NRL
National Radiation Laboratory

Radioactive fallout in the South Pacific: A History

Part 2: Radioactivity measurements in the Pacific Islands

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RADIOACTIVE FALLOUT IN THE SOUTH PACIFIC: A HISTORY

PART 2: RADIOACTIVITY MEASUREMENTS IN THE PACIFIC ISLANDS

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ABSTRACT

This report summarises results of the environmental radioactivity monitoring programme maintained in the Pacific islands by the National Radiation Laboratory since 1961. Monitoring was commenced during the nuclear weapons tests at Christmas Island, then extended to a greater number of sites during the French atmospheric tests at Mururoa (1966 - 1974) and maintained at that level until 1985 when the network was scaled down to its present baseline level of monitoring at Rarotonga only. Emphasis is placed on the monitoring of the French tests as the largest local source of short-lived fallout. An attempt is made to correct the original data for decay between sampling and analysis.

Total beta activity deposition was monitored at Tarawa, Funafuti, Suva, Nandi, Samoa, Niue, Tonga, Aitutaki and Rarotonga, plus some early measurements at Penrhyn, Manihiki, Nukunonu, Raoul Island and Mangaia. Total annual depositions were highest in 1966, with an average over all monitoring sites of 40.7 kBq/m^2. One particular test in 1966 caused heavy fallout at Samoa and Niue where depositions of 268 and 109 kBq/m^2 respectively, were recorded. During the period 1962 to 1974 the annual average deposition was in the range 0.1 to 40.7 kBq/m^2. After 1974 levels decreased to about 0.1 kBq/m^2 due largely to natural lead-210.

Atmospheric beta activity was monitored at Nandi, Suva, Samoa, Tonga and Rarotonga, plus early measurements at Penrhyn and Niue. The highest level recorded in a single measurement was 22.4 Bq/m^3 (after decay correction) at Rarotonga in 1974. Average levels during monitoring periods, 1962 to 1974, were in the range 0.002 to 1.4 Bq/m^3. Levels remained below the limit of detection after 1974, until a high-volume air sampler was installed at Rarotonga in 1986 after which the annual average level was recorded as 0.07 mBq/m^3.

Strontium-89,90 deposition was monitored at Suva (Fiji) and Rarotonga. Maximum ^{90}Sr deposition was recorded in 1963 and 1964 at 91 Bq/m^2, while cumulative deposition peaked in 1972 at 700 Bq/m^2.

Iodine-131 in cows' milk was monitored at Fiji and Samoa between 1966 and 1974 with levels recorded in the range 0.1 to 4 Bq/l.

Environmental gamma radiation levels were monitored during test periods at Penrhyn, Aitutaki, Rarotonga, Samoa, Niue and Tonga, with early measurements at Manihiki, Pukapuka, Nukunonu, and Faleolo (Samoa), and Sataua (Samoa). Levels never exceeded minimum reporting levels.

The average effective dose commitment for the South Pacific island population due to the entire history of atmospheric weapons tests is estimated to be 1.1 millisievert.

INTRODUCTION

Nuclear weapons were tested with detonations in the atmosphere during the period 1945 to 1980, resulting in the deposition of radioactive products of nuclear fission and neutron activation over the earth's surface, as fallout.

In 1957 the New Zealand government gave its Department of Health the responsibility for monitoring environmental radioactivity levels in New Zealand and Fiji. This monitoring was undertaken by the National Radiation Laboratory (NRL, then known as the Dominion X-Ray and Radium Laboratory, DXRL). Programme design commenced in 1958; limited monitoring began in 1959; and a full programme commenced in 1960.

In March 1962 the New Zealand government announced further that, in view of the forthcoming US tests at Christmas Island, NRL would set up an independent monitoring network covering the New Zealand Pacific territories and Western Samoa. This involved an extensive series of measurements of radioactivity in various environmental media during 1962 and early 1963, and less intensive monitoring during 1963 - 1965.

When the French government announced that atmospheric weapons tests were to be conducted in the Tuamotu Archipelago at Mururoa and Fangataufa, commencing in 1966, NRL again undertook extensive environmental monitoring operations throughout the South Pacific islands. This monitoring commenced with the first French tests of 1966, and continued through to 1985, though atmospheric tests were terminated in 1974. In 1985 the programme was reduced to a "baseline" level to maintain observations of radioactivity in the South Pacific environment, and to provide early warning and measurement of any influx of radioactive pollution into the South Pacific region, from any source.

These Pacific monitoring operations, during the period 1960 to 1990, are reviewed in this report which brings together and summarises the extensive compilation of data comprising 70 NRL reports published during the period. These reports were often repetitious and readers unfamiliar with the subject may have experienced considerable difficulty in sifting data from them, particularly with the early reports in the series. This review is intended to make the data collected over three decades more accessible to other researchers.

It is emphasised that this report is primarily a compilation and summary of data. Dosimetric aspects are discussed briefly in the final chapter but are not dealt with exhaustively.

Limitations of this report

The Pacific island nuclear weapon test fallout monitoring operation was remotely conducted, with samples returned to the New Zealand based laboratory for analysis. Significant delays were incurred during transport of the samples. As many fission products are short-lived, these delays made interpretation of the results difficult. In reporting monitoring results, NRL adopted the practice of reporting radioactivity levels *as at time of measurement.* The real issue which needed addressing, however, was what the levels had been *at the time of sample collection.* Techniques are available for determining the age of weapon test debris and the laboratory used these wherever it was possible to do so with scientific accuracy - in practice, this was not often. Unless the reader is particularly aware of the important distinction between results pertaining to *time of measurement* and *time of collection*, the NRL reports can present a slightly distorted picture of the level of fallout deposited in the Pacific islands, particularly during the French test programme when pronounced transient changes in radioactivity levels were common due to the proximity of the tests.

This report is a retrospective attempt to address this deficiency by re-analysing all fallout monitoring data collected during the French atmospheric testing programme at Mururoa and correcting data for radioactive decay, back to the time of sample collection. The decay correction procedure is described in full below. It was impossible to do this with a scientifically satisfactory degree of accuracy and the author has had to resort to rather subjective assessments in the

formulation of scenarios in which debris were attributed to particular tests. However, the report at least represents an "educated assessment" of the fallout impact in the Pacific islands.

The fact that subjective processes were used in the decay corrections places a severe limitation on the interpretation of the report - it cannot be claimed to be accurate, but rather a step towards a better understanding.

All data, corrected and uncorrected, have been included in Appendix 1 to allow other workers to make their own alternative assessments if necessary.

Report format

This review is mainly concerned with the results of monitoring conducted during the French tests at Mururoa which were the most significant and local source of short-lived fallout in the region's history. Monitoring operations are summarised for each of 4 periods: 1961 - 1965, 1966 - 1974 (the French test period), 1975 - 1985, and 1986 and beyond. The review of each of these periods includes a listing of the original NRL reports from which data were obtained, a description of the monitoring programme pertaining to that period, and a summary of the radioactivity measurements. During the 1966 - 1974 period results for each year are treated separately.

The important features of each data section of the report are the summaries of fallout deposition and atmospheric levels, as derived from original NRL data with decay corrections where appropriate. Graphs of levels versus time have been included to illustrate their variability and the relationship between fallout "incidents" and tests. Brief general comments are included in the text in order to amplify data in the graphs and tables. Radiological assessments in a later chapter are based on the summary tables only.

The unit of radioactivity used throughout the report is the becquerel, Bq: 1 Bq = 1 decay event per second. Atmospheric total beta activity (TBA) concentrations are in becquerels or millibecquerels (mBq) per cubic metre; deposition data are in becquerels or kilobecquerels (kBq) per square metre.

WEAPONS TESTS AND FALLOUT

There were three distinct periods of atmospheric weapons tests: an "early" period, 1945 - 1958, of tests by the US, USSR and UK, culminating in the 1958 Moratorium on testing; a "peak" period, 1961 - 1962, including high-yield "hydrogen bomb" tests by the US and USSR, and culminating in the Limited Test Ban Treaty of 1963; and a "late" period, 1964 - 1980, including tests by China and France.

The number of atmospheric tests conducted each year, their combined fission yields, and nationality, are illustrated in Figs 1 and 2. The US and USSR were, of course, the main contributors to the test numbers. The period of maximum yield was 1962 (Fig 2), with most attributable to USSR tests.

Fallout health significance

Fallout radionuclides, comprising fission and neutron activation products, included many with short half-lives, of hours, days or weeks. Although these soon decayed away to non-detectable levels, they caused transient increases in environmental radioactivity as contaminated air masses passed overhead or as material was deposited on the ground. The total beta activity in air and rainwater gave a measure of the effect of these materials.

Some radionuclides associated with weapon debris persisted in the environment - strontium-90 and caesium-137, for example, are still detectable in environmental samples, albeit at extremely low levels.

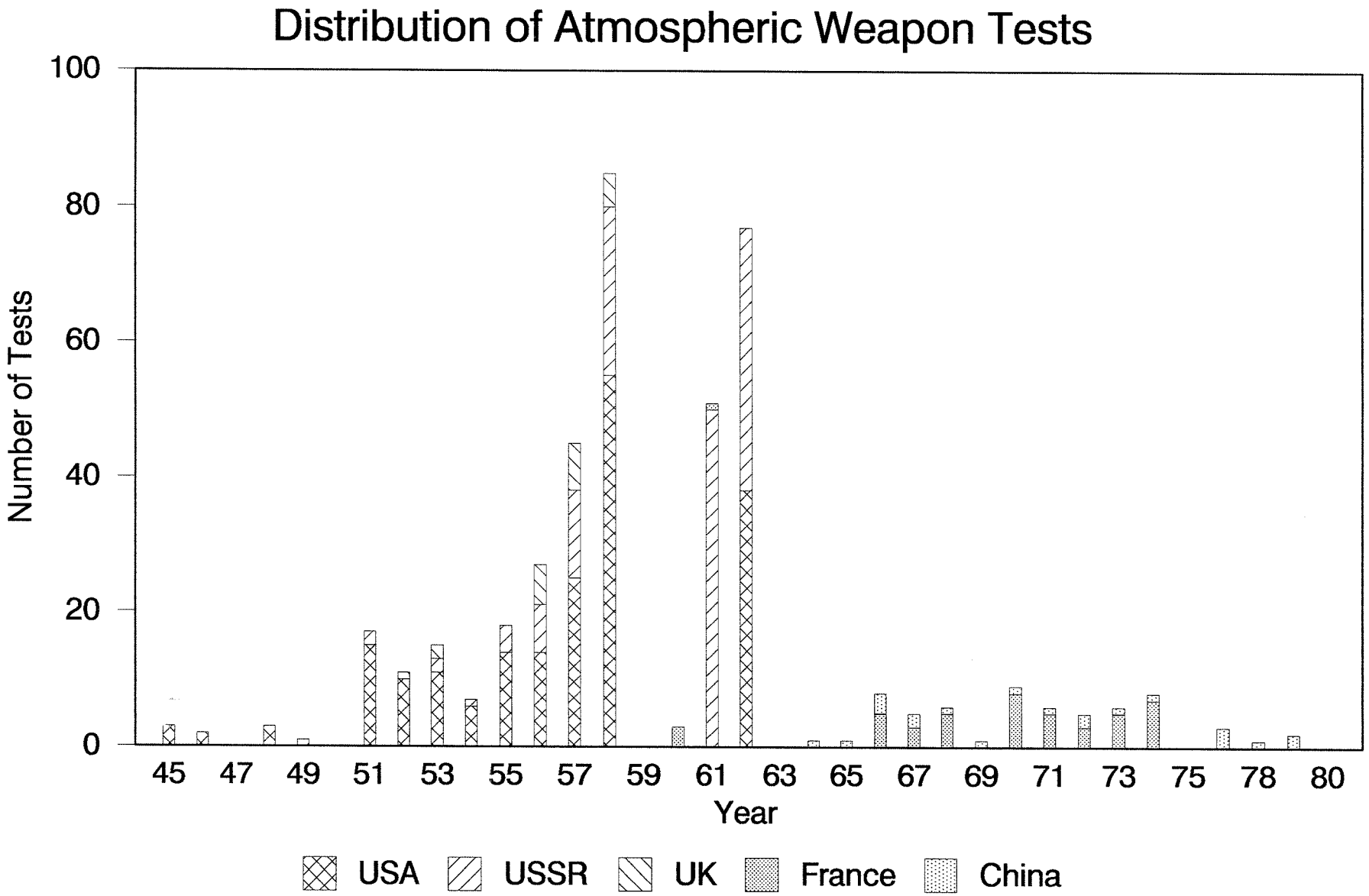


Fig 1. The distribution of atmospheric nuclear weapon tests according to year of detonation and country of origin.

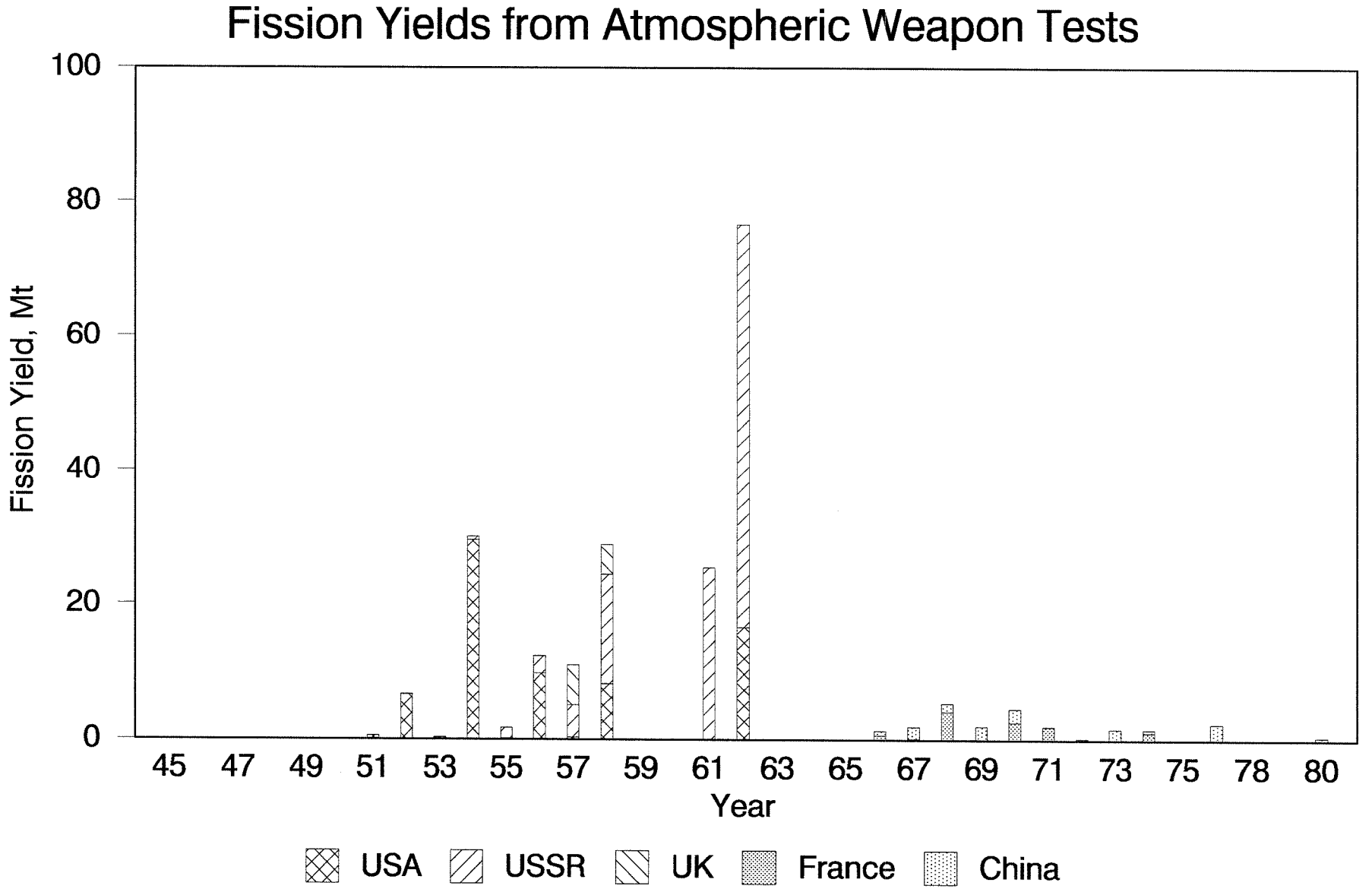


Fig 2. The distribution of total fission yield (megatonne TNT equivalent) according to year and country of origin.

For a radionuclide to be considered a potential hazard to human health, it had to satisfy the following criteria:

1. High yield: be produced in high yield and therefore be present in the environment in easily detectable amounts.

2. Long half-life: have a half-life long enough to allow entry into the foodchain and human metabolic processes, yet not so long that few atoms would decay in a human life time.

3. Easily metabolised: enter the human body easily through foodchains or inhalation.

4. Retained in the body: be readily absorbed by, and retained in, the human body, usually in a particular organ.

Radionuclides which satisfied these criteria became the focus of attention in fallout monitoring operations, worldwide. There were principally three: Iodine-131 which, although not particularly long-lived (half-life 8 days) is readily assimilated by the body and concentrated in the thyroid gland; strontium-90 which is long-lived (half-life 28.5y) and chemically similar to calcium and therefore retained in bones; caesium-137, also long-lived (half-life 30y) and, being chemically similar to potassium, is deposited in muscle tissue (although its major dose contribution is due to external irradiation).

Fallout monitoring operations therefore generally involved measurement of concentrations of some or all of these radionuclides in rainwater (as the route of entry to foodchains) and in foodstuffs, particularly cows' milk. In addition, the total beta activities of the atmosphere and rainwater were monitored to provide information on trends in levels and as screening tests of the degree of environmental contamination at any time. Environmental gamma radiation levels, due to material deposited in the ground, were also monitored as a check on external radiation exposure.

Fallout mechanism

The distribution of bomb debris in the environment, from detonations in the atmosphere, depends primarily on the yield of the detonation and meteorological conditions.

Low-yield detonations (up to a few hundred kilotonne TNT equivalent), conducted at ground level or within the troposphere (the lower 12 km of atmosphere), injected almost all of their debris into the troposphere. It was then deposited as either ***local fallout***, comprising larger particles carried by prevailing winds and deposited in 1 or 2 days within a zone extending several hundred kilometres downwind from the detonation site; or ***tropospheric fallout***, comprising smaller particles which remained aloft long enough to be transported around the globe by prevailing high-altitude winds, often circling the globe several times before dispersing, and being deposited in a band around the earth about the latitude of the detonation.

Atmospheric circulatory patterns are such that there is limited interchange of tropospheric air between the Northern and Southern Hemispheres. Low yield tests conducted in either hemisphere therefore deposited relatively little fallout in the opposite hemisphere. Debris from detonations at Christmas Island, very near the Equator, were detected promptly in the South Pacific, but tests further north (eg, USSR) had much less impact in the Southern Hemisphere.

In the case of French tests at Mururoa debris were generally carried high enough with the fireball to enter the high altitude westerly winds, and were carried eastward. In such cases debris were detected at the central South Pacific islands about 2 weeks after detonation, and often again after a further two weeks (after another passage around the globe). There were many instances, however, when debris were transported westward, directly over the central South Pacific - test C, 1966, was a dramatic example. This presumably occurred when debris were caught by the prevailing surface easterly winds, resulting in local fallout over many Pacific islands.

High-yield detonations (more than 1 megatonne TNT equivalent) produced a fireball containing so much energy that debris were carried to much greater heights, injecting most into the stratosphere. The residence time of aerosol particles in the stratosphere is up to about 2 years during which weapons debris were dispersed around the globe. The ***stratospheric fallout*** from these tests was thus deposited slowly over a period of months to years after detonation, with more being deposited in mid-latitude areas (including New Zealand) than in equatorial or polar regions.

There was, of course, much overlap between the above simplified descriptions and both tropospheric and stratospheric fallout would be expected from any nuclear detonation in the atmosphere, with the relative amounts of each depending on the energy yield of the detonation.

In 1966 a New Zealand government report gave an interesting background to the understanding of fallout at the time, meteorological factors, the expected effects of French testing, and the design of the monitoring network. Because of its usefulness as background material, the report has been reproduced in Appendix 2.

DECAY CORRECTION

The NRL monitoring programme was dependent on samples being transported to the laboratory in Christchurch, New Zealand, for analysis. Unfortunately, air services to many of the island monitoring sites were infrequent or irregular, particularly during the 1960s. This difficulty was partly overcome by the use of special Royal New Zealand Air Force flights but, even so, delays between sample collection and measurement were often significant - up to 2 months or more on occasions.

This delay caused a major difficulty with the total beta activity (TBA) measurements where short-lived materials were often major contributors.

The NRL reports acknowledged this problem and clearly stated that results were reported on an ***at time of measurement*** basis. When air filter or rainwater TBA levels were attributable to a particular detonation decay corrections were made, but this was only done in the early (1962) monitoring programme and during the 1973 and 1974 periods of the French testing programme.

The error introduced by a long delay between collection and measurement was significant and an attempt has been made in this review to correct TBA measurements for decay wherever possible, during the French testing period. Unavoidably, this was often done on a subjective basis. The method used to make these corrections is described here in full. All data for deposited and atmospheric TBA are given in the Appendix so other researchers can reassess results if more accurate methods are devised.

The purpose of this exercise was to at least partially overcome the inadequacy of the NRL data in portraying the actual situation which existed at the time of sample collection.

Decay correction method

The problem of decay correction involved 2 factors: firstly, determining which periods of elevated TBA deposition could be attributed to particular detonations, and which detonations were relevant; and secondly, correcting TBA levels for decay once detonation assignments had been made.

Recognition and assignment of TBA "peaks": Periods of elevated TBA deposition were not necessarily due to recent tests, but may simply have been deposition of global (and regional) fallout during periods of heavy rainfall. The ***concentration*** of TBA in rainwater was considered a better indicator of whether or not fresh debris were present. Periods when TBA concentration was "unusually" high were considered as periods when fresh debris were present.

Whether or not the concentration was unusually high was determined using a successive averaging approach, as follows:

1. TBA concentration for each weekly sampling period was calculated, ignoring weeks where the rainfall was less than 5 mm (because anomalous concentration data may result with very low rainfall).

Concentration (Bq/l) = Deposition (Bq/m^2)/Rainfall (mm)

2. Any concentration greater than 100 Bq/l was listed as "high" and withdrawn from the data set. The remaining data were averaged and the standard deviation (sd) of the data calculated.

3. Any concentration greater than the mean + 1 sd was considered high and withdrawn.

4. The mean and sd were recalculated.

5. Any concentration greater than the mean + 1 sd was considered high and withdrawn.

6. The 3 sets of withdrawn data were then combined and assumed to represent periods in which fresh debris, attributable to a particular test, were present.

Comparison of results of this procedure with original NRL data in cases where TBA peaks had already been attributed to particular tests, indicated excellent agreement between the two sets of peak identifications.

Assigning the TBA "peaks" to particular tests was done largely subjectively. If the period of elevated TBA was short-lived, this was taken to mean the parent test was fairly recent - ie, the contaminated air mass was still relatively intact and the debris had not spread over a wide area. Elevated TBA spread over more than one week, on the other hand, could have meant a more distant test. So the assessment was made subjectively depending on likely positioning of peaks and tests. Assignments to tests given in the original NRL reports were used whenever available.

TBA levels not considered high were assumed to be due to longer lived debris and were not corrected for decay because a large fraction of the short-lived material would have decayed before sample collection.

Decay correction: Once a source test had been identified, the activity at collection was estimated as follows.

The sum of all exponential decays in mixtures of fission products (as found on air filters or in rain samples) approximates the Way-Wigner $T^{-1.2}$ power law[1], where T is the time after production (detonation). The activities of such a mixture, A_1 and A_2, after times T_1 and T_2 respectively, are related as follows:

$$A_1 / A_2 = (T_1 / T_2)^{-1.2}$$

This equation was applied in the model below with definitions:

A_1 = activity at mid-collection
A_2 = activity at measurement
T_1 = time between detonation and mid-collection
T_2 = time between detonation and measurement.

For example, if a rainwater sample had a mid-collection date 10 days after the test to which it was ascribed, but was not analysed for another 10 days, the activity at time of measurement would have been lower than that at collection by a factor of 2.3.

Decay corrections to TBA levels were often significant. The test C event of 1966, for example, resulted in TBA deposition in Samoa of 66.6 kBq/m^2, at time of measurement, as reported in NRL report F-21. Correction for decay as above gave a deposition, at time of collection, of over 256 kBq/m^2.

ALL TBA DATA PRESENTED IN THIS REPORT, FOR THE PERIOD 1966 - 1971, HAVE BEEN ANALYSED BY THE ABOVE PROCESS, AND ARE CONSIDERED TO APPROXIMATELY REPRESENT THE SITUATION AS AT TIME OF SAMPLE COLLECTION. DATA FOR 1973 AND 1974 WERE CORRECTED FOR DECAY IN THE ORIGINAL NRL REPORTS.

Apart from the obvious subjective component, there are other sources of error in the above method. The use of the mid-collection time for a one week rainwater collection, for example, would cause an error if the radioactive material was deposited at the beginning or end of the week. The sampling programme design, however, makes this error unavoidable.

In spite of the difficulties, the depositions estimated in this review are likely to portray the situation at mid-collection more realistically than the original NRL reports where corrections were not made.

With air filters, the time delay problem was significantly reduced because filters were changed daily, rather than weekly, and able to be returned to the laboratory rapidly by airmail. Any sharp peak in atmospheric TBA levels was attributed to a recent test as described above, and corrected accordingly. Elsewhere the data were corrected by an average factor of 1.2, as derived empirically in the NRL reports[2].

REFERENCE LEVELS

The main purpose of the NRL environmental monitoring programme was to safeguard the health of the population of the Pacific region. This was to be achieved through the institution of exposure control methods if environmental radioactivity reached unacceptable levels. The definition of levels which would be unacceptable was a difficult task, yet it is not possible to make judgements on the relative significance of monitoring results if there is no baseline or *reference level* to compare them with.

In 1959 the International Commission on Radiological Protection (ICRP) published a report on permissible doses for internal radiation[3], applicable to workers occupationally exposed to radiation. The ICRP also recommended that doses to the public should be 1/30th of occupational exposure. These recommendations, together with those of the British Medical Research Council[4], became the basis of the NRL reference levels.

These reference levels were intended as levels above which more intense monitoring would be undertaken and possible counter-measures prepared. They were not "hazardous" levels but simply points of reference for use in planning - they were well below levels considered, by the most authoritative scientific opinion available at the time, to be of any health significance.

The monitoring programme of the 1960 - 1966 period was slightly different to that used during the French tests and, because different techniques were used and early recommendations modified, reference levels changed too. Those applied in the two periods are discussed separately below.

Early monitoring period[5]

External radiation: The ICRP recommended 100 millisievert (mSv) as the maximum permissible genetic dose to the whole population, from conception to age 30, due to all man-made radiation sources, with up to 50 mSv being allowed for non-medical exposure. It was therefore proposed that action should be taken at external radiation levels giving a dose, integrated to infinite time, of 25 mSv separately for either external radiation or for the effects of radionuclides deposited in the body. Action levels were defined in three levels: **Level 1**: causing an integrated dose in 30y of 25 mSv for fission products older than 15d, or to an integrated dose of 10 mSv in 3 months for fission products younger than 15d. This level was regarded as a warning level requiring more frequent monitoring if exceeded. **Level 2**: giving an accumulated dose in 3 months of 25 mSv. This level would require immediate action in the form of intensive monitoring and the preparation of counter-measures. **Level 3**: giving an accumulated dose in two weeks of 25 mSv. At this level counter-measures would begin.

Food and water contamination: Maximum permissible levels for occupational radiation exposure proposed by Summers and Gaske[6] were used as the basis for defining permissible contamination levels. This work was based was on the criterion that contamination levels persisting for a 40h working week should not lead to a genetic dose of greater than 1 mSv. The ICRP[3] recommendation that public exposure should be limited to 1/30th that of workers occupationally exposed to radiation was added, and a 3 tier system of levels A, B and C (requiring action as above) for short exposures (3 months) and a maximum permissible level for continuous exposure, were defined. These levels varied with fission product age as described below:

Action levels for food and water contamination: TBA (Bq/g)

Initial age	Short exposure A	B	C	Continuous exposure
12h	555	2220	2220	2.0
1d	296	1110	1110	1.9
5d	74	333	740	1.7
10d	55	185	740	1.7
30d	18	74	555	1.5

Air contamination: It was reasoned that any external exposure due to contaminated air would be transitory only, and the maximum permissible level was set at 25 times the maximum level for ***continuous*** occupational exposure, as follows:

Maximum total gamma activity in air, Bq/m^3

Initial age	Transient	Continuous exposure
12h	400 000	185
1d	300 000	166
5d	137 000	111
10d	89 000	74
30d	44 000	37

French test monitoring

The reference levels described above, as adopted during the early 1960s were refined when the French testing programme commenced. The monitoring programme then involved the measurement of concentrations of ^{131}I in milk, ^{90}Sr in rain and TBA in rain and air. Environmental gamma measurements were also continued. Iodine-131, ^{90}Sr and ^{137}Cs were

monitored in milk in New Zealand. Reference levels for concentrations of these particular radionuclides and for TBA had to be established. Although ^{137}Cs and ^{90}Sr were not monitored in milk in the Pacific islands, the derivation of the relevant reference levels is described here because the rationale involved was similar to that used in other derivations.

The ICRP[7] defined "dose limits" with the philosophy that risks associated with radiation, for workers occupationally exposed to radiation, should not be greater than any other risks associated with the occupation. Dose limits for the public were to be 1/10 of those for radiation workers.

The NRL reference levels were calculated to be *no greater than one third of the concentration which, if sustained indefinitely, would lead to exposure at the level of an ICRP "public" dose limit.* This incorporated the factor of 1/30th originally suggested by the ICRP, making allowance for the risk to children.

Strontium-90: The ICRP maximum body burden for workers was 74 kBq; the human skeleton contains about 1 kg calcium; maximum permissible concentration in bone was therefore 74 Bq/g Ca; the observed ratio of diet-concentration:bone-concentration is 4; so the maximum concentration in milk would be 296 Bq/g Ca (for radiation workers); public limits were 1/30th of this, so the final reference level would be **10 Bq/g Ca**. The basing of the reference level on the amount of calcium in the sample recognised the fact that strontium and calcium are chemically similar and that their ratio in the body could not exceed that in diet.

Caesium-137: The ^{137}Cs reference level was based on ICRP recommendations for intake by workers. It was assumed that one third of the daily intake of ^{137}Cs came from milk, and that the daily average consumption was 0.5 litres. The ICRP[3] maximum permissible level for drinking water for radiation workers (168h week) was 7400 Bq/litre, with a maximum daily intake of 2.2 litres, or 16280 Bq; dividing this by 30 gave a daily intake of 543 Bq; assuming one third of the daily intake is from milk implies a maximum intake, from milk, of 180 Bq; average consumption assumed to be 0.5 litre/day, and the potassium content of milk assumed to be 1.4 g/l, so the maximum permissible concentration was **260 Bq/g potassium.** The reference level was thus linked to the amount of potassium (chemically similar to caesium) in the diet, as described above for strontium and calcium.

Iodine-131: Initially the recommendation of the British Medical Research Council[4] was adopted as a maximum permissible level of 5 Bq/litre. This was later increased to 7.4 Bq/l (by rounding the initial units upwards).

Total beta activity: Reference levels for TBA in air and rain were derived taking account of published studies by Summers and Gaske[6] and Booth[8], pertaining to mixed fission products 10 to 80 days old. These publications suggested maximum permissible levels for occupational exposure[6] and public exposure[8]. To allow comparison of the two sets of data, the occupational limits were divided by 30 to convert to public limits, and again by 3 to convert to continuous exposure. Then the most pessimistic (lowest) result was chosen as a reference level, as follows:

TBA in air:	11 Bq/m^3
TBA in rain:	220 Bq/l

Environmental gamma radiation: A "reporting level" was defined as 3 μGy/h, which was considerably lower than the "action levels" described above for the early Pacific tests. This was basically a lower level of interest above which monitoring may have been intensified. In 1973 this was reduced to 0.5 μGy/h.

Summary

The following reference levels were applied during the French tests in the Pacific:

Medium	Radioactivity	Reference level
milk	strontium-90	10 Bq/g Ca
	caesium-137	260 Bq/g K
	iodine-131	7.4 Bq/l
air	TBA	11 Bq/m^3
rainwater	TBA	220 Bq/l
gamma radiation		3 μGy/h

These reference levels were based on the most authoritative information available at the time, and were deliberately conservative.

In the NRL annual reports monitoring results for each year were compared with these reference levels. If no reference level had been exceeded during the year it was stated that the reported levels **"do not constitute a public health hazard".**

PACIFIC ISLANDS MONITORING: 1961 - 1965

The first monitoring conducted in the Pacific islands was in the form of ^{90}Sr deposition measurements at Suva, Fiji, with quarterly sample collections, commencing in January 1961.

When the US testing programme at Christmas Island was announced for 1962 more extensive monitoring operations were undertaken.

Data references: DXRL F1 - F9; NRL F10 - F19.

Detailed information on the 1962 monitoring programme and the rationale behind it is given in report DXRL F5.

Monitoring sites

The monitoring programme was designed in consultation with Departments of Health, External Affairs, Scientific and Industrial Research, Island Territories, the RNZAF and New Zealand Meteorological Service. The 1962 programme included measurements of environmental radiation and radioactivity in samples as follows:

Monitoring:	Gamma	Rain	Tankwater	Food	Air
Penrhyn	•	•	•	•	•
Manihiki	•	•	•	•	
Pukapuka	•				
Nukunonu	•	•	•	•	
Funafuti		•			
Tarawa		•			
Samoa:Apia	•	•		•	•
Samoa:Faleolo	•				
Samoa:Sataua	•				
Niue	•	•			•
Rarotonga	•	•		•	•

The geographic location of all monitoring sites used in Pacific monitoring are shown in Fig 3.

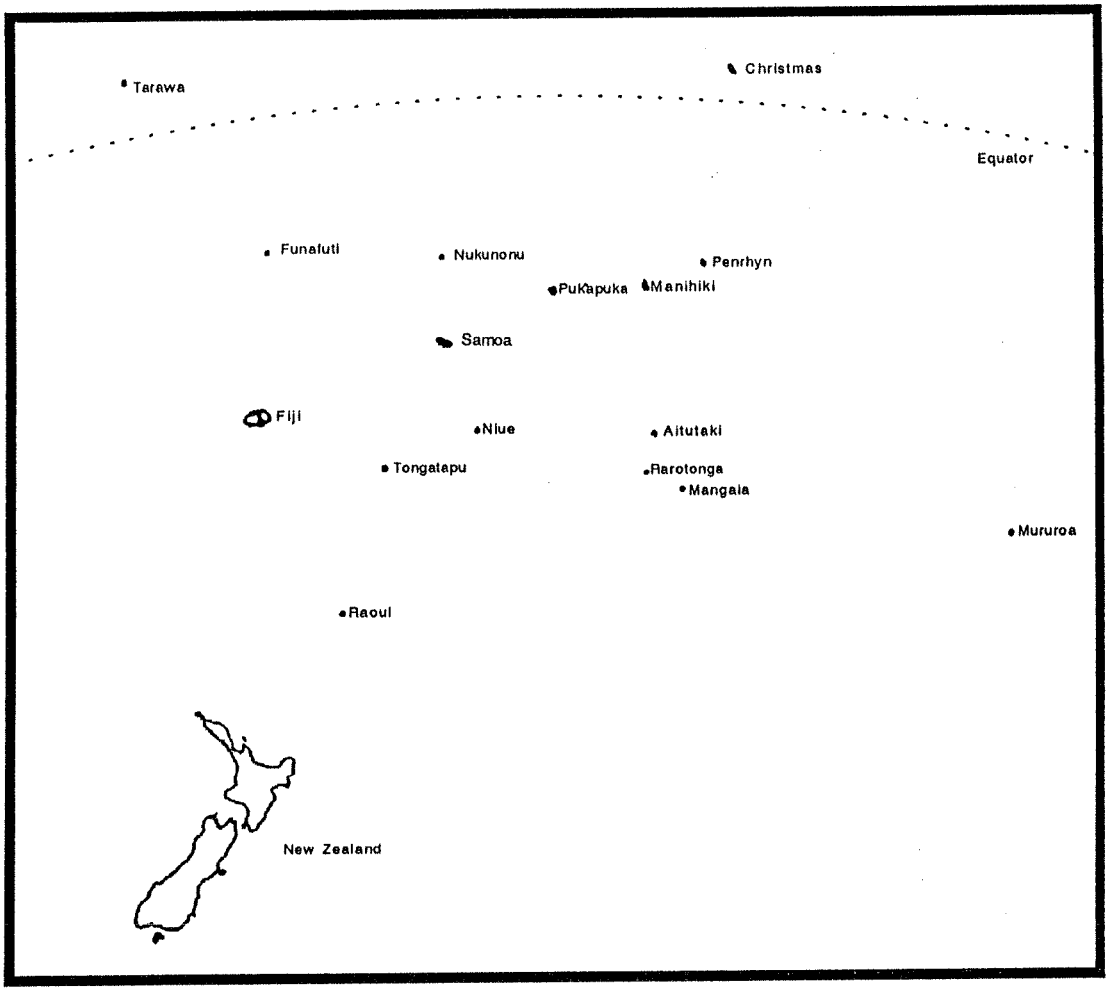


Fig 3. The location of all islands which at various times were involved in the National Radiation Laboratory environmental radioactivity monitoring programme. Christmas Island and Mururoa atoll are also shown.

MONITORING RESULTS: 1962

TBA rain

Rainwater samples were analysed usually 2 - 4 weeks after collection (occasionally up to 8 weeks). Total depositions for the monitored period (at time of measurement) were as follows:

Site	kBq/m^2	Period
Penrhyn	4.9	Apr-Jul
Manihiki	0.6	Apr-Jul
Nukunonu	0.8	Apr-Aug
Funafuti	3.3	Apr-Dec
Tarawa	3.0	Apr-Dec
Apia	6.4	Apr-Aug
Niue	1.6	Apr-Jul
Rarotonga	3.6	Apr-Dec

The 3 most radioactive deposition samples were as follows:

Samoa	week ending 20/5/62	0.004 Bq/m^2
Nukunonu	week ending 28/6/62	0.004 Bq/m^2
Penrhyn	week ending 23/5/62	0.003 Bq/m^2.

Drinking water

Rainwater tanks were sampled at Nukunonu, Manihiki and Penrhyn in June - August. TBA levels were in the range 2 Bq/l to 12 Bq/l.

Food

About 800 samples of land and sea foods, representative of typical island diets, were analysed for TBA (including natural nuclides). Two samples were collected per day, 1 land and 1 sea food, at Manihiki, Nukunonu, Penrhyn, Rarotonga, and Samoa.

The highest TBA level measured was 780 Bq/kg (Penrhyn, June 62, with measurement 6 weeks after collection). All TBA results included contributions from natural radionuclides.

Overall range:	7 - 780 Bq/kg
Average:	60 Bq/kg (standard deviation 28 Bq/kg).

Air

Total gamma activity maxima and averages during the above monitoring periods, estimated at time of collection, were as follows (for the purposes of this report "total gamma activity" can be assumed to be synonymous with "total beta activity"):

Site	maximum Bq/m^3	average Bq/m^3
Penrhyn	8.46*	5.61
Apia	0.56	0.03
Niue	0.93	0.03
Rarotonga	1.0	0.02

* debris reached Penrhyn within 3h of detonation, on 3 May 1962.

MONITORING RESULTS: 1963 - 1965

The intensive monitoring programme of 1962 was conducted only during the 1962 test series and was discontinued early in 1963, apart from some TBA deposition measurements in the first 3 months of that year.

Total depositions of TBA during the 3 months were:

Funafuti	90 Bq/m^2
Tarawa	70 Bq/m^2
Rarotonga	130 Bq/m^2
Apia	70 Bq/m^2

Some food samples from Rarotonga were also analysed for TBA during that period, with an overall average result of 27 Bq/kg.

Strontium deposition

The only continuous measurements conducted in the Pacific during the 1961 - 1965 period were the ^{90}Sr deposition measurements at Fiji. Limited ^{89}Sr measurements were performed as well. Total annual depositions are shown below.

	^{90}Sr Bq/m^2	^{89}Sr Bq/m^2
1961	31.5	
1962	60.3	2444
1963	90.7	104
1964	91.4	
1965	73.3	

Implications for future monitoring

A significant component of the fallout monitoring programme during this early testing period was the analysis of foodstuffs collected in the islands. Because all samples had to be returned to NRL for analysis, often with long delays in transit, the foodstuff monitoring proved to be very difficult in practice. All steps in the process - sample collection, preservation, transport, importation and analyses - proved difficult. Furthermore, the analytical results indicated that foodstuffs were not significantly contaminated.

Because of the practical difficulties and the fact that little information was gained from the analyses, it was decided that routine foodstuff monitoring would not be included in future monitoring operations unless reference levels in air and rainwater were exceeded. Subsequent monitoring therefore focused on measurement of contamination levels in the foodchain precursors of air and rainwater. The only foodstuff routinely monitored during later test series was dairy milk or milk powder.

PACIFIC ISLAND MONITORING OPERATIONS: 1966 - 1974

The environmental monitoring operation designed for the period of French testing commenced on 1 July 1966, as described below.

Total beta activity in the atmosphere

Total beta activity (TBA) in the atmosphere was monitored by drawing air (using *Edwards RB4* or *EB3* vacuum pumps) through 11 cm diameter glass fibre filters (*Whatman* GF/A), at a flow rate of approximately 4.2 m^3/h, with a total daily volume sampled of 100 m^3.

The filters were changed daily and returned to Christchurch for beta activity measurement using a *Beckman Wide Beta II* counting system with a 12.5 cm diameter gas-flow proportional counter and a 0.5 mg/cm^2 window. The background count rate was 14 cpm and the counting efficiency (based on ^{40}K) was 57%. The counting time was normally 20 minutes.

The monitoring sites and periods involved are indicated in the table below. The Samoa site was at Apia, and the Tonga site was Nuku'alofa, Tongatapu.

	Nandi	Suva	Samoa	Tonga	Rarotonga	Period
1966	•				•	Jul-Dec
1967	•	•	•			Jun-Sep
1968	•	•	•	•		Jul-Nov
1970	•	•	•	•		May-Oct
1971	•	•	•	•		Jun-Oct
1972	•	•	•	•		Jun-Sep
1973	•	•	•	•		Jul-Oct
1974	•	•	•	•	•	Jun-Oct

In this report the results for only one of the Fiji monitoring sites are reported - Nandi. Levels at Suva generally followed similar patterns to those at Nandi.

Total beta activity in rainwater

The total beta activity in rainwater was assessed by collecting weekly samples using a polythene funnel (9.9 cm diameter) and bottle. The collection bottle contained a small volume of mixed carrier solution containing milligram quantities of Sr, Ba, Cs, Zr, La and Y in dilute nitric acid.

At the end of each one week period, the bottle was returned to NRL where the water was evaporated to dryness on an 11 cm diameter stainless steel planchette. The beta activity of the residue was determined using a *Beckman Wide Beta II* counting system with a gas-flow proportional counter. The background count rate (with a clean planchette) was 6 cpm and the counting efficiency (based on ^{40}K) was 55%. A counting time of 20 minutes was normally used.

The monitoring sites involved are described in the table below. Monitoring periods were the same as those given above for atmospheric monitoring.

Site	1966	1967	1968	1970	1971	1972	1973	1974
Tarawa	•	•	•	•	•	•	•	•
Funafuti	•	•	•	•	•	•	•	•
Nandi	•	•	•	•	•	•	•	•
Suva	•	•	•	•	•	•	•	•
Samoa	•	•	•	•	•	•	•	•
Niue	•	•	•	•	•	•	•	•
Tonga	•	•	•	•	•	•	•	•
Aitutaki	•	•	•	•	•	•	•	•
Rarotonga	•	•	•	•	•	•	•	•
Mangaia	•							
Raoul	•							
Penrhyn	•	•						

In this report the TBA-rainwater results for Fiji are given for one site only - Suva - the site with the heaviest rainfall.

Strontium isotopes in rainwater

For $^{89,90}Sr$ deposition measurements, rainwater was collected for one month periods in a 30 cm diameter stainless steel pot. The pot contained a small volume of Sr carrier solution. At the end of the month the pot was returned to NRL for analysis by radiochemical methods published elsewhere[9].

This monitoring was conducted continuously at Suva and Rarotonga, commencing in 1961 and June 1966 respectively.

Iodine-131 in milk

Iodine-131 levels in cows' milk were assessed with weekly 1 litre samples collected in Suva and Apia (Samoa) and transported to NRL. Each sample was treated with 40 ml *Deacidite FFIP* anion exchange resin, and the resin analysed by gamma spectroscopy. These measurements were conducted during the monitoring periods given above for atmospheric TBA measurements.

Environmental gamma radiation

Environmental gamma radiation monitors (hand-held geiger counters) were deployed at Penrhyn, Aitutaki, Rarotonga, Samoa, Niue and Tonga during each year's monitoring period. During 1966 it was also conducted at Mangaia. The most sensitive range on the instruments was 0 - 5 μGy/h. Readings were taken 90 cm above ground level, several times a day.

Monitoring results

Monitoring results for each year of the 1966 to 1974 test series are described in the following chapters. Deposition data and atmospheric radioactivity data for each year are tabulated in Appendix 1, together with estimates of decay-corrected deposition based on subjective assignments to particular tests or the original NRL assignments (in 1966, 1973 and 1974). Tests each year are labelled alphabetically, in chronological order. In the deposition summary tables the total deposition attributed to each test at each monitoring site is tabulated (wherever such test attributions were made). Total depositions for the monitoring period (including deposition between ascribed peaks) are also given, together with average depositions attributed to particular tests. Atmospheric radioactivity is described in terms of average levels for the monitoring period and peak levels recorded.

MONITORING RESULTS: 1966

Test series

Five tests were conducted during 1966, as described below:

Test	Date	Yield(kt)
A	3/7	20 - 200
B	27/7	20 - 200
C	12/9	20 - 200
D	25/9	20 - 200
E	5/10	200 - 1000

Data References: NRL F 21, F 22, F 23.

TBA deposition

Total beta activity deposition profiles during the 1966 monitoring period are shown in Fig 4.

Debris attributed to tests C, D, E and, to a lesser extent, B, were evident at most sites, as shown in the summary table below, while test A debris were evident at Funafuti, Penrhyn and, in a smaller amount, at Suva.

Debris were detected at several sites in the first week after detonation (or early in the second week) indicating westward debris transport from Mururoa. This resulted in very heavy radioactive deposition at Samoa and Niue after test C as described below. Test A was also detected in the first week after detonation at Penrhyn.

Heaviest deposition attributable to any test was recorded at Samoa after test C: 256.2 kBq/m^2. Total deposition for the test series ranged from 3.7 kBq/m^2 at Raoul Island to 267.8 kBq/m^2 at Samoa. Average depositions from the five tests ranged from 0.7 kBq/m^2 (test B) to 38 kBq/m^2 (test C), with an overall average for the series of 40.7 kBq/m^2. Excluding the localised Samoa and Niue depositions, the average deposition from test C was 2.4 kBq/m^2 and the overall average 7.9 kBq/m^2. During 1966 Samoa received the heaviest deposition recorded to date in the South Pacific: 267.8 kBq/m^2.

Average concentrations during the series ranged from 4 Bq/l at Raoul Island to 69 Bq/l at Niue.

PACIFIC ISLANDS DEPOSITION 1966

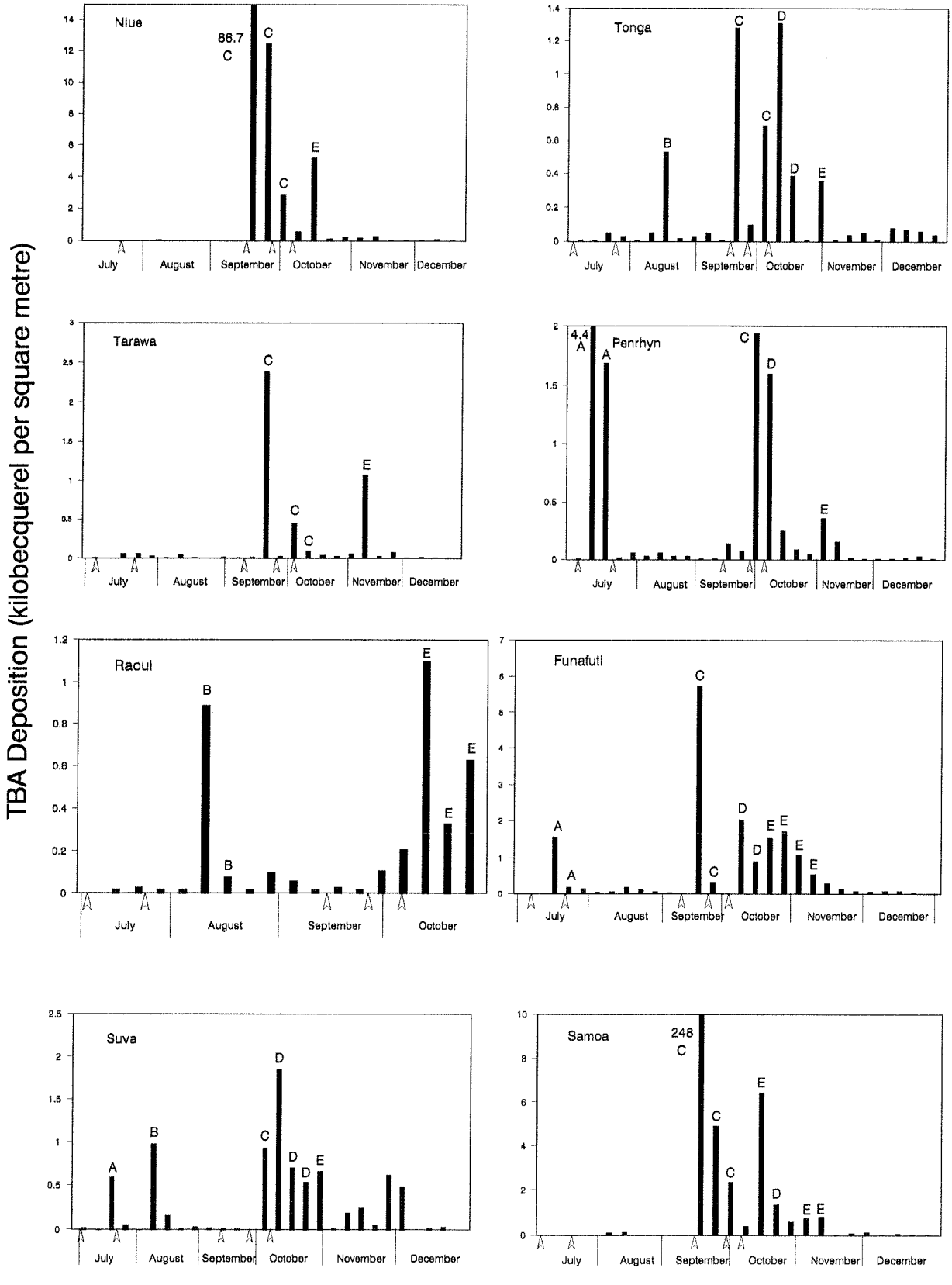


Fig 4. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1966 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - E. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

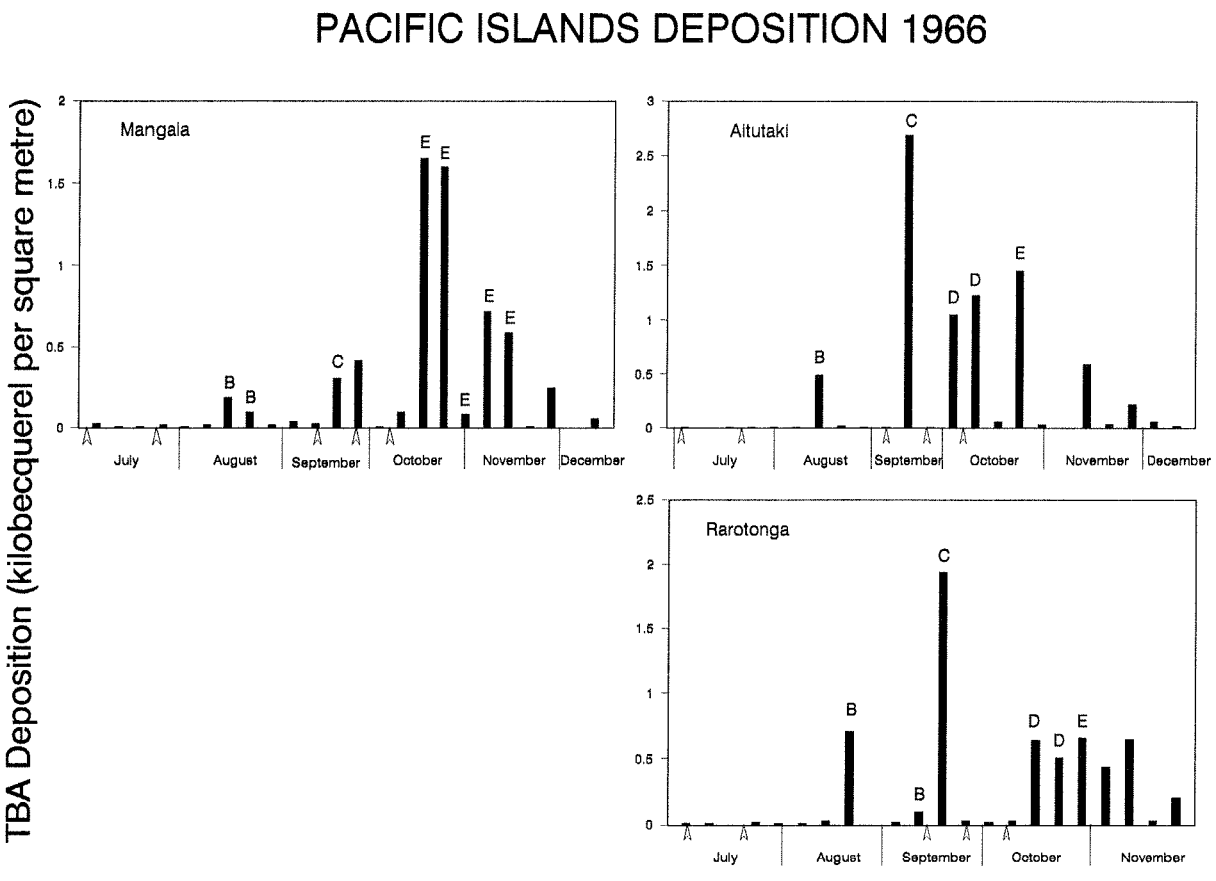


Fig 4. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1966 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - E. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were as follows (dates are mid-collection).

Site	Date	Test	Depn	Conc
Tarawa	21/9	C	2.4	16
Funafuti	21/9	C	5.8	19
Suva	11/10	D	1.9	39
Samoa	17/9	C	248.9	1039
Niue	17/9	C	86.7	1384
Tonga	11/10	D	1.3	11
Aitutaki	19/9	C	2.7	27
Rarotonga	18/9	C	1.9	5
Mangaia	17/1	E	1.6	15
Penrhyn	9/7	A	4.4	9
Raoul	13/8	E	1.1	7

Deposition summary: 1966

Depositions in kBq/m^2 from each of the tests, together with the totals and averages for the period are given below.

	A	B	C	D	E	Total
Tarawa			3.0		1.1	4.7
Funafuti	1.8		6.1	2.9	4.9	17.3
Suva	0.6	1.0	0.9	3.1	0.8	8.6
Samoa			256.2	1.4	8.2	267.8
Niue			102.0		5.5	109.1
Tonga		0.5	2.0	1.7	0.4	5.3
Raoul		1.0			2.1	3.7
Penrhyn	6.0		1.9	1.6	0.4	11.1
Aitutaki		0.5	2.7	2.3	1.5	8.0
Rarotonga		0.8	1.9	1.2	0.7	6.1
Mangaia		0.3	0.4		4.7	6.3
Average:	2.8	0.7	37.7	2.0	2.8	40.7

Atmospheric TBA

Trends in atmospheric TBA at Nandi and Rarotonga during the 1966 monitoring period are shown in Fig 5.

Peaks in activity levels were attributed to particular tests in the original NRL reports. Unfortunately, there were considerable delays between collection and analysis of Rarotonga filters, of 2 - 3 weeks, requiring large decay corrections (for example, the highest level after test E was reported as 0.67 Bq/m^3, and amended to 4.9 Bq/m^3 in the present study).

Debris from tests A, B, and D caused small peaks in TBA levels, of up to several hundred mBq/m^3, 2 to 3 weeks after detonation, consistent with eastward debris transport from Mururoa. Tests C and E, in contrast, caused significant elevations in TBA levels at Nandi and Rarotonga respectively, 4 - 5 days after detonation. There was an interesting disparity between atmospheric measurements and deposition results. Test C was detected in surface air at Nandi but not in rain at Suva during the same period, presumably due to low rainfall (1.8 mm during the week).

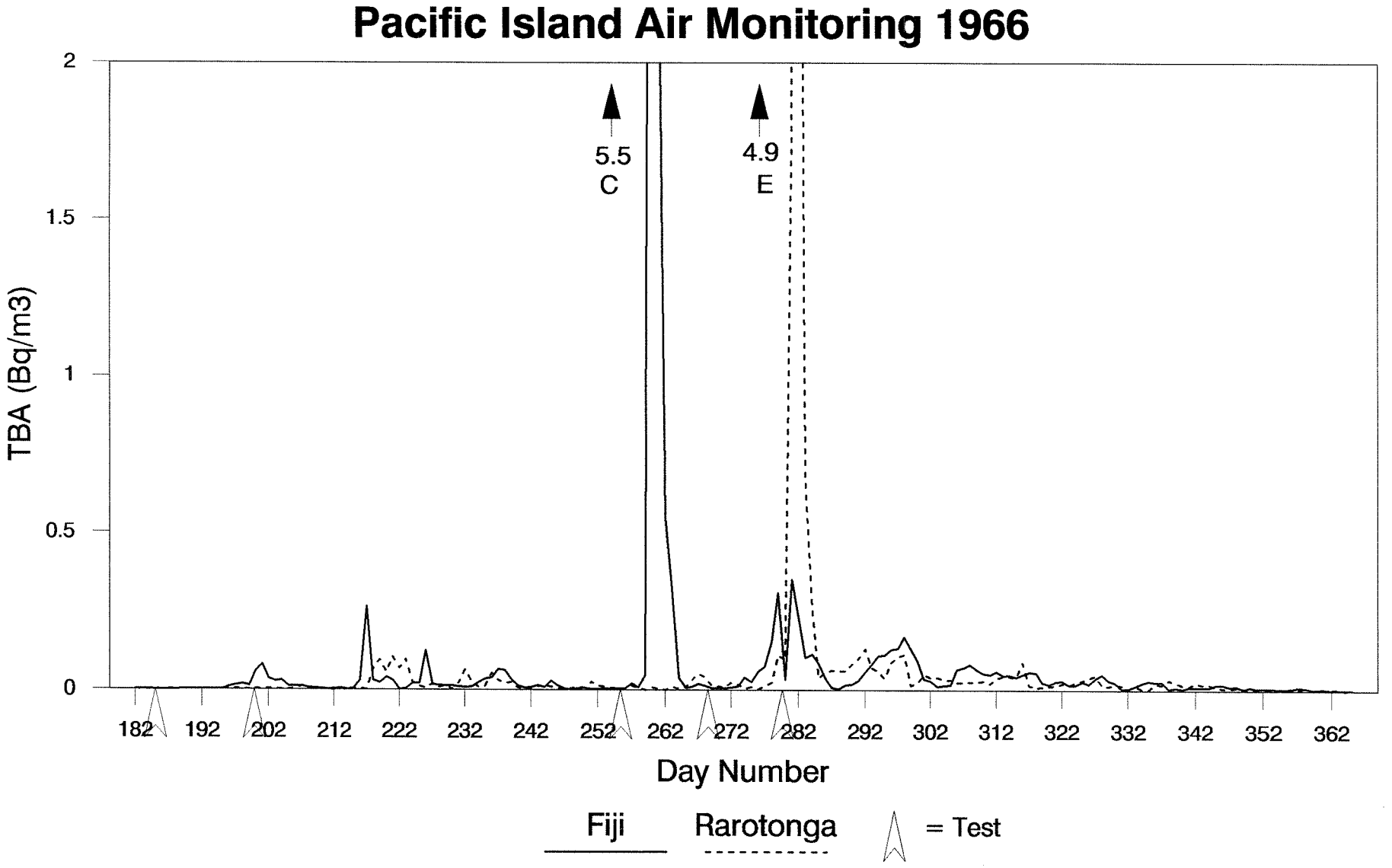


Fig. 5. Total beta activity in surface air, Bq/m^3, at Fiji and Rarotonga during the 1966 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - E. Peak TBA periods, attributed to tests C and E are identified and in those cases the graphed level has been corrected for decay between sample collection and measurement.

Test C was detected in rain at Rarotonga but not in surface air. This was presumably due to altitudinal factors with rainout at Rarotonga from high altitude air masses without detection in surface air, and with circulation into surface air by the time the air mass reached Fiji. Test E was detected promptly in air at Rarotonga but not in rain, presumably due to low rainfall (0.3 mm during the week). This incident highlights the need for both atmospheric and deposition monitoring in fallout studies.

Test E debris were detected at Rarotonga before test D debris - confirming their transport in opposite directions from Mururoa.

Gamma spectroscopic analysis of the September 17 Nandi (test C) filter revealed the presence of ^{239}Np, ^{147}Nd, ^{99}Mo, ^{99m}Te, ^{132}Te, ^{132}I, ^{131}I, ^{141}Ce, ^{141}Pr, ^{103}Ru, and ^{95}Zr.

Maximum and average TBA levels (Bq/m^3) during the monitoring period are given below:

Site	Maximum	Date	Average
Nandi	5.5	17/9	0.08
Rarotonga	4.9	9/10	0.06

Strontium-89,90 deposition

Monthly ^{90}Sr deposition at Suva and Rarotonga during the test series remained at levels similar to those measured before tests commenced.

Total ^{90}Sr depositions at Suva (whole year) and Rarotonga (July-December) were 44 and 16 Bq/m^2, with rainfalls of 2101 and 773 mm respectively. The maximum monthly deposition was 6.7 Bq/m^2.

Strontium-89 was detected in rainwater at Suva and Rarotonga every month, July to December, with average monthly depositions during that period of 117 and 44 Bq/m^2, respectively.

Iodine-131 in milk

Iodine-131 levels in milk averaged 6.6 Bq/l at Suva during October and 1.7 Bq/l in November. At Apia levels were slightly lower: 3.9 Bq/l in October and 1.1 Bq/l in November. Peak levels recorded were: Suva (8/10) 9.1 Bq/l; Apia (6/10) 7.0 Bq/l.

Environmental gamma radiation

Environmental gamma radiation levels did not approach the minimum reporting level of 3 μGy/h at any site during the test series.

The level generally averaged 0.2 μGy/h although at Samoa it peaked at 0.6 μGy/h on 15 September, during the test C deposition event, returning to 0.2 μGy/h by 30 September.

MONITORING RESULTS: 1967

Test series

Three tests were conducted during 1967, as described below:

Test	Date	Yield(kt)
A	6/6	1 - 20
B	28/6	20 - 200
C	3/7	20 - 200

Data references: NRL F 25, F 26, F 27, F 28.

TBA deposition

Total beta activity deposition profiles during the 1967 monitoring period are shown in Fig 6.

The close spacing of tests B and C prevented distinction between them on the basis of fallout deposition. Debris which could have come from either or both of these tests were attributed to test C in this report, as this gave the "worst case" scenario. Debris attributed to test C were therefore evident at most monitoring sites, as shown in the summary table below. Test A debris were evident at only Tarawa, Funafuti and Samoa, and its prompt appearance at Samoa suggests at least some of the debris were carried westward, as supported by atmospheric data below.

Elevated TBA levels were generally recorded at 2 or 3 week intervals after detonation, consistent with eastward debris transport. Exceptions to this were observed in the Cook Islands with peaks in deposition at Rarotonga in the first week after test C, and soon after at Aitutaki.

Aitutaki received the maximum deposition in any 1967 weekly sampling period - 25 kBq/m^2 - after tests B and C.

The heavy deposition at Rarotonga and Aitutaki would have been expected in a westward transport scenario. Debris deposited heavily at Funafuti in July could have originated in either test B or C, but the deposition would primarily have been an artifact of rainfall - Funafuti was experiencing consistently wet weather, averaging 68 mm per week during June and July.

Total depositions for the test series ranged from 1.0 kBq/m^2 at Niue to 31.3 kBq/m^2 at Funafuti. Average depositions from the tests ranged from 1.7 kBq/m^2 (test A) to 11.5 kBq/m^2 (test C scenario), with an overall average for the entire series of 12.6 kBq/m^2.

Average concentrations during the monitoring period ranged from 4 Bq/l at Niue to 39 Bq/l at Tarawa.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were:

Site	Date	Test	Depn	Conc
Tarawa	18/7	C	8.7	107
Funafuti	16/7	C	17.3	134
Suva	23/7	C	0.9	12
Samoa	11/7	C	2.9	24
Niue	31/7	C	0.2	5
Tonga	23/7	C	0.9	9
Aitutaki	12/7	C	24.6	245
Rarotonga	3/7	C	20.2	22

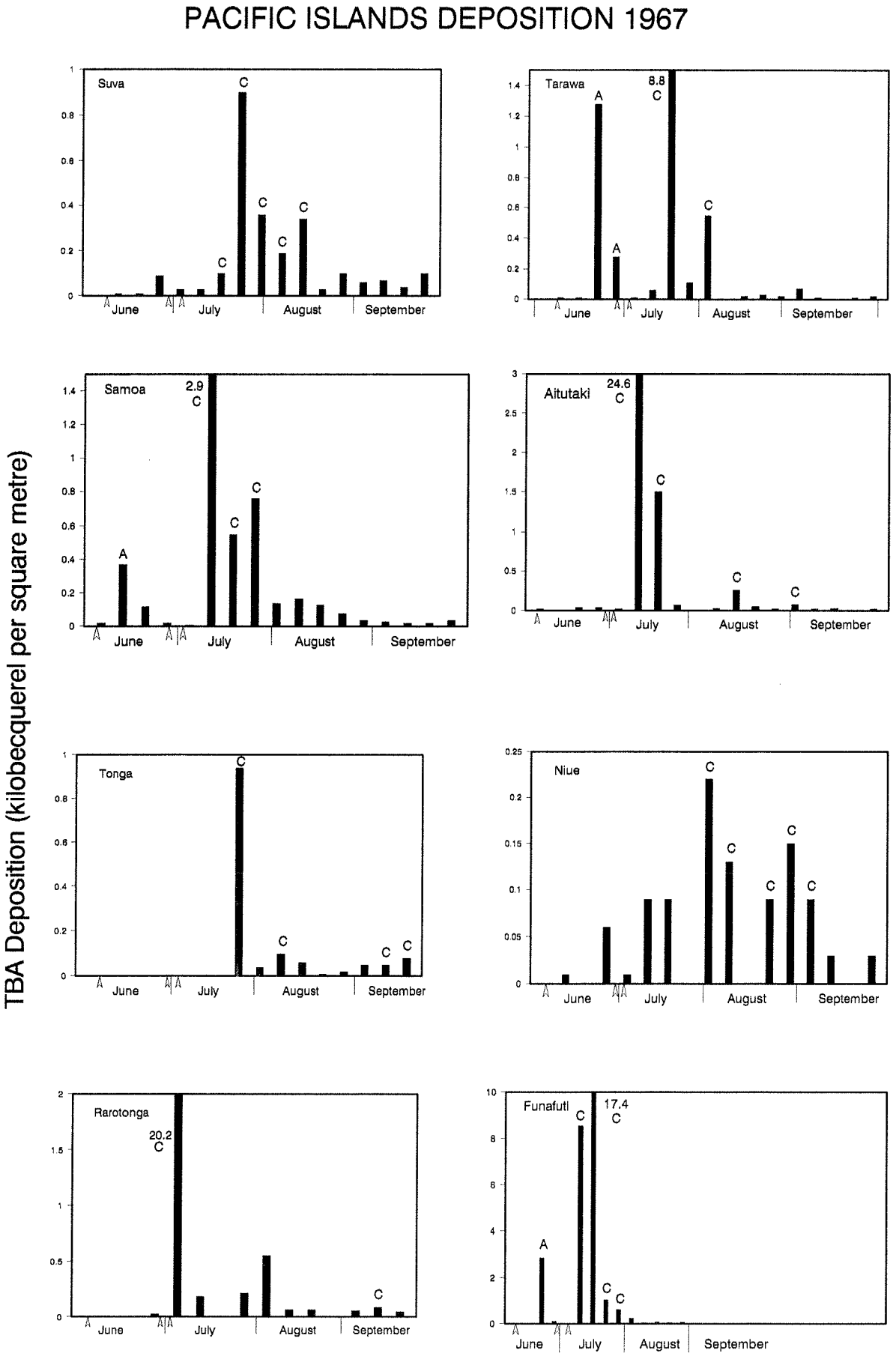


Fig 6. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1967 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - C. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1967

Deposition, kBq/m^2, attributed to each test, and totals and averages for the monitoring period, are given below.

	A	C	Total
Tarawa	1.56	9.30	11.2
Funafuti	2.87	27.60	31.3
Suva		1.89	2.5
Samoa	0.37	4.20	5.7
Niue		0.68	1.0
Tonga		1.04	1.3
Aitutaki		26.43	26.8
Rarotonga		20.5	21.6
Average:	1.6	11.5	12.6

Atmospheric TBA

Trends in atmospheric TBA levels during the 1967 monitoring period are shown in Fig 7.

There were clearly pronounced peaks on two occasions at Samoa and smaller peaks at Nandi. The data for these peak periods were corrected for decay in the present study by attributing them subjectively to tests A and C (although test B could have contributed in the latter case, as mentioned above).

The two Samoa peaks, of 12 June and 13 July, occurred 6 and 10 days after tests A and C respectively, suggesting westward debris transport from Mururoa, at least in the former case. The peaks occurring later in July at Nandi may have been due to continued westward transport or eastward transport of another component of the contaminated air mass.

Average and maximum (Bq/m^3) for the monitoring period are given for each site below:

Site	Maximum	Date	Average
Nandi	0.23	24/7	0.02
Samoa	1.61	13/7	0.06

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1967 were 29 and 23 Bq/m^2, with rainfalls of 2851 and 2490 mm respectively. The maximum deposition in any month was 4.8 Bq/m^2.

Strontium-89 was detected in rainwater at Suva every month, June to October, with an average monthly deposition during that period of 72 Bq/m^2. At Rarotonga ^{89}Sr was detected during June, July and September (no August sample obtained) with an average monthly deposition, in those months, of 254 Bq/m^2.

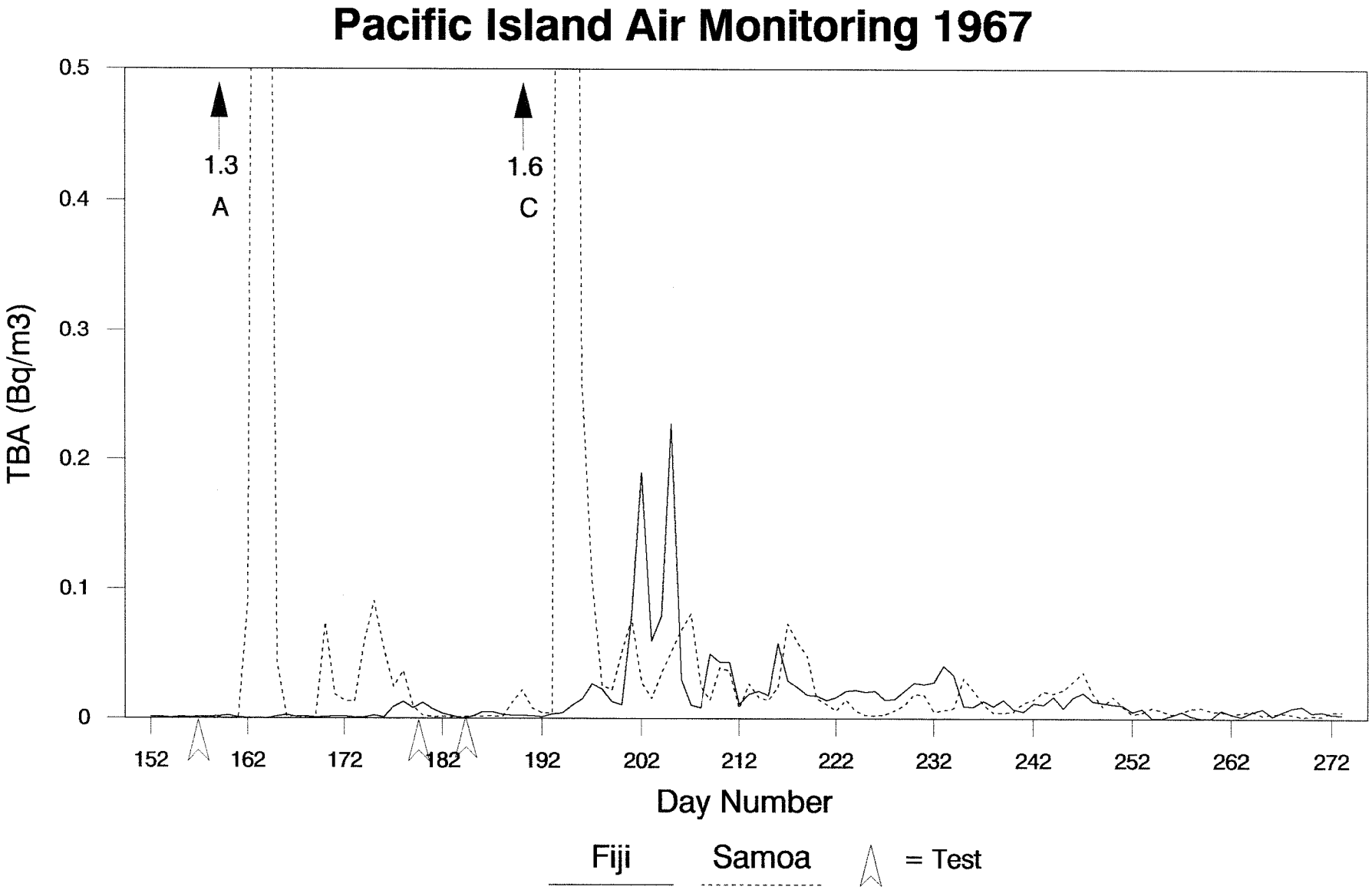


Fig 7. Total beta activity in surface air, Bq/m^3, at Fiji and Samoa during the 1967 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - C. Peak TBA periods, attributed to tests A and C, are identified and in those cases the graphed level has been corrected for decay between sample collection and measurement.

Iodine-131 in milk

Milk from Suva and Apia (Samoa) was contaminated less heavily with ^{131}I in 1967 than in 1966, averaging 0.9 Bq/l and 3.1 Bq/l respectively, with a maximum level in any one sample of 26 Bq/l (Samoa).

Environmental gamma radiation

Environmental gamma radiation levels did not exceed (or approach) the minimum reporting level of 3 μGy/h, at any site.

MONITORING RESULTS: 1968

Test series

Five tests were conducted during 1968, including two high yield ("hydrogen bomb") tests, as described below:

Test	Date	Yield(kt)
A	8/7	20 - 200
B	16/7	200 - 1000
C	4/8	20 - 200
D	25/8	>1000
E	9/9	>1000

Data references: NRL F 29, F 30, F 31, F 32, F 33.

TBA deposition

Deposition profiles for the 1968 monitoring period are shown in Fig 8.

Debris attributed to tests B, C, D and E were recorded at most sites. Generally, debris were evident no sooner than the second week after detonation, suggesting no westward transport occurred. An exception was the appearance of test B debris promptly at Rarotonga.

The averages of depositions attributed to each test ranged from 1.5 kBq/m^2 for test C to 4.3 kBq/m^2 for test B. Total depositions for the test period ranged from 1.9 kBq/m^2 at Tarawa to 24.8 kBq/m^2 at Rarotonga, with an overall average of 10.3 kBq/m^2. The heaviest deposition in any sampling period was at Rarotonga after test B: 18.5 kBq/m^2.

Average concentrations during the test series ranged from 4.2 Bq/l at Niue to 14 Bq/l at Suva.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were:

Site	Date	Test	Depn	Conc
Tarawa	7/8	B	0.3	14
Funafuti	30/8	D	5.1	17
Suva	29/7	B	1.0	19
Samoa	18/9	E	2.1	12
Niue	22/9	E	2.3	5
Tonga	12/8	C	2.8	23
Aitutaki	7/8	B	3.5	14
Rarotonga	17/7	B	18.5	15

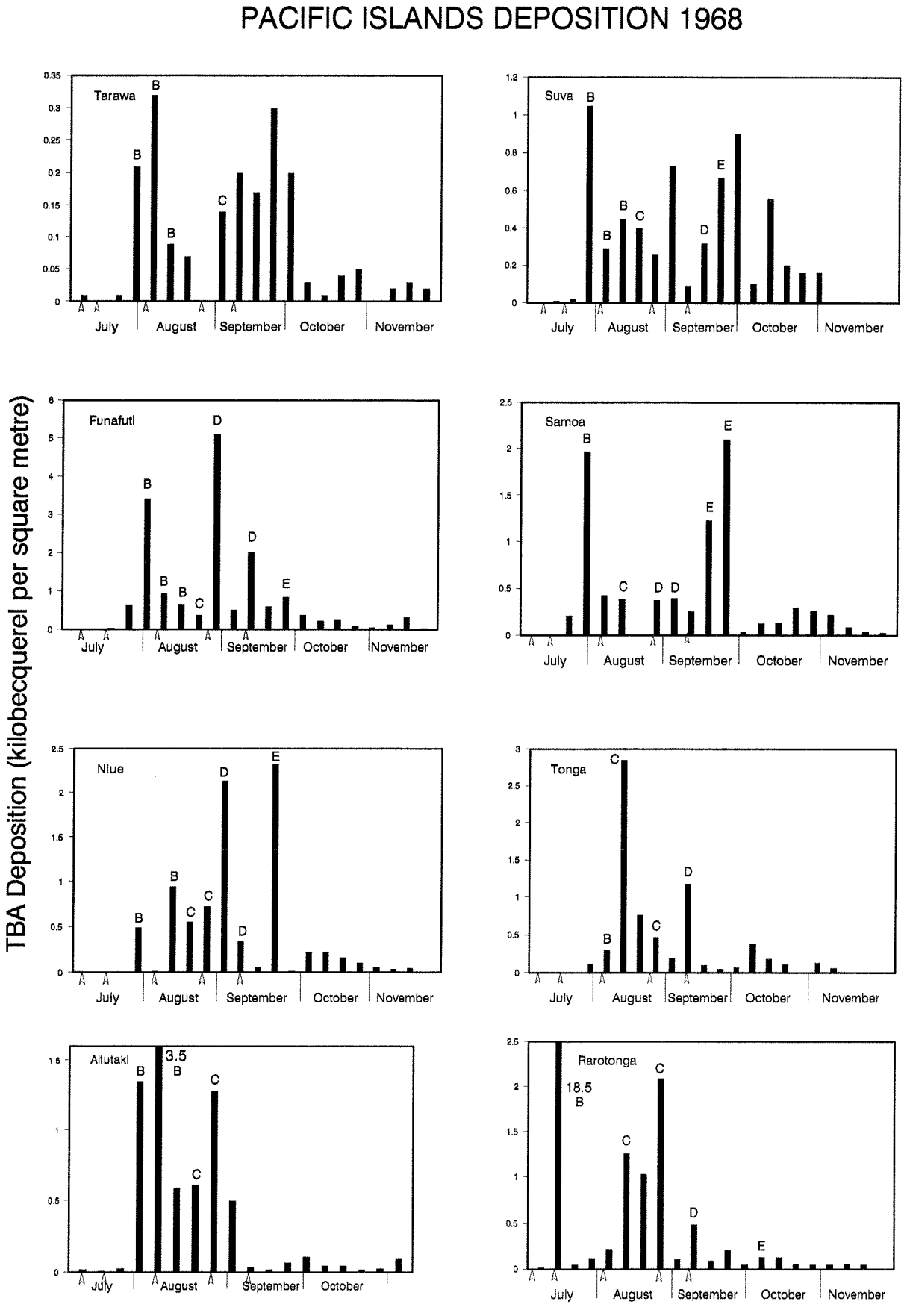


Fig 8. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1968 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - E. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1968

Deposition, kBq/km^2, attributed to each test, and totals and averages for the monitoring period, are given below.

	A	B	C	D	E	Total
Tarawa		0.62	0.14			1.9
Funafuti		4.99	1.02	7.66	0.84	16.6
Suva		1.79	0.40	0.32	0.67	6.4
Samoa		1.97	0.39	0.77	3.33	8.6
Niue		1.45	1.29	2.49	2.33	8.6
Tonga		0.30	3.32	1.18		7.0
Aitutaki		4.82	1.89			8.3
Rarotonga		18.52	3.12	0.49	0.13	24.8
Average:		4.31	1.45	2.15	1.46	10.3

Atmospheric TBA

Trends in atmospheric TBA levels during the 1968 monitoring period are shown in Fig 9.

TBA levels were elevated at all monitoring sites during the monitoring period, with some pronounced peaks which presumably occurred during successive passes of contaminated air masses circling the globe.

There was insufficient correlation between peaks and detonations for any of the peaks to have been attributed with any certainty to westward debris transport and debris age determinations were not carried out by NRL at the time. In this report, all data were multiplied by a factor of 1.2, as an "average" correction factor (derived empirically in the original NRL reports[2]) for the delay between sampling and measurement.

The maximum level of 0.38 Bq/m^3 was recorded at Samoa on 27 August.

Average and maximum levels (Bq/m^3) for the monitoring period at each site are given below:

Site	Maximum	Date	Average
Nandi	0.21	15/8	0.05
Samoa	0.38	27/8	0.04
Tonga	0.17	14/8	0.05

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1968 were 38 and 23 Bq/m^2, with rainfalls of 2122 mm and 1721 mm, respectively. The maximum deposition in any month was 14 Bq/m^2.

Strontium-89 was detected in rainwater at both sites during the period July to December, with an average monthly deposition (at both sites) of 290 Bq/m^2.

Iodine-131 in milk

At Suva and Apia ^{131}I levels in milk averaged 1.3 and 1.0 Bq/l respectively, during the monitoring period, with a highest level in any one collection of 5 Bq/l (Suva).

Environmental gamma radiation

Environmental gamma radiation levels did not exceed (or approach) the minimum reporting level of 3 μGy/h, at any site.

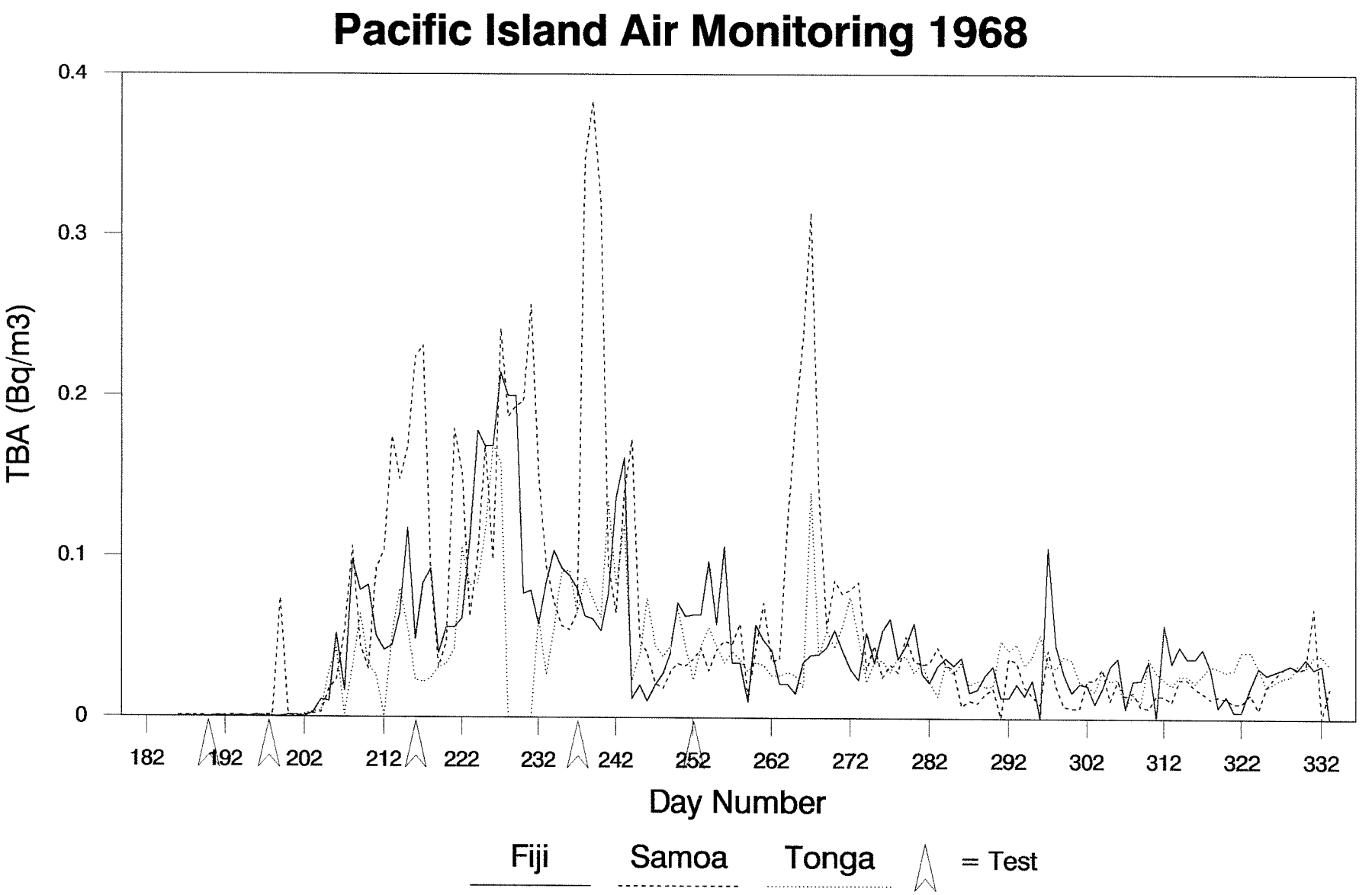


Fig 9. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa and Tonga during the 1968 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa.

MONITORING RESULTS: 1969

Test series

No tests were conducted by France during 1969.

Data references: NRL F 34, F 35, F 36, F 37, F 38.

Monitoring:

Because there were no atmospheric tests during 1969, the monitoring programme normally maintained during test series was not activated that year.

The only monitoring conducted in the Pacific area was the measurement of strontium isotopes in rain at Suva and Rarotonga.

Monitoring results

The total ^{90}Sr depositions for the year at Suva and Rarotonga were 48 Bq/m^2 and 26 Bq/m^2, respectively.

Traces of ^{89}Sr were detected in rainwater during the first half of the year, with monthly depositions averaging 17 Bq/m^2 (both sites) during that period. During the second half of the year it was barely detectable, with monthly depositions of about 3 Bq/m^2.

MONITORING RESULTS: 1970

Test series

Eight tests were conducted during 1970, including two high-yield tests:

Test	Date	Yield(kt)
A	16/5	1 - 20
B	23/5	200 - 1000
C	31/5	>1000
D	25/6	1 - 20
E	4/7	>1000
F	28/7	<1
G	3/8	20 - 200
H	7/8	200 - 1000

Data references: NRL F 39, F/40, F/41, F/42, F/43.

TBA deposition

Total beta activity deposition profiles for the 1970 monitoring period are shown in Fig 10.

Debris from tests A and F, both low yield, were not identified at any site; debris from tests C, E, G and H contributed to elevated TBA levels at most sites. Debris from tests B and D were detected at few sites, as described in the summary table below. Except where specifically indicated by NRL measurements (Aitutaki, 13/8), no distinction is made here between G and H because they were separated by only 4 days - the effective detonation date of "test GH" was taken as the August 5, the midpoint.

Test GH debris appeared at Aitutaki in the first week after detonation, indicating limited westward transport, but in all other cases the time between detonation and detection was at least 2 weeks.

The most significant deposition occurred at Aitutaki after test H: 3.4 kBq/m^2.

Average depositions from particular tests ranged up to 1.9 kBq/m^2 (test GH). Total depositions due to the entire series ranged from 1.0 kBq/m^2 at Tarawa to 8.5 kBq/m^2 at Funafuti, with an overall average total of 4.4 kBq/m^2.

Average concentrations ranged from 3 Bq/l at Tarawa to 11 Bq/l at Tonga.

Maximum weekly depositions (kBq/m^2) and resultant concentrations at each site were:

Site	Date	Test	Depn	Conc
Tarawa	7/7	C	0.4	6
Funafuti	13/8	GH	2.7	15
Suva	24/6	C	0.8	5
Samoa	19/8	GH	1.3	60
Niue	12/7		0.4	4
Tonga	30/6	C	0.6	19
Aitutaki	13/8	H	3.4	8
Rarotonga	17/9	GH	0.7	9

PACIFIC ISLANDS DEPOSITION 1970

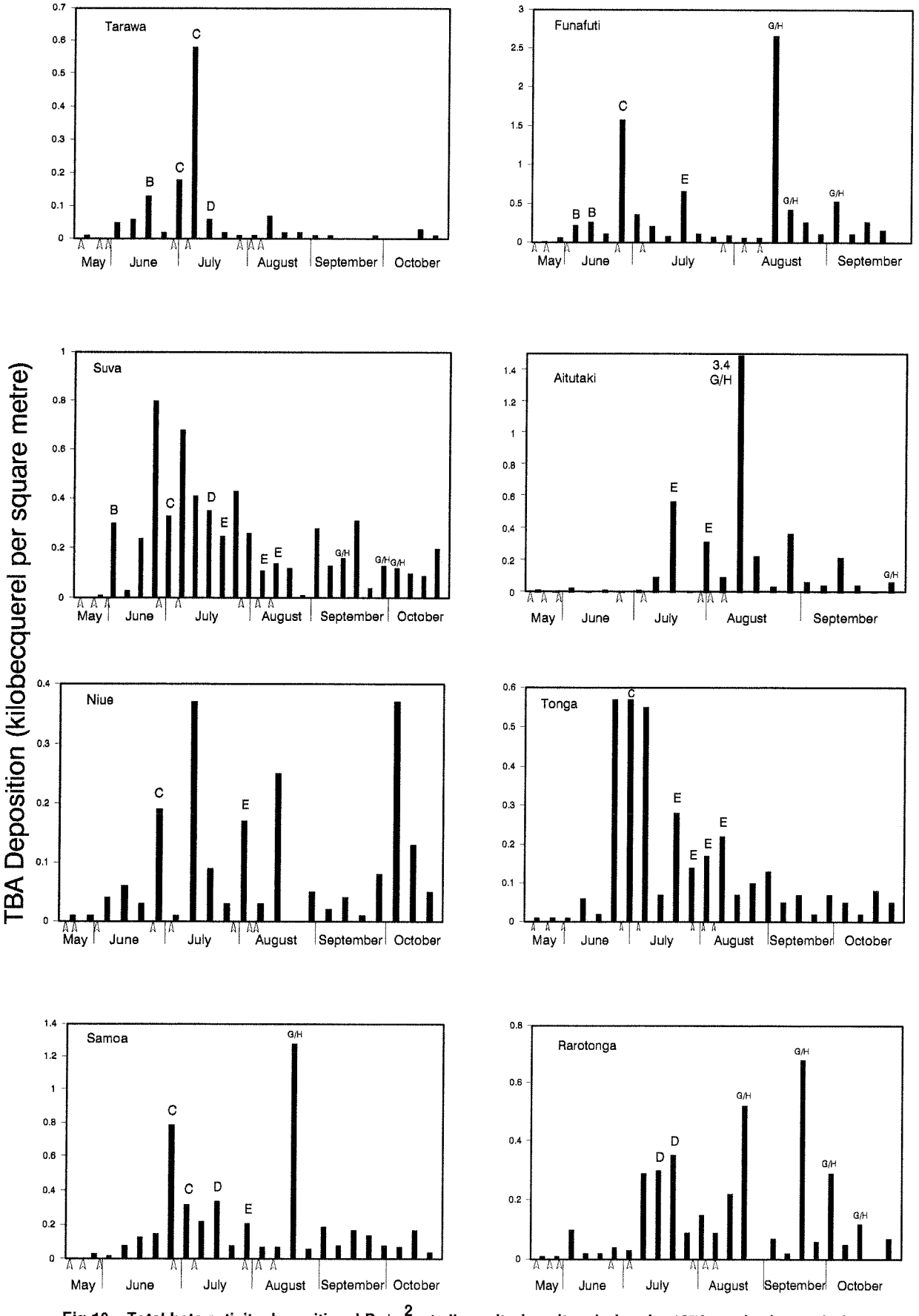


Fig 10. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1970 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - H. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1970

Deposition, kBq/m^2, attributed to each test, and totals and averages for the monitoring period, are given below:

	A	B	C	D	E	F	GH	Total
Tarawa		0.13	0.47	0.06				1.0
Funafuti		0.48	1.58		0.66		3.46	8.5
Suva		0.37	0.33	0.35	0.50		0.50	6.0
Samoa			0.96	0.34	0.21		1.28	4.6
Niue			0.19		0.17		0.80	2.0
Tonga			0.57		0.82			3.4
Aitutaki					0.90		3.51	5.8
Rarotonga				0.66			1.61	3.6
Average:		0.30	0.68	0.35	0.54		1.86	4.4

Atmospheric TBA

Trends in atmospheric TBA levels are shown in Fig 11.

TBA levels were elevated at all sites during the test series, though only one prominent peak occurred - at Samoa, August 12 - 18. This was attributed to westward transport of debris from tests G and H. The TBA level in this Samoa peak was corrected for decay by assuming an "average" detonation date for this event, of 5 August. All other data were multiplied by an assumed average correction factor of 1.2 to account for the usual 4 day interval between collection and measurement.

Westward transport was also suspected after tests B and C, based on measurements in New Zealand, though no dramatic rises in TBA were recorded at the Pacific island sites.

Average and maximum levels (Bq/m^3) for the monitoring period are given below:

Site	Maximum	Date	Average
Nandi	0.14	27/6	0.02
Samoa	1.21	16/8	0.05
Tonga	0.16	15/7	0.03

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1970 were 34 and 35 Bq/m^2, with rainfalls of 3184 mm and 2144 mm, respectively. The maximum deposition in any month was 9.6 Bq/m^2.

Strontium-89 was measured in rainwater at both sites, May - December, with an average monthly deposition during that time of 140 Bq/m^2 at Suva and 147 Bq/m^2 at Rarotonga.

Iodine-131 in milk

Iodine-131 levels in milk at Suva and Apia averaged 0.7 Bq/l and 1.3 Bq/l respectively, during the monitoring period, with a highest level in any single collection of 13.7 Bq/l (at Apia).

Environmental gamma radiation

Environmental gamma radiation levels did not approach or exceed the minimum reporting level of 3 μGy/h, at any site.

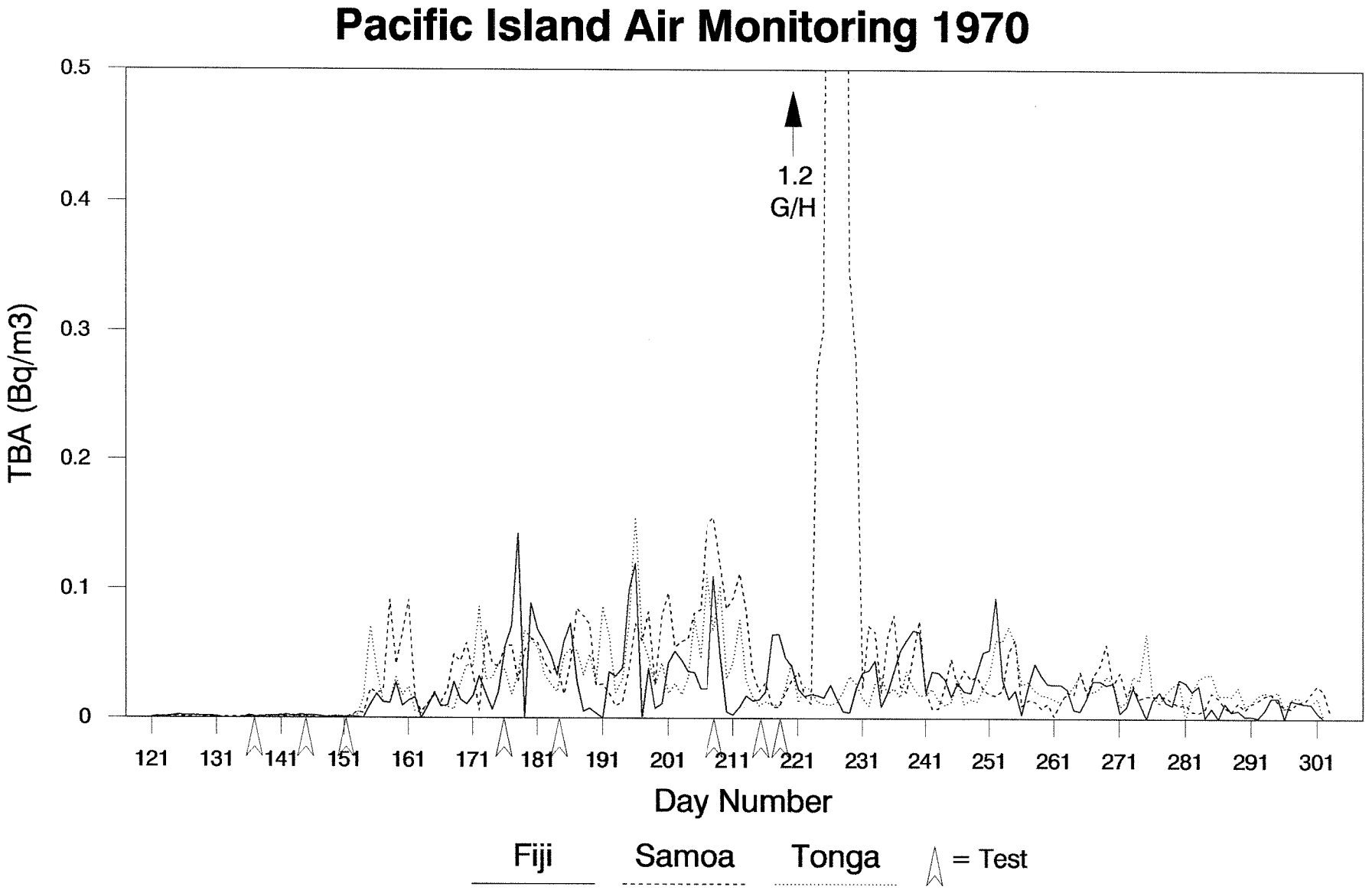


Fig 11. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa and Tonga during the 1970 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - H. The peak TBA period, attributed to test "G/H" is identified and the graphed level has been corrected for decay between sample collection and measurement.

MONITORING RESULTS: 1971

Test series

Five tests were conducted during 1971, including one high-yield test:

Test	Date	Yield(kt)
A	6/6	20 - 200
B	13/6	200 - 1000
C	5/7	1 - 20
D	9/8	1 - 20
E	15/8	>1000

Data references: NRL F/44, F/45, F/46, F/47, F/48.

TBA deposition

Total beta activity deposition profiles for the 1971 monitoring period are shown in Fig 12.

Debris from tests B, C and E were detectable at most sites, while tests A and D had little effect. Debris were usually detected at intervals of at least 2 weeks after detonation, indicating eastward transport, although activity attributed to tests B and C appeared at Samoa in the second week, consistent with the atmospheric measurements, described below.

The heaviest weekly deposition was at Samoa after test B, with 5.0 kBq/m^2 deposited.

Average attributable depositions from each test ranged up to 1.7 kBq/m^2 (test B). Total depositions for the entire series ranged from 1.2 kBq/m^2 at Tarawa to 9 kBq/m^2 at Samoa, with an overall average of 4.6 kBq/m^2.

Average concentrations ranged from 3 Bq/l at Funafuti to 28 Bq/l at Samoa.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were:

Site	Date	Test	Depn	Conc
Tarawa	28/6	B	0.2	5
Funafuti	9/9	E	1.2	8
Suva	30/6	B	1.0	53
Samoa	22/6	B	5.0	42
Niue	16/7	C	2.2	17
Tonga	13/9	E	0.4	10
Aitutaki	15/7	C	1.9	24
Rarotonga	24/7	C	0.7	20

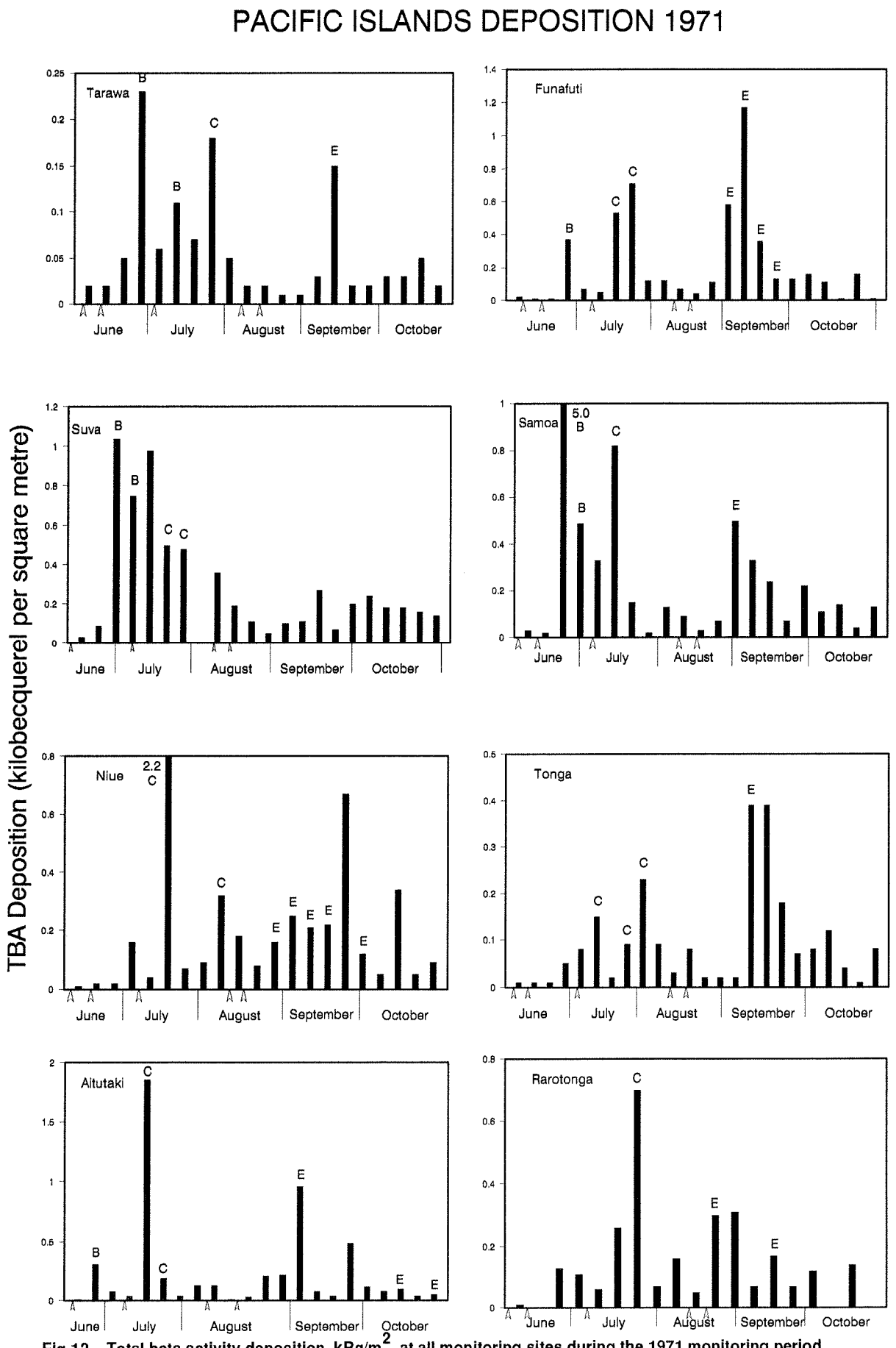


Fig 12. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1971 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - E. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1971

Deposition, kBq/m^2, attributed to each test, and totals and averages for the monitoring period, are given below.

	A	B	C	D	E	Total
Tarawa		0.34	0.18		0.15	1.2
Funafuti		0.37	1.24		2.24	5.0
Suva		1.79	0.98			6.2
Samoa		5.51	0.82		0.50	9.0
Niue			2.53		0.95	5.4
Tonga			0.47		0.39	2.3
Aitutaki		0.31	2.05		1.12	5.2
Rarotonga			0.70		0.47	2.7
Average:		1.7	1.1		0.9	4.6

Atmospheric TBA

No decay corrections were made by NRL this year in its tabulations, though age determination was undertaken during the initial peaks in TBA in June. Trends in TBA levels during the monitoring period are shown in Fig 13.

TBA levels were elevated throughout the period with marked peaks occurring in June at Samoa and Tonga due to debris from tests A and B, transported westward from Mururoa; while the second Samoa peak (June 27 - July 2) was due to eastward transport from Mururoa after the same tests.

This bidirectional transport seems to have been a characteristic of the 1971 test series, with debris from most tests being detected sooner than would have been expected from purely eastward transport. This was, however, not reflected in the deposition data described above.

The prominent July peak at Samoa (Fig. 13) was attributed in this review to test C and the data for this and the Tonga peaks were appropriately corrected for decay. All other data were multiplied by an average correction factor of 1.2 to account for the usual 4 day delay between collection and measurement.

Average and maximum TBA levels (Bq/m^3) for the monitoring period are summarised below:

Site	Maximum	Date	Average
Nandi	0.10	23/9	0.03
Samoa	1.83	20/6	0.11
Tonga	0.28	29/6	0.04

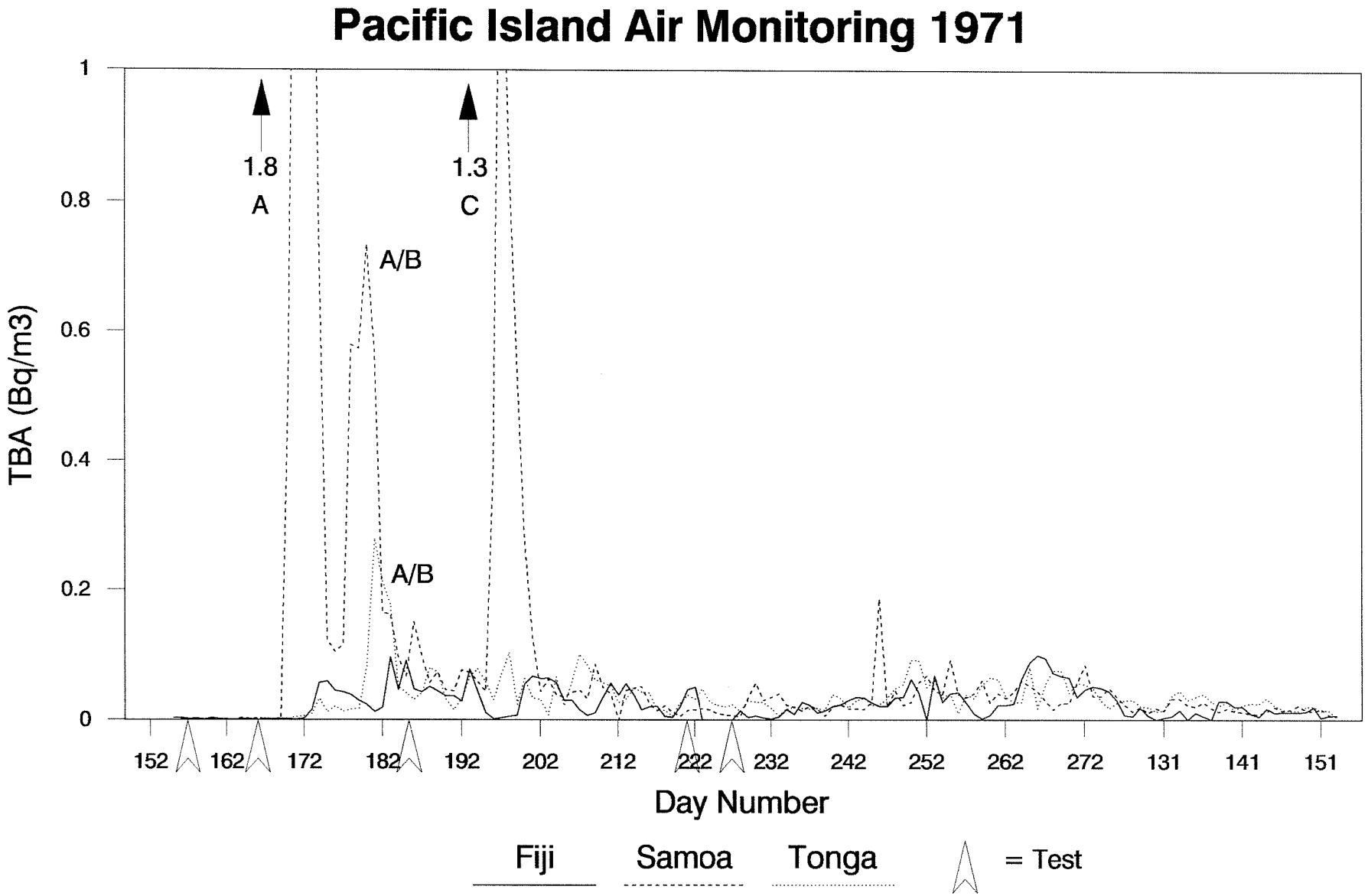


Fig 13. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa and Tonga during the 1971 monitoring period. Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - E. Peak TBA periods, attributed to tests A, C and an A/B mixture, are identified and in those cases the graphed level has been corrected for decay between sample collection and measurement.

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1971 were 52 Bq/m^2 and 35 Bq/m^2, with 2810 mm and 1993 mm of rain, respectively. The maximum deposition in any month was 10.4 Bq/m^2.

Strontium-89 was detected in rainwater at both sites throughout the year, with an average monthly deposition of 153 Bq/m^2 at Suva and 68 Bq/m^2 at Rarotonga.

Iodine-131 in milk

At Suva and Apia ^{131}I levels in milk averaged 0.7 Bq/l and 1.9 Bq/l, respectively, with a highest level in any sample of 17 Bq/l (at Apia).

Environmental gamma radiation

Environmental gamma radiation levels did not approach or exceed the minimum reporting level of 3 μGy/h, at any site.

MONITORING RESULTS: 1972

Test series

There were 3 low-yield tests during 1972:

Test	Date	Yield(kt)
A	26/6	<1
B	1/7	1 - 20
C	28/7	1 - 20

Data references: NRL F/49, F/50.

There were no significant "fallout events" during 1972 and the data presented here are directly from the above reports without correction or tabulation in the Appendix.

TBA deposition

There were only very low levels of TBA deposition during 1972, with total depositions for the test period being in the range 0.14 Bq/m^2 (at Funafuti) to 0.28 kBq/m^2 (at Tonga), and the overall average 0.22 kBq/m^2.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were as follows:

Site	Date	Depn	Conc
Tarawa	4/8	0.03	0.3
Funafuti	31/8	0.02	0.3
Suva	25/8	0.06	1.0
Samoa	11/8	0.03	0.3
Niue	11/9	0.05	0.2
Tonga	28/8	0.04	0.4
Aitutaki	14/7	0.03	1.1
Rarotonga	15/9	0.04	3.7

There were no periods when deposition or concentration were sufficiently high for it to be attributed to any particular test.

Total depositions for the test period are summarised below:

Site	Depn (kBq/m^2)
Tarawa	0.23
Funafuti	0.14
Suva	0.21
Samoa	0.24
Niue	0.23
Tonga	0.28
Aitutaki	0.21
Rarotonga	0.25
Average:	0.22

Atmospheric TBA

During the 1972 monitoring period atmospheric TBA remained below 0.01 Bq/m^3. There were only small transient increases in activity, barely discernible above normal fluctuations, 2 to 3 weeks after each test, as shown in Fig 14.

The TBA maxima and averages (Bq/m^3) for the monitoring period were:

Site	Maximum	Date	Average
Fiji	0.008	23/8	0.002
Samoa	0.006	19/8	0.001
Tonga	0.006	20/8	0.002

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1972 were 35 Bq/m^2 and 28 Bq/m^2, with 3950 mm and 1400 mm of rain, respectively. Maximum deposition in any month was 6.7 Bq/m^2.

Strontium-89 was detected only during the first half of the year, as residual fallout from the 1971 tests. The average monthly deposition during the year was 9.8 Bq/m^2 at Suva and 2.8 Bq/m^2 at Rarotonga.

Iodine-131 in milk

Iodine-131 was not detected in milk at either Suva or Rarotonga during 1972. The limit of detection was 0.07 Bq/l.

Environmental gamma radiation

Environmental gamma radiation levels did not approach or exceed the minimum reporting level of 3 μGy/h, at any site.

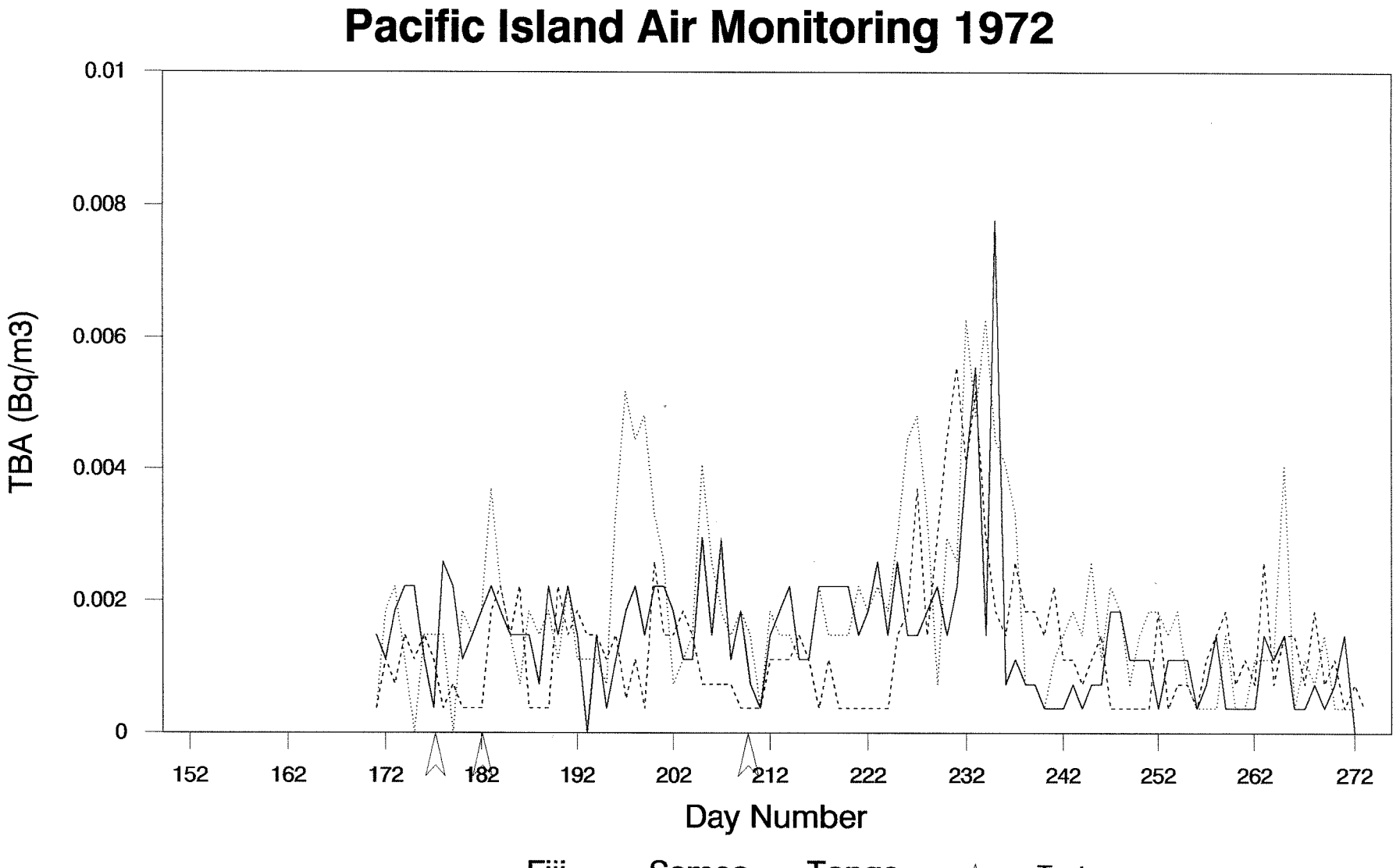


Fig. 14. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa and Tonga during the 1972 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa.

MONITORING RESULTS: 1973

Test series

Five tests were conducted in 1973, all of low yield:

Test	Date	Yield(kt)
A	22/7	1 - 20
B	29/7	<1
C	19/8	1 - 20
D	25/8	<1
E	29/8	1 - 20

Data references: NRL F/51, F/52.

During 1973 the origin dating of fallout debris and correction for decay were carried out in these NRL reports. Data were not subsequently altered in the present report.

TBA deposition

Total beta activity deposition profiles for the 1973 monitoring period are shown in Fig 15.

Tests A, B and D had little impact at any site. Test C clearly involved westward debris transport with detection in the first week at all sites except Tarawa and Funafuti. Westward transport also occurred after test E with detection in the first week at Aitutaki and Rarotonga (and in air at Samoa), and in the second week at Tarawa, Funafuti and Niue. Limited westward transport, at least as far as Niue, seems to have occurred after test D as well.

The determination of fission product ages by NRL in 1973 allowed the estimation that westerly transport from Mururoa to the Cook Islands took about 4 days, while to Funafuti and Kiribati took about 8 days. It is interesting that debris were detected so early at Tarawa which is not only a great distance from Mururoa, but also over the Equator.

Total depositions for the test period ranged from 0.5 kBq/m^2 at Tarawa to 20.0 kBq/m^2 at Aitutaki, with an average deposition over the whole region of 5.4 kBq/m^2. The heaviest weekly deposition was recorded at Aitutaki after test C: 9.7 kBq/m^2.

Average depositions after tests C and E were 2.4 kBq/m^2 and 4.3 kBq/m^2, respectively.

Average concentrations during the test series ranged from 3 Bq/l at Suva to 188 Bq/l at Aitutaki.

Maximum weekly depositions (kBq/m^2) and resultant concentrations (Bq/l) at each site were:

Site	Date	Test	Depn	Conc
Tarawa	10/9	E	0.3	330
Funafuti	3/9	E	2.5	123
Suva	24/8	C	0.4	10
Samoa	26/8	C	3.6	46
Niue	24/8	C	1.3	32
Tonga	27/8	C	1.3	140
Aitutaki	2/9	E	9.7	810
Rarotonga	2/9	E	7.6	260

PACIFIC ISLANDS DEPOSITION 1973

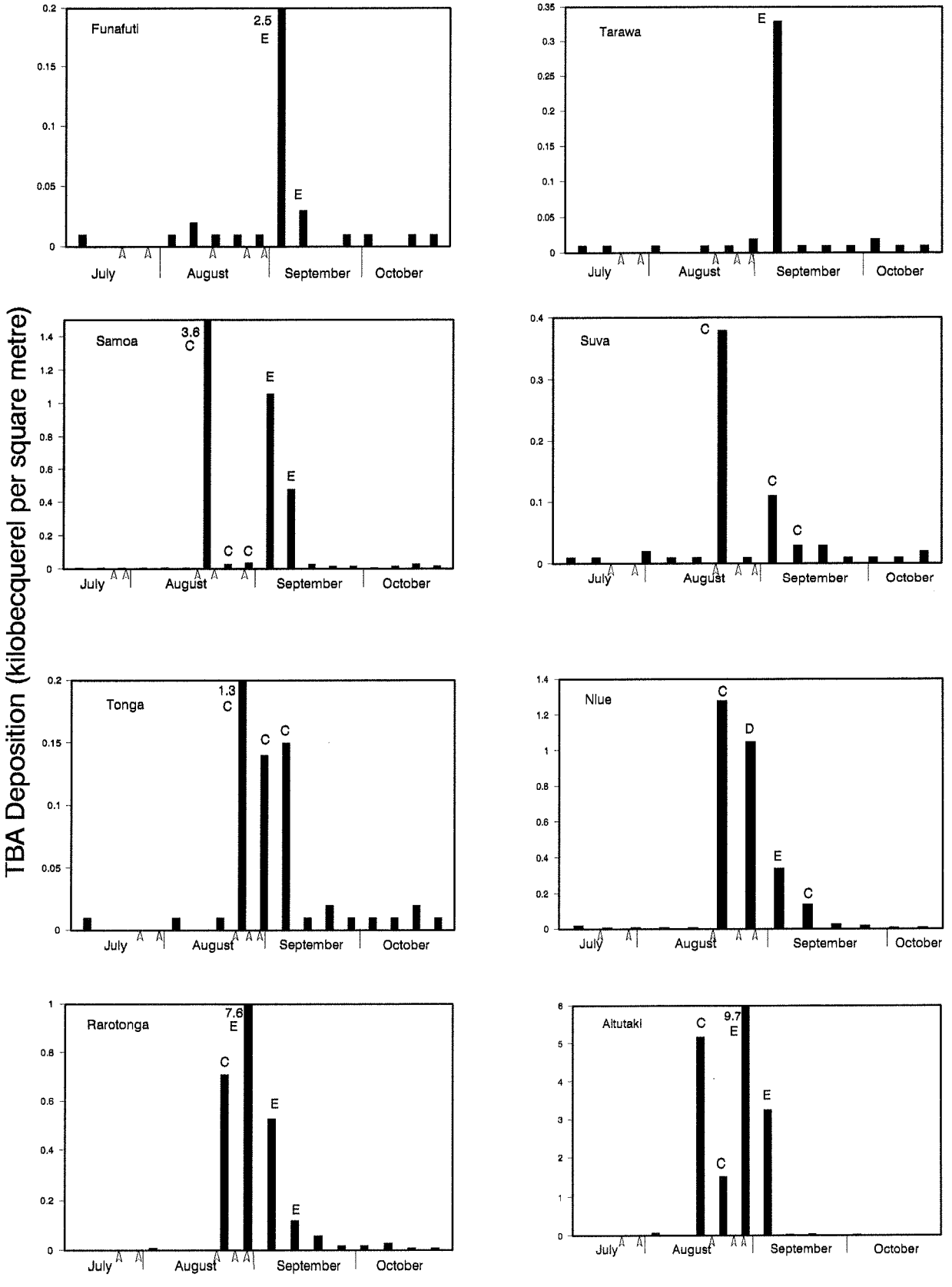


Fig 15. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1973 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - E. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1973

Deposition, kBq/m^2, attributed to each test, and totals and averages for the monitoring period, are given below:

	A	B	C	D	E	Total
Tarawa					0.33	0.5
Funafuti					2.48	2.6
Suva			0.52			0.7
Samoa			3.67		1.54	5.4
Niue			1.43	1.06	0.34	3.0
Tonga			1.55			1.7
Aitutaki			6.71		12.99	20.0
Rarotonga			0.71		8.27	9.1
Average:			2.4	1.1	4.3	5.4

Atmospheric TBA

Three monitoring sites were involved during 1973 - Samoa, Tonga, Fiji (Nandi and Suva), with monitoring results as shown in Fig 16.

The most significant impact occurred at Samoa due to tests C and E, involving westward transport of debris: on 25 August TBA levels reached 4.3 Bq/m^3, comprising 6 day old fission products from test C. Fresh test C debris were also recorded in rainwater at that time. Levels peaked again at Samoa on 5 September, comprising 7 day old debris from test E.

At Tonga the TBA peaked on August 26 at 0.2 Bq/m^3, due to test C debris, and again at 0.03 Bq/m^3 on 19 September due to test E debris.

Tests C and E had relatively little impact at Nandi, causing peaks of 0.02 and 0.01 Bq/m^3, respectively.

Tests A, B and D appear to have had little effect on atmospheric TBA, though test D may have contributed to the September peaks.

For tests where debris were identified, maximum levels (Bq/m^3) are shown below:

Site	Test C	Test E
Nandi	0.02	0.01
Samoa	4.33	1.61
Tonga	0.20	0.03

Average and maximum TBA (Bq/m^3) levels for the monitoring period are given below:

Site	Average	Maximum	Date
Nandi	0.002	0.02	27/8
Samoa	0.12	4.33	25/8
Tonga	0.004	0.20	26/8

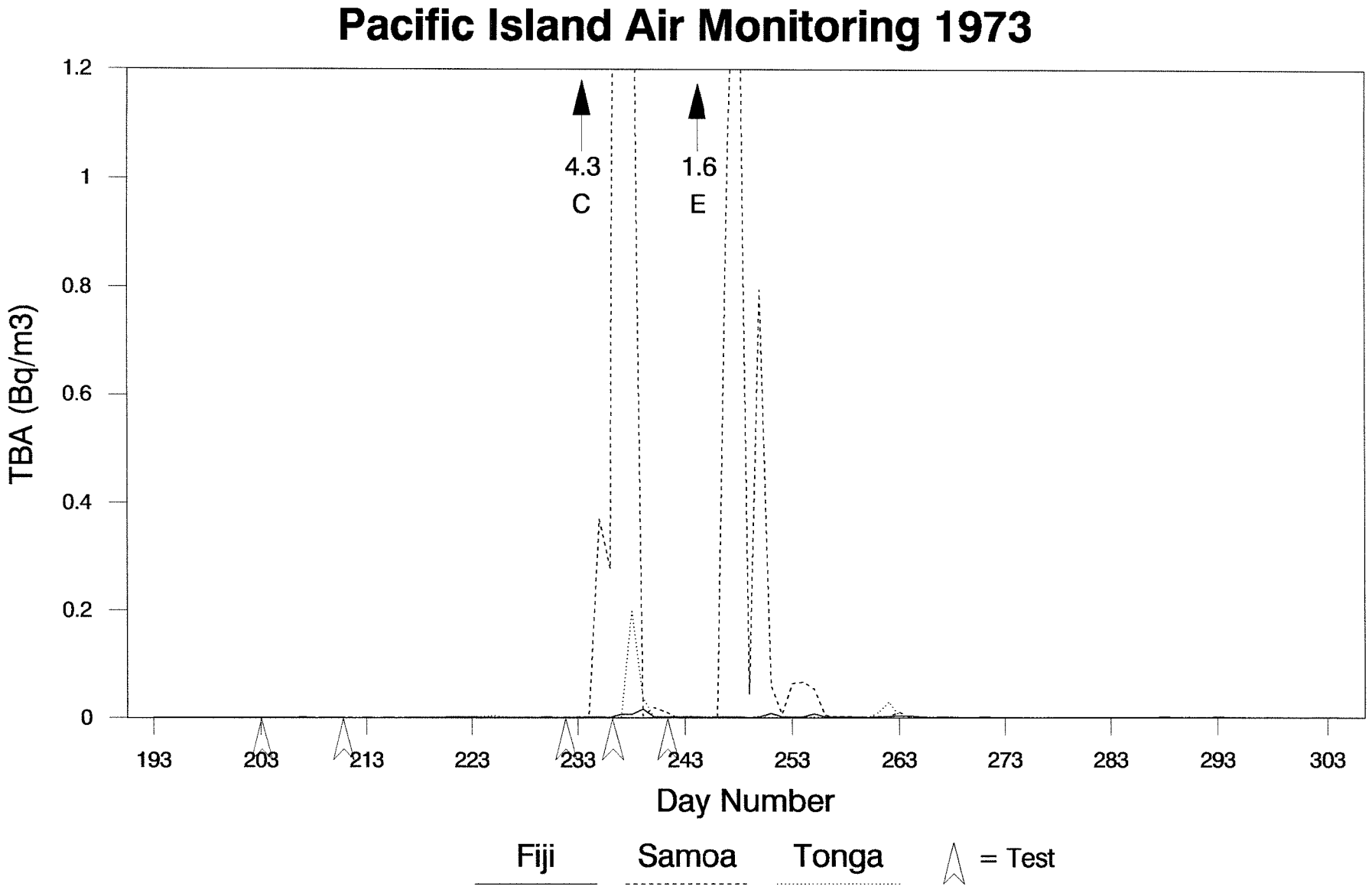


Fig 16. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa and Tonga during the 1973 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - E. Peak TBA periods, attributed to tests C and E, are identified and in those cases the graphed level has been corrected for decay between sample collection and measurement.

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1973 were 14 and 21 Bq/m^2, with 3620 mm and 2080 mm of rain, respectively. The maximum deposition in any month was 4 Bq/m^2.

Strontium-89 was detected in only one monthly rainwater sample at Suva (7 Bq/m^2, September). It was detected during September and November at Rarotonga, with depositions of 233 and 7 Bq/m^2, respectively. The relatively heavy deposition in September would have been due to the westward transport of debris from test E.

Average monthly depositions for the monitoring period were: Suva 3 Bq/m^2; Rarotonga 80 Bq/m^2.

Iodine-131 in milk

Iodine-131 levels in milk during July - October averaged 0.1 Bq/l at Suva and 0.4 Bq/l at Apia, with a highest level in any single sample of 3.3 Bq/l (at Apia).

Environmental gamma radiation

During 1973 a "level of interest" of 0.5 μGy/h was established (below the minimum reporting level of 3 μGy/h). This level was not reached during 1973, at any site.

Radioactivity in migratory fish

A short term study of artificial radioactivity in migratory fish was commenced in late 1972 and continued through 1973.

Initially 19 samples of albacore and skipjack tuna and kahawai caught in New Zealand coastal waters (late 1972 and early 1973) were analysed for ^{137}Cs to provide "background levels". The ^{137}Cs level was less than the limit of detection in most cases, with results in the range <1 Bq/kg to 2 Bq/kg (wet weight basis).

During the Pacific monitoring period 38 samples caught near Apia, comprising rainbow runner, skipjack and yellowfin tuna, were analysed. The ^{137}Cs levels were in the range <1 Bq/kg to 4 Bq/kg. Other gamma-emitting radionuclides, ^{140}Ba, ^{131}I and ^{65}Zn, were not detected in the samples.

Natural ^{40}K levels in the samples were of the order of 160 Bq/kg.

MONITORING RESULTS: 1974

Test series

Seven tests were conducted during 1974:

Test	Date	Yield(kt)
A	17/6	1 - 20
B	8/7	20 - 200
C	18/7	1 - 20
D	26/7	1 - 20
E	15/8	20 - 200
F	25/8	1 - 20
G	15/9	200 - 1000

Data references: NRL F/53, F/54.

During 1974 the origin dating of fallout debris and correction for decay were carried out in these NRL reports. Data were not subsequently altered in this report.

TBA deposition

Total beta activity deposition profiles during the 1974 monitoring period are shown in Fig 17.

Debris from tests B, C, E, F and G were detected in rainwater at most sites, while tests A and B had relatively little impact, as shown in the summary table below.

In most cases debris were detected 2, 3, 5 or more weeks after detonation, consistent with eastward transport from Mururoa. Westerly transport was evident after test C and to a limited extent after tests A and B, as shown by peaks in TBA at Funafuti and Aitutaki in the first week after test A, at Aitutaki after test B, and more widely after test C.

The most significant weekly deposition occurred after test C at Aitutaki: 9.6 kBq/m^2.

The average depositions due to each test ranged from 0.4 kBq/m^2 (test D) to 3.3 kBq/m^2 (test C). Total depositions due to the entire series ranged from 2.6 kBq/m^2 at Tarawa to 18.2 kBq/m^2 at Aitutaki, with an overall average total of 7.5 kBq/m^2.

Average concentrations ranged from 8 Bq/l at Tarawa to 343 Bq/l at Aitutaki.

Maximum weekly depositions (kBq/m^2), with resultant concentrations (Bq/l) at each site were:

Site	Date	Test	Depn	Conc
Tarawa	27/7	C	1.4	19
Funafuti	17/7	C	4.4	59
Suva	5/9	E	1.3	10
Samoa	23/7	C	3.0	338
Niue	2/8	C	1.0	109
Tonga	29/7	B	2.7	42
Aitutaki	21/7	C	9.6	4790
Rarotonga	21/7	C	1.0	33

It is interesting that the results of test C were so different at Rarotonga and Aitutaki when the islands are only 200 km apart but 2200 km from Mururoa.

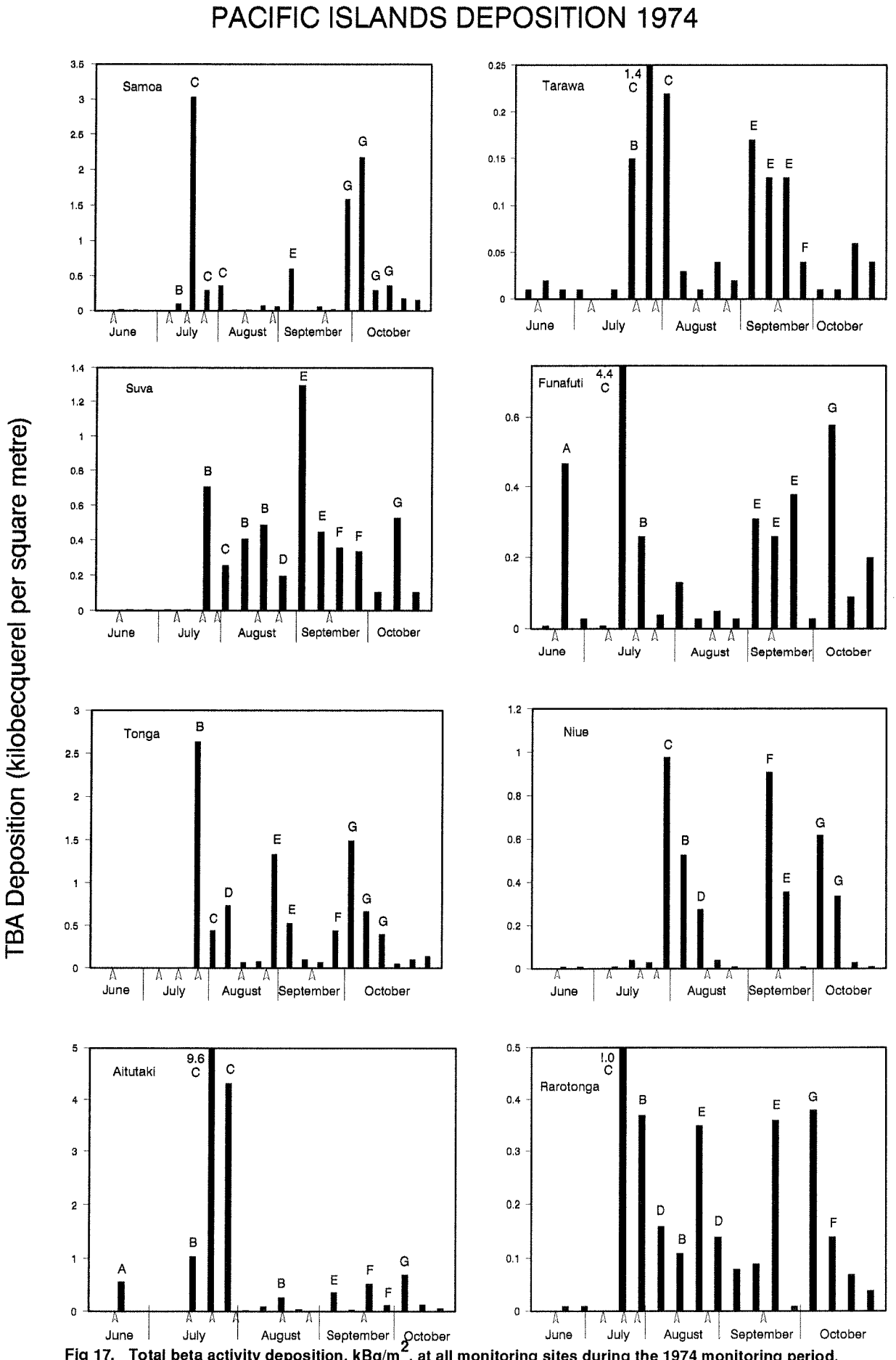


Fig 17. Total beta activity deposition, kBq/m^2, at all monitoring sites during the 1974 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissae, and are named chronologically, A - G. Periods of heavy deposition which were attributed to a particular test are identified by a letter corresponding to the test of origin, and in those cases the graphed deposition has been corrected for decay between sample collection and measurement.

Deposition summary: 1974

Deposition, kBq/m^2, attributed to each test, and totals and averages for the monitoring period, are given below:

	A	B	C	D	E	F	G	Total
Tarawa		0.15	1.66		0.43	0.04		2.6
Funafuti	0.47	0.26	4.40		0.95		0.59	7.3
Suva		1.62	0.26	0.20	1.74	0.70	0.53	5.3
Samoa		0.12	3.71		0.61		4.44	9.6
Niue		0.53	0.98	0.28	0.36	0.91	0.96	4.2
Tonga		2.65	0.45	0.75	1.88	0.45	2.59	9.5
Aitutaki	0.58	1.33	13.91		0.38	0.68	0.71	18.2
Rarotonga		0.48	0.99	0.30	0.71	0.14	0.39	3.3
Average:	0.5	0.9	3.3	0.4	0.9	0.5	1.56	7.5

TBA in atmosphere

Atmospheric monitoring involved 4 pacific sites in 1974: Fiji, Samoa, Tonga and Rarotonga. Trends in atmospheric TBA levels during the monitoring period are shown in Fig 18.

During June transient increases in TBA were recorded at Samoa, Fiji and Tonga due to westward debris transport after test A, reaching a maximum of 0.22 Bq/m^3 at Samoa on 24 June. During the period 16 - 18 July TBA levels again rose at all monitoring sites, due to westward transport of debris from test B, peaking at 0.57 Bq/m^3 at Rarotonga. The most marked rise in TBA occurred during the period 21 - 23 July, due to westward transport after test C, peaking at 22.4 Bq/m^3 at Samoa and comprising 3 day old fission products. This event was also detected at Rarotonga where levels rose to 0.55 Bq/m^3, averaged over a 4 day collection period (it is unfortunate that daily filter changing was omitted during that particular period). Throughout August, September and October TBA levels remained elevated but there were no more sudden increases and debris were 2 to 3 weeks old at collection.

Test C debris also attributed to deposited TBA at all monitoring sites in the first week after detonation, as discussed above. Deposition of debris from tests A and B was recorded in the first week at Aitutaki only.

The deposition of fresh debris from test C at Funafuti and Tarawa, in addition to the results recorded for Samoa and Rarotonga, suggests the debris trajectory was westward initially, over the Cook Islands, before curving to the north west, largely missing Tonga, Fiji and perhaps even Niue. Some debris from test C were detected in Suva on 22 July, though it was not evident at Nandi.

Tests D, E, F and G caused no pronounced increases in atmospheric TBA levels, although they would inevitably have contributed to the generally elevated levels recorded during the test period.

For tests from which debris were identified, maximum levels (Bq/m^3) are shown below:

Site	Test A	Test B	Test C
Nandi		0.19	
Samoa	0.22	0.43	22.40
Tonga		0.55	
Rarotonga		0.57	0.55*

* averaged over a 4 day sampling period.

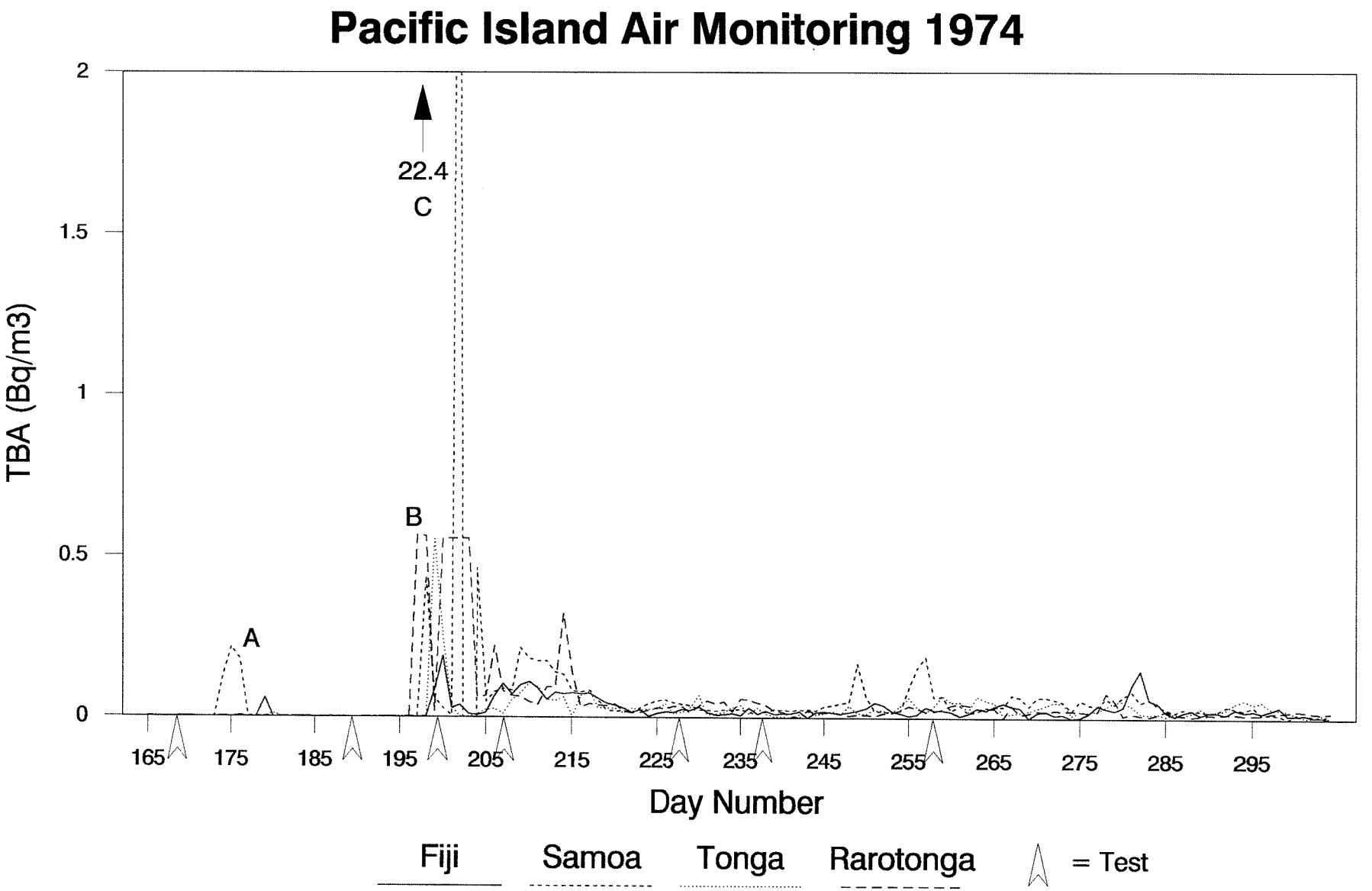


Fig 18. Total beta activity in surface air, Bq/m^3, at Fiji, Samoa, Tonga and Rarotonga during the 1974 monitoring period.
Weapon test dates are indicated by the arrowheads on the abscissa, and are named chronologically, A - G. Peak TBA periods, attributed to tests A, B and C, are identified and in those cases the graphed level has been corrected for decay between sample collection and measurement.

Average and maximum TBA levels (Bq/m^3) for the monitoring period are summarised below:

Site	Average	Maximum	Date	Test
Nandi	0.03	0.19	19/7	B
Samoa	0.27	22.42	22/7	C
Tonga	0.03	0.55	18/7	B
Rarotonga	0.06	0.57	16/7	B

Strontium-89,90 deposition

Total ^{90}Sr depositions at Suva and Rarotonga during 1974 were 10 and 12 Bq/m^2, with 3050 mm and 2180 mm of rain, respectively. The maximum deposition in any month was 3 Bq/m^2.

Strontium-89 was detected in rainwater during July - October at Suva, and during July - December at Rarotonga, with monthly average depositions during those months of 221 and 128 Bq/m^2, respectively.

Iodine-131 in milk

Iodine-131 levels in milk at Suva and Apia, during the period June - November, averaged 0.6 Bq/l and 0.9 Bq/l, respectively. The highest level in any single sample was 15 Bq/l (at Apia).

Environmental gamma radiation

The environmental gamma radiation "level of interest" established in 1973, of 0.5 μGy/h, was not reached during 1974.

PACIFIC ISLANDS MONITORING: 1975 - 1985

The French atmospheric testing programme was terminated in 1974. The environmental monitoring programme continued in order to detect any venting to the atmosphere of debris from the underground tests.

Monitoring programme

The programme was modified to the following format which was followed until 1986:

TBA in air: monitored with thrice-weekly filter changes at Fiji (Nandi), Samoa, Tonga, Aitutaki and Rarotonga. This was commenced in June 1975 and continued thereafter. During 1977 the old *Edwards* vacuum pumps were replaced with *Thomas 107* diaphragm pumps which were easier to maintain and transport. They also sampled air at a lower flow-rate (1 m^3/h), resulting in a rise in the limit of detection from 0.3 to 1.1 mBq/m^3.

TBA in rain: monitored with weekly collections, as before, at Fiji (Suva), Samoa, Tonga, Aitutaki and Rarotonga, commencing in May 1975 and continued to mid-1986.

Strontium-90 in rain: Monitoring continued with monthly collections at Fiji (Suva) and Rarotonga.

Environmental gamma radiation: daily monitoring of environmental gamma radiation levels at Penrhyn continued during the second half of 1975 and through 1976. These measurements were terminated at the end of 1976.

Data references: NRL F/55 (1975), F/56 (1976), F/57 (1977), F/58 (1978), F/59 (1979), F/60 (1980), F/61 (1981), F/62 (1982), F/63 (1983), F/64 (1984), F/65 (1985).

Monitoring results for the entire period are described below.

Atmospheric TBA

During 1975 the maximum atmospheric TBA level recorded at any Pacific site was 2.6 mBq/m^3, and the site average levels were about the same: 0.4 mBq/m^3.

From 1976 to 1985 atmospheric TBA levels did not exceed the limit of detection, 1.1 mBq/m^3, at any Pacific site.

TBA deposition

Total annual deposition at each site is given in the summary table below. Note that in 1975 data were available for the second half year only and, in 1986, for the first half year only. In these years the data were multiplied by 2 to provide approximate annual values for the table below.

Average TBA depositions, Bq/m^2, and rainfall (cm) at all sites, for each year.

	Fiji	Samoa	Tonga	Aitutaki	Rarotonga	Average	Rain
1975	180	280	140	220	280	220	200
1976	100	110	150	140	110	120	220
1977	110	170	130	140	150	140	170
1978	160	230	210	230	220	210	220
1979	120	120	250	220	190	180	200
1980	100	180	70	200	160	140	240
1981	170	210	180	180	190	190	200
1982	130	160	130	170	140	150	170
1983	26	31	32	140	97	70	130
1984	24	48	15	55	61	40	180
1985	88	83	118	78	47	80	190
1986		170	80	230	120	120	230

The TBA deposition rate decreased at all sites during 1983 - 1985. The rainfall at all sites was also lower than usual during these years. It seems likely that this TBA "trough" was connected with some meteorological phenomenon which also resulted in less rainfall, rather than to a genuine change in environmental radioactivity levels.

Much of the deposited TBA, particularly in the later years of this period, would have been due to naturally occurring ^{210}Pb. Lead-210 deposition was monitored at Suva (and periodically at Rarotonga) as an adjunct to the ^{90}Sr measurements. The average annual deposition at Suva, 1968 - 1980, was 80 Bq/m^2.

Strontium-90 deposition

The amount of ^{90}Sr deposited at Suva and Rarotonga each year decreased steadily during the period, reaching the limit of detection (0.1 Bq/m^2) in 1985. This is shown in the tabulation below which includes annual deposition data for the two sites since 1961, together with the average deposition at New Zealand sites (given for comparison).

Bq/m^2	Fiji	Rarotonga	NZ Average
1961	32		43
1962	60		56
1963	91		68
1964	91		130
1965	73		110
1966	44	32	49
1967	29	23	34
1968	38	23	28
1969	48	26	44
1970	34	35	36
1971	52	35	51
1972	35	28	30
1973	14	21	12
1974	10	12	9.4
1975	8.5	5.2	9.9
1976	4.4	4.4	4.2
1977	3.0	1.1	2.6
1978	3.0	1.5	2.4
1979	2.6	0.7	2.7
1980	1.7	2.0	2.2
1981	1.4	0.9	1.7
1982	0.9	0.6	1.2
1983	0.7	0.4	0.8
1984	0.2	0.2	0.6
1985	<0.1	<0.1	<0.1

Environmental gamma radiation

No increases in gamma radiation levels above the normal background level were recorded at Penrhyn during 1975 and 1976.

PACIFIC AREA MONITORING: 1986 - 1990 AND ONWARDS

By the end of 1985 artificial radioactivity levels in the South Pacific and New Zealand environments had reached the limits of detectability, as described in the previous section. During 1985 NRL announced that it was reviewing its monitoring operations in order to reduce the effort to a level more commensurate with the health significance of contamination then being detected.

Monitoring conducted during 1975 - 1985 had shown that atmospheric venting from the French underground tests was not occurring to any detectable degree. The emphasis of the monitoring programme was therefore changed to provide a capability of detecting any influx of radioactivity into the South Pacific region, from any source. This programme required an increase in monitoring sensitivity, but could be satisfactorily conducted with fewer monitoring sites.

The new monitoring programme was implemented in 1986. This involved the closing down of all Pacific island monitoring sites except Rarotonga, and all the New Zealand monitoring sites except Kaitaia and Hokitika. Each of these sites was equipped with a high-volume air sampler (*Secomak 575/1*) in order to increase sensitivity for atmospheric radioactivity.

The *Secomak* pumps sample air through polycarbonate filters (*Microdon FA2311*, 20 x 25 cm) at a rate of approximately 3 m^3/min, increasing the daily volume sampled by a factor of 180 over the *Thomas 107* pumps used in the Pacific area previously. Filters are changed once per week, each containing particulate matter from about 30 000 m^3 of air.

The filters are analysed for gamma-emitting materials by high-resolution gamma spectroscopy, and a filter core analysed for TBA, with a limit of detection for the latter of 0.04 mBq/m^3.

The analysis of filters by gamma spectroscopy provides an opportunity to measure levels of naturally occurring radioactive nuclides in the atmosphere, particularly ^{7}Be and, commencing in 1988, the NRL Environmental Radioactivity Annual Reports give data on levels of natural atmospheric radioactivity.

In order to increase the detectability of ^{90}Sr in rainwater, monthly samples are aggregated into two 6-monthly determinations per year.

The transition to this programme in the Pacific area occurred in mid-1986. From then onwards the Pacific programme has been as follows:

Site:	Rarotonga
Atmospheric measurements:	Gamma emitters and TBA, with weekly samples
Deposition measurements:	TBA, with weekly collections ^{90}Sr, with monthly collection.

All equipment used in the earlier monitoring programme was serviced and put into storage at NRL for rapid redeployment if necessary.

Data references: NRL F/66 (1986), F/67 (1987), F/68 (1988), F/69 (1989), F/70 (1990).

Monitoring results

Average atmospheric TBA levels and annual depositions at Rarotonga are tabulated for each year below:

	TBA_{air} mBq/m^3	TBA_{rain} Bq/m^2	$^{90}Sr_{rain}$ Bq/m^2
1986	0.07	120	0.1 ± 0.2
1987	0.07	n.r.	n.r.
1988	0.06	75	<0.1
1989	0.08	88	0.1 ± 0.2
1990	0.08	80	0.2 ± 0.2

(n.r. = no result)

No gamma-emitting fission products were detected on any air filters during the period (the limit of detection was of the order of 1 microbecquerel per m^3, for weekly average concentration).

Natural ^7Be levels in the atmosphere averaged about 3 mBq/m^3 each year.

There were no transient increases in radioactivity levels which may have been attributable to the Chernobyl nuclear reactor accident of April 26, 1986.

The annual TBA deposition levels during the period were very similar to the annual ^{210}Pb depositions recorded at Suva during the earlier monitoring period (discussed above), suggesting that the TBA was largely of natural origin.

Strontium-90 in rain remained below or near the limit of detection throughout the period.

SUMMARY

Atmospheric TBA

Average and maximum values of atmospheric TBA recorded during monitoring periods at all sites at which monitoring was undertaken, in each year since 1962, are tabulated below.

Site	Average (mBq/m^3)	Maximum (mBq/m^3)
1962	1420	84545
1963	93	130
1964	n.m.	n.m.
1965	n.m.	n.m.
1966	75	5506
1967	50	1769
1968	47	383
1969	n.m.	n.m.
1970	34	1004
1971	58	1478
1972	2	10
1973	33	4329
1974	85	22422
1975	0.4	2.6
1976	<1.1	<1.1
1978	<1.1	<1.1
1979	<1.1	<1.1
1980	<1.1	<1.1
1981	<1.1	<1.1
1982	<1.1	<1.1
1983	<1.1	<1.1
1984	<1.1	<1.1
1985	<1.1	<1.1
1986	0.07	0.23
1987	0.07	0.15
1988	0.06	0.16
1989	0.08	0.18
1990	0.08	0.16

n.m. = no monitoring

The most significant atmospheric radioactivity level occurred at Penrhyn in 1962 though a high concentration was also detected at Samoa after test C, 1974. The test C event of 1966 was marked more by deposition than atmospheric concentration.

TBA deposition

Total depositions, in kBq/m^2 (rounded), recorded at each site (excluding Raoul, Mangaia, Penrhyn and other 1962 sites where measurements were conducted for 1 or 2 years only) and yearly average depositions of all sites are given below.

	Ta	Fu	Su	Sa	Ni	To	Ai	Ra$^+$	Avg
62*	3.0	3.3		6.4	1.6			3.6	3.6
63*	0.1	0.1		0.1				0.1	0.1
64									
65									
66	4.7	17.3	8.5	268	109	5.3	8.0	6.1	40.7
67	11.2	31.3	2.5	5.4	1.0	1.3	26.8	21.6	12.6
68	1.9	16.6	6.4	8.6	8.6	7.0	8.3	24.8	10.3
69									
70	1.0	8.5	6.3	4.6	2.0	3.4	5.8	3.6	4.4
71	1.2	5.0	6.2	9.0	5.4	2.3	5.2	2.7	4.6
72	0.2	0.1	0.2	0.2	0.2	0.3	0.2	0.3	0.2
73	0.5	2.6	0.7	5.4	3.0	1.7	20.0	9.1	5.4
74	2.6	7.3	5.3	9.6	4.2	9.5	18.2	3.3	7.5
75			0.18	0.28		0.14	0.22	0.28	0.22
76			0.10	0.11		0.15	0.14	0.11	0.12
77			0.11	0.17		0.13	0.14	0.15	0.14
78			0.16	0.23		0.21	0.23	0.22	0.21
79			0.12	0.12		0.25	0.22	0.19	0.18
80			0.10	0.18		0.07	0.20	0.16	0.14
81			0.17	0.21		0.18	0.18	0.19	0.19
82			0.13	0.16		0.13	0.17	0.14	0.15
83			0.03	0.03		0.03	0.14	0.10	0.07
84			0.02	0.05		0.02	0.06	0.06	0.04
85			0.09	0.08		0.12	0.08	0.05	0.08
86				0.17		0.08	0.23	0.12	0.12
87									
88								0.08	0.08
89								0.09	0.09
90								0.08	0.08

* = incomplete year's data

$^+$ = first 2 letters of each site name given.

The following observations are clear in the above data:

1. The Christmas Island tests had an impact, in terms of TBA deposition, during 1962, but the situation rapidly returned to "normal" in 1963, with depositions returning to levels typical of natural ^{210}Pb plus global fallout.

2. The Mururoa tests of 1966 - 1974 had the major impact on the Pacific region, in terms of TBA deposition.

3. After 1974 TBA deposition levels returned to normal ^{210}Pb plus global fallout levels.

Average annual deposition for each year during the entire period, 1962 - 1990, are plotted in Fig 19. Total beta activity deposition due to the French tests is summarised in Fig 20 which shows annual totals for each site during the period 1966 - 1974.

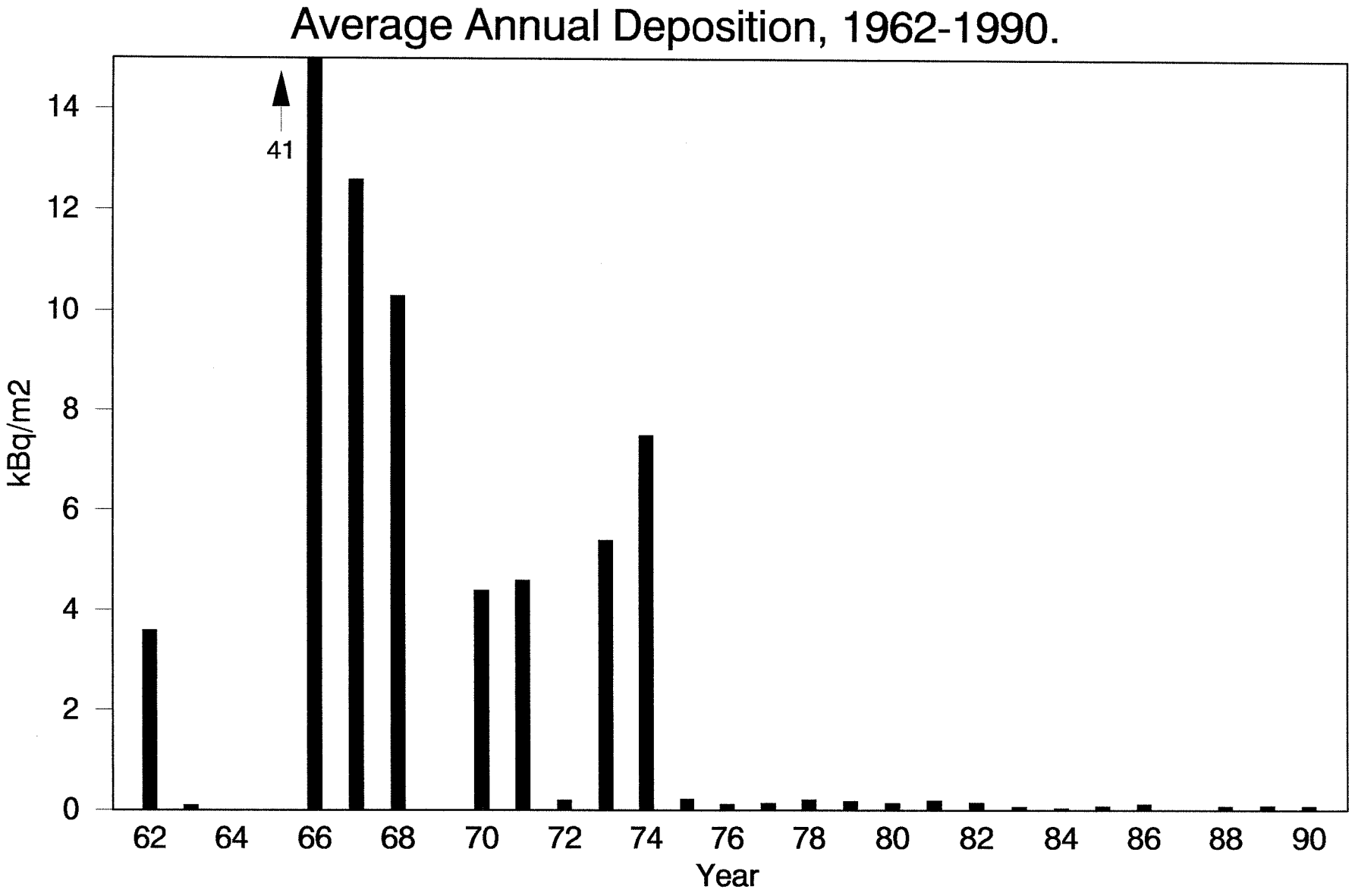
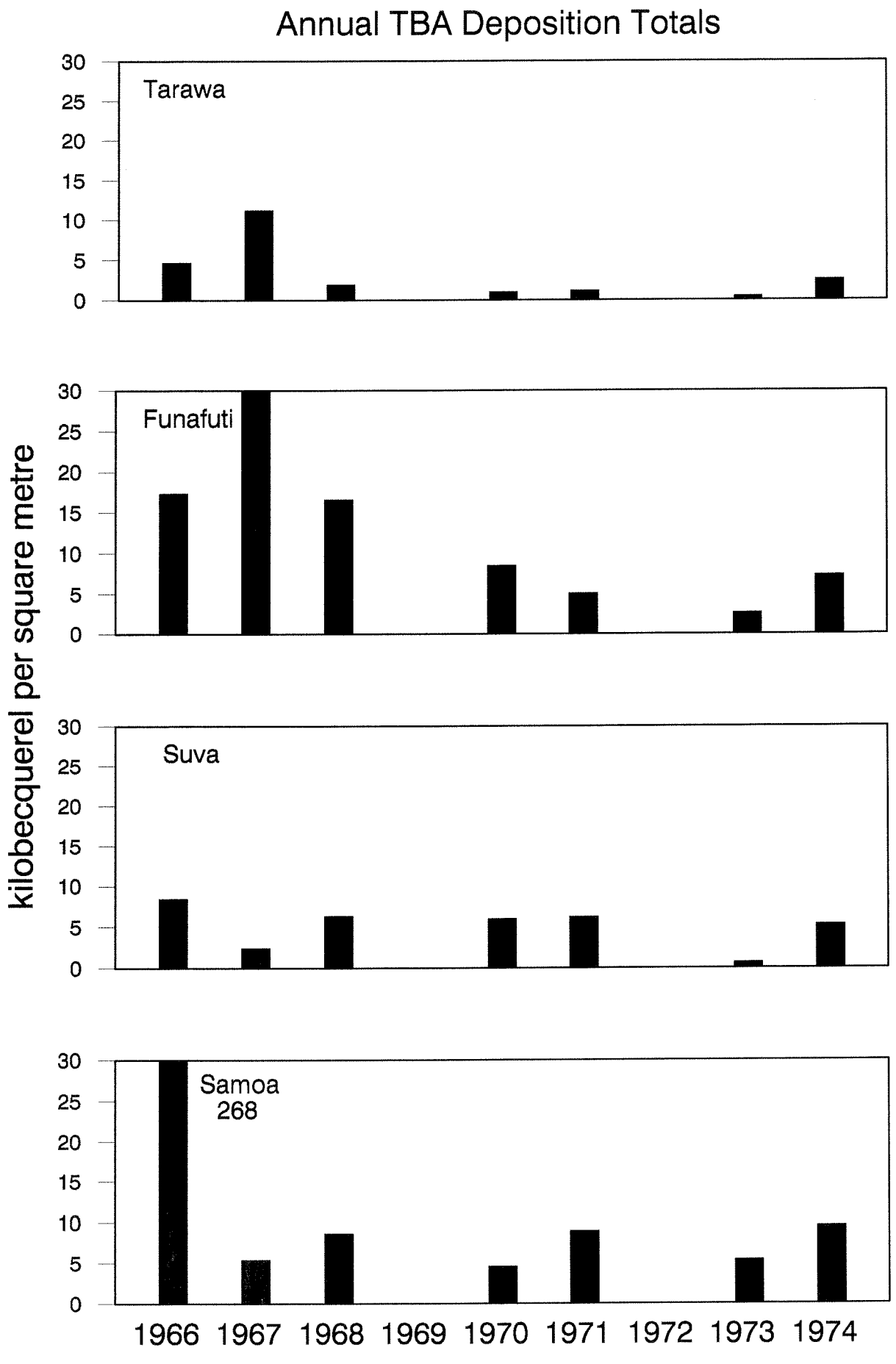


Fig 19. Average TBA deposition recorded in the South Pacific region during the period 1962 - 1990.
The data shown are the average of depositions recorded each year at all the monitoring sites operating during the year.


Annual TBA Deposition Totals
kilobecquerel per square metre
Tarawa
Funafuti
Suva
Samoa
268
30
25
20
15
10
5
0
1966
1967
1968
1969
1970
1971
1972
1973
1974

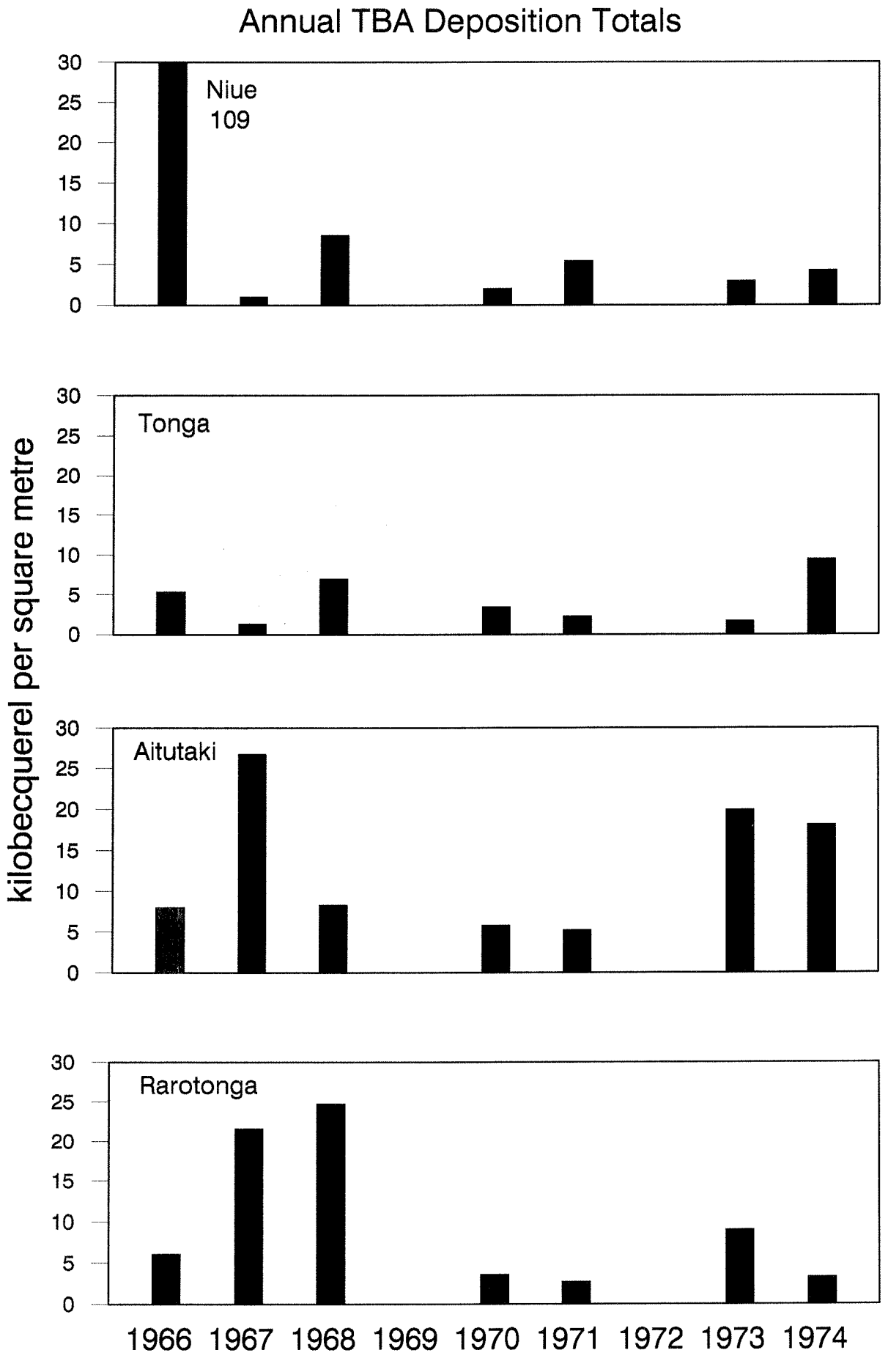


Fig 20. Annual total TBA depositions at each of the Pacific monitoring sites during the period 1966 - 1974.

Discussion of deposition due to Mururoa tests

An indication of the relative effects of the Mururoa tests at each of the Pacific island sites monitored can be obtained by summing annual depositions at each site, during the period 1966 - 1974. These 9-year totals are tabulated below, together with total rainfalls recorded during the monitoring periods, and resultant overall average TBA concentrations.

Total depositions 1966 - 1974

Site	TBA depn kBq/m^2	Rainfall cm	Concentration Bq/l
Tarawa	23.3	268	9
Funafuti	88.7	787	11
Suva	36.1	476	8
Samoa	310.8	624	50
Niue	133.4	307	43
Tonga	30.8	330	9
Aitutaki	92.5	298	31
Rarotonga	71.5	322	22

Samoa and Niue were the most affected areas, with Aitutaki, Funafuti and Rarotonga being the second most affected group. Tarawa, Suva and Tonga were the least affected.

These data are plotted in Fig 21, where it can be seen that TBA depositions at Tarawa, Suva, Tonga and Funafuti are roughly in proportion with rainfall (concentrations similar; all in the range 8 - 12 Bq/l), while at Rarotonga, Aitutaki, Niue and Samoa the deposition is out of proportion with rainfall (concentrations 22, 31, 44 and 50 Bq/l, respectively). This suggests different processes may have been involved in causing the deposition at these groups of sites.

Total depositions values for Samoa and Niue were obviously strongly influenced by the heavy deposition resulting from test C in 1966. If the deposition data are "normalised" for this event - by ignoring the extreme depositions at the two sites in 1966, and assuming more typical values of 10 kBq/m^2 at each of them - the following data are obtained:

Deposition data with 1966 test C event normalised

Site	TBA depn kBq/m^2	Rainfall cm	Concentration Bq/l
Niue	35.8	307	12
Samoa	52.8	624	8

If these data are combined with those for the other sites given above and replotted, the distribution shown in Fig 22 is obtained.

In this "normalised" case the only sites which have concentrations outside the 8 - 12 Bq/l range are Aitutaki and Rarotonga.

In general terms, it therefore seems that Aitutaki and Rarotonga (and presumably other islands in the Cook group) were most influenced by local fallout due to westward transport of debris from Mururoa, with the overall average concentrations there being higher than at other sites. The similarity of concentrations at the other sites suggests the deposition there was more due to eastward debris transport, with the rate of deposition being similar throughout the whole region. The exception to this was the particular case of the 1966 test C, which was a unique event in that it caused heavy deposition at Samoa and Niue.

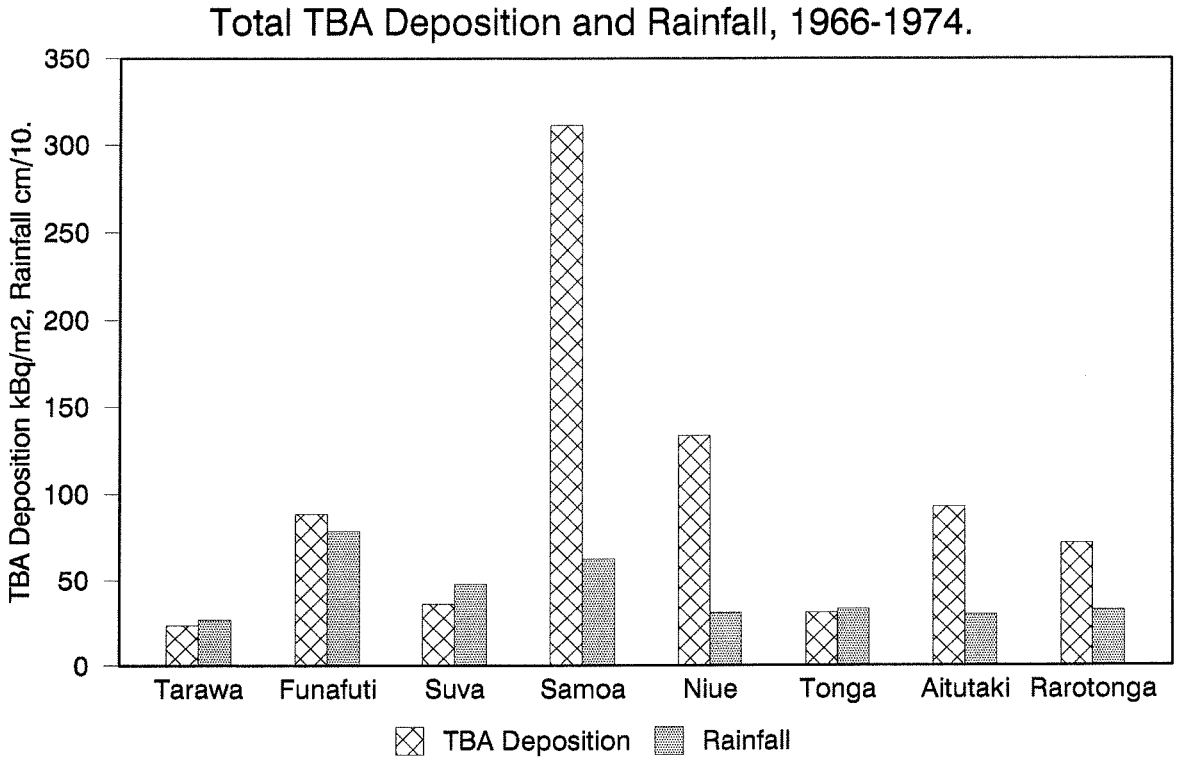


Fig 21. Total TBA deposition, kBq/km^2, and rainfall, cm, recorded at the monitoring sites indicated, during the period 1966 - 1974. For scaling purposes rainfall data have been divided by 10.

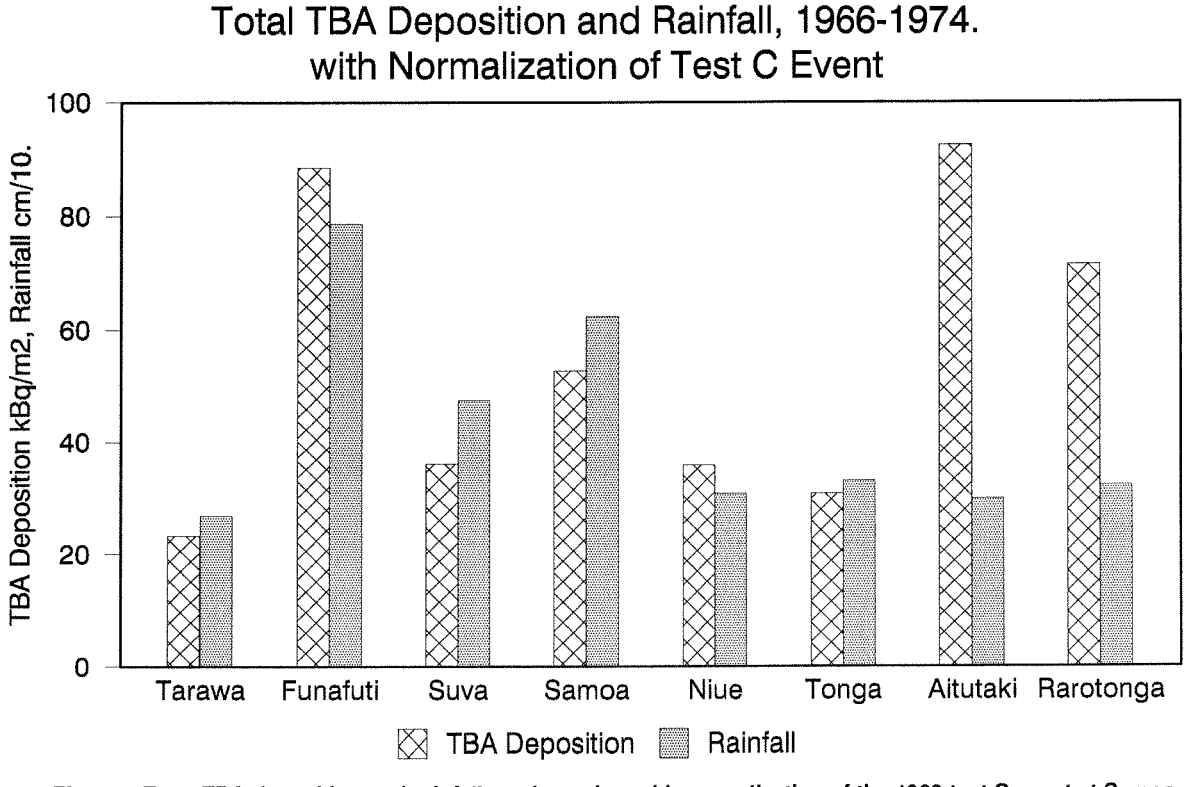


Fig 22. Total TBA deposition and rainfall as above, but with normalization of the 1966 test C event at Samoa and Niue.

Strontium-90 deposition

Strontium-90 deposition at Fiji, 1961 - 1985, and Rarotonga, 1966 - 1990, are summarised above. Data for the period before 1961 have been obtained from early UK Atomic Energy Authority reports[10], as follows: 1955 16 Bq/m^2, 1956 39 Bq/m^2, 1957 33 Bq/m^2, 1958 56 Bq/m^2, 1959 40 Bq/m^2, 1960 36 Bq/m^2.

(The 1985 data include an estimate for a 3 month period for which no result was given; the 1955 level is an upper limit estimate based the only result reported (for July - September); the 1959 level is an upper limit only.)

Annual total depositions at Suva and Rarotonga are plotted in Fig 23. As reported earlier[11] for ^{90}Sr deposition in New Zealand, there seems to have been 3 distinct "eras" of ^{90}Sr deposition:

Pre 1962: peaking in 1958
1962-1967: peaking in 1963/4
1967-1975: peaking in 1972.

These different periods were presumably due mainly to early US and USSR tests; US and USSR tests of 1961 and 1962; and French tests of 1966-1974, respectively.

The 2 year delay between the 1961 and 1962 tests and the peak deposition was also observed in New Zealand and represents the long residence time in the stratosphere (up to 2 years) of debris from high-yield tests. The maximum deposition, recorded in 1963 and 1964, was 91 Bq/m^2, with a corresponding average concentration for each year of 0.025 and 0.031 Bq/l, respectively. This peak occurred slightly earlier at Fiji than in New Zealand where deposition in 1964 was significantly higher than in 1963[11].

Cumulative deposition peaked at 700 Bq/m^2 in 1972, as shown in Fig 23.

Although data are not available for Pacific island sites, it is likely that annual deposition patterns would have been similar throughout the broad latitudinal band encompassing most islands mentioned in this report, with actual levels depending primarily on rainfall.

Iodine-131 in milk

Average concentrations of ^{131}I in milk, recorded during the monitoring periods each year, and the highest value recorded in any single collection, are tabulated below.

Averages:	Fiji Bq/l	Samoa Bq/l	Maximum Bq/l
1966	4.2	2.5	9
1967	0.9	3.1	26
1968	1.3	1.0	5
1970	0.7	1.3	14
1971	0.7	1.9	17
1972	<0.1	<0.1	
1973	0.1	0.4	3
1974	0.6	0.9	15

Environmental gamma radiation

Environmental gamma radiation levels never reached the minimum reporting level, 3 μGy/h, at any site where measurements were conducted, at any time.

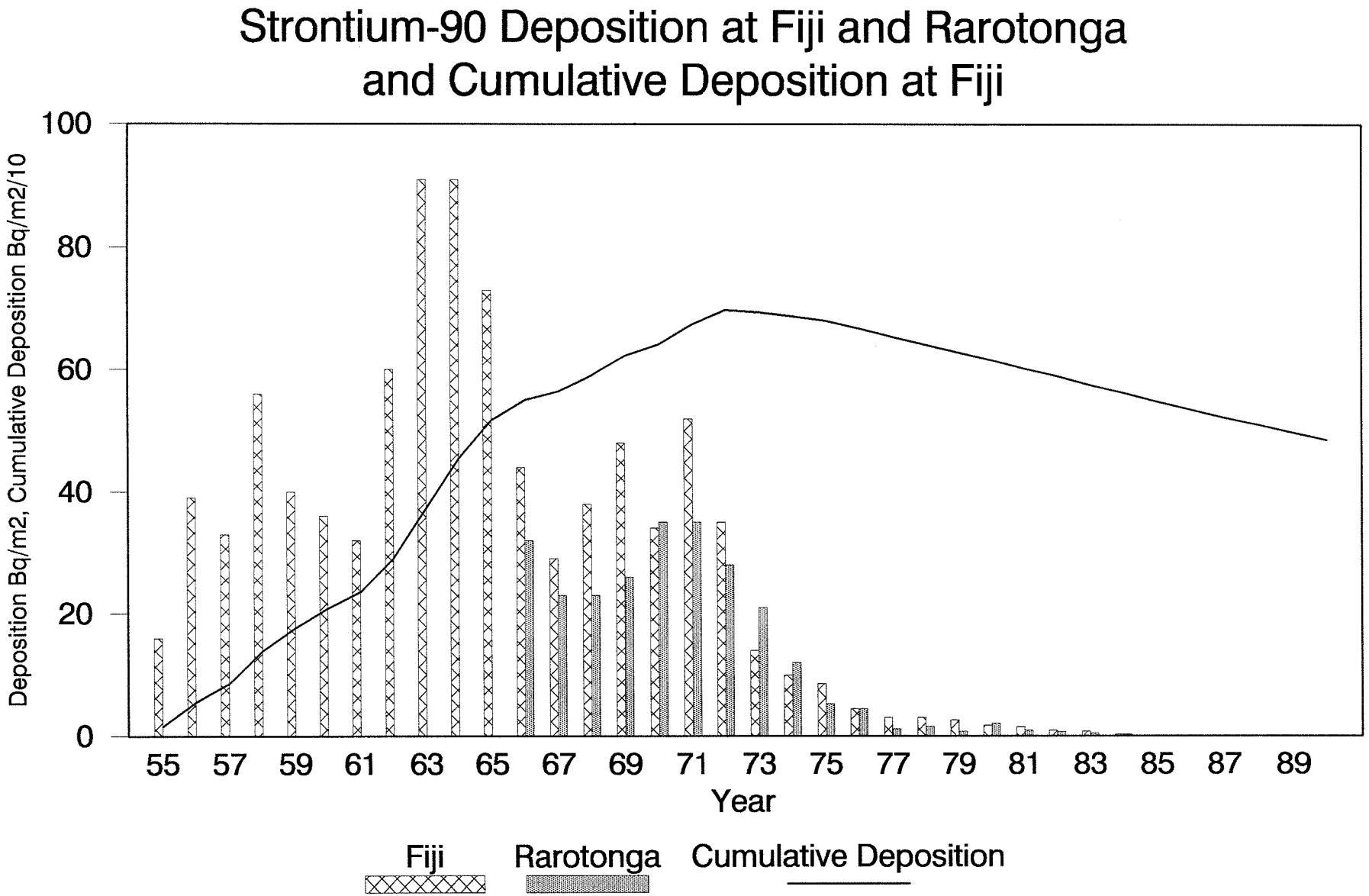


Fig 23. Annual ^{90}Sr deposition at Fiji (Suva) and Rarotonga during the period 1955 - 1990. Cumulative ^{90}Sr deposition at Fiji is also shown.

RADIATION EXPOSURE OF THE SOUTH PACIFIC POPULATION

An upper limit for the radiation exposure received by the population of the Pacific islands included in the NRL monitoring network can be estimated from the results summarised in this report, with the adoption of pessimistic assumptions regarding the distribution of fallout over the region.

Comparison with reference levels

Reference levels, as described above, pertained to radioactivity levels maintained indefinitely. In comparing monitoring results with reference levels it is therefore appropriate to consider long term average results. The table below compares the highest monitoring-period average levels measured at any site with reference levels (RL). Peak levels also tabulated are short term levels only.

	TBA rain, Bq/l		TBA air, Bq/m^3		^{131}I milk, Bq/l	
	avg	peak	avg	peak	avg	peak
1962			5.6	84.6		
1966	194	10840	0.08	5.5	4.2	9
1967	110	1260	0.07	1.8	3.1	26
1968	20	920	0.06	0.4	1.3	5
1970	20	90	0.05	1.0	1.3	14
1971	20	190	0.11	1.5	1.9	17
1972		4	<0.01	0.01	<0.1	
1973	45	810	0.10	4.3	0.4	3
1974	64	4790	0.24	22	0.9	15
RL	**220**		**11**		**7.4**	

The environmental gamma radiation level did not reach the minimum reporting level at any time.

There were periods, as shown above, when transient (peak) radioactivity levels exceeded reference levels. At the time, this would have resulted in a close watch being maintained on monitoring results to check that levels subsequently decreased.

The longer term average levels, however, never exceeded the reference levels during the French tests, nor were they exceeded during the earlier tests - hence the often-repeated statement that "levels constituted no public health hazard". Even the revision of deposited TBA levels would not have altered that statement.

In 1966 the maximum average TBA-rain concentration at Samoa was close to the reference level due to the effect of test C that year. Even so, this average level applied for the relatively short term period of 6 months only, so that the year average was about half the tabulated value.

Estimation of dose commitment

It is impossible to accurately determine the actual radiation doses received by the Pacific island populations during the various test series but upper limits can be estimated assuming most pessimistic conditions.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) described, in its 1982 report[12], the various contributions made by different fission products and other bomb debris to human exposure.

The major contributions to exposure to the gonads, red bone marrow, bone surfaces, and lungs, as representing sources of possible genetic and somatic effects, are summarised below. The figures for each radiation source represent the percentage of the estimated total exposure contributed to the population in the south temperate zone.

Exposure	Source	Gonads	Red marrow	Bone surfaces	Lungs
External	Short-lived material*	19%	8%	6%	11%
	^{137}Cs*	40%	17%	13%	24%
Internal	^{14}C	18%	38%	26%	13%
	^{90}Sr		27%	44%	5%
	^{137}Cs*	18%	8%	6%	11%
Total		95%	98%	95%	64%

* Actual dose the same to each organ type listed.

For the gonads and bone components the remaining 2-5% of the totals represents the combined effects of ^{3}H (1 - 3%) and ^{55}Fe, ^{89}Sr, ^{106}Ru, ^{144}Ce, ^{239}Pu, ^{241}Pu and ^{241}Am. In the case of the lungs the remaining fraction is contributed mainly by ^{144}Ce (19%) and ^{106}Ru (13%). Sites more affected by local fallout, however, would receive higher percentage contributions from short-lived material.

Estimated doses due to the major contributors - short-lived material, ^{137}Cs and ^{90}Sr - are discussed below. Carbon-14 was not measured in the NRL programme and the UNSCEAR estimates have been used in that case.

External exposure

As described in the table above, external radiation exposure is due principally to short-lived materials and ^{137}Cs deposited on the ground. The corrected values for deposited total beta activity and ^{90}Sr deposition presented in this report can be used to derive estimates for external exposure from these sources, as follows.

Short-lived material: The 1982 UNSCEAR report gave conversion factors for assessment of effective dose equivalent commitments due to external radiation for the principal gamma emitting fission products. As these fission products are also beta emitters, an estimate of their deposition is provided by the total beta activity measurements, using data on the composition of weapons debris at various times after detonation provided by the US Environmental Measurements Laboratory, EML[13].

The most significant deposition events occurred in short time intervals soon after tests, so an age at deposition of 7 days was used in calculating the composition factors (based on EML handbook[13]) in the table below where: ***Dose factor***[12] = 10^{-8} Gy/(Bq/m^2), ***TBA composition***[13] = fraction of 7 day old debris; and ***Overall factor*** = product of dose factor and TBA composition, in units of Gy/(Bq TBA/m^2), x 10^{-8}. (Gy = gray, the unit of absorbed dose.)

Nuclide	Dose factor	TBA composition	Overall factor
Cs-137	39		
Zr-95	2.4	0.12	0.29
Ru-103	0.28	0.2	0.056
Ru-106	1.2	0.02	0.024
Ba-140	0.5	0.03	0.015
Ce-141	0.03	0.10	0.003
Ce-144	0.19	0.04	0.008
Sum (excluding ^{137}Cs)			0.4

The dose commitments due to external exposure (excluding ^{137}Cs), based on TBA deposition at each site are shown below. Data were converted to air dose to tissue dose by applying a factor of 0.7[12], and the shielding effects of buildings were neglected.

Dose = (Bq/m^2) x 0.4 x 0.7/100000 mGy

Deposition = total TBA deposition 1966 - 1974, as shown below.

Site	Deposition Bq/m^2	Dose mGy
Tarawa	23300	0.1
Suva	36100	0.1
Tonga	30800	0.1
Rarotonga	71500	0.2
Funafuti	88700	0.2
Aitutaki	92500	0.3
Niue	133400	0.4
Samoa	310800	0.9
Average:	98400	0.3

The average dose commitment due to short-lived material was thus about 0.3 mGy. This estimate does not include deposition prior to 1966 but the limited data available for 1962 indicate an average TBA deposition (over the sites at which measurements were then made) of 3000 Bq/m^2. This is only 3% of the average deposition due to the French tests, and would have increased the above dose commitment negligibly.

Caesium-137: Deposition data for ^{137}Cs are not available but deposition can be estimated for Suva by applying the generally accepted $^{137}Cs/^{90}Sr$ ratio of 1.6 to the Suva ^{90}Sr data: total ^{90}Sr deposition at Suva, 1955-1985, was 900 Bq/m^2 so ^{137}Cs deposition would have been of the order of 1400 Bq/m^2.

Using the dose factor in the table above, the dose commitment would be 1400 x 39 x 0.7/100000 mGy = **0.4 mGy**.

Although this applies to Suva only, it at least gives an indication of the order of the dose commitment at other Pacific island sites - it is adopted below as a general "Pacific" value.

Actual exposures due to the above sources would have been lower than these estimates because of shielding by buildings and the fact that debris were often older than 7 days.

Internal exposure

Dose commitments for internal exposure due to ^{90}Sr and ^{137}Cs can also be estimated using UNSCEAR dose factors[12].

Strontium-90: Three components of the dose-delivery pathway must be considered: transfer from deposition to diet; transfer from diet to tissue; and conversion of tissue level to dose.

(a) Transfer deposition to diet: UNSCEAR[14] gave a factor of 0.004 ($Bq\ a/kg_{diet}$)/($Bq/m^2_{deposited}$). The UNSCEAR considered this an underestimate for diets containing less meat and milk than western diets, with transfer being about twice as great in Southern Hemisphere than in the Northern. In this review it was pessimistically assumed that the factor was twice the above value.

(b) Transfer diet to bone: UNSCEAR[12] reported a factor of 38 Bq a/kg in bone per Bq a/kg in diet.

(c) Bone to dose: UNSCEAR[12] reported the following factor for use in converting bone levels to dose: 1.9 μGy per Bq a/kg in red bone marrow, and 4.2 μGy per Bq a/kg in bone surfaces.

The overall dose factor was the product of the above: red bone marrow 0.6, and bone surfaces 1.3, μGy per $Bq/m^2_{deposited}$.

Assuming a total ^{90}Sr deposition as at Suva, of 900 Bq/m^2, the dose commitments to the red bone marrow and bone surfaces would therefore be 0.54 mGy and 1.17 mGy, respectively.

Caesium-137: As in the ^{90}Sr case above, the UNSCEAR factors relating ^{137}Cs deposition to dose commitment were as follows:

Transfer from deposition to diet: 9 (mBq a/kg)/(Bq/m^2)

Transfer from diet to tissue: (2.6 Bq a/kg)/(Bq a /kg_{diet})

Conversion to dose: 2.4x $x10^{-6}$ Gy/(Bq a/kg)

Assuming a total ^{137}Cs deposition of 1400 Bq/m^2, as derived above, the average dose commitment would be 0.1 mGy.

Summary of dose commitments

The above estimates of external and internal exposure due to TBA, ^{90}Sr and ^{137}Cs are summarised in the table below together with UNSCEAR estimates for ^{14}C contributions and internal lung dose.

Exposure, mGy	Source	Gonads	Red marrow	Bone surfaces	Lungs
External	Short-lived material	0.3	0.3	0.3	0.3
	^{137}Cs	0.4	0.4	0.4	0.4
Internal	^{14}C*	0.08	0.37	0.34	0.09*
	^{90}Sr		0.5	1.17	0.03*
	^{137}Cs	0.1	0.1	0.1	0.08*
Total dose commitment, mGy		0.9	1.7	2.3	0.9

* data from UNSCEAR[12]

The lung dose should be increased by a factor of 1.56 because only 64% of the total lung dose is derived from the above source components.

Overall, the upper limits for the average individual dose commitment due to nuclear test debris in the Pacific islands would thus be of the order of:

0.9 mGy to gonads
1.7 mGy to red bone marrow
2.3 mGy to bone surfaces
1.4 mGy to lungs.

The UNSCEAR[12] estimates of these commitments, for the south temperate zone, were 0.4, 1.0, 1.3 and 0.7 mGy for the above organs, respectively.

These dose commitment estimates were used in the present study to derive an estimate of the effective dose commitment by applying the current ICRP[15] tissue weighting factors and assuming

the gonad dose (0.9 mGy) applied to all other organs not listed above, with the following conclusion.

The estimated average individual effective dose commitment for the South Pacific island population, due to atmospheric nuclear weapon tests, was 1.1 millisievert; with a range within the islands of the NRL monitoring network of 0.9 to 1.7 millisievert.

This estimated average is similar to that indicated by data (for Fiji only) published in the report of the 1983 Scientific Mission to Mururoa[16], 0.7 mSv, and less than the world population average annual effective dose commitment due to natural background radiation, of 2.4 mSv[17].

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Note: 70 fallout monitoring reports are referred to in each of the data sections of this report by their code names.

Reports DXRL F1 to NRL-F18 have the title *Fallout in New Zealand* and were published by the Dominion X-Ray and Radium Laboratory or the National Radiation Laboratory, Christchurch, in the year indicated.

Reports NRL-F19 to NRL-F/46 have the title *Environmental radioactivity in New Zealand* and were published by the National Radiation Laboratory in the year indicated.

Reports NRL/47, 49, 51, 53 have the title *Environmental radioactivity: fallout from nuclear weapons tests conducted by France in the South Pacific from .... to ....., 19..* and were published by the National Radiation Laboratory in the year indicated.

Reports NRL/48, 50, 52 and 54 - 70 have the title *Environmental radioactivity annual report* and were published by National Radiation Laboratory, Christchurch, in the year indicated.

APPENDICES

APPENDIX 1

Total beta activity measured as deposition and in the atmosphere at Pacific island sites, 1966 - 1974.

In the deposition tables:

Sample mid-collection ("collect") dates and dates of measurement ("measure") are given as day numbers (Jan 1 = day 1)

Measured deposition is given in original units (millicuries per km^2) and in Bq/m^2.

Rainfall for the sampling period is recorded in mm.

"Peaks" refer to periods of high TBA concentration in rainwater where deposition was attributed to the test indicated by the letter given. For these periods, TBA was corrected for decay between collection and measurement, and the corrected deposition listed in right hand column.

"Conc" = TBA concentration in rainwater.

In the atmospheric TBA tables:

Atmospheric concentrations are given in mBq/m^3.

APPENDIX 2

"Radioactive contamination from nuclear weapons"

APPENDIX 1

TBA DEPOSITION 1966
Detonation Day Numbers; A=184, B=201, C=255, D=268, E=278.

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
TARAWA							
183	195	26.2	.3	11		.42	11
189	203	18.3	.1	4		.20	4
196	222	178.1	1.7	63		.35	63
203	211	21.6	1.7	63		2.91	63
210	218	68.5	.8	30		.43	30
217	229	0	.4	15			15
222	229	.2	1.4	52		259.00	52
229	241	1.5	.2	7		4.93	7
236	244	T	.1	4			4
243	251	63.7	.6	22		.35	22
250	258	.8	.3	11		13.88	11
257	265	48.2	.5	19		.38	19
264	271	76.2	32.4	1199	C	15.73	2391
271	279	2.3	.8	30		12.87	30
278	286	70.1	8.7	322	C	4.59	461
285	293	11.2	2.1	78	C	6.94	103
292	299	3.6	1.1	41		11.31	41
299	307	.8	.7	26		32.38	26
306	319	1.3	1.5	56		42.69	56
313	321	96.3	22.9	847	E	8.80	1085
320	369	26.4	.8	30		1.12	30
327	369	33	2.1	78		2.35	78
337	370	2.8	.4	15		5.29	15
348	370	37.8	.6	22		.59	22
356	369	32.5	.2	7		.23	7
362	377	47.8	.4	15		.31	15
		869.2		3064		17.84	4657
FUNAFUTI							
183	195	39.4	.3	11		.28	11
189	203	31.8	.4	15		.47	15
196	208	126.5	18.5	685	A	5.41	1573
203	211	10.9	3.5	130	A	11.88	197
210	218	44.7	4.1	152		3.39	152
216	230	69.1	1.7	63		.91	63
222	229	33.8	1.9	70		2.08	70
229	238	137.4	5.1	189		1.37	189
235	245	172.2	3.4	126		.73	126
240	251	151.9	2	74		.49	74
248	258	72	1.2	44		.62	44
257	265	90	.9	33		.37	33
264	278	98.5	50.4	1865	C	18.93	5749
271	279	7.4	5.5	204	C	27.50	331
248	286	38.1	.4	15		.39	15
285	293	73.6	34.7	1284	D	17.44	2039
292	301	143.3	16.7	618	D	4.31	905
297	307	69.3	25.4	940	E	13.56	1561
302	314	56.9	28.7	1062	E	18.66	1727
307	319	102.3	19.4	718	E	7.02	1088
313	321	35.3	11.9	440	E	12.47	564
320	328	72.5	8	296		4.08	296
326	336	55.5	3.7	137		2.47	137
333	343	43.9	2.3	85		1.94	85
341	354	143.8	2	74		.51	74
347	357	196.1	2.2	81		.42	81
352	370	152.3	2.2	81		.53	81
359	370	27	.8	30		1.10	30
364	374	12.4	.4	15		1.19	15
		2307.9		9535		5.18	17326
SUVA							
185	196	67.1	.9	33		.50	33
193	203	8.6	.4	15		1.72	15
200	208	17.3	9.9	366	A	21.17	596
207	214	7.1	1.7	63		8.86	63
214	221	2.5	.4	15		5.92	15
221	228	33.6	18.6	688	B	20.48	987
228	236	15.2	4.7	174		11.44	174
235	244	1	.6	22		22.20	22
242	251	48.3	1	37		.77	37
249	258	6.3	.9	33		5.29	33
256	263	8.1	.5	19		2.28	19
263	269	1.8	.7	26		14.39	26
270	299	T	.1	4			4
277	284	14.5	18.2	673	C	46.44	938
284	291	31	32.6	1206	D	38.91	1864
291	301	3.8	12.5	463	D	121.71	713
298	307	11.7	10.6	392	D	33.52	537
303	308	64.8	18.1	670	E	10.33	833
306	314	T	.6	22			22
312	319	2.5	5.4	200		79.92	200
319	327	19.8	7	259		13.08	259
326	336	29.5	1.5	56		1.88	56
331	336	81.8	17	629		7.69	629
337	347	57.5	13.3	492		8.56	492
346		NS					
354	370	17.3	.8	30		1.71	30
361	377	50.8	1	37		.73	37
		601.9		6623		17.76	8634
SAMOA							
187	203	50.6	.3	11		.22	11
197	230	54.2	.3	11		.20	11
204	221	18.5	.7	26		1.40	26
211	221	20.8	.3	11		.53	11
218	229	46.3	3.8	141		3.04	141
225	231	63.5	4.3	159		2.51	159
232	244	34.3	1	37		1.08	37
239	248	0	.3	11			11
246	255	71.4	.6	22		.31	22
253	262	9.4	.5	19		1.97	19
260	270	64.1	1800	66600	C	1039.00	248897
266	277	13	57.9	2142	C	164.79	4922
273	280	51.8	43.4	1606	C	31.00	2382
281	290	76.7	11.7	433		5.64	433
287	294	37.6	87.3	3230	E	85.91	6443
295	306	82	24.7	914	D	11.15	1377
302	312	140.2	17.3	640		4.57	640
309	320	30.2	14.8	548	E	18.13	788
316	325	69.1	18.3	677	E	9.80	874
323	332	3.6	1.3	48	E	13.36	48
330	339	34.6	3.2	118		3.42	118

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
337	348	133.3	4.4	163		1.22	163
344	354	56.2	1.6	59		1.05	59
351	369	73	2.9	107		1.47	107
358	370	79.6	1.8	67		.84	67
364	374	58.1	1.4	52		.89	52
		1372.1		77852		50.13	267817
NIUE							
190	229	28	.3	11		.40	11
197	229	3.3	.2	7		2.24	7
204	229	4.6	.2	7		1.61	7
212	257	39	.5	19		.47	19
218	256	78	1.5	56		.71	56
225	257	2.8	.7	26		9.25	26
232	257	19.8	1.2	44		2.24	44
241	285	1.3	.6	22		17.08	22
248	284	3	.4	15		4.93	15
253	284	2	.3	11		5.55	11
260	284	7.6	284.2	10515	C	1383.61	86684
267	314	122.7	49.8	1843	C	15.02	12458
275	314	72.4	21.3	788	C	10.89	2886
282	318	68.6	15.4	570		8.31	570
289	318	49.5	29.9	1106	E	22.35	5208
296	347	16.8	3.6	133		7.93	133
303	342	29.2	6.2	229		7.86	229
311	347	3.1	5.1	189		60.87	189
317	347	6.9	3.9	144	E	20.91	286
324	383	3.3	1	37		11.21	37
332	383	28.3	1.7	63		2.22	63
337	383	2.5	.8	30		11.84	30
344	383	3.1	2.4	89		28.65	89
350	383	4.1	1	37		9.02	37
		599.9		15991		68.55	109117
TONGA							
185	211	5.8	.3	11		1.91	11
193	211	5.3	.2	7		1.40	7
200	227	29	1.4	52		1.79	52
207	227	5.3	.8	30		5.58	30
214	242	6.6	.3	11		1.68	11
221	242	3.8	1.4	52		13.63	52
228	256	10.2	6.1	226	B	22.13	530
235	256	5.6	.6	22		3.96	22
242	269	30	.8	30		.99	30
247	270	150	1.3	48		.32	48
254	280	4.3	.3	11		2.58	11
263	284	12.4	7.4	274	C	22.08	1284
270	280	14.2	2.7	100		7.04	100
277	294	14	9.4	348	C	24.84	691
284	292	70.6	21.7	803	D	11.37	1306
291	301	19.1	6.9	255	D	13.37	394
298	319	T	.4	15			15
304	319	21.8	5.6	207	E	9.50	358
312	325	T	.4	15			15
319	328	T	1.1	41			41
326	336	9.4	1.3	48		5.12	48
333	353	1.5	.2	7		4.93	7
340	369	41.7	2.2	81		1.95	81
348	369	12.2	1.9	70		5.76	70
356	375	48.5	1.6	59		1.22	59
363	375	74.5	1.1	41		.55	41
		595.8		2864		5.85	5315
RAOUL							
185	242	3.8	.1	4		.97	4
193	242	22.8	.6	22		.97	22
200	242	33.5	.8	30		.88	30
208	242	8.6	.5	19		2.15	19
215	242	24.9	.6	22		.89	22
222	242	25.9	10.8	400	B	15.43	892
229	242	13.7	1.3	48	B	3.51	76
236	328	4.3	.5	19		4.30	19
241	329	64.5	2.7	100		1.55	100
246	332	68.1	1.6	59		.87	59
253	332	16	.5	19		1.16	19
260	329	47.8	.8	30		.62	30
267	329	40.9	.5	19		.45	19
273	332	80.5	3	111		1.38	111
279	328	88.6	5.6	207		2.34	207
286	328	18.5	3.3	122	E	6.60	1101
293	328	5.3	2.1	78	E	14.66	330
301	328	22.1	6.7	248	E	11.22	629
		589.8		1554		3.89	3686
PENRHYN							
184	266	12.9	.2	7		.57	7
190	266	21.6	5.1	189	A	8.74	4351
197	266	22.6	5	185	A	8.19	1687
204	266	T	.5	19			19
210	266	56.7	1.7	63		1.11	63
218	266	21.1	.8	30		1.40	30
225	266	43.7	1.7	63		1.44	63
232	266	13.2	.7	26		1.96	26
239	266	25.4	.8	30		1.17	30
246	350	35	.3	11		.32	11
253	350	72.5	.4	15		.20	15
260	349	60.8	3.7	137		2.25	137
266	349	48.5	2.1	78		1.60	78
273	349	34.8	7.2	266	C	7.66	1936
281	349	5.8	4.8	178	D	30.62	1595
288	349	3.8	6.8	252		66.21	252
295	350	26.4	2.3	85		3.22	85
302	350	21.4	1.3	48		2.25	48
309	350	18.3	3.5	130	E	7.08	356
316	350	35.8	4.2	155		4.34	155
323	350	24.6	.6	22		.90	22
330	350	21	.2	7		.35	7
337	351	.2	.2	7		37.00	7
344	350	4.6	.3	11		2.41	11
352	351	39.2	.6	22		.57	22
358	350	44.7	.8	30		.66	30
364	351	9.4	.3	11		1.18	11
		724		2076		7.16	11054
AITUTAKI							
185	211	26.2	.3	11		.42	11

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
192	210	T	.1	4			4
199	211	.5	.3	11		22.20	11
206	244	19.8	.3	11		.56	11
212	244	21.8	.2	7		.34	7
220	244	T	.2	7			7
227	248	27.2	6.5	241	B	8.84	489
234	248	7.9	.5	19		2.34	19
241	269	T	.2	7			7
255	285	4.1	.3	11		2.71	11
262	284	18	13.2	488	C	27.13	2689
269	299	.6	.4	15		24.67	15
276	294	3.6	6.9	255	D	70.92	1050
283	320	8.2	7.5	278	D	33.84	1234
290	342	15.8	1.6	59		3.75	59
297	342	54.1	9.1	337	E	6.22	1446
304	342	1	.9	33		33.30	33
311	250	.3	.1	4		12.33	4
318	248	257.7	16	592		2.30	592
325	253	13	1.1	41		3.13	41
332	356	151.5	6	222		1.47	222
339	368	67.6	1.6	59		.88	59
346	368	.8	.6	22		27.75	22
		699.7		2734		11.40	8044
RAROTONGA							
184	213	6.1	.3	11		1.82	11
191	213	4.1	.2	7		1.80	7
198	213	1	.1	4		3.70	4
205	213	11.2	.5	19		1.65	19
211	248	35.3	.4	15		.42	15
219	248	6.4	.4	15		2.31	15
226	248	3.6	.7	26		7.19	26
233	249	63	11.8	437	B	6.93	710
240	267	.3	.1	4		12.33	4
247	269	17	.5	19		1.09	19
254	284	5.3	1.6	59	B	11.17	101
261	284	63.2	7.9	292	C	4.63	1936
268	284	1.8	.9	33		18.50	33
275	294	.5	.5	19		37.00	19
282	312	.3	.9	33		111.00	33
289	312	21.8	7.1	263	D	12.05	638
296	320	25.6	6.6	244	D	9.54	513
303	320	31.5	9.6	355	E	11.28	662
310	346	86.1	12	444		5.16	444
317	343	152.7	17.5	648		4.24	648
324	347	.3	.8	30		98.67	30
331	348	49	5.6	207		4.23	207
		586.1		3182		16.67	6093
MANGAIA							
185	211	12.2	.8	30		2.43	30
192	227	16.8	.2	7		.44	7
199	227	2.3	.2	7		3.22	7
205	228	38.1	.6	22		.58	22
213	248	18.5	.4	15		.80	15
220	248	17	.5	19		1.09	19
227	248	15.2	2.5	93	B	6.09	188
234	266	9.9	1.2	44	B	4.48	100
241	269	1.5	.5	19		12.33	19
248	308	30.2	1	37		1.23	37
255	308	12.7	.8	30		2.33	30
262	308	90.2	8.4	311		3.45	311
269	308	19.6	2.3	85	C	4.34	420
276	308	.8	.4	15		18.50	15
283	308	1	2.7	100		99.90	100
290	320	23.9	9.9	366	E	15.33	1647
297	319	69.6	17.2	636	E	9.14	1602
304	320	1	1.4	52	E	51.80	92
311	347	63.8	8	296	E	4.64	717
317	336	30.2	9.9	366	E	12.13	590
325	348	0	.4	15			15
332	369	224.3	6.8	252		1.12	252
338		NS		0			0
345	388	16.5	1.5	56		3.36	56
		715.3		2871		9.95	6290

TBA DEPOSITION 1967
Detonation Day Numbers; A=157, B=179, C=184.

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
TARAWA							
153	159	T	.1	4			4
158	170	38.6	.3	11		.29	11
164	173	T	.3	11			11
172	179	13.9	21.9	810	A	58.29	1283
179	187	33.2	5.2	192	A	5.80	279
186	193	1	.2	7		7.40	7
193	201	28.9	1.5	56		1.92	56
200	209	48	138.4	5121	C	106.68	8748
208	215	.3	3	111		370.00	111
214	227	46.7	9.7	359	C	7.69	553
221	234	47	(.1				
228	237	1.8	.6	22		12.33	22
235	244	8.6	.7	26		3.01	26
243	262	7.9	.5	19		2.34	19
249	262	57.7	1.9	70		1.22	70
256	270	3.8	.2	7		1.95	7
260		NS					
264	270	.8	.2	7		9.25	7
270	282	15.7	.4	15		.94	15
		353.9		6849		39.27	11229
FUNAFUTI							
157	170	71.6	.3	11		.16	11
164	173	119.9	.4	15		.12	15
171	180	71.4	42.7	1580	A	22.13	2866
178	187	26.2	3.1	115		4.38	115
186	195	19.6	.9	33		1.70	33
192	201	63.5	93.7	3467	C	54.60	8566
197	202	87.9	317.7	11755	C	133.73	17371
201	209	59.2	18	666	C	11.25	1058
207	215	59.2	11.8	437	C	7.38	625
214	227	98.7	6.4	237		2.40	237
220	234	55.4	1.4	52		.94	52
227	237	16.8	2	74		4.40	74
235	244	30.7	1.6	59		1.93	59
240	249	62.7	1.8	67		1.06	67
248	263	24.4	1.1	41		1.67	41
256	289	35.1	.7	26		.74	26
263	270	49.8	.8	30		.59	30
		952.1		18663		14.66	31245
SUVA							
156	165	.3	.1	4		12.33	4
163	171	6.8	.3	11		1.63	11
170	178	3.8	.2	7		1.95	7
177	185	39.2	2.4	89		2.27	89
184	193	10.4	.9	33		3.20	33
191	202	10.4	.8	30		2.85	30
198	207	5.1	1.5	56	C	10.88	101
205	215	47.2	15.3	566	C	11.99	903
212	220	14.5	7.1	263	C	18.12	355
219	227	6.6	4	148	C	22.42	189
226	237	21.3	6.9	255	C	11.99	338
233	241	2.3	.7	26		11.26	26
240	249	11.2	2.6	96		8.59	96
247	257	16.3	1.5	56		3.40	56
254	269	63.2	1.8	67		1.05	67
261	271	177.5	1.2	44		.25	44
268	278	27.2	2.6	96		3.54	96
		463.3		1846		6.72	2445
SAMOA							
158	173	110.5	.4	15		.13	15
166	173	5.6	5	185	A	33.04	369
172	181	43.4	3.2	118		2.73	118
179	187	45.5	.4	15		.33	15
186	192	20.6	.2	7		.36	7
193	200	60.5	39.2	1450	C	23.97	2893
200	213	20.1	7.3	270	C	13.44	551
206	213	66.3	14.7	544	C	8.20	758
213	226	25.6	3.9	144		5.64	144
221	229	103.1	4.5	167		1.61	167
228	241	99.6	3.5	130		1.30	130
235	249	43.1	2.1	78		1.80	78
242	254	27.2	1.2	44		1.63	44
249	262	12.9	.7	26		2.01	26
256	263	11.2	.5	19		1.65	19
263	278	5.3	.5	19		3.49	19
270	282	97.3	1	37		.38	37
		797.8		3267		5.98	5390
NIUE							
157	191	20.1	.1	4		.18	4
164	192	31.4	.2	7		.24	7
171	192	10.9	.1	4		.34	4
178	219	57.2	1.6	59		1.03	59
185	215	T	.2	7			7
192	220	71.6	2.5	93		1.29	93
199	215	T	2.3	85			85
206		49.8	Sam. lost				
213	249	16	2.3	85	C	5.32	224
220	249	5.3	1.7	63	C	11.87	128
227		43.9	Sam. lost				
234	277	8.4	1.1	41	C	4.85	86
241	275	6.1	2.3	85	C	13.95	149
248	275	9.1	1.6	59	C	6.51	90
255	277	16.5	.8	30		1.79	30
263		1.3	Sam.lost				
269	305	15.7	.7	26		1.65	26
		363.3		648		4.08	992
TONGA							
204	221	50	12.1	448	C	8.95	937
213	227	2.8	1	37		13.21	37
220	242	3.6	1.5	56	C	15.42	98
227	241	25.9	1.5	56		2.14	56
234	249	.8	.2	7		9.25	7
241	254	1.5	.5	19		12.33	19
248	262	20.3	1.3	48		2.37	48
255	263	40.4	1.3	48		1.19	48
263	275	66	2.1	78		1.18	78
		211.3		796		7.34	1328

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
AITUTAKI							
156	220	28.2	.5	19		.66	19
163	220	50.6	.3	11		.22	11
171	220	53.6	1.2	44		.83	44
178	220	21.8	1	37		1.70	37
186	220	30.5	.4	15		.49	15
192	220	16.5	109.3	4044	C	245.10	24585
199	220	9.7	14.2	525	C	54.16	1502
208	382	145.8	1.9	70		.48	70
215	382	16.5	.3	11		.67	11
219	382	12.7	.8	30		2.33	30
226	382	10.2	1.1	41	C	3.99	262
231	382	58.9	1.4	52		.88	52
237	382	1.5	.4	15		9.87	15
244	382	6.4	.5	19	C	2.89	78
251	382	11.2	.4	15		1.32	15
258	384	13.5	.7	26		1.92	26
265	382	2.8	.2	7		2.64	7
272	382	1.3	.4	15		11.38	15
		491.7		4995		18.97	26794
RAROTONGA							
157	179	14	.3	11		.79	11
164	179	22.6	.3	11		.49	11
171	193	22.1	.3	11		.50	11
178	193	11.9	.7	26		2.18	26
188	207	114.8	67	2479	C	21.59	20225
199	220	1.3	5	185		142.31	185
204	220	T	.3	11			11
209	256	41.1	5.8	215		5.22	215
218	256	86.1	15	555		6.45	555
226	256	4.1	1.8	67		16.24	67
232	256	1.5	2	74		49.33	74
242		NS					
254	277	T	1.7	63			63
261	285	6.1	1.8	67	C	10.92	92
268	285	13.2	1.4	52		3.92	52
		338.8		3826		21.66	21598

TBA DEPOSITION 1968

Detonation Day Numbers; A=189, B=197, C=216, D=237, E=252.

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
TARAWA							
190	200	4.3	.2	7			7.00
198	214	16.5	.1	4		.22	4.00
205	214	3.8	.2	7			7.00
212	228	9.7	2.4	89	B	9.15	212.20
219	232	12.7	4.9	181	B	14.28	316.50
226	241	5.6	1.5	56	B	9.91	91.53
233	241	1.3	1.9	70			70.00
240	255	T	<.1				
247	255	7.9	2.9	107	C	13.58	141.33
254	270	52.3	5.5	204		3.89	204.00
261	270	26.4	4.7	174		6.59	174.00
268	287	93.3	8.1	300		3.21	300.00
275	287	45	5.5	204		4.52	204.00
282	298	3.3	.7	26			26.00
289	302	0	.2	7			7.00
296	218	15.7	1.2	44		2.83	44.00
303	316	9.4	1.4	52		5.51	52.00
310	325	T	.1	4			4.00
317	325	9.6	.5	19		1.93	19.00
324	337	42.2	.7	26		.61	26.00
331	357	23.4	.5	19		.79	19.00
		382.4		1598		6	1928.56
FUNAFUTI							
188	200	68.6	.1	4		.05	4.00
193	200	T	.1	4			4.00
200	214	52.2	.9	33		.64	33.00
207	214	17.8	9.2	340	B	19.12	643.47
213	224	90.4	49.3	1824	B	20.18	3417.76
220	232	19.1	15.2	562	B	29.45	930.79
228	241	19.1	7.3	270	C	14.14	651.68
235	241	14	7.1	263	C	18.76	365.16
242	255	64.5	29.7	1099	D	17.04	5111.18
249	256	16.5	8.1	300	D	18.16	520.20
256	270	47.5	28.3	1047	D	22.04	2030.96
263	270	158.3	16.1	596		3.76	596.00
270	287	26.9	10.2	377	E	14.03	838.22
277	287	54.6	10.2	377		6.91	377.00
284	302	60.2	5.8	215		3.56	215.00
291	302	77.1	7.1	263		3.41	263.00
298	316	30	2.1	78		2.59	78.00
305	316	21.6	1.4	52		2.40	52.00
312	325	34	3.1	115		3.37	115.00
319	326	150.4	8.4	311		2.07	311.00
324	339	20.3	.9	33		1.64	33.00
		1043.1		8162		10	16590.42
SUVA							
189	198	53.4	<.1				
196	204	6.9	.2	7		1.07	7.00
203	211	15.5	.6	22		1.43	22.00
210	218	31	15.9	588	B	18.98	1046.00
217	226	2.5	5	185	B		288.94
224	232	14.3	9	333	B	23.29	454.66

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
231	249	7.9	4.2	155	C	19.67	400.27
238	249	19.3	7.1	263		13.61	263.00
245	253	74.4	19.7	729		9.80	729.00
252	261	.8	2.5	93			93.00
259	267	6.4	6	222	D	34.69	322.10
266	274	11.9	10.6	392	E	32.96	674.62
273	283	156.7	24.3	899		5.74	899.00
278	287	2	2.8	104			104.00
284	291	33.6	15	555		16.52	555.00
291	298	15.7	5.4	200		12.73	200.00
298	305	11.2	4.2	155		13.88	155.00
305	316	30.3	4.4	163		5.37	163.00
312		NS					
319		NS					
326	333	.8	.1	4			4.00
333	340	0	<.1				
		494.6		5069		13	6380.60
APIA							
190	198	6.9	.1	4		.54	4.00
198	205	13	.2	7		.57	7.00
205	214	43.1	5.6	207		4.81	207.00
212	224	78.8	26.3	973	B	12.35	1970.08
219	249	161.3	11.7	433		2.68	433.00
226	233	10.2	5.6	207	C	20.31	391.68
233	248	0	<.1	0			0.00
240	249	14.2	10.2	377	D	26.58	377.00
247	255	7.4	5.3	196	D	26.50	397.01
254	262	46.5	7.1	263		5.65	263.00
261	272	48.8	12.7	470	E	9.63	1225.04
268	283	80.3	25.7	951	E	11.84	2102.93
275	282	0	1.1	41			41.00
282	290	15.2	3.6	133		8.76	133.00
289	302	47.5	3.7	137		2.88	137.00
295	303	70.4	8.1	300		4.26	300.00
302	312	341.4	7.3	270		.79	270.00
309	317	117.5	6	222		1.89	222.00
317	324	19.3	2.5	93		4.79	93.00
324	331	7.4	1.1	41		5.50	41.00
331	338	.3	.8	30			30.00
		1129.5		5354		8	8644.74
NUIE							
190	205	3.3	.1	4			4.00
197	246	23.4	.2	7		.32	7.00
204	245	1.3	.1	4			4.00
211	246	11.9	3	111	B	9.33	499.12
217	245	2	.4	15			15.00
224	274	56.1	7.3	270	B	4.81	949.90
232	274	22.4	3.2	118	C	5.29	555.29
239	274	40.9	6.5	241	C	5.88	729.72
246	274	2	10.6	392	D		2139.24
253	304	7.6	1.7	63	D	8.28	350.75
260	303	28	1.6	59		2.11	59.00
265	303	92.5	12.2	451	E	4.88	2327.63
271	303	9.2	.5	19		2.01	19.00
278	304	78.8	6.3	233		2.96	233.00
287	331	66.6	6.1	226		3.39	226.00

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
294	332	53.3	4.6	170		3.19	170.00
301	330	59.2	3	111		1.88	111.00
309	367	38.6	1.6	59		1.53	59.00
316	367	42.7	1	37		.87	37.00
323	367	38.4	1.3	48		1.25	48.00
330	367	0	.3	11			11.00
		678.2		2649		3	8554.64
TONGA							
190	198	6.1	.2	7		1.21	7.00
197	214	8.6	.1	4		.43	4.00
204	218	.3	.3	11			11.00
211	224	10.4	3.3	122		11.74	122.00
218	226	12.7	5.5	204	B	16.02	299.76
225	240	38.6	23.7	877	C	22.72	2845.20
232	239	144.7	20.6	762		5.27	762.00
239	253	8.9	7.2	266	C	29.93	471.31
246	260	24.9	5.2	192		7.73	192.00
253	260	57.7	20.7	766	D	13.27	1183.86
260	273	7.9	2.6	96		12.18	96.00
267	275	1	1.3	48			48.00
274	281	.8	1.9	70			70.00
281	291	45.7	10.2	377		8.26	377.00
288	304	37.6	4.9	181		4.82	181.00
295	304	9.7	3	111		11.44	111.00
302	309	T	.1	4			4.00
309	323	19.6	3.5	130		6.61	130.00
316	324	4.6	1.5	56			56.00
323	330	1.8	.2	7			7.00
330	338	0	.1	4			4.00
334	343	0	.1	4			4.00
		441.6		4299		11	6986.13
AITUTAKI							
190	268	3.6	.4	15			15.00
197	268	2.8	.3	11			11.00
205	268	26.9	.7	26		.96	26.00
213	267	8.4	6.2	229	B	27.31	1348.24
219	267	62	23.4	866	B	13.96	3472.39
225	267	65.8	15.8	585		8.88	585.00
231	267	5.1	3.8	141	C	27.57	610.60
238	267	20.6	12.6	466	C	22.63	1278.64
245	267	50.6	13.6	503		9.94	503.00
253	329	6.9	1	37		5.36	37.00
260	329	.3	.4	15			15.00
267	326	16.5	1.8	67		4.04	67.00
274	326	18.8	3	111		5.90	111.00
281	326	11.4	1.3	48		4.22	48.00
288	326	5.1	1.3	48		9.43	48.00
295	329	2.3	.6	22			22.00
302	358	7.1	.9	33		4.69	33.00
310	358	122.7	2.6	96		.78	96.00
		436.9		3319		10	8326.87
RAROTONGA							
191	225	14	.4	15		1.06	15.00
198	226	21.8	8.8	326	B	14.94	18516.63
204	225	8.9	1.3	48		5.40	48.00

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
211	224	4.6	3.1	115			115.00
218	231	2.5	5.9	218			218.00
224	247	154	34.2	1265		8.22	1265.00
230	253	31	8.7	322	C	10.38	1033.26
238	253	101.8	30.2	1117	C	10.98	2085.18
245	267	61.5	2.9	107		1.74	107.00
252	267	18.3	5.8	215	D	11.73	493.02
259	273	16.8	2.3	85		5.07	85.00
266	296	34.3	5.7	211		6.15	211.00
273	266	13.5	1.3	48		3.56	48.00
280	294	7.4	2.1	78	E	10.50	126.40
287	323	26.7	3.6	133		4.99	133.00
294	322	4.8	1.6	59			59.00
301	329	4.6	1.3	48			48.00
311	344	3.8	1.4	52			52.00
322	344	44	1.6	59		1.35	59.00
329	357	10.2	1.3	48		4.72	48.00
333	357	1	.2	7			7.00
		585.5		4577		6	24772.488

TBA DEPOSITION 1970

Detonation Day Numbers; A=136,B=143,C=151,D=176,E=185,F=209,G=215,H=219

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
TARAWA							
139	160	19.6	.2	7		.38	7
146	160	4.1	.03	1			1
153	161	27.4	1.33	49		1.80	49
160	168	32.5	1.51	56		1.72	56
167	174	25.9	2.51	93	B	3.59	126
174	182	1	.66	24			24
181	188	7.6	1.69	63	C	8.23	80
188	197	48	8.05	298	C	6.21	387
195	204	11.7	1.04	38	D	3.29	61
202	209	2	.51	19			19
209	217	.8	.32	12			12
216	231	5.3	.38	14		2.65	14
223	231	97.8	1.9	70		.72	70
230	238	.3	.42	16			16
237	246	1.3	.41	15			15
244	258	.3	.31	11			11
251	260	1.3	.21	8			8
258	267	0	.06	2			2
265	274	0	.1	4			4
272	282	T	.34	13			13
279	289	0	.06	2			2
286		Sam.lost					
293	306	2.3	.73	27			27
300	313	.5	.15	6			6
		289.7		848		3.17	1011
FUNAFUTI							
142	160	26.4	.15	6		.21	6
150	162	127	1.53	57		.45	57
158	168	20.1	3.16	117	B	5.82	216
163	174	25.9	4.16	154	B	5.94	260
170	182	127	2.84	105		.83	105
177	189	55.9	27.09	1002	C	17.93	1580
184	197	120.4	9.84	364		3.02	364
191	204	52.3	5.75	213		4.07	213
196	208	77.7	2.07	77		.99	77
200	208	49.5	10.73	397	E	8.02	663
202	209	71.4	3.07	114		1.59	114
206	217	51.6	1.81	67		1.30	67
211	217	45.5	2.3	85		1.87	85
215	225	89.4	1.69	63		.70	63
219	231	56.4	1.67	62		1.10	62
226	238	63.2	25.97	961	G/H	15.20	2656
233	247	105.7	11.73	434		4.11	434
238	251	116.8	7.02	260		2.22	260
242	257	65	2.88	107		1.64	107
247	260	34.3	9.34	346	G/H	10.08	532
254	267	54.9	2.98	110		2.01	110
261	274	40.9	5.38	199	G/H	4.87	272
264	274	72.6	4.42	164		2.25	164
		1549.9		5460		4.18	8465
SUVA							
140	147	t	.11	4			4

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
147	154	12.4	.19	7		.57	7
155	167	9.9	3.49	129	B	13.04	297
162	187	22.8	.87	32		1.41	32
168	177	96	6.51	241		2.51	241
175	183	177	21.6	799		4.52	799
182	189	6.9	6.98	258	C	37.43	330
187	194	63.5	18.25	675		10.63	675
190	196	55.9	11.12	411		7.36	411
196	208	9.7	5.38	199	D	20.52	350
203	215	6.4	3.71	137	E	21.45	253
208	217	143.8	11.64	431		2.99	431
212	222	82.5	6.91	256		3.10	256
217	226	6.4	2.26	84	E	13.07	113
224	236	5.1	2.69	100	E	19.52	137
231	240	31.5	3.23	120		3.79	120
238	246	t	.39	14			14
245	257	26.2	7.47	276		10.55	276
252	260	4.8	3.43	127			127
259	267	10.2	3.42	127	G/H	12.41	156
264	274	108	8.42	312		2.88	312
268	274	1	.95	35			35
272	282	8.4	2.96	110	G/H	13.04	134
280	302	9.1	2.17	80	G/H	8.82	115
287	300	5.8	2.11	78	G/H	13.46	96
294	306	16.5	2.42	90		5.43	90
301	315	115.6	5.47	202		1.75	202
		1035.4		5334		9.21	6012
APIA							
141	154	8.4	<.1				
149	161	30.6	.72	27		.87	27
155	162	.8	.47	17			17
161	168	52.3	2.09	77		1.48	77
166	170	87.4	3.5	130		1.48	130
169	177	24.6	4.06	150		6.11	150
175	182	51.1	15.64	579	C	11.32	787
182	188	6.9	3.75	139	C	20.11	172
189	196	52.8	6.07	225		4.25	225
196	203	13.7	6.31	233	D	17.04	335
203	215	1.3	2.06	76			76
210	218	6.1	4.05	150	E	24.57	209
216	224	14.7	1.79	66		4.51	66
224	231	22.9	1.96	73		3.17	73
231	240	11.7	19.08	706	G/H	60.34	1281
238	246	4.1	1.51	56			56
245	257	58.4	5.27	195		3.34	195
252	264	18.8	2.12	78		4.17	78
259	273	86.4	4.53	168		1.94	168
266	279	59.4	3.9	144		2.43	144
273	286	11.4	2.19	81		7.11	81
280	288	24.1	1.82	67		2.79	67
287	295	90.4	4.7	174		1.92	174
294	306	8.9	1.09	40		4.53	40
		747.2		3651		9.17	4627
NIUE							
143	188	15.5	.21	8		.50	8
150	188	8.1	.33	12		1.51	12
157	188	14	1.03	38		2.72	38
164	188	34.5	1.53	57		1.64	57
172	217	25.4	.85	31		1.24	31
179	217	10.9	1.83	68	C	6.21	189
186	217	.8	.36	13			13
193	217	84.3	9.95	368		4.37	368
200	243	19.1	2.39	88		4.63	88
207	244	1.8	.8	30			30
214	244	8.4	1.93	71	E	8.50	167
221	244	0	.78	29			29
228	274	7.1	.95	35	G/H	4.95	253
235	273	0	.11	4			4
242	274	2	1.29	48			48
249	274	0	.65	24			24
256	306	2.3	1.04	38			38
263	306	0	.22	8			8
270	306	47.5	2.26	84		1.76	84
280	329	28.7	4.97	184	G/H	6.41	367
291	329	23.6	2.1	78	G/H	3.29	128
298	329	5.6	.99	37	G/H	6.54	54
		339.6		1353		3.39	2039
TONGA							
139	146	T	.39	14			14
146	160	1.3	.14	5			5
153	162	3.6	.32	12			12
160	170	5.1	1.55	57		11.25	57
167	177	.8	.67	25			25
174	182	52.6	15.38	569		10.82	569
181	188	23.4	11.97	443	C	18.93	570
188	196	45.5	14.98	554		12.18	554
195	217	1.8	1.79	66			66
202	210	8.1	4.75	176	E	21.70	279
209	217	5.1	2.7	100	E	19.59	141
216	223	8.6	3.7	137	E	15.92	175
223	231	10.9	4.77	176	E	16.19	222
230	243	9.7	1.91	71		7.29	71
237	247	19.8	2.77	102		5.18	102
243	258	28.2	3.61	134		4.74	134
251	265	5.8	1.41	52		8.99	52
258	265	2	1.92	71			71
265	274	1.3	.5	19			19
272	281	14.5	1.84	68		4.70	68
279	288	.5	1.28	47			47
286	294	T	.57	21			21
293	306	27.4	2.25	83		3.04	83
299	308	4.8	1.4	52			52
		280.8		3055		11.46	3410
AITUTAKI							
142	264	.3	.45	17			17
149	264	3.8	.15	6			6
156	264	1.5	.7	26			26
163	265	33.5	.33	12		.36	12
170	264	3.3	.48	18			18
177	265	T	.25	9			9
184	265	11.2	.6	22		1.98	22
191	265	38.6	2.57	95		2.46	95

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
198	265	9.1	1.75	65	E	7.12	573
205	264	T	.21	8			8
212	265	5.6	2.36	87	E	15.59	322
219	265	41.4	2.71	100		2.42	100
226	265	58.9	12.48	462	G/H	7.84	3442
230	265	54.1	6.1	226		4.17	226
234	265	3.3	1.16	43			43
240	266	95.5	9.92	367		3.84	367
247	302	17.5	1.83	68		3.87	68
253	302	3	1.31	48			48
258	302	62.7	6.01	222		3.55	222
261	302	54.6	1.23	46		.83	46
263	302	.5	.19	7			7
268	302	5.3	1.01	37	G/H	7.05	69
		503.7		1991		4.07	5745
RAROTONGA							
141	161	102.5	.17	6		.06	6
149	167	6.4	.29	11		1.68	11
157	168	4.3	2.61	97			97
164	182	9.9	.56	21		2.09	21
171	201	1.3	.5	19			19
178	198	21.3	1.09	40		1.89	40
185	195	2.8	.68	25			25
190	203	113.2	7.92	293		2.59	293
194	205	11.7	4.63	171	D	14.64	304
199	230	12.7	3.43	127	D	9.99	353
206	230	1	2.34	87			87
213	238	1.5	4	148			148
220	238	40.6	2.36	87		2.15	87
227	261	82	6.07	225		2.74	225
233	260	19.3	4.28	158	G/H	8.21	519
240		NS		0			0
247	286	40.6	2.02	75		1.84	75
254	286	4.3	.6	22			22
261	288	42.9	10.41	385	G/H	8.98	684
268	281	1	1.72	64			64
275	295	9.1	5.49	203	G/H	22.32	290
282	293	1	1.24	46			46
289	316	5.6	2.19	81	G/H	14.47	119
294	322	73.4	.1	4		.05	4
298	316	36.1	1.87	69		1.92	69
		644.5		2463		5.98	3605

TBA DEPOSITION 1971

Detonation Day Numbers; A=157, B=164, C=186, D=221, E=227.

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
TARAWA							
159	169	61.2	.52	19		.31	19
166	176	12.2	.43	16		1.30	16
173	183	23.4	1.33	49		2.10	49
180	189	25.9	3.67	136	B	5.24	232
187	200	22.6	1.66	61		2.72	61
194	211	18.6	1.68	62	B	3.34	107
201	210	3.2	1.79	66		20.70	66
208	221	27.9	2.83	105	C	3.75	183
215	231	20.1	1.24	46		2.28	46
222	231	12.8	.51	19		1.47	19
229	238	9.5	.57	21		2.22	21
236	246	.1	.28	10		103.60	10
243	263	1.5	.27	10		6.66	10
250	266	1.3	.78	29		22.20	29
257	271	17.6	2.58	95	E	5.42	151
264	281	14.5	.61	23		1.56	23
271	281	6.3	.49	18		2.88	18
277	287	3.0	.88	33		10.85	33
284	295	4.2	.75	28		6.61	28
292	306	64.6	1.38	51		.79	51
299	309	28.5	.43	16		.56	16
		379.0		913		9.84	1188
FUNAFUTI							
157	169	4.3	.45	17		3.87	17
162	179	9.7	.35	13		1.34	13
169	188	58.2	.40	15		.25	15
176	189	46.0	4.18	155	B	3.36	373
183	197	25.9	1.77	65		2.53	65
190	203	18.3	1.46	54		2.95	54
197	222	12.4	3.44	127	C	10.26	528
204	221	46.9	8.66	320	C	6.83	712
211	224	49.4	3.25	120		2.43	120
218	239	73.3	3.33	123		1.68	123
225	238	34.2	1.80	67		1.95	67
232	246	18.4	1.07	40		2.15	40
239	253	46.4	3.00	111		2.39	111
246	271	29.5	5.68	210	E	7.12	576
252	271	71.0	15.98	591	E	8.33	1165
259	277	57.1	5.68	210	E	3.68	359
267	281	25.0	2.54	94	E	3.76	135
274	299	67.2	3.52	130		1.94	130
281	299	77.1	4.30	159		2.06	159
288	309	38.0	2.98	110		2.90	110
295	307	2.3	.18	7		2.90	7
300	320	74.5	4.32	160		2.15	160
304	320	15.2	.14	5		.34	5
		900.3		2904		3.36	5043
SUVA							
170	180	17.8	.94	35		1.95	35
177	188	22.1	2.47	91		4.14	91
181	189	12.4	17.65	653	B	52.67	1037
186	196	21.6	12.91	478	B	22.11	749
194	207	87.2	26.48	980		11.24	980
201	208	16.3	8.50	315	C	19.29	498

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
208	218	7.7	8.23	305	C	39.55	477
215		NS		0			
223	231	42.1	9.79	362		8.60	362
230	238	24.2	5.23	194		8.00	194
236	244	16.6	2.99	111		6.66	111
243	252	.8	1.30	48		60.13	48
250	259	11.1	2.75	102		9.17	102
257	271	15.1	3.03	112		7.42	112
262	273	96.9	7.36	272		2.81	272
267	274	1.8	1.92	71		39.47	71
274	286	100.8	5.35	198		1.96	198
280	294	185.2	6.46	239		1.29	239
285	301	160.8	4.82	178		1.11	178
291	302	77.7	4.97	184		2.37	184
298	307	57.6	4.19	155		2.69	155
303	313	43.0	3.81	141		3.28	141
		1018.8		5223		13.30	6234
APIA							
160	169	71.1	.78	29		.41	29
167	179	29.5	.47	17		.59	17
174	196	29.7	33.63	1244	B	41.90	5025
181	194	1.8	6.67	247	B	137.11	488
188	196	36.9	8.82	326		8.84	326
195	211	13.0	6.52	241	C	18.56	822
202	210	1.1	4.04	149		135.89	149
209	218	.4	.59	22		54.58	22
216	237	22.4	3.57	132		5.90	132
223	235	32.8	2.41	89		2.72	89
230	239	1.1	.75	28		25.23	28
237	259	9.6	1.81	67		6.98	67
244	258	8.5	6.59	244	E	28.69	501
251	281	53.6	9.02	334		6.23	334
258	301		6.51	241			241
265	300	9.4	1.91	71		7.52	71
272	299	88.3	6.03	223		2.53	223
279	312	15.8	2.93	108		6.86	108
286	300	3.5	3.81	141		40.28	141
293	329	2.5	1.21	45		17.91	45
300	312	37.6	3.40	126		3.35	126
		468.6		4124		27.60	8984
NIUE							
161	235	4.6	.34	13		2.73	13
170	235	3.3	.56	21		6.28	21
177	235	0.0	.63	23			23
184	235	27.4	4.21	156		5.69	156
191	235	44.2	1.14	42		.95	42
198	235	23.6	11.05	409	C	17.32	2212
206	235	3.8	1.96	73		19.08	73
213	235	1.0	2.42	90		89.54	90
219	235	15.6	5.37	199	C	12.74	319
226	235	36.8	4.81	178		4.84	178
233	239	18.8	2.08	77		4.09	77
240	250	7.0	2.22	82	E	11.73	163
247	258	5.8	3.93	145	E	25.07	246
254	266	2.7	3.57	132	E	48.92	205
261	267	16.1	4.80	178	E	11.03	216
269	286	314.7	18.22	674		2.14	674
276	286	7.5	2.62	97	E	12.93	121
282	291	0.0	1.42	53			53
289	314	85.8	9.28	343		4.00	343
296	313	2.8	1.30	48		17.18	48
303	314	68.3	2.40	89		1.30	89
		689.8		3120		14.17	5361
TONGA							
159	169	15.5	.34	13		.81	13
166	176	1.8	.25	9		5.14	9
173	183	2.0	.25	9		4.63	9
180	197	16.5	1.40	52		3.14	52
187	197	4.1	2.07	77		18.68	77
194	207	6.9	1.27	47	C	6.81	150
201	210	T	.66	24			24
208	221	6.1	1.38	51	C	8.37	89
215	223	18.0	4.58	169	C	9.41	227
219	224	59.4	2.42	90		1.51	90
223	231	.8	.69	26		31.91	26
229	239	32.3	2.24	83		2.57	83
236	250	1.0	.61	23		22.57	23
243	253	.3	.45	17		55.50	17
250	263	T	.49	18			18
257	267	28.9	7.52	278	E	9.63	393
262	277	96.1	10.57	391		4.07	391
266	274	68.5	4.98	184		2.69	184
271	281	4.0	1.82	67		16.84	67
278	286	2.6	2.06	76		29.32	76
285	307	84.1	3.29	122		1.45	122
292	307	2.1	1.04	38		18.32	38
299	314	2.0	.36	13		6.66	13
304	320	106.0	2.15	80		.75	80
		559.0		1957		11.85	2270
AITUTAKI							
169	189	T	.25	9			9
176	189	8.9	3.51	130	B	14.59	313
183	211	21.3	2.12	78		3.68	78
190	208	3.0	1.06	39		13.07	39
197	218	21.3	13.92	515	C	24.18	1855
204	216	2.3	2.83	105	C	45.53	193
211	229	T	1.05	39			39
218	229	2.8	3.55	131		46.91	131
223	235	58.1	3.60	133		2.29	133
226	265	3.9	.39	14		3.70	14
232	265	2.6	.76	28		10.82	28
238	271	77.6	5.76	213		2.75	213
241	267	83.7	5.96	221		2.63	221
246	266	50.7	10.98	406	E	8.01	963
253	271	4.9	2.20	81		16.61	81
260	284	T	1.17	43			43
267	286	95.2	13.34	494		5.18	494
274	286	4.0	3.24	120		29.97	120
281	302	3.0	2.06	76		25.41	76
288	302	11.8	2.16	80	E	6.77	102
295	314	18.3	.99	37		2.00	37
302	314	5.8	1.15	43	E	7.34	51
		479.2		3036		14.29	5235
RAROTONGA							
163	194	1.0	.16	6		5.92	6
170	189	13.5	.06	2		.16	2

Day Numbers Collect.	Measure.	Rain mm	Measured Dep'n mCi/km2	Bq/m2	Peaks	Conc. Bq/l	Corrected Deposition Bq/m2
177	197	4.3	3.53	131		30.37	131
184	197	19.8	2.85	105		5.33	105
191	208	.5	1.59	59		117.66	59
198	224	37.8	6.90	255		6.75	255
205	223	15.5	8.53	316	C	20.36	702
212	244	13.3	1.80	67		5.01	67
219	244	25.5	4.25	157		6.17	157
226	252	18.6	1.31	48		2.61	48
233	252	5.1	1.45	54	E	10.52	297
243	267	103.7	8.28	306		2.95	306
254	265	2.7	1.88	70		25.76	70
261	274	6.1	3.07	114	E	18.62	168
268	341	44.2	2.02	75		1.69	75
275	343	24.3	3.15	117		4.80	117
282	NS			0			0
289	342	28.6	3.83	142		4.95	142
296	341	5.8	.05	2		.32	2
		370.3		2024		13.50	2709

TBA DEPOSITION 1973

Detonation Day Numbers; A=203,B=210,C=231,D=237,E=241

Day No. Collect.	Rain mm	Measured mCi/km2	Dep'n Bq/m2	Peaks	Conc. Bq/l
TARAWA					
193	0	.2	7		
200	0	.3	11		
207	0	<0.1	0		
215	1	.2	7		7.40
222	9	.1	4		.41
229	1	.2	7		7.40
236	1	.2	7		7.40
243	t	.5	19		
250	1	9.0	333	E	333.00
257	0	.4	15		
264	t	.3	11		
271	1	.3	11		11.10
277	14	.6	22		1.59
285	1	.2	7		7.40
292	2	.3	11		5.55
	31		474		42.36
FUNAFUTI					
193	3	.2	7		2.47
197	22	<.1	0		
204	47	<.1	0		
211	15	<.1	0		
218	0	.3	11		
225	68	.5	19		.27
232	38	.4	15		.39
235	11	.2	7		.67
239	35	.4	15		.42
246	20	66.2	2449	E	122.47
253	10	.9	33	E	3.33
261	28	<.1	0		.00
267	1	.2	7		7.40
274	6	.2	7		1.23
279	87	.1	4		.04
287	136	.4	15		.11
295	83	.2	7		.09
	610		2597		10.68
SUVA					
193	9	.3	11		1.23
200	72	.3	11		.15
205	5	.1	4		.74
212	87	.5	19		.21
219	1	.3	11		11.10
226	3	.2	7		2.47
233	37	10.3	381	C	10.30
240	6	.4	15		2.47
246	12	2.9	107	C	8.94
253	7	.9	33	C	4.76
260	17	.7	26		1.52
267	91	.4	15		.16
274	14	.3	11		.79
281	18	.3	11		.62
289	70	.5	19		.26
	449		681		3.05

Day No. Collect.	Rain mm	Measured mCi/km2	Dep'n Bq/m2	Peaks	Conc. Bq/l
APIA					
193	9	.3	11		1.23
200	2	.2	7		3.70
207	49	.2	7		.15
214	81	.4	15		.18
221	3	.4	15		4.93
228	63	.4	15		.23
235	79	97.4	3604	C	45.62
240	7	.7	26	C	3.70
242	19	1.1	41	C	2.14
246	13	28.6	1058	E	81.40
249	13	13.1	485	E	37.28
257	29	.9	33		1.15
263	73	.6	22		.30
271	161	.5	19		.11
277	64	.2	7		.12
283	131	.6	22		.17
291	76	.7	26		.34
297	84	.5	19		.22
	956		5432		10.17
NIUE					
194	25	.5	19		.74
204	13	.2	7		.57
212	7	.3	11		1.59
219	5	.2	7		1.48
226	9	.4	15		1.64
233	40	34.7	1284	C	32.10
240	59	28.5	1055	D	17.87
246	22	9.1	337	E	15.30
254	25	3.9	144	C	5.77
261	31	.9	33		1.07
268	19	.6	22		1.17
275	1	.4	15		14.80
282	1	.2	7		7.40
	257		2956		7.81
TONGA					
193	81	.2	7		.09
194	4	<.1	0		.00
201	11	.1	4		.34
208	5	<.1	0		.00
215	9	.3	11		1.23
222	1	.1	4		3.70
229	6	.2	7		1.23
236	9	34.2	1265	C	140.60
243	9	3.8	141	C	15.62
250	104	4.0	148	C	1.42
257	35	.4	15		.42
264	62	.5	19		.30
271	1	.3	11		11.10
278	5	.2	7		1.48
285	4	.2	7		1.85
292	82	.5	19		.23
297	21	.2	7		.35
	449		1672		10.59
AITUTAKI					
193	3	.1	4		1.23
200	1	<.1	0		
207	2	.2	7		3.70
214	214	2.0	74		.35
221	60	.5	19		.31
228	3	140.0	5180	C	1726.67
235	6	41.3	1528	C	254.68
242	12	263.0	9731	E	810.92
249	17	88.2	3263	E	191.96
256	12	1.1	41	E	3.39
263	7	1.3	48		6.87
270	3	.5	19		6.17
277	9	.9	33		3.70
283	77	.2	7		.10
290	3	.2	7		2.47
297	17	.6	22		1.31
	446		19984		177.28
RAROTONGA					
193	10	.1	4		.37
200	2	<.1	0		
207	6	<.1	0		
214	75	.2	7		.10
221	125	<.1	0		
228	2	NS	0		
235	9	19.1	707	C	78.52
242	29	206.0	7622	E	262.83
249	7	14.3	529	E	75.59
256	15	3.3	122	E	8.14
263	16	1.6	59		3.70
270	12	.6	22		1.85
277	17	.5	19		1.09
283	96	.8	30		.31
290	3	.2	7		2.47
297	10	.3	11		1.11
	434		9139		36.34

TBA DEPOSITION 1974
Detonation Day Numbers; A=168,B=189,C=199,D=207,E=227
F=237,G=258.

Day No. Collect.	Rain mm	Measured mCi/km2	Dep'n Bq/m2	Peaks	Conc. Bq/l
TARAWA					
164	7	.3	11		1.59
170	22	.5	19		.84
177	6	.3	11		1.85
184	56	.3	11		.20
190	NS				
196	37	.4	15		.40
198	19	4.1	152	B	7.98
205	77	39.0	1443	C	18.74
214	15	5.9	218	C	14.55
221	2	.9	33		16.65
228	5	.2	7		1.48
235	4	1.2	44		11.10
242	1	.6	22		22.20
249	8	4.7	174	E	21.74
256	18	3.4	126	E	6.99
263	30	3.6	133	E	4.44
270	6	1.1	41	F	6.78
277	T	.2	7		
284	T	.3	11		
291	45	1.5	56		1.23
300	15	1.2	44		2.96
	373		2579		7.87
FUNAFUTI					
164	55	.2	7		.13
174	16	12.8	474	A	29.60
181	39	.9	33		.85
188	16	.3	11		.69
195	75	119.0	4403	C	58.71
202	9	7.0	259	B	28.78
209	3	1.2	44		14.80
216	57	3.6	133		2.34
222	22	.9	33		1.51
229	16	1.4	52		3.24
238	33	.9	33		1.01
252	20	8.5	315	E	15.73
259	24	7.0	259	E	10.79
266	31	10.2	377	E	12.17
273	2	.9	33		16.65
280	23	15.8	585	G	25.42
287	11	2.3	85		7.74
294	55	5.3	196		3.57
	507		7333		12.98
SUVA					
165	2	<.1	0		
172	7	.3	11		1.59
179	6	.4	15		2.47
186	25	.2	7		.30
193	1	.2	7		7.40
200	32	19.3	714	B	22.32
214	29	6.9	255	C	8.80
222	158	11.2	414	B	2.62
229	57	13.3	492	B	8.63
238	8	5.4	200	D	24.98
245	131	35.0	1295	E	9.89
256	76	12.1	448	E	5.89
263	19	9.7	359	F	18.89
270	13	9.2	340	F	26.18
277	1	3.0	111		111.00
284	76	14.4	533	G	7.01
299	60	2.9	107		1.79
	701		5310		14.43
APIA					
166	1	<.1	0		
173	117	.7	26		.22
178	91	.5	19		.20
180	11	.1	4		.34
187	1	.1	4		3.70
194	12	3.1	115	B	9.56
201	9	82.2	3041	C	337.93
208	2	8.2	303	C	151.70
215	10	9.9	366	C	36.63
222	3	.5	19		6.17
229	0	.6	22		
236	1	2.1	78		77.70
243	13	1.9	70		5.41
250	79	16.5	611	E	7.73
255	T	.3	11		
257	4	2.0	74		18.50
264	1	.9	33		33.30
271	74	43.0	1591	G	21.50
278	114	58.8	2176	G	19.08
281	14	8.2	303	G	21.67
285	37	10.0	370	G	10.00
292	20	4.8	178		8.88
299	150	4.3	159		1.06
	764		9572		38.56
NUIE					
164	0	<.1	0		
169	10	.3	11		1.11
176	9	.2	7		.82
183	0	<.1	0		
190	4	.2	7		1.85
197	2	1.0	37		18.50
204	32	.8	30		.93
211	9	26.4	977	C	108.53
218	19	14.3	529	B	27.85
225	62	7.6	281	D	4.54
232	4	1.2	44		11.10
239	3	.2	7		2.47
246	NS	NS	0		
253	23	24.7	914	F	39.73
260	26	9.7	359	E	13.80
267	0	.2	7		
275	11	16.7	618	G	56.17
281	28	9.1	337	G	12.03
288	2	.7	26		12.95
296	9	.3	11		1.23
	253		4203		19.60

Day No. Collect.	Rain mm	Measured mCi/km2	Dep'n Bq/m2	Peaks	Conc. Bq/l
TONGA					
164	1	.2	7		7.40
171	3	.2	7		2.47
179	11	.4	15		1.35
186	4	<.1	0		
193	T	.2	7		
200	T	<.1	0		
207	63	71.5	2646	B	41.99
214	16	12.2	451	C	28.21
221	56	20.2	747	D	13.35
228	12	2.1	78		6.48
235	6	2.3	85		14.18
242	101	36.3	1343	E	13.30
249	62	14.5	537	E	8.65
256	18	3.0	111		6.17
263	3	2.1	78		25.90
270	17	12.1	448	F	26.34
277	150	40.6	1502	G	10.01
278	18	18.3	677	G	37.62
284	39	11.1	411	G	10.53
291	2	1.6	59		29.60
298	92	3.1	115		1.25
302	84	4.1	152		1.81
	758		9476		15.08
AITUTAKI					
164	0	<.1	0		
171	9	15.6	577	A	64.13
178	42	.7	26		.62
183	1	.1	4		3.70
185	45	.3	11		.25
192	1	28.3	1047	B	1047.10
199	2	259.0	9583	C	4791.50
206	16	117.0	4329	C	270.56
213	2	1.1	41		20.35
220	18	3.0	111		6.17
227	15	7.5	278	B	18.50
234	15	1.6	59		3.95
241	11	.9	33		3.03
248	27	10.3	381	E	14.11
255	2	1.4	52		25.90
262	3	14.7	544	F	181.30
269	4	3.7	137	F	34.23
276	37	19.3	714	G	19.30
284	11	4.0	148		13.45
297	26	1.9	70		2.70
	287		18145		343.20
RAROTONGA					
165	7	<.1	0		
171	4	.3	11		2.78
180	69	.2	7		.11
190	3	<.1	0		
199	30	26.7	988	C	32.93
210	8	10.0	370	B	46.25
221	5	4.4	163	D	32.56
228	5	2.9	107	B	21.46
235	16	9.5	352	E	21.97
242	16	3.8	141	D	8.79
249	9	2.1	78		8.63
256	6	2.5	93		15.42
263	18	9.7	359	E	19.94
270	1	.4	15		14.80
277	31	10.4	385	G	12.41
284	13	3.7	137	F	10.53
291	5	1.8	67		13.32
298	10	1.2	44		4.44
	256		3315		14.80

TBA in Air 1966

Date	Day No	Nandi mBq/m3	Rarotonga mBq/m3	Date	Day No	Nandi mBq/m3	Rarotonga mBq/m3
July 1	182	.74	.74	27	239	33.67	22.94
2	183	.74	.37	28	240	12.21	6.29
3	184	.74	.37	29	241	5.92	3.33
4	185	.37	.74	30	242	7.40	4.44
5	186	.37	.37	31	243	14.06	10.36
6	187	.37	.74	Sept 1	244	7.77	12.58
7	188	.37	.74	2	245	27.75	9.62
8	189	1.11	.74	3	246	12.21	4.81
9	190	2.22	2.22	4	247	2.59	2.22
10	191	2.22	2.22	5	248	1.85	5.55
11	192	2.22	1.85	6	249	4.81	8.88
12	193	1.11	1.85	7	250	5.92	7.03
13	194	1.48	.74	8	251	2.96	24.42
14	195	1.11	.74	9	252	3.33	11.84
15	196	8.51	2.96	10	253	4.81	9.99
16	197	14.80	3.33	11	254	3.33	6.66
17	198	17.39	1.11	12	255	4.07	5.55
18	199	12.95	1.48	13	256	5.18	2.96
19	200	58.09	2.59	14	257	20.35	11.84
20	201	79.92	1.48	15	258	7.40	5.92
21	202	34.41	2.96	16	259	45.14	
22	203	26.64	2.22	17	260	5505.60	7.40
23	204	30.34	1.48	18	261	2588.52	2.59
24	205	10.36	1.85	19	262	547.23	.37
25	206	11.47	3.70	20	263	318.94	9.62
26	207	11.10	11.10	21	264	38.11	2.59
27	208	7.03	4.81	22	265	6.66	8.51
28	209	5.18	1.85	23	266	9.99	28.86
29	210	3.70	1.11	24	267	18.87	49.95
30	211	1.85	1.11	25	268	11.84	39.59
31	212	3.70	.37	26	269	6.29	14.80
August 1	213	5.18	.74	27	270	6.29	10.36
2	214	2.22	.37	28	271	7.03	8.14
3	215	2.59	2.59	29	272	7.77	22.94
4	216	30.34	3.70	30	273	11.47	16.65
5	217	262.70	2.22	Oct 1	274	39.22	4.44
6	218	30.34	64.01	2	275	25.16	9.62
7	219	22.57	94.35	3	276	57.35	2.59
8	220	39.59	54.76	4	277	73.63	11.10
9	221	28.86	103.23	5	278	152.81	22.94
10	222	1.48	67.71	6	279	307.10	109.52
11	223	2.59	95.46	7	280	33.30	94.35
12	224	19.61	21.46	8	281	349.28	1758.24
13	225	20.35	10.73	9	282	231.99	4925.81
14	226	122.84	5.55	10	283	102.12	674.88
15	227	15.54	19.24	11	284	111.74	261.22
16	228	14.06	7.40	12	285	82.14	37.74
17	229	11.84	12.58	13	286	36.26	56.24
18	230	12.95	1.11	14	287	7.40	61.42
19	231	8.88	19.98	15	288	2.59	59.94
20	232	7.77	62.90	16	289	15.91	59.20
21	233	8.88	24.05	17	290	17.76	79.92
22	234	21.09	8.51	18	291	29.60	98.05
23	235	34.78	11.10	19	292	55.50	129.13
24	236	37.74	52.17	20	293	79.55	68.82
25	237	63.27	28.86	21	294	107.30	58.09
26	238	60.31	20.35	22	295	108.41	35.52

TBA in Air 1966

Date	Day No	Nandi mBq/m3	Rarotonga mBq/m3
23	296	127.65	85.47
24	297	131.72	103.97
25	298	167.24	111.37
26	299	129.13	14.80
27	300	89.91	21.09
28	301	34.41	48.10
29	302	28.49	39.59
30	303	11.47	38.85
31	304	14.43	32.56
Nov 1	305	15.54	31.82
2	306	64.38	22.94
3	307	69.56	24.05
4	308	79.55	25.16
5	309	64.38	25.16
6	310	51.43	27.75
7	311	48.47	19.98
8	312	57.72	37.00
9	313	44.77	42.55
10	314	46.25	41.81
11	315	41.44	38.85
12	316	48.84	85.47
13	317	55.87	13.69
14	318	55.13	7.77
15	319	23.68	8.88
16	320	17.39	11.84
17	321	26.64	13.69
18	322	28.12	19.61
19	323	16.28	15.17
20	324	15.91	22.94
21	325	26.64	29.97
22	326	19.24	36.63
23	327	35.89	44.40
24	328	48.10	15.54
25	329	29.23	12.21
26	330	23.68	17.02
27	331	4.44	13.69
28	332	5.55	5.18
29	333	11.84	14.06
30	334	21.46	3.70
Dec 1	335	27.75	1.85
2	336	25.16	18.87
3	337	24.42	16.65
4	338	4.44	31.82
5	339	7.40	24.05
6	340	4.44	15.91
7	341	8.88	12.95
8	342	9.99	21.09
9	343	8.88	16.65
10	344	9.25	17.02
11	345	16.65	10.36
12	346	17.39	6.66
13	347	11.47	6.29
14	348	12.21	7.40
15	349	4.44	5.92
16	350	9.62	3.70
17	351	7.03	2.96
18	352	5.92	5.18
19	353	6.29	2.22
20	354	4.81	2.59
21	355	4.07	.37
22	356	7.03	3.33
23	357	8.88	3.70
24	358	7.40	7.77
25	359	2.59	2.59
26	360	2.59	5.92
27	361	2.59	3.33
28	362	1.85	3.70
29	363	1.48	4.07
30	364	.74	
31	365	1.11	

TBA in AIR 1967

Date	Day No	Nandi mBq/m3	Samoa mBq/m3	Suva mBq/m3
June 1	152	1.11		.37
2	153	1.11	.37	.74
3	154	.37	.37	1.48
4	155	1.11	.37	1.48
5	156	.74	.37	1.11
6	157	1.11	.37	1.11
7	158	1.11	.74	1.11
8	159	1.48	.74	1.11
9	160	2.22	.37	1.48
10	161	.74	.37	.37
11	162	.37	89.91	.37
12	163	.37	1330.15	.74
13	164		1054.13	1.11
14	165	1.48	43.29	1.48
15	166	2.59	1.11	1.11
16	167	1.11	1.48	.74
17	168	1.48	1.11	1.11
18	169	.74	.37	.74
19	170	1.11	74.00	.37
20	171	1.48	18.50	1.85
21	172	1.48	13.69	.74
22	173	.74	12.95	1.11
23	174	.74	59.57	2.22
24	175	2.22	90.28	3.33
25	176	.74	54.02	3.33
26	177	8.88	24.79	11.84
27	178	12.95	37.00	8.88
28	179	7.77	9.62	7.77
29	180	12.21	2.22	14.43
30	181	7.03	1.11	2.96
July 1	182	3.70	1.48	3.33
2	183	1.85	1.11	1.48
3	184	.37	1.11	1.48
4	185	1.48	1.85	7.40
5	186	4.81	1.48	9.99
6	187	4.81	1.85	2.22
7	188	2.96	1.11	4.44
8	189	2.22	12.58	.74
9	190	2.22	22.20	1.11
10	191	1.85	7.77	1.85
11	192	1.11	4.07	1.85
12	193	3.33	4.07	1.48
13	194	4.07	1420.80	2.22
14	195	10.36	1609.50	11.84
15	196	15.17	258.63	7.77
16	197	27.01	107.30	13.69
17	198	22.94	25.90	22.94
18	199	12.95	22.20	27.38
19	200	10.73	51.43	53.65
20	201	80.66	76.96	81.03
21	202	190.18	28.12	110.26
22	203	59.94	15.54	129.13
23	204	79.55	35.15	81.03
24	205	227.18	52.17	94.72
25	206	30.34	68.45	49.95
26	207	10.36	81.03	15.54
27	208	8.51	25.16	18.50
28	209	50.32	14.43	31.08
29	210	43.66	39.22	56.98
30	211	43.66	37.00	21.09
31	212	11.10	7.77	11.84
August 1	213	18.87	27.01	15.91
2	214	21.09	16.28	18.13
3	215	17.76	14.06	43.29
4	216	58.09	24.79	104.71
5	217	29.23	73.26	17.02
6	218	24.05	58.83	44.40
7	219	18.13	48.47	17.39
8	220	17.39	15.54	16.65
9	221	14.06	11.10	21.46
10	222	16.28	5.92	18.87
11	223	21.09	14.43	29.60
12	224	21.83	5.92	17.39
13	225	20.35	2.59	21.83
14	226	21.09	2.22	15.17
15	227	14.43	2.96	7.03
16	228	14.80	5.92	13.32
17	229	21.09	10.36	15.54
18	230	27.75	18.50	18.50
19	231	26.64	18.13	4.81
20	232	28.12	5.55	7.77
21	233	40.70	6.29	32.56
22	234	33.30	7.77	29.60
23	235	9.25	31.08	7.77
24	236	8.88	21.46	14.06
25	237	13.69	11.10	18.87
26	238	9.62	4.44	16.65
27	239	14.43	4.44	14.06
28	240	7.03	5.18	5.92
29	241	5.55	12.21	8.88
30	242	11.84	14.43	16.28
31	243	10.73	20.72	9.25
Sept 1	244	16.65	19.24	13.69
2	245	7.77	22.20	3.70
3	246	16.28	28.86	16.28
4	247	19.61	35.52	17.76
5	248	13.32	18.87	15.91
6	249	12.21	9.25	12.58
7	250	11.10	16.65	14.80
8	251	10.36	9.25	1.48
9	252	5.18	3.33	5.55
10	253	7.40	4.81	4.07
11	254	.37	8.51	7.77
12	255	.37	5.92	4.07
13	256	2.59	3.33	1.48
14	257	5.55	5.18	14.80
15	258	1.85	7.77	11.84
16	259	.37	8.14	4.44
17	260	.37	5.92	6.29
18	261	6.29	5.18	12.95
19	262	3.33	3.70	5.92
20	263	1.48	4.44	2.96
21	264	5.55	5.92	7.03
22	265	7.40	2.59	5.92

TBA in AIR 1967

Date	Day No	Nandi mBq/m3	Samoa mBq/m3	Suva mBq/m3
23	266	1.85	3.70	3.70
24	267	5.55	4.07	10.73
25	268	8.14	3.33	15.17
26	269	9.62	1.48	14.80
27	270	4.44	2.22	11.47
28	271	5.18	1.85	9.99
29	272	3.33	5.55	8.88
30	273	2.96	5.55	

TBA in Air 1968

Day	Day No	Nandi mBq/m3	Samoa mBq/m3	Tonga mBq/m3	Suva mBq/m3
July 1	182				
2	183				
3	184				
4	185				.37
5	186	.44	.89		.37
6	187	.44	.89	.89	.37
7	188	.44	.89	.44	.37
8	189	.44	.89	.44	.37
9	190	.44	.44	.44	.74
10	191	.89	.44	.44	.37
11	192	.44	.89	.44	.37
12	193	.44	1.33	.44	.37
13	194	.89	.44	.44	.37
14	195	.44	.44	.44	.37
15	196	1.33	.44	.44	1.11
16	197	.44	1.33	.89	.37
17	198	.44	1.33	.89	.37
18	199	.44	73.70	.44	1.11
19	200	1.33	1.33	.89	.74
20	201	1.33	.44	.44	.37
21	202	.44	1.33	1.78	1.85
22	203	2.66	2.22	3.11	5.92
23	204	10.66	2.66	4.00	12.58
24	205	9.77	17.32	27.97	8.88
25	206	51.95	23.09	42.18	45.51
26	207	16.43	53.28	1.78	16.28
27	208	98.12	106.12	31.08	247.16
28	209	78.59	43.96	63.49	108.04
29	210	81.70	29.75	32.41	55.87
30	211	50.17	92.35	25.75	34.04
31	212	41.29	103.90	.44	40.33
August 1	213	44.40	174.49	51.06	68.08
2	214	64.38	148.30	79.48	85.84
3	215	117.66	168.28	55.94	91.02
4	216	48.40	224.22	23.53	56.98
5	217	83.47	231.32	21.76	70.30
6	218	92.35	89.69	24.42	57.72
7	219	39.52	31.08	30.64	40.70
8	220	55.94	46.18	32.86	34.04
9	221	55.94	179.38	42.18	40.33
10	222	61.27	151.85	104.78	51.43
11	223	111.89	62.16	81.70	181.67
12	224	178.04	100.79	83.03	183.89
13	225	168.72	169.16	115.88	176.86
14	226	168.72	97.68	169.16	191.29
15	227	214.45	241.54	158.51	161.32
16	228	199.80	186.92		88.43
17	229	199.80	193.58		183.15
18	230	76.81	196.25		95.46
19	231	78.59	256.63		76.96
20	232	57.72	150.52	61.72	58.09
21	233	83.92	94.13	26.20	93.24
22	234	103.45	71.48	54.61	64.38
23	235	93.24	56.83	90.58	69.56
24	236	88.36	54.17	91.46	89.17
25	237	79.92	65.27	64.82	56.98
26	238	62.60	347.21	86.14	65.86
27	239	60.83	383.17	73.70	64.38
28	240	53.72	319.68	61.72	65.12
29	241	76.37	94.57	134.98	138.38
30	242	136.75	64.82	82.14	165.39
31	243	161.62	140.30	120.32	161.32
Sept 1	244	11.54	172.72	23.09	35.52
2	245	19.98	48.40	38.63	45.14
3	246	10.21	39.96	74.15	58.46
4	247	20.42	20.87	44.40	68.08
5	248	27.53	18.20	37.74	47.36
6	249	40.85	28.86	44.40	49.21
7	250	71.04	33.30	67.49	75.85
8	251	62.60	31.97	43.96	55.50
9	252	63.49	35.96	23.53	55.13
10	253	63.49	42.62	43.51	61.79
11	254	97.24	28.86	55.94	95.46
12	255	57.72	41.74	44.40	63.27
13	256	106.12	47.51	33.74	71.41
14	257	33.74	45.29	40.85	54.02
15	258	33.74	58.16	35.96	32.93
16	259	9.77	13.32	28.86	18.50
17	260	57.28	42.18	34.19	45.51
18	261	47.95	71.04	32.41	44.03
19	262	41.74	35.08	26.20	27.75
20	263	20.87	35.96	26.20	24.79
21	264	20.87	121.21	27.97	21.83
22	265	15.10	185.15	26.20	28.86
23	266	34.19	235.76	19.09	29.23
24	267	38.63	314.35	139.86	25.16
25	268	39.07	139.86	38.18	33.67
26	269	43.51	55.50	54.17	46.99
27	270	54.17	85.25	43.07	52.54
28	271	41.29	76.81	56.83	50.32
29	272	30.19	79.48	74.59	45.14
30	273	23.53	83.92	49.28	58.09
Oct 1	274	52.84	29.75	22.20	58.09
2	275	33.74	44.84	35.08	38.48
3	276	53.72	24.86	35.52	63.64
4	277	61.27	32.86	28.42	50.69
5	278	36.41	27.97	36.85	43.29
6	279	44.40	50.17	38.18	39.96
7	280	58.61	35.08	27.97	65.49
8	281	27.53	32.86	33.74	29.97
9	282	21.76	33.74	22.64	16.28
10	283	31.97	43.51	13.32	24.42
11	284	36.85	32.86	32.86	32.56
12	285	32.41	30.19	27.53	42.92
13	286	37.30	7.55	34.19	29.23
14	287	15.98	10.66	20.42	27.01
15	288	17.76	9.32	23.09	24.79
16	289	26.64	15.10	19.09	28.49
17	290	31.97	18.20	19.98	34.04
18	291	12.43	.44	47.95	18.87
19	292	12.43	36.85	41.74	26.27
20	293	20.87	34.63	45.73	72.15
21	294	13.76	19.09	32.41	40.70
22	295	23.53	13.76	38.18	31.82

TBA in Air 1968

	Day	Day No	Nandi mBq/m3	Samoa mBq/m3	Tonga mBq/m3	Suva mBq/m3
	23	296		8.44	51.50	45.88
	24	297	105.67	41.74	31.97	57.35
	25	298	44.84	19.98	30.64	30.34
	26	299	27.53	7.55	37.74	29.60
	27	300	15.98	6.22	35.96	29.60
	28	301	21.31	6.22	22.64	28.12
	29	302	20.42	23.53	19.98	19.61
	30	303	8.88	23.53	16.43	14.06
	31	304	18.20	30.64	28.86	25.90
Nov	1	305	31.97	10.66	23.09	30.71
	2	306	36.85	23.53	24.42	24.79
	3	307	5.77	13.76	6.66	5.55
	4	308	23.09	15.98	14.65	
	5	309	23.53	7.10	9.32	
	6	310	35.52	6.22	36.85	
	7	311		14.21	28.42	
	8	312	57.72	13.32	23.98	
	9	313	33.74	10.21	19.98	
	10	314	43.96	23.98	26.20	
	11	315	36.85	23.98	26.20	
	12	316	36.85	18.65	21.76	
	13	317	42.62	15.98	27.08	
	14	318	31.08	11.99	32.41	
	15	319	6.66	13.32	31.08	
	16	320	13.76	11.99	28.86	
	17	321	4.00	9.32	30.19	
	18	322	4.00	9.32	40.85	7.03
	19	323	19.09	15.10	40.85	22.20
	20	324	31.52	5.33	31.52	33.30
	21	325	27.08	19.54	19.09	29.23
	22	326	28.86	25.75	22.20	25.16
	23	327	30.64	30.19	25.31	28.86
	24	328	32.86	32.86	25.75	31.45
	25	329	30.64	29.75	33.30	33.30
	26	330	36.85	32.41	31.08	33.30
	27	331	30.64	67.93	38.18	27.75
	28	332	32.86		38.63	28.86
	29	333		18.65	32.86	31.82

TBA in Air 1970

Date	Day No	Nandi mBq/m3	Suva mBq/m3	Samoa mBq/m3	Tonga mBq/m3
May 1	121	.44	.44	.44	.44
2	122	.89	1.33	.44	.44
3	123	.89	.89	.89	.89
4	124	1.33	1.78	.44	.89
5	125	2.22	2.22	1.33	1.33
6	126	1.78	1.33	.44	1.33
7	127	1.78	1.33	.44	.89
8	128	1.33	1.78	1.78	.89
9	129	1.33	1.78	.44	.44
10	130	1.33	1.33	.44	.44
11	131	.89	.89	.44	.00
12	132				.00
13	133				.00
14	134				.00
15	135				.44
16	136	1.78	1.78	.44	.44
17	137	.44	.89	.44	.89
18	138	.89	1.33	.44	.89
19	139	1.33	.89	.44	.89
20	140	1.33	1.33	1.33	.89
21	141	1.78	1.33	.44	.44
22	142	2.22	1.33	.89	.89
23	143	.89	1.78	1.78	.44
24	144	2.22	2.66	.89	.44
25	145	1.78	.44	.89	.44
26	146	1.78	.44	.44	1.33
27	147	1.33	.44	.89	.44
28	148	.44	.44	.44	.89
29	149	.44	.44	.89	1.33
30	150	.44	.44	1.33	.44
31	151	.44	.44	.44	2.22
June 1	152	.89	1.33	.89	2.22
2	153	.44	1.33	4.88	15.98
3	154	.00	5.33	3.55	71.04
4	155	10.66	18.20	22.20	36.85
5	156	18.65	17.32	19.09	12.88
6	157	11.99	23.98	20.87	11.10
7	158	11.54	24.42	91.02	31.08
8	159	27.08	54.61	41.29	17.32
9	160	9.32	23.53	65.27	23.98
10	161	13.76	18.20	91.02	5.77
11	162	15.98	9.32	15.98	3.55
12	163	.00	3.55	4.88	11.54
13	164	9.32	13.32		20.42
14	165	19.54	12.88	17.76	9.77
15	166	8.88	4.00	11.54	8.44
16	167	9.77	8.88	22.20	6.66
17	168	27.53	4.88	48.84	26.64
18	169	14.21	23.09	43.51	40.85
19	170	10.66	8.88	57.72	39.07
20	171	16.87	51.95	33.74	85.69
21	172	31.97	75.48	5.77	29.75
22	173	18.65	44.84	67.04	31.08
23	174	6.22	18.65	42.18	42.62
24	175	20.42	6.66	39.52	35.96
25	176	55.94	73.26	55.94	18.20
26	177	71.48	43.51	55.94	33.30
27	178	142.52	48.84	28.42	67.49
28	179		57.72	51.50	61.72
29	180	88.80	69.71	61.72	53.72
30	181	68.82	72.82	58.16	33.30
July 1	182	58.61	59.05	43.07	26.20
2	183	48.84	42.18	34.63	20.42
3	184	32.86	23.09	40.40	47.95
4	185	59.05	64.82	18.20	53.28
5	186	73.26	115.88	43.51	51.95
6	187	28.42	44.84	84.80	32.86
7	188	5.33	45.73	79.03	48.84
8	189	7.55	8.44	72.37	27.08
9	190	3.55	6.66	25.31	86.14
10	191		20.87	26.20	63.94
11	192	35.52	56.39	19.09	19.54
12	193	32.41	63.94	9.32	29.75
13	194	38.63	53.28	12.88	72.82
14	195	98.57	106.56	37.74	155.40
15	196	119.44	108.78	72.82	61.27
16	197		52.39	59.50	46.62
17	198	38.18	51.06	82.14	25.31
18	199	7.55	23.53	26.20	42.62
19	200	11.10	59.94	79.03	19.09
20	201	43.07	44.84	97.24	26.64
21	202	51.50	47.95	54.61	18.65
22	203	44.84	33.30	59.05	31.52
23	204	35.96	33.30	61.27	77.70
24	205	35.08	35.08	81.25	46.18
25	206	22.64	47.06	83.92	112.78
26	207	22.64	66.16	150.07	67.49
27	208	109.67	98.12	155.84	102.56
28	209	47.95	71.04	118.99	30.64
29	210	4.88	28.86	84.80	43.07
30	211	2.66	20.87	92.80	75.92
31	212	8.88	16.87	111.89	28.86
August 1	213	17.32	38.18	83.03	16.87
2	214	13.76	6.66	35.52	9.77
3	215	14.21	12.43	20.87	12.88
4	216	20.42	26.20	27.08	10.66
5	217	64.38	55.94	8.44	10.21
6	218	64.82	39.52	8.44	23.53
7	219	47.06	33.30	19.54	42.62
8	220	39.96	48.84	28.86	12.43
9	221	22.20	31.08	35.08	24.42
10	222	16.87	16.87	16.87	22.20
11	223	18.65	22.64	11.10	12.88
12	224	17.76	23.98	268.18	11.10
13	225	15.98	16.87	300.59	10.66
14	226	25.75	13.32	1051.84	12.43
15	227	14.65	10.66	840.49	20.87
16	228	5.33	8.88	1205.46	31.97
17	229	4.44	24.86	348.98	26.64
18	230	23.53	27.53	273.50	15.54
19	231	35.08	.00	22.64	9.77
20	232	36.85	28.42	71.48	26.64
21	233	44.40	35.08	66.60	32.41
22	234	8.88	17.76	19.98	19.09

TBA in Air 1970

Date	Day No	Nandi mBq/m3	Suva mBq/m3	Samoa mBq/m3	Tonga mBq/m3
23	235	20.42	29.75	63.49	23.09
24	236	35.96	42.18	79.48	16.43
25	237	51.95	43.51	24.86	35.96
26	238	59.94	51.06	19.98	24.42
27	239	67.93	45.73	49.28	17.76
28	240	66.60	29.75	75.48	18.20
29	241	19.98	17.32	20.87	22.64
30	242	35.96	21.76	7.55	14.21
31	243	35.08	31.52	7.55	10.21
Sept 1	244	29.75	30.64	25.31	13.32
2	245	16.43	19.54	45.73	30.19
3	246	27.08	13.76	23.98	11.10
4	247	20.87	7.10	37.30	14.65
5	248	19.54	20.42	29.75	13.32
6	249	35.52	30.19	31.97	22.64
7	250	50.62	34.63	22.64	32.86
8	251	52.84	59.94	18.65	59.94
9	252	93.24	55.94	17.76	59.05
10	253	29.75	18.65	21.31	70.60
11	254	15.10	17.32	50.62	57.28
12	255	21.31	43.51	60.83	26.20
13	256	3.11	12.43	9.77	27.97
14	257	24.86	37.74	14.21	21.31
15	258	42.18	34.63	13.32	18.20
16	259	32.86	33.74	7.99	16.87
17	260	26.64	29.75	11.10	14.65
18	261	26.20	26.64	1.78	12.88
19	262	26.20	27.53	12.88	19.09
20	263	22.20	17.76	20.42	24.86
21	264	6.66	6.22	18.65	33.74
22	265	5.77	8.88	35.96	20.87
23	266	16.43	20.42	18.65	20.87
24	267	28.86	38.63	32.41	23.53
25	268	28.86	26.20	40.40	31.97
26	269	25.75	31.97	56.83	27.97
27	270	27.08	.89	25.31	8.88
28	271	4.00	11.10	35.08	13.32
29	272	8.88	29.75	17.76	31.97
30	273	23.98	22.64	25.75	29.30
Oct 1	274	11.99	18.65	15.54	65.27
2	275		17.76	17.32	17.76
3	276	14.21	19.09	17.32	11.10
4	277	20.42	21.31	16.43	19.54
5	278	12.43	12.88	16.43	24.86
6	279	10.21	22.64	13.32	27.97
7	280	29.75	31.08	9.77	.00
8	281	27.53	20.42	11.10	19.09
9	282	20.87	23.09	5.77	30.64
10	283	25.31	29.30	4.44	33.30
11	284	.44	16.87	7.55	33.74
12	285	7.99	33.30	19.54	17.76
13	286		34.63	15.98	17.76
14	287	11.54	10.66	8.88	17.32
15	288	5.33	10.66	5.33	23.98
16	289	6.22	5.33	12.43	9.77
17	290	1.78	3.55	6.66	11.99
18	291	1.78	12.43	11.54	17.76
19	292	.44	11.99	14.21	20.42
20	293	6.22	17.32	17.76	18.65
21	294	15.98	23.09	19.09	20.87
22	295	15.98	18.20	12.88	7.10
23	296		21.76	8.88	15.10
24	297	14.21	17.76	7.99	16.43
25	298	12.88	14.65	13.32	11.54
26	299	11.54	16.43	12.88	11.10
27	300	11.10	16.87	19.54	15.98
28	301	4.44	15.98	25.75	
29	302		16.43	20.87	
30	303		8.88	3.11	
31	304		6.22		

TBA in Air 1971

Date	Day No	Nandi mBq/m3	Suva mBq/m3	Samoa mBq/m3	Tonga mBq/m3
June 1	152				
2	153				
3	154				
4	155	2.66			
5	156	2.66		1.33	.44
6	157	1.78		.89	.44
7	158	2.22		1.33	1.33
8	159	.89		.44	1.33
9	160	2.66		1.78	1.33
10	161	1.33		.89	.44
11	162	.89		1.78	.89
12	163	.89		.89	.44
13	164	1.33		2.66	.89
14	165	1.33		1.78	.44
15	166			2.22	.89
16	167	1.33	2.66	1.33	2.22
17	168	1.33	2.66	1.33	1.33
18	169	1.78	2.66	2.22	2.22
19	170	1.78	.89	508.38	2.22
20	171	.89	1.33	1831.50	4.44
21	172	2.22	4.44	1160.62	5.77
22	173	15.54	21.76	1485.18	9.32
23	174	56.83	102.12	752.14	32.41
24	175	59.05	76.81	123.43	11.99
25	176	44.84	53.28	103.90	20.42
26	177	42.18	39.52	115.88	12.43
27	178	38.18	44.40	578.09	15.98
28	179	28.42	35.52	572.32	17.76
29	180	22.64	27.53	733.93	83.47
30	181	11.99	156.73	567.88	279.28
July 1	182	18.65	52.39	164.28	212.68
2	183	95.46	81.70	161.62	177.60
3	184	46.62	83.92	95.46	49.73
4	185	90.58	67.93	67.04	40.85
5	186	47.06	32.86	149.63	31.08
6	187	42.62	36.85	98.57	40.85
7	188	50.62	68.38	56.83	79.03
8	189	43.96	31.97	73.26	73.26
9	190	36.85	27.08	45.29	32.86
10	191	36.85	48.84	44.40	15.10
11	192	27.97	39.96	75.92	31.97
12	193	77.70	76.81	72.37	66.16
13	194	43.07	70.60	58.61	77.26
14	195	10.21	52.39	43.51	58.61
15	196	1.33	20.87	392.05	30.64
16	197	2.66	37.30	1370.18	70.15
17	198	5.33		874.68	102.56
18	199	7.10	80.36	555.44	23.53
19	200	54.61	110.11	281.50	63.05
20	201	66.60	79.92	127.43	33.74
21	202	63.05	61.27	43.51	30.19
22	203	63.49	57.28	62.16	7.55
23	204	57.28	55.06	39.07	65.27
24	205	29.30	34.63	34.19	21.31
25	206	29.30	38.18	41.74	57.72
26	207	15.54	27.08	45.73	100.34
27	208	6.66	15.10	31.97	84.36
28	209	10.66	24.86	84.80	61.72
29	210	34.19	57.72	49.73	57.28
30	211	55.94	60.38	39.52	51.95
31	212	37.74	56.39		25.75
August 1	213	55.50	47.95	44.84	31.97
2	214	38.18	46.18	48.84	48.40
3	215	15.10	23.09	50.62	42.18
4	216	19.98	33.30	24.42	41.29
5	217	20.87	9.77	13.32	14.65
6	218	4.88	5.33	21.31	14.65
7	219	4.00	11.54	11.10	5.77
8	220	19.98	41.29	5.33	24.86
9	221	46.62	48.40	14.21	37.30
10	222	50.17	44.84	15.54	31.52
11	223		35.52	16.43	47.06
12	224		20.87	15.54	27.53
13	225		20.87	9.77	22.20
14	226		25.75	7.55	19.98
15	227		25.31	6.22	22.64
16	228	13.32	12.43	5.33	12.43
17	229	4.00	5.77	33.74	28.42
18	230	6.22	19.54	56.39	27.08
19	231	2.66	21.31	29.30	25.75
20	232	1.33	12.43	34.63	17.32
21	233	4.44	16.43	39.52	7.10
22	234	15.98	18.20	21.76	16.87
23	235	7.99	19.09	18.65	19.54
24	236	26.20	31.08	13.32	17.76
25	237	21.76		21.31	16.43
26	238	10.21	24.42	16.43	17.76
27	239	13.32	43.96	5.77	15.54
28	240	20.87	21.31	19.54	39.07
29	241	23.09	35.08	23.09	31.52
30	242	29.30	30.19	16.43	18.20
31	243	34.63	31.97	16.43	28.42
Sept 1	244	33.30	23.53	15.98	33.74
2	245	25.75	20.87	26.20	22.20
3	246	20.87	11.99	186.04	22.64
4	247	20.87	36.85	19.98	32.86
5	248	33.74	35.52	43.96	48.40
6	249	34.19	27.97	21.76	54.17
7	250	62.60	30.64	26.64	91.02
8	251	41.74	43.07	56.83	91.46
9	252		94.13	67.93	49.73
10	253	67.93	62.16	45.29	60.83
11	254	26.64	52.39	37.74	34.63
12	255	40.40	42.62	91.91	40.40
13	256	41.74	16.43	38.63	9.77
14	257	25.75	34.63	34.63	37.74
15	258	8.88	22.64	39.96	32.41
16	259	1.78	16.43	60.38	52.84
17	260	7.10	17.76	25.75	64.38
18	261	21.76	29.75	40.40	62.16
19	262	22.20	31.97	32.86	35.08
20	263	23.98	63.05	42.62	26.20
21	264	61.27	16.43	59.50	26.20
22	265	87.02	99.01	51.95	80.36

TBA in Air 1971

Date		Day No	Nandi mBq/m3	Suva mBq/m3	Samoa mBq/m3	Tonga mBq/m3
	23	266	99.01	102.12	43.07	17.32
	24	267	94.13	96.79	28.86	54.61
	25	268	71.48	72.82	15.10	75.04
	26	269	66.60	75.48	25.75	75.48
	27	270	64.82	66.16	24.42	40.85
	28	271	34.63	43.51	56.39	56.39
	29	272	46.62	55.06	83.47	54.17
	30	273	51.06	47.95	35.52	47.51
Oct	1	274	48.84	49.73	35.52	28.42
	2	275	43.07	50.17	48.40	17.76
	3	276	29.30	22.64	35.08	24.86
	4	277	6.66	9.32	23.09	29.75
	5	278	5.33	11.10	11.99	29.30
	6	128	18.20	35.52	18.65	20.42
	7	129	5.77	4.88	10.21	19.09
	8	130		3.11	17.32	12.88
	9	131	3.11	11.54	13.76	14.65
	10	132	5.33	51.95	31.97	36.41
	11	133	14.65		31.97	43.96
	12	134		4.88	21.76	30.19
	13	135	10.66	8.44	19.54	35.08
	14	136	5.33	10.21	26.64	39.52
	15	137		19.09	17.76	27.53
	16	138	27.97	31.08	11.99	21.31
	17	139	27.97	31.08	16.87	26.64
	18	140	19.54	26.20	12.88	14.65
	19	141	19.98	21.31	11.10	22.20
	20	142	9.32	14.65	8.88	25.31
	21	143	4.44	2.66	7.99	23.98
	22	144	16.43	8.44	12.88	32.41
	23	145	10.21	9.77	18.65	21.31
	24	146	11.10	13.76	13.76	15.98
	25	147	11.54	7.10	15.54	13.76
	26	148	11.10	9.77	21.31	13.76
	27	149	11.99	14.21	14.65	19.98
	28	150	19.09	17.76	11.99	19.54
	29	151	3.11	6.22	16.43	13.32
	30	152	6.22	6.22	7.55	14.65
	31	153	7.10	6.22	4.88	3.55

TBA in Air 1972

Date	Day No	Nandi mBq/m3	Suva mBq/m3	Samoa mBq/m3	Tonga mBq/m3
June 20	171	1.48	1.85	.37	.37
21	172	1.11	1.85	1.11	1.85
22	173	1.85	3.33	.74	2.22
23	174	2.22	2.59	1.48	1.11
24	175	2.22	2.22	1.11	
25	176	1.11	1.48	1.48	1.48
26	177	.37	3.70	1.11	1.48
27	178	2.59	2.59	.37	1.48
28	179	2.22	2.22	.74	
29	180	1.11	2.22	.37	1.85
30	181	1.48	1.85	.37	1.48
July 1	182	1.85	2.22	.37	1.85
2	183	2.22	3.33	1.85	3.70
3	184	1.85	1.11	2.22	2.22
4	185	1.48	1.48	1.48	1.48
5	186	1.48	1.11	2.22	.74
6	187	1.48	1.85	.37	1.85
7	188	.74	2.22	.37	1.48
8	189	2.22	2.96	.37	1.85
9	190	1.48		2.22	1.11
10	191	2.22	2.59	1.48	2.22
11	192	1.48	1.85	1.85	1.11
12	193	.00	.74	1.48	1.11
13	194	1.48	1.85	1.48	1.11
14	195	.37	1.11	1.11	.74
15	196	1.11	2.96	1.48	3.33
16	197	1.85	3.33	.52	5.18
17	198	2.22	4.07	1.11	4.44
18	199	1.48	4.44	.37	4.81
19	200	2.22	4.44	2.59	3.33
20	201	2.22	3.33	1.48	2.59
21	202	1.85	1.11	1.48	.74
22	203	1.11	1.85	1.85	1.11
23	204	1.11	2.22	1.48	1.48
24	205	2.96	3.33	.74	4.07
25	206	1.48	2.59	.74	2.59
26	207	2.96	1.85	.74	1.85
27	208	1.11	1.11	.74	1.48
28	209	1.85	.74	.37	1.85
29	210	.74	.37	.37	1.48
30	211	.37	.37	.37	.37
31	212	1.48	2.22	1.11	1.85
August 1	213	1.85	1.85	1.11	1.48
2	214	2.22	.37	1.11	1.48
3	215	1.11	1.48	1.48	1.11
4	216	1.11	1.48	1.11	1.11
5	217	2.22	2.96	.37	2.22
6	218	2.22	2.96	1.11	1.48
7	219	2.22	2.22	.37	1.48
8	220	2.22	2.22	.37	1.48
9	221	1.48	2.22	.37	2.22
10	222	1.85	2.96	.37	1.85
11	223	2.59	2.22	.37	2.22
12	224	1.48	1.85	.37	1.85
13	225	2.59	1.85	1.48	2.96
14	226	1.48	2.59	1.85	4.44
15	227	1.48	2.22	3.70	4.81
16	228	1.85	3.33	1.48	3.33
17	229	2.22	1.48	2.96	.74
18	230	1.48	1.85	4.44	2.96
19	231	2.22	2.22	5.55	2.59
20	232	4.07	8.51	4.07	6.29
21	233	5.55	9.99	5.18	4.81
22	234	1.48	7.40	2.96	6.29
23	235	7.77	8.14	1.85	4.44
24	236	.74	2.59	1.48	4.07
25	237	1.11	2.22	2.59	3.33
26	238	.74	1.11	1.85	.74
27	239	.74	.37	1.85	.74
28	240	.37	.74	1.48	.37
29	241	.37	.74	2.22	1.11
30	242	.37	.74	1.11	1.48
31	243	.74	1.11	1.11	1.85
Sept 1	244	.37	1.11	.74	1.48
2	245	.74	1.11	1.11	2.59
3	246	.74	.74	1.48	1.11
4	247	1.85	1.11	.37	2.22
5	248	1.85	2.22	.37	1.85
6	249	1.11	1.48	.37	.74
7	250	1.11	2.22	.37	1.48
8	251	1.11	.74	.37	1.85
9	252	.37	1.85	1.85	1.85
10	253	1.11	2.59	.37	1.48
11	254	1.11	1.48	.74	1.85
12	255	1.11	.37	.74	.74
13	256	.37	1.85	.37	.37
14	257	.74	.74	1.11	.37
15	258	1.48	.74	1.48	.37
16	259	.37	.37	1.85	1.48
17	260	.37	.37	.74	.37
18	261	.37	.37	1.11	.37
19	262	.37	.74	.74	1.11
20	263	1.48	1.11	2.59	1.11
21	264	1.11	2.22	.74	1.11
22	265	1.48	1.85	1.48	4.07
23	266	.37	2.22	1.48	.37
24	267	.37	.37	.74	1.11
25	268	.74	.37	1.85	.74
26	269	.37	.37	.74	1.48
27	270	.74	.00	1.11	.37
28	271	1.48	1.11	.37	.37
29	272		1.11	.74	.37
30	273		.74	.37	

TBA in AIR 1973

Date	Day No	Nandi mBq/m3	Samoa mBq/m3	Tonga mBq/m3
July 12	193	.74	.74	.74
13	194	.74		.74
14	195	.74		1.11
15	196	.74	.74	.37
16	197	.37	.74	.37
17	198	.74	.74	
18	199	.74	.74	
19	200	.74		.74
20	201	.74		
21	202	.74	.37	.74
22	203	.37	.74	.74
23	204	1.11		.74
24	205	.74	.74	1.11
25	206	1.11	.37	.74
26	207	1.48		.74
27	208		1.11	.37
28	209	1.11	.74	.74
29	210	.37		
30	211		.74	.37
31	212			.74
August 1	213	.37		
2	214			.37
3	215	.37	.74	
4	216		.37	
5	217	.74	.37	
6	218	1.11	.37	.37
7	219	1.11	.37	
8	220	1.11	1.11	
9	221	1.48	.74	1.48
10	222	1.48	1.11	.74
11	223	1.48		.74
12	224	1.11	.74	2.59
13	225	1.11	1.11	4.07
14	226	.74	1.11	2.22
15	227	1.11	.37	1.11
16	228	1.11	.74	1.11
17	229	.37	.74	.74
18	230	1.85	1.11	.74
19	231	1.11	.74	.74
20	232	.37	.37	1.48
21	233	1.11	1.85	.74
22	234	1.48	1.85	1.11
23	235	1.85	370.00	1.11
24	236	.74	277.50	.74
25	237	6.29	4329.00	1.11
26	238	6.29	1753.80	200.91
27	239	16.28	3.33	38.11
28	240	2.22	18.87	1.11
29	241	1.85	11.84	1.48
30	242	1.48	2.22	1.85
31	243	2.22	2.22	2.96
Sept 1	244	1.85	1.11	1.48
2	245	1.11	1.11	1.48
3	246	1.85	1.85	1.48
4	247	1.85	1058.20	.74
5	248	1.85	1609.50	1.48
6	249		44.77	1.11
7	250	2.22	795.50	2.59
8	251	8.14	60.68	.74
9	252	1.48	6.66	1.11
10	253	2.22	63.64	1.11
11	254	1.48	66.23	1.48
12	255	7.03	53.65	1.48
13	256	1.48	4.44	1.11
14	257	1.85	2.96	.37
15	258	2.22	2.96	.74
16	259	1.48	1.85	.74
17	260	1.11	1.48	1.11
18	261	1.48	2.96	9.99
19	262	2.59	2.59	29.23
20	263	3.33	9.62	3.33
21	264	3.70	.74	1.85
22	265	1.85	.74	1.85
23	266	1.11	.74	1.48
24	267	1.48	1.11	1.85
25	268	.74	1.48	1.48
26	269	1.11	1.11	1.11
27	270	1.11	.74	.74
28	271	1.85	.37	.37
29	272	.37		
30	273	.37	.37	
Oct 1	274	1.11	1.11	.74
2	275		.37	.37
3	276			.37
4	277		.74	1.11
5	278	.74		.74
6	279	.37	.74	.74
7	280	1.11	.74	.74
8	281	.37	1.11	.74
9	282	.74		.37
10	283	.74		1.11
11	284	.74		
12	285	1.11	.74	.74
13	286	1.11	.74	.74
14	287	1.11	1.11	.74
15	288	2.22	.37	.74
16	289	1.11		.74
17	290		.37	1.48
18	291	.74	.74	1.11
19	292	.37	.74	.74
20	293	1.48		.74
21	294	.74	.74	.37
22	295	.74	.74	.74
23	296		.37	.37
24	297		.37	.37
25	298	.74	.74	.37
26	299		1.11	
27	300			.74
28	301			
29	302	.37	.37	
30	303	.74	.74	1.11
31	304	.74		.37

TBA in AIR 1974

Date	Day No	Nandi mBq/m3	Samoa mBq/m3	Tonga mBq/m3	Rarotonga mBq/m3
June 13	164				
14	165		.74	.37	.74
15	166			.74	.37
16	167			.37	.37
17	168		.37		.37
18	169	.74		.37	
19	170	.74			
20	171	.37			
21	172	.37			.37
22	173	.37			
23	174	.74	127.65		
24	175	.37	216.08		
25	176	.37	177.60	.74	2.96
26	177	.37	1.85		
27	178		1.85	.37	.37
28	179	56.98	1.48	.37	.74
29	180	.37		11.10	
30	181	.74		.74	
July 1	182	.37	1.11	.74	
2	183	.37	.74	.74	.74
3	184	.74		.74	
4	185	.37		.37	
5	186	.37		1.11	
6	187	.37	1.48	.37	
7	188	.37	1.48		.37
8	189	.37		.37	
9	190	.37	.37	.37	
10	191	1.11	.74		
11	192	.37	.74		
12	193	.74		.37	.74
13	194	.74			.37
14	195	.37		.74	
15	196	.74			
16	197	.37	.74		566.10
17	198	.74	432.90	1.85	562.40
18	199	85.10	58.09	551.30	16.28
19	200	188.70	27.38	254.93	555.00
20	201	27.38	4.44	30.34	555.00
21	202	36.63	3622.30	1.11	555.00
22	203	8.51	22422.00	1.48	555.00
23	204	5.55	462.50	7.77	61.05
24	205	13.32	46.62	22.20	65.12
25	206	65.12	77.70	24.42	219.78
26	207	102.86	86.95	11.10	79.92
27	208	70.30	81.77	51.80	65.12
28	209	99.16	214.23	75.11	62.16
29	210	109.15	180.93	103.97	44.77
30	211	87.69	173.90	93.98	38.11
31	212	52.91	173.90	52.91	92.87
August 1	213	75.48	139.49	50.69	92.87
2	214	70.67	133.57	61.42	320.05
3	215	75.11	80.29		138.01
4	216	71.04	78.07	67.34	29.97
5	217	73.63	82.51	78.44	41.44
6	218	58.46	54.02	29.23	36.26
7	219	42.18	20.72	26.64	34.41
8	220	35.89	18.50	27.38	39.59
9	221	27.75	19.61	11.84	18.13
10	222	15.17	15.54	26.64	14.43
11	223	22.94	28.86	22.57	15.17
12	224	3.33	41.07	24.42	21.09
13	225	12.21	50.32	25.90	29.23
14	226	17.02	52.54	40.33	25.16
15	227	15.17	44.03	12.21	32.56
16	228	24.79	39.22	15.17	33.30
17	229	21.83	36.63	29.97	14.06
18	230	31.45	22.94	67.34	34.78
19	231	14.80	21.83	8.51	50.32
20	232	8.14	19.24	10.73	40.33
21	233	8.88	22.57	15.54	47.73
22	234	12.58	22.94	29.60	15.91
23	235	5.92	23.68	36.26	56.61
24	236	28.49	17.02	12.21	53.28
25	237	10.73	10.36	28.12	43.66
26	238	19.61	16.65	12.21	37.00
27	239	10.73	23.68	2.59	19.61
28	240	12.58	23.31	3.33	16.65
29	241	12.58	21.46	1.11	6.66
30	242	17.39	22.94	9.25	.00
31	243	.00	24.05	19.61	21.09
Sept 1	244	17.02	21.83	8.88	12.95
2	245	18.87	33.30	14.43	15.54
3	246	15.17	37.00	18.50	14.80
4	247	11.84	42.18	11.10	10.73
5	248	16.28	48.84	36.63	6.66
6	249	20.35	166.50	13.69	9.62
7	250	28.49	62.53	12.21	8.51
8	251	45.51	21.83	24.05	6.29
9	252	37.74	17.76	20.35	12.95
10	253	19.98	16.28	15.91	14.80
11	254	14.06	20.35	36.63	22.57
12	255	6.29	89.17	61.42	35.15
13	256	10.36	153.92	31.82	28.86
14	257	31.82	186.11	16.65	18.87
15	258	22.20	62.53	35.15	19.61
16	259	22.57	64.75	68.45	25.53
17	260	17.39	20.72	46.62	38.11
18	261	6.29	37.37	46.99	41.07
19	262	13.32	14.43	19.61	37.00
20	263	28.49	19.98	64.75	27.01
21	264	22.94	29.97	51.43	25.53
22	265	34.78	31.82	45.14	28.49
23	266	44.40	33.67	10.73	.00
24	267	34.78	67.71	13.69	36.26
25	268	30.34	62.16	16.65	9.99
26	269	.00	35.52	20.72	14.80
27	270	15.91	62.16	28.12	20.35
28	271	19.24	62.16	37.37	18.87
29	272	8.88	56.61	46.99	22.94
30	273	9.99	48.84	45.14	21.09
Oct 1	274	.00	20.72	9.25	20.72
2	275	3.33	52.54	19.24	17.76
3	276	15.54	39.59	17.76	15.91
4	277	38.48	36.26	23.31	19.61

TBA in AIR 1974

Date	Day No	Nandi mBq/m3	Samoa mBq/m3	Tonga mBq/m3	Rarotonga mBq/m3
5	278	28.12	60.31	35.52	75.48
6	279	22.20	42.92	49.21	52.17
7	280	32.93	66.97	51.80	7.40
8	281	101.75	81.40	35.15	14.06
9	282	147.63	46.62	14.80	8.88
10	283	54.39	58.46	11.10	5.92
11	284	45.14	37.37	15.17	11.84
12	285	18.13	27.01	7.40	22.57
13	286	7.03	18.87	16.65	12.58
14	287	18.50	27.38	11.10	8.51
15	288	23.68	22.20	16.28	5.55
16	289	9.99	23.31	28.12	9.25
17	290	18.13	18.87	19.61	11.84
18	291	18.13	21.09	21.46	9.99
19	292	11.47	35.15	27.38	14.06
20	293	26.64	30.34	46.25	14.43
21	294	19.24	23.68	54.39	10.36
22	295	22.57	36.63	43.29	10.36
23	296	15.91	11.47	49.21	10.36
24	297	24.42	14.43	29.60	16.28
25	298	33.67	11.47	27.01	18.13
26	299	10.36		22.57	19.98
27	300	10.73	13.32	14.06	22.94
28	301	11.84	11.47	4.44	20.72
29	302	5.18	8.88	4.07	16.65
30	303	5.18	4.81	12.58	15.54
31			14.06	2.96	16.28

debris. The correlation between the instrument readings and the appropriate guide level reading will be made at the National Radiation Laboratory on the basis of the local measurements transmitted by radio in all cases where a predetermined "reporting level" has been exceeded.

7. The "reporting level" has been set below the level which, under the worst possible conditions, would correspond to the "guide level". Even if a local operator observes a radiation level of five times the "reporting level", not more than one-fourth of the permissible radiation dose will be received as a result of two days' exposure to the fall-out, and not more than one-third during four days' exposure. Thus the hazards assessment based on the "reporting level" gives adequate time to take precautionary measures if these are found to be necessary. In the extremely unlikely event of radiation levels exceeding five times the "reporting level", simple prearranged protective measures will be put into operation locally. These arrangements will ensure that protective measures will be taken only when they are justified by the radiation levels reached.

(b) *Sampling for Laboratory Analysis*

8. Because the above arrangements provide adequate warning of any health hazard in the Pacific islands, there is no need to collect and analyse – as a matter of routine – samples of food and drinking water from the areas monitored. For the purpose of detecting even slight traces of radioactivity which may reach the islands, rainwater collectors are being placed at all the above stations and at Raoul, Funafuti, Tarawa, and at Nandi (Fiji), in addition to the one which has been operated for many years at Lauthala Bay (Fiji). In addition, an air sampler is to be operated at Rarotonga and at Nandi (Fiji). These samplers pump air through a filter which is periodically replaced and sent to the National Radiation Laboratory for measurement of radioactivity.

9. It could happen that New Zealand would receive fall-out which has travelled round the earth before it reaches the islands closer to the test site, but because of the time elapsed, its radioactivity would be low. Therefore, within New Zealand, the established fall-out monitoring network of the National Radiation Laboratory is being augmented by:

(a) Measuring the filters from the established air samplers at Auckland and Christchurch daily, and using a further sampler at Wellington.

(b) Measuring the strontium-89 content of rain collected by the established network of collecting stations. The presence of the short-lived strontium-89 would indicate the collection of relatively fresh fission products.

(c) Additional fresh milk collections will be made at Auckland, New Plymouth, Wellington, Greymouth, Christchurch, and Dunedin, to check for the presence of iodine-131.

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APPENDIX 2

RADIOACTIVE CONTAMINATION FROM NUCLEAR WEAPONS

Presented to the House of Representatives by Leave

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ASSESSMENT OF HEALTH HAZARDS TO NEW ZEALAND AND TO SOME PACIFIC AREAS FROM THE PROPOSED FRENCH TESTS OF NUCLEAR WEAPONS

A Report to the Prime Minister
by

Dr J. F. Gabites, Director of the Meteorological Service.

Mr T. A. Rafter, Director of the Institute of Nuclear Sciences, Department of Scientific and Industrial Research.

Mr G. E. Roth, Director of the National Radiation Laboratory, Department of Health.

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A. INTRODUCTION

1. The present report has been prepared at the request of the Prime Minister to provide the Government with a concise and up to date summary of:

(a) Information on existing levels of radioactive contamination in New Zealand from nuclear weapons tests made in the past;

(b) Assessments of health hazards caused by this radioactive contamination; and

(c) Assessments of possible health hazards to New Zealand and to some Pacific Islands (Western Samoa, the Cook Islands, Niue, and the Tokelau Islands) from the planned French tests of nuclear weapons in the Tuamotu Archipelago.

2. Throughout this Report we have used as basis for all assessments of somatic and genetic radiation hazards the findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[1], the Recommendations of the International Commission on Radiological Protection (ICRP)[2], the findings of the ICRP Task Group of Committee 1 on the Evaluation of Risks from Radiation[3], and the findings of the British Medical Research Council.[4]

3. The conclusions we have reached agree with those reported in May 1964 by the Special Committee set up by the Council of the Royal Society of New Zealand[5], and they agree with the conclusions reached in the Report of the Australian National Radiation Advisory Committee published in November 1965.[6]

4. In preparing the present Report we have freely drawn on the published work of scientists in New Zealand and overseas; we have incorporated – in greatly condensed form – the results of extensive unpublished investigations by departmental officers engaged in radiation protection work in New Zealand, and we have freely used and quoted the findings of competent international and national organisations.

B. EXISTING LEVELS OF RADIOACTIVE CONTAMINATION FROM NUCLEAR WEAPONS

(a) NUMBER, MAGNITUDE, AND LOCATION OF PAST NUCLEAR EXPLOSIONS

5. During the period 1945–62 more than 423 nuclear weapons were exploded.[7] This figure does not necessarily give a complete account of all explosions because it appears that sometimes a series of explosions had been announced as a single detonation. An analysis of the announced 423 detonations, up to the partial nuclear test ban treaty 1963, shows that the United States caused 271 detonations; the U.S.S.R. 124; the United Kingdom 23; and France 5. Some 121 of these announced 423 nuclear detonations took place in the Pacific area. The United States carried out 100 of these detonations (mainly during the Bikini, Eniwetok, Johnston, and Christmas Island tests) while the United Kingdom carried out 21 of its 23 tests in Australia and in the Pacific (12 at Monte Bello Island, Woomera and Maralinga, and nine at Christmas Island).

Table 1: Approximate Fission Yield and Total Yield in Megatons of Nuclear Weapons Tests Conducted in the Atmosphere by all Nations

Years	Fission Yield		Total Yield	
	Air	Surface	Air	Surface
1945–51	0·02	0·5	0·2	0·6
1952–54	1	37	1	59
1955–56	5·6	7·5	11	17
1957–58	31	9	57	28
1961	25		120	
1962	76		217	
Subtotal	139	54	406	105
Total	193		511	

6. Table 1 presents data published by the United Nations in 1964[1] and shows that the "total yield" of all weapons exploded up to the beginning of the partial nuclear test ban treaty 1963, was approximately equivalent to 511 megatons of TNT. Of this total, 193 megatons resulted from nuclear fission, the reaction used in the original type of atomic bomb which contributes most heavily to contamination by radioactive substances. The remaining 318 megatons of the total

yield resulted from thermonuclear reactions of the type used in "Hydrogen bombs", causing relatively less contamination. Approximately 300 megatons of the 511 megatons total yield of all nuclear weapons tests were contributed by the 1961–62 series of tests conducted by the U.S.S.R., and tables 2 and 3[7] [8] give an analysis of the approximate yields of nuclear weapons tests held in the past, excluding, however, the relatively insignificant tests conducted in 1964 and 1965 on the Chinese mainland.

Table 2: Approximate Fission Yield in Megatons of Nuclear Weapons Tests Conducted

Year	United States and United Kingdom	U.S.S.R.
1945	0·06	
1946	0·04	
1948	0·1	
1951	0·5	0·06
1952–1954	37	0·5
1955	0·2	4
1956	9	
1957–58	19	21
1961–62	15	85
Subtotal	82	111
Total	193	

Table 3: Approximate Distribution of Fission Yield in Megatons for all Tests

Years	Airbursts	Ground Surface Bursts	Water Surface Bursts
1945–58	37·8	21·4	32·6
1961–62	101	---	---

(b) DISPERSAL OF RADIOACTIVE DEBRIS

7. Radioactive debris from a nuclear explosion in the atmosphere is carried upward by the rising volume of heated air. The height it attains depends on the amount of heat released and on the temperature conditions in the atmosphere at the time. As it rises the hot air expands, becomes diluted, cools, and eventually reaches a level where its temperature matches that of its surroundings. Here it spreads out and soon becomes indistinguishable from the surrounding air, apart from the dust it carries.

8. Several distinct layers can be recognised in the atmosphere. Lowest is the troposphere or stirred layer, with temperature generally decreasing upwards, that offers only moderate resistance to the rising hot air. Next above is the much more resistant stratosphere, with constant or increasing temperature, in which the rising air soon loses its buoyancy and reaches equilibrium. In the tropics the stratosphere begins at about 50,000 or 55,000 ft; in higher latitudes the underlying troposphere is shallower and more variable, and the stratosphere is usually reached somewhere between 25,000 and 40,000 ft.

9. Debris from small nuclear explosions in the kiloton range may remain entirely within the troposphere. Even in the tropics, however, debris from bursts of the order of 0·1 megaton can be expected to penetrate at least some distance into the stratosphere. In the megaton range debris is likely to reach heights of 80,000 to 100,000 ft.

10. The subsequent dispersal of the debris after its ascent, and its eventual deposition on the surface of the earth, may be influenced by many factors.

11. The coarser particles of debris fall through the air with appreciable speeds, carried along in turn by the air currents they traverse, and reach the ground as "early fall-out". Most of this gravitational deposition occurs during the first 12 to 24 hours. In the case of a surface burst, where the fireball touches the ground, large amounts of earthy material may be incorporated and may bring down much of the radioactive material with it as early fall-out.

12. The finer particles floating in the troposphere may drift for days or weeks, spreading progressively both horizontally and vertically as they become separated by eddies or are carried up and down by convection currents. Most eventually reach the ground by being brought down by raindrops.

13. Fine particles carried into the stratosphere may float there for months or even years. Because of the stratified nature of the layer the particles do not spread in the vertical direction nearly as rapidly as in the horizontal, even though the stratospheric currents carrying them may climb or descend as a whole. There is, however, a continual interchange of air between stratosphere and troposphere. From time to time currents of stratospheric air descend into the troposphere, especially in the vicinity of depressions or jet streams, and soon lose their identity. By such means radioactive particles may be carried down into the troposphere, and once there may be brought to the ground by rainfall. Because of the preferred locations of storms and jet streams, the delayed deposition of debris from the stratosphere is mainly in the higher rainfall areas of the middle and high latitudes. It is usually greatest in the hemisphere of original injection, and this accounts for the very marked differences in fall-out levels between the Northern and Southern Hemispheres shown in Figs 5 to 9.

14. Differences in prevailing meteorological conditions (e.g., average rainfall) – even between relatively near locations such as Christchurch and Greymouth – can also account for very large differences in fall-out levels, as shown in Figs 3 and 4.

(c) PRESENT LEVELS OF INDIVIDUAL FALL-OUT COMPONENTS

15. A great deal of very painstaking work by many laboratories throughout the world has provided an accurate account of the changes in fall-out levels since the beginning of large-scale testing of nuclear weapons. Most of these measurements are undertaken to obtain an accurate basis for the assessment of health hazards from those fall-out components which – if present in large enough amounts – are potentially hazardous. In September 1957 the Department of Health was charged, under a Cabinet directive, with the responsibility for the monitoring of environmental radioactive contamination in New Zealand and its associated Island Territories. Subsequently the network of New Zealand collecting stations shown in Fig. 1 has been established to provide the necessary samples of air, water, soil, and milk for their analysis for strontium-90, caesium-137, and iodine-131.

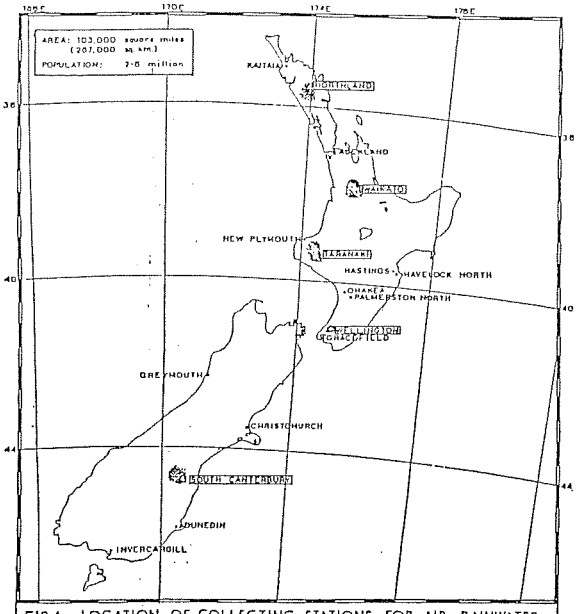


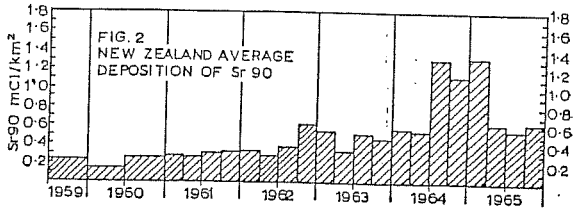
FIG 1 LOCATION OF COLLECTING STATIONS FOR AIR, RAINWATER, SOIL AND MILK SAMPLES IN NEW ZEALAND.

Collection areas not confined to a single location but extending over part of a province or district are shown thus: NAME

16. In addition to the fall-out measurements made for the control of possible health hazards, many investigations are made of individual fall-out components which – while not presenting a health hazard – provide valuable scientific information, e.g., on the carbon cycle in nature and on the distribution of carbon-14. In New Zealand such investigations are carried out at the Institute of Nuclear Sciences of the D.S.I.R.[10]

(1) *Strontium-90*

17. The fall-out component presenting the greatest long-term health hazard is strontium-90. It has a half-life of about 28 years, i.e., it takes 28 years for its radioactivity to decay to half its original value. It behaves chemically similar to calcium and – like calcium – is deposited in the human bone.



18. Fig. 2 gives the New Zealand average quarterly deposition of strontium-90 during the period 1958–65, while Figs 3 and 4 show the levels of strontium-90 in rain and in milk during the same period at Christchurch and at Greymouth, i.e., the collecting stations which consistently show the lowest and highest levels respectively.[9] Fig. 5 compares the total accumulation of strontium-90 from rain in

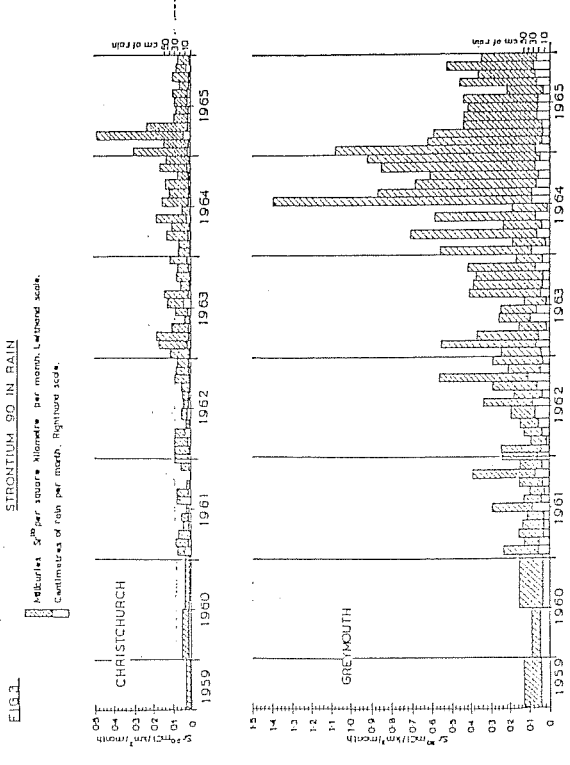


FIG 3

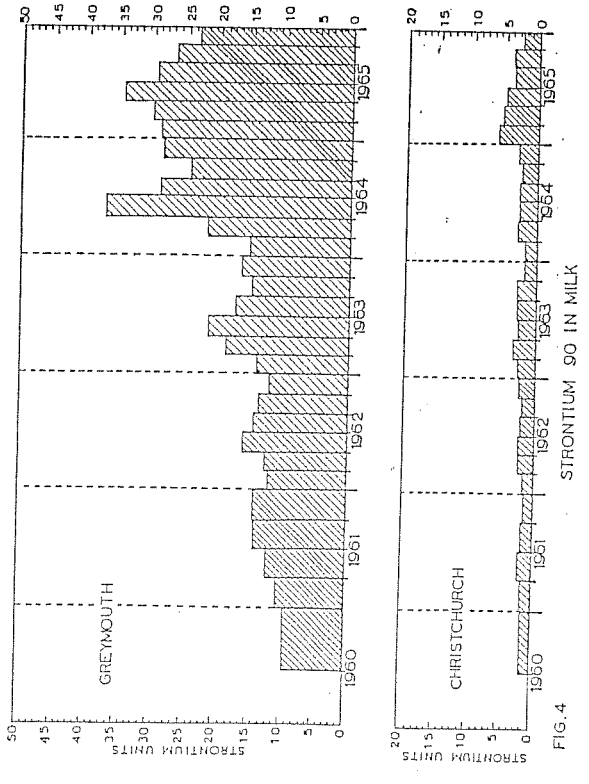


FIG. 4

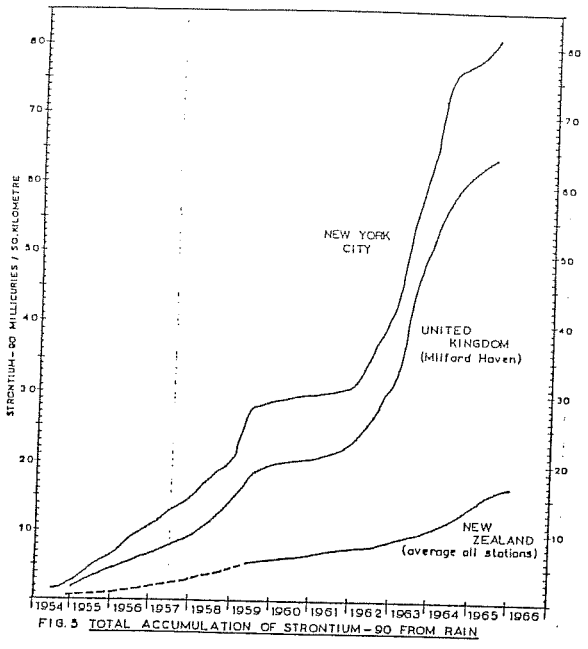


FIG. 5 TOTAL ACCUMULATION OF STRONTIUM-90 FROM RAIN

New Zealand, the United Kingdom, and New York City, while Figs 6 and 7 provide a comparison of the deposition of strontium-90 in the northern and southern hemispheres. Fig. 8 gives not only a

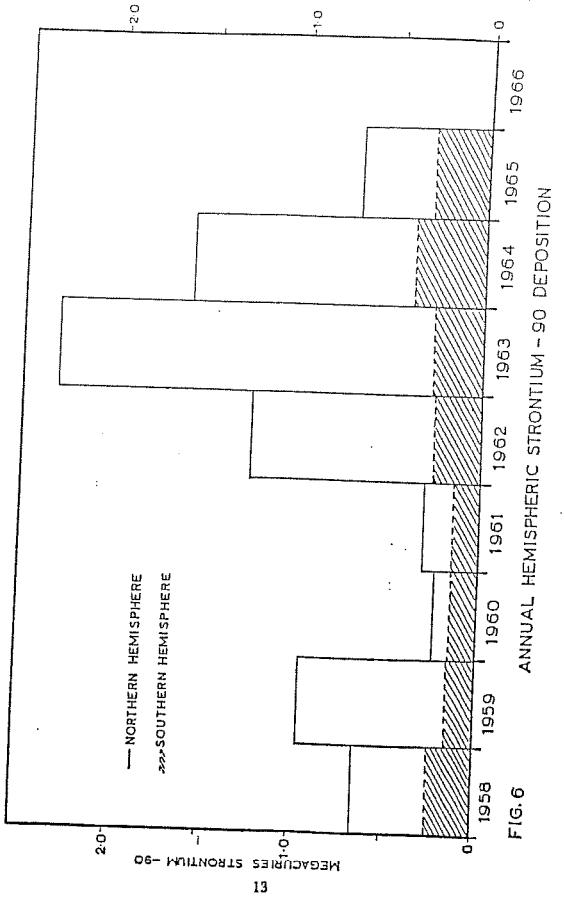


FIG. 6

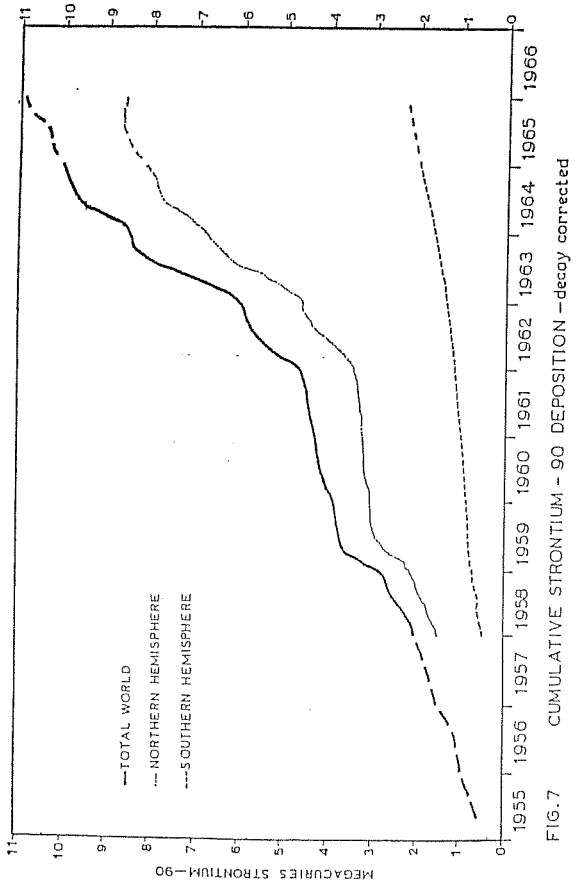


FIG. 7

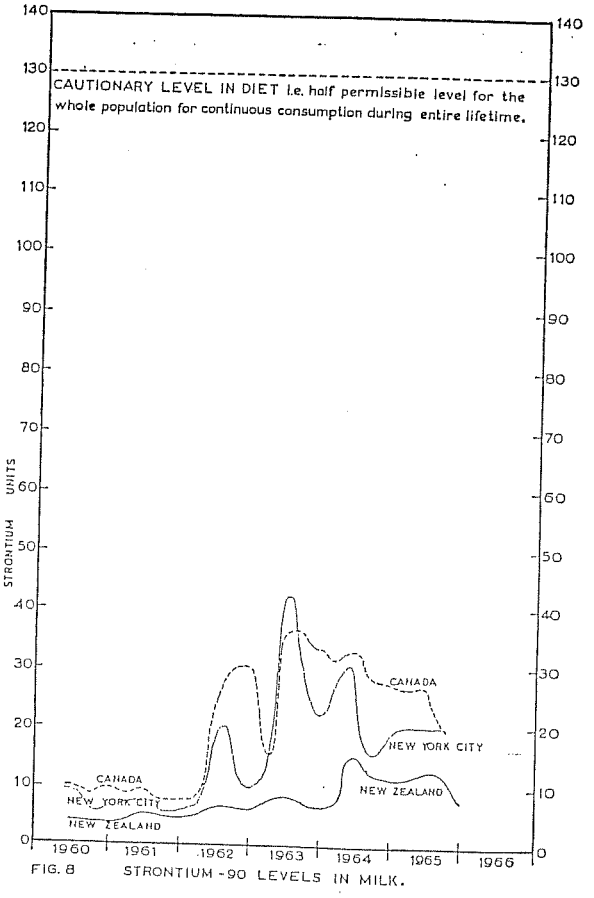


FIG. 8 STRONTIUM-90 LEVELS IN MILK.

graphical comparison of the levels of strontium-90 in Canadian, New York City, and New Zealand milk, but it also allows a ready comparison of these levels with the "cautionary level" of strontium-90 in diet, i.e., one-half of the "permissible level" in diet, derived from the recommendations made by the British Medical Research Council on the "permissible levels" for the concentration of strontium-90 in human bone.[4]

19. Because the strontium-90 level in the total diet (expressed in Strontium Units) differs relatively little from that in milk, a comparison of the levels in New Zealand milk with the "cautionary level" provides some guidance on the general situation in New Zealand. In doing this, however, it must be emphasised that the "cautionary level" refers to continuous lifetime exposure. Average levels over an extended period, such as one year, are therefore more meaningful than individual results. The all-station average for New Zealand milk for the 12 months ending December 1965 is 8·9 per cent of the "cautionary level" for the whole population, or about 4·5 per cent of the "permissible level" for the whole population.[6]

(II) *Iodine-131*

20. Iodine-131 loses half its radioactivity in about eight days and provides a sensitive indicator for the presence of "fresh" fall-out. It is very effectively concentrated in the human thyroid and presents a short-term hazard through the contamination of food, such as fresh milk produced by animals grazing on contaminated pastures. Since the radioactivity of milk rises and falls rapidly following each deposition of newly formed fall-out, it is appropriate to consider the average level taken over a year, and to compare it with the average "permissible level" for the population as a whole.[4]

21. During the nuclear tests in the Pacific in 1962, checks were made for Iodine-131 in milk, both in Australia and in New Zealand. A number of results were obtained in Australia showing increased deposition towards the north. In Tasmania the average level for the year was about 0·5 per cent of the "permissible level". Only one New Zealand sample gave a measurable value, indicating an average level for the country below that for Tasmania.

(III) *Caesium-137*

22. Caesium-137, when taken into the human body, is distributed fairly uniformly throughout the entire body. Its radioactivity decays to half the original value in about 30 years but it is retained in the body for a much shorter time than strontium-90 because half of it is eliminated in about four months.[1] It presents a much smaller health hazard than strontium-90. The current levels of caesium-137 in New Zealand milk are less than 1 per cent of the "permissible level" for the whole population.[6]

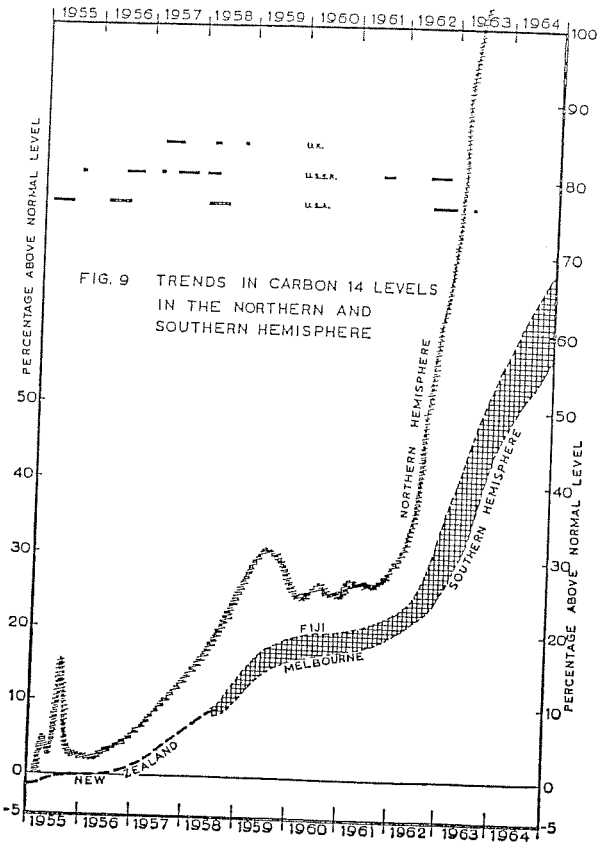


FIG. 9 TRENDS IN CARBON 14 LEVELS IN THE NORTHERN AND SOUTHERN HEMISPHERE

(IV) *Carbon-14*

23. Unlike the other fall-out components considered until now, carbon-14 is produced naturally in the earth's atmosphere. Prior to the nuclear weapons tests a balance had been reached between the natural production of carbon-14 in the atmosphere, and its ultimate removal from our environment by fixation in ocean sediments. An indication of the increase in carbon-14 in the Northern and Southern Hemisphere due to the explosions of nuclear weapons is given in Fig. 9. Even though carbon-14 takes 5,700 years to decay to half of its original radioactivity, and even though the total amount of carbon-14 in the biosphere had increased by about 70 per cent to a maximum in 1965, by the year 2150 the biospheric content of carbon-14 due to weapons tests conducted until now will have decreased to less than 3 per cent.

24. Averaged over the period from 1964 to the year 2000, radiation dose to tissue from fall-out carbon-14 will be about half that from natural carbon-14, which itself contributes only about 1 per cent of the normal dose to the body from all natural sources.[6]

C. ASSESSMENT OF HEALTH HAZARDS FROM EXISTING RADIOACTIVE CONTAMINATION

25. It is generally known that the hazards of atomic radiation are of two kinds: hereditary, resulting in congenital abnormalities in later generations; and non-hereditary, or somatic, resulting in diseases such as cancer and leukaemia. Both types of hazards are also caused by many other toxic agents in our environment. The amount and type of radiation administered, together with the way in which it is administered, have a bearing on the effects which will be produced, similar to the effects produced by drugs.

(a) AVERAGE NATURAL BACKGROUND RADIATION

26. The health hazards of fall-out radiation can best be understood by comparing their radiation dose levels with the levels of natural background radiation to which humans have been exposed since the beginning of time. This is also the way in which the United Nations Scientific Committee on the Effects of Atomic Radiation now presents its findings.[1]

27. Natural background radiation consists of several components: cosmic radiation from outer space; radiation reaching us from the soil and walls of buildings and from the air surrounding us; and radiation given off by naturally occurring radioactive substances within our own bodies.

28. The magnitude of the background radiation varies considerably from place to place. Marsden[12] and many others[1] have made extensive measurements of natural radioactivity on a wide variety of substances. One of these naturally occurring radioactive substances in our environment is lead-210. New Zealand measurements of this naturally occurring substance in rain[1] have shown that, during 1965, it had about the same level of radioactivity in rain as strontium-90. In fact, the naturally occurring lead-210 and its decay products contributes a higher radiation dose to organs of the human body than strontium-90. However, it would appear on present evidence that even the radiation dose to the body from natural lead-210 and its decay products is smaller[1] than the radiation dose delivered continuously to our body organs by the naturally occurring radioactive component of potassium (potassium-40) which forms part of our daily diet – and has done so since the beginning of time.

29. The "average" natural background radiation has been determined after very extensive investigations all over the world. This "average" natural background radiation to which humans have

been exposed since the beginning of time is, of course, subject to very wide variations, and millions of people have been exposed for generation after generation to many times the so-called "average" natural background radiation, throughout their whole lifetime. People living in the mountainous areas of Bolivia, Equador, Colombia, Peru, and in the Himalayas receive between three and six times as much cosmic radiation as people living in the lowlands. As to the terrestrial radiation: some seven million people in France – about one-sixth of the total population of France – get between three and seven times as much natural background radiation from the soil they live on than would be "average". A few hundred thousand people living on thorium sands in the Kerala region in India get up to 56 times as much as "normal" radiation from the soil on which they live, and on the average about 26 times as much.[1] Furthermore, merely moving from a wooden house into one built of brick or concrete may double or treble the amount of natural background radiation from terrestrial sources to which we are exposed.

30. The amount of naturally occurring radioactive substances which we take into our bodies and which can account for a substantial part of our radiation exposure is also subject to very large variations. For example, the radon concentration in natural waters in public supplies may vary between 0·2 and 700,000 pico-curies per litre, a factor of several millions. Similarly, the radium content of human bodies which, of course, contributes to the radiation we receive from our own built-in internal sources, shows variations in the range between three and 1,400 pico-curies, with corresponding large variations in the internal radiation dose.[1]

31. Thus, throughout the ages, huge population groups have been continuously – throughout their entire lives – exposed to natural radiation levels 20 times as high and higher than the "average" or "normal" natural background radiation level.

(b) DOSE COMMITMENT FROM EXISTING RADIOACTIVE CONTAMINATIONS

32. In its 1962 and 1964 Reports, the United Nations Scientific Committee on the Effects of Atomic Radiations[1] evaluates existing radiation hazards from fall-out by assessing the total dose to the entire population of the world from all nuclear explosions until the beginning of the partial nuclear test ban treaty 1963. It expresses this hazard as a "dose commitment". This gives an indication of the *total* dose which *all* the nuclear tests made so far will give to the entire population of the world during all the years to come. This enables a ready correlation between the effects of fall-out and that of the naturally occurring radioactivity of the earth.

33. The United Nations Committee calculated that the effects produced in all the future generations of the entire world population, by all the nuclear bomb tests made until now are no larger than

those produced if the "average" natural radiation background were doubled for a relatively short period. Doubling the "average" natural radiation background for nine months would produce equivalent genetic effects; doubling it for 20 months would cause equivalent somatic effects in the bone marrow, and doubling it for 32 months would produce equivalent somatic effects in the cells lining the bone surfaces.

34. If it is remembered that millions of people have lived for countless generations in areas where the naturally occurring radiation is at a level several times that of the "average" natural radiation – not just twice the "average" level for a few months – the hazard from the existing fall-out contamination will be seen in its true perspective.

D. ASSESSMENT OF POSSIBLE HEALTH HAZARDS FROM FRENCH TESTS IN THE PACIFIC

(a) NATURE OF TESTS

35. The French tests are expected to be carried out in the vicinity of Mururoa Atoll (22°S 139°W) in the Tuamotu Group, some 750 miles ESE from Tahiti and 1,350 miles east of Rarotonga (see Fig. 10).

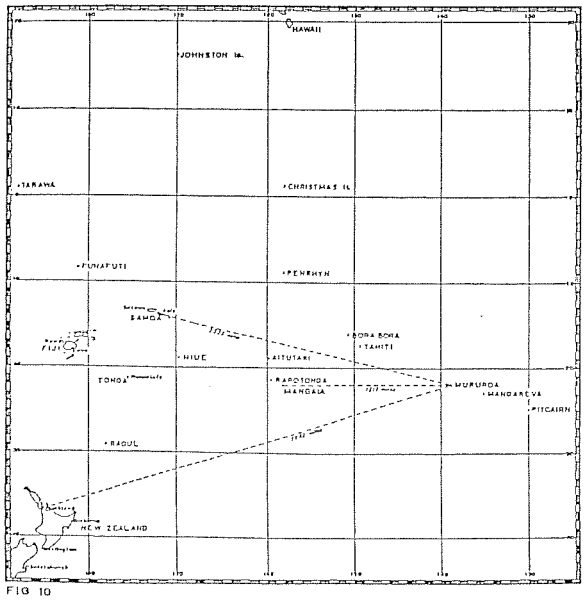


FIG 10

36. For the purpose of estimating possible health hazards the committee has assumed a testing programme spread over several years producing a maximum fission yield of 15 megatons, derived from a variety of detonations ranging from 100 kilotons to 10 megatons, on the supposition that fission would provide half the energy for the detonations from half a megaton upwards, and the whole of the energy for smaller detonations. In estimating the worst effects that could occur under different circumstances the committee considered both surface and air bursts.

(b) METEOROLOGICAL CONSIDERATIONS

Wind Régime Over Test Area

37. The wind structure over the test area normally shows an alternation between easterlies and westerlies in successive layers. The troposphere, in which convection, cloud development, and rain formation take place, varies in depth from about 45,000 to 60,000 ft but is most often about 50,000 to 55,000 ft deep.

(I) *Winds in Lower Troposphere*

38. The low-level winds in the vicinity of the test area are controlled mainly by anticyclones centred further south, usually in latitudes from 25° to 40°S. Winds from the east, north-east, and south-east predominate and are particularly persistent over the zone extending northwards from the test area. To the south, however, these easterly trade winds are less regular, and are interrupted from time to time by winds from other quarters. This often happens when cyclone systems are passing eastwards in latitudes 30° to 40°S.

39. The low-level easterlies vary in depth, tending to be deeper in summer than winter and deeper to the north than the south. Over the test area they commonly have a depth of 3,000 to 8,000 ft. Because they are so shallow they can affect the drift of early fall-out debris from a typical air burst only in the last stages of its descent. They can, however, be important in the case of a near-surface burst that involves large quantities of soil or water. Some of the radioactive materials can then be left in the stem of the cloud and travel with the low-level winds. From their nature, however, most of these materials will soon fall to the surface.

(II) *Winds in Upper Troposphere*

40. Above the surface easterlies the winds through the remainder of the troposphere are predominantly from a westerly quarter. Westerlies are strongest and most persistent in winter and spring (June to November), when there is usually a westerly jet stream located around 40,000 or 45,000 ft somewhere south of the area, usually in latitudes around 25° to 35°S. In summer and autumn the westerlies are weaker and less regular and winds can blow from an easterly quarter for 10–20 per cent of the time.

41. Sometimes the jet stream to the south flows directly eastward but more often meanders around the hemisphere along a wave-like path in latitudes 25° to 40°S, with wind speeds often exceeding 100 m.p.h. and occasionally reaching 200 m.p.h. Speeds fall off rather sharply above and below the jet stream and on either side.

42. Over the test area itself winds average about 60 m.p.h. at the 45,000 ft level from June to November, and occasionally reach 80 or 90 m.p.h. when the jet stream to the south approaches within 200 or 300 miles.

43. On the equatorial side of the jet stream part of the current breaks off from time to time into anticyclonic (anti-clockwise) eddies several hundred miles across. When such an eddy develops or moves close to the test area the eastward-moving airstream from there may be turned back towards the west.

(III) *Winds in the Stratosphere*

44. Winds at levels above 60,000 or 70,000 ft blow from the east through most of the year. The easterlies are usually strong in summer and autumn; in winter and early spring, however, when the westerlies are strong in the troposphere below, westerlies often extend further up into the stratosphere and replace the easterlies but are much lighter than in the troposphere. The exact sequence of alternation between strong easterlies and weak westerlies in the stratosphere is complicated and not the same from year to year.

(c) DISPERSAL OF DEBRIS FROM FRENCH TESTS

(I) *Early fall-out*

45. A testing agency can be expected to await the appearance of a favourable wind pattern to ensure that local contamination from early fall-out will not endanger neighbouring communities. Early fall-out from the Mururoa tests would miss inhabited islands if confined either to a sector to the south (between SE and SSW) or to a sector between NE and E.

46. Wind patterns that would confine the early fall-out to the southern sector and would not be accompanied by unfavourable weather conditions, would be rather infrequent and usually of short duration. Conditions favouring early fall-out in the east-north-east sector would occur more frequently, especially in winter and spring.

47. Not all wind patterns that would be favourable for air bursts would also be suitable for surface bursts because of the likelihood of debris from the stem cloud being carried in some other direction by low-level winds. With patience, however, the conditions to ensure that all significant early fall-out occurred over the open sea could be found.

48. Because most of the gravitational deposition would be completed within about a day, significant levels of early fall-out would not extend beyond a few hundred miles from the test site and would not be expected to reach any of the islands with which New Zealand is associated.

(II) *Delayed Deposition from Stratosphere*

49. The delayed deposition of fine particles that virtually float in the atmosphere is sometimes described as tropospheric fall-out or stratospheric fall-out according to whether the debris is confined to the troposphere or is initially carried up into the stratosphere.

50. Fine particles injected into the stratosphere from high level or high yield detonations may drift around the globe for months or years before being carried down into the troposphere and so being exposed to precipitation processes. Their eventual deposition occurs principally in the temperate regions of the same hemisphere, although a proportion of them may reach the other hemisphere. Most will eventually reach the ground in the higher rainfall areas.

51. The assumed fission yield of 15 megatons from the proposed French tests would be equivalent to about 8 per cent of the total fission yield in the Northern Hemisphere so far. A deposition of long-lived products in the Southern Hemisphere equivalent to 8 per cent of those of the Northern Hemisphere would not represent a great addition to the deposition already received from Northern Hemisphere tests (see Figs 5, 6, 7). The general level of radioactivity in the Southern Hemisphere could still be expected to remain well below that of the Northern Hemisphere.

(III) *Delayed Deposition from Troposphere*

52. Most of the particles floating in the troposphere reach the ground within a period of days or weeks, depending on how soon the air carrying them enters a rain-producing weather system.

53. The particular wind patterns that would ensure that the early fall-out occurred in the sector east-north-east from Mururoa might not always ensure that the fine particles still floating in the troposphere would continue to drift eastward. On some occasions the air current carrying them could swing northward in an anti-cyclonic eddy and eventually turn westward or even complete a circle. On such occasions the slowly diffusing particles could be carried over the Tokelau group, Samoa, or the Cook Islands in five or six days from their initial release. The decaying radioactive particles drifting overhead would not reach the ground in significant quantities unless brought down by rain.

(d) SIGNIFICANCE OF FALL-OUT ON LAND

54. Drift of decaying radioactive particles high overhead would be of no consequence unless rain occurred. Should rain occur on an island when a cloud of fine debris is passing over it, measurable levels of radiation could result. Only debris which is so deposited within a matter of days after a test could have any significance. The probability of this occurring in the islands of concern to New Zealand is not very great. For places more remote from the test site, e.g., New Zealand, the chances of significant levels of contamination being caused by tropospheric fall-out are even more unlikely.

55. Mr J. F. McCahon, Principal Radiation Officer of the National Radiation Laboratory, has made an extensive analysis of possible fall-out levels on the various islands, and of the radiation doses the inhabitants could receive externally from the increase in the level of background radiation, and internally from consuming contaminated food and drinking water. A relationship has been established between the increase in external radiation from the deposition of recently produced nuclear debris, and the resulting radiation dose to the population from internal and external radiation sources. This relationship makes is possible to estimate at an early time – from a relatively simple measurement of the gamma radiation emitted by the fall-out lying on the ground – the eventual dose commitment of the population. This also makes it possible to establish levels for various actions which correspond to chosen radiation dose levels in the population.

56. Details of the permitted exposure levels and of the monitoring network being set up in the Pacific are given in Appendix 2.

(e) SIGNIFICANCE OF FALL-OUT ON THE SEA

57. Most of the debris from the French tests will descend onto the sea. Although the oceans eventually provide gigantic diluting media even for the vast quantities of radioactivity produced by weapons tests, there are two factors of relatively short-term concern. One is the production from early fall-out of a limited volume of highly radioactive water, and the other is the capability of some sea organisms to concentrate certain elements from sea water within their body tissues.

58. Based on assumptions which would cause the "maximum hazard", a detailed study was made at the National Radiation Laboratory by the Assistant Director, Mr H. J. Yeabsley, of the possibility of a significant contamination of the sea foods in those Pacific islands for which New Zealand has a special concern. In this analysis use was made of the results of radiological surveys of the Pacific [9][11] which followed previous testing in the area, and consideration was given to the following possibilities:

(i) A heavily contaminated volume of water drifting from near the test site to one of the islands of concern to New Zealand;

(ii) Tropospheric debris being deposited by rain into the sea near an island, under the assumed condition that the island itself was missed by the rainstorm, the local monitoring station therefore not recording the event;

(iii) Consumption on an island of migratory fish which have become contaminated in a highly radioactive part of the ocean, remote from the island where the fish were caught.

59. The study showed that the French tests were likely to cause heavily contaminated areas in the sea up to a few hundred miles from the test site, with consequential local contamination of fish and sea food; the study also showed conclusively that there is only an extremely remote chance of the French tests significantly polluting the sea food in any island with which New Zealand is closely associated.

E. CONCLUSIONS

60. The committee considered the potential hazards from the proposed French nuclear tests and compared them with the evaluated effects from all previous nuclear tests.

61. The Committee concluded that:

1. Testing of nuclear weapons up to the present time does not and will not present a significant health hazard to the people of New Zealand or the Pacific Territories with which it is associated.

2. The proposed French tests will add fractionally but not significantly to the long-lived fall-out in these areas.

3. The general levels of such radioactive contamination in the Southern Hemisphere will remain below those already existing in the Northern Hemisphere.

4. Although it is not possible to give an assurance that no contamination by fresh fission products will occur on any Pacific island with which New Zealand is associated, any significant contamination can result only from a series of unlikely occurrences which make the event extremely improbable.

5. For New Zealand the chance of significant levels of contamination being reached is even more unlikely than for the islands in the Pacific.

6. The proposed monitoring network being set up in the Pacific, and the extension of the existing network in New Zealand by the National Radiation Laboratory of the Department of Health, as outlined in Appendix 2, will provide prompt warning in the unlikely event of a condition arising which requires that precautions be taken.

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APPENDIX 1: EXPLANATION OF SCIENTIFIC TERMS USED

Gamma Radiation: Penetrating radiation, similar to X-rays, emitted during the decay of many radioactive materials.

Megaton: One million tons. The term is conventionally used to describe the force of a nuclear explosion by comparing it with that of the equivalent amount of TNT.

Nuclear: Concerning the nucleus of an atom, i.e., the positively charged core with which is associated practically the whole mass of the atom.

Nuclear Fission: A nuclear reaction in which a heavy nucleus splits into two approximately equal parts with the release of a large amount of energy. The new atoms so formed are normally both radioactive.

Thermonuclear Reaction: A nuclear reaction in which two light nuclei are fused into a single nucleus under the influence of extremely high temperatures, usually of the order of millions of degrees. A considerable amount of energy is released in the case of very light nuclei such as hydrogen.

Strontium Units: Number of pico-curies of strontium-90 per gram of calcium. 1 pico-curie = 2·22 nuclear transformations per minute.

Sr^{90} *mCi/km²*: Millicures of strontium-90 per square kilometer. 1 millicurie = 37 million nuclear transformations per second.

APPENDIX 2: MONITORING NETWORK

(a) *Local Measurements*

1. The International Commission on Radiological Protection (ICRP)[9] recommends that the annual radiation dose to individual members of the public resulting from peacetime industrial uses of radiation, should not exceed one-tenth of that permitted to people exposed to radiation in their employment. The New Zealand authorities have adopted this ICRP recommendation in setting permissible radiation levels for the operation of the Monitoring Network.

2. Although it is extremely unlikely that significant amounts of fall-out will reach any Pacific island with which New Zealand is associated, a remote possibility exists that measurable amounts of fall-out could be deposited with rain. Therefore instruments for the direct measurement of the resulting radiation are being provided for use on Rarotonga, Mangaia, Aitutaki, Penrhyn, Tonga, Niue, and Samoa. These measuring instruments and various fall-out collecting devices are being set up in the islands and members of the staff of the National Radiation Laboratory will undertake the training and instruction of local residents in the operation of these devices.

3. People in an area subjected to fall-out may receive radiation either from the radioactive material in their surroundings (external sources), or from radioactive materials taken into their bodies with food, drink, and air (internal sources). In the absence of counter measures, exposure from internal radiation sources is usually more important, but it is possible to set levels of external radiation at which the total dose from both radiation sources (internal and external) will not exceed the permissible dose.

4. In the operation of the monitoring network, the assessment of fall-out hazard is based on the measurement of gamma-radiation given off by fall-out lying on the ground. Since the debris of nuclear explosions consists of a mixture of a large number of different radioactive substances, most of which rapidly lose their radioactivity within the first few hours after the explosion, it is possible that levels of gamma radiation which are readily measurable may still only represent negligible health hazards.

5. To make a meaningful assessment of the health hazard presented by any given radiation level from fall-out lying on the ground, it is necessary to take into consideration the age of the nuclear debris producing this radiation, and physical characteristics of the measuring instrument used.

6. For the operation of the monitoring network a "guide level" has been derived which corresponds to the permissible population dose. This "guide level" is indicated by different readings on the scale of the monitoring instruments, depending on the length of time which has elapsed between the explosion and the deposition of the nuclear