Adsorption of I^- and IO_3^- onto 63 Japanese Soils

Satoshi YOSHIDA, Yasuyuki MURAMATSU and Shigeo UCHIDA

Division of Radioecology, National Institute of Radiological Sciences
3609, Isozaki, Hitachinaka-shi, Ibaraki-Pref. 311-12, Japan

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Soil-solution distribution coefficients, K_d s, of I^- and IO_3^- were measured by a batch method for 63 soil samples collected from upland fields, paddies, forests and open areas throughout Japan. The soil properties were also measured. The K_d s for air-dried soils ranged widely from 0.07 to 262 l kg⁻¹ for I^- and from 0.36 to 127 l kg⁻¹ for IO_3^- . The medians for I^- and IO_3^- were 6.25 and 6.48 l kg⁻¹, respectively. The K_d s (both I^- and IO_3^-) for Andosols, one of the most typical Japanese soils derived from deposits of volcanic ash, were higher than those for the other soils. The K_d s for sandy samples were low. Relatively good correlations were found between K_d s and active-Al, active-Fe, TOC, total-N and water content. The results indicated that I was adsorbed on the surfaces of sesquioxides of Fe and Al, noncrystalline silicates such as allophane, organic materials and complexes of metals with humus.

Key Words : radioiodine, iodide, iodate, adsorption, soil, distribution coefficient

1. Introduction

Iodine is an essential nutrient element for humans and plays an important role in thyroid gland function. Therefore, it is important to study the behavior of anthropogenic radioiodine in the environment released from nuclear facilities and atmospheric nuclear weapon tests. Particular attention has been paid to ¹²⁹I because of its long half-life (1.57×10^7 y). The transport of I in the soil and its root uptake by plants is expected to be related to its adsorption behavior in the soil-water system. Soil-solution distribution coefficient (K_d), which is defined as the ratio of radionuclide concentration in the soil solid phase to that in the solution phase, is commonly used to represent the radionuclide adsorption onto soil. Some K_d s for I have been reported¹⁾⁻⁵⁾. However, the K_d s vary widely according to soil conditions and properties, and the number of the data for Japanese soils is limited. More data on K_d s are necessary to understand I behavior in Japanese soil environments.

As the major chemical forms of I in the system are iodide (I^-) and iodate (IO_3^-), several investigations are reported for the role of soil components on the adsorption properties for I^- and IO_3^- . Strong retention of I^- and IO_3^- on soils rich in organic material has been reported through many studies^{2),6),7)}. The IO_3^- is readily adsorbed by active-Al and active-Fe existing as free sesquioxides⁸⁾⁻¹⁰⁾. It has been reported that the microbial activity and extracellular enzymes play an important role in the adsorption of I^- ^{4),11)}. Muramatsu et al.^{5),12)} carried out radiotracer experiments on the adsorption of I for some Japanese soils, and found that both I^- and IO_3^- were adsorbed well from aqueous solution onto Andosols, which are derived from deposits of volcanic ash and containing relatively high amount of organic matter. The soil covers about 49% of upland fields and 11% of paddies in Japan. Muramatsu et al.⁵⁾ also reported that I^- was adsorbed by the soil fraction which was unstable at about 150°C, while IO_3^- was preferentially bound to the soil fraction, which was stable against the

heat treatment. Yoshida et al.¹³⁾ suggested that the high IO_3^- adsorption on Andosols was caused by the high adsorbability of IO_3^- on allophane (noncrystalline silicates) and/or sesquioxides of Al and Fe. However, details of the soil fractions associated with I and the adsorption mechanisms for other soil types are not well known yet.

This paper focuses on the adsorption experiments of I^- and IO_3^- for 63 soil samples collected from upland fields, paddies, forests and open areas throughout Japan. K_d s of air-dried soils were determined both for I^- and IO_3^- . Relationships between K_d and 10 soil properties, including active-Al and active-Fe (extractable Al and Fe by the mixture of oxalic acid and ammonium oxalate) and total organic carbon, are discussed.

2. Materials and Methods

2.1 Soil samples

Sixty-three soil samples were collected from the surface of upland fields (25 samples), paddies (22 samples), forests (5 samples) and open areas (11 samples) throughout Japan. Most of them belonged to one of the major soil types found in Japan such as Andosols, Red and Yellow soils, Gray Lowland soils and Gley soils. They were air-dried at room temperature for about 1 month and then sieved (2 mm ϕ).

2.2 Adsorption Experiment

Each 3 g of air-dried soil sample was weighed in a polyethylene bottle and 30 ml of de-ionized water containing radioiodine tracer ($^{125}\text{I}^-$ or $^{125}\text{IO}_3^-$) was added, and shaken with a mechanical shaker (150 rpm) at 23°C. Methods for preparation of the I tracers were described in detail in Muramatsu et al.⁵⁾. After certain shaking periods (*i.e.* 1 h, 1 d, 3 d, 7 d, 10 d and 14 d), the mixture was centrifuged at 4 000 rpm. A 0.5 ml aliquot of the supernatant solution was taken with a micropipette for the ^{125}I activity measurement with an automatic well type NaI scintillation counter

(Aloka ARC-300). The counting error was about 3%. The errors inherent in the repeated batch experiments were of the order of a few percent. The distribution coefficient (K_d) was calculated according to the following equation;

$$K_d = \frac{(C_i - C_f) \times V}{C_f \times W}$$

where C_i is the initial concentration of ^{125}I in the solution (cpm l^{-1}); C_f , the concentration of ^{125}I in the supernatant solution after shaking with the soil sample (cpm l^{-1}); V , the solution volume (l); W , the soil weight (kg).

2.3 Analysis of soil

The soils were analyzed for 10 soil properties, *i.e.* water content, soil-pH (H_2O), cation exchange capacity (CEC), anion exchange capacity (AEC), total-Al, total-Fe, active-Al, active-Fe, total organic carbon (TOC) and total-N. The water content was determined by drying the soil at 110°C for 5 h. For pH (H_2O), soil was shaken with de-ionized water with soil water ratio of 1 : 2.5. CEC was measured according to the Schollenberger's method¹⁴⁾. AEC was measured by the method proposed by Wada and Okamura¹⁵⁾ with some modifications: The soil was saturated with 1 M NH_4Cl (pH = 5.0), then adsorbed chloride was extracted with 1 M NaNO_3 and determined. For the determination of total-Al and total-Fe, the samples were decomposed in mixed acid (15 ml 60% HNO_3 + 4 ml 48% H_2SO_4 + 5 ml 46% HF). Concentrations of Al and Fe were determined with an inductively coupled plasma atomic emission spectrometer (Seiko, SPS 1100H). Active-Al and active-Fe were extracted by the Tamm reagent (0.14 M oxalic acid + 0.20 M ammonium oxalate)¹⁶⁾ for 2 h and determined with the inductively coupled plasma atomic emission spectrometer. TOC and total-N were determined with a reference type thermal conductivity detector (Yanagimoto, CHN corder MT-3). Carbonate was decomposed with HCl prior to the TOC

determination.

3. Results and Discussion

3.1 Effect of shaking time on adsorption

The effect of shaking time on adsorption of radioiodine onto soil are shown in Fig. 1. In most soils, the adsorption percentages became constant after 7 d both for I^- and IO_3^- . However, a longer time was required to reach the steady state for some soils such as O-10 for I^- and F-9 for IO_3^- . Therefore, the K_d s used in the following discussion were calculated from the data taken at 14 d.

3.2 K_d s and soil properties

The K_d s and properties for each soil sample are shown in Table 1. The K_d values ranged widely from 0.07 to 262 l kg⁻¹ for I^- and from 0.36 to 127 l kg⁻¹ for IO_3^- . The medians for I^- and IO_3^- were 6.25 and 6.48 l kg⁻¹, respectively. The median value for I^- was comparable with the K_d s for cultivated Parabrown Earth soil (Alfisol; median, 7.6 l kg⁻¹) reported by Bunzl et al.¹⁾. However, higher values (more than 100 l kg⁻¹) were reported for Gley soil, Peatland and Brown Earth soil (Cambisol) by Bunzl and Schimmack³⁾. In comparison with the K_d s for other radionu-

Fig. 1 Effect of shaking time on adsorption of (1) I^- and (2) IO_3^- by soils.

F-1 (○); F-9 (□); P-9 (◆); O-10 (▲)

Table 1 Distribution coefficients (K_d s) for iodine and soil properties

Sample code*	Soil type**	I^-K_d	$IO_3^-K_d$	soil-pH	CEC	AEC	total-Al	total-Fe	act-Al	act-Fe	TOC	total-N	H_2O (1 kg^{-1})
		(1 kg^{-1})	(1 kg^{-1})		(meq kg^{-1})	(meq kg^{-1})					(g kg^{-1})	(g kg^{-1})	
F-01		9.18	8.13	5.29	114	0.9	3 340	770	155	279	6.9	0.8	0.024
F-02		3.28	4.53	5.38	100	0.7	3 340	756	156	295	6.5	0.7	0.022
F-03		2.68	1.89	5.82	114	0.8	2 550	390	37	89	16.5	1.6	0.016
F-04		1.92	1.50	5.84	93	1.8	2 670	408	35	90	17.5	1.6	0.014
F-05		10.3	9.40	7.31	139	2.8	3 160	390	51	85	24.8	2.4	0.028
F-06		3.56	2.46	6.68	144	3.3	3 860	503	88	106	11.1	1.1	0.036
F-07	a	14.7	10.8	6.43	254	5.2	4 080	2 000	1 960	679	60.4	4.6	0.073
F-08	gr	10.6	4.40	6.87	216	3.7	3 640	981	262	532	19.0	1.0	0.045
F-09	gr	2.36	2.08	4.92	119	1.4	3 050	641	180	249	10.2	1.9	0.013
F-10	a	262	127	5.27	166	66.9	4 260	1 150	2 020	548	42.7	3.2	0.082
F-11		3.26	3.46	5.87	142	1.5	3 570	954	789	195	25.2	2.4	0.063
F-12		3.36	3.79	5.33	208	1.0	2 850	613	155	119	41.3	4.6	0.059
F-13	s	0.25	0.41	6.44	14	1.0	2 410	510	12	28	0.6	0.1	0.003
F-14	s	0.07	0.42	7.09	14	<0.5	2 800	405	9	18	0.6	0.1	0.003
F-17	ry	5.82	4.84	6.21	104	1.7	2 840	683	118	83	10.0	1.2	0.040
F-19	gr	1.33	1.02	6.90	8	<0.5	2 670	614	67	67	7.9	0.9	0.017
F-21	ry	2.98	4.48	5.36	60	0.9	2 780	286	34	27	8.2	1.0	0.008
F-23	ry	2.91	25.9	5.98	144	3.6	4 420	1 620	148	102	11.5	1.2	0.027
F-25	a	26.9	33.8	5.80	239	2.4	3 160	956	1 530	541	92.9	4.4	0.067
F-27	a	19.8	30.1	5.74	342	<0.5	4 120	938	2 000	408	96.8	6.1	0.099
F-29	a	30.8	36.0	5.87	217	3.2	4 340	1 190	1 750	344	51.4	4.0	0.108
F-31	a	11.2	12.2	6.49	132	1.4	3 750	1 240	1 600	507	27.4	2.5	0.089
F-33	gr	6.84	7.14	8.34	267	1.4	3 270	859	43	48	11.3	1.4	0.045
F-35	a	16.9	21.7	5.73	96	3.1	3 210	1 060	804	162	16.7	1.5	0.041
F-37		2.74	2.27	7.11	166	1.4	3 130	802	67	97	11.5	1.4	0.027
P-01		1.86	3.86	5.72	106	1.6	3 300	757	125	226	9.3	1.4	0.028
P-02		1.88	3.80	5.93	103	1.7	2 950	795	119	226	7.3	9.9	0.024
P-03		8.01	4.31	5.60	73	1.2	2 480	281	62	110	14.3	1.4	0.014
P-04		3.92	2.45	6.52	161	1.6	3 500	677	109	213	23.9	1.4	0.024
P-05		9.99	5.32	5.26	84	1.6	3 210	390	133	128	15.6	1.6	0.016
P-06		9.74	6.40	5.53	84	1.4	3 170	372	130	140	14.3	1.6	0.013
P-07		10.6	6.48	6.08	140	0.8	3 330	704	179	272	30.0	1.7	0.024
P-08		0.52	1.03	6.88	80	0.6	3 000	415	39	61	4.7	0.5	0.016
P-09	a	48.1	37.3	5.80	178	1.6	3 730	1 450	1 640	641	48.7	3.6	0.060
P-10	gr	6.59	4.90	5.54	153	2.2	3 480	870	437	274	20.4	1.8	0.043
P-11		6.25	4.17	7.43	390	<0.5	2 870	761	113	218	20.0	2.2	0.052
P-12	g	12.7	11.3	5.69	140	0.8	3 230	863	99	235	17.0	2.0	0.025
P-13	gr	27.0	24.4	4.80	122	0.7	3 200	815	124	147	15.2	1.9	0.014
P-14	a	99.3	85.9	5.06	335	1.5	3 650	1 030	2 110	512	102	7.2	0.102
P-15	gr	8.70	7.36	5.56	90	<0.5	2 930	1 020	165	171	21.6	2.6	0.039
P-16	gr	6.63	5.38	5.95	110	<0.5	2 980	455	32	76	13.7	1.5	0.009
P-18	ry	27.0	25.3	6.06	160	<0.5	2 850	469	87	133	20.6	2.3	0.019
P-20	g	1.60	1.68	5.95	286	<0.5	3 440	641	123	103	19.0	2.0	0.033
P-22	gr	9.39	7.33	6.42	235	<0.5	3 380	637	59	107	20.0	1.9	0.030
P-24	a	9.07	10.4	7.04	427	1.6	3 600	854	1 900	453	77.1	5.1	0.098

Sample code*	Soil type**	$I^{-}-K_d$	$IO_3^{-}-K_d$	soil-pH	CEC	AEC	total-Al	total-Fe	act-Al	act-Fe	TOC	total-N	H_2O
		($l\ kg^{-1}$)	($meq\ kg^{-1}$)		($mmol\ kg^{-1}$)	($g\ kg^{-1}$)							
P-26	g	13.3	12.3	5.73	222	<0.5	2 760	677	46	222	21.0	2.1	0.045
P-28	gr	5.66	5.14	5.92	184	<0.5	3 000	621	83	75	18.4	1.6	0.035
Of-14	a	7.92	8.86	5.14	262	4.3	3 300	1 140	1 370	367	101	2.6	0.090
Of-20	ry	2.53	2.33	5.12	86	1.6	2 090	695	33	29	15.2	0.1	0.017
Of-38	b	2.93	9.88	5.08	216	<0.5	3 250	482	272	97	54.0	3.7	0.044
Of-39	b	3.76	13.1	5.00	199	1.0	3 240	483	276	101	46.1	3.7	0.050
Of-40	b	3.51	16.2	5.03	188	1.2	3 140	475	270	93	54.0	3.6	0.043
O-02	v	17.0	28.9	5.54	86	69.8	5 120	1 530	3 360	988	14.6	1.5	0.121
O-03	v	4.81	9.77	5.45	140	21.2	6 000	483	5 560	310	5.1	0.9	0.111
O-04	a	58.0	44.6	4.34	328	10.2	2 800	881	2 150	469	181	8.5	0.278
O-05	v	0.11	9.16	5.74	156	14.2	5 670	372	4 740	245	4.4	0.8	0.129
O-07	s	2.82	2.37	5.56	25	1.2	2 020	256	37	53	8.3	0.7	0.004
O-08	s	1.05	0.77	5.40	15	0.8	1 960	251	37	56	4.5	0.2	0.003
O-09	p	9.53	13.3	4.94	352	<0.5	1 840	402	182	156	213	16.6	0.119
O-10	ry	5.67	58.4	4.72	181	1.7	4 590	1 690	164	80	13.8	1.7	0.033
O-30	s	0.15	0.44	6.78	14	0.5	2 810	426	10	6	0.3	0.1	0.003
O-31	s	0.11	0.36	7.03	12	0.4	2 340	364	15	13	0.3	0.1	0.004
O-32	ry	13.9	17.5	5.56	86	3.5	2 520	786	456	258	9.7	0.9	0.032
Mean		14.6	13.8	5.89	156	4.2	3 270	746	649	218	30.3	2.5	0.046
Std		35.3	21.0	0.76	95	12.1	775	368	1 110	193	39.1	2.6	0.044
Median		6.25	6.48	5.74	140	1.4	3 200	683	133	147	16.5	1.6	0.033
Min		0.07	0.36	4.34	8	0.4	1 840	251	9	6	0.3	0.1	0.003
Max		262	127	8.34	427	69.8	6 000	2 000	5 560	988	213	16.6	0.278

* Sample code : (F) upland field, (P) paddy, (Of) forest, (O) open area

** Soil type : (a) Andosols, (g) Gley soils, (s) Sand-dune Regosols, (ry) Red and Yellow soils, (gr) Gray Lowland soils, (v) Volcanogeneous Regosols, (p) Peat soils, (b) Brown Forest soils, (no mark) others or unknown

clides, the medians for I^- and IO_3^- were smaller than those for ^{54}Mn ($270\ l\ kg^{-1}$), ^{60}Co ($1\ 740\ l\ kg^{-1}$), ^{65}Zn ($1\ 760\ l\ kg^{-1}$), ^{85}Sr ($500\ l\ kg^{-1}$) and ^{137}Cs ($1\ 900\ l\ kg^{-1}$) for 36 Japanese air-dried agricultural soils¹⁷⁾.

The K_{ds} for I (I^- and IO_3^-) were correlated with active-Al, active-Fe, TOC and total-N independently of soil type, as shown in Fig. 2, indicating the important contribution of active-Al, active-Fe and organic materials on the adsorption of I . Good correlations were also found between water content and K_{ds} . The water contents may represent the surface area of these materials²¹⁾. The results suggested that I is adsorbed on the surface of the materials mentioned above. No

correlations were observed between K_{ds} and soil-pH, total-Al or total-Fe.

The K_{ds} do not differ significantly between upland and paddy soils. The medians for I^- were $3.56\ l\ kg^{-1}$ for upland fields and $8.89\ l\ kg^{-1}$ for paddies, and those for IO_3^- were $4.53\ l\ kg^{-1}$ for upland fields and $5.89\ l\ kg^{-1}$ for paddies. In this study, the K_{ds} were measured under aerobic condition. As the paddies are flooded during the cultivation period, oxidation-reduction potentials in paddies are lower than those in upland fields. The field K_{ds} (*in situ* K_{ds}) for paddy soils may be influenced by the low oxidation-reduction potentials.

Average values for K_{ds} and soil properties for 8

Fig. 2 Binary plots of K_d for I^- (○) and IO_3^- (□) versus soil properties. (1) active-Al, (2) active-Fe, (3) TOC, (4) total-N, (5) water content

Table 2 Average distribution coefficient and soil properties for 8 different soil types

	<i>n</i>		I^-K_d	$IO_3^-K_d$	soil-pH	CEC	AEC	total-Al	total-Fe	act-Al	act-Fe	TOC	total-N	H_2O (kg^{-1})
			($l\ kg^{-1}$)	($l\ kg^{-1}$)		($meq\ kg^{-1}$)	($mmol\ kg^{-1}$)	($mmol\ kg^{-1}$)	($mmol\ kg^{-1}$)	($mmol\ kg^{-1}$)	($mmol\ kg^{-1}$)	($g\ kg^{-1}$)	($g\ kg^{-1}$)	
Andosols	12	Mean	50.4	38.2	5.73	248	8.5	3 670	1 160	1 740	469	74.8	4.4	0.099
		Std	68.7	33.7	0.69	93	17.8	461	301	366	133	42.4	1.9	0.057
Volcanogeneous	3	Mean	7.31	15.9	5.58	127	35.1	5 600	795	4 550	514	8.0	1.1	0.120
Regosols		Std	7.12	9.17	0.12	30	24.7	363	522	908	336	4.7	0.3	0.007
Red and Yellow	7	Mean	8.69	19.8	5.57	117	1.9	3 160	890	149	102	12.7	1.2	0.025
soils		Std	8.31	18.2	0.51	41	1.1	889	508	134	73	3.9	0.6	0.010
Gray Lowland	10	Mean	8.51	6.92	6.12	150	1.2	3 160	751	145	175	15.8	1.7	0.029
soils		Std	6.74	6.17	1.00	73	1.0	275	174	119	140	4.6	0.5	0.014
Gley soils	3	Mean	9.20	8.43	5.79	216	0.6	3 140	727	89	187	19.0	2.0	0.034
		Std	5.38	4.79	0.11	60	0.1	284	97	32	59	1.6	0.0	0.008
Sand-dune	6	Mean	0.74	0.80	6.38	16	0.7	2 390	369	20	29	2.4	0.2	0.003
Regosols		Std	0.99	0.72	0.67	4	0.3	334	92	12	19	3.0	0.2	0.000
Brown Forest	3	Mean	3.40	13.1	5.04	201	0.9	3 210	480	273	97	51.4	3.7	0.046
soils		Std	0.35	2.58	0.03	12	0.3	50	4	2	3	3.7	0.0	0.003
Peat soil	1		9.53	13.3	4.94	352	<0.5	1 840	402	182	156	213	16.6	0.119

different soil types were calculated and are listed in Table 2. In Volcanogeneous Regosols, Brown Forest soils and Red and Yellow soils, K_d for IO_3^- was clearly higher than that for I^- . The concentrations of active-Al and active-Fe in Volcanogeneous Regosols were high. The samples, O-3 and O-5, are known as "Kanuma soil", mostly consisted of allophane (noncrystalline silicates). There is some evidence that IO_3^- is readily adsorbed by active-Al and active-Fe existing as free sesquioxides⁸⁾⁻¹⁰⁾ and noncrystalline silicates¹³⁾. The adsorption can be explained in terms of specific adsorption, presumably similar to the phosphate adsorption reported in many papers¹⁸⁾⁻²⁰⁾. High K_d (IO_3^-) for Volcanogeneous Regosols observed in this study can be explained by the specific IO_3^- bonding onto active-Al and active-Fe existing as free sesquioxides and/or allophane. The I^- is adsorbed on the positive charges which appeared on the surface of active-Al and active-Fe¹³⁾. Higher K_d s of Brown Forest soils for IO_3^- ($13.1\ l\ kg^{-1}$) than for I^- ($3.40\ l\ kg^{-1}$) might be explained by relatively high active-Al content in the soils. High K_d s (IO_3^-) for Red and Yellow

soils were observed in F-23 and O-10, in which the total-Al and total-Fe were high. The active-Al and active-Fe were not high in these soils. The details of the adsorption mechanisms for Red and Yellow soils were not clear.

The K_d s (both I^- and IO_3^-) for Andosols were higher than those for the other soils. It is known that Andosols, derived from volcanic ash, contain allophane, sesquioxides of Al and Fe and complexes of these metals with humus. The high concentrations of active-Al, active-Fe, TOC and total-N in the soil are related to these materials. In the case of IO_3^- , the specific bonding onto active-Al and active-Fe existing as free sesquioxides and allophane is important¹³⁾. However, the high I^- adsorption on Andosol could not be explained analogously. High contents of organic materials may be related to high K_d s of I^- . The importance of organic materials and complexes of organic materials with inorganic materials as well as microorganisms have been mentioned^{4),7),8),11)}. Muramatsu et al.⁵⁾ indicated that the K_d s of organic soils for I^- were markedly decreased by air-drying as well as heating treatment. In the

present study, air-dried soils were used in order to compare the K_d s for I with those for other radio-nuclides and to compare the K_d s between different type of soils under the same conditions. In the case of wet soils, the role of microorganisms and organic materials (including enzymes) might be more important. Therefore, the *in situ* K_d s for Andosols should be higher than those measured in the present study. The high AEC values (8.5 meq kg^{-1}) for Andosols indicate the existence of a positive charge where the anions can be adsorbed. Both I^- and IO_3^- seem to be partly adsorbed by the positive charges at the surfaces of active-Al, active-Fe and organic matter through electrostatic forces.

The lowest K_d s (both I^- and IO_3^-) were observed for Sand-dune Regosols. The low concentrations of active-Al, active-Fe, TOC and total-N in the soils suggest the lack of adsorption sites for I. No significant differences were observed among Red and Yellow soils, Gray Lowland soils and Gley soils both for I^- and IO_3^- .

The results suggested that I^- and IO_3^- were associated on the surfaces of sesquioxides of Fe and Al, noncrystalline silicates such as allophane, organic materials and complexes of metals with humus. The K_d s of I^- and IO_3^- for air-dried soils can roughly be predicted using information of selected soil properties such as active-Al, active-Fe, TOC, total-N and water content. However, the batch K_d s measured for air-dried soils differ from those measured under other conditions in many cases. For example, the air-drying treatment decreases the K_d s for organic soils as mentioned above. These differences should be taken into account when the K_d s are used for the assessment of I behavior in actual fields.

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要 旨

日本の土壌 63 試料に対する I^- と IO_3^- の吸着

吉田 聡, 村松康行, 内田滋夫

放射線医学総合研究所環境放射生態学研究部

311-12 茨城県ひたちなか市磯崎 3609

日本各地の畑, 水田, 森林等で採取した土壌 63 試料について, ^{125}I を用いたバッチ実験により, I^- と IO_3^- の分配係数 (K_d) を求めた。風乾土壌に対する K_d は土壌によって大きく異なり, I^- で $0.07 - 262 \text{ l kg}^{-1}$, IO_3^- で $0.36 - 127 \text{ l kg}^{-1}$ であった。中央値は I^- で 6.25 l kg^{-1} , IO_3^- で 6.48 l kg^{-1} であった。黒ぼく土に対する I^- と IO_3^- の K_d は他の土壌に対するものより明らかに大きかった。一方, 砂質土壌に対する K_d は小さかった。 K_d は活性な Al と Fe (シュウ酸+シュウ酸アンモニウム溶液で抽出可能な Al と Fe), 総有機炭素, 総窒素および水分含量と相関があった。これらのことから, 土壌中の酸化鉄(III), 酸化アルミニウム, アロフェン等の非晶質粘土鉱物, 有機物および有機物と無機物の錯体が I の吸着に関与していることが示唆された。