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Radiological Bioconcentration Factors for Aquatic, Terrestrial, and Wetland Ecosystems at the Savannah River Site (U)

by

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TABLE OF CONTENTS

LIST OF TABLES

Radiological Bioconcentration Factors for Aquatic, Terrestrial, and Wetland Ecosystems at the Savannah River Site

Carol L. Cummins

Executive Summary

As a result of operations at the Savannah River Site (SRS), over 50 radionuclides have been released to the atmosphere and to onsite streams and seepage basins (Cummins et al. 1991a). Now, many of these radionuclides are available to aquatic and/or terrestrial organisms for uptake and cycling through the food chain. Knowledge about the uptake and cycling of these radionuclides is now crucial in evaluating waste management and clean-up alternatives for the site.

Numerous studies have been conducted at the SRS over the past forty years to study the uptake and distribution of radionuclides in the Savannah River Site environment. In many instances, bioconcentration factors have been calculated to quantify the uptake of a radionuclide by an organism from the surrounding medium (i.e., soil or water). In the past, it has been common practice to use bioconcentration factors from the literature because site-specific data were not readily available. However, because of the variability of bioconcentration factors due to experimental or environmental conditions, site-specific data should be used when available.

This report compiles and summarizes site-specific bioconcentration factors for selected radionuclides released at the Savannah River Site (SRS). An extensive literature search yielded site-specific bioconcentration factors for cesium, strontium, cobalt, strontium, plutonium, americium, curium, and tritium. These eight radionuclides have been the primary radionuclides studied at SRS because of their long half lives or because they are major contributors to radiological dose from exposure. For most radionuclides, it was determined that the site-specific bioconcentration factors were higher than those reported in literature. This report also summarizes some conditions that affect radionuclide bioavailablity to and bioconcentration by aquatic and terrestrial organisms.

I. INTRODUCTION

The Savannah River Site (SRS) was operated from 1952 to 1988 to produce materials (primarily tritium and plutonium-239) used in the fabrication of nuclear weapons. Throughout most of this period, five reactors, two chemical separation facilities, a heavy water extraction facility, a nuclear fuel and target fabrication facility, waste management facilities, and the Savannah River Technology Center operated to fulfill the site mission. Since 1988, the primary mission of SRS has shifted to waste management and environmental restoration activities. However, the SRS continues to handle nuclear materials for government and some civilian purposes.

As a result of the site's operations, over 50 radionuclides have been released to the atmosphere and to onsite streams and seepage basins (Cummins et al. 1991a). When these radionuclides were released, many became available to aquatic and/or terrestrial organisms for uptake and cycling through the food chain. Knowledge about the uptake and cycling of these radionuclides is now crucial in determining waste management and clean-up alternatives for the site. Fortunately, the distribution of radionuclides in the Savannah River Site environment has been studied for the past forty years.

The uptake of a radionuclide by an organism from the surrounding medium (i.e., soil or water) can be quantified by calculating bioconcentration factors. Once calculated, bioconcentration factors can be used for many different purposes. They can be used to predict radionuclide concentrations in whole organisms, or their tissues, from the knowledge of the radionuclide concentration in the surrounding medium. Bioconcentration factors can also be used for dose assessment. Bioconcentration factors can also be used as a means to predict ecological risk to organisms in the environment.

In the past, it has been common practice to use bioconcentration factors from the literature because site-specific data were not readily available. However, because of the variability of bioconcentration factors due to environmental and/or experimental conditions, this practice may inaccurately estimate the true uptake and concentration of radionuclides. Site-specific bioconcentration factors should be used whenever available.

This report is a compilation of site-specific bioconcentration factors for selected radionuclides released from SRS. Site-specific bioconcentration factors have been calculated for cesium, strontium, cobalt, plutonium, americium, curium, and tritium.

In addition to the site-specific bioconcentration factors, literature values are provided for comparison. This report does not attempt to interpret the data presented; its primary purpose is to compile and establish a database for site-specific bioconcentration factors.

Objectives

The objectives of this report are to:

1. Provide site-specific bioconcentration factors for selected radionuclides
2. Establish a database which can be updated as new information becomes available.
3. Compare SRS bioconcentration factors with published literature values
4. Summarize conditions affecting radionuclide bioavailablity and bioconcentration

Format

This report is divided into seven chapters. Chapter II provides some discusses the concept of bioconcentration factors, including the definition and variability of the bioconcentration factors and the bioavailability of radionuclides to biota from soil and water. Chapters III - VII summarize the bioconcentration factors for cesium, cobalt, strontium, transuranics (plutonium americium, and curium), and tritium, respectively. Chapters III - VII are further divided into sections which discuss aquatic and then terrestrial and wetland bioconcentration factors.

Additional bioconcentration factors were obtained for sulfur-35, chromium-51, manganese-54, zinc-65, cerium-144, and radium-226. However, due to the limited amount of data, there is no chapter to discuss these factors. The data are presented only in the Appendices.

Appendices A and B contain comprehensive tables, which provide detailed information about how each bioconcentration factor was calculated, the location and number of samples, and the literature reference from which the bioconcentration factor was obtained. Aquatic and terrestrial and wetland bioconcentration factors are given in Appendices A and B, respectively. Data in the Appendices are sorted first by radionuclide and second by the organism for which the bioconcentration factor is available.

The bioconcentration factors given in this report were calculated from measured concentrations. In reporting each bioconcentration factor, the tissue or tissues of the organism analyzed are specified. The bioconcentration factors are based on a dry weight basis, unless otherwise noted. If conversion factors were available in the publication for conversion to wet-weight, the conversion factor is also given.

The data presented within this report were collected by searching the literature for site-specific bioconcentration factors. All listed publications of Savannah River Ecology Laboratory (SREL) were reviewed and the appropriate documents obtained. A key word search of the PINT database and a review of SRS environmental monitoring reports yielded additional publications.

II. CONCEPT OF BIOCONCENTRATION FACTORS

Definition of Bioconcentration Factor

The bioconcentration factor for an organism or tissue is defined as the steady state ratio of radionuclide concentration in the organism or tissue to that in the reference medium (Vanderplog et al. 1975):

$BCF = [C]_{org} / [C]_{med}$

where, BCF is the bioconcentration factor

$[C]_{org}$ is the concentration of the radionuclide in the organism or tissue

$[C]_{med}$ is the concentration of the radionuclide in the specific medium (e.g., water, soil)

For this report, aquatic bioconcentration factors were calculated with water being the reference medium. Terrestrial and wetland bioconcentration factors were calculated with soil being the reference medium. Any deviations will be noted in the comprehensive tables found in the Appendices.

The primary simplifying assumption (which will be used in this report) in using the bioconcentration factor is that the radionuclides are taken up directly from the reference material. However, this may not be entirely true in all cases. With aquatic bioconcentration factors, the organism may take up radionuclides from the sediment and/or food in addition to water. With terrestrial bioconcentration factors, uptake of radionuclides may occur from deposition or from food (at higher trophic levels).

Before using a bioconcentration factor, it is important to know if the bioconcentration factor chosen is appropriate for its intended use. Certain elements have an affinity for different tissues and these attributes will be reflected in the bioconcentration factor. For example, in dose assessment activities, bioconcentration factors for the edible portion of the organism are most important. However, in terms of ecological risk, whole-body bioconcentration factors may be most important.

Variability of Bioconcentration Factors

Bioconcentration factors can vary greatly depending on environmental as well as experimental conditions. Each of these conditions must be considered when choosing the appropriate bioconcentration factor to use.

Environmental Conditions

There are numerous environmental conditions that will affect the bioconcentration factor for an organism. Some of these conditions, which are discussed below, include the length of residence in a contaminated area, species and individual uptake variations, the chemical state of the radionuclide, and contributions from deposition.

The length of residence in a contaminated area is an environmental condition that will affect both aquatic and terrestrial bioconcentration factors. Organisms, which are confined exclusively to the contaminated area, tend to have higher concentration factors than those organisms that are free to enter and leave the area (Whicker et al. 1989).

There will also be variations in uptake among species and among individuals within a species. The type of food chain, as well as the metabolism of an organism, will have an impact on uptake (Thompson et al., 1972). For terrestrial organisms, soil-to-plant concentration factors can also be expected to exhibit seasonal variation (Garten et al. 1975a).

The chemical state of the radionuclide will also affect the bioconcentration factor. Radionuclides exist in different chemical forms in aquatic and terrestrial systems, and their different forms have different availabilities to different organisms. In most cases, uptake of the radionuclide is similar to that of the stable element analog.

A major environmental condition to consider when determining a terrestrial bioconcentration factor is deposition. Deposition must be considered because it overestimates the bioconcentration factor and does not give a true indication of uptake. In experimental studies of plant-to-soil uptake, green house experiments are usually performed to eliminate overestimates from deposition. However, greenhouse results are difficult to extrapolate to field responses because of differences in climate and root growing conditions. Greenhouse experiments can, however, provide information relative to the effect of environmental factors on bioavailability which are often difficult to obtain from field experiments (Adriano et al. 1981a). Several terrestrial bioconcentration studies summarized in this report were performed in a greenhouse after soil samples were collected from the study area. If an experimental study was conducted in the field, it is noted in the table. The field experiments summarized in this document were not affected by deposition.

Experimental Conditions

Experimental conditions which affect bioconcentration factors are not dependent on the radionuclide or location. These variations result from artifacts of analysis and evaluation and presentation of data. Some experimental factors, which are discussed below, include sampling error, analytical error, and calculation methods.

Representative samples must be collected in order to obtain appropriate bioconcentration factors. Samples that are not representative will result in an inaccurate estimate of the true bioconcentration factor. It is also important for the organism and reference medium to have reached a steady state at the time of sample collection and measurement. If a steady state has not been reached, the bioconcentration factor will not be appropriate. For aquatic systems, collecting filtered or unfiltered water will also affect the bioconcentration factor. A significant fraction of some elements in water may be in the suspended phase (90% in some cases); therefore, bioconcentration factors in filtered water samples may be much larger than bioconcentration factors in unfiltered water (Vanderplog et al. 1975).

When analyzing environmental samples, the concentrations of radionuclides or stable elements in most environmental samples are so low that serious problems can be encountered with their measurement (Vanderplog et al. 1975). Many radionuclides are below detection limits and can not be measured. In other cases, there may be a large uncertainty associated with a particular measurement. In most cases it is not possible to determine the analytical errors of the measurements associated with particular studies. Therefore, it is assumed that the analytical error associated with the measurements is negligible in relation to variations due to environmental conditions.

The calculation method can also have a significant influence on the bioconcentration factor. For example, bioconcentration factors expressed in terms of dry weight of the organism are higher than those calculated using wet weight concentrations. In this report the wet or dry weight information is given in the tables in Appendices A and B.

It is also important to know for what tissue or tissues of the organism the bioconcentration factor was calculated. Some radionuclides have affinities for certain tissues and the bioconcentration factor will vary depending on how it is reported. Whole-body factors may not be the same as tissue-specific factors.

Bioavailability of Radionuclides to Biota from Water

Aquatic organisms can assimilate radionuclides from their food, from direct uptake from water, or by both mechanisms (Reichle et al. 1970). Radionuclides exist in a wide variety of physiochemical forms in natural waters. Such forms include dissolved ionic species, inorganic associations, complexes with organic molecules, adsorption to and precipitation on solids, and incorporation in biological materials or crystalline structures (Vanderplog et al. 1975). These different forms have different availabilities to the aquatic food chain. Algae (unicellular and multicellular), for example, concentrate elements from the soluble phase. Aquatic vascular plants accumulate elements from both the soluble phase as well as from the interstitial water of sediment. Aquatic animals, especially filter feeders, may accumulate radionuclides from the suspended phase (Vanderplog et al. 1975).

Radionuclides enter the food webs not only from water, but also from bottom sediments; thus, the availability of some radionuclides to the food web will vary with sediment type. Benthic invertebrates accumulate radionuclides from bottom sediments. Fishes may accumulate radionuclides indirectly from bottom sediment by ingestion of benthic invertebrates and also directly by incidental ingestion of sediment with prey (Vanderplog et al. 1975).

The chemical composition of water can also influence the bioconcentration of radionuclides in biota. It has been established that for cesium, strontium, and cobalt there is a relationship between the bioconcentration factor and the chemical composition of the water. The bioconcentration of cesium is related to the concentration of potassium and suspended solids in the water. For strontium, the concentration of calcium in the water affects uptake of strontium in fish. The concentration of calcium does not appear the affect strontium uptake in other aquatic organisms. The uptake of cobalt appears to be affected by the eutrophy (as defined by the nutrient content) of the water; Uptake tends to decrease with increasing eutrophy of the water (Vanderplog et al. 1975).

Bioavailability of Radionuclides to Biota from Soil

The uptake of a radionuclide from soil by plants depends on various interrelated soil properties including texture, clay content, dominant clay mineral, cation exchange capacity, exchangeable cations, pH, and organic matter content. Uptake also varies with the chemical and physical forms of the radionuclide, the plant species, plant part, stage of growth, as well as with management practice and the manner in which the radionuclide is introduced into the soil (Ng 1982).

When a radionuclide is introduced into the soil in soluble form, it can adsorb on clays, precipitate as an oxide or hydroxide, chelate with soil organic molecules, or remain in solution. The manner in which the radionuclide is distributed among these various fractions will determine how long it will remain at the site of deposition and the extent to which it will be available for uptake by plants (Eisenbud 1973).

As a general rule, radioisotopes present in soil will pass into the root system in the same manner as nonradioactive isotopes of the same or analogous cations. The element may or may not be required for normal metabolism, and some elements like iodine, cobalt, uranium, and radium are known to be present in plants although they serve no metabolic function (Eisenbud 1973). Radioisotopes of elements ordinarily present in soil and normally utilized in plant metabolism are absorbed in a manner independent of their radioactive properties. According to Nishita (1961), the relative uptake of radionuclides from soils is Sr>>I>Ba>Cs, Ru>Ce>Y, Pm, Nb, Zr>Pu. Uptake of long-lived radionuclides by plants from the soil depends on whether the radionuclide is within the reach of the plant's roots and the extent to which the radionuclide is chemically available.

Determining bioconcentration factors at higher trophic levels introduces more variables which may affect the bioconcentration factor. Terrestrial organisms can assimilate radionuclides from any combination of their food, from direct uptake from soil, or by deposition. Species composition and food preferences, as well as radionuclide assimilation and turnover rates, will also influence trophic transfer. At the top of the food chain, species can assimilate radionuclides through the respiratory tract, skin, and gastrointestinal track (usually the most important) (Reichle et al. 1970).

III. CESIUM

Introduction

Cesium is one of the most important radionuclides to consider at SRS because it is a primary radionuclide released at SRS and is the major contributor to the maximum individual dose from liquid releases (consumption of fish). Cesium is a minor contributor to dose (<1%) from atmospheric releases (Carlton, et al. 1992a). Cesium-137 is a gamma emitter, has a 30-year half-life, and is the primary radioisotope of cesium that will be considered in this report.

Radiocesium at SRS originated primarily in the fuel and targets that were irradiated during nuclear materials production. The greatest releases of cesium occurred during the early years of operation when cesium was released to onsite seepage basins and site streams. The majority of cesium was released from the separations areas which are located in F and H areas of the site (Carlton, et al. 1992a). Approximately 1,900 Ci of cesium has been released to seepage basins and streams and 4 Ci of cesium has been released to the atmosphere (Cummins et al. 1991a).

Aquatic Bioconcentration Factors

Cesium is one of the rarest alkali metals and exists primarily as free ions in solution. Because of cesium's large size and small charge, it does not tend to form complex ions in solution. However, cesium is strongly adsorbed by suspended materials, especially clays and can be removed from the soluble phase to varying degrees (Vanderplog et al. 1975).

The aquatic food chain accumulates cesium not only from the soluble phase of water but also from suspended and bottom sediments and from absorption from food. However, most of the uptake is expected to result from ingestion of sediment or ingestion of prey that has ingested sediment. Differences in sediment type among water bodies contribute to the variability in uptake of cesium-137 in aquatic organisms.

The concentration of cesium in the soluble phase tends to decrease with increasing suspended solids concentration (Vanderplog et al. 1975). Organisms which accumulate cesium from the soluble phase will usually have lower bioconcentration factors at higher suspended solids concentrations than the same organisms at lower suspended solids concentrations.

Because of the chemical similarities and relative abundances of cesium and potassium, the bioconcentration factor for cesium in aquatic organisms (except algae) can be related to the concentration of potassium in the water (Vanderplog et al. 1975). Bioconcentration factors tend to increase with decreasing concentrations of potassium in water. Elevated concentration factors for cesium in aquatic species at SRS have been associated with low concentrations of potassium in water (Whicker et al. 1990).

Aquatic bioconcentration factors for cesium-137 are summarized in Table 3-1. More detailed information about the conditions for which the bioconcentration factor was calculated is found in Appendix A.

Site-specific bioconcentration factors for algae ranged from 1,200 to 4,500. Zooplankton had a bioconcentration factor of 71,000. Bioconcentration factors for benthic macroinvertebrates at SRS ranged from 8,000 to 12,000. Whicker et al. (1989) reported that the elevated bioconcentration factors for the zooplankton and benthic macroinvertebrates were probably due to the high surface to volume ratios of the organisms; thus allowing their surfaces, as well as their guts, to carry measurable cesium-137 activity.

The maximum bioconcentration factor for aquatic macrophytes, 37,000, was found in Fanwort, a rooted vascular plant. Bladderwort, a floating vascular plant, had a bioconcentration factor of 17,000. The emergent wetland plants, knotweed and smartweed, had the lowest bioconcentration factors, with a range from 716 to 3,420 in the leaves.

Because fishes may accumulate cesium from bottom sediment by ingestion of benthic invertebrates and also by ingestion of sediment with prey (Vanderplog et al. 1975), fish were divided into categories in this report based on their feeding habits. The maximum bioconcentration factor for all fish (muscle) was 48,000 in the gizzard shad, which feeds on detritus and plankton. For surface and midwater insectivores (shiners and mosquitofish), bioconcentration factors ranged from 891 to 11,300. For insect and bottom invertebrate feeders (bluegill, sunfish, pirate perch), bioconcentration factors in the flesh ranged from 691 to 1,330. For piscivores (bass and pickerel), bioconcentration factors ranged from 1,200 to 39,000. For benthic invertebrate and fish feeders (catfish), bioconcentration factors ranged from 908 to 29,000.

Freshwater shrimp and crayfish had bioconcentration factors of 867 and 997, respectively. Bioconcentration factors in the soft tissue of clams ranged from 220 to 300.

Wildlife species also had high bioconcentration factors. Waterfowl (composite of 7 samples) had a bioconcentration factor of 19,000 in the muscle. A composite of 10 turtles had a bioconcentration factor of 13,000 in the muscle. Water snakes (composite of 2) had a bioconcentration factor of 2,600.

These site-specific bioconcentration factors are orders of magnitude higher than values reported in the literature. As stated earlier, the relatively high bioconcentration factors of cesium-137 in fish flesh can be largely explained by the low concentrations of potassium in the water.

Table 3-1: Bioconcentration Factors for Cesium in Aquatic Ecosystems

	SRS Calculated Values				Non-SRS Values		
Cesium-137	Minimum	Maximum	Mean[a]	N[b]	Literature Ranges[c]	Vanderplog Recommendation	NRC Values[d]
Algae	1,200	4,500		2	1,016 - 3,400	1,000	
Beetles		480		1			
Clam, tissue	220	300		1	42 - 600		
Clam, shell & bone		25		1			
Detritus		938		1			
Fish muscle (surface and midwater insectivores)	891	11,300	7,009	8		$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	2,000
Fish muscle (Insect and bottom invertebrate feeders)	691	1,334	911	4	410 - 9,500	$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	2,000
Fish muscle (Piscivores)	908	39,000	10,980	5	400 - 14,000	$15{,}000/[K_w]$ [e,f] $3{,}000/[K]_w$ [g]	2,000
Fish muscle (Benthic invertebrate and fish feeders)	1,200	29,000		2	1,200 - 6,800	$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	2,000
Fish muscle (detritus and plankton feeders)		48,000		1	40 - 510	$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	2,000
Fish bone (Insect and bottom invertebrate feeders)		600		1	430 - 1,182	$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	
Fish bone (Piscivores)		500		1	700 - 1,430	$15{,}000/[K]_w$ [e,f] $3{,}000/[K]_w$ [g]	
Fish bone (Benthic invertebrate and fish feeders)		800		1	40 - 9,500	$5{,}000/[K]_w$ [e,f] $1{,}000/[K]_w$ [g]	

a Means not calculated for fewer than four data points

b N = number of values

c Literature Sources: Blaylock (1982), Coughtrey and Thorne (1985), Jorgensen et al. (1991), Till and Meyer (1983), Vanderplog et al. (1975)

d NRC values - Factors provided by the Nuclear Regulatory Commission (NRC 1977, Table A-1) for freshwater fish and invertebrates for use in calculating dose in the absence of site-specific data

e $[K]_w$ = *stable potassium concentration in water in ppm*

f clear water - suspended solids concentration less than 50 ppm

g turbid water - suspended solids concentration greater than 50 ppm

Table 3-1: Bioconcentration Factors for Cesium in Aquatic Ecosystems (cont'd)

	SRS Calculated Values				Non-SRS Values		
Cesium-137	Minimum	Maximum	Mean[a]	N[b]	Literature Ranges[c]	Vanderplog Recommendation	NRC Values[d]
Insects (Dragonflies)		648		1			
Macroinvertebrates, larvae	8,000	12,000		2	830 - 11,000	1,000	1,000
Macrophyte (rooted vascular)	295	37,000	22,460	5	130 - 1,500	1,000	
Macrophyte (Floating vascular)		17,000		1			
Macrophyte (emergent wetland)	716	3,420		3	90 - 600		
Mussels		300		1	42 - 600	1,000	
Shellfish (crayfish and shrimp)	867	997		2	240 - 1,300		
Snails		260		1	600	1,000	
Snakes		2,600		1			
Spiders		1,280		1			
Turtles. muscle		13,000		1		1,000	
Turtles, shell & bone		1,100		1		1,000	
Waterfowl, muscle		19,000		1	1,000-2,200	3,000	
Waterfowl, bone		290		1		3,000	
Zooplankton		71,000		1	501-586		

a Means not calculated for fewer than four data points
b N = number of values
c Literature Sources: Blaylock (1982), Coughtrey & Thorne (1985), Jorgensen et al. (1991), Till and Meyer (1983), Vanderplog et al. (1975)
d NRC values - Factors provided by the Nuclear Regulatory Commission (NRC 1977, Table A-1) for freshwater fish and invertebrates for use in calculating dose in the absence of site-specific data

Terrestrial and Wetland Bioconcentration Factors

Table 3-2 summarizes the terrestrial and wetland bioconcentration factors for cesium-137. Uptake of cesium-137 by plants from soil decreases with increasing concentrations of exchangeable potassium in the soil. Elevated concentration factors for cesium have been associated with soils of high organic matter content, low pH, or low clay content (Ng 1982). In areas of high clay content, root uptake of cesium is slight and folial absorption is the main portal of entry of cesium-137 into the food web (Eisenbud 1973).

Native flora, including alder, arrowhead, fungi, myrtle, pine, red maple, smartweed, turkey oak, water tupelo, and willow, have been studied in the field to determine cesium-137 uptake. Contributions from deposition were negligible. Individual bioconcentration factors for native flora ranged from 0.39 in smartweed stems to 27.9 in smartweed roots. Both samples were collected from Steel Creek. Uptake in the plant leaves ranged from 0.0053 in pine trees to 20.8 in arrowhead.

Numerous greenhouse studies on grasses and agricultural crops have also been performed. Cesium-137 uptake has been determined for corn, soybeans, wheat, bahia grass, and clover. Bioconcentration factors in the grasses ranged from 0.8 in clover to 7.59 in Bahia grass. Mean bioconcentration factors for agricultural crops were 0.56 for corn, 0.50 for soybeans, and 0.10 for wheat.

The site-specific bioconcentration factors determined for plants and grasses are higher than values reported in the literature (Table 2) and are probably due to the low clay content of the soils at the SRS.

Anderson et al. (1973) studied the relationships between the levels of cesium-137 in plants and arthropods in Steel Creek. This has been the only site-specific study to determine cesium accumulation and movement throughout a large wetland system. The results of this study produced an average bioconcentration factor of 0.51 for primary consumers to primary producers and an average bioconcentration factor of 0.96 for secondary consumers to primary consumers.

Bioconcentration of cesium-137 in SRS deer has also been studied. Bioconcentration factors for white-tailed deer (muscle) on the SRS range from 0.22 to 4.8. These values are comparable to literature values.

Table 3-2: Bioconcentration Factors for Cesium in Terrestrial and Wetland Ecosystems

	SRS Calculated Values				Non-SRS Values	
Cesium-137	Minimum	Maximum	Mean[a]	N[b]	Literature Ranges[c]	NRC Values[d]
Alder, leaves		2.3		1	2.5 - 32.6	
Alder, roots		3.2		1		
Alder, stems		0.90		1		
Aphids (pc/pp)[e]	0.33	0.52		3	0.20 - 0.48	
Aphids (sc/pc)[f]	0.28	0.68	0.52	4	0.50 - 1.11	
Arrowhead, leaves	0.4	20.8	5.90	12		
Arrowhead, roots	0.54	13.7		2		
Bahia Grass	1.6	7.59	5.31	5	0.000027 - 0.68 (nonsandy soils)	0.01
Beetles (pc/pp)	0.42	0.96		3	0.20 - 0.48	
Beetles (sc/pc)	0.41	1.2	0.77	4	0.50 - 1.11	
Clover	0.8	1.3		3	0.06 - 0.352	
Corn, grain		0.01		1	0.029	
Corn, leaves	0.062	2.53	0.807	6		
Corn, stems	0.17	0.79	0.37	5	0.026	
Crickets (pc/pp)	0.69	1.3		3	0.20 - 0.48	
Crickets (sc/pc)	0.66	2.1		4	0.50 - 1.11	
Dry forage		3		1	0.00048 - 0.031 (coarse soil)	
Fresh Vegetables		0.9		1	0.004 - 0.471	
Fungi	4.8	18.4	10.1	20		
Myrtle, leaves		7.1		1	2.5 - 32.6	
Myrtle, roots		7.6		1		
Myrtle, stems		3.8		1		
Pine Trees, leaves	0.0052	2.37		2	0.1 - 10	
Red Maple	0.16	15.4	3.03	27		

a Means not calculated for fewer than four data points
b N = Number of values
c Literature Sources: Anderson et al. (1973), Crossley (1963 and 1969), Dahlman et al (1975), Evans and Decker (1968), Hardy and Bennett (1977), Haselow (1991), Marei et al. (1972), Miller (1963), Nishita et al. (1958), Ng (1982), Till and Meyer (1983)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data
e pc/pp = primary consumer to primary producer bioconcentration factor
f sc/pc = secondary consumer to primary consumer bioconcentration factor

Table 3-2: Bioconcentration Factors for Cesium in Terrestrial and Wetland Ecosystems (cont'd)

	SRS Calculated Values				Non-SRS Values	
Cesium-137	Minimum	Maximum	Mean[a]	N[b]	Literature Ranges[c]	NRC Values[d]
Rice, foliage	0.53	0.96	0.73	4		
Rice, grain	0.36	0.70	0.53	4		
Smartweed, leaves	0.60	11.8	3.49	4		
Smartweed, roots	0.84	27.9		2		
Smartweed, stems	0.39	12.2		2		
Snakes		2.94		1		
Soybeans, bean	0.26	1.66	0.70	5		
Soybeans, stems	0.14	0.37	0.22	5		
Spiders (pc/pp)[e]	0.45	0.92		3	0.20 - 0.48	
Spiders (sc/pc)[f]	0.41	1.3		4	0.50 - 1.11	
Tree bark (maple, sweetgum, and poplar)		0.039		1		
Tree leaf (maple, sweetgum, and poplar)		0.27		1		
Tree wood (maple, sweetgum, and poplar)		0.11		1		
Turkey Oak	7.9	25.7		3		
Water Tupelo, leaves	0.41	0.85		2		
Water Tupelo, roots	3.2	7.0		2		
Water Tupelo, stems	0.72	4.0		2		
Wheat, grain	0.06	0.18	0.1	4	0.0017 - 0.045	
White-tailed Deer, muscle	0.22	4.8	1.56	8	0.6 - 3.3	
Willow, leaves		3.8		1	2.5 - 32.6	
Willow, roots		6.2		1		
Willow, stems		1.3		1		

a Means not calculated for fewer than four data points
b N = Number of values
c Literature Sources: Anderson et al. (1973), Crossley (1963 and 1969), Dahlman et al (1975), Evans and Decker (1968), Hardy and Bennett (1977), Haselow (1991), Marei et al. (1972), Miller (1963), Nishita et al. (1958), Ng (1982), Till and Meyer (1983)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data
e pc/pp = primary consumer to primary producer bioconcentration factor
f sc/pc = secondary consumer to primary consumer bioconcentration factor

IV. STRONTIUM

Introduction

Radiostrontium at SRS originated primarily in the fuel and targets that were irradiated in the nuclear materials production areas. The greatest releases of strontium occurred during the early years of operation in the reactor facilities when strontium was released to onsite seepage basins and site streams (Carlton et al. 1992b). Approximately 104 Ci of strontium has been released to seepage basins and streams and 3 Ci of strontium has been released to the atmosphere (Cummins et al. 1991a). Strontium-90 has a half-life of 28 years and is the primary radioisotope that is considered in this report. Strontium-89,90 is also considered, but it is assumed that all of the strontium present is strontium-90 (half life of Strontium-89 is 52 days).

In 1992, radiostrontium contributed 18% of the total maximum individual dose from liquid releases and less than 1% from atmospheric releases (Carlton, et al. 1992b).

Aquatic Bioconcentration Factors

Strontium has physiochemical properties similar to calcium and both appear mainly in ionic form in water. Strontium is not strongly sorbed by suspended particulate matter in water and is thus available in the water for uptake.

The primary means of calcium and strontium uptake in most aquatic organisms occurs directly from the water. The gill membrane of fishes are the primary sites of calcium and strontium uptake. Only about one-tenth of the calcium and strontium taken up by fishes is through the food chain. Therefore, trophic level appears to have little effect on the bioconcentration factor of strontium (Vanderplog et al. 1975). A negative correlation has been demonstrated between the concentration of calcium in water and the strontium uptake in fish (Blaylock 1982; Vanderplog et al. 1975).

Table 4-1 summarizes the site-specific bioconcentration factors for strontium. The site-specific bioconcentration factor for strontium in blue-green algae was 600. For strontium in macroinvertebrates, bioconcentration factors were 520 in insect nymph larvae and 54,000 in gastropod larvae.

For macrophytes, bioconcentration factors ranged from 2,100 in the white-water lily (rooted vascular plant) to 9,400 in bladderwort (floating vascular plant).

Because of strontium's similarity to calcium, the maximum bioconcentration factors for strontium in vertebrates are found in the bone. Bioconcentration factors in fish bone ranged from 1,700 in piscivores (large-mouth bass) to 63,000 (also in the piscivores). Muscle bioconcentration factors in fish were <48.

The strontium-90 bioconcentration factors calculated for SRS aquatic systems are higher than those reported in the literature (Table 4-1).

Table 4-1: Bioconcentration Factors for Strontium in Aquatic Ecosystems

	SRS Calculated Values				Non-SRS Values		
Strontium-89,90	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**Vanderplog Recommendation**	**NRC Values[d]**
Algae		600		1	120 - 2,300	2,000	
Fish muscle (Insect and bottom invertebrate feeders)		<48		1	1.7 - 92	5.18 - 1.21 ln $[Ca]_W$[e]	30
Fish muscle (Piscivores)		<48		1	1.3 - 125	5.18 - 1.21 ln $[Ca]_W$	30
Fish muscle (Benthic invertebrate and fish feeders)		<48		1		5.18 - 1.21 ln $[Ca]_W$	30
Fish bone (Insect and bottom invertebrate feeders)		2,400		1	50 - 8,810	5.18 - 1.21 ln $[Ca]_W$	
Fish bone (Piscivores)		1,700		1	2,400	5.18 - 1.21 ln $[Ca]_W$	
Fish bone (Benthic invertebrate and fish feeders)		2,100		1	2,400 - 8,000	5.18 - 1.21 ln $[Ca]_W$	

Strontium-90	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**Vanderplog Recommendation**	**NRC Values[d]**
Clam, shell		1,330		1	2,640 - 3,246	6.8E04/$[Ca]_W$[e]	
Fish muscle (Piscivores)		3,400		1	1.3 - 125	5.18 - 1.21 ln $[Ca]_W$	30
Fish muscle (Benthic invertebrate and fish feeders)		610		1		5.18 - 1.21 ln $[Ca]_W$	30
Fish bone (Piscivores)		63,000		1	2,400	5.18 - 1.21 ln $[Ca]_W$	
Fish bone (Benthic invertebrate and fish feeders)		57,000		1	50 -8,810	5.18 - 1.21 ln $[Ca]_W$	
Fish bone (detritus and plankton feeders)		51,000		1	2,400	5.18 - 1.21 ln $[Ca]_W$	
Macroinvertebrates, larvae	520	54,000	27,300	2	300 - 720		100
Macrophytes (Rooted vascular)	2,100	8,500	5,500	4	3- 240		
Macrophytes (Floating vascular)		9,400		1	30 - 240		
Zooplankton		3,900		1	0.1 - 10		

a Mean not calculated for fewer than four data points
b N = Number of Values
c Literature Sources: Blaylock (1982), Coughtrey and Thorne (1985), Till and Meyer (1983), Vanderplog et al. (1975)
d NRC values - Factors provided by the Nuclear Regulatory Commission (NRC 1977, Table A-1) for freshwater fish and invertebrates for use in calculating dose in the absence of site-specific data
e $[Ca]_w$ = stable calcium concentration in water in ppm

Terrestrial and Wetland Bioconcentration Factors

Strontium is soluble in water, is poorly retained in SRS soils, and is thus, subject to migration and uptake. The exchangeable calcium in soil is the most important factor in determining the extent of strontium absorption by plant roots (Ng 1982). The bioconcentration factor for strontium has been shown to be negatively correlated with the exchangeable calcium in the soil. The bioconcentration factor also decreases with increasing clay and organic matter in the soil.

Russell and Squire (1958) made some general conclusions about the physiology of strontium absorption and distribution in vegetation: 1) an equilibrium does not occur between strontium in the shoots and in the roots, 2) upward translocation appears to be an irreversible process, 3) very little redistribution of strontium occurs in the plant, and 4) the greatest accumulation of strontium occurs in the leaves.

Table 4-2 summarizes terrestrial and wetland site-specific bioconcentration factors. Site-specific bioconcentration factors for strontium-90 in agricultural crops ranged from 0.15 corn grain to 13.1 in corn leaves. In native flora, concentration factors ranged from 0.81 in tree wood to 11 in the tree bark. Concentration factors for tree leaves ranged from 0.88 in pine trees to 3.8 in a maple, sweetgum, and poplar composite. These bioconcentration factors are comparable to those observed in other sandy, southeastern soils.

Table 4-2: Bioconcentration Factors for Strontium in Terrestrial and Wetland Ecosystems

Strontium-90	SRS Calculated Values: Minimum	Maximum	Mean[a]	N[b]	Non-SRS Values: Literature Ranges[c]	NRC Values[d]
Corn, grain		0.15		1	0.034 - 0.11	0.017
Corn, leaves		13.1		1		
Pine Trees, leaves	0.88	1.69		2	0.1 - 20	
Soybeans		2.51		1		
Tree wood (maple, sweetgum, and poplar)		0.81		1		
Tree bark (maple, sweetgum, and poplar)		11		1		
Tree leaf (maple, sweetgum, and poplar)		3.8		1		

a Mean not calculated for fewer than four data points
b N = Number of values
c Literature Sources: Coughtrey and Thorne (1985) and Ng (1982)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data

V. COBALT

Introduction

Two principal sources of radiocobalt in natural environments are the result of fallout from nuclear weapons detonation and from nuclear reactor and fuel reprocessing operations. At the SRS, cobalt-60 has been released primarily to aquatic systems, and to a lesser extent to terrestrial systems. Cobalt-60 is a negligible contributor to dose at SRS (<1%) (Arnett et al. 1993). Approximately 84 Ci of cobalt-60 has been released to onsite streams and seepage basins, while 0.1 Ci has been released to the atmosphere (Cummins et al. 1991a). Cobalt-60 is a gamma emitter, has a half-life of 5.3 years, and is the primary radioisotope of cobalt considered in this report.

Aquatic Bioconcentration Factors

When in solution, cobalt tends to form complexes with dissolved organic matter, making the cobalt less available for uptake. Vanderplog et al. (1975) noted that cobalt bioconcentration factors tend to decrease with increasing eutrophy (as defined by the nutrient content) of water. Cobalt is an essential component of vitamin B_{12} and is a nutritional requirement for fish health. The highest concentrations of cobalt are found in the kidney and spleen; cobalt does not concentrate in fish muscle (Poston and Klopfer 1988). Cobalt is also an essential element for some bacteria, fungi, several species of blue green algae and several species of mammals. Therefore, uptake of the radioisotope is expected in these organisms.

Harvey (1969) conducted the only study at SRS to determine a bioconcentration factor for cobalt-60 in aquatic systems. The bioconcentration factor for the soft tissue of clams was 790. Although it is not known from where these samples were taken onsite, the value can be compared to the 10,000 bioconcentration factor for cobalt in mesotrophic and oligotrophic waters or 400 bioconcentration factor for cobalt in eutrophic waters (Vanderplog et al. 1975). The NRC-recommended bioconcentration factor for freshwater invertebrates is 200 (NRC 1977, Table A-1).

Terrestrial and Wetland Bioconcentration Factors

Cobalt is taken up by plants, although it is not an essential element for higher plants. It is, however, an essential element in animal nutrition (Adriano et al. 1977).

Table 5-1 summarizes terrestrial and wetland bioconcentration factors for cobalt. Adriano et. al (1977) studied the uptake of cobalt-60 by bush beans and corn in Dothan and Troupe soils. The results indicated that uptake of cobalt-60 was affected by plant species and soil type. Bean leaves preferentially accumulated cobalt-60 in comparison with corn leaves. Concentration factors in the bush beans ranged from 0.4 in the Troupe soil to 2.82 in the Dothan soil. Bioconcentration factors in the corn ranged from 0.13 in the Troupe soil to 0.56 in the Dothan soil. Bioconcentration factors for the corn were highest in the leaf.

Murphy (1992) studied the uptake of radionuclides, including cobalt-60, at the Savannah River Laboratory (SRL) seepage basins and reports bioconcentration factors of 0.61 and 0.018 in pine trees in the SRL Basin 4 and around the basin edge, respectively.

Table 5-1: Bioconcentration Factors for Cobalt in Terrestrial and Wetland Ecosystems

	SRS Calculated Values				Non-SRS Values	
Cobalt-60	**Minimum**	**Maximum**	**Mean**	**N[a]**	**Literature Ranges[b]**	**NRC Values[c]**
Bush Bean, leaves	0.40	2.82	1.19	4		
Bush Bean, stem	0.793	2.32	1.56	2		
Corn, leaves	0.209	0.563	0.386	2		
Corn, stem	0.127	0.269	0.198	2		
Pine Trees, leaves	0.018	0.61	0.31	2	0.01 - 1	

a N = Number of Values
b Literature Sources: Till and Meyer 1983
c NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data.

VI. TRANSURANICS

Introduction

The transuranics, plutonium, americium, and curium are man-made elements and have no stable isotopes. The chemistry of these elements is generally complex because they assume different valence states, depending on environmental conditions. These elements have no known biological function.

Plutonium was produced at SRS during operations of five production reactors and released in small quantities during the processing of fuel and targets in chemical separations facilities. Approximately 13 Ci have been released to onsite streams and seepage basins, while approximately 4 Ci have been released to the atmosphere (Cummins et al. 1991a). Virtually all releases have occurred in the separations facilities located in F and H Areas (Carlton, et al. 1992b). Plutonium is a small contributor to the maximum individual dose from both liquid (8%) and atmospheric (5%) releases (Arnett et al. 1993). Plutonium-238 and plutonium-239 are the primary plutonium radioisotopes that are considered in this report with half-lives of 87.4 years and 24,000 years, respectively.

Other transuranics that have been released at SRS and will be considered in this report include americium-241 and curium-244. Approximately 0.28 Ci of americium-241 and 0.82 Ci of curium-244 have been released to streams and seepage basins, and approximately 0.0052 Ci of americium-241 and 0.091 Ci curium-244 have been released to the atmosphere. These radionuclides are negligible contributors to dose (<1%) (Arnett et al. 1993). Americium-241 has a half life of 458 years and curium-244 has a half life of 17.6 years.

Aquatic Bioconcentration Factors

Whicker et al. (1989) studied the distribution of various radionuclides, including transuranics, in Pond B. Bioconcentration factors were calculated for americium-241, curium-244, plutonium-238, and plutonium-239. In all cases, the maximum bioconcentration factors were found in macroinvertebrate larvae. The bioconcentration factors reported by Whicker et al. 1989 are higher than those factors reported in the literature (Table 6-1).

Transuranic elements are known to be fixed by clay minerals and complexed by organic matter which may decrease their availability. Zooplankton and benthic insect larvae have high surface to volume ratios. This allows their surfaces as well as their guts to carry sediment and sestonic particles, which adsorb transuranic particles; thus resulting in higher bioconcentration factors. (Whicker et al. 1989).

Aquatic macrophytes also showed high concentration factors, which could have resulted from sediment adsorbing to the leaves which were not cleansed of all periphyton prior to processing (Whicker et al. 1989). Vertebrate bone and muscle, which are not affected by transuranic adsorption, had lower bioconcentration factors. The lower bioconcentration factors for waterfowl may be the result of their short residence time on Pond B.

Americium-241 values ranged from 650 in waterfowl muscle to 240,000 in macroinvertebrate larvae; curium-244 values ranged from 84 in the water shield (floating vascular plant) to 19,000 in macroinvertebrate larvae; plutonium-238 ranged from 2,600 in fish muscle (piscivores) to 840,000 in macroinvertebrate larvae; and plutonium-239 ranged from 850 in waterfowl muscle to 190,000 in macroinvertebrate larvae.

Table 6-1: Bioconcentration Factors for Transuranics in Aquatic Ecosystems

	SRS Calculated Values				Non-SRS Values	
Plutonium-238	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Fish muscle (Piscivores)		2,600		1	25	3.5
Fish muscle (Benthic invertebrate and fish feeders)		12,000		1		
Fish bone (Piscivores)		17,000		1		
Macroinvertebrates, larvae		840,000		1		
Macrophyte (rooted vascular)	17,000	78,000	45,250	4		
Macrophyte (Floating vascular)		91,000		1		
Turtles, muscle		14,000		1		
Turtles, shell & bone		19,000		1		
Waterfowl, muscle		3,800		1		
Waterfowl, bone		18,000		1		
Plutonium-239	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Fish muscle (Piscivores)		5,600		1	0.4 - 25	3.5
Macroinvertebrates, larvae		190,000		1	587 - 30,000	
Macrophyte (rooted vascular)	6,600	52,000	26,150	4	230 - 9,000	
Macrophyte (Floating vascular)		100,000				
Turtle, muscle		6,600		1		
Waterfowl, muscle		850		1		
Zooplankton		23,000		1	122 - 5,600	

a Mean not calculated for fewer than four data points
b N = Number of values
c Literature Sources: Blaylock (1982), Till and Meyer (1983), Vanderplog et al. (1975), Whicker et al. (1989), Eyman and Trabalka (1980)
d NRC values - Factors provided by the Nuclear Regulatory Commission (NRC 1977, Table A-1) for freshwater fish and invertebrates for use in calculating dose in the absence of site-specific data

Table 6-1: Bioconcentration Factors for Transuranics in Aquatic Ecosystems (cont'd)

	SRS Calculated Values				Non-SRS Values	
Americium-241	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Fish muscle (Piscivores)		2,500		1	50	25
Fish bone (Benthic invertebrate and fish feeders)		4,200		1		
Macroinvertebrate, larvae	78,000	240,000				
Macrophyte (rooted vascular)	1,400	21,000		3		
Macrophyte (Floating vascular)		75,000		1		
Turtle, muscle		5,600		1		
Waterfowl, muscle		650		1		

Curium-244	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Fish muscle (Piscivores)		410		1	50	25
Fish muscle (Benthic invertebrate and fish feeders)		91		1		
Fish bone (Piscivores)		1,400		1		
Macroinvertebrate, larvae	1,400	19,000		2		25
Macrophyte (rooted vascular)		780		1		
Macrophyte (Floating vascular)	84	370		3		
Turtle, muscle		110		1		
Turtle, shell & bone		190		1		
Waterfowl, muscle		110		1		

a Mean not calculated for fewer than four data points
b N = Number of values
c Literature Sources: Blaylock (1982), Till and Meyer (1983), Vanderplog et al. (1975), Whicker et al. (1989), Eyman and Trabalka (1980)
d NRC values - Factors provided by the Nuclear Regulatory Commission (NRC 1977, Table A-1) for freshwater fish and invertebrates for use in calculating dose in the absence of site-specific data

Terrestrial and Wetland Bioconcentration Factors

Plant uptake of transuranic radionuclides is influenced by soil pH, Eh (oxidation state), cation exchange capacity, texture, organic matter, fertilizers, and other treatments. Transuranic elements are fixed by clay minerals and complexed by organic matter which may affect their availability. Higher pH generally decreases metal uptake, whereas chelate additions usually increase uptake (McLeod et al. 1981).

Plant properties also influence uptake of transuranic nuclides. Plant roots excrete protons, organic and amino acids, chelators, and other substances, all of which have an effect on the uptake and translocation of many metals, including transuranics. The depth of rooting is another factor that affects plant uptake. Nuclides in lower horizons of soil may be mobilized by deep roots, but not mobilized by shallow roots. Decomposition of plant residues influences both uptake and recycling (Adriano et al. 1980b).

The sources of elements and particle size also affects availability of transuranics. Small particles are more subject to weathering and they release nuclides faster than do large particles. Oxides are less available than other forms. The transuranic elements themselves differ in phytoavailability (Pu<Am<Cm<Np) (Adriano et al. 1980b).

Although root uptake is generally small, transuranic elements that have been incorporated into plant tissues may be chemically bound to proteins, lipids, and other organic the vegetative parts. Very little is translocated to the grain or edible portion (Adriano et al. 1981b).

Site-specific bioconcentration factors for americium-241 ranged from 0.03 to 0.12 for bahia grass and from 0.00014 to 0.00025 in pine trees. These values are comparable to literature values (Table 6-2).

Bioconcentration factors for curium-244 in agricultural crops ranged from 0.0031 in corn to 0.028 in soybean. In native vegetation, concentration factors ranged from 0.0021 in trees to 0.0499 in clover.

The maximum bioconcentration factor for plutonium-239,240 was in rice (0.025). A bioconcentration factor of 0.17 was calculated for plutonium-239 in corn.

Kirkham et al. (1979) studied total plutonium concentrations in white-tailed deer from the Savannah River site. Bioconcentration factors were calculated based on honeysuckle to deer uptake. The concentration factors ranged from 0.014 in the muscle to 0.175 in the bone. Concentration factors were also calculated based on soil to deer uptake. These factors ranged from 0.001 in the muscle to 0.015 in the bone.

Table 6-2: Bioconcentration Factors for Transuranics in Terrestrial and Wetland Ecosystems

	SRS Calculated Values				Non-SRS Values	
Total Plutonium	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Corn, grain		0.00006		1		
Corn, leaves		0.0006		1		
Soybeans		0.003		1		
Wheat		0.002		1	3.8E-08 - 0.04	0.00025
White-tailed deer, bone	0.015	0.175	0.095	2	0.023 - 0.350	
White-tailed deer, liver	0.013	0.148	0.081	2	0.035 - 0.533	
White-tailed deer, lungs	0.006	0.073	0.040	2	0.033 - 0.50	
White-tailed deer, muscle	0.001	0.0014	0.0012	2	0.01 - 0.15	
Plutonium-238	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Bahia Grass	0.00006	0.0056	0.0013	5		
Clover	0.00015	0.067	0.013	5	1E-05 - 1E-04	
Corn, leaves	0.00017	0.019	0.0042	7	0.01	
Corn, stalk	0.00021	0.45		3	0.01 - 10	
Pine Trees, leaves	0.00015	0.0047		2	0.006 - 0.1	
Rice, foliage	0.00026	0.00049	0.00033	4		
Rice, grain	0.00009	0.00036	0.00021	4		
Soybeans, beans	0.00052	0.26		3		
Soybean, stems	0.00068	0.16		2		
Tree wood (maple, sweet-gum, and poplar)		0.000033		1		
Tree bark (maple, sweet-gum, and poplar)		0.00027		1		
Tree leaf (maple, sweetgum, and poplar)		0.00030		1		
Wheat, grain	0.00037	0.035		3	1E-08 - 0.001	
Wheat, stems	0.00024	0.0014	0.0032	5		

a Mean not calculated for fewer than four data points
b N = Number of Values
c Literature Source: Adams et al. (1975), Coughtrey and Thorne (1985), Kirkham et al. (1979), Ng (1982), Romney et al. (1970), Shulz et al (1976), and Wallace (1976)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data

Table 6-2: Bioconcentration Factors for Transuranics in Terrestrial and Wetland Ecosystems (cont'd)

	SRS Calculated Values				Non-SRS Values	
Plutonium-239	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Corn, stalk	0.072	0.017		2		
Plutonium-239,240	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Bahia Grass	0.000089	0.0044		3		
Clover	0.00014	0.02		3		
Corn, leaves	0.00021	0.014		3		
Corn, stalk	0.0016	0.017		3		
Pine Trees, leaves	0.00012	0.0073		2	0.006 - 0.1	
Rice, foliage	0.0075	0.025		2		
Rice, grain	0.0079	0.015		2		
Soybean, bean	0.00056	0.074		3		
Soybean, stem	0.00072	0.054		3		
Wheat, grain	0.00042	0.029		3		
Wheat, vegetation	0.00018	0.013		3		

a Mean not calculated for fewer than four data points
b N = Number of Values
c Literature Source: Adams et al. (1975), Coughtrey and Thorne (1985), Ng (1982), Romney et al. (1970), Shulz et al (1976), and Wallace (1976)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data

Table 6-2: Bioconcentration Factors for Transuranics in Terrestrial and Wetland Ecosystems (cont'd)

	SRS Calculated Values				Non-SRS Values	
Americium-241	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Bahia Grass	0.03	0.12	0.067	6	2.3E-7 - 0.005	0.00025
Pine Trees, leaves	0.00014	0.00025		2	0.0001 - 0.1	
Curium-242,244	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Pine Trees, leaves	0.0052	0.021	0.013	2	1E-06 - 1.7	
Curium-244	**Minimum**	**Maximum**	**Mean[a]**	**N[b]**	**Literature Ranges[c]**	**NRC Values[d]**
Bahia Grass	0.0075	0.0115		3		
Clover	0.0391	0.0499		3		
Corn, ear		0.0031		1		
Corn, leaves	0.011	0.0244		3		
Corn, stalk		0.0097		1		
Rice, foliage	0.0020	0.0023	0.0022	4		
Rice, grain	0.0013	0.0045	0.0024	4		
Soybean, bean		0.0045		1		
Soybean, stem	0.013	0.028		2		
Tree wood (maple, sweet-gum, and poplar)		0.0036		1		
Tree bark (maple, sweet-gum, and poplar)		0.0021		1		
Tree leaf (maple, sweetgum, and poplar)		0.0075		1		
Wheat, stem	0.0035	0.0069		2		
Wheat, grain		0.0033		1		

a Mean not calculated for fewer than four data points
b N = Number of Values
c Literature Source: Adams et al. (1975), Coughtrey and Thorne (1985), Ng (1982), Romney et al. (1970), Shulz et al (1976), and Wallace (1976)
d NRC values - Factors for fresh-weight vegetation provided by the Nuclear Regulatory Commission (NRC 1977, Table E-1) for use in calculating dose in the absence of site-specific data

VII. TRITIUM

Introduction

Tritium has been released to the environment as a result of many operations at the Savannah River Site. Releases have occurred from reactor operations, recovery of transuranic elements, recovery of tritium, laboratory research, and heavy water rework. Over 24 million curies of tritium have been released to the atmosphere, and approximately 1.5 million curies of tritium have been released to seepage basins and streams (Cummins et al. 1991a). Tritium contributes approximately 90% of the committed dose to the maximum individual from atmospheric releases and approximately 35% from liquid releases (Arnett et al. 1993). Tritium has a half-life of 12.4 years

Tritium is an isotope of hydrogen and behaves similarly in the environment to the other isotopes of hydrogen, protium and deuterium. Hydrogen is the most abundant element on earth in terms of the number of atoms. It forms an enormous number of compounds, including its association with carbon in almost all organic compounds. In terms of abundance and mobility, water is the most important compound of hydrogen (Murphy 1993).

Aquatic Bioconcentration Factors

Tritium enters aquatic systems in the form of tritiated water (HTO). Tritiated water behaves like HOH and mixes rapidly with the tissue water of aquatic organisms. The observation that the ratio of tritium to hydrogen in organisms is similar to that in their environment suggests that there is no biomagnification up the food chain (Murphy 1993).

Vanderplog et al. (1975) concluded that the bioconcentration factor for tritium was approximately one. The biological half-life of tritium in fish is <1 day; thus the concentration of tritium in fish will follow closely the concentration of tritium in the water to which the fish have been exposed to in the past day or less. A tritium uptake study by Eaton and Murphy (1992) indicated that the tritium activity of the tissue water of fish was approximately equal to the activity of the source water.

Organic tritium is also present in aquatic systems. The sources of organic tritium are from the incorporation of tritiated water by photosynthesis (algae and other aquatic plants) and from the uptake of detritus of either terrestrial or aquatic origin. The transfer of organic tritium through the food chain from photosynthetic or detritus inputs depends on the nature of the organic material consumed (Murphy 1993). However, once incorporated, the metabolic turnover of organic tritium in fish are on the order of months to years (Eaton and Murphy 1992). A tritium uptake study by Eaton and Murphy (1992) determined that the tritium activity of the organic matter of the fish was approximately equal to the activity of the water measured in the previous year.

Terrestrial and Wetland Bioconcentration Factors

Tritium can enter terrestrial vegetation by two mechanisms—vapor exchange with the atmosphere and root uptake of soil water. Atmospheric tritium oxide reaches equilibrium with vegetation in matter of hours and takes place through the stoma on the leaf surface. Uptake of soil water occurs through the roots and is influenced by the capillary tension holding water in the soil, the root density, and the root depth (Murphy 1993). Equilibrium is reached in a matter of days. Once in the vegetation, tritium has a high turnover rate, and concentrations in the vegetation will lie between the concentration of the different sources of water in the leaves.

There have been no measurements of tritium in soil water; thus, no bioconcentration factors have been calculated for vegetation/soil. However, it has been determined that tritium activity in the soil is similar to that in the rainwater (Sweet and Murphy 1984). There have been bioconcentration factors determined for vegetation exposure to atmospheric tritium oxide. Murphy (1984) calculated a vegetation/air ratio of 0.77. Hamby and Bauer (1993) calculated a vegetation/air ratio of 0.54.

Tritium concentrations in animals is similar to that in vegetation in that the concentration results from tritium transport to and from the animal through numerous paths (Robertson 1973 and Yousef 1973). However, the two primary sources of exposure for animals are from drinking water and from food. The water turnover time for most species is less than 10 days, which suggests that most animal species, like vegetation, will respond to day to day changes of tritium in their environment. However, unlike vegetation, animals are mobile and will contain water that is averaged over the area in which they range (Murphy 1993). There have been no site-specific studies performed to calculate tritium bioconcentration factors for animals.

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Appendix A

AQUATIC BIOCONCENTRATION FACTORS

Appendix A

AQUATIC BIOCONCENTRATION FACTORS

The following tables present bioconcentration factors that are specific to the Savannah River Site. The data were obtained from articles distributed internally at the SRS as well as from articles published in technical journals. An attempt was made to collect every available article that contained site specific bioconcentration factors, or data from which bioconcentration factors could be calculated; however, all information was probably not obtained. These tables should provide sufficient information to allow one to decide the whether or not a bioconcentration factor is appropriate for the intended use. If more information is needed, the literature article should be reviewed. For reference, Figure 1 (Appendix C) shows the SRS, its streams and areas. Each table is divided into the following columns:

1. **Medium** - Organism or class of organisms for which the bioconcentration factor was calculated
2. **Organsim** - More specific information (e.g., the scientific name, the common name, the tissue part) about the organism for which the bioconcentration factor was calculated
3. **BCF** - The bioconcentration factor in scientific notation
4. N - the sample size - if "comp" is given, then a certain number of samples were collected and composited before analysis, so that only one analysis was performed. If a number is given, the bioconcentration factor was calculated from the mean value of that number of analyses on the medium.
5. **General** - The general area onsite from which the sample was collected.
6. **Specific** - More specific information about where the sample was collected
7. **Radionuclide** - The radionuclide for which the bioconcentration factor was calculated.
8. **Comments** - Additional information about the experimental conditions for the study
9. **Reference** - The reference from which the data were taken

Other abbreviations that are used in the tables include:

LTR - Lower Three Runs
Donora St. - Donora Station

Media	Organism	BCF	N	Location		Radionuclide	Conditions	Reference
				General	Specific			
Fish (Type 3)*	Large-mouth Bass, flesh (*Micropterus salmoides*)	2.50E+03		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Fish (Type 4)*	Bullhead catfish, bone (*Ictalurus natalis*)	4.20E+03		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macroinvertebrate	Benthic, Gastropods, larvae	7.80E+04	comp	Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macroinvertebrate	Benthic, Insect nymphs, larvae	2.40E+05	comp	Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Fanwort (*Cabomba caroliniana*)	2.10E+04		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Water-shield (*Brasenia schreberi*)	2.10E+03		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	White water-lilly (*Nymphaea odorata*)	1.40E+03		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 2)**	Bladderwort (*Utricularia floridana*)	7.50E+04		Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Sediment		1.10E+06	15	Pond B	0-3 cm	Am-241	dry weight, filtered water	Whicker et. al. 1989
Turtle	Yellow-bellied Slider (*Trachemys scripta*), muscle	5.60E+03	10	Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Waterfowl	American Coot (*Fulica americana*), muscle	6.50E+02	5	Pond B		Am-241	dry weight, filtered water	Whicker et. al. 1989
Clam	*Lampsilis radiata*, soft tissue	9.00E+02				Ce-144	wet weight	Harvey 1969
Fish (Type 3)*	Large-mouth Bass, bone (*Micropterus salmoides*)	1.40E+03		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Fish (Type 3)*	Large-mouth Bass, flesh (*Micropterus salmoides*)	4.10E+02		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Fish (Type 4)*	Bullhead catfish, flesh (*Ictalurus natalis*)	9.10E+01		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macroinvertebrate	Benthic, Gastropods, larvae	1.40E+03		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macroinvertebrate	Benthic, Insect nymphs, larvae	1.90E+04		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Fanwort (*Cabomba caroliniana*)	3.70E+02		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Water-shield (*Brasenia schreberi*)	8.40E+01		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	White water-lilly (*Nymphaea odorata*)	1.90E+02		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 2)**	Bladderwort (*Utricularia floridana*)	7.80E+02		Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Sediment		1.50E+04	15	Pond B	0-3 cm	Cm-244	dry weight, filtered water	Whicker et. al. 1989
Turtle	Yellow-bellied Slider, (*Trachemys scripta*), muscle	1.10E+02	10	Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Turtle	Yellow-bellied Slider, (*Trachemys scripta*), shell & bone	1.90E+02	10	Pond B		Cm-244	dry weight, filtered water	Whicker et. al.1989
Waterfowl	American Coot, (*Fulica americana*), muscle	1.10E+02	5	Pond B		Cm-244	dry weight, filtered water	Whicker et. al. 1989
Clam	*Lampsilis radiata*, soft tissue	7.90E+02				Co-60	wet weight	Harvey 1969

Media	Organism	BCF	N	Location: General	Location: Specific	Radionuclide	Conditions	Reference
Clam	*Lampsilis radiata*, soft tissue	4.40E+02				Cr-51	wet weight	Harvey 1969
Algae	Blue-green	1.20E+03	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Algae	Oedogonium	4.50E+03		LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Beetles	Whirligig (*Dineutes* sp.)	4.80E+02	494	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Clam	*Elliptio complanata*	3.00E+02	91	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Clam	*Lampsilis radiata*, shell	2.50E+01				Cs-137	wet weight	Harvey 1969
Clam	*Lampsilis radiata*, soft tissue	2.20E+02				Cs-137	wet weight	Harvey 1969
Crayfish	*Procambarus hirsutus*	9.97E+02	89	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Detritus	producer	9.38E+02		LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 1)*	Coastal Shiners (*Notropis petersoni*)	1.09E+03	195	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 1)*	Mosquitofish (*Gambusia holbrooki*)	8.91E+02	223	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 1)*	Mosquitofish, Female *Gambusia holbrooki*)	7.90E+03	28	Pond B	North Lake	Cs-137	dry weight, dw/ww ratio = 0.28	Newman and Brisbin 1990
Fish (Type 1)*	Mosquitofish, Female (*Gambusia holbrooki*)	8.47E+03	55	Pond B	Outlet Bay	Cs-137	dry weight, dw/ww ratio = 0.25	Newman and Brisbin 1990
Fish (Type 1)*	Mosquitofish, Female (*Gambusia holbrooki*)	7.36E+03	31	Pond B	Inlet Canal	Cs-137	dry weight, dw/ww ratio = 0.27	Newman and Brisbin 1990
Fish (Type 1)*	Mosquitofish, Male (*Gambusia holbrooki*)	8.76E+03	28	Pond B	North Lake	Cs-137	dry weight, dw/ww ratio = 0.26	Newman and Brisbin 1990
Fish (Type 1)*	Mosquitofish, Male (*Gambusia holbrooki*)	1.03E+04	29	Pond B	Outlet Bay	Cs-137	dry weight, dw/ww ratio = 0.22	Newman and Brisbin 1990
Fish (Type 1)*	Mosquitofish, Male (*Gambusia holbrooki*)	1.13E+04	19	Pond B	Inlet Canal	Cs-137	dry weight, dw/ww ratio = 0.26	Newman and Brisbin 1990
Fish (Type 2)*	Bluegill, bone (*Lepomis macrochirus*)	6.00E+02	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 2)*	Bluegill, flesh (*Lepomis macrochirus*)	9.00E+02	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 2)*	Dollar Sunfish (*Lepomis marginatus*)	6.91E+02	5	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 2)*	Pirate Perch (*Aphredoderus sayanus*)	7.20E+02	33	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 2)*	Red breast Sunfish (*Lepomis auritus*)	1.33E+03	3	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 3)*	Large-mouth Bass (*Micropterus salmoides*)	2.80E+03	4	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 3)*	Large-mouth Bass, bone (*Micropterus salmoides*)	5.00E+02	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 3)*	Large-mouth Bass, flesh (*Micropterus salmoides*)	3.90E+04		Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Fish (Type 3)*	Large-mouth Bass, flesh *Micropterus salmoides*)	1.20E+03	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 3)*	Pickerel (*Esox* spp.)	9.08E+02	6	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Fish (Type 4)*	Bullhead catfish, bone (*Ictalurus natalis*)	8.00E+02	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 4)*	Bullhead catfish, flesh (*Ictalurus natalis*)	2.90E+04		Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Fish (Type 4)*	Bullhead catfish, flesh (*Ictalurus natalis*)	1.20E+03	comp	Par Pond		Cs-137	wet weight	Harvey 1964
Fish (Type 5)*	Gizzard Shad, muscle (*Dorosoma cepedianum*)	4.80E+04		Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989

				Location				
Media	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Insects	Dragonflies (*Anisoptera*)	6.48E+02	118	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Macroinvertebrate	Benthic, Gastropods, larvae	1.20E+03		Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macroinvertebrate	Benthic, Insect nymphs, larvae	8.00E+03		Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Fanwort (*Cabomba caroliniana*)	3.70E+04	32	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	Floating heart (*Nymphoides cordata*)	3.10E+04	29	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	*Potomogeton pectinatus*	2.95E+02		LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Macrophyte (Type 1)**	Water-shield (*Brasenia schreberi*)	2.50E+04	48	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 1)**	White water-lilly (*Nymphaea odorata*)	1.90E+04	41	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 2)**	Bladderwort (*Utricularia floridana*)	1.70E+04	39	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Macrophyte (Type 3)**	Smartweed (*P. punctatum*)	7.16E+02	72	LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Macrophyte (Type 3)**	Smartweed, leaves (*P. punctatum*)	3.42E+03	6	LTR		Cs-137		Gladden 1979
Macrophyte (Type 3)**	Smartweed, roots (*P. punctatum*)	4.66E+03	6	LTR		Cs-137		Gladden 1979
Macrophyte (Type 3)**	Knotweed (*P. densiflorum*)	7.34E+02	78	LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Sediment		3.20E+04	15	Pond B	0-3 cm	Cs-137	dry weight, filtered water	Whicker et. al. 1989
Shrimp	*Palaemonetes paludosus*	8.67E+02	505	LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Snails	*Capeloma* sp.	2.60E+02	397	LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Snakes	Water Snakes (*Natrix sipedon*)	2.60E+03	2	LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Spiders	Fishing (*Dolomedes sexpunctatus*)	1.28E+03	78	LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Suspended Particles	>5 um	4.24E+03		LTR	Donora St.	Cs-137	wet weight	Shure and Gottschalk 1975
Suspended Particles	>80 um	2.25E+03		LTR		Cs-137	wet weight	Shure and Gottschalk 1975
Turtle	Yellow-bellied Slider, (*Trachemys scripta*), muscle	1.30E+04	10	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Turtle	Yellow-bellied Slider, (*Trachemys scripta*), shell & bone	1.10E+03	10	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Waterfowl	American Coot, (*Fulica americana*), bone	2.90E+02	1	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Waterfowl	American Coot, (*Fulica americana*), muscle	1.90E+04	7	Pond B		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Zooplankton		7.10E+04	15	H Area		Cs-137	dry weight, filtered water	Whicker et. al. 1989
Clam	*Lampsilis radiata*, shell	1.15E+03				Mn-54	wet weight	Harvey 1969
Clam	*Lampsilis radiata*, soft tissue	2.38E+03				Mn-54	wet weight	Harvey 1969

				Location				
Media	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Fish (Type 3)*	Large-mouth Bass, bone (*Micropterus salmoides*)	1.40E+03	comp	Par Pond		Zn-65	wet weight	Harvey 1964
Fish (Type 3)*	Large-mouth Bass, flesh (*Micropterus salmoides*)	6.00E+02	comp	Par Pond		Zn-65	wet weight	Harvey 1964
Fish (Type 4)*	Bullhead catfish, bone (*Ictalurus natalis*)	3.00E+03	comp	Par Pond		Zn-65	wet weight	Harvey 1964
Fish (Type 4)*	Bullhead catfish, flesh (*Ictalurus natalis*)	8.00E+02	comp	Par Pond		Zn-65	wet weight	Harvey 1964

* Fish
Type 1 = surface and midwater insectivores
Type 2 = Insect and bottom invertebrate feeders
Type 3 = Piscivores
Type 4 = Benthic invertebrate and fish feeders
Type 5 = Detritus and Plankton feeders

** Macroinvertebrate Types
Type 1 = Rooted vascular
Type 2 = Floating vascular
Type 3 = emergent wetland

APPENDIX B

TERRESTRIAL AND WETLAND BIOCONCENTRATION FACTORS

APPENDIX B

TERRESTRIAL AND WETLAND BIOCONCENTRATION FACTORS

The following tables present bioconcentration factors that are specific to the Savannah River Site. The data were obtained from articles distributed internally at the SRS as well as from articles published in technical journals. An attempt was made to collect every available article that contained site specific bioconcentration factors, or data from which bioconcentration factors could be calculated; however, all information was probably not obtained. These tables should provide sufficient information to allow one to decide the whether or not a bioconcentration factor is appropriate for the intended use. If more information is needed, the literature article should be reviewed. For reference, Figure 1 (Appendix C) shows the SRS, its streams and areas. Each table is divided into the following columns:

1. **Medium** - Organism or class of organisms for which the bioconcentration factor was calculated
2. **Organsim** - More specific information (e.g., the scientific name, the common name, the tissue part) about the organism for which the bioconcentration factor was calculated
3. **BCF** - The bioconcentration factor in scientific notation
4. N - The sample size - if "comp" is given, then a certain number of samples was collected and composited before analysis, so that only one analysis was performed. If a number is given, the bioconcentration factor was calculated from the mean value of that number of analyses on the medium.
5. **General** - The general area onsite from which the sample was collected.
6. **Specific** - More specific information about where the sample was collected
7. **Radionuclide** - The radionuclide for which the bioconcentration factor was calculated.
8. **Comments** - Additional information about the experimental conditions for the study
9. **Reference** - The reference from which the data were taken

Other abbreviations that are used in the tables include:

Boiling Sp. - Boiling Springs
Burial Grnd - Burial Ground
Donora St. - Donora Station
E Boundary - Eastern Boundary of SRS, west of Barnwell Nuclear Fuel Plant
FMB - Fourmile Branch
Martin Mill. - Martin Millet
NE SRS - Northeast Savannah River Site
Pat. Mill - Patterson Mill
SRL - Savannah River Laboratory

Medium	Organism	BCF	N	Location		Radionuclide	Conditions	Reference
				General	Specific			
Bahia Grass	*Paspalum notatum*	1.20E-01				Am-241	Dothan Soil, 100 days after germination, greenhouse	Adriano et al 1980b
Bahia Grass	*Paspalum notatum*	8.00E-02				Am-241	Dothan Soil, 130 days after germination, greenhouse	Adriano et al 1980b
Bahia Grass	*Paspalum notatum*	5.90E-02				Am-241	Dothan Soil, 180 days after germination, greenhouse	Adriano et al 1980b
Bahia Grass	*Paspalum notatum*	4.00E-02				Am-241	Troupe Soil, 100 days after germination, greenhouse	Adriano et al 1980b
Bahia Grass	*Paspalum notatum*	7.50E-02				Am-241	Troupe Soil, 130 days after germination, greenhouse	Adriano et al 1980b
Bahia Grass	*Paspalum notatum*	3.00E-02				Am-241	Troupe Soil, 180 days after germination, greenhouse	Adriano et al 1980b
Pine Tree	Leaves	1.40E-04	12	SRL	Basin 4	Am-241		Murphy 1992
Pine Tree	Leaves	2.50E-04	16	SRL	Basin Edge	Am-241		Murphy 1992
Pine Tree	Leaves	2.10E-02	12	SRL	Basin 4	Cm-242,244		Murphy 1992
Pine Tree	Leaves	5.20E-03	16	SRL	Basin Edge	Cm-242,244		Murphy 1992
Bahia Grass	*Paspalum notatum*	7.75E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Bahia Grass	*Paspalum notatum*	1.15E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Bahia Grass	*Paspalum notatum*	7.50E-03	7	H Area/FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Clover	*Trifolium repens*	4.99E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Clover	*Trifolium repens*	3.91E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Clover	*Trifolium repens*	4.90E-02	7	H Area/FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Corn	*Zea mays*, Ear	3.10E-03	7	H Area/FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Corn	*Zea mays*, Leaves	2.44E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Corn	*Zea mays*, Leaves	1.05E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Corn	*Zea mays*, Leaves	2.40E-02	7	H Area/FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Corn	*Zea mays*, Stalk	9.70E-03	7	H Area/FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Rice	Belle Patna, foliage	2.20E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Belle Patna, Grain	1.70E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, foliage	2.30E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, Grain	1.30E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, foliage	2.10E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, Grain	1.90E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, foliage	2.00E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, Grain	4.50E-03	6	H Area/FMB	Floodplain	Cm-244	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Soybean	*Glycine max*, Bean	4.50E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Soybean	*Glycine max*, Stem	1.35E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Soybean	*Glycine max*, Stem	2.79E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Soybean	*Glycine max*, Stem	1.30E-02	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Tree	Maple, sweetgum, and poplar, Bark	2.10E-03	9	H Area/ FMB	Floodplain	Cm-244	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Leaves	7.50E-03	9	H Area/ FMB	Floodplain	Cm-244	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Wood	3.60E-03	9	H Area/ FMB	Floodplain	Cm-244	Field experiment	Pinder et. al. 1984
Wheat	*Triticum aestivum*, Grain	3.30E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Wheat	*Triticum aestivum*, Stem	3.62E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Wheat	*Triticum aestivum*, Stem	6.88E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Wheat	*Triticum aestivum*, Stem	3.50E-03	7	H Area/ FMB	Floodplain	Cm-244	sand=69%, silt=11%, clay=20%, greenhouse	Adriano et. al. 1981b
Bush Bean	*Phaselous vulgaris*, young leaves	2.82E+00	4			Co-60	Sand=63%, clay=30%, Dothan Soil, greenhouse	Adriano et. al. 1977
Bush Bean	*Phaselous vulgaris*, old leaves	5.20E-01	4			Co-60	Sand=63%, clay=30%, Dothan Soil, greenhouse	Adriano et. al. 1977
Bush Bean	*Phaselous vulgaris*, old leaves	4.00E-01	4			Co-60	Sand=82%, clay=12%, Troupe Soil, greenhouse	Adriano et. al. 1977
Bush Bean	*Phaselous vulgaris*, stem	2.32E+00	4			Co-60	Sand=63%, clay=30%, Dothan Soil, greenhouse	Adriano et. al. 1977
Bush Bean	*Phaselous vulgaris*, stem	7.93E-01	4			Co-60	Sand=82%, clay=12%, Troupe Soil, greenhouse	Adriano et. al. 1977
Bush Bean	*Phaselous vulgaris*, young leaves	1.02E+00	4			Co-60	Sand=82%, clay=12%, Troupe Soil, greenhouse	Adriano et. al. 1977
Corn	*Zea mays*, Leaves	5.63E-01	4			Co-60	Sand=63%, clay=30%, Dothan Soil, greenhouse	Adriano et. al. 1977
Corn	*Zea mays*, Leaves	2.09E-01	4			Co-60	Sand=82%, clay=12%, Troupe Soil, greenhouse	Adriano et. al. 1977
Corn	*Zea mays*, stem	2.69E-01	4			Co-60	Sand=63%, clay=30%, Dothan Soil, greenhouse	Adriano et. al. 1977
Corn	*Zea mays*, Stem	1.27E-01	4			Co-60	Sand=82%, clay=12%, Troupe Soil, greenhouse	Adriano et. al. 1977
Pine Tree	Leaves	6.10E-01	12	SRL	Basin 4	Co-60		Murphy 1992
Pine Tree	Leaves	1.80E-02	16	SRL	Basin Edge	Co-60		Murphy 1992
Alder	*Alnus serrulata*, leaves	2.30E+00	16	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Alder	*Alnus serrulata*, roots	3.20E+00	16	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Alder	*Alnus serrulata*, species mean	2.10E+00	16	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Alder	*Alnus serrulata*, stem	9.00E-01	16	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Aphids	Homoptera	6.80E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Araneae	Anderson et. al. 1973
Aphids	Homoptera	6.70E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Coleoptera	Anderson et. al. 1973
Aphids	Homoptera	4.30E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Orthoptera	Anderson et. al. 1973

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Aphids	Homoptera	2.80E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Andropogon	Anderson et. al. 1973
Aphids	Homoptera	5.20E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Alnus	Anderson et. al. 1973
Aphids	Homoptera	3.30E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Myrica	Anderson et. al. 1973
Aphids	Homoptera	3.90E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Homoptera/Salix	Anderson et. al. 1973
Arrowhead	*Sagittaria latifolia*, leaves	4.00E-01	40	Beaver Dam	backwater	Cs-137	Org matter=15.7%, soil moist.=63.7%, 6.4 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	7.00E+00	40	Par Pond	West cove	Cs-137	Org matter=1.5%, soil moist.=24.5%, 0.6 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	4.00E-01	40	Pen Branch	backwater	Cs-137	Org matter=42.1%, soil moist.=83.5%, 12.6 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	7.10E+00	40	Pond C		Cs-137	Org matter=2.2%, soil moist.=24.3%, 1.1 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	3.60E+00	40	Steel Creek		Cs-137	Org matter=3.5%, soil moist.=39.8%, 2.1 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	4.40E+00	40	Steel Creek		Cs-137	Org matter=3.3%, soil moist.=37.4%, 1.5 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	4.50E+00	40	Steel Creek		Cs-137	Org matter=4.7%, soil moist.=43.1%, 1.9 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	1.07E+01	40	Steel Creek		Cs-137	Org matter=2.5%, soil moist.=29.7%, 0.9 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	7.90E+00	40	Steel Creek		Cs-137	Org matter=4.1%, soil moist.=39.3%, 2.1 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	3.30E+00	40	Steel Creek		Cs-137	Org matter=4.0%, soil moist.=41.4%, 1.7 ppm K	Garten and Paine 1977
Arrowhead	*Sagittaria latifolia*, leaves	2.08E+01	56	Steel Creek	delta	Cs-137		Sharitz et. al. 1975
Arrowhead	*Sagittaria latifolia*, leaves	6.50E-01	13	Steel Creek	delta	Cs-137		Sharitz et. al. 1975
Arrowhead	*Sagittaria latifolia*, roots	1.37E+01	56	Steel Creek	delta	Cs-137		Sharitz et. al. 1975
Arrowhead	*Sagittaria latifolia*, roots	5.40E-01	13	Steel Creek	delta	Cs-137		Sharitz et. al. 1975
Bahia Grass	*Paspalum notatum*	5.20E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 1st year	Adriano et. al. 1984
Bahia Grass	*Paspalum notatum*	7.56E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Bahia Grass	*Paspalum notatum*	7.59E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Bahia Grass	*Paspalum notatum*	4.61E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Bahia Grass	*Paspalum notatum*	1.60E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
Beetles	Coleoptera	4.20E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Salix	Anderson et. al. 1973
Beetles	Coleoptera	9.30E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Araneae	Anderson et. al. 1973
Beetles	Coleoptera	4.10E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Andropogon	Anderson et. al. 1973
Beetles	Coleoptera	1.20E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Homoptera	Anderson et. al. 1973
Beetles	Coleoptera	9.60E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Alnus	Anderson et. al. 1973
Beetles	Coleoptera	4.90E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Myrica	Anderson et. al. 1973
Beetles	Coleoptera	5.50E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Coleoptera/Orthoptera	Anderson et. al. 1973
Clover	*Trifolium repens*	1.30E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 1st year	Adriano et. al. 1984

Medium	Organism	BCF	N	Location: General	Location: Specific	Radionuclide	Conditions	Reference
Clover	*Trifolium repens*	9.30E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Clover	*Trifolium repens*	8.00E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Corn	Grain	1.00E-02	13	Burial Grnd		Cs-137	Roots did not penetrate waste	Gay 1982
Corn	Leaves	6.20E-02	13	Burial Grnd		Cs-137	Roots did not penetrate waste	Gay 1982
Corn	*Zea mays*, Leaves	2.53E+00	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 1st year	Adriano et. al. 1984
Corn	*Zea mays*, Leaves	7.40E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Corn	*Zea mays*, Leaves	7.30E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Corn	*Zea mays*, Leaves	2.40E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Corn	*Zea mays*, Leaves	5.40E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
Corn	*Zea mays*, Stems	7.90E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 1st year	Adriano et. al. 1984
Corn	*Zea mays*, Stems	2.80E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Corn	*Zea mays*, Stems	3.80E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Corn	*Zea mays*, Stems	1.70E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Corn	*Zea mays*, Stems	2.30E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
Crickets	Orthoptera	6.60E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Andropogon	Anderson et. al. 1973
Crickets	Orthoptera	1.30E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Alnus	Anderson et. al. 1973
Crickets	Orthoptera	6.90E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Myrica	Anderson et. al. 1973
Crickets	Orthoptera	8.40E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Salix	Anderson et. al. 1973
Crickets	Orthoptera	1.60E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Araneae	Anderson et. al. 1973
Crickets	Orthoptera	1.60E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Coleoptera	Anderson et. al. 1973
Crickets	Orthoptera	2.10E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Orthoptera/Homoptera	Anderson et. al. 1973
Dry forage		3.00E+00		Par Pond		Cs-137		Whicker et. al. 1993
Fresh vegetables		9.00E-01		Par Pond		Cs-137		Whicker et. al. 1993
Fungi	Agaric	1.34E+01	22	LTR	Pat. Mill	Cs-137	All substrates	Hay 1977
Fungi	Agaric	9.30E+00	21	LTR	Martin-Mill.	Cs-137	All substrates	Hay 1977
Fungi	Agaric	9.60E+00	4	LTR	Pat. Mill	Cs-137	Standing stumps	Hay 1977
Fungi	Agaric	1.84E+01	3	LTR	Martin-Mill.	Cs-137	Standing stumps	Hay 1977
Fungi	Agaric	1.50E+01	12	LTR	Pat. Mill	Cs-137	Prone logs	Hay 1977
Fungi	Agaric	6.70E+00	10	LTR	Martin-Mill.	Cs-137	Prone logs	Hay 1977
Fungi	Agaric	1.34E+01	3	LTR	Pat. Mill	Cs-137	Fallen branch	Hay 1977
Fungi	Agaric	1.00E+01	7	LTR	Martin-Mill.	Cs-137	Fallen branch	Hay 1977
Fungi	Agaric	1.04E+01	3	LTR	Pat. Mill	Cs-137	Soil/Litter	Hay 1977

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Fungi	Agaric	1.15E+01	1	LTR	Martin-Mill.	Cs-137	Soil/Litter	Hay 1977
Fungi	Bracket	8.90E+00	48	LTR	Pat. Mill	Cs-137	All substrates	Hay 1977
Fungi	Bracket	7.40E+00	50	LTR	Martin-Mill.	Cs-137	All substrates	Hay 1977
Fungi	Bracket	7.40E+00	13	LTR	Pat. Mill	Cs-137	Standing stumps substtates	Hay 1977
Fungi	Bracket	6.40E+00	17	LTR	Martin-Mill.	Cs-137	Standing stumps substtates	Hay 1977
Fungi	Bracket	1.13E+01	17	LTR	Pat. Mill	Cs-137	Prone logs substtates	Hay 1977
Fungi	Bracket	4.80E+00	10	LTR	Martin-Mill.	Cs-137	Prone logs substtates	Hay 1977
Fungi	Bracket	7.50E+00	18	LTR	Pat. Mill	Cs-137	Fallen branch substtates	Hay 1977
Fungi	Bracket	1.15E+01	23	LTR	Martin-Mill.	Cs-137	Fallen branch substtates	Hay 1977
Fungi	Total	1.01E+01	70	LTR	Pat. Mill	Cs-137	All substrates	Hay 1977
Fungi	Total	8.00E+00	71	LTR	Martin-Mill.	Cs-137	All substrates	Hay 1977
Myrtle	*Myrica cerifera*, leaves	7.10E+00	13	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Myrtle	*Myrica cerifera*, roots	7.60E+00	13	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Myrtle	*Myrica cerifera*, species mean	6.20E+00	13	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Myrtle	*Myrica cerifera*, stems	3.80E+00	13	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Pine Tree	Leaves	2.37E+00	12	SRL	Basin 4	Cs-137		Murphy 1992
Pine Tree	Leaves	5.20E-03	16	SRL	Basin Edge	Cs-137		Murphy 1992
Red Maple	*Acer rubrum*, leaves	7.3E-01	comp	LTR	Boiling Sp.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	2.0E-01	comp	LTR	Boiling Sp.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	2.1E+00	comp	LTR	Boiling Sp.	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	3.47E+00	comp	LTR	Donora St.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	1.2E+00	comp	LTR	Donora St.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	5.45E+00	comp	LTR	Donora St.	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	1.6E-01	comp	LTR	Martin-Mill	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	1.7E-01	comp	LTR	Martin-Mil	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, leaves	5.7E-01	comp	LTR	Martin-Mil	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	8.5E-01	comp	LTR	Boiling Sp.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	1.6E+00	comp	LTR	Boiling Sp.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	2.1E+00	comp	LTR	Boiling Sp.	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	8.3E+00	comp	LTR	Donora St.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	2.3E+00	comp	LTR	Donora St.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	7.6E+00	comp	LTR	Donora St.	Cs-137	90 m transect	Ragsdale and Shure 1973

				Location				
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Red Maple	*Acer rubrum*, roots	3.0E-01	comp	LTR	Martin-Mill	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	3.0E-01	comp	LTR	Martin-Mil	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, roots	9.0E-01	comp	LTR	Martin-Mil	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	1.43E+00	comp	LTR	Boiling Sp.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	2.29E+00	comp	LTR	Boiling Sp.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	4.03E+00	comp	LTR	Boiling Sp.	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	1.54E+01	comp	LTR	Donora St.	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	4.43E+00	comp	LTR	Donora St.	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	1.31E+01	comp	LTR	Donora St.	Cs-137	90 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	6.4E-01	comp	LTR	Martin-Mill	Cs-137	30 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	6.1E-01	comp	LTR	Martin-Mil	Cs-137	60 m transect	Ragsdale and Shure 1973
Red Maple	*Acer rubrum*, young roots	1.65E+00	comp	LTR	Martin-Mil	Cs-137	90 m transect	Ragsdale and Shure 1973
Rice	Belle Patna, foliage	5.30E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Belle Patna, Grain	3.60E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, foliage	9.60E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, Grain	6.10E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, foliage	7.00E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, Grain	4.60E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, foliage	7.10E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, Grain	7.00E-01	6	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Smartweed	*Polygonum punctatum*	6.30E-01		LTR		Cs-137		Gladden 1979
Smartweed	*Polygonum punctatum*	9.20E-01		LTR		Cs-137		Gladden 1979
Smartweed	*Polygonum punctatum*, Leaves	1.18E+01	18	Steel Creek	delta	Cs-137	Soil <100 pCi/g Cs-137	Sharitz et. al. 1975
Smartweed	*Polygonum punctatum*, Leaves	6.00E-01	102	Steel Creek	delta	Cs-137	Soil >100 pCi/g Cs-137	Sharitz et. al. 1975
Smartweed	*Polygonum punctatum*, Roots	2.79E+01	18	Steel Creek	delta	Cs-137	Soil <100 pCi/g Cs-137	Sharitz et. al. 1975
Smartweed	*Polygonum punctatum*, Roots	8.40E-01	102	Steel Creek	delta	Cs-137	Soil >100 pCi/g Cs-137	Sharitz et. al. 1975
Smartweed	*Polygonum punctatum*, Stems	1.22E+01	18	Steel Creek	delta	Cs-137	Soil <100 pCi/g Cs-137	Sharitz et. al. 1975
Smartweed	*Polygonum punctatum*, Stems	3.90E-01	102	Steel Creek	delta	Cs-137	Soil >100 pCi/g Cs-137	Sharitz et. al. 1975
Snakes		2.94E+00				Cs-137	snakes/small mammals	Brisbin et al. 1974
Soybeans	*Glycine max*, Beans	1.66E+00	10	Burial Grnd		Cs-137	Roots did not penetrate waste	Gay 1982
Soybeans	*Glycine max*, Beans	7.00E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Soybeans	*Glycine max*, Beans	5.90E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Soybeans	*Glycine max*, Beans	2.90E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Soybeans	*Glycine max*, Beans	2.60E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
Soybeans	*Glycine max*, Stems	1.50E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 1st year	Adriano et. al. 1984

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Soybeans	*Glycine max*, Stems	2.80E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Soybeans	*Glycine max*, Stems	3.70E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Soybeans	*Glycine max*, Stems	1.40E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Soybeans	*Glycine max*, Stems	1.70E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
Spiders	Araneae	9.20E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Alnus	Anderson et. al. 1973
Spiders	Araneae	4.10E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Andropogon	Anderson et. al. 1973
Spiders	Araneae	4.50E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Myrica	Anderson et. al. 1973
Spiders	Araneae	1.30E+00	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Homoptera	Anderson et. al. 1973
Spiders	Araneae	5.00E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Salix	Anderson et. al. 1973
Spiders	Araneae	6.00E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Orthoptera	Anderson et. al. 1973
Spiders	Araneae	9.90E-01	comp	Steel Creek	Floodplain	Cs-137	Old-Field Habitat - Araneae/Coleoptera	Anderson et. al. 1973
Tree	Maple, sweetgum, and poplar, Bark	3.90E-02	9	H Area/ FMB	Floodplain	Cs-137	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Leaves	2.70E-01	9	H Area/ FMB	Floodplain	Cs-137	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Wood	1.10E-01	9	H Area/ FMB	Floodplain	Cs-137	Field experiment	Pinder et. al. 1984
Turkey Oak	*Quercus laevis*, leaves	7.9E+00	4	E Boundary	0-15cm	Cs-137	Sandhills community, sand=91%, clay=3, silt=6	Croom 1978
Turkey Oak	*Quercus laevis*, leaves	1.29E+01	4	E Boundary	0-25 cm	Cs-137	Sandhills community, sand=91%, clay=3, silt=	Croom 1978
Turkey Oak	*Quercus laevis*, leaves	2.57E+01	4	E Boundary	5-25 cm	Cs-137	Sandhills community, sand=91%, clay=3, silt=6	Croom 1978
Water Tupelo	*Nyssa aquatica*, Leaves	8.50E-01	15			Cs-137	inundated soil, greenhouse	McLeod and Dawson 1980
Water Tupelo	*Nyssa aquatica*, Leaves	4.10E-01	15			Cs-137	unsaturated soil, greenhouse	McLeod and Dawson 1980
Water Tupelo	*Nyssa aquatica*, Root	7.00E+00	15			Cs-137	inundated soil, greenhouse	McLeod and Dawson 1980
Water Tupelo	*Nyssa aquatica*, Root	3.20E+00	15			Cs-137	unsaturated soil, greenhouse	McLeod and Dawson 1980
Water Tupelo	*Nyssa aquatica*, Stem	7.20E-01	15			Cs-137	inundated soil, greenhouse	McLeod and Dawson 1980
Water Tupelo	*Nyssa aquatica*, Stem	4.00E+00	15			Cs-137	unsaturated soil, greenhouse	McLeod and Dawson 1980
Wheat	*Triticum aestivum*, Grain	1.80E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 2nd year	Adriano et. al. 1984
Wheat	*Triticum aestivum*, Grain	1.00E-01	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 3rd year	Adriano et. al. 1984
Wheat	*Triticum aestivum*, Grain	6.00E-02	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 4th year	Adriano et. al. 1984
Wheat	*Triticum aestivum*, Grain	7.00E-02	7	H Area/ FMB	Floodplain	Cs-137	silt=11%, clay=20%, greenhouse, 5th year	Adriano et. al. 1984
White Tailed Deer	*Odocoileus virginianus*, Muscle	3.80E-01	562			Cs-137	muscle (wet)/Rumen contents (dry)	Haselow 1991
White Tailed Deer	*Odocoileus virginianus*, Muscle	6.80E-01				Cs-137	muscle (wet)/Rumen contents (dry)	Brisbin and Smith 1975
White Tailed Deer	*Odocoileus virginianus*, Muscle	7.00E-01	369			Cs-137	muscle (wet)/Rumen contents (dry)	Rabon 1968
White Tailed Deer	*Odocoileus virginianus*, Muscle	2.27E+00				Cs-137	muscle (dry)/Rumen contents (dry)	Brisbin and Smith 1975
White Tailed Deer	*Odocoileus virginianus*, Muscle	2.32E+00	562			Cs-137	muscle (dry)/Rumen contents (dry)	Haselow 1991

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
White Tailed Deer	*Odocoileus virginianus*, Muscle	2.20E-01	562			Cs-137	muscle (wet)/Feces (dry)	Haselow 1991
White Tailed Deer	*Odocoileus virginianus*, Muscle	1.14E+00	562			Cs-137	muscle (dry)/Feces (dry)	Haselow 1991
White Tailed Deer	*Odocoileus virginianus*, Muscle	4.80E+00				Cs-137	muscle (wet)/diet	Jenkins and Findley 1971a
White Tailed Deer	*Odocoileus virginianus*	1.32E+00				Cs-137	whole body/rumen	Brisbin and Smith 1975
White Tailed Deer	*Odocoileus virginianus*	5.10E-01	571			Cs-137	rumen contents (dry)/rumen contents (dry)	Haselow 1991
Willow	*Salix nigra*, leaves	3.80E+00	24	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Willow	*Salix nigra*, roots	6.20E+00	24	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Willow	*Salix nigra*, species mean	3.80E+00	24	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Willow	*Salix nigra*, stems	1.30E+00	24	Steel Creek	Floodplain	Cs-137	field experiment	Garten et. al. 1975a
Bahia Grass	*Paspalum notatum*	4.00E-04	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Bahia Grass	*Paspalum notatum*	5.60E-03	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Bahia Grass	*Paspalum notatum*	6.60E-05	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Bahia Grass	*Paspalum notatum*	6.00E-05	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Bahia Grass	*Paspalum notatum*	1.90E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Clover	*Trifolium repens*	6.10E-04	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Clover	*Trifolium repens*	6.70E-02	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Clover	*Trifolium repens*	4.20E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Clover	*Trifolium repens*	4.10E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Clover	*Trifolium repens*	1.47E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Corn	*Zea mays*, Leaves	1.70E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Corn	*Zea mays*, Leaves	3.40E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Corn	*Zea mays*, Leaves	7.50E-04	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Leaves	1.90E-02	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Leaves	1.80E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	6.80E-04	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	3.60E-02	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	2.10E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, standing vegetation	4.50E-01	10	NE SRS		Pu-238	sand=66%, silt=6%, clay=28%, greenhouse, after 30 days	Hersloff and Corey 1978
Corn	*Zea mays*, standing vegetation	1.50E-01	10	NE SRS		Pu-238	sand=66%, silt=6%, clay=28%, greenhouse, after 50 days	Hersloff and Corey 1978

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Pine Tree	Leaves	4.70E-03	12	SRL	Basin 4	Pu-238		Murphy 1992
Pine Tree	Leaves	1.50E-04	16	SRL	Basin Edge	Pu-238		Murphy 1992
Rice	Belle Patna, foliage	3.10E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Belle Patna, Grain	9.00E-05	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, foliage	2.60E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, Grain	3.60E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, foliage	4.90E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Nato, Grain	2.60E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, foliage	2.60E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Starbonnet, Grain	1.40E-04	6	H Area/ FMB	Floodplain	Pu-238	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Soybean	*Glycine max*, Bean	2.40E-03	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Bean	2.60E-01	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Bean	5.20E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	8.30E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Soybean	*Glycine max*, Stem	1.06E-03	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Soybean	*Glycine max*, Stem	3.00E-03	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	1.60E-01	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	6.80E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Tree	Maple, sweetgum, and poplar, Bark	2.70E-04	9	H Area/ FMB	Floodplain	Pu-238	Field experiment, corrected for uptake only	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Leaves	3.00E-04	9	H Area/ FMB	Floodplain	Pu-238	Field experiment, corrected for uptake only	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Wood	3.30E-05	9	H Area/ FMB	Floodplain	Pu-238	Field experiment, corrected for uptake only	Pinder et. al. 1984
Wheat	*Triticum aestivum*, Grain	1.80E-03	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Grain	3.50E-02	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Grain	3.70E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Stem	2.40E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 1st year	Adriano et. al. 1986
Wheat	*Triticum aestivum*, Stem	1.04E-03	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, clay=20%, greenhouse, 4th year	Adriano et. al. 1986
Wheat	*Triticum aestivum*, Vegetation	6.80E-04	7	H Area	Field 1	Pu-238	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Vegetation	1.40E-02	7	H Area	Field 2	Pu-238	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Vegetation	2.50E-04	7	H Area/ FMB	Floodplain	Pu-238	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, standing vegetation	1.70E-01	10	NE SRS		Pu-239	sand=66%, silt=6%, clay=28%, greenhouse, after 30 days	Hersloff and Corey 1978
Corn	*Zea mays*, standing vegetation	7.20E-02	10	NE SRS		Pu-239	sand=66%, silt=6%, clay=28%, greenhouse, after 50 days	Hersloff and Corey 1978
Bahia grass	*Paspalum notatum*	8.90E-05	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Bahia grass	*Paspalum notatum*	2.30E-03	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Bahia grass	*Paspalum notatum*	4.40E-03	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Clover	*Trifolium repens*	1.40E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Clover	*Trifolium repens*	1.90E-02	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Clover	*Trifolium repens*	2.00E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Leaves	2.10E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Leaves	6.10E-03	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Leaves	1.40E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	1.60E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	1.00E-02	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Corn	*Zea mays*, Stalk	1.70E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Pine Tree	Leaves	7.30E-03	12	SRL	Basin 4	Pu-239,240		Murphy 1992
Pine Tree	Leaves	1.20E-04	16	SRL	Basin Edge	Pu-239,240		Murphy 1992
Rice	Belle Patna, foliage	7.50E-03	6	H Area/ FMB	Floodplain	Pu-239,240	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Belle Patna, Grain	7.90E-03	6	H Area/ FMB	Floodplain	Pu-239,240	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, foliage	2.50E-02	6	H Area/ FMB	Floodplain	Pu-239,240	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, Grain	1.50E-02	6	H Area/ FMB	Floodplain	Pu-239,240	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Soybean	*Glycine max*, Bean	5.60E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Bean	7.40E-02	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Bean	3.90E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	7.20E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	4.70E-02	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Soybean	*Glycine max*, Stem	5.40E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Grain	4.20E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Grain	1.00E-02	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Grain	2.90E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Vegetation	1.80E-04	7	H Area	Field 1	Pu-239,240	sand=70%, silt=7%, clay=23%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Vegetation	4.10E-03	7	H Area	Field 2	Pu-239,240	sand=77%, silt=8%, clay=16%, greenhouse	McLeod et. al. 1981
Wheat	*Triticum aestivum*, Vegetation	1.30E-02	7	H Area/ FMB	Floodplain	Pu-239,240	sand=69%, silt=11%, clay=20%, greenhouse	McLeod et. al. 1981
Rice	Belle Patna, foliage	4.00E-01	6	H Area/ FMB	Floodplain	Ra-226	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	Belle Patna, Grain	6.90E-01	6	H Area/ FMB	Floodplain	Ra-226	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, foliage	1.80E+00	6	H Area/ FMB	Floodplain	Ra-226	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Rice	IR-1561, Grain	1.03E+00	6	H Area/ FMB	Floodplain	Ra-226	silt=11%, clay=20%, greenhouse	Adriano et. al. 1981a
Tree	Maple, sweetgum, and poplar, Bark	7.00E-01	9	H Area/ FMB	Floodplain	Ra-226	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Leaves	2.00E+00	9	H Area/ FMB	Floodplain	Ra-226	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Wood	1.00E-02	9	H Area/ FMB	Floodplain	Ra-226	Field experiment	Pinder et. al. 1984

				Location				
Medium	Organism	BCF	N	General	Specific	Radionuclide	Conditions	Reference
Corn	*Zea mays*, Grain	1.50E-01	13	Burial Grnd		Sr-90	Roots did not penetrate waste	Gay 1982
Corn	*Zea mays*, Leaves	1.31E+01	13	Burial Grnd		Sr-90	Roots did not penetrate waste	Gay 1982
Pine Tree	Leaves	1.69E+00	12	SRL	Basin 4	Sr-90		Murphy 1992
Pine Tree	Leaves	8.80E-01	16	SRL	Basin Edge	Sr-90		Murphy 1992
Soybeans	*Glycine max*,	2.51E+00	10	Burial Grou		Sr-90	Roots did not penetrate waste	Gay 1982
Tree	Maple, sweetgum, and poplar, Bark	1.10E+01	9	H Area/ FMB	Floodplain	Sr-90	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Leaves	3.80E+00	9	H Area/ FMB	Floodplain	Sr-90	Field experiment	Pinder et. al. 1984
Tree	Maple, sweetgum, and poplar, Wood	8.10E-01	9	H Area/ FMB	Floodplain	Sr-90	Field experiment	Pinder et. al. 1984
Corn	*Zea mays*, Grain	6.00E-05	6	H Area	South Field	Total Pu	Vaucluse soil, pH=4.6, greenhouse	Adriano et. al. 1980a
Corn	*Zea mays*, Leaves	6.00E-04	6	H Area	South Field	Total Pu	Vaucluse soil, pH=4.6, greenhouse	Adriano et. al. 1980a
Soybeans	*Glycine max*, Whole plant	3.00E-03	10	H Area	South Field	Total Pu	Vaucluse soil, pH=4.6, greenhouse	Adriano et. al. 1980a
Wheat	*Triticum aestivum*, Straw	2.00E-03	10	H Area	South Field	Total Pu	Vaucluse soil, pH=4.6, greenhouse	Adriano et. al. 1980a
White Tailed Deer	*Odocoileus virginianus*, Bone	1.50E-02	3	H Area		Total Pu	Dry weight, Animal/Soil	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Bone	1.75E-01	3	H Area		Total Pu	Dry weight, Animal/Vegetation (honeysuckle)	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Liver	1.30E-02	3	H Area		Total Pu	Dry weight, Animal/Soil	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Liver	1.48E-01	3	H Area		Total Pu	Dry weight, Animal/Vegetation (honeysuckle)	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Lungs	6.00E-03	3	H Area		Total Pu	Dry weight, Animal/Soil	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Lungs	7.30E-02	3	H Area		Total Pu	Dry weight, Animal/Vegetation (honeysuckle)	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Muscle	1.00E-03	3	H Area		Total Pu	Dry weight, Animal/Soil	Kirkam et. al. 1979
White Tailed Deer	*Odocoileus virginianus*, Muscle	1.40E-03	3	H Area		Total Pu	Dry weight, Animal/Vegetation (honeysuckle)	Kirkam et. al. 1979

APPENDIX C

MAP OF SAVANNAH RIVER SITE

FIGURE 1. SAVANNAH RIVER SITE