PULSTAR REACTOR ANNUAL REPORT TO

UNITED STATES NUCLEAR REGULATORY COMMISSION

for

01 July 1995 - 30 June 1996

NCSU NUCLEAR REACTOR PROGRAM

26 August 1996

Reference: PULSTAR Technical Specifications
Section 6.7.5

Docket No. 50-297

Department of Nuclear Engineering
North Carolina State University
Raleigh, North Carolina 27695

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 July 1995 - 30 June 1996

The following report is submitted in accordance with Section 6.7.5 of the PULSTAR Technical Specifications:

6.7.5.a Brief Summary

Reactor operations have been routine during this reporting period. With the exception of an auto-ranging circuit malfunction in the new Linear Power Monitor, there have not been any unexpected maintenance or operational problems.

(1) Reactor Operating Experience:

The NCSU PULSTAR Reactor has been utilized for the following:

a.	Teaching and Short Courses	66.1	hours
b.	Faculty and Graduate Student Research	213.1	
c.	Isotope Production	51.4	
d.	Neutron Activation Analysis	886.0	
e.	Beam Tube Facilities	0.0	
f.	Nuclear Training (Utilities)	43.6	
g.	PULSTAR Reactor Training	4.9	
h.	Reactor Cal/Measurements & Surveillance	49.2	
i.	Reactor Health Physics Surveillance	6.5	
j.	Reactor Sharing	0.0	
	TOTAL	1,320.8	hours

Same reporting period 1994-1995 1,526.5 hours

A cross section of experiments performed in the reactor:

a. Reactor thermal power measurements for teaching laboratories.
b. Neutron temperature measurements for teaching laboratories.
c. Neutron diffusion length in graphite for teaching laboratories.
d. Neutron Activation Analysis of filters, tissue, sediments/soil, rain/river water, vegetation, wood pulp, fibers, resins, ceramics, coal, fly ash, tar, oil residue, and graphite.
e. Prompt gamma analysis of boron.
f. Neutron fluence and spectral measurements.
g. Transmutation of silicon for semiconductor research.

(2) Changes in Performance Characteristics Related to Reactor Safety:

None

(3) Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has revealed no significant or unexpected trends in reactor systems performance during this report period. The annual facility and records inspection was determined to be satisfactory by the Reactor Safety and Audit Committee.

6.7.5.b Total Energy Output:

473.3 Megawatt • hours 19.7 Megawatt • days

Pulse Operations:

None

Reactor was Critical:

573.0 hours

Cumulative Total Energy Output Since Initial Criticality:

19,417.2 Megawatt • hours 809.1 Megawatt • days

6.7.5.c Number of Emergency and Unscheduled Shutdowns:

(1) Unscheduled Shutdowns - 3 total

a. Linear Channel auto-ranging failure - 2
b. Secondary cooling pipes froze

(2) Inadvertent SCRAMs - 1 total

a. Loss of 24 VAC bus

Explanation of (1)a. above:

The newly installed Linear Power Monitor in the Linear Channel failed to automatically range during a startup. The reactor operator terminated the power increase and shut down the reactor. After performing calibrations, the reactor was restarted and the monitor failed in the same manner. The monitor was returned to the manufacturer for repair. As of this report the monitor has not been returned. The original Linear Picoammeter was re-installed and reactor operations were resumed.

Explanation of (1)b. above:

The unusually cold winter caused secondary water in a vertical section of pipe adjacent to the cooling tower to freeze. When primary heat could no longer be rejected, the reactor was shut down. Reactor operations resumed after the pipe was thawed.

Explanation of (2)a. above:

Insulation on a 24 VAC control wire, which is normally flexed as the instrument is racked in and out of the console for calibration, was abraded to the point that the conductor momentarily shorted to ground blowing the 24 VAC bus fuse. The abraded area was repaired and similar wires on other instruments were subsequently inspected. Additionally, a "spiral wrap" protective covering was added to the wires that are flexed.

6.7.5.d Major Maintenance Operations:

None

6.7.5.e Changes in Facility, Procedures, Tests, and Experiments:

1. Design Changes

   a. DC 95-2 authorized the replacement of the Source Range and Linear Power Monitor chart recorders.

   b. DC 95-3 installed an additional SCRAM circuit to monitor primary coolant temperature and automatically shut off primary pump when pool water level drops to the Safety System Setting. It also included Revision 14 to the PULSTAR Operations Manual.

   c. DC 96-1 authorized the re-installation of the original Linear Picoammeter in the console while the new Linear Power Monitor is being repaired by the manufacturer.

2. Procedure Changes

   a. PC 17-95 was Revision 15 to the PULSTAR Operations Manual. This document addressed the procedural differences required by the newly installed nuclear instruments. It also implemented the most recent revision to the PULSTAR Emergency Plan.

   b. PC 18-95 was Revision 16 to the PULSTAR Operations Manual. This document incorporated commitments to the NRC concerning procedures for abnormal equipment behavior and clarified the Startup Checklist Procedure.

   c. PC 8-96 was Revision 17 to the PULSTAR Operations Manual. This document addressed procedural differences required to re-install the original Linear Picoammeter while the new Linear Power Monitor is being repaired.

   d. A total of thirty-four procedures were written or revised covering the calibration of newly installed equipment described in (1) above, reactor operations, and ten Health Physics procedures. These procedures have been reviewed and/or approved by the Reactor Safety and Audit Committee (RSAC) and the Radiation Protection Committee (RPC).

6.7.5.f Radioactive Effluent:

A. Liquid Waste (summarized by quarters)

1. Radioactivity Released During the Reporting Period:

Period	(a) No. of Batches	(b) Total μCi	(c) Tot. Vol. Liters	(d)[1] Diluent Liters	(e) Tritium μCi
01 Jul - 30 Sep 95	2	53	6.8E3	2.2E5	30
01 Oct - 31 Dec 95	3	47	1.0E4	2.7E5	19
01 Jan - 31 Mar 96	0	0	0	0	0
01 Apr - 30 Jun 96	1	16	2.7E3	1.0E4	15

(f) 116 μCi total activity released during this reporting period.

(g) 64 μCi of tritium were released during this reporting period.

2. Identification of Fission and Activation Products:

The gross beta-gamma activity of the batches in (a) above were less than 2×10^{-5} μCi/ml. Isotopic analyses of these batches indicated low levels of typical corrosion and activation products. No fission products were detected.

3. Disposition of Liquid Effluent not Releasable to Sanitary Sewer System:

All liquid effluent were released to the sanitary sewer. Radioactivity and concentrations were within 10 CFR 20 limits when diluted by the minimum daily campus discharge of 2.8E6 liters. Solubility tests were performed for all discharges made after 01 January 1996 as discussed in USNRC Information Notice 94-07.

[1] Based on gross beta activity only. Tritium did not require further dilution.

B. Gaseous Waste (summarized monthly)

1. Radioactivity Discharged During the Reporting Period (in Curies) for:

(a) Gases:

Year	Period	Total Time In Hours	Curies
1995	01 Jul - 31 Jul	744	0.107
	01 Aug - 31 Aug	744	0.264
	01 Sep - 30 Sep	720	0.319
	01 Oct - 31 Oct	744	0.295
	01 Nov - 30 Nov	720	0.158
	01 Dec - 31 Dec	744	0.0
1996	01 Jan - 31 Jan	744	0.240
	01 Feb - 29 Feb	696	0.325
	01 Mar - 31 Mar	744	0.318
	01 Apr - 30 Apr	720	0.168
	01 May - 31 May	744	0.071
	01 Jun - 30 Jun	720	0.062
	Totals	8,784	2.327

(b) Particulates with a half-life of greater than eight days:

Filters from the particulate monitoring channel were analyzed upon removal. There was no particulate activity indicated on any filter during this reporting period.

2. Gases and Particulates Discharged During the Reporting Period:

(a) Gases:
Total activity of argon-41 release was 2.327 curies.

The yearly average concentration of argon-41 released from the PULSTAR reactor facility exhaust stack during this period was 6.93×10^{-9} μCi/cc. This is below the regulatory limit of 1×10^{-8} μCi/cc. (10 CFR 20 Appendix B)

(b) Particulates:
See gaseous waste l.(b) above.

C. Solid Waste from Reactor[2]

1. Total volume of solid waste - 57.5 ft^3 (1.63 m^3)

2. Total activity of solid waste - 1.96 mCi

3. Dates of shipments and disposal:

   All waste is in storage at the NCSU Environmental Health and Safety Center disposal facility.

6.7.5.g Personnel Radiation Exposure Report

Twenty-six members of the faculty and staff were monitored for external radiation exposure during the reporting period. Two of the twenty-six received measurable exposure which ranged from 0.01 to 0.02 rem. Total person-rem for the faculty and staff was 0.03.

Approximately 20 film badges were issued to graduate students, temporary staff, short course participants, and visitors. Radiation exposures ranged to 0.03 rem. The majority of these exposures were in the "no measurable exposure" range.

6.7.5.h Summary of Radiation and Contamination Surveys Within the Facility

Radiation and contamination surveys performed within the facility by the PULSTAR staff indicated that:

- external radiation levels in the majority of areas were <2 mrem/h
- contamination levels in most areas were not detectable
- when contamination was detected, the area or item was confined or decontaminated
- external radiation levels in the remaining areas were as expected due to reactor operations

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[2] Due to the failure of North Carolina to license a low level radioactive waste site, solid waste generated at the PULSTAR Reactor can no longer be shipped for burial and must be stored on campus. A total of 44.1 ft^3 (1.25 m^3) of spent resins with an activity of 1.31 mCi from previous years of operation were de-watered and processed for future land burial or incineration. The remaining solid waste is composed of compacted trash, debris, and sources/samples that are no longer useful.

6.7.5.i Description of Environmental Surveys Outside of the Facility

See Attachment A prepared by the Radiation Protection Division of the Department of Environmental Health and Safety.

Perimeter surveys were performed adjacent to the Reactor Building by the PULSTAR staff and indicated that:

- external radiation levels were at background levels for most areas (10 μrem/h)
- contamination levels were not detectable
- Net external radiation levels ranged up to 20 μrem/h in some areas when the reactor was operating at power. However, external radiation levels were at background levels in routinely occupied spaces.

ATTACHMENT A

NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT
OF
ENVIRONMENTAL HEALTH AND SAFETY

RADIATION PROTECTION DIVISION

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JULY 1, 1995 - JUNE 30, 1996

PREPARED BY

RALTON J. HARRIS
AND
JOY L. DOUGLASS

TABLE OF CONTENTS

1. INTRODUCTION

The Environmental Radiation Surveillance Program exists to provide routine measurements of the university environment surrounding the PULSTAR Reactor. The specific objectives of this program include:

1) Providing information that assesses the adequacy of the protection of the university community and the public-at-large;

2) Meeting requirements of regulatory agencies;

3) Verifying radionuclide containment in the reactor facility;

4) Meeting legal liability obligations; and

5) Providing public assurance and acceptance.

During 1995, the Director of the Environmental Health and Safety Center created a committee to assess the environmental monitoring program for the PULSTAR Reactor. This committee issued a detailed report entitled "Report of the Committee to Assess the Environmental Monitoring Program for the North Carolina State PULSTAR Reactor" in which several recommendations were proposed regarding modifications to this program. This information is summarized in Table 1 which has been excerpted from the committee's report. In brief, the committee recommended the following changes:

1) Discontinue the monthly milk sampling, but instead collect and analyze one milk sample in alternate years.

2) Discontinue the semi-annual vegetation collection, but instead collect and analyze one vegetation sample in alternate years.

3) Change the frequency of air sampling from continuous sampling with filters being collected each week (7-day cycle) to a periodic sampling mode in which air samplers are operated for only one week (7 days) during each 3 month period of the year.

4) Move the air sampler at David Clark Labs to the Environmental Health and Safety Center.

5) Move the air sampler at Withers Hall to North Hall (a student dormitory).

At the present date of this report, all the recommended changes have been implemented with the exception of Number 5. The Physical Plant Division of NCSU has expressed a concern about potential damage to the rubber-lined roof

of North Hall which may result if the air sampling station is located at that site. This issue has not been resolved as yet. In an attempt to achieve partial compliance with the committee's recommendations, a TLD station has been located at North Hall to monitor environmental gamma radiation levels.

Table 1:
Current and Projected Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University

Sample	Activity Measured	Conducted By	Frequency	Recommended Change	Basis For Measurement
Stack Gases	Gross Gamma	N.E.	Continuous	None	10 CFR 20 T.S. 6.7.5
Stack Particles	Gross Beta Indiv. Gamma Emitters	N.E. N.E.	Monthly	None	10 CFR 20 T.S. 6.7.5
Water from Reactor Facility	Gross Beta Gross Gamma Tritium	N.E. N.E. N.E.	Prior to Discharge (~ Monthly)	None	10 CFR 20 T.S. 6.7.5 City of Raleigh Ordinance
Air/Particles at 5 Campus Stations*	Gross Beta Indiv. Gamma Emitters	RPO/EHSC RPO/EHSC	Weekly Weekly	Quarterly Change Locations#	10 CFR 20 10 CFR 20
Air/Dosage at 7 Campus Stations+	TLD Dosimeter	RPO/EHSC	Quarterly	Change Locations#	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Indiv. Gamma Emitters	RPO/EHSC RPO/EHSC	Quarterly Quarterly	None None	NCSU NCSU
Vegetation NCSU Campus	Gross Beta Gamma	RPO/EHSC RPO/EHSC	Semi-annually	Discontinue Discontinue	NCSU NCSU
Milk Local Dairy	I-131	RPO/EHSC	Monthly	Discontinue	NCSU

Abbreviations Used in Table:

N.E. = Nuclear Engineering/Reactor Facility; RPO/EHSC = Radiation Protection Office.

*These 5 stations include:
Withers, Riddick, Broughton, Hill Library and David Clark Labs.

+These 7 stations include: the PULSTAR stack, a control station (EHSC) and the 5 air sampling stations.

2. AIR MONITORING (TABLES 2.1, 2.2, AND 2.3; FIGURES 2a THROUGH 2f)

Figures 2a through 2f show bar graphs of gross beta activity (fCi/cubic meter vs. week number). The highest gross beta activity observed was 34.4 $fCim^{-3}$ at the Broughton station during the week of 11-23-95. The annual campus average was 15.1 $fCim^{-3}$. Beginning in January 1996, air monitoring frequency has been changed such that air sampling is performed for one week during each quarter each year. This change is reflected in the figures 2a - 2f.

Table 2.2 lists LLD values for several gamma emitters which would be indicative of fission product activity. No gamma activity due to any of these radionuclides was detected.

During 1995-96, the air monitoring equipment was rebuilt and fitted with new 3/4 H.P. electric motors and air pumps to provide a more reliable system.

Table 2.3 lists regulatory limits, alert levels, and average background levels for airborne radioactivity.

TABLE 2.1 LOCATION OF AIR MONITORING STATIONS

SITE	DIRECTION[1]	DISTANCE[2] (meters)	ELEVATION[3] (meters)
BROUGHTON	SOUTHWEST	125	-17
*DAVID CLARK LABS	WEST	500	-18
LIBRARY	NORTHWEST	192	+11
RIDDICK	SOUTHEAST	99	-14
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3

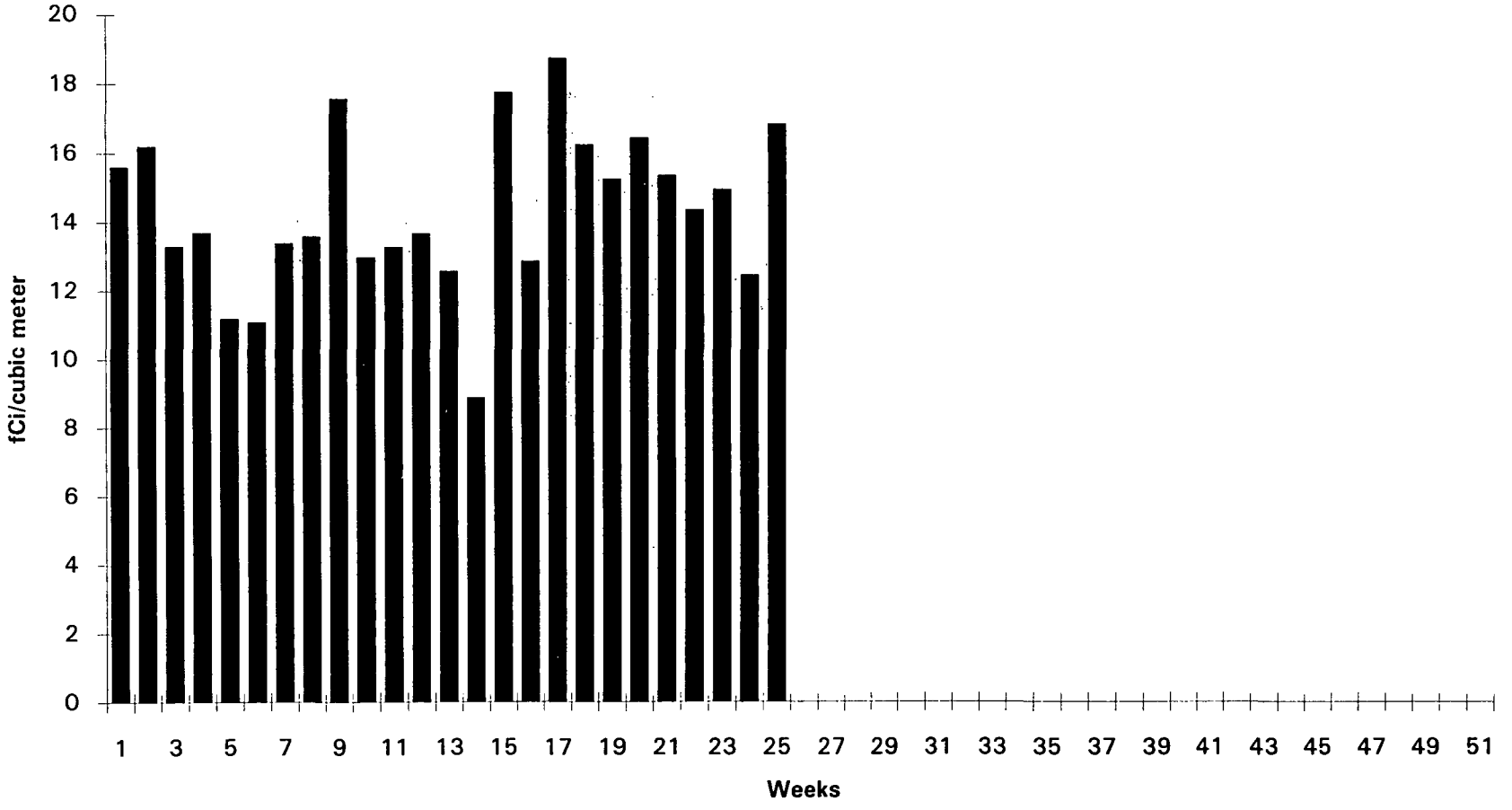
[1]DIRECTION - DIRECTION FROM REACTOR STACK
[2]DISTANCE - DISTANCE FROM REACTOR STACK
[3]ELEVATION - ELEVATION RELATIVE TO THE TOP OF THE REACTOR STACK

*The station at David Clark Labs was relocated to the EH & S Center in January 1996.

FIGURE 2a
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3

CLARK

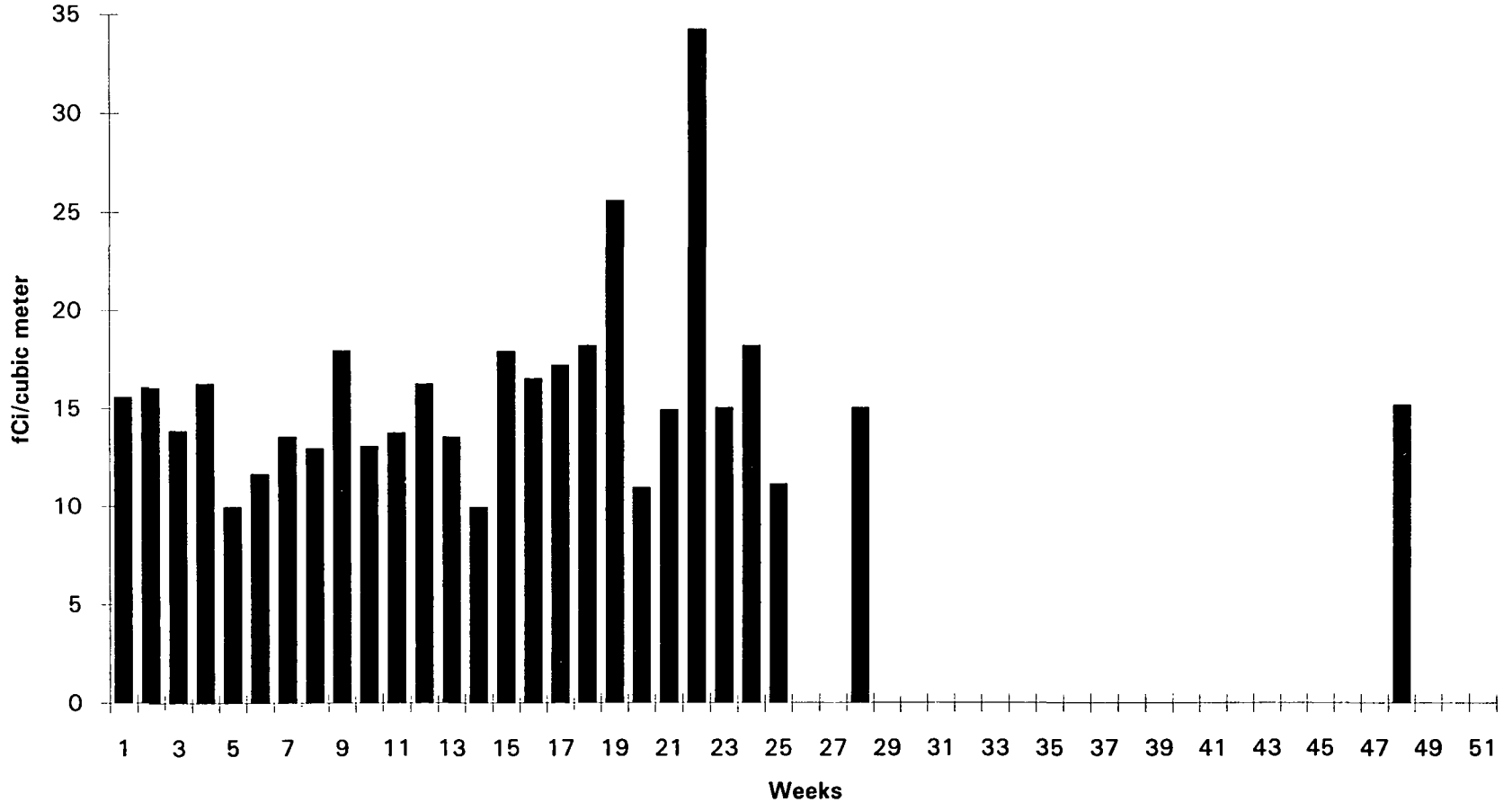


WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

FIGURE 2b
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3

BROUGHTON

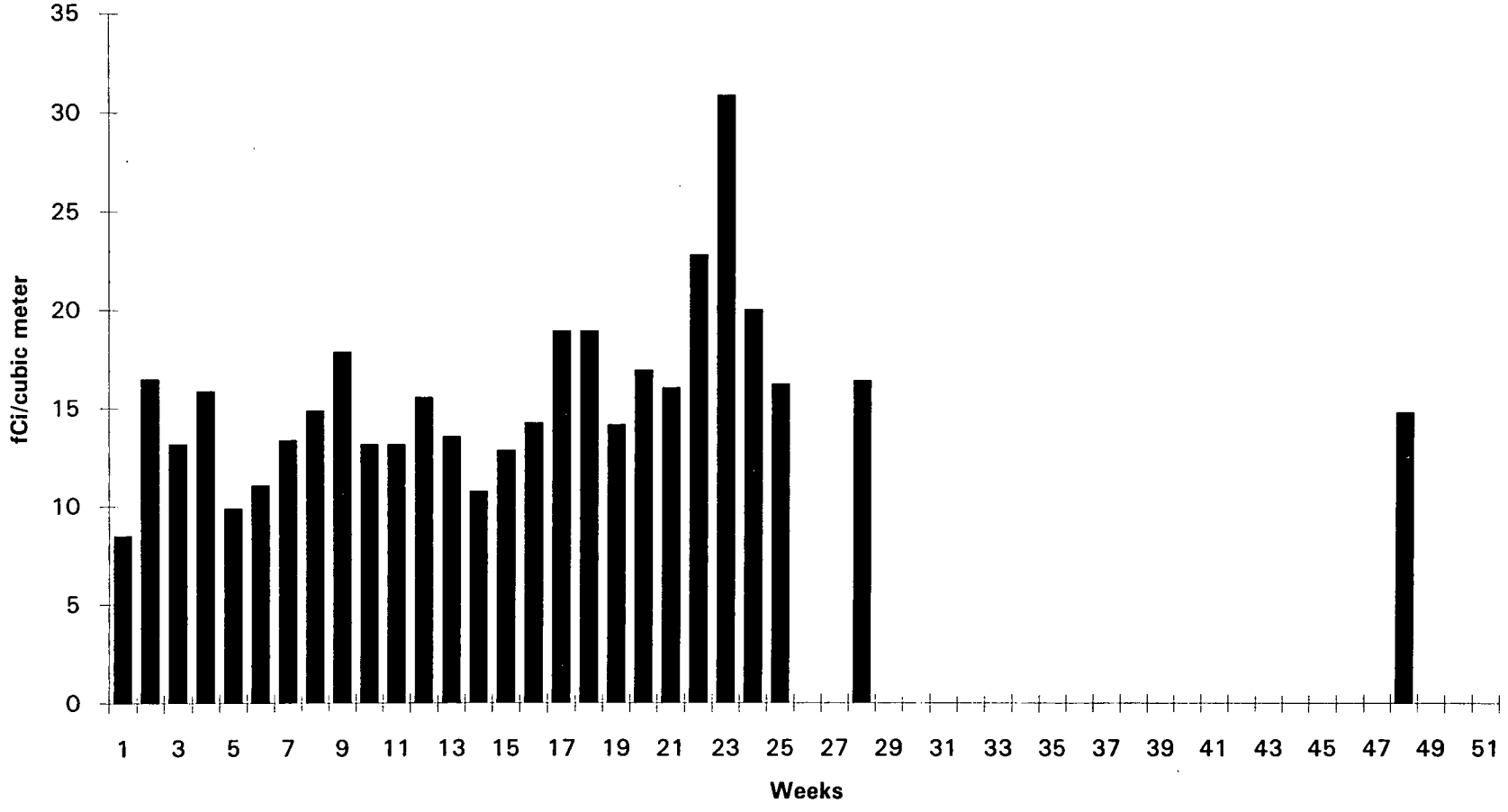


WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

FIGURE 2c
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3

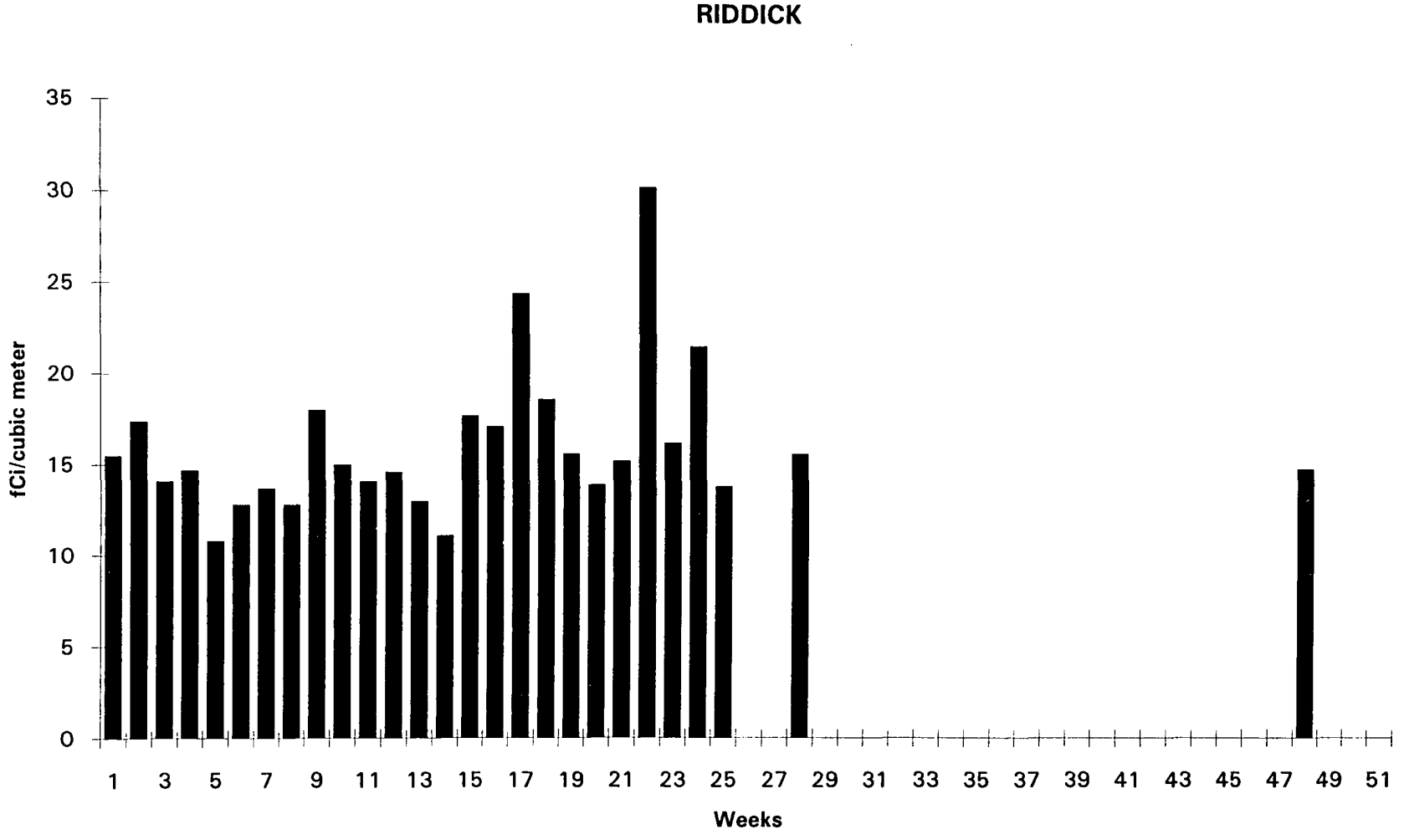
WITHERS



WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

FIGURE 2d
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3

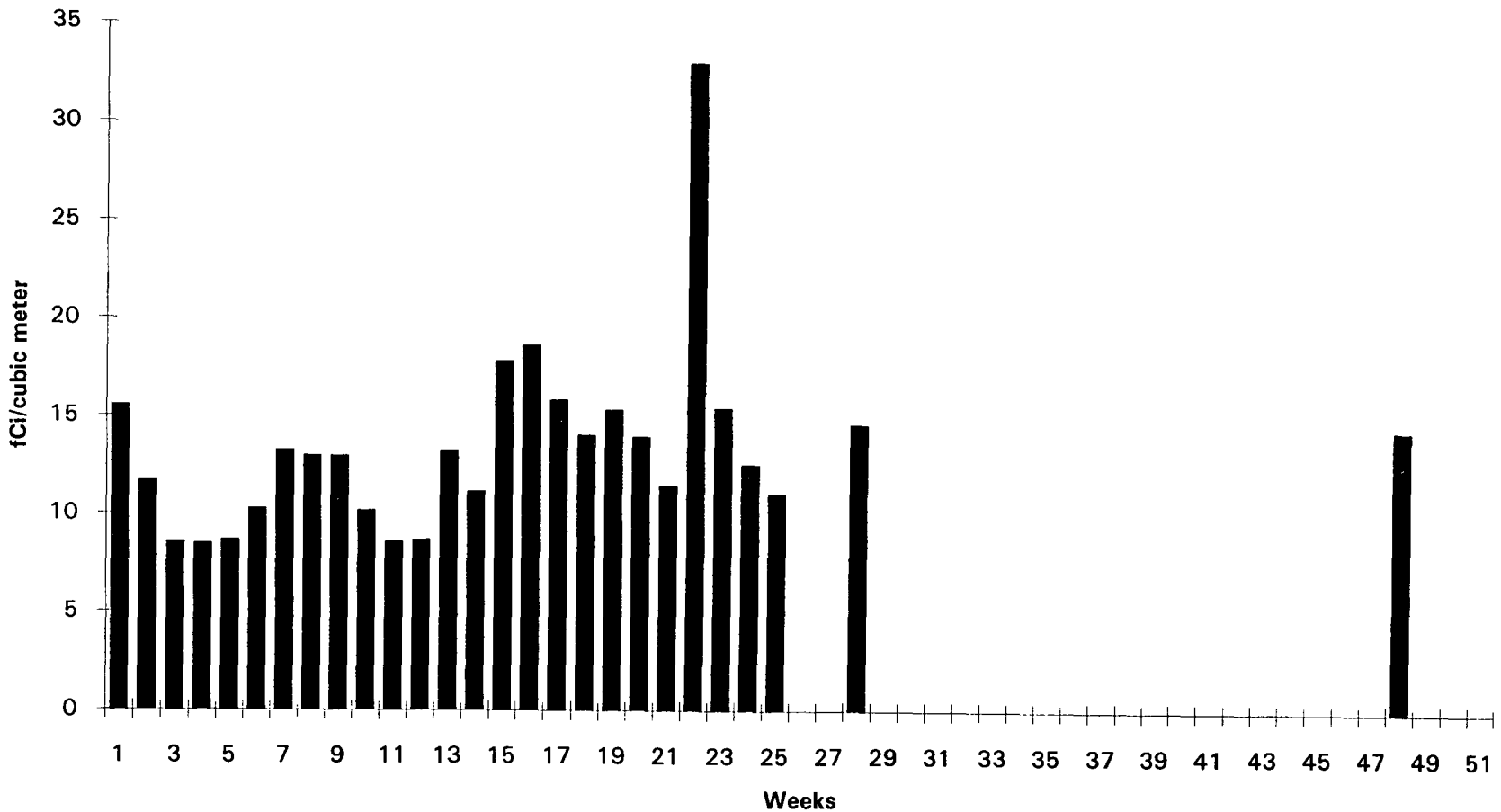


WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

FIGURE 2e
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3

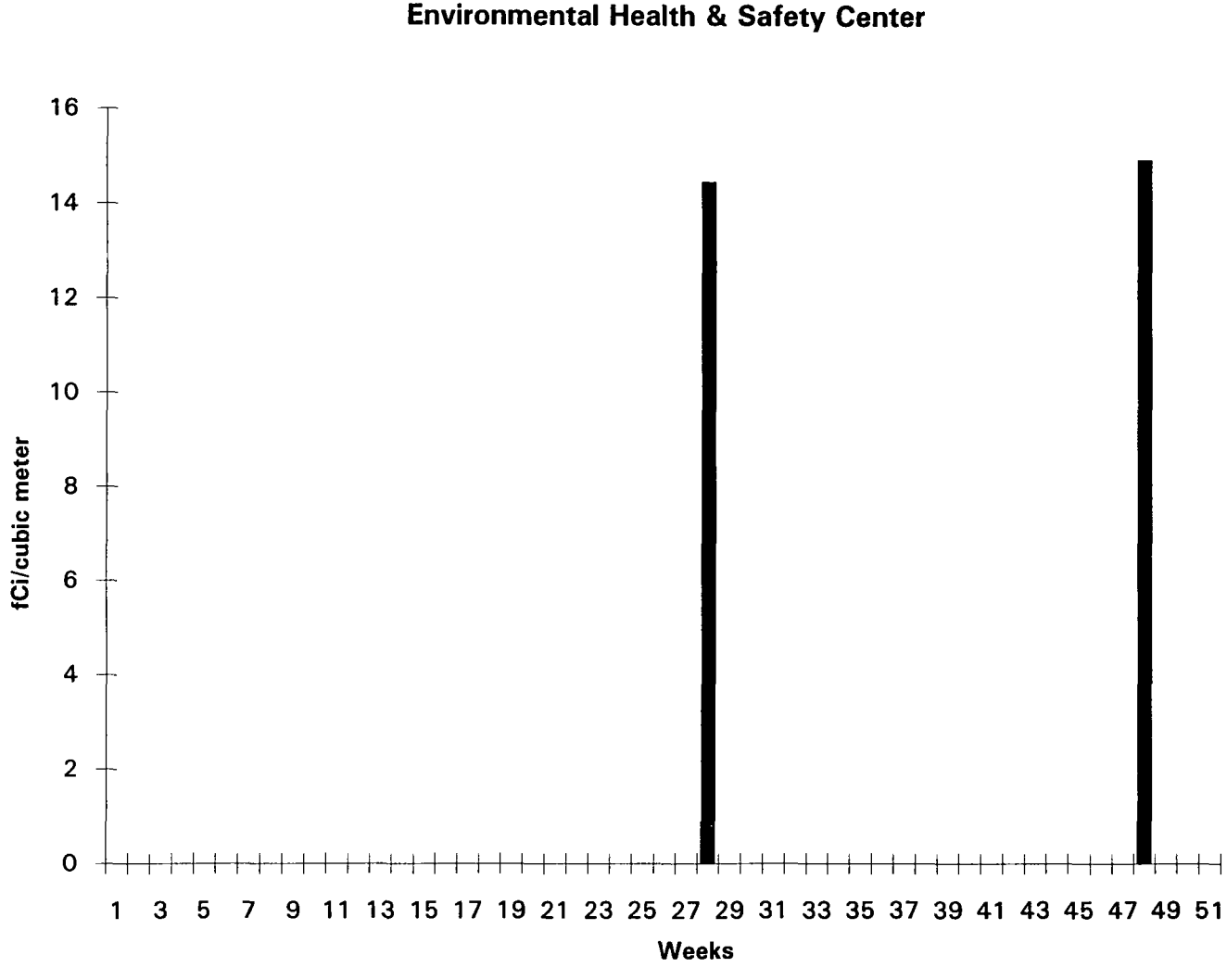
LIBRARY



WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

FIGURE 2f
AIRBORNE GROSS BETA ACTIVITY
N.C. STATE UNIVERSITY CAMPUS

REGULATORY LIMIT =1000 fCi/M^3
ALERT LEVEL = 500 fCi/M^3
LLD ~ 1 fCi/M^3



WEEK NUMBER FROM JUNE 29, 1995 THROUGH MAY 29, 1996
JUNE 29 BEGINS AT WEEK #1

TABLE 6.1	ENVIRONMENTAL TLD EXPOSURES (mR/QUARTER YEAR ± 2s)						
DATE	WITHERS	RIDDICK	BROUGHTON	LIBRARY	DAVID CLARK	PULSTAR STACK	CONTROL
04/25/95 - 06/29/95	8.2 ± 1.2	15.7 ± 3.1	10.8 ± 1.5	10.1 ± 1.6	29.3 ± 33.3	5.5 ± 1.2	13.9 ± 1.9
06/29/95 - 10/03/95	22.7 ± 11.	26.8± 2.5	20.7 ± 2.3	20.1 ± 1.7	34.3 ± 18.8	21.0 ± 1.2	23.4 ± 1.1
10/03/95 - 01/05/96	17.4 ± 0.6	23.6 ± 4.9	18.6 ± 1.5	19.8 ± 1.5	20.2 ± 2.7	22.0 ± 1.4	20.5 ± 1.0
01/05/96 - 04/03/96	18.1 ± 1.1	25.4 ± 1.2	18.5 ± 1.9	24.4 ± 2.2	16.5 ± 0.9	21.9 ± 1.5	23.1 ± 1.4
04/03/96- 07/01/96	17.3 ± 1.5	24.3 ± 1.8	19.3 ± 1.3	2.7 ± 18.	15.8 ± 0.6	19.5 ± 0.9	24.6 ± 5.6
The large error term in the exposure for David Clark Labs, 29.3 ± 33.3 mR, is unexplained.							
It may have been due to some fault in TLD processing.							

TABLE 2.3 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi m^{-3})

NUCLIDE	REGULATORY LIMIT	ALERT LEVEL	AVERAGE N.C. BACKGROUND LEVEL
GROSS ALPHA	20	10	4
GROSS BETA	1000	500	100
Cs-137	5×10^5	10	2
Ce-144	2×10^5	100	0
Ru-106	2×10^5	30	0
I-131	1×10^5	10	0

Reference: Environmental Radiation Surveillance Report 1986-88, State of N.C. Radiation Protection Section

3. MILK (TABLE 3.1)

Milk samples are collected each month from the Campus Creamery and the Lake Wheeler Road Dairy. Previously, samples were obtained from the Randleigh Dairy Farm but it is no longer operational. Beginning in January 1996 milk sampling schedules have been revised to be performed in alternate years.

No I-131 activity was detected in any of these samples.

TABLE 3.1 I-131 IN COWS' MILK (pCi liter^{-1} ± 2 σ) LLD ~ 3 pCi liter^{-1}

	pCi liter^{-1}	
DATE	CAMPUS CREAMERY	LAKE WHEELER
JULY 1995	≤ 3.0	≤ 3.0
AUGUST 1995	≤ 3.0	≤ 3.0
SEPTEMBER 1995	≤ 3.0	≤ 3.0
OCTOBER 1995	≤ 3.0	≤ 3.0
NOVEMBER 1995	≤ 3.0	≤ 3.0
DECEMBER 1995	≤ 3.0	≤ 3.0

4. SURFACE WATER (TABLES 4.1 AND 4.2)

Table 4.1 gives the gross alpha and beta activities for water from Rocky Branch at points where it enters (ON) and exits (OFF) the campus. The LLD values for gross alpha and beta activities are ~ 0.4 pCi liter^{-1} and ~ 0.4 pCi liter^{-1}, respectively. For gross alpha activity the Alert Level is 5 pCi liter^{-1} and the Regulatory Limit is 15 pCi liter^{-1}. For gross beta activity the Alert Level is 5 pCi liter^{-1} and the Regulatory Limit is 50 pCi liter^{-1}. Samples with gross alpha or beta activities exceeding these Alert Levels would require gamma analysis to identify the radionuclides present. The LLD values in Table 4.2 are for the second quarter of 1996.

TABLE 4.1 GROSS ALPHA AND BETA ACTIVITY IN SURFACE WATER (pCi liter^{-1} ± 2σ)

*LLDα ~ 0.4 pCi liter^{-1} LLDβ ~ 0.4 pCi liter^{-1}

		pCi liter^{-1}	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
THIRD QUARTER 1995	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
FOURTH QUARTER 1995	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
FIRST QUARTER 1996	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4
SECOND QUARTER 1996	ON	< 0.4	< 0.4
	OFF	< 0.4	< 0.4

*LLD VALUES ARE DETERMINED QUARTERLY

TABLE 4.2 LLD VALUES FOR GAMMA EMITTERS IN SURFACE WATER

NUCLIDE	LLD (pCi liter^{-1})*
Co-60	0.4
Zn-65	0.7
Cs-137	0.3
Cs-134	0.4
Sr-85	0.4
Ru-103	0.3
Ru-106	3.0
Nb-95	0.4
Zr-95	0.5

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1996

5. VEGETATION (TABLE 5.1 AND 5.2)

Table 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. The reported activities are all below the Alert Level of 20 pCi $gram^{-1}$. Table 5.2 lists LLD values for several gamma emitters. No gamma activity due to any of these radionuclides has been observed in campus vegetation. The beta and gamma activities are reported as pCi per gram of green vegetation. Beginning in January of 1996, the vegetation sampling has been revised to be performed in alternate years.

TABLE 5.1 GROSS BETA ACTIVITY IN CAMPUS VEGETATION * LLD ~ 0.5 pCi g^{-1}

SAMPLE DATE	SAMPLE LOCATION	(pCi g^{-1} ±2σ)
DECEMBER 1995	NORTH CAMPUS	3.6 ± 0.1
DECEMBER 1995	SOUTH CAMPUS	2.6 ± 0.1
DECEMBER 1995	EAST CAMPUS	2.5 ± 0.1
DECEMBER 1995	WEST CAMPUS	2.5 ± 0.2

*LLD values are determined semiannually

TABLE 5.2 LLD VALUES FOR GAMMA EMITTERS IN VEGETATION

NUCLIDE	LLD (pCi gram^{-1})*
Co-60	0.01
Zn-65	0.02
Cs-137	0.01
Cs-134	0.01
Sr-85	0.01
Ru-103	0.01
Nb-95	0.01
Zr-95	0.02

*LLD VALUES ARE FOR THE 2ND QUARTER OF 1996

6. THERMOLUMINESCENT DOSIMETERS (TLDs) (TABLE 6.1)

TLD analysis is contracted to Teledyne Isotopes for determination of ambient gamma exposures. The dosimeters are $CaSO_4$ doped with dysprosium and have a manufacturer-stated sensitivity of 0.5 ± 0.15 mR (90% C.L.). Exposures are integrated over a three-month period at each of the five air monitor stations listed in Table 2.1 and also at the top of the PULSTAR Reactor stack. During July 1996, a TLD station was added to North Hall which is a student dormitory located 402 meters northeast of Burlington Labs. Also, the TLD station on David Clark Labs was moved to the Environmental Health and Safety Center. A control station is located in Room 107 of the Environmental Safety Center. Table 6.1 gives the data for these seven (7) monitoring locations.

The observed exposures are those expected to be produced by background radiations in this area of North Carolina. The data of Table 6.1 agrees well with the state-wide average exposure rate of ~ 18 - 20 mR per quarter year.

Table 2.2 Aerially Transported Gamma Activity				(fCi m E-3)					
					NUCLIDES				
SAMPLING PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
1995									
06/29 - 07/06	0.17	0.24	0.31	0.47	0.26	2.28	0.23	0.41	1.36
07/06 - 07/13	0.24	0.40	0.39	0.60	0.33	3.10	0.39	0.46	1.96
07/13 - 07/20	0.27	0.43	0.38	0.60	0.34	3.10	0.42	0.49	2.14
07/20 - 07/27	0.17	0.40	0.32	0.57	0.30	2.80	0.29	0.37	1.43
07/27 - 08/03	0.17	0.38	0.33	0.55	0.30	3.10	0.32	0.36	1.47
08/03 - 08/10	0.31	0.47	0.48	0.67	0.46	4.50	0.50	0.53	2.24
08/10 - 08/17	0.18	0.37	0.35	0.62	0.33	3.30	0.33	0.44	1.52
08/17 - 08/24	0.19	0.37	0.34	0.52	0.33	3.10	0.38	0.39	1.58
08/24 - 08/31	0.21	0.36	0.34	0.53	0.31	3.10	0.34	0.37	1.58
08/31 - 09/07	0.17	0.30	0.29	0.49	0.29	2.70	0.31	0.33	1.39
09/07 - 09/14	0.17	0.37	0.33	0.51	0.29	2.80	0.35	0.35	1.45
09/14 - 09/21	0.17	0.33	0.27	0.50	0.28	2.70	0.29	0.33	1.33
09/21 - 09/28	0.18	0.31	0.28	0.46	0.28	2.40	0.27	0.35	1.26
09/28 - 10/05	0.14	0.29	0.28	0.39	0.23	2.30	0.26	0.28	1.17
10/05 - 10/12	0.16	0.31	0.27	0.47	0.26	2.40	0.26	0.33	1.16
10/12 - 10/19	0.17	0.30	0.25	0.43	0.21	2.30	0.28	0.28	1.16
10/19 - 10/26	0.19	0.34	0.29	0.47	0.22	2.60	0.29	0.29	1.51
10/26 - 11/02	0.17	0.29	0.22	0.40	0.23	2.30	0.25	0.28	1.27
11/02 - 11/09	0.16	0.29	0.25	0.45	0.25	2.20	0.24	0.31	1.29
11/09 - 11/16	0.18	0.28	0.27	0.43	0.26	2.30	0.26	0.31	1.31
11/16 - 11/28	0.18	0.31	0.26	0.42	0.27	2.40	0.27	0.33	1.38
11/28 - 12/06	0.17	0.31	0.29	0.38	0.27	2.60	0.29	0.30	1.46
12/06 - 12/13	0.15	0.30	0.34	0.60	0.41	2.30	0.24	0.34	1.32
12/13 - 12/20	0.16	0.29	0.33	0.55	0.39	2.40	0.25	0.33	1.29
12/20 - 12/29	0.16	0.26	0.27	0.50	0.36	2.10	0.24	0.31	1.29
1996									
01/15-01/22	0.17	0.28	0.33	0.48	0.29	2.28	0.27	0.34	1.37
05/22-05/29	0.16	0.3	0.31	0.52	0.25	2.35	0.29	0.38	1.39

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory of the Radiation Protection Office has participated in the U.S. EPA Environmental Laboratory Intercomparison Studies Program during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques. In January 1996, the Radiation Protection Office was informed that due to uncertainties in EPA's budget, the distribution of some performance evaluation samples would be discontinued. Accordingly, this laboratory received only air filters for the 1995-96 intercomparison studies. The results of the intercomparison studies are given in Tables 7.1 a-c. All samples are analyzed in triplicate and reported as an average value with an experimental sigma (1s).

The Radiation Protection Office is currentlly attempting to obtain blind performance evaluation samples from another source.

Appendix 1 gives an explanation of the quantities listed in the tables and an example calculation.

TABLE 7.1a GROSS ALPHA ACTIVITY AIR FILTER -- INTERCOMPARISON STUDY 25 AUGUST 1995

The known value for gross alpha activity is 25.0 pCi/filter with an expected laboratory precision of 6.3 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS ALPHA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
26.1	25.8	26.5	0.35	0.066	26.13	-0.14	0.31

STATISTICAL SUMMARY OF 182 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	27.10	Grand Avg	26.65
Std. Dev.	6.47		3.98
Variance	41.88		15.83
% Coef. of Var.	23.88		14.93
% deviation of mean from known value	8.40		6.62
Norm. dev. of mean from known value	0.32		0.42
Median	26.00		25.88
% deviation of median from known value	4.00		3.53
Nor. dev. of median from known value	0.15		0.22

TABLE 7.1b GROSS BETA ACTIVITY AIR FILTER - INTERCOMPARISON STUDY 25 AUGUST 1995

The known value for gross beta activity is 86.6 pCi/filter with an expected laboratory precision of 10.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

GROSS BETA

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	(known)
81.3	83.8	79.5	2.16	0.254	81.53	-1.01	-0.88

STATISTICAL SUMMARY OF 182 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	89.82	Grand Avg	87.38
Std. Dev.	21.06		8.81
Variance	443.62		77.54
% Coef. of Var.	23.45		10.08
% deviation of mean from known value	3.71		0.90
Norm. dev. of mean from known value	0.15		0.09
Median	87.48		87.30
% deviation of median from known value	1.02		0.81
Nor. dev. of median from known value	0.04		0.08

TABLE 7.1c ^{137}Cs ACTIVITY AIR FILTER - INTERCOMPARISON STUDY 25 AUGUST 1995

The known value for Cesium-137 activity is 25.0 pCi/filter with an expected laboratory precision of 5.0 (1s, 1 determination).

NCSU - ENVIRONMENTAL LABORATORY RESULTS

^{137}Cs

Res. 1	Res. 2	Res. 3	Exper. Sigma	Rng anal (R + SR)	Average	Normalized deviation (grand-avg)	Normalized deviation (known)
30.0	30.0	30.0	0.00	0.000	30.00	1.09	1.73

STATISTICAL SUMMARY OF 182 PARTICIPANTS

Statistic	Respondents		Non-outliers
Mean	28.06	Grand Avg	26.85
Std. Dev.	9.86		3.88
Variance	97.27		15.08
% Coef. of Var.	35.15		14.46
% deviation of mean from known value	12.24		7.39
Norm. dev. of mean from known value	0.31		0.48
Median	26.33		26.33
% deviation of median from known value	5.33		5.33
Nor. dev. of median from known value	0.14		0.34

8. CONCLUSIONS

The data obtained during this period do not show any fission product activities. The observed environmental radioactivity is due primarily to radon progeny, primordial radionuclides (e.g. K-40) and those radionuclides (e.g., Be-7) which originate in the upper atmosphere as the result of cosmic ray interactions. These facts justify the conclusion that the PULSTAR Reactor facility continues to operate safely and does not release fission product materials into the environment.

9. ACKNOWLEDGMENTS

This office is greatly indebted to Mr. Bill Crocker for his untiring efforts in collecting the environmental samples. Great appreciation is also expressed to Mr. Thomas Brackin for his work in repairing the air samplers.

The graphs and arrangement of this report are available due to the assistance of Ms. Joy L. Douglass.

APPENDIX 1

The vertical columns in Tables 7 are identified as columns 1-8 from left to right.

Column 1,2,3: Laboratory results given in triplicate.

Column 4: Standard deviation (1s) of the experimental results.

Column 5: Normalized range value in "mean range + standard error of the range".

Column 6: Average value of the triplicate analysis.

Column 7: Normalized deviation from the grand average value of all laboratories expressed in σ_m units.

Column 8: Normalized deviation from the known value expressed in σ_m units.

The following example calculation gives a set of data, the mean value, the experimental sigma, and the range. These statistics provide measures of the central tendency and dispersion of the data.

The normalized range is computed by first finding mean range, R, the control limit, CL, and the standard error of the range, σ_R. The normalized range measures the dispersion of the data (precision) in such a form that control charts may be used. Control charts allow one to readily compare past analytical performance with present performance. In the example, the normalized range equals 0.3 which is less than 3 which is the upper control level. The precision of the results is acceptable.

The normalized deviation is calculated by computing the deviation and the standard error of the mean, σ_m. The normalized deviation allows one to measure central tendency (accuracy) readily through the use of control charts. Trends in analytical accuracy can be determined in this manner. For this example, the normalized deviation is -0.7 which falls between +2 and -2 which are the upper and lower warning levels. The accuracy of the data is acceptable.

Finally, the experimental error of all laboratories, the grand average, and the normalized deviation from the grand average are calculated in order to ascertain the performance of all the laboratories as a group. Any bias in methodology or instrumentation may be indicated by these results.

EXAMPLE CALCULATIONS

Experimental Data:

Known value = μ = 3273 pCi ^{3}H/liter on September 24, 1974

Expected laboratory precision = σ = 357 pCi/liter

Sample	Result
X_1	3060 pCi/liter
X_2	3060 pCi/liter
X_3	3240 pCi/liter

Mean = $\bar{x}$

$$\bar{x} = \frac{\sum_{x=i}^{N} X_i}{N} = \frac{9360}{3} = 3120 \text{ pCi/liter}$$

where N = number of results = 3

Experimental sigma = s

$$s = \sqrt{\frac{\sum_{i=1}^{N} (X_i)^2 - \frac{(\sum_{i=1}^{N} X_i)^2}{N}}{N-1}}$$

$$s = \sqrt{\frac{(3060)^2+(3060)^2+(3240)^2-\frac{(3060+3060+3240)^2}{3}}{2}}$$

s = 103.9 pCi/liter

Range = r

r = | maximum result - minimum result |

r = |3240 - 3060|

r = 180 pCi/liter

Range Analysis (RNG ANLY)*

Mean range = $\bar{R}$

$\bar{R} = d_2\sigma$ where d_2** = 1.693 for N = 3

$= (1.693)(357)$

$\bar{R}$ = 604.4 pCi/liter

Control limit = CL

$CL = \bar{R} + 3\sigma_R$

$= D_4\bar{R}$ where D_4** = 2.575 for N = 3

$= (2.575)(604.4)$

CL = 1556 pCi/liter

Standard error of the range = σ_R

$\sigma_R = (R + 3\sigma_R - \bar{R}) \div 3$

$= (D_4\bar{R} - \bar{R}) \div 3$

$= (1556 - 604.4) \div 3$

σ_R = 317.2 pCi/liter

Let Range = $r = w\bar{R} + x\sigma_R$ = 180 pCi/liter

Define normalized range = w + x

for $r > \bar{R}$, w = 1

then $r = w\bar{R} + x\sigma_R = \bar{R} + x\sigma_R$

or $x = \dfrac{r - \bar{R}}{\sigma_R}$

therefore $w + x = 1 + x = 1 + \dfrac{r - \bar{R}}{\sigma_R}$

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*Rosentein, M., and A. S. Goldin, "Statistical Techniques for Quality Control of Environmental Radioassay," AQCS Report Stat-1, U.S. Department of Health Education and Welfare, PHS, November 1964.
**From table "Factors for Computing Control Limits," Handbook of Tables for Probability and Statistics, 2nd Edition, The Chemical Rubber Co., Cleveland, Ohio, 1968, p. 454.

for $r \leq R$, $x = 0$

then $r = w\bar{R} + x\sigma_R = w\bar{R}$

or $$w = \frac{r}{\bar{R}}$$

therefore $$w + x = w + 0 = \frac{r}{\bar{R}}$$

since $r < \bar{R}$, $(180 < 604.4)$

$$w + x = \frac{180}{604.4}$$

$$w + x = 0.30$$

Normalized deviation of the mean from the known value = ND

Deviation of mean from the known value = D

$$D = \bar{x} - \mu$$

$$= 3120 - 3273$$

$$D = -153 \text{ pCi/liter}$$

Standard error of the mean = σ_m

$$\sigma_m = \frac{\sigma}{\sqrt{N}}$$

$$= \frac{357}{\sqrt{3}}$$

$$\sigma_m = 206.1 \text{ pCi/liter}$$

$$ND = \frac{D}{\sigma_m}$$

$$= \frac{-153}{206.1}$$

$$ND = -0.7$$

Control limit = CL

$$CL = (\mu \pm 3\sigma_m)$$

Warning limit = WL

WL = $(\mu \pm 2\sigma_m)$

Experimental sigma (all laboratories) = s_t

$$s_t = \sqrt{\frac{\sum_{i=1}^{N} x_i^2 - \frac{(\sum_{i=1}^{N} x_i)^2}{N}}{N-1}}$$

$$= \sqrt{\frac{162639133 - \frac{(49345)^2}{15}}{14}}$$

s_t = 149 pCi/liter

Grand Average = GA

$$GA = \frac{\sum_{i=1}^{N} x_i}{N}$$

$$= \frac{49345}{15}$$

GA = 3290 pCi/liter

Normalized deviation from the grand average = ND'

Deviation of the mean from the grand average = D'

D' = $\overline{x}$ - GA

= 3120 - 3290

D' = -170 pCi/liter

$$ND' = \frac{D'}{\sigma_m}$$

$$= \frac{-170}{206.1}$$

ND' = - 0.8