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Volcanic Ashfall Risk Assessment of the Sakurajima *Taisho* Eruption to the Contemporary Japan

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Japan is home to 10% of the world's active volcanoes and has suffered many volcanic disasters in the past. Japan Meteorological Agency (JMA) listed 47 active volcanoes in Japan that have a high possibility to erupt within 100 years. Apart from the direct impact from an eruption such as earthquake swarms, poisonous gases and lahar mudflows, Japan also suffered from massive ashfall when large eruption occurred. Apparently, volcanic ashes emitted from a large eruption could travel far away and disturbing socio-economic activities, from damaging critical infrastructures and buildings, disrupting airline transportations, to even causing health problems. Deposited ashes on the roof have chances to both collapse buildings and short-circuit the electricity, in power generation stations as well as in transmission stations when considerable amount of wet ashes penetrated inside. Settled volcanic ashes are directly affecting life and livelihoods, such as: destroying vegetation, crops, and pastures; clogging drainage systems and contaminating water supplies; also disrupting the traffic and damaging the vehicles on roads. Furthermore, despite shallow thickness accumulation, ashfall affect strongly on the transportation fields, forcing airports, ports and roads to be closed; amplifying the disturbance in the networks.

As illustration, when Mt. Fuji erupted in 1707 (The *Hōei* Eruption), the eruptive materials were blown into Kashima Pass (280 km away from the vent), and this event caused the worst ashfall disaster in the Japanese history. It reported that there was no death toll directly from the eruption.

However, it brought severe damages that starved out the population in nearby areas and blew ashfall to distant places, such as Yokohama and Tokyo, within the same day as the eruption occurred, causing respiratory problems for the residents. Those evidences reflect that the impacts from enormous ashfall dispersed during large eruption can be further worsen by the wind condition that can bring ashfall to further and wider spaces. Accordingly, the damage caused by ashfall hazards will depend on the total amount of discharged ashfall during an eruption and the wind condition at the time of eruption.

Another example of such catastrophic event is when Mt. Sakurajima in Kyushu erupts. Within the last six centuries, Mt. Sakurajima has at least three explosive eruptions: the *Bunmei* (1471), *Ane`i* (1779), and *Taisho* (1914) eruptions; the latter is considered as the biggest eruption in Japan during the twentieth century. The *Taisho* eruption caused enormous damage to its surroundings by releasing a lava flow, pumice, volcanic ash, and other eruptive substances of about 2 km^3 ejecta in total and claimed 56 lives. Such eruptive volume is about ten times that of the 1990-1995 Unzen volcano eruption, and its total volume exceeded the above mentioned the *Hōei* eruption of Mt. Fuji. Unfortunately, it is found that precursory phenomena preceding the *Taisho* eruption is now reappearing in Mt. Sakurajima, indicating that there will be another similar-scale eruption 130 years after the last large eruption. In consequence, Sakurajima volcano has significant probability to erupt with *Taisho*-scale eruption approximately within the next 25~30 years.

The present densely populated and modernized cities require comprehensive volcanic risk reduction strategies, especially for inhabitants who live closely to the actively erupting volcano. One of the necessary actions for lessening the impacts of ashfall hazards is to assess the risk in the infrastructures, human lives, and economic impacts to make a better response plan. The rareness of volcanic eruption as a natural phenomenon bring discrepancies between the recorded impacts in the past and the upcoming effects in the future. As the time intervals between eruptions mostly exceed human life spans, the current built environment is vastly different compared when the last eruption occurred. There are also increasing vulnerabilities and far greater impacts can be foreseen when the eruptions with similar or stronger scale happened again shortly.

The previous *Taisho* eruption brought calamities not only in nearby locations but also in almost all over Japan, up to Tohoku Prefecture in Honshu Island and some smaller islands in the vicinity of Tokyo. Therefore, it is also crucial to assess the risk and develop comprehensive risk analysis to a broader range as larger population will be exposed when the ashfall arrive in major cities like Fukuoka, Osaka, and Tokyo. We approach this issue by carrying out a risk assessment for upcoming *Taisho*-like eruption, focusing primarily to the ashfall impacts, by replicating the past *Taisho* eruption event down to minutes as precise as possible. Here, we conduct numerical simulation of volcanic ash transport using well-known PUFF model with long-term wind data from 1958 to 2019, provided by JRA-55 reanalysis data from the Japan Meteorological Agency (JMA. In order to further investigate the ashfall dispersion to distal locations on all around Japan, we set the simulation period of the PUFF model to 96 hours after the eruption started with four different eruption starting times (4 am, 10 am, 4 pm, 10 pm JST).

The simulation produces daily ashfall deposit from the *Taisho* eruption from 30.0° to 45.9° north latitude, and 128.5° and 148.6° east longitude, covering Japan with 0.1° increment. We also provide deeper observation range focusing on Kagoshima Prefecture as the closest affected urban area from the explosive eruption, within 30°30’ to 32°30’ north latitude, and 129° to 132° east longitude (0.01° increment). The simulation produces the ashfall deposit amount every day on each observation point in Japan, then further analyzed to provide ashfall risk analysis to contemporary Japan in a various degree. We present the risk assessment mainly towards comprehensive sectors: airport closures risk, roads blockage risk, and collapsing building risk, following the damage threshold set based on the research done by the JMA and Mt. Fuji Volcanic Disaster Prevention Working Group, with 0.2 mm depth ash deposit as the baseline for airport closures, 3 cm depth for roads blockage, and 30 cm depth for collapsing buildings.

Assuming the exact eruption scenario happened similarly to the past will give an insightful input on how such large eruption would affect contemporary Japan. This study provides useful input to extend further study on particular ashfall risk analysis and decision-making process, supporting both future researchers and emergency managers to analyze and plan crisis responses over different condition. Accordingly, by covering the risk assessment for all over Japan region, this research will provide unforeseen probable impacts to farther area and remain to be utilized to more extensive studies for both ashfall risk analysis and countermeasures plan building.