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Community perceptions of protective practices to prevent ash exposures around Sakurajima volcano, Japan

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ABSTRACT

Whilst, globally, volcanic eruptions are unusual and cause anxiety in affected communities, people living near Sakurajima volcano, Japan are exposed to frequent ashfall with little-to-no official intervention. As part of a wider project, this study assessed how this apparently normalised experience affects residents' perceptions of health impacts, and whether it is important to protect themselves from ash inhalation. A survey of 749 residents found little evidence of normalisation. Respondents identified a range of symptoms (including eye irritation, low mood, sore throat, cough) perceived to be associated with ash exposure, with 67% experiencing at least one symptom. Only 6% of respondents thought it was not important to protect themselves, and path analysis showed that protection was particularly important to older people and those with existing respiratory disease, who were more likely to rate ash as harmful or associate symptoms with exposures. Therefore, some of the most vulnerable sectors of this community are adversely impacted by ash. However, despite the local government recommending protective measures, most respondents said they had not received advice, but would like to. They took actions that they thought were effective (keeping windows/doors closed) or were easily available (wearing surgical masks). Other research has shown that industry-certified (e.g., N95) masks are more effective than surgical masks. Here, respondents recognised this, but high-efficiency masks were rarely used, probably due to unavailability. The results demonstrate a need to provide ash-affected communities with targeted, evidence-based information on options for effective protection, coupled with ensuring that communities have access to suggested interventions.

1. Introduction

Sakurajima, one of Japan's most active stratovolcanoes, is located on the southern margin of the Aira Caldera, protruding into Kagoshima Bay (Fig. 1). Once an island, it is now connected to the Osumi Peninsula, to the east, by a lava flow which was emplaced during the 1914 Taisho eruption. During times of volcanic activity, the communities surrounding the volcano have been exposed to frequent ashfall events, a situation which is rather unusual, globally. Ashfall from Sakurajima volcano increased substantially in 1972 (Fig. 2) and between 2009 and 2015 the volcano was in a phase of enhanced activity with frequent eruptions (sometimes several per day) totalling between 450 and 1000 explosions per year (see Fig. 2 and [1]). On August 15, 2015, there was an increase in the frequency of volcanic earthquakes, with the seismic source located just under Sakurajima Minami-dake crater, accompanied by an increase in deformation of the volcano's flanks indicating new magma intrusion. The Japan Meteorological Agency increased the volcanic eruption warning level to 4 ('Prepare to Evacuate') out of 5 ('Evacuate'). Following this event, there was a sharp decrease in the number of explosions (47 in 2016 and 81 in 2017) although activity increased again in 2018 and 2019 (246 and 228 explosions, respectively) [2].

Hillman et al. [3] examined the physicochemical characteristics of Sakurajima ash particles and found that the Vulcanian-style eruptions (relatively low explosivity) which are common at Sakurajima, generate ash with a low content of respirable material (<4 μm diameter) meaning that, often, much of the ash generated may not be sufficiently fine-grained to enter the deep lung, where chronic diseases may be triggered. Nevertheless, since 2009, the volcano has generated

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substantial ash, in the region of 500–3500 g/m^2/year (Fig. 2), of which a considerable proportion will be inhalable (<100 μm diameter). The respiratory health hazard of inhalable volcanic ash has been a cause for concern since the eruption of Mount St. Helens volcano, USA in 1980 (e.g. [4,5]). As with ash from Mount St. Helens, the Sakurajima ash also tends to contain the crystalline silica mineral cristobalite (usually < 5 wt. % of a bulk sample [3]); which is known to cause silicosis in some silica industries [6] and is classed as a Group 1 carcinogen [7]. It is a matter of contention as to whether volcanic crystalline silica is toxic [8,9]. Thus, consideration of the possible respiratory hazard is important.

Due to this exposure, Sakurajima volcano has been a focus of intense epidemiological and clinical research over the past 30 years with more than 30 studies conducted by Japanese universities and government institutions (see reviews in Refs. [3,4]). Whilst some studies have concluded that there is a major health risk (e.g. Ref. [10]), there are currently insufficient studies on chronic exposures to ash, so its pathogenic potential (e.g., development of diseases such as lung cancer or silicosis) remains unclear [4].

Since it is still uncertain how, or whether, certain physicochemical characteristics of ash influence toxicity (e.g. Refs. [4,8,11]), and because it is often impossible to assess these characteristics in a timely way to inform immediate public health advice when an eruption occurs, the World Health Organization promotes a precautionary approach and advises people to stay indoors when ash is airborne, or to wear light-weight, disposable respiratory protection while outdoors [12]. This advice, and similar advice from the International Volcanic Health Hazard Network is used, and adapted, by health agencies and NGOs around the world (see global ash advice summary database at: [13]). At the time of conducting this study (2016), there was no specific scientific evidence on which types of respiratory protection would be effective at preventing volcanic ash inhalation in community settings.

In the years of heavy ashfall, such as 1985 and 1991, the Kagoshima City government advised countermeasures by distributing brochures in which the following advice could be found: 'Do not let volcanic ashfall enter the eyes', 'Wear masks and long sleeves; use umbrellas', 'Wash off ash that has fallen on the skin', and 'Gargle with large amounts of water' (e.g., Kagoshima City, 1985 and Fig. 3: Kagoshima City, 1991).

Nowadays, residents are being advised to implement the following countermeasures outlined on the Kagoshima City website (Health for Adults and Elderly People section; [14]). The advice includes: refrain

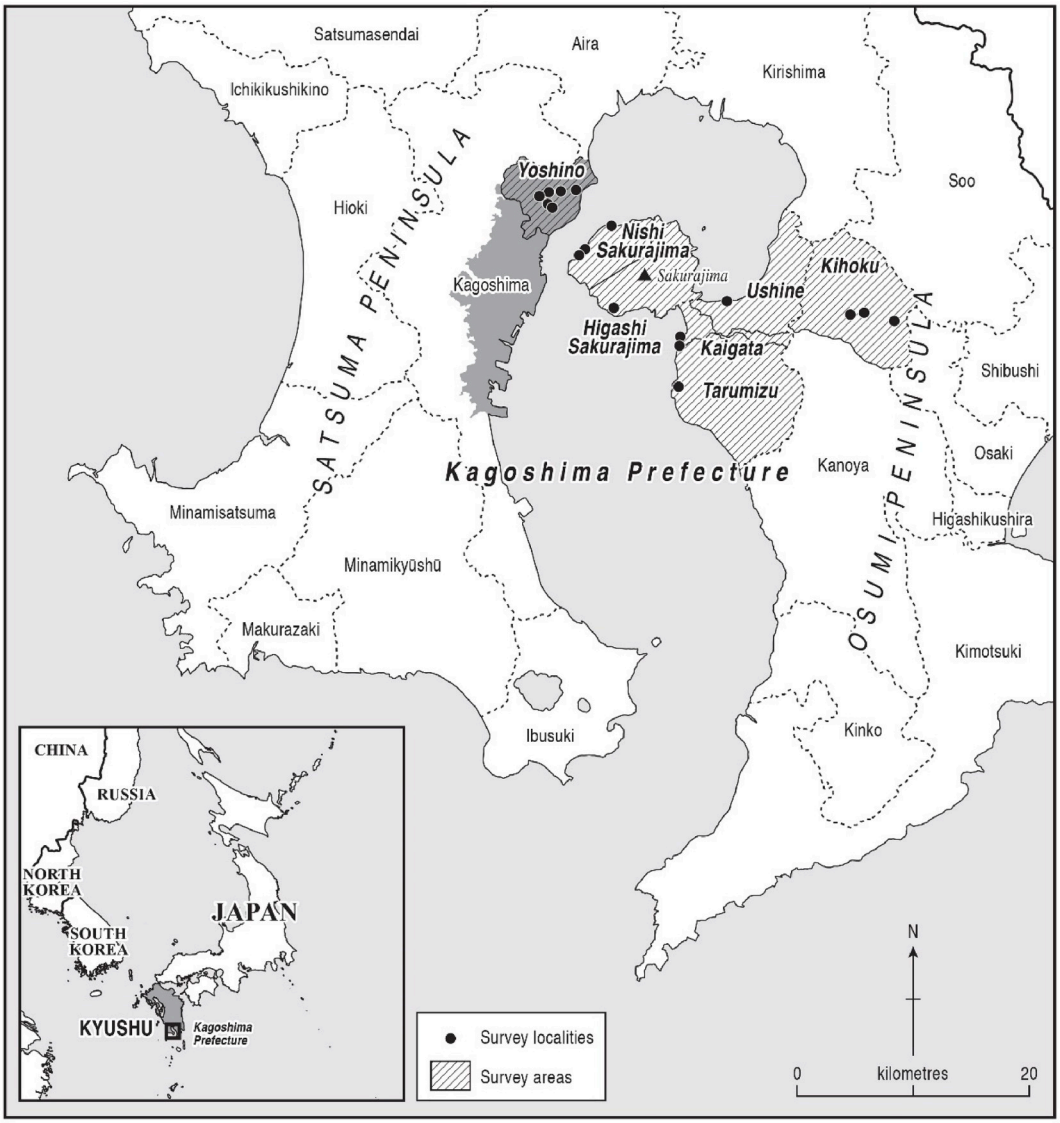


Fig. 1. Map of the survey areas. Hashed lines and bold font represent the districts where surveys were conducted, with white background representing rural areas and dark grey shading covering urban locations. Dots represent specific communities where surveys were conducted.

from going out when there is heavy ashfall; wear hats, masks, and long sleeves, and use umbrellas when going out during periods of heavy ashfall; gargle when you return home; wash off ash from exposed areas such as the face and hands; take measures to prevent ash from getting into your eyes; and in cases of entry of ashfall into the eyes, wash the eyes with clean water, without rubbing. Please see an ophthalmologist (specialist) if you experience difficulty in removing ashfall.

Further to these examples, there is a notification on this website regarding the provision of free, monthly health consultation services on ashfall in 10 public health centres at different locations throughout Kagoshima City for concerned individuals (although, anecdotally, one health centre informed the authors that only a few people visit the health centre for this purpose). In addition, visitors to Sakurajima Island can download or obtain a printed brochure from the Geopark (available in Japanese or English), which mentions that one may choose to protect oneself: "You'd better wear the mask when volcanic ash falls, however it doesn't mean that you can't go out without masks. You may realize that there are few people wearing masks to solve volcanic ash when you go to the city of Kagoshima." (available at: http://www.sakurajima-kinkowan-geo.jp/en/en-sakurajima-kinkowan/en-okite/).

The advice currently offered is quite limited, and is not actively publicised, as far as we were able to ascertain. This may reflect the view of the Kagoshima City government that there are no clear findings of a causal association between volcanic ash exposure and adverse health effects (as documented in a report from an 'opinion exchange' meeting of experts organised by the Kagoshima Prefecture administration in September 2010, on the health risks of inhaling Sakurajima volcanic ash; archived at https://web.archive.org/web/20160410165531/www.pref.kagoshima.jp/ae06/kenko-fukushi/kenko-iryo/nanbyo/shippeitaisaku.html). Sakurajima volcano is also one of the greatest tourism resources in Kagoshima and excessive anxiety about volcanic activity may lead to negative rumours which could adversely affect the tourism industry [15].

Well-developed and targeted public information about natural hazards and associated public health interventions should be based on solid scientific evidence (about both the risk associated with the hazard and the effectiveness of interventions), and perceptions (both of authorities and the general public) of these will influence the uptake of interventions and advice. This study was part of a larger project ('Health Interventions in Volcanic Eruptions'; HIVE) which aimed to generate this evidence. Simultaneous with this study, laboratory and field experiments tested the effectiveness and wearability of respiratory protection worn during ash exposures [16–18]. For this study, a questionnaire survey was used, in conjunction with qualitative interviews (to be published separately), to understand the motivations, influences and barriers related to whether people will wear respiratory protection. Here we present the data collected from selected communities around Sakurajima. Equivalent surveys were also conducted in communities in Indonesia and Mexico, which are affected less frequently by volcanic ashfall, and selected findings from all three locations have already been reported in Covey et al. [19].

The Covey et al. [19] paper adopted a cross-cultural comparative approach to specifically examine the use of respiratory protection across the three communities. The paper tested the hypothesis, derived from theories such as Protection Motivation Theory [20], that the decision to use a facemask for respiratory protection was motivated by threat appraisal (e.g., perceptions of the harm caused by ash inhalation and worry about the effects of the ash) and coping appraisal (e.g., beliefs about mask efficacy). The influence of barriers to wearing a facemask, such as cost and lack of availability, conceptualised within the resource-related attributes of the Protective Action Decision Model [21], were also examined. Through structural equation modelling, important differences were found in the predictive ability of the threat appraisal and coping appraisal constructs across the three countries. For example, perceptions of harm and worry were stronger predictors of mask use in Japan and Indonesia whereas, in Mexico, beliefs about mask efficacy were more important. The modelling also enabled us to explore how sociodemographic variants of mask use were mediated by the theoretical constructs. For example, in Japan we found that the tendency for older people to wear masks more frequently than younger people was related to their increased perceptions of harm and worry about the consequences of ash inhalation.

The survey also investigated a broader range of issues over and above understanding the motivations for mask use (published in Covey et al. [19]) and, in this paper, we report additional findings from the Japanese sample. The Japanese sample was unique from the Mexican and Indonesian samples in the sense that the community around Sakurajima volcano had been frequently exposed to volcanic ash, on an almost daily basis, for many years. Also, as noted previously, although the Kagoshima City and Prefecture governments provided some information and advice about protection from the ashfall, it was not actively publicised or easily found. This, therefore, provided us with the opportunity to study the experiences, perceptions, and responses of a community in which the presence of potentially hazardous ash in the environment may have

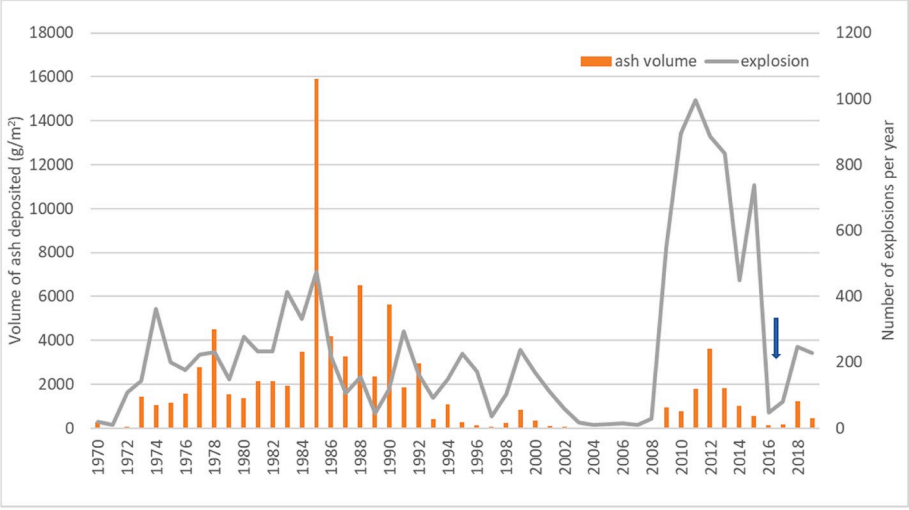
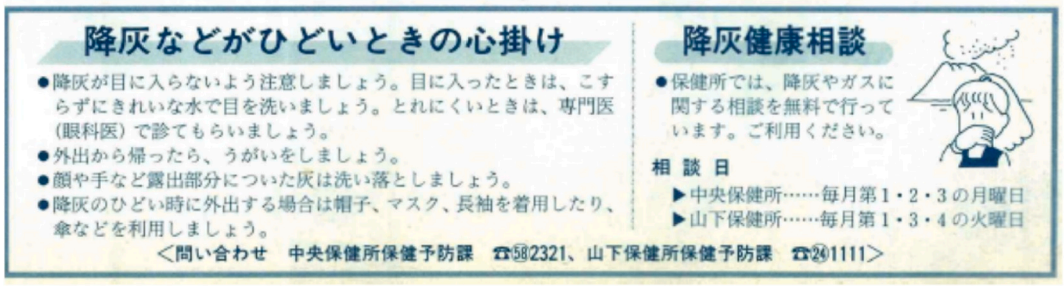


Fig. 2. Annual number of eruptions of Sakurajima and volume of volcanic ash deposited, between 1970 and 2019. Arrow represents timeframe of the survey. Source: Japanese Meteorological Agency. (http://www.jma-net.go.jp/kagoshima/vol/data/skr_exp_num.html and http://www.jma-net.go.jp/kagoshima/vol/data/skr_ash_vol.html).



降灰などがひどいときの心掛け

- 降灰が目に入らないよう注意しましょう。目に入ったときは、こすらずにきれいな水で目を洗いましょう。とれにくいときは、専門医（眼科医）で診てもらいましょう。
- 外出から帰ったら、うがいをしましょう。
- 顔や手など露出部分についた灰は洗い落としましょう。
- 降灰のひどい時に外出する場合は帽子、マスク、長袖を着用したり、傘などを利用しましょう。

降灰健康相談

- 保健所では、降灰やガスに関する相談を無料で行っています。ご利用ください。

相談日

▶中央保健所……毎月第1・2・3の月曜日
▶山下保健所……毎月第1・3・4の火曜日

<問い合わせ　中央保健所保健予防課　☎58-2321、山下保健所保健予防課　☎24-1111>

Measures during heavy ash fall

- Prevent ash from getting into your eyes. If ash is inside your eyes, do not rub your eyes. Wash your eyes using clean water. If you cannot remove ash, go to see a doctor.
- Gargle when you return home.
- Wash attached ash at exposed parts such as the face and hands etc.
- Wear a cap, mask and a long-sleeved shirt or use an umbrella when ash falls heavily.

Ash fall health consultation

- Health consultation service regarding volcanic ashfall or gas is provided at health care centers for free. Please do not hesitate to contact us if you have any problem.

Consultation day:

- every 1st, 2nd and 3rd Monday at Central health care center
- every 1st, 3rd and 4th Monday at Yamashita health care center

<Contact　Central Health care center: 58-2321　Yamashita Health care center: 24-1111>

Figure 3. Notification to residents regarding countermeasures for ashfall in the city bulletin (with translation below). Kagoshima Citizen's Forum May 1, 1991 issue.

become normalised. The theme of normalisation and the experiential dimensions that volcanic ash and eruptive events generate in the local population are explored more deeply in our HIVE project's anthropological ethnographic study (to be published).

Given that the Kagoshima City government do recommend use of respiratory protection for ash exposures, even if it is not well publicised, as a starting point, we wanted to find out whether the communities in the vicinity of Sakurajima volcano had actually received any advice either about the health effects of the ashfall or about how to protect themselves. Having gauged what, if any, information they had received we also enquired whether they would like any advice about how to protect themselves from ashfall and from whom they would like to receive that advice. This insight is important for the development and targeting of future public information.

We also wanted to investigate, for the first time, the community's experience of living with ash and its perceived effects on their health. We were particularly interested in identifying which types of physical symptoms (e.g., coughing or difficulty breathing), psychological symptoms (e.g., low mood, stress) and functional difficulties (e.g., trouble sleeping, loss of appetite) people thought were being brought on by or made worse by their regular exposure to volcanic ash. Geographical variants of the symptom experience were analysed by comparing the experiences of people living in urban (Kagoshima city) or rural (Sakurajima island and surrounding districts of Kihoku, Ushine and Kaigata) areas along with sociodemographic factors such as age, gender, and educational level. We also investigated whether people's experiences of symptoms shape their views, more generally, about how much harm they perceive the ashfall might be doing to their health and the importance they place on protection. If people are experiencing symptoms that they attribute to ashfall, to them it is having a tangible effect on their health, and we might therefore expect they will be more likely to recognise the danger for their future health and place more importance on protecting themselves from that danger. The framework for our analysis is shown in Fig. 4; we used path analysis to explore the extent to which the influence of geographical and sociodemographic factors on ratings of the importance of protection were mediated by people's

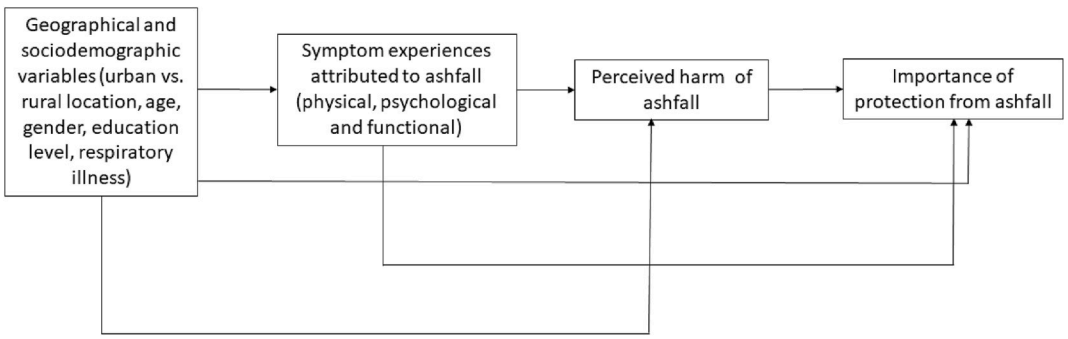


Fig. 4. Framework to demonstrate analytical relationships investigated.

experience of symptoms and perceptions of harm. By examining the determinants of people's general motivation to protect themselves from inhaling the ash this analysis builds upon the data reported in Covey et al. [19] which focussed on a specific behavioural response (i.e., using a mask).

Further issues specific to mask use in the Sakurajima residents are also addressed in this paper. Agencies responsible for public protection during hazardous events, such as volcanic eruptions, may have to make ethically-challenging decisions about recommendation and provision of interventions, based on little evidence of the risk from the hazard or the effectiveness of the intervention [22]. In relation to agency decision-making on mask procurement, distribution and uptake, for example, it is important to know whether communities can readily access masks, their perceptions of effectiveness and what makes them attractive to wear. We therefore asked our respondents to comment on their perceived effectiveness of a range of potential interventions for ash exposure reduction, where masks were obtained from (if people wore them), and the features of facial protection that are important to them. Also, given that Japanese people may be wearing facemasks for other purposes other than protection against ash (e.g., to protect themselves from infectious diseases or from urban traffic pollution), we documented what those situations were and asked ourselves whether the same demographic variants of mask use in volcanic ash situations identified in Covey et al. [19] carried over to other situations where people use facemasks.

2. Method

2.1. Sample and sampling procedure

The survey was conducted with respondents aged over 13 living in either urban (Yoshino district of Kagoshima City) or rural areas (Sakurajima Island, Kihoku, Ushine and Kaigata) near the study volcano (Fig. 1). These areas have experienced heavy ashfall in recent years and, dependent on wind direction, there are seasonal variations in the amount of ashfall. Yoshino-Kagoshima City tends to experience greatest ashfall in the summer whereas, in the rural areas of our study (to the east of the volcano), ashfall increases in the winter. This survey was conducted from 17 July to November 4, 2016 during which time there were only two explosions which produced a total of 74 g/m^2 of volcanic ash fall at the Kagoshima observation point (Fig. 2).

The sample was recruited using a quota sampling method designed to match the demographic characteristics of the populations in each region from local census data (Statistics Bureau Japan, 2010). This was deemed a more practical approach than random sampling which can suffer from low response rates, particularly in Japanese society where the people are concerned about abuse of their personal data [23].

In rural areas, housing density in agricultural areas is lower than in built-up areas and it was not practical to visit house-to-house to recruit respondents for the survey. Therefore, respondents were recruited via health/leisure activities, community groups, fishery cooperatives, and social welfare organisations, details of which were provided by the town office, who also gave permission for the survey to be conducted in their locality. In the urban area, respondents were recruited at a range of activities organised by community-based not-for-profit organisations and neighbourhood associations. We also selected survey participants at a sports festival organised and run by the community unions which is one of the biggest events in the area and where many people were willing to take part. There were, however, some difficulties recruiting respondents from the youngest age-group (13–19 years), not least because signed parental consent was required for individuals under 18 to take part. This meant that, as shown in Table 1, although the sample recruited was larger than intended (total sample 749 rather than 600) the youngest age-group and less well-educated people were under-represented in our sample. We therefore need to be cautious when interpreting our findings as representing the opinions or actions of the general population, particularly when those opinions or actions differ by age or education level.

Table 1
Demographic characteristics of respondents in the urban and rural districts.

	Urban (N = 431)[a]		Rural (N = 318)[a]	
	N (%)	Census %	N (%)	Census %
Age group				
13–39 years	125 (29.0%)	43%	93 (29.2%)	28%
40–59 years	123 (28.5%)	26%	100 (31.5%)	25%
60+ years	183 (42.5%)	31%	125 (39.3%)	47%
Gender				
Male	180 (41.8%)	47%	145 (45.6%)	46%
Female	251 (58.2%)	53%	173 (54.4%)	54%
Educational level				
No formal education	3 (0.7%)	30.3%	9 (2.8%)	38.3%
Primary/junior high	28 (6.5%)		56 (17.6%)	
High school	178 (41.3%)	69.7%	132 (41.5%)	61.7%
College/graduate	191 (44.3%)		109 (34.3%)	
Missing[b]	31 (7.2%)		12 (3.8%)	
Occupational status				
Full-time paid work	106 (24.6%)		104 (32.7%)	
Part-time paid work	90 (20.9%)		51 (16.0%)	
Self-employed	28 (6.5%)		28 (8.8%)	
Voluntary/unpaid	4 (0.9%)		1 (0.3%)	
Looking after family	11 (2.6%)		3 (0.9%)	
In training/education	26 (6.0%)		6 (1.9%)	
Retired	19 (44%)		14 (4.4%)	
Not working	121 (28.1%)		85 (26.7%)	
Other	4 (0.9%)		14 (4.4%)	
Missing[b]	22 (5.1%)		12 (3.8%)	
Respiratory health problem				
One or more	113 (26.2%)		64 (20.1%)	
Asthma	28 (6.5%)		20 (6.3%)	
Bronchitis	18 (4.2%)		5 (1.6%)	
COPD	3 (0.7%)		0 (0%)	
Lung cancer	1 (0.2%)		0 (0%)	
Cystic fibrosis	0 (0%)		0 (0%)	
Tuberculosis	0 (0%)		0 (0%)	
Allergic rhinitis	90 (20.9%)		52 (16.4%)	
Other	2 (0.5%)		2 (0.6%)	
When they last noticed ash				
Last 24 h	13 (3.0%)		10 (3.1%)	
Few days ago	17 (3.9%)		34 (10.7%)	
About a week ago	16 (3.7%)		18 (5.7%)	
About a month ago	49 (11.4%)		54 (17.0%)	
Few months ago	263 (61.0%)		167 (52.5%)	
About a year ago	33 (7.7%)		20 (6.3%)	
More than a year ago	40 (9.3%)		15 (4.7%)	

[a] The data for the whole sample are reported in Covey et al. [19].
[b] Missing – question not answered.

2.2. Survey design

As described in Covey et al. [19]; the survey was administered by trained researchers and lasted no more than 20–30 min. The survey was administered in Japanese, which had been professionally translated from English from a version developed by the project team. The final version of the survey was produced following two phases of piloting in the local communities. Further details of the translation procedures, piloting, and rationale for the design of the questions and scales is provided in Covey et al. [19] (p5).

The draft and final surveys were approved by the Department of Earth Sciences Ethics Board at Durham University, UK (REF: ESE20170403CH). Informed consent was acquired from each participant prior to answering the survey, and from the parents/guardians of respondents aged 13 to 18. No personal data were recorded in any of the data spreadsheets and individuals were not identified in the reporting of the results.

The final version of the survey included the following measures which are of relevance to this paper.

Table 2
Sources of information about the health effects of volcanic ash.

	Information about the health effects	Advice about protection	Would like advice from:
Kagoshima local government	23.8%	18.8%	43.8%
National Institute of Public Health (NIPH)	0%	0.1%	0.4%
Japanese Meteorological Agency (JMA)	13.0%	13.1%	26.8%
Japanese Red Cross	2.8%	2.1%	3.9%
NGO other	0.3%	0%	0%
Community organization	5.6%	6.5%	8.9%
Youth Men's Association	0.9%	1.5%	0.7%
Women's association	1.1%	1.7%	1.1%
Religious leader	0.7%	0.5%	0.4%
Elders of the community	1.2%	1.9%	1.3%
Traditional healer	1.2%	0.4%	0.5%
Scientist	3.3%	1.5%	5.9%
Friend, family or relative	7.5%	6.3%	3.9%
Police	1.6%	3.7%	2.1%
Fire brigade	2.9%	6.1%	7.9%
Military	0.9%	1.5%	1.9%
Doctor/health professional	12.1%	4.7%	21.9%
Teacher/educator	3.3%	2.9%	3.9%
Employer	2.9%	4.0%	2.8%
Social/community worker	1.9%	1.3%	2.0%
Other (e.g., neighbours, TV, radio, mass communication)	0.8%	0.7%	1.1%

Demographic characteristics and health problems: Respondents were asked to ascribe themselves to their age group (13–19 years, 20–39 years, 40–59 years, 60–79 years, 80 years and above [1]), gender (male, female, other), occupational status (full-time paid work, part-time paid work, self-employed, voluntary/unpaid work, looking after family, in training/education, retired, not working at the moment, other), and highest educational level (no formal education/incomplete elementary or junior school, elementary or junior school, high school, junior college or technical college, college and graduate, other). They were also asked whether they had any existing respiratory health problems from the list shown in Table 1.

Experience with ashfall: Respondents were asked when they last noticed volcanic ash in the air on a scale from: 1 (in the last 24 h), 2 (a few days ago), 3 (about a week ago), 4 (about a month ago), 5 (a few months ago), 6 (about a year ago), 7 (more than a year ago).

Information and advice about ashfall: Respondents were asked where they received information from about the health effects of volcanic ash and how to protect themselves from the list of sources provided in Table 2. They were also asked which of these sources they would prefer to receive advice from and which type of media they would like to receive advice through (see Table 3 for list provided).

Health symptoms linked to ashfall: Respondents were asked whether they had experienced any health symptoms which they think occur with, or are made worse by, exposure to volcanic ash. The list of symptoms provided is shown in Table 4.

Perceived harm: Respondents were asked how harmful they thought that breathing in the ash might be to their health on a scale from 0 (no harm), 1 (a little harm), 2 (quite harmful), 3 (very harmful). A 'can't say' option was provided.

Importance of protection: Respondents were asked whether they thought it was important to protect themselves from breathing in volcanic ash on a scale from 0 (not at all important), 1 (a little important), 2 (quite important), to 3 (very important). A 'can't say' option was provided.

Effectiveness of protective actions: Respondents were asked how effective they thought a list of different types of actions would be in protecting them from breathing in the ash on a scale from 0 (not at all effective), 1 (a little effective), 2 (quite effective), to 3 (very effective). A 'can't say' option was provided. The list of actions is shown in Table 5 and included five different types of masks that they were shown pictures of (surgical mask, fashion mask, scooter mask, hard cup mask, high efficiency mask with certification such as N95). The five masks types were identified based on a pilot study in Indonesia [24] and confirmation through piloting, for this survey, that these were recognised forms of protection.

Mask procurement: Respondents were asked from where they obtained their masks, from the list shown in Table 6.

Mask use across different situations: Respondents were asked whether or not they had worn facemasks in a range other situations as well as when there is volcanic ash in the air. Options provided are shown in Table 7.

Important features of facial protection: Respondents were asked to rate what features were important to them when considering whether to use facial protection when there is volcanic ash in the air. The list of features is shown in Table 8. Each feature was rated in terms of its importance on a scale from 0 (not at all important), 1 (a little important), 2 (quite important), to 3 (very important).

It should be noted that some of the data used in this paper are also reported in Covey et al. [19]. Table 1 (p4) in Covey et al. [19] reports the demographic characteristics and respiratory health problems of the whole Japanese sample and Table 4 (p8) reports descriptive statistics from the ratings of perceived harm (i.e., percentages and mean ratings) and the ratings of harm were used in the structural modelling (Table 5 p10 and Fig. 3 p11). In this paper, the demographic characteristics and respiratory health problems are split according to whether the respondents were from urban or rural areas (see Table 1) and a different type of path analysis was conducted on the ratings of harm (further details in Section 2.3).

2.3. Data analysis

Data were analysed using IBM SPSS with AMOS 24. Descriptive analyses included computing frequencies, percentages and means from ordinal rating scales. Principal Components Analysis (with Varimax rotation and Kaiser normalisation) was used to examine which groups of symptoms were associated with one another. Because the symptom data were binary, the analysis was based on a tetrachoric correlation matrix that was generated using the SPSS syntax provided by Lorenzo-Seva and Ferrando [25]. Path analysis was used to explore the analytical relationships shown in Fig. 4. The coefficients (non-standardised b coefficients) were estimated using maximum likelihood estimation. However, since our endogenous (dependent) variables were measured on ordinal rather than interval/ratio scales Markov chain Monte Carlo (MCMC) estimation was used to estimate the coefficients [26]. Binary and ordinal logistic regressions were used to examine the geographical and demographic variants (i.e., location (urban vs, rural), age, gender, education level and respiratory illness) of respondents' answers to a number of questions such as the type of media they preferred for receiving future advice about volcanic ashfall, the types of situations in which they used a mask, and their ratings of the importance of different features of facial protection. The assumptions set out by SPSS for binary logistic (https://statistics.laerd.com/spss-tutorials/binomial-logistic-regression-using-spss-statistics.php) and ordinal regression (https://statistics.laerd.com/spss-tutorials/ordinal-regression-using-spss-statistics.php) were checked: i.e., Variance Inflation Factors were computed to check for no multicollinearity between independent variables, the Box-Tidwell procedure checked that there was a linear relationship between ordinal independent variables treated as continuous (i.e., age, education level) and the dependent variables, and tests of

[1] Because of small numbers of respondents in the 13–19 age-group, the 13–19 years and 20–39 age-groups were pooled together for the data shown in Table 1 and for subsequent analyses.

Table 3
Media for receiving future advice.

		Odds Ratios				
		Location[a]	Age[b]	Gender[c]	Educational level[d]	Respiratory illness[e]
Newspaper/magazine	43.4%	1.31	1.47***	0.88	1.43**	1.07
Poster	17.4%	1.17	1.01	0.99	1.36*	1.94**
Leaflet or pamphlet	16.7%	1.26	1.04	1.06	1.95***	1.49
Television	77.6%	1.14	1.53***	0.68*	1.19	0.83
Radio	38.2%	1.15	1.77***[f]	1.36	1.01	1.07
Internet/website	27.4%	1.07	0.51***[g]	0.91	1.97***	1.21
Social media	7.5%	1.24	0.58**	2.08*	1.65*[h]	1.42
In person	11.3%	0.69	0.83	0.60*	0.84	1.72*
Other (e.g., weather report, cell phone)	0.7%	–	–	–	–	–

*p < .05, **p < .01, ***p < .001.
[a] 0 = rural, 1 = urban.
[b] 1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years.
[c] 0 = female. 1 = male.
[d] 0 = no formal education, 1 = elementary/junior high school, 2 = high school, 3 = college/graduate.
[e] 0 = no respiratory illness, 1 = respiratory illness.
[f] The Box-Tidwell test showed that the assumption of lineary between age and choosing a radio to receive advice about ashfall did not hold. Analysis of age as a categorical rather than ordinal variable showed that respondents aged 40–59 years and over 60 years were significantly more likely to choose a radio to receive advice than respondents aged 13–39 years (ORs = 3.86, 3.71, ps < .001).
[g] The Box-Tidwell test showed that the assumption of lineary between age and choosing the internet to receive advice about ashfall did not hold. Analysis of age as a categorical rather than ordinal variable showed that respondents aged 13–39 years and 40–59 years significantly more likely to choose the internet to receive advice than respondents aged over 60 (ORs = 4.38, 4.15, ps < .001).
[h] The Box-Tidwell test showed that the assumption of lineary between education level and choosing social media to receive advice about ashfall did not hold. Analysis of education level as a categorical rather than ordinal variable showed that respondents educated to senior high school level were less likely to choose social media to receive advice than college graduates (OR = 0.363, p = .004).

Table 4
Symptoms perceived to be experienced or made worse by ash exposures.

	N (%)		N (%)		N (%)
Symptom group 1	225 (30.0%)	*Symptom group 2*	441 (58.9%)	*Excluded symptoms*	
Sore throat	114 (15.2%)	Eye irritation	377 (50.3%)	Tiredness/ fatigue	19 (2.5%)
Cough	85 (11.3%)	Stress	165 (22.0%)	Flu-like symptoms	14 (1.9%)
Stuffy nose	58 (7.7%)	Low mood	112 (15.0%)	Trouble sleeping	7 (0.9%)
Runny nose	53 (7.1%)	Skin irritation	49 (6.5%)	Loss of appetite	5 (0.7%)
Phlegm	42 (5.6%)			Chest pain	5 (0.7%)
Shortness of breath	27 (3.6%)			Muscle pain	3 (0.4%)
Wheeziness	16 (2.1%)			Other	3 (0.4%)
Headache	12 (1.6%)				

Table 5
Ratings of effectiveness of actions taken to prevent inhalation of ash.

	Mean rating of effectiveness[a]	Percentage adopting action during heavy ashfall[b]
Keep windows and doors closed	2.28	96.9%
High efficiency mask	2.25	4.6%
Limit time spent outdoors	2.03	85.2%
Hard cup mask	1.92	5.6%
Clean the house	1.85	84.8%
Handkerchief or cloth over mouth/nose	1.76	72.5%
Wet or clean ash outdoors	1.73	75.2%
Surgical mask	1.69	64.2%
Wear a hat	1.52	75.3%
Scooter mask	1.52	1.8%
Tie a scarf or bandana over the mouth/nose	1.50	25.2%
Wear a shawl or veil over the face	1.45	23.6%
Use an umbrella/parasol	1.44	65.0%
Hold a hand over mouth/ nose	1.42	71.6%
Fashion mask	1.28	5.4%

[a] 0 = not at all effective, 1 = a little effective, 2 = quite effective, 3 = very effective.
[b] The percentages adopting each action in heavy ashfall are also reported in Covey et al. [19].

parallel lines checked the proportional odds assumption when ordinal regressions were conducted. In the Results section we highlight instances where violations of any of these assumptions influence our findings.

3. Results

3.1. Demographic characteristics and experience of ashfall

Demographic characteristics of the survey respondents are shown in Table 1. As noted previously, the youngest age-groups and people with fewer years of formal schooling are under-represented in the sample particularly in the urban area. The gender mix is also slightly over-represented by females. In terms of educational level, the majority of the sample are educated to at least high school level. Just over a quarter of the sample in the urban area indicated that they have one or more respiratory health problem (26.2%) compared to about a fifth in the rural area (20.1%). Most of the problems were attributable to allergic rhinitis (20.9% urban area, 16.4% rural area) and asthma (6.5% urban area, 6.3% rural area). As expected from the timing of the survey, most respondents, in both the rural and urban locations, last experienced ashfall a few months prior to the survey taking place.

3.2. Information and advice about ashfall

As shown in Table 2, the Kagoshima Local Government was the most common source of information about the health effects of volcanic ash, although only a minority of 23.8% had received information from that

Table 6
If they used a mask during ashfall where did they get it from? (Percentages relate to the number of people who used each type of mask during heavy ashfall).

	Surgical (N = 482)	Fashion mask (N = 42)	Scooter mask (N = 14)	Hard-cup mask (N = 27)	High-efficiency mask (N = 35)
Shop	65.1%	59.5%	50.0%	44.2%	42.9%
Government	0.8%	0	0	0	2.9%
NGO	0.2%	0	0	0	0
Friends/ family	5.8%	4.8%	0	9.3%	0
Employer	2.5%	0	0	0	0
School/ College	0.2%	0	0	0	0
Doctor	1.5%	0	0	0	8.6%
Other	0.6%	0	0	0	0
Missing[a]	31.1%	38.1%	50.0%	51.2%	45.7%

[a] Question not answered, possibly indicating that respondent didn't know where mask was from.

source and only 18.8% had received any advice about protection. Very few respondents had received information from any of the other sources apart from the Japanese Meteorological Agency (13.0%) and doctors or health professionals (12.1% for information on the health effects). People did receive some information via friends and family (7.5%), but the low percentage indicates that it is not a topic that is regularly discussed. Almost no respondents currently receive advice from a national-level public health agency or from NGOs, nor want to in the future.

Nearly half of the respondents (43.8%) indicated that they would like advice about the health effects of volcanic ash and health protection from the Kagoshima Local Government (i.e. many more than currently receive advice from them). People also see the Japanese Meteorological Agency, which provides monitoring data and warnings on eruptive activity, as an organization from which they would like to receive such advice. Doctors/health professionals were also chosen as a key source for future advice. Although 7.5% of respondents currently receive advice from friends/family, only 3.9% would like advice in the future through that route.

It should be noted that 37.0% of respondents did not select any of the

Table 7
Mask use in different situations.

	%	Odds ratios				
		Location[a]	Age[b]	Gender[c]	Educational level[d]	Respiratory illness[e]
To protect from inhaling ash during heavy ashfall	67.6%	0.83	1.45***	0.57**	1.39**	2.77***
To prevent exposing others when you have a cold/flu or other infectious disease	92.0%	2.35**	0.93	0.36**	1.84**	4.67*
To prevent exposing yourself to colds/flu and other infectious diseases	87.4%	2.06**	0.88	0.32***	1.60**	1.51
To avoid inhaling dust when cleaning the house or sweeping	53.4%	1.15	0.87	0.80	1.41**	1.93***
During hay fever season	33.8%	1.50	0.80*[g]	0.86	0.99	5.70***
To avoid inhaling exhaust/traffic fumes	20.5%	0.82	1.32*	0.77	1.05	1.20
To keep face warm	18.9%	1.32	0.79	0.59*	1.05	1.13
To hide face in public	14.6%	0.70	0.46***	0.29***	1.29	1.61
For fashion reasons[f]	1.0%	–	–	–	–	–

*p < .05, **p < .01, ***p < .001.
[a] 0 = rural, 1 = urban.
[b] 1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years.
[c] 0 = female. 1 = male.
[d] 0 = no formal education, 1 = elementary/junior high school, 2 = high school, 3 = college/graduate.
[e] 0 = no, 1 = yes.
[f] Logistic regression not appropriate due to lack of variance in mask use frequency (i.e., 99% of respondents never wore a mask for this reason).
[g] The assumption of lineary between age and wearing a mask during hay fever season did not hold. Analysis of age as a categorical rather than ordinal variable showed that respondents aged 40–59 years were significantly more likely to undertake this action than those aged over 60 (OR = 1.76, p = .011). There was no significant difference between 13 and 39 year olds and those over 60 (OR = 1.45, p = .102) or between 13-39 year olds and 40–59 year olds (OR = 1.22, p = .37).

Table 8
Features of facial protection (for volcanic ash protection) which are important to people.

	Not at all important	Mean rating	Odds ratios[a]				
			Location[b]	Age[c]	Gender[d]	Educational level[e]	Respiratory illness[f]
Is effective protection	7.3%	1.66	1.38*[2,3]	1.04	0.75*[1,3]	1.39**[1,3]	1.04
Is affordable	12.1%	1.69	1.42*[2]	0.69***	0.67**[2]	1.52***[3]	1.36
Is convenient/easy to use	10.5%	1.76	1.13	0.72***[1]	0.76	1.52***[3]	1.39*[1,2]
Is comfortable to use	14.6%	1.70	1.28	0.59***	0.81	1.34**[3]	1.24
Does not make you too hot	16.0%	1.59	1.42*[1,3]	0.66***	0.75*[3]	1.55***[1,3]	1.27
Does not affect your breathing	14.0%	1.76	1.29	0.63***	0.71*[2]	1.55***[3]	1.34
Does not create humidity/moisture	17.1%	1.56	1.30	0.69***	0.73*	1.55***[3]	1.28
Does not cause you embarrassment	44.5%	0.89	1.88***	0.61***	0.71*[3]	1.35**[2,3]	1.41*[1,3]
Is fashionable	63.3%	0.52	1.63**[2,3]	0.64***	0.63**[2,3]	1.36*[2,3]	0.95

[a]The tests of parallel lines for all the ordinal regressions were significant which suggests that the coefficients are different across response categories. Tests of the effects at each cumulative split of the dependent variables were conducted and we denote cases were the coefficients were not significant - i.e., [1]The coefficient was not significant when the dependent variable was dichotomised 0 = 0; 1 = 1,2,3; [2]The coefficient was not significant when the dependent variable was dichotomised 0 = 0,1; 1 = 2,3; [3]The coefficient was not significant when the dependent variable was dichotomised 0 = 0,1,2; 1 = 3.
[a] 0 = not at all important, 1 = a little important, 2 = quite important, 3 = very important.
[b] 0 = rural, 1 = urban.
[c] 1 = 13–39 years, 2 = 40–59 years, 3 = 60+ years.
[d] 0 = female. 1 = male.
[e] 0 = no formal education, 1 = elementary/junior high school, 2 = high school, 3 = college/graduate.
[f] 0 = no respiratory illness, 1 = respiratory illness.

sources (which included an 'other' option). A binary logistic regression showed that males and less well educated people were more likely not to select any of the sources of advice (gender OR = 1.69, p = .001; education level OR = 0.56, p < .001).

To help local agencies consider how to provide public information, should there be a need in the future, we also asked through what media people would like to receive advice (Table 3). Overall, the respondents most wanted to receive information via television (77.6%), newspaper/magazine (43.4%) or via radio (38.2%) and binary logistic regression showed that older people were more likely to choose these options. Common dissemination techniques of public health/hazard information (poster/leaflet) were not very popular (~17%), although respondents with higher education levels were more likely to choose these options. The respondents were also not very interested in receiving advice through more modern forms of communication (internet 27.4%; social media 7.5%), although binary logistic regressions show that younger people and those with higher levels of education were more likely to choose these types of media. Women were more likely to want information via television or in person and men preferred social media. There was also a significant preference for posters and in-person information by people with respiratory illnesses. Location (urban vs. rural) was not a factor in these decisions.

3.3. Health symptoms linked to ash exposure, perceived harm of ashfall, and importance of respiratory protection

Around two thirds of the respondents (67%) said that they had experienced at least one symptom which they believed occurred, or was made worse, by exposure to volcanic ash. As shown in Table 4, of the specific symptoms experienced, eye irritation was the most common (50.3%) followed by stress (22.2%). Other symptoms, including those of the respiratory tract such as sore throats, coughs and stuffy/runny nose, were reported by fewer than 20% of respondents.

Principal Components Analysis with Varimax rotation and Kaiser normalisation was used to identify groups of symptoms that were most closely associated with each other. It should be noted that the tetrachoric correlation matrix produced from all symptoms was not positive definite. This means that the sample covariance matrix was singular (i.e., the matrix cannot be inverted and has determinant zero) which can happen when there are linear interdependencies among the variables and some variable turns out to be an exact linear combination of other variables. To address this issue, the most highly correlated symptoms (i.e. r > 0.80) were excluded from the matrix. The excluded symptoms are shown in Table 4 and it is also worth noting that most of these symptoms are reported by very few respondents. The rotated solution on the included symptoms produced two components – symptom group 1 (shortness of breath, wheeziness, cough, phlegm, sore throat, runny nose, stuffy nose and headache); symptom group 2: (eye irritation, skin irritation, stress and low mood). This is an interesting pattern of results and suggests that the psychological effects of the ashfall are more closely linked to symptoms causing general irritations to the skin and eyes rather than the types of respiratory symptoms that we might expect people to experience with the ashfall. As shown in Table 4, the irritation and psychological (group 2) symptoms were also experienced by more people (58.9%) than the respiratory/headache (group 1) symptoms (30.0%).

The majority of respondents thought that it was important to protect themselves from inhaling ash (a little important 42.3%; quite important 30.4%; very important 18%). Very few respondents (6%) thought that it was not at all important and 3.2% said they 'can't say'. Covey et al. (2019; Table 4) reported that, in the Japan sample, most respondents also thought the ash to be harmful to their health (a little harmful 50.3%; quite harmful 21.1%; very harmful 13.6%). Few respondents (10.8%) thought that the ash was not harmful and 4.1% responded that they 'can't say'.

A path analysis using AMOS 24 Graphics was used to explore the analytical relationships shown in Fig. 4. In this analysis we examined how geographical and sociodemographic variables (i.e., location (urban vs. rural), age, gender, education level, and respiratory illness), were related to the experience of symptoms, perceptions of harm and ratings of importance of protection. Symptom experiences were coded according to the two groupings identified from the Principal Components Analysis – i.e., whether respondents reported one or more symptom in either group 1 (respiratory/headache) or group 2 (skin/eye irritation, low mood, stress). None of the excluded symptoms were experienced by enough respondents to make their inclusion in the analysis reliable. Coefficients for the direct and indirect paths shown in Fig. 4 (non-standardised b values) were estimated using Markov chain Monte Carlo (MCMC) maximum likelihood estimation. Only significant paths[2] are shown in Fig. 5 (location (urban vs. rural) and gender were not significantly related to any of the endogenous variables and are therefore not included in the figure). The analysis showed that people with a respiratory illness were more likely to report one of the symptoms from group 1 (respiratory/headache) (b = 0.228) whereas older people and those who were more highly educated were more likely to report a symptom from group 2 (skin/eye irritation, low mood, stress) (age b = 0.049; education level b = 0.078). The experience of one or more symptom from either group was also related to ratings of the importance of protection and these effects were mediated through perceptions of harm (symptom group 1 b = 0.350 and 0.580; symptom group 2 b = 0.414 and 0.581). The only direct path to ratings of importance of protection was from age (b = 0.128). This suggests that the tendency for older people to rate protection from the ash as more important than younger people can only be partially explained by their increased reporting of one of more of the group 2 symptoms (b = 0.049) or their higher ratings of harm (b = 0.087).

3.4. Protective actions rated as most effective

In Covey et al. [19] Table 2 (p6) we reported the percentage of the Japanese sample who took various types of protective actions during periods of heavy ashfall. In this paper we extend this analysis by examining whether the actions most commonly undertaken (i.e., keeping windows and doors closed 96.9%; limiting time spent outdoors 85.2%; cleaning the house 84.8%, and using physical barriers on the face such as holding a hand 71.6%, or handkerchief/cloth over the mouth/nose 72.5%, or wearing a face mask 67.6%) are also the actions rated as most effective. The ratings of effectiveness of each action are reported in Table 5 and it is notable that the mean ratings are not significantly correlated with the percentages adopting each action (r_s = 0.359, p = .09). In particular, the choice of which type of mask to wear (i.e., surgical, fashion, scooter, hard cup or high efficiency mask) would appear to be unrelated to beliefs about which type of mask is most effective (r = .100, p = .436) illustrated by the finding that the rarely used high efficiency mask was rated as much more effective than the most commonly used surgical mask. So, if we compute the correlation again, removing all masks except the surgical one, then the relationship is highly significant (r_s = 0.809, p = .002). This suggests that the types of actions most commonly undertaken are generally also the actions rated as most effective, but people's choices about which specific type of facemask to use to protect themselves from inhaling the ash are unrelated to their beliefs about which type of mask they think is most effective.

3.5. Mask use

The remaining analysis focuses more specifically on mask use. We report data in Table 6 on where different types of masks were obtained

[2] MCMC estimation uses a Bayesian model in which significance is determined by the probability that the credible interval does not include zero.

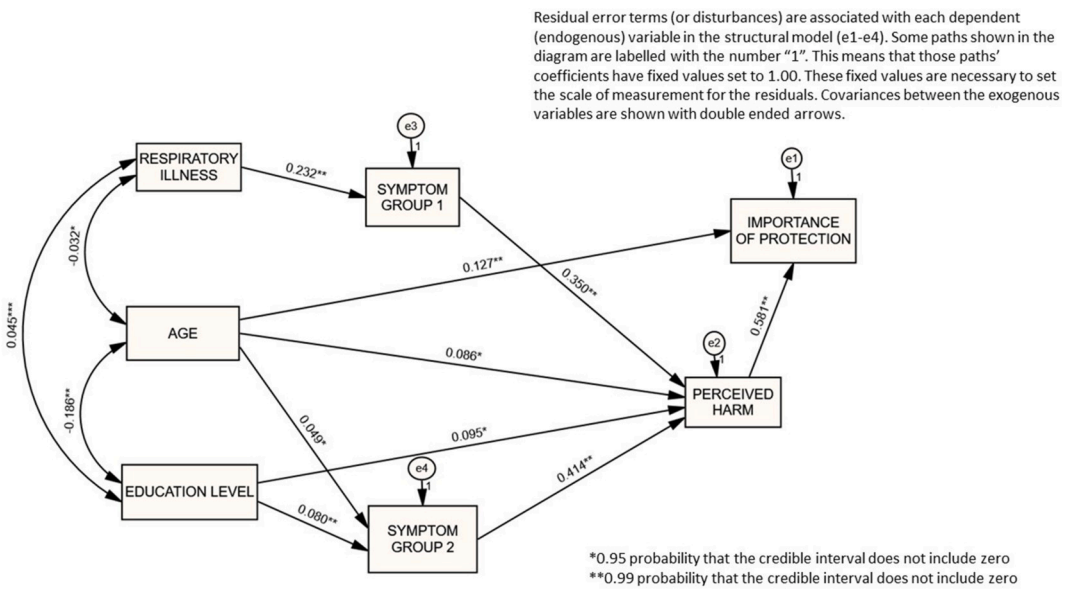


Fig. 5. Path analysis exploring the relationship between demographic variables, symptom experience, perceptions of harm and importance of protection from ashfall.

from, if the respondents wore them. Although we had a substantial number of non-responses for this question, potentially because people did not know where they obtained their masks from, Table 6 shows that the majority of respondents obtained masks from shops. Small numbers of respondents (less than 10%) obtained masks from friends, family and doctors. But the government and local NGOs rarely provided masks.

Given that people may already be wearing a mask for other purposes when volcanic ashfall starts, or may wear one for other purposes but not for protection against ash, it was important to document what those situations might be and how often people are wearing masks anyway. As shown in Table 7, in their daily lives respondents were most likely to wear masks to prevent exposing others, or themselves, to infectious diseases. 92% of respondents said they wore a mask to prevent exposing others when they have a cold/flu or other infectious disease compared to 67.6% wearing a mask to protect themselves from breathing in heavy ashfall. Mask use was not as common in most of the other situations although just over half (53.4%) of respondents said that they wore a mask to avoid inhaling dust when cleaning/sweeping and around a third (33.8%) during the hay fever season (which is especially related to cedar tree pollen, generally from January to May with an approximate peak in February and March). The majority of our respondents did not wear masks just for fashion reasons, to hide the face in public, to keep their face warm or to avoid traffic fumes.

Binary logistic regression analyses showed that females, those with higher levels of education, and those with respiratory illness were more likely to wear masks across a range of situations including protection from ashfall, and to prevent exposing others or themselves to infectious diseases. Although many respondents never wear a mask during hay fever season, those with existing respiratory illness were much more likely to wear a mask for that purpose than those respondents without pre-existing diseases. These findings suggest that the reasons why these types of people use masks more frequently is not specific to the volcanic ash situation. The effect of age on mask use was different, however. Whereas older respondents were more likely to wear a mask to protect themselves from breathing in volcanic ash, younger respondents were more likely to wear masks in other situations such as during hay fever season or to hide their face in public.

To further understand decision-making around mask use, we examined the features of masks which made them attractive to wear. Table 8 shows that masks being convenient/easy to use, not affecting breathing and being comfortable ranked the highest. Whether the mask was fashionable was deemed the least important factor (63.3% of respondents said fashion was not at all important) and the respiratory protection not causing embarrassment was also not considered important by almost half the respondents (44.5%). Ordinal logistic regression showed that younger people and more educated people were much more likely to consider any one of (or a range of) the factors as being important (with the exception of the effectiveness of protection for younger people) and women were also more likely to consider the factors important in their decision making. Although embarrassment and fashion were not considered important by many, those who did find them to be important factors were much more likely to be in urban locations, women and younger people.

4. Discussion

The use of respiratory protection in dusty industries is often heavily regulated, ensuring that all exposed workers are protected through fit-testing to guarantee effective use of the chosen respirator (e.g., Ref. [27]). For community exposures to anthropogenic or geogenic airborne particulate pollutants, there are currently no regulations related to personal protection and, whilst the World Health Organization does recommend the use of masks to reduce exposure to ash, its advice is currently limited. Therefore, it is up to local agencies and individuals to make ethically-challenging decisions on whether to recommend, distribute and use masks during ashfall and other air pollution crises [22].

In Japan, whilst existing advice clearly does include the use of masks (see links to webpages in the Introduction, and Fig. 3), the Kagoshima City and Prefecture governments do not distribute masks during small eruptions. In planning this study, we were told on many occasions, by colleagues and the public, that mask use was not recommended by local or national bodies (so it was a surprise to find that official advice did recommend their use, that masks are stockpiled for major disasters and, indeed, the Kirishima City Government distributed 10,800 masks to elementary and junior high school students during the Shinmoedake eruption in 2011 [28]). In this context of normalisation of a potentially-hazardous frequent event, and existing confusion between the available advice and the perceived lack of advice, we discuss the findings of this study.

Our survey showed that many respondents would value more advice about the health effects of ash and about how to protect themselves than they are currently receiving. In particular, they would wish to receive that information from the Kagoshima local government and the Japan Meteorological Agency (JMA) and local health professionals. JMA is responsible for ashfall forecasts but also currently offers some limited advice on ash protection (http://www.jma.go.jp/jp/ashfall/img/ashfall_category.png; for the English version, substitute '/jp' with '/en'). If the local governmental disaster management or public health offices decided to produce new guidance and disseminate it through health centres and local community groups, for example, it seems that traditional routes for doing so (leaflets, pamphlets and posters) may not prove to be popular (although those with existing respiratory illness preferred such products). Provision of such information through existing media (e.g., community-based magazines, or local television programmes) may be more successful, especially for women. Although internet-based information was not highlighted as a preferred medium (27%, Table 3), it is currently used by the Kagoshima government and JMA, so updates could easily be made to existing advice.

The report of the Kagoshima Prefecture government's opinion exchange (see Introduction) stated that experts agreed that there were acute, transient symptoms from ash exposure. Our question related to perception of symptoms caused/exacerbated by ash certainly concurs with this statement, with 67% of respondents attributing one or more health symptom to ash exposure. So, potentially, a substantial sector of the general population may experience symptoms which could affect their wellbeing and possibly their livelihoods, which may have knock-on effects for the local society. The Principal Components Analysis revealed that groups of symptoms were associated with each other. For example, those with wheeziness, were also likely to experience other respiratory tract symptoms, and those experiencing stress might also experience low mood and skin/eye irritation. Together, these indicate that people affected by ash may well be suffering from several related conditions that affect their wellbeing. Those respondents who had existing respiratory disease felt most affected by further respiratory symptoms attributed to ash exposures, again showing an exacerbation of health issues which is likely to impact overall wellbeing. We suggest that further work should investigate what the impact of these individually minor symptoms is, collectively, on individuals' mental health, livelihoods and wellbeing, given the prolonged exposures received. It would also be important to further understand why older people and those with higher levels of education were more likely to experience mental health symptoms and eye/skin irritation as a result of ash exposure.

The frequency of ashfall events, and lack of government intervention in community protection, up to July 2016 meant that we expected the communities to have experienced a normalisation of concern regarding ash exposure, whereby an ashfall event would be treated much like rainfall, instead of a crisis. A key aim of this study was, therefore, to understand whether experience of symptoms from ash exposure influenced people's perceptions of harm from the ash and their thoughts on the importance of protection. Firstly, only 6% of the cohort did not think it was important to take protective actions against inhaling ash. This implies that the volcano, and its activity, play a major role in many people's actions. As also reported in Covey et al. [19]; the World Health Organization (WHO) advice to reduce exposure by staying indoors and closing doors/windows has high uptake in the Sakurajima area (even if it might be due to common sense, rather than people being directly aware of the WHO advice) with 97% of respondents taking this action and 85% limiting time outdoors. This uptake likely reflects the quality of housing in the Kagoshima area, with residences, for the most part, being sealable (i.e., having window panes in the window frames and proper doors, and with no ventilation gaps between the walls and the roofs), as well as having cooling systems indoors during hot weather.

The results of the path analysis showed that people with existing respiratory illness were more likely to experience a range of respiratory tract symptoms attributed to ash exposures. Experiencing one or more symptom made it more likely that a person would perceive that the ash was harmful. Likewise, perceptions of harm were related to people's opinion on the importance of protection. Therefore, people in our cohort were more likely to think that protection was important if they had existing respiratory disease, experienced health symptoms attributable to ash exposures and perceived that ash was harmful or simply if they were older. This insight tells us that, even though ashfall is a part of life around Sakurajima volcano, it is not actually normalised for some of the most vulnerable population. These are the people who are most likely to benefit from evidence-based advice on how to reduce their exposure to ash.

In our analysis of the perceived effectiveness of various protective measures, hard-cup and high-efficiency masks were perceived as being more effective than surgical masks even though, as reported in Covey et al. [19], surgical masks were by far the most commonly used type of mask. At the time of conducting the survey, there was no evidence on the effectiveness of any form of respiratory protection against volcanic ash but recent experiments for the Health Interventions in Volcanic Eruptions project have shown that surgical masks are more effective at filtering fine ash than hard-cup ones (~88% mean filtration efficiency compared to 58%) and less effective than N95 industry-certified ('high efficiency') masks (99%) [17]. However, when fit to face was taken into account, Steinle et al. [18] found that surgical masks performed poorly, in comparison to N95 masks (35% mean total inward leakage [TIL] compared to 9%) although, by adding an additional layer of cloth over the surgical mask, TIL could be improved to 24%.

The use of surgical masks over masks rated as being more effective by the respondents could relate to their ubiquity and ease of procurement in Japanese society. Surgical masks are widely available in convenience stores and pharmacies (as shown in Table 6). In fact, the range of surgical masks in Japan extends beyond the regular masks worn in healthcare settings. Convenience stores also stock sophisticated '$PM_{2.5}$' surgical masks which look like surgical masks but may have additional filtration efficiency (measured at 98% by Ref. [17]; for one brand). The '$PM_{2.5}$' surgical masks are designed to prevent the wearer from inhaling particulate matter sub-2.5 μm diameter – from urban pollution - rather than preventing transfer of body fluids from the wearer, as with a regular surgical mask. Whilst some of these '$PM_{2.5}$' surgical masks also have additional features to aid fit, effectiveness is still impacted in comparison to N95 masks, due to mask design (22% TIL for one brand; [18]). Also, the lack of valve on the '$PM_{2.5}$' surgical mask hinders comfort as humidity cannot be released easily. Our survey did not differentiate between regular surgical masks and these enhanced ones, so it is possible that some people's perceptions of their effectiveness was influenced by their knowledge of the more sophisticated masks, which could be easily confused with regular ones.

In relation to use of masks for other purposes besides ash exposure reduction, people wear masks to prevent others being exposed to their own infectious respiratory diseases or to stop themselves being exposed to others'. Here, around 90% of respondents wore masks for those reasons, especially in urban areas. Although we did not ask the question, it is evident from any stroll around Kagoshima that people wear surgical masks, which likely explains why they are the most popular mask for ash protection. There are other, more subtle, cultural reasons why people wear facemasks in Japan, related to mask use as a self-protective risk ritual against a series of perceived threats from the outer world [29]. Additionally, as documented in several recent media articles, masks are used as a way of hiding the face, making it look smaller and accentuating the eyes (e.g., https://matcha-jp.com/en/2245). In our study, females were found to wear masks more than males across a range of situations as well as ash exposure, including to hide their face in public (also highly significant for younger people). This self-consciousness in social situations resembles the interpersonal fear or phobia well-described for the Japanese context. Acute embarrassment and self-consciousness on a wide spectrum, including social phobia, are well-studied phenomena for Japan, where the specific nosological category of *taijin kyofusho*

(interpersonal phobia) was coined in the 1920s to describe a behaviour of shunning contact with others for fear of creating offence with one's own body, unpleasant odours, or appearance [30–33]. Our study's results also strongly reflect ubiquity of mask use in Japanese society, particularly among young women.

However, although we found that older people were more likely to wear masks for ash protection, they were no more likely to wear masks for most of the other reasons (apart from avoiding inhaling exhaust/traffic fumes). The effect of age on mask use is therefore more specific to particular hazards and, for ash protection, might be explained by findings reported in Covey et al. [19] where we show that the health effects of inhaling ash is more of a concern for older people than younger people. Young people do not worry so much about the harmful effects of inhaling ash and this might explain why they are less likely than older individuals to wear masks for ash protection. If there were a major ashfall event, or if new medical evidence arose confirming a major health risk, the results reported here and in Covey et al. [19] suggest that, in order to increase mask use in the younger age group, targeted education to address their lack of concern about ash inhalation could be successful.

With regards to decisions surrounding mask procurement (or distribution by agencies) the question about features of facial protection which are important to the respondents revealed that they were fairly ambivalent in relation to most features, with mean ratings between 'a little important' and 'quite important'. The feature rated most important was convenience/easy to use and the cohort thought embarrassment and fashion were the least important factors. It was also clear, however, that younger people, women, and those with higher educational levels and/or respiratory disease were more likely to find various features important. So, if agencies were to distribute masks in Japan, choosing masks that are effective, yet easy to use, would likely result in the greatest uptake.

4.1. Study limitations

A concern with any questionnaire survey is recall bias, especially because the volcano entered a period of relative dormancy around the start of the survey period, but most respondents recalled that they had experienced ashfall within the past few months (and prior to that point, exposure may have been frequent, depending on location), thereby minimizing the risk of bias in the responses.

The recruitment of respondents for the survey aimed to match the demographic characteristics of the local populations, based on census data, as described in the Method section. The final sample did not completely reflect the local demographics, so, as mentioned in the Method section, we have been careful not to extrapolate the findings from our cohort as being the opinions and actions of the wider population, but they give a good indication of the status quo.

The survey was conducted in Japanese, and although every care was taken to accurately translate the survey from English, including using professional translators and conducting independent back translation to English, it is possible that minor errors might have occurred or some misunderstandings, based on understanding of the meaning of phraseology.

5. Conclusions and implications

This study aimed to gauge whether residents affected by Sakurajima volcano's frequent ash emissions were normalised to the hazard or whether they perceived the ash to be affecting their health and considered exposure reduction practices to be important and effective. This, in turn, would indicate how and where to target public advice about the hazard and on community protection. The results of this survey have highlighted how community perceptions and preferences can differ from existing official advice and evidence-based knowledge, and vary amongst different sectors of the community. Our analysis shows that our respondents' perceptions of the importance of protection (ash exposure reduction measures) are related to their belief in the ash being harmful which, in turn, is mediated by people's perception that their health is adversely affected by exposure to the ash. Those with existing respiratory illness were more likely to perceive symptoms, but age and education level also directly impacted perceptions of harm and the importance of protection. People are wanting to protect themselves from inhaling volcanic ash, through a range of measures, and their choice of surgical masks rather than high-efficiency masks is probably based on convenience (ease of purchase and the fact that they wear such masks for other reasons) rather than perceptions of effectiveness. If people who wanted effective protection were to switch to industry-certified (i.e., N95) masks, consideration would have to be given to the wide-spread and continual provision of such masks across the communities, given that volcanic activity is increasing again (there were 246 explosions in 2018, compared to 47 in 2016 and 81 in 2017). Whilst this could become the responsibility of the local government, given the nature of this chronic hazard, provision of accurate public information on options for effective protection might increase awareness and consumer demand might then result in stocking of such masks in local shops and pharmacies. This paper provides critical information for agencies who may be making difficult decisions on the types of masks to recommend, if not actually provide, and such information should be taken into account in an ethically-driven decision making process [22]. This research may lead to changes in approach by local authorities in Japan, but also encourages other community leaders to consider the need to respond to community concerns during volcanic eruptions, even if they are frequent and appear normalised.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2020.101525.

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