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Submission from Ontario Power Generation

Mémoire d'Ontario Power Generation

In the Matter of

À l'égard de

Darlington Nuclear Generation Station: Update on Alpha Contamination Event

Centrale nucléaire de Darlington : Mise à jour sur l'événement de contamination alpha

Action Item from November 8, 2018 Commission Meeting

Mesure de suivi de la réunion de la Commission du 8 novembre 2018

Commission Meeting

Réunion de la Commission

February 20, 2019

Le 20 février 2019

Canada

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ONTARIO POWER GENERATION

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December 19, 2018

CD# N-CORR-00531-19471

MS. N. RIENDEAU
Director
Darlington Regulatory Program Division
Canadian Nuclear Safety Commission
280 Slater Street
Ottawa, ON K1P 5S9

Dear Ms. Riendeau:

Response to Commission Direction re: DNGS RWSB Internal Contamination Event

Reference: 1. CNSC Letter, N. Riendeau to D. Reiner, S. Gregoris and B. Duncan, "Darlington NGS: Darlington Retube Waste Processing Building - February 2018 Internal Contamination Event - Directions of the Commission", November 28, 2018, e-Doc 5719278, CD# N-CORR-00531-19439.

The purpose of this letter is to provide a response to the comments provided via e-mail to the CNSC President by Dr. F. Greening, as directed by the Commission at a Public Meeting of November 8, 2018, and reaffirmed in Reference 1.

Attachment 1 provides OPG's response to each of the comments. In support of the responses, four (4) Enclosures have been included in this correspondence, as listed in Table 1. Due to the Confidential and Proprietary nature of the Enclosures, OPG requests they not be released to third parties without prior written approval.

If you have any questions, please contact Mr. Robin Manley, Vice President, Nuclear Regulatory Affairs and Stakeholder Relations at 905-839-6746, extension 5264, or at robin.manley@opg.com.

Sincerely,

Brian Duncan
Senior Vice President, Nuclear Fleet Operations
Ontario Power Generation Inc.

Enc.

cc: A. Viktorov - CNSC (Ottawa)
K. Hazelton - CNSC Site Office (Darlington)
E. Leader - CNSC Site Office (Pickering)

TABLE 1

List of Enclosures

Item #	Document
Enclosure 1 (OPG Confidential)	AMEC Report, Radiological Source Term Characterization Strategy applicable to DNGS Refurbishment, OPG Document: NK38-REP-09701-0515372
Enclosure 2	Kinectrics C-14 Smears Analytical Report
Enclosure 3	Kinectrics - RWPB PT Smears
Enclosure 4 (OPG Confidential)	OPG Report, Dose Assessment for a Contamination Incident at DNGS (SCR N-2018-03429), OPG Document: OPG-REP-03416.4-10005-P

ATTACHMENT 1

Response to Dr. F. Greening E-mail to President of CNSC, dated October 30, 2018

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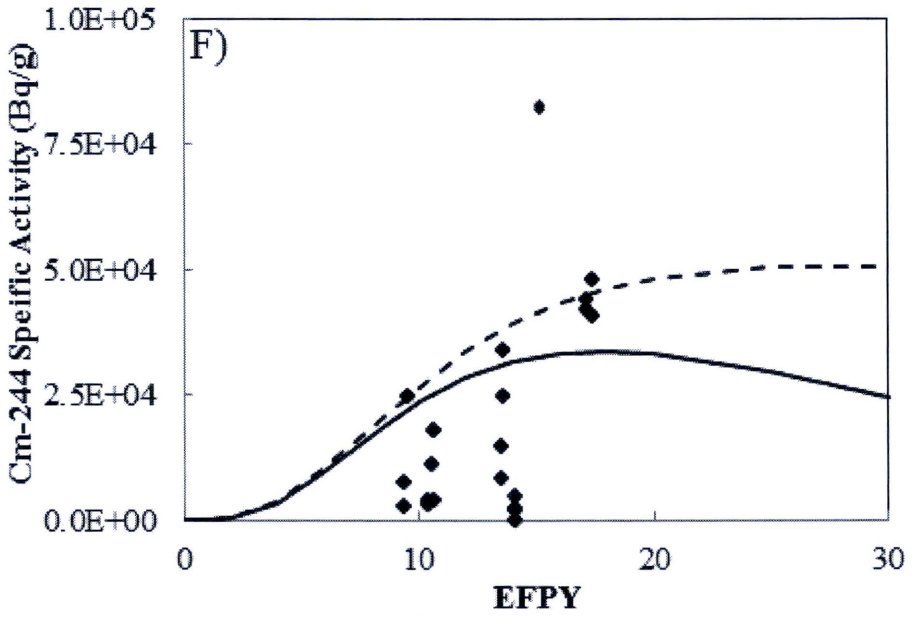
Attachment 1

Response to Dr. F. Greening E-mail to President of CNSC, dated October 30, 2018

Questions	Response	Enclosure
(i) Why has the C-14 contribution to the refurbishment workers' inhalation dose from the Feb 2018 lidding event been ignored when OPG considers it to be *the major contributor* to the dose from a hypothetical retube waste container accident?	OPG had considered the contribution of carbon-14 while ascertaining total assignable dose to the refurbishment workers involved in the February 2018 event. The contribution to dose from C-14 was different in the February 2018 situation compared to the hypothetical situation referenced in OPG's *Western Waste Management Facility Safety Assessment Report* (W-REP-01320-00008-R000) due to the two unique scenarios. Although both situations are retube waste container events, they involve different radionuclide exposure pathways. Section 3.2.5 of the safety report, entitled *Accident Scenario: Dropped Retube Waste Container,* describes a specific accident scenario in which a container is dropped and all gaseous radionuclides (including carbon dioxide and carbon particulate) within the container are assumed to be released. This does not apply to the February 2018 alpha uptake event as the container was not dropped. The February 2018 uptake was a contamination event, a result of loose contamination on the outside of the container. A more relevant report for dose predictions is NK38-REP-09701-0515372 *Radiological Source Term Characterization Strategy applicable to DNGS Refurbishment* report by AMEC NSS (Enclosure 1), which attributes most of the dose from loose contamination for pressure tube activities to Cm-243/244 based off smear sample data. All annulus gas systems of OPG stations now employ carbon dioxide as the annulus gas, the particulate form of C-14 is much reduced. The potential contribution of particulate C-14 to loose contamination dose was estimated to be essentially 0% for pressure tube removal activities. Therefore our assessment is that C-14 particulate personal monitoring was not required. No C-14 dose has been assigned. Workplace smear samples were taken in the RWPB and analyzed for C-14 (Enclosure 2). Results were less than 0.42 Bq/smear. These results support the assessment that C-14 monitoring was not required. Based on the above, OPG believes that no enhancements to current processes related to monitoring workers for particulate C-14 exposure in the RWPB are required.	**Refer to Enclosure 1.** **Refer to Enclosure 2.**

Questions	Response	Enclosure
(ii) Has OPG considered the contribution of *tritium* to the refurbishment workers' inhalation dose from the Feb 2018 event?	OPG always considers the contribution of tritium to radiation exposures of workers at our nuclear plants, and we have a robust tritium dosimetry program. OPG had considered the contribution of tritium while ascertaining total assignable dose to the refurbishment workers involved in the February 2018 event. As part of the follow up, both workers submitted urine bioassays for analysis. Results for both workers indicated tritium concentrations below the derived recording level of 18.5 kBq/L (0.5 µCi/L); thus no tritium committed dose was assigned. Routine bioassay samples submitted as part of the bioassay program were also well below the derived recording level. Primary Heat Transport System (PHTS) components such as the pressure tubes and calandria tubes are dried prior to removal, hence the liquid D2O and tritium vapour hazard is significantly minimized. Airborne tritium surveys in the Retube Waste Processing Building (RWPB) are performed as part of the radiation hazard survey program, and routinely results are 0 MPCa, and none above 0.1 MPCa. In conclusion, there was no appreciable tritium source term to cause an exposure, the workers were monitored for tritium, and no recordable tritium exposure occurred, therefore no tritium dose was assigned. OPG believes that additional enhancements to current processes related to monitoring workers for tritium exposure in the RWPB are not required.	
(iii) The contradictory claims by OPG as to whether or not the pressure tube waste container being processed in the RWPB at the time of the exposure incident was *the first* such container, needs to be resolved.	OPG appreciates that the wording used to verbally describe the sequence of events may have been unclear at times. OPG would like to clarify the following points: • The RWPB tooling involves two independent and duplicate Processing Lines (Line #1 and Line #2). • The Darlington Storage Overpack (DSO) containing pressure tube coupons which was the source for the February event was the first one for Line #2, and the second processed in the RWPB. • The first DSO processed in the RWPB was processed on Line #1, and no adverse contamination levels were measured. • The second DSO processed in the RWPB was processed on Line #2. The event occurred during the lidding operations of this DSO. The investigation did not identify any need to enhance the engineering barriers or controls. However, the radiation protection monitoring that was performed was not to expectations, and corrective actions were established through the corrective action process, to improve monitoring and oversight.	

Questions	Response	Enclosure
(iv) Could OPG justify the claim that it was *not anticipated* that high levels of contamination existed in the RWPB near the VRS and that it did not expect the motion of the lids would result in high levels of contamination being introduced to the lidding area?	On the contrary, in the planning for the Refurbishment Project, elevated contamination levels were anticipated by OPG during the lidding process, which is the primary reason that dedicated robust enclosures were constructed around the hardware stations for containing and controlling the spread of contamination. In addition to the engineered barriers, an administrative barrier was implemented in anticipation of potential contamination level changes. The procedure required a Radiation Protection Coordinator to perform a survey for loose contamination between the fastening of the inner and outer lids. The OPG radiation protection program elements for monitoring and controlling the hazards to protect workers is sound. As part of the OPG investigation, opportunities were identified to enhance the application of the process to ensure staff recognized good pre-job briefing techniques and what types of surveys would be required.	
(v) Was OPG not aware of the valuable OPEX from Point Lepreau's 2009 discovery of high levels of alpha contamination associated with the operation of a pressure tube waste VRS?	OPG was fully aware of the OPEX from Point Lepreau's contamination event in 2009. Additionally, OPG performed benchmarking at Bruce Power in 2013 with a focus on refurbishment OPEX, including tooling performance. Elevated contamination (both beta/gamma and alpha) was anticipated and OPEX from Point Lepreau and Bruce Power was incorporated into the design of the DNGS Volume Reduction System (VRS). The Darlington system features a higher degree of remote and automated operations along with a more robust containment system and shielding around the VRS Press itself (where volume reduction takes place). The primary design target was to control contamination at the source and this was largely successful, as is evident from surveys conducted around the VRS itself (on the Waste Tooling Platform) and on the flasks. Although OPG believes that no additional enhancements to the engineering processes are required, OPG has revised the Radiation Exposure Permit for this work to incorporate the OPEX from our February 2018 event.	

Questions	Response	Enclosure
(vi) Does OPG have reliable measurements of *the inventory of Cm-244* in its pressure tube wastes?	OPG has an active waste characterization program, including pressure tube measurements and Darlington End Fitting and Liner Tube data. A partial summary of the CANDU pressure tube data analysis was published (3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration Ottawa Marriott Hotel, Ottawa, ON, Canada, September 11-14, 2016. Measurements, from several CANDU units, indicate that Cm-244 is present in significant amounts in pressure tube material. OPG continues to conduct measurements to increase the extent of its waste characterization database. The included graphic shows a general distribution of Cm-244 specific activity vs Equivalent Full Power Years for various CANDU units. 	

Questions	Response	Enclosure
(vii) Does OPG have any information on *the surface concentration of loose or fixed Cm-244* on its pressure tube wastes?	Assuming this question is related to the Darlington Unit 2 pressure tubes extracted during Refurbishment, OPG provides the following response: OPG performed workplace monitoring by taking 'smears' (contamination samples) from various work surfaces, and these were analysed. These work place surfaces, that may have come into contact with removed reactor core components (e.g. pressure tubes and end fittings), are the surfaces that workers may be exposed to, not the PT directly. These workplace smears provide a good surrogate for the radionuclide composition of loose contamintation on pressure tube wastes and are important for understanding potential worker exposures. It is not ALARA to get the workplace smears of the PT that were processed because of the extremely high dose rates on the pressure tubes themselves. Several smears taken within the Retube Waste Processing Building (RWPB) were sent for radionuclide analysis (Enclosure 3). The smears were analyzed for the Cm 243/244 as well as other radioisotopes. Each smear was taken over 100 cm^2. The average Cm-243/244 result was 15.2 Bq/smear; Processing Line #2 results up to 22.4 Bq/smear. These isotopes and the activity quantity were identified in the fecal samples for the workers, and Cm-244 was the isotope of interest used to bound the potential upper dose. The contamination monitoring processes that have been established by OPG, per our program, provide appropriate radionuclide characterization for hazard assessment and worker safety. OPG believes that additional enhancements to current processes are not required in this regard.	**Refer to Enclosure 3.**

Questions	Response	Enclosure
(viii) Would OPG and/or the CNSC provide an update on the status of its radionuclide inventory verification plan and in particular, report on how it has been applied to the validation of OPG's pressure tube waste inventory	OPG has an ongoing waste characterization program that has been in place for many years and has many years of data for radionuclides produced from CANDU Power Reactors. In response to a 2014 DGR Joint Review Panel information request, OPG provided a Waste Inventory Verification Plan (WIVP). This documented the direction and intent of OPG's waste characterization program. This program is incorporated into OPG's management system for waste characterization: • OPG's Nuclear Waste Management Program, W-PROG-WM-0001 provides direction on waste characterization. • OPG's Nuclear Waste Characterization Procedure (W-PROC-WM-0096) ensures OPG is consistent with international guidance and standards on nuclear waste characterization in the production of OPG's integrated and comprehensive L&ILW characterization plan. OPG has a Waste Characterization Plan for Low- and Intermediate-Level Waste. This plan is the current implementation of the WIVP. It identifies L&ILW characterization priorities for a nominal five year window, and provides a general schedule to guide the program. The plan is updated periodically taking into account the waste stream safety significance and results of sampling since the previous revision. The OPG waste characterization program has included measurements and analysis of pressure tubes. A partial summary of the data and analysis was published as a conference paper in 2016. Measurements and analysis have continued since then, per the Waste Characterization Plan. As part of our ongoing Waste Characterization program, the database will be re-assessed as additional data is accumulated. As part of our ongoing operations, the Waste Characterization procedure and plans are reviewed and updated on a periodic basis. OPG therefore believes that additional specific enhancement actions are not required as a result of this event. OPG notes that this item is not related to the events of February 2018.	

Questions	Response	Enclosure
(ix) Could OPG provide data on the particle size of the alpha-contaminated dust inhaled by two refurbishment workers in February 2018	OPG did not perform particle sizing measurements. This was not necessary for several reasons. The dose assessment was performed as an inhalation exposure using the most conservative parameters, so performing a particle size measurement would at most confirm the dose, and potentially lower the dose assignment. However, the work involved in doing such measurements is not justified for such low doses, lower than Action Levels and much lower than Administrative Limits much less dose limits. The dose assessment models used the default worst case parameters using ICRP and industry values of 5 µm AMAD. Particle size measurement is only required under industry guidance (and OPG past practice) if non-conservative particle sizes are proposed to be used for dose assessment. OPG therefore believes that no additional enhancements to current dose assessment procedures are required.	
(x) Could OPG provide information on the calculations it used to estimate the radiation dose to the two exposed refurbishment workers – in particular what particle size and lung solubility were assumed in OPG's dosimetric calculations?	The inhalation dose calculations were performed based on fecal and urine bioassay measurements (actinides, beta emitters and gamma emitters), corroborated with whole body counting measurements for gamma emitters (Enclosure 4). Of actinides, only Cm-242 and 243/244 were detected in the fecal samples for both workers. For actinides the potential intake was derived using two methods: a) ICRP excretion functions, and b) WBC measurements for Zr/Nb-95 and the ratio of Zr/Nb-95 to actinides as determined from the fecal samples. To provide an upper bound on the potential dose, the highest of the two potential intake values was used to calculate the dose from actinides. The highest intake values were obtained from the WBC Zr/Nb-95 measurements along with the fecal sample Zr/Nb-95 ratio to actinides. The default ICRP inhalation parameters for particle size (5 µm AMAD) and lung solubility (type M for Cm-242 and 243/244) were used. The doses were sufficiently small that no additional work to refine dose assessment models (e.g. for less conservative parameters than the ICRP default parameters) were warranted for the final dose assignment. The selection of the solubility type for the dosimetry of the Darlington event is compatible with the findings of CNL Report No. 153-121110-REPT-080 *Characterization of Alpha Radiation Hazards*. OPG therefore believes that no additional enhancements to the current dose assessment processes are required.	**Refer to Enclosure 4.**

Questions	Response	Enclosure
(xi) Is OPG (and the CNSC) aware of the findings of CNL's *Characterization of Alpha Radiation Hazards*, Report No. 153-121110-REPT-080, issued April 2016? Were these findings applied to the dosimetry of the Darlington event?	OPG is aware of the work presented in CNL Report No. 153-121110-REPT-080 *Characterization of Alpha Radiation Hazards*. The results of this work was reviewed by OPG. The selection of the solubility type for the dosimetry assessment of the Darlington event is compatible with the findings of this CNL report, specifically CM-244 solubility Type M when from irradiated UO_2 fuel. As described in the answer to x) above, application of OPG's dosimetry program in the February 2018 event is compatible with this report. OPG therefore believes that additional enhancements to current alpha dose assessment procedures are not required.	
(xii) Will OPG confirm that, starting in April 2017, alpha particulate was detected for the first time in Darlington's airborne emissions and has continued to be detected to this day, (Oct 2018)? And will OPG acknowledge that the source of these highly radiotoxic emissions is the dispersal of alpha-contaminated dust by refurbishment activities on Darlington Unit 2?	Detection of alpha particulate in airborne emissions is dependent on the laboratory use of very low level counting statistics. As continual improvement in technology occurs, OPG has periodically improved its detection capability for various radionuclide emissions. Prior to April 2, 2017, Darlington chemistry and environment lab analyses typically used 100 mBq (2.8 pCi) as the Minimum Detectable Activity (MDA) for its airborne stack samples. From April 2, 2017 and onwards the MDA of 6.7 mBq (0.183 pCi) was used, which improved identification of very low activity. The detected and reported levels of alpha particulates are orders of magnitude below our Derived Release Limits and were reported with a higher number than previously in April 2017 because of more sensitive detection. OPG makes environmental emission monitoring data publicly available on www.opg.com. Total weekly alpha airborne emissions average less than $2*10^4$ Bq for 2017 Q2 through 2018 Q1 inclusive, and were fairly constant prior to, during and post volume reduction activities in the RWPB, which ended the first week of March 2018. The airborne particulate emissions were measured and reported for the same time period. The airborne emissions for particulate remained constant or decreased somewhat during the volume reduction activities in the RWPB. Total emissions are a combination of all the activities at Darlington. The alpha airborne emissions cannot be attributed to a specific unit, work activity or to Refurbishment activities. OPG therefore believes that additional enhancements to current processes related to release or detection of airborne alpha particulate are not required.	

Questions	Response	Enclosure
(xiii) OPG has acknowledged that the RP Coordinator in charge of the safety of the two exposed refurbishment workers was "*weak in RP fundamentals due to lack of knowledge and experience*". This begs a number of questions: Was the RP Coordinator qualified to do his (or her) job or not? If he *was* qualified, then how could he lack the knowledge and experience to do the job? But if he was *not* qualified, *then why was he hired to do the job in the first place*?	The OPG radiation protection training program applies the Systematic Approach to Training (SAT) model as expected by industry standards and CNSC expectations. The objective of the SAT model is to guide the development of performance-based training to support job performance requirements and individual development. OPG has an approved radiation protection training program which applies to Radiation Protection Coordinators (RPC) such as the RPC who provided protection to the two workers exposed in this event. OPG has thoroughly investigated the event, per our normal practice, and in doing so identified the causes of the event. Those causes are described in the documentation provided to CNSC. In response to the specific question at hand, the investigation determined that the radiation protection coordinator was trained and qualified according to OPG's approved radiation protection training program. In March 2018, OPG initiated a common cause investigation (N-2018-05204) looking for common elements amongst several Station Condition Records. As part of the investigation, interviews were conducted with many RP staff to seek information related to all of these events, including the RWPB alpha uptake event. Immediate enhancement actions to our Radiation Technician training have been implemented based on the findings of the investigation. The corrective action plan has one open action to perform an effectiveness review of our corrective actions that is on track for completion January 13, 2019. Continuing training of RPCs is also ongoing to sustain and add proficiency to the workforce. The question quotes an excerpt of the findings of that investigation but does not provide any context. The essence of this finding, in combination with the fact that the worker was qualified, is this: Experience on first time activities cannot be taught solely in the classroom and requires some on the job experience. Therefore learning will occur as workers gain additional experience in new activities, e.g. the lidding operation on the two lines in the RWPB. Coming out of the event, there are enhancements OPG has made to improve the speed that learning can occur. We have developed dynamic learning activities to teach and give experience in our radiological work areas, for example to ensure staff recognize good pre-job briefing techniques and what types of surveys would be required for certain tasks. Additional surveys such as during-job and post-job were also reviewed as well as data management and documentation. Crew mentors have been developed and implemented to foster learning.	

Questions	Response	Enclosure
(xiv) Does OPG stand by its claim that the performance of *two* workers, who were simply lidding some waste containers, could be on the refurbishment project's critical path, or could somehow adversely affect the schedule of a billion-dollar project?	OPG could not find a reference to support the question's statement that OPG has claimed that the job being performed by these workers was on critical path or that it was adversely affecting the schedule of the project. The fact is that the project's primary critical path activity at the time was the Pressure Tube removal and movement of Pressure Tube flasks activities in the Unit 2 reactor vault. As part of project schedule risk management, the flow of work in the RWPB Volume Reduction System processes was designed for two independent process lines. The ability for those lines to process incoming Pressure Tubes (in flasks received from Unit 2 Vault) was essential to the overall Pressure Tube removal process. The RWPB Volume Reduction component could have impacted critical path if one, or both, of the process lines became unavailable to the point of all flask movements stopping, due to the number of flasks available. However, this did not occur. Nonetheless, the investigation identified, and OPG recognized, the impact of production focus on RPCs, and for that reason took actions to address this issue. OPG has long had in place procedures that gives workers the right not just to refuse work but in fact to stop work. OPG procedure N-PROC-RA-0010 Facility Access And Working Rights (Radiological), Section 1.1.2 Right to Stop Work sets out the procedural requirement for a knowledgeable worker who observes another "worker performing or about to perform an activity in non-compliance with the RP Procedures" which includes: "Instruct the worker to stop work immediately and the worker shall comply." OPG has recognized in our investigation that with activities "near" the critical path there can be a perception that production targets must be met. To guard against the negative effects of perceived production pressure and reinforce that safety is always the overriding priority, an enhancement action was taken to author and issue A Stop Work Authority memorandum (NK38-CORR-09071-0705287) to all refurbishment RP staff, providing examples of radiological criteria and expectations around response. The safety priority continues to be reinforced by RP oversight in the field, and Refurbishment line management. OPG therefore believes that no additional enhancement actions are required.	

OPG CONFIDENTIAL

ENCLOSURE 1

Radiological Source Term Characterization Strategy applicable to DNGS Refurbishment

OPG Document: NK38-REP-09701-0515372

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ONTARIO POWER GENERATION

NK38-REP-09701-0515372

Radiological Source Term Characterization Strategy applicable to DNGS Refurbishment

R0098/RP/002 R01

September 24, 2014

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5.15.1 FP1 radionuclide fingerprint

FP1 fingerprint was derived mainly based on smear samples collected from DNGS areas, included in the "FC" category.

Pu-241/Co-60 ratio determined directly from samples in this category was considered unrepresentative (one sample, high activity) and was not used. The Pu-241/Co-60 ratio derived from SG category samples was used instead.

This radionuclide fingerprint is most likely applicable for the pressure tube removal activities. According to Level 1 refurbishment activities [13], fuel channel removal series are planned to start approximately 9 months after shutdown.

The following statements apply based on the examination of graphs associated with this fingerprint (Figure 38, Figure 39 and Figure 40):

- At the start of a work series, the radionuclide mix will likely be such that the transuranics dose contribution will represent around 90% of the total dose. The dose contribution will continue to increase during the work series.

- During the work series, DTM radionuclides (other than transuranics, but including Fe-55) will likely contribute to AFP dose with approximately 10%. However, due to significant TRU content of the mix, the overall contribution is likely to be negligible.

Figure 38: FC mix type (FP1) – dose contributions by radionuclide category

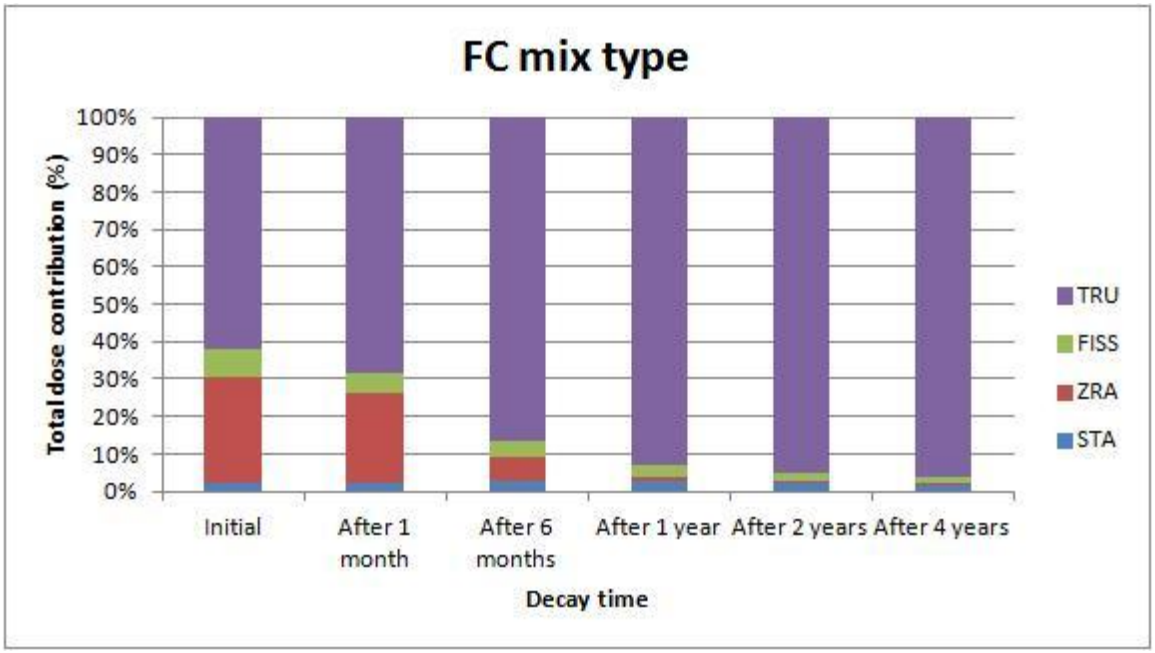


Figure 39: FC mix type (FP1) – TRU dose contributions

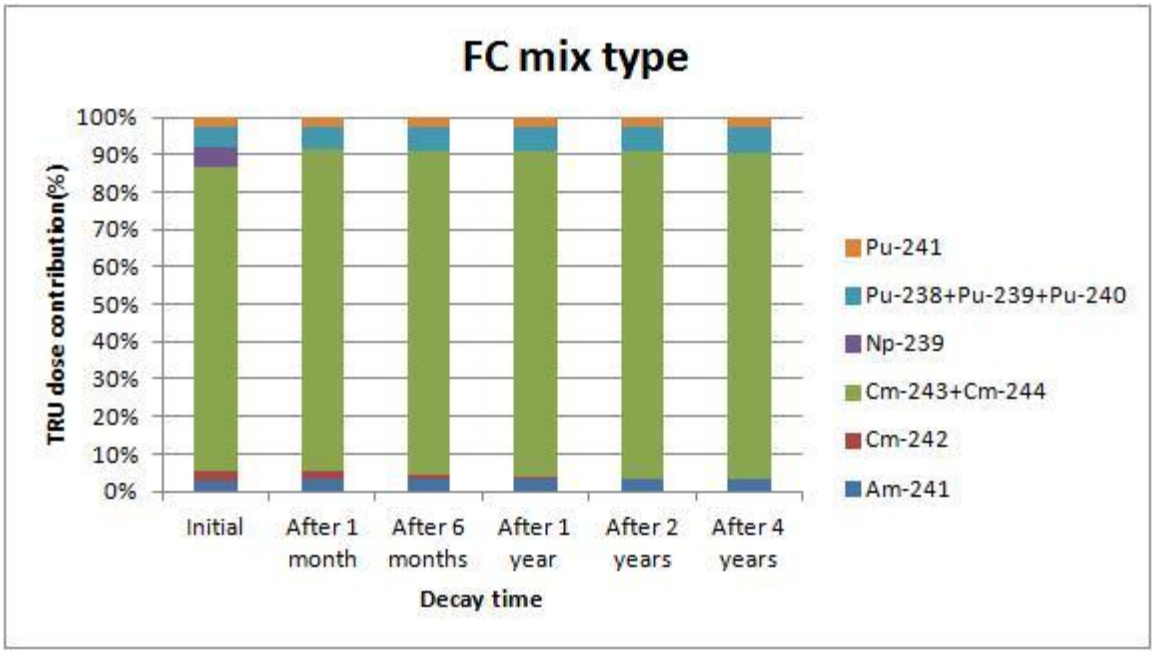
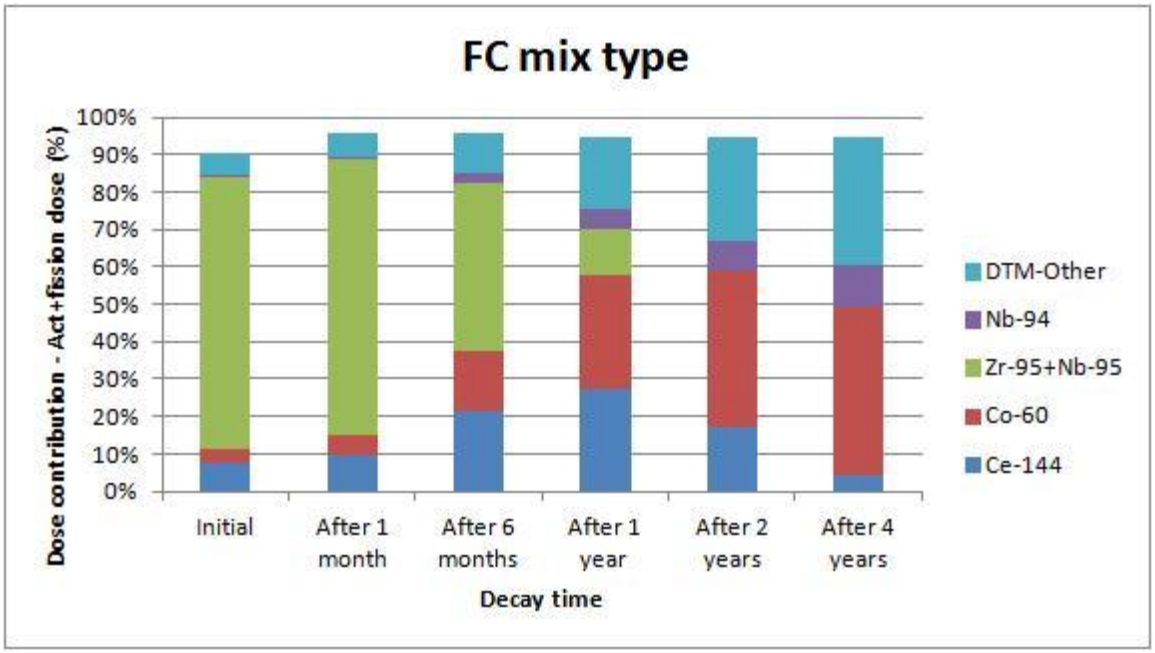


Figure 40: FC mix type – AFP dose contributions[2]



[2] Selected radionuclides only; listed contributions are relative to AFP total dose.

Appendix A: Radionuclide fingerprint calculations

As part of the analysis 7 (seven) fingerprints named FP1 to FP7 were derived. For details of how those were calculated refer to the main report.

This appendix lists the relevant information used to derive the fingerprints such as which ratios were used, from which data sets and how they were combined.

The following clarifications apply:

- In Sections A.2 to A.8, the "Calculation info" column provides details of which ratios were used in the calculations and the data sets from which they were extracted.

  For example the meaning of "Cm-243+Cm-244(1)/U(1)/Co-60(1)" is as follows: the final Cm-242 ratio was calculated using Cm-242 to Cm-243+Cm-244 ratio from data set #1, Cm-243+Cm-244 to U ratio from data set #1 and U to Co-60 ratio from data set #1.

- In Section A.9, ratio names are listed in the following format "x:y/z", where "x" represents the data set number and "y/z" is the ratio name.

  For example the meaning of "2:Cm-242/Cm-243+Cm-244" is as follows: ratio of Cm-242/Cm-243+Cm-244 calculated from dataset number 1.

A.1 LIST OF DATA SETS USED TO DERIVE RADIONUCLIDE FINGERPRINTS FP1 TO FP6

Data set	Source of information
DS1	DNGS smears data - FC category samples
DS2	DNGS smears data - SG category samples
DS3	DNGS ORIGEN fuel studies - at discharge
DS4	DNGS-ORIGEN activation studies of PT material - at discharge
DS5	DNGS-ORIGEN activation studies of EF material - at discharge
DS6	DNGS - PHT fingerprint based on radiochemistry data
DS7	DNGS smears data - P/C category samples
DS8	DNGS smears data - PHT purification category samples
DS9	DNGS oxiprobe data
DS10	DNGS smears data - SF category samples
DS11	DNGS - Moderator fingerprint based on radiochemistry data
DS12	DNGS-ORIGEN activation studies of CT material - at discharge

A.2 FP1 CALCULATION INFO

Radionuclide	Calculation info
Ag-110m	Ce-144(3)/U(1)/Co-60(1)
Am-241	U(1)/Co-60(1)
As-76	Co-60(6)
Ba-140	Ce-144(6)/U(1)/Co-60(1)
C-14	Nb-94(4)/Co-60(1)
Ce-141	Ce-144(1)/U(1)/Co-60(1)
Ce-144	U(1)/Co-60(1)
Cm-242	Cm-243+Cm-244(1)/U(1)/Co-60(1)
Cm-243+Cm-244	U(1)/Co-60(1)
Co-58	Co-60(6)
Co-60	Reference radionuclide
Cr-51	Co-60(1)
Cs-134	Cs-137(1)/Co-60(1)
Cs-137	Co-60(1)
Eu-154	Ce-144(2)/U(1)/Co-60(1)
Eu-155	Ce-144(3)/U(1)/Co-60(1)
Fe-55	Co-60(1)
Fe-59	Co-60(1)
Hf-181	Nb-94(1)/Co-60(1)
I-131	Co-60(6)
In-114m	Nb-94(4)/Co-60(1)
La-140	Ba-140(6)/Ce-144(6)/U(1)/Co-60(1)
Mn-54	Co-60(1)
Mo-99	Co-60(6)
Nb-94	Co-60(1)
Nb-95	Zr-95(6)/Co-60(1)
Nd-147	Ce-144(3)/U(1)/Co-60(1)
Ni-63	Co-60(1)
Np-239	Ba-140(3)/Ce-144(6)/U(1)/Co-60(1)
Pm-147	Ce-144(3)/U(1)/Co-60(1)
Pr-143	Ce-144(3)/U(1)/Co-60(1)
Pu-238	U(1)
Pu-239+Pu-240	U(1)
Pu-241	U(2)/Co-60(1)
Ru-103	Ru-106(1)/U(1)/Co-60(1)

Radionuclide	Calculation info
Ru-106	U(1)/Co-60(1)
Sb-122	Sb-124(6)/Co-60(1)
Sb-124	Co-60(1)
Sb-125	Co-60(1)
Sc-46	Co-60(1)
Sc-47	Sc-46(6)/Co-60(6)
Sn-113	Co-60(1)
Sr-89	Sr-90(3)/U(1)/Co-60(1)
Sr-90	U(1)/Co-60(1)
Ta-182	Sc-46(4)/Co-60(1)
Te-132	Ba-140(3)/Ce-144(6)/U(1)/Co-60(1)
Y-90	Sr-90(3)/U(1)/Co-60(1)
Y-91	Co-60(1)
Zn-65	Co-60(1)
Zr-93	Zr-95(4)/Co-60(1)
Zr-95	Co-60(1)
U	Co-60(1)

Appendix B: Breakdown of dose contributions by radionuclide

This appendix includes the detailed data on dose contributions to the total dose calculated for each radionuclide fingerprint derived for the present project. For calculations, it was assumed that airborne contamination with a similar fingerprint is inhaled. For additional details refer to the main report.

B.1 DETAILED DOSE CONTRIBUTIONS USING FP1 RADIONUCLIDE FINGERPRINT

Radionuclide	Initial	After 1 month	After 6 months	After 1 year	After 2 years	After 4 years
Ag-110m	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Am-241	2.00%	2.00%	3.00%	3.00%	3.00%	3.00%
As-76	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
Ba-140	0.30%	0.06%	0.00%	0.00%	0.00%	0.00%
C-14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ce-141	0.03%	0.02%	0.00%	0.00%	0.00%	0.00%
Ce-144	3.00%	3.00%	3.00%	2.00%	0.90%	0.20%
Cm-242	2.00%	2.00%	1.00%	0.50%	0.10%	0.00%
Cm-243+Cm-244	51.00%	59.00%	75.00%	81.00%	83.00%	84.00%
Co-58	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Co-60	1.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Cr-51	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cs-134	0.02%	0.03%	0.03%	0.03%	0.02%	0.01%
Cs-137	0.02%	0.03%	0.04%	0.04%	0.04%	0.04%
Eu-154	0.07%	0.08%	0.10%	0.10%	0.10%	0.10%
Eu-155	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fe-55	0.20%	0.30%	0.30%	0.30%	0.20%	0.20%
Fe-59	0.30%	0.30%	0.03%	0.00%	0.00%	0.00%
Hf-181	0.30%	0.20%	0.02%	0.00%	0.00%	0.00%
I-131	1.00%	0.09%	0.00%	0.00%	0.00%	0.00%
In-114m	0.20%	0.10%	0.02%	0.00%	0.00%	0.00%
La-140	0.30%	0.06%	0.00%	0.00%	0.00%	0.00%
Mn-54	0.02%	0.03%	0.02%	0.02%	0.00%	0.00%
Mo-99	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Nb-94	0.20%	0.30%	0.30%	0.40%	0.40%	0.40%

Radionuclide	Initial	After 1 month	After 6 months	After 1 year	After 2 years	After 4 years
Nb-95	10.00%	8.00%	2.00%	0.30%	0.00%	0.00%
Nd-147	0.10%	0.02%	0.00%	0.00%	0.00%	0.00%
Ni-63	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Np-239	3.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pm-147	0.05%	0.06%	0.07%	0.06%	0.05%	0.03%
Pr-143	0.30%	0.09%	0.00%	0.00%	0.00%	0.00%
Pu-238	2.00%	2.00%	3.00%	3.00%	3.00%	4.00%
Pu-239+Pu-240	2.00%	2.00%	3.00%	3.00%	3.00%	3.00%
Pu-241	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Ru-103	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Ru-106	0.10%	0.20%	0.20%	0.10%	0.07%	0.02%
Sb-122	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%
Sb-124	0.10%	0.10%	0.03%	0.00%	0.00%	0.00%
Sb-125	0.03%	0.03%	0.03%	0.03%	0.03%	0.02%
Sc-46	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%
Sc-47	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sn-113	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sr-89	1.00%	0.80%	0.10%	0.01%	0.00%	0.00%
Sr-90	0.60%	0.70%	0.90%	1.00%	1.00%	1.00%
Ta-182	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%
Te-132	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%
Y-90	0.01%	0.02%	0.02%	0.02%	0.02%	0.03%
Y-91	0.05%	0.04%	0.00%	0.00%	0.00%	0.00%
Zn-65	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%
Zr-93	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Zr-95	18.00%	15.00%	4.00%	0.60%	0.01%	0.00%

ENCLOSURE 2

Kinectrics C-14 Smears Analytical Report

11-Dec-2018

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Analytical and Environmental Services Laboratory

Test Report

Report Number: 18-12914
Version: 1
Report Date: 11-Dec-2018

Attn: Monique Stuive
OPG Darlington NGS
PO Box 4000, Holt Road S
Bowmanville ON M5G 1X6
Canada

Purchase Order: AN00275560L1
Sample(s) received: 11-Dec-2018

Authorized by:

Ruwan Wijesundera, MASc
Scientist
Ruwan.Wijesundera@Kinectrics.com

Description: *EMERGENCY* Smear Samples.

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-12914-1	Rails North Line 1	Smear		06-Dec-2018
18-12914-2	Floor North Line 1	Smear		06-Dec-2018
18-12914-3	Floor South Line 1	Smear		06-Dec-2018

Special Instructions:

Version comment: Initial report.

Analytical and Environmental Services Laboratory

Test Report

Report Number: 18-12914
Version: 1
Report Date: 11-Dec-2018

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-12914-1	Rails North Line 1	Smear		06-Dec-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha (Direct Count)	1.83	Bq/sample	0.4	0.02		10-Dec-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	295	Bq/sample	60	0.09		10-Dec-18	Gas Flow Proportional Counting*
Ag-110m	<1	Bq/sample	NA	1		10-Dec-18	Gamma Spectrometry*
Ce-141	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Ce-144	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Co-58	<0.8	Bq/sample	NA	0.8		10-Dec-18	Gamma Spectrometry*
Co-60	202	Bq/sample	20	1		10-Dec-18	Gamma Spectrometry*
Cr-51	<4	Bq/sample	NA	4		10-Dec-18	Gamma Spectrometry*
Cs-134	0.906	Bq/sample	0.4	0.4		10-Dec-18	Gamma Spectrometry*
Cs-137	3.6	Bq/sample	0.5	0.6		10-Dec-18	Gamma Spectrometry*
Eu-154	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Eu-155	<0.9	Bq/sample	NA	0.9		10-Dec-18	Gamma Spectrometry*
Fe-59	<1	Bq/sample	NA	1		10-Dec-18	Gamma Spectrometry*
Mn-54	5.26	Bq/sample	0.6	0.8		10-Dec-18	Gamma Spectrometry*
Nb-94	25.7	Bq/sample	2	0.6		10-Dec-18	Gamma Spectrometry*
Nb-95	12	Bq/sample	0.9	6		10-Dec-18	Gamma Spectrometry*
Pm-148	<4	Bq/sample	NA	4		10-Dec-18	Gamma Spectrometry*
Ru-103	<0.7	Bq/sample	NA	0.7		10-Dec-18	Gamma Spectrometry*
Ru-106	<5	Bq/sample	NA	5		10-Dec-18	Gamma Spectrometry*
Sb-124	<0.9	Bq/sample	NA	0.9		10-Dec-18	Gamma Spectrometry*
Sb-125	13	Bq/sample	2	2		10-Dec-18	Gamma Spectrometry*
Sn-113	<0.7	Bq/sample	NA	0.7		10-Dec-18	Gamma Spectrometry*
Zn-65	<3	Bq/sample	NA	3		10-Dec-18	Gamma Spectrometry*
Zr-95	5.57	Bq/sample	0.8	1		10-Dec-18	Gamma Spectrometry*
C-14	0.42	Bq/Sample	0.2	0.3		11-Dec-18	LSC*

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-12914-2	Floor North Line 1	Smear		06-Dec-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha (Direct Count)	0.37	Bq/sample	0.08	0.02		10-Dec-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	37.5	Bq/sample	8	0.09		10-Dec-18	Gas Flow Proportional Counting*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Ag-110m	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Ce-141	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Ce-144	<1	Bq/sample	NA	1		10-Dec-18	Gamma Spectrometry*
Co-58	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Co-60	12.2	Bq/sample	0.9	0.3		10-Dec-18	Gamma Spectrometry*
Cr-51	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Cs-134	<0.2	Bq/sample	NA	0.2		10-Dec-18	Gamma Spectrometry*
Cs-137	<0.2	Bq/sample	NA	0.2		10-Dec-18	Gamma Spectrometry*
Eu-154	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Eu-155	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Fe-59	<0.6	Bq/sample	NA	0.6		10-Dec-18	Gamma Spectrometry*
Mn-54	0.261	Bq/sample	0.2	0.2		10-Dec-18	Gamma Spectrometry*
Nb-94	1.92	Bq/sample	0.2	0.2		10-Dec-18	Gamma Spectrometry*
Nb-95	0.778	Bq/sample	0.2	0.2		10-Dec-18	Gamma Spectrometry*
Pm-148	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Ru-103	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Ru-106	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Sb-124	<0.4	Bq/sample	NA	0.4		10-Dec-18	Gamma Spectrometry*
Sb-125	2.82	Bq/sample	0.6	0.5		10-Dec-18	Gamma Spectrometry*
Sn-113	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Zn-65	<0.7	Bq/sample	NA	0.7		10-Dec-18	Gamma Spectrometry*
Zr-95	<0.4	Bq/sample	NA	0.4		10-Dec-18	Gamma Spectrometry*
C-14	0.4	Bq/Sample	0.2	0.3		11-Dec-18	LSC*

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-12914-3	Floor South Line 1	Smear		06-Dec-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha (Direct Count)	0.55	Bq/sample	0.1	0.02		10-Dec-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	39.9	Bq/sample	8	0.09		10-Dec-18	Gas Flow Proportional Counting*
Ag-110m	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Ce-141	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Ce-144	<1	Bq/sample	NA	1		10-Dec-18	Gamma Spectrometry*
Co-58	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Co-60	21.2	Bq/sample	2	0.3		10-Dec-18	Gamma Spectrometry*
Cr-51	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Cs-134	<0.2	Bq/sample	NA	0.2		10-Dec-18	Gamma Spectrometry*

Analytical and Environmental Services Laboratory

Test Report

Report Number: 18-12914
Version: 1
Report Date: 11-Dec-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Cs-137	0.484	Bq/sample	0.2	0.2		10-Dec-18	Gamma Spectrometry*
Eu-154	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Eu-155	<0.5	Bq/sample	NA	0.5		10-Dec-18	Gamma Spectrometry*
Fe-59	<0.6	Bq/sample	NA	0.6		10-Dec-18	Gamma Spectrometry*
Mn-54	0.748	Bq/sample	0.2	0.3		10-Dec-18	Gamma Spectrometry*
Nb-94	2.09	Bq/sample	0.3	0.3		10-Dec-18	Gamma Spectrometry*
Nb-95	0.764	Bq/sample	0.2	0.3		10-Dec-18	Gamma Spectrometry*
Pm-148	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Ru-103	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Ru-106	<2	Bq/sample	NA	2		10-Dec-18	Gamma Spectrometry*
Sb-124	<0.4	Bq/sample	NA	0.4		10-Dec-18	Gamma Spectrometry*
Sb-125	3.75	Bq/sample	0.6	0.5		10-Dec-18	Gamma Spectrometry*
Sn-113	<0.3	Bq/sample	NA	0.3		10-Dec-18	Gamma Spectrometry*
Zn-65	<0.7	Bq/sample	NA	0.7		10-Dec-18	Gamma Spectrometry*
Zr-95	<0.4	Bq/sample	NA	0.4		10-Dec-18	Gamma Spectrometry*
C-14	<0.4	Bq/Sample	0.2	0.4		11-Dec-18	LSC*
Comments	Even though Nb-95 is above the detection limit, the expected Zr-95 activity based upon activity ratios, is lower than the detection limit of the instrument.						

Instruments Used

Name	Serial Number	Last Calibration	Calibration Due
ENV-GAMMA-DET#1	53098	12-Sep-2018	12-Sep-2020
ENV-GAMMA-DET#2	1953466	12-Sep-2018	12-Sep-2020
Gross Alpha/Beta Counter	527860	04-Oct-2018	04-Oct-2020
Perkin Elmer Tri-Carb 2900TR (LSC for C-14)	DG11061765	07-Nov-2018	07-Nov-2020

The Analytical and Environmental Services Laboratory of Kinectrics is accredited by the Standards Council of Canada as conforming with ISO 17025.

The DL is the reported detection limit. All analytical data is subject to uncertainty, and is a function of the sample matrix, method and instrumental variations. As a general guideline, it can be expressed as +/-50% of the result at the detection limit (RDL) and approximately +/-10% of the result at greater than 10 times the RDL. Results in this report relate only to the items/samples tested and to all the items tested, as received. All tests are as defined by our understanding of customer requirements.

TECHNIQUE '*' = ISO 17025 accredited
TECHNIQUE '¤' = Indicates a modified test method
TECHNIQUE '†' = Indicates a sub-contracted analysis

ENCLOSURE 3

Kinectrics - RWPB PT Smears

25-Apr-2018

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Analytical and Environmental Services Laboratory

Test Report

Report Number: 18-10425
Version: 1
Report Date: 25-Apr-2018

Attn: Jeff Johansson
OPG Darlington NGS
PO Box 4000, Holt Road S
Bowmanville ON M5G 1X6
Canada

Purchase Order: AN00275560L1
Sample(s) received: 27-Mar-2018

Authorized by:

Rob Taylor
Senior Scientist - Radiochemistry
Rob.Taylor@kinectrics.com

Description: Smear Samples

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-1	RWPB Line #1 Hardware Station Platform	Smear	Darlington	20-Feb-2018
18-10425-2	RWPB Line #1 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018
18-10425-3	RWPB Line #1 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018
18-10425-4	RWPB DSO Decon Rubber Area Floor	Smear	Darlington	20-Feb-2018
18-10425-5	RWPB DSO Decon Rubber Area Floor	Smear	Darlington	20-Feb-2018
18-10425-6	RWPB Line #2 Hardware Station Platform	Smear	Darlington	20-Feb-2018
18-10425-7	RWPB Line #2 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018
18-10425-8	RWPB Line #2 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018
18-10425-9	RWPB DSO Line #2 lifting Laptop	Smear	Darlington	20-Feb-2018
18-10425-10	RWPB DSO Line #2 Lifting Laptop	Smear	Darlington	20-Feb-2018

Special Instructions: Plase refer to PO 275560 for analysis details. NOTE: C-14 analysis not required on any smears.

Version comment: Initial report.

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-1	RWPB Line #1 Hardware Station Platform	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Beta	1240	Bq/smp	250	0.9		28-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<3.8	Bq/smp	NA	3.8		26-Mar-18	Gamma Spectrometry*
Ce-141	<3	Bq/smp	NA	3		26-Mar-18	Gamma Spectrometry*
Ce-144	12.9	Bq/smp	3.5	5.5		26-Mar-18	Gamma Spectrometry*
Co-58	<2.9	Bq/smp	NA	2.9		26-Mar-18	Gamma Spectrometry*
Co-60	539	Bq/smp	59.3	1.6		26-Mar-18	Gamma Spectrometry*
Cr-51	<29.9	Bq/smp	NA	29.9		26-Mar-18	Gamma Spectrometry*
Cs-134	7.7	Bq/smp	1.7	2.4		26-Mar-18	Gamma Spectrometry*
Cs-137	15.3	Bq/smp	2	2.3		26-Mar-18	Gamma Spectrometry*
Eu-152	<4.9	Bq/smp	NA	4.9		26-Mar-18	Gamma Spectrometry*
Eu-154	<1.7	Bq/smp	NA	1.7		26-Mar-18	Gamma Spectrometry*
Eu-155	<2.1	Bq/smp	NA	2.1		26-Mar-18	Gamma Spectrometry*
Fe-59	<5	Bq/smp	NA	5		26-Mar-18	Gamma Spectrometry*
Gd-153	<2.8	Bq/smp	NA	2.8		26-Mar-18	Gamma Spectrometry*
Hf-181	<4.1	Bq/smp	NA	4.1		26-Mar-18	Gamma Spectrometry*
Mn-54	43.7	Bq/smp	4.5	2.4		26-Mar-18	Gamma Spectrometry*
Nb-94	83.6	Bq/smp	8.1	2.4		26-Mar-18	Gamma Spectrometry*
Nb-95	880	Bq/smp	77.2	2.9		26-Mar-18	Gamma Spectrometry*
Pm-148	<907	Bq/smp	NA	907		26-Mar-18	Gamma Spectrometry*
Ru-103	<4.5	Bq/smp	NA	4.5		26-Mar-18	Gamma Spectrometry*
Ru-106	<22.6	Bq/smp	NA	22.6		26-Mar-18	Gamma Spectrometry*
Sb-124	<2.9	Bq/smp	NA	2.9		26-Mar-18	Gamma Spectrometry*
Sb-125	7.6	Bq/smp	3.7	5.9		26-Mar-18	Gamma Spectrometry*
Sc-46	<3.4	Bq/smp	NA	3.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<2.9	Bq/smp	NA	2.9		26-Mar-18	Gamma Spectrometry*
Zn-65	10.8	Bq/smp	3.9	5.9		26-Mar-18	Gamma Spectrometry*
Zr-95	391	Bq/smp	34.7	5.4		26-Mar-18	Gamma Spectrometry*
Pu-238	0.051	Bq/smp	0.008	0.004		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.047	Bq/smp	0.006	0.004		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.033	Bq/smp	NA	0.033		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.342	Bq/smp	0.045	0.003		09-Apr-18	Chemical Separation/ Alpha Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Cm-243+244	12.8	Bq/smp	8.97	0.012		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	5630	Bq/smp	620	1.5		11-Apr-18	Chemical Separation/LSC*
Ni-63	14.1	Bq/smp	1.6	0.5		10-Apr-18	Chemical Separation/LSC*
Sr-90	4.4	Bq/smp	0.7	0.3		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	4.8	Bq/smp	1.1	0.9		13-Apr-18	Chemical Separation/LSC
U-234	0.000804	Bq/smp	0.0001	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	0.000758	Bq/smp	0.0001	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC
Gross Alpha	12.8	Bq/smp	3.2	0.3		28-Mar-18	Gas Flow Proportional Counting*

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-2	RWPB Line #1 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	9	Bq/smp	2.7	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	4	Bq/smp	1.2	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	844	Bq/smp	169	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	531	Bq/smp	106	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<2.4	Bq/smp	NA	2.4		26-Mar-18	Gamma Spectrometry*
Ce-141	<2.1	Bq/smp	NA	2.1		26-Mar-18	Gamma Spectrometry*
Ce-144	8	Bq/smp	2	3.5		26-Mar-18	Gamma Spectrometry*
Co-58	<1.8	Bq/smp	NA	1.8		26-Mar-18	Gamma Spectrometry*
Co-60	326	Bq/smp	20	1		26-Mar-18	Gamma Spectrometry*
Cr-51	<19.3	Bq/smp	NA	19.3		26-Mar-18	Gamma Spectrometry*
Cs-134	4.4	Bq/smp	0.9	1.3		26-Mar-18	Gamma Spectrometry*
Cs-137	9.7	Bq/smp	1	1.3		26-Mar-18	Gamma Spectrometry*
Eu-152	<3.2	Bq/smp	NA	3.2		26-Mar-18	Gamma Spectrometry*
Eu-154	<1.2	Bq/smp	NA	1.2		26-Mar-18	Gamma Spectrometry*
Eu-155	<1.7	Bq/smp	NA	1.7		26-Mar-18	Gamma Spectrometry*
Fe-59	<3.3	Bq/smp	NA	3.3		26-Mar-18	Gamma Spectrometry*
Gd-153	<2.1	Bq/smp	NA	2.1		26-Mar-18	Gamma Spectrometry*
Hf-181	<2.7	Bq/smp	NA	2.7		26-Mar-18	Gamma Spectrometry*
Mn-54	23.7	Bq/smp	2	1.3		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Nb-94	53.3	Bq/smp	3	1.5		26-Mar-18	Gamma Spectrometry*
Nb-95	571	Bq/smp	30	1.8		26-Mar-18	Gamma Spectrometry*
Pm-148	<575	Bq/smp	NA	575		26-Mar-18	Gamma Spectrometry*
Ru-103	<2.9	Bq/smp	NA	2.9		26-Mar-18	Gamma Spectrometry*
Ru-106	<13.2	Bq/smp	NA	13.2		26-Mar-18	Gamma Spectrometry*
Sb-124	<2	Bq/smp	NA	2		26-Mar-18	Gamma Spectrometry*
Sb-125	<3.3	Bq/smp	NA	3.3		26-Mar-18	Gamma Spectrometry*
Sc-46	<2.2	Bq/smp	NA	2.2		26-Mar-18	Gamma Spectrometry*
Sn-113	<1.9	Bq/smp	NA	1.9		26-Mar-18	Gamma Spectrometry*
Zn-65	<3.7	Bq/smp	NA	3.7		26-Mar-18	Gamma Spectrometry*
Zr-95	254	Bq/smp	10	3.3		26-Mar-18	Gamma Spectrometry*
Pu-238	0.029	Bq/smp	0.009	0.011		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	<0.01	Bq/smp	NA	0.01		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	0.086	Bq/smp	0.017	0.011		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-242	0.125	Bq/smp	0.021	0.037		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	10	Bq/smp	1.23	0.048		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	3270	Bq/smp	360	1.2		11-Apr-18	Chemical Separation/LSC*
Ni-63	25	Bq/smp	2.8	0.7		10-Apr-18	Chemical Separation/LSC*
Sr-90	2.8	Bq/smp	0.4	0.4		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	2.2	Bq/smp	0.51	1.3		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-3	RWPB Line #1 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	4	Bq/smp	1.2	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	1.7	Bq/smp	0.51	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	473	Bq/smp	95	0.9		28-Mar-18	Gas Flow Proportional Counting*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Beta (Direct Count)	258	Bq/smp	52	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<1.6	Bq/smp	NA	1.6		26-Mar-18	Gamma Spectrometry*
Ce-141	<1.5	Bq/smp	NA	1.5		26-Mar-18	Gamma Spectrometry*
Ce-144	3.4	Bq/smp	2	2.5		26-Mar-18	Gamma Spectrometry*
Co-58	<1.2	Bq/smp	NA	1.2		26-Mar-18	Gamma Spectrometry*
Co-60	229	Bq/smp	10	0.8		26-Mar-18	Gamma Spectrometry*
Cr-51	<13.4	Bq/smp	NA	13.4		26-Mar-18	Gamma Spectrometry*
Cs-134	3.1	Bq/smp	0.6	0.9		26-Mar-18	Gamma Spectrometry*
Cs-137	5.4	Bq/smp	0.6	0.8		26-Mar-18	Gamma Spectrometry*
Eu-152	<2.1	Bq/smp	NA	2.1		26-Mar-18	Gamma Spectrometry*
Eu-154	<0.8	Bq/smp	NA	0.8		26-Mar-18	Gamma Spectrometry*
Eu-155	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Fe-59	<2.2	Bq/smp	NA	2.2		26-Mar-18	Gamma Spectrometry*
Gd-153	<1.4	Bq/smp	NA	1.4		26-Mar-18	Gamma Spectrometry*
Hf-181	<1.9	Bq/smp	NA	1.9		26-Mar-18	Gamma Spectrometry*
Mn-54	17	Bq/smp	1	0.8		26-Mar-18	Gamma Spectrometry*
Nb-94	37.2	Bq/smp	2	0.9		26-Mar-18	Gamma Spectrometry*
Nb-95	401	Bq/smp	20	1.3		26-Mar-18	Gamma Spectrometry*
Pm-148	<403	Bq/smp	NA	403		26-Mar-18	Gamma Spectrometry*
Ru-103	<2.1	Bq/smp	NA	2.1		26-Mar-18	Gamma Spectrometry*
Ru-106	<9.6	Bq/smp	NA	9.6		26-Mar-18	Gamma Spectrometry*
Sb-124	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Sb-125	4	Bq/smp	1	2.1		26-Mar-18	Gamma Spectrometry*
Sc-46	<1.4	Bq/smp	NA	1.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Zn-65	<2.8	Bq/smp	NA	2.8		26-Mar-18	Gamma Spectrometry*
Zr-95	178	Bq/smp	8	2.3		26-Mar-18	Gamma Spectrometry*
Pu-238	0.019	Bq/smp	0.006	0.01		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	<0.01	Bq/smp	NA	0.01		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.028	Bq/smp	NA	0.028		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.087	Bq/smp	0.022	0.008		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	3.08	Bq/smp	0.388	0.003		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	1410	Bq/smp	160	0.8		11-Apr-18	Chemical Separation/LSC*
Ni-63	15.2	Bq/smp	1.7	0.6		10-Apr-18	Chemical Separation/LSC*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Sr-90	1.1	Bq/smp	0.2	0.3		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	1.4	Bq/smp	0.33	1.3		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	0.000366	Bq/smp	5E-5	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-4	RWPB DSO Decon Rubber Area Floor	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	29.2	Bq/smp	7.3	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	25.9	Bq/smp	6.5	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	4230	Bq/smp	850	0.9		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	3370	Bq/smp	670	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<6.1	Bq/smp	NA	6.1		26-Mar-18	Gamma Spectrometry*
Ce-141	<4.9	Bq/smp	NA	4.9		26-Mar-18	Gamma Spectrometry*
Ce-144	32.9	Bq/smp	6	9.4		26-Mar-18	Gamma Spectrometry*
Co-58	<4.7	Bq/smp	NA	4.7		26-Mar-18	Gamma Spectrometry*
Co-60	2250	Bq/smp	300	2.8		26-Mar-18	Gamma Spectrometry*
Cr-51	<48.8	Bq/smp	NA	48.8		26-Mar-18	Gamma Spectrometry*
Cs-134	23.1	Bq/smp	3	3.9		26-Mar-18	Gamma Spectrometry*
Cs-137	47.5	Bq/smp	5	3.8		26-Mar-18	Gamma Spectrometry*
Eu-152	<7.4	Bq/smp	NA	7.4		26-Mar-18	Gamma Spectrometry*
Eu-154	<2.7	Bq/smp	NA	2.7		26-Mar-18	Gamma Spectrometry*
Eu-155	<3.7	Bq/smp	NA	3.7		26-Mar-18	Gamma Spectrometry*
Fe-59	<8	Bq/smp	NA	8		26-Mar-18	Gamma Spectrometry*
Gd-153	<4.5	Bq/smp	NA	4.5		26-Mar-18	Gamma Spectrometry*
Hf-181	<6.7	Bq/smp	NA	6.7		26-Mar-18	Gamma Spectrometry*
Mn-54	135	Bq/smp	10	3.9		26-Mar-18	Gamma Spectrometry*
Nb-94	382	Bq/smp	40	3.9		26-Mar-18	Gamma Spectrometry*
Nb-95	3720	Bq/smp	300	5.1		26-Mar-18	Gamma Spectrometry*
Pm-148	<1470	Bq/smp	NA	1470		26-Mar-18	Gamma Spectrometry*
Ru-103	<7.4	Bq/smp	NA	7.4		26-Mar-18	Gamma Spectrometry*
Ru-106	<34.6	Bq/smp	NA	34.6		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Sb-124	<4.6	Bq/smp	NA	4.6		26-Mar-18	Gamma Spectrometry*
Sb-125	23.4	Bq/smp	6	9.5		26-Mar-18	Gamma Spectrometry*
Sc-46	<5.4	Bq/smp	NA	5.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<4.8	Bq/smp	NA	4.8		26-Mar-18	Gamma Spectrometry*
Zn-65	48	Bq/smp	8	9.7		26-Mar-18	Gamma Spectrometry*
Zr-95	1660	Bq/smp	200	8.6		26-Mar-18	Gamma Spectrometry*
Pu-238	0.134	Bq/smp	0.029	0.014		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.076	Bq/smp	0.019	0.012		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.091	Bq/smp	NA	0.091		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.789	Bq/smp	0.125	0.011		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	25.9	Bq/smp	3.18	0.005		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	13000	Bq/smp	1400	2.3		11-Apr-18	Chemical Separation/LSC*
Ni-63	220	Bq/smp	24	0.6		10-Apr-18	Chemical Separation/LSC*
Sr-90	12.1	Bq/smp	2	0.3		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	10.9	Bq/smp	1.4	1.2		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	0.000102	Bq/smp	2E-5	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		18-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-5	RWPB DSO Decon Rubber Area Floor	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	1.1	Bq/smp	0.3	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	0.6	Bq/smp	0.18	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	137	Bq/smp	27	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	82.5	Bq/smp	16.5	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<1.2	Bq/smp	NA	1.2		26-Mar-18	Gamma Spectrometry*
Ce-141	<0.9	Bq/smp	NA	0.9		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Ce-144	<1.7	Bq/smp	NA	1.7		26-Mar-18	Gamma Spectrometry*
Co-58	<0.9	Bq/smp	NA	0.9		26-Mar-18	Gamma Spectrometry*
Co-60	58.1	Bq/smp	4	0.4		26-Mar-18	Gamma Spectrometry*
Cr-51	<9.2	Bq/smp	NA	9.2		26-Mar-18	Gamma Spectrometry*
Cs-134	<0.7	Bq/smp	NA	0.7		26-Mar-18	Gamma Spectrometry*
Cs-137	1.9	Bq/smp	0.4	0.5		26-Mar-18	Gamma Spectrometry*
Eu-152	<1.5	Bq/smp	NA	1.5		26-Mar-18	Gamma Spectrometry*
Eu-154	<0.5	Bq/smp	NA	0.5		26-Mar-18	Gamma Spectrometry*
Eu-155	<0.9	Bq/smp	NA	0.9		26-Mar-18	Gamma Spectrometry*
Fe-59	<1.6	Bq/smp	NA	1.6		26-Mar-18	Gamma Spectrometry*
Gd-153	<1.1	Bq/smp	NA	1.1		26-Mar-18	Gamma Spectrometry*
Hf-181	<1.1	Bq/smp	NA	1.1		26-Mar-18	Gamma Spectrometry*
Mn-54	3.8	Bq/smp	0.5	0.6		26-Mar-18	Gamma Spectrometry*
Nb-94	8.9	Bq/smp	0.8	0.6		26-Mar-18	Gamma Spectrometry*
Nb-95	90.6	Bq/smp	5	0.8		26-Mar-18	Gamma Spectrometry*
Pm-148	<259	Bq/smp	NA	259		26-Mar-18	Gamma Spectrometry*
Ru-103	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Ru-106	<6.7	Bq/smp	NA	6.7		26-Mar-18	Gamma Spectrometry*
Sb-124	<0.9	Bq/smp	NA	0.9		26-Mar-18	Gamma Spectrometry*
Sb-125	<1.8	Bq/smp	NA	1.8		26-Mar-18	Gamma Spectrometry*
Sc-46	<1	Bq/smp	NA	1		26-Mar-18	Gamma Spectrometry*
Sn-113	<0.9	Bq/smp	NA	0.9		26-Mar-18	Gamma Spectrometry*
Zn-65	<1.9	Bq/smp	NA	1.9		26-Mar-18	Gamma Spectrometry*
Zr-95	41.9	Bq/smp	3	1.5		26-Mar-18	Gamma Spectrometry*
Pu-238	<0.021	Bq/smp	NA	0.021		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDL due to lower Pu recovery.						
Pu-239+240	<0.019	Bq/smp	NA	0.019		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDL due to lower Pu recovery.						
Am-241	0.029	Bq/smp	0.01	0.015		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-242	<0.037	Bq/smp	NA	0.037		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	1	Bq/smp	0.136	0.048		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	513	Bq/smp	56	0.9		11-Apr-18	Chemical Separation/LSC*
Ni-63	0.9	Bq/smp	0.2	0.7		10-Apr-18	Chemical Separation/LSC*
Sr-90	<0.4	Bq/smp	NA	0.4		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	<4.3	Bq/smp	NA	4.3		13-Apr-18	Chemical Separation/LSC

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
	Elevated MDL due to lower Pu recovery.						
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-6	RWPB Line #2 Hardware Station Platform	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	2.5	Bq/smp	0.8	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	1.2	Bq/smp	0.36	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	207	Bq/smp	41	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	134	Bq/smp	27	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<1.6	Bq/smp	NA	1.6		26-Mar-18	Gamma Spectrometry*
Ce-141	<1.5	Bq/smp	NA	1.5		26-Mar-18	Gamma Spectrometry*
Ce-144	<3.2	Bq/smp	NA	3.2		26-Mar-18	Gamma Spectrometry*
Co-58	<1.2	Bq/smp	NA	1.2		26-Mar-18	Gamma Spectrometry*
Co-60	65.6	Bq/smp	8	0.7		26-Mar-18	Gamma Spectrometry*
Cr-51	<13.7	Bq/smp	NA	13.7		26-Mar-18	Gamma Spectrometry*
Cs-134	1.4	Bq/smp	0.7	1		26-Mar-18	Gamma Spectrometry*
Cs-137	2.61	Bq/smp	0.7	1		26-Mar-18	Gamma Spectrometry*
Eu-152	<1.9	Bq/smp	NA	1.9		26-Mar-18	Gamma Spectrometry*
Eu-154	<0.8	Bq/smp	NA	0.8		26-Mar-18	Gamma Spectrometry*
Eu-155	<1	Bq/smp	NA	1		26-Mar-18	Gamma Spectrometry*
Fe-59	<1.9	Bq/smp	NA	1.9		26-Mar-18	Gamma Spectrometry*
Gd-153	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Hf-181	<1.8	Bq/smp	NA	1.8		26-Mar-18	Gamma Spectrometry*
Mn-54	3.8	Bq/smp	0.8	0.8		26-Mar-18	Gamma Spectrometry*
Nb-94	14.6	Bq/smp	2	1.1		26-Mar-18	Gamma Spectrometry*
Nb-95	143	Bq/smp	20	1.3		26-Mar-18	Gamma Spectrometry*
Pm-148	<408	Bq/smp	NA	408		26-Mar-18	Gamma Spectrometry*
Ru-103	<2	Bq/smp	NA	2		26-Mar-18	Gamma Spectrometry*
Ru-106	<9.9	Bq/smp	NA	9.9		26-Mar-18	Gamma Spectrometry*
Sb-124	<1	Bq/smp	NA	1		26-Mar-18	Gamma Spectrometry*
Sb-125	<2.6	Bq/smp	NA	2.6		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Sc-46	<1.4	Bq/smp	NA	1.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<1.3	Bq/smp	NA	1.3		26-Mar-18	Gamma Spectrometry*
Zn-65	<2.7	Bq/smp	NA	2.7		26-Mar-18	Gamma Spectrometry*
Zr-95	64.6	Bq/smp	7	2.5		26-Mar-18	Gamma Spectrometry*
Pu-238	0.015	Bq/smp	0.007	0.012		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.037	Bq/smp	0.012	0.011		06-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	0.063	Bq/smp	0.03	0.029		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-242	0.049	Bq/smp	0.029	0.03		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	1.55	Bq/smp	0.231	0.139		05-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	636	Bq/smp	70	0.7		11-Apr-18	Chemical Separation/LSC*
Ni-63	5.1	Bq/smp	1.1	0.5		10-Apr-18	Chemical Separation/LSC*
Sr-90	0.7	Bq/smp	0.1	0.3		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	<2	Bq/smp	NA	2		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-7	RWPB Line #2 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	20	Bq/smp	5	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	23.2	Bq/smp	5.8	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	4200	Bq/smp	840	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	3260	Bq/smp	650	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<5.3	Bq/smp	NA	5.3		26-Mar-18	Gamma Spectrometry*
Ce-141	<4.8	Bq/smp	NA	4.8		26-Mar-18	Gamma Spectrometry*
Ce-144	30.4	Bq/smp	5.1	8.1		26-Mar-18	Gamma Spectrometry*
Co-58	<4	Bq/smp	NA	4		26-Mar-18	Gamma Spectrometry*
Co-60	1640	Bq/smp	90	2.2		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Cr-51	<45.3	Bq/smp	NA	45.3		26-Mar-18	Gamma Spectrometry*
Cs-134	16.6	Bq/smp	2	2.6		26-Mar-18	Gamma Spectrometry*
Cs-137	24.9	Bq/smp	2	2.7		26-Mar-18	Gamma Spectrometry*
Eu-152	<6.3	Bq/smp	NA	6.3		26-Mar-18	Gamma Spectrometry*
Eu-154	<2.7	Bq/smp	NA	2.7		26-Mar-18	Gamma Spectrometry*
Eu-155	<3.9	Bq/smp	NA	3.9		26-Mar-18	Gamma Spectrometry*
Fe-59	<6.8	Bq/smp	NA	6.8		26-Mar-18	Gamma Spectrometry*
Gd-153	<4.8	Bq/smp	NA	4.8		26-Mar-18	Gamma Spectrometry*
Hf-181	<6.1	Bq/smp	NA	6.1		26-Mar-18	Gamma Spectrometry*
Mn-54	81.9	Bq/smp	4	2.7		26-Mar-18	Gamma Spectrometry*
Nb-94	302	Bq/smp	20	3.3		26-Mar-18	Gamma Spectrometry*
Nb-95	2980	Bq/smp	200	4.3		26-Mar-18	Gamma Spectrometry*
Pm-148	<1340	Bq/smp	NA	1340		26-Mar-18	Gamma Spectrometry*
Ru-103	<6.7	Bq/smp	NA	6.7		26-Mar-18	Gamma Spectrometry*
Ru-106	<24.7	Bq/smp	NA	24.7		26-Mar-18	Gamma Spectrometry*
Sb-124	<4.1	Bq/smp	NA	4.1		26-Mar-18	Gamma Spectrometry*
Sb-125	21.4	Bq/smp	4	6.6		26-Mar-18	Gamma Spectrometry*
Sc-46	<4.7	Bq/smp	NA	4.7		26-Mar-18	Gamma Spectrometry*
Sn-113	<4.3	Bq/smp	NA	4.3		26-Mar-18	Gamma Spectrometry*
Zn-65	36.8	Bq/smp	5	6.2		26-Mar-18	Gamma Spectrometry*
Zr-95	1320	Bq/smp	60	7.8		26-Mar-18	Gamma Spectrometry*
Pu-238	0.094	Bq/smp	0.033	0.031		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.06	Bq/smp	0.025	0.028		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.134	Bq/smp	NA	0.134		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.78	Bq/smp	0.165	0.031		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	22.4	Bq/smp	2.8	0.117		09-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	9510	Bq/smp	1050	2.6		11-Apr-18	Chemical Separation/LSC*
Ni-63	281	Bq/smp	31	1.1		10-Apr-18	Chemical Separation/LSC*
Sr-90	477	Bq/smp	70	0.6		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	8.2	Bq/smp	1.89	2.3		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-8	RWPB Line #2 Hdwr Stn-Trolley floor area	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	17.6	Bq/smp	4.4	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	18.5	Bq/smp	4.6	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	3410	Bq/smp	680	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	2830	Bq/smp	570	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<6.9	Bq/smp	NA	6.9		26-Mar-18	Gamma Spectrometry*
Ce-141	<5.9	Bq/smp	NA	5.9		26-Mar-18	Gamma Spectrometry*
Ce-144	29.2	Bq/smp	6.9	10.9		26-Mar-18	Gamma Spectrometry*
Co-58	<5.5	Bq/smp	NA	5.5		26-Mar-18	Gamma Spectrometry*
Co-60	1688	Bq/smp	200	2.8		26-Mar-18	Gamma Spectrometry*
Cr-51	<57.6	Bq/smp	NA	57.6		26-Mar-18	Gamma Spectrometry*
Cs-134	11.8	Bq/smp	3	4.5		26-Mar-18	Gamma Spectrometry*
Cs-137	28.6	Bq/smp	3	3.6		26-Mar-18	Gamma Spectrometry*
Eu-152	<8.9	Bq/smp	NA	8.9		26-Mar-18	Gamma Spectrometry*
Eu-154	<3.2	Bq/smp	NA	3.2		26-Mar-18	Gamma Spectrometry*
Eu-155	<4.3	Bq/smp	NA	4.3		26-Mar-18	Gamma Spectrometry*
Fe-59	<9.2	Bq/smp	NA	9.2		26-Mar-18	Gamma Spectrometry*
Gd-153	<5.3	Bq/smp	NA	5.3		26-Mar-18	Gamma Spectrometry*
Hf-181	<8	Bq/smp	NA	8		26-Mar-18	Gamma Spectrometry*
Mn-54	79.3	Bq/smp	8	4.5		26-Mar-18	Gamma Spectrometry*
Nb-94	314	Bq/smp	30	4.5		26-Mar-18	Gamma Spectrometry*
Nb-95	3190	Bq/smp	300	5.5		26-Mar-18	Gamma Spectrometry*
Pm-148	<1770	Bq/smp	NA	1770		26-Mar-18	Gamma Spectrometry*
Ru-103	<8.7	Bq/smp	NA	8.7		26-Mar-18	Gamma Spectrometry*
Ru-106	<43.5	Bq/smp	NA	43.5		26-Mar-18	Gamma Spectrometry*
Sb-124	<5.8	Bq/smp	NA	5.8		26-Mar-18	Gamma Spectrometry*
Sb-125	28.8	Bq/smp	7	11.2		26-Mar-18	Gamma Spectrometry*
Sc-46	<6.2	Bq/smp	NA	6.2		26-Mar-18	Gamma Spectrometry*
Sn-113	<5.7	Bq/smp	NA	5.7		26-Mar-18	Gamma Spectrometry*
Zn-65	35.5	Bq/smp	8	11.2		26-Mar-18	Gamma Spectrometry*
Zr-95	1410	Bq/smp	100	10.2		26-Mar-18	Gamma Spectrometry*
Pu-238	0.102	Bq/smp	0.027	0.025		11-Apr-18	Chemical Separation/ Alpha Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Pu-239+240	0.069	Bq/smp	0.02	0.022		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.134	Bq/smp	NA	0.134		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.542	Bq/smp	0.089	0.011		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	18	Bq/smp	2.21	0.045		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	7560	Bq/smp	830	2.5		11-Apr-18	Chemical Separation/LSC*
Ni-63	222	Bq/smp	24	1.3		10-Apr-18	Chemical Separation/LSC*
Sr-90	8	Bq/smp	1	0.7		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	9.5	Bq/smp	2.19	2.6		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		14-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-9	RWPB DSO Line #2 lifting Laptop	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	17.3	Bq/smp	4.3	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Alpha (Direct Count)	15.4	Bq/smp	3.9	0.1		26-Mar-18	Gas Flow Proportional Counting*
Gross Beta	4450	Bq/smp	890	0.8		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta (Direct Count)	3480	Bq/smp	700	0.1		26-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<8.4	Bq/smp	NA	8.4		26-Mar-18	Gamma Spectrometry*
Ce-141	<6.3	Bq/smp	NA	6.3		26-Mar-18	Gamma Spectrometry*
Ce-144	16.1	Bq/smp	5.9	9.6		26-Mar-18	Gamma Spectrometry*
Co-58	<6.3	Bq/smp	NA	6.3		26-Mar-18	Gamma Spectrometry*
Co-60	3460	Bq/smp	200	3.9		26-Mar-18	Gamma Spectrometry*
Cr-51	<57.7	Bq/smp	NA	57.7		26-Mar-18	Gamma Spectrometry*
Cs-134	9.2	Bq/smp	3	4.5		26-Mar-18	Gamma Spectrometry*
Cs-137	25.8	Bq/smp	3	3.7		26-Mar-18	Gamma Spectrometry*
Eu-152	<11.4	Bq/smp	NA	11.4		26-Mar-18	Gamma Spectrometry*
Eu-154	<3.5	Bq/smp	NA	3.5		26-Mar-18	Gamma Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Eu-155	<5.2	Bq/smp	NA	5.2		26-Mar-18	Gamma Spectrometry*
Fe-59	<11.7	Bq/smp	NA	11.7		26-Mar-18	Gamma Spectrometry*
Gd-153	<6.1	Bq/smp	NA	6.1		26-Mar-18	Gamma Spectrometry*
Hf-181	<7.5	Bq/smp	NA	7.5		26-Mar-18	Gamma Spectrometry*
Mn-54	73.6	Bq/smp	5	5.3		26-Mar-18	Gamma Spectrometry*
Nb-94	283	Bq/smp	10	5.3		26-Mar-18	Gamma Spectrometry*
Nb-95	3030	Bq/smp	100	6.4		26-Mar-18	Gamma Spectrometry*
Pm-148	<1680	Bq/smp	NA	1680		26-Mar-18	Gamma Spectrometry*
Ru-103	<8.3	Bq/smp	NA	8.3		26-Mar-18	Gamma Spectrometry*
Ru-106	<41	Bq/smp	NA	41		26-Mar-18	Gamma Spectrometry*
Sb-124	<7.5	Bq/smp	NA	7.5		26-Mar-18	Gamma Spectrometry*
Sb-125	25.8	Bq/smp	6	8.7		26-Mar-18	Gamma Spectrometry*
Sc-46	<7.4	Bq/smp	NA	7.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<5.5	Bq/smp	NA	5.5		26-Mar-18	Gamma Spectrometry*
Zn-65	44.2	Bq/smp	8	11.2		26-Mar-18	Gamma Spectrometry*
Zr-95	1310	Bq/smp	60	11.8		26-Mar-18	Gamma Spectrometry*
Pu-238	0.06	Bq/smp	0.02	0.028		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.051	Bq/smp	0.018	0.025		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.116	Bq/smp	NA	0.116		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	0.391	Bq/smp	0.072	0.012		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	16.6	Bq/smp	2.05	0.005		11-Apr-18	Chemical Separation/ Alpha Spectrometry*
Fe-55	7990	Bq/smp	880	1.7		11-Apr-18	Chemical Separation/LSC*
Ni-63	803	Bq/smp	88	0.6		10-Apr-18	Chemical Separation/LSC*
Sr-90	8.1	Bq/smp	1	0.3		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	9.4	Bq/smp	2.17	3		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		18-Apr-18	Chemical Separation/LSC

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-10425-10	RWPB DSO Line #2 Lifting Laptop	Smear	Darlington	20-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Gross Alpha	52.3	Bq/smp	13.1	0.3		28-Mar-18	Gas Flow Proportional Counting*
Gross Beta	7430	Bq/smp	1490	0.8		28-Mar-18	Gas Flow Proportional Counting*
Ag-110m	<11.6	Bq/smp	NA	11.6		26-Mar-18	Gamma Spectrometry*
Ce-141	<9.6	Bq/smp	NA	9.6		26-Mar-18	Gamma Spectrometry*
Ce-144	42.2	Bq/smp	8.8	13.8		26-Mar-18	Gamma Spectrometry*
Co-58	<9	Bq/smp	NA	9		26-Mar-18	Gamma Spectrometry*
Co-60	3140	Bq/smp	400	4.6		26-Mar-18	Gamma Spectrometry*
Cr-51	<95.4	Bq/smp	NA	95.4		26-Mar-18	Gamma Spectrometry*
Cs-134	29.3	Bq/smp	5	6.1		26-Mar-18	Gamma Spectrometry*
Cs-137	64.1	Bq/smp	7	5.5		26-Mar-18	Gamma Spectrometry*
Eu-152	<15.5	Bq/smp	NA	15.5		26-Mar-18	Gamma Spectrometry*
Eu-154	<5.3	Bq/smp	NA	5.3		26-Mar-18	Gamma Spectrometry*
Eu-155	<7.1	Bq/smp	NA	7.1		26-Mar-18	Gamma Spectrometry*
Fe-59	<15.8	Bq/smp	NA	15.8		26-Mar-18	Gamma Spectrometry*
Gd-153	<8.8	Bq/smp	NA	8.8		26-Mar-18	Gamma Spectrometry*
Hf-181	<13.1	Bq/smp	NA	13.1		26-Mar-18	Gamma Spectrometry*
Mn-54	171	Bq/smp	20	5.9		26-Mar-18	Gamma Spectrometry*
Nb-94	554	Bq/smp	50	7.4		26-Mar-18	Gamma Spectrometry*
Nb-95	5700	Bq/smp	500	9.1		26-Mar-18	Gamma Spectrometry*
Pm-148	<2920	Bq/smp	NA	2920		26-Mar-18	Gamma Spectrometry*
Ru-103	<14.3	Bq/smp	NA	14.3		26-Mar-18	Gamma Spectrometry*
Ru-106	<70.7	Bq/smp	NA	70.7		26-Mar-18	Gamma Spectrometry*
Sb-124	<9.1	Bq/smp	NA	9.1		26-Mar-18	Gamma Spectrometry*
Sb-125	27.3	Bq/smp	10	16.1		26-Mar-18	Gamma Spectrometry*
Sc-46	<10.4	Bq/smp	NA	10.4		26-Mar-18	Gamma Spectrometry*
Sn-113	<9.3	Bq/smp	NA	9.3		26-Mar-18	Gamma Spectrometry*
Zn-65	77.7	Bq/smp	10	16.8		26-Mar-18	Gamma Spectrometry*
Zr-95	2510	Bq/smp	200	16.8		26-Mar-18	Gamma Spectrometry*
Pu-238	0.166	Bq/smp	0.06	0.044		10-Apr-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	0.109	Bq/smp	0.048	0.041		10-Apr-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.367	Bq/smp	NA	0.367		10-Apr-18	Chemical Separation/ Alpha Spectrometry*
	Elevated MDA due to interference from Cm-244.						
Cm-242	1.1	Bq/smp	0.257	0.055		10-Apr-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	41	Bq/smp	5.13	0.025		10-Apr-18	Chemical Separation/ Alpha Spectrometry*

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Fe-55	19300	Bq/smp	2100	3.7		11-Apr-18	Chemical Separation/LSC*
Ni-63	391	Bq/smp	43	0.9		10-Apr-18	Chemical Separation/LSC*
Sr-90	14.6	Bq/smp	2	0.5		04-Apr-18	Chemical Separation & GFPC or LSC*
Pu-241	17.6	Bq/smp	2.2	3.4		13-Apr-18	Chemical Separation/LSC
U-234	<0.0006	Bq/smp	NA	0.0006		27-Mar-18	ICPMS*
U-235	<0.00006	Bq/smp	NA	6E-5		27-Mar-18	ICPMS*
U-238	0.000169	Bq/smp	3E-5	6E-5		27-Mar-18	ICPMS*
Y-91	<10	Bq/smp	NA	10		18-Apr-18	Chemical Separation/LSC
Comments	Direct Gross Alpha and Beta could not be completed on sample 1 and 10 due to loose particulate on the smear which would contaminate the instrument and cause cross-contamination between samples.						

Instruments Used

Name	Serial Number	Last Calibration	Calibration Due
Alpha Spectrometer 516-10	10224476	06-Dec-2016	06-Dec-2018
Alpha Spectrometer 516-3	10224474	22-Mar-2018	22-Mar-2020
Alpha Spectrometer 516-4	10224474	22-Mar-2018	22-Mar-2020
Alpha Spectrometer 516-5	10222516	22-Mar-2018	22-Mar-2020
Alpha Spectrometer 516-6	10222516	22-Mar-2018	22-Mar-2020
Alpha Spectrometer 516-9	10224476	06-Dec-2016	06-Dec-2018
ENV-GAMMA-DET#1	53098	01-Aug-2016	01-Aug-2018
ENV-GAMMA-DET#2	1953466	01-Aug-2016	01-Aug-2018
Gross Alpha/Beta Counter	527860	06-Oct-2016	06-Oct-2018
Gas Flow Proportional Counter for Sr-90	527860	13-Feb-2017	13-Feb-2019
Varian 820 ICPMS	IP0810M006	Calibrated Before Use	
Perkin Elmer Tri-Carb 2900TR (LSC for Fe-55)	DG11061765	14-Dec-2016	14-Dec-2018
Perkin Elmer Tri-Carb 2900TR (LSC for Ni-63)	DG11061765	21-Nov-2016	21-Nov-2018

The Analytical and Environmental Services Laboratory of Kinectrics is accredited by the Standards Council of Canada as conforming with ISO 17025.

The DL is the reported detection limit. All analytical data is subject to uncertainty, and is a function of the sample matrix, method and instrumental variations. As a general guideline, it can be expressed as +/-50% of the result at the detection limit (RDL) and approximately +/-10% of the result at greater than 10 times the RDL. Results in this report relate only to the items/samples tested and to all the items tested, as received. All tests are as defined by our understanding of customer requirements.

TECHNIQUE '*' = ISO 17025 accredited
TECHNIQUE '¤' = Indicates a modified test method
TECHNIQUE '†' = Indicates a sub-contracted analysis

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ENCLOSURE 4

Dose Assessment for a Contamination Incident at DNGS (SCR N-2018-03429)

OPG Document: OPG-REP-03416.4-10005-P

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Title:

DOSE ASSESSMENT FOR A CONTAMINATION INCIDENT AT DNGS (SCR N-2018-03429)

Dose Assessment For A Contamination Incident At DNGS (SCR N-2018-03429)

OPG-REP-03416.4-10005-P

2018-03-12

Project ID: N/A

OPG Confidential

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Table of Contents

1.0 INTRODUCTION

This report documents the results of the dose assessment for a contamination event which occurred at Darlington NGS on the night of February 05, 2018. Two individuals were found to be contaminated in the Retube Waste Processing Building (RWPB) after working in the Waste Tooling System (WTS) hardware station rubber area. The individuals were decontaminated and able to clear whole body monitors into Zone 1. The workers were requested to perform measurements using the Whole Body Counter (WBC) located in the Darlington Operations and Service Building (OSB). WBC results indicated that some portion of the contamination was internal.

2.0 DESCRIPTION OF INCIDENT AND RESPONSE

The circumstances of this event are under investigation and will be documented in SCR N-2018-03429.

On February 5th, at approximately 22:00, two workers entered the Hardware Station of the Retube Waste Tooling System (WTS) to fasten lids on a Retube Waste Container/Dry Storage Overpack (RWC/DSO). This work involves using torque wrenches to secure lidding bolts on the RWC and DSO lids.

The work site is a rubber area due to the presence of loose contamination on the RWC/DSO. Pre-work surveys identified up to 400 cpm loose contamination on the RWC lid. Workers were wearing washable Anti-C's, gloves, and booties. No respiratory protection or PAS sampling was used. Workers were signed on to REP 31745.

Upon exit from the work area, workers alarmed a whole body monitor at 01:09 on February 6th. A Radiation Protection (RP) technician performed follow up surveys and initiated decontamination activities. Workers were able to clear RWPB whole body monitors by 01:16. Workers alarmed monitors at the construction lunch room at 01:27. An RP Coordinator (RPC) followed up and performed further decontamination. Whole Body Counter measurements were initiated at 02:52.

3.0 SUMMARY OF DOSIMETRIC MEASUREMENTS

3.1 WBC Measurements

WBC measurements for DISN [redacted] are presented in Table 1. "Automatic" counts are measurements performed with the routine settings (90 seconds count time, facing the detectors). Investigative counts are performed with a 5 minutes count time in different orientations as instructed by the Health Physicist investigating the exposure.

Table 1

Count ID	Date and Time	Results	Count Type
11135953	2018-02-06 2:58	Zr+Nb-95=38.0 nCi MDA=16.6 nCi	Automatic (90 s)
11135955	2018-02-06 3:04	Co-60=5.6 nCi MDA=4.6 nCi Zr+Nb-95=32.7 nCi MDA=10.8 nCi	Automatic (90 s)
11135993	2018-02-06 21:33	Zr+Nb-95=17.0 nCi MDA=5.6 nCi	Front, Investigative (5 min)
11135994	2018-02-06 21:40	Zr+Nb-95=5.6 nCi MDA=4.3 nCi	Back, Investigative (5 min)
11135996	2018-02-06 22:43	Zr+Nb-95=8.0 nCi MDA=7.7 nCi	Automatic (90 s)
11136169	2018-02-12 20:49	No activity detected	Front, Investigative (5 min)
Subsequent counts indicated no activity			

WBC measurements for DISN [redacted] are presented in Table 2.

Table 2

Count ID	Date and Time	Results	Count Type
11135951	2018-02-06 2:52	Co-60=3.9 nCi < MDA. MDA=5.2 nCi Zr+Nb-95=40.9 nCi MDA=10.7 nCi	Automatic (90 s)
11135952	2018-02-06 2:55	Co-60=4.6 nCi < MDA. MDA=5.2 nCi Zr+Nb-95=45.0 nCi MDA=12.1 nCi	Automatic (90 s)
11135954	2018-02-06 3:01	Zr+Nb-95=14.3 nCi MDA=8.2 nCi	Automatic (90 s)
11135991	2018-02-06 21:18	Co-60=4.9 nCi MDA=2.8 nCi Zr+Nb-95=17.3 nCi MDA=3.9 nCi	Front, Investigative (5 min)
11135992	2018-02-06 21:26	Zr+Nb-95=25.7 nCi MDA=5.4 nCi	Back, Investigative (5 min)
11135995	2018-02-06 22:38	Zr+Nb-95=14.1 nCi MDA=9.0 nCi	Automatic (90 s)
11136165	2018-02-12 19:40	Zr+Nb-95=14.5 nCi MDA=13.8 nCi	Automatic (90 s)
11136167	2018-02-12 19:46	Zr+Nb-95=6.5 nCi < MDA. MDA=7.9 nCi	Automatic (90 s)
11136171	2018-02-12 21:30	Zr+Nb-95=13.1 nCi MDA=5.2 nCi	Front, Investigative (5 min)
11136444	2018-02-21 18:54	No activity detected	Automatic (90 s)
Subsequent counts indicated no activity			

3.2 Bioassay Measurements

DISN [redacted] submitted a fecal sample on Feb 09 at 20:23, and DISN [redacted] submitted a fecal sample on Feb 09 at 10:00 (a.m.).

The samples were shipped to Kinectrics on February 13, and the results were received on March 01, 2017. The samples were analyzed for transuranics (Am, Cm, and Pu isotopes), gamma emitters, and in addition for Fe-55 and Pu-241. The results and details on limits of detection and analysis methods are presented in Appendices A and B.

3.3 Other Measurements

Urine samples, nasal swabs and mouth rinse were collected from the worker and submitted for analysis at the Darlington Chemistry Laboratory. The nasal swabs and moth rinse were analyzed by gamma spectrometry (qualitative analysis only). Non-NORM radionuclides were detected in the nose swabs (Zr-95, Nb-95, and Co-60), but not in the mouth rinse. The urine samples were analyzed for tritium only, and the results were below the recording level (0.5 µCi/L).

4.0 DOSE ASSESSMENT

4.1 Methodology

The dose assessments for internal exposures are performed in accordance to procedures associated to N-MAN-03416.2-10000, Radiation Protection Program – Internal Dosimetry [R-5]. For the exposures described in this report, the applicable procedures are:

- N-HPS-03416.2-0007, Internal Dosimetry of Transuranics [R-6].
- N-HPS-03416.2-0005, Internal Dosimetry of Mixed Fission and Activation Products (MFAP) [R-7].
- N-PROC-RA-0012, Dosimetry and Dose Reporting [R-8].

- N-HPS-03413.1-0004, Creating and Maintaining Dose Records [R-9].

For these exposures the suspected hazards were MFAPs and alpha emitters (transuranics). The dosimetry for gamma-emitting MFAPs is relatively simple and it is based on WBC measurements. The dosimetry for transuranics is summarized in Figure 1 below (from [R-6]). Since PAS were not worn by the workers involved in this event, the dosimetry for transuranics is based on fecal sample measurements, corroborated with information from WBC measurements as described in the rest of this report.

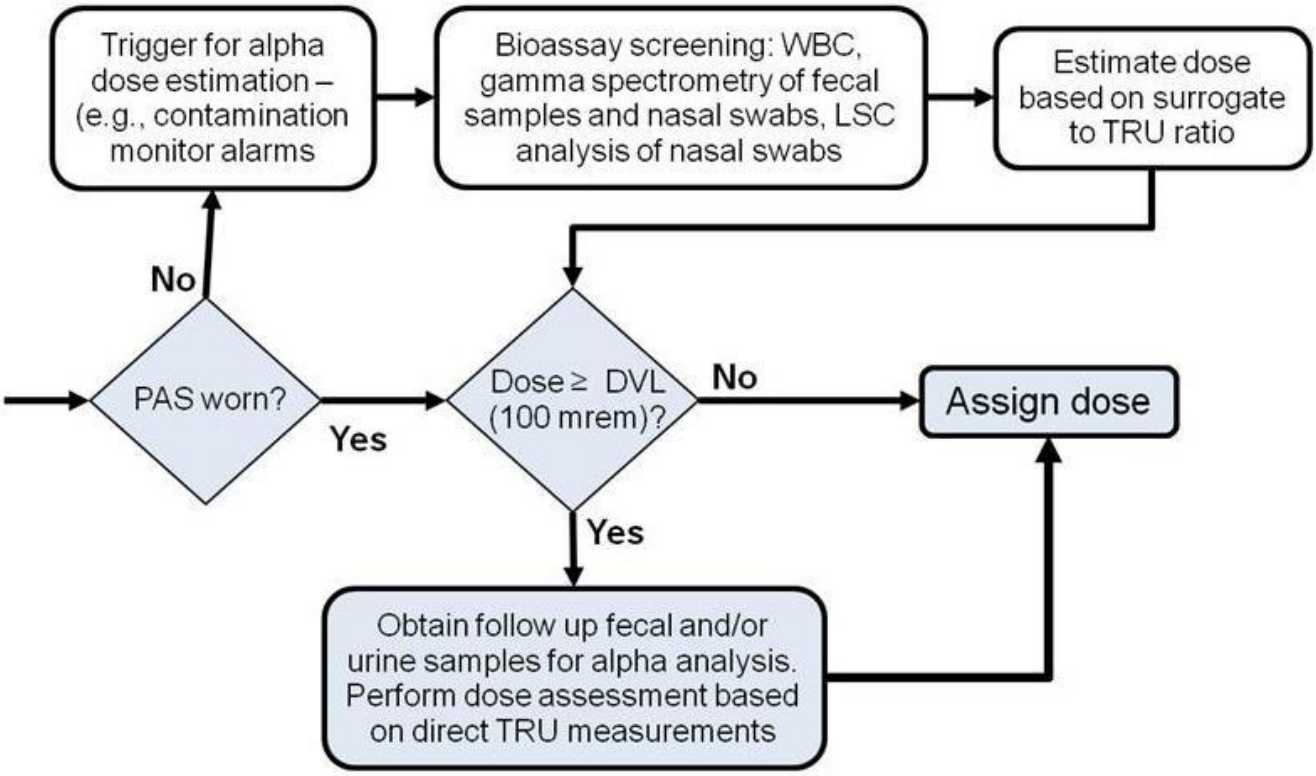

Figure 1 Main components of the Dosimetry for Transuranics

4.2 Dose Calculations

The work occurred between 22:00 and 24:00 on February 05, so for the purpose of this assessment February 05 is considered day 0 of the event. Thus the fecal samples were submitted at day 4 after the event, and for calculating intakes based on the fecal sample results the fecal excretion fractions for day 4 were used.

The results of the dose calculations using the fecal samples are presented in Table 3 for DISN [redacted] and Table 4 for DISN [redacted]. For the calculations in Tables 3 and 4 it was assumed that the exposures occurred by inhalation, since this is the more restrictive situation. The particle size used was 5 µm AMAD, as this is the standard particle size for nuclear industry [R-1]. The solubility type for Curium isotopes was selected based on ICRP 68 defaults (only type M solubility is provided by ICRP 68 for

Cm), while for all other radionuclides the solubility type was conservatively selected based on the type with the highest dose coefficient. In any case the intakes and doses are sufficiently small that refinement of the calculations with different exposure parameters (particle size, path if exposure, solubility type) is not warranted [R-2] and it would not make a significant difference.

Table 3

Radionuclide	DISN [redacted], Sample Date 09 Feb 2018	Units	DISN [redacted] Intake (Bq)	DISN [redacted] Dose (mrem)	Dose coeff, mrem/Bq	Fecal excretion fraction, Day 4	Assumed Solubility Type
Am-241	<0.54	mBq/Sample					
Cm-242	0.73	mBq/Sample	2.21E-02	8.18E-03	3.70E-01	3.30E-02	Type M
Cm-243+244	32	mBq/Sample	9.70E-01	1.94E+00	2.00E+00	3.30E-02	Type M
Pu-238	<0.27	mBq/Sample					
Pu-239+240	<0.41	mBq/Sample					
Pu-241	<0.5	Bq/Sample					
Fe-55	12.1	Bq/Sample	4.32E+02	5.19E-02	1.20E-04	2.80E-02	Type F
Ce-141	<0.031	Bq/Sample					
Ce-144	<0.134	Bq/Sample					
Co-58	<0.033	Bq/Sample					
Co-60	1.09	Bq/Sample	1.63E+01	5.04E-02	3.10E-03	6.70E-02	Type S
Cr-51	<0.237	Bq/Sample					
Cs-134	<0.256	Bq/Sample					
Cs-137	<0.031	Bq/Sample					
Eu-154	<0.1	Bq/Sample					
Eu-155	<0.068	Bq/Sample					
Fe-59	<0.092	Bq/Sample					
Gd-153	<0.078	Bq/Sample					
K-40	26	Bq/Sample					
Mn-54	0.105	Bq/Sample	3.28E+00	8.53E-04	2.60E-04	3.20E-02	Type S
Nb-94	0.297	Bq/Sample	5.82E+00	5.42E-02	9.30E-03	5.10E-02	Type S
Nb-95	3.19	Bq/Sample	5.15E+01	4.37E-03	8.50E-05	6.20E-02	Type S
Ru-103	<0.04	Bq/Sample					
Ru-106	<0.305	Bq/Sample					
Sb-124	<0.054	Bq/Sample					
Sb-125	<0.084	Bq/Sample					
Sc-46	<0.041	Bq/Sample					
Sn-113	<0.067	Bq/Sample					
Zn-65	<0.079	Bq/Sample					
Zr-95	1.33	Bq/Sample	2.08E+01	5.40E-03	2.60E-04	6.40E-02	Type S
			Total:	**2.11**			

Table 4

Radionuclide	DISN [redacted], Sample Date 09 Feb 2018	Units	DISN [redacted] intake (Bq)	DISN [redacted] Dose (mrem)	Dose coeff, mrem/Bq	Fecal excretion fraction, Day 4	Assumed Solubility Type
Am-241	<0.61	mBq/Sample					
Cm-242	5.41	mBq/Sample	1.64E-01	6.07E-02	3.70E-01	3.30E-02	Type M
Cm-243+244	29.2	mBq/Sample	8.85E-01	1.77E+00	2.00E+00	3.30E-02	Type M
Pu-238	<0.30	mBq/Sample					
Pu-239+240	<0.45	mBq/Sample					
Pu-241	<0.5	Bq/Sample					
Fe-55	5.84	Bq/Sample	2.09E+02	2.50E-02	1.20E-04	2.80E-02	Type F
Ce-141	<0.025	Bq/Sample					
Ce-144	<0.091	Bq/Sample					
Co-58	<0.023	Bq/Sample					
Co-60	0.966	Bq/Sample	1.44E+01	4.47E-02	3.10E-03	6.70E-02	Type S
Cr-51	<0.184	Bq/Sample					
Cs-134	<0.026	Bq/Sample					
Cs-137	<0.021	Bq/Sample					
Eu-154	<0.065	Bq/Sample					
Eu-155	<0.078	Bq/Sample					
Fe-59	<0.054	Bq/Sample					
Gd-153	<0.084	Bq/Sample					
K-40	15	Bq/Sample					
Mn-54	0.103	Bq/Sample	3.22E+00	8.37E-04	2.60E-04	3.20E-02	Type S
Nb-94	0.274	Bq/Sample	5.37E+00	5.00E-02	9.30E-03	5.10E-02	Type S
Nb-95	3.06	Bq/Sample	4.94E+01	4.20E-03	8.50E-05	6.20E-02	Type S
Ru-103	<0.029	Bq/Sample					
Ru-106	<0.233	Bq/Sample					
Sb-124	<0.04	Bq/Sample					
Sb-125	<0.065	Bq/Sample					
Sc-46	<0.029	Bq/Sample					
Sn-113	<0.029	Bq/Sample					
Zn-65	<0.05	Bq/Sample					
Zr-95	1.35	Bq/Sample	2.11E+01	5.48E-03	2.60E-04	6.40E-02	Type S
			CED (mrem)	**1.96**			

The data show that the doses are small (~ 2 mrem for both individuals), and are dominated by Cm243/244. The uncertainties associated with fecal sampling are discussed in [R-4] (Table 6.1) and [R-3] (Table 4.10). Based on these references, the fecal sample values are assumed to have a log-normal distribution, and the scattering factor (geometric standard deviation) for 24 hour fecal samples is taken to be 3. Thus the 95% confidence interval for the doses calculated based on the fecal sample results is (0.2 mrem, 18 mrem) for each worker.

The intakes were calculated also from WBC measurements. For Zr+Nb-95, the intakes were calculated using the Whole Body retention factors, while for all other radionuclides the intakes were calculated by scaling the Zr+Nb-95 intakes using scaling factors derived from the measurement of fecal samples. Since there are not enough non zero WBC measurements to perform data fitting, the WBC Zr+Nb-95 measurements giving the most reasonable conservative intakes were used (instead of determining a ”best estimate of intake” using the maximum likelihood method [R-3]) , as shown in Table 5 (highlighted cells).

Note that the intake of Zr+Nb-95 (262 nCi) calculated for DISN [redacted] based on the measurements at day 7 (on Feb 12) is not compatible with any of the initial WBC measurements, indicating that the measurements on Feb 12 (~13 nCi Zr+Nb-95) are most likely due to external residual contamination on some article of clothing (the worker has been on removal from radioactive work between Feb 06 and Feb 12, so there was no likely uptake of Zr+Nb-95 after Feb 06). A Zr+Nb-95 intake of his amount (262 nCi) would result in much higher initial WBC measurements. For example, the three WBC measurements on Feb 06 in the evening (at 21:18, 21:26 and 22:38) ranged from 14 to 25 nCi depending on the orientation in the counter. This is much lower than the expected value of 174 nCi expected if the intake value was taken to be 262 nCi (based on WB retention fractions of 0.66 for Nb-95 and 0.67 for Zr-95 at 0.75 days after intake for inhalation of type S 5µm AMAD material. In addition no measurable activity was detected for the WBC measurements for DISN [redacted] on day 16 and 17 after the event, while an intake of 262 nCi Zr+Nb-95 would result in ~10 nCi whole body activity on day 16 and day 17 (above the MDA of ~ 6 nCi for those measurements). For reference the Nb-95 and Zr-95 whole body retention fractions used in these calculations for at various times after the intake are given in Appendix C (from ICRP OIR Data Viewer).

Based on these considerations, the most reasonable conservative Zr+Nb-95 intakes are 50 nCi (1850 Bq) for DISN [redacted], and 59.2 nCi (2191 Bq) for DISN [redacted].

Table 5

File	DISN	Date Time	Zr/Nb-95 Activity (nCi)	Zr/Nb-95 WBC Retention Fraction	Zr+Nb-95 Intake based on WBC (nCi)
11135953	[redacted]	2018-02-06 2:58	38	7.60E-01	50
11135955	[redacted]	2018-02-06 3:04	32.7		
11135993	[redacted]	2018-02-06 21:33	17	6.70E-01	25.4
11135994	[redacted]	2018-02-06 21:40	5.57		
11135996	[redacted]	2018-02-06 22:43	8.01		
11136169	[redacted]	2018-02-12 20:49	0		
11135951	[redacted]	2018-02-06 2:52	40.9		
11135952	[redacted]	2018-02-06 2:55	45	7.60E-01	59.2
11135954	[redacted]	2018-02-06 3:01	14.3		
11135991	[redacted]	2018-02-06 21:18	17.3		
11135992	[redacted]	2018-02-06 21:26	25.7	6.70E-01	38.4
11135995	[redacted]	2018-02-06 22:38	14.1		
11136165	[redacted]	2018-02-12 19:40	14.5		
11136167	[redacted]	2018-02-12 19:46	6.5		
11136171	[redacted]	2018-02-12 21:30	13.1	5.0E-02	262.0

Since it is likely that there was some external contamination (especially for DISN [redacted]), the intake calculated from the WBC measurements is probably overestimated, even when looking at the 95% confidence interval of the intakes calculated based on the fecal sample) (if using the fecal samples measurement, the calculated Zr+Nb-95 intakes are a factor of 26 and 31 smaller than when using WBC measurements, see Table 6).

Table 6

	DISN [redacted]	DISN [redacted]
Likely upper bound of Zr+Nb-95 intake based on WBC measurements (Bq)	1850	2191
Zr+Nb-95 intake based on fecal samples (Bq)	72	70

Because intakes and doses are relatively small, no additional fecal or urine sampling were warranted to refine the results, but the more conservative values of intakes (i.e.,

those obtained from the initial WBC measurement) will be used for dose calculation [R-6][R-2], [R-6], [R-7]. For this reason, the WBC results were used to establish the Zr+Nb-95 intakes, and the fecal sample results were used to calculate scaling factors for all other nuclides, and subsequently the scaling factors were used to calculate the intakes for these radionuclides. The results of these calculations are shown in Tables 7 and 8. Note that in these tables the scaling factors include the decay correction for Zr-95 and Nb-95 (4 days). Based on the conservative assumptions made above, the doses are likely to represent an upper bound of the actual doses received by the workers. Since these doses are relatively low, no further refinement of the calculations is warranted [R-2], [R-6], [R-7].

The new ICRP 134 dose coefficients and parameters for the reference bioassay functions were used for calculating the doses (where available, as noted in the tables). For Curium-242, 243, 244, and for Mn-54 the new Occupational Intakes of Radionuclides (OIR) models are not yet available so ICRP 68 dose coefficients were used. The ICRP 134 dose coefficients and parameters were taken from the electronic data viewer available on the ICRP 134 web page (see Figure 1 and Figure 2 for data on Nb-95 for example).

Table 7

Radionuclides identified in fecal samples	DISN [redacted] Activity in Fecal Sample (Bq)	DISN [redacted] Scaling Factors to Zr+Nb-95	DISN [redacted] Intake (Bq)	DISN [redacted] Dose (mrem)	Dose coeff, mrem/Bq	Notes
Cm-242	0.00073	0.0002	0.3	0.10	3.70E-01	Type M, ICRP 68, p. 71
Cm-243+244	0.032	0.0066	12.2	24.45	2.00E+00	Type M, ICRP 68, p. 71, using Cm-243 dose coeff (Cm-244 is 1.7 mrem/Bq)
Fe-55	12.1	2.4990	4623.2	0.55	1.20E-04	Type F, ICRP 134
Co-60	1.09	0.2251	416.5	1.29	3.10E-03	Type S, ICRP 134
Mn-54	0.105	0.0217	40.1	0.00	1.20E-04	Type M, ICRP 68, p. 28
Nb-94	0.297	0.0613	113.5	1.06	9.30E-03	Type S, ICRP 134
Nb-95	3.19	0.7058	1305.6	0.11	8.50E-05	Type S, ICRP 134
Zr-95	1.33	0.2942	544.4	0.14	2.60E-04	Type S, ICRP 134

DISN [redacted] Dose (mrem)	
Dose TRU (NDR Type Y)	24.56
Dose MFAP (NDR Type Q)	3.16

Table 8

Radionuclides identified in fecal samples	DISN [redacted] Activity in Fecal Sample (Bq)	DISN [redacted] Scaling Factors to Zr+Nb-95	DISN [redacted] Intake (Bq)	DISN [redacted] Dose (mrem)	Dose coeff, mrem/Bq	Notes
Cm-242	0.00541	0.0011	2.5	0.93	3.70E-01	Type M, ICRP 68, p. 71
Cm-243+244	0.0292	0.0062	13.5	27.09	2.00E+00	Type M, ICRP 68, p. 71, using Cm-243 dose coeff (Cm-244 is 1.7 mrem/Bq)
Fe-55	5.84	1.2368	2709.5	0.33	1.20E-04	Type F, ICRP 134
Co-60	0.966	0.2046	448.2	1.39	3.10E-03	Type S, ICRP 134
Mn-54	0.103	0.0218	47.8	0.01	1.20E-04	Type M, ICRP 68, p. 28
Nb-94	0.274	0.0580	127.1	1.18	9.30E-03	Type S, ICRP 134
Nb-95	3.06	0.6939	1520.1	0.13	8.50E-05	Type S, ICRP 134
Zr-95	1.35	0.3061	670.6	0.17	2.60E-04	Type S, ICRP 134

DISN [redacted] Dose (mrem)	
Dose TRU (NDR Type Y)	28.02
Dose MFAP (NDR Type Q)	3.21

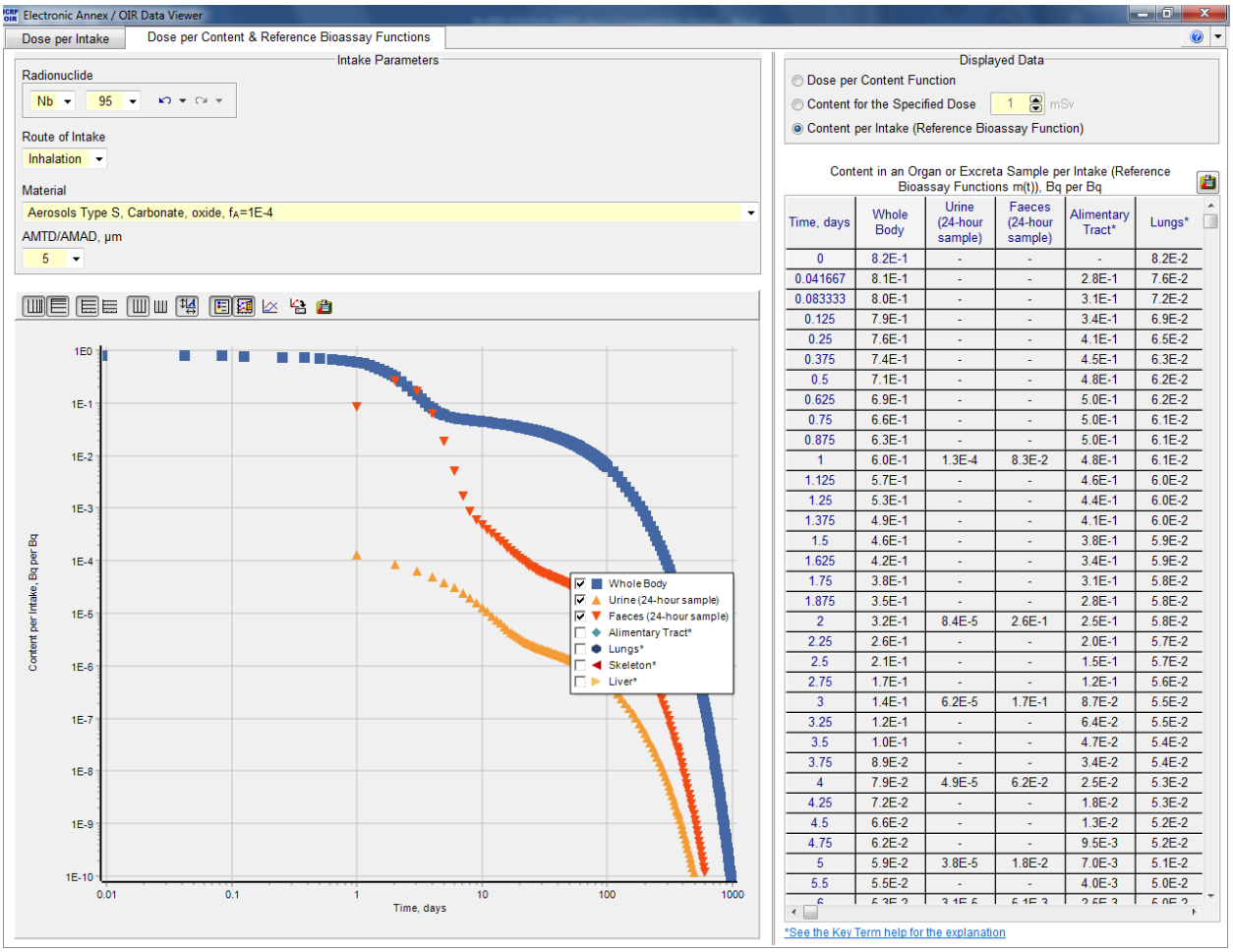

Figure 2 OIR Data Viewer for Nb-95 Reference Bioassay Functions

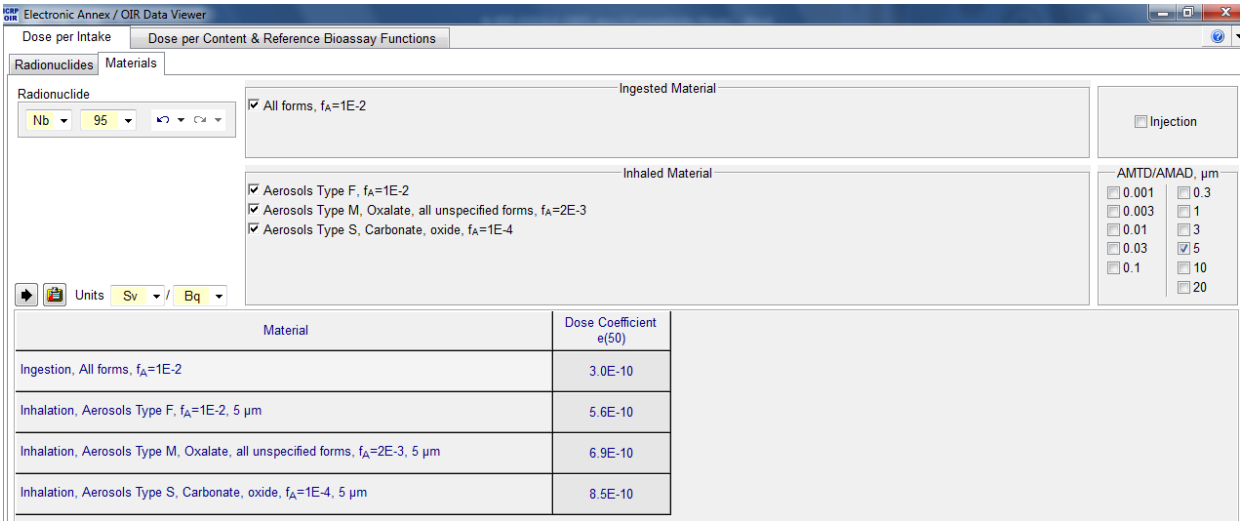

Figure 3 OIR Data Viewer for Nb-95 Committed Dose Coefficients

5.0 SUMMARY

For these exposures, the site Responsible Health Physicist or qualified delegate should assign Committed Effective Doses as shown in Tables 9 and 10 below, in accordance to N-HPS-03413.1-0004, Creating and Maintaining Dose Records [R-9].

Table 9

DISN [redacted] Dose (mrem)	
Dose TRU (NDR Type Y)	24.56
Dose MFAP (NDR Type Q)	3.16

Table 10

DISN [redacted] Dose (mrem)	
Dose TRU (NDR Type Y)	28.02
Dose MFAP (NDR Type Q)	3.21

6.0 REFERENCES

[R-1] M.-D. Dorrian and M.R. Bailey, Particle Size Distributions of Radioactive Aerosols Measured in Workplaces, Radiation Protection Dosimetry 60(2): 119-133, 1995.

[R-2] Marsh et al., A Structured Approach for the Assessment of Internal Dose: The IDEAS Guidelines, Radiation Protection Dosimetry Vol. 127, No. 1–4, pp. 303–310, 2007.

[R-3] EURADOS Report 2013-01: C. M. Castellani et al. "IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring data".

[R-4] NCRP REPORT No. 164 Uncertainties in Internal Radiation Dose Assessment, July 20, 2009.

[R-5] N-MAN-03416.2-10000, Radiation Protection Program – Internal Dosimetry.

[R-6] N-HPS-03416.2-0007, Internal Dosimetry of Transuranics.

[R-7] N-HPS-03416.2-0005, Internal Dosimetry of Mixed Fission and Activation Products (MFAP).

[R-8] N-PROC-RA-0012, Dosimetry and Dose Reporting.

[R-9] N-HPS-03413.1-0004, Creating and Maintaining Dose Records.

Appendix A: Fecal Sample Results, DISN [redacted]

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-AL-00016-1	[redacted]	Feces	Pickering	09-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limit	Analyzed On dd-mmm-yy	Technique
Am/Cm Recovery	80	%				23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.54	mBq/Sample	NA	0.54		23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Cm-242	0.73	mBq/Sample	0.49	0.22		23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	32	mBq/Sample	5.02	0.67		23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu Recovery	89.2	%				23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-238	<0.27	mBq/Sample	NA	0.27		23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	<0.41	mBq/Sample	NA	0.41		23-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-241	<0.5	Bq/Sample	NA	0.5		26-Feb-18	Chemical Separation/LSC
Fe-55	12.1	Bq/Sample	3.6	0.2		26-Feb-18	Chemical Separation/LSC*
Ce-141	<0.031	Bq/Sample	NA	0.031		16-Feb-18	Gamma Spectrometry*
Ce-144	<0.134	Bq/Sample	NA	0.134		16-Feb-18	Gamma Spectrometry*
Co-58	<0.033	Bq/Sample	NA	0.033		16-Feb-18	Gamma Spectrometry*
Co-60	1.09	Bq/Sample	0.057	0.036		16-Feb-18	Gamma Spectrometry*
Cr-51	<0.237	Bq/Sample	NA	0.237		16-Feb-18	Gamma Spectrometry*
Cs-134	<0.256	Bq/Sample	NA	0.256		16-Feb-18	Gamma Spectrometry*
Cs-137	<0.031	Bq/Sample	NA	0.031		16-Feb-18	Gamma Spectrometry*
Eu-154	<0.1	Bq/Sample	NA	0.1		16-Feb-18	Gamma Spectrometry*
Eu-155	<0.068	Bq/Sample	NA	0.068		16-Feb-18	Gamma Spectrometry*
Fe-59	<0.092	Bq/Sample	NA	0.092		16-Feb-18	Gamma Spectrometry*
Gd-153	<0.078	Bq/Sample	NA	0.078		16-Feb-18	Gamma Spectrometry*
K-40	26	Bq/Sample	0.99	0.34		16-Feb-18	Gamma Spectrometry*
Mn-54	0.105	Bq/Sample	0.021	0.031		16-Feb-18	Gamma Spectrometry*
Nb-94	0.297	Bq/Sample	0.028	0.033		16-Feb-18	Gamma Spectrometry*
Nb-95	3.19	Bq/Sample	0.09	0.04		16-Feb-18	Gamma Spectrometry*
Ru-103	<0.04	Bq/Sample	NA	0.04		16-Feb-18	Gamma Spectrometry*
Ru-106	<0.305	Bq/Sample	NA	0.305		16-Feb-18	Gamma Spectrometry*
Sb-124	<0.054	Bq/Sample	NA	0.054		16-Feb-18	Gamma Spectrometry*
Sb-125	<0.084	Bq/Sample	NA	0.084		16-Feb-18	Gamma Spectrometry*
Sc-46	<0.041	Bq/Sample	NA	0.041		16-Feb-18	Gamma Spectrometry*
Sn-113	<0.067	Bq/Sample	NA	0.067		16-Feb-18	Gamma Spectrometry*
Zn-65	<0.079	Bq/Sample	NA	0.079		16-Feb-18	Gamma Spectrometry*
Zr-95	1.33	Bq/Sample	0.08	0.06		16-Feb-18	Gamma Spectrometry*

Appendix B: Fecal Sample Results, DISN [redacted]

Sample ID	Sample Name	Matrix	Sample Point	Sample Date
18-AL-00015-1	[redacted]	Feces	Pickering	09-Feb-2018

Parameter / Analyte	Result	Units	Uncert.	DL	Spec. Limt	Analyzed On dd-mmm-yy	Technique
Am/Cm Recovery	74.8	%				22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Am-241	<0.61	mBq/Sample	NA	0.61		22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Cm-242	5.41	mBq/Sample	1.59	0.26		22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Cm-243+244	29.2	mBq/Sample	4.86	0.77		22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu Recovery	86.8	%				22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-238	<0.30	mBq/Sample	NA	0.3		22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-239+240	<0.45	mBq/Sample	NA	0.45		22-Feb-18	Chemical Separation/ Alpha Spectrometry*
Pu-241	<0.5	Bq/Sample	NA	0.5		26-Feb-18	Chemical Separation/LSC
Fe-55	5.84	Bq/Sample	1.8	0.2		26-Feb-18	Chemical Separation/LSC*
Ce-141	<0.025	Bq/Sample	NA	0.025		16-Feb-18	Gamma Spectrometry*
Ce-144	<0.091	Bq/Sample	NA	0.091		16-Feb-18	Gamma Spectrometry*
Co-58	<0.023	Bq/Sample	NA	0.023		16-Feb-18	Gamma Spectrometry*
Co-60	0.966	Bq/Sample	0.109	0.023		16-Feb-18	Gamma Spectrometry*
Cr-51	<0.184	Bq/Sample	NA	0.184		16-Feb-18	Gamma Spectrometry*
Cs-134	<0.026	Bq/Sample	NA	0.026		16-Feb-18	Gamma Spectrometry*
Cs-137	<0.021	Bq/Sample	NA	0.021		16-Feb-18	Gamma Spectrometry*
Eu-154	<0.065	Bq/Sample	NA	0.065		16-Feb-18	Gamma Spectrometry*
Eu-155	<0.078	Bq/Sample	NA	0.078		16-Feb-18	Gamma Spectrometry*
Fe-59	<0.054	Bq/Sample	NA	0.054		16-Feb-18	Gamma Spectrometry*
Gd-153	<0.084	Bq/Sample	NA	0.084		16-Feb-18	Gamma Spectrometry*
K-40	15	Bq/Sample	1.77	0.2		16-Feb-18	Gamma Spectrometry*
Mn-54	0.103	Bq/Sample	0.019	0.024		16-Feb-18	Gamma Spectrometry*
Nb-94	0.274	Bq/Sample	0.021	0.032		16-Feb-18	Gamma Spectrometry*
Nb-95	3.06	Bq/Sample	0.27	0.03		16-Feb-18	Gamma Spectrometry*
Ru-103	<0.029	Bq/Sample	NA	0.029		16-Feb-18	Gamma Spectrometry*
Ru-106	<0.233	Bq/Sample	NA	0.233		16-Feb-18	Gamma Spectrometry*
Sb-124	<0.04	Bq/Sample	NA	0.04		16-Feb-18	Gamma Spectrometry*
Sb-125	<0.065	Bq/Sample	NA	0.065		16-Feb-18	Gamma Spectrometry*
Sc-46	<0.029	Bq/Sample	NA	0.029		16-Feb-18	Gamma Spectrometry*
Sn-113	<0.029	Bq/Sample	NA	0.029		16-Feb-18	Gamma Spectrometry*
Zn-65	<0.05	Bq/Sample	NA	0.05		16-Feb-18	Gamma Spectrometry*
Zr-95	1.35	Bq/Sample	0.13	0.04		16-Feb-18	Gamma Spectrometry*

Appendix C: ICRP OIR Whole Body Retention Fractions

Inhalation of type S 5 µm AMAD aerosols

Time, days	Nb-95	Zr-95
0	8.20E-01	8.20E-01
0.125	7.90E-01	7.90E-01
0.25	7.60E-01	7.60E-01
0.375	7.40E-01	7.40E-01
0.5	7.10E-01	7.20E-01
0.75	6.60E-01	6.70E-01
1	6.00E-01	6.10E-01
1.5	4.60E-01	4.60E-01
2	3.20E-01	3.20E-01
2.5	2.10E-01	2.20E-01
3	1.40E-01	1.50E-01
3.5	1.00E-01	1.10E-01
4	7.90E-02	8.20E-02
4.5	6.60E-02	6.90E-02
5	5.90E-02	6.20E-02
5.5	5.50E-02	5.80E-02
6	5.30E-02	5.60E-02
6.5	5.10E-02	5.50E-02
7	5.00E-02	5.40E-02
7.5	4.90E-02	5.30E-02
8	4.80E-02	5.20E-02
8.5	4.80E-02	5.20E-02
9	4.70E-02	5.10E-02
9.5	4.60E-02	5.10E-02
10	4.50E-02	5.00E-02
11	4.40E-02	4.90E-02
12	4.30E-02	4.80E-02
13	4.20E-02	4.70E-02
14	4.10E-02	4.70E-02
15	4.00E-02	4.60E-02
16	3.90E-02	4.50E-02
17	3.80E-02	4.40E-02