NRL - F/52

DEPARTMENT OF HEALTH
NEW ZEALAND

ENVIRONMENTAL RADIOACTIVITY ANNUAL REPORT

1973

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

JUNE 1974

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.
J.E. Dobbs	Technical Officer, Gamma Spectroscopy.
M.A. Findlay(Mrs)	Technician.

The assistance of the mechanical and electronic workshops, the draughting and clerical sections of the Laboratory is gratefully acknowledged.

It is with regret that we record the sudden death of Mr Dobbs early this month. We wish to acknowledge the sterling work he has given to the Laboratory over the last eighteen years.

H.J. YEABSLEY
DIRECTOR

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SUMMARY

During 1973 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, however, the country-wide average deposit decreased to 0.3 mCi/km^2, less than one-tenth the 1964 maximum. It is estimated that at the end of 1973 about 20% of the total strontium-90 deposition on New Zealand had come from French tests in the South Pacific.

The concentration of strontium-90 and caesium-137 in milk reflect the changes in fallout deposition. The average levels during 1973 were the lowest since measurements commenced.

Results for the extended monitoring programme covering the five low, or very low, yield nuclear tests in the 1973 French test series were published in the previous report (NRL-F/51, November 1973). It is expected that future deposition of long-lived material from the 1973 series will be negligible.

During 1973 the levels of radioactive contamination were small percentages of the reference levels. The long-term average levels since measurements commenced are also small percentages of the reference levels. It is considered, therefore, that the levels reported herein do not constitute a public health hazard.

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 1971 and 1972 annual reports (1)(2) especially the first of these which summarised all the earlier reports, and discussed global fallout and specific radionuclides of potential health significance.

During July and August 1973 France conducted her seventh series of nuclear 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 (3).

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 also 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 (4). 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 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.

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

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(1) "Environmental Radioactivity". Annual Report 1971, Report No. NRL-F/48, June 1972.

(2) "Environmental Radioactivity". Annual Report 1972, Report No. NRL-F/50, April 1973.

(3) "Environmental Radioactivity. Fallout From Nuclear Weapons Tests Conducted by France in the South Pacific During July and August 1973, and Comparisons with Previous Test Series". Report No. NRL-F/51, November 1973.

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

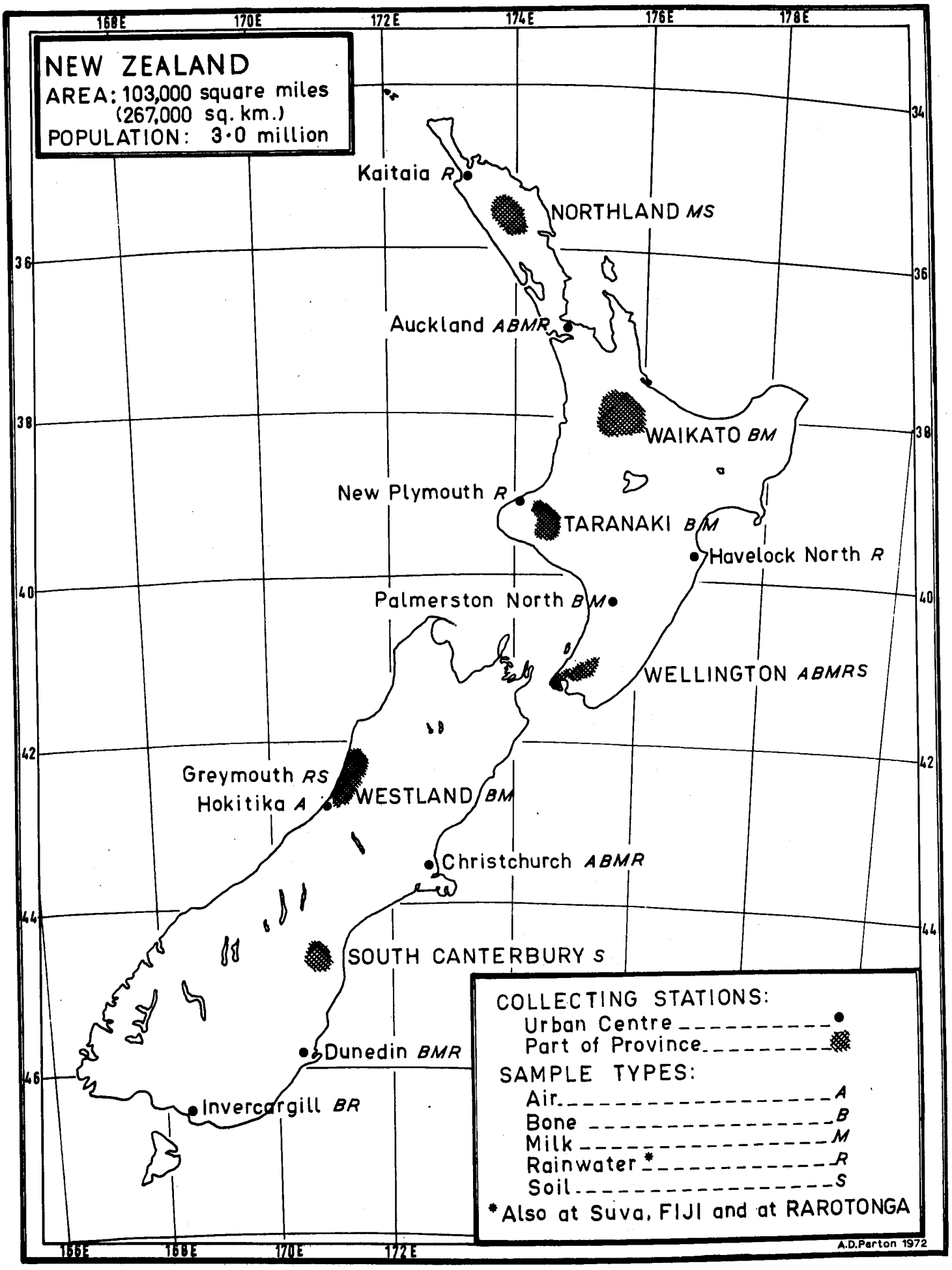

Fig. 1 COLLECTING STATIONS IN NEW ZEALAND

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 one 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 possible 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.

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

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* Not a routine measurement (see NRL-F/51 for results of ^{131}I measurements during the special monitoring programmes).

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 10 APPENDIX for individual results during 1973.) During the extended programme covering French nuclear tests, however, filters were changed daily at the New Zealand stations and also at four Pacific Island stations (see Report No. NRL-F/51 for individual results during the 1973 programme).

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 1971 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 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 results thus confirm unofficial statements by the news media of the low power of the devices reported to have been detonated during these two series.

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

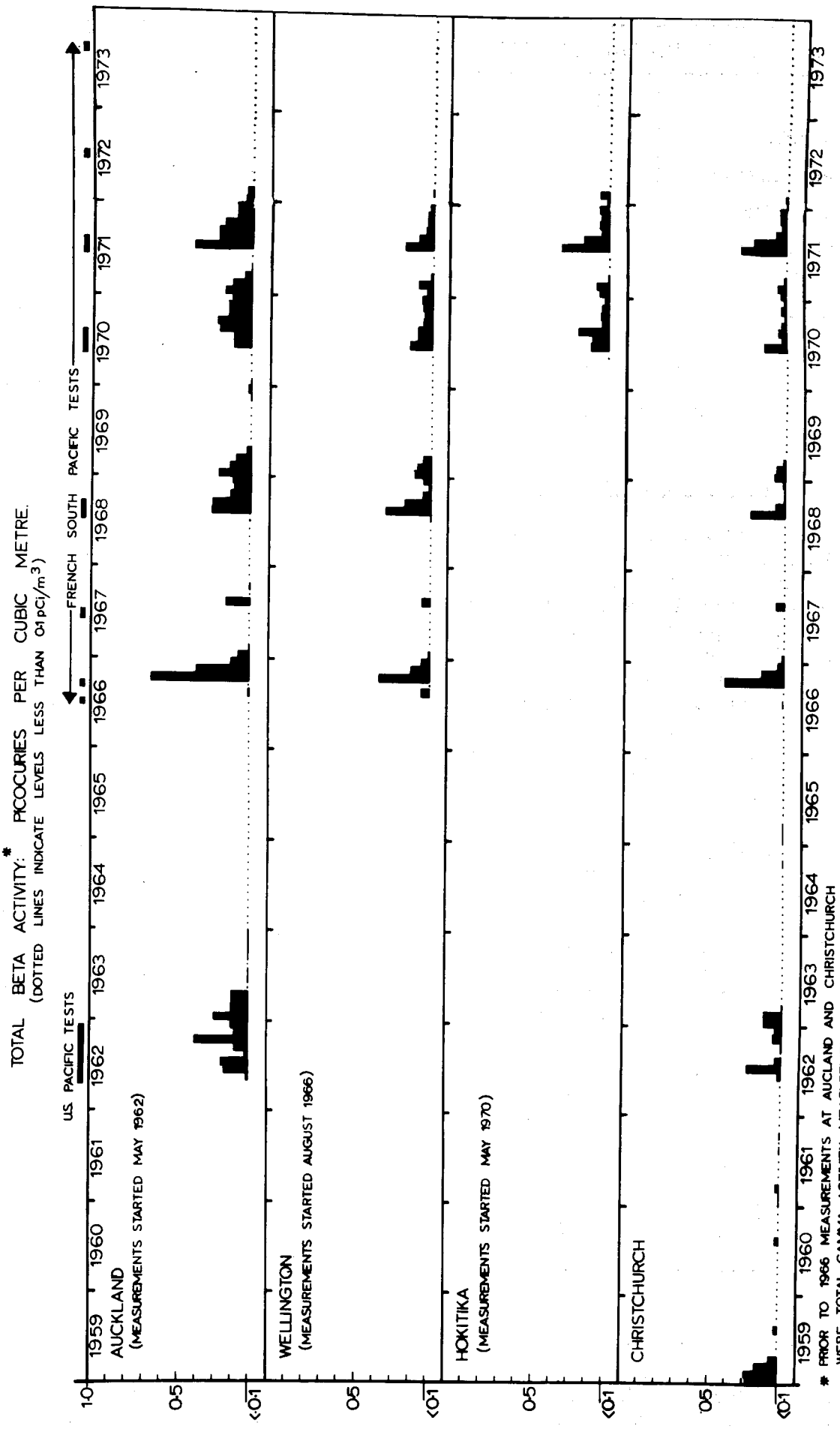


Fig. 2 FISSION PRODUCTS IN AIR - MONTHLY AVERAGES

TABLE 1 TOTAL BETA ACTIVITY IN AIR - ANNUAL AVERAGES (pCi/m^3)								
	1966	1967	1968	1969	1970	1971	1972	1973
Auckland	0.14	0.08	0.12	0.12	0.16	0.21	0.06	0.02
Wellington	0.10*	0.05	0.10	0.09	0.12	0.12	0.05	0.01
Hokitika					0.12*	0.16	0.05	0.02
Christchurch	0.11	0.06	0.07	0.07	0.10	0.15	0.05	0.02
* Estimate								

During 1973 levels of fission products in air at the New Zealand stations were the lowest recorded since measurements commenced and were very small fractions of the Reference Level.

2. Fission Products in Rain

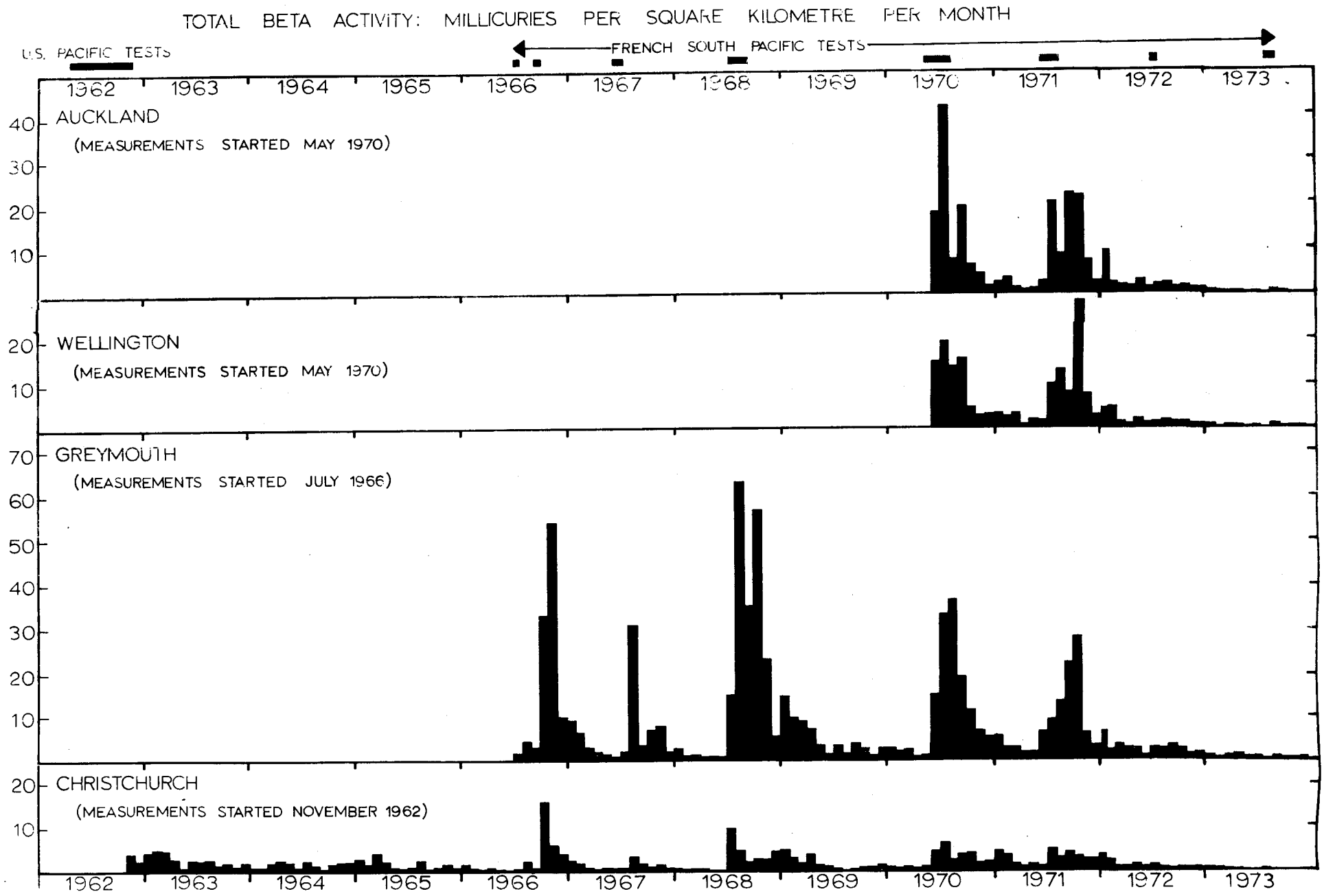
Weekly funnel and bottle collections of rainwater are made at four New Zealand stations on a routine basis, and are measured for total beta activity. Increases in the levels of fission products in rainwater samples have occurred concurrently with increases in air radioactivity. The weekly depositions, 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
Auckland								101(1)	98	25	5
Wellington								75(1)	80	22	7
Greymouth				106(2)	77	205	61	133	99	33	8
Christchurch	28	15	17	32	14	28	18	26	32	15	4
(1) May to December only. (2) July to December only.											

During 1973 the deposition of mixed fission products (total beta activity) was the lowest recorded. (See TABLE 11 APPENDIX for the results for individual weekly collections during 1973 and for the average concentration in rain during the year at each station.) The average concentration at each station was less than 8 picocuries per litre during the year - a very small fraction of the Reference Level.

Fig. 2 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 1973 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 12 and Fig. 9 in the APPENDIX for individual station results of monthly collections.)

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
NEW ZEALAND															
Kaitaia	139				1.8	4.1	3.1	1.6	1.0	0.9	1.5	1.0	2.0	0.9	0.4
Auckland	120	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
New Plymouth	150				2.0	5.3	4.2	1.9	1.3	1.0	1.5	1.2	1.9	0.9	0.3
Havelock Nth	74	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
Wellington	125	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
Greymouth	239	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
Christchurch	55	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
Dunedin	62				1.0	1.8	2.0	0.7	0.6	0.4	0.7	0.5	0.8	0.6	0.2
Invercargill	107	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
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
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
Rarotonga	208								0.9*	0.7	0.7	1.0	0.9*	0.8	0.6

The mean annual rainfall is for the years 1963 to 1973 inclusive (at Rarotonga: 1967 to 1973 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 reaching a minimum in 1968.

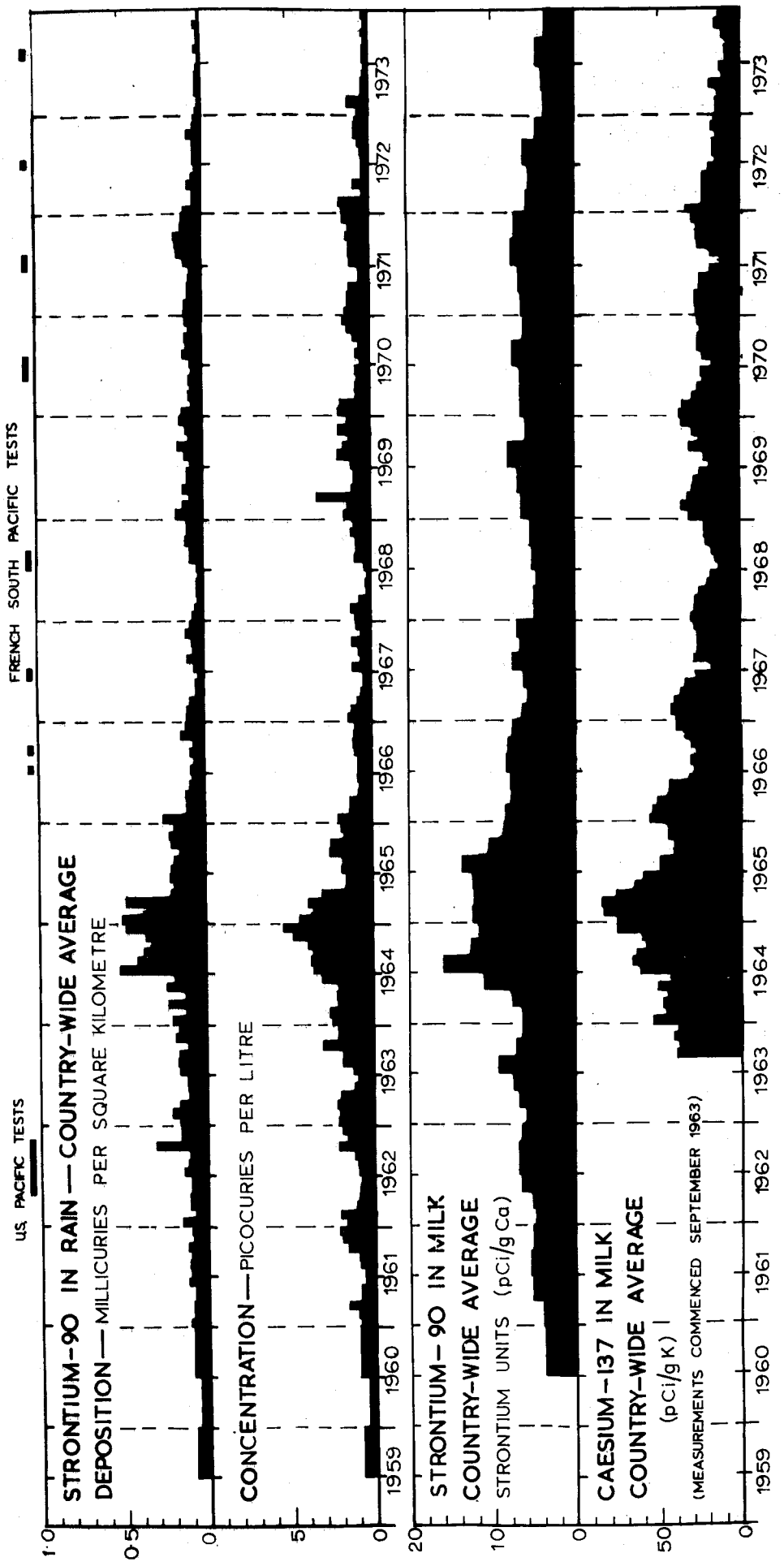


Fig. 4 COUNTRY-WIDE AVERAGE LEVELS OF LONG-LIVED RADIONUCLIDES IN RAIN AND MILK

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 34 nuclear devices are reported to have been exploded in the atmosphere from 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. 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 the minimum in 1968, although still only about one-third of the peak value in 1964.

During 1972 the annual deposit again fell to the minimum value which was recorded in 1968, and during 1973 this trend continued with average depositions being about half those of the previous year.

In Section 5 (Strontium-89/Strontium-90 Activity Ratios) the half-yearly country-wide average depositions of strontium-90 from the early 1961-1962 tests and from 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 seven 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 where 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 (5)(6) 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 stratospheric 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. Levels would have fallen below those listed for recent years but for the continuing nuclear weapons tests in the atmosphere, by China in the northern hemisphere, and by France in the southern hemisphere. Such testing has maintained the annual depositions at a relatively steady level during recent years. However, there has been a decrease during 1972 and particularly during 1973.

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(5) "Radioactive Fallout in Air and Rain, Results to the middle of 1973". United Kingdom Atomic Energy Authority, AERE-R 7540.

(6) "Fallout Program, Quarterly Summary Report, April 1, 1974". Health and Safety Laboratory, United States Atomic Energy Commission, HASL-281.

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

Year	Northern Hemisphere Stations		New Zealand Average
	Milford Haven	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	(0.15) to end of June only.	(0.38) 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, however, this trend was reversed, the reduction from radioactive decay was very slightly greater than the small increment from fallout during the year.

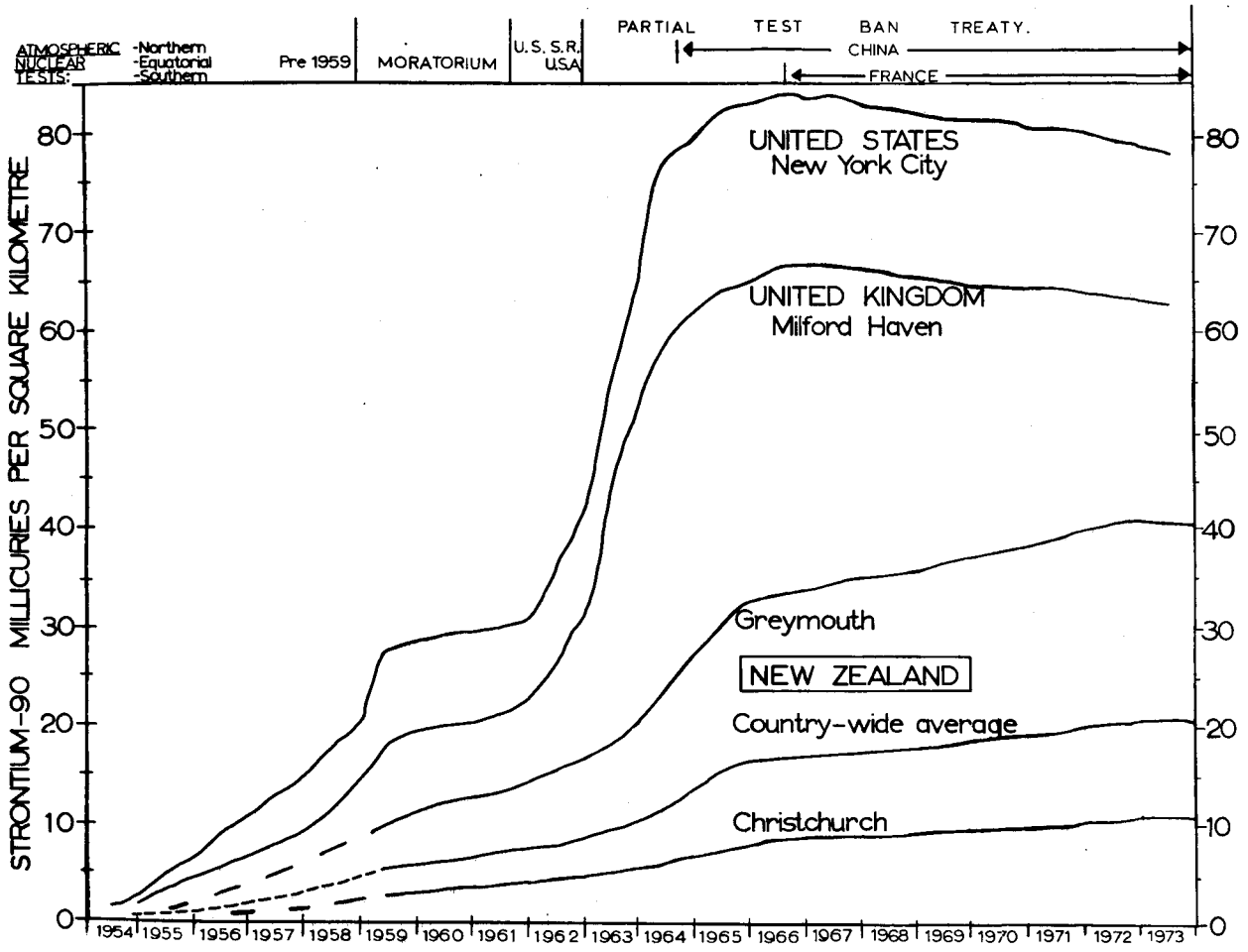

Fig. 5 CUMULATIVE DEPOSITION OF STRONTIUM-90 - COMPARISON

In Section 5 (Strontium-89/Strontium-90 Activity Ratios) it is estimated that about 20% of the average cumulative deposition of strontium-90 on New Zealand at the end of 1973 derived from the French Pacific tests.

3. Strontium-90 in Soil

The accumulation of strontium-90 at selected New Zealand sites has also been evaluated by direct measurement in soil samples.

Early measurements were undertaken jointly by the U.S. Department of Agriculture's Soil Survey Laboratory, and the U.S. Atomic Energy Commission's Health and Safety Laboratory (HASL), as part of their world-wide soil sampling programme. They conducted the final sampling for this programme from 1965 to 1967 when the maximum cumulative deposit had been reached in the northern hemisphere (see Fig. 5). The results of this programme were published in a series of reports (7).

The New Zealand soil samples collected at the end of 1963 were used for intercomparison of measurements by this Laboratory (NRL) and HASL. Thereafter this Laboratory measured the New Zealand samples during the final stages of the world-wide programme and continued these measurements after the conclusion of that programme.

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(7) "Strontium-90 on the Earth's Surface". United States Atomic Energy Commission, (1959 Results, TID-6567); (1960-1961 Results, TID-17090); (1961-1967 Results, TID-24341).

A special world-wide soil sampling programme was again conducted by HASL from October 1970 to January 1971 (8). The main purpose of this programme was to measure the world-wide deposition of plutonium resulting from a satellite failure and burn-up in April 1964. However, HASL also measured strontium-90 in these samples and duplicates of the New Zealand samples were taken for our own measurements and for further intercomparison.

The results of strontium-90 measurements on New Zealand samples are shown in TABLE 5.

TABLE 5 STRONTIUM-90 IN NEW ZEALAND SOILS mCi/km^2

DATE OF SAMPLING	DEPTH OF SAMPLING	LABORATORY	NORTH AUCKLAND	WELLINGTON JUDGEFORD	WELLINGTON TAITA	GREYMOUTH	SOUTH CANTERBURY
End 1953	15 cm	HASL	<0.1	<0.1			<0.1
Feb.1955	"	HASL		0.7			
Apr.1956	"	HASL	1.5	1.3			0.8
Mar.1958	"	HASL	2.5	3.7			3.1
Jun.1959	"	HASL	5.5	6.1			4.2
End 1960	20 cm	HASL	5.2	7.8	5.1		4.6
End 1963	20 cm	HASL	10.2	10.5	9.0	16.7	6.3
		NRL	9.9	10.3	8.8	16.8	5.9
End 1965	"	NRL	12.9		12.4	23.0	9.1
End 1967	"	NRL	14.1			20.8	8.4
Jul.1968	"	NRL			11.2		
End 1968	"	NRL	13.7		11.5	19.0	8.3
Oct.1970	30 cm	HASL	16			24	12
		NRL	16		12	24	12
End 1972	"	NRL	12.2		20.1	27.6	13.9

Up to about 1963 direct measurements of strontium-90 in soil gave results in good agreement with those calculated from the measured deposition in rainwater. Since then, however, the direct measurements have given significantly lower values than those expected from rainwater analysis and it has been necessary to increase progressively the depth of soil sampling in an attempt to overcome this discrepancy. At the end of 1972 the concentration of strontium-90 in soil to a depth of 30 cm at Greymouth was only about two-thirds that expected from measurements in rain, and at Northland the discrepancy was even greater. It is of some interest that a considerable proportion of the deposited strontium-90 has now permeated to a depth where its uptake in grass and contamination of the food chain is unlikely. It appears that it may be necessary to sample to about twice the present depth to recover all the strontium-90. A profile study is now being planned to determine the degree of penetration and the concentration at various depths at the four routine soil sampling stations and also at Taranaki.

The results of the special world-wide 1970 soil measurement programme indicated that the average level of strontium-90 in New Zealand soils was in reasonable agreement with the average level for other 30° - 50° south latitude sites. The average level for the 30° - 50° north latitude sites was about 70 mCi/km^2, about four times higher. The New York City measurement was 98 mCi/km^2, i.e. somewhat higher than that shown in Fig. 5.

(8) "Global Inventory and Distribution of Pu-238 From SNAP-9A". Health and Safety Laboratory, United States Atomic Energy Commission, HASL-250.

4. Natural Radionuclides in Soil

A survey has been conducted to determine the terrestial radiation dose arising from the presence of naturally-occurring radioactivity in New Zealand soils. About 300 soil samples, representing wide-spread sampling throughout the country, were provided by the Soil Bureau of the Department of Scientific and Industrial Research. These samples have been analysed by gamma spectroscopy for the concentration of naturally-occurring radionuclides of the uranium and thorium series and potassium-40.

The concentrations measured ranged widely from the minimum detectable levels to the maximum levels shown in TABLE 6. (The minimum detectable levels were 50 pCi/Kg for the uranium and thorium series and 340 pCi/Kg for potassium-40.) The average concentrations, and the approximate dose rates in air one metre above the ground resulting from these average levels are also given in the table.

TABLE 6 NATURALLY-OCCURRING RADIOACTIVITY IN NEW ZEALAND SOILS

	Concentration (pCi/Kg)		Dose Rate (mRAD/yr)
	Maximum	Average	Average
Potassium-40	25,000	9,400	16
Uranium series	1,700	630	12
Thorium series	2,400	800	22
			TOTAL: 50

Maximum dose rates from terrestial radiation at particular localities are about twice the average value, i.e. about an additional 50 mRAD per year.

The dose rates may be compared with those arising from cumulative fallout. The country-wide average cumulative deposition of strontium-90 (Fig. 5) is about 20 mCi/km^2. Taking the ratio of caesium-137 to strontium-90 as 1.5:1, the dose rate from the average cumulative deposition of caesium-137 would be about 2 mRAD per year, assuming that all the caesium-137 is on the surface. However, high rainfall areas have about twice the average cumulative deposition giving an additional dose rate of about 2 mRAD per year. These calculations for fallout dose rates are upper limits as considerable leaching of the fallout radionuclides occurs, with consequent deeper penetration into the soil and attenuation of the radiation. After a number of years of weathering such attenuation could reduce the values above by an order of magnitude.

5. Strontium-89/Strontium-90 Activity Ratios

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 1973 are given in TABLE 13 APPENDIX.) Knowledge of activity ratios and dates of nuclear tests often gives useful information about the origin of the deposited strontium-90.

Strontium-89 has a half-life of only 50 days. It is therefore 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 (5). 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 of 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 following observations apply to the data shown in Fig. 6 and are based on the New Zealand country-wide average value of the ratio each mid-month and the average strontium-90 deposit for that month:

(1) U.S.A. Pacific Tests (Values of the Ratio During 1962, 1963)

The U.S.A. Pacific tests (Operation Dominic in the Christmas and Johnston Island areas) comprised 36 reported detonations (9) during April to July and October, November 1962. In addition, 31 U.S.S.R. tests were reported to have occurred at the Arctic and Siberian test sites during September to November 1961 and a further 37 during August to December 1962 (9).

When atmospheric nuclear testing is thus extended in time, production and decay of strontium-89 from the earlier tests is overlapped by that from subsequent tests. The net result is an apparent half-time in the decrease of the ratio which is longer than 50 days. It is generally not possible, therefore, to draw lines with the correct slope through the plotted points in Fig. 6 for this period.

(2) French Pacific Tests - 1966, 1967

The first two French Pacific series starting July 1966 were of relatively short duration and comprised low to intermediate power nuclear tests only. Radioactive debris from these tests, therefore, would largely be limited to tropospheric injection, and be rapidly removed by settling and wash-out in the following months.

The short pause during August in the 1966 series is noticeable as two distinct injections and subsequent declines of the activity ratio. Two features are worth noting during the 1966-67 series. Firstly, activity ratios do not extrapolate back to 185 at the time of these series. It is calculated that during the second half of 1966 about 14% of the New Zealand country-wide average deposition of strontium-90 came from the 1966 French tests. During 1967 about 15% derived from French Pacific tests. The rest of the measured strontium-90 deposition was delayed stratospheric

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(9) "Fallout Program, Quarterly Summary Report, January 1, 1964." Health and Safety Laboratory, United States Atomic Energy Commission, HASL-142.

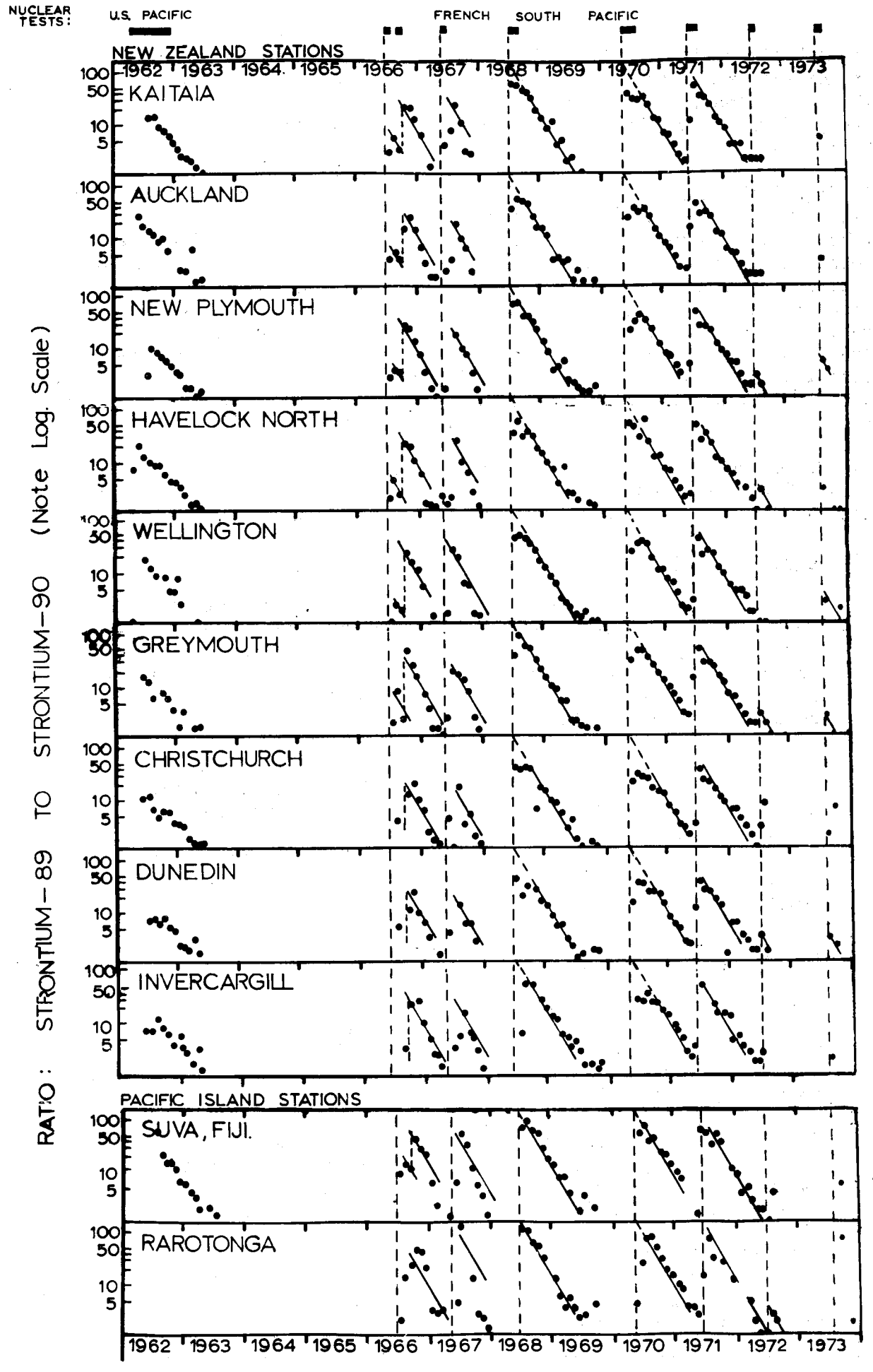

Fig. 6 STRONTIUM-89/STRONTIUM-90 RATIO IN RAINWATER

fallout from the earlier 1961-1962 nuclear tests. Secondly, the half-time in the decrease of the ratio appears to be somewhat shorter than 50 days. This is probably explained by rapid removal of strontium-89 from the troposphere combined with further deposition of strontium-90 from the stratospheric reservoir from the early 1961-1962 tests. By December 1967 the activity ratio had fallen to 1 and measurement of strontium-89 was discontinued.

(3) French Pacific Tests 1968, and the Chinese Test of December 1968 (Values of the ratio during 1968 and 1969)

During the first half 1968 it is not possible to calculate the proportion of strontium-90 due to the French tests. It is assumed that tropospheric removal of the earlier French Pacific debris was substantially complete and that most of the strontium-90 deposit came from the remaining stratospheric reservoir. At the start of the second half 1968, the third series of French tests commenced. Activity ratios immediately increased to values higher than those previously recorded. For the first time during French Pacific tests, two high yield tests were included resulting in stratospheric injection of fission products. Later in the year a high yield (3 megaton) Chinese nuclear test was conducted at Lop Nor on 27 December. Because there were no French tests in 1969 the decrease in the activity ratio was able to be followed right through to the end of 1969 when it fell below 1 during December. Using this data and making reasonable assumptions about the contribution of the individual tests in the 1968 French series, the following interesting conclusions were reached:

(a) During the second half 1968, about 43% of the New Zealand average strontium-90 deposit was from the 1968 French tests. During the first half 1969 the proportion increased to about 54%, the remainder being "old" strontium-90 from the stratospheric reservoir.

(b) During the second half 1969, about 75% of the strontium-90 came from the 1968 French tests, about 15% came from the Chinese test of December 1968, and only about 10% was "old" strontium-90. The stratospheric reservoir from the early 1961-62 tests at this time appeared to be largely depleted.

The reasons for attributing some of the strontium-90 deposit during late 1969 to interhemispheric transfer from the Chinese test of December 1968 were given in a previous report of this series (10) and are recapitulated here:

From mid-1968 through to about August 1969 measured activity ratios could be extrapolated back to the final nuclear test of the 1968 French Pacific series without exceeding the formation ratio of 185. From September to November 1969, however, the average value of the ratio no longer decreased and actually increased in November. For these months values of the ratio could not be extrapolated back to the time of the French tests without the formation ratio being significantly exceeded. This was a clear indication of more recent atmospheric nuclear testing.

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(10) Annual Summary 1969, Report No. NRL-F38.

The only such testing reported was the Chinese test of 27 December 1968. Inspection of the literature at about that time (11) and more recently (6) confirmed that at some stations in the Pacific slightly north of the equator, notably Majuro Island (7°5'N, 171° 23'E) and Truk Island (7° 28'N, 151° 51'E) elevated values of the ratio occurred during the latter half of 1968 after the French tests. A further elevation then occurred during March to July 1969 at Majuro Island, and April, June and July 1969 at Truk Island. These later periods coincided with those at many northern hemisphere stations where elevated values of the ratio resulted from the Chinese test of December 1968. Measurements at several stations in Chile bordering the South Pacific and particularly at Pretoria in South Africa, where slight increases in the ratio were recorded during September to November 1969, tend to confirm this view. A recent paper by Telegadas (6) discusses the distribution of radioactivity in the stratosphere from Chinese and French high yield nuclear tests. In particular a mixture of Chinese 1968 and French 1968 debris is shown in the southern hemisphere from about mid-1969. By October 1969 the mixture had progressed to more than 40° S.

(4) French Pacific Tests 1970 and 1971

During the 1970 French series two high yield tests were included. There was also another 3 megaton Chinese test reported during October 1970. During the 1971 French series one high yield test was included. Values of the activity ratio indicate that French debris predominates in fallout over New Zealand following these series. It is possible that traces of "old" strontium-90 and Chinese test strontium-90 are present. However, any such traces are completely overshadowed by French test strontium-90 and are not able to be evaluated.

(5) French Pacific Tests 1972 and 1973

The most noticeable feature of these series is the low power of all the nuclear devices tested. Only a very small fraction of the strontium-90 deposited came from tropospheric deposition following these tests. The decreasing strontium-90 deposition during 1972 and 1973 derived mainly from earlier French series, and during 1973 strontium-90 deposition over New Zealand was the lowest recorded since measurements commenced. At Rarotonga the relatively high value of the ratio in the September 1973 sample resulted from a westerly tropospheric excursion of fission products probably from the final explosion of the series on 29 August. See Report No. NRL-F/51 (3).

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 also been totalled and corrected for radioactive decay. Such calculations show that, at the end of 1973, about 20% of the country-wide cumulative deposition on New Zealand was attributable to the French Pacific tests. This cumulative deposition is the total deposition, corrected for radioactive decay as shown in Fig. 5.

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(11) "Fallout Programme, Quarterly Summary Report, April 1, 1970". Health and Safety Laboratory, United States Atomic Energy Commission. HASL-224 APPENDIX.

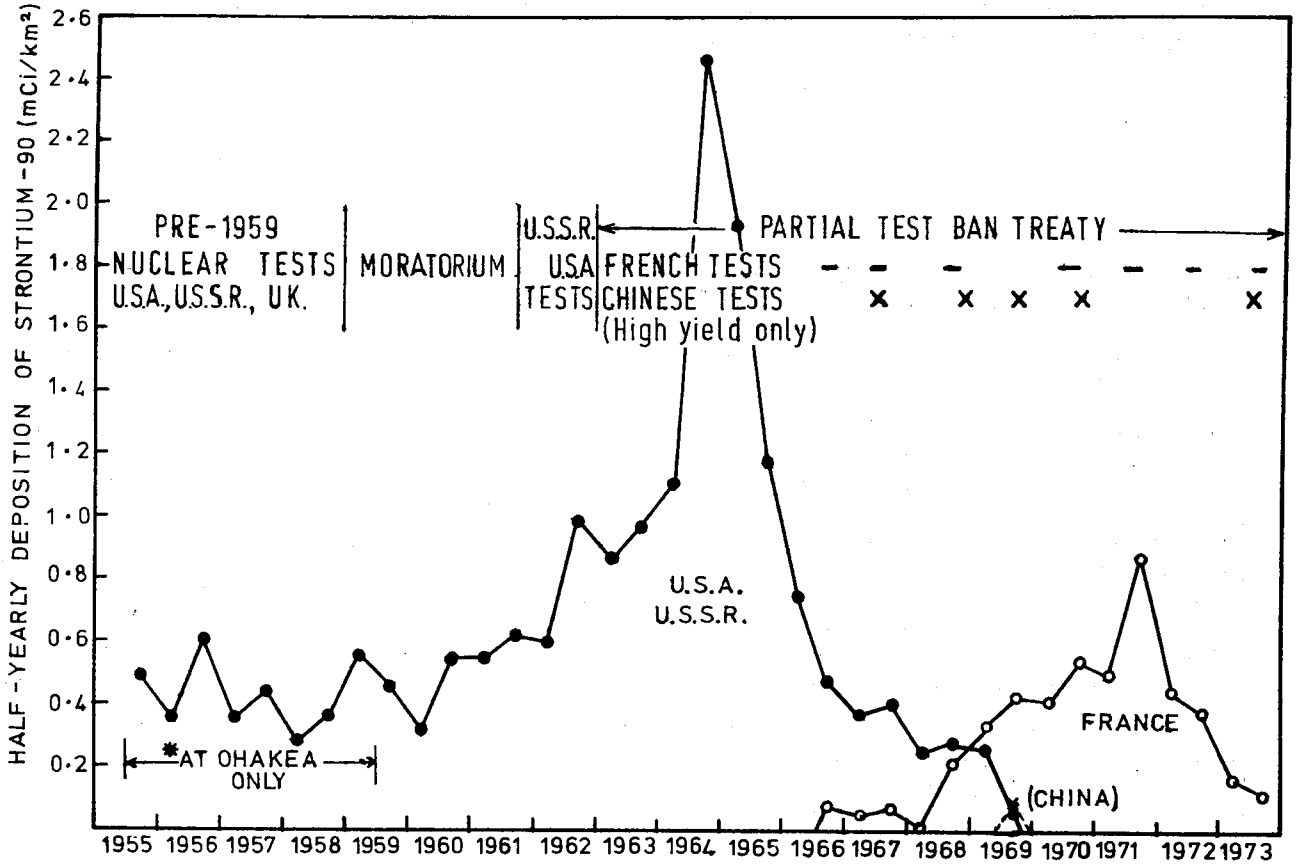

Fig. 7 HALF-YEARLY AVERAGE DEPOSITION OF STRONTIUM-90 ON NEW ZEALAND FROM ATMOSPHERIC NUCLEAR TESTS BY VARIOUS COUNTRIES

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.

6. Strontium-90 in Milk

(a) At Nine New Zealand Stations

The average concentration of strontium-90 in milk at all stations during 1973 was the lowest since measurements commenced in 1961. TABLE 7 lists the average yearly level at each station, and also the country-wide averages (see also Fig. 4. For individual results, see TABLE 14 and Fig. 10 in the APPENDIX).

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 1964-1965 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.

TABLE 7 AVERAGE LEVELS OF STRONTIUM-90 IN MILK - STRONTIUM UNITS (pCi/g Ca) 1961 - 1973

STATIONS	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	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	6.6
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	5.8
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	5.8
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	10.6
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	4.9
Wellington*					8.8	6.1	5.4	4.8	5.1	4.7	4.8	4.1	3.5	5.3
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	18.6
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	2.2
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	3.4
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	7.0

* Wellington Average 1965-1973

Due to the French tests, milk levels stopped decreasing in 1968 and increased slightly during the next three years. However, following the subsequent decline in deposition of strontium-90 in rain during 1972 and 1973, milk levels again declined reaching the minimum recorded level of 4.1 pCi/g Ca in 1973.

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 Canadian (12) and New York City (6) milk.

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

(12) "Data From Radiation Protection Programs"; "Radiation Surveillance in Canada", RPD Report Series of the Radiation Protection Division, Department of National Health and Welfare, Canada.

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 strontium-90 deposition in the two hemispheres, the milk levels have been about the same.

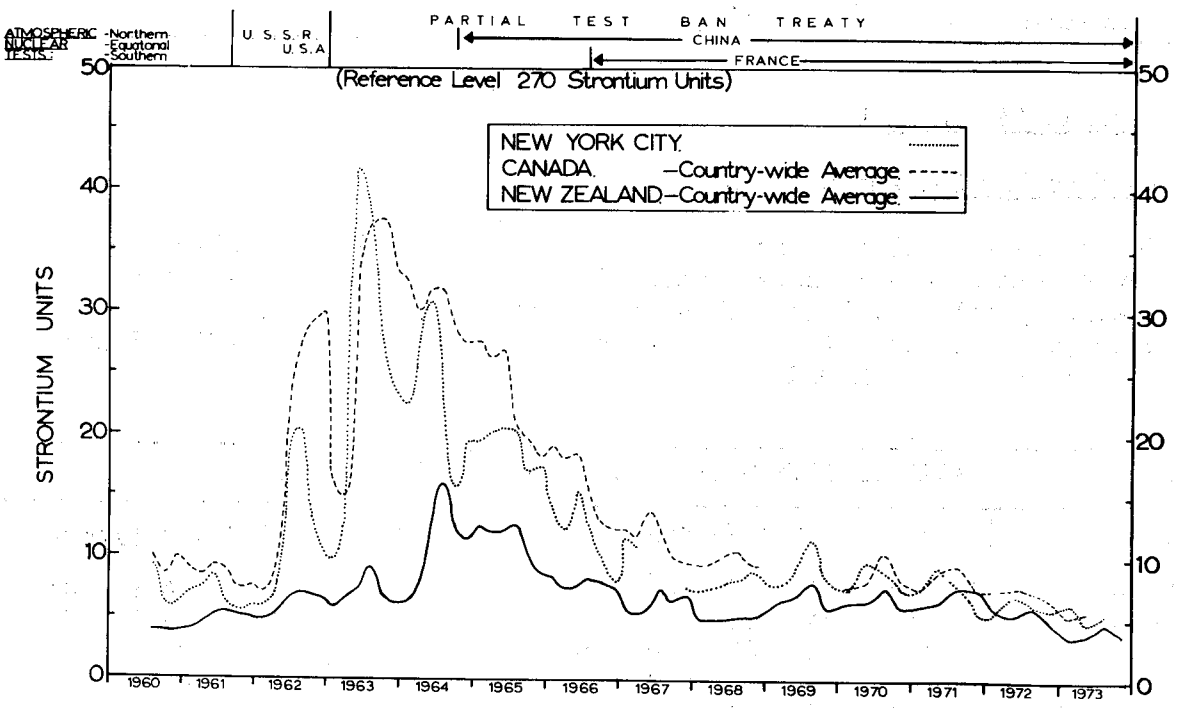

Fig. 8 STRONTIUM-90 LEVELS IN MILK - COMPARISON

(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. Therefore the levels in diet must also be considered over similarly extended periods.

It is appropriate to attempt a hazard assessment as follows:

Assume that the average level in New Zealand milk during the period 1962 to 1973 inclusive was maintained indefinitely in the average New Zealand diet as a whole. Furthermore consider the discrimination against strontium in its passage from diet to bone (the observed ratio of Strontium Units in bone to Strontium Units in diet is 1 to 4).

Under these hypothetical equilibrium conditions the bone levels of New Zealanders would not exceed the levels listed in TABLE 8.

TABLE 8 STRONTIUM-90 HAZARD ASSESSMENT (1962 - 1973)

Station	Strontium Units		% of Reference Level
	Milk	Bone	
Lowest Level (Christchurch)	2.2	0.6	0.8%
Highest Level (Westland)	18.6	4.7	6.9%
Country-wide Average	7.0	1.8	2.6%

7. Caesium-137 in Milk

(a) At Nine New Zealand Stations

The average level of caesium-137 in milk during 1973 was also the lowest since measurements commenced in 1964. TABLE 9 lists the average yearly level at each station and also the country-wide averages (see also Fig. 4. For individual results see TABLE 15 and Fig. 11 in the APPENDIX).

TABLE 9 AVERAGE LEVELS OF CAESIUM-137 IN MILK - pCi/g K

STATIONS	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Average
Northland	49	54	37	26	15	27	22	23	21	14	29
Auckland	51	53	33	26	18	26	18	18	15	9	27
Waikato	69	84	60	48	36	41	35	36	28	21	46
Taranaki	168	185	141	123	102	101	89	80	72	49	111
Palmerston Nth	19	26	11	7	3	5	6	7	2	3	9
Wellington	25*	29	18	13	7	9	11	9	7	4	13
Westland	76	77	43	33	21	38	39	30	22	14	39
Christchurch	7	11	4	3	1	2	4	3	2	1	4
Dunedin	11	18	9	5	3	4	5	5	4	2	7
Country-wide Average	53	60	39	31	23	28	25	23	19	13	32

* 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 a previous annual report NRL-F/48(1).

(b) Comparison of Measured Levels with the Reference Level

During the period 1964 to 1973 inclusive the country-wide average level was 32 pCi/g K which is about 0.5% of the reference level. At the highest level station, Taranaki, the average level over the same

period was 111 pCi/g K, about 1.6% 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.

8. Lead-210 in Rain

The measurement of naturally-occurring lead-210 deposition in rain was continued during 1973. 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. 12 APPENDIX. Earlier results, including higher results during 1965 at four stations and references to levels in milk, were discussed in a previous annual report NRL-F/48 (1).

During 1973 the New Zealand country-wide average deposition was about 1.6 mCi/km^2, the same as for 1972. During the last six years the annual deposition has averaged about 1.5 mCi/km^2 for the New Zealand stations. During the same period the annual deposition of strontium-90 from weapons tests has averaged about 0.9 mCi/km^2.

9. Strontium-90, Radium-226, and Lead-210 in Human Bone

This monitoring programme commenced in 1961 to determine strontium-90 concentrations in human bone samples in New Zealand and correlate them with strontium-90 levels in fallout deposition and in milk in this country. With the decrease in the rate of strontium-90 fallout during recent years, and the difficulty of obtaining suitable samples, especially in the younger age groups, this programme is now being concluded.

The results for 103 samples so far analysed were listed and discussed in the previous annual report NRL-F/50 (2). It has been confirmed that the levels obtained do not exceed calculated values based on accepted figures for variation of uptake with age, and on appropriate dietary levels. The results for a further 21 samples, many in the process of being analysed, will complete the programme, and all results will be presented in the next annual report of this series. Unless the deposition rate increases significantly, strontium-90 monitoring in future will be confined to measuring the deposition in rain and the levels in milk.

This programme was also extended to include measurement of the naturally-occurring bone seekers radium-226 and lead-210, and the results have been tabled alongside the strontium-90 results (1)(2). When the final results are given in the next annual report the opportunity will be taken to correct a high bias in some of the results reported for lead-210. This bias does not apply to those samples with sample numbers less than No. 56, and is due to the presence of lead-210 in one of the analytical reagents used more recently. Sufficient material is held to reanalyse the later samples for this natural radionuclide.

MISCELLANEOUS INFORMATION

1. International Intercomparison of Measurements

During 1973 this Laboratory again participated in international intercomparisons of environmental radioactivity measurements. The programmes were organised by The International Atomic Energy Agency; The International Reference Centre for Radioactivity, W.H.O.; and The U.S. Environmental Protection Agency.

The types of environmental samples measured for radionuclide content were: milk, total diet, and marine sediment. Radionuclides and elements measured were: strontium-89, strontium-90, iodine-131, caesium-137, barium-140, cerium-144, ruthenium-106, potassium, and calcium.

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 a previous annual report NRL-F/48 (1).

The procedures for radiostrontium in various media are detailed in a technical report (13) 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 (14) and are available as a detailed technical report from this Laboratory on request (15).

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

(14) "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.

(15) "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 10 TOTAL BETA ACTIVITY OF AIR FILTER SAMPLES : 1973

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		Wellington		Hokitika		Christchurch	
Date	pCi/m^3	Date	pCi/m^3	Date	pCi/m^3	Date	pCi/m^3
Jan. 1	0.02	Jan. 1	0.01	Jan. 1	0.01	Jan. 1	0.03
" 3	0.02	" 3	0.04	" 3	0.03	" 3	0.04
" 5	0.03	" 5	0.03	" 5	0.02	" 5	0.03
" 8	0.02	" 8	0.02	" 8	0.01	" 8	0.03
" 10	0.02	" 10	0.02	" 10	0.03	" 10	0.03
" 12	0.03	" 12	0.02	" 14	0.03	" 12	0.01
" 15	0.04	" 15	0.03	" 17	0.03	" 15	0.04
" 17	0.03	" 17	0.03	" 22	0.04	" 17	0.02
" 19	0.03	" 19	0.04	" 24	0.01	" 19	0.04
" 22	0.05	" 22	0.03	" 26	0.02	" 22	0.02
" 24	0.02	" 24	0.01	" 29	0.02	" 24	0.01
" 26	0.04	" 26	0.02			" 26	0.02
" 29	0.03	" 29	0.01			" 29	0.01
Jan. Av.	0.03	Jan. Av.	0.02	Jan. Av.	0.02	Jan. Av.	0.03
Jan. 31	0.03	Jan. 31	0.03	Feb. 2	0.03	Jan. 31	0.04
Feb. 2	0.04	Feb. 2	0.02	" 5	0.02	Feb. 2	0.03
" 5	0.02	" 5	0.03	" 7	<0.01	" 5	0.02
" 7	0.02	" 7	0.01	" 8	0.03	" 7	0.03
" 9	0.02	" 9	0.03	" 10	<0.01	" 9	0.02
" 12	0.02	" 12	<0.01	" 12	0.02	" 12	0.01
" 14	0.03	" 14	0.02	" 14	0.02	" 14	0.02
" 16	0.02	" 16	0.03	" 16	0.03	" 16	0.03
" 19	0.02	" 19	0.02	" 19	0.04	" 19	0.01
" 21	0.04	" 21	0.03	" 21	0.02	" 23	0.02
" 23	0.02	" 23	0.02	" 23	0.02	" 26	0.02
" 26	0.02	" 26	0.01	" 26	0.02		
Feb. Av.	0.03	Feb. Av.	0.02	Feb. Av.	0.02	Feb. Av.	0.02
Feb. 28	0.02	Feb. 28	0.04	Feb. 28	0.02	Mar. 2	0.03
Mar. 2	0.03	Mar. 2	0.02	Mar. 2	0.01	" 5	0.01
" 5	0.01	" 5	0.02	" 5	0.02	" 7	0.03
" 7	0.05	" 7	0.03	" 7	0.03	" 9	0.03
" 9	0.02	" 9	0.02	" 9	0.02	" 12	0.03
" 12	0.02	" 12	0.03	" 12	0.02	" 14	0.02
" 14	0.01	" 14	<0.01	" 14	0.02	" 16	0.02
" 16	0.02	" 16	0.02	" 16	0.01	" 19	0.02
" 19	0.03	" 19	0.02	" 19	0.02	" 21	0.03
" 21	0.03	" 21	0.02	" 21	0.02	" 23	0.04
" 23	0.03	" 23	0.02	" 23	0.02	" 26	0.02
" 26	0.01	" 26	<0.01	" 26	<0.01	" 28	0.02
" 28	0.06	" 28	0.02	" 28	0.02		
Mar. Av.	0.03	Mar. Av.	0.02	Mar. Av.	0.02	Mar. Av.	0.03

(continued)

Auckland		Wellington		Hokitika		Christchurch	
Date	pCi/m^3	Date	pCi/m^3	Date	pCi/m^3	Date	pCi/m^3
Mar. 30	0.02	Mar. 30	0.01	Mar. 30	0.02	Mar. 30	0.02
Apr. 2	0.01	Apr. 2	0.02	Apr. 2	0.02	Apr. 2	0.01
" 4	0.03	" 4	0.03	" 4	0.02	" 4	N.S.
" 6	0.01	" 6	<0.01	" 6	0.02	" 6	0.02
" 9	0.02	" 9	0.01	" 9	N.S.	" 9	0.03
" 11	0.01	" 11	<0.01	" 11	0.03	" 11	0.02
" 13	0.02	" 13	0.01	" 13	0.02	" 13	0.01
" 16	0.02	" 16	<0.01	" 16	0.01	" 16	<0.01
" 18	0.03	" 18	0.01	" 18	0.01	" 18	0.01
" 20	0.01	" 20	0.02	" 20	<0.01	" 24	0.01
" 23	0.01	" 23	<0.01	" 23	0.03	" 27	0.02
" 25	0.02	" 25	<0.01	" 27	0.06		
" 27	0.02	" 27	0.04				
Apr. Av.	0.02	Apr. Av.	0.01	Apr. Av.	0.02	Apr. Av.	0.02
Apr. 30	0.02	Apr. 30	0.02	Apr. 30	0.05	Apr. 30	N.S.
May 2	0.02	May 2	<0.01	May 2	<0.01	May 2	0.01
" 4	0.02	" 4	<0.01	" 4	<0.01	" 4	<0.01
" 7	<0.01	" 7	<0.01	" 7	<0.01	" 7	<0.01
" 9	0.02	" 9	<0.01	" 9	<0.01	" 9	<0.01
" 11	0.01	" 11	0.01	" 11	<0.01	" 14	<0.01
" 14	<0.01	" 14	0.01	" 14	<0.01	" 16	0.01
" 16	0.01	" 16	<0.01	" 16	<0.01	" 18	<0.01
" 18	<0.01	" 18	<0.01	" 18	<0.01	" 21	0.01
" 21	0.01	" 21	<0.01	" 21	<0.01	" 23	0.01
" 23	0.01	" 23	<0.01	" 23	<0.01	" 25	<0.01
" 25	0.01	" 25	<0.01	" 25	<0.01	" 28	<0.01
" 28	0.01	" 28	<0.01	" 28	<0.01	" 30	0.01
" 30	<0.01	" 31	<0.01	" 30	<0.01		
May Av.	0.01	May Av.	<0.01	May Av.	<0.01	May Av.	<0.01
Jun. 1	0.01	Jun. 1	<0.01	Jun. 1	<0.01	Jun. 1	0.01
" 4	0.02	" 4	<0.01	" 4	<0.01	" 5	0.01
" 6	0.01	" 6	<0.01	" 6	<0.01	" 6	<0.01
" 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	0.01	" 15	0.02
" 18	<0.01	" 18	<0.01	" 13	0.01	" 18	0.01
" 20	0.03	" 20	0.01	" 20	0.01	" 20	0.02
" 22	0.01	" 22	0.01	" 22	<0.01	" 22	0.01
" 25	0.01	" 25	<0.01	" 25	<0.01	" 25	0.01
" 27	<0.01	" 27	0.01	" 27	0.01	" 27	N.S.
" 29	<0.01	" 29	<0.01	" 29	0.01	" 29	0.01
Jun. Av.	0.01	Jun. Av.	<0.01	Jun. Av.	<0.01	Jun. Av.	0.01

(continued)

Auckland Date	pCi/m^3	Wellington Date	pCi/m^3	Hokitika Date	pCi/m^3	Christchurch Date	pCi/m^3
Jul. 2	<0.01	Jul. 2	<0.01	Jul. 2	<0.01	Jul. 2	0.01
" 4	<0.01	" 4	0.01	" 4	0.01	" 4	0.02
" 6	<0.01	" 6	<0.01	" 6	<0.01	" 6	0.01
" 9	0.01	" 9	<0.01	" 9	<0.01	" 9	<0.01
" 11	0.01	" 11	<0.01	" 11	0.01	" 11	<0.01
" 13	<0.01	" 13	<0.01	" 13	0.01	" 13	<0.01
" 16	<0.01	" 16	<0.01	" 16	0.01	" 16	<0.01
" 18	0.04	" 18	<0.01	" 18	0.01	" 18	<0.01
" 20	<0.01	" 20	<0.01	" 20	<0.01	" 20	0.01
" 23	<0.01	" 23	<0.01	" 23	0.01	" 23	0.02
" 24	0.01	" 24	<0.01	" 24	<0.01	" 24	<0.01
" 25	0.01	" 25	<0.01	" 25	<0.01	" 25	<0.01
" 26	0.02	" 26	<0.01	" 26	0.01	" 26	<0.01
" 27	<0.01	" 27	<0.01	" 27	0.02	" 27	0.01
" 28	0.02	" 28	<0.01	" 28	<0.01	" 28	<0.01
" 29	<0.01	" 29	0.01	" 29	<0.01	" 29	0.02
" 30	0.01	" 30	<0.01	" 30	0.01	" 30	0.02
" 31	0.01	" 31	<0.01	" 31	<0.01	" 31	0.02
Jul. Av.	<0.01	Jul. Av.	<0.01	Jul. Av.	<0.01	Jul. Av.	<0.01

Monthly Averages During The Special Monitoring Programme*

Aug. Av.	0.04	Aug. Av.	0.03	Aug. Av.	0.02	Aug. Av.	0.03
Sep. Av.	0.02	Sep. Av.	0.02	Sep. Av.	0.02	Sep. Av.	0.02
Oct. Av.	0.01	Oct. Av.	<0.01	Oct. Av.	<0.01	Oct. Av.	0.01

Oct. 31	<0.01	Oct. 31	<0.01	Oct. 31	0.02	Oct. 31	0.01
Nov. 2	0.01	Nov. 2	<0.01	Nov. 2	<0.01	Nov. 2	<0.01
" 5	<0.01	" 5	<0.01	" 5	<0.01	" 6	0.01
" 7	<0.01	" 7	<0.01	" 7	<0.01	" 7	0.01
" 12	<0.01	" 9	<0.01	" 9	<0.01	" 8	<0.01
" 14	0.02	" 12	0.01	" 12	0.02	" 12	<0.01
" 16	0.01	" 14	0.01	" 14	<0.01	" 14	<0.01
" 19	<0.01	" 16	<0.01	" 16	<0.01	" 16	<0.01
" 21	0.02	" 19	<0.01	" 19	0.01	" 19	0.01
" 23	<0.01	" 21	<0.01	" 21	<0.01	" 21	<0.01
" 26	<0.01	" 23	<0.01	" 23	<0.01	" 26	<0.01
" 28	<0.01	" 26	<0.01	" 26	<0.01	" 28	<0.01
		" 28	0.01	" 28	0.02		
Nov. Av.	<0.01	Nov. Av.	<0.01	Nov. Av.	<0.01	Nov. Av.	<0.01
Nov. 30	<0.01	Nov. 30	<0.01	Nov. 30	<0.01	Nov. 30	<0.01
Dec. 3	0.01	Dec. 3	0.01	Dec. 3	0.04	Dec. 3	<0.01
" 5	0.02	" 5	<0.01	" 5	<0.01	" 5	<0.01
" 7	0.01	" 7	<0.01	" 7	<0.01	" 7	0.01
" 10	0.01	" 10	<0.01	" 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	<0.01
" 19	<0.01	" 19	<0.01	" 19	<0.01	" 19	<0.01
" 21	0.01	" 21	<0.01	" 21	0.01	" 21	<0.01
" 24	<0.01	" 24	<0.01	" 24	<0.01	" 24	<0.01
" 26	0.01	" 26	0.01	" 26	<0.01	" 28	0.01
" 28	0.01	" 28	<0.01	" 28	0.01		
Dec. Av.	0.01	Dec. Av.	<0.01	Dec. Av.	<0.01	Dec. Av.	<0.01

1973 Av.	0.02	1973 Av.	0.01	1973 Av.	0.02	1973 Av.	0.02

* During the special monitoring programme, from August to October inclusive, air filter samples were changed daily. Individual results, including those from four Pacific Island stations, were given in the report on monitoring fallout from the French nuclear tests during 1973. Report No. NRL-F/51 (3).

TABLE 11 TOTAL BETA ACTIVITY OF WEEKLY RAINWATER SAMPLES : 1973

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 cm	Auckland mCi/km^2	Wellington cm	Wellington mCi/km^2	Greymouth* cm	Greymouth* mCi/km^2	Christchurch cm	Christchurch mCi/km^2
Dec. 29	0.1	0.1	<0.1	0.1	1.2	0.1	nil	0.1
Jan. 5	1.0	<0.1	4.2	0.4	1.9	0.2	1.6	0.2
" 12	1.1	0.2	0.7	0.1	3.9	0.2	trace	<0.1
" 19	0.2	0.1	0.4	0.2	4.8	0.4	0.8	0.2
" 26	0.8	0.1	<0.1	0.2	1.7	0.1	0.2	0.2
January	3.2	0.6	5.4	1.0	13.5	1.0	2.6	0.7
Feb. 2	trace	<0.1	0.2	0.1	1.4	0.2	nil	0.1
" 9	0.3	0.2	0.2	0.1	1.2	0.1	0.4	0.2
" 16	1.4	0.1	0.2	0.1	nil	0.1	nil	0.1
" 23	nil	<0.1	nil	<0.1	1.1	0.1	nil	0.1
February	1.7	0.4	0.6	0.3	3.7	0.5	0.4	0.5
Mar. 2	0.3	<0.1	2.7	0.3	4.3	0.3	0.3	0.1
" 9	2.2	0.2	3.3	0.1	2.7	0.2	2.2	0.1
" 16	0.6	0.1	0.3	<0.1	2.5	0.2	1.5	0.1
" 23	1.2	<0.1	3.0	0.1	1.5	0.1	0.3	<0.1
March	4.3	0.4	9.3	0.6	11.0	0.8	4.3	0.4
Mar. 30	0.5	<0.1	1.3	0.2	1.5	0.1	0.5	0.1
Apr. 6	2.7	0.1	0.2	0.1	0.4	0.2	0.1	<0.1
" 13	0.5	<0.1	1.0	<0.1	7.9	0.3	<0.1	0.1
" 20	2.5	0.1	3.5	0.3	10.6	0.4	0.5	0.1
" 27	0.3	<0.1			6.7	0.2	0.2	<0.1
April	6.5	0.3	6.0	0.6	27.1	1.2	1.3	0.4
May 4	1.1	<0.1	1.2	<0.1	10.7	0.2	0.3	<0.1
" 11	2.7	0.1	5.3	0.2	4.7	0.1	3.8	0.1
" 18	2.2	<0.1	1.7	<0.1	8.5	0.2	1.0	<0.1
" 25	0.7	<0.1	<0.1	<0.1	6.0	0.1	trace	0.1
May	6.7	0.2	8.3	0.3	29.9	0.6	5.1	0.3
Jun. 1	4.3	<0.1	4.1	0.1	2.9	0.3	1.4	<0.1
" 8	4.7	0.2	0.6	0.2	0.9	<0.1	0.7	<0.1
" 15	nil	<0.1	0.7	<0.1	nil	<0.1	0.1	0.1
" 22	3.6	0.1	5.0	<0.1	7.7	0.2	1.4	<0.1
June	12.6	0.4	10.4	0.4	11.5	0.6	3.6	0.2
Jun. 29	trace	0.1	1.0	<0.1	0.5	<0.1	1.0	<0.1
Jul. 6	0.5	<0.1	2.2	<0.1	<0.1	<0.1	0.1	<0.1
" 13	0.4	<0.1	1.2	<0.1	nil	<0.1	1.0	<0.1
" 20	8.8	<0.1	4.4	<0.1	1.4	<0.1	2.0	<0.1
" 27	0.3	<0.1	0.2	<0.1	1.5	<0.1	0.6	<0.1
July	10.0	0.3	9.0	0.2	3.5	0.3	4.7	0.1

(continued)

Collection	Auckland		Wellington		Greymouth*		Christchurch	
	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2	cm	mCi/km^2
Aug. 3	2.4	0.1	2.2	<0.1	5.4	0.2	8.1	<0.1
" 10	2.4	0.4	7.3	0.9	7.8	0.6	1.3	0.1
" 17	3.2	0.1	4.1	0.3	2.0	<0.1	1.7	0.1
" 24	1.3	<0.1	0.1	<0.1	3.7	0.1	nil	<0.1
August	9.3	0.7	13.7	1.3	18.9	1.0	11.1	0.3
Aug. 31	2.2	0.2	1.4	0.1	5.8	0.1	2.8	<0.1
Sep. 7	2.4	<0.1	1.5	<0.1	7.5	0.2	<0.1	0.1
" 14	3.7	0.2	1.7	0.1	2.1	<0.1	0.5	<0.1
" 21	4.6	0.1	1.9	<0.1	3.8	0.2**	0.2	<0.1
September	12.9	0.5	6.5	0.3	19.2	0.6	3.5	0.2
Sep. 28	2.2	<0.1	0.6	<0.1			0.4	<0.1
Oct. 5	0.7	<0.1	nil	<0.1	2.1	<0.1	nil	<0.1
" 12	2.0	<0.1	2.3	0.1	3.2	0.2	0.3	<0.1
" 19	1.9	<0.1	6.1	0.1	3.5	0.1	0.8	<0.1
" 26	0.4	<0.1	0.7	0.2	5.1	0.2	trace	<0.1
October	7.2	0.3	9.7	0.5	13.9	0.6	1.5	0.2
Nov. 2	1.1	0.1	3.4	0.2	9.2	0.2	1.1	<0.1
" 9	4.0	<0.1	4.7	0.2	5.8	0.1	4.0	0.1
" 16	1.5	0.1	1.7	0.2	9.8	0.2	0.5	<0.1
" 23	0.5	<0.1	2.1	<0.1	5.9	0.2	<0.1	<0.1
November	7.1	0.3	11.9	0.6	30.7	0.7	5.7	0.2
Nov. 30	0.5	<0.1	0.6	<0.1	1.1	0.2	0.2	<0.1
Dec. 7	2.4	<0.1	trace	<0.1	<0.1	<0.1	0.3	<0.1
" 14	0.2	0.2	4.3	0.1	3.2	0.1	2.0	<0.1
" 21	1.7	<0.1	7.1	0.2	0.7	N.S.	0.9	0.1
December	4.8	0.3	12.0	0.4	5.0	0.3	3.4	0.2
1973 total	86.3	4.7	102.8	6.5	187.9	8.2	47.2	3.7

Average Concentration (pCi/litre)

During 1973	5.4	6.3	4.4	7.8

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

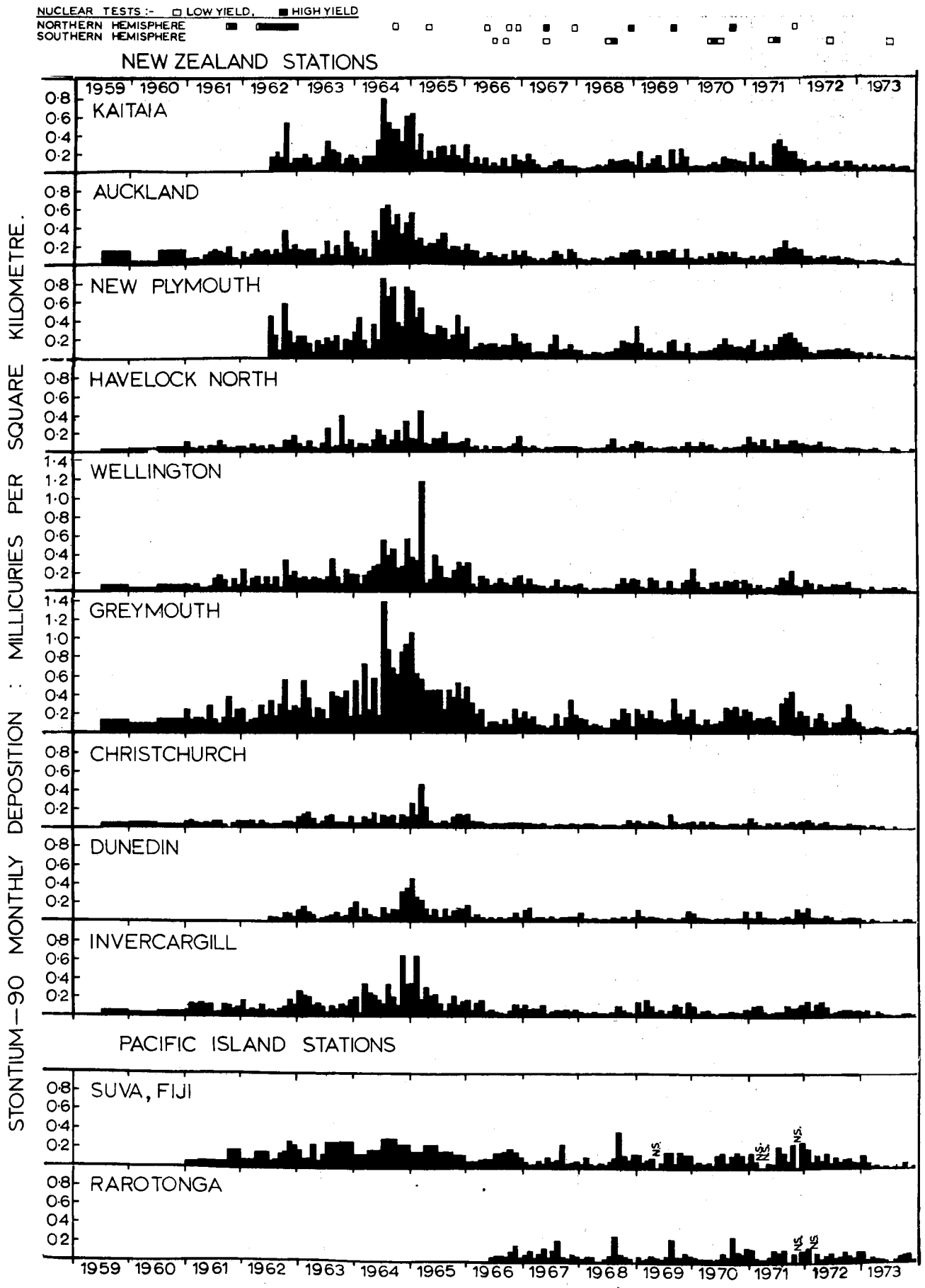
** 2 week collection.

TABLE 12

STRONTIUM-90 IN RAIN : 1973

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Monthly Average
Kaitaia	Rainfall cm	8.0	3.4	3.7	17.8	9.0	18.0	12.4	16.7	7.6	6.2	9.6	2.1	115	
	Deposition mCi $^{90}Sr/km^2$	0.04	0.06	0.02	0.06	0.03	0.05	0.04	0.05	0.02*	0.03	0.03	<0.01	0.43	
	Concentration pCi ^{90}Sr/litre	0.1	1.6	0.5	0.3	0.3	0.3	0.3	0.3	0.2 *	0.4	0.3	0.4		0.4
Auckland	Rainfall cm	3.1	1.7	4.8	5.8	6.9	12.6	9.8	9.9	14.3	5.1	7.8	4.3	86	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.01	0.02	(0.03)*	0.02	0.02	0.01	0.03	0.05	0.02	0.02	0.01	0.26	
	Concentration pCi ^{90}Sr/litre	0.7	0.7	0.3	(0.5) *	0.3	0.2	0.1	0.3	0.3	0.4	0.3	0.3		0.4
New Plymouth	Rainfall cm	8.3	0.4	21.1	8.5	15.6	13.9	7.9	17.6	18.7	7.3	14.9	3.4	138	
	Deposition mCi $^{90}Sr/km^2$	0.05	0.01	0.05	0.02	0.04	0.02	0.01	0.04	0.03	0.02	0.03	0.02	0.34	
	Concentration pCi ^{90}Sr/litre	0.5	2.6	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.5		0.5
Havelock North	Rainfall cm	5.0	1.5	4.1	3.8	7.2	12.8	4.6	10.6	10.0	2.3	10.2	5.6	78	
	Deposition mCi $^{90}Sr/km^2$	0.02	0.01	0.02	0.03	0.01	<0.01	<0.01	0.04	0.02	0.01	0.01	0.02	0.20	
	Concentration pCi ^{90}Sr/litre	0.5	0.6	0.6	0.7	0.2	<0.1	0.2	0.4	0.2	0.4	0.1	0.4		0.4
Wellington	Rainfall cm	5.0	1.7	10.7	3.8	10.7	15.0	8.1	14.0	7.7	10.3	10.4	6.6	104	
	Deposition mCi $^{90}Sr/km^2$	0.03	0.02	0.06	0.02	0.02	0.03	0.03	0.05	0.03	0.04	0.03	0.01	0.37	
	Concentration pCi ^{90}Sr/litre	0.6	1.0	0.5	0.6	0.2	0.2	0.4	0.4	0.3	0.4	0.2	0.2		0.4
Greymouth	Rainfall cm	11.9	4.2	13.5	21.8	33.8	10.5	2.0	20.3	20.2	10.7	33.8	14.6	197	
	Deposition mCi $^{90}Sr/km^2$	0.07	0.04	0.06	0.07	0.06	0.05	<0.01	0.04	0.05	0.04	0.07	0.02	0.58	
	Concentration pCi ^{90}Sr/litre	0.6	0.9	0.4	0.3	0.2	0.5	0.4	0.2	0.3	0.4	0.2	0.2		0.4
Christchurch	Rainfall cm	2.7	0.5	4.2	1.1	5.3	3.9	4.1	11.2	3.2	1.5	5.8	3.5	47	
	Deposition mCi $^{90}Sr/km^2$	0.03	0.01	0.03	0.01	0.02	<0.01	<0.01	0.02	<0.01	0.01	0.01	0.01	0.16	
	Concentration pCi ^{90}Sr/litre	1.1	2.7	0.8	1.0	0.4	<0.1	0.1	0.2	0.2	1.0	0.2	0.3		0.7
Dunedin	Rainfall cm	2.8	0.5	5.6	9.3	5.3	0.8	1.3	8.5	1.8	6.9	9.7	2.4	55	
	Deposition mCi $^{90}Sr/km^2$	0.03	<0.01	0.03	0.02	0.01	<0.01	<0.01	0.02	<0.01	0.02	0.02	0.01	0.18	
	Concentration pCi ^{90}Sr/litre	1.1	1.0	0.5	0.2	0.3	<0.1	0.6	0.3	0.3	0.3	0.2	0.5		0.5
Invercargill	Rainfall cm	5.4	8.1	6.2	14.3	16.3	6.6	3.5	4.6	5.5	11.8	13.0	3.3	99	
	Deposition mCi $^{90}Sr/km^2$	0.05	0.06*	0.02	0.05	0.04	0.01	<0.01	0.01	0.01	0.02	0.02	0.01	0.30	
	Concentration pCi ^{90}Sr/litre	0.9	0.8 *	0.3	0.3	0.3	0.2	0.3	0.3	0.2	0.2	0.1	0.3		0.4
New Zealand Country-wide Average	Rainfall cm	5.8	2.4	8.2	9.6	12.2	10.5	6.0	12.6	9.9	6.9	12.8	5.1	102	
	Deposition mCi $^{90}Sr/km^2$	0.04	0.02	0.03	0.03	0.03	0.02	0.01	0.03	0.02	0.02	0.03	0.01	0.29	
	Concentration pCi ^{90}Sr/litre	0.7	1.3	0.5	0.5	0.3	0.2	0.3	0.3	0.2	0.4	0.2	0.3		0.4
Suva, Fiji	Rainfall cm	18.0	38.5	79.9	72.1	19.4	32.0	23.1	13.6	11.4	11.4	20.3	22.2	362	
	Deposition mCi $^{90}Sr/km^2$	0.11	0.05	0.03	0.04	0.01	0.03	0.01	0.02*	0.02	0.05	<0.01	0.02	0.39	
	Concentration pCi ^{90}Sr/litre	0.6	0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1 *	0.2	0.4	<0.1	0.1		0.2
Rarotonga	Rainfall cm	48.4	8.3	31.9	12.1	11.1	14.8	4.4	21.8	6.7	13.1	10.0	25.7	208	
	Deposition mCi $^{90}Sr/km^2$	0.10*	0.03	0.05	0.03	0.03	0.02	0.01*	.03*	0.07	0.08*	0.09	0.02	0.56*	
	Concentration pCi ^{90}Sr/litre	0.2	0.3	0.2	0.3	0.3	0.1	0.2 *	0.1 *	1.1	0.6 *	0.9	<0.1		0.4

* No result available. The value given is an estimate.



COLLECTIONS STARTED AT INDIVIDUAL STATIONS
FROM JULY 1959 TO JUNE 1966, AS SHOWN.

N.S. No Sample

Fig. 9 STRONTIUM-90 IN RAIN - INDIVIDUAL STATIONS

TABLE 13	STRONTIUM-89 DEPOSITION AND THE RATIO STRONTIUM-89 TO STRONTIUM-90 IN RAIN : 1973												
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	0.3	*	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	5	*	<1	<1	<1
Auckland	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	4	<1	<1	<1	<1
New Plymouth	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.2	0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	6	4	<1	<1	<1
Havelock North	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	3	<1	1	1	<1
Wellington	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	3	<1	<1	2	<1
Greymouth	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	3	1	<1	<1	1
Christchurch	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	2	7	<1	<1	<1
Dunedin	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	3	2	<1	<1	<1
Invercargill	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	2	<1	<1	<1	<1
New Zealand Country-wide Average	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	3	2	<1	<1	<1
Suva, Fiji	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	<0.1	*	0.2	<0.1	<0.1	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	<1	*	6	<1	<1	<1
Rarotonga	Deposition mCi $^{89}Sr/km^2$	-	-	-	-	-	-	*	*	6.3	*	0.2	<0.1
	Ratio $^{89}Sr/^{90}Sr$	-	-	-	-	-	-	*	*	88	*	2	<1

* No result available.

\- Measurements discontinued.

TABLE 14	STRONTIUM-90 IN MILK : 1973				
Stations	"Strontium Units" pCi/g Ca				
	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Average
Northland	4.2	2.4	4.8	3.8	3.8
Auckland	3.3	2.8	4.0	3.4	3.4
Waikato	4.5	2.7	4.0	2.6	3.5
Taranaki	3.6	6.5	6.6	6.0	5.7
Palmerston North	2.6	2.6	3.3	2.4	2.7
Wellington	3.1	3.6	4.1	3.3	3.5
Westland	10.5	11.6	11.1	10.0	10.8
Christchurch	1.1	1.3	1.4	1.1	1.2
Dunedin	1.6	1.6	2.6	1.6	1.9
Country-wide Average	3.8	3.9	4.7	3.8	4.1

TABLE 15	CAESIUM-137 IN MILK : 1973												
Stations	pCi/g K												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Northland	18	13	13	22	9	12	12	13	8	11	22	15	14
Auckland	12	16	10	9	8	8	6	6	8	8	11	9	9
Waikato	25	27	26	29	15	18	16	14	16	21	23	20	21
Taranaki	52	56	56	86	46	54	32	39	28	41	55	45	49
Palmerston North	2	2	<1	3	3	<1	4	4	2	4	3	4	3
Wellington	4	5	5	2	2	3	5	3	2	5	5	7	4
Westland	17	15	18	18	16	9	6	11	8	13	15	20	14
Christchurch	2	<1	2	1	2	1	1	1	1	1	1	1	1
Dunedin	4	2	<1	<1	1	1	<1	2	2	3	2	3	2
Country-wide Average	15	15	14	19	11	12	9	10	8	12	15	14	13

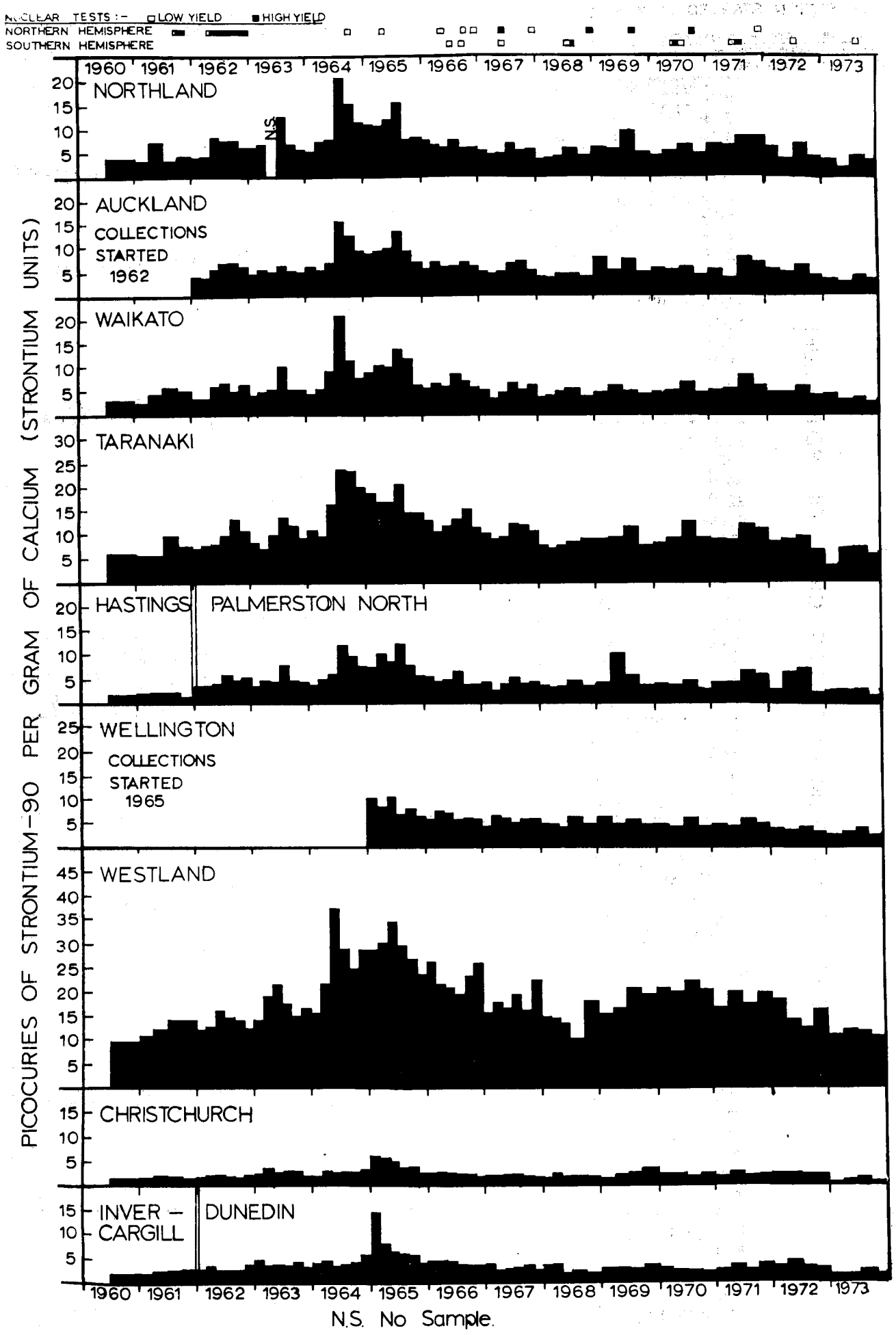


Fig. 10 STRONTIUM-90 IN MILK - INDIVIDUAL STATIONS

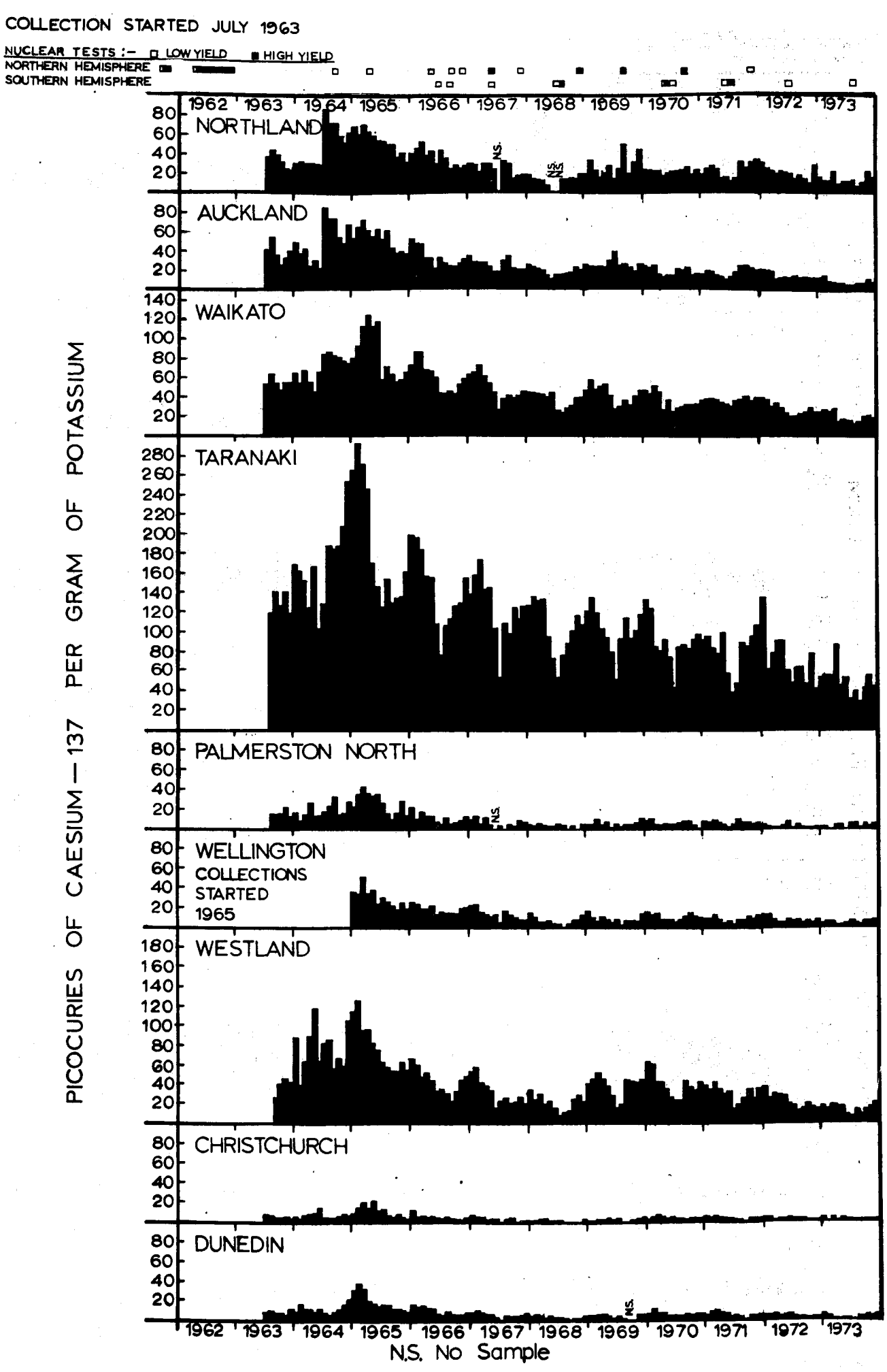
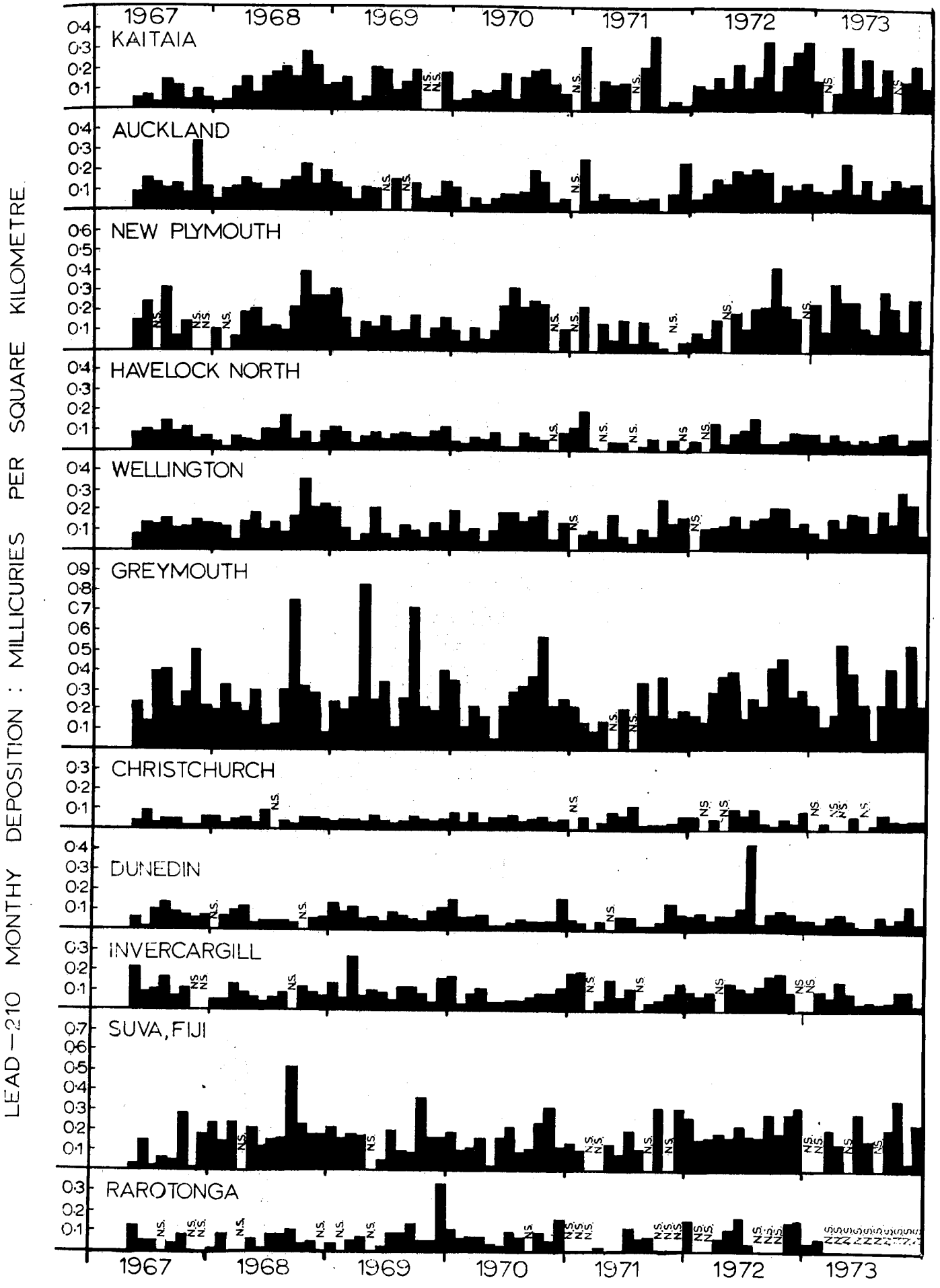


Fig. 11 CAESIUM-137 IN MILK - INDIVIDUAL STATIONS



N.S. No Sample or No Results Available.

Fig. 12 LEAD-210 IN RAIN - INDIVIDUAL STATIONS

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.