NORTH CAROLINA STATE UNIVERSITY

DEPARTMENT OF NUCLEAR ENGINEERING

PULSTAR REACTOR ANNUAL REPORT

DOCKET NUMBER 50-297

For the Period: 01 January 2019 - 31 December 2019

The following annual report for 2019 is submitted in accordance with Section 6.7.4 of the North Carolina State University PULSTAR Reactor Technical Specifications:

6.7.4.a Brief Summary:

Reactor operations have been routine during this reporting period.

i Operating experience including a summary of experiments performed.

The reactor facility had a total of 2551 utilization hours. The utilization hours exceeded critical hours (1627 h) since there was typically more than one user of the reactor facility at a given time. The following is a brief summary of the types of experiments performed:

Teaching Laboratories, Short Courses, Research and Services:

- Core thermal power measurements
- Dynamic reactivity measurements
- Axial power and peaking factor measurements (flux mapping)
- Reactor power determination using photodiode arrays
- Neutron fluence and spectral measurements
- In-core detector certification
- Accelerated lifetime testing for nuclear detectors
- Neutron radiography
- Positron production facility
- Neutron Diffraction
- Isotope Production
- Crude oil
- Food samples
- Fish tissues
- Laboratory animal tissue
- Human hair, nails, and urine
- Polymers and plastics
- Sediment/soil/rocks
- Silicon crystals
- Textiles
- Water

ii Changes in Performance Characteristics Related to Reactor Safety:

None

iii Results of Surveillance, Tests, and Inspections:

The reactor surveillance program has revealed no significant or unexpected trends in reactor systems performance during this reporting period. The Reactor Safety and Audit Committee (RSAC) performed its annual audit for the facility and determined that all phases of operation and supporting documents were in compliance.

6.7.4.b Energy Output and Critical Hours:

Total Energy Output in 2019:	64.6 Megawatt·days
Critical hours in 2019:	1626.7 hours
Cumulative Total Energy Output Since Initial Criticality:	2047.8 Megawatt·days

6.7.4.c Number of Emergency and Unscheduled Shutdowns:

Emergency Shutdowns - NONE

Unscheduled Shutdowns – One

18-DEC-2019 SHUTDOWN due to Cable Malfunction on the Neutron Imaging Shutter. On December 18, 2019, at approximately 10:15, the neutron radiographer notified the control room that the neutron imaging facility shutter would not open even though all permits were satisfied. The RO then notified the DSRO as required. Upon investigation, it was found that the cable which opens that shutter had come loose from the cable clamps. The reactor was shutdown at 10:35 to reduce radiation levels while the cable was reattached. A Neutron Imaging Facility Periodic Inspection Report was completed and the facility was returned to service.

The reactor was authorized for restart at 11:53.

6.7.4.d Corrective and Preventative Maintenance:

Preventative maintenance, tests and calibrations are scheduled, performed and tracked utilizing the PULSTAR Surveillance File System. Each major component of the Reactor Safety System defined in Section 3.3, and all surveillance required by Section 4 of the Technical Specifications are monitored by this file system to ensure that maintenance and calibrations are performed in a timely manner. All historical data relating to those components, in addition to many other sub-systems, are maintained in these files.

844 PS-1-05-3A (PS-1-05-1) – Safety Channel Detector – The housing for the Safety Channel uncompensated ion chamber was found to be leaking. The housing was removed from the pool and the o-ring along with the HV and signal cables were replaced. The housing was returned to the pool and the channel tested satisfactory and was returned to service.

845 PS-1-05-3A – Safety Channel – The Safety Channel was returned the manufacturer for cleaning and routine inspection and maintenance. The channel was modified to make it functionally identical to the Linear Channel (refer to Control Number 835) so that in the future the Safety and Linear will be redundant channels. The actual operation of the channel will not change at this time.

846 PS-1-03-4A – Linear Channel – The Linear Channel was returned the manufacturer for cleaning and routine inspection and maintenance. The channel was modified to make it functionally identical to the Safety Channel (refer to Control Number 836) so that in the future the Safety and Linear will be redundant channels. The actual operation of the channel will not change at this time.

847 PS-1-02-1 (PS-1-02-4B) – LogN Channel – During the performance of the startup checklist the LogN Channel non-op light would not reset. Upon investigation, the HV cable connector was found to be faulty. The connector was replaced and the channel tested satisfactory and was returned to service.

848 PS-6-14 – Sump Pump –The intermediate bearing on the sump pump shaft seized causing an over-current trip of the sump pump motor. The bearing was replaced and the sump was returned to service.

849 PS-1-11-1 – Temperature Switch – During the semiannual calibration of the Temperature Switch Channel, Temperature Switch No.2 (an installed spare), failed when it was opened up for adjustment. A new switch was ordered and installed.

850 PS-3-02-5A – Auxiliary Generator – A low natural gas alarm was received in the control room during the late afternoon of May 21, 2019. At the time, the reactor had already been shutdown and secured for the day. A temporary diesel generator was installed and tested satisfactory. Natural Gas supply was restored on June 7, 2019. The Auxiliary Generator tested satisfactory and was returned to service.

851 PS-4-06-10 – Thermal Column – The lower aluminum trim piece which surrounds the thermal column was found to have deformed in the upward direction. A structural engineering firm inspected the area and concluded that the deformation was caused by the interaction of aluminum and concrete in the presence of water. This trim piece is cosmetic in nature and will be cut out and replaced.

852 PS-2-01-1B – Reactor Air Compressor – The reactor air compressor could not maintain maximum rated CFM when under full load. Upon investigation a finger valve on the low pressure side was found to be broken. The low pressure side finger valves were replaced and the compressor tested satisfactory and was returned to service.

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

Facility Changes

Design changes to the reactor facility are reviewed to determine whether or not a 10 CFR Part 50.59 evaluation was required. Evaluations were performed for all design changes.

835 Safety Channel Modification –The Safety Channel was send back to the manufacturer for general maintenance and to make it functionally identical to the Linear Channel. The power supply was replaced, a compensation voltage power supply was added for future use and the bi-stable trips were reordered to match the Linear Channel trips. The Flow/Flapper Enable trip was changed to automatically reset.

836 Linear Channel Modification –The Linear Channel was send back to the manufacturer for general maintenance. The Automatic Channel Enable trip was changed to automatically reset when it is within band.

Document Changes

Procedure changes were reviewed to determine whether or not a 10 CFR Part 50.59 evaluation was required.

Based on the screening reviews none required a full 10 CFR 50.59 evaluation.

834 Emergency Procedure 2 – *Off-site Notification Revision 22* – This revision updates the North Carolina authentication code list.

837 NRP-OP-101 – *Reactor Startup and Shutdown Revision 11* – This revision to the startup checklist to reflect that the Safety Channel Flow/Flapper Enable now automatically resets. See Control Number 835.

837 NRP-OP-103 – *Reactor Operation Revision 4* – This revision to the procedure to reflect that the Automatic Channel Enable now automatically resets. See Control Number 836.

838 NRP-OP-202 – *Service Water Revision 2* – This revision updates the valve numbers to be consistent with the service water system as described in the FSAR.

Test and Experiments

None.

Other Changes

820 License Renewal – An updated Safety Analysis Report was submitted on August 9, 2019. The submittal incorporated an updated Safety Analysis in Support of Fueled Experiments for the NCSU PULSTAR Reactor, therefore, NCSU withdrew the separate license amendment request regarding fueled experiments dated December 4, 2018.

An updated Technical Specifications was submitted on September 10, 2019. The update contained revised power levels, incorporated discussions during an NRC site visit and included revised specifications for fueled experiments.

Other Items

None.

6.7.4.f Radioactive Effluent:

Liquid Waste (summarized by quarters)

i. Radioactivity Released During the Reporting Period:

Releases to the sanitary sewer are given below:

Period	(1)	(2)	(3)	(4)[1]	(5)
2019	Number of Batches	Total μCi	Total Volume Liters	Diluent Liters	Tritium μCi
01 JAN – 31 MAR	2	287	6,461	6,586	285
01 APR – 30 JUN	2	310	6,472	6,721	305
01 JUL – 30 SEP	5	231	16,446	18,035	200
01 OCT – 31 DEC	2	98	6,586	7,624	78
2019	868 μCi of tritium was released during this year.				
2019	926 μCi of total activity was released during this year.				
[1]Based on gross beta activity only. Tritium did not require further dilution.					

ii. Identification of Fission and Activation Products:

The gross beta-gamma activity of the batches in (i) 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.

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

All liquid effluent met the requirements of 10 CFR Part 20 for release to the sanitary sewer.

Gaseous Waste (summarized monthly)

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

(1) Gases:

Year	Month	Total Time Hours	Curies
2019	JANUARY	744	0.134
	FEBRUARY	672	0.036
	MARCH	744	0.077
	APRIL	720	0.040
	MAY	744	0.493
	JUNE	720	0.364
	JULY	744	0.361
	AUGUST	744	0.600
	SEPTEMBER	720	0.538
	OCTOBER	744	0.586
	NOVEMBER	720	0.738
	DECEMBER	744	0.492
	TOTAL	8760	4.459

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

Particulate filters from the Stack Particulate Monitoring Channel were analyzed upon removal. There was no particulate activity with a half-life greater than 8 days detected.

ii. Gases and Particulates Discharged During the Reporting Period:

(1) Gases:

Total activity of Argon-41 released was 4.483 Curies in 2019.

The yearly average concentration of Argon-41 released from the PULSTAR reactor facility exhaust stack in 2019 was 2.2×10^{-8} μCi/ml. Dose calculations for the year were performed using methods given in the Final Safety Analysis Report and gave results less than the 10 CFR Part 20 constraint level of 10 mrem. These results are consistent with environmental monitoring data given in Attachment A.

(2) Particulates:

Refer to gaseous waste i.(2) above. No activation or fission products were detected.

Solid Waste from Reactor

i. Total Volume of Solid Waste Packaged

Total volume of solid waste was 34 ft^3.

ii. Total Activity Involved

Total activity for solid waste was 0.437 mCi.

iii. Dates of shipments and disposal

Transfer of solid radioactive waste to the university broad scope radioactive materials license was made in April 2019, August 2019, and September 2019. The University Environmental Health and Safety Center arranges disposal of hazardous wastes.

6.7.4.g Personnel Radiation Exposure Report:

Thirty-three individuals were monitored for external radiation dose during the reporting period. Internal dose monitoring was not required for any individual. Collective deep dose-equivalent for 1 Jan 2019 to 31 Dec 2019 was 3.070 person-rem. Individual deep dose-equivalent ranged from 0.000 rem to 0.983 rem with an average of 0.093 rem. Three individuals were above 0.250 rem.

6.7.4.h Summary of Radiation and Contamination Surveys Within the Facility:

Radiation and contamination surveys performed within the facility indicated that:

- Radiation in the majority of areas was 5 mrem/h or less.
- Radiation in the remaining areas was higher due to reactor operations.
- Contamination in most areas was not detectable. When contamination was detected, the area or item was confined or decontaminated.

6.7.4.i Description of Environmental Surveys Outside of the Facility:

Refer to Attachment A for results of environmental sampling and analysis.

Radiation surveys performed in unrestricted areas near the reactor facility indicated that:

- Radiation was at background levels for most areas (background is approximately 10 µrem/h).
- Contamination was not detectable.
- Net radiation readings ranged from 0 to 30 µrem/h while the reactor was operating at power. Radiation was at background levels in all routinely occupied spaces.
- Water samples from Rocky Branch Creek and an on-site ground water monitoring well were analyzed in 2019 for tritium, gross beta activity, gross alpha activity, and gamma radiation. All sample results were consistent with background radioactivity. Environmental monitoring of Rocky Branch Creek and groundwater is routinely performed in accordance with facility procedures.

ATTACHMENT A

PULSTAR REACTOR

ENVIRONMENTAL RADIATION SURVEILLANCE REPORT

FOR THE PERIOD
JANUARY 1, 2019 - DECEMBER 31, 2019

NORTH CAROLINA STATE UNIVERSITY

ENVIRONMENTAL HEALTH AND SAFETY CENTER

RADIATION SAFETY DIVISION

by

Ralton J. Harris
Environmental Health Physicist

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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.

Table 1
Environmental Monitoring Programs for the PULSTAR Reactor at North Carolina State University

Sample	Activity Measured	Conducted By	Previous Frequency	Current Frequency	Basis For Measurement
Stack Gases	Gross Gamma	N.E.	Continuous	Continuous	10 CFR 20 T.S. 6.7.4
Stack Particles	Gross Beta Gamma Emitters	N.E. N.E.	Monthly	Monthly	10 CFR 20 T.S. 6.7.4
Water from Reactor Facility	Gross Beta Gross Gamma Tritium	N.E. N.E. N.E.	Prior to Discharge (~ Monthly)	Prior to Discharge (~ Monthly)	10 CFR 20 T.S. 6.7.4 City of Raleigh Ordinance
Air Particles at 4 Campus Stations*	Gross Beta Gamma Emitters	RSD RSD	Weekly Weekly	Quarterly Quarterly	10 CFR 20 10 CFR 20
Air Dose at 7 Campus Stations+	OSD Dosimeter	RSD	Quarterly	Quarterly	10 CFR 20
Surface Water Rocky Branch Creek	Gross Beta Gamma Emitters Tritium	RSD RSD N.E.	Quarterly Quarterly ----------	Quarterly Quarterly Quarterly	NCSU NCSU 10 CFR 20
Vegetation NCSU Campus	Gross Beta Gamma	RSD RSD	Semi-annually	Every Other Year	NCSU NCSU
Milk Local Dairy	I-131	RSD	Monthly	Every Other Year	NCSU

Abbreviations Used in Table:
N.E. = Nuclear Engineering/Reactor Facility; RSD = Radiation Safety Division.
*These 4 stations include:
Withers, Daniels, Polk and the Environmental Health & Safety Center.
+These 7 stations include: PULSTAR Reactor and the 4 air sampling stations, North Hall and a control station (EH&S).

2. AIR MONITORING (TABLES 2.1, 2.2, 2.3 and 2.4)

Air monitoring is performed continually for one week during each of four (4) quarters during the year. The data in Table 2.2 are for gross beta activity levels measured during the year. The highest gross beta activity observed was 19.8 fCi/cubic meter at the Polk Hall station during the week of 12/05/2019 to 12/12/2019. The annual campus average value was 12.1 fCi/cubic meter.

Table 2.3 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.

Table 2.4 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)
DANIELS	SOUTHEAST	90	-8
WITHERS	NORTHEAST	82	-6
EH & S CENTER	WEST	1230	-3
NORTH HALL **	NORTHEAST	402	-4
POLK HALL	WEST	100	-7

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

TABLE 2.2 Airborne Gross Beta Activity (fCi/cubic meter ± 2σ)

PERIOD	Polk	Daniels	Withers	EH&S
2019				
03/12-03/19	16.4 ± 1.2	10.4 ± 1.0	15.6 ± 1.2	7.1 ± 1.0
06/12-06/19	9.1 ± 1.0	11.5 ± 1.0	6.8 ± 0.9	15.7 ± 1.2
09/12-09/19	12.1 ± 1.1	8.3 ± 1.0	6.4 ± 0.9	15.8 ± 1.2
12/05-12/19	19.8 ± 1.3	17.3 ± 1.3	8.4 ± 1.0	12.1 ± 1.2

TABLE 2.3 Airborne Gamma Activity LLD Values (fCi/cubic meter)

PERIOD	Co-57	Co-60	Nb-95	Zr-95	Ru-103	Ru-106	Cs-137	Ce-141	Ce-144
2019									
03/12- 03/19	0.21	0.35	0.29	0.47	0.27	2.37	0.26	0.38	1.22
06/12 - 06/19	0.20	0.37	0.28	0.48	0.28	2.48	0.29	0.34	1.28
09/12 - 09/19	0.18	0.35	0.31	0.54	0.33	2.51	0.29	0.43	1.40
12/05 - 12/12	0.17	0.37	0.37	0.50	0.32	2.41	0.29	0.39	1.41

TABLE 2.4 REGULATORY LIMITS, ALERT LEVELS, AND BACKGROUND LEVELS FOR AIRBORNE RADIOACTIVITY (fCi M^{-3}).

NUCLIDE	REGULATORY LIMIT	INVESTIGATION LEVEL	*AVERAGE N.C. BACKGROUND LEVEL
GROSS BETA	1000	500	20
Cs-137	2×10^5	100	2
Ce-134	2×10^5	100	0
Nb-95	2×10^6	100	0
Zr-95	400	100	0

* This data represents an average value measured in North Carolina at various locations. Excerpted from *2009 Environmental Surveillance Report* produced by the NC Department of Health and Human Services Radiation Protection Section.

3. **MILK** (TABLE 3.1)

Milk samples are collected every other year from the Campus Creamery and the Lake Wheeler Road Dairy as processed milk and raw milk and analyzed for I-131.

TABLE 3.1 I-131 IN COW′S MILK (pCi Liter^{-1} ± 2 σ) LLD ~ 2 pCi Liter^{-1}

	pCi Liter^{-1}	
DATE	Campus Creamery	Lake Wheeler
10-07-19	Not Detected	Not Detected

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), behind Carmichael Gymnasium (GYM) and exits (OFF) the campus. The LLD value for gross alpha and beta activities is ~ 0.4 pCi Liter^{-1}. For gross alpha activity the Investigation Level is 5 pCi Liter^{-1} and the Regulatory Limit is 15 pCi Liter^{-1}. For gross beta activity the Investigation Level is 12.5 pCi Liter^{-1} and the Regulatory Limit is 50 pCi Liter^{-1}. Gamma analysis of all samples was also performed. All the results are consistent with the presence of naturally-occurring radionuclides and none of the gamma emitters listed in Table 4.2 were detected.

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

LLD_α ~ 0.4 pCi Liter^{-1} LLD_β ~ 0.4 pCi Liter $^{-1}$

		pCi Liter $^{-1}$	
DATE	LOCATION	GROSS ALPHA	GROSS BETA
FIRST QUARTER 2019	ON	0.1 ± 0.2	4.4 ± 0.7
	OFF	0.1 ± 0.2	4.5 ± 0.7
	GYM	0.2 ± 0.2	5.7 ± 0.8
SECOND QUARTER 2019	ON	0.2 ± 0.2	3.8 ± 0.7
	OFF	0.2 ± 0.2	6.2 ± 0.8
	GYM	0.2 ± 0.2	3.8 ± 0.7
THIRD QUARTER 2019	ON	0.1 ± 0.2	4.9 ± 0.7
	OFF	0.1 ± 0.2	5.2 ± 0.8
	GYM	0.2 ± 0.2	3.7 ± 0.7
FOURTH QUARTER 2019	ON	0.0 ± 0.2	4.6 ± 0.7
	OFF	0.2 ± 0.2	3.9 ± 0.7
	GYM	0.2 ± 0.2	4.6 ± 0.7

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

5. VEGETATION (TABLE 5.1 & 5.2)

Tables 5.1 gives gross beta activities for grass samples collected on the NCSU Campus. Table 5.2 lists LLD values for several gamma emitters. No gamma emitters were detected.
The vegetation sampling is performed every other year.

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

SAMPLE DATE	SAMPLE LOCATION	(pCi $g^{-1} \pm 2\sigma$)
09-30-19	NORTH CAMPUS	3.6 ± 0.3
09-30-19	SOUTH CAMPUS	5.6 ± 0.4
09-30-19	EAST CAMPUS	4.7 ± 0.4
09-30-19	WEST CAMPUS	3.8 ± 0.3

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

6. OPTICALLY STIMULATED DOSIMETERS (TABLE 6.1)

Dosimeter analysis is contracted to Landauer, Inc. for determination of ambient radiation exposures. Exposures are integrated over a three-month period at each of the air monitor stations listed in Table 2.1 and at the PULSTAR Reactor facility. A control dosimeter is located in the Environmental Health & Safety Center. Table 6.1 gives the dose equivalent data for these seven (7) locations.

The dose equivalents are reported as millirem per quarter year. Readings which fall below the dosimeters' minimum measurable quantities (i.e., 1 millirem for gamma radiations and 10 millirem for beta radiation) are reported by the contract vendor with the designation **"M"**. The observed readings are typically within the expected range for natural background radiation levels.

The 2nd quarter dosimeters were radiographed by the U.S. Postal Service during shipment to the vendor company for routine dose evaluation. A standard control was used by the vendor company for the background. All dose readings for this period have been marked with an " * ".

TABLE 6.1 ENVIRONMENTAL DOSIMETER DOSES - Millirem per Quarter

Period	**Control**	Polk	Withers	Daniels	EHS	North	PULSTAR
2019							
01/01-03/31	53	**M,M**	**M,M**	**M,M**	**M**	**M**	6
04/01-06/30	29 *	4,4 *	1,3 *	5,6	7 *	19 *	31 *
07/01-09/30	50	**M,M**	**M,M**	**M,M**	**M**	**M**	9
10/01-12/31	46	**M**	**M**	**M,M**	**M**	4	14

7. QUALITY CONTROL INTERCOMPARISON PROGRAM

The Environmental Radiation Surveillance Laboratory (ERSL) in the Radiation Safety Division has analyzed samples provided by the U.S. DOE Mixed-Analyte Performance Evaluation Program (MAPEP Test Session 41) Radiological and Environmental Sciences Laboratory (RESL) during this reporting period. The objective of this program is to provide laboratories performing environmental radiation measurements with unknowns to test their analytical techniques. Due to DOE/MAPEP funding issues, cross-check test samples are currently not being supplied for gross alpha/beta water and gross alpha/beta air filter analyses.

The MAPEP value listed in the Tables 7.1 (a-c) to which the ERSL results are compared is the mean of replicate determinations for each nuclide. The MAPEP uncertainty is the standard error of the mean.

For each reported radiological analyte, the laboratory result and the reference value may be used to calculate a relative bias:

$$\%\text{Bias} = \frac{(100)(\text{Laboratory Result} - \text{RESL Reference Value})}{\text{RESL Reference Value}}$$

The relative bias will place the laboratory result in one of three categories:

Acceptable…… Bias $\leq$ 20%
Acceptable with Warning... 20% < Bias $\leq$ 30%
Not Acceptable…… Bias > 30%

TABLE 7.1a

MULTINUCLIDE WATER SAMPLE - INTERCOMPARISON STUDY
01 August 2019

The sample consists of a spiked aliquot of acidified water (~5 % HNO_3). The reported values and the known values are given in Bq/Liter.

	***NCSU - ENVIRONMENTAL LABORATORY RESULTS**			
Radionuclide	***Reported Value**	***Reported Error**	**MAPEP Value**	**Acceptance Range**
Co60	**8.78**	**0.53**	**8.8**	**6.2 – 11.4**
Cs137	**19.44**	**0.43**	**18.4**	**12.9 – 23.9**
Cs134	**0.3**	**0.5**	**--------**	**False + Test**
Co57	**16.55**	**0.32**	**15.6**	**10.1 – 20.3**
Mn54	**18.85**	**0.42**	**20.6**	**14.4 – 26.8**
Zn65	**21.01**	**1.03**	**20.3**	**14.2 – 26.4**
Gross Alpha	**1.46**	**0.39**	**1.06**	**0.32 – 1.80**
Gross Beta	**2.47**	**0.29**	**3.32**	**1.66 – 4.98**

Note: The entry "------"indicates no analyte was present for purposes of conducting a False Positive (+) Test.

TABLE 7.1b

MULTINUCLIDE AIR FILTER - INTERCOMPARISON STUDY
01 August 2019

The sample consists of one 50 mm diameter glass fiber filter which has been spiked with a solution and dried. The reported values and the known values are given in Bq/filter.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	0.70	0.02	0.815	0.571 – 1.060
Cs137	1.42	0.02	1.58	1.11 – 2.05
Cs134	0.03	0.05	-----	False + Test
Co57	1.24	0.01	1.16	0.81 –1.51
Mn54	1.49	0.02	1.37	0.96 – 1.78
Zn65	1.49	0.06	1.06	0.74 – 1.38
Gross Alpha	0.387	0.024	0.528	0.158 – 0.898
Gross Beta	0.942	0.022	0.937	0.469 – 1.406

Note: The entry "------"indicates no analyte was present for purposes of conducting a False Positive (+) Test.

TABLE 7.1c

MULTINUCLIDE VEGETATION SAMPLE - INTERCOMPARISON STUDY
01 August 2019

The sample consists of a spiked sample of vegetation. The reported values and the known values are given in Bq/sample.

***NCSU - ENVIRONMENTAL LABORATORY RESULTS**

Radionuclide	*Reported Value	*Reported Error	MAPEP Value	Acceptance Range
Co60	4.26	0.09	5.30	3.71 – 6.89
Cs137	3.49	0.09	3.28	2.30 – 4.26
Cs134	0.3	0.2	------	False + Test
Co57	4.73	0.05	4.57	3.20 – 5.94
Mn54	3.65	0.08	4.49	3.14 – 5.84
Zn65	3.92	0.11	2.85	2.00 – 3.71

Note: The entry "------" indicates no analyte was present for purposes of conducting a False Positive (+) Test.

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 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.