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Investigation of Cadmium Contamination Using Hair of the Japanese Macaque, *Macaca fuscata*, from Shimokita Peninsula, Aomori Prefecture in Japan

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Abstract The cadmium (Cd) contents in hair of macaques (n = 45, *Macaca fuscata*) living on the Shimokita Peninsula were investigated. The mean Cd contents in the hair of Japanese (n = 34, 5.01 μg/g) and macaques (3.05 μg/g) tendency to be higher than those of animals living other areas. The Cd contents of hair of wild macaques were significantly ($p < 0.01$) lower than that of humans, although three were no significant difference between Cd contents of humans and that of the macaque in captivity. The hair of the macaque was suggested as a useful sample for measurement of Cd contamination in the environment.

Keywords Cadmium · Biological monitoring · Japanese macaque · Wildlife

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In our previous studies, the degree of contamination with cadmium (Cd) in wild birds (Mochizuki et al. 2002, 2011) and domestic animals (Ueda et al. 2011) was investigated in order to quantify the degree of contamination with Cd in animals. The toxicity of Cd was also investigated using experimental animals (Mochizuki et al. 2008; Ueda et al. 2009). In previous studies, we used the kidney and liver, because it is well known that high levels of Cd accumulate in such organs (Friberg et al. 1974). However, the use of these samples requires sacrifice of the animal. Although organ biopsy is used in clinical practice, this technique is not realistic for studies of wildlife. On the other hand, hair samples allow the researcher to measure the degree of contamination of an animal without killing it. The hair is an important component of excretory metabolism and is therefore an appropriate type of sample for use in research on the degree of contamination of animals. Thus, many researchers have used hair samples in studies of the degree of contamination of animals such as wildlife (Rainwater et al. 2009) and humans (Durska 2001; Shah et al. 2006).

In the present study, we investigated the degree of contamination with Cd in hair obtained from Japanese macaques (*Macaca fuscata*) living on the Shimokita Peninsula of Aomori Prefecture in Japan. The Japanese macaque, which is also called the snow monkey, is very famous because most other monkeys are tropical animals. The macaques that live in Shimokita Peninsula are famous internationally because this area is the northern limit of habitation of all primates except humans. Thus, the Japanese macaques in this area were designated as a natural monument in 1970. In the present study, the Cd content in the hair of these macaques was investigated, and the results from the macaque were compared with those from Japanese people to investigate the possibility of biological monitoring using the hair of the macaque.

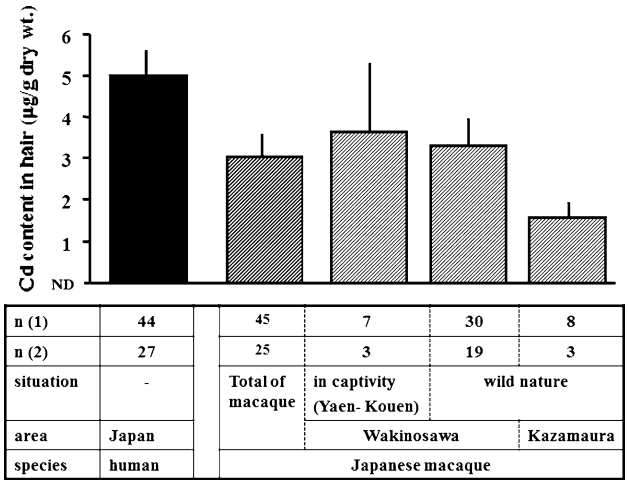
Materials and Methods

Body hair obtained from macaques, which included 12 male, 21 female and 12 of unknown sex, was used in the present study. The sampling area is shown in Fig. 1. The macaques of the Yaen-Kouen in Wakinosawa area (n = 7) were captive-raised animals, and other the macaques (n = 38; Wakinosawa area, n = 30, Kazamaura area, n = 8) were in their natural state. Samples were collected from the macaques using scissors, both from anesthetized macaque in traps and from macaques that had been killed in traffic accidents. Hairs that were shed as a result of grooming were also collected. All samples were collected by a Japanese nonprofit organization, Nihonzaru Field Station, in 2008. The collection of samples and the handling of macaques were carried out in accordance with the law governing wildlife. In addition, a total of 44 scalp hair samples (female, n = 18; male, n = 16; age, 19–66 years) were collected from Japanese people in 2008. The collection of samples from humans was performed in accordance with ethical regulations.

All samples were dried, weighed and digested, and an atomic absorption spectrometer (Z-8200, Hitachi, Japan) was employed for analysis of Cd. The recovery rate (addition of 2 ppm of Cd, n = 3) was 92.3 ± 0.43%. Lotus 2001 (Lotus Development), Excel 2010 (Microsoft Corporation, USA), and JUMP (SAS Institute, Japan) were used for the statistical analyses. The limit of detection was 0.002 ppm in this study. Non-detectable data were recalculated by the method of half of detection limits. Significance differences in mean values were detected using the Wilcoxon signed-rank test in the JUMP program.

Results and Discussion

The Cd contents in body hair obtained from the macaques and the scalp hair from humans are summarized in Fig. 2. The mean Cd content of hair from Japanese people measured in the present study was 5.01 μg/g dry wt. This value is higher than the mean Cd contents in hair obtained from humans who live in other countries such as Pakistan (0.380 μg/g, Shah et al. 2006), Libya (0.530 μg/g, Shah et al. 2006), Poland (0.13 μg/g, Durska 2001) and Korea (geometric mean, 52.6 ng/g, Kim and Kim 2011). It is well known that the Cd content in the environment in Japan is higher than that of other countries (Asami 2001; Friberg



n (1)	44		45	7	30	8
n (2)	27		25	3	19	3
situation	-		Total of macaque	in captivity (Yaen- Kouen)	wild nature	
area	Japan			Wakinosawa		Kazamaura
species	human		Japanese macaque			

Fig. 2 The Cd contents of hair of humans and Japanese macaque. n(1): number of samples including ND, n(2):number of ND

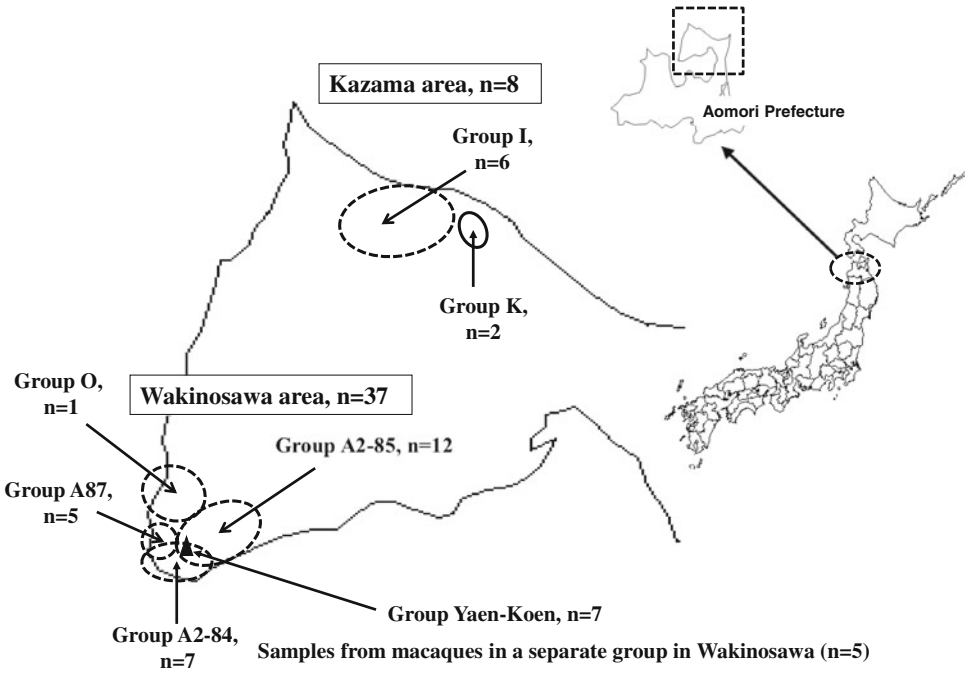


Fig. 1 The sampling area used in the present study. Each *circle* indicated the range of the macaques in each group. Samples from macaques in a separate group (n = 5) were collected in the Wakinosawa area

et al. 1974). It has also been reported that high Cd contents occur in Japanese food (Asami 2001) and clinical materials such as kidney specimens and, feces (Asami 2001); this suggests that the high Cd content of the hair of Japanese people was influenced by the Japanese environment and food.

The mean Cd content in the hair of the macaques ($n = 45$) was 3.05 μg/g dry wt. Although this value was significantly lower ($p < 0.01$) than that of the human samples, it is also higher than the results from animals living in other areas, such as the European hedgehog (*Erinaceus europaeus*, 0.04 μg/g, Rautio et al. 2010), reindeer in Russia (*Rangifer tarandus*, 0.63 ppm, Medvedev 1999). There are few appropriate studies that describe the Cd content in hair of any primates except humans. However, a study was performed on lemurs: Rainwater et al. (2009) reported the levels of various metals, including Cd, in the hair of ring-tailed lemurs (*Lemur catta*) in Madagascar. The Cd contents in the hair of the lemurs were not above the limit of detection, although the Cd contents of 20 samples (44%) of the hair of macaques reported in the present study were above the limit of detection.

It is thought that the Cd levels in macaque hair obtained in this study were also influenced by the Japanese environment. Given high Cd contents were found in the hair of Japanese macaques as well as in that of Japanese people, it is suggested that biological monitoring may be performed using samples of hair from the Japanese macaque. When the Cd contents in the hair of Japanese people and that of the macaque were classified by habitat, the Cd contents of hair from the macaques in Wakinosawa (except the macaques fed in Yaen-Kouen) and Kazamaura were significantly lower than those of others ($p < 0.01$). However, there were no significant differences between the Cd contents in hair from humans and that of the macaques fed in Yaen-Kouen, Wakinosawa. It is thought that the macaques reared in captivity were influenced by provision of artificial feed and their environment.

In addition, the Cd levels in the hair of the macaques were compared with respect to the sampling area. The Cd levels obtained from macaques living in the Kazamaura area were lower than those of other groups, although a significant difference was not obtained. A higher Cd content in soil in the Wakinosawa area (0.542–0.742 ppm) than that of the Kazamaura area (0.0326–0.142 ppm) was reported from a geological survey in Japan (AIST 2004). Thus, the higher level of Cd in the hair of macaques in the Wakinosawa area was thought to have been influenced by the environment of the macaque.

The results of the present study suggest that hair from the macaque is a useful sample for use in studies of the degree of contamination with Cd in the environment.

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References

AIST (National Institute of Advanced Industrial Science and Technology) (2004) Geological survey of Japan (in Japanese with English abstract)

Asami T (2001) Heavy metal pollution in soils of Japan. Agne Gijutsu Center, Tokyo (in Japanese)

Durska G (2001) Levels of lead and cadmium in pregnant women and newborns and evaluation of their impact on child development. Ann Acad Med Stetin 47:49–60

Friberg L, Piscator M, Nordberg GF, Kjellström T (1974) Cadmium in the environment, 2nd edn. CRC press, Ohio (trans. into Japanese: Ishiyaku Publisher)

Kim M, Kim K (2011) Biomonitoring of lead and cadmium in the hair and fingernails of elderly Korean subjects. Biol Trace Elem Res 143:794–802

Medvedev N (1999) Levels of heavy metals in Karelian wildlife, 1989–91. Environ Monit Assess 56:177–193

Mochizuki M, Hondo R, Kumon K, Sasaki R, Matsuba H, Ueda F (2002) Cadmium contamination in wild birds as an indicator of environmental pollution. Environ Monit Assess 73:229–235

Mochizuki M, Mori M, Hondo R, Ueda F (2008) A new index for evaluation of cadmium pollution in birds and mammals. Environ Monit Assess 137:35–49

Mochizuki M, Mori M, Hondo R, Ueda F (2011) The biological monitoring of wild birds -Part 2: the possibility of a new index for biological monitoring. Int J Energ Environ Econ 19:535–545

Rainwater TR, Sauther ML, Rainwater KAE, Mills RE, Cuozzo FP, Baohong Z, McDaniel LN, Abel MT, Marsland EJ, Weber MA, Jacky IAY, Platt SG, Cobb GP, Anderson TA (2009) Assessment of organochlorine pesticides and metals in ring-tailed lemurs (*Lemur catta*) at Beza Mahafaly Special Reserve, Madagascar. Am J Primatol 71:998–1010

Rautio A, Kunnasranta M, Valtonen A, Ikonen M, Hyvärinen H, Holopainen IJ, Kukkonen JVK (2010) Sex, age, and tissue specific accumulation of eight metals, arsenic, and selenium in the European hedgehog (*Erinaceus europaeus*). Arch Environ Contam Toxicol 59:642–651

Shah MH, Shaheen N, Khalique A, Alrabti AA, Jaffar M (2006) Comparative metal distribution in hair of Pakistani and Libyan population and source identification by multivariate analysis. Environ Monit Assess 114:505–519

Ueda F, Mori M, Takano T, Ochiai Y, Hondo R, Mochizuki M (2009) Basic investigation for an epidemiological study on cadmium contamination of wildlife—cadmium distribution in the rat body after intravenous cadmium exposure. In: Mastorakis N, Helmis C, Papageorgiou CD, Bulucea CA, Panagopoulos T (eds) Proceedings of 5th international conference on energy, environment, ecosystem and sustainable development, Energy, environment, ecosystems, development and landscape architecture, energy and environmental engineering series. World Scientific and Engineering Academy and Society Press, pp 57–63

Ueda F, Mori M, Mochizuki M, Hondo R (2011) The analysis using new index for cadmium contamination in poultry. The proceedings of 9th Asia Pacific Poultry Conference, Taipei, Taiwan, p 325