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Deposition of atmospheric ^{137}Cs in Japan associated with the Asian dust event of March 2002

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Abstract

Considerable deposition of ^{137}Cs was observed in the northwestern coastal area of Japan in March 2002. Since there were no nuclear explosions or serious nuclear accidents in the early 2000s, transport of previously contaminated dust appears to be the only plausible explanation for this event. In March 2002, there was a massive sandstorm on the East Asian continent, and the dust raised by the storm was transported across the sea to Japan. This dust originated in Mongolia and northeastern China, in an area distant from the Chinese nuclear test site at Lop Nor or any other known possible sources of ^{137}Cs. Our radioactivity measurements showed ^{137}Cs enrichment in the surface layer of grassland soils in the area of the sandstorm, which we attributed to accumulation as a result of past nuclear testing. We suggest that the grassland is a potential source of ^{137}Cs-bearing soil particles. Since the late 1990s, this area has experienced drought conditions, resulting in a considerable reduction of vegetation cover. We attribute the prodigious release of ^{137}Cs-bearing soil particles into the atmosphere during the sandstorm and the subsequent deposition of ^{137}Cs in Japan to this change.

Keywords: ^{137}Cs; Radionuclide; Fallout; Asian dust; Soil erosion; Desertification

1. Introduction

^{137}Cs is an anthropogenic radionuclide with a half-life of 30 years that originated from nuclear explosions and from accidental releases such as the Chernobyl nuclear reactor accident. The atmospheric testing of nuclear weapons from 1945 to 1980 was the primary cause of environmental contamination by this radionuclide. Each test resulted in the uncontrolled release of substantial quantities of radioactive materials that were dispersed in the atmosphere and later deposited worldwide (UNSCEAR, 2000, p.158). Since the cessation of atmospheric testing in 1980, apart from the Chernobyl nuclear reactor accident in 1986, there has been no known serious atmospheric contamination by ^{137}Cs. Therefore, ^{137}Cs concentrations in

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the atmosphere were expected to decline during the late 1980s and the 1990s. The ^{137}Cs that originated from atmospheric testing was transported within the stratosphere and deposited gradually over wide areas. The stratospheric half-residence time of radioactive particles is estimated to be about 1 year (Krey and Krajewsky, 1970), and the ^{137}Cs component in the stratosphere was expected to decrease to negligible levels in the 1990s. Atmospheric ^{137}Cs that originated from the Chernobyl nuclear accident is also believed to have declined rapidly since 1986 because most of it was controlled by transport within the troposphere, where its half-residence time is less than 1 month (Aoyama, 1988; Aoyama et al., 1991).

However, ^{137}Cs was detected in recent surface sampling in Japan. This indicates that ^{137}Cs has entered the troposphere from existing reservoirs and has subsequently been deposited in Japan as a direct consequence of an event other than pre-1980 nuclear testing or the Chernobyl nuclear accident. Reservoirs of anthropogenic radionuclides may exist in the ocean and on land. On the basis of sea-salt transport and ^{137}Cs content in surface seawater, Igarashi et al. (2003) determined that the oceanic contribution to the annual deposition of ^{137}Cs on land, at less than 0.2%, is negligible. Thus, Igarashi et al. (2003) assumed that the land surface is the major reservoir of ^{137}Cs. The detection of recent deposits of ^{137}Cs appears to be the result of re-suspension by wind uplift of soil particles contaminated by past nuclear testing, followed by re-deposition (Igarashi et al., 2003). Igarashi et al. (2005) associated regular peaks of ^{137}Cs deposition in Japan in spring with Asian dust. Recent desertification on the East Asian continent has increased the frequency of sandstorms and the resultant suspension of soil particles (Xu, 2006). This would be expected to result in an increase of ^{137}Cs deposition in Japan.

Although current levels of monthly ^{137}Cs deposition in Japan are less than 1 Bq m^{-2} (Japan Chemical Analysis Center, 2003) and seem to have no effect on human health, the long-term effect of human exposure to ^{137}Cs is not clear. Investigating the source area and transport process of the ^{137}Cs deposited in Japan is essential to allow prediction of future deposition and for evaluation of its possible effects on human health. In this study, we used meteorological data and field survey results to examine the recent transport and deposition of ^{137}Cs associated with Asian dust phenomena.

2. Data and methods

We obtained a nationwide data set of ^{137}Cs deposition in Japan from the radiation database maintained by the Ministry of Education, Culture, Sports, Science and Technology (the MEXT database, http://www.kankyo-hoshano.go.jp/en/index.html), and examined monthly variations of ^{137}Cs deposition in Japan using radiochemical analysis data from the database. Furthermore, we obtained SPM (suspended particulate matter) concentration data and surface meteorological data for Japan from the Environmental Information Center in Japan and the Japan Meteorological Agency to investigate the relationship between ^{137}Cs deposition and meteorological factors.

The frequency of sandstorms and other dust-raising phenomena in East Asia was determined and mapped from surface meteorological data. Six-hourly (four times a day) meteorological data based on SYNOP reports for East Asia were obtained from the Japan Meteorological Agency. SYNOP is a numerical code used for reporting weather observations. SYNOP reports are typically sent worldwide every 3 or 6 h from land-based weather stations. The code numbers 07, 08, 09, 30–35, and 98 in current SYNOP weather records indicate dust-raising events, such as sandstorms and sand whirls. The code number 06 was excluded from our study because it refers to dust already suspended in the air, rather than dust raised by wind in the area of the weather station. Dust outbreak frequency was defined as the number of sandstorms and other dust-raising phenomena recorded as a percentage of the total number of weather observations (Kurosaki and Mikami, 2003) made within a month at each station. However, records were incomplete at a considerable number of stations. As the monthly frequency calculated from few observation records would be unreliable, only data sets with a threshold value of 100 observations per month were included in our study.

To identify the type of land cover of areas where dust-raising phenomena were frequently observed, Global Ecosystems data (Global Land Cover Characteristics Version 2) were obtained from the US Geological Survey (http://edcsns17.cr.usgs.gov/glcc/). For our study, the Global Ecosystems land cover types were categorized in seven groups (Table 1).

Table 1
Land cover groups used in this study, derived from US Geological Survey Global Land Cover Characteristics (GLCC)

Defined land cover groups	Original codes in GLCC global ecosystems legend
Forest and woods	4, 5, 21–24, 26, 27, 29, 33, 34, 43, 60–62, 90, and 91
Grassland	2, 10, 40, and 42
Shrubs	16, 17, 51, and 64
Grass, shrubs, and crops	94
Cropland	19, 30, 31, 36–38, 55–58, 93, and 96
Desert	8, 11, and 50
Others	1, 9, 12, 14, 44, 45, 53, and 63