International Journal of Primatology, Vol. 14, No. 2, 1993

Soil-Eating by *Alouatta* and *Ateles*

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Received December 3, 1990; accepted June 18, 1991

Among 12 species of New World monkeys studied in La Macarena Region and the River Caquetá basin of Colombia, only Alouatta seniculus *and* Ateles belzebuth *were frequently observed to eat soil. They do this at particular sites on the ground called "salados" by local people. They also eat termite nests found on tree trunks. Only* Ateles *drink the water of salado sites. The chemical properties of 17 soil samples and 5 water samples were analyzed. The results are discussed in relation to the question of why* Alouatta *and* Ateles *eat soil.*

KEY WORDS: soil-eating; *Aloatta seniculus*; *Ateles belzebuth*; chemical properties.

INTRODUCTION

Many cases of soil-eating (geophagy) have been recorded among catarrhine species, including *Presbytis, Macaca, Papio*, and *Pan* (Davies *et al.*, 1988; Inoue, 1987; Hall, 1962; Goodall, 1963), which spend most of their daily lives on the ground, but relatively little is known of this habit among the platyrrhines. Since 1971, I have studied 12 species of New World monkeys which are characterized by an arboreal life style in Neotropical forest—the River Caquetá basin and La Macarena Region of Colombia (Izawa, 1975; Izawa and Nishimura, 1988). Among them, only *Alouatta seniculus* and *Ateles belzebuth* eat soil (Izawa, 1975; Izawa *et al.*, 1979). They do this at particular sites, called "salados" by local people. They also eat termite nests (termitaria) found on tree trunks. Only *Ateles* drinks the water from salados. Here, I report observations of geophagy and the chemical properties of soils and water ingested by *Alouatta* and *Ateles*, and discuss why they do so. All samples were collected from the study area in the

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0164-0291/93/0400-0229$07.00/0

middle reaches of the River Duda, bordering the west end of La Macarena National Park in Colombia. The geography, vegetation, primate fauna, and climate of the study area are described by Izawa (1980; Izawa and Tokuda, 1988; Izawa and Nishimura, 1988).

SUBJECTS AND METHODS

Frequency of Utilization by a Group of *Alouatta*

During 203 full days between July 1987 and June 1990, in which I followed a group of *Alouatta* (MN-1 group) from one sleeping site to the next, they utilized two salado sites on the right bank of the River Duda on 30 days (S-1 and S-2 in Fig. 1). Highly nervous monkeys of the MN-1 group moved easily down to the two salado sites by seizing hold of suspended tree branches and vines from the top of the cliff 40–50 m above the water. After reaching the cliff, they apparently kept lookout while repeatedly sitting, resting, moving slowly over short distances, and lazily feeding, usually for 1 hr or so but sometimes for up to 3–4 hr. In the midst of this, if an observer was spotted, if someone passed along the observation trail on the cliff (Filo 1 in Fig. 1), if a canoe with an outboard motor passed by on the river, or if an assistant worked on the sands by the river in front of the camp, they abandoned the location. They were interrupted thus on 18 days.

The MN-1 group also ate the soil of termitaria (*Constrictoterms cavifrons*). During 1987–1989, the monkeys used a termitarium at a hilltop and another at a valley bottom (T-1 and T-2 in Fig. 1). After these were exhausted, they began to use another on the same hilltop, one on a slope, and another in the valley (T-3, T-4, and T-5 in Fig. 1). These five termitaria were located on tree trunks between 3 and 5 m and above the forest floor.

The proportion of days in which salado sites and termitaria were utilized is 0.40. If interruptions are included, the proportion increases to 0.49 (Table I). Salado soil and termitaria were never eaten on the same day. There is no marked difference among months.

Samples and Methods of Analysis

Three sets of soil and water samples were collected at different times. Each set was sent to different institutes and laboratories for analyzing chemical properties.

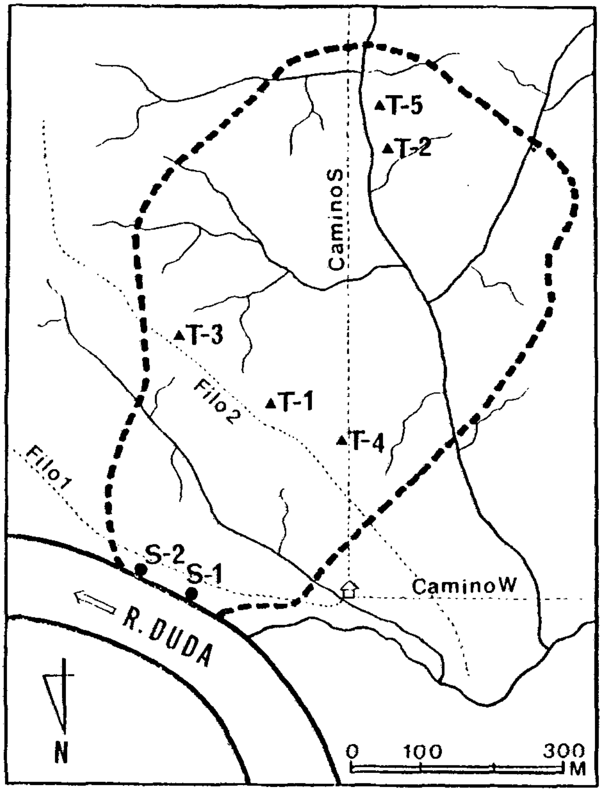

Fig. 1. Salado sites and termitaria used by the MN-1 *Alouatta* group. The home range of the MN-1 group is enclosed by the thick dashes. (●) Salado sites; (▲) termitaria; (· · · ·) main observation trails. The camp site is designated by the short white arrow.

One set of samples (Sample 1; $N = 5$) was collected in January 1988 in the home range of an *Alouatta* group (MN-1) and sent to the Institute of Genetic Ecology at Tohoku University. Among them, S-1 was collected from a salado site, while T-1 and T-3 were from termitaria (Fig. 1). The two other samples (C-1 and C-2) were brown forest floor soils (5–10 cm below the surface) and were collected at two sites, chosen at random, where monkeys of the MN-1 group did not eat (Fig. 2).

The soil samples were air-dried, ground in a mortar, and sieved. Material smaller than 2 mm was used for chemical analyses. Procedures for analyses followed mainly the *Standard Technique of Soil Analyses and*

Table I. Frequency of the Utilization of Salado Sites and Termitaria by the MN-1 Group between 1987 and 1990

Number of days	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
A. Full observation	20	7	12	14	4	18	8	39	23	10	17	31	203
B. Utilization of salado site	6	1	1	2	0	5	0	4	5	1	2	3	30
C. Utilization of termitaria	1	2	3	3	1	3	3	13	9	3	7	4	52
D. Interruption of use of the site	2	0	3	0	2	1	1	2	1	1	2	3	18
B + C + D/A	0.40	0.43	0.58	0.36	0.75	0.50	0.50	0.49	0.65	0.50	0.65	0.32	0.49
B + C/A	0.35	0.43	0.33	0.36	0.25	0.44	0.38	0.44	0.60	0.40	0.53	0.23	0.40

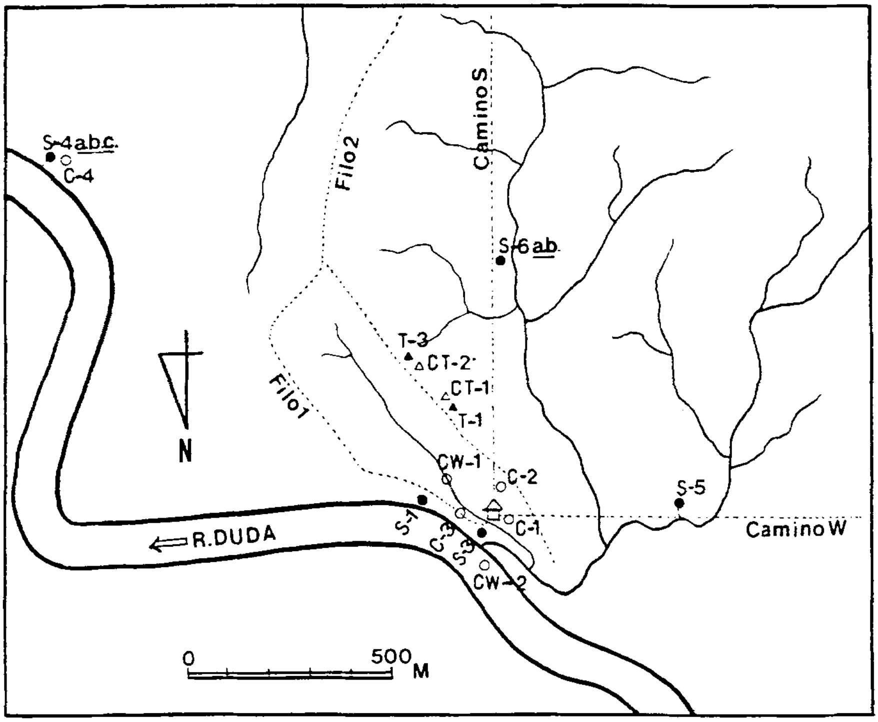

Fig 2. Collection points for the soil and water samples. (●) Salado sites; (▲) termitaria used by the monkeys; (○, △) controls.

Measurement (Editorial Committee for Standard Technique of Soil Analyses and Measurement, 1986). Exchangeable Ca, Mg, K, and Na were extracted with 1 *N* ammonium acetate and measured with an atomic absorption spectrophotometer (Ca and Mg) or a flame photometer (K and Na). Available phosphate was determined by the Trnog method. Soluble chlorine was extracted with water and determined by the mercury(II) thiocyanate method. Free iron oxide content was measured by the *o*-phenanthroline colorimetric method after extraction by the sodium hydrosulfite–EDTA method. Soil pH (H_2O) was determined electrometrically in a 1:2.5 soil/water mixture.

Another set of samples (Sample 2; N = 12) was collected in July and September 1988 and was sent to the Laboratory of Biology at Nagoya Gakuin University. Among them, S-1, T-1, and T-3 are samples collected from the same sites as described in the first set. S-3 was collected from another salado site on the same bank of the River Duda where another *Alouatta* group (MN-2) frequently ate soil. C-3 was collected from the forest floor near the cliff as a control. This point was just under the route where the MN-2 group moved from tree to tree to reach the S-3 location for eating soil. S-4a, S-4b, and S-4c were collected from one salado site by a brooklet in the forest. This salado site is a large one—approximately 7 × 5 m. S-4a was the soil that a group (MN-10) and a solitary male of *Alouatta* ate frequently. The MN-10 group of *Alouatta* and a group of *Ateles* (MB-1) often ate the soil sampled as S-4b. The MB-1 group of *Ateles* frequently ate the soil sampled as S-4c. C-4 was the soil of the forest floor, which was never eaten, 10 m away from the salado site. S-5 was collected from another salado site in the forest. It was often utilized by the MN-2 group of *Alouatta* and a group of *Ateles* (MB-2). CT-1 and CT-2 are soils of termitaria on tree trunks, near those of T-1 and T-3. The MN-1 group of *Alouatta* often passed through these trees but never ate the termite nests. Those termitaria of *Labiotermes labralis* are almost black.

Soil samples were air-dried, ground in mortars, and sieved. Material smaller than 2 mm was used for chemical analyses. All results were reported on the basis of 105°C oven-dried weights. Sample 1 was measured and exchangeable minerals were extracted with 1 *N* ammonium acetate.

When *Alouatta* eats soils, aqueous conditions of the minerals render them more available for absorption by the monkey. Therefore, water-soluble Ca, Mg, K, and Na were extracted with distilled water and measured with an atomic absorption spectrophotometer. Available phosphate was determined by the Trnog method. Soil pH (H_2O) was determined electrometrically in a 1:1 soil/water mixture at 20°C.

A third set of samples (Sample 3; $N = 5$) was collected in February 1975 and was sent to the Ishikawa Research Laboratory for Public Health and Environment. These samples were taken from salado sites by brooklets in the forest from which *Ateles* frequently drank. These salado sites were like small bogs because of daily usage by many herbivorous mammals. Two water samples, labeled S-6a and S-6b, were collected from one salado site. S-6a was collected near a dike, and S-6b at the center of the bog. S-5 was collected from another salado site. As a control, CW-1 was collected from a stream and CW-2 from the river.

EC stands for electric conductivity. Titration was used for the analyses of C1, Ca, and Mg. Atomic absorption spectrophotometry followed digestion with nitric acid and perchloric acid for Cd, Pb, Cu, and Zn. Flame photometry was used for Na and K.

RESULTS

Does the MN-1 group of *Alouatta* eat salado soil and termitaria selectively? Results of analysis of Sample 1 (Table II) apply to this question.

Among five soil samples, S-1 is characterized by the highest Ca and Na contents. Its pH (H_2O) value is the highest, at 5.4. Both termitaria soils (T-1 and T-3) contain relatively large amounts of K, P and Cl. The levels of Ca, Mg, and Na are also higher than those in the comparable forest floor soils (C-1 and C-2, respectively). The iron contents of T-1 and T-3 are fairly high, though lower than those of S-1, C-1 and C-2. Soils of C-1 and C-2 are acidic, with pH (H_2O) values < 3.9. Compared with the other samples, levels of P, Ca, and Mg are remarkably low in C-2 soil.

Consequently, I could detect no nutrient which was contained uniformly in all of the soils eaten at higher or lower amounts than the levels in the soils not eaten. However, the difference in pH values between the two types of soils was clear; *Alouatta* preferred more neutral soils. The results suggest that *Alouatta* ate soil for its minerals. In the study area, Ca and Na in salado soil and Ca, K, P, and Cl in termitaria soils are potentially important elements to induce soil-eating. It is notable that the high concentrations of some minerals, Ca, K, Na, and Cl, impart a salty taste.

Next I examine whether these reasons are applicable to other groups of *Alouatta* and *Ateles*. Results of analyses of Sample 2 are in Table III.

Comparing S-1, S-3, and C-3, C-3 is highest in Ca, lowest in Mg, and intermediate in K, Na, and P. It is possible that *Alouatta* chose the special soil for Mg. However, there is little difference between C-3 and S-3. It is more reasonable to think that it avoids Ca, but this does not explain why it chose to eat certain soils. The total Ca, Mg, K, and Na content, which is likely to contribute to a salty taste, in C-3 is 60.2 mg/100 g, which is slightly greater than in S-1 or S-3. This does not explain the soil-eating. The pH values show no remarkable difference among the three samples.

Next I compared S-4a, S-4b, S-4c, S-5, and C-4. While S-4c registers the highest values in Ca, Mg, and Na of these samples, S-4a registers the lowest overall. Among individual elements only K is the lowest in C-4. Accordingly, if *Ateles* selected S-4c for Ca, Mg, and Na, then it is puzzling why *Alouatta* never ate C-4 instead of S-4a. C-4 is higher in salty elements than S-4a. P is lower in C-4 than in S-4a and S-4b. This may be one of the reasons why *Alouatta* eat salado soil. However, P is the same in S-5, which does not prove that this was what they sought.

Table II. Chemical Properties of Five Soil Samples

	Soils eaten			Soils not eaten	
	Salado	Termitaria		Forest floors	
	S-1	T-1	T-3	C-1	C-2
Ca (mg/100 g)	663.14	207.74	543.64	5.188	285.24
Mg (mg/100 g)	92.62	87.10	147.16	18.24	135.04
K (mg/100 g)	11.41	22.14	40.92	10.70	17.57
Na (mg/100 g)	8.30	1.42	2.36	0.81	1.85
P_2O_5 (mg/100 g)	0.656	5.75	13.13	Trace	0.400
Cl (mg/100 g)	3.01	12.50	7.09	4.03	4.11
Fe (mg/100g)	550.05	401.60	296.50	485.00	470.00
pH (H_2O)	5.4	4.6	4.4	3.9	3.3

Table III. Chemical Properties of 12 Soil Samples

	Bank of the river				Forest floor				Termitaria			
	Eaten		Not eaten		Eaten			Not eaten	Eaten		Not eaten	
	S-1	S-3	C-3	S-4a	S-4b	S-4c	S-5	C-4	T-1	T-3	CT-1	CT-2
Ca (mg/100 g)	10.2	8.3	14.4	11.8	12.4	16.6	12.7	12.6	6.0	5.8	7.7	17.5
Mg (mg/100 g)	9.8	10.3	9.0	7.8	8.2	11.7	8.6	7.9	7.0	7.0	7.7	12.8
K (mg/100 g)	16.6	15.6	15.7	17.5	16.9	38.1	16.1	16.5	16.8	16.4	16.5	17.4
Na (mg/100 g)	18.8	25.4	21.1	24.5	31.4	29.6	28.4	25.8	19.5	18.5	17.7	18.9
P_2O_5 (mg/100 g)	2.4	1.8	2.0	3.5	1.6	1.3	1.1	1.1	5.3	2.3	3.8	2.2
pH (H_2O)	4.6	4.9	4.8	5.4	4.8	4.9	5.8	5.1	5.1	4.5	5.3	4.2

Among T-1, T-3, CT-1, and CT-2, CT-2, from a termitarium which *Alouatta* did not eat, is highest in Ca, Mg, and K and second highest in Na. Therefore, if *Alouatta* wanted these elements, it should have eaten termitaria of *Labiotermes* instead of *Constrictotermes*. Moreover, a comparison of the salty taste showed that both values of CT-1 and CT-2 are higher than those of T-1 and T-3. As for P, the difference between the two termitaria is not clear enough to draw a conclusion.

Another view, that *Alouatta* might want different elements from the different soils (that is, those of the salado site on the bank of the river, salado site by the brooklet in the forest, and termitaria of *Constrictotermes*), should also be considered. For example, the MN-1 *Alouatta* ate only soils from the salado site on the bank of the river and termitaria of *Constrictotermes*, so the comparison should be made between them. Among S-1, S-3, T-1, and T-3, the first two samples are relatively high in Ca, Mg, and Na, and the last two in P. The proposition that the MN-1 group sought Ca, Mg, and Na at salado sites, and P from termitaria, leads one to ask why *Alouatta* did not eat CT-1 or CT-2, which are short distances from T-1 and T-3, respectively, and which contain more Ca, Mg, and K than S-1 and S-3 and abundant P. The pH values are not remarkably different among those samples.

Conclusions based on the above results only are as follows: (1) None of the elements analyzed appeared to explain the soil-eating habits of *Alouatta*—none were decisive in determining why Alouatta eat the soils of salado sites and termitaria selectively; and (2) it is also difficult to conclude that *Alouatta* wanted different elements from the various soils.

Now, I examine why *Ateles* drinks salado water. Results of analyses of the third set (Sample 3) are shown in Table IV.

The samples of water from three salado sites had EC two to three times higher than water from the river and stream, henceforth termed normal water. Nine ionic elements that could have produced this were analyzed. Na was two to three times higher in salado water than the normal water. Cl in S-6a was remarkably high, while S-6b and S-5 were similar or somewhat higher than that of river water but low compared with stream water. This means that salado water did not always contain more Cl than the normal water. Ca was higher in S-6b and S-5 but similar in S-6a and CW-1. Mg was similar to Cl. Therefore, a common characteristic of salado water was a high Na concentration; this was not true for K.

A salty taste could be one of the positive factors which led *Ateles* to drink salado water. However, it is difficult to diagnose the sense of taste. If the total value of Cl, Ca, Mg, Na, and K is supposed to relate to a salty taste, then the total was 58.9 for S-6a, 29.9 for S-6b, 43.8 for S-5, 34.0 for CW-1, and 16.3 for CW-2. Water from the salado sites would provide a

Table IV. Chemical Properties of Five Samples of Water

	Drunk			Not drunk	
	S-6a	S-6b	S-5	CW-1	CW-2
EC (μV/cm)	189	148	185	45.5	88.0
Ca (ppm)	3.0	6.6	6.3	3.0	4.8
Mg (ppm)	1.6	3.0	2.8	1.0	1.9
K (ppm)	13.9	6.4	11.1	15.7	5.5
Na (ppm)	17.3	9.5	18.3	6.3	4.6
Cl (ppm)	23.1	4.4	5.3	8.0	4.4
Cd (ppm)	0.008	0.000	0.000	0.000	0.000
Pb (ppm)	0.196	0.196	0.196	0.294	0.294
Cu (ppm)	0.030	0.000	0.015	0.046	0.000
Zn (ppm)	0.017	0.072	0.010	0.014	0.010

saltier taste than the river water does. Results of this study suggest that the drinking habits of *Ateles* probably relate to ingesting salts, but they are not conclusive.

Cu, Pb, Cd, and Zn were also analyzed. The level of Pb was low in salado water, being only half that in the normal water. Since Pb is regarded as harmful to animals, this is reasonable. The concentrations of the other elements are too low in the five samples to merit discussion.

There are two problems left. One is that salado water contained about twice as many free ions as normal water did, which suggests that other, unanalyzed elements must be present. It is possible that the animals were selecting concentrations of an unidentified element. The other is whether *Ateles* intentionally chose salado water or not. As I mentioned before, the salado sites, where *Ateles* drank, were very muddy, so that when they drank, they ingested notable quantities of soil. Whether there is a relationship between an element in the water and the drinking habits of *Ateles* must be regarded as unsolved.

DISCUSSION

Among the 12 species of New World monkeys that I have studied, only *Alouatta seniculus* and *Ateles belzebuth* ate salado soil and termitaria of *Constrictotermes*, and only *Ateles* drank salado water. Also, unlike other New World monkeys, *Alouatta* and *Ateles* never eat animal food and so are completely herbivorous. Furthermore, the terrestrial mammals and birds, including tapirs (*Tapirus terrestris*), two species of peccary (*Tayassu tajacu* and *T. pecari*), deer (*Mazama* sp.), pacas (*Agouti paca*), guans

(*Aburria pipile*), and several kinds of parrots (*Aratinga* sp., *Touit* sp., and *Amazona* sp.), that I observed utilizing salado sites are also herbivores. Accordingly, a vegetarian diet is closely related to the utilization of salado sites.

Soil-eating has been observed among many species of primates, and several hypotheses been proposed to explain it, including the absorption of plant toxins and tannins, the intake of mineral content, particularly sodium, an antacid function, and the intake of phosphate (Schaller, 1963; Poirier, 1970; Hladik *et al.,* 1974; Goltenboth, 1976; Hladik, 1977; Eudy, 1978; McKey, 1978; Oates, 1978; Davies *et al.,* 1988). But I cannot draw decisive conclusion from the analyses of several chemical properties and pH of limited samples about why *Alouatta* and *Ateles* eat soil or about how they select mineral-rich sources. There is no obvious reason why soil-eating should serve a single function or the same function at different times (Davies *et al.,* 1988).

However, the following points must be taken into consideration: (1) *Alouatta* and *Ateles* are both herbivores, but the former eats mainly young leaves and the latter eats mainly ripe fruit. Furthermore, *Lagothrix,* which lives sympatrically in the study area, eats more young leaves than *Ateles* does but never eats soil. Unlike *Alouatta* and *Ateles*, however, *Lagothrix* often eats insects. (2) Arboreal primates avoid the forest floor, perhaps to avoid predators. Accordingly *Alouatta* and *Ateles* may utilize special sites, which are relatively safe, even though the mineral components of other soils are similar. Stark (1970) noted that most soils of the Amazon basin are poor in soluble nutrients because of leaching by abundant rainfall. (3) for clarifying the chemical properties of salado soils and termitaria, it may be important where we collect control samples of soil. (4) It is possible that the difference in consumption of termitaria between species of termites does not depend on the mineral components but, instead, may be due to differences in behavior between the two termites. *Labiotermes* may defend its termitaria chemically in a way that makes the soil unpalatable, but *Constrictotermes* does not. Further study of these issues is needed.

ACKNOWLEDGMENTS

This study was supported by Grants in Aid of Monbusho International Scientific Research Program Nos. 61041009, 63041018, and 02041009 and by the 1975 Grant-in-Aid for Science and Culture Fund from the Ministry of Education, Science and Culture, Japan. I wish to thank all of the Colombian and Japanese members of these projects, especially

Dr. Yoshihiko Hirabuki of Miyagi University of Education, Dr. Koshin Kimura of Nagoya Gakuin University, Dr. Akinori Mizuno of the Japan International Cooperation Agency, and Dr. Carlos A. Mejia of Universidad de Los Andes for their collaboration during this study and Dr. Kazuo Sato of Tohoku University, Dr. Akihide Takehara of Iwate University, Dr. Yoshihisa Ohnishi of Nagoya Gakuin University, the staff of Insituto Nacional de Investigaciones Geologico-Mineras in Colombia, and Dr. Haruo Mine of the Ishikawa Research Laboratory for Public Health and Environment in Ishikawa Prefecture for their help in the analyses. I am also grateful to Dr. Peter S. Rodman of University of California for critical reading of the manuscript.

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