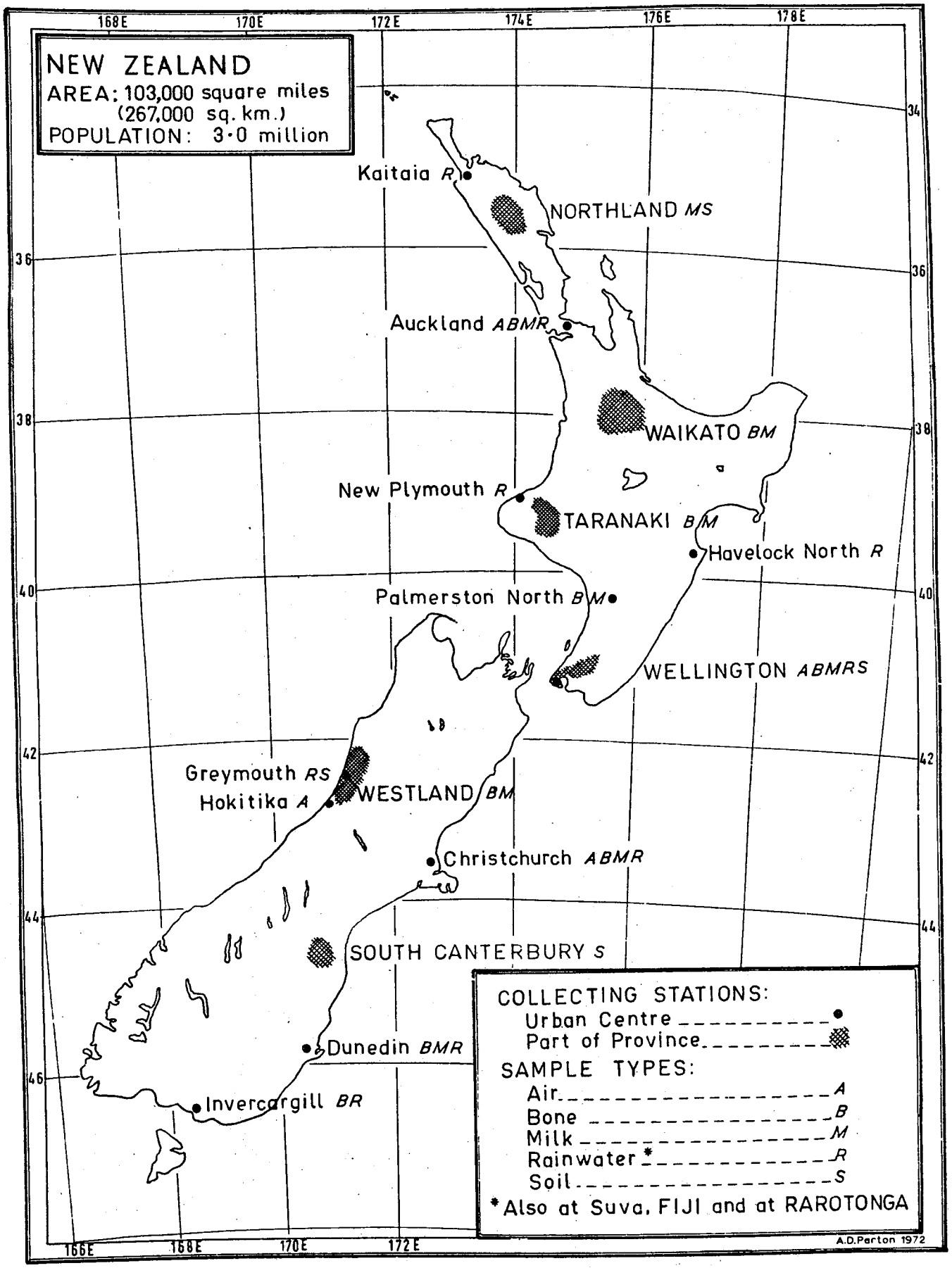

Fig. 1 Collecting stations in New Zealand

regularly accepted in every day living. These dose limits are in fact one-tenth of the annual Maximum Permissible Doses for radiation workers. The Commission emphasizes that all controlled radiation exposures should be kept to the minimum practicable and that the risks should be justified in terms of benefits that would not otherwise be received. Although the latter criterion does not apply in the present case, the following "Reference Levels" have been derived from these dose limits, making allowance for the risk to children. In no case is a reference level greater than one-third of the concentration which, if maintained indefinitely, would lead to a dose limit. The media and radionuclides listed are those generally accepted as the key items for monitoring fallout contamination, and the units of concentration are those used in the reports of this Laboratory.

Reference Levels

In Milk :	Strontium-90	(picocuries per gram of calcium)	270
	Caesium-137	(picocuries per gram of potassium)	7,000
	Iodine-131*	(picocuries per litre)	200
In Air :	Mixed fission products between 10 and 80 days old	(picocuries per cubic metre)	300
In Rainwater :	Mixed fission products between 10 and 80 days old	(picocuries per litre)	6,000

The I.C.R.P. dose limits specify annual exposures and therefore for those concentrations which can change rapidly with time, such as mixed fission products in air or in rain, or iodine-131 in milk, the average values over the year, rather than transient values, should be compared with the reference levels.

If, during any single year, the average levels do not greatly exceed the reference levels then any resulting increase in risk to the health of an individual would be insignificant. Such a non-beneficial irradiation of the general population should be prevented if practicable but should it occur it would not justify the disruption and risks associated with remedial action and therefore would not be described as a public health hazard.

Comparison of Reference Levels with Natural Radiation Background

Under the condition of continuing weapons tests, long-lived radioactive debris, accumulating in the environment, and the regular presence of short-lived material, may cause exposure over many years. In this context it is helpful to compare the average (over many years) of the annual doses from fallout with that due to background radiation to which the human race has always been exposed.

The level of background radiation varies markedly from place to place. For reference purposes, however, the "average" annual dose received from the natural environment may be taken as about 120 millirads.

There are a number of areas with large populations where the annual background dose is several times this value. No survey has to date demonstrated that there is a health hazard associated with living in such a region. On the other hand it has not been possible to demonstrate that there is a threshold dose below which no effect on health is produced.

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* Not a routine measurement (see NRL-F/53 for results of ^{131}I measurements during the special monitoring programmes).

If the reference levels were maintained indefinitely, they would each lead to a dose rate of the same order as that received from average natural background radiation. Thus if a long term average level is expressed as a percentage of a reference level then the resulting risk will be about the same percentage of any risk which may be eventually attributed to radiation from the natural environment.

BETA ACTIVITY OF AIR FILTER AND RAINWATER COLLECTIONS

1. FISSION PRODUCTS IN AIR

Normally the short-lived decay products of naturally-occurring radon account for most of the beta activity in air. Ground level air over continents has a beta activity commonly ranging between 60 and 600 picocuries per cubic metre, but under certain conditions the beta activity may be up to ten times the upper value of this range.

Air filter samples which are collected for measurement of fission products are held for four days to allow this natural radioactivity to decay away and are then measured for residual beta activity which is due to radioactive fallout. Hereafter the term "total beta activity" refers only to this residual radioactivity due to fission products.

Air is monitored continuously at four New Zealand stations, the filters normally being changed three times each week. (See TABLE 8 APPENDIX for individual results during 1974.) During the extended programme covering French nuclear tests, however, filters were changed daily at the New Zealand stations and also at five Pacific Island stations. The individual daily results have been published separately (2).

In the absence of fresh fission products in the atmosphere, the levels of "total beta activity" in air have usually been less than 0.1 picocuries per cubic metre (typically 0.01 to 0.03 pCi/m^3). Since 1959, however, when measurements first commenced at Christchurch, transient increases in the levels, due to atmospheric nuclear tests, have been observed.

In Fig. 2 the average monthly levels are shown for the four New Zealand stations. The increases caused by nuclear tests, conducted by the United States in the Pacific in 1962, and by the French in the South Pacific from 1966 to 1974 are apparent. The progressive reduction in the levels after each test series is also apparent. This is particularly noticeable after the 1966 and 1967 French tests in which weapons in the kiloton range only were tested. The relatively rapid removal from the troposphere by deposition is characteristic of such tests. The 1968, 1970 and 1971 French test series, however, have each included one or more weapons in the megaton range and the higher altitude of injection of fission products caused a delay in the subsequent transfer to the troposphere. This delay is apparent in Fig. 2.

During the 1972 and 1973 French low power nuclear test series, fresh fission products in air were occasionally present at extremely low levels, barely detectable above the residual level from previous tests.

The 1974 French nuclear test series comprised seven low to intermediate power tests. During the latter half of 1974 fresh fission material was readily detectable, but at levels which were, in most cases, less than those measured during Pacific tests prior to 1972.

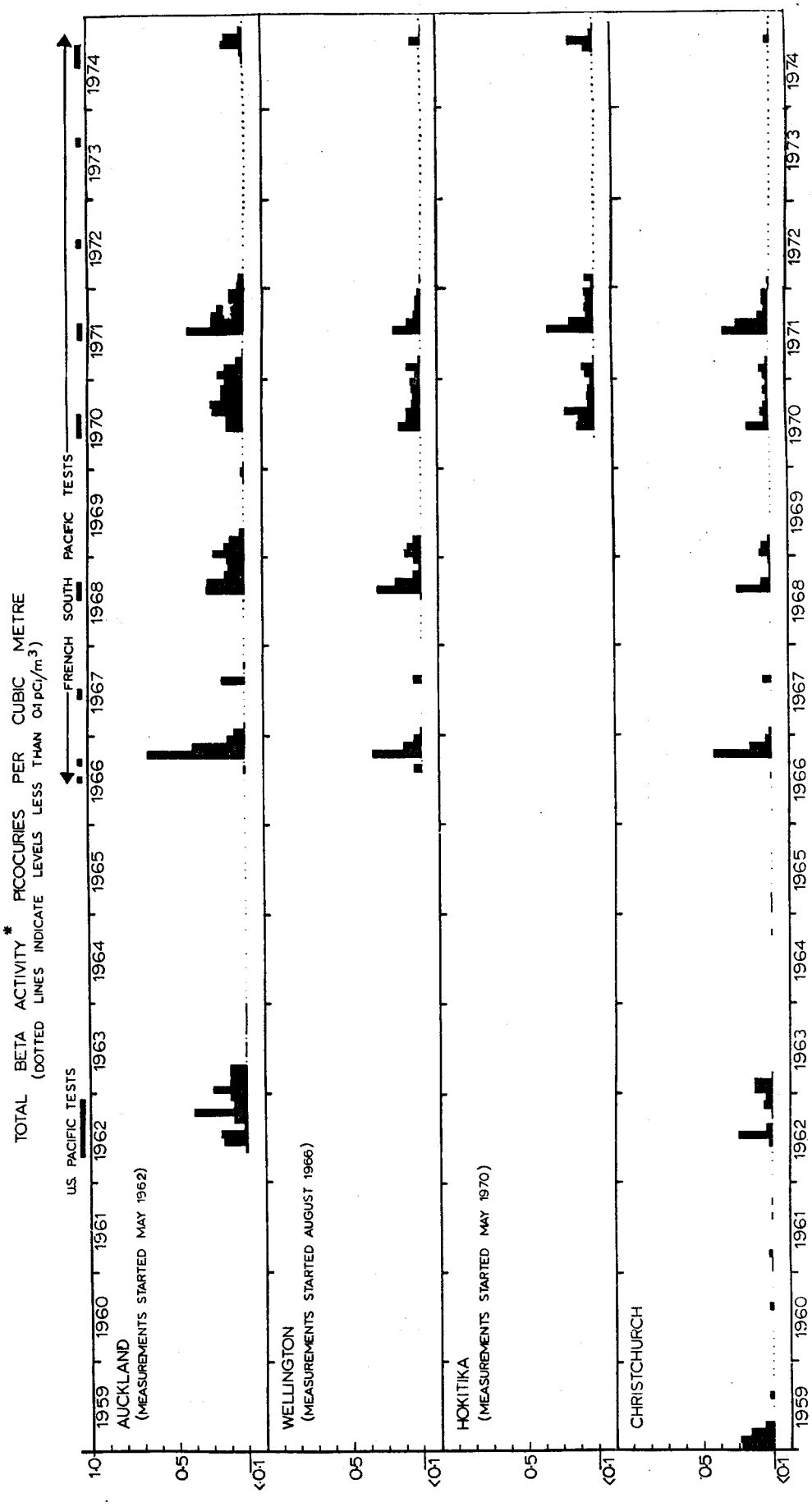

Fig. 2 Fission products in air - monthly averages

The monthly average levels shown in Fig. 2 have been averaged for each year since 1966, where possible, and are shown in TABLE 1.

TABLE 1 TOTAL BETA ACTIVITY IN AIR - ANNUAL AVERAGES (pCi/m^3)

	1966	1967	1968	1969	1970	1971	1972	1973	1974
Auckland	0.14	0.08	0.12	0.12	0.16	0.21	0.06	0.02	0.08
Wellington	0.10*	0.05	0.10	0.09	0.12	0.12	0.05	0.01	0.05
Hokitika					0.12*	0.16	0.05	0.02	0.07
Christchurch	0.11	0.06	0.07	0.07	0.10	0.15	0.05	0.02	0.05

* Estimate

During 1974 levels of fission products in air at the New Zealand stations were very small fractions of the Reference Level.

2. FISSION PRODUCTS IN RAIN

Weekly funnel and bottle collections of rainwater are made at four New Zealand stations on a routine basis, and are measured for total beta activity. Increases in the levels of fission products in rainwater samples have occurred concurrently with increases in air radioactivity. The weekly depositions, totalled for each month, are shown in Fig. 3 as millicuries per square kilometre per month. It is evident that peak depositions coincide with nuclear tests. The difference in levels at Greymouth and Christchurch illustrates clearly the rainfall dependent nature of fallout deposition. Although these two stations are geographically close, and are at approximately the same latitude, they are separated by mountain ranges and represent the extremes in rainfall for the four stations.

The monthly depositions shown in Fig. 3 are summed for each year and listed in TABLE 2. (It should be realised that such a presentation of the results, although allowing some comparison, is not entirely valid where relatively fresh fission material is concerned - much of the material deposited during the year will have decayed by the end of that year.)

TABLE 2 SUM OF MONTHLY DEPOSITIONS DURING EACH YEAR
Total Beta Activity - Millicuries per Square Kilometre

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Auckland								101*	98	25	5	59
Wellington								75*	80	22	7	60
Greymouth				106**	77	205	61	133	99	33	8	42
Christchurch	28	15	17	32	14	28	18	26	32	15	4	22

* May to December only.
** July to December only.

The results for the individual weekly depositions, and the average concentrations for the year, are given for each station in TABLE 9 APPENDIX. The average concentrations ranged from 18 to 70 pCi/litre which are very small fractions of the Reference Level.

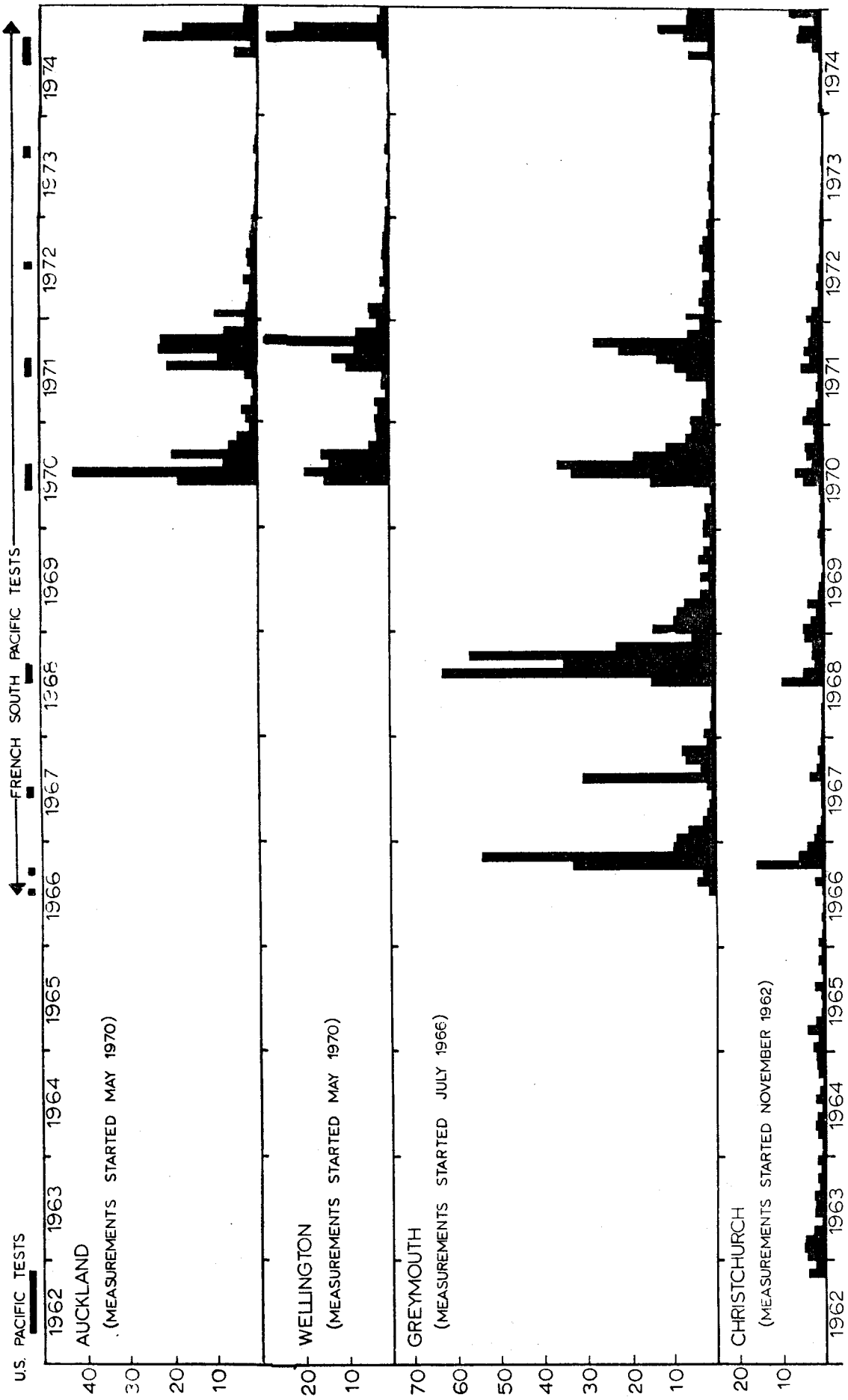

Fig. 3 Fission products in rain - monthly deposition

SPECIFIC RADIONUCLIDES

The most potentially hazardous long-term fallout radionuclides are strontium-90 and caesium-137. Fig. 4 shows the periods of nuclear testing in the Pacific and compares the New Zealand country-wide average values of strontium-90 deposition and concentration in rain. The resulting levels of strontium-90 and caesium-137 contamination in New Zealand milk are also shown. These levels are discussed in more detail in the following sections:

1. STRONTIUM-90 IN RAIN

(a) At Nine New Zealand and Two Pacific Island Stations

Monthly pot collections of rainwater for measurement of strontium-90 deposition have been conducted routinely since about 1960. During 1974 strontium-90 deposition at all stations was the lowest on record. TABLE 3 lists the annual deposition at each station, and the country-wide average deposition each year since measurements commenced. (See also TABLE 10 and Fig. 10 in the APPENDIX for monthly results for individual stations.)

TABLE 3 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

Station	Mean Annual Rainfall (cm)	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
NEW ZEALAND																
Kaitaia	138				1.8	4.1	3.1	1.6	1.0	0.9	1.5	1.0	2.0	0.9	0.4	0.3
Auckland	117	1.2	1.1	1.8	2.0	4.0	2.9	1.3	0.9	0.7	1.3	0.9	1.3	0.7	0.3	0.2
New Plymouth	149				2.0	5.3	4.2	1.9	1.3	1.0	1.5	1.2	1.9	0.9	0.3	0.3
Havelock Nth	76	0.7	0.8	1.0	1.0	1.6	1.7	0.8	0.5	0.6	0.7	0.6	1.0	0.5	0.2	0.2
Wellington	130	0.8	1.1	1.8	2.0	3.4	3.9	1.6	1.0	0.9	1.1	1.2	1.2	0.8	0.4	0.3
Greymouth	237	1.5	2.2	2.8	3.7	7.8	5.9	2.2	1.7	1.4	2.2	2.1	2.5	1.8	0.6	0.5
Christchurch	57	0.5	0.7	0.7	1.2	1.3	1.7	0.7	0.4	0.4	0.7	0.5	0.7	0.4	0.2	0.2
Dunedin	63				1.0	1.8	2.0	0.7	0.6	0.4	0.7	0.5	0.8	0.6	0.2	0.2
Invercargill	105	0.5	1.2	1.2	1.7	3.0	2.8	1.1	0.9	0.5	1.2	0.7	1.1	0.9	0.3	0.2
Country-wide Average		0.9	1.2	1.6	1.8	3.6	3.1	1.3	0.9	0.8	1.2	1.0	1.4	0.8	0.3	0.3
PACIFIC ISLANDS																
Suva, Fiji	300		1.0	1.6	2.4	2.5	2.0	1.2	0.8	1.0	1.3	0.9	1.5*	0.9	0.4	0.3
Rarotonga	209								0.9*	0.7	0.7	1.0	0.9*	0.8	0.6	0.3

The mean annual rainfall is for the years 1963 to 1974 inclusive (at Rarotonga: 1967 to 1974 inclusive)

* Estimate

The large scale northern hemisphere (U.S.S.R.) and Pacific area (U.S.A.) nuclear tests, which were conducted in 1961 and 1962 before the signing of the Partial Test Ban Treaty, resulted in a delayed stratospheric fallout over New Zealand. The maximum deposition from these tests was recorded in late 1964 and early 1965. Thereafter the annual deposition steadily decreased until 1968.

Since 1966 smaller scale French nuclear tests have been conducted in the South Pacific each year except 1969. Each of these test series, lasting from one to three months and comprising from three to eight nuclear explosions, has taken place during the southern hemisphere winter. To date 41 nuclear devices are reported to have been exploded in the atmosphere during these tests, most of them being in the low or medium power (kiloton) range. However, megaton explosions are reported to have occurred twice in 1968, twice in 1970 and once in 1971 (2).

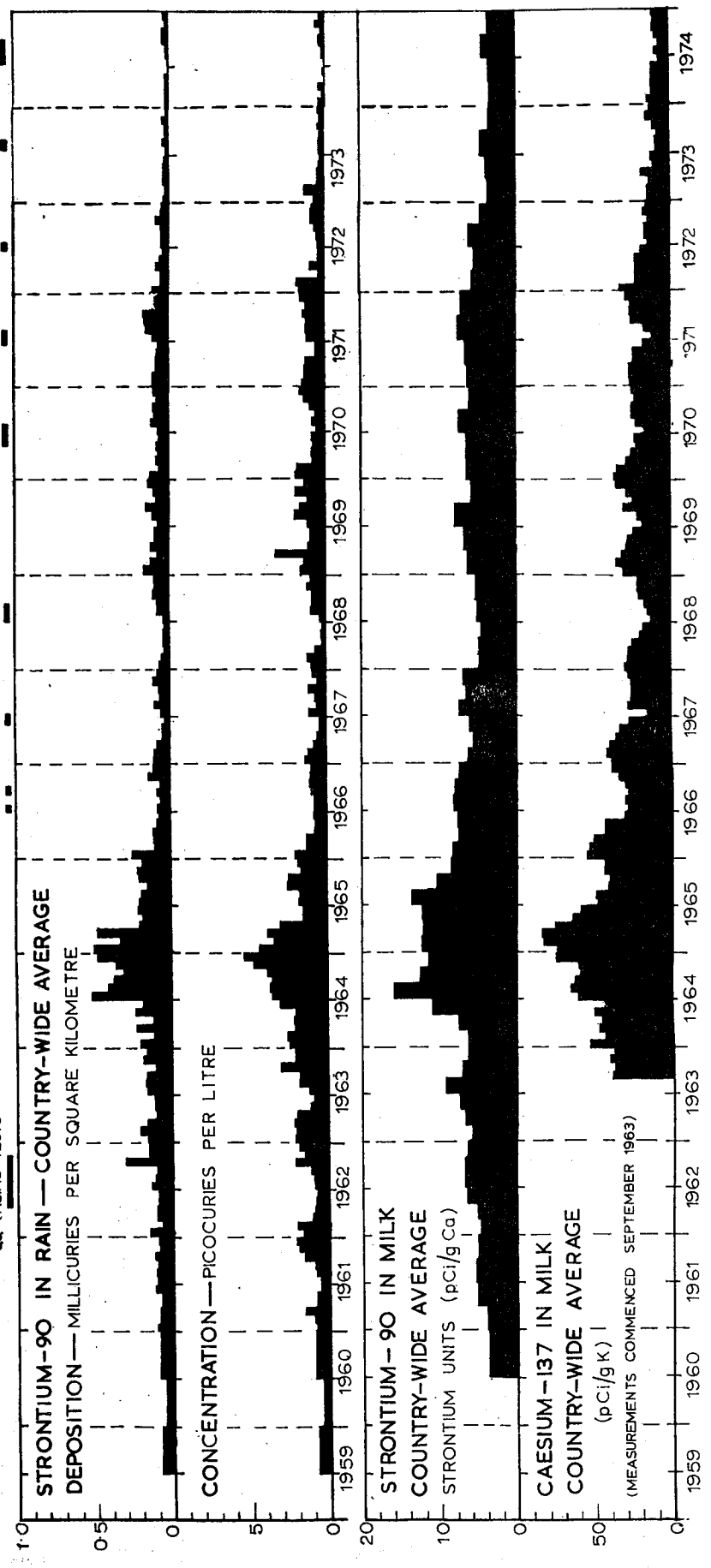

Fig. 4 Country-wide average levels of long-lived radionuclides in rain and milk

As a result of these South Pacific tests the annual rate of strontium-90 deposit over New Zealand increased during the period 1969 to 1971 and was about 50% higher than in 1968, although still only about one-third of the peak value in 1964. During 1972 the annual deposit again fell to the 1968 value and during 1973 and 1974 this trend continued with average depositions being less than half those for 1968.

In Section 3, Fig. 7, the half-yearly country-wide average depositions of strontium-90 attributed to the early 1961-1962 U.S. and U.S.S.R. tests, and to the French tests, are plotted separately.

At the two Pacific Island stations the values, in general, have been similar to the New Zealand country-wide average during the past eight years. However, it is interesting to note that during the year of maximum deposition of stratospheric fallout in 1964, the deposit at Suva was significantly lower than the New Zealand average despite the much higher annual rainfall at Suva. This illustrates a significant characteristic of stratospheric fallout, namely that the tropics receive less global fallout than the mid-latitudes.

(b) Comparison With Two Northern Hemisphere Stations

Two collection sites in the northern hemisphere were continuing measurements of deposition of strontium-90 in rain have been made since about 1954 are Milford Haven in the United Kingdom and New York City. The published results (4) (5) for annual deposition at these collecting stations are compared with the New Zealand country-wide average annual deposition in TABLE 4.

It will be seen from TABLE 4 that the peak depositions from the 1961, 1962 stratospheric injections occurred in 1963 at the northern hemisphere stations and in 1964 in New Zealand. The delay in deposition in the southern hemisphere is explained by the delay in interhemispheric transfer of statospheric debris. TABLE 4 shows also that the maximum annual deposits at the two northern hemisphere stations were about six times higher than the New Zealand maximum and that levels subsequently fell rapidly and became about the same at all three stations from about 1969.

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(4) "Radioactive Fallout in Air and Rain, Results to the middle of 1974".
United Kingdom Atomic Energy Authority, AERE-R 7832.

(5) "Environmental Quarterly, April 1, 1975".
Health and Safety Laboratory, Energy Research and Development Administration, New York, HASL-291.

TABLE 4 ANNUAL DEPOSITION OF STRONTIUM-90 mCi/km^2

Year	Northern Hemisphere Stations		New Zealand Average
	Milford Haven (U.K.)*	New York City	
1954	2.0 (up to end of 1954)	2.8 (Feb.-Dec. incl.)	
1955	2.4	3.6	
1956	2.5	4.4	
1957	2.6	4.4	
1958	5.4	6.2	
1959	5.7	8.7	
1960	1.8	1.6	0.9
1961	2.5	2.4	1.2
1962	9.3	12.3	1.6
1963	20.9	23.8	1.8
1964	11.7	15.9	3.6
1965	4.8	5.5	3.1
1966	3.1	2.4	1.3
1967	1.2	1.6	0.9
1968	1.2	1.3	0.8
1969	0.9	1.4	1.2
1970	1.2	1.5	1.0
1971	1.4	1.4	1.4
1972	0.6*	0.7	0.8
1973	0.3	0.4	0.3
1974	(0.3)to end of June only	(0.9)to end of October only	0.3

* Starting 1972 deposition is evaluated in a bulked sample from seven United Kingdom stations (including Milford Haven).

2. STRONTIUM-90 CUMULATIVE DEPOSITION

The annual depositions listed in TABLE 4 have been totalled, corrected for radioactive decay, and are presented in Fig. 5 as cumulative deposition. In order to show the range in New Zealand, the values for the highest rainfall station Greymouth, and the lowest rainfall station Christchurch, are also presented. (The dotted portions of the curves for the New Zealand stations up to mid-1959 are estimates based on some soil measurements undertaken by the U.S. Department of Agriculture at that time.)

For the northern hemisphere stations the most significant feature of Fig. 5 is the steep rise in the curves during the years of maximum fallout rate, and the relatively high cumulative deposition after 1964. The plateaux in these curves represent a sharp drop in the rate of fallout. This is evident at about 1960 after the Test Moratorium of 1959 and 1960, and also after about 1965 following the Partial Test Ban Treaty. The interesting situation was reached after 1966 that the reduction due to radioactive decay of the accumulated strontium-90 was slightly greater than the annual increment from fallout, so that there is a distinct downward trend in each curve.

In New Zealand, however, where the total accumulation is much less, the reduction due to radioactive decay has been less significant. The injection of fresh fission material into the southern hemisphere during the French nuclear tests has caused a rate of fallout somewhat greater than the rate of radioactive decay, thus resulting in the continuing slight upward trend, to the end of 1972, as shown in Fig. 5. During 1973 and 1974, however, this trend was reversed, the reduction from radioactive decay was very slightly greater than the small increment from fallout during each year.

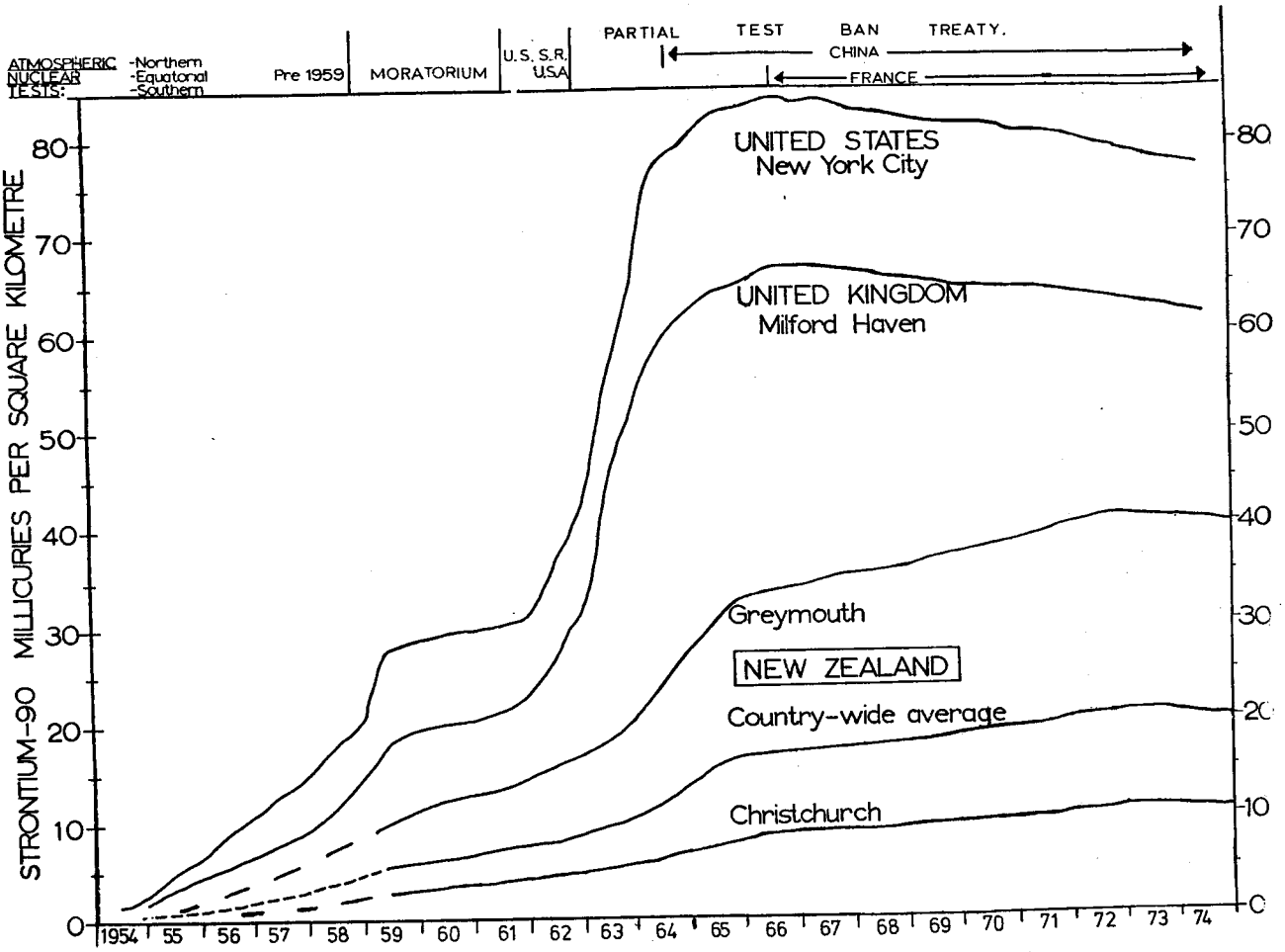

Fig. 5 Cumulative deposition of strontium-90 - comparison

The cumulative deposition has also been evaluated frequently by measuring strontium-90 in soil at four selected New Zealand sites. Results to the end of 1972 were given in the 1973 annual report of this series (1). A comparison of these direct measurements with calculated results from fallout deposition, indicated that a significant penetration of strontium-90 was occurring in the soil. Despite the increase in depth of sampling from an initial depth of 15 cm to 20 cm in 1960, and to 30 cm in 1970, direct measurements gave lower values than those calculated. Towards the end of 1974 a special survey was started and soils were sampled at the four routine sites and also at Stratford, Taranaki to a depth of 75 cm in 15 cm layers. The analysis of radionuclides in these "profile" samples is in progress.

3. STRONTIUM-89/STRONTIUM-90 ACTIVITY RATIOS (Determination of the Origin of Strontium-90)

Routine monthly collections of rainwater, which are analysed for strontium-90 deposition, are also analysed for strontium-89 deposition during periods of atmospheric nuclear tests. The activity ratio $^{89}Sr/^{90}Sr$ is then calculated for each collection. (Values for strontium-89 deposition and the activity ratio during 1974 are given in TABLE 11 APPENDIX.) Knowledge of the activity ratios and dates of nuclear tests often allows estimates of the origin of the deposited strontium-90.

Strontium-89 has a half-life of only 50 days. It is of minor health significance compared with strontium-90 which has a half-life of 28 years. However, the initial radioactivity of strontium-89, at formation, is much higher than that of strontium-90. In the calculations used here an activity ratio of 185 at the time of fission has been used (4). Thereafter the value of the ratio falls with a half-life of 50 days (the decay of the longer lived strontium-90 during the period of interest may be ignored).

In Fig. 6 the activity ratios at mid-month are plotted for each station since 1962. The ratios are plotted on a logarithmic scale from 1 to 185 (the ratio at formation). When the ratio falls below 1, strontium-89 measurements are discontinued. The logarithmic presentation allows the exponential decay of the ratio to be shown linearly and the straight lines drawn in Fig. 6 show 50-day half-life decay. If a point representing the ratio at mid-month lies on a decay line which extrapolates to a ratio of 185 at the time of a nuclear test (or a brief series of tests) then practically all the strontium-90 deposited in that collection comes from that test or brief test series. Extrapolated values less than 185 allow the proportion of strontium-90 deriving from such tests to be calculated.

The interpretation of Fig. 6 and discussion of values of the activity ratio during the period 1962 to the end of 1973 were given in the 1973 annual report of this series (1). The proportion of the strontium-90 deposition on New Zealand which was attributed to French Pacific testing, as calculated from values of the activity ratio, was also given for different time periods.

Because of the limited number and low power of the nuclear devices tested during 1972 and 1973, the average deposition of strontium-90 on New Zealand decreased steadily during this period, and in the first half 1974 levels fell to less than 0.01 mCi/km^2, i.e. the limit of detection, during May and June. After the start of the 1974 Pacific test series in June strontium-90 deposition increased slightly ranging between 0.02 and 0.04 mCi/km^2 per month during the second half 1974. Calculations from the monthly values of the activity ratio, which ranged from 26 to 81 during this period, indicate that about 90% of the strontium-90 fallout on New Zealand during the latter part of 1974 originated from that years's tests.

The conclusions reached from an analysis of strontium-90 deposition and the activity ratio data are summarised and shown in Fig. 7. The half-yearly strontium-90 deposits from French nuclear testing have been totalled and corrected for radioactive decay. Such calculations show that, at the end of 1974, about 22% of the country-wide cumulative deposition on New Zealand was attributable to the French Pacific tests.

The annual strontium-90 deposits at the two Pacific Island stations have generally been similar to the New Zealand average deposit since 1966. Prior to that results from Suva, Fiji only are available and for that period, annual deposits at Suva were generally less than the New Zealand averages.

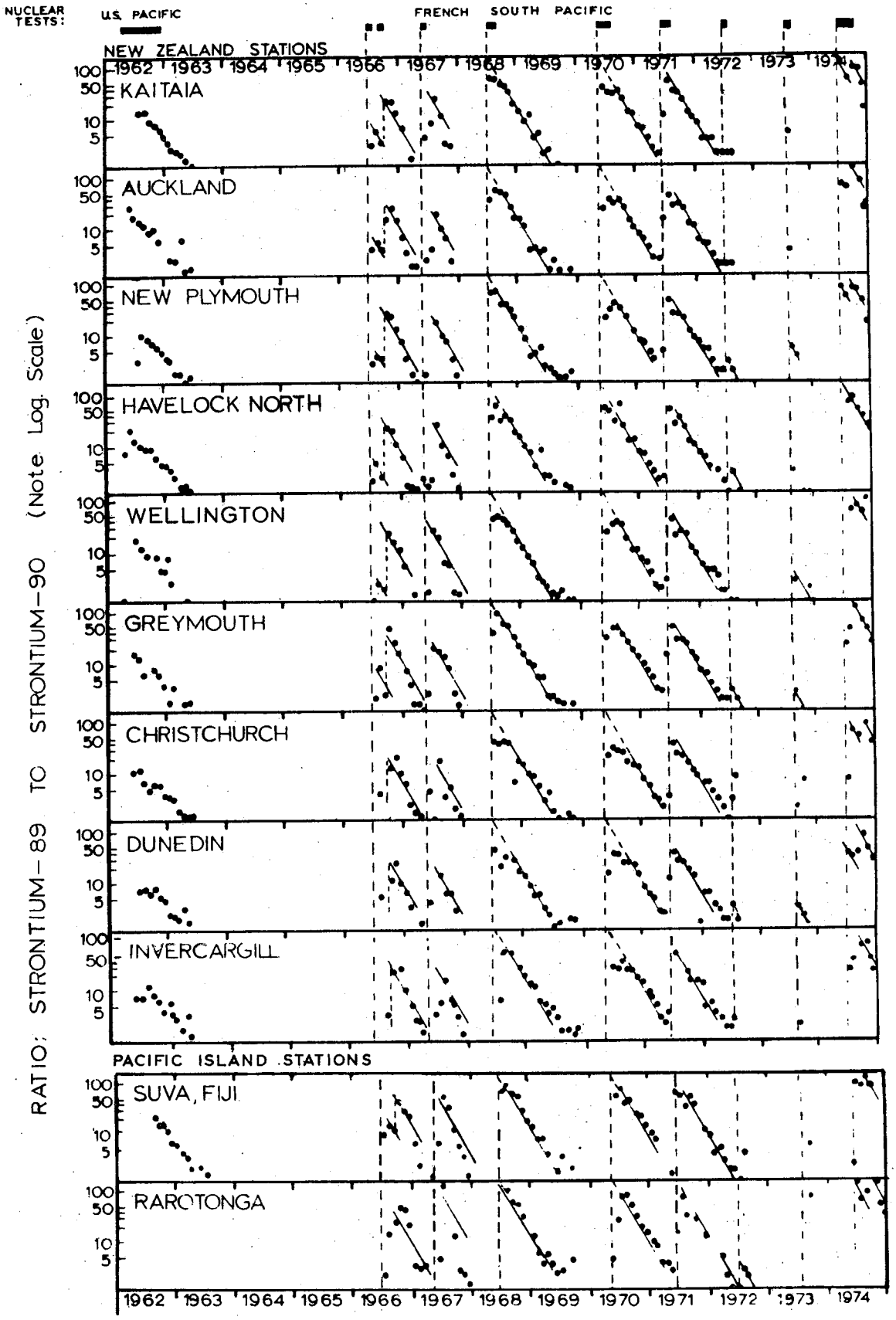

Fig. 6 Strontium-89/Strontium-90 ratio in rainwater

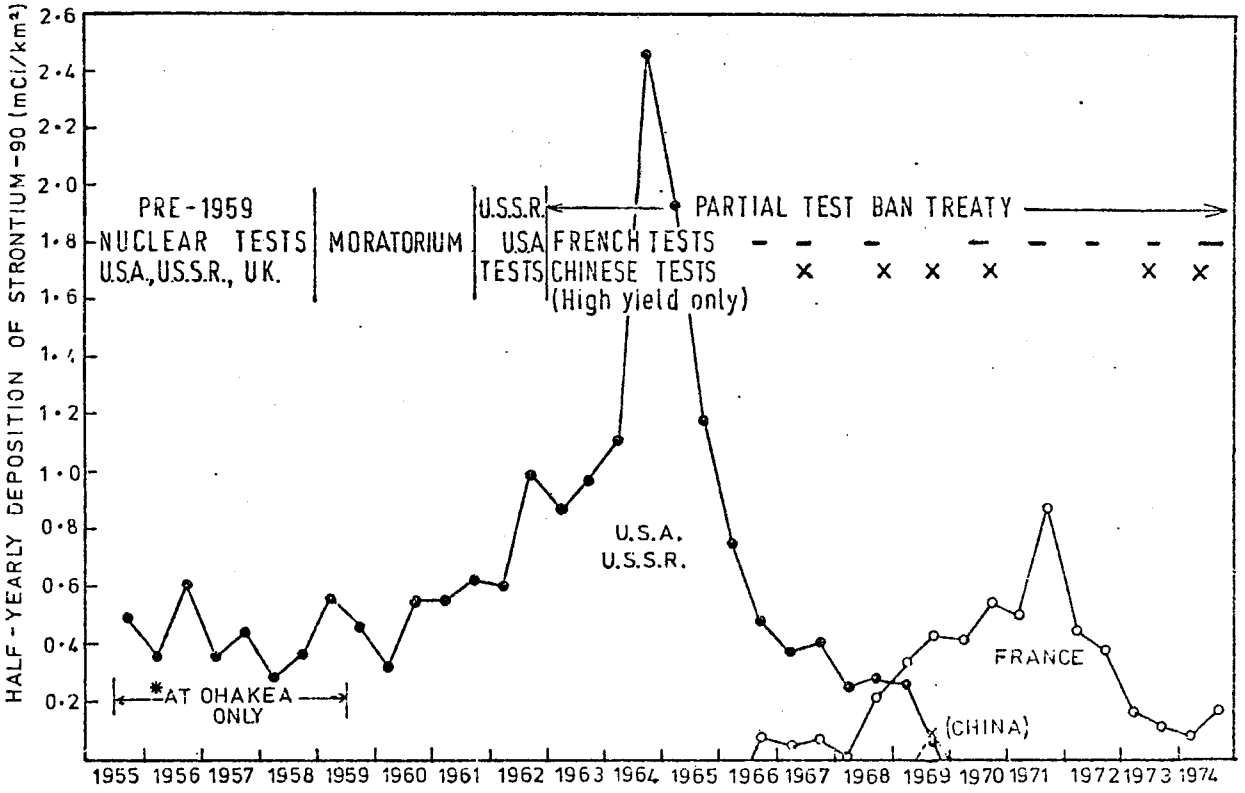

Fig.7 Half-yearly average deposition of strontium-90 on New Zealand from atmospheric nuclear tests by various countries

4. STRONTIUM-90 IN MILK

(a) At Nine New Zealand Stations

The average concentration of strontium-90 in milk during 1974 was the lowest since measurements commenced in 1961. TABLE 5 lists the average yearly level at each station, and also the country-wide averages. The country-wide averages are also shown graphically in Fig. 4. (Individual station results are presented in TABLE 12 and Fig. 11 in the APPENDIX.)

TABLE 5 AVERAGE LEVELS OF STRONTIUM-90 IN MILK - STRONTIUM UNITS (pCi/g Ca) 1961 - 1974

STATIONS	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	Av.
Northland	4.5	6.3	7.5	11.2	10.6	6.5	5.1	4.1	6.3	5.2	7.3	4.8	3.8	3.3	6.2
Auckland		5.5	5.3	9.1	9.4	6.1	5.2	3.8	6.0	5.1	5.8	4.6	3.4	3.0	5.6
Waikato	4.1	4.9	5.6	9.5	9.8	6.3	5.0	4.1	5.4	5.2	6.0	4.4	3.5	2.7	5.5
Taranaki	7.1	9.4	9.9	17.1	16.7	12.5	10.4	8.0	9.4	9.7	10.2	8.2	5.7	5.4	10.0
Palmerston Nth		4.3	4.9	7.1	8.4	4.8	3.9	3.6	5.8	3.6	5.0	5.0	2.7	2.5	4.7
Wellington*					8.8	6.1	5.4	4.8	5.1	4.7	4.8	4.1	3.5	3.0	5.0
Westland	12.7	13.5	17.2	26.0	28.8	22.7	17.8	14.0	17.9	21.0	18.3	14.7	10.8	8.8	17.4
Christchurch	1.6	2.1	2.7	2.6	4.3	2.4	1.9	1.6	1.7	2.2	2.0	1.9	1.2	1.3	2.1
Dunedin		3.0	3.7	4.1	7.4	4.0	3.1	2.4	3.0	2.5	3.0	3.1	1.9	1.9	3.3
Country-wide Average		6.1	7.1	10.8	11.6	7.9	6.4	5.2	6.7	6.6	6.9	5.6	4.1	3.5	6.6

* Wellington Average 1965-1974

Average levels in New Zealand milk reached their maximum values of 10.8 and 11.6 pCi/g Ca during 1964 and 1965 when the rate of strontium-90 deposition was also a maximum. Milk levels then fell steadily reaching a minimum of 5.2 pCi/g Ca in 1968, about half the 1964-65 maximum. This indicates that the level in milk is mainly dependent on current fallout rates rather than on the cumulative deposit in the soil. However, the decrease in milk levels during the period 1965 to 1968 was at a slower rate than the decrease in annual strontium-90 deposit during this period, because of some uptake by the grass of the deposit in the soil. Due to the commencement of the French Pacific nuclear tests in 1966, milk levels stopped decreasing after 1968 and increased slightly during the next three years. However, following the subsequent decline in deposition of strontium-90 in rain during the period 1972 to 1974 milk levels again declined reaching the minimum recorded level of 3.5 pCi/g Ca in 1974.

Milk samples from the lowest and highest rainfall stations, i.e. Christchurch and Westland, give the range of strontium-90 contamination in New Zealand milk. Generally the extent of this range is from about one-third to nearly three times the country-wide average.

(b) Comparison with two Northern Hemisphere Stations

In Fig. 8 the country-wide average levels of strontium-90 in New Zealand milk are compared with levels in New York City milk (5), and in Canadian milk (6).

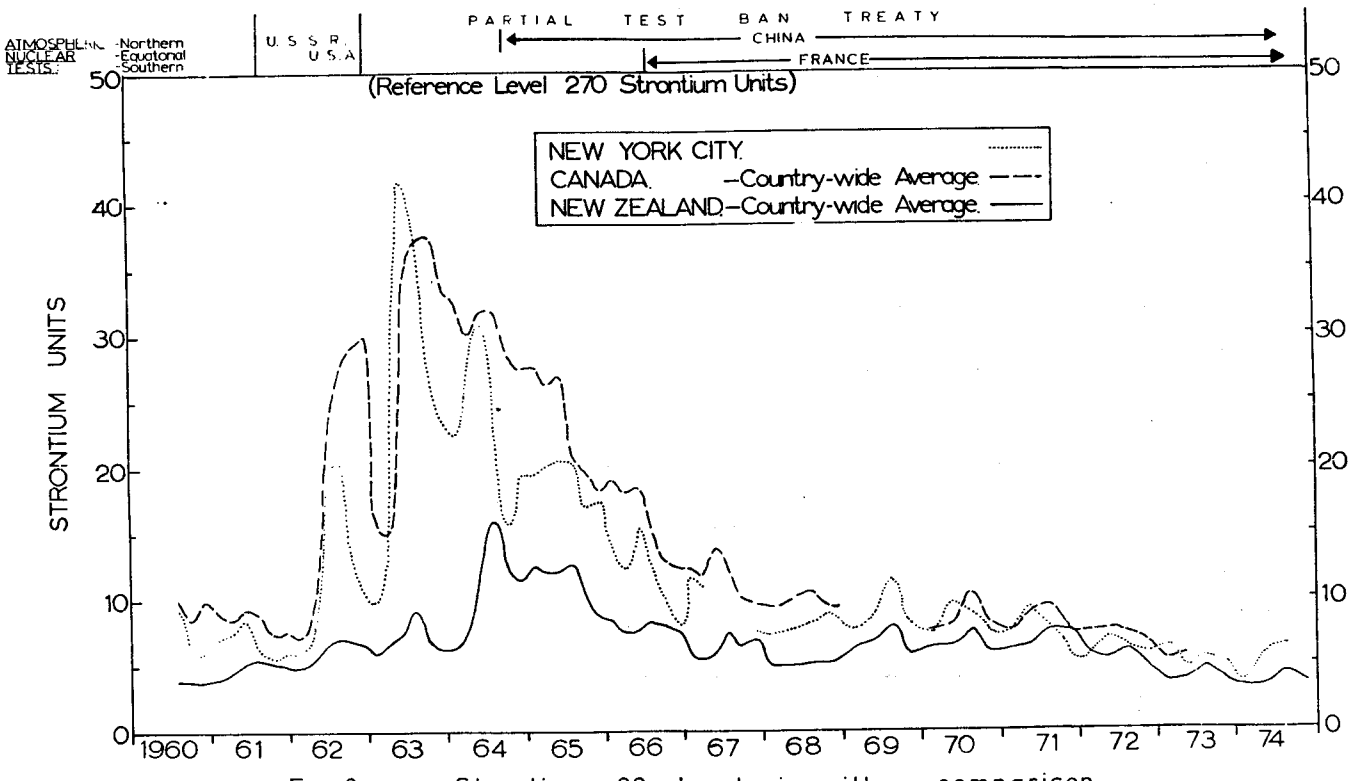

Fig. 8 Strontium-90 levels in milk - comparison

(6) "Data From Radiation Protection Programs"; "Radiation Surveillance in Canada"; "Environmental Radioactivity Surveillance"; Reports of the Radiation Protection Bureau, Health and Welfare, Canada.

Fallout from the 1961 and 1962 tests resulted in maximum strontium-90 levels in milk in Canada and at New York City in 1963 and 1964, whereas maximum levels in New Zealand occurred about one year later in 1964 and 1965. Fig. 8 indicates that maximum levels in the northern hemisphere were two to three times higher than those in New Zealand. Subsequently levels decreased and in recent years, with similar rates of strontium-90 deposition in the two hemispheres, the milk levels have been about the same.

(c) Comparison of Measured Levels with the Reference Level

In order to assess any potential health hazard arising from ingestion of strontium-90 in the diet (or in milk, which for practical purposes we may assess in place of diet as a whole), it is essential to consider long-term average levels. The dose to the critical organ, bone, over an extended period, establishes the degree of potential somatic risk. (See also 7. STRONTIUM-90, ... in HUMAN BONE.) Therefore the levels in diet must also be considered over similarly extended periods.

During the period 1962 to 1974 inclusive the country-wide average level in milk was 6.6 "Strontium Units" or about 2.4% of the reference level. The highest average level was for Westland, 17.4 S.U. (6.4% of the reference level), and the lowest average level was for Christchurch, 2.1 S.U. (0.8% of the reference level).

5. CAESIUM-137 IN MILK

(a) At Nine New Zealand Stations

The average level of caesium-137 in milk during 1974 was also the lowest since measurements commenced in 1964. TABLE 6 lists the averages yearly level at each station and also the country-wide averages. The country-wide averages are also shown graphically in Fig. 4. (Individual station results are presented in TABLE 13 and Fig. 12 in the APPENDIX.)

TABLE 6 AVERAGE LEVELS OF CAESIUM-137 IN MILK - pCi/g K

STATIONS	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	Av.
Northland	49	54	37	26	15	27	22	23	21	14	7	27
Auckland	51	53	33	26	18	26	18	18	15	9	7	25
Waikato	69	84	60	48	36	41	35	36	28	21	16	43
Taranaki	168	185	141	123	102	101	89	80	72	49	41	105
Palmerston Nth	19	26	11	7	3	5	6	7	2	3	2	8
Wellington	25*	29	18	13	7	9	11	9	7	4	3	12
Westland	76	77	43	33	21	38	39	30	22	14	8	36
Christchurch	7	11	4	3	1	2	4	3	2	1	1	4
Dunedin	11	18	9	5	3	4	5	5	4	2	1	6
Country-wide Average	53	60	39	31	23	28	25	23	19	13	10	30

* Estimate

The highest levels were recorded in 1964 and 1965 and they have steadily decreased since then except for a slight increase in 1969 and 1970. The higher levels at Taranaki due to the "soil effect" have been discussed in the 1971 annual report of this series (1).

(b) Comparison of Measured Levels with the Reference Level

During the period 1964 to 1974 inclusive the country-wide average level was 30 pCi/g K which is about 0.4% of the reference level. At the highest level station, Taranaki, the average level over the same period was 105 pCi/g K, about 1.5% of the reference level, whereas at Christchurch, the lowest level station, the average was 4 pCi/g K, about 0.06% of the reference level.

6. LEAD-210 IN RAIN

The measurement of naturally-occurring lead-210 deposition in rain was continued during 1974. The evaluation was made in samples from the stations routinely supplying rainwater collections for strontium-90 determination.

Lead-210 is produced in the atmosphere by decay of radon which has diffused from land surfaces. The subsequent deposition is rainfall dependent like strontium-90, so that high rainfall areas such as Greymouth show elevated values compared to low rainfall areas such as Christchurch.

Individual station monthly deposits, since May 1967 when measurements were started at all stations, are shown in Fig. 13 APPENDIX. Earlier results, including higher results during 1965 at four stations and references to levels in milk, were discussed in the 1971 annual report of this series (1).

During 1974 the New Zealand country-wide average deposition was about 1.3 mCi/km^2, slightly lower than the annual deposition during the previous two years. During the last seven years the annual deposition has averaged about 1.4 mCi/km^2 at the New Zealand stations. During the same period the annual deposition of strontium-90 from weapons tests has averaged about 0.8 mCi/km^2.

7. STRONTIUM-90, RADIUM-226, AND LEAD-210 IN HUMAN BONE

A survey was commenced in 1961 to determine strontium-90 concentrations in New Zealand human bone samples and correlate the levels with fallout deposition and also with levels in milk. The opportunity was also taken to measure concurrently the levels of the long-lived, naturally-occurring, bone seekers radium-226 (half-life 1600 years), and one of its main long-lived daughter products lead-210 (half-life 22 years).

Because of the decline in the rate of strontium-90 fallout during recent years, and the difficulty of obtaining suitable samples, particularly in the younger age groupings, this survey was terminated at the end of 1974. The results for the 118 samples analysed are listed in TABLE 14 APPENDIX, where they are presented in panels in chronological order. Within each panel results are listed according to rainfall area, and within each area the listing is in order of age at death.

(a) Strontium-90

The measured concentrations range from less than 0.1 to 3.2 "Strontium Units" (pCi/g Ca). A statistical evaluation of the results confirms the expected trends, i.e. average levels are higher in high rainfall areas where strontium-90 depositions and concentrations in milk are generally higher, and levels are also higher in young bone formed during the past 10 to 15 years of global fallout. It has also been confirmed that levels do not exceed the calculated values based on accepted figures for variation of uptake with age, and on the measured dietary levels.

The results are best summarised by classifying the samples according to three different age groups and three consecutive time periods as presented in TABLE 7 and Fig. 9. While there are insufficient samples to justify further subdivision it is noted that the higher values in the ranges indicated are associated with high rainfall areas.

TABLE 7 STRONTIUM-90 IN HUMAN BONE 1961-1974

Period	Age Group (Years)	Number of Samples	90 Sr (pCi/g Ca) Min.-Max.	Mean ± ESD*
1961	0-5	11	0.7-3.2	1.68 ± 0.77
to	6-20	10	0.5-1.6	1.04 ± 0.40
1964	>20	15	<0.1-0.9	0.25 ± 0.25
1965	0-5	9	1.5-3.0	2.08 ± 0.56
to	6-20	39	0.5-2.4	1.29 ± 0.45
1968	>20	9	0.2-0.8	0.50 ± 0.17
1969	0-5	2	1.8-2.2	2.00 ± 0.35
to	6-20	15	1.0-2.6	1.44 ± 0.41
1974	>20	6	0.4-1.3	0.90 ± 0.30

* Estimated Standard Deviation

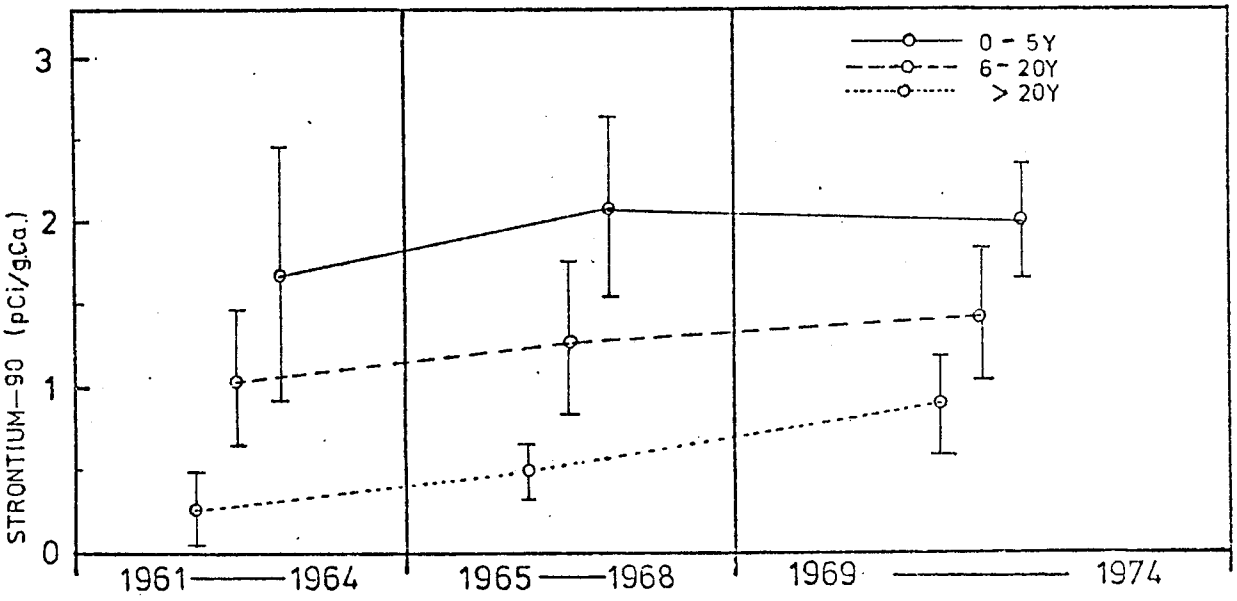

Fig. 9 Strontium-90 in human bone (graphical presentation of Table 7)

A comparison with other published results shows that for each age group the New Zealand level averaged over a long period was about two-thirds of the corresponding level for the northern hemisphere. On the other hand following the years of peak fallout the New Zealand bone values, particularly for the younger age groups, were much smaller fractions of the northern hemisphere values. For instance in the United Kingdom (7) maximum values of about 9 pCi/g Ca were measured in the one-month to two-year age group during 1964-1965, decreasing to maximum values of about 2 pCi/g Ca for the over 20 age group in 1966. By 1970 levels in the U.K. approximated 2 pCi/g Ca for all groups and the survey was terminated.

The notable trends which are readily observable in overseas studies are also detectable in the New Zealand results, despite the limited number of samples and the resulting relatively large standard deviations. For example, the relatively rapid rate of replacement and mineral turnover in young bone compared to older bone accounts for the transient changes in strontium-90 concentrations in these samples. The level in young bone tends to reflect to a considerable extent the current fallout rate, whereas the slow rate of mineral turnover in adult bone results in a lower level and reflects the average fallout rate over a longer time.

If the decline in fallout deposition is maintained it is anticipated that levels in New Zealand will tend to even out for all age groups at about one pCi/g Ca and slowly decline thereafter. The dose from one pCi/g Ca to bone cells is about 2 mrad/year, and to bone marrow is about 1½ mrad/year (8).

(b) Radium-226 and Lead-210

Radium-226 levels in human bone are not expected to depend on rainfall nor on age of subject. Excepting occupational exposure or accidental ingestion, levels reflect the concentration in the local diet, which in turn depends on the radium content of the soil and potable waters.

The level of lead-210 in bone might be expected to differ from that of its parent radium-226, because of the different chemical properties causing fractionation in the biosphere. Moreover, a precursor of lead-210 is the noble gas radon-222 with a half-life sufficiently long to allow appreciable diffusion from the soil. The radon which escapes produces lead-210 in the atmosphere which is eventually deposited on the surface as "natural fallout". Lead-210 thus becomes readily available to plants by foliar absorption and root uptake. Lead-210 concentrations in surface layers of soil would thus be expected to be higher than radium-226 concentrations and this situation may also extend to food chains and human bone.

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(7) "Assay of strontium-90 in human bone in the United Kingdom", Results for 1970, Medical Research Council, Monitoring Report No. 19. Her Majestys Stationery Office, London.

(8) "Ionizing Radiation : Levels and Effects". A report of the United Nations Scientific Committee on the Effects of Atomic Radiation. Vol. 1, Levels, para. 206. United Nations, New York, 1972.

Studies of lead-210 and radium-226 profiles in some New Zealand soils (9), measurements in New Zealand milk samples (10), and the results for human bone in TABLE 14 confirm these expectations.

Analysis of the results show no correlation of radium-226 or lead-210 levels with rainfall or age of subject.

The means and standard deviations of the 111 radium-226 results, and the 107 lead-210 results (omitting sample No. 7 which involved occupational exposure) are 0.019 ± 0.015 pCi/g ash and 0.061 ± 0.039 pCi/g ash respectively. The activity concentration of lead-210 in New Zealand human bone is thus, on the average, about three times higher than that of radium-226.

An overseas study (11) of 128 bone samples mostly from Illinois, where the radium-226 content of well water is higher than normal, gave average values of 0.037 pCi/g ash for radium-226 and 0.146 pCi/g ash for lead-210 (i.e. about twice the New Zealand values).

In a later study (12) it was considered that the concentration of lead-210 in air should be lower over the ocean than over the continents because of the known lower concentration of the precursor radon-222. Consequently the lead-210 content in populations breathing ocean air may be lower than that in similar populations breathing continental air. A survey was therefore undertaken and lead-210 was measured in bones of Puerto Ricans and the results were compared with the midwest U.S. results. This comparison showed that the mean lead-210 concentration in the Caribbean Island samples was about 60% that of the continental U.S. samples. Definite conclusions were not drawn, however, about the importance of the atmosphere as a source of lead-210 and further dietary surveys were advocated. It is interesting to observe that in a New Zealand survey (13) of leaf tobacco from four countries it was demonstrated that the lead-210 content (as measured by the polonium-210 concentration) of New Zealand tobacco was about one-third that of U.S. and South African tobaccos and even less than one-third that of Rhodesian tobacco. It may be considered that tobacco leaf could be taken as typical of vegetation in general and ingestion may be a major uptake factor.

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(9) "Profiles of lead-210 and radium-226 in four New Zealand soils". T. Baltakmens, New Zealand J. of Sc., Vol. 17, 435-439, 1974.

(10) "Lead-210 in New Zealand Milk". T. Baltakmens, Australian J. of Sc., 31, 3, September 1968.

(11) "Measurement of the Natural Contents of RaD (Pb^{210}) and RaF (Po^{210}) in Human Bone - Estimates of Whole-Body Burdens". R. B. Holtzman. Health Physics, 9, 4, April 1963.

(12) "^{210}Pb (RaD) in Inhabitants of a Caribbean Island". Richard B. Holtzman. Health Physics, 11, 6, June 1965.

(13) "Polonium-210 in Leaf Tobacco from Four Countries". L. P. Gregory. Science, 150, 3692, Oct. 1, 1965.

The mean levels of radium-226, radium-228 (assumed to be one-third the radium-226 level), and lead-210 in the U.S. survey (11) were estimated to give a dose to the skeleton of about 48 mrem/year. Similar calculations for the New Zealand results give an estimated average dose to the skeleton of about 23 mrem/year. This value is equivalent to about twelve times the dose from strontium-90 at a mean level of one "Strontium Unit".

MISCELLANEOUS INFORMATION

1. INTERCOMPARISON OF MEASUREMENTS

During 1974 this Laboratory again participated in intercomparison measurements of strontium-90, strontium-89, iodine-131, caesium-137, barium-140, and potassium in liquid milk samples provided by the U.S. Environmental Protection Agency.

2. TECHNICAL INFORMATION ON MEASUREMENT PROCEDURES

Technical information on collection procedures and methods of evaluation used in obtaining the results published in this report were discussed in the 1971 annual report of this series (1).

The procedures for radiostrontium in various media are detailed in a technical report (14) which is available from this Laboratory on request.

The procedures for strontium-90, radium-226, and lead-210 in human bone were published recently in outline (15) and are available as a detailed technical report from this Laboratory on request (16).

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(14) "The Determination of Radiostrontium in Rainwater, Soil, Milk and Bone". L. P. Gregory, National Radiation Laboratory, Report No. NRL-RM/3, 1970.

(15) "A Simplified Separation of Strontium, Radium, and Lead from Environmental Media by Precipitation Followed by Fractional Elution". L. P. Gregory, ANALYTICAL CHEMISTRY, Vol. 44, page 2113, October 1972.

(16) "The Determination of Strontium-90, Radium-226, and Lead-210 in Human Bone". L. P. Gregory, National Radiation Laboratory, Report No. NRL-RM/4, March 1974.

APPENDIX

List of Tables and Figures in the Appendix

TABLE 8 TOTAL BETA ACTIVITY OF AIR FILTER SAMPLES : 1974

Picocuries per Cubic Metre (at measurement time - four days after collection)

Collection: From 9.00 a.m. on the date shown to 9.00 a.m. on the following date (filters changed routinely three times each week*)

N.S. No Sample Received.

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
Dec. 31	N.S.	Dec. 31	<0.01	Dec. 31	<0.01	Jan. 1	0.01
Jan. 2	0.02	Jan. 2	<0.01	Jan. 2	<0.01	" 4	0.01
" 4	<0.01	" 4	<0.01	" 4	<0.01	" 7	0.02
" 7	0.01	" 7	<0.01	" 7	<0.01	" 9	0.01
" 9	0.01	" 9	<0.01	" 9	<0.01	" 11	0.01
" 11	0.01	" 11	<0.01	" 11	0.02	" 14	0.01
" 14	<0.01	" 14	0.01	" 14	<0.01	" 16	<0.01
" 16	0.02	" 16	<0.01	" 16	<0.01	" 18	<0.01
" 18	0.05	" 18	<0.01	" 18	<0.01	" 21	0.01
" 21	0.03	" 21	<0.01	" 21	0.01	" 23	<0.01
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" 25	0.01	" 25	<0.01	" 25	<0.01	" 28	0.01
" 28	N.S.	" 28	0.01	" 28	N.S.	" 30	0.01
" 30	<0.01	" 30	0.01	" 30	<0.01		
Jan. Av.	0.02	Jan. Av.	<0.01	Jan. Av.	<0.01	Jan. Av.	0.01
Feb. 1	0.01	Feb. 1	0.01	Feb. 1	<0.01	Feb. 1	0.01
" 4	<0.01	" 4	<0.01	" 4	0.01	" 4	<0.01
" 6	<0.01	" 6	<0.01	" 6	<0.01	" 7	0.02
" 8	<0.01	" 8	<0.01	" 8	<0.01	" 8	<0.01
" 11	<0.01	" 11	0.01	" 11	0.01	" 11	<0.01
" 13	<0.01	" 13	<0.01	" 13	0.01	" 13	<0.01
" 15	<0.01	" 15	0.01	" 15	0.07	" 15	<0.01
" 18	0.01	" 18	0.01	" 18	0.01	" 18	<0.01
" 20	0.01	" 20	0.02	" 20	0.02	" 20	<0.01
" 22	<0.01	" 22	0.01	" 22	<0.01	" 22	<0.01
" 25	<0.01	" 25	0.01	" 25	0.01	" 25	0.02
" 27	0.01	" 27	0.02	" 27	0.02	" 27	<0.01
Feb. Av.	<0.01	Feb. Av.	0.01	Feb. Av.	0.02	Feb. Av.	<0.0
Mar. 1	<0.01	Mar. 1	<0.01	Mar. 1	0.02	Mar. 1	<0.01
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" 6	0.02	" 6	0.02	" 6	<0.01	" 6	<0.01
" 8	0.02	" 8	0.01	" 8	N.S.	" 8	<0.01
" 11	<0.01	" 11	<0.01	" 11	<0.01	" 11	<0.01
" 13	<0.01	" 13	0.02	" 13	<0.01	" 13	<0.01
" 15	<0.01	" 15	<0.01	" 15	0.02	" 15	<0.01
" 18	<0.01	" 18	<0.01	" 18	<0.01	" 18	<0.01
" 20	0.01	" 20	<0.01	" 20	0.01	" 20	0.01
" 22	<0.01	" 22	0.01	" 22	0.01	" 22	0.01
" 25	0.02	" 25	0.01	" 25	0.02	" 25	<0.01
" 27	0.02	" 27	<0.01	" 27	0.01	" 27	0.01
" 29	<0.01	" 29	0.02	" 29	0.02	" 29	<0.01
Mar. Av.	0.01	Mar. Av.	0.01	Mar. Av.	0.01	Mar. Av.	<0.01

(continued)

TABLE 8 - continued

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
Apr. 1	<0.01	Apr. 1	0.02	Apr. 1	0.01	Apr. 1	<0.01
" 3	0.01	" 3	<0.01	" 3	<0.01	" 3	<0.01
" 5	<0.01	" 5	<0.01	" 5	0.01	" 5	<0.01
" 8	<0.01	" 8	<0.01	" 8	<0.01	" 8	<0.01
" 10	<0.01	" 10	0.01	" 10	0.02	" 10	<0.01
" 12	<0.01	" 12	<0.01	" 12	<0.01	" 11	<0.01
" 15	<0.01	" 15	<0.01	" 15	<0.01	" 17	<0.01
" 17	0.01	" 17	0.01	" 17	0.01	" 19	<0.01
" 19	0.01	" 19	<0.01	" 19	<0.01	" 22	<0.01
" 22	<0.01	" 22	<0.01	" 22	<0.01	" 24	0.01
" 24	<0.01	" 24	<0.01	" 24	0.02	" 26	<0.01
" 26	<0.01	" 26	<0.01	" 26	<0.01	" 29	<0.01
" 29	<0.01	" 29	0.02	" 29	0.02		
Apr. Av.	<0.01	Apr. Av.	<0.01	Apr. Av.	<0.01	Apr. Av.	<0.01
May 1	<0.01	May 1	<0.01	May 1	0.01	May 1	<0.01
" 3	<0.01	" 3	<0.01	" 3	<0.01	" 3	0.01
" 6	<0.01	" 6	0.01	" 6	0.02	" 6	0.02
" 8	<0.01	" 8	<0.01	" 8	<0.01	" 8	<0.01
" 10	<0.01	" 10	<0.01	" 10	<0.01	" 10	<0.01
" 13	<0.01	" 13	<0.01	" 13	<0.01	" 13	<0.01
" 15	<0.01	" 15	0.01	" 15	<0.01	" 15	<0.01
" 17	0.02	" 17	<0.01	" 17	<0.01	" 17	<0.01
" 20	0.01	" 20	0.02	" 20	0.01	" 20	<0.01
" 22	0.01	" 22	<0.01	" 22	0.01	" 22	<0.01
" 24	0.01	" 24	<0.01	" 24	0.01	" 24	<0.01
" 27	0.01	" 27	0.01	" 27	<0.01	" 27	<0.01
" 29	0.01	" 29	0.01	" 29	<0.01	" 29	<0.01
May Av.	0.01	May Av.	<0.01	May Av.	<0.01	May Av.	<0.01
May 31	<0.01	May 31	<0.01	May 31	0.01	May 31	<0.01
Jun. 3	<0.01	Jun. 3	0.01	Jun. 3	<0.01	Jun. 4	<0.01
" 5	0.02	" 5	0.01	" 5	0.02	" 7	0.01
" 7	0.01	" 7	<0.01	" 7	0.01	" 10	0.01
" 10	0.02	" 10	<0.01	" 10	<0.01	" 12	<0.01
" 12	<0.01	" 12	<0.01	" 12	0.01	" 14	<0.01
" 14	<0.01	" 14	<0.01	" 14	<0.01	" 17*	<0.01
" 17*	0.01	" 17*	<0.01	" 17*	0.02	" 18	<0.01
" 18	<0.01	" 18	0.02	" 18	0.02	" 19	<0.01
" 19	0.02	" 19	0.01	" 19	<0.01	" 20	<0.01
" 20	0.02	" 20	0.02	" 20	0.02	" 21	<0.01
" 21	0.02	" 21	<0.01	" 21	<0.01	" 22	<0.01
" 22	0.01	" 22	0.01	" 22	0.02	" 23	<0.01
" 23	<0.01	" 23	0.01	" 23	0.04	" 24	<0.01
" 24	<0.01	" 24	0.01	" 24	<0.01	" 25	<0.01
" 25	<0.01	" 25	0.02	" 25	<0.01	" 26	<0.01
" 26	<0.01	" 26	<0.01	" 26	<0.01	" 27	<0.01
" 27	0.02	" 27	<0.01	" 27	<0.01	" 28	<0.01
" 28	<0.01	" 28	0.02	" 28	<0.01	" 29	0.01
" 29	0.01	" 29	0.02	" 29	<0.01	" 30	0.02
" 30	0.03	" 30	0.01	" 30	<0.01		
Jun. Av.	0.01	Jun. Av.	0.01	Jun. Av.	<0.01	Jun. Av.	<0.01

(continued)

*Daily changing started.

TABLE 8 - continued

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
Monthly Averages During the Special Monitoring Programme*							
Jul. Av.	0.11	Jul. Av.	0.08	Jul. Av.	0.04	Jul. Av.	0.04
Aug. Av.	0.12	Aug. Av.	0.08	Aug. Av.	0.14	Aug. Av.	0.07
Sep. Av.	0.26	Sep. Av.	0.15	Sep. Av.	0.25	Sep. Av.	0.13
Oct. Av.	0.24	Oct. Av.	0.11	Oct. Av.	0.12	Oct. Av.	0.11
Nov. 1	0.06	Nov. 1	0.11	Nov. 1	0.08	Nov. 1	0.07
" 4	0.19	" 4	0.08	" 4	0.14	" 4	0.08
" 6	0.15	" 6	0.17	" 6	0.16	" 6	0.11
" 8	0.16	" 8	0.11	" 8	0.09	" 8	0.08
" 11	0.25	" 11	0.11	" 11	0.06	" 11	0.09
" 13	0.29	" 13	0.19	" 13	0.10	" 13	0.04
" 15	0.08	" 15	0.08	" 15	0.03	" 18	0.06
" 18	0.06	" 18	0.04	" 18	0.07	" 20	0.04
" 20	0.10	" 20	0.06	" 20	0.06	" 22	0.05
" 22	0.06	" 22	0.07	" 22	0.09	" 25	0.09
" 25	0.11	" 25	0.10	" 25	0.12	" 27	0.09
" 27	0.13	" 27	0.07	" 27	0.13	" 29	0.13
" 29	0.13	" 29	0.10	" 29	0.16		
Nov. Av.	0.13	Nov. Av.	0.10	Nov. Av.	0.10	Nov. Av.	0.08
Dec. 2	0.08	Dec. 2	0.07	Dec. 1	0.03	Dec. 2	0.06
" 4	0.09	" 4	0.06	" 4	0.05	" 4	0.07
" 6	0.08	" 6	0.08	" 6	0.04	" 6	0.03
" 9	0.04	" 9	0.05	" 9	0.03	" 9	0.04
" 11	0.05	" 11	0.05	" 11	0.05	" 11	0.05
" 13	0.08	" 13	0.07	" 13	0.04	" 13	0.05
" 16	0.08	" 16	0.07	" 16	0.11	" 16	0.05
" 18	0.14	" 18	0.15	" 18	0.14	" 18	0.14
" 20	0.09	" 20	0.05	" 20	0.09	" 20	0.09
" 23	0.08	" 22	0.06	" 23	0.08	" 23	0.05
" 25	0.07	" 24	0.05	" 25	0.16	" 27	0.08
" 27	0.09	" 26	N.S.	" 26	0.08		
" 30	0.05	" 28	N.S.	" 30	0.09		
Dec. Av.	0.08	Dec. Av.	0.07	Dec. Av.	0.08	Dec. Av.	0.07
1974 Av.	0.08	1974 Av.	0.05	1974 Av.	0.07	1974 Av.	0.05

* During the special monitoring programme, from July to October inclusive, air filter samples were changed daily. Individual results, including those from five Pacific Island stations, were given in the report on monitoring fallout from the French nuclear tests during 1974 (2).

TABLE 9 TOTAL BETA ACTIVITY OF WEEKLY RAINWATER SAMPLES : 1974

Deposition: mCi/km^2 (at time of measurement - about four days after collection)

Collection: From date shown to start of next collection.

Rainfall: cm

N.S. No Sample Received.

Collection	Auckland		Wellington		Greymouth*		Christchurch	
	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2
Dec. 28	<0.1	<0.1	1.2	<0.1	11.2	0.3	1.1	0.1
Jan. 4	trace	<0.1	0.2	0.1	6.1	0.1	1.5	0.2
" 11	0.3	0.1	0.1	<0.1	0.5	<0.1	0.3	<0.1
" 18	0.1	0.2	0.6	<0.1	0.3	<0.1	0.5	<0.1
" 25	trace	N.S.	trace	<0.1	0.2	<0.1	<0.1	<0.1
January	0.4	0.4	2.1	0.3	18.3	0.5	3.4	0.5
Feb. 1	0.1	<0.1	1.1	0.1	7.3	0.2	0.3	<0.1
" 8	<0.1	<0.1	5.2	0.1	13.3	0.1	4.7	<0.1
" 15	trace	0.1	0.7	<0.1	3.0	0.2	2.0	<0.1
" 22	3.3	<0.1	3.8	<0.1	2.2	0.1	1.6	0.2
February	3.4	0.3	10.8	0.4	25.8	0.6	8.6	0.3
Mar. 1	0.5	<0.1	1.9	<0.1	4.3	0.2	1.8	0.1
" 8	0.1	<0.1	0.1	<0.1	5.9	<0.1	0.6	0.1
" 15	2.3	0.2	5.1	N.S.	0.3	<0.1	3.7	0.1
" 22	<0.1	<0.1	nil	<0.1	nil	<0.1	nil	<0.1
March	2.9	0.2	7.1	(0.1)	10.5	0.4	6.1	0.4
Mar. 29	<0.1	<0.1	<0.1	<0.1	18.3	0.2	<0.1	<0.1
Apr. 5	6.1	0.1	5.8	<0.1	7.6	<0.1	1.6	0.1
" 12	5.5	<0.1	11.6	<0.1	7.5	0.1	10.5	<0.1
" 19	0.4	<0.1	11.2	0.2	0.5	<0.1	2.8	0.1
" 26	0.2	<0.1	4.2	<0.1	nil	<0.1	1.2	<0.1
April	12.3	0.2	32.8	0.4	33.9	0.5	16.2	0.3
May 3	0.6	<0.1	2.1	0.1	1.6	<0.1	1.1	<0.1
" 10	0.3	<0.1	2.8	N.S.	3.2	0.1	0.1	<0.1
" 17	0.4	0.1	0.8	<0.1	2.9	0.1	<0.1	<0.1
" 24	6.2	<0.1	11.8	<0.1	5.0	0.1	4.0	<0.1
May	7.5	0.3	17.5	0.3	12.7	0.4	5.3	0.2
May 31	0.5	<0.1	1.5	<0.1	nil	<0.1	0.5	<0.1
Jun. 7	2.8	<0.1	2.7	<0.1	0.3	<0.1	0.6	<0.1
" 14	2.1	<0.1	5.3	0.1	1.4	<0.1	4.0	<0.1
" 21	2.6	<0.1	0.4	<0.1	6.6	<0.1	0.2	<0.1
June	8.0	0.2	9.9	0.2	8.3	0.2	5.3	0.2
Jun. 28	0.8	<0.1	12.5	<0.1	1.7	<0.1	1.2	<0.1
Jul. 5	3.0	<0.1	7.4	<0.1	4.7	<0.1	1.1	<0.1
" 12	1.2	<0.1	2.2	0.1	12.7	1.7	2.6	<0.1
" 19	3.3	2.6	1.7	0.7	7.9	2.1	0.1	<0.1
" 26	5.1	3.0	4.5	0.5	7.1	2.0	1.0	0.4
July	13.4	5.7	28.3	1.4	34.1	5.9	6.0	0.5

(Continued)

TABLE 9 - continued

Collection	Auckland cm	Auckland mCi/km^2	Wellington cm	Wellington mCi/km^2	Greymouth* cm	Greymouth* mCi/km^2	Christchurch cm	Christchurch mCi/km^2
Aug. 2	3.4	0.7	3.3	0.4	1.7	0.3	0.7	0.4
" 9	1.0	0.3	1.0	0.4	1.0	0.2	2.2	0.4
" 16	3.1	0.5	3.3	0.9	1.0	0.4	1.5	0.6
" 23	1.3	0.3	2.5	0.6	0.3	0.1	3.6	0.4
August	8.8	1.8	10.1	2.3	4.0	1.0	8.0	1.8
Aug. 30	1.7	0.5	4.9	1.7	4.6	0.9	7.8	3.8
Sep. 6	2.8	3.0	2.4	6.8	1.9	0.8	0.2	0.2
" 13	1.4	1.8	6.1	3.6	4.3	4.1	0.2	0.4
" 20	3.1	20.6	1.8	13.6	3.5	1.1	0.3	0.4
" 27	1.4	0.3	3.7	2.6	0.2	0.2	1.7	0.4
September	10.4	26.2	18.9	28.3	14.5	7.1	10.2	5.2
Oct. 4	2.8	12.8	11.2	13.5	18.7	9.2	3.8	1.4
" 11	1.9	3.8	2.0	2.8	nil	0.1	trace	0.7
" 18	1.1	0.5	7.4	2.9	5.6	1.4	1.5	1.1
" 25	0.7	0.3	4.4	2.7	3.9	2.1	3.3	1.4
October	6.5	17.4	25.0	21.9	28.2	12.8	8.6	4.6
Nov. 1	0.6	2.4.	0.7	0.7	3.2	0.7	<0.1	0.2
" 8	0.1	0.6	1.6	0.9	11.5	5.0	0.1	0.3
" 15	0.3	0.3	0.8	0.4	0.3	0.2	0.8	0.1
" 22	trace	0.3	nil	0.3	0.1	0.4	trace	0.4
November	1.0	3.6	3.1	2.3	15.1	6.3	1.0	1.0
Nov. 29	4.4	0.8	0.5	0.5	6.6	2.0	nil	0.3
Dec. 6	2.5	0.4	3.6	0.7	10.3	0.9	1.1	3.4
" 13	trace	<0.1	0.1	0.3	1.2	0.3	0.9	0.2
" 20	0.7	0.8	0.2	0.2	3.3	2.2	<0.1	2.1
" 27	2.0	0.9	0.1	0.4	nil	0.7	<0.1	0.8
December	9.6	3.0	4.5	2.1	21.4	6.1	2.0	6.8
1974 total	84.2	59.3	170.1	60.0	226.8	41.8	80.7	21.8

Average Concentration (pCi/litre)

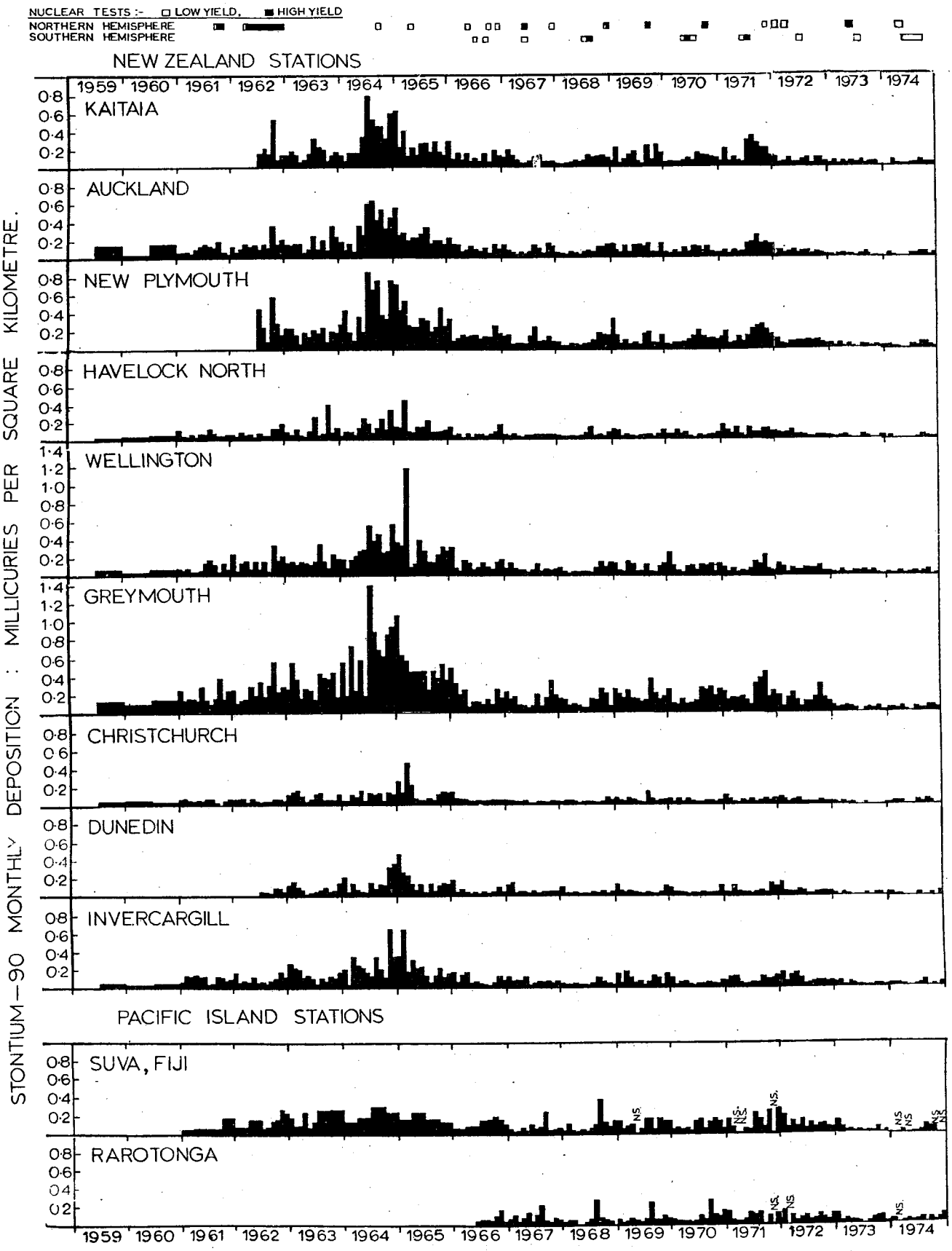
During 1974	70	35	18	27

* Collections at Greymouth start one day later than the date listed.

TABLE 10 STRONTIUM-90 IN RAIN : 1974

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Monthly Average
Kaitaia	Rainfall cm	1.3	8.2	5.0	15.4	12.0	11.4	19.4	14.7	10.5	9.7	12.4	5.2	125	
	Deposition mCi $^{90}Sr/km^2$	<0.01	<0.01	0.06	0.01	0.01	0.01	0.02	0.03	0.07	0.04	0.04	0.04	0.34	
	Concentration pCi ^{90}Sr/litre	0.5	<0.1	1.3	<0.1	0.1	0.1	0.1	0.2	0.7	0.4	0.4	0.7		0.4
Auckland	Rainfall cm	0.4	3.5	2.9	12.3	7.4	7.9	12.8	9.2	10.3	6.5	1.0	9.6	84	
	Deposition mCi $^{90}Sr/km^2$	<0.01	0.02	0.01	<0.01	<0.01	<0.01	0.02	0.02	0.05	0.05	0.01	0.03	0.23	
	Concentration pCi ^{90}Sr/litre	0.7	0.5	0.5	<0.1	0.1	<0.1	0.2	0.2	0.5	0.7	1.3	0.3		0.4
New Plymouth	Rainfall cm	4.5	9.9	1.4	21.9	14.4	5.3	26.8	14.8	11.0	20.4	6.2	5.4	142	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.02	0.01	0.01	<0.01	<0.01	0.03	0.02	0.07	0.07	0.03	0.02	0.31	
	Concentration pCi ^{90}Sr/litre	0.4	0.2	0.9	<0.1	<0.1	0.1	0.1	0.2	0.6	0.3	0.5	0.4		0.3
Havelock North	Rainfall cm	1.4	5.1	9.9	12.6	4.0	23.1	9.3	8.7	8.8	7.3	1.0	3.7	95	
	Deposition mCi $^{90}Sr/km^2$	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.03	0.01	0.01	0.15	
	Concentration pCi ^{90}Sr/litre	0.6	0.4	<0.1	<0.1	0.2	<0.1	<0.1	0.2	0.5	0.4	1.2	0.3		0.3
Wellington	Rainfall cm	4.8	8.0	7.8	43.1	16.1	13.6	27.9	13.8	15.2	22.1	4.1	4.5	181	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.01	0.01	0.03	0.01	0.02	0.03*	0.02	0.03	0.07	<0.01	0.02*	0.28	
	Concentration pCi ^{90}Sr/litre	0.4	0.1	0.2	<0.1	<0.1	0.1	0.1*	0.2	0.2	0.3	0.2	0.4*		0.2
Greymouth	Rainfall cm	8.8	26.1	10.5	33.9	12.7	9.5	29.5	10.3	11.3	28.2	15.2	20.6	217	
	Deposition mCi $^{90}Sr/km^2$	0.04	0.04	0.02	0.06	0.01*	<0.01	0.05	0.02	0.02	0.07	0.07	0.05	0.46	
	Concentration pCi ^{90}Sr/litre	0.5	0.2	0.2	0.2	<0.1*	<0.1	0.2	0.2	0.2	0.2	0.5	0.3		0.2
Christchurch	Rainfall cm	3.2	8.4	6.2	16.2	5.3	5.9	5.9	8.1	10.2	8.6	1.0	2.0	81	
	Deposition mCi $^{90}Sr/km^2$	0.01	0.02	0.02	<0.01	<0.01	<0.01	0.03	0.01	0.03	0.02	<0.01*	<0.01	0.17	
	Concentration pCi ^{90}Sr/litre	0.4	0.2	0.3	<0.1	0.1	<0.1	0.5	0.2	0.3	0.2	0.6*	0.3		0.3
Dunedin	Rainfall cm	5.7	5.0	1.6	5.5	4.7	3.6	10.6	2.9	1.2	13.1	3.0	11.1	68	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.01	0.01	<0.01	<0.01	<0.01	0.02*	<0.01	<0.01	0.02	<0.01	0.04	0.16	
	Concentration pCi ^{90}Sr/litre	0.3	0.3	0.7	0.2	0.1	<0.1	0.2*	0.3	0.5	0.2	0.3	0.3		0.3
Invercargill	Rainfall cm	5.1	9.7	3.7	6.1	10.3	10.2	13.6	3.6	1.7	5.6	2.3	9.4	81	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.02*	0.01	<0.01	<0.01	0.01	0.02	0.05	<0.01	0.01	<0.01	0.03	0.19	
	Concentration pCi ^{90}Sr/litre	0.3	0.2*	0.4	<0.1	<0.1	0.1	0.1	1.4	0.1	0.2	0.4	0.4		0.3
New Zealand Country-wide Average	Rainfall cm	3.9	9.3	5.4	18.6	9.7	10.1	17.3	9.6	8.9	13.5	5.1	7.9	119	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.02	0.02	0.02	<0.01	<0.01	0.02	0.02	0.04	0.04	0.02	0.03	0.25	
	Concentration pCi ^{90}Sr/litre	0.5	0.2	0.5	<0.1	0.1	<0.1	0.2	0.3	0.4	0.3	0.6	0.4		0.3
Suva, Fiji	Rainfall cm	17.4	8.9	53.1	31.9	54.2	5.2	5.7	26.9	18.4	14.1	25.3	43.6	305	
	Deposition mCi $^{90}Sr/km^2$	<0.01	*	0.02	*	0.01	0.01	0.02	0.08	0.06	0.06	*	*	(~0.3)	
	Concentration pCi ^{90}Sr/litre	<0.1	*	<0.1	*	<0.1	0.3	0.4	0.3	0.3	0.5	*	*		(~0.2)
Rarotonga	Rainfall cm	20.4	22.9	32.2	24.6	20.1	16.8	30.6	4.7	3.5	3.8	12.0	26.2	218	
	Deposition mCi $^{90}Sr/km^2$	0.03	*	0.01	0.02	0.01	0.02	0.05	<0.01	0.05	0.01	0.04	0.07	(~0.3)	
	Concentration pCi ^{90}Sr/litre	0.1	*	<0.1	<0.1	<0.1	0.1	0.2	0.2	1.6	0.4	0.4	0.3		0.3

* No result available - any value given is an estimate.



Collections started at individual stations from July 1959 to June 1966 as shown
N.S. = no sample

Fig.10 Strontium-90 in rain - individual stations

TABLE 11 STRONTIUM-89 DEPOSITION AND THE RATIO STRONTIUM-89 TO STRONTIUM-90 IN RAIN : 1974

Station	At mid-month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Kaitaia	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	2.5	1.9	6.9	3.2	1.8	0.6
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	125	56	93	81	41	17
Auckland	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	1.3	1.1	7.0	3.5	0.3	0.7
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	56	51	146	73	24	28
New Plymouth	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	2.3	1.3	5.1	5.4	1.4	0.4
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	78	57	78	77	42	18
Havelock North	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	0.3	0.8	3.3	1.4	0.4	0.3
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	*	61	74	47	31	25
Wellington	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	*	1.3	2.4	4.5	0.8	*
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	*	60	71	62	(110)	*
Greymouth	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	1.0	1.0	2.4	3.9	2.9	1.4
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	21	45	109	58	41	27
Christchurch	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	0.3	0.7	1.4	1.5	<0.1	0.2
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	7	59	47	81	*	(38)
Dunedin	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	0.4	0.3	0.2	1.9	0.4	1.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	38	30	38	77	46	29
Invercargill	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	0.4	2.1	0.4	0.7	0.4	0.9
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	28	43	(70)	81	41	26
New Zealand Country-wide Average	Deposition mCi $^{89}Sr/km^2$	-	-	-	<0.1	<0.1	<0.1	1.1	1.2	3.2	2.9	0.9	0.7
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	<1	<1	<1	50	51	81	71	47	26
Suva, Fiji	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	<0.1	<0.1	2.3	7.0	8.8	5.7	*	*
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	<1	2	98	85	139	88	*	*
Rarotonga	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	<0.1	<0.1	9.2	0.5	4.3	2.1	2.2	2.4
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	<1	≤1	180	58	80	(153)	50	34

* No result available.
\- Measurements discontinued.
() Values of the ratio are very approximate because of the very low values of ^{90}Sr measured.

TABLE 12	STRONTIUM-90 IN MILK : 1974				
Stations	"Strontium Units" pCi/g Ca				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
Northland	2.9	3.1	3.9	3.4	3.3
Auckland	2.8	2.5	3.6	2.9	3.0
Waikato	2.5	1.8	4.0	2.6	2.7
Taranaki	5.2	4.5	6.8	5.1	5.4
Palmerston North	2.0	2.6	3.2	2.3	2.5
Wellington	2.6	2.8	3.6	2.8	3.0
Westland	8.4	8.6	9.8	8.4	8.8
Christchurch	1.1	1.3	1.5	1.3	1.3
Dunedin	1.4	2.1	2.3	1.7	1.9
Country-wide Average	3.2	3.3	4.3	3.4	3.5

TABLE 13	CAESIUM-137 IN MILK : 1974												
Stations	pCi/g K												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Northland	14	6	6	12	4	5	1	4	5	13	9	8	7
Auckland	10	10	14	8	5	4	5	5	6	8	3	8	7
Waikato	19	21	19	20	18	12	14	14	13	17	17	17	16
Taranaki	52	47	49	41	51	24	48	20	42	38	38	42	41
Palmerston North	4	<1	1	<1	4	3	1	<1	2	2	2	<1	2
Wellington	5	3	2	5	3	4	<1	2	1	2	2	2	3
Westland	13	12	8	10	10	3	4	5	4	9	10	11	8
Christchurch	2	<1	<1	1	2	1	<1	<1	1	<1	<1	1	1
Dunedin	1	1	1*	2	2	<1	<1	<1	<1	1	<1	2	1
Country-wide Average	13	11	11	11	11	6	8	6	8	10	9	10	10

* Estimate

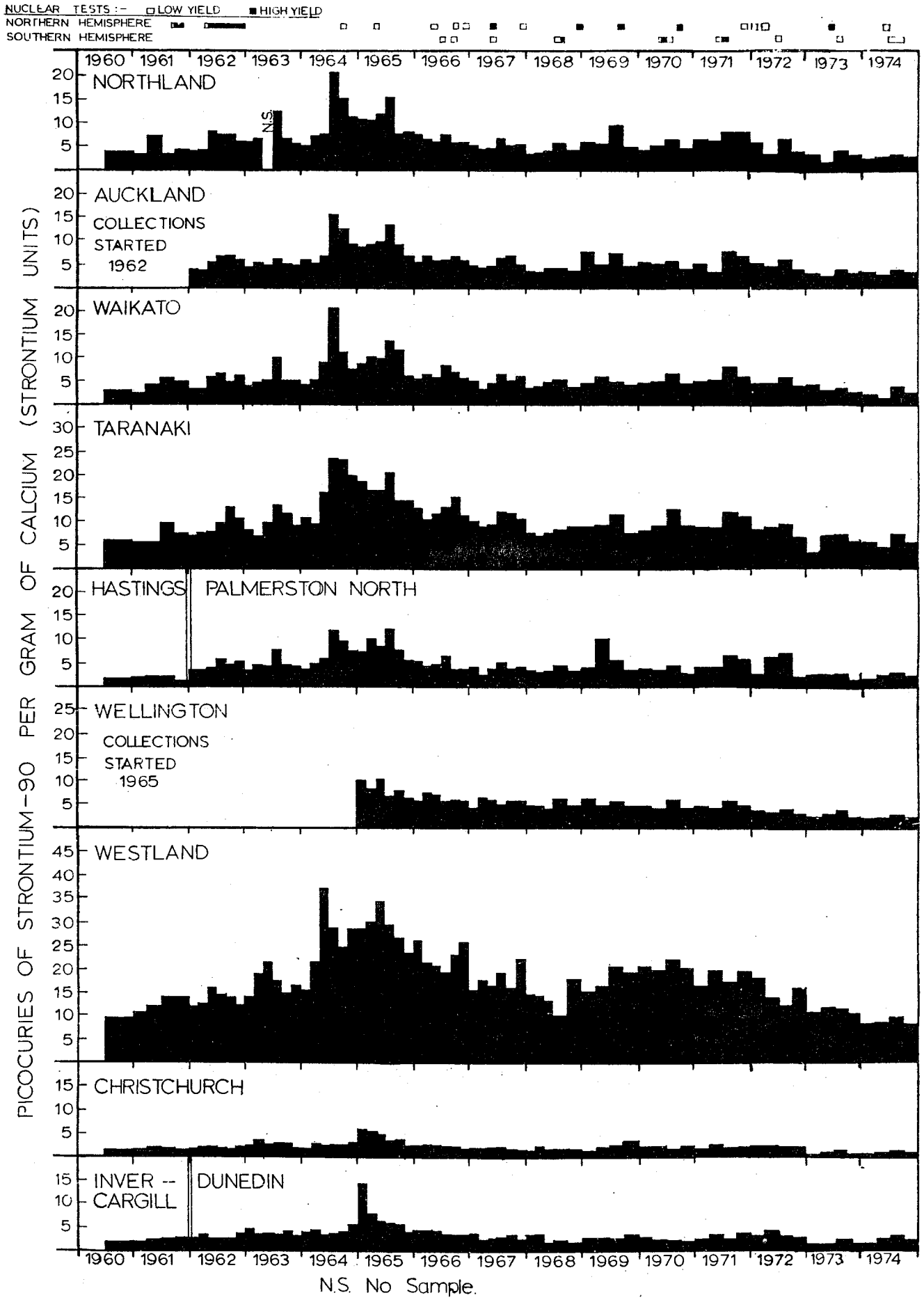


Fig.11 Strontium-90 in milk - individual stations

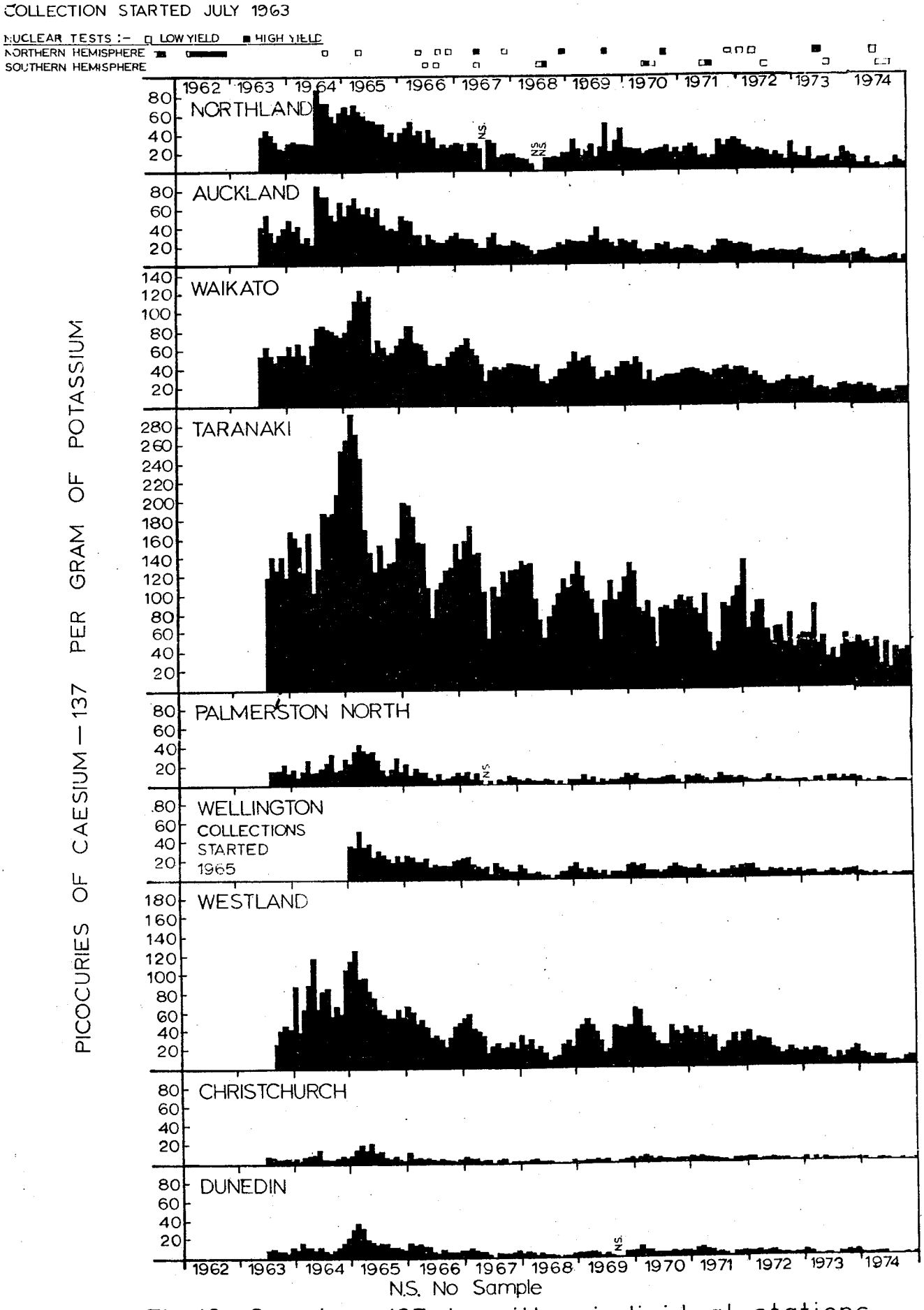
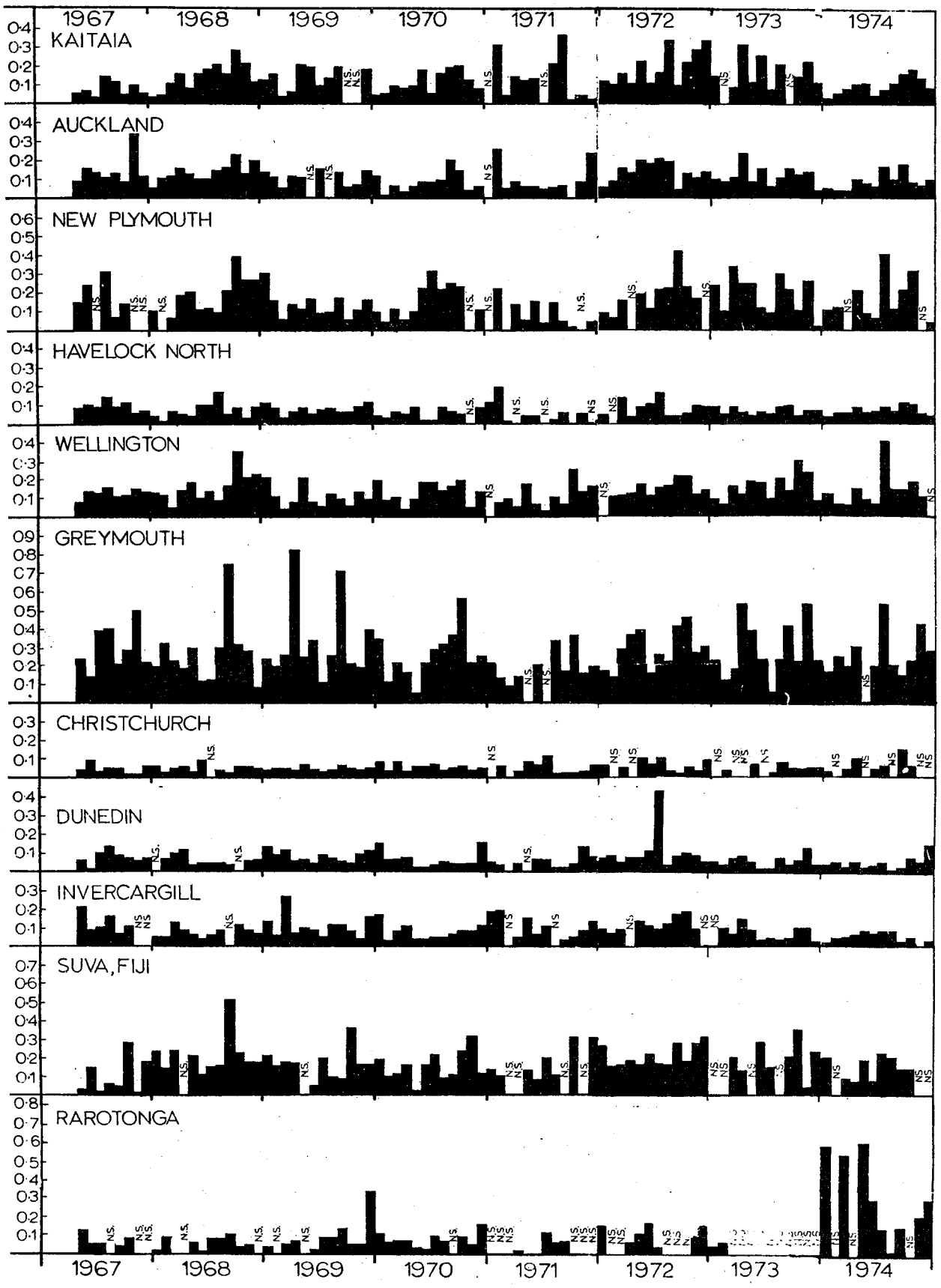


Fig.12 Caesium-137 in milk - individual stations



N.S. No Sample or No Results Available.

Fig. 13 Lead-210 in rain - individual stations

TABLE 14

RADIONUCLIDES IN HUMAN BONE

Rainfall Area: The areas within New Zealand from which samples have been obtained are classified according to mean annual rainfall:

Low : less than 100cm per year
Medium: 100 to 150cm per year
High : more than 150cm per year

Age at Death: y year, m month, SB stillborn

Bone Type: F femur, H humerus, L longbones, V vertebrae, R rib, S skull

Sample Data					Radionuclide Levels ***		
					Artificial	Naturally-Occurring	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
3	Low	7/61	5m	F,V,R	0.9	0.016	0.047
4	"	7/61	9y	F,V	0.6	0.011	0.053
7*	"	9/61	23y	F,V	0.7	0.214	0.355
1	"	6/61	53y	F	<0.1	0.026	0.101
2	"	7/61	60y	F	<0.1	0.011	0.099
33	"	9/61	78y	H	0.2	0.012	0.054
34	"	9/61	79y	H	0.1	0.013	0.040
29	"	2/61	83y	H	0.1	0.017	0.050
5	High	9/61	68y	F	0.2	0.012	0.080
31	"	11/61	68y	H	0.3	0.010	0.074
8	"	10/61	80y	F	<0.1	0.040	0.106
6	"	9/61	85y	F	<0.1	0.010	0.111
10	Low	5/62	7y	F	0.5	0.020	0.094
36	"	1/62	56y	H	0.3	0.009	0.118
32	Medium	2/62	53y	H	0.3	0.046	0.193
30	"	2/62	67y	H	0.2	-	-
19	High	12/62	9m	F	3.2	0.036	0.079
11	"	11/62	1y	F	2.1	-	-
12	"	11/62	2y	F	1.2	0.020	0.060
23	"	12/62	8y	F	1.6	0.026	0.078
9	"	5/62	16y	F	1.4	0.017	0.150
15	"	11/62	16y	F	0.6	0.013	0.057
14	"	11/62	19y	V,R	0.9	0.013	0.190
13	"	11/62	72y	V	0.9	0.021	0.173
16	Low	11/63	4y	F	2.3	0.009	0.094
16				V	2.5		
35	Medium	6/63	84y	H	0.3	0.041	0.077
17	High	8/63	1y	F	2.1	0.026	0.096
27	"	12/63	3y	L	2.2	0.012	0.085
18	"	8/63	5y	F	1.3	0.010	0.076
22	"	7/63	5y	F	1.4	0.008	0.050
21	"	1/63	7y	F	0.9	0.026	0.151
20	"	2/63	19y	F	1.4	0.023	0.072

(continued)

TABLE 14 - continued

Sample Data					Radionuclide Levels ***		
					Artificial	Naturally-Occurring	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
25	Low	4/64	SB	L	1.0	-	-
25				R	1.0	-	-
25				V	0.9	-	-
26	Low	4/64	SB	L	0.6	-	-
26				R	0.9	-	-
26				V	0.8	-	-
26				S	0.7	-	-
24	Low	4/64	6y	F	1.2)	0.021	0.069
24				V	1.0)		
28	High	2/64	6y	L	1.4	0.008	0.058
74	Low	11/66	3y	F	3.0	0.014	-
46	"	7/66	7y	F	1.9	0.009	0.036
42	"	6/66	16y	F	1.0	0.074	0.098
43	"	6/66	19y	F	0.5	0.010	0.057
49**	-	9/66	18y	F	0.5	0.023	0.085
58	Low	7/66	20y	F	0.9	0.017	0.035
71	",	11/66	21y	F	0.5	0.037	0.042
68	Low	8/66	23y	F	0.4	0.010	0.055
79	Medium	12/66	2y	F	1.5	0.011	0.038
52	"	8/66	3y	F	2.1	0.036	0.046
72	"	11/66	3y	F	1.5	0.013	0.018
86	"	12/66	3y	F	2.4	0.030	0.036
41	"	6/66	3y	F	2.4	0.020	0.069
83	"	11/66	5y	F	1.5	0.016	0.055
44	"	6/66	7y	F	2.0	0.006	0.048
47	"	7/66	7y	F	2.3	0.013	0.037
56	"	8/66	7y	F	1.5	0.010	0.076
80	"	12/66	7y	F	2.1	0.021	0.046
62	"	8/66	8y	F	1.4	0.016	0.051
81	"	11/66	8y	F	1.4	0.030	0.064
61	"	8/66	9y	F	1.4	0.014	0.046
53	"	8/66	9y	F	1.3	0.022	0.054
65	"	9/66	9y	F	1.3	0.142	-
76	"	11/66	9y	F	1.0	0.020	0.052
84	"	12/66	10y	F	1.2	0.029	0.061
73	"	11/66	12y	F	1.2	0.016	0.025
59	"	9/66	13y	F	1.2	0.017	0.045
60	"	8/66	14y	F,V	1.2	0.013	0.008
51	"	8/66	14y	F	1.1	0.024	0.038
87	"	12/66	14y	F	1.0	0.012	0.040
63	"	8/66	15y	F	1.1	0.010	0.041
78	"	12/66	15y	F	1.8	0.031	0.026
55	"	8/66	16y	F	1.7	0.016	0.063
50	"	10/66	16y	F	0.9	0.030	0.067
75	"	11/66	16y	F	0.9	0.014	0.037
77	"	12/66	16y	F	1.0	0.010	0.016
38	"	6/66	17y	F	1.0	0.021	0.047
82	"	11/66	17y	F	1.1	0.033	0.118
70	"	10/66	18y	F	1.0	0.038	0.080
64	"	7/66	19y	F	0.9	0.018	0.033

(continued)

TABLE 14 - continued

Sample Data					Radionuclide Levels ***		
					Artificial	Naturally-Occurring	
Sample No.	Rainfall Area	Date of Death	Age at Death	Bone	Strontium-90 pCi/g Ca	Radium-226 pCi/g ash	Lead-210 pCi/g ash
45	Medium	6/66	20y	F	0.9	0.010	0.046
57	"	7/66	22y	F	0.6	0.011	0.028
48	"	8/66	22y	F	0.6	0.010	0.042
69	"	10/66	22y	F	0.8	0.013	0.037
40	"	6/66	24y	F	0.5	0.012	0.073
54	"	8/66	25y	F	0.4	0.019	0.042
85	"	12/66	27y	F	0.2	0.012	0.027
39	"	6/66	31y	F	0.5	0.016	0.093
67	High	8/66	14y	F	2.4	0.017	0.048
37	"	5/66	17y	F	1.0	0.014	0.058
66	"	8/66	17y	F	1.4	0.016	0.019
89	Low	1/67	18y	F	1.0	0.023	0.036
91	High	7/67	3y	F	2.6	0.008	0.030
92	"	12/67	15y	F	1.4	0.014	0.046
90	"	6/67	16y	F	1.9	0.026	0.022
93	High	4/68	5y	F	1.7	0.022	-
94	"	8/68	15y	F	1.6	0.026	0.020
111	High	4/69	3y	F	1.8	0.013	-
110	"	10/69	17y	F	2.6	0.014	0.030
106	High	9/70	7y	F	1.3	0.010	0.011
108	"	1/70	12y	F	1.1	0.009	0.022
109	"	5/70	14y	F	1.5	0.011	0.032
107	"	6/70	17y	F	1.2	0.028	0.032
99	Medium	2/71	12y	F	1.2	0.013	0.025
102	"	5/71	14y	H	1.7	0.012	0.015
96	"	4/71	15y	V	1.1	0.011	0.031
101	"	5/71	15y	L	1.6	0.012	0.011
100	"	4/71	16y	F	1.2	0.012	0.042
97	"	4/71	18y	-	1.0	0.041	0.059
98	"	4/71	51y	-	1.3	0.011	0.095
95	"	4/71	76y	V	1.1	0.024	0.072
103	"	4/71	84y	V	-	-	0.090
105	High	7/71	3y	F	2.2	0.014	-
113	"	1/71	7y	F	1.5	0.009	0.053
104	"	9/71	14y	F	1.1	0.016	0.021
112	High	1/72	16y	F	1.8	0.013	0.038
114	"	1/72	16y	F	1.7	0.019	0.057
115	Medium	3/74	21y	F	0.9	0.009	0.009
117	"	5/74	24y	V	0.4	0.022	0.073
118	"	5/74	37y	V	0.9	0.012	0.117
116	"	5/74	63y	V	0.8	0.017	0.196

* Occupationally exposed to luminizing materials.
** Resident in New Zealand a very short time - most of life spent in Australia.
*** To convert approximately pCi/g Ca into pCi/g ash multiply by 0.39.

NOTE: The high bias in the lead-210 values previously reported for all samples with sample numbers greater than No. 56 has now been corrected in this tabulation. (see Report No. NRL-F/52 p.23).

UNITS

The unit of radioactivity is the Curie (3.7×10^{10} disintegrations per second). This unit, however, is too large for environmental levels of radioactivity and smaller subdivisions are used:

the millicurie (mCi) . . . . . one thousandth of a Curie;

the picocurie (pCi) . . . . . one millionth of a millionth of a Curie (2.22 disintegrations per minute).

1. Radioactive fallout in rain is expressed as:

(a) Deposition - millicuries per square kilometre (mCi/km^2)

(b) Concentration - picocuries per litre (pCi/litre)

$$pCi/litre = \frac{mCi/km^2 \times 100}{\text{centimetres of rain}}$$

2. Strontium-90 contamination in milk and bone is given in "Strontium Units":

picocuries of strontium-90 per gram of calcium . . . pCi/g Ca.

Caesium-137 contamination in milk is given as:

picocuries of caesium-137 per gram of potassium . . pCi/g K.

Radium-226 and lead-210 contamination in bone is given as:

picocuries per gram of ash . . . . . pCi/g ash.

Note: One litre of whole milk contains approximately 1.2 g of calcium and 1.4 g of potassium.