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Evaluation of Savannah River Site Americium-241 Source Terms Between 1971 and 1999 Using Bioassay Frequency Tables

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
06/10/2019	00	New report initiated in order to evaluate Savannah River Site ^{241}Am source terms between 1971 and 1999 using bioassay frequency tables. Incorporates formal internal and NIOSH review comments. Initiated by James M. Mahathy.

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ACRONYMS AND ABBREVIATIONS

ACD	Analytical Chemistry Division
ADS	Analytical Development Section
ALARA	as low as is reasonably achievable
CFR	Code of Federal Regulations
CHTS	Chemical and Hydrogen Technology Section
CLAB	Central Laboratory Facility
cm	centimeter
D&D	decontamination and decommissioning
D&R	dismantling and removal
DAC	derived air concentration
decon	decontamination
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
E&I	Electrical and Instrumentation
EU	enriched uranium
FEB	Facilities Evaluation Board
FP	fission product
ft	foot
HEPA	high-efficiency particulate air
HLC	high-level cave
HLW	high-level waste
HP	Health Physics
HPRED	Health Protection Radiation Exposure Database
HTO	tritiated water vapor
IA	induced activity
in.	inch
L	liter
LSC	liquid scintillation counting
mo	month
MPPF	Multi-Purpose Processing Facility
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
NMD	Nuclear Materials Division
NOCTS	NIOSH-Division of Compensation Analysis and Support Claims Tracking System
OEI	Office of Enforcement and Investigation
ORAU	Oak Ridge Associated Universities
PUREX	plutonium-uranium extraction
RA	Radiological Area
RBA	Radiological Buffer Area

RBOF	Receiving Basin for Offsite Fuel
RCA	radiologically controlled area
RCG	radioactivity concentration guide
RCO	Radiological Control Operations
RM	Reactor Maintenance
RQB	radiation qualification badge
RWP	Radiation Work Permit
SCD	Separations Chemistry Division
SED	Separations Engineering Division
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SWE	Solid Waste Engineering
T&T	Traffic and Transportation
TNX	code designation for Semi-works Laboratory
WBC	whole-body count
WSRC	Westinghouse Savannah River Corporation
yr	year
µCi	microcurie

1.0 INTRODUCTION

On January 11, 2018, SC&A submitted a memorandum, "Missing or Incomplete Radiological Source Terms," to the Savannah River Site (SRS) Work Group of the Advisory Board on Radiation and Worker Health (SC&A 2018).

In 1999, a sitewide characterization effort at SRS identified ^{241}Am in areas that had not previously required routine bioassay sampling for ^{241}Am. The memorandum was a review of and details on SC&A's finding that some SRS workers in those areas were enrolled in incorrect bioassay programs under Radiation Work Permits (RWPs).

SC&A provided Site Research Database (SRDB) references for their finding and posed several questions about the implications of the finding on the ability to achieve sufficiently accurate dose reconstructions. In their conclusion they state (SC&A 2018):

> *SC&A believes that … there was a clear deficiency recognized that may have impacted the proper bioassay enrollment of workers under RWPs prior to the implementation of a new site-wide formal policy, "Specifications of Urine Bioassay Requirements on Radiological Work Permits," issued on March 10, 1999. Lack of proper specification of radionuclides of significance for internal dosimetry may have led to unmonitored exposures for which dose reconstruction with sufficient accuracy may not be feasible. This concern should be investigated further to ascertain its significance, scope, and implications for dose reconstruction.*

The results of the investigation into the finding are provided in this report.

2.0 INTERNAL DOSIMETRY PROGRAM SELF-ASSESSMENT

In 1998, the SRS Facilities Evaluation Board (FEB) audited the Solid Waste Division (LaBone 1998). The audit noted that although the recommended routine bioassay requirements in Manual 5Q1.1, Procedure 506 (5Q1.1-506), *In Vivo and In Vitro Bioassay Scheduling and Administration* (e.g., WSRC 1996), specified only plutonium and strontium bioassays for workers at the burial ground, documentation showed the presence of curium. Investigation with Solid Waste Division personnel "resolved the concern over performing RWP sampling for curium … due to inaccessibility to the curium present and the fact that plutonium is always present with the curium." However, a pilot program was established for the solid waste disposal facilities to develop guidelines for selecting the radionuclides of concern for routine urine bioassays (Findley 1998).

In early 1999, the U.S. Department of Energy (DOE) Office of Enforcement and Investigation (OEI) requested all DOE sites review their dose evaluation programs. The SRS contractor Westinghouse Savannah River Corporation (WSRC) established an internal assessment team to review the overall internal dosimetry program. A February 9, 1999, report from this team indicated that one of the areas evaluated was the method of identifying the predominant radionuclides in facilities to ensure appropriate bioassay sample analysis (WSRC 1999a, p. 11). In July 1999, the OEI issued a report summarizing responses from all DOE sites as a list of 31 general deficiencies and recommended that all contractors review their programs against this list.

Item B.8 on the list was, "Workers enrolled in incorrect routine bioassay program." WSRC said in its November 2, 1999, report documenting their review of the 31 general deficiencies that this item was an SRS issue and that they had previously determined that "in some areas site workers were potentially exposed to americium, but that radionuclide was not recognized as an issue when preparing RWPs for those areas." This report does not say which areas or workers were involved (Morgan 1999).

WSRC answered Item B.8 by listing improvements that were made in the documentation and review of the radiological hazards. It referenced "Specification of Urine Bioassay Requirements on Radiological Work Permits" (Farrell and Findley 1999), which defined a formalized method of determining radiological source terms for bioassay compliance. Farrell and Findley (1999) also contained summaries from characterization reports from all eight WSRC divisions at SRS. The summary listed each radionuclide that contributed 10% or more of the internal dose from inhalation for locations or waste streams under each division (Farrell and Findley 1999).

Before March 1999, site bioassay control procedures included a table of locations and job functions with recommended routine bioassay sampling types and frequencies. The radioisotope selection for each location was primarily based on process knowledge. The 1998 FEB audit found that some individuals responsible for establishing the bioassay requirements in RWPs were relying solely on the tables instead of establishing the radioisotopes actually present as required by the procedures (LaBone 2004).

In March 1999, the bioassay sample frequency table was removed from the bioassay control procedures. All radioisotopes that contributed 10% or more of the internal dose from inhaled material were to be considered for bioassay sampling when writing RWPs.

3.0 IN VIVO AND IN VITRO BIOASSAY MONITORING

SRS implemented bioassay programs to cover 35 facilities that processed actinides, fission products, and tritium (Thomas et al. 1993). From 1971 through 1999, SRS performed in vivo and in vitro sampling for radioactive material using both routine and special sampling.

For monitoring purposes, SRS assessed three ranges of internal exposure probability:

- Workers "likely" to exceed 100 millirem annually and therefore be required to have routine bioassay monitoring under 10 CFR 835.402(c);

- Workers with "reasonable potential" for exposure, those workers unlikely to exceed 100 millirem annually but whose tasks required used respiratory protection while handling large amounts of unencapsulated radioactive materials; and

- Workers with "no potential," those who did not encounter unencapsulated sources nor used respiratory protection for radiological exposure.

No workers were considered to fall into the first range because none was considered to have routine internal exposures in excess of 100 millirem annually. Workers with "reasonable potential" for internal exposure were included in the Routine Bioassay Sampling Program. The Special Bioassay Sampling Program was designed for assessing "inadvertent intakes" of radioactive material that could exceed the 100-mrem threshold (LaBone 2001).

The bioassay program was part of an overall strategy described as "Defense in Depth" and included a zero-intake policy, engineered and procedural controls, personal protective equipment, and surveillance. This surveillance included air monitoring, facility and personnel contamination surveys, and the routine bioassay program (LaBone 1997).

3.1 ROUTINE BIOASSAY SAMPLING PROGRAM

Workers supplied urine samples on a prescheduled routine basis to be analyzed for tritium, plutonium, strontium, neptunium, uranium, enriched uranium (EU), americium, curium, californium, and fission products (FP) and induced activity (IA). Workers also supplied routine samples as requested when

necessitated by working under RWP with bioassay requirements. Internally deposited radioisotopes were measured directly in workers by the use of whole-body counters and chest counters. Details on the analysis techniques and their detection efficiencies are available in ORAUT-TKBS-0003, *Savannah River Site* (ORAUT 2005).

A worker's enrollment in the program was based on the radioactive hazards associated with the facility where the individual worked and the type of work the worker normally performed. Enrollment in the program was defined by building or specific operation and by the task, such as operators, laboratory personnel, supervisory personnel, etc.

Tables in the bioassay control procedures defined urine bioassay types and sample frequencies. Whole-body count (WBC) and chest count frequencies were listed in the tables or described in the procedures. Except for the Construction Division, workers assigned to the listed buildings with the specified jobs were to have prescheduled routine bioassays according to these tables. Until 1992, Construction Division workers had separate requirements for routine bioassay in the procedures and were not required to use the bioassay frequency tables.

Job-specific sampling was used to sample workers, including Construction Division workers, who needed to enter locations with bioassay requirements not covered by prescheduled bioassay testing. These bioassay requirements were placed on RWPs when respiratory protection was used. A definition of the job-specific sampling from September 1997 was (Findley 1997a):

> *Job-specific urine sampling is also known as "RWP (Radiation Work Permit) sampling" and is administered exclusively by radiological control personnel. RWPs are written to describe a specific scope of work to be performed. Additional information such as the expected radiological hazards to be encountered, respiratory protection if needed, and dosimetry requirements are listed on the RWP. Based on the degree and nature of the radiological hazards it may be necessary to request each worker performing "hands on" work to leave a urine bioassay sample, hence the term "job-specific sampling." If a worker is wearing respiratory protection and is not on an appropriate routine sampling program then a job-specific sample should be requested.*

The Routine Bioassay Sampling Program, including both the prescheduled and the job-specific bioassays, was not used at SRS to detect and assess the intake of actinides. It was a "final quality control check that exposure control measures and workplace monitoring programs worked" (ORAUT 2017a). It was implemented in excess of the regulatory requirements; none of the SRS workers met the 10 CFR Part 835 definition for requiring bioassay (ORAUT 2017a).

3.2 SPECIAL BIOASSAY SAMPLING PROGRAM

SRS designed the Special Bioassay Sampling Program to assess "inadvertent intakes" of radioactive material that could exceed the 100-mrem threshold (WSRC 1990a, p. 36). Under this program, samples were required in response to unusual or unanticipated circumstances such as being involved in a contamination incident or from the results of air sampling. Intakes of radionuclides were assigned to the worker's record of exposure when positive results of special bioassay sampling were confirmed.

The Special Bioassay Sampling Program did not use the bioassay frequency tables. Selection of the bioassay type for follow-up samples included obtaining information about the sources of exposure from air sample results, including isotopic composition (WSRC 1987).

In an interview with a former SRS employee who worked exclusively in internal dosimetry between 1986 and 2005, the former employee was asked about the source terms not including ^{241}Am in certain locations leading to some workers not enrolling in the correct routine bioassay programs. In the

response, the former employee stated that “we did not have this problem for special samples, where we always required specification of the source term by analysis of the contamination that triggered collection of the sample” (SC&A 2018). In another interview on a similar topic, the same former employee stated that starting in 1986, SRS analyzed all bioassay samples by isotopic analysis (ORAUT 2013, p. 3).

3.3 WHOLE-BODY AND CHEST COUNTS

3.3.1 Chest Counting

Chest counting was initially performed using a 5-in.-diameter thin NaI detector from 1966 to around 1971. In 1971, a phoswich detection system was implemented that used a NaI/CsI sandwiched detector. This system was modified to a dual phoswich system in 1972 that remained in use until around 1987 or 1988. The phoswich chest counter was capable of measuring ^{241}Am, ^{244}Cm, and ^{252}Cf, in addition to uranium and plutonium radioisotopes (ORAUT 2005). Two examples of combined WBC and chest count reports are provided in Attachment B, one from 1983 for a laboratory technician and one from 1998 for a construction laborer (SRS 1975–2018).

In the early 1980s, two germanium detector systems were in use by SRS for chest counting, each with a single lithium-drifted solid-state germanium detector. The germanium detectors required cooling with liquid nitrogen and provided a much higher gamma resolution. The 51-mm-diameter by 20-mm-thick germanium detectors were “low energy extended energy range” detectors. The phoswich detectors were kept as backup as late as 1990 (WSRC 1990a, p. 409; DuPont 1987, p. 129).

A new facility was placed in operation in April 1994 that included a graded liner in the shielding for reduced low-energy gamma background. A report from 1994 described the chest counter (WSRC 1993, p 16):

> *The counter consists of an array of six high-purity germanium detectors that are placed over the chest region during counting. The counting chamber is located in a 9' by 12' by 8' high room that is constructed of 12" thick pre-World War II battleship steel. A 1/4" thick lead lining covers the inside walls and ceiling of the chamber.*

In 1992 new limits based on lifetime committed dose instead of annual dose led to a significantly smaller amount of plutonium that had to be measured in a worker. Chest counting was no longer feasible for meeting plutonium requirements but was still used for ^{241}Am. The overall result was a reduced number of chest counts performed annually (Taylor et al. 1995, p. 69).

3.3.2 Whole-Body Counting

The Whole Body Counting Facility at SRS was used since 1960 to measure fission product activities directly in workers by counting them in a shielded room using a 4- by 8-in. NaI detector. The monitored individual sat in a reclining chair positioned in an arc around the detector; this was referred to as the “40-cm arc geometry” in bioassay monitoring reports. Bioassay via this method was not used for plutonium and americium due to their low-energy emissions. It is reported this detector was in service until September 1995. In the early 1970s, WBCs using an array of NaI detectors were implemented (Figure 3-1). WSRC-IM-90-139 (WSRC 2001) indicates five 4- by 4-in. detectors were used, while WSRC-RP-95-234 (Taylor et al. 1995) says that four 4- by 5-in. detectors were used. In addition, in the mid-1980s, WBCs using standup geometry and large (4-by-4-by-16-in. or 5-by-3-by-16 in.) NaI detectors were implemented. The counting room was an 8-ft by 10-ft room with 8-ft ceilings and was constructed of 12 in. of pre-WWI battleship steel and 0.25 in. of lead for shielding (WSRC 1990a, p. 417).

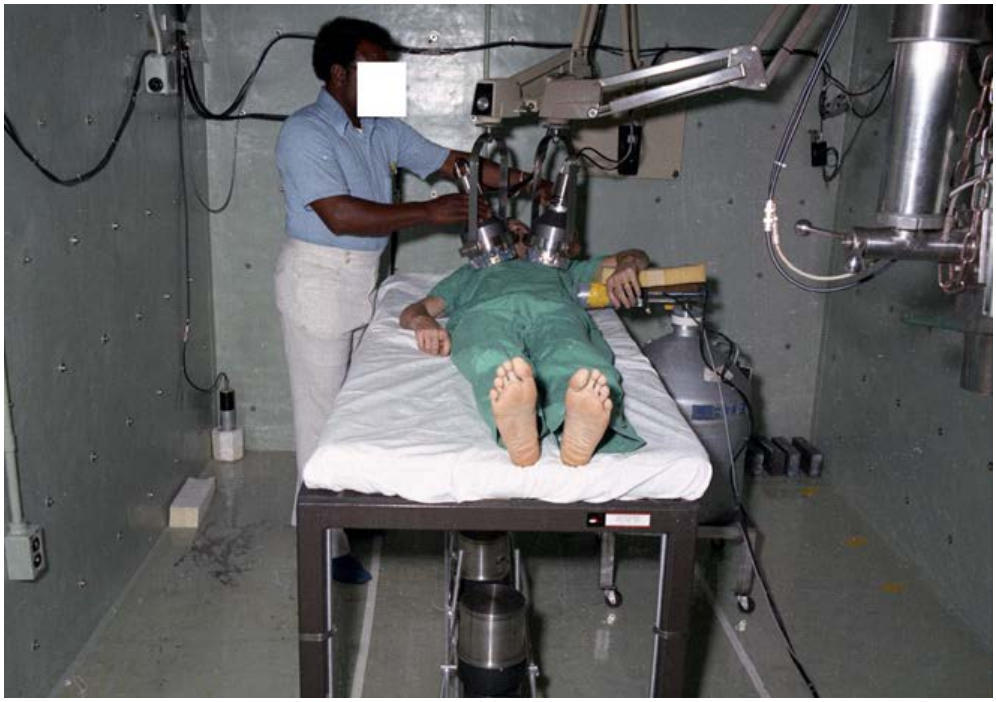

Figure 3-1. Whole-body counter used in the 1970s (Baker 2018)

In 1988, the site began using Fastscan whole-body counters. These were commercially available standup counters that used large NaI detectors and a shadow shield arrangement that allowed much shorter counting time, 2 to 4 minutes, while retaining the necessary sensitivity. Two Fastscan counters were mounted in trucks so that they could be moved as needed (WSRC 1990a, p. 410). A third was installed at the Whole Body Counting Facility. By 1992, five Fastscan units were in use. The number of WBCs went from approximately 5,000 in 1986 to over 25,000 in 1990, while the number of chest counts remained relatively even between 2,000 and 3,000 per year (McFee 1992).

Two examples of combined WBC and chest count reports are provided in Attachment B, one from 1983 for a laboratory technician and one from 1998 for a construction laborer (SRS 1975–2018).

Details on the equipment used and its detection efficiencies can be found in ORAUT-TKBS-0003 (ORAUT 2005).

3.3.3 Whole-Body Count and Chest Count Totals

In the 1970s through the 1980s the Health Physics (HP) Division issued a series of monthly reports listing the numbers of positive urine bioassay results, positive WBCs, positive chest counts, and total numbers of chest and WBCs (DuPont 1982a to 1982e, 1983a and 1983b, 1984a to 1984e, 1985a to 1985i; Wasser 1984; ORNL 1979). A positive result was when the radioactive material was detected above a given threshold. A complete series of these reports between January 1972 and December 1981 was reviewed. For 1972 and 1973, the WBCs and chest counts were combined as one value. Monthly totals for the number of counts and the number of individuals counted were reported. Between December 1973 and December 1974, the number of chest counts and individuals getting chest counts were reported separately. In January 1975, the WBC and chest counts were combined to one value again in the reports and remained combined through December 1981 for all monthly reports. The monthly totals from these reports were added to provide annual totals and are shown in Table 3-1 and plotted in Figure 3-2. Note that 1974 is a sum of reported WBCs solely.

Table 3-1. WBCs and chest counts, 1972 to 1985.

Year	WBCs and chest counts
1972	1,302
1973	1,115
1974	1,756
1975	2,143
1976	1,736
1977	1,974
1978	2,148
1979	2,042
1980	2,190
1981	2,763
1982	2,641
1984	2,704
1985	2,454[a]

a. For 1985, the year to date total from November was used. HP Division monthly reports for 1983 have not yet been acquired from SRS.

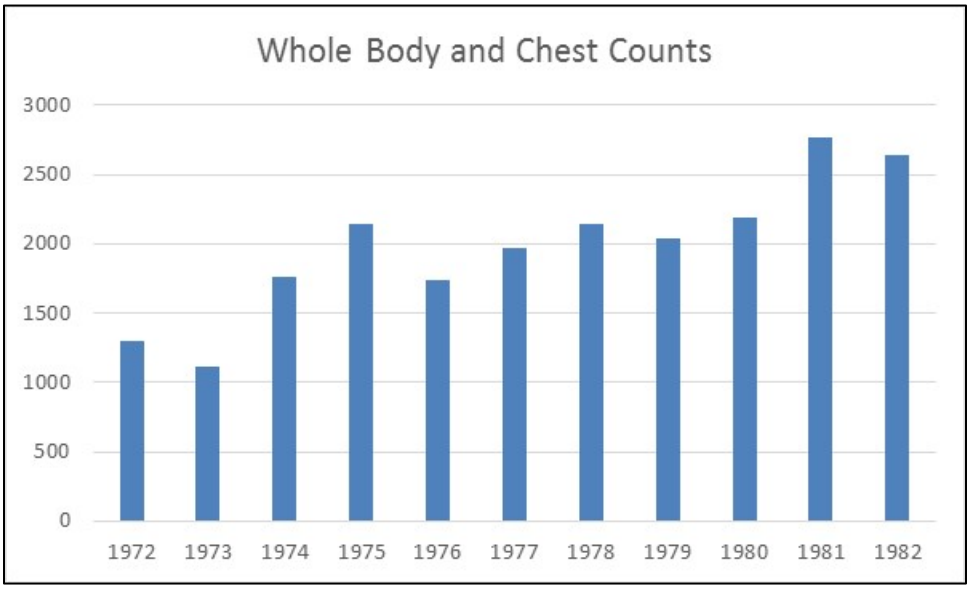

Figure 3-2. WBCs and chest counts, 1972 to 1982.

Totals for later years were found in a presentation by SRS given at an internal dosimetry users group meeting in 1992. The presentation included a graph of the annual number of WBCs and a graph of the total number of chest counts between 1986 and 1992. These graphs are copied as Figures 3-3 and 3-4 (McFee 1992).

For 1974, each HP Division monthly report listed the number of WBCs and the number of chest counts (Table 3-2 and Figure 3-4). The data showed that generally the number of chest counts was similar to the number of WBCs in the month but several months showed significant differences between the two monthly totals.

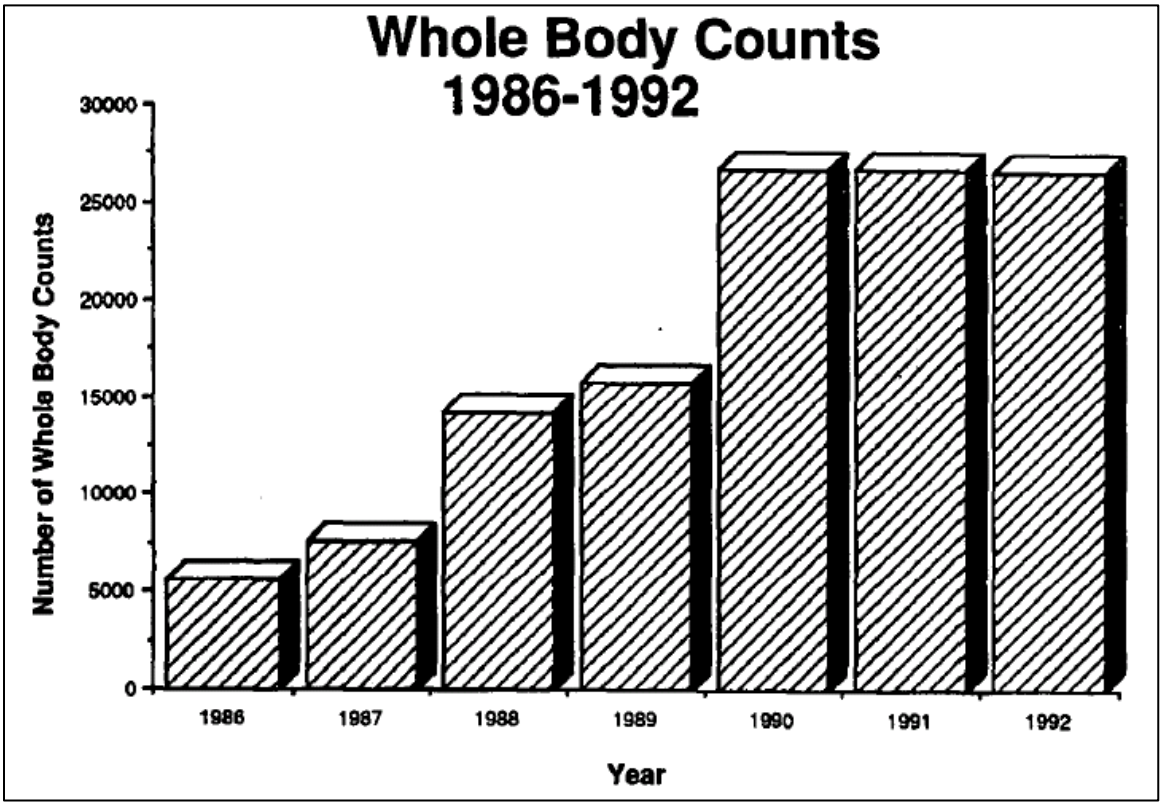

Figure 3-3. WBCs, 1986 to 1992.

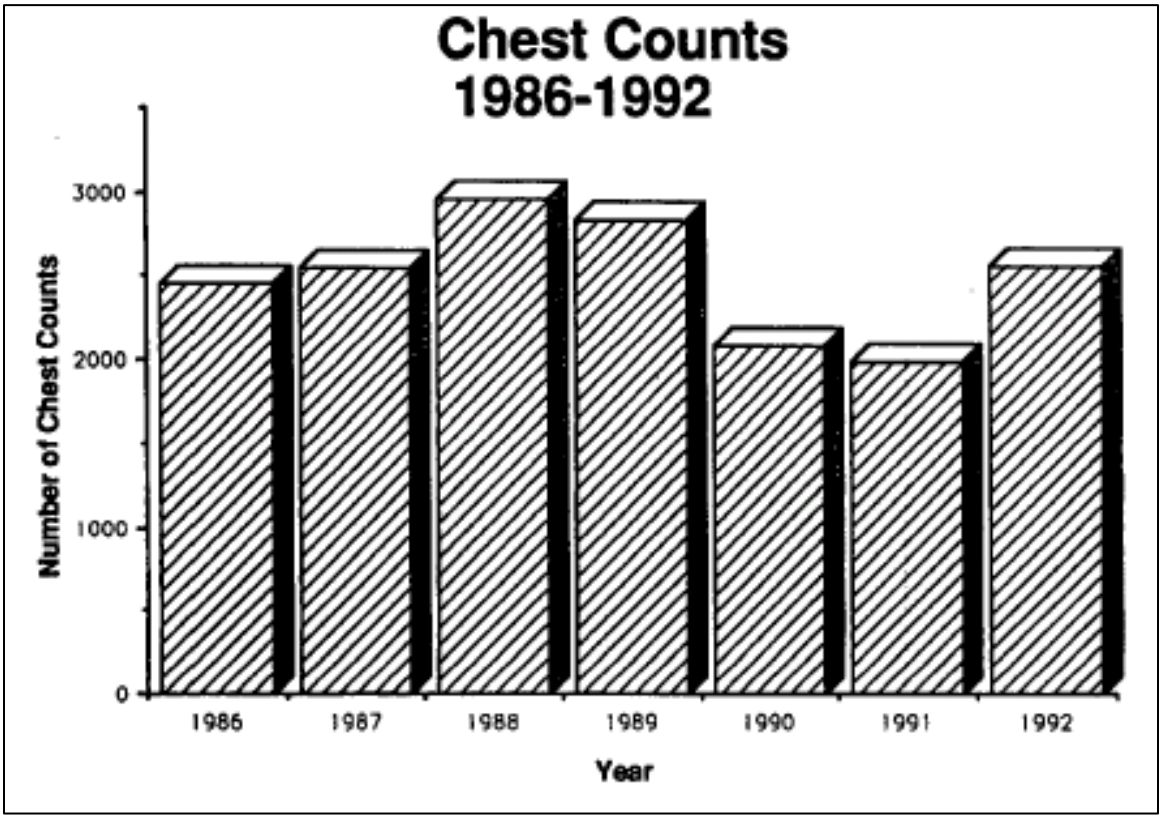

Figure 3-4. Chest counts, 1986 to 1992.

Table 3-2. WBCs and chest counts, 1974.

Month	WBCs	Chest counts
Jan	167	143
Feb	146	141
Mar	175	175
Apr	152	167
May	162	181
Jun	126	131
Jul	90	51
Aug	119	20
Sep	172	160
Oct	211	97
Nov	93	17
Dec	143	143

The 1974 reports also listed the numbers of workers who had only WBCs, only chest counts, and both (Table 3-3 and Figure 3-5). For the entire year, 24% of the workers had only WBCs, 8% had only chest counts, and 69% had both. Note that the month of November had 3 chest counts, 46 WBCs, and no combined chest and WBCs. Note, too, that in some months, the numbers of WBC and chest counts exceed the numbers of workers. This is due to some workers receiving multiple counts during the year.

Table 3-3. Workers with only WBCs, only chest counts, or both, 1974.

Month	WBC only	WBC and chest	Chest only
Jan	12	138	28
Feb	17	125	7
Mar	22	156	6
Apr	21	121	22
May	24	120	15
Jun	18	98	13
Jul	14	23	11
Aug	68	8	1
Sep	16	93	2
Oct	88	69	4
Nov	46	0	3
Dec	3	68	1

3.4 ROUTINE BIOASSAY SAMPLE FREQUENCY TABLES

The bioassay frequencies were established in procedure DPSOL 193-302, *Bioassay Control,* for the 1960s through 1988 (DuPont 1968a, 1970, 1971a, 1971b, 1976, 1978, 1989a). This procedure was replaced on March 9, 1988, by DPSOL 193-211, *Bioassay Control* (DuPont 1989b, p. 118).

In 1992, the procedures were revised into a new format and the bioassay frequency table was listed in 5Q1.1-506, *Routine In Vivo and In Vitro Bioassay Scheduling and Administration* (WSRC 1992a; 1995a, p. 9; 1996, p. 117). The bioassay frequency table was removed from the procedure as of Revision 10, effective March 2, 1999 (WSRC 1999b, p. 16).

Although the amount of detail on the frequency and types of Routine Bioassay Sampling Program samples varied between procedures, significantly larger portions of each procedure dealt with Special Bioassay Sampling Program samples, including specifics on their types and collection methods.

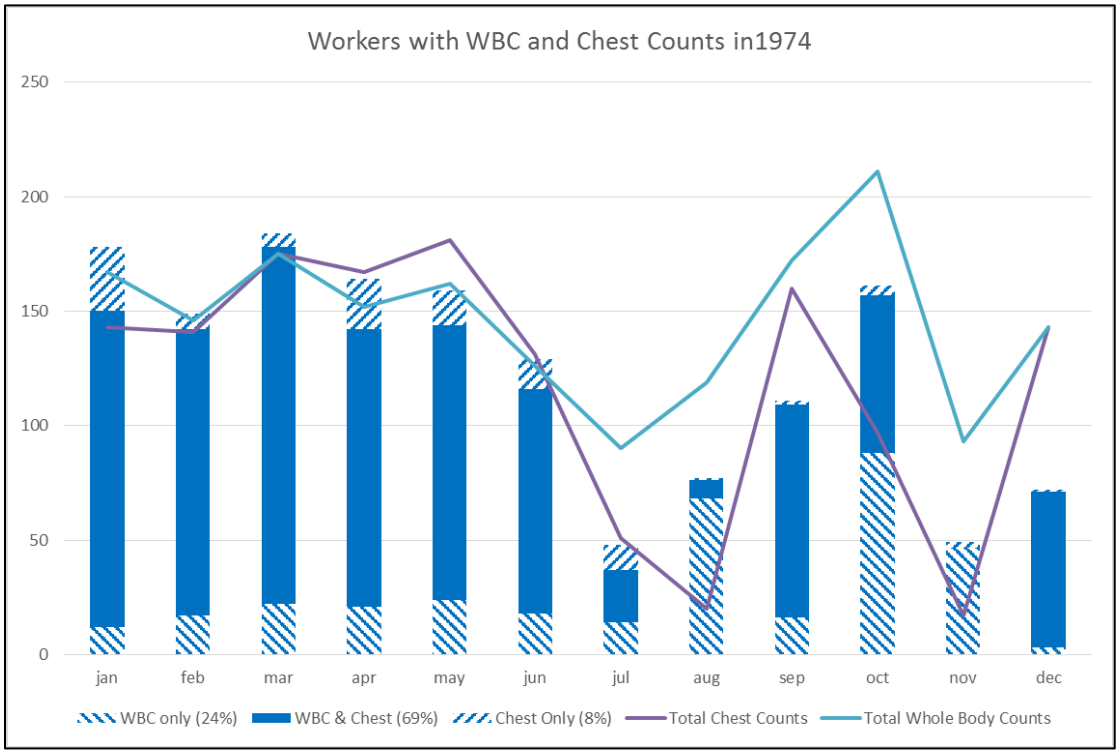

Figure 3-5. WBCs and chest counts, 1974.

The frequencies for bioassay sampling under the Routine Bioassay Sampling Program were based on locations and job descriptions under the DPSOL procedures. In all of the procedures that defined the bioassay requirements between 1971 and 1999, the frequencies were based on exposure potential. For example, in 1971 the frequency for a plutonium urine bioassay varied between once every 3 years for "minimum potential" personnel assigned to nonprocess sections and patrolmen to twice a year samples for laboratory personnel and personnel in process sections of selected buildings. In 1992, with the introduction of the 5Q1.1 procedures, all personnel were defined into three categories of potential risk. Category I personnel were to provide Am/Cm/Cf urine bioassay samples twice yearly for Building 773-A, Category II personnel were to provide Am/Cm/Cf urine bioassay samples once a year, and Category IIII personnel were not required to provide samples. With the revisions in March 1999, routine bioassay samples were required annually for all workers who worked in radiologically controlled areas (RCAs).

3.4.1 DPSOL 193-302, Bioassay Control, Revision 5, September 1, 1971

In DPSOL 193-302, the types and frequencies of routine bioassay sampling were shown in table form with the urine bioassay analytes shown for specific areas and tasks such as Operators or Reactor Department Personnel. The types of samples for urine bioassay listed in DPSOL 193-302, Revision 5 included tritium, plutonium, neptunium, fission products, EU, uranium, and combined americium/curium/californium (Am/Cm/Cf) shown as one type (DuPont 1971b).

For the chest count frequencies, the table included a column for EU and one column for all of plutonium, americium, curium, and californium, as one type. The frequencies were shown in samples per year for each type, typically one to four samples per year. The footnotes indicated certain jobs that required more frequent samples, such as a requirement for weekly uranium urine samples for A-Line operators.

Routine urine sampling for Am/Cm/Cf was indicated twice a year for analytical chemistry, high-level caves (HLC), building services, radiation control, maintenance and other selected personnel in

Building 773A, and sample aisle operators in Building 221-F. Sampling for Am/Cm/Cf was indicated annually for selected clerical, supervisory, and 100-Area personnel.

The table was under the heading "Routine Bioassay Sampling Frequencies (excluding Construction Division)." The routine requirements for the Construction Division personnel were listed in the text after the table and indicated a minimum of one sample per year for fission products and one sample every 3 years for plutonium with tritium at a frequency to be specified by DPSOP 40-1 or by Construction Job Plans and for other radionuclides as specified by Construction Job Plans. DPSOP 40-1 was the procedure *Radiation and Contamination Control*. A 1968 copy of the procedure described bioassay only in general terms, stating that urine samples would be routinely analyzed for employees in Regulated Zones and Radiation Danger Zones (DuPont 1968b, p. 107).

A WBC and chest count were required for new Construction Division employees who had previously "worked in Radiation Zones at another installation where radioactive materials were handled." A WBC or chest count was required for Construction Division employees whenever there was a confirmed uptake of radioactive material or when HP supervision considered it necessary after a contamination incident. These were also required for terminating employees with a previous WBC or chest count at the site.

The bioassay sampling frequency table from DPSOL 193-302, Revision 5, is provided as Table A1 (DuPont 1971a).

3.4.2 DPSOL 193-302, Bioassay Control, Revision 7, October 15, 1976

In Revision 7, the table had been reduced from 17 categories to 9. The types of analyses in the table for urine remained the same with the addition of a type "F⁻". Although it is not explained in the text of the procedure, this might indicate fluoride. Contemporary bioassay data show fluoride results alongside results for radioactive materials. The only entry in the F column is for selected personnel in Category C including Buildings 221-HB Line, 221-FB Line, JB-Line, 235-F, 772-F, and 773-A (DuPont 1976).

The footnotes described many of the details of the personnel to be sampled. For example, in both instances where the Am/Cm/Cf analysis was required, the indication was footnote "f," which stated, "Selected personnel in 221-F, 211-F, and 773-A sampled for Am-Cm once a year." This is consistent with Revision 5 for 221-F and 773-A but with annual sampling instead of twice yearly sampling for 773-A. Building 211-F was not listed in the earlier Revision 5.

The table was in the procedure Section 3.1.d, "Routine urine samples and chest count frequencies." The WBC requirements and chest count requirements were not listed separately in the procedure. The requirements changed to "in vivo" counts. Rather than the chest counting frequency columns, there were two columns for in vivo counts frequencies as annually or every 2 years for most categories and once every 3 years for Category A, defined as personnel with minimum potential for exposure. This in vivo requirement is applied to more categories and is more frequent than the chest count requirement in Revision 5.

The requirements for the Construction Division precede the table in the procedure. All Construction Division personnel were to provide annual routine samples for fission products and samples every 3 years for plutonium. All Construction Division personnel with a confirmed uptake were to have an in vivo count.

The bioassay sampling frequency table from DPSOL 193-302, Revision 7, is provided as Table A2 (DuPont 1976).

3.4.3 DPSOL 193-302T, Bioassay Control, Revision 0, February 25, 1985

DPSOL193-302T, *Bioassay Control* (DuPont 1985j), stated that it was a duplicate of Revision 8 of DPSOL193-302 and was to remain in effect until DPSOL 193-211 was issued. The T indicated "temporary."

In the bioassay frequency table, the categories were replaced with specific areas or buildings with a notation for "All assigned personnel", "Selected personnel", or personnel specified by job or activity. For each area or building, one or more "suggested code" is listed to indicate both the frequency and analysis type, such as "A" for three times a year plutonium, "B" for annual plutonium, etc. The areas and materials sampled appear to be consistent with DPSOL 193-302, Revision 7.

Routine annual samples for Am/Cm/Cf are listed for selected Analytical Chemistry Division (ACD), Separations Engineering Division (SED), Separations Chemistry Division (SCD), Nuclear Materials Division (NMD), HLC, radiation control, building services, and maintenance personnel in Building 773-A and selected personnel in Building 221-F. Routine twice-yearly sampling for Am/Cm/Cf is listed for selected personnel in Buildings 773-A and 221-F.

Chest and whole-body counting requirements were combined as "in vivo" counting. The frequencies for in vivo counts were linked to urinalysis frequencies for plutonium, EU, and Am/Cm/Cf in a table in the procedure, In Vivo Counting Frequency, reproduced below as Table 3-4.

Table 3-4. In vivo counting frequency reproduced from DPSOL 193-302T.[a]

Urine sampling nuclide	Urine sampling samples/year	Shift employees counts/year	Day employees counts/year
Pu	0.3	0.3	0
Pu	1-2	2	1
Pu	4	2	2
EU	4	2	1
EU	12	2	2
Am/Cm/Cf	1-2	2	1
Am/Cm/Cf	4	2	2

a. Source: DuPont (1985j).

The above urine and in vivo sampling frequencies (DuPont 1985j, p. 36) are under Section 1, Operations, and are followed by Section 2, Construction Division. Routine urine samples for Construction Division workers were required annually for "Fission products and/or Induced Activity" and every 3 years for plutonium. Tritium was required as indicated in DPSOP 40 and Construction Job Plans. All other radioisotopes for routine bioassay samples were specified by HP in Construction Job Plans.

No required frequencies for in vivo counts were listed in the procedure for Construction Division personnel.

The bioassay sampling frequency table and a table of codes used in it (Tables A and B from DPSOL 193-211) are provided as Table A-3.

3.4.4 DPSOL 193-211, Bioassay Control, Revision 0, March 9, 1989

The bioassay frequency table in DPSOL 193-211 maintained a similar design as DPSOL 193-302T with the requirements listed by building or area and, except for the Fission Product/Induced Activity codes, the table used an identical code list. The table lists the minimum urine sampling frequencies suggested for the work assignments listed. The Fission Product/Induced Activity codes were removed from both the code list and from the bioassay frequency table. All remaining analyses for

plutonium, EU, uranium, Am/Cm/Cf, neptunium, and strontium remained as before and were applied similarly (DuPont 1989b).

Under the section Routine Urine Sampling Frequencies was the statement, “Employees who change work assignments will have their bioassay frequency codes updated to match the work group they are joining.”

Am/Cm/Cf was only listed for Building 773-A. Routine annual samples were required for selected ACD, SED, SCD, NMD, HLC, radiation control, building services, and maintenance personnel. Routine samples were required twice yearly from selected personnel and had the added notation “Maximum potential.”

Routine monitoring for FP and IA radioisotopes was by whole-body counting. Section 2.0, In-Vivo Counting, contains a list of minimal detectable activities for the whole-body counting with the heading “Fastscan (Fission Products-Induced Activity).”

For routine in vivo count frequencies, a similar table was included as in the previous DPSOL 193-302T for Operations employees “with a potential for uptake of actinides.” The table indicated annual in vivo counts for all other operations employees providing plutonium, EU, or Am/Cm/Cf samples except those employees who provided routine plutonium samples once every 3 years. Routine whole-body counting is not required by the procedure, but it does include:

> *An in-vivo count shall be performed whenever an employee's bioassay sample (except tritium) indicates he has a confirmed uptake, or when he has been involved in a contamination incident and a count is considered necessary by Health Protection.*

Construction Division requirements were also separated in this procedure, and the requirements were in greater detail. The procedure stated that all Construction Division personnel were to provide a routine annual 1-L urine sample. It added requirements for an annual WBC for Construction Division workers with a potential exposure to FP and IA and a sample every 3 years for potential exposure to plutonium. Frequencies for tritium and other nuclides were covered by DPSOP 40 and Construction Job Plans.

The bioassay frequency table from DPSOP 193-211 is provided as Table A-4 (DuPont 1989b, p. 122).

3.4.5 Manual 5Q1.1, Procedure 506, In Vivo and In Vitro Bioassay Scheduling and Administration, Revision 0, December 16, 1992

The initial version of the bioassay scheduling procedure in the 5Q1.1 format eliminated separate requirements for Construction Division workers (WSRC 1992a). In the Scope section, it stated:

> *The guidance provided in this procedure applies to all Site personnel including WSRC, DOE, BSRI, Construction, WSI, and subcontractor personnel (permanent subcontractors such as Forestry, EBASCO, SREL, etc. as well as short-term, or temporary, subcontractors) and serves as a reference for Health Protection Department (HPD) personnel in prescribing and auditing Site bioassay programs.*

This procedure also introduced three categories of employees based on their risk of intake of radioactive materials. All requirements in the Minimum Bioassay Schedules for SRS Facilities table were listed by category:

- The Category I Bioassay Program was applied to personnel with a higher probability of intake—those who wore respiratory protection, or who routinely performed hands-on work in posted Contamination or Airborne Radioactivity Areas.

- The Category II Bioassay Program was for personnel with a lower probability of intake—those who did not routinely wear respiratory protection or work in posted Contamination or Airborne Radioactivity Areas, but who regularly entered RCAs where protective clothing was required.

- The Category III Bioassay Program was for those personnel with essentially no risk of intake—those who were not required to routinely enter RCAs where protective clothing was required, and who were not performing tasks requiring work in Contamination or Airborne Radioactivity Areas.

A fourth group, nonradiation workers, were those employees who worked onsite but did not enter RCAs. If any nonradiation workers needed to enter RCAs, they were required to have a WBC and to follow the site visitor requirements.

The procedure also defined some workers as "Roving Employees," those whose job assignments required them to enter RCAs in different facilities across the site during the course of their regular work. The definition included site support personnel and subcontracted construction workers. The guidance required each worker to be categorized as I, II, or III, depending on the facilities where the majority of their time was spent. It warned against automatically selecting the most conservative category because this would "oversample the workforce, produce high bioassay sample processing costs, and result in unnecessary delays in analyzing valid sample requests."

The Routine Bioassay Program Assignment section stated:

> *Personnel who wear respiratory protection or who work in posted Contamination or Airborne Radioactivity Areas must be sampled for the nuclide to which they are potentially exposed, via either the routine sampling program or non-routine, job-specific sampling program.*

The Minimum Bioassay Schedules for SRS Facilities table lists each facility, then each work area within the facility, then the bioassay types and frequencies for Category I, Category II, and (for some locations) Category III workers. For those areas where Category III workers are listed, the requirements include annual WBCs and for some of those areas, monthly tritium sampling.

Although the codes in the table were changed from those in DPSOL 193-211, the urine bioassay types were the same: plutonium, strontium, tritium, uranium, EU, and Am/Cm/Cf.

In this procedure, the routine WBC frequencies and chest count frequencies were listed separately. Routine annual chest counts were required for Category I workers assigned to facilities that handle actinides. Chest counts were also required for a randomly selected percentage of Category II workers at actinide facilities, although the percentage amount is not stated.

The Minimum Bioassay Schedules for SRS Facilities table contains an entry for roving employees subdivided by those working in RCAs excluding uranium handling facilities and those working in RCAs including uranium handling facilities. For both, Category I workers were required to have annual chest counts.

The area names are not identical to the areas in the bioassay frequency table in DPSOL 193-211 but, where the areas can be matched together, there were changes in the routine bioassay types. Annual strontium sampling was added for 221-F Canyon, 221-F A-Line, and certain areas in Buildings 773-A,

772-F, and 241-84H. The 400-Areas, C-Area, K-Area, L-Area, and P-Area no longer required plutonium sampling.

Routine bioassay samples twice a year for Am/Cm/Cf are listed for the Savannah River Technology Center (SRTC) Building 773-A Chemistry Technology Section, Analytical Development Section (ADS), and high-level cave Category I workers and for Buildings 773-A, 776-A Maintenance and Electrical and Instrumentation (E&I) Category I workers. Routine bioassay samples annually for Am/Cm/Cf are listed for Buildings 773-A, 776-A Maintenance/E&I Category II workers. Building 776-A, the Liquid Waste Handling Facility (WSRC 1990a, p. 349), is not listed in previous bioassay frequency tables.

Table A-5, Minimum Bioassay Schedules for SRS Facilities, from 5Q1.1-506, Revision 0, is provided as Table A-5 (WSRC 1992a).

3.4.6 Manual 5Q1.1, Procedure 506, In Vivo and In Vitro Bioassay Scheduling and Administration, Revision 5, April 1, 1996

The differences in the Minimum Bioassay Schedules for SRS Facilities tables between Revisions 0 and 5 were minor. Some facilities were no longer listed separately, such as the C-, K-, L-, and P-Areas, and a new area was added, Building 221-S/512-S (WSRC 1996). Building 221-S is the Vitrification Building within the Defense Waste Processing Facility and houses the process equipment used to vitrify high-level radioactive waste. Building 512-S is part of the transfer system between the tank farm and Building 221-S (WSRC 2015).

No changes were made in the types of urine bioassay, although some plutonium and tritium requirements were reduced in frequency. Two work areas in Building 221-F, the New Special Recovery Area and the Plutonium Storage Facility, dropped an annual requirement for a chest count.

This revision listed a new worker group for bioassay purposes. The Category IV Bioassay Program was for those workers who infrequently entered Radiological Buffer Areas (RBAs) for administrative or oversight purposes. It stated that “Category IV employees are not required to submit any bioassay samples nor have in-vivo counts.” There are no entries in the Minimum Bioassay Schedules for SRS Facilities table for Category IV workers.

This procedure contained a job-specific sampling section that required bioassay samples for the radionuclides of concern for work under RWPs or Standing RWPs that required the use of respiratory protection. The requirement was met by either being on a routine bioassay program as indicated on the worker’s Radiation Qualification Badge (RQB) or by providing a sample following the work activity.

3.4.7 Manual 5Q1.1, Procedure 506, In Vivo and In Vitro Bioassay Scheduling and Administration, Revision 10, March 2, 1999

As a result of the response to the internal FEB audit, the OEI report, and the Notice of Violation issued by DOE under 10 CFR Part 820, major changes were made to the site bioassay programs and implemented in March 1999, including the method of sample collection and schedule for annual samples. Revision 10 of 5Q1.1-506 (WSRC 1999b) included the note:

> *Effective 3/1/99, a new routine bioassay program was implemented sitewide. This program requires workers to bring urine samples to 735-28 when their annual WBC is due. To transition into this program and randomize the population of affected workers, all WBC expiration dates have been set to the worker's birth month. During this transition, the time between WBCs may exceed 12 months (up to 23 months). After this transition period, WBCs will resume on an annual basis.*

Categories for workers were removed from the procedure. The selection of workers to participate in the routine bioassay program was changed from a description of their likelihood of exposure to those workers having Radiological Worker I or Radiological Worker II training. Workers without such training were not on a routine bioassay program.

Annual WBCs were required for all workers with a Radiological Worker I or II qualification. Routine chest counts were required for workers who worked in SRTC, FB-Line, HB-Line, 772-F, or 772-IF and wore respiratory protection.

All routine urine bioassay samples with the exception of tritium were to be collected annually in conjunction with the WBC. Tritium samples were to be collected every 30 days. During the year, workers who entered areas under a RWP that required bioassay types not indicated on their RQB would have their badges punched to indicate the analysis needed. The badge was presented with the sample and a new badge issued showing the expiration date of the WBC and, as applicable, the chest count.

The bioassay frequencies table was no longer included in 5Q1.1-506. Radiological Workers I and II were to provide bioassay samples during the year as specified on the RWPs they worked under with the types tracked by the holes punched into their RQBs, which were turned in with their annual samples.

3.4.8 Specification of Urine Bioassay Requirements on Radiological Work Permits

The sitewide characterization effort in 1999 resulted in the memorandum, "Specification of Urine Bioassay Requirements on Radiological Work Permits" (Farrell and Findley 1999). It listed default bioassay requirements by each of the eight operational areas:

- Nuclear Materials Stabilization and Storage Division,
- High Level Waste Management Division,
- Solid Waste Division,
- Spent Fuels Storage Division,
- Facilities Decommissioning Division,
- Defense Programs Division,
- Savannah River Technology Center, and
- Central Laboratory Facility (CLAB).

These requirements were taken from characterization reports prepared by each division. It summarized each radioisotope that contributed 10% or more of the internal dose through inhalation for each location or waste stream. For the CLAB, 10 waste streams were defined, each with its own specified radionuclides defined by the origin of the wastes from Building 772-F or 772-1F laboratory modules.

The list of radionuclides in the procedure for urine bioassay sample analysis was:

- Pu, plutonium (^{238}Pu and ^{239}Pu),
- U, uranium (^{234}U, ^{235}U, and ^{238}U),
- Np, neptunium (^{237}Np),
- Am, americium/curium/californium (^{241}Am, ^{244}Cm, ^{252}Cf),
- Sr, strontium (S-90), and
- H, hydrogen (H-3).

The list had a note below saying “The Am bioassay sampling program also provides analysis for Curium and Californium.”

With the exception of tritium and uranium, routine urine bioassay for the listed radionuclides was to be specified for work under all RWPs where respiratory protection was required. For uranium, routine urine bioassay sampling was to be specified on RWPs when uranium contamination was present in M-Area and H-Area and for other locations when RWPs required respiratory protection. Routine urine bioassays for tritium were required for K-, L-, C-, P-, R-, and M-Areas, the Receiving Basin for Offsite Fuel (RBOF), CLAB Waste Stream J for work under RWPs in High Contamination Areas or Airborne Contamination Areas established due to the presence of tritium.

A table summarizing the locations, the radioisotopes that contribute more than 10% of the internal dose, and their relative dose fractions from Farrell and Findley (1999) is provided as Table A-7.

A comparison of the source terms data in Farrell and Findley (1999) and the bioassay frequency table from 5Q1.1-506 is provided in Table A-8. This table selects all locations and waste streams from Farrell and Findley (1999) and their radioisotopes that contribute 10% or more of the dose along with comparable locations from the 1996 procedure 5Q1.1-506, Revision 5, and the recommended analyses.

Two locations in Farrell and Findley (1999) indicate Am/Cm/Cf only and no other radioisotopes: F-Wing Boot Waste Stream and Californium Waste Stream (773-A F-Wing californium facilities). Both are from 773-A, which had previously recommended routine bioassay samples for Am/Cm/Cf, strontium, and plutonium.

Six locations have Am/Cm/Cf bioassay sample requirements that did not have them in the matched areas in 5Q1.1-506, Revision 5:

1. Multi-Purpose Processing Facility (MPPF),
2. Building 221-H/Outside Facilities,
3. F- & H-Area Tanks,
4. RBOF, K- and L-Areas,
5. C-, P-, and R- Areas, and
6. Casks Waste Stream [high-level waste (HLW) sludge].

These six locations also listed plutonium as a bioassay requirement and had listed plutonium previously. The relative dose contribution from ^{241}Am at the MPPF was 99%. At the 221-H/Outside facilities, 8% was from ^{241}Am with 12% from ^{244}Cm. The remaining locations did not have the relative dose contributions provided in Farrell and Findley (1999).

With the exception of the MPPF (processed americium), the Californium Waste Stream (from the former californium processing facilities in Building 773-A), and the F-Wing Waste Stream (from the air handling system in the F-Wing of 773-A), for the majority of locations the ^{241}Am was present as a decay product of ^{241}Pu. The activity of the americium was a calculable fraction of the plutonium activity based on the age of the material since separation. If the time since separation is not known, ratios can be estimated based on the age of the plutonium.

In each of the above locations showing americium as a new routine bioassay requirement, plutonium was listed in this report and previously listed in the bioassay frequency tables as a routine bioassay requirement.

Four CLAB Streams listed Am/Cm/Cf, which was not recommended for Buildings 772-F or for 772-1F locations previously:

1. CLAB Waste Stream E (Building 772-F laboratory modules L131, L138, L139, L146, L147, L154, L155, and L171),

2. CLAB Waste Stream G (772-F/772-4F filter room),

3. CLAB Waste Stream H (Building 772-F laboratory modules L142, L143, L146, L147, L174, L175, and L183), and

4. CLAB Waste Stream J [Building 772-F laboratory modules waste disposed of in the 772-F liquid scintillation counting (LSC) drum].

Each of these waste streams also listed plutonium. Plutonium was a recommended routine bioassay sample for both 772-F and 772-1F previously. The relative dose contributions from ^{241}Am for these four waste streams range from 67% to 89%.

Note that Building 773-A was the Main Technical Laboratory Building and Building 772-F was the CLAB. These laboratories received samples from various processes and wastes across the site. The samples varied greatly in concentrations and relative activity ratios.

Other differences between the required radioisotopes in Farrell and Findley (1999) and those recommended in 5Q1.1-506, Revision 5, were the addition of tritium for RBOF, K- and L-Areas, the addition of strontium and plutonium for RBOF, K- and L-Areas, and the addition of tritium for CLAB Waste Stream I and CLAB Waste Stream J.

4.0 AMERICIUM, CURIUM, AND CALIFORNIUM SOURCE TERMS FROM BIOASSAY FREQUENCY TABLES

The radioisotopes listed in the bioassay frequency tables show the expected dominant radioisotopes for SRS facilities in relation to internal dose. The bioassay frequency tables do not provide information about volumes, forms of the material, accessibility by workers, or time frames narrower than the procedure revisions.

With the sitewide characterization effort in 1999, the application of the Am/Cm/Cf routine bioassay sample in 10 new areas was the largest source term change identified, although it was added in two cases not as the dominant radioisotope but due to the new rule requiring the inclusion of all radionuclides that provide 10% or more of the internal dose. One location, the MPPF, was listed for the first time as a distinct location from the building that housed it, Building 221-F.

4.1 URINE BIOASSAY

The single Am/Cm/Cf bioassay analysis was used to measure ^{241}Am, ^{244}Cm, and ^{252}Cf. A source with any one of those isotopes or with any combination of those isotopes would be measured by Am/Cm/Cf urine bioassay sampling.

Only one location in Farrell and Findley (1999) was shown to have ^{252}Cf contribute more than 10% of the dose, and that was the Californium Waste Stream in 773-A. Building 773-A has listed Am/Cm/Cf bioassay in the bioassay frequency tables consistently since 1971.

Between 1971 and 1999, the locations for recommended Am/Cm/Cf for routine bioassays and for use on RWPs are shown in Table 4-1. With the sitewide characterization in 1999, 10 new locations and waste streams were added outside of Building 773-A for routine Am/Cm/Cf bioassays. The 10 locations are listed in Table 4-1 as “1999–not 773-A.” The report included the relative dose contributions from the selected radionuclides for 7 of the 10 locations.

Table 4-1. Areas with recommended routine Am/Cm/Cf bioassay sampling.[a]

Year	Buildings
1971	773-A, 221-F
1976	773-A, 221-F, 211-F
1985	773-A, 221-F
1989	773-A
1992	773-A, 776-A
1996	773-A, 776-A
1999–773-A	776-D Waste Stream (773-A 776-5A), B-Process Waste Stream (773-A), F-Wing Boot Waste Stream, ADS-1 Waste Stream (Analytical Development System Laboratories), Non-Canyon Waste Stream (773-A non-CHTS, ADS laboratories), Californium Waste Stream (773-A F Wing Cf facilities)
1999–not 773-A	MPPF, 221-H/Outside Facilities, F- & H-Area Tanks, RBOF, K- and L-Areas, C-, P-, and R-Areas, Casks Waste Stream (HLW sludge), CLAB Waste Stream E, CLAB Waste Stream G , CLAB Waste Stream H, and CLAB Waste Stream J

a. ADS = Analytical Development Section; CHTS = Chemical and Hydrogen Technology Section.

The B-Process Waste Stream (773-A), and F-Wing Boot Waste Stream are compared to Building 773-A, which has previously shown Am/Cm/Cf requirements.

The MPPF was not listed separately in previous bioassay frequency tables. The MPPF is wholly within Building 221-F, for which the tables indicated routine Am/Cm/Cf bioassays for selected personnel up to March 1989 when DPSOL 193-211 came into effect. No routine urine bioassay requirement for Am/Cm/Cf was listed for Building 221-F or the MPPF from 1989 until the source term analysis report in 1999. Note, however, that routine plutonium urine samples were listed for select personnel in Building 221-F in each of the bioassay frequency tables between 1971 and 1999, and annual chest counts were required for personnel in 221-F as described below. A further description of MPPF bioassay is provided in Section 5.4.

Data collected for ORAUT-OTIB-0081, *Internal Coworker Dosimetry Data for the Savannah River Site* (ORAUT 2016), for the years between 1966 and 1987 include routine urine Am/Cm/Cf results. That data can be found in DuPont (1956–1961, 1961–1969, 1963–1970, 1968–1972, 1969, 1969–1973, 1970–1973, 1973–1978, 1973–1979, 1978–1983, 1979–1980, 1980–1981a, 1980–1981b, 1981–1986, 1986–1989). A total of 10,469 routine urine sample results for Am/Cm/Cf from the coworker study were reviewed and 598 of those or 6% were for Area F.

SRS calculated committed effective dose equivalent and maintained a database for those workers who received a dose greater than 10 mrem (WSRC 2008, p. 97; ORAUT 2004, 2017b). Figure 5-1 lists all Am/Cm/Cf doses and the number of workers who were confirmed to have received an exposure greater than 10 mrem for the years 1960 through 2005.

The RBOF and the K- and L-Reactor areas under the Spent Fuel Storage Division listed americium with the 1999 characterization. The K and L process water and disassembly basin water waste streams were isotopically analyzed along with the RBOF and found to be similar in composition. Americium was present as a plutonium decay product due to the age of the stored fuel. The requirement for routine plutonium and Am/Cm/Cf urine bioassays was applied for those areas when respirators were required due to the presence of particulate materials, such as for disassembly basin workers.

4.2 CHEST COUNTS

Americium exposures, along with curium, californium, and plutonium, were also monitored through chest counts. Table 4-2 summarizes the locations and worker categories with annual or more frequent chest count requirements in the Bioassay Control procedures. There were separate

bioassay requirements in the procedures for operations and construction personnel until the 1992 version of 5Q1.1, Procedure 506, *Routine In Vivo and In Vitro Scheduling and Administration* (WSRC 1992a). After 1992, the procedures explicitly state that the requirements apply to all personnel.

Table 4-2. Summary of annual chest count requirements from the bioassay control procedures and tables.

Year	Operations workers	Construction workers
1971	Workers in specified jobs in 221-H, 221-F, 772-F, 221-H B-Line, 221-F B-Line, JB-Line, 235-F, 773-A	After event or confirmed uptake (special bioassay) or when terminating if worker had previous WBC or chest count
1976	Workers in specified jobs in 221-FH, 241-FH, 211-FH, 723-F, A-Line, 643-G, 244-H, 772-F, 235-F, 200-FH, 773-A, 100 Areas, 221-HB Line, 221-FB Line, JB-Line, 235-F, 322-M, 772-F, 773-A, 321-M, and certain Reactor Department personnel	After confirmed uptake (special bioassay) or when terminating if worker had worked in areas where radioactive materials were present
1985	All workers with annual routine Pu, EU, or Am/Cm/Cf urine bioassay requirements	No requirement listed
1989	All workers with annual routine Pu, EU, or Am/Cm/Cf urine bioassay requirements	"As specified by area Health Protection in Construction Job Plan."
1992	Category I workers and random Category II workers assigned to facilities with actinides; all Category I Roving Employees	Same requirements for all workers
1996	Category I workers and random Category II workers assigned to facilities with actinides; all Category I Roving Employees	Same requirements for all workers
1999	Workers who wear respirators in SRTC, FB Line, HB Line, 772-F or 772-1F	Same requirements for all workers

In the 1999 characterization, the MPPF waste stream was listed with ^{241}Am providing 99% of the dose fraction. The MPPF was not listed separately in previous bioassay frequency tables and is wholly within Building 221-F, for which the tables indicated annual chest counts during this entire period. Note that plutonium urine bioassay was listed for Building 221-F, and chest counts that were initiated by positive plutonium urine bioassay would distinguish and quantify any ^{241}Am uptakes.

5.0 DOSE RECONSTRUCTION CONSIDERATIONS

Routine bioassay sampling provides greater confidence in the controls and monitoring programs in place, but it was not the basis for assignment of dose at SRS nor is it the only source of dose information available for dose reconstruction. The Routine Bioassay Sampling Program was used to monitor the controls in place. The Special Bioassay Sampling Program was used to evaluate and assign worker internal exposure for any suspected uptakes of radionuclides. Information from SRS for claimants includes all bioassay results from both sampling programs.

The sitewide characterization in 1999 identified three places where americium was present and plutonium contributed less than 10% of the dose. All had routine monitoring requirements between 1971 and 1999 that would have identified uptakes of americium. The B-Process Waste Stream in 773-A, and the F-Wing Boot Waste Stream had listed requirements for Am/Cm/Cf urine bioassay and annual chest counts. Building 221-F had requirements for Am/Cm/Cf urine bioassay until 1989 and had requirements for annual chest counts through 1999.

5.1 AIR SAMPLING

SRS used radioactivity concentration guides (RCGs) in the 1970s to determine when respiratory protection was required. The Guide for americium was 6×10^{-12} µCi/cm^3. For plutonium, it was

2×10^{12} µCi/cm^3, and for unidentified alpha activity it was 2×10^{-12} µCi/cm^3. All other Guides in use were equal to or lower than americium (DuPont 1974).

By the 1990s, the site used one-tenth of the derived air concentrations (DACs) as the threshold for determining an airborne radioactivity area. One-tenth of the DAC for americium was 2×10^{-13} µCi/cm^3, for plutonium, it was 2×10^{-13} µCi/cm^3, and for unidentified alpha, it was 2×10^{13} µCi/cm^3. All other DACs in use were equal to or lower than americium (WSRC 1990b).

Because ^{241}Am is a decay product of ^{241}Pu, both were generally found in the same source term with the ratio of americium to plutonium a function of the age of the material. For both RCGs and DACs, plutonium was the controlling and limiting radionuclide.

Any indication of failure of the controls such as a break in containment, skin contamination, or high air sample readings would lead to the Special Bioassay Sampling Program with followup bioassay sampling based on the isotopes found to be present, identified by methods including isotopic analysis of the air samples.

5.2 CHEST COUNTS

Routine chest counts were used to monitor exposures to Am/Cm/Cf providing additional data beyond the routine urine bioassay samples. These routine chest counts were required from a greater population than that working in the areas listed for Am/Cm/Cf in the bioassay frequency tables. Chest count data are routinely included in claimant exposure records from SRS. Totals are listed in Section 3.3.3 above.

A review of a dataset created for dose reconstruction and used as source data for the SRS coworker study found 1,039 records showing ^{241}Am results obtained by chest counts for 469 individual workers. These were from a population of 28,000 total records for 4,920 individuals. Of these, 365 were associated with Building 221-F. The dataset was created from claimant records provided by SRS. The 469 individual workers included both construction and non-construction workers, as indicated by their job titles. Two examples of combined WBC and chest count reports are provided in Attachment B, one from 1983 for a laboratory technician (SRS 1995) and one from 1998 for a construction laborer (SRS 1975–2018).

5.3 ROUTINE URINE BIOASSAY

A series of annual reports titled *Savannah River Plant History Plantwide Activities* contained annual totals of urine samples received by the Bioassay Laboratory between 1972 and 1987 (DuPont 1983c, p. 282; 1987; 1988). Totals were provided for several analytes including Am/Cm/Cf. The 1990 Health Protection Annual Report listed the number of samples processed through the Bioassay Laboratory for the years 1982 through 1990 (WSRC 1992b).

A review of the Health Protection Radiation Exposure Database (HPRED) provided annual totals of urine bioassay samples and Am/Cm/Cf samples between 1991 and 2005.

The HPRED database also included indicators for routine and special samples. For americium, 91% of the samples were flagged as routine and 9% were flagged as special. Samples flagged as baseline, termination, and routine followup were included in the routine totals.

The data for the SRS coworker study agrees closely with the totals for the years 1972 to 1988. Annual totals from the *Savannah River Plant History Plantwide Activities* reports, the HPRED database, and the SRS coworker study are shown in Table 5-1. Figure 5-1 shows the overall trend in americium samples from 1971 through 2005.

Table 5-1. Annual totals for urine bioassay samples, 1972 to 2005.

Year	Am/Cm/Cf	Routine	Special
1968	480	NA	NA
1969	1,194	NA	NA
1970	2,730	NA	NA
1971	2,016	NA	NA
1972	1,820	NA	NA
1973	1,332	NA	NA
1974	1,274	NA	NA
1975	891	NA	NA
1976	761	NA	NA
1977	593	NA	NA
1978	446	NA	NA
1979	664	NA	NA
1980	387	NA	NA
1981	344	NA	NA
1982	375	NA	NA
1983	324	NA	NA
1984	334	NA	NA
1985	244	NA	NA
1986	540	NA	NA
1987	420	NA	NA
1988	389	NA	NA
1989	489	NA	NA
1990	888	NA	NA
1991	833	720	113
1992	617	568	49
1993	318	230	88
1994	301	249	52
1995	390	313	77
1996	412	269	143
1997	689	476	213
1998	1,200	664	536
1999	1,827	1,601	226
2000	2,441	2,296	145
2001	2,622	2,449	173
2002	2,612	2,535	77
2003	2,798	2,760	38
2004	2,532	2,484	48
2005	2,350	2,311	39

The data collected for the SRS coworker study include in most cases the area associated with the sample. For the routine urine Americium results, 36% listed the area as “773”, 8% were for area “A”, and 6% were for area “F”. Over a third, 39%, listed the area as “none”.

5.4 ROUTINE BIOASSAY NOT REQUIRED IN BIOASSAY PROCEDURES

Although the MPPF was not listed in the bioassay procedures before 1999 and Building 221-F did not have a requirement for Am/Cm/Cf bioassay samples between 1989 and 1999, routine urine bioassay sampling for americium was required on job-specific RWPs during that time.

The MPPF was inactive for much of the 1990s. In 1995, DOE made a commitment to process an inventory of americium and curium solution stored in F-Canyon using vitrification. SRS planned a demonstration project for the vitrification program that included operations in the MPPF (WSRC

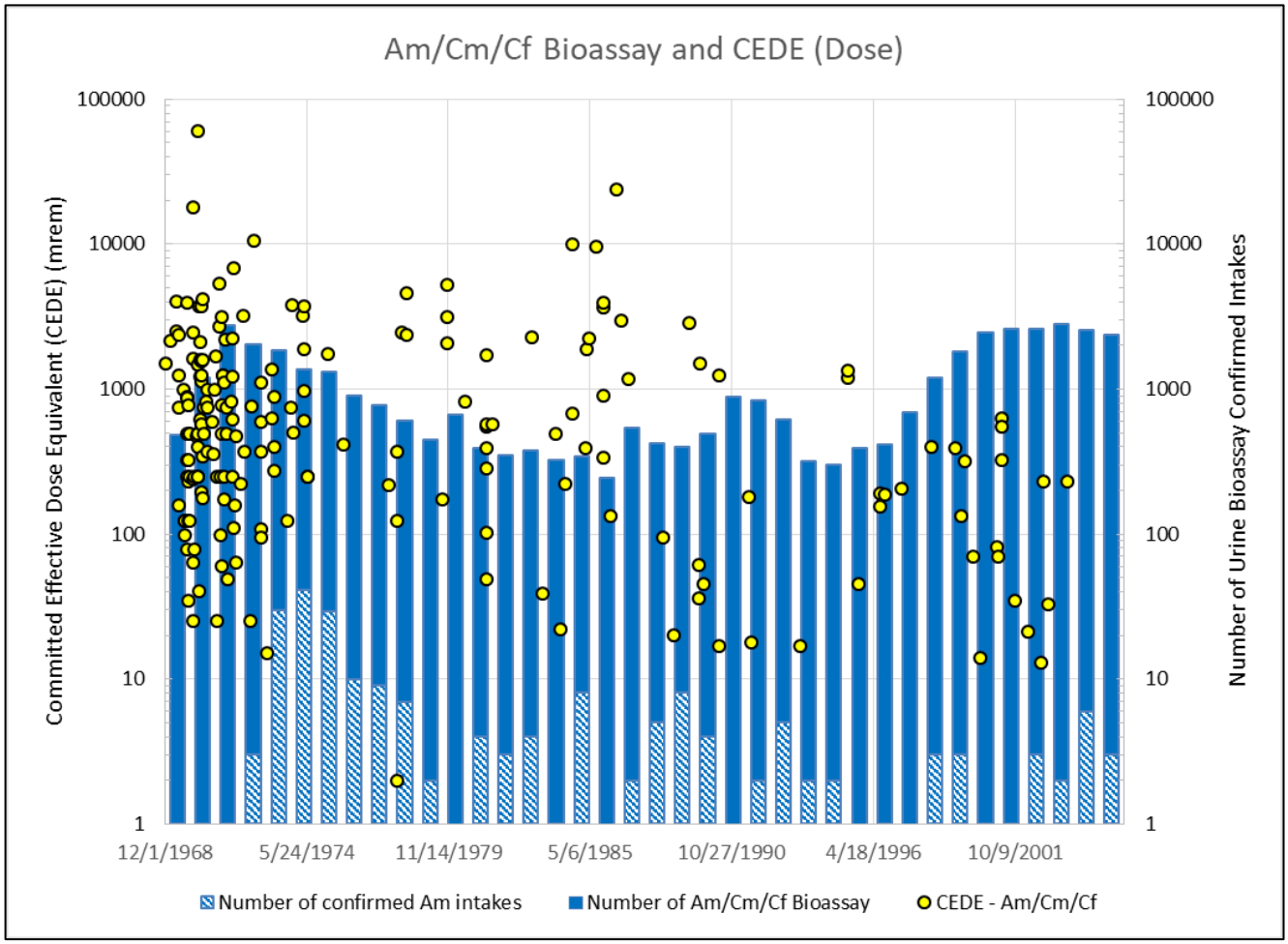

Figure 5-1. Americium samples, 1972 to 2005 combined with data from the SRS Intake Database (ORAUT 2004, 2017b).

1995b, p. 24). "Modification to the MPPF required to support this project include dismantling and removal (D&R) of existing equipment to provide space for new systems/equipment" (WSRC 1997, p. 6). The processing and vitrification of the americium/curium solution for this demonstration project did not occur in the 1990s and was scheduled to happen in 2004 and 2005 (DOE 2000, p. 73).

Eight RWPs and their sign-in sheets were located that covered work in the MPPF in 1996 and 1998. Three also included Post-Job As Low As is Reasonably Achievable (ALARA) Review forms (WSRC 1996–1998). These RWPs and their dates, job descriptions, and protective measures are listed in Table 5-2. A total of 34 workers signed in to one or more of these RWPs.

The box for "Job-Specific RWP" was checked on each RWP and only plutonium, strontium, and americium were checked under the Job Specific Bioassay Requirements. Additional requirements were written on the RWP under Special Precautions, including in each a requirement that "Workplace air sampling will be conducted." The RWPs listed one or more tasks to accomplish the job and listed protective clothing and respirator requirements for each task.

The sign-in sheets associated with the RWPs included the worker's printed name, signature, social security number, date and time of entry, and the date and time of exit. Some of the later RWPs used only the last four digits of the social security number.

Table 5-2. MPPF RWPs (WSRC 1996–1998).

RWP number	Issue date	Job description	Job-specific bioassay	Respirator requirement	Workplace air sampling?	Number of workers	Earliest sign-in date	Latest sign-in date
96-FC-200 Rev 0	06/04/1996	Construction to D&R Transite ceiling panels in MPPF first level	Pu, Sr, Am	Full face or none based on task	Yes	6	06/10/1996	04/06/1998
96-FC-202 Rev 0	07/10/1996	Install oil filled shielding window in Cell #8 in MPPF	Pu, Sr, Am	Full face or none based on task	Yes	7	07/15/1996	07/15/1996
96-FC-202 Rev 1	09/04/1996	Prepare window frame to install new window	Pu, Sr, Am	Fresh air hood or none based on task	Yes	7	09/05/1996	10/08/1996
96-FC-202 Rev 2	09/24/1996	Prepare window frame to install new window	Pu, Sr, Am	Fresh air hood or none based on task	Yes	9	06/11/1996	10/09/1996
98-FC-103 Rev 0	01/06/1998	Remove manipulators in MPPF 1st level and transport to SRTC for decontamination and repair. Reinstall manipulators after repairs are complete.	Pu, Sr, Am	Plastic suit[a], full face, fresh air hood, or none based on task	Yes	7	01/07/1998	01/27/1998
98-FC-103 Rev 1	01/20/1998	Remove manipulators in MPPF 1st level and transport to SRTC for decontamination and repair. Reinstall manipulators after repairs are complete.	Pu, Sr, Am	Full face, fresh air hood, or none based on task and area	Yes	9	01/07/1998	04/01/1998
98-FC-103 Rev 2	04/08/1998	Remove manipulators in MPPF 1st level and transport to SRTC for decontamination and repair. Reinstall manipulators after repairs are complete.	Pu, Sr, Am	Full face, fresh air hood, or none based on task and area	Yes	6	03/16/1998	05/18/1998
98-FC-115 Rev 0	01/26/1998	Decontamination hut and open dampers in MPPF Lab on 2nd level	Pu, Sr, Am	Plastic suit, fresh air hood, or none based on task	Yes	5	01/27/1998	01/27/1998

a. A fully encapsulating suit with supplied air (DuPont 1968b, p. 66).

The HPAREA bioassay sample database was used to find each worker's next americium, plutonium, or strontium urine bioassay sample after their latest sign-in date for any of the RWPs. Their sign-in dates and subsequent bioassay dates are listed in Table 5-3. All 34 workers had strontium analyses and plutonium analyses within 1.3 years of the date.

Table 5-3. Workers signed in to one or more MPPF RWPs (WSRC 1996–1998).

Worker	Earliest sign-in date	Latest sign-in date	Americium sample	Plutonium sample	Strontium sample
1	06/10/1996	06/10/1996	06/17/1996	12/11/1996	06/11/1997
2	06/10/1996	06/11/1996	11/21/2000	10/07/1996	10/07/1996
3	06/10/1996	06/13/1996	07/10/1996	10/07/1996	10/07/1996
4	06/10/1996	01/07/1998	02/18/1998	03/18/1998	03/18/1998
5	06/12/1996	06/13/1996	12/22/1999	06/27/1996	12/10/1996
6	06/13/1996	09/17/1996	None	12/15/1997	12/15/1997
7	07/15/1996	07/15/1996	04/07/1998	08/03/1996	08/03/1996
8	07/15/1996	07/15/1996	10/14/1996	03/05/1997	03/05/1997
9	07/15/1996	07/15/1996	07/12/1999	07/16/1996	07/16/1996
10	07/15/1996	07/15/1996	04/05/1998	12/07/1996	12/07/1996
11	07/15/1996	01/20/1998	01/21/1998	03/18/1998	03/18/1998
12	07/15/1996	05/18/1998	09/02/1998	09/02/1998	09/02/1998
13	07/15/1996	05/18/1998	08/04/1998	08/04/1998	02/08/1999
14	09/05/1996	09/11/1996	10/02/1996	10/02/1996	10/02/1996
15	09/05/1996	09/17/1996	None	10/15/1996	10/15/1996
16	09/05/1996	09/17/1996	03/14/2000	03/03/1997	03/03/1997
17	09/16/1996	09/26/1996	None	08/21/1997	08/21/1997
18	09/17/1996	03/16/1998	04/07/1998	04/07/1998	10/09/1998
19	09/25/1996	09/25/1996	12/03/1998	1/201/1997	06/08/1997
20	09/25/1996	09/26/1996	None	03/18/1997	03/18/1997
21	09/25/1996	10/08/1996	None	12/18/1996	12/18/1996
22	09/25/1996	10/08/1996	05/02/2000	11/11/1996	11/11/1996
23	10/09/1996	10/09/1996	02/10/1999	02/11/1997	08/14/1997
24	01/07/1998	01/07/1998	03/26/1998	02/13/1998	03/26/1998
25	01/07/1998	05/18/1998	09/29/1998	09/29/1998	04/22/1999
26	01/15/1998	01/15/1998	09/21/1999	03/03/1998	09/05/1998
27	01/27/1998	01/27/1998	04/02/1998	05/26/1998	05/26/1998
28	01/27/1998	04/01/1998	07/07/1998	07/28/1998	07/28/1998
29	01/27/1998	04/01/1998	04/04/1998	09/09/1998	04/05/1999
30	03/16/1998	03/16/1998	04/07/1998	08/01/1998	02/05/1999
31	04/01/1998	04/01/1998	04/03/1998	08/21/1998	08/21/1998
32	04/06/1998	04/06/1998	09/04/1998	07/21/1998	07/21/1998
33	04/06/1998	04/06/1998	11/04/1998	06/10/1998	06/10/1998
34	04/06/1998	04/06/1998	02/29/2000	08/05/1998	02/15/1999

Twenty-nine workers had americium analyses within 4.5 years of their latest sign-in date. Five workers did not have americium bioassay samples after their last sign-in date. Termination dates in HPAREA show that 3 of the 5 left SRS less than one year after their last sign-in date for these RWPs.

These 5 workers without the follow-on americium analyses signed into 5 RWPs on 10 different dates. The sign-in sheets were reviewed to find all other workers who signed in for the same RWP on the same day. For each of these 5 workers in all cases, one or more other workers signed into the same RWP on the same date who also later had an americium bioassay analyses.

Five of the 34 workers were found in NOCTS and an additional 5 were found in comprehensive exposure records in the SRDB (SRS 1975–2018). Of these, 6 had lung counts after their last sign-in date. Table 5-4 lists these workers and the lung count dates.

Table 5-4. Lung count dates for MPPF workers with data in NOCTS or SRDB (SRS 1975–2018).

Worker	Earliest sign-in date	Latest sign-in date	In NOCTS	In SRDB	Lung count
1	06/10/1996	06/10/1996	No	Yes	None
2	06/10/1996	06/11/1996	No	Yes	11/04/1997
5	06/12/1996	06/13/1996	No	Yes	12/15/1997
6	06/13/1996	09/17/1996	Yes	No	None
10	07/15/1996	07/15/1996	Yes	No	12/29/2005
12	07/15/1996	05/18/1998	Yes	No	08/11/1999
16	09/05/1996	09/17/1996	Yes	No	03/17/2009
15	09/05/1996	09/17/1996	No	Yes	None
23	10/09/1996	10/09/1996	No	Yes	None
30	03/16/1998	03/16/1998	Yes	No	02/01/2006

There was no indication found in the available exposure data for the workers or in the paperwork with the RWPs that any internal exposures occurred. The three Post-Job ALARA forms each indicated no exposure events had occurred and estimated a total of “0.00 man-rem” for the job.

6.0 CONCLUSIONS

The required types and locations for routine bioassay sample analyses remained largely constant between 1971 and 1999 with a few areas adding and dropping analytes in procedure revisions. The definitions of workers to be routinely sampled varied in almost each procedure revision but focused on workers most likely to be in contact with radioactive materials.

Routine bioassay samples were used at SRS only to monitor other work controls and were not used to assess dose. The Special Bioassay Sampling Program was used whenever internal exposure was suspected and provided results for dose assessment. In 1999, the sitewide characterization effort identified all radioisotopes that contributed 10% or greater to internal exposure for each location or waste stream. Analyses for these radioisotopes were to be included on RWPs. These were also required analytes for routine bioassay samples from workers doing work under any RWPs when working with actinides whenever respiratory protection was required.

The bioassay procedures and RWP requirements were for routine bioassay sampling. Workers were also monitored by personnel contamination surveys and by air sampling programs. Any indication of internal exposures from this monitoring or from any positive results obtained in the Routine Bioassay Sampling Program led to further sampling under the Special Bioassay Program, which was used to assign dose. Results from the routine program were not used to assign dose; instead they were used to monitor work conditions.

Sufficient accuracy is achieved in dose reconstructions when the available information allows a maximum estimate of worker exposure. Worker exposure records from SRS, including routine bioassay sample results, special bioassay sample results, chest count results, and WBC results, provide that information.

6.1 RESPONSE TO SC&A COMMENTS

SC&A asked questions about the conditions at SRS before 1999 and described the facility source terms at SRS before 1999 as “inadequate”. The term “inadequate” is their professional judgment. A different interpretation is that the changes in the routine bioassay program after the characterization effort were continuous improvements in worker monitoring.

SC&A referenced “Field Protocols for Determining Radionuclides of Interest in a Facility Radiobioassay Program” and found it to be a “lessons learned” of experience gained with the WSRC

source term characterization program originally implemented 6 years earlier in 1999. In this reference, WSRC quotes the site policy for routine and special bioassays (Hadlock et al. 2005):

> *A routine bioassay program is designed to detect (previously unknown) intakes of radionuclides that a person has a "reasonable potential" to assimilate. This is in contrast to a special bioassay program, which is designed to assess intakes of specific radionuclides to which a person has been exposed. The key point here is that:*
>
> - *A special bioassay program is initiated in response to a real, measurable source term, e.g., the material that is on an air filter paper.*
> - *A routine bioassay program is initiated in response to a "hypothetical" source term, e.g., a particular mix of radionuclides that might typically be expected to be present on any given day at a particular location.*
> - *The specification of the source term for a routine bioassay program is largely a professional judgment because we are trying to predict the mixture of radionuclides that a person might be exposed to at some undetermined time in the future and there is a limited amount of information available to make the prediction.*
> - *Great care must be taken to match a special bioassay program to the source term because the bioassay program is being used to demonstrate compliance with the federal rule 10 CFR Part 835.*
> - *An occasional mismatch between the routine bioassay program and the source term is to be expected and is not an indication of an inadequate bioassay program.*

This policy from 2005 is consistent with the SRS distinction between routine bioassay sampling and special bioassay sampling before 1999 and with the changes implemented in 1999. It clearly separates the adequacy of a source term for samples under the Routine Bioassay Sampling Program used to monitor workers not known to be exposed from the adequacy of a source term for assessing dose to workers with suspected internal exposure under the Special Bioassay Sampling Program.

6.1.1 Americium and Curium

The two radioisotopes mentioned in the SC&A memorandum are ^{241}Am and ^{244}Cm. The changes in the use of the Am/Cm/Cf bioassay sample requirement and the result of the 1999 characterization effort are discussed above in Section 4.0.

Central to the issue of ^{241}Am at SRS is the fact that it is a decay product of ^{241}Pu with a half-life of approximately 432 years. Freshly separated plutonium has little americium, but it continues to increase in relative activity as the plutonium ages. The ratio of ^{241}Am activity to the total alpha activity in a 6% reference plutonium mix goes from 0.1% after 2 weeks to 6.5% after 5 years (DOE 2006, p. 123).

A quote from the former internal dosimetry employee in the SC&A memorandum touches on this (SC&A 2018): "I think that when SRS moved from the production phase to the decontamination and decommissioning (D&D) phase in the 1990s there were changes in the source terms that were not fully anticipated because of the change in mission." This was a change from working with freshly separated production materials to older waste materials with increased amounts of americium.

As an incidental benefit, this buildup of americium can make the mixture "somewhat easier to detect by in vivo methods" (DOE 2006, p. 121). Chest counts at SRS to monitor plutonium exposures would also have identified associated americium exposures.

The MPPF RWPs illustrate a case where americium existed without any associated plutonium. Potential exposures in 1996 and 1998 would have resulted from existing MPPF contamination. This contamination was just as it was characterized later in 1999 and reported in Farrell and Findley (1999); there was no new production during this period. Although all workers had Sr and Pu bioassays, if any internal exposure had occurred, the dose would have been due primarily to ^{241}Am. Exposure to ^{241}Am would have been assessed by workplace air sampling, through lung counts, and through ^{241}Am bioassay analyses.

All were monitored directly or indirectly for internal exposure to ^{241}Am:

- Air sampling was required on each RWP.
- Some, although not all, workers had subsequent lung counts.
- All 34 workers either had ^{241}Am analyses or worked under the same RWP on the same day as another worker with subsequent ^{241}Am analyses.

6.1.2 References Quoted by SC&A

SC&A (2018) provides five references from the SRDB:

1. "Understanding Urine Bioassay Sampling," Revision 3, November 7, 1997 (Findley 1997b).

   This reference states that in 1997 SRS had identified the issue that some RWP bioassay requirements were written to meet the bioassay frequency tables rather than being based on the identification of the radioisotopes actually present. It states that SRS removed the linkage between the RWP procedure 5Q1.1-504, *Radiological Work Permit*, and the bioassay frequency table in 5Q1.1-506, In Vivo and In Vitro Bioassay Scheduling and Administration.

2. "Specification of Bioassay Requirements on Radiological Work Permits," August 13, 1998 (Findley 1998).

   This reference is a memorandum describing the status, in 1998, after the internal FEB audit and during the pilot program for the Burial Ground. Further details on this are described above in Section 2.0.

3. "Missed Dose from Curium Intakes by Solid Waste Workers," August 25, 1998 (LaBone 1998).

   SC&A wrote, "The author seems to be suggesting that there is no need to be concerned about missing radionuclides for bioassay purposes because any such routine monitoring is not required for dose assessment under 10 CFR Part 835 regulations, in any case. This position seems to be at odds with other WSRC documentation and will need further follow-up."

   Research for this report indicates that WSRC was consistent in its use of the bioassay sampling program; routine bioassay samples were collected to confirm the adequacy of the overall worker protection program. The argument being made in this reference is that there was no indication of exposures to the workers. It includes the statement, "This could be a valid concern for a special urine sample, but for the reasons given below, is not a concern for a routine urine sample."

Investigation of the curium found at the Burial Ground indicated that it was inaccessible and that it was part of a mixture that included plutonium, which was a component of the worker's routine bioassay sampling (Findley 1998). Exposure to curium could not have occurred without concurrent exposure to plutonium. That is, any indication of internal exposure identified in a plutonium urine bioassay obtained through the Routine Bioassay Sampling Program would have triggered the Special Bioassay Sampling Program and an analysis of the source term for all radionuclides present.

4. "Specifications of Urine Bioassay Requirements on Radiological Work Permits," March 10, 1999 (Farrell and Findley 1999).

   This is Farrell and Findley (1999), the summarized results of the 1999 characterization, and includes the process implemented in March 1999 for identifying and annually revisiting source terms. This report is discussed above in Section 3.4.8.

5. "Response to the Compilation of PAAA Internal Dosimetry Issues," November 2, 1999 (Morgan 1999).

   This is the report from WSRC that summarized its response to the 31 general deficiencies identified by OEI. Its response to Item B.8 is described above in Section 2.0.

6.1.3 Questions Raised by SC&A

In their memorandum, *Missing or Incomplete Radiological Source Terms*, SC&A asked five questions about the 1999 recharacterization concerning both the use of the bioassay data by SRS and the effects on National Institute for Occupational Safety and Health (NIOSH) dose reconstruction.

1. *What are the ramifications to dose reconstruction with sufficient accuracy if RWP job-specific bioassays neglected to include relevant radionuclides, particularly for certain facilities where complex, mixed, or unusual radioactive sources existed, e.g., SRTC, solid waste, burial grounds, tank farms, and decontamination and decommissioning projects?*

   There are not any ramifications to dose reconstruction because the relevant radionuclides were included in the bioassay program. There were relatively few changes in the bioassay monitoring by area from 1971 through 1999 with the exception of americium as discussed in Section 4.0 of this report.

   Job-specific routine bioassay samples were required across many site locations. The locations, the analytes for these locations, and the personnel participating in the Routine Bioassay Sampling Program varied in the procedures between 1971 and 1999. The routine bioassay results along with routine lung counts, routine WBCs, workplace air sampling, workplace surveys, and worker monitoring were used to monitor the effectiveness of worker protections. The Special Bioassay Sampling Program was in place to measure and assess actual internal exposures. It was designed to measure worker exposures for anyone at SRS who had the potential for an internal exposure that exceeded 100 millirem (WSRC 1990a, p. 36).

   Dose reconstruction reviews all available bioassay data for the worker, including WBCs, chest counts, and bioassay results. Workers who were not monitored for a specific analyte and who may be reasonably expected to have worked in an area with that analyte will be assigned dose using ORAUT-OTIB-0081, *Internal Coworker Dosimetry Data for the Savannah River Site* (ORAUT 2016).

2. *If WSRC instituted such a policy in March 1999 requiring the RCOs to base bioassay monitoring on actual, updated workplace characterization versus expert judgment or longstanding facility knowledge, how incomplete were bioassays (including RWPs) prior to this date with regard to appropriately targeted radionuclides?*

   There is no indication that bioassays under the Special Bioassay Program were incomplete. Most radionuclides targeted under the Routine Bioassay Program were not incomplete because their monitoring requirements did not change. Although routine monitoring requirements for americium did change, in almost all locations the presence of americium can be assumed and calculated from the age of the plutonium. In addition, in areas where americium was present without plutonium, such as at the MPPF, routine bioassay samples were required on RWPs and then collected and analyzed.

   The March 1999 policy changes applied solely to the Routine Bioassay Sampling Program. The routine program along with routine lung counts, routine WBCs, workplace air sampling, workplace surveys, and worker monitoring were used to monitor the effectiveness of worker protections. The routine sampling was applied broadly to workers who were not expected to have internal uptake of radionuclides that would exceed 100 millirem. The Special Bioassay Sampling Program was triggered whenever there was an indication or suspicion of an uptake by a worker. This included high air sample results, skin contamination events, failure of protective clothing or protective barriers, and elevated results found by the routine program.

   Air sampling was one of the primary methods of worker protection and would detect alpha activity in the air regardless of the source alpha-emitting radionuclide. For example, the 1990 *Internal Dosimetry Technical Basis Manual* required continuous air monitoring for workers entering RCAs and listed the components of a monitoring program for SRS transuranic workers to include urine bioassay, chest counts, fecal bioassay, and personal air samplers (portable breathing-zone air samplers worn by the workers) (WSRC 1990a, p. 235). Another example is found in the systems analysis of Building 772-F (Durant and Pritchard 1986), which describes the building's air monitoring system as "designed to continuously monitor for particulate alpha contamination in air and provide prompt and adequate warning if [the] concentration of airborne alpha contamination increases above a preset alarm level" (Durant and Pritchard 1986, p. 32).

   Bioassay monitoring for the purposes of establishing worker exposures as required under 10 CFR Part 835 and earlier DOE Orders was performed under the Special Bioassay Sampling Program. The program, along with workplace air monitoring, surveys, and scans, is considered to have met the DOE requirements and is therefore a "complete" program. The SRS program, however, exceeded those requirements with the Routine Bioassay Sampling Program.

   Dose reconstruction by NIOSH uses all bioassay data from SRS and, where necessary, uses ratios of expected radionuclides to address intakes that were not measured by the site. Due to the ingrowth of ^{241}Am in ^{241}Pu, it would be expected in any aged plutonium sources. Particular to the characterization results showing ^{241}Am as providing more than 10% of the dose in locations not previously established for routine Am/Cm/Cf bioassay monitoring, the ^{241}Am contribution to the dose can be calculated for these locations using estimates of the age of the ^{241}Pu present, as has been calculated at other sites.

3. *How does this impact dose reconstruction with sufficient accuracy if workers were incorrectly enrolled in bioassay programs, with potential exposure to key radiological sources not evaluated?*

There is no indication workers were enrolled incorrectly in the bioassay programs. The March 1999 change in policy by SRS does not impact the accuracy of dose reconstruction by NIOSH. In addition, coworker models can be used to estimate exposures for unmonitored workers.

The issues discussed by SC&A relate solely to the collection of samples under the Routine Bioassay Sampling Program.

The Special Bioassay Sampling Program was designed to assess inadvertent intakes of radioactive material that could exceed 100 millirem to the worker (WSRC 1990a, p. 36). Workers with suspected or confirmed uptakes of radionuclides were monitored under the Special Bioassay Sampling Program. New requirements for routine bioassays do not indicate that workers in those areas were previously "incorrectly enrolled." They were enrolled in the Routine Bioassay Program according to the requirements in place at that time.

Dose reconstruction by NIOSH uses all bioassay data from SRS, which includes the worker's nonroutine special bioassay results and routine bioassay results, such as WBC and chest count results.

4. *What is the significance of an apparent lack of ongoing facility source term characterization to adequate internal dose monitoring during the 1990s with the advent and growth of new activities and programs involving new and complex radiological sources, e.g., decontamination and decommissioning (D&D), solid waste management, environmental cleanup, and SRTC?*

   The March 1999 sitewide source term characterization did not affect the adequacy of SRS to monitor workers for internal dose. It did change urine bioassay requirements for the Routine Bioassay Program, however the Routine Program was implemented in excess of the DOE regulatory requirements. No worker at SRS met the 10 CFR Part 835 definition for bioassay monitoring.

   This source term characterization relates solely to the selection of analyses for routine bioassay samples, including job-specific (RWP) samples. There is no indication in the research for this report or in the references cited by the SC&A memorandum of a lack of radioisotopic characterization from special bioassay sampling.

   The 1999 sitewide characterization effort did result from the instance of ^{244}Cm found unexpectedly in the Burial Ground, although it was determined to be not an issue there because it was inaccessible to the workers and because plutonium was always present with the curium.

   Most of the changes identified after the 1999 characterization effort involved stored wastes and specific waste streams. The shift in mission as SRS moved from production into cleanup in the 1990s resulted in working with aging plutonium and higher relative amounts of americium. Americium sources measured in the 1999 characterization can be accounted for in earlier years using plutonium age estimates, as have been at other sites.

   Note, however, that the addition of Am/Cm/Cf bioassays in certain areas was also due to a new requirement implemented with Farrell and Findley (1999) to include all radioisotopes for routine bioassay that contributed to 10% or more of the internal dose. Routine monitoring for the dominant nuclide would still have provided confirmation in the adequacy of the worker protection program, the stated purpose of routine bioassay sampling. In addition, routine sampling requirements for americium were applied in job-specific RWPs before 1999 at locations identified in Farrell and Findley (1999) to have americium and not listed for routine bioassays in the pre-1999 procedures.

Special bioassay sampling was indicated where there was an indication of an exposure that could exceed 100 millirem within one year. There were many fewer special bioassay samples collected than routine bioassay samples. The coworker model uses all applicable bioassay data including results from special and routine bioassay samples.

5. *If key radionuclides such as americium had been missed, what other sources were not reflected on RWPs over time and what are the ramifications for dose reconstruction with sufficient accuracy for those workers potentially affected?*

   Key radionuclides were not "missed" before 1999 in the Routine Bioassay Sampling Program; there was a change in the methods used to list radionuclides required under the Routine Bioassay Program. The March 1999 change in policy by SRS does not impact the accuracy of dose reconstruction by NIOSH. In addition, coworker models could be used to estimate exposures for any unmonitored workers.

   In March 1999, there was a change in the methods used to select locations and analytes for routine bioassay sampling. Procedures between 1971 and 1999 listed the requirements for the Routine Bioassay Sampling Program. This program was used across many site locations to confirm workplace controls. Routine bioassay sampling was also applied by job-specific RWPs. Any indication of an internal exposure led to the Special Bioassay Sampling Program, which included requirements for isotopic analysis of the source term for that potential exposure. The Special Bioassay Sampling Program was not limited to the analytes required by the Routine Bioassay Sampling Program nor did it rely on results from that program.

   Changes between bioassay frequency tables between 1971 and 1999 for the routine sampling are described in Section 3.4 of this report. A comparison of the isotopes by location and waste stream in the 1999 characterization effort and published in Farrell and Findley (1999) and the preceding bioassay frequency table from 5Q1.1-506, In Vivo and In Vitro Bioassay Scheduling and Administration, Revision 5, is found in Table A-8.

   Dose reconstruction reviews all bioassay data for the worker, including WBCs, chest counts, and bioassay results. For SRS, the routine bioassay sample results were collected for workers not known to have received an intake of radioactive material, and special bioassay samples were collected for workers suspected to have had an intake due to events such as elevated air sample results, skin contamination, wounds, and failures in protective equipment.

   Sufficient accuracy is achieved in dose reconstructions when the available information allows a maximum estimate of worker exposure. Worker exposure records from SRS, including routine bioassay sample, special bioassay sample, chest count, and WBC results, provide that information.

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ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS

LIST OF TABLES

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Table A-1. Routine bioassay sampling frequencies excluding construction division, DPSOL 193-302, Revision 5 (DuPont 1971b), samples per year.[a,b]

Worker category/personnel description	H^3 (urine)	Pu (urine)	FP (urine)	EU (urine)	U (urine)	Am, Cm, Cf (urine)	EU (chest)	Pu, Am, Cm, Cf (chest)
Category A: Minimum Potential (Except HTO). Personnel assigned to 284-F & -H, 704-F & -H, 706-F & -H, 717-F, and nonprocess sections of other facilities; patrolmen.	N/A	(c)	N/A	N/A	N/A	N/A	N/A	N/A
Category B: 221-F &-H Fourth Level. Separations supervision; all Separations Technology personnel, control room operators, janitors, and clerical personnel.	N/A	1	1	N/A	N/A	N/A	N/A	N/A
Category C: 221-H & H-Area Outside Facilities. All operators (except control room and sample aisle), HP personnel, and selected Power, E&I, and maintenance personnel assigned to 22l-H process areas; all personnel assigned to H-Area outside facilities.	2	1	2	1	N/A	N/A	N/A	N/A
Category D: 221-H Sample Aisle. All 221-H sample aisle operators.	N/A	2	2	2	N/A	N/A	N/A	1
Category E: 221-F Sample Aisle. All 221-F sample aisle operators; selected 772-F personnel.	N/A	2	2	N/A	N/A	2	N/A	1
Category F: 221-F, 723-F, & 643-G. All operators (except control room and sample aisle), HP personnel, and selected power, E&I, and Maintenance personnel assigned to 221-F process areas; all personnel assigned to 723-F and 643-G.	N/A	1	2	N/A	N/A	N/A	N/A	N/A
Category G: 221-H B-Line, 221-F B-Line, JB-Line, & 235-F. All personnel assigned to process sections in 235-F, and all assigned personnel in other facilities.	N/A	2	2	N/A	N/A	N/A	N/A	1
Category H: F-Area Outside Facilities. All assigned personnel.	N/A	(c)	2	N/A	4[d]	N/A	N/A	N/A
Category J: 772- F (Excluding UO_3 Section). All assigned personnel.	N/A	2	2	1	1	N/A	N/A	1[e]
Category K: 313-M. All assigned personnel.	N/A	N/A	N/A	N/A	4	N/A	N/A	N/A
Category L: 322-M. All assigned personnel (excluding personnel processing samples from field). 320-M. All laboratory and selected RM personnel. 773-A. Reactor Engineering group and 777-M assigned personnel.	N/A	(c)	N/A	1	4	N/A	N/A	N/A
Category M: 3 22-M. Personnel processing samples from the field. 772-F, UO_3 Section. All assigned personnel.	N/A	(c)	1	1	4	N/A	N/A	N/A
Category M: 321-M. All assigned personnel.	N/A	1	N/A	4[f]	N/A	N/A	2[g]	N/A

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Worker category/personnel description	H^3 (urine)	Pu (urine)	FP (urine)	EU (urine)	U (urine)	Am, Cm, Cf (urine)	EU (chest)	Pu, Am, Cm, Cf (chest)
Category T: 100-Area, 105 Building. Reactor Department personnel from Charge and Discharge crews, purification, and pump room observation; control room and monitor operators, all 100-Area HP, Maintenance, and T&T personnel; all E&I personnel assigned to 105 Buildings, T&T personnel in Central Shops; and selected Reactor Technology and 400-Area personnel.	(h)	N/A	1[i]	N/A	N/A	N/A	N/A	N/A
Category V: 773-A. Analytical Chemistry, HLCs, Building Services, Radiation Control, and maintenance personnel.	N/A	(c)	1	N/A	N/A	2	N/A	1[e]
Category W: 773-A. Selected clerical, supervisory personnel, and selected 100-Area personnel.	N/A	(c)	N/A	N/A	N/A	1	N/A	N/A
Category X: 232-H, 234-H, 237-H, & 238-H. All assigned personnel. 241·H & 244-H. Selected personnel.	(h)	(c)	N/A	N/A	N/A	N/A	N/A	N/A
700-Area: Shop personnel.[j]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

a. FP = fission product; HLC = high-level cave; HTO = tritiated water vapor; N/A = not applicable; RM = Reactor Maintenance; T&T = Traffic and Transportation.
b. Neptunium analysis is performed when requested by area HP. Np has never been detected without at least an equal amount of Pu.
c. One sample every 3 years.
d. Except A-Line where operators are sampled weekly.
e. Selected personnel.
f. Except casting area where operators are sampled monthly.
g. Only personnel assigned to casting area.
h. Sample frequency established by local procedures.
i. Samples are also analyzed for IA.
j. 700-area shop personnel provide samples as considered by HP.

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Table A-2. Bioassay frequencies, DPSOL 193-302, Revision 7 (DuPont 1976, p. 4).[aa]

Category and personnel work assignment	Pu	EU	U	IA, FP	Am, Cm, Cf	Sr	H^3	F	In vivo counts/yr (days)	In vivo counts/yr (shift)
(Category A) Minimum potential: Personnel working in tritium facilities, 200-FH facilities not mentioned below, 723-A Environmental Effects Division, and 305-M. Selected 100-Area and 773-A personnel.	1/3	N/A	N/A	N/A	N/A	N/A	(b)	N/A	1/3[c]	1/3
(Category B) 221-FH: All operators, Separations Technology, HP, and fourth-level personnel: E&I, Maintenance, Clerical, and Service Department personnel assigned to process areas. 241-FH, 211-FH, 723-F, A-Line, 643-0, and 244-E: All assigned personnel. 772-F and 235-F: Personnel assigned to non-process areas. Patrol and T&T: All personnel assigned to 200-FH Areas. 773-A: Selected clerical and supervisory personnel. 100-Areas: Selected personnel.	1	(d)	(e)	N/A	(f)	(g)	N/A	N/A	1	2
(Category C) 221-HB Line, 221-FB Line, JB-Line: All assigned personnel. 235-F: Personnel assigned to process areas. 772-F: Personnel assigned to process areas. 773-A: Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	2	(d)	N/A	N/A	(f)	N/A	N/A	(c)	1[h]	2
(Category K) 313-M: All assigned personnel.	N/A	N/A	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Category L) 322-M and 772-F (UO_3 Section): All assigned personnel. 320-M: All laboratory and selected RM personnel. 773-A: Reactor Engineering and 777-M personnel.	1/3	1	4	N/A	N/A	N/A	N/A	N/A	(i)	(i)
(Category N) 321-N: All assigned personnel except those in Casting Area.	1	4	N/A	N/A	N/A	N/A	N/A	N/A	1/3	1
(Category R): Used by Personnel Monitoring to designate personnel with a confirmed transuranic uptake. Area HP can increase sample frequencies with job assignments warrant. Do not change category letter.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Category and personnel work assignment	Pu	EU	U	IA, FP	Am, Cm, Cf	Sr	H^3	F	In vivo counts/yr (days)	In vivo counts/yr (shift)
(Category T): Reactor Department personnel from CH purification and pump room observation; control room and monitor operators; all 100-Area HP, Maintenance, and T&T personnel; E&I and Service personnel assigned to 105 buildings; T&T personnel in Central Shops and 610-C; selected Reactor Technology, Project, and 400-Area personnel.	1[c]	N/A	N/A	1	N/A	N/A	(b)	N/A	1[j]	1[j]
(Category U) 321-M: All personnel assigned to Casting Area.	1	12	N/A	N/A	N/A	N/A	N/A	N/A	2	2

a. IA = induced activity; N/A = not applicable.
b. Sample frequency established by local procedures.
c. Selected personnel.
d. Selected personnel in 221-H, 211-H, and 772-F sampled for EU four times a year.
e. A-Line assigned personnel in F-Area sampled weekly; samples collected after day(s) of rest and before exposure.
f. Selected personnel in 221-F, 211-F, and 773-A sampled for Am-Cm once a year.
g. Selected personnel assigned to waste management work sampled for Sr once a year.
h. All B-Line and JB-Line personnel and 772-F lab attendants counted twice a year.
i. 322-M personnel processing 200-Area samples and 772-F (UO3 Section) personnel counted once a year.
j. Selected day and all shift personnel; urine sample not required if in vivo count scheduled.

Table A-3. Bioassay frequencies, DPSOL 193-302T, Revision 0 (DuPont 1985j).[a]

Personnel	Work assignment	Suggested code
100-400 Areas	Selected day personnel and all shift Reactor Department CH, purification, pump observation room, and monitor operators.	N
100-400 Areas	Reactor control room operators; HP, Maintenance, T&T, E&I, and Service personnel assigned to 105 Building, T&T personnel in Central Shops and 618-G; selected Reactor Technology, Project, and selected 400-Area personnel.	AP
100-400 Areas	Maximum potential. Selected personnel.	B
100-400 Areas	Other personnel assigned to 105 Building. Selected 400-Area personnel.	P
200-Areas	Personnel working in tritium facilities or 200-FH facilities not mentioned below.	A
221-FH; 723-F; 643-G; A-Line; 241-FH; 244-H	All Separations operators; Sep. Tech, HP, and other 4th-level personnel; E&I, Maintenance, Clerical, and Service Dept. personnel assigned to process areas.	B
235-F; 772-F	Selected personnel.	B
221-F	Selected personnel.	BT
211-H	Selected personnel.	BG
643-G	Selected personnel assigned to waste management work.	BX
221-FB Line, JB-Line	All assigned personnel.	C
235-F	Personnel assigned to process areas.	CW
772-F	Personnel assigned to laboratories in the PUREX and Pu sections.	CE
221-F	Selected personnel.	CU
221-H; 772-F	Selected personnel.	CG
221 HB-Line	All assigned personnel.	D
300-Areas; 313-M	All assigned personnel.	L
322-M	UO_3 sections and other selected personnel.	BEL
322-M	All other assigned personnel.	AEL
320-M	All laboratory and selected RM personnel.	EL
321-M	All personnel assigned to charge prep, casting, and machining area.	BH
321-M	All other assigned personnel.	BG
773-A	Minimum potential.	A
773-A	Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and maintenance personnel.	CT
773-A	Reactor engineering and 777-M personnel.	AEL
773-A	Selected clerical and supervisory personnel.	B
773-A	Maximum potential. Selected personnel.	CFLU

a. PUREX = plutonium-uranium extraction.

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Description of Code

Nuclide	Samples/year	Code
Pu	0.3	A
Pu	1	B
Pu	2	C
Pu	4	D
EU	1	E
EU	2	F
EU	4	G
EU	12	H
Natural U	1	J
Natural U	2	K
Natural U	4	L
Natural U	12	M
Fission product induced activities	0	N
Fission product induced activities	1	P
Fission product induced activities	2	R
Fission product induced activities	4	S
Am, Cm, and Cf	1	T
Am, Cm, and Cf	2	U
Am, Cm, and Cf	4	V
Np	1	W
Sr	1	X
Sr	2	Y
Sr	4	Z

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Table A-4. Bioassay frequency table, DPSOL 193-211, Revision 0 (DuPont 1989b).[a,b]

Personnel	Work assignment	Suggested code
100-400 Areas, all Reactor Area Departments and Construction	Selected day personnel and all shift Reactor Department CH, purification, pump observation room, and monitor operators. Maintenance, T&T, E&I, and Service personnel assigned to 105 building, T&T personnel in Central Shops and 618-G; selected Reactor Technology, Project, and selected 400-Area personnel.	A
100-400 Areas, all Reactor Area Departments and Construction	HP, selected CH.	B
211-H	Selected personnel.	BG
643-G	Selected personnel assigned to waste management work.	BX
FB-Line	Operators and first-line supervisors. Solid Waste Engineering (SWE) mechanics.	D
FB-Line	Other assigned personnel.	B
HB-Line	Operators.	DW
HB-Line	Other assigned personnel.	BW
235-F	Operators.	DW
235-F	Other assigned personnel.	BW
A-Line (F)	All assigned personnel.	BM
772-F	Personnel assigned to laboratories in the PUREX and Pu sections.	CE
221-F	Selected personnel.	B
221-H	Selected personnel.	CG
313-M	All assigned personnel.	L
322-M	All assigned personnel.	BGL
320-M	All laboratory and selected RM personnel.	GL
321-M	All personnel assigned to charge prep, Casting, and machining, and assembly weld areas	BH
321-M	All other assigned personnel.	BG
773-A	Minimum potential.	A
773-A	Selected ACD, SED, SCD, NMD, HLC, Radiation Control, Building Services, and Maintenance personnel.	CT
773-A	Reactor Engineering and 777-M personnel.	AEL
773-A	Selected clerical and supervisory personnel.	B
773-A	Maximum potential. Selected personnel.	CFLU
221-S	All assigned personnel.	BX
250-S	All assigned personnel.	BX

Personnel	Work assignment	Suggested code
210-Z	All assigned personnel.	BX
247-F	Personnel who perform work in process core.	H
247-F	Personnel who do not perform work in process core.	G

a. Source: DuPont (1989b).
b. Codes are identical to those in Table A-3 above.

Table A-5. Minimum bioassay schedules for SRS facilities, Manual 5Q1.1, Procedure 506, Revision 0 (WSRC 1992a, p. 41).

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
SRTC 773-A	Chemical Technology Section	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Am, Cm, and Cf, 2/yr	Pu02; Am02
SRTC 773-A	Chemical Technology Section	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
SRTC 773-A	ADS	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 1/yr	Pu01; Sr01; Am01
SRTC 773-A	ADS	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
SRTC 773-A	Interim Waste Section	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
SRTC 773-A	Defense Waste Section	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
SRTC 773-A	HLCs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 2/yr	Pu01; Sr01; Am02
SRTC 773-A	Materials Technology Section (Fab Lab)	Category I	WBC, 1/yr	Uranium, 12/yr; Pu, 1/yr	U12; Pu01
SRTC 773-A	Materials Technology Section (Fab Lab)	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
779-A	Equipment Engineering. Section	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
779-A	Equipment Engineering. Section	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
773-A; 776-A	Maintenance/E&I	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1/yr; Am, Cm, and Cf, 2/yr	Pu02; Sr01; Am02
773-A; 776-A	Maintenance/E&I	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 1/yr	Pu01; Sr01; Am01
SRTC	Environmental Control Inspector	Category III	WBC, 1/yr	None required	X00
SRTC	All RCAs	Category III	WBC, 1/yr	None required	X00
C-Area	All RAs	Category I	WBC, 1/yr	Tritium (job-specific sampling)	TJS
C-Area	All RCAs	Category III	WBC, 1/yr	Tritium, 12/yr	T12
K-Area	All RAs	Category I	WBC, 1/yr	Tritium (job-specific sampling)	TJS
K-Area	All RCAs	Category III	WBC, 1/yr	Tritium, 12/yr	T12
L-Area	All RAs	Category I	WBC, 1/yr	Tritium (job-specific sampling)	TJS
L-Area	All RCAs	Category III	WBC, 1/yr	Tritium, 12/yr	T12
P-Area	All RAs	Category I	WBC, 1/yr	Tritium (job-specific sampling)	TJS
P-Area	All RCAs	Category III	WBC, 1/yr	Tritium, 12/yr	T12
400-Areas	All RAs	Category I	WBC, 1/yr	Tritium (job-specific sampling)	TJS
400-Areas	All RCAs	Category III	WBC, 1/yr	Tritium, 12/yr	T12
TNX	All RCAs	Category I	WBC, 1/yr	EU, 4/yr	EU04
TNX	All RCAs	Category II & III	WBC, 1/yr	None required	X00
221-F Canyon	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
221-F Canyon	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F Canyon	All RCAs	Category III	WBC, 1/yr	None required	X00
221-F A-Line & 211-F (Outside Facilities)	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
221-F A-Line & 211-F (Outside Facilities)	All U RCAs	Category I	WBC, 1/yr	Uranium, 12/yr	U12
221-F A-Line & 211-F (Outside Facilities)	All RCAs	Category II & III	WBC, 1/yr	None required	X00
221-F B-Line	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr	Pu04
221-F B-Line	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
221-F B-Line	All RCAs	Category III	WBC, 1/yr	None required	X00
221-F New Special Recovery	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr	Pu04
221-F New Special Recovery	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F New Special Recovery	All RCAs	Category III	WBC, 1/yr	None required	X00
221-F Pu Storage Facility	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr	Pu04
221-F Pu Storage Facility	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F Pu Storage Facility	All RCAs	Category III	WBC, 1/yr	None required	X00
235-F	All RCAs excluding Np Line	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr	Pu04
235-F	All RCAs excluding Np Line	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
235-F	All RCAs excluding Np Line	Category III	WBC, 1/yr	None required	X00
235-F	All RCAs including Np Line	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr; Np, 1/yr	Pu04; Np01
235-F	All RCAs including Np Line	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
235-F	All RCAs including Np Line	Category III	WBC, 1/yr	None required	X00
772-F	PUREX & Pu Sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
772-F	PUREX & Pu Sections	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-F	Uranium Section	Category I	WBC, 1/yr; chest count, 1/yr	EU, 2/yr	EU02
772-F	Uranium Section	Category II	WBC, 1/yr	EU, 1/yr	EU01
772-F	All RCAs in all sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; EU, 1/yr; Sr, 1 yr	Pu02; EU01; Sr01
772-F	All RCAs in all sections	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-F	All RCAs	Category III	WBC, 1/yr	None required	X00

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
772-1F	PUREX & Pu Sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
772-1F	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-1F	All RCAs	Category III	WBC, 1/yr	None required	X00
247-F	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
247-F	All RCAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
247-F	All RCAs	Category III	WBC, 1/yr	None required	X00
221-H Canyon	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; EU, 4/yr	Pu02; EU04
221-H Canyon	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr	Pu01; EU01
221-H Canyon	All RCAs	Category III	WBC, 1/yr	None required	X00
221-H B-Line	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr; Np, 1/yr	Pu04; Np01
221-H B-Line	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-H B-Line	All RCAs	Category III	WBC, 1/yr	None required	X00
211-H	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 1/yr; EU, 4/yr	Pu01; EU04
211-H	All RCAs	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr	Pu01; EU01
211-H	All RCAs	Category III	WBC, 1/yr	None required	X00
232-H	All RAs	Category I	WBC, 1/yr (if entering Line III)	Tritium (job-specific sampling)	TJS
232-H	Assignment to RCAs	Category II	WBC, 1/yr (if entering Line III)	Tritium, 1/week	T52
232-H	All RCAs	Category III	WBC, 1/yr (if entering Line III)	Tritium, 12/year	T12
234-H	All RAs	Category I	None required	Tritium (job-specific sampling)	TJS
234-H	Assignment to RCAs	Category II	None required	Tritium, 1/week	T52
234-H	All RCAs	Category III	None required	Tritium, 12/year	T12
238-H	All RAs	Category I	None required	Tritium (job-specific sampling)	TJS
238-H	Assignment to RCAs	Category II	None required	Tritium, 1/week	T52
238-H	All RCAs	Category III	None required	Tritium, 12/year	T12
244-H	All RCAs	Category I & II	WBC, 1/yr	Pu, 1/yr	Pu01
244-H	All RCAs	Category III	WBC, 1/yr	None required	X00
241-F	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
241-F	All RCAs	Category II & III	WBC, 1/yr	None required	X00
241-H	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 2 yr	Pu01; Sr02
241-H	All RCAs	Category II & III	WBC, 1/yr	None required	X00
299-H	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
299-H	All RCAs	Category II & III	WBC, 1/yr	None required	X00
241-84H	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
241-84H	All RCAs	Category II & III	WBC, 1/yr	None required	X00
643-E; 643-1E & Support Facilities	All RCAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
643-E; 643-1E & Support Facilities	All RCAs	Category II & III	WBC, 1/yr	None required	X00
210-Z	All RCAs	Category I & II	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
210-Z	All RCAs	Category III	WBC, 1/yr	None required	X00
313-M	All RCAs	Category I & II	WBC, 1/yr	U, 12/yr	U12
313-M	All RCAs	Category III	WBC, 1/yr	None required	X00
320-M	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr; uranium, 12/yr	EU04; U12
320-M	All RCAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
320-M	All RCAs	Category III	WBC, 1/yr	None required	X00
321-M	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
321-M	All RCAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
321-M	All RCAs	Category III	WBC, 1/yr	None required	X00
322-M	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr; uranium, 12/yr	EU04; U12
322-M	All RCAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
322-M	All RCAs	Category III	WBC, 1/yr	None required	X00
341-M & 341-1M	All RCAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
341-M & 341-1M	All RCAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
341-M & 341-1M	All RCAs	Category III	WBC, 1/yr	None required	X00
Roving Employees	RCAs excluding U handling facilities	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1/yr	Pu02; Sr01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
Roving Employees	RCAs excluding U handling facilities	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
Roving Employees	RCAs excluding U handling facilities	Category III	WBC, 1/yr	None required	X00
Roving Employees	RCAs including U handling facilities	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; EU, 2/yr; Sr, 1/yr	Pu02; EU02; Sr01
Roving Employees	RCAs including U handling facilities	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr; Sr, 1/yr	Pu01; EU01; Sr01
Roving Employees	RCAs including uranium handling facilities	Category III	WBC, 1/yr	None required	X00

a. RA = Radiological Area; TNX = code designation for Semi-works Laboratory.

Table A-6. Minimum bioassay schedules for SRS facilities, Manual 5Q1.1, Procedure 506, Revision 5 (WSRC 1996).[a]

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
SRTC	Chemical Technology	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Am, Cm, and Cf, 2/yr	Pu02; Am02
SRTC	Chemical Technology	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
SRTC	Analytical Development	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 1/yr	Pu01; Sr01; Am01
SRTC	Analytical Development	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
SRTC	Interim Waste	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
SRTC	Defense Waste	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
SRTC	High-Level Cave	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 2/yr	Pu01; Sr01; Am02
SRTC	Materials Technology (Fab Lab)	Category I	WBC, 1/yr	U, 12/yr; Pu, 1/yr	U12; Pu01
SRTC	Materials Technology (Fab Lab)	Category II	WBC, 1/yr	Pu, 1/yr	Pu01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
SRTC	Equipment Engineering	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
SRTC	Equipment Engineering	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
SRTC	Support Personnel (Maintenance/E&I, RCO, Construction, etc.)	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1/yr; Am, Cm, and Cf, 2/yr	Pu02; Sr01; Am02
SRTC	Support Personnel (Maintenance/E&I, RCO, Construction, etc.)	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr; Am, Cm, and Cf, 1/yr	Pu01; Sr01; Am01
SRTC	All RBAs	Category III	WBC, 1/yr	None required	X00
100-Areas & 400-Area	All RBAs	Category I, II, & III	WBC, 1/yr	Tritium, 1/mo[b]	T30
TNX	All RBAs	Category I	WBC, 1/yr	EU, 4/yr	EU04
TNX	All RBAs	Category II & III	WBC, 1/yr	None required	X00
221-F Canyon	All RBAs	Category I	WBC, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
221-F Canyon	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F Canyon	All RBAs	Category III	WBC, 1/yr	None required	X00
221-F A-Line & 211-F (Outside Facilities)	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
221-F A-Line & 211-F (Outside Facilities)	All U RBAs	Category I	WBC, 1/yr	U, 12/yr	U12
221-F A-Line & 211-F (Outside Facilities)	All RBAs	Category II & III	WBC, 1/yr	None required	X00
221-F B-Line	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 4/yr	Pu04
221-F B-Line	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F B-Line	All RBAs	Category III	WBC, 1/yr	None required	X00
221-F New Special Recovery	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr	Pu01
221-F New Special Recovery	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
221-F New Special Recovery	All RBAs	Category III	WBC, 1/yr	None required	X00
221-F Plutonium Storage Facility	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr	Pu01
221-F Plutonium Storage Facility	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-F Plutonium Storage Facility	All RBAs	Category III	WBC, 1/yr	None required	X00
235-F	All RBAs excluding Np Line	Category I	WBC, 1/yr	Pu, 4/yr	Pu04
235-F	All RBAs excluding Np Line	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
235-F	All RBAs excluding Np Line	Category III	WBC, 1/yr	None required	X00
235-F	All RBAs including Np Line	Category I	WBC, 1/yr	Pu, 4/yr; Np, 1/yr	Pu04; Np01
235-F	All RBAs including Np Line	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
235-F	All RBAs including Np Line	Category III	WBC, 1/yr	None required	X00
772-F	PUREX & Pu Sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
772-F	PUREX & Pu Sections	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-F	U Section	Category I	WBC, 1/yr; chest count, 1/yr	EU, 2/yr	EU02
772-F	U Section	Category II	WBC, 1/yr	EU, 1/yr	EU01
772-F	All RBAs in all sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; EU, 1/yr; Sr, 1 yr	Pu02; EU01; Sr01
772-F	All RBAs in all sections	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-F	All RBAs	Category III	WBC, 1/yr	None required	X00
772-IF	PUREX & Pu sections	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1 yr	Pu02; Sr01
772-IF	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
772-IF	All RBAs	Category III	WBC, 1/yr	None required	X00
247-F	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
247-F	All RBAs	Category II	WBC, 1/yr	EU, 1/yr	EU01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
247-F	All RBAs	Category III	WBC, 1/yr	None required	X00
221-H Canyon	All RBAs	Category I	WBC, 1/yr	Pu, 2/yr; EU, 4/yr	Pu02; EU04
221-H Canyon	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr	Pu01; EU01
221-H Canyon	All RBAs	Category III	WBC, 1/yr	None required	X00
221-H, B-Line	All RBAs	Category I	WBC, 1/yr	Pu, 4/yr; Np, 1/yr	Pu04; Np01
221-H, B-Line	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr	Pu01
221-H, B-Line	All RBAs	Category III	WBC, 1/yr	None required	X00
211-H	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; EU, 4/yr	Pu01; EU04
211-H	All RBAs	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr	Pu01; EU01
211-H	All RBAs	Category III	WBC, 1/yr	None required	X00
232-H, Line III	All RBAs	Category I, II, & III	WBC, 1/yr	Tritium 1/mo[b]	T30
232-H; 233-H; 234-H; 238-H	All RBAs	Category I, II, & III	None Required	Tritium 1/mo[b]	T30
244-H	All RBAs	Category I & II	WBC, 1/yr	Pu, 1/yr	Pu01
244-H	All RBAs	Category III	WBC, 1/yr	None required	X00
241-F	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
241-F	All RBAs	Category II & III	WBC, 1/yr	None required	X00
241-H	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 2 yr	Pu01; Sr02
241-H	All RBAs	Category II & III	WBC, 1/yr	None required	X00
299-H	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
299-H	All RBAs	Category II & III	WBC, 1/yr	None required	X00
241-84H	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
241-84H	All RBAs	Category II & III	WBC, 1/yr	None required	X00
643-E; 643-1E; Burial Ground & Support Facilities	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
643-E; 643-1E; Burial Ground & Support Facilities	All RBAs	Category II & III	WBC, 1/yr	None required	X00
210-Z	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
210-Z	All RBAs	Category II & III	WBC, 1/yr	None required	X00
221-S; 512-S	All RBAs	Category I	WBC, 1/yr	Pu, 1/yr; Sr, 1 yr	Pu01; Sr01
221-S; 512-S	All RBAs	Category II & III	WBC, 1/yr	None required	X00
313-M	All RBAs	Category I & II	WBC, 1/yr	U, 12/yr	U12
313-M	All RBAs	Category III	WBC, 1/yr	None required	X00
320-M	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr; U, 12/yr	EU04; U12
320-M	All RBAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
320-M	All RBAs	Category III	WBC, 1/yr	None required	X00
321-M	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
321-M	All RBAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
321-M	All RBAs	Category III	WBC, 1/yr	None required	X00
322-M	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr; U, 12/yr	EU04; U12
322-M	All RBAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
322-M	All RBAs	Category III	WBC, 1/yr	None required	X00
341-M & 341-1M	All RBAs	Category I	WBC, 1/yr; chest count, 1/yr	EU, 4/yr	EU04
341-M & 341-1M	All RBAs	Category II	WBC, 1/yr	EU, 1/yr	EU01
341-M & 341-1M	All RBAs	Category III	WBC, 1/yr	None required	X00
Roving Employees	RBAs excluding uranium handling facilities	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; Sr, 1/yr	Pu02; Sr01
Roving Employees	RBAs excluding uranium handling facilities	Category II	WBC, 1/yr	Pu, 1/yr; Sr, 1/yr	Pu01; Sr01
Roving Employees	RBAs excluding uranium handling facilities	Category III	WBC, 1/yr	None required	X00
Roving Employees	RBAs including uranium handling facilities	Category I	WBC, 1/yr; chest count, 1/yr	Pu, 2/yr; EU, 2/yr; Sr, 1/yr	Pu02; EU02; Sr01

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Facility	Work area	Worker classification	In vivo requirements	In vitro requirements	Schedule code
Roving Employees	RBAs including uranium handling facilities	Category II	WBC, 1/yr	Pu, 1/yr; EU, 1/yr; Sr, 1/yr	Pu01; EU01; Sr01
Roving Employees	RBAs including uranium handling facilities	Category III	WBC, 1/yr	None required	X00
SREL[c]	N/A	N/A	N/A	N/A	N/A

a. RBA = Radiological Buffer Area; RCO = Radiological Control Operations.
b. For personnel entering RBAs >1/mo. where sampling is required. For other, less frequent entry, job specific samples should be left (bioassay code X-00 assigned).
c. Routine program not required under normal conditions. Contact Bioassay Customer Representative for guidance for special work or unusual occurrences.

Table A-7. Source terms from Farrell and Findley (1999).

Location or waste stream	Radioisotope	Dose fraction
221-F B Line	Pu	98% Pu
235-F	Pu, Np	99% Pu
221-F Canyon/Outside Facilities	Pu	95% Pu
MPPF	Pu, Am	99% Am
221-F A-Line	U	97% U
221-H B-Line	Pu	94% Pu
221-H/Outside Facilities	Pu, Am, Np	68% Pu 8% Am 12% Cm
221-H A-Line	U	98% U
F- & H-Area Tanks	Pu, Am, Sr	Not provided
DWPF (200-S Area)	Pu	Not provided
Low Level Waste Sort Facility	Pu	Not provided
RBOF, K- and L-Areas	Pu, Am, H	Not provided
C-, P-, and R-Areas	H, Pu, Am, Sr	Not provided
M-Areas	H, U	Not provided
H-Area (Tritium Production Facilities)	H, U	Not provided
776-D Waste Stream (773-A 776-5A)	Pu, Am	88% Pu 11% Am
B-Process Waste Stream (773-A)	Pu, Am	83% Am 17% Cm
C-Process Waste Stream (773-C)	Pu	93% Pu
F-Wing Boot Waste Stream	Am	71% Am 29% Cm
SCH-3-D Waste Stream (773-A)	Pu, Am	70% Cm 24% Pu 6% Am
776-4A HEPA Filters Waste Stream	Pu, Am	78% Pu 7% Am 15% Cm
ADS-1 Waste Stream (Analytical Development System Laboratories)	Pu, Am	88% Pu 11% Am & Cm
Canyon Waste Stream (773-A CHTS , ADS laboratories)	Pu	97% Pu
Non-Canyon Waste Stream (773-A non CHTS, ADS laboratories)	Pu, Am	76% Pu 23% Cm
Casks Waste Stream (HLW sludge)	Pu, Am	82% Cm 17% Pu
Casks Waste Stream (HLW supernate)	Pu	99% Pu
Californium Waste Stream (773-A F Wing Cf facilities)	Am	100% Cf
CLAB Waste Stream A (Building 772-1F Laboratory Modules L120, L122, L126, L127, and L130)	Pu	99% Pu
CLAB Waste Stream B (772-1F Laboratory Modules L125, L128, L129, L132, L137, L156, 772-1F Cells (including Cell exhaust system) and 772-1F Filter Room)	Pu	94% Pu
CLAB Waste Stream C (Building 772-1F Laboratory Modules L108, L121, L133, L149, L150, L152, Off Gas Exhaust, RCO Exhausts, 772-1F drain line exhaust, 772-1F vacuum systems and Building 772-F Shielded Area/Fan Room, Liquid By-Product Tanks, Laboratory Module L162 and the 772-4F Area)	Pu	99% Pu
CLAB Waste Stream D (Building 772-1F Laboratory Module L134)	Pu, U	78% Pu 16% U

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Location or waste stream	Radioisotope	Dose fraction
CLAB Waste Stream E (Building 772-F Laboratory Modules L131, L138, L139, L146, L147, L154, L155, and L171)	Pu, Am	67% Am 32% Pu
CLAB Waste Stream F (772-F Laboratory Modules L126, L130, L158, L159, and L163)	Pu	97% Pu
CLAB Waste Stream G (772-F/772-4F filter room)	Pu, Am	79% Pu 18% Am
CLAB Waste Stream H (Building 772-F Laboratory Modules L142, L143, L146, L147, L174, L175, and L183)	Pu, Am	89% Am 11% Pu
CLAB Waste Stream I (Building 772-F Laboratory Modules L110, L111, and L119)	H	100% H
CLAB Waste Stream J (Building 772-F Laboratory Modules, which is disposed of in the 772F LSC drum)	Pu, Am, H	53% Am, 33% H, 12% Pu

a. DWPF = Defense Waste Processing Facility; HEPA = high-efficiency particulate air.

Table A-8. Source terms from Farrell and Findley (1999) versus Manual 5Q1.1, Procedure 506, Revision 5, minimum bioassay schedules.

Farrell and Findley (1999) location or waste stream	Farrell and Findley (1999) analyses	Manual 5Q1.1, Procedure 506, Revision 5 location	Manual 5Q1.1, Procedure 506, Revision 5 analyses
221-F B Line	Pu	221-F B Line	Pu
235-F	Pu, Np	235-F	Pu, Np
221-F Canyon/Outside Facilities	Pu	221-F Canyon	Pu, Sr, U
MPPF	Pu, Am	221-F Canyon	Pu, Sr, U
221-F A-Line	U	221-F A-Line and 221-F	Pu, Sr, U
221-H B-Line	Pu	221-H B line	Pu, Np
221-H/Outside Facilities	Pu, Am, Np	221-H Canyon	Pu, U
221-H A-Line	U	221-H Canyon	Pu, U
F- & H- Area Tanks	Pu, Am, Sr	241-F, 241-H	Pu, Sr, Pu
DWPF (200-S Area)	Pu	241-H	Pu
Low Level Waste Sort Facility	Pu	643-E, 643-1E and Support Facilities	Pu, Sr
RBOF, K- and L-Areas	Pu[a], Am[a], H	244-H, K-Area, L-Area	Pu; H
C-, P-, and R-Areas	H, Pu, Am, Sr	C-Area, P-Area	H
M-Area	H, U	313-M, 321-M, 322-M, 342-M, and 341-M	U
H-Area (Tritium Production Facilities)	H, U	232-H, 234-H, 238-H	H
776-D Waste Stream (773-A 776-5A)	Pu, Am	773-A, 776-A	Pu, Sr; Pu, Sr, Am
B-Process Waste Stream (773-A)	Pu, Am	773-A, Analytical Development Division	Pu, Sr, Am
C-Process Waste Stream (773-C)	Pu	773-A, Analytical Development Division	Pu, Sr, Am

ATTACHMENT A
BIOASSAY FREQUENCIES AND SOURCE TERMS (continued)

Farrell and Findley (1999) location or waste stream	Farrell and Findley (1999) analyses	Manual 5Q1.1, Procedure 506, Revision 5 location	Manual 5Q1.1, Procedure 506, Revision 5 analyses
F-Wing Boot Waste Stream	Am	773-A, Analytical Development Division	Pu, Sr, Am
SCH-3-D Waste Stream (773-A)	Pu, Am	773-A	Pu, Am
776-4A HEPA Filters Waste Stream	Pu, Am	776-A	Pu, Sr, Am
ADS-1 Waste Stream (Analytical Development System Laboratories)	Pu, Am	773-A, Analytical Development Division	Pu, Sr, Am
Canyon Waste Stream (773-A CHTS, ADS laboratories)	Pu	773-A, Analytical Dev. Division, Chem. Tech. Section	Pu, Sr, Am
Non-Canyon Waste Stream (773-A non CHTS, ADS laboratories)	Pu, Am	773-A, Int. Waste Section, Def. Waste Section; 773-A, Mat. Science Section; 773A, HLC	Pu, Sr; U, Pu; Pu, Sr, Am
Casks Waste Stream (HLW sludge)	Pu, Am	773-A	Pu, Sr
Casks Waste Stream (HLW supernate)	Pu	773-A	Pu, Sr
Californium Waste Stream (773-A F Wing Cf facilities)	Am	773-A, HLC, Analytical Development Division	Pu, Sr, Am
CLAB Waste Stream A (Building 772-1F Laboratory Modules L120, L122, L126, L127, and L130)	Pu	772-1F	Pu, Sr
CLAB Waste Stream B (772-1F Laboratory Modules L125, L128, L129, L132, L137, L156, 772-1F Cells (including Cell exhaust system) and 772-1F Filter Room)	Pu	772-1F	Pu, Sr
CLAB Waste Stream C (Building 772-1F Laboratory Modules L108, L121, L133, L149, L150, L152, Off Gas Exhaust, RCO Exhausts, 7721F drain line exhaust, 772-1F vacuum systems and Building 772F Shielded Area/Fan Room, Liquid By-Product Tanks, Laboratory Module L162 and the 772-4F Area)	Pu	772-1F	Pu, Sr
CLAB Waste Stream D (Building 772-1F Laboratory Module L134)	Pu, U	772-1F	Pu, Sr
CLAB Waste Stream E (Building 772-F Laboratory Modules L131, L138, L139, L146, L147, L154, L155, and L171)	Pu, Am	772-F	Pu, U, Sr
CLAB Waste Stream F (772-F Laboratory Modules L126, L130, L158, L159, and L163)	Pu	772-F	Pu, U, Sr

Farrell and Findley (1999) location or waste stream	Farrell and Findley (1999) analyses	Manual 5Q1.1, Procedure 506, Revision 5 location	Manual 5Q1.1, Procedure 506, Revision 5 analyses
CLAB Waste Stream G (772-F/772-4F filter room)	Pu, Am	772-F	Pu, U, Sr
CLAB Waste Stream H (Building 772-F Laboratory Modules L142, L143, L146, L147, L174, L175, and L183)	Pu, Am	772-F	Pu, U, Sr
CLAB Waste Stream I (Building 772-F Laboratory Modules L110, L111, and L119)	H	772-F	Pu, U, Sr
CLAB Waste Stream J (Building 772-F Laboratory Modules which is disposed of in the 772-F LSC drum)	Pu, Am, H	772-F	Pu, U, Sr

a. For those RWPs requiring respiratory protection due to the presence of particulate contamination such as for disassembly basin workers.

ATTACHMENT B
EXAMPLES OF WHOLE-BODY AND CHEST COUNT REPORTS

LIST OF FIGURES

ATTACHMENT B
EXAMPLES OF WHOLE-BODY AND CHEST COUNT REPORTS

SAVANNAH RIVER PLANT
IN VIVO COUNT RESULTS

NAME [ ] DEPT LAB HEIGHT (M) [ ]

PR# [ ] LOCATION 772-F WEIGHT (KG) [ ]

DATE 5 5 83 AGE [ ] CHEST WALL (CW) 2.2

TIME 11:15 SEX [ ] COUNT, SEC 1800

SPECIAL COUNT, REF DPSTN 2011 FOR INTERPRETATION.

WHOLE BODY COUNT (NAI) MDA@95%CL

NUCLIDE	ENERGY(MEV)	GROSS	BKGD	NET	CALC	DIFF	COUNTS	NCI
CE-144	0.104 TO 0.145	6658	6093	565	747	-182	387	16
CR-51	0.290 TO 0.349	7405	7324	81	326	-245	409	13
I-131	0.334 TO 0.400	6240	5996	244	208	36	369	17
RU-106	0.449 TO 0.539	6059	6047	12	222	-210	371	10
CS-137	0.625 TO 0.704	3879	3829	50				
ZR-NB-95	0.710 TO 0.800	3205	3214	-9	100	-109	270	8
ZN-65	1.050 TO 1.160	2580	2425	155	229	-74	242	4
CO-60	1.105 TO 1.250	3199	2911	198	238	-40	263	2
CO-60	1.250 TO 1.375	2115	1961	154	219	-65	219	2
K-40	1.344 TO 1.534	4207	3357	850				

GM POTASSIUM = 85 NCI CS-137 = -0.86

CHEST COUNT (NAI)

EMISSION	ENERGY(MEV)	GROSS	BKGD	NET	CALC	DIFF	DL
L X RAY	0.014 TO 0.022	438	313	125	97	28	47
	0.022 TO 0.047	943	347	596	546	50	69
AM 241	0.048 TO 0.066	940	337	603	535	68	68
	0.066 TO 0.089	1096	461	635	704	-69	79
K SCATTER	0.090 TO 0.127	1245	481	764			

ISOTOPE	MDA @95% CL (NCI)
AM 241	0.15
PU 239	27
PU 238	10
CM 244	13

Figure B-1. WBC and chest count report, 1983 (SRS 1995).

ATTACHMENT B
EXAMPLES OF WHOLE-BODY AND CHEST COUNT REPORTS

ASCOS-Plus | Printed:12-OCT-1998 09:32:40 | Page: 1

Subject name:
Work Location: 321-M
Counter Location: 735-4B
Reason: Routine
Count type: Individual
Height:
Sex:
CWT: 2.9757
Comment: ROUTINE CHEST COUNT(DOOR CLOSED)

Identification #:
Count Started: 12-OCT-1998 09:02:21
Intake Date: 12-OCT-1998 09:02:21
Frequency:
Operator: KWILLIAMS
Weight:
Date of Birth:

Counter: LUNG CHAIR #1
Arrangement/Geometry: STD/L1SUM
Detector: LUNGS
Analysis limits: 50 to 2045

Facility: WESTINGHOUSE SAVANNAH RIVER CO.
Elapsed Live Time: 0 00:30:00.00
Elapsed Real Time: 0 00:30:00.10
Count Rate: 1.327 1.266 1.857 1.519 0.00 0.00 0.00 0.00

Peak Search Results for STD/L1SUM

Nuclide	Energy (keV)	Activity (nCi)	%Error (2 SD)	%Gain	Fit	Area	Centroid (ch)	Comments
PB-214	351.98	0.198	63.4	0.03	0.48	21	1758.36	BKGD-YK

Nuclide Results for STD/L1SUM

Nuclide	Activity (nCi)	%Error (2 SD)	Comments
CS-137	< 1.78		MDA activity reported
PB-212	<0.160		MDA activity reported
PB-214	0.198	63.4	
AC-228	<0.527		MDA activity reported
TH-234	< 1.21		MDA activity reported
U-235	<9.947E-02		MDA activity reported
NP-237	<0.328		MDA activity reported
PU-238	< 93.4		MDA activity reported
PU-239	< 240.		MDA activity reported
AM-241	<0.141		MDA activity reported
totals:	0.198		

Energy Calibration Performed: 4-AUG-1998 13:29:46. STD/L1SUM Efficiency Calibration Performed: 5-AUG-1998 15:32:59.
Libraries Used: ND_WBC_LIB:LOW-ENERGY.WLB,ND_WBC_LIB:LOW-ENERGY.WLB,ND_WBC_LIB:LOW-ENERGY.WLB
Analyses By: GAMMAM V1.2,PEAKEFF V2.2,NID V3.2,MINACT V2.5

Reviewed by: Date: 10.14.98

Figure B-2. WBC and chest count report, 1998 (SRS 1975–2018).