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Report

Report of Preliminary Survey on Ambient Dose Rate and Particulate Matter in Catania, Italy

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Human health effects due to several factors originating from volcanic activity have been observed around volcanos. This report summarizes a preliminary survey of the ambient dose equivalent rate and $PM_{2.5}$ and PM_{10} in Catania, Italy, where one of the most active volcanoes of Mt. Etna is located. The ambient dose equivalent rate and indoor radon concentration were higher than those in other countries, probably because of the volcanic rocks used as building materials. In contrast, the concentrations of $PM_{2.5}$ and PM_{10} during the survey were low, indicating that the air quality was clean. Further detailed investigations will be conducted in the future.

Key words: environmental radiation, particulate matters, field survey

1. Introduction

Radon is a radioactive gas generated by the decay of radium in soil and rocks. Radon gas exhaled from the ground diffuses into the atmosphere or moves into dwellings through cracks and slabs. Owing to its relatively long half-life (~3.8 days), it easily accumulates in closed spaces such as mines, caves, and dwellings without ventilation systems. Exposure to radon and its progeny is a well-known secondary cause of lung cancer following tobacco smoking[1)]. On the other hand, radon gas is also utilized as a tracer for atmospheric dispersion and as a precursor of volcanic activities and earthquakes[2-4)]. According to previous reports, radon gas may be released from magma due to gas pulses related to eruptive activity, leading to observations of high radon concentration[5)].

There is a lot of active volcanoes across the world. Especially in the central and southern parts of Italy, there are several active volcanoes, such as Mt. Etna, Stromboli, and Vesuvius. Numerous investigations pertaining to volcanic eruptions and seismic activities have been undertaken in these regions[5-7)]. In Mt. Etna, many volcanic activities were observed every year, and volcanic ash was released during the eruptions. After the release, ash is advected to the southeast in most cases due to the wind direction[8)], where there are several cities and towns, including Catania. Catania is located in the southeastern part of Sicilia Island (Fig. 1), with a population of 1,074,434 as of 1st Jan, 2023[9)]. Residents living around Mt. Etna have faced crises caused by lava outflows several times in the past. Recently, the volcanic activity of Mt. Etna has been constantly monitored 24 hours a day throughout a year, and real-time data are available from the website of the National Institute of Geophysics and Volcanology (INGV) in Italy[10)]. Real-time monitoring data are utilized

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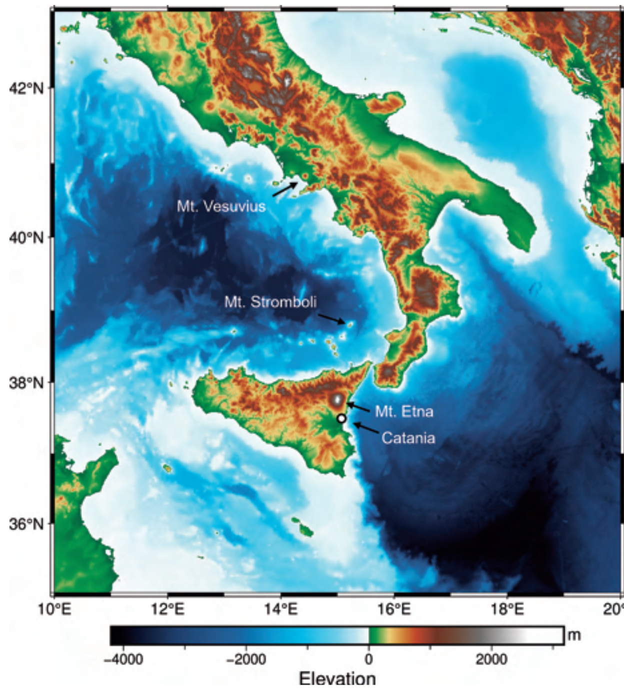

Fig. 1. Geographical locations of the main volcanoes in Italy.

for flight safety and to promote a better understanding of volcanic activity and its effects on residents. Volcanic sulfur dioxide (SO_2) and other parameters are also monitored by the INGV, which causes environmental changes[11]. The effects of volcanic ash on human health have been investigated and several studies have shown the possibility of respiratory effects[12]. Boffetta et al. also reported a geographic analysis of the incidence of thyroid cancer on Mt. Etna[13]. There are many possible factors influencing human health, and multidisciplinary research on physical, chemical, biological, and medical aspects is necessary to reveal comprehensive health effects.

In 2018, Hirosaki University established a Memorandum of Understanding (MoU) with the University of Catania for collaborative activities including an exchange program. We have continued to discuss collaborative research on the health effects on residents around Mt. Etna since signing the MoU. We eventually started collaborative research in 2023 to provide a better understanding of the health risks associated with volcanic activity and to contribute to the development of effective strategies to protect public health in volcano-prone areas, including Japan, which is one of the most volcanic countries in the world. A preliminary survey was conducted during a visit to the University of Catania for a face-to-face meeting in March 2024. This report summarizes the results of the survey.

Fig. 2. Measurement sites of ambient dose equivalent rate and concentrations of $PM_{2.5}$ and PM_{10} around (a) Mt. Etna and (b) Catania. Site B is not shown in Figure 2(b), as it is the same as site A.

2. Measurement of Ambient Dose Rate, Particulate Matters and Radon Concentration

The ambient dose equivalent rate was measured using a pocket survey meter (PDR-111; Aloka Co. Ltd., Japan) at 14 sites in Catania and Mt. Etna, as shown in Figure 2. Concentrations of $PM_{2.5}$ and PM_{10} (particulate matter smaller than 2.5 μm and 10 μm, respectively) were also obtained by a portable particulate monitor (Series500, Aeroqual, US) at the same sites. For continuous

Table 1. Ambient dose equivalent rate and concentrations of $PM_{2.5}$ and PM_{10} measured at Catania and Mt. Etna

Site ID	Site	Ambient dose equivalent rate* (nSv h^{-1})	$PM_{2.5}$ (μg m^{-3})	PM_{10} (μg m^{-3})
A	Hotel room	108 ± 16	1	8
B	Entrance of hotel	103 ± 15	3	13
C	University square	88 ± 13	3	16
D	In front of Cathedral of Sant'Agata	88 ± 13	5	17
E	Pacini garden	69 ± 10	4	16
F	San Francesco d'Assisi square	107 ± 16	4	29
G	Castle Ursino	68 ± 10	3	14
H	Ancient Greek-Roman Theatre of Catania	101 ± 15	3	11
I	Dante Alighieri Square	52 ± 8	3	11
J	Crociferi Street	98 ± 15	4	20
K	Villa Bellini	74 ± 11	3	13
L	Monti Rossi	79 ± 12	4	10
M	House submerged in lava	91 ± 14	1	3
N	Belvedere of Rifugio Sapienza	69 ± 10	1	17

*An uncertainty was calculated using a measurement accuracy of 15% according to the specification.

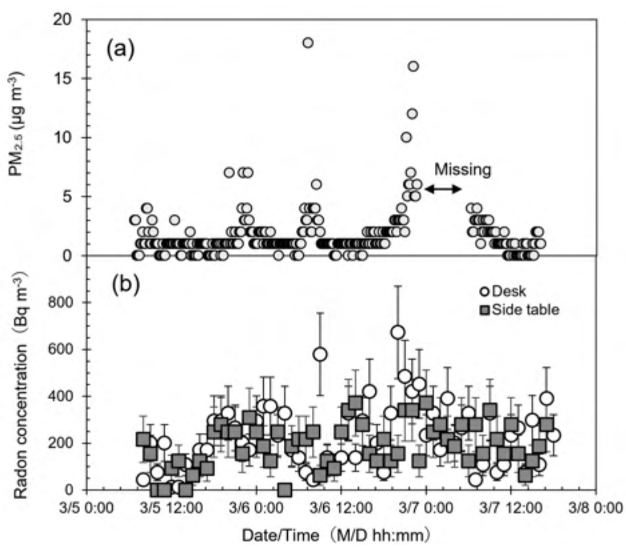

Fig. 3. Obtained data by continuous measurement. (a) $PM_{2.5}$ concentration outside the hotel room on the 3rd floor and (b) radon concentrations in the hotel room on the 2nd floor.

monitoring of $PM_{2.5}$, a $PM_{2.5}$ monitor (PS-2, SIBATA Scientific Technology Ltd., Japan) was deployed outside the window of the hotel room on the 3rd floor. The calibration factor was 1.0 for both the pocket survey meter and the $PM_{2.5}$ monitor. Radon concentration was monitored using a portable radon monitor (AlphaE, Bertin Technologies, France) in the hotel room on the 2nd floor. The continuous measurement was conducted in the hotel room as the hotel was a restored aristocratic building that is similar to the building where local people in Catania are still living or working.

The measured ambient dose equivalent rate and concentrations of $PM_{2.5}$ and PM_{10} at each site are summarized in Table 1. Figure 3 shows the concentrations of $PM_{2.5}$ and radon by the continuous measurements. The ambient dose equivalent rate ranged from 52 to 108 nSv h^{-1} with an average of 85 nSv h^{-1}. The average was slightly higher than the dose rate observed in Japan, which was approximately 62 nSv h^{-1} on average[14, 15]. Note that the average ambient dose equivalent rate was calculated by converting an average absorbed dose rate in air using a conversion factor of 1.224[16]. In addition, a mean radon concentration measured in the hotel room was evaluated to be 210 Bq m^{-3} with a maximum value of 673 Bq m^{-3}, which is much higher than the world mean indoor concentration (i.e., 40 Bq m^{-3})[17]. One reason could be the difference in geological features. A lot of buildings in Catania are composed of volcanic rocks produced by eruptions of Mt. Etna which include relatively high radionuclide concentrations. The ^{226}Ra concentration in rock samples from Mt. Etna was reported to be 61.8 Bq kg^{-1}, which is higher than the world average value for earth materials (i.e., 40 Bq kg^{-1}), resulting in a high dose rate and radon concentration[5, 17]. According to a previous report[18], radon concentration at schools and dwellings ranged from 11 to 634 Bq m^{-3}, corresponding to our result.

The concentrations of $PM_{2.5}$ and PM_{10} measured at 14 sites were in the ranges of 1-5 μg m^{-3} and 8-29 μg m^{-3}, respectively. The $PM_{2.5}$ concentration by continuous monitoring ranged from 0 to 18 μg m^{-3}. A high concentration above 10 μg m^{-3} was observed only four times during continuous monitoring, probably due to exhaust emissions from vehicles. Although the measured concentrations included a large uncertainty in such a low concentration range, it was found that the air quality was quite clean from the obtained low concentration of $PM_{2.5}$, compared with the global mean of 20.17 μg m^{-3} in 2015[19]. It should be noted that no eruption of Mt. Etna occurred during the survey. Thus, monitoring should be conducted during eruptions to release volcanic ash that produces PMs.

3. Summary

A preliminary survey of the ambient dose equivalent rate and concentrations of $PM_{2.5}$ and PM_{10} was conducted in Catania, Italy, where one of the most active volcanoes, Mt. Etna, is located as the first step of research to evaluate the human health effects from many possible influential factors originating from volcanoes. The mean ambient dose equivalent rate and indoor radon concentration were 85 nSv h^{-1} and 210 Bq m^{-3}, respectively, which were higher than those in other countries, probably because of the volcanic rocks used for building materials. On the other hand, the concentrations of $PM_{2.5}$ and PM_{10} during the survey were lower than the global mean value, indicating that the air quality was clean at least during the period of survey. For a more detailed analysis, a large-scale survey will be carried out in cooperation with our collaborators.

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Author contributions

Conceptualization, M.H.; Methodology, Y.T., M.H., and N.A.; Formal analysis, Y.T., M.H., and N.A.; Investigation, Y.T., M.H., and N.A.; Data acquisition and interpretation, Y.T., M.H., and N.A.; Supervision, M.H.; Validation, Y.T., M.H., and N.A.; Writing-original draft, Y.T.; Writing-review and editing, Y.T., M.H., and N.A.
All authors have read and agreed to the published version of the manuscript.

Reference

1. WHO. WHO Handbook on Indoor Radon: a Public Health Perspective. Geneva: WHO; 2009.
2. Omori Y, Nagahama H, Yasuoka Y, Muto J. Radon degassing triggered by tidal loading before an earthquake. Sci Rep. 2021;11(1):4092.
3. Giammanco S, Sims KWW. Chapter 7 Monitoring volcanic activity through combined measurements of CO_2 efflux and (^{222}Rn) and (^{220}Rn) in soil gas: an application to Mount Etna, Italy. In: Sims KWW, Maher K, Schrag DP, editors. Isotopic Constraints on Earth System Processes. Hoboken: Wiley; 2022. p. 167–202.
4. Sukanya S, Noble J, Joseph S. Application of radon (^{222}Rn) as an environmental tracer in hydrogeological and geological investigations: an overview. Chemosphere. 2022;303:135141.
5. Giammanco S, Bonfanti P, Neri M. Radon on Mt. Etna (Italy): a useful tracer of geodynamic processes and a potential health hazard to populations. Front Earth Sci. 2023;11:1176051.
6. Doronzo DM, Di Vito MA, Arienzo I, Bini M, Calusi B, Cerminara M, *et al*. The 79 CE eruption of Vesuvius: a lesson from the past and the need of a multidisciplinary approach for developments in volcanology. Earth Sci Rev. 2022;231:104072.
7. Iezzi AM, Buzard RM, Fee D, Matoza RS, Gestrich JE, Jolly AD, *et al*. UAS-based observations of infrasound directionality at Stromboli volcano, Italy. Geophys Res Lett. 2023;50(8):e2023GL102905.
8. Andronico D, Spinetti C, Cristaldi A, Buongiorno MF. Observations of Mt. Etna volcanic ash plumes in 2006: an integrated approach from ground-based and polar satellite NOAA–AVHRR monitoring system. J Volcanol Geotherm Res. 2009;180(2):135–47.
9. Istituto Nazionale di Statistica (Istat). Population and households – population [Internet]. [cited 2024 Mar 29]. Available from: https://www.istat.it/en/population-and-households?data-and-indicators.
10. Istituto Nazionale di Geofisica Vulcanologia. Real-time data. [cited 2024 Mar 29] Available from: https://www.ingv.it/en/.
11. Marshall LR, Maters EC, Schmidt A, Timmreck C, Robock A, Toohey M. Volcanic effects on climate: recent advances and future avenues. Bull Volcanol. 2022;84(5):54.
12. Barone G, De Giudici G, Gimeno D, Lanzafame G, Podda F, Cannas C, *et al*. Surface reactivity of Etna volcanic ash and evaluation of health risks. Sci Total Environ. 2021;761:143248.
13. Boffetta P, Memeo L, Giuffrida D, Ferrante M, Sciacca S. Exposure to emissions from Mount Etna (Sicily, Italy) and incidence of thyroid cancer: a geographic analysis. Sci Rep. 2020;10(1):21298.
14. Abe S. Efforts to obtain Japanese profile of ambient natural radiation exposure. Jpn J Health Phys. 1982;17(2):169–93. (in Japanese)
15. Omori Y, Hosoda M, Takahashi F, Sanada T, Hirao S, Ono K, *et al*. Japanese population dose from natural radiation. J Radiol Prot. 2020;40(3):R99–140.
16. Shimo M, Sanada T, Fujitaka K, Minato S. Radiation dose attributed to natural radiations. Isot News. 2013;706:23–32. (In Japanese)
17. UNSCEAR. UNSCEAR 2000 Report, Sources and Effects of Ionizing Radiation; Volume I: Annex B Exposures from Natural Radiation Sources. New York: United Nations; 2000.
18. Catalano R, Immè G, Mangano G, Morelli D, Tazzer AR. Indoor radon survey in Eastern Sicily. Radiat Meas. 2012;47(1):105–10.
19. Yang D, Ye C, Wang X, Lu D, Xu J, Yang H. Global distribution and evolvement of urbanization and PM2.5 (1998–2015). Atmos Environ. 2018;182:171–8.