5a

PNL-2740

UC-11

**A Research Report for the
Rockwell Hanford Operations**

**Behavior of Technetium and
Iodine in a Hanford Sand and
Associated Subsoil: Influence of
Soil Aging on Uptake by
Cheatgrass and Tumbleweed**

D. A. Cataldo

March 1979

**Prepared for the
U.S. Department of Energy**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

PNL-2740

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

The views, opinions and conclusions contained in this report are those of the contractor and do not necessarily represent those of the United States Government or the United States Department of Energy.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$ ____*; Microfiche \$3.00

*Pages	NTIS
	Selling Price
001-025	\$4.00
026-050	\$4.50
051-075	\$5.25
076-100	\$6.00
101-125	\$6.50
126-150	\$7.25
151-175	\$8.00
176-200	\$9.00
201-225	\$9.25
226-250	\$9.50
251-275	\$10.75
276-300	\$11.00

3 3679 00049 3280

BEHAVIOR OF TECHNETIUM AND IODINE
IN A HANFORD SAND AND ASSOCIATED SUBSOIL:
INFLUENCE OF SOIL AGING ON UPTAKE
BY CHEATGRASS AND TUMBLEWEED

D. A. Cataldo

March 1979

Prepared for the U.S. Department of Energy
under Rockwell Hanford Operations
Contract EY-77-C-06-1030
and under Pacific Northwest Laboratory
Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

The comparative availability to plants of $^{99}\text{TcO}_4^-$ and $^{125}\text{I}^-$ amended Rupert soil and associated subsoil was determined for soils aged after amendment for periods of 1, 10, 30, and 100 days prior to planting. Concentration ratios for cheatgrass (Bromus tectorum) grown on Rupert soil and subsoil amended with $^{99}\text{TcO}_4^-$ ranged from 185 to 91 and 466 to 309, respectively; values for tumbleweed (Salsola Kali) ranged from 148 to 82 and 881 to 173 when grown on Rupert soil and subsoil, respectively. Concentration ratios for both cheatgrass and tumbleweed grown on Rupert soil amended with $^{125}\text{I}^-$ ranged from 0.95 to 0.25; values for cheatgrass and tumbleweed grown on subsoil ranged from 3.5 to 1.3 and 13 to 5.8, respectively. Analyses of concentration ratios, shoot concentrations and percentage of spike absorbed indicate a reduction in plant availability of both ^{99}Tc and ^{125}I over the 100-day soil-aging period. This may result from immobilization of $^{99}\text{TcO}_4^-$ and anion exchange reactions for $^{125}\text{I}^-$.

ACKNOWLEDGMENT

This document represents an applied ecology study prepared for the Rockwell Hanford Operation-Hanford intercontractor support agreements. In conducting this study, we have drawn extensively on the large data base and the professional staff supported by the Environmental Sciences Program, Office of Environmental Research (formally DBER) of the Department of Energy.

CONTENTS

EXECUTIVE SUMMARY	ii
ACKNOWLEDGMENT	iii
LIST OF TABLES	vi
INTRODUCTION	1
MATERIALS AND METHODS	2
Plant Cultures	2
Soil Preparation	3
Soil Amendment and Radionanalysis	3
RESULTS	4
DISCUSSION AND CONCLUSIONS	10
REFERENCES	13

LIST OF TABLES

1.	Size Distributions of Soils	3
2.	Properties of Soil Samples	4
3.	Elemental Analysis of Hanford Area Soils (<100 mesh)	6
4.	Growth Behavior of Cheatgrass and Tumbleweed Plants Grown Under Controlled Conditions in Rupert Sand and Subsoil B	7
5.	Absorption of $^{99}\text{TcO}_4^-$ by Cheatgrass and Tumbleweed Grown on Rupert and Subsoil B Aged for Various Periods Prior to Planting	8
6.	Absorption of $^{125}\text{I}^-$ by Cheatgrass and Tumbleweed Grown on Rupert and Subsoil B, Aged for Various Periods Prior to Planting	9

INTRODUCTION

Technetium-99 and Iodine-129 represent two radionuclides of long-term concern for waste management. While primarily confined to liquid wastes, both can have volatile chemical forms. Recent studies at Hanford using arid calcareous soils (Routson and Cataldo, 1977; Wildung et al., 1974) and elsewhere using high organic matter, low pH Minnesota soils (Gast, 1975) have shown Tc to be readily available for plant uptake. Concentration ratios (CR) range from 100 to 1000 in these studies. The unusual bioavailability of Tc compared to other radionuclides appears to be a function of both its soil chemistry and its biological similarity to nutrient anions required for plant growth. There is little systematic data available to describe the behavior of I^- in Hanford soils.

Studies with Tc have dealt exclusively with the soluble pertechnetate species (TcO_4^-), which under aerobic conditions and soil pH of below approximately 6.0 can be expected to be the major soluble species (Dezoudor and Pourboix, 1966). Soil sorption studies have generally shown TcO_4^- to be sorbed in significant quantities only in high organic matter, low pH soils (Gast, 1975; Wildung et al., 1974). K_d values for pertechnetate have been shown to be 0 to 0.12 for Hanford sands and low CEC South Carolina subsoils (Routson et al., 1977). In studies with a series of soils varying in chemical and physical properties, K_d values were shown to vary from 0.007 to 2.8 and were correlated with % organic matter, CEC and pH (Wildung et al., 1974).

The low sorption values of Tc in soils result in a large proportion of soluble and potentially available Tc for plant absorption. This coupled with the fact that plants possess an effective mechanism for absorbing TcO_4^- accounts for the comparatively high CR values. Laboratory studies with hydroponically grown plants have shown that the plant root possesses an efficient mechanism for absorption of TcO_4^- over a broad range in concentration (Cataldo et al., 1975). Analysis of absorption kinetics demonstrated a classical type of multiphasic absorption characteristic of nutrient ion absorption. This suggests that TcO_4^- is behaving as an analog of an essential nutrient and being accumulated by similar mechanisms. Ion competition studies supported this contention in that SO_4^{2-} and $H_2PO_4^-$ were effective in interfering with TcO_4^- absorption.

The behavior of iodide and methyl-iodide in 22 soils varying widely in properties has been described by Wildung et al. (1974), and K_d values shown to range from 0.8 to 52.6 and 0.1 to 3.1, respectively. In these studies, soil sorption was only weakly correlated with % silt in the case of iodide and % organic carbon, CEC and % clay in the case of methyl-iodide. Organic forms of iodine (C_1 to C_8 alkanes) are receiving increased attention as a result of their volatile nature and potential for dissemination in the environment.

Under controlled laboratory conditions, I^- absorption by plants has been shown to be under metabolic regulation over the concentration range of 5×10^{-9} to $10^{-6} M$ (Kaufholz and Reiniger, 1977). Agronomic plants grown on Ritzville soil amended with carrier-free $^{125}I^-$, exhibited CR values of 1.25 to 0.53 (Cline and Klepper, 1975). These values were increased by three orders of magnitude when carrier iodide (5 to 15 ppm) was added to soil. In a companion study with wheat, CR values were shown to decrease from 0.93 to 0.07 for 5-day-old shoots when soils were aged for 2 to 80 days prior to planting, suggesting the presence of soil mechanisms for reducing the plant availability of I^- amended to soils (Klepper, 1976).

The present study investigates the uptake of $^{99}TcO_4^-$ and $^{125}I^-$ by cheatgrass and tumbleweed grown on Rupert sand from a waste management area and on an associated subsoil. In addition, the influence of soil aging of Tc and I on uptake was studied to determine possible long-term trends in plant availability.

MATERIALS AND METHODS

Plant Cultures. The plants employed in this study were cheatgrass (Bromus tectorum) and tumbleweed (Salsola kali). These annuals are introduced species that are well adapted to an arid climate and readily invade disturbed areas on the Hanford Reservation. Plants were germinated and grown in one kg of soil packed into quart cartons lined with plastic. Four replicates of each treatment and a control were prepared and placed in a growth chamber and maintained for 60 days with 20C day and 12C night temperatures, 14 hr photoperiod and ambient humidity (approximately 30% RH). Seedlings were thinned to a single plant per pot, irrigated 3 times a week with distilled water to maintain soil moisture at ~ 0.3 bar, and fertilized periodically with NH_4NO_3 solution added with irrigation water (total N added was 82 $\mu g/g$ soil).

Soil Preparation. Soils studied were Rupert loamy sand and an adjacent subsoil. The Rupert sand was collected from an area 200 yd west of the 218-W-3A waste burial grounds and represents the upper 4 in. of soil. The subsoil was obtained from the 218-W-3A waste burial grounds, trench 13. The sand and subsoil were quartered and sieved through a 6.35 mm screen; more than 99.9% of the Rupert sand passed the screen, while greater than 47% of the subsoil was retained and consisted of gravel. The less than 6.35 mm fraction of subsoil was employed in uptake studies and termed subsoil B. The Rupert sand and the subsoil B were further sieved using 2 mm and 100 mesh sieves; particle distributions are shown in Table 1. The less than 2 mm component was employed for particle size analysis, CEC, pH, and the less than 100 mesh was used for mineralogy studies.

Soil Amendment and Radionalysis. Soils were amended with $^{99}\text{TcO}_4^-$ traced with $^{95\text{m}}\text{TcO}_4^-$. The final soil concentration of ^{99}Tc was 3.6 pg $^{99}\text{Tc/g}$ dry weight soil. Iodine was supplied as carrier-free $^{125}\text{I}^-$; final soil concentration was 0.9 pg/g dry wt soil. During amendment, the Rupert sand and subsoil B were brought to 13% and 8% moisture by weight, respectively. Subsoil B was overlain with 1.5 cm of unamended Rupert soil to permit growth of seedlings. Soils were held in environmentally controlled chambers for 1, 10, 30, 60, and 100 days prior to planting with cheatgrass and tumbleweed. After 60 days, plants were harvested, oven dried at 60C for 12 hr, weighed and the $^{95\text{m}}\text{Tc}$ and ^{125}I content determined by gamma spectrometry. CR values were calculated from activity of $^{95\text{m}}\text{Tc}$ or $^{125}\text{I/g}$ dry wt plant tissue $\div$ activity/g dry wt soil.

TABLE 1. Size Distributions of Soils

<u>Particle Size</u> mm	<u>Soil</u>	
	<u>Rupert</u>	<u>Subsoil</u>
	% dry wt	
6.35	0.1	48.1
2.00 - 6.35	1.8	13.3
0.25 - 2.0	42.2	33.8
0.25	55.9	4.8

RESULTS

The vast majority of studies concerned with radionuclide availability to plants have dealt with surface soils, however, the shallow land burial of solid wastes results in subsoils being brought to the surface. Since little research has been conducted on the comparative bioavailability of radionuclides in Hanford subsoils, the following study was undertaken. Rupert loamy sand is common on the Hanford Reservation and has been employed in previous studies on ^{99}Tc availability to plants (Routson and Cataldo, 1977). Table 2 gives the properties of Rupert sand and subsoil B. While similar in texture and CEC, they differ markedly in % OM and pH. Elevated levels of extractable carbonates and sodium are often associated with soil pH values above 8.2.

Preliminary studies with subsoil B showed it to be less than conducive to growth of cheatgrass and tumbleweed as evidenced by reduction in dry matter production. Acidification to reduce pH did not alleviate the problem. Attempts to reduce exchangeable Na^+ with river water (20 column volumes/4 wk) while reducing extractable Na^+ from 134 ppm to 30 ppm (compared with 5 ppm Na^+ for Rupert, 5:1 extract) was only partially successful. While inhibition of germination was alleviated and growth was promoted, exchangeable Na^+ levels rapidly increased to pre-leach levels (less than 7 days) thereby only temporarily resolving the problem.

TABLE 2. Properties of Soil Samples

Property	Soil	
	Rupert Loamy Sand	Subsoil B Loamy Sand
Sand, 50 μ m (%)	84.1	78.8
Silt, 2-50 μ m (%)	8.5	5.3
Clay, 2 μ m (%)	7.4	15.9
CEC (meg/100g)	5.3	5.7
pH	6.8	8.5
organic carbon (%)	0.25	0.05

Analysis of the elemental composition of these soils shows the distribution of macroions to be relatively similar (Table 3). Microions which may influence the plant availability or soil sorption of $^{99}\text{TcO}_4^-$ and $^{125}\text{I}^-$ are also shown. In the case of $^{99}\text{TcO}_4^-$, SO_4^{2-} , PO_4^{3-} and MoO_4^{2-} have been shown to affect plant absorption (Cataldo et al., 1975), while the halides I, Br, Cl and F may be important to $^{125}\text{I}^-$ absorption. Subsoil B has a substantially higher content of each of these potentially interfacing anions. The relative behavior of $^{99}\text{TcO}_4^-$ and $^{125}\text{I}^-$ with respect to plant absorption was investigated using Rupert sand and its associated subsoil to better understand the fate of these nuclides in Hanford soils.

Although cheatgrass and tumbleweed are well adapted to conditions on the Hanford Reservation, preliminary studies with subsoil B showed a significant growth reduction compared with Rupert sand (Table 4). Under these conditions, cheatgrass and tumbleweed exhibit an 80 and 93% reduction in shoot dry matter production when grown on subsoil B. This inhibition was not alleviated by altering either available soil moisture or nitrogen supply. The effect may, therefore, be due to either adverse soil pH or the high salt (Na^+) level of the subsoil or possibly nutrient deficiencies such as phosphorous. This overall growth inhibition was also expressed in premature flowering of tumbleweed; flowering occurred between 20 and 35 days with plants grown on subsoil as compared to the normal flowering at approximately 50 days. In light of the differential growth behavior using these two soils, the following data on plant absorption should be considered with respect to situations which may be encountered in the field (i.e., presence of soil overburden and availability of the nuclides to deep rooted plants; and disturbed subsoils, weathered and/or modified to support plant growth).

A comparison of CR values for cheatgrass and tumbleweed grown on $^{99}\text{TcO}_4^-$ amended Rupert sand maintained for 1 to 100 days prior to planting show a 50% reduction over the 100 day aging period (Table 5). CR values decreased from 185 to 91 and 148 to 82 for cheatgrass and tumbleweed, respectively. A similar trend is seen with tumbleweed grown on subsoil B, where CR values were reduced by 80% when soils were aged for 100 days prior to planting (CR values reduced from 881 to 173). CR values calculated for cheatgrass grown on subsoil were

TABLE 3. Elemental Analysis of Hanford Area Soils
(<100 mesh)

Elemental Composition	Rupert	Subsoil B
Macro-ions		
	- - - - % - - - - -	
Si	28.2	28.6
Al	6.28	5.77
Fe	4.92	4.55
Mg	1.26	1.29
Ca	2.93	3.42
K	1.55	1.70
Na	1.88	1.33
Ba	0.14	0.20
Micro-ions		
	- - - - ppm - - - - -	
I	0.58	6.8
Br	4.5	21
Cl	14	76
F	640	960
S	32	290
P	2400	3700
Mo	1.6	4.5

quite variable, resulting most likely from a variable degree of root penetration through the Rupert sand overlay into the spiked subsoil which was required for germination and growth. The substantially higher Cr values obtained for cheatgrass and tumbleweed grown on subsoil B (approximately 4 fold) result from markedly higher shoot concentrations of ⁹⁹Tc. However, as noted in Table 4, plants grown on subsoil B even with the Rupert sand overlay had a marked reduction in dry matter production which accounts for the increased CR values

TABLE 4. Growth Behavior of Cheatgrass and Tumbleweed Plants Grown Under Controlled Conditions in Rupert Sand and Subsoil B

Plant Species	Soil	Growth Parameters	
		Shoot Dry Wt/Plant ^a	Flowering Time
		- - -g- - -	
Cheatgrass	Rupert	1.39 ± 0.05	NA ^b
	Subsoil B	0.27 ± 0.10	NA
Tumbleweed	Rupert	2.42 ± 0.10	50-55 days
	Subsoil B	0.17 ± 0.02	20-35 days

^amean ± SD (n = 12)

^bnot applicable

and shoot concentrations for ⁹⁹Tc. This effect was seen in the % uptake of ⁹⁹Tc from soils following 60 days of uptake (Table 5). Plants grown on Rupert sand removed from 20 to 40% of the supplied ⁹⁹Tc, while plants grown on subsoil B removed from 4 to 16% of the available ⁹⁹Tc.

Plant absorption data for ¹²⁵I⁻ are shown in Table 6. CR values for cheatgrass and tumbleweed grown on Rupert sand are relatively comparable over the 1 to 100-day treatment period, ranging from 0.95 to 0.25. Plants grown on subsoil B exhibited substantially higher CR values as in the case of ⁹⁹Tc. These CR values ranged from 4 to 1 for cheatgrass and 13 to 6 for tumbleweed plants grown on subsoils aged from 1 to 100 days prior to planting. As noted previously (Table 4), dry matter production was reduced for plants grown on subsoil B and this resulted in increased concentration of ¹²⁵I⁻ in shoot tissues. A comparison of the relative availability of ¹²⁵I⁻, based on % of soil ¹²⁵I⁻ absorbed, shows ¹²⁵I⁻ amended to subsoil B to be about twice as available as ¹²⁵I⁻ amended to Rupert sand in studies with tumbleweed. Comparison of the relative proportion of ¹²⁵I⁻ absorbed from these soils by cheatgrass is difficult since significant variability in dry matter production was noted with aged subsoils.

TABLE 5. Absorption of $^{99}\text{TcO}_4^-$ by Cheatgrass and Tumbleweed Grown on Rupert and Subsoil B Aged for Various Periods Prior to Planting

Soil	Time Prior To Planting	Plant Species	Plant Availability ^a		
			Shoot Concentration	Concentration Ratio ^b	Uptake ^c
	day		pg ⁹⁹ Tc/g		%
Rupert	1	Cheatgrass	664 $\pm$ 68	185 $\pm$ 20	30
	10		506 $\pm$ 23	140 $\pm$ 6	24
	30		574 $\pm$ 72	159 $\pm$ 19	27
	100		329 $\pm$ 50	91 $\pm$ 15	20
	1	Tumbleweed	534 $\pm$ 21	148 $\pm$ 7	41
	10		441 $\pm$ 33	123 $\pm$ 11	40
	30		403 $\pm$ 10	112 $\pm$ 4	38
	100		297 $\pm$ 28	82 $\pm$ 8	33
Subsoil B ^d	1	Cheatgrass	1670 $\pm$ 326	446 $\pm$ 114	14
	10		1780 $\pm$ 244	493 $\pm$ 59	12
	30		2310 $\pm$ 556	640 $\pm$ 152	13
	100		1117 $\pm$ 205	309 $\pm$ 55	4
	1	Tumbleweed	3161 $\pm$ 289	381 $\pm$ 114	16
	10		1820 $\pm$ 300	544 $\pm$ 189	11
	30		1600 $\pm$ 301	444 $\pm$ 87	12
	100		619 $\pm$ 91	173 $\pm$ 29	7

^amean $\pm$ SD (n = 4)

^bConcentration ratio = pg $^{99}\text{Tc/g}$ dry wt shoot - pg $^{99}\text{Tc/g}$ dry wt soil

^cRupert (1000 g pot) contained 3132 pg ^{99}Tc /870 g dry wt soil; Subsoil B contained 3312 pg ^{99}Tc /920 g dry wt soil

^dSubsoil B had a 1.5 cm overlay of unamended Rupert soil

TABLE 6. Absorption of $^{125}\text{I}^-$ by Cheatgrass and Tumbleweed Grown on Rupert and Subsoil B, Aged for Various Periods Prior to Planting

Soil	Time Prior To Planting	Plant Species	Plant Availability ^a		Uptake ^c
			Shoot Concentration	Concentration Ratio ^b	
	day		pg $^{125}\text{Tc/g}$		%
Rupert	1	Cheatgrass	0.86 $\pm$ 0.04	0.95 $\pm$ 0.04	0.16
	10		0.69 $\pm$ 0.01	0.77 $\pm$ 0.02	0.11
	30		0.42 $\pm$ 0.06	0.47 $\pm$ 0.07	0.06
	100		0.23 $\pm$ 0.02	0.26 $\pm$ 0.03	0.04
	1	Tumbleweed	0.86 $\pm$ 0.09	0.96 $\pm$ 0.09	0.28
	10		0.59 $\pm$ 0.07	0.66 $\pm$ 0.09	0.18
	30		0.32 $\pm$ 0.11	0.36 $\pm$ 0.11	0.09
	100		0.21 $\pm$ 0.02	0.24 $\pm$ 0.02	0.08
Subsoil B ^d	1	Cheatgrass	3.15 $\pm$ 0.24	3.49 $\pm$ 0.18	0.08
	10		3.97 $\pm$ 1.24	4.44 $\pm$ 1.53	0.02
	30		1.90 $\pm$ 0.29	2.14 $\pm$ 0.51	0.15
	100		1.13 $\pm$ 0.19	1.27 $\pm$ 0.24	0.05
	1	Tumbleweed	11.7 $\pm$ 1.50	13.1 $\pm$ 2.1	0.64
	10		10.30 $\pm$ 2.15	11.4 $\pm$ 2.0	0.39
	30		6.63 $\pm$ 0.73	7.37 $\pm$ 0.73	0.18
	100		5.20 $\pm$ 0.93	5.78 $\pm$ 1.06	0.05

^amean $\pm$ SD (n = 4)

^bConcentration ratio = pg $^{99}\text{Tc/g}$ dry wt shoot - pg $^{99}\text{Tc/g}$ dry wt soil

^cRupert (1000 g pot) contained 783 pg I^- /870 g dry wt soil; Subsoil B contained 828 pg I^- /920 g dry wt soil

^dSubsoil B has a 1.5 cm overlay of unamended Rupert soil

DISCUSSION AND CONCLUSIONS

The physical characteristics and mineralogy of Rupert sand and the subsoil are relatively similar once the gravel (greater than 6.35 mm) is removed from the latter (Tables 1, 2 and 3). Specific differences include pH, % organic matter, and the content of halides (I, Br, Cl, and F) and potential analogs of Tc (S, available P, and Mo). While it is not possible to correlate specific physical and chemical properties of these soils with plant availability using only two soil types, comparative differences may aid in interpreting biological behavior. Comparisons of these data should be carefully considered in light of the phytotoxic nature of the subsoil compared with Rupert sand. This inhibition of growth (Table 4) even with a Rupert sand overlay, has a dramatic effect on both CR values and shoot concentrations. However, % uptake values for amended soils can be used to place relative availability into perspective. While the extent of growth inhibition increased with soil aging and was not readily alleviated by leaching, exposure of subsoils to the environment and long-term weathering may partially correct this phytotoxicity.

CR values for cheatgrass and tumbleweed plants grown on Rupert sand containing $^{99}\text{TcO}_4^-$ and planted 1 day after amendment were 185 and 148, respectively (Table 5). These values are approximately 50% of those reported previously (Routson and Cataldo, 1977). While growth conditions were comparable, the present study employed only one plant/1000 g pot as compared with 3 to 4 in previous experiments. This permitted a more rapid growth of plants and subsequent dilution of tissue concentration. This tissue dilution effect has been noted with Cs and Sr (Routson and Cataldo, 1978). An interesting aspect of these data is the observed change in availability of ^{99}Tc over the 1 to 100-day pre-aging period. Although K_d values determined over relatively short periods suggest the TcO_4^- (valence VII) is not sorbed to any significant extent in low organic matter soils, the present studies show ^{99}Tc availability to decrease with soil residence time. This decrease in ^{99}Tc availability could result from soil depletion or

immobilization of ^{99}Tc by soil microflora and/or reduction of Tc (VII) in the soil to lower valences and formation of insoluble Tc species. A similar reduction in ^{99}Tc availability is seen with plants grown on subsoil B. Although CR values for plants grown on subsoil B are substantially higher than those on Rupert sand, the proportion of the supplied ^{99}Tc accumulated by cheatgrass and tumbleweed is twice as high for Rupert sand.

CR values for cheatgrass and tumbleweed grown on Rupert sand amended with $^{125}\text{I}^-$ range from 1 to 0.2 following aging of spiked soils for 1 to 100 days, respectively (Table 6). These are similar in magnitude to CR values obtained for crop plants grown on Ritzville soils (Cline and Klepper, 1975). As in the case of ^{99}Tc , CR values for $^{125}\text{I}^-$ decrease with increasing soil residence time, suggesting either a change in chemical form, soil sorption, or biological immobilization (soil microflora). Cheatgrass and tumbleweed grown on subsoil B exhibited substantially higher CR values than for Rupert sand. CR values for cheatgrass varied from 4 to 1.3 over the 1 to 100-day aging period, respectively. Contrary to the results with ^{99}Tc , the greatest absorption (% uptake) of $^{125}\text{I}^-$ was found with tumbleweed grown on subsoil B which was aged for 1 to 30 days prior to planting. While it is possible to understand the change in availability of $^{99}\text{TcO}_4^-$ amended to soils, based on insolubilization reactions, the observed decrease in $^{125}\text{I}^-$ availability to plants is not readily explained away. Equilibrium diagrams for iodine suggest that $^{125}\text{I}^-$ should be stable and predominate in these soils (Dezoudor and Pourboix, 1966). If so, the change in plant availability of $^{125}\text{I}^-$ may result from anion exchange reactions over time or possibly a loss of I from soils via volatilization of I_2 or organic forms of I. A preliminary check of the extent of volatilization of $^{125}\text{I}^-$ from soils indicates a loss rate of 0.024% per day (unpublished data). While this can account for 2.4% of the original spike over the 100 day period, it cannot account for the approximate 75% reduction in $^{125}\text{I}^-$ absorption observed with soil aging.

The present study describes the comparative plant availability of $^{99}\text{TcO}_4^-$ and $^{125}\text{I}^-$ amended to Rupert soil and associated subsoil B. For freshly amended Rupert (day 1), CR values are approximately 107 for both cheatgrass and tumbleweed, while CR values for cheatgrass and tumbleweed grown on freshly amended subsoil B are substantially higher, 450 and 800, respectively. However, analysis of % uptake by plants show less total absorption by plants grown on subsoil B than Rupert soil. Depletion rates for plants grown on Rupert and subsoil B were 35 and 15%, respectively. In the case of $^{125}\text{I}^-$, CR values are similar for both cheatgrass and tumbleweed grown on Rupert soil (0.95), and substantially higher for plants grown on subsoil B. CR values for $^{125}\text{I}^-$ freshly amended to subsoil B were 3.1 and 11.7 for cheatgrass and tumbleweed, respectively. Percentage uptake was greater for tumbleweed grown on subsoil B, followed by tumbleweed grown on Rupert.

An important aspect of these data is the reduction in availability of both ^{99}Tc and ^{125}I over the 1 to 100-day aging period prior to planting, this amounted to a 2- to 5-fold reduction in both shoot CR values and shoot concentrations. While CR values obtained for plants on freshly amended soils is consistent with previous studies, the reduced availability of both Tc and I with soil aging is contrary to present available data on K_d values for TcO_4^- and I^- . Additional investigations are warranted to evaluate possible anion exchange mechanisms in these soils and evaluation of the chemical fate and behavior of both TcO_4^- and I^- in calcareous soils and subsoils typical of the Hanford area.

REFERENCES

Cataldo, D. A., R. E. Wildung, and T. R. Garland. 1976. Accumulation of technetium by plants. II. Potential mechanisms for uptake and toxicity. In: Pacific Northwest Laboratory Annual Report for 1975, BNWL-2000 Pt 2, p. 40-42.

Cline, J. F., and E. W. Klepper. 1975. Iodine-125 accumulation in plant parts: Influence of water use rate and stable iodine content of soil. Health Phys. 28:801-804.

Dezoudor, N., and M. Pourboix. 1966a. Iodine. In: Atlas of Electrochemical Equilibrium in Aqueous Solutions. p. 514. Pergamon Press, NY.

Dezoudor, N., and M. Pourboix. 1966b. Technetium. In: Atlas of Electrochemical Equilibrium in Aqueous Solutions. p. 294. Pergamon Press, NY.

Gast, R. G. 1975. The behavior of technetium-99 in soils and plants. C00-2447-1. NTIS.

Kaufholz, H., and P. Reiniger. 1977. Uptake of iodide by excised bean roots. Physiol. Plant 41:42-44.

Klepper, E. W. 1976. Radioiodine uptake by wheat plants with time after amendment to soil. BNWL-SA-5682. Battelle, Pacific Northwest Laboratories, Richland, WA.

Routson, R. C., and D. A. Cataldo. 1977. Tumbleweed and cheatgrass uptake of ^{99}Tc from five Hanford soils. BNWL-2183. Battelle, Pacific Northwest Laboratories, Richland, WA.

Routson, R. C., and D. A. Cataldo. 1978. A growth chamber study of the affect of soil concentration and plant age in the uptake of Sr and Cs by tumbleweed. Commun. Soil Sci. Plant Anal. 9:215-229.

Routson, R. C., G. Jansen, and A. V. Robinson. 1977. ^{241}Am , ^{237}Np , and ^{99}Tc sorption on two United States subsoils from differing weathering intensity areas. Health Phys. 33:311-317.

Wildung, R. E., T. R. Garland, and D. A. Cataldo. 1977. Accumulation of technetium by plants. Health Phys. 32:314-317.

Wildung, R. E., R. C. Routson, R. J. Serne, and T. R. Garland.. 1974. Pertechetate, iodide and methyl iodide retention by surface soils. In: Battelle, Pacific Northwest Laboratory Annual Report for 1974, BNWL-1950 Pt 2, p. 37-40.

DISTRIBUTION

<u>No. of Copies</u>		<u>No. of Copies</u>	
<u>OFFSITE</u>			
1	A. A. Churm DOE Chicago Patent Group 9800 S. Cass Avenue Argonne, IL 60439		R. J. Gimera M. K. Harmon W. F. Heine R. E. Isaacson J. E. Kinzer C. W. Manry D. A. Marsh H. E. McGuire L. P. McRae R. M. Mitchell G. C. Owens D. Paine (10) J. V. Panesko J. H. Roecker J. A. Swenson D. D. Wodrich
27	DOE Technical Information Center		
1	R. E. Franklin Office of Health and Environmental Research U.S. DOE Germantown Headquarters Bldg. Germantown, MD 20767		
7	D. Saire DWPR U.S. DOE Germantown Headquarters Bldg. Germantown, MD 20767	43	<u>Pacific Northwest Laboratory</u> H. D. Burkholder D. A. Cataldo (20) J. F. Cline B. W. Compton (4) J. P. Corley J. J. Fuquay T. R. Garland K. R. Price W. H. Rickard R. G. Schreckhise N. H. Sherer J. K. Soldat B. E. Vaughan R. E. Wildung Technical Information (5) Publication Coordinator (2)
<u>ONSITE</u>			
10	<u>DOE Richland Operations</u> J. C. Cummings O. J. Elgert R. E. Gerton B. R. Goranson P. G. Harris J. L. Rhoades M. W. Shupe M. W. Tiernan M. G. White M. J. Zamorski		
30	<u>Rockwell Hanford Operations</u> H. Babad D. J. Brown L. E. Bruns J. L. Deichman R. D. Fox		