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AUTHOR(S): J.W. Nyhan
G.C. White
G. Trujillo

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SOIL PLUTONIUM AND CESIUM IN STREAM CHANNELS AND BANKS OF LOS ALAMOS LIQUID EFFLUENT-RECEIVING AREAS*

J.W. Nyhan, G.C. White and G. Trujillo

Box 1663, Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract-Stream channel sediments and adjacent bank soils found in three intermittent streams used for treated liquid effluent disposal at Los Alamos, New Mexico were sampled to determine the distribution of ^{238}Pu, $^{239,240}Pu$, and ^{137}Cs. Radionuclide concentrations and inventories were determined as functions of distance downstream from the waste outfall and from the center of the stream channel, soil sampling depth, stream channel-bank physiography, and the waste use history of each disposal area.

Radionuclide concentrations in channel sediments were inversely related to distances up to 10 km downstream from the outfalls. For sites receiving appreciable waste effluent additions, contaminant concentrations in bank soils decreased with perpendicular distances greater than 0.38 m from the stream channel, and with stream bank sampling depths greater than 20-40 cm. Concentrations and total inventories of radionuclides in stream bank soils generally decreased as stream bank height increased. Inventory estimates of radionuclides in channel sediments exhibited coefficients of variation that ranged from 0.41 to 2.6, reflecting the large variation in radionuclide concentrations at each site.

Several interesting temporal relationships of these radionuclides in intermittent streams were gleaned from the varying waste use histories of the three effluent-receiving areas. Eleven years after liquid wastes were added to one canyon, the major radionuclide inventories were found in the stream bank soils, unlike most of the other currently-used receiving areas. A period of time greater than six years

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seems to be required before the plutonium in liquid wastes currently added to the canyon is approximately equilibrated with the plutonium in the bank soils. These observations are discussed relative to waste management practices in these southwestern intermittent streams.

INTRODUCTION

Over 850 million tons of suspended materials and associated environmental contaminants are carried to the ocean each year by streams in the U.S. (Dal3). Highest sediment yields per unit area are usually encountered in the arid and semiarid western states where intermittent streams predominate (Re74). In spite of this fact, little is known about the fate of environmental contaminants in ephemeral streams of such arid and semiarid areas.

Considerable research studying environmental contaminants in intermittent streams has been done at the Los Alamos National Laboratory in northern New Mexico. The concentration and inventory of sodium, nitrate, chloride and total dissolved solids in effluents added to a Los Alamos intermittent stream was compared to levels of these residual chemicals in an underlying aquifer (Pu77). However, most of the studies have delt with the distribution and inventories of transuranic elements and ^{137}Cs in plants, animals and soils in 12 sampling locations in each of three canyon systems (Hak73; Hak74; Hak76a; Hak76b, Hak80a; Ny76a; Ny76b; Ny76c; Ny78b; Wh79). The soils portion of these studies focused solely on contaminants in stream channel sediments, with the exception of one study, which compared the distribution of mercury, ^{137}Cs, and plutonium in channel sediments and adjacent bank soils (Hak80b).

The objective of the research reported here was to determine the distribution of ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ in stream channel sediments and adjacent bank soils in three canyons which have received liquid radioactive discharges for varying lengths of time. Radionuclide concentrations and inventories were determined as functions of distance from the liquid waste outfall, of sampling depth, and of physiographic characteristics of each intensive study area. Highly replicated sampling of various segments of the stream channels in each canyon also provided an estimate of the variation in radionuclide concentrations, stream channel dimensions, and radionuclide inventories.

SITE DESCRIPTIONS AND METHODS

The three intermittent stream study areas are oriented in an east-west direction in an elevational gradient of 1500 m within 25 km by air, starting at the Rio Grande (1650 m elevation) and rising into the Jemez Mountains (3170 m). The waste effluent streams in the three canyons all originate at about 2200 m in Effluent-Mortandad, DP-Los Alamos and Acid-Pueblo Canyons located in Los Alamos and Santa Fe counties, New Mexico. These three canyon systems have received radioactive liquid wastes from the Los Alamos National Laboratory for varying lengths of time: Effluent-Mortandad Canyon since 1963, DP-Los Alamos Canyon since 1953, and Acid-Pueblo Canyon from 1944 to 1963. The aqueous discharges to these canyons results from Laboratory and/or domestic sewage effluents, wich flow to about 2 km from the waste outfalls before infiltrating the sandy alluvium present in the stream channel (Table 1). Downstream physical transport of contaminants beyond this point occurs solely via runoff events caused by snowmelt and late summer rainstorms. The surrounding biota and soils of these canyons were previously described in detail (Mi77; Ny78a).

The soils of nine, 100-m long intensive study areas located in the three canyon systems (Table 1) were sampled in May of 1974 to determine radionuclide concentrations in the stream channels and in the adjacent stream banks. Ten 30-cm soil cores were randomly collected from the center of the stream channel at each of the sites. Soil cores were also collected to 60-cm depths at distances of 0.02, 0.1, 0.2, 0.38, and 10 m perpendicular to the stream channel at the center of the 100-m long site to characterize the lateral distribution of radionuclides. The stream channel cores were frozen and sectioned into 0-7.5 and 7.5-30 cm segments; stream bank cores were treated similarly, but sectioned into 0-10, 10-20, 20-40, and 40-60 cm segments. Detailed descriptions of soil sampling techniques and ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ assays were given previously (Ny76b; Ny76c).

The inventories of Laboratory-added radionuclides in stream channel and stream-bank soils were calculated for 1 m long sections whose width depended on either

stream width or bank dimensions and whose depth depended on the distance to bedrock. the width of the bank soils was calculated assuming a width of 0.38 m, since the soils at the adjancent sampling locations 10 m from the stream channel generally contained fallout levels of radionuclides. In the shallow streambank soils, the penetration depth of the core sample to bedrock dictated the soil depth; however, the deep bank soils found at some study sites normally contained nondetectable concentrations of radionuclides below the 40-cm depth, which was arbitrarily set as the maximum depth at which Laboratory-added radionuclides were found.

Statistical analysis of the radionuclide inventory data was performed with a Statistical Package for the Social Sciences (Ni75).

RESULTS AND DISCUSSION

Radionuclides Concentrations in Channel Sediments and Bank Soils

Soil cores collected from the stream channel and banks were sectioned into segments to characterize the vertical distribution of radionuclides at each intensive study area. The concentrations of ^{137}Cs are given as a function of soil depth for Site I in Mortandad Canyon (Fig. 1). The ^{137}Cs concentrations of channel sediments collected next to the north bank down to tuff bedrock decreased from 542 to 473 pCi/g for the 0-7.5 cm and 7.5-16 cm depths, respectively. Surface soil samples from the north bank collected only 2 cm away from the edge of the stream channel contained 85 to 92% lower concentrations of ^{137}Cs than adjacent channel samples (Fig. 1), and exhibited even more pronounced changes in radionuclide concentrations with depth, i.e. - bank samples collected at the 20-40 cm depth exhibited 100-fold lower ^{137}Cs concentrations than bank samples from the 0-10 cm depth (Fig. 1). The vertical distribution of radionuclides changed 2180 m downstream at Site III in this canyon, where the site sediments do not come into direct contact with liquid effluents (Table 1). Radionuclide contamination above worldwide fallout levels at this site was confined solely to the top 10 cm of the stream bank soils on both sides of the stream.

Radionuclide concentrations generally decreased with both distance from the liquid waste outfall and distance from the stream channel in all three effluent-receiving areas. This pattern is illustrated by the ^{137}Cs data for two sites in DP-Los Alamos Canyon (Fig. 2), where soil ^{137}Cs concentrations are shown as a function of distance from the edge of the stream channel and soil depth. The two core segments collected in the stream channel from the 0-7.5 cm depth at each site exhibited ^{137}Cs concentrations of 11.9 and 13.2 pCi/g at Site I and 7.52 and 4.96 pCi/g at Site II (Fig. 2). Concentrations of ^{137}Cs in the stream bank soils at Site I in this canyon system ranged from 14.5 to 511 pCi/g for samples collected from 0.02 to 0.38 m from the stream channel. Bank samples collected further than 0.38 m away from the stream channel generally contained world-wide fallout levels of ^{137}Cs - about 1 pCi ^{137}Cs/g (Fig. 2). The latter distribution pattern was found for all bank soil samples collected in every transect run perpendicular to the stream channel at every intensive site studied.

Several transects in DP-Los Alamos Canyon demonstrated minimal soil ^{137}Cs concentrations in the middle of the transect before the concentrations rebounded to larger radionuclide levels (Fig. 2). This pattern only occurs at certain soil depths and can be explained by site hydrologic relationships. At Site I, for example, bank soils close to the stream channel exhibited cesium concentrations that increased with depth, probably reflecting the gradual vertical and upward movement of liquid effluents from the channel sediments into the bank soils at this site. Ten meters from the stream channel, fallout levels of ^{137}Cs were encountered on this transect: none of the latter hydrologic effects were observed, and radionuclide concentrations decreased with soil depth (Fig. 2). At 100 m, worldwide fallout levels of ^{137}Cs were again encountered, only with decreased ^{137}Cs concentrations detected in the surface soils relative to samples collected deeper in the soil profile (Fig. 2). Since both of these 100 m locations are located on talus slopes, where non-contaminated debris from the adjacent cliffs was observed to be subjected to water erosion at the surface of these

sampling locations, this probably resulted in a dilution of the ^{137}Cs in the surface soils (Fig. 2).

Other physiographic features of the stream channels and banks also influenced the distribution of radionuclides at most of the sites. Six out of seven of the sites exhibited decreasing concentrations of radionuclides with increasing bank height, reflecting the observation that low stream banks are exposed to radioactive liquid effluents more frequently than high stream banks during waste discharges and runoff events. For example, the average bank heights out to 0.38 m from the channel at Site I in Mortandad Canyon (Fig. 3) ranged from 22 cm on the south bank to 62 cm on the north bank of this transect. The lower bank soils at this location demonstrated ^{238}Pu concentrations ranging from 0.58 to 2.8 $\mu Ci/m^2$, whereas the higher bank exhibited levels ranging from only 0.042 to 0.077 μCi $^{238}Pu/m^2$ (Fig. 3). Corresponding to this increase in bank height, average ^{137}Cs and $^{239,240}Pu$ concentrations in the bank soils decreased by 91% and 83%, respectively. Generally, bank height differences of 5-10 cm observed in most of the intensive sites resulted in small differences in radionuclide concentrations. Channel width was also not found to be related to bank height, bank shape or radionuclide concentrations. Thus, channel widths, which varied from 0.45 to 3.9 m, were quite independent of radionuclide concentrations or bank heights, which, when measured 0.38 m from the stream channel, varied from 0.13 to 0.86 m.

The relationships amongst the various radionuclides, ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ in the channel and bank samples at each site can provide useful information concerning the depositional and migratory behaviors of these species. The relationship between cesium and plutonium ($^{239,240}Pu$) concentrations in the channel sediments and bank soils for each site are presented in the log-log plots of Fig. 4. Visual inspection of these graphs shows a strong positive relationship between cesium and plutonium concentrations in the channel and bank samples at Site III of Mortandad Canyon and in

the channel samples at Site II of DP-Los Alamos Canyon. The channel sediments and bank soils from Acid-Pueblo Canyon and the bank soils from DP-Los Alamos Canyon show little correlation between ^{137}Cs and $^{239,240}Pu$. The relationship between the logs of the plutonium and cesium concentrations was then quantified by determining the correlation coefficients presented in Table 2.

The interrelations of the radionuclides studied appear to be closely tied to the waste use history in each of the waste disposal areas previously described in detail (Hak73). Mortandad Canyon, which is currently receiving liquid effluents, exhibited very significant Cs-Pu concentration correlations for almost all of the samples collected in this canyon. In contrast, samples collected from Acid-Pueblo Canyon, which has not been used as a disposal area since 1963, seldomly portrayed a significant Cs-Pu concentration correlation in either sediment or soil samples (Table 2). These observations, coupled with a detailed analysis of the vertical distribution of radionulcides in the bank soils in these two canyons supports the idea that the reason for the latter lack of correlation is that ^{137}Cs migrates through the sediments and soils of a liquid waste disposal area more rapidly than plutonium, an observation that has great waste management implications in southwestern streams. Thus, the Cs/Pu activity ratios in bank soils and sediments significantly changed with soil depth in Acid-Pueblo Canyon (^{137}Cs had a much more uniform vertical distribution than plutonium in the bank soils; channel sediments contained relatively more ^{137}Cs than plutonium with increased sampling depth), but not in Mortandad Canyon. Assuming that the Cs/Pu activity ratio of the liquid wastes was relatively constant during the use history of each canyon, this means that ^{137}Cs did continue to migrate through the Acid-Pueblo Canyon bank profiles and channel sediments since 1963.

Radionuclide Inventories

The calculations of the total amounts of radionuclides in the stream channel soils at each study site are presented in Table 3 as the average and the coefficient of variation of the amounts of ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ in the sediments. Sites

I, II, and III in Mortandad Canyon show typically decreasing inventories of radionuclides in the channel soils with increasing distance from the outfall. All of the stream channel soils below the three effluent outfalls contained amounts of radionuclides greater than those in the background site in Mortandad Canyon, which was located upstream from the effluent outfall. The coefficients of variation of the amounts of radionuclides in the stream channel soils ranged from 0.41 to 2.6, due mainly to the large variation in the concentrations of isotopes within the 10 sampling locations at each site, and not due to the relatively small variation (0.17 and 0.44) in stream channel dimensions within the sites (Table 3).

The inventories of radionuclides in the stream banks of each study area are given in Table 4. Since these streambank soils were located about 50 m downstream within each 100-m long intensive site, the inventories of radionuclides in the stream channel soils at this specific location are listed in this table for comparison. Nearly all of the sites contained more $^{239,240}Pu$ in the bank soils than ^{238}Pu, regardless of the $^{239,240}Pu$ to ^{238}Pu ratio in the channel sediments, which reflect the higher ^{238}Pu concentrations currently being added in liquid effluents in Mortandad and DP-Los Alamos Canyons. Evidently, the ^{238}Pu which has been added to laboratory wastes since 1968 is equilibrating with the channel sediments more rapidly than with the bank soils.

The bank soils at Site I in Mortandad Canyon contained only 6.75% of the ^{137}Cs and 2.79% of the ^{238}Pu at this site (Table 2), reflecting the fact that liquid wastes move very quickly through this site and react mainly with the channel sediments. By the time the liquid discharges of radioactive effluents have reached Site II in Mortandad Canyon, the flow rate has decreased and more time is available for the reaction of the radionuclides with the bank soils. No liquid effluents reach Site III in Mortandad Canyon, so the small amounts of radionuclides in the bank soils at this site result

from surface contamination of the bank soils (Fig. 3) during runoff events, which carry contaminated sediments downstream.

The two sites in Acid-Pueblo Canyon contain very large porportions of radionuclides in their streambank soils (Table 4). One explanation for this distribution is probably that this canyon has not been used for waste disposal since 1964, and runoff events have since scoured the radioactive channel sediments away, leaving most of the radionuclides in the bank soils.

The inventory data for plutonium was compared with the cesium inventories to determine differences in behavior of these radionuclides. Plots of the logarithms of the plutonium inventories verses the cesium inventories are presented (Fig. 5) for channel sediments and bank soils collected at all three intensive study sites in Mortandad and Acid-Pueblo Canyons. The data were subjected to covariance analysis as a function of intensive site characteristics, stream channel-stream bank differences, and an interaction term involving radionuclide inventory and channel-bank relationships. The results of the Mortandad Canyon samples showed that the plutonium-cesium regression lines for the channel sediments and the stream bank soils had the same slopes and intercepts. This indicated that no significant difference was detected between the migration of cesium and plutonium into either the bank soils or the channel sediments. When this same statistical methodology was applied to the Acid-Pueblo Canyon samples (Fig. 5), no significant relationship was found between the plutonium and cesium inventories. Since Acid-Pueblo Canyon has not received wastes since 1963, this difference, as discussed previously, seems to indicate the relationship between the cesium and the plutonium inventory at a site gradually changes and degrades with time, such as by differential leaching of radionuclides from the soils at the site.

The relationship between physiography and radionuclide inventories in the stream banks was not quite as pronounced as the physiography - concentration interactions described previously. The radionuclide inventories in bank soils at four out

of the seven intensive sites were inversely related to stream bank height. For example, radionuclide inventories in the bank soils at Site I in Mortandad Canyon were decreased by 91, 95, and 83% for ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$, respectively, as the bank height was increased from 21.8 to 61.7 cm. However, the bank soils at the remaining three sites showed no clear-cut relationship between the inventory of individual radionuclides and bank height: inventories of some radionuclides would decrease with bank height, whereas other radionuclides would show just the opposite pattern. Although the reason for this latter more variable relationship is unclear, it could be that a pronounced difference in bank height is needed before a significant difference in radionuclide inventory can be detected in stream bank soils.

CONCLUSIONS

Concentrations and inventories of plutonium and cesium in stream channel sediments and adjacent bank soils were determined as functions of horizontal distances from the waste outfall and from the stream channel, and of sampling depth, a few physiographic and hydrologic properties of each intensive study area, and the waste use history of three effluent-receiving areas. Radionuclide concentrations in channel sediments generally decreased with distances up to 10 km fromthe outfalls, an important observation in waste management practices dealing with the control of released contaminants. At sites receiving appreciable amounts of waste effluents, stream bank soils exhibited radionuclide concentrations that decreased with distances greater than 0.38 m from the stream channel and with sampling depths greater than 20-40 cm, probably due to the higher reactivity and lower permeability of these finer-textured soils (loams) relative to the coarser-textured channel sediments (sands). Radionuclide concentrations and inventories were also influenced by stream bank physiographic relationships: concentrations and total amounts of radionuclides were inversely related to bank height within the segment of the stream channel normally exposed to surface flows of effluent discharges and runoff events. Coefficients of variation of radionuclide inventory estimates in channel sediments ranged from 0.41 to 2.6, due largely to the variability in radionuclide concentrations at each site.

The fact that the three liquid effluent-receiving areas had different waste use histories allowed several observations to be made about the long-term disposition of environmental contaminants added to these typical southwestern intermittent streams. Eleven years after the last time Acid-Pueblo Canyon was used as an effluent-receiving area, the major inventory of radionuclides was not found in the stream channel soils, but rather in the soils in the adjacent stream banks, which thus appear to be a reservoir of radionuclides long after the effluent-receiving area is decommissioned. This observation is easily explained by differences in residence times of channel sediments verses adjacent bank soils in watersheds no longer receiving waste discharges: sediments are directly exposed to violent runoff events, which sweep channel sediments and easily eroded bank soils rapidly downstream, eventually leaving less contaminated sediments and contaminated stable bank soils behind.

The other interesting observation related to waste use history had to do with ratios of plutonium isotopes found in stream bank soils and channel sediments relative to the ratios in current effluents. Channel sediments closely reflect the isotopic ratios of plutonium found in current effluents (Hak73), but bank soils contained plutonium ratios different from either of these types of samples. A period of time greater than six years (the period of time corresponding to the initiation of large ^{238}Pu disposals in Mortandad Canyon in 1968 up through our 1974 sample collection date) is evidently required before the plutonium in current liquid wastes is equilibrated with the bank soil plutonium in these intermittent streams. This is an important aspect to keep in mind in waste management clean-up practices, ie- contaminants in liquid wastes currently added to an intermittent stream could be removed by removing only channel sediments and only a small portion of the bank soils from these canyons.

Although a preliminary examination of the radionuclide concentrations and inventories in stream bank soils was studied, much additional research is needed to elucidate the role of stream bank soils in retarding contaminant movement in

southwestern intermittent streams. More detailed studies need to be performed examining contaminant variability in bank soils, distribution of contaminants as functions of distance from the stream bank and characteristics of the stream channel-bank interface, and residence times of contaminated channel sediments and bank soils as influenced by runoff events and vegetative cover. Solubility of radionuclides and other contaminants in soils and sediments should also be studied in the field for a clear understanding of environmental mobility and transport of contaminants. Comparisons of the distribution of radionuclides and other contaminants will have to be made across different hydrologic conditions at the channel-bank interface of streams in the southwest so that contaminant transport can be knowledgeably interpreted and improved waste management practices implemented.

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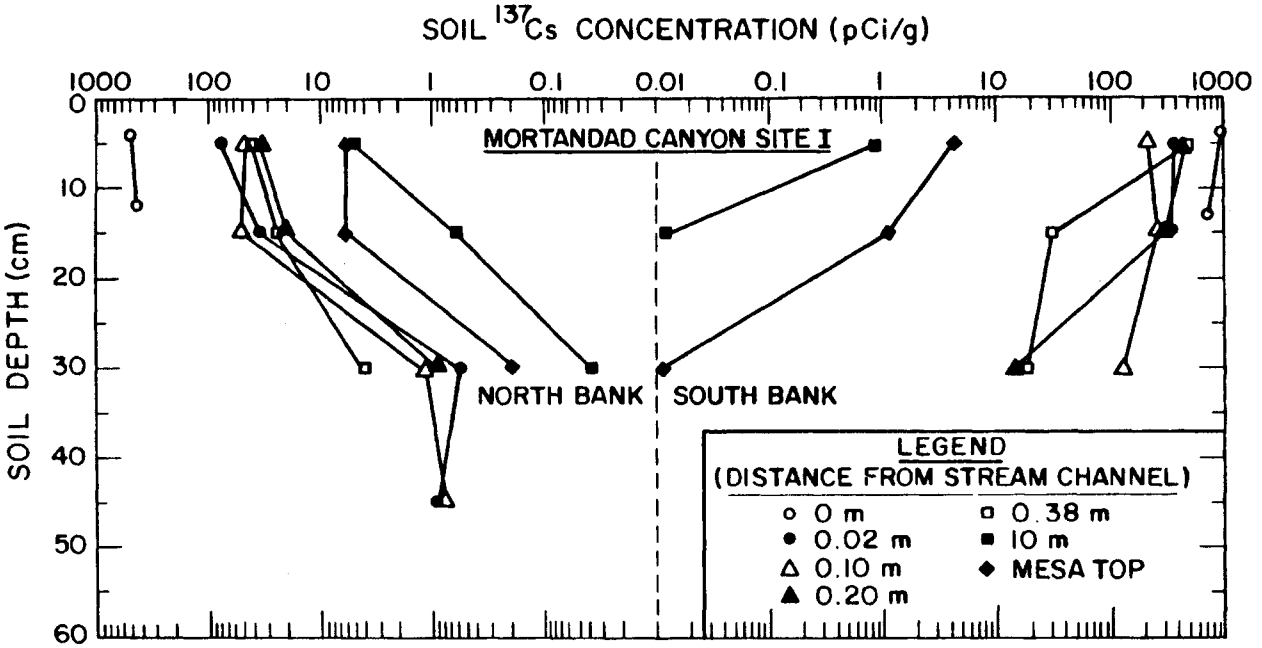

Figure 1. Cesium concentration as a function of soil depth at Site I in Mortandad Canyon.

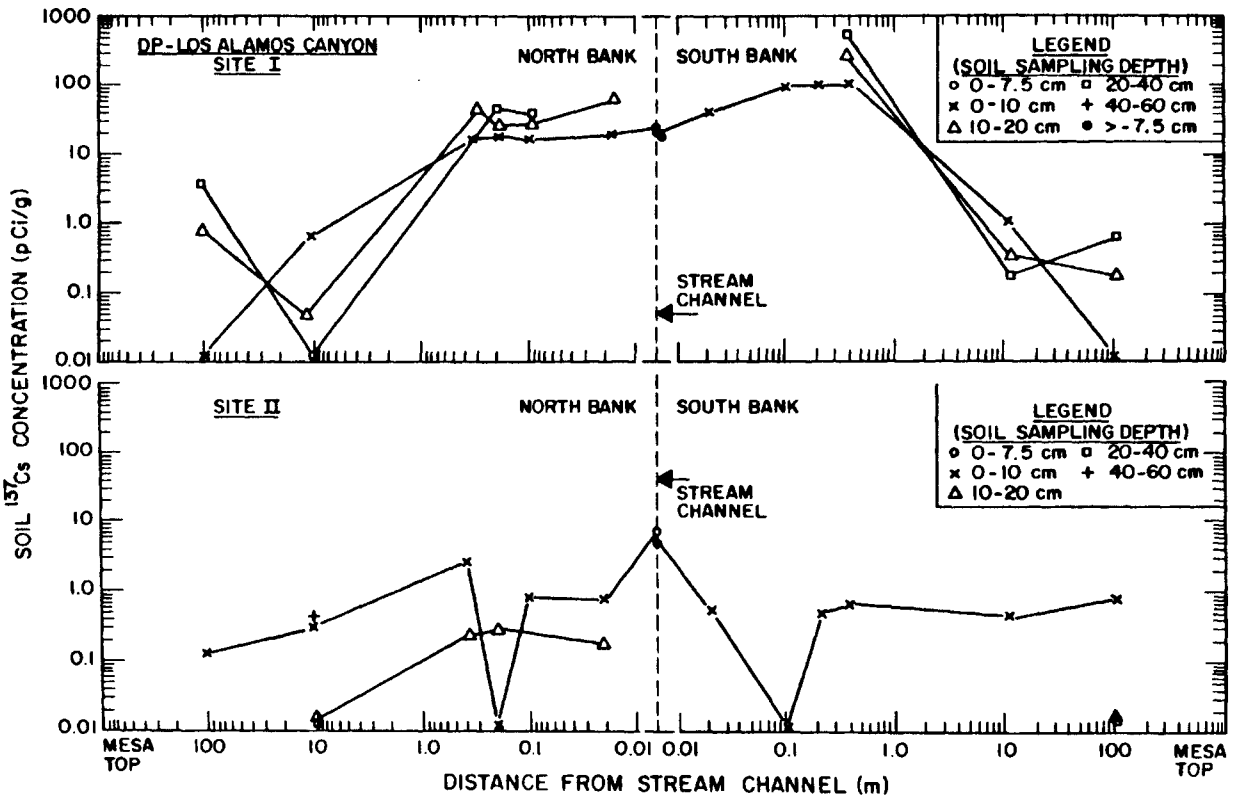

Figure 2. Cesium concentrations as a function of distance from the stream channel at Site I and Site II in DP-Los Alamos Canyon.

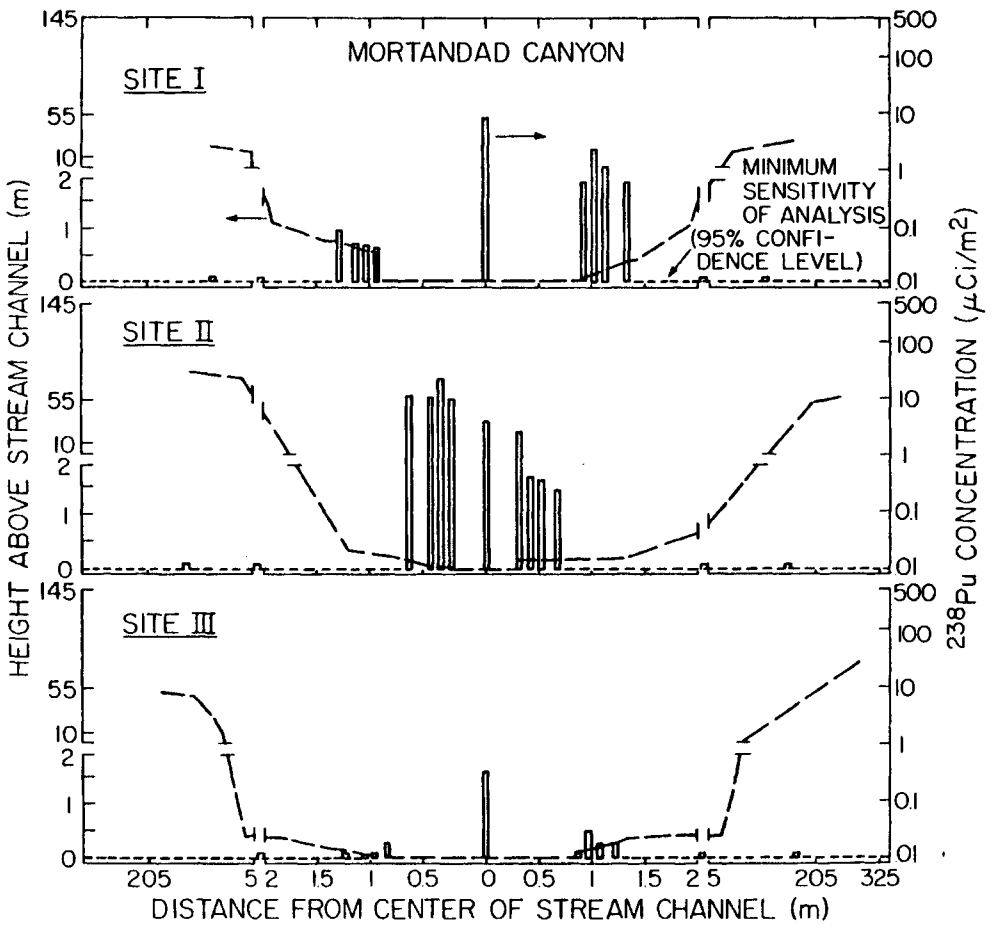

Figure 3. Concentration of ^{238}Pu in samples from Mortandad Canyon as a function of distance from the center of the stream channel and height above the stream channel.

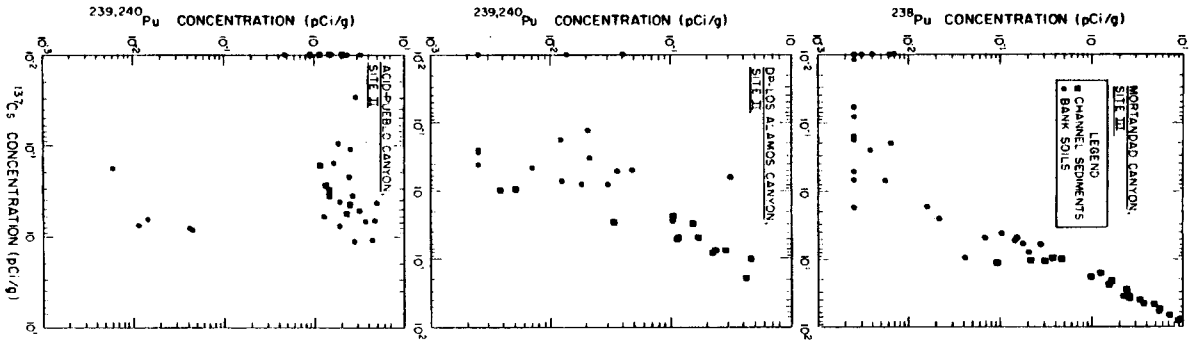

Figure 4. Relationship between plutonium and cesium concentrations in channel sediments and bank soils at Site III in Mortandad Canyon, at Site II in DP-Los Alamos Canyon, and at Site II in Acid-Pueblo Canyon.

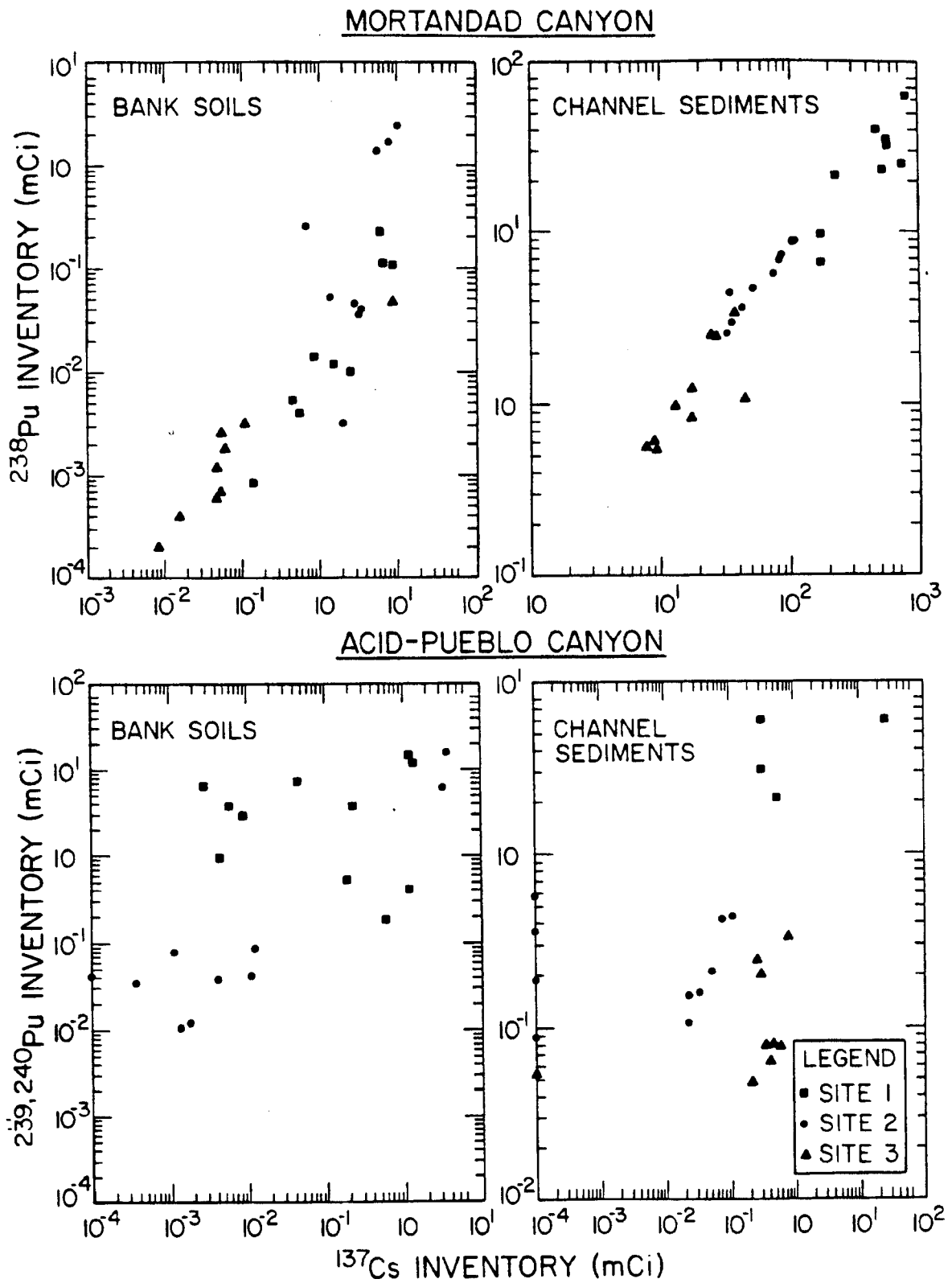

Figure 5. Relationship between plutonium and cesium inventories in channel sediments and stream bank soils in Mortandad and Acid-Pueblo Canyons.

TABLE 1. Intensive Study Area Locations and Relationships to Discharged Liquid Effluents.

Study Area	Distance from Effluent Outfall (m)	Direct Contact of Site Sediments with Discharged Liquid Effluents
Mortandad Canyon		
Background Site	-550†	No
Site I	320	Yes
Site II	1,250	Yes
Site III	2,500	No
DP-Los Alamos Canyon		
Site I	190	Yes
Site II	2,560	No
Site III††	10,300	No
Acid-Pueblo Canyon		
Site I	170	Yes
Site II	3,540	No

† Negative number represents distance upstream from effluent outfall.

†† Site III is located below the confluence of DP-Los Alamos and Acid-Pueblo Canyons.

TABLE 2. Results of Statistical Analysis of Relationship of Plutonium and Cesium in Channel Sediments and Bank Soils

Canyon	Site	Correlation coefficient (r) for the relationship between log Pu concentration (pCi/g) and log ^{137}Cs concentration (pCi/g) for Channel Sediments	Bank Soils
Mortandad	I	0.785**[†](18)[††]	0.889**(34)
	II	0.101ns(20)	0.891**(36)
	III	0.915**(19)	0.839**(19)
DP-Los Alamos	I	0.510* (17)	0.754**(25)
	II	0.917**(13)	0.396ns(13)
	III	0.212ns(9)	---
Acid-Pueblo	I	0.702* (9)	0.383ns(22)
	II	0.576ns(10)	0.127ns(21)

[†] Symbols *, **, and ns represent statistical levels of significance at the 0.05 and 0.01 levels, and a nonsignificant relationship, respectively.

[††] Number in parenthesis represents number of samples in comparison.

TABLE 3. Inventories of ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ in Stream Channels of Study Areas.

Intensive study area	Dimensions of stream channel (m)		Average µCi radionuclides in stream channel		
	Width	Length	^{137}Cs	^{238}Pu	$^{239,240}Pu$
Mortandad Canyon					
Background Site	0.60 (.44)†	1	0.015 (1.2)	0.000022 (2.4)	0.0021 (1.0)
Site I	2.1 (.20)	1	470 (.50)	29 (.60)	4.2 (.78)
Site II	1.7 (.37)	1	65 (.45)	5.5 (.41)	1.2 (.46)
Site III	1.8 (.41)	1	21 (.60)	1.4 (.71)	.52 (.47)
DP-Los Alamos Canyon					
Site I	.89 (.28)	1	3.4 (.89)	.033 (.91)	.18 (2.6)
Site II	2.2 (.24)	1	2.0 (1.2)	.0032 (1.1)	.054 (1.2)
Site III	5.5 (.17)	1	.38 (.61)	.0034 (1.3)	.13 (.77)
Acid-Pueblo Canyon					
Site I	1.5 (.23)	1	5.4 (2.1)	.049 (.73)	5.4 (.55)
Site II	1.2 (.22)	1	.032 (1.2)	.0020 (.75)	.27 (.61)

†Number in parenthesis represents the coefficient of variation ($s/\bar{x}$).

TABLE 4. Inventories of soil ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ in Stream Channel and Bank Soils of Intensive Study Areas.

Intensive study area	Radionuclide	Amounts of radionuclides (μCi) in soils of: Stream Channel	Both banks (0-0.38 m from channel)	% Inventory in bank soils
Mortandad Canyon				
Site I	^{137}Cs	349	25.3	6.75
	^{238}Pu	16.6	0.477	2.79
	$^{239,240}Pu$	1.90	0.979	34.0
Site II	^{137}Cs	79.4	35.0	30.6
	^{238}Pu	6.71	5.96	47.0
	$^{239,240}Pu$	1.19	1.04	46.7
Site III	^{137}Cs	13.3	0.402	2.94
	^{238}Pu	0.691	0.0107	1.53
	$^{239,240}Pu$	0.427	0.0347	7.52
DP-Los Alamos Canyon				
Site I	^{137}Cs	2.23	32.9	93.7
	^{238}Pu	0.0219	0.159	87.8
	$^{239,240}Pu$	0.0283	1.06	97.4
Site II	^{137}Cs	1.74	0.0699	3.89
	^{238}Pu	0.00231	0.000148	6.02
	$^{239,240}Pu$	0.0481	0.0248	34.0
Acid-Pueblo Canyon				
Site I	^{137}Cs	0.424	0.788	65.0
	^{238}Pu	0.0238	0.121	83.5
	$^{239,240}Pu$	2.59	25.6	90.8
Site II	^{137}Cs	0.00	0.0320	100
	^{238}Pu	0.00301	0.00230	43.3
	$^{239,240}Pu$	0.137	0.344	71.6

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