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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
08/16/2011	00	This report describes activities performed by the Savannah River Site (SRS) related to the burning of radioactive solvent waste with the objective of determining the feasibility of reconstructing internal doses potentially received from exposures to fission product and alpha radionuclides. Incorporates formal NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by James M. Mahathy and Joseph S. Guido.

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ACRONYMS AND ABBREVIATIONS

cm	centimeter
cpm	counts per minute
ft	foot
g	gram
gal	gallon
L	liter
m	meter
mL	milliliter
MPC	maximum permissible concentration
NIOSH	National Institute for Occupational Safety and Health
pCi	picocurie
SRS	Savannah River Site
µCi	microcurie

1.0 INTRODUCTION

A series of burning/rubble pits was used at the Savannah River Site (SRS) from site construction through 1974 to dispose of various types of wastes. The burning pits were set up at the Central Shops Area and in F-Area to burn construction wastes. As reactors were built and brought on line, rubble pits were installed near each reactor to burn construction waste and other nonradioactive waste items including scrap materials and volatile organic materials. Mostly nonradioactive materials were burned in pits in D-, F-, K-, L-, P-, and R-Areas. There were also burning pits for nonradioactive materials at the TNX facility and the metals burning pit. A pit for burning radioactive waste was constructed in the Radioactive Waste Burial Ground, 643-G. Burning pits were created by bulldozing open trenches between 8 to 12 ft deep and from 250 to 400 ft long. The waste was burned about once a month (RAC 2001). At 643-G, solvent was burned in an 8 × 8 × 4-ft steel pan with a rain shed over the top; the pan was replaced in 1964 due to corrosion by a longitudinally halved 400-gal tank (DuPont 1973).

Materials Burned

Most of the radioactive materials burned at the SRS Radioactive Waste Burial Ground were spent and degraded solvents, such as tributyl phosphate and kerosene collected from the separations areas. Before being burned, the solvents were washed as part of SRS solvent recovery (DuPont 1958a). SRS implemented an improved solvent washing procedure in May 1955 that used a higher concentration of NaOH in the caustic wash followed by an additional water wash to remove residual caustic material and the associated activity more efficiently (DuPont 1955). A continuous solvent wash system was implemented in the 200-Area in 1956 (Christl 1956). As an example of solvent washing results, the SRS Works Technical Department reported that as of May 28, 1956, hot solvent gamma activities in F-Area for the previous 4 weeks had averaged 2.2×10^4 cpm/mL unwashed; and 4.5×10^3 cpm/mL washed (DuPont 1956b). Residues from the washing process that were too high to burn were stored in tanks to enable decay of short-lived fission product activity. Residues were monitored by gross gamma, gross beta, and gross alpha analysis, as needed, before being burned (DuPont,1956c,d, 1957a,b, 1958b, 1963a, 1965a). The gamma activity level in 1957 was 4,000 cpm/mL (DuPont 1957b). By 1960, the SRS Health Physics Section had implemented a gamma activity limit of 1,000 cpm/mL; solvents exceeding that amount could not be burned (DuPont 1960). In addition, gamma dose rates were measured at the burning pit (DuPont 1957b, 1963a,b, 1965a).

Information and data about the burning of solvents have been reported in some Works Technical Department monthly progress reports. A total of 170,000 gallons of solvent were burned prior to February 1964 and it is believed that the best estimate of the total amount burned to be 400,000 gallons between 1956 and 1972 (RAC 2001). Table 1-1 below provides a tabular summary of monthly quantities burned, based on available data.

Monthly reports suggest that burning was not continuous and varied tremendously from month to month ranging from zero to 19600 gal (in one week in May 1962). Burning rates were sparsely reported as well. The initial burn rate reported in February 1956 was 2 gal/min (Dupont 1956a) and was reported as 0.2 gal/min in the May 1956 (Dupont 1956b). In a December 1956 report, the burn rate was noted as ‘accelerated’ to 100 gal/hr (Dupont 1957c). The notion that a 1 gal/min burn rate was standard is further supported by a May 1963 document indicating trial burning at an accelerate rate of 3 gal/min which produced a smoke plume while no airborne activity was detected at a burning rate of 1 gallon per minute (Dupont 1963d).

The number of burning days for each month may be conservatively bounded using the 95th percentile of the data in Table 1-1 (7400 gal) and apply a burring rate of 1 gal/min. This corresponds to a total of 5 burning days per month and may be used in conjunction with the intake estimates presented later in

section 3 of this document to provide a claimant favorable estimate of internal exposure from solvent burning activities.

Table 1-1. Estimate of solvent burned.

Period	Gallons burned		Period	Gallons burned
02/56	200		9/58–10/58	2,894[a]
3/56–4/56	1,380[a]		11/58–3/60	3,400[a]
05/56	830		04/60	1,000
06/56	690		5/60–7/60	6,650[a]
07/56	5,300		8/60–4/62	30,389[a]
08/56	4,000		05/62	19,600
9/56–10/56	4,980[a]		6/62–12/63	27,495[a]
11/56	870		1/64–3/64	21,600[a]
12/56	10,700		04/64	4,000
01/57	3,300		5/64–12/64	57,600[a]
02/57	0		01/65	3,000
03/57	1,930		02/65	5,000
04/57	270		03/65	8,533[a]
05/57	3,565		04/65	1,800
06/57	1,126		5/65–7/65	25,600[a]
07/57	1,790		08/65	1,800
08/57	1,447[a]		9/65–10/65	17,067[a]
09/57	0		11/65	9,000
10/57	0		12/65	7,250
11/57–12/57	2,894[a]		01/66	800[a]
01/58	1,115		02/66	0
2/58–6/58	7,555[a]		3/66–8/66	4,800[a]
07/58	8,180		09/66	7,800
08/58	2,050		10/66–12/73	68,800[a]

a. Indicates calculated average based on summary data and quantities accounted for in intervening months

2.0 RADIOLOGICAL MONITORING

The SRS performed downwind air monitoring during the infrequent (as many as 3 days per month) (DuPont 1956b) burning events. Ground-water monitoring was also performed but is not the subject of this report. Stationary sampling using adhesive paper and monitoring of vegetation around the perimeter of the burial ground indicated negligible fallout from the solvent burning (DuPont 1973). RAC 2001 stated that the release of radionuclides from solvent burning had been negligible through 1970.

NIOSH has identified summary results of the fission product air monitoring data mentioned above. The data were recorded in monthly reports and other documents (Butler 1956; DuPont 1956e,f, 1957c,d,e,f,g, 1958a,b, 1960, 1963c,d, 1965a). Maximum permissible concentrations (MPCs) for fission products in air was 200 pCi/m^3. Results of air monitoring are not provided for all months because the formats of the monthly reports varied during the period of solvent burning (RAC 2001). The fission product monitoring results, assumed to be gross beta analyses, are provided in Table 2-1.

The 3,500 pCi/m3 recorded in April 1965 resulted from the handling and burial of a highly contaminated heat exchanger. Some solvent was burned, but DuPont (1965a) implies that the high-fission product resulted from the burial of the heat exchanger head and evaporator.

NIOSH has obtained maximum air monitoring results from four events in which solvents containing plutonium alpha wastes were burned. These results are shown in Table 2-2.

Only two results showed detectable activity: 2 pCi/m^3 (April 1963c) and 88 pCi/m^3 (August 1965) (Dupont 1963c, DuPont 1965b). The maximum result, obtained on July 30, 1965 during field sampling, exceeded the 1965 site radioactivity concentration guide (RCG) for Pu by a factor of 44. That particular operation was conducted over an 11-day period; about 1800 gal of spent process solvent was burned. The measured alpha air concentration had increased with each of four batches burned in that event; presumably due to a buildup of activity in the residue. Dupont 1965b states that solvent was more highly contaminated with alpha radiation than any previously burned solvent. That burning event was shut down immediately after the high result was obtained (DuPont 1965b).

Table 2-1. Burning pit fission product air monitoring data (pCi/m^3).[a]

Month	Maximum measured air concentration	Radioactivity concentration guide	Reference
February 1956	20	200	Butler 1956
July 1956	20	200	DuPont 1956d
August 1956	24	200	DuPont 1956e
October 1956	160.00	200	DuPont 1956f
December 1956	1.0	200	DuPont 1957c
January 1957	1.0	200	DuPont 1957d
May 1957	< 1.0	200	DuPont 1957e
June 1957	1.0	200	DuPont 1957b
July 1957	< 1.0	200	DuPont 1957f
August 1957	< 1.0	200	DuPont 1957g
July 1958	31.8	200	DuPont 1958b
April 1959	90.0	200	DuPont 1960
January 1958	< 1.0	200	DuPont 1958a
April 1963	300	200	DuPont 1963c
May 1963	380	200	DuPont 1963d
April 1965	3,500	200	DuPont 1965a

a. Data represent maximum result measured during event monitoring when multiple samples were collected. Individual air sample results can be obtained from SRS air sample log sheets.

Table 2-2. Burning pit alpha activity product air monitoring data (pCi/m^3).[a]

Month	Maximum measured alpha air concentration	Reference
July 1958	No detectable activity	DuPont 1958b
April 1963	2[b]	DuPont 1963
May 1964	No detectable activity	DuPont 1964
July 20–30, 1965	88	DuPont 1965b

a. Data represent maximum result measured during event monitoring when multiple samples were collected.
b. Individual air sample results can be obtained from SRS air sample log sheets.

Monitoring for alpha emitters was based on assay of the degraded solvent to be burned. Burned solvent was also monitored by gross alpha analysis in 1958, although no alpha activity was detected (DuPont 1958b).

3.0 POTENTIAL INTAKE ANALYSIS

While RAC 2001 reported that the release of radionuclides from solvent burning was considered to have been negligible, NIOSH analyzed the available air monitoring data to estimate air concentrations of fission products and from plutonium.

3.1 FISSION PRODUCTS RADIONUCLIDES

The air concentration data listed in Table 2-1 were analyzed using the methodology in ORAUT-PROC-0095 (ORAUT-2005) for the purpose of determining the 95th percentile of the airborne concentration distribution.

Given the small set of air monitoring data, the 95th-percentile air concentration of fission product radionuclides (1,800 pCi/m^3) was used as the basis for calculation of a daily intake quantity of fission product radionuclides. This air concentration was applied to a 180-day-old nuclide mixture yielding intake quantities shown below in Table 3-1 (ORAUT 2007). Inhalation intakes were calculated assuming an exposure duration of 40 hrs a month (i.e., 5 8 hr days), 12 months a year, for a total annual air inhalation of 576 m^3. Ingestion intakes in units of pCi/d were calculated by multiplying the air concentration in units of pCi/m^3 by a factor of 0.2 (NIOSH 2004) and were further adjusted to calendar day intakes by multiplying by a factor of 60 (i.e., 5 burning days per month * 12 months = 60 buring days / yr)).

Table 3-1. Fission product radionuclide annual intake quantities (pCi) from 95th percentile gross beta air concentration – 1965 - 1972.

Radionuclide	Inhalation intake	Ingestion intake
Ce-141	2.E+04	5.E+02
Ce-144	2.E+05	5.E+03
Cs-134	6.E+03	1.E+02
Cs-137	2.E+04	5.E+02
Eu-155	2.E+03	3.E+01
Fe-55	2.E+04	4.E+02
Nb-95	3.E+05	6.E+03
Pm-147	6.E+04	1.E+03
Ru-103	4.E+04	7.E+02
Ru-106	9.E+04	2.E+03
Sr-89	6.E+04	1.E+03
Sr-90	2.E+04	4.E+02
Y-91	1.E+05	2.E+03
Zr-95	1.E+05	3.E+03

3.2 ALPHA-EMITTING RADIONUCLIDES

The burning of degraded solvents containing alpha emitters (plutonium) was reported in only four of the monthly described events – one each in 1958 (DuPont 1958b), 1963 (DuPont 1963c), 1964 (DuPont 1964) and 1965 (DuPont 1965b); maximum gross alpha air concentrations were also reported with two of these four burning events (Table 3-2). SRS reported "no detectable activity" from field analysis performed for the 1958 and 1964 events. Due to the limited monthly number of burning events containing alpha activity in degraded solvents, NIOSH assumes that concentrations of uranium and plutonium were negligible in most burns. However, to bound potential intakes of alpha activity, NIOSH used the two positive air monitoring results to derive a bounding air concentration of plutonium released from solvent burning. The two measured air concentrations differed by a factor of 44. While the higher sample exceeded the RCG by a factor of 44, the smaller result was equal to the 1965 RCG (2 pCi/m^3). An air concentration of 2 pCi/m^3 should be used to bound intakes of total plutonium from 1956 through 1964 and from 1966 through 1972. An air concentration of total plutonium of 88 pCi/m^3 should be used to bound intakes of plutonium for 1965 only.

Table 3-2 presents inhalation and ingestion intakes based on the air concentrations assumptions discussed above. Inhalation intakes were calculated assuming an exposure duration of 40 hrs a month (i.e., 5 8 hr days), 12 months a year, for a total annual air inhalation of 576 m^3. Ingestion intakes in units of pCi/d were calculated by multiplying the air concentration in units of pCi/m^3 by a factor of 0.2 (NIOSH 2004) and were further adjusted to calendar day intakes by multiplying by a factor of 60 (i.e., 5 burning days per month * 12 months = 60 buring days / yr)).

Table 3-2. Plutonium annual intake quantities (pCi) based on gross alpha air concentration.

Period	Inhalation intake	Ingestion intake
1956–1964, 1966–1972	1152	24
1965	50688	1056

4.0 POTENTIAL INTAKE ANALYSIS

NIOSH has found adequate data to describe the burning process, to characterize the source term, and to quantify air concentrations that resulted through the release of radioactive emissions from the burning process. Further, while SRS stated that releases of radioactivity resulting from solvent burning were negligible, NIOSH can estimate potential and plausible intakes of fission products radionuclides and plutonium for SRS workers involved in waste operations.

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