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Instrumental Neutron Activation Analysis Data for Cloud-Water Particulate Samples, Mount Bamboo, Taiwan, March 22–24, 2002

Open-File Report 2013–1147

U.S. Department of the Interior
U.S. Geological Survey

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By Neng-Huei Lin, Guey-Rong Sheu, Gregory A. Wetherbee, and Timothy M. Debey

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U.S. Department of the Interior
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Contents

Abstract 1
Introduction 1
  Purpose and Scope 2
Methods 3
  Cloud-Water Sampling 3
  Filter Analysis by INAA 5
Quality Assurance 5
Data 6
Acknowledgments 12
References Cited 12

Figures

1. Cloud-water sampling location on summit of Mount Bamboo, Taiwan 2
2. Cloud-water sampler on summit of Mount Bamboo, Taiwan 3
3. Cloud-water filtration apparatus and filtered particulate samples on 0.45-micron filters 4

Tables

1. Elemental composition data for blank filter samples 6
2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan cloud-water samples 7

Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Volume	
milliliter (mL)	0.034	ounce, liquid (oz)
liter (L)	1.057	quart (qt)
	Mass	
microgram (μg)	3.527×10^{-8}	ounce, avoirdupois (oz)
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
	Neutron flux	
neutrons per square centimeter per second (φ, in $n/cm^2/s$)	No conversion needed	
	Radioactivity	
microCuries (μCi)	No conversion needed	

Abbreviations Used in This Report

^{28}Al	aluminum isotope with atomic mass 28
ASRC	Atmospheric Science Research Center (cloud-water collector)
^{133}Ba	barium isotope with atomic mass 133
BQS	Branch of Quality Systems
cm	centimeters
^{137}Cs	cesium isotope with atomic mass 137
^{60}Co	cobalt isotope with atomic mass 60
DASNCU	Department of Atmospheric Sciences, National Central University, Taiwan
E	east
^{152}Eu	europium isotope with atomic mass 152
HPGe	high-purity germanium
INAA	Instrumental neutron activation analysis
keV	thousand electron volts
m	meters
MeV	million electron volts
MFS, Inc.	Advantec MFS, Incorporated
mg/L	milligrams per liter
micron, (μm)	micrometer
mm	millimeters
μCi	microCuries
μg	micrograms
mL	milliliters
N	north
n/cm^2/s, (φ)	neutrons per square centimeter per second
NIST	National Institute of Standards and Technology
USGS	United States Geological Survey

Instrumental Neutron Activation Analysis Data for Cloud-Water Particulate Samples, Mount Bamboo, Taiwan, March 22–24, 2002

By Neng-Huei Lin[1], Guey-Rong Sheu[1], Gregory A. Wetherbee[2], and Timothy M. Debey[2]

Abstract

Cloud water was sampled on Mount Bamboo in northern Taiwan during March 22–24, 2002. Cloud-water samples were filtered using 0.45-micron filters to remove particulate material from the water samples. Filtered particulates were analyzed by instrumental neutron activation analysis (INAA) at the U.S. Geological Survey National Reactor Facility in Denver, Colorado, in February 2012. INAA elemental composition data for the particulate materials are presented. These data complement analyses of the aqueous portion of the cloud-water samples, which were performed earlier by the Department of Atmospheric Sciences, National Central University, Taiwan. The data are intended for evaluation of atmospheric transport processes and air-pollution sources in Southeast Asia.

Introduction

The Department of Atmospheric Sciences at National Central University of Taiwan (DASNCU) has conducted atmospheric deposition monitoring on the summit of Mount Bamboo, Taiwan, since 1995. The summit of Mount Bamboo is frequently engulfed in clouds (fig. 1) (Lin and Peng, 1999). This makes the site conducive to collection of cloud-water samples to measure wet-deposition of atmospheric pollutants by cloud-water deposition to the land surface in fog droplets. DASNCU scientists have published results of cloud-water deposition on Mount Bamboo to evaluate transport of acid-producing compounds (Lin and Peng, 1999), mercury (Sheu and Lin, 2011), and Asian dust (Wang and others, 2010). These studies provide information on sources of air pollution and atmospheric transport processes of the pollutants in Southeast Asia.

Mount Bamboo is located 17 kilometers (km) from the South China Sea coastline of Taiwan, inside Yang-Ming-Shan National Park, and north of Taipei City. Coordinates for the site are 25°11.2'N, 121°32.1'E (fig. 1). The summit is 1,103 meters (m) above mean sea level. Monsoonal flow, frontal passages, and orographic lifting contribute to cloud formation at the summit and make the site conducive to cloud-water sampling (Sheu and Lin, 2011).

[1]National Central University, Taiwan
[2]U.S. Geological Survey

Purpose and Scope

This report contains data for elemental analysis of solid particles filtered from cloud-water samples collected on the summit of Mount Bamboo, Taiwan, during a cloud inundation event during March 22–24, 2002. These data are presented to contribute to further global study of atmospheric transport of polluted air and wet-deposition of air pollutants to the Earth's surface. On a smaller scale, the data are intended for the identification of air-pollution sources and transport processes specific to Southeast Asia. No interpretation of the data is provided herein.

Elemental composition of the filtered particles was measured by INAA using the TRIGA research reactor located at the U.S. Geological Survey (USGS) National Reactor Facility in Denver, Colorado. INAA involves exposure of sample media to a neutron flux provided by a nuclear reactor and is advantageous because this analysis does not destroy, or alter, elemental composition. The neutron flux activates the elements in the samples, causing them to become temporarily radioactive. Radioactive elements that decay by gamma-ray emission are then measured by gamma spectrometry. INAA is described in more detail by Alfassi (1990), Landsberger and others (1985) and Koeberl (1993).

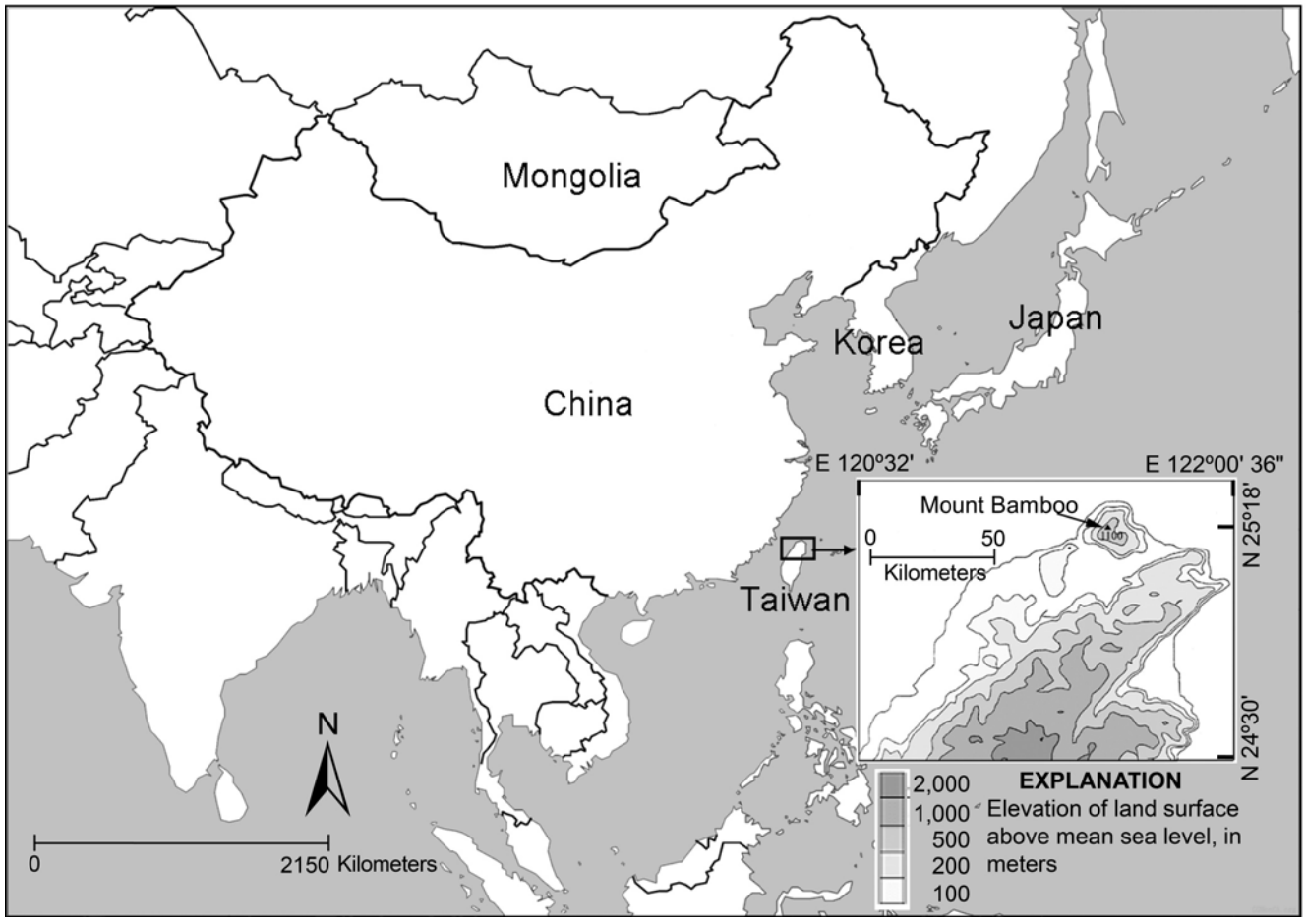

Figure 1. Cloud-water sampling location on summit of Mount Bamboo, Taiwan.

Radioactive isotopes that decay by processes other than gamma-ray emission cannot be measured by gamma spectrometry. Other gamma-emitting isotopes have half-lives that are too short for practical analysis by gamma spectrometry; therefore, the elemental data presented herein do not describe the

complete elemental composition of the particulate portion of the cloud-water samples. Though carbon, nitrogen, silicon, and sulfur are important constituents in atmospheric particulates (Gilles and others, 1989; Pakkanena and others, 2001; Wang and others, 2010), they are not included in the reported results as these elements are not easily measured by INAA. After a suitable decay period, the samples may be analyzed further for constituents not measured by INAA.

Methods

Cloud-Water Sampling

Cloud water was sampled at the DASNCU monitoring station on Mount Bamboo using an Atmospheric Science Research Center (ASRC)–type passive collector (fig. 2). The collector is described by Mohnen and Kadlecek (1989), DeFelice and Saxena (1990), and Saxena and Lin (1990). The ASRC collector was mounted 1.6 m above the roof surface of a 2.4-m high building. The ASRC collector was deployed at the time of cloud inundation to expose multiple Teflon strings to the ambient atmosphere. Sample collection occurred when cloud-water droplets coalesced onto the strings. The condensed droplets slid down the strings and were collected into sample bottles via a Teflon funnel and tubing.

Sequential cloud-water samples were collected over a 40-hour period beginning March 22, 2002 at 20:00 local time, and ending March 24, 2002 at 12:00 local time. Samples were filtered on site by vacuum filtration onto MFS, Inc., 47-millimeter (mm) diameter, 0.45-micron, mixed cellulose ester filters (fig. 3). After the samples were filtered, the liquid fraction was stored in plastic sample bottles and preserved at 4 °C for later analysis. Filters were stored in clean plastic petri-dishes with plastic covers (fig. 3). Three blank filter samples were prepared by rinsing the filters with deionized water, storing both the filters and the filtrate for analysis.

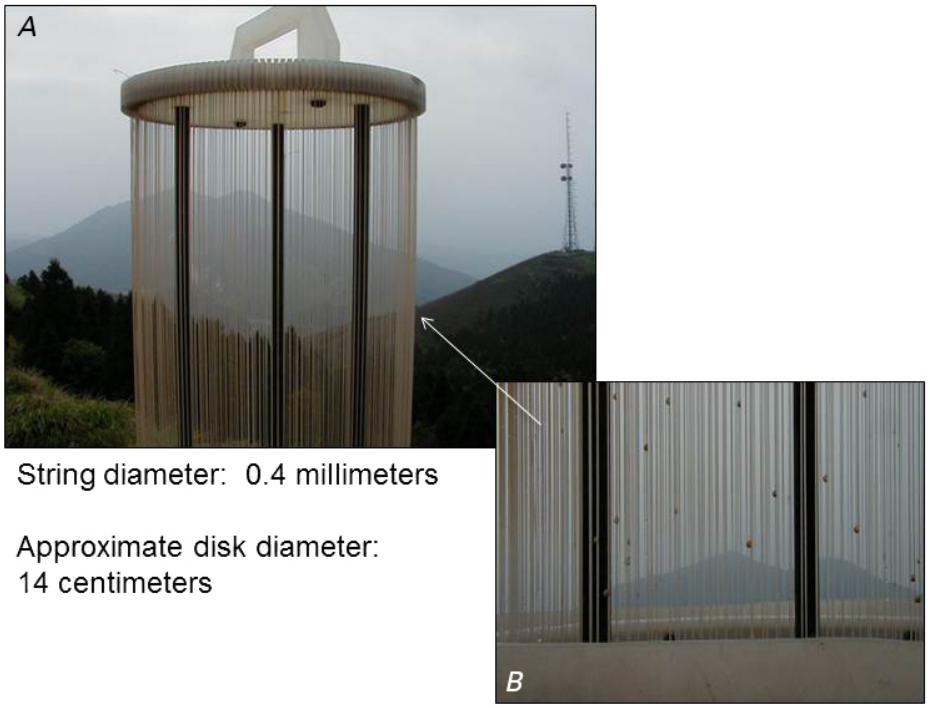

Figure 2. (*A*) Cloud-water sampler on summit of Mount Bamboo, Taiwan, with (*B*) enlarged view of condensed cloud-water droplets.

Figure 3. *(A)* Cloud-water filtration apparatus, and *(B)* filtered particulate samples on 0.45-micron filters in chronological order from top left to bottom right.

Filter Analysis by INAA

Particulate samples were stored at a constant relative humidity (RH) of 40 percent for 9 years. Upon learning of the filters in the summer of 2011, personnel from the USGS offered to analyze the samples for DASNCU using INAA. Filter samples were shipped to the USGS, Branch of Quality Systems, in Denver, Colorado, for initial preparation, whereby each sample was placed in an individual ultrapure polypropylene vial with snap-seal lid. The vials were labeled with black marker, which is known to contain some trace metals. Blank samples were labeled with the same marker for consistency. Samples were then submitted to the TRIGA research reactor located at the USGS National Reactor Facility in Denver, Colorado, for INAA analyses.

The filter samples were irradiated twice and analyzed by gamma spectrometry three times using the USGS TRIGA reactor. The samples were initially irradiated for 30 seconds at a neutron flux of 7.5×10^{11}, neutrons per square centimeter per second ($n/cm^2/s$ (φ)). This first irradiation on November 18, 2011 was followed by a decay period of approximately 10 minutes, and then samples were analyzed through a 10-minute gamma spectrum collection. This short irradiation and quick analysis helped identify short-lived radioisotopes such as ^{28}Al.

Samples were irradiated the second time on November 29, 2011 for 6 hours at a neutron flux of 2.5×10^{12} $n/cm^2/s$ (φ). Samples were then allowed to decay for approximately 3 days, then analyzed through an 8-hour gamma spectrum collection. The third, and final, gamma spectrum collection of about 1.5 hours occurred approximately three weeks later. These longer and more intense irradiations, coupled with the longer decay intervals and increased spectrum collection times helped identify and quantify the longer lived radioisotopes.

Gamma spectrometry was accomplished using two high-purity germanium (HPGe) detector systems. The first was a Canberra 14 percent relative efficiency detector; the second an Ortec 40 percent relative efficiency detector. Detector efficiency calibration was performed for the sample-to-detector geometries used in this study. The detectors were maintained at -195.73 °C with liquid nitrogen to eliminate extraneous thermal noise. A lead shield surrounded the sample and detector to reduce incident background radiation.

Quality Assurance

The energy response calibration was performed using ^{152}Eu check sources. These check sources emit a wide energy range of gamma rays, with a useable range from approximately 122 thousand electron volts (keV) to 1.528 million electron volts (MeV). Energy calibration checks were performed several times during each 8-hour work day to ensure that the gamma peaks remained within 1 keV of the certified values.

Efficiency calibrations were performed using National Institute of Standards and Technology (NIST) traceable calibration standards manufactured by Eckert & Ziegler, Valencia, California. Two standards were used for the calibration geometry identical to the filters: (1) 0.5 microCurie (μCi) of ^{60}Co, and (2) 0.055 μCi of ^{137}Cs plus 0.575 μCi of ^{133}Ba. Both standards had a geometry identical to the filters to ensure similar response. These isotopes cover a gamma energy range from 88 keV to 1,332 keV. The efficiency calibrations were performed once at the beginning of the work, and the calibration curves were stored in the analyzer's internal memory. Three blank filter samples were prepared by DASNCU and analyzed by INAA. A mean "blank value" was determined for each isotope from these three analyses. The cloud-water particulate-sample analyses were subsequently "blank corrected" by subtracting the mean blank values from the total amount of each isotope detected in the cloud-water particulate samples, and the final results are presented in table 2.

Data

Table 1. Elemental composition data for blank filter samples prepared by Department of Atmospheric Sciences, National Central University, Taiwan, and analyzed at the U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA.

[P1-03B_8, P1-07B_D, P1-05_B_; B, blank sample identifier numbers; nd, not detected; -228, -211, -212, -214, -219, isotope atomic masses]

Element	Mass (micrograms per filter)			*Mean mass (micrograms per filter)*
	P1-03B_8	P1-07B_D	P1-05_B_B	
Actinium-228 (^{228}Ac)	nd	5.4×10^{-11}	nd	*5.4×10^{-11}*
Aluminum	9.7	4.9	46	*20*
Antimony	0.18	0.12	0.09	*0.13*
Arsenic	0.13	0.04	0.03	*0.07*
Bismuth-214 (^{214}Bi)	2.2×10^{-12}	2.1×10^{-12}	2.1×10^{-11}	*8.4×10^{-12}*
Bromine	2.3	1.9	3.1	*2.4*
Cadmium	3.5	27	1.9	*11*
Cerium	0.08	nd	nd	*0.08*
Chlorine	28	38	35	*34*
Chromium	0.02	0.41	0.53	*0.32*
Cobalt	0.26	2.9	3.8	*2.3*
Copper	175	41	nd	*108*
Gold	2.7×10^{-3}	1.6×10^{-3}	2.1×10^{-3}	*2.1×10^{-3}*
Iron	12	13	23	*16*
Lanthanum	7.6×10^{-3}	1.0×10^{-2}	8.7×10^{-3}	*8.8×10^{-3}*
Lead-212 (^{212}Pb)	2.4×10^{-12}	8.4×10^{-11}	7.2×10^{-10}	*2.7×10^{-10}*
Lead-214 (^{214}Pb)	2.9×10^{-12}	2.5×10^{-12}	9.5×10^{-12}	*5.0×10^{-12}*
Manganese	0.12	0.051	1.3	*0.49*
Mercury	1.4×10^{-3}	nd	nd	*0.014*
Molybdenum	0.32	0.96	0.61	*0.63*
Nickel	nd	nd	nd	*nd*
Scandium	1.2×10^{-3}	nd	5.6×10^{-4}	*8.6×10^{-4}*
Sodium	nd	nd	13	*13*
Tantalum	nd	nd	nd	*nd*
Tin	1.3	nd	nd	*1.3*
Tungsten	3.1	0.26	0.48	*1.3*
Uranium	nd	3.1	19	*11*
Vanadium	0.02	0.03	0.07	*0.04*
Zinc	32	11	9.6	*18*

Table 2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan, cloud-water samples, collected by Department of Atmospheric Sciences, National Central University, Taiwan, March 2002, and analyzed by instrumental neutron activation analysis at the U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA, August 2012.

[All values are micrograms per filter; -228, -211, -212, -214, -219 isotope atomic masses, <b, measured value less than average blank value; nd, not detected; E+##, ×10 to positive exponent ##; E-##, ×10 to negative exponent ##]

Sample ID	Collection date, time	Element								
		Actinium-228	Aluminum	Antimony	Arsenic	Barium	Bismuth-211	Bismuth-214	Bromine	Cadmium
1	3/22/2002, 20:00	nd	1.5E+03	4.2E-01	3.2E+00	1.4E+04	1.6E-13	nd	1.5E+00	5.2E+02
3	3/22/2002, 22:00	nd	1.1E+03	5.7E-01	1.2E+01	1.5E+01	nd	<b	7.7E+00	1.1E+03
5	3/23/2002, 00:00	4.2E-10	3.0E+02	1.9E-01	2.9E+00	nd	2.0E-13	6.3E-12	1.2E+01	<b
7	3/23/2002, 02:00	nd	1.0E+03	6.2E-01	1.8E+01	3.4E+03	nd	<b	1.3E+01	1.1E+03
9	3/23/2002, 04:00	nd	4.0E+03	3.0E-01	6.3E+00	8.2E+02	nd	<b	6.4E+00	8.9E+02
11	3/23/2002, 06:00	nd	4.4E+02	9.0E-01	2.3E+01	7.2E+00	nd	<b	3.8E+01	2.9E+02
13	3/23/2002, 07:00	nd	7.9E+02	2.0E-01	2.0E+00	5.3E+00	nd	<b	1.2E+01	5.8E+02
14	3/23/2002, 08:00	nd	2.9E+02	2.8E-01	8.9E+00	4.7E+00	nd	<b	1.3E+01	5.7E+01
15	2/23/2002, 09:00	4.4E-10	5.4E+02	6.5E-01	3.4E+01	1.6E+01	nd	9.6E-12	4.7E+01	nd
16	3/23/2002, 10:00	nd	6.0E+02	8.7E-01	4.5E+01	nd	2.4E-13	<b	3.4E+01	1.1E+03
17	3/23/2002, 11:00	nd	5.5E+03	7.0E+00	2.1E+02	1.1E+05	nd	nd	2.4E+01	nd
18	3/23/2002, 12:00	nd	5.3E+03	4.6E+00	1.2E+02	9.7E+04	1.6E-12	nd	1.3E+01	1.4E+04
19	3/23/2002, 14:00	nd	3.1E+03	2.3E+00	1.4E+02	8.2E+04	nd	nd	2.6E+01	2.0E+02
20	3/23/2002, 15:00	nd	6.0E+03	1.8E+00	2.9E+01	1.4E+05	nd	7.4E-12	6.2E+00	7.4E+03
21	3/23/2002, 16:00	nd	5.3E+03	2.1E+00	4.7E+01	5.9E+04	nd	nd	1.2E+01	5.7E+02
22	3/23/2002, 17:00	nd	1.9E+03	1.9E+00	4.8E+01	1.4E+04	nd	8.9E-12	1.6E+01	2.2E+03
23	3/23/2002, 18:00	nd	1.2E+03	1.1E+00	8.0E+00	1.5E+04	nd	<b	2.7E+01	4.1E+02
24	3/23/2002, 19:00	nd	8.0E+02	4.6E-01	3.2E+00	1.1E+05	3.2E-12	<b	7.2E+00	nd
25	3/23/2002, 20:00	nd	6.5E+02	2.6E-01	2.2E+00	4.6E+02	nd	<b	1.6E+00	nd
26	3/23/2002, 21:00	3.0E-10	4.1E+02	2.5E-01	2.2E+00	nd	2.7E-13	8.2E-12	4.9E+00	nd
27	3/23/2002, 22:00	nd	4.5E+02	1.1E+00	4.1E+00	5.0E+00	nd	<b	7.3E+00	6.0E+02
28	3/24/2002, 00:00	2.9E-10	2.0E+02	7.1E-01	2.9E+00	nd	2.0E-12	7.0E-12	3.0E+01	3.0E+02
29	3/24/2002, 12:00	5.7E-10	4.4E+02	1.3E+00	7.9E+00	nd	1.6E-12	1.1E-11	4.3E+01	4.5E+02
31	3/24/2002, 14:00	nd	2.7E+01	4.8E+00	1.5E+02	1.1E+04	nd	<b	6.3E+01	3.2E+03

Table 2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan cloud-water samples, collected by Department of Atmospheric Sciences, National Central University, Taiwan, March 2002, and analyzed by instrumental neutron activation analysis at U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA, August 2012.—Continued

[All values are micrograms per filter; -228, -211, -214, -212, -219 isotope atomic masses; <b, measured value less than average blank value; nd, not detected; E+##,×10 to positive exponent ##; E-##, ×10 to negative exponent ##]

Sample ID	Collection date, time	Element								
		Cerium	Cesium	Chlorine	Chromium	Cobalt	Copper	Europium	Gold	Indium
1	3/22/2002, 20:00	1.6E+00	2.5E-01	nd	6.8E+03	1.5E-01	nd	1.3E-02	1.3E-02	nd
3	3/22/2002, 22:00	4.1E+00	2.1E-01	nd	6.8E+03	<b	nd	1.0E-02	3.1E-03	nd
5	3/23/2002, 00:00	1.9E-01	nd	nd	2.4E+03	3.2E-01	nd	nd	8.3E-04	nd
7	3/23/2002, 02:00	1.4E+00	2.5E-01	<b	9.5E+03	<b	nd	8.5E-03	2.2E-03	nd
9	3/23/2002, 04:00	1.2E+00	2.3E-01	<b	6.5E+03	7.6E-01	nd	6.4E-03	3.4E-03	nd
11	3/23/2002, 06:00	1.4E+00	9.9E-02	nd	5.6E+03	<b	nd	nd	3.6E-03	nd
13	3/23/2002, 07:00	5.3E-01	8.9E-02	<b	1.7E+03	1.8E-01	nd	nd	3.2E-04	nd
14	3/23/2002, 08:00	7.5E-01	nd	<b	3.1E+03	<b	nd	nd	1.9E-03	nd
15	2/23/2002, 09:00	6.1E-01	1.2E-01	<b	3.7E+03	4.7E-01	nd	8.4E-03	3.2E-03	1.3E+04
16	3/23/2002, 10:00	1.3E+00	1.5E-01	9.1E-01	5.2E+03	<b	nd	5.4E-03	1.9E-03	nd
17	3/23/2002, 11:00	1.7E+01	9.4E-01	nd	2.8E+04	1.1E+00	nd	nd	1.3E-02	nd
18	3/23/2002, 12:00	1.7E+01	9.0E-01	nd	2.9E+04	8.9E-01	nd	3.5E-02	5.8E-03	nd
19	3/23/2002, 14:00	1.3E+01	1.0E+00	nd	2.7E+04	1.1E+00	nd	5.2E-02	1.0E-02	nd
20	3/23/2002, 15:00	4.2E+00	8.8E-01	nd	2.8E+04	1.2E+00	nd	4.7E-02	2.1E-03	nd
21	3/23/2002, 16:00	1.1E+01	3.7E-01	nd	1.1E+01	7.0E-02	nd	2.5E-02	4.1E-03	nd
22	3/23/2002, 17:00	1.8E+00	3.8E-01	nd	1.2E+04	7.8E-01	nd	1.7E-02	3.5E-03	nd
23	3/23/2002, 18:00	1.9E+00	2.6E-01	nd	8.8E+03	5.1E-01	nd	6.1E-03	6.2E-03	nd
24	3/23/2002, 19:00	7.1E-01	2.4E-01	nd	8.3E+03	3.1E-01	nd	nd	8.7E-04	nd
25	3/23/2002, 20:00	6.3E-01	5.3E-02	nd	3.7E+03	<b	nd	nd	1.8E-03	nd
26	3/23/2002, 21:00	4.1E-01	nd	<b	3.3E+03	7.6E-01	nd	3.1E-03	1.2E-03	nd
27	3/23/2002, 22:00	2.0E+00	nd	<b	1.9E+03	<b	nd	nd	1.5E-03	nd
28	3/24/2002, 00:00	3.4E-01	nd	<b	2.2E+03	4.7E-01	nd	nd	2.4E-02	nd
29	3/24/2002, 12:00	3.2E-01	nd	<b	2.8E+03	nd	nd	6.7E-03	5.9E-03	nd
31	3/24/2002, 14:00	3.7E+00	2.5E-01	nd	1.6E+03	4.9E-01	nd	2.6E-02	2.0E-02	nd

Table 2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan cloud-water samples, collected by Department of Atmospheric Sciences, National Central University, Taiwan, March 2002, and analyzed by instrumental neutron activation analysis at U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA, August 2012.—Continued

[All values are micrograms per filter; -228, -211, -214, -212, -219 isotope atomic masses; <b, measured value less than average blank value; nd, not detected; E+##,×10 to positive exponent ##; E-##, ×10 to negative exponent ##]

Sample ID	Collection date, time	Element								
		Iron	Lanthanum	Lead-212	Lead-214	Manganese	Mercury	Molybdenum	Nickel	Radon-219
1	3/22/2002, 20:00	1.1E+03	5.0E-01	<b	nd	1.1E+01	3.8E-01	<b	7.7E+00	nd
3	3/22/2002, 22:00	4.2E+02	2.5E-01	<b	<b	8.3E+00	4.3E-02	2.0E+00	6.4E+00	nd
5	3/23/2002, 00:00	1.3E+02	1.1E-01	6.5E-10	4.0E-12	2.6E+00	nd	2.8E-01	nd	nd
7	3/23/2002, 02:00	3.8E+02	5.1E-01	<b	nd	9.5E+00	1.5E-01	1.8E+00	2.0E+00	nd
9	3/23/2002, 04:00	3.9E+02	4.2E-01	<b	nd	9.3E+00	1.8E-01	7.7E-01	5.0E+00	nd
11	3/23/2002, 06:00	1.5E+02	1.7E-01	<b	<b	3.3E+00	nd	5.5E+00	1.2E+00	nd
13	3/23/2002, 07:00	1.7E+02	2.2E-01	nd	nd	4.1E+00	7.8E-02	8.7E-01	3.7E+00	nd
14	3/23/2002, 08:00	1.1E+02	1.6E-01	9.4E-11	<b	1.8E+00	<b	4.3E+00	1.3E+00	nd
15	2/23/2002, 09:00	2.1E+02	2.1E-01	9.2E-10	5.1E-12	3.7E+00	nd	3.0E+00	3.5E+00	nd
16	3/23/2002, 10:00	2.7E+02	4.3E-01	3.9E-10	<b	8.0E+00	9.5E-02	1.3E+01	nd	nd
17	3/23/2002, 11:00	2.0E+03	1.9E+00	<b	nd	4.2E+01	5.0E-03	nd	7.6E+00	nd
18	3/23/2002, 12:00	1.8E+03	2.3E+00	<b	3.6E-12	4.6E+01	<b	8.0E+00	4.0E+00	nd
19	3/23/2002, 14:00	1.5E+03	2.3E+00	<b	nd	4.0E+01	5.3E-01	8.2E+00	5.4E+00	nd
20	3/23/2002, 15:00	1.6E+03	1.4E+00	3.6E-10	6.8E-12	3.5E+01	4.6E-02	1.8E+00	4.8E+00	nd
21	3/23/2002, 16:00	1.0E+03	1.3E+00	<b	<b	2.5E+01	1.6E-02	4.9E-01	3.5E+00	nd
22	3/23/2002, 17:00	6.4E+02	7.7E-01	6.7E-10	6.4E-12	1.4E+01	3.2E-03	2.3E+00	nd	nd
23	3/23/2002, 18:00	4.3E+02	6.3E-01	nd	nd	9.3E+00	1.7E-01	3.1E+00	3.8E+00	nd
24	3/23/2002, 19:00	3.8E+02	4.1E-01	4.9E-10	nd	7.7E+00	1.1E-01	nd	nd	nd
25	3/23/2002, 20:00	2.4E+02	2.1E-01	<b	<b	3.9E+00	<b	5.6E-01	nd	nd
26	3/23/2002, 21:00	1.5E+02	1.7E-01	4.5E-10	1.3E-11	3.2E+00	nd	4.4E-01	nd	nd
27	3/23/2002, 22:00	1.9E+02	1.3E-01	<b	<b	4.9E+00	1.8E-02	<b	nd	nd
28	3/24/2002, 00:00	7.8E+01	8.7E-02	1.3E-10	<b	2.0E+00	2.1E-02	1.8E+00	1.4E+00	nd
29	3/24/2002, 12:00	9.8E+01	1.5E-01	4.2E-10	2.4E-12	3.5E+00	8.7E-03	1.7E+00	nd	nd
31	3/24/2002, 14:00	9.1E+02	1.5E+00	<b	2.6E-11	1.5E+00	1.9E-01	2.4E+01	nd	nd

Table 2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan cloud-water samples, collected by Department of Atmospheric Sciences, National Central University, Taiwan, March 2002, and analyzed by instrumental neutron activation analysis at U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA, August 2012.—Continued

[All values are micrograms per filter; -228, -211, -214, -212, -219 isotope atomic masses; <b, measured value less than average blank value; nd, not detected; E+##,×10 to positive exponent ##; E-##, ×10 to negative exponent ##]

Sample ID	Collection date, time	Element								
		Ruthenium	Scandium	Selenium	Silver	Sodium	Tantalum	Tin	Tungsten	Uranium
1	3/22/2002, 20:00	nd	3.6E-01	2.9E-02	1.0E+02	3.4E+02	1.1E+02	nd	7.6E-01	nd
3	3/22/2002, 22:00	nd	2.8E-01	nd	nd	2.5E+02	1.5E+01	2.2E+00	5.4E+00	nd
5	3/23/2002, 00:00	nd	9.9E-02	nd	nd	7.8E+01	nd	nd	2.0E+00	nd
7	3/23/2002, 02:00	nd	3.4E-01	3.0E-03	nd	2.7E+02	1.5E+01	nd	3.1E+01	nd
9	3/23/2002, 04:00	nd	2.9E-01	nd	nd	2.6E+02	1.5E+01	nd	2.1E+00	nd
11	3/23/2002, 06:00	nd	1.2E-01	3.1E-02	nd	1.2E+02	nd	nd	1.7E+02	<b
13	3/23/2002, 07:00	nd	1.4E-01	nd	nd	1.0E+02	nd	nd	3.2E+00	nd
14	3/23/2002, 08:00	nd	8.2E-02	nd	nd	5.1E+01	nd	nd	6.4E+00	<b
15	2/23/2002, 09:00	nd	1.8E-01	nd	nd	1.0E+02	nd	nd	nd	nd
16	3/23/2002, 10:00	nd	2.5E-01	nd	nd	1.5E+02	nd	nd	2.2E+01	nd
17	3/23/2002, 11:00	nd	1.4E+00	9.0E-01	nd	1.0E+03	3.6E+01	nd	nd	nd
18	3/23/2002, 12:00	8.7E-01	1.4E+00	5.1E-01	1.8E+02	9.2E+02	5.0E+01	nd	2.0E+01	nd
19	3/23/2002, 14:00	3.1E-01	1.4E+00	2.2E-01	nd	9.6E+02	3.3E+01	nd	3.3E+01	nd
20	3/23/2002, 15:00	nd	1.2E+00	nd	nd	7.2E+02	4.1E+01	nd	4.2E+00	2.0E+00
21	3/23/2002, 16:00	4.9E-02	7.5E-01	nd	nd	5.7E+02	2.8E+01	nd	7.7E+00	nd
22	3/23/2002, 17:00	1.5E-01	5.8E-01	4.2E-01	nd	3.8E+02	1.6E+01	nd	nd	<b
23	3/23/2002, 18:00	1.3E-02	3.9E-01	nd	5.8E+02	3.1E+02	3.3E+00	nd	9.6E+00	nd
24	3/23/2002, 19:00	5.8E-02	3.0E-01	2.2E-01	nd	1.8E+02	nd	nd	nd	nd
25	3/23/2002, 20:00	6.9E-02	1.5E-01	2.0E-01	nd	1.1E+02	nd	nd	<b	nd
26	3/23/2002, 21:00	nd	1.3E-01	nd	nd	6.7E+01	nd	<b	<b	nd
27	3/23/2002, 22:00	nd	1.1E-01	1.3E-01	nd	6.7E+01	nd	nd	2.2E+00	nd
28	3/24/2002, 00:00	nd	5.5E-02	nd	nd	2.9E+01	nd	nd	1.3E+01	nd
29	3/24/2002, 12:00	nd	9.6E-02	nd	nd	9.0E+01	nd	nd	2.0E+01	nd
31	3/24/2002, 14:00	3.2E-01	7.5E-01	4.5E-02	3.4E+02	6.2E+01	nd	nd	nd	nd

Table 2. Blank-corrected elemental composition of particulates filtered from Mount Bamboo, Taiwan cloud-water samples, collected by Department of Atmospheric Sciences, National Central University, Taiwan, March 2002, and analyzed by instrumental neutron activation analysis at U.S. Geological Survey National Reactor Facility, Denver, Colorado, USA, August 2012.—Continued

[All values are micrograms per filter; -228, -211, -214, -212, -219 isotope atomic masses; <b, measured value less than average blank value; nd, not detected; E+##,×10 to positive exponent ##; E-##, ×10 to negative exponent ##]

Sample ID	Collection date, time	Element		
		Vanadium	Zinc	Zirconium
1	3/22/2002, 20:00	2.3E+00	4.4E+01	nd
3	3/22/2002, 22:00	1.8E+00	7.2E+02	nd
5	3/23/2002, 00:00	4.3E-01	<b	nd
7	3/23/2002, 02:00	1.6E+00	<b	nd
9	3/23/2002, 04:00	3.8E+00	<b	nd
11	3/23/2002, 06:00	7.8E-01	<b	nd
13	3/23/2002, 07:00	1.1E+00	<b	nd
14	3/23/2002, 08:00	5.1E-01	<b	nd
15	2/23/2002, 09:00	7.5E-01	<b	nd
16	3/23/2002, 10:00	1.1E+00	<b	nd
17	3/23/2002, 11:00	8.5E+00	1.4E+01	nd
18	3/23/2002, 12:00	7.6E+00	1.6E+04	nd
19	3/23/2002, 14:00	5.4E+00	2.6E-01	nd
20	3/23/2002, 15:00	7.9E+00	1.5E+03	nd
21	3/23/2002, 16:00	6.3E+00	4.3E+03	1.2E+00
22	3/23/2002, 17:00	2.8E+00	<b	4.4E+01
23	3/23/2002, 18:00	1.8E+00	<b	nd
24	3/23/2002, 19:00	1.4E+00	nd	5.3E-01
25	3/23/2002, 20:00	8.8E-01	<b	nd
26	3/23/2002, 21:00	5.5E-01	<b	nd
27	3/23/2002, 22:00	8.3E-01	5.2E+02	nd
28	3/24/2002, 00:00	2.6E-01	<b	nd
29	3/24/2002, 12:00	6.0E-01	<b	nd
31	3/24/2002, 14:00	<b	<b	nd

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