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Many Montserratians relocated to the UK following the volcanic eruption in 1995. The aim of this study (funded by the Department of Health) was to obtain early warning of any increased risk of respiratory ill-health among them that might be associated with exposure to volcanic dust on the island. The target study group comprised all Montserratians registered with the Montserrat Community Support Trust in the UK.

Following a two-phase pilot study, data were collected by postal questionnaire on personal details, respiratory symptom occurrence, smoking habit, occupation and potential exposure to volcanic ash. Questionnaires were completed by 465 respondents (response rate 25%).

Prevalence of respiratory symptoms in the study group was somewhat higher than in the general UK population. We think this is due in part to the effects of moving to a new country with different climate and population immunities. There was also plausible evidence of an association between the occurrence of symptoms and exposure from heavy ash clearing activities in Montserrat, but no evidence that other ash exposures (residential, house cleaning) increased symptom occurrence.

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CONTENTS

SUMMARY

BACKGROUND

Volcanic eruptions have occurred on the island of Montserrat intermittently since July 1995. Following the first major volcanic eruption, residents of the Southern part of the island were evacuated, many moved to the North of the island or left the island altogether. Between three and four thousand Montserratians relocated to the United Kingdom, most of whom left Montserrat between July and December 1995. The volcanic eruptions have at times generated high concentrations of volcanic ash containing up to 30% cristobalite, a polymorph of crystalline silica. Possible health risks from this exposure include the non-specific respiratory effects of high concentrations of particulate, and the possible risk of silicosis, although silicosis usually develops following prolonged occupational exposure to high concentrations of silica. The UK Department of Health therefore commissioned the IOM to carry out an investigation of the respiratory health of the Montserratians who had relocated to the UK. A companion study of Montserratians who remained on the island, commissioned by the Department for International Development is also being carried out by the IOM and will be reported separately.

The overall aim of the study was to obtain early warning of any increased risk of respiratory ill-health among Montserratians evacuated to Britain that might be associated with exposure to volcanic dust on Montserrat, as a starting point for any more detailed investigations, if appropriate. The study was a postal questionnaire survey of all Montserratians registered with the Montserrat Community Support Trust (MCST), a Montserratian run organisation funded by the Home Office, which provides support to and links with Montserratians in the UK. The support of the MCST was invaluable in easing mistrust of the survey among Montserratians and, in an attempt to maximise response, the questionnaires were sent out by and returned to the MCST.

METHODS

The questionnaire was designed to record personal information, information on respiratory symptom occurrence (asthma symptoms, asthma attacks, breathlessness and chronic bronchitis), smoking habit, exposure to volcanic ash on Montserrat and other occupational exposures. The final version of the questionnaire was designed by the IOM in consultation with the Department of Health, MCST, Montserrat Government Office and the Home Office. Two pilot studies were carried out prior to the main study mailing. Response to the first of these was very poor, and the questionnaire was shortened and simplified before the second pilot study took place. Response to the second pilot study was higher than for the first. The main study mailing took place in September 2000.

Estimates of individual exposures to volcanic ash were calculated from responses to the postal questionnaire in combination with estimated concentrations for different activities and occupations on the island. These concentrations were based on a number of dust sampling exercises which had taken place on the island since the eruption in 1995. Four types of exposure were calculated:

- Residential exposure: background exposure from residence in specified areas of the island in specific time periods
- Heavy ash exposure: exposure from participating in heavy ash clearing activities
- Domestic cleaning exposure: exposure from cleaning of individuals' homes
- Occupational exposure: exposure experienced occupationally.

For individuals with complete (non-missing) data for all four exposure variables, a total exposure to volcanic ash was calculated.

Residential exposure was estimated using data recorded on place of residence on the island in each of five time periods – July to December 1995, January to December 1996, January to June 1997, July to December 1997 and January to December 1998. Heavy ash exposure and domestic cleaning exposure were estimated from questions on the frequency with which these tasks were carried out. Full lifetime occupational histories were used in the estimation of occupational exposures. Each job held on the island was allocated to one of eight occupational groups and the time spent working in each of these groups after July 1995 was calculated. This information was then combined with the concentration data and summed across occupational groups to provide total occupational exposure.

Presence of respiratory symptoms was investigated for each individual. Asthma symptoms were defined to be wheezing or whistling in the chest plus two of tightness in the chest first thing in the morning, shortness of breath during the day when not doing anything strenuous and being woken at night by shortness of breath. Breathlessness was defined as being short of breath walking with people of your own age on level ground. Chronic bronchitis was defined as coughing up phlegm for at least three months each year and asthma attacks were defined from a direct question, have you ever had an attack of asthma.

Respondents were asked when their symptoms had first started. This was to allow the identification of symptoms which had first started on Montserrat and those which started only after arrival in the UK. However, although the limited information from the pilot study had not indicated difficulties with these questions, ambiguous information was provided by several of the respondents reporting symptoms. Analyses of symptoms which first occurred on Montserrat were therefore limited to relatively few subjects who answered the timescale questions unambiguously. Consequently much of the analysis was based on the presence of symptoms regardless of timescale.

Prevalence of symptoms overall and by age, sex, smoking habit and exposure variables was examined descriptively using tabular and graphical methods. Associations between symptoms and exposure were examined using logistic regression methods.

RESULTS

Responses were received from 465 individuals (39% men, 60% women, 1% did not give information on gender) from 255 households, a response rate of around 26%. The majority (91%) were non-smokers, with men and older subjects most likely to smoke. Of the 465 responders, 30% reported at least one respiratory symptom. Prevalence of symptoms ranged from 7% with asthma attacks, through 14% with asthma and 14% with chronic bronchitis to 18% with breathlessness. Symptoms were more prevalent in current smokers and among older subjects, with the exception of asthma attacks which were most common in children.

No association was found between risk of reporting symptoms and exposure due to place of residence on the island or due to domestic cleaning. Risks of reporting asthma, chronic bronchitis and asthma attacks were statistically significantly related to exposure from heavy ash clearing tasks. Exposure-related risks of reporting these symptoms were increased, but not statistically significant, for symptoms which first occurred on Montserrat. Total exposure to volcanic ash was available for 52% of the study group. In this subgroup there was evidence that the risk of reporting each of the four symptoms increased with increasing exposure for symptoms overall and, more strongly, for symptoms which first occurred on Montserrat.

DISCUSSION

The low response rate in the study raises questions about the representativeness of the respondents. The Montserratians who relocated to the UK were likely to be different from those remaining on Montserrat. In particular, women, children and those with existing respiratory conditions were encouraged to leave the island after the first volcanic eruption, while those employed in occupations directly involved with the consequences of the eruption were more likely to remain on the island.

Montserratians in the UK who had health problems may also have been more likely to respond to the questionnaire than those who did not have health problems, although this does not necessarily always apply. These factors may have led to some bias in the estimation of respiratory symptom prevalence, and if such biases have occurred they are more likely to have resulted in an increase in the prevalences reported.

However, selection and non-response biases are less likely to have affected any exposure-response relations which were examined within the study group, with respondents with lower exposures acting as internal controls. Insofar as they are affected, the combination of higher symptom prevalence and low exposures could over-estimate any effects of exposure on the respiratory health of Montserratians more generally.

Overall, the prevalence of respiratory ill-health among the participants in this study seems somewhat higher than in the general UK population. There are several possible contributing factors. Among these, there is plausible evidence of an association between heavy ash exposure and the occurrence of these symptoms, but no evidence that other exposures increased symptoms occurrence. We think it likely therefore that any increase in the risk of silicosis is small, though we did not investigate silicosis directly. The companion study will help to clarify this.

The study does not provide clear guidance on the need for future studies of the population. If there had been no evidence, or strong evidence, of an excess of symptoms and an association with ash exposure then it would have been clear whether or not a follow-up study was warranted. As it is, we consider that the results of the current study suggest that there may be a case for a follow-up questionnaire study of this group in some years time. The results of the companion study of Montserratians on the island, available in a few months time, will provide additional information which will help in deciding whether further follow-up is justified.

1. INTRODUCTION

The island of Montserrat is a mountainous island of approximately 39 square miles, situated in the Eastern Caribbean chain of islands about 27 miles south-west of Antigua. It is a United Kingdom Overseas Territory and a resident Governor represents the British crown. The island rises in a series of mountain slopes to a high point of over 1000m in the Soufriere Hills towards the south of the island. On 18 July 1995, the Soufriere Hills volcano began to erupt, with the initial stage of the eruption releasing small amounts of ash and steam. The first large eruption occurred on 21 August 1995, which blanketed the main town of Plymouth in a thick ash cloud and caused darkness for around 15 minutes. Shortly after this eruption, the first evacuation of Southern Montserrat was initiated. Volcanic activity continued over the next two years, culminating in major pyroclastic flows during summer 1997 and a major dome collapse to the north-east on 21 September 1997 which destroyed the airport terminal building. Since then the volcano has continued to be active, with periods of dome growth, further dome collapse and pyroclastic flows.

Following the volcanic eruptions, the southern part of Montserrat (including Plymouth, St Patrick's and areas south of the airport) was evacuated during 1995 and 1996, with residents moving to the north of the island or leaving the island altogether. Cork Hill was evacuated in June 1997 and other central areas, such as Salem and Old Towne, by September 1997, when the island was divided into three risk zones (Figure 1):

- Exclusion Zone: no admittance except for scientific monitoring and National Security
- Central Zone: residential zone only, all residents on heightened state of alert.
- Northern Zone: area with significantly lower risk, suitable for residential and commercial occupation.

Since 1995, the population of the island has decreased from 10,639 (1991 Census) to approximately 4000 with most of the exodus occurring before the end of 1997. Many former residents left the island for nearby Caribbean islands and for the United States, while because of its status as an Overseas Territory, 3000 - 4000 relocated to the United Kingdom.

Ash from the volcanic activity on Montserrat has at times generated high concentrations of respirable dust in inhabited parts of the island. Up to 30% of the ash comprises cristobalite, a highly toxic polymorph of crystalline silica. Preliminary laboratory studies indicate that the mixed dust is inflammatory and cytotoxic. PM_{10} dust concentrations in inhabited areas have for extended periods averaged up to 0.5 $mg.m^{-3}$, with higher short-term peaks of 1 – 2 $mg.m^{-3}$ over periods of a few days. Possible health risks include the non-specific effects of high concentrations of particulate, and the possible risk of silicosis from the cristobalite in the dust, although silicosis usually develops following prolonged occupational exposure to high concentrations of silica. The UK Department of Health therefore commissioned the IOM to carry out an investigation of the respiratory health of the Montserratians who had relocated to the UK. The IOM have also been commissioned, by the Department for International Development, to carry out a health survey of Montserratians who remained on the island; the results from the two surveys will be reported separately.

The current study is a postal questionnaire survey of Montserratians in the UK, to determine the baseline levels of respiratory ill health and to collect information to allow the estimation of individual levels of exposure to volcanic ash. A medical survey, including chest radiography and lung function testing was also considered, but it was decided that a postal survey would be the quickest and most cost-effective method of providing early information on the health status of the study population. If exposure to volcanic ash did have an effect on the respiratory health of the population, we would expect to find indications of this in the questionnaire survey. If no evidence was found of an association between respiratory symptoms prevalence and ash exposure, it is unlikely that a medical

survey would find increased risk of radiographic or lung function changes. In addition, radiographic changes would be expected to develop more slowly than respiratory symptoms and so a medical survey now may be too early to expect any changes to be detectable radiologically. A postal questionnaire survey therefore provides a good starting point for the assessment of respiratory ill health among Montserratians in the UK.

In early discussions about the study design it was acknowledged that there might be difficulties both in identifying and contacting Montserratians now living in the UK, and in encouraging them to complete and return a health questionnaire. No official register exists of Montserratians who currently reside in the UK although a charitable group, the Montserrat Community Support Trust, holds contact details for many of those living in the UK. (The Montserrat Community Support Trust is a Montserratian-run organisation, funded by the Home Office, which provides support to and links with Montserratians relocated in the UK.)

The disruption caused by moving from Montserrat, unfamiliarity with a new country and variations in literacy might also have an influence on the willingness and ability of the Montserratians to take part in a health survey. The study was therefore commissioned in this context, as a 'baseline' health survey of the Montserratians now living in the UK, and not as an investigation of exposure-response associations. Specifically, the purpose of the proposed investigation was to *obtain early warning* of any increased risk of respiratory ill-health which might be associated with exposure to volcanic dust on Montserrat. Possibly Montserratians were influenced in their decision on whether to leave the island by their health or that of their families, and this could result in a study population which was not representative of the original island population. Because the focus of the current study was on Montserratians in the UK, this was acceptable. However the concurrent study of Montserratians on the island will complement this study usefully and comparisons between the two populations will be of interest.

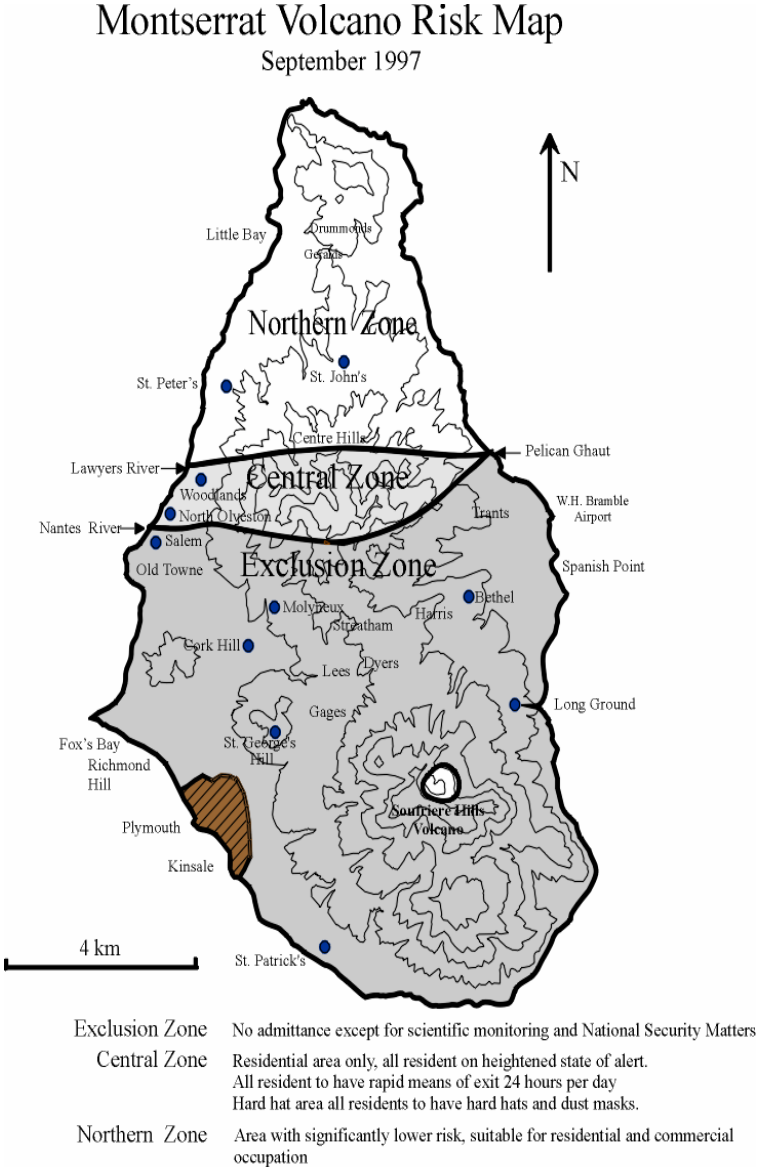

Figure 1 Montserrat risk zones in September 1997

2. AIMS AND OBJECTIVES

2.1 OVERALL AIM

The overall aim of the study was to obtain early warning of any increased risk of respiratory ill-health among Montserratians evacuated to Britain that might be associated with exposure to volcanic dust on Montserrat.

2.2 SPECIFIC OBJECTIVES

The specific objectives of the study were:

i. To establish current levels of respiratory ill health among Montserratians who had relocated to the UK, in the context of the selection and other biases which are unavoidable in this study group

ii. To estimate individual exposures to volcanic ash

iii. To carry out analyses of any association between respiratory ill-health and volcanic ash exposure, and interpret the results in the light of the known biases in the data

iv. To make recommendations for the planning of subsequent studies at five year intervals to track any further change in these health indices and their relations with exposure.

The results of the present study will provide information on the current respiratory health status of Montserratians in the UK and allow early determination of whether there is an excess of respiratory symptoms. The study results will indicate the nature and extent of exposure to volcanic ash, providing knowledge of the between-individual variability in exposure (giving information on the likelihood of finding any relationships linking health and exposure from analyses within the study group, now or in the future). They will also provide early information on whether there is any relationship between symptoms and exposure.

To aid in the planning of the nature and frequency of any follow-up study, the present study will have identified and contacted a population of Montserratians in the UK. The information on current health status and any associations between ill health and ash exposure will be useful in determining whether follow-up medical surveys are indicated and in the selection of individuals to participate in these surveys based on their levels of exposure and current health status.

3. METHODS

3.1 OUTLINE OF STUDY DESIGN

The study was a postal questionnaire survey of Montserratians who had left the island following the volcanic eruption in 1995 and who had relocated to the UK. A questionnaire on respiratory symptoms, smoking habits, occupational history and history of exposure to volcanic ash on Montserrat was sent, by the Montserrat Community Support Trust (MCST), to all identified Montserratian households residing in the UK. Each adult in the household was asked to complete a questionnaire, and it was requested that a questionnaire be completed for each child in the household. The questionnaires were then to be returned to the MCST by post. Subsequently, local meetings were held at a number of locations across the country to encourage participation and to answer any concerns or queries about the survey. Identification details were removed from the completed questionnaires by the MCST, and the questionnaires were then sent by the MCST to the IOM for data processing and statistical analysis.

The survey was carried out in conjunction with a survey of social conditions organised by the Home Office. One social conditions questionnaire was included in the mailing to each household, and these questionnaires were also returned, by post, to the MCST and subsequently forwarded to the Home Office.

3.2 IDENTIFICATION OF STUDY POPULATION

The target study population was all residents of Montserrat who had come to live in the UK following the volcanic activity on the island in the mid-1990s. No official records were available which contained identification information for this target population. However, the Montserrat Community Support Trust, a support group set up to help the former residents of Montserrat with any problems they may have had after arrival in the UK, held a database of names and addresses of around 1000 relevant households. The target study group was therefore defined to be all members of all households included in the MCST database.

3.3 QUESTIONNAIRE DESIGN

The postal questionnaire was designed to record personal information, information on respiratory symptom occurrence, smoking habit, exposure to volcanic ash on Montserrat and other occupational exposures. The first draft of the questionnaire was designed by members of the IOM study team. It was then discussed in detail with representatives of the Department of Health, Montserrat Community Support Trust, Montserrat Government Office, Home Office and others with extensive knowledge of the island. Some modifications were made following these discussions, and a pilot study was then carried out (see section 3.4). A copy of the final version of the questionnaire is shown in Appendix 1.

Information requested on the questionnaire comprised:

- Personal details – name, address, age and sex. Names and addresses were collected to enable a follow-up survey to be carried out if necessary. To preserve the anonymity of the health data, these contact details were written on the front cover of the questionnaire and were removed by the MCST before the data were forwarded to the IOM. The details are stored securely by the MCST. Age and sex were recorded to allow the analysis of the health information by these factors (Questionnaire Section H).

- International Union against Tuberculosis and Lung Disease (IUATLD, 1986) bronchial symptoms questionnaire questions on chest symptoms (Section A) - subjects who answered yes to any of these questions were also asked supplementary questions on the date on which they first had the symptoms, and whether or not they had improved since coming to the UK.

- MRC respiratory symptoms questionnaire (MRC, 1986) questions on breathlessness (Section B) - for those subjects answering positively, supplementary questions were asked about the date on which they first had breathlessness and whether or not it had improved since coming to the UK.

- Direct questions on medical diagnoses of asthma attacks (Section C).

- MRC (1986) questionnaire questions on cough and phlegm production (Section D) – these questions were adapted for self-administration by combining the separate questions on cough and phlegm into a joint question on 'coughing up phlegm'. The term 'mucus from your chest' was also included in the question as it was thought that many respondents might not understand the term 'phlegm'. For those reporting symptoms of cough and phlegm, the persistence of the symptoms and the time frame in which they occurred was established using supplementary questions.

- Smoking history - sufficient to categorise subjects as current tobacco smokers, ex tobacco-smokers or lifelong non tobacco-smokers (Section E). Information from discussions with the MCST suggested that those Montserratians who smoked tobacco tended to smoke manufactured cigarettes only, and so separate questions on hand-rolled cigarettes, cigars and pipes were not included.

- Residence in Montserrat and clearing of volcanic ash (Section F) - included questions about time spent on Montserrat and recorded place of residence in five calendar periods. Questions about dustiness of occupation and residence were included as well as questions on the frequency of use of dust masks. This information was later combined with data from the repeated dust surveys on the island and records of volcanic events to construct an exposure profile for each individual (see Section 3.7).

- Full occupational history (Section G) - to record each job held since finishing full-time education, in Montserrat and in the UK. The information requested followed the format used in the OPCS census questionnaire and adapted by the IOM for use in a study of the UK upholstery industry (Scott *et al*, 1993). Additional information was requested on the location of jobs within Montserrat.

3.4 PILOT STUDIES

Before the main study mailing took place, a pilot study was carried out. The principal aim of the pilot study was to identify any areas of ambiguity or difficulty in the design of the questionnaire. In addition, it was used to estimate the likely rate of response to the study and the accuracy of the database of households held by the MCST. Four copies of the health questionnaire and one copy of the Home Office social conditions questionnaire were sent to each of a random sample of 50 households from the MCST database.

Of the 50 households to which questionnaires were sent out, replies (containing both the IOM and Home Office questionnaires) were received from 13. Fifteen (30%) of the questionnaires were returned by Royal Mail, as undeliverable giving a response rate for households of 13/35 delivered (37%). The reasons for this relatively poor level of response were not clear, but were likely to include:

- the length of the questionnaires
- the complexity of the questionnaires
- distrust of official (government) forms
- incorrect contact details on the MCST database, resulting in the high percentage being undelivered.

To address these issues, a number of changes were made. Major changes were made to shorten and simplify the Home Office social conditions questionnaire, while the IOM health questionnaire was also shortened. A programme of publicity was started, including articles in the Montserrat Community newsletter, and community group meetings were arranged across the country to answer queries about the study and to ease the fears concerning officialdom. Finally, the MCST undertook to update their contact details database.

Following the alterations to the questionnaires a second pilot study was carried out. Responses were received from 16 households within the first four weeks, compared to six during the same time period in the first pilot study. It was therefore decided to use these versions of the health and social conditions questionnaires in the main study mailing (Appendix 1). Prior to the main mailing, the MCST completed the updating of their contact details database.

3.5 POSTAL SURVEY

The main study mailing took place in September 2000. All Montserratians currently living in the UK, whose names and addresses were held by the MCST, were sent an envelope containing four copies of the IOM health questionnaire, one copy of the Home Office social conditions questionnaire, a covering letter inviting them to participate in the study, and a pre-paid envelope for the return of the completed questionnaires to the MCST. After three weeks had elapsed from the first mailing, a reminder letter was sent to those who had not yet responded. Community meetings were also held in a number of venues across England, at which the study was further publicised and at which individuals could ask questions about the survey.

When each reply was received by the MCST, the personal details and questionnaire ID numbers were checked. These details have been stored securely by the MCST so that correspondence between health results and personal details will be possible if further follow-up medical surveys take place. The social conditions questionnaires (which were anonymous) were forwarded to the Home Office and the health questionnaires, after removal of identification data, were forwarded to the IOM.

3.6 DATA PROCESSING AND VALIDATION

3.6.1 Data coding and data entry

The questionnaire was designed to allow for direct data entry from the completed forms. However it was necessary to code the occupational history data prior to entry onto computer. Each job was coded according to the Standard Occupational Coding system (SOC, Office of Population Censuses and Surveys, 1990) and the industry within which it occurred was coded using the Standard Industrial Coding system (SIC, Office for National Statistics, 1997). The coding was carried out by a member of IOM staff who has extensive experience of the use of these occupational coding schemes. Jobs were additionally coded according to a classification of the main dusty occupations on the island as follows:

1 The Royal Montserrat Defence Force

2 The Royal Montserrat Police Force and Fire Officers

3 Public Works Department (includes heliport workers)

4 Montserrat Water Authority

5 Montserrat Electricity Services Limited

6 Montserrat Port Authority (including Customs)

7 Montserrat Volcano Observatory and Emergency Operations Centre

8 Gardeners, Roadside workers, Cleaners and Farmworkers

9 Other occupations

Finally, the geographical location of each job held on Montserrat was assigned a numerical code. These codes were subsequently grouped into eight principal areas of the island (see Appendix 2 for details).

Data from the questionnaires was double-punched by experienced computer operators using a data entry program set up specifically for this questionnaire, and amendments made where data entry errors had occurred.

3.6.2 Data validation

Following the entry of the data onto computer, comprehensive data validation checks were carried out. These included tabular and graphical descriptions of the data and the identification of invalid combinations of answers to specific questions. Apparent invalid or inconsistent responses were checked in the study database and, where necessary, on the original questionnaires, and responses were set to missing or invalid where appropriate.

3.7 EXPOSURE ESTIMATION

A detailed description of the dust measurements and exposure estimation for residents of Montserrat has been reported elsewhere (Searl *et al*, in preparation); the main points are summarised below.

3.7.1 Sampling of volcanic ash

Composition of the ash

The composition of volcanic ash collected from ash deposits on the island was investigated using a variety of analytical techniques (Baxter *et al*, 1999). Two main methods have been used to assess concentrations of airborne dust and levels of personal exposure to dust and cristobalite. Firstly cyclone samplers were used to collect samples of respirable dust on filters following standard occupational hygiene methods (Health and Safety Executive, 1997), and these samples were analysed by X-ray diffraction to determine their cristobalite content (Health and Safety Executive, 1994). The respirable fraction represents those particles that can penetrate to the small airways in the deep lung and is used widely in workplace monitoring. The second sampling method involved using a continuous reading aerosol monitor, the Dust Trak, supplied by TSI Incorporated to measure concentrations of PM_{10} in real time. The PM_{10} fraction is widely used for environmental monitoring. It is approximately equivalent to the ISO thoracic fraction and represents the particles that penetrate to the lung (median diameter is 10μm).

Environmental surveys

Detailed surveys of environmental concentrations of respirable airborne dust and cristobalite on Montserrat were undertaken using cyclone samplers in September 1996, June 1997, June 1998 and April 2000. Some additional measurements were made by staff based at the Montserrat Volcanic Observatory (MVO) using cyclone samplers between the two main measurement campaigns in 1996 and 1997 and during the course of 1997. These measurements were made over time periods of between 8 and 24 hours. Further measurements of environmental concentrations of PM_{10} were made during June 1997 using a Dust Trak monitor. Additional information about typical dust levels was derived from interviews with islanders about how frequently ash fell and how long conditions remained noticeably dusty after each ash fall. Between September 1997 and November 1998 and again between May 1999 and August 1999 daily measurements of PM_{10} were made at various locations in the occupied part of the island using Dust Trak monitors. Information collected by the MVO about the primary distribution of ash from the volcano has provided additional information about the potential for individuals to be exposed to volcanic ash.

Personal surveys

Detailed surveys of personal exposures to respirable airborne dust and cristobalite on Montserrat were undertaken using cyclone samplers and Dust Trak monitors in September 1996, June 1997, June 1998 and April 2000. Although it is impossible to measure personal exposures precisely using a Dust Trak, the measurements were made of concentrations of PM_{10} as close to the breathing zone of those undertaking the activities as was practicable. The measurements therefore should be reasonably representative of personal exposure. The cyclone samples were collected following the methodology outlined in MDHS 14/2 (Health and Safety Executive, 1997). The sampling periods were typically between 4 and 8 hours depending on shift length. Further specific assessments of personal exposures to PM_{10} were made during the course of 1998 using Dust Trak monitors, including surveys of the exposure of school children, roadworkers, MVO staff and people engaged in ash clearing operations. This additional monitoring allowed an assessment of the typical levels of exposure to PM_{10} associated with specific tasks under different conditions. For example, levels of exposure associated with ash clearing were measured for inside and outside operations during both wet and dry weather. Some of these measurements were made over a full working day, but most were made over shorter periods. Specific measurements were made for each type of activity such as sweeping, shovelling, dusting, mopping and beating mattresses (over time periods of 15 to 90 minutes). Records were also kept of the typical time spent by individuals undertaking ash clearing operations including both regular cleaning and more occasional operations cleaning buildings that had been left unoccupied for periods of months in Old Towne and Salem.

3.7.2 Assessment of mean concentrations over the course of the eruption

Residential concentrations

The exposure of islanders to volcanic ash was considered in terms of exposure associated with their place of residence on the island, exposure associated with their occupation (if known) and exposure associated with other potentially dusty activities. Concentrations were estimated for seven time periods chosen to represent periods of differing mean concentrations due to volcanic activity and weather conditions and for five geographic areas. These time periods were January to December 1996, January to June 1997, July to December 1997, January to December 1998, January to August 1999, September to December 1999, January to December 2000 and the geographic areas were:

Plymouth: Plymouth, Kinsale, St Patrick's, Harris/Spanish Point/Long Ground;

Cork Hill: Cork Hill, Richmond Hill, St George's;

Salem: Salem, Frith, Old Towne;

Woodlands: Woodlands, Olveston;

North: All areas further to the north of the island including Cavalla Hill, Davy Hill, St Peter's, Brades and St Johns.

Estimates of exposure associated with place of residence were based on estimated long term mean concentrations of airborne particulate in different areas of the island. These estimates were based on measurement data but as there were no complete sets of measurement data for any of the time periods of interest for any location, it was necessary to extrapolate from the measurement data. This was done partly by classifying days into four categories of dustiness based on the Department of Health criteria for PM_{10} for the island: alert level (>300μgm^{-3}), very high (101-300μgm^{-3}) raised (50-100μgm^{-3}) and low (<50μgm^{-3}). The proportion of days in each dustiness category in each year or part year considered was based on PM_{10} measurement data where available. Otherwise the proportion was estimated subjectively from accounts of the level of volcanic activity, interview information from a range of individuals on the island and extrapolation from measurement data. Rainfall information collected by the Forestry Development Office for 1999-2000 was also used in the assessment of the probable portion of days of differing dustiness for periods for which no monitoring data were available. The estimated proportions of days of differing levels of dustiness were used to estimate mean levels of dustiness for each area.

Occupational concentrations

The typical concentration assigned to each occupation and to potentially dusty activities undertaken outside of work, such as clearing ash from properties and domestic cleaning, was also based on measurement data. The assignation of different concentrations was based on the full shift personal exposure measurements made with cyclone samplers and also the Dust Trak measurements of concentrations associated with specific activities. The Dust Trak measurements were particularly useful for assessing the impact of relatively short-term exposures such as those associated with cleaning. Details on the concentrations used are given in Chapter 4.

3.7.3 Derivation of estimated individual exposures

For each individual in the study group, separate estimates were calculated for residential and occupational exposures. Time spent living in each of five areas of the island in each of seven time periods was combined with the estimated long-term average concentration for that area/time combination to calculate a cumulative residential exposure index. For some individuals, the information provided on place of residence was incomplete. Where possible, residential exposure estimates have been made based on the incomplete data, by making assumptions on residence in missing time periods (details are in Appendix 3). These individuals were identifiable during the analysis as having less reliable residential exposures and any influence they might have had on the key findings was investigated and is described in the results section. Key analyses were also repeated including only those individuals with complete and reliable residential information. For a few individuals, little or no residential information was provided and these were excluded from all analyses in relation to residential exposure.

Occupational exposure indices were calculated by combining the information provided in the detailed lifetime occupational histories with the concentrations described above for occupational groups, in the seven different time periods. Where the occupational data were comprehensive enough, a cumulative occupational exposure index was calculated for each individual. For several of the study respondents, the occupational history was completed only sparsely and it did not prove possible to calculate any occupational exposure index. In order to include as many subjects as possible in the analysis of health in relation to occupational exposure, categorical variables were also created where possible, which indicated whether an individual had ever worked in specified occupational groups, following the volcanic eruption in 1995. For some respondents little or no occupational information was provided and these were excluded from analyses of health in relation to occupational exposure.

Exposures from ash clearing and separately for domestic cleaning were calculated using the information provided in the questionnaire on how often the subjects were involved in clearing large quantities of ash, and how often it was necessary to clean volcanic dust from inside the building where they were living.

Where sufficient information about an individual was available their overall level of exposure to the volcanic ash was estimated as the sum of the cumulative exposures to ash associated with their place of residence, their occupation, ash clearing and domestic cleaning activities.

3.8 RESPIRATORY SYMPTOMS

The symptom responses of particular interest were those representing asthma, breathlessness on exertion and chronic bronchitis, each defined using the self-administered questionnaire. Some analyses were also carried out for asthma attacks reported directly by the study participants, but it was not possible to determine the calendar period in which any attacks of asthma occurred. The symptom definitions used in the analysis were as follows:

Asthma: Individuals were classified as having asthma if they reported wheezing and whistling in their chest (a positive answer to Q1) and at least two of questions 2 to 4: tightness in the chest first thing in the morning, shortness of breath during the day when not doing anything strenuous, and being woken at night by shortness of breath. This definition is the same as that used during IOM studies of workers in the furniture upholstery industry (Scott *et al*, 1993), and of asthma in the community (Cowie *et al*, 1997). Questions 5 and 6 were used to determine the time period over which the individuals had had the symptoms reported.

Breathlessness: Presence of breathlessness was defined as being short of breath walking with people of your own age on level ground (Q7). This is the definition used in the Medical Research Council questionnaire on respiratory symptoms (MRC, 1986).

Chronic bronchitis: Presence of chronic bronchitis was defined as the presence of cough and phlegm for at least three months each year. Individuals were classified as having symptoms of chronic bronchitis if they responded positively to

i. **either** question 14: coughing up phlegm first thing in the morning **and/or** question 15: coughing up phlegm during the day or at night **and**

ii. answered positively to question 16: do you cough up phlegm like this on most days for as much as three months each year.

Asthma attacks: Presence of asthma attacks was defined by a positive answer to 'Have you ever had an attack of asthma?'

3.9 STATISTICAL METHODS

The distribution of the study population in terms of area of domicile in Montserrat, age, sex, smoking habit, occupation and exposure to ash and any other relevant factors was described using a series of tables and graphical presentations.

Prevalence of symptoms was compared by cross-tabulation with age, sex, smoking habit, present and past occupations, area of domicile in Montserrat and indices of exposure to ash.

Formal statistical modelling using logistic regression methods was used to study simultaneously the risks associated with multiple explanatory variables (Draper and Smith, 1998; Collett, 1991). The response variables in separate logistic analyses were binary variables representing the presence/absence of each symptom. Explanatory variables included age, sex, smoking and exposure

indices, with interactions as appropriate. The best-fitting models were identified using an iterative process, examining the influence of the explanatory variables separately and in combination.

Results of the statistical analyses are reported for prevalences and exposure-response relationships based on the data as provided by the study participants. No adjustments were made in the calculations of statistical significance to take account of the known biases in the data set. However, the results have been interpreted in the light of these biases and selection effects.

4. DERIVATION OF INDIVIDUAL EXPOSURES

The measurement data combined with other information about weather and volcanic activity were used to generate the estimated concentrations associated with place of residence, occupation and activities involving cleaning and clearing of the dust (for details see Appendix 4). For each individual, an exposure index was calculated based on the data provided on place of residence by time period, frequency of heavy ash clearing and domestic cleaning and lifetime occupational history. The exposure indices were expressed in units of $\mu g.m^{-3}$.months exposure, time averaged for continuous exposure over 24 hours each day for 7 days a week (in contrast to workplace exposure indices that are more commonly expressed in terms of exposure at work over a calendar period). The exposure levels shown in Tables 4.1, 4.5, 4.7 and 4.11 are estimated typical respirable concentrations, based on dust sampling measurements of both PM_{10} and respirable dust levels. Results from the dust sampling exercises on the island suggest that the levels of "PM_{10}" recorded by the DustTrak samplers are only slightly higher than levels of respirable dust measured using cyclone samplers. (The Dust Trak samplers are calibrated using Arizonian road dust and it is possible that they underestimate levels of PM_{10} on Montserrat.) The values given in the sections below represent our best estimates of respirable dust levels derived from measurements from both sources.

4.1 RESIDENTIAL EXPOSURE

Exposure levels by place of residence and time period

Table 4.1 shows estimated typical levels of exposure to respirable dust by place of residence and time period, based on the measurement data described above.

Table 4.1 Typical levels of exposure (μgm^{-3}) associated with environmental concentrations by place of residence and time period

	Time period						
Place of residence	**1996 Jan-Dec**	**1997 Jan-June**	**1997 Jul-Dec**	**1998 Jan-Dec**	**1999 Jan-Aug**	**1999 Sept - Dec**	**2000 Jan-Dec**
Plymouth	100	250	300	nd	nd	nd	nd
Cork Hill	60	200	250	nd	60	25	30
Salem	40	100	200	30	80	25	40
Woodlands	25	60	80	25	55	20	25
North	20	30	40	25	45	20	20

nd = not done

Patterns of residence on Montserrat by time period

For each participant, the number of months spent in residence in each of the five areas of the island in each of the time periods was derived from the data recorded in response to question 23 on the questionnaire. Details of the derivation are given in Appendix 3. Information on place of residence was collected only up to the end of 1998, however very few study participants remained on the island after this date (Table 4.2). Nineteen individuals (4%) did not give information on date of leaving Montserrat, however comparison of their residential histories with those of other family members allowed the allocation of dates of leaving for nine of the 19 missing values.

The majority of the study group (62%) left Montserrat during the second half of 1997. Dates of leaving within this time period were evenly spread between July and November 1997, peaking in September and October, with only thirteen departures during December 1997. For the 37 subjects who did remain on the island after 1998, it was assumed that their place of residence in 1999 and/or 2000 was the same as in 1998.

Table 4.2 Distribution of dates of leaving Montserrat for 451 study participants*

Dates of leaving		No of subjects
1995:	July - December	3
1996:	January - June	7
	July - December	32
1997:	January - June	27
	July - December	279
1998:	January - June	39
	July - December	27
1999:	January - June	17
	July - December	11
2000:	January - June	6
	July - December	3

*10 subjects had missing data. 4 subjects gave dates prior to the eruption of the volcano in 1995 (Jan 1955, May 1956, October 1957, February 1990).

Overall 297 subjects (64%) provided complete (or almost complete) residential information by time period and 168 (36%) subjects provided incomplete or invalid information. For many of those with incomplete data, it was possible to allocate residential data based on extrapolation of the data given by that individual, supplemented where relevant by comparisons with information provided by other family members (Appendix 3). Results below are shown for the whole study group, and separately for the 297 subjects who provided complete information.

Tables 4.3 and 4.4 show the number of subjects reporting residence in each of the five areas by time period for the whole study group and the 'reliable' subgroup respectively. Fifty-one subjects had completely missing data on residential information. Some subjects reported living in two different areas within a time period and so are included in the table more than once in some time periods.

Table 4.3 Reported residence in Montserrat by time period - whole study group. Each cell contains number of subjects reporting residence in each area/time period.

	Time period				
Area	**Jul-Dec 95**	**1996**	**Jan-June 97**	**Jul-Dec 97**	**1998**
Plymouth	157	79	41	0	0
Cork Hill	80	78	48	11	1
Salem	64	103	81	122	29
Woodlands	17	27	24	26	1
North	100	133	162	171	35

Table 4.4 Reported residence in Montserrat by time period - 'reliable' study group. Each cell contains number of subjects reporting residence in each area/time period.

	Time period				
Area	**Jul-Dec 95**	**1996**	**Jan-June 97**	**Jul-Dec 97**	**1998**
Plymouth	104	36	5	0	0
Cork Hill	62	61	34	11	1
Salem	46	81	66	59	6
Woodlands	16	25	19	23	1
North	71	98	118	131	23

Similar patterns are seen in tables 4.3 and 4.4. The number of residents in the Plymouth area declined steadily over time. The number of residents in Cork Hill also declined over time, but the decline starts at the end of 1996, compared to the end of 1995 in Plymouth. There was an increase in the number of residents in Salem and Woodlands between 1995 and 1996, perhaps caused in part by those moving out of Plymouth, followed by a gradual decline through 1997. Residence in the north area increased steadily between 1995 and 1997. For all areas there was a sharp drop in the number of residents in 1998, caused by the large evacuation from the island in the latter half of 1997.

Calculation of residential exposure index

A residential exposure index was calculated for each subject by multiplying the time in months in each area and time period by the relevant concentration level in $\mu g.m^{-3}$ and totalling the exposures over time periods. Residential exposure was calculated for 414 subjects and ranged from 0 to 5160 $\mu g.months.m^{-3}$. The 13 subjects with zero residential exposure were from nine family groups. They had either left the island for the UK immediately after the first volcanic eruption in 1995, or had lived elsewhere outwith Montserrat between the eruption occurring and leaving for the UK.

The average residential exposure was much lower among those with 'reliable' residential histories (mean = 1050 $\mu g.months.m^{-3}$) than among those with less reliable data (mean = 2110 $\mu g.months.m^{-3}$). Those with less reliable indices were also, on average, older than those with reliable data, and proportionally more of them were men. After adjustment for these age and sex differences, 'reliable' residential exposure indices were still statistically significantly lower than less reliable residential exposure indices. The distribution of residential exposures is shown in Figure 4.1.

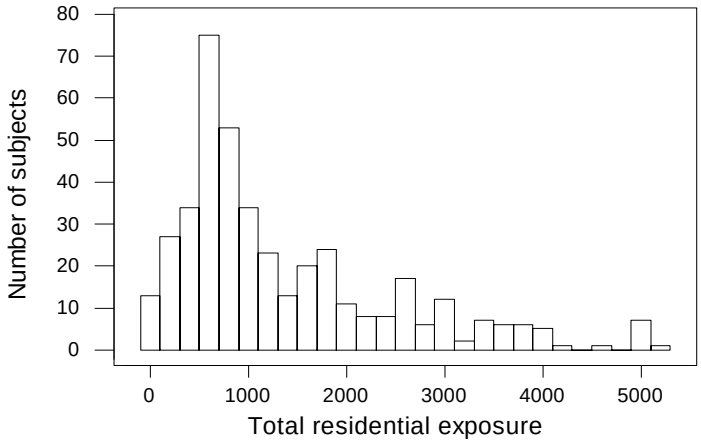

Figure 4.1: Distribution of residential exposure (µg.months.m^{-3})

4.2 EXPOSURE FROM HEAVY ASH CLEARING ACTIVITIES

Heavy ash clearing

Table 4.5 gives the levels of exposure experienced by individuals carrying out heavy ash clearing (quantities greater than 1mm thickness – for example digging out a driveway; clearing a roof). It was assumed that ash clearing was carried out in four-hour periods, as in general Montserratians would spend around half a day on each ash clearing task. Exposure levels are given by time period. Because of the nature of the job, exposures would be expected to be the same level regardless of the geographical area in which the clearing took place.

Table 4.5 Estimated exposure to volcanic ash associated with heavy ash clearing (µg.m^{-3}).

Activity	1996 Jan-Dec	1997 Jan-June	1997 Jul-Dec	1998 Jan-Dec	1999 Jan-Aug	1999 Sept - Dec	2000 Jan-Dec
Heavy ash clearing	5000	10000	10000	5000	5000	3000	4000

Individual exposure indices for heavy ash clearing were calculated using the information provided on the frequency with which they cleared ash since 1995, and their length of residence on the island before leaving for the UK. Length of residence on the island was calculated from the residential histories provided by the survey participants and so was subdivided into 'reliable' and 'less reliable' as described above, time spent outwith Montserrat before coming to the UK was excluded from the calculations.

The exposure experienced from heavy ash clearing was scaled to be in comparable units to the residential exposure index. This was done by calculating the proportion of each month spent on heavy ash clearing tasks, and multiplying it by the total number of months spent on the island in each time period. Time specific exposures were then summed to provide an estimate of total exposure from ash clearing. Proportion of the month spent doing heavy ash clearing was calculated using the responses to question 24 on the questionnaire ('Since 1995, how often were you involved in clearing large quantities of ash (greater than 1mm in thickness) from buildings, roads or other surfaces ?'), and is summarised in Table 4.6.

Table 4.6 Calculation of proportion of month spent on heavy ash clearing tasks

Response to Q24	Heavy ash clearing tasks per month		
	Average number	Total hours	Proportion[1]
Never	0.0	0.0	0.000
Once or twice a month	1.5	6.0	0.008
Once or twice a week	6.0	24.0	0.032
Daily (not main occupation)	20.0	80.0	0.108
Daily (main occupation)	20.0	80.0	0.108

[1] Proportion calculated as Total hours clearing / Total hours in month (24hrs x 31 days = 744 hours)

Exposure from heavy ash clearing was calculated for 368 subjects, excluding those with missing or invalid data in the residential histories (51 subjects) or for question 24 (57 subjects). Eleven of these subjects had missing data for both variables. Exposure from ash clearing ranged from 0 to 30100 μg.months.m^{-3}. As for residential exposure, exposure from ash clearing was higher among those with less reliable residential histories (mean = 6986 μg.months.m^{-3}, compared to 5008 μg.months.m^{-3} among those with reliable residential data); and this difference remained after adjustment for age and sex differences. The distribution of exposure from heavy ash clearing tasks is shown in Figure 4.2 (overleaf).

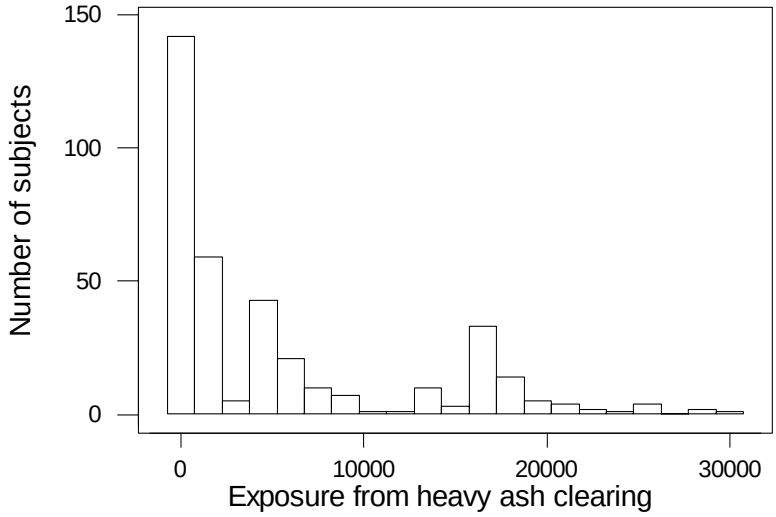

Figure 4.2 Distribution of exposure due to heavy ash clearing tasks (μg.months.m^{-3})

4.3 EXPOSURE FROM DOMESTIC CLEANING ACTIVITIES

The levels of exposure from domestic cleaning undertaken by people in their own properties has been estimated in terms of the increment on their mean 24 hour exposure assuming that about one hour per day would be spent on housework. Table 4.7 shows the estimated increment on 24-hour exposure due to domestic cleaning by time period and area of residence.

Table 4.7 Estimated increment in 24 hour mean exposure (μg.m^{-3}) due to domestic cleaning in different areas of residence (assuming that an individual spends about 1 hour cleaning on each occasion).

Residential Area	1996 Jan-Dec	1997 Jan-June	1997 Jul-Dec	1998 Jan-Dec	1999 Jan-Aug	1999 Sept - Dec	2000 Jan-Dec
Plymouth	100	250	250	100	nd	nd	nd
Cork Hill	100	200	250	100	100	100	100
Salem	50	100	100	50	60	30	50
Woodlands	30	50	50	15	20	10	20
North	10	10	10	5	10	5	10

nd = not done

Individuals' exposures due to domestic cleaning were calculated from data on length of residence in each area in each time period, frequency of cleaning their property and level of exposure. The number of months spent in residence in each area and time period were available from the detailed residential histories. Information on frequency of domestic cleaning was available from question 26 on the questionnaire ('During the three months before you left Montserrat how often was it necessary to clean volcanic dust from inside the building where you were living at the time ?'). It was assumed that this was the frequency with which each individual cleaned their residence throughout their time on Montserrat.

The proportion of each month spent on domestic cleaning was calculated from the responses to question 26, and is summarised in Table 4.8. The exposure levels in Table 4.7 refer to total exposure for the 24 hour period in which the cleaning took place.

Table 4.8 Calculation of proportion of month spent on domestic cleaning tasks

Response to Q26	Domestic cleaning tasks per month	
	Average no of days when cleaning was done	Proportion [1]
Never	0.0	0.000
Once or twice a month	1.5	0.048
Once or twice a week	6.0	0.194
Once a day	20.0	0.645
More than once a day	31.0	1.000

[1] Proportion calculated as Average no of days when cleaning was done / Total days in month (31)

Exposure from domestic cleaning was calculated for 369 subjects, excluding those with relevant data which was missing or invalid. Exposure from domestic cleaning ranged from 0 to 5100 μg.months.m^{-3}, with a mean level of 564 μg.months.m^{-3}. As for residential and heavy ash clearing exposure, exposure from cleaning was higher among those with less reliable residential histories (mean = 901 μg.months.m^{-3}, compared to 445 μg.months.m^{-3} among those with reliable residential data); and this difference remained after adjustment for age and sex differences. The distribution of exposure from domestic cleaning is shown in Figure 4.3.

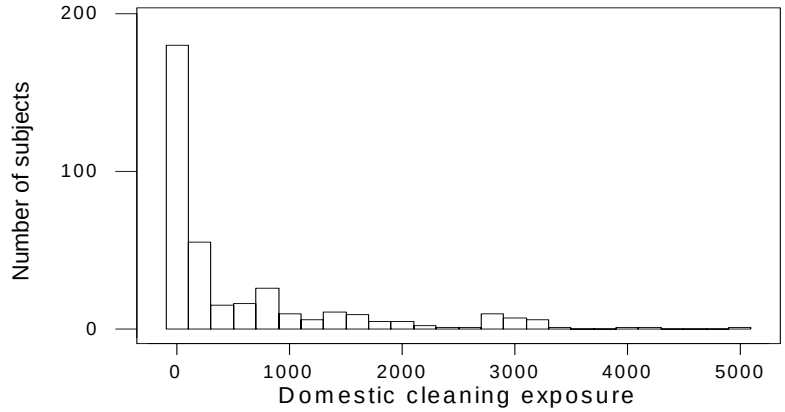

Figure 4.3 Distribution of exposure due to domestic cleaning tasks (µg.months.m^{-3})

4.4 OCCUPATIONAL EXPOSURE

Availability of occupational history data

Occupational exposures for each individual were calculated from the lifetime occupational history as reported in the postal questionnaire. Individuals were asked if they had ever been in paid employment and, if so, were asked to complete a detailed list of jobs held with dates of start and finish of each job, and geographical location of each job held while on Montserrat. Table 4.9 summarises the availability of detailed occupational histories for the members of the study group.

Table 4.9 Availability of occupational histories, subdivided by age group and whether the subject reported ever having been in paid employment

	Have you ever been in paid employment?					
	No		Yes		Missing	
Age group	OH*	No OH	OH	No OH	OH	No OH
<16	0	60	0	0	0	37
16-19	1	15	4	1	0	7
20-29	0	13	25	10	6	6
30-39	1	3	40	6	4	11
40-49	2	11	21	6	9	2
50+	5	42	36	16	15	28
Missing	0	2	5	3	2	10
Total	9	146	131	42	36	101

*OH denotes occupational history available

On the basis of the information presented in Table 4.9, the 465 study participants were divided into three groups:

i. Respondents with no potential occupational exposure

ii. Respondents with potential occupational exposure (which may be zero)

iii. Respondents with missing information and who cannot be unambiguously classified into groups i. or ii.

These three occupational exposure groups were defined as follows:

i. Respondents with no potential occupational exposure (192; 41%):

97	aged under 16 at time of survey
86	replying 'no' to paid employment and not completing an OH
2	replying 'no' to paid employment, and completing an OH which contained no valid job information
7	aged 16-19 who omitted the question on paid employment and did not complete an OH

ii. Respondents with potential occupational exposure (174; 38%)

131	replying 'yes' to paid employment and completing an OH
7	replying 'no' to paid employment but completing an OH which contained valid job information
36	who omitted the question on paid employment and completed an OH

iii. Respondents with missing potential occupational exposure (99; 21%)

42	replying 'yes' to paid employment but not completing an OH
57	aged 20+ who omitted the question on paid employment and did not complete an OH

Distribution of occupations

Occupational exposures for the 192 subjects with no potential occupational exposure were set to zero, and for the 99 subjects with missing information on occupational exposure were set to missing. The occupational histories of the 174 subjects with potential occupational exposure were then examined in more detail.

Across the 174 subjects a total of 430 jobs were reported, of which 340 (79%) were held while the individual was on Montserrat. Each job held on Montserrat was allocated to one of eight occupational groups (OG), shown in Table 4.10. The table shows the total number of jobs held in each occupational group and the number of individuals who ever worked in each occupational group, subdivided by whether they worked in the OG before or after 1995. Jobs were designated 'after 95' if they ended in 1995 or later. For some individuals, information on the time period for work on Montserrat was missing and so cannot be allocated to before or after 1995. These individuals are shown in the 'missing' column of the table. A few individuals worked in more than one OG and so are included more than once in the table.

Table 4.10 Distribution of occupational groups (OGs) for jobs held on Montserrat. For three of the 340 jobs, the data provided was not detailed enough to allocate to an OG.

		No of subjects			
Occupational Group	**No of jobs**	**Before 95**	**After 95**	**Missing**	**Total**
A: MDF, police	5	1	3	0	4
B: Port workers	6	3	1	1	5
C: Gardeners	5	2	2	1	5
D: Roadworkers	7	0	2	2	4
E: Housekeepers	45	9	12	13	34
F:Utilities, farmworkers, drivers, heliport	44	8	11	13	32
G: Construction	18	5	1	3	9
H: Other	207	15	61	38	114
Total	337	43	93	71	207

In total, 89 individuals had worked in at least one of the OGs after the volcanic eruption in 1995 (four of these worked in two OGs and are included twice in the table total of 93 individuals). The majority of these (61; 69%) worked in the 'other' category, with relatively few in the dustier jobs. The most frequently reported dusty jobs were housekeeping and utilities, farmworkers and drivers.

Calculation of occupational exposures

The 89 individuals who worked on Montserrat following the eruption were potentially exposed to volcanic ash in the course of their work. Table 4.11 shows the estimated 8hr exposures associated with different occupations across the time periods of interest. In the calculation of occupational exposure these exposure levels were scaled to equivalent 24hr exposures (by dividing by 5), so that they could be combined with the residential, ash-clearing and domestic cleaning exposures to calculate a total exposure per individual.

Table 4.11 Typical levels of exposure (μgm^{-3}) as 8 hour TWA associated with different occupations

	1996 Jan-Dec	1997 Jan-Jun	1997 Jul-Dec	1998 Jan-Dec	1999 Jan-Aug	1999 Sept - Dec	2000 Jan-Dec
MDF, Police	1000	2000	2000	400	300	50	50
Port Workers	1500	3000	200	60	150	40	50
Gardeners	700	1400	1400	400	400	50	200
Roadworkers	4000	4000	5000	600	800	200	200
Housekeepers	300	450	450	250	300	50	50
Utilities, farmworkers, drivers, heliport	600	450	450	300	300	50	100
Construction	800	1000	1000	600	1000	600	700
Other* in Plymouth including Rice Mill	150	500	nd	nd	nd	nd	nd
Other in Cork Hill	150	400	nd	nd	nd	nd	nd
Other elsewhere	60	100	100	60	150	50	50

*Other: office, retail, health care, education. MVO, C&W

nd = not done

The time in months spent working in each occupational group in each time period was calculated and combined with the data on exposure level to calculate an occupational exposure for each OG in each time period. These were then summed across time period to calculate a total occupational exposure for each OG. For the 110 of the 174 subjects who had complete information across all eight OGs (78 of whom had worked in Montserrat after 1995) total occupational exposure was calculated, by summing exposures across all OGs. Total occupational exposure ranged from 0 to 7200 $\mu g.months.m^{-3}$, with a mean value of 819 $\mu g.months.m^{-3}$ for all those with occupational histories, and a mean value of 1170 $\mu g.months.m^{-3}$ among the 78 subjects with non-zero occupational exposures. The distribution of the occupational exposures is shown in Figure 4.4.

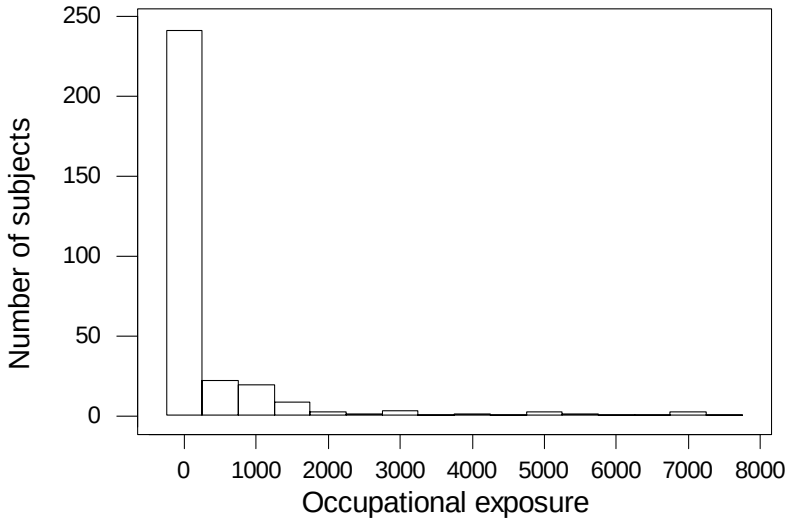

Figure 4.4 Distribution of occupational exposure (µg.months.m^{-3})

Among the 78 subjects with non-zero occupational exposures, average exposure was statistically significantly higher among the 28 men (2001 µg.months.m^{-3}) than among the 49 women (696 µg.months.m^{-3}). Differences in exposure between age groups were not significant, but exposure levels were lower among the 20-29 year olds. Occupational exposures for the two ex-smokers were very high.

Examination of the distribution of occupational exposure across all 302 subjects for whom the variable could be calculated again showed significantly higher exposures among men (mean: 491 µg.months.m^{-3}) than among women (mean: 184 µg.months.m^{-3}). Exposures also differed significantly by age group, with the lowest levels occurring among the 20-29 year olds and the over-50s. Again the six ex-smokers had, on average, very high occupational exposure levels.

4.5 SUMMARY OF EXPOSURE AVAILABILITY

Of the 465 study participants, estimated exposures were available as follows:

- 302 subjects had occupational exposure estimates
- 414 subjects had residential exposure estimates, of which 117 were based on data which were less reliable
- 368 subjects had heavy ash clearing exposure estimates, of which 92 were from less reliable data
- 369 subjects had domestic cleaning exposure estimates, of which 96 were from less reliable data

In total, 240 of the 465 participants (52%) had estimated exposure for all four exposure types, and so had an estimated total exposure to volcanic ash. Of these 240 subjects, for 59 some part of their non-occupational exposures was based on less reliable data. Figure 4.5 shows the distribution of total exposures.

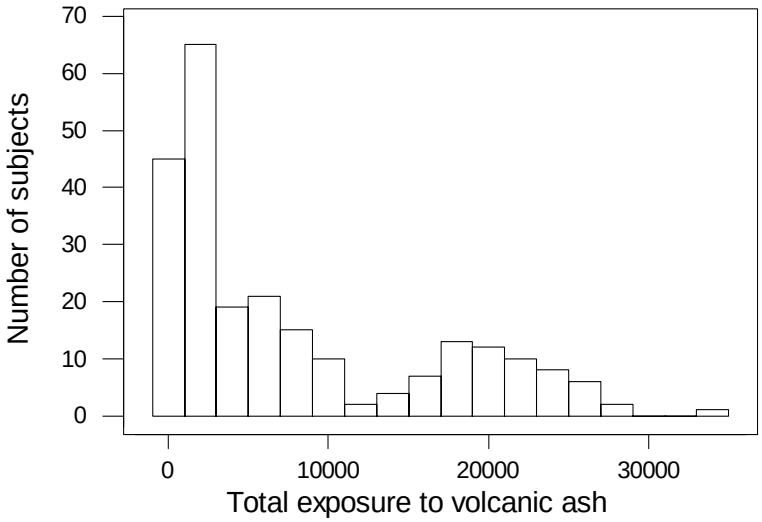

Figure 4.5 Distribution of total exposure to volcanic ash (µg.months.m^{-3})

4.6 ASSOCIATIONS BETWEEN EXPOSURE VARIABLES

Figure 4.6 shows the relationships between individual exposures due to residential, occupational, heavy ash clearing or domestic cleaning. Associations between each of the exposure indices and total exposure to volcanic ash are also shown.

The strongest correlations were between exposure from domestic cleaning tasks and residential exposure (correlation coefficient 0.667) both of which were strongly based on the residential histories provided by each individual; and between exposure due to heavy ash clearing tasks and total exposure to volcanic ash. Levels of exposure due to heavy ash clearing were substantially higher than for any of the other exposure sources, and so individuals with high heavy ash exposure also had high levels of total exposure (which was calculated by summing the exposures from the four sources).

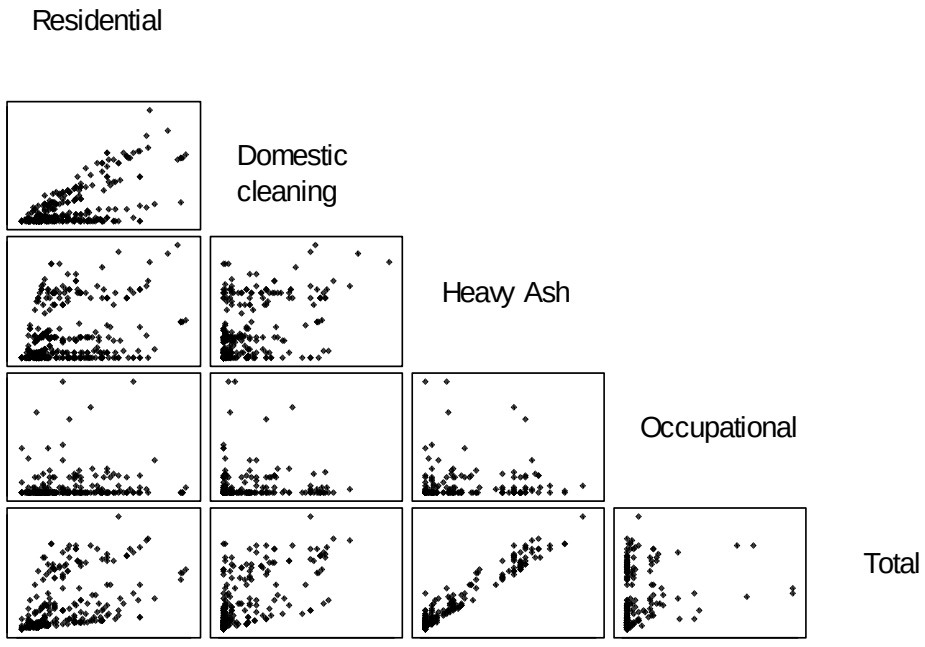

Figure 4.6 Association between individual exposure variables

5. SURVEY RESULTS AND RELATIONS WITH EXPOSURE

5.1 SURVEY RESPONSE

Responses were received concerning 465 individuals from 255 households. Questionnaires had been mailed to approximately 1000 households throughout the UK. Responses were therefore obtained from around 26% of households.

5.2 CHARACTERISTICS OF STUDY POPULATION

Of the 465 respondents, 180 (39%) were recorded as male and 279 (60%) as female; six respondents did not give information on gender. Table 5.1 shows the distribution of the study group by age group and sex (excluding 25 subjects with missing data for one or both of the variables).

Table 5.1 Distribution of study group by age group and sex. Each cell contains number of subjects *and percentage of row total*

	Age Group												
Sex	**<16**		**16-19**		**20-29**		**30-39**		**40-49**		**50+**		**All**
Male	43	*25*	14	*8*	18	*10*	25	*14*	16	*9*	57	*33*	173
Female	54	*20*	14	*5*	42	*16*	40	*15*	35	*13*	82	*31*	267
All	97	*22*	28	*6*	60	*14*	65	*15*	51	*12*	139	*32*	440

More than one quarter of the study group were aged less than 20, with 22% aged less than 16. Around a third of respondents were aged over 50. There was little difference in the age distribution for men and women, with the average age for women (38.2 years) slightly higher than for men (36.9 years).

Of the 426 respondents who provided information on smoking habit, the great majority (386, 91%) were lifelong non-smokers, 14 (3%) were ex-smokers and 26 (6%) were current smokers at the time of survey. Only three (1%) of the 259 women who completed the smoking questions were current smokers and the remaining 256 were all non-smokers. Men were more likely than women to be current or ex-smokers. Among the 161 men giving smoking information, 22 (14%) were current smokers, 14 (9%) were ex-smokers and 125 (78%) were non-smokers.

Table 5.2 shows the distribution of the study group by age group and smoking habit. Prevalence of smoking increased with age, with all of the under-20s being reported as lifelong non-smokers. Among the older subjects, 6% to 9% of those aged 20 to 49 were current or ex-smokers, compared to 20% among the over-50s. Of the three women who were current smokers, one was aged 20-29, one was aged 30-39 and the other did not give information on age.

Table 5.2 Distribution of study group by age group and smoking habit. Each cell contains number of subjects *and percentage of column total*

Smoking	Age Group													
Habit	**<16**		**16-19**		**20-29**		**30-39**		**40-49**		**50+**		**All**	
Non	90	*100*	22	*100*	55	*93*	58	*94*	40	*91*	103	*80*	368	*91*
Ex	0	*0*	0	*0*	1	*2*	0	*0*	0	*0*	12	*9*	13	*3*
Current	0	*0*	0	*0*	3	*5*	4	*6*	4	*9*	14	*11*	25	*6*
All	90		22		59		62		44		129		406	

5.3 SYMPTOM PREVALENCE

5.3.1 Overall prevalence of respiratory symptoms

The definitions of the symptoms investigated in the study have been given in section 3.8 above. There were three main symptom complexes of interest – asthma, breathlessness and chronic bronchitis. Some analyses were also carried out for subjects who had ever had an attack of asthma. Table 5.3 shows the overall prevalence of each of these symptoms. Further details for each symptom are given in the following sections.

Table 5.3 Overall prevalence of asthma, breathlessness, asthma attacks, and chronic bronchitis. *Percentages are of the total number of subjects in the study group who completed the questions relevant to each symptom.*

Symptom	Number of subjects with valid responses	Number of subjects with symptom	Percentage of subjects with symptom
Asthma	436	62	*14*
Breathlessness	421	75	*18*
Asthma attack ever	426	31	*7*
Chronic bronchitis	420	59	*14*

A total of 331 individuals did not report any of the above symptoms, 70 reported one symptom, 38 reported two symptoms, 23 reported three symptoms and only three reported all four symptom complexes. Asthma and breathlessness tended to be reported together, by 37 individuals, i.e. 60% of those reporting breathlessness and 49% of those who reported asthma. Some of the similarities in the results for asthma and breathlessness shown below are therefore due to the overlap between the two groups of individuals.

5.3.2 Asthma

Of the 465 study participants, 436 (167 men, 263 women, 6 with missing information on gender) completed the questions on asthma. Sixty-two subjects reported asthma, of whom 32 were women and 28 were men. Prevalence among women (12%) was therefore lower than among men (17%). Table 5.4 shows the prevalence of asthma by age and smoking group.

Table 5.4 Prevalence of asthma by age group and smoking habit. Each cell contains number *(percentage)* of subjects with asthma. Percentages based on fewer than 10 subjects are given in brackets.

Smoking Habit	Age Group													
	<16		**16-19**		**20-29**		**30-39**		**40-49**		**50+**		**All**	
Non	10	*12*	2	*9*	3	*6*	4	*7*	4	*11*	19	*20*	42	*12*
Ex	-	-	-	-	1	*(100)*	-	-	-	-	2	*(22)*	3	*30*
Current	-	-	-	-	1	*(33)*	0	*(0)*	1	*(25)*	7	*54*	9	*38*
All	***10***	**12**	2	*9*	5	*9*	4	*7*	5	*12*	28	*24*	54	*14*

Prevalence of asthma overall, among non-smokers and among the relatively few current smokers, was highest for those aged over 50. Proportionally more current and ex-smokers than non-smokers reported asthma, both overall and within the 50+ age group. The number of current and ex-smokers in the younger age groups was too small to discern any clear trends, although where the sparse data existed, the prevalence tended to be lowest for non-smokers.

The prevalence of asthma was also slightly higher among children (aged less than 16) than among adults aged 20-49.

Of the 62 subjects with asthma, 58 provided information on changes in their symptoms since coming to the UK. Twenty subjects (34%) said that their symptoms had improved, 14 (24%) said that they had stayed the same and 10 (17%) that they had got worse. Fourteen subjects reported that their symptoms had started only since they arrived in the UK.

Subjects with asthma were also asked the date on which they first experienced their symptoms. Some discrepancies were found between the response to this question and whether the subject stated that their symptoms had started only since they arrived in the UK (i.e. subjects reported that the symptoms had started before they came to the UK, but gave a date of first occurrence that was later than their date of leaving Montserrat for the UK). The 62 subjects were therefore divided into three groups:

i. First occurrence of symptoms before coming to the UK (26 subjects; 42%)

ii. First occurrence of symptoms after coming to the UK (14 subjects; 23%)

iii. First occurrence of symptoms unknown or contradictory (22 subjects; 35%)

Of the subjects in group iii), four did not give information on when the symptoms first occurred, and the remaining 18 all reported that their symptoms occurred prior to coming to the UK but gave missing or contradictory date of first occurrence.

The proportion of individuals with asthma which first started after coming to the UK was the same among men and women, however none of the cases among current smokers started after coming to the UK.

Of the 26 subjects with asthma which started while they were still on Montserrat, 11 (42%) said that their symptoms had improved since coming to the UK, eight (31%) said they had stayed the same and seven (27%) said they had got worse.

The high level of ambiguity in the responses to the questions on when the symptoms first occurred showed that the study respondents had had difficulty in completing this section, and cast some doubt about the accuracy of the classification into groups i. and ii. above. Because of this, subsequent analyses were carried out using as responses (a) everyone who reported any asthma regardless of timescale and (b) the small subset of subjects in group i. who reported symptoms which we believe first occurred on Montserrat.

5.3.3 Breathlessness

Of the 421 subjects who completed the question on breathlessness, 75 (18%) reported getting short of breath when walking with people of their own age on level ground. Prevalence of breathlessness was similar in men (26 subjects, 17%) and women (47 subjects, 19%). The distribution by age and smoking group of subjects with breathlessness is shown in Table 5.5.

Table 5.5 Prevalence of breathlessness by age group and smoking habit. Each cell contains number *(percentage)* of subjects with breathlessness. Percentages based on fewer than 10 subjects are given in brackets.

Smoking	**Age Group**													
Habit	**<16**		**16-19**		**20-29**		**30-39**		**40-49**		**50+**		**All**	
Non	10	*13*	4	*18*	4	*8*	8	*15*	7	*18*	23	*27*	56	*17*
Ex	-	-	-	-	0	*(0)*	-	-	-	-	3	*(27)*	3	*25*
Current	-	-	-	-	1	*(33)*	0	*(0)*	2	*(67)*	6	*43*	9	*38*
All	***10***	**13**	4	*18*	5	*9*	8	*14*	9	*21*	32	*29*	68	*18*

Prevalence of breathlessness was higher among subjects aged 40 or more, and lowest among the 20-29 age group. Overall, and within each age group, current smokers were more likely than ex-smokers or non-smokers to report symptoms of breathlessness.

Seventy-one of the individuals reporting symptoms of breathlessness provided information on changes since coming to the UK. Sixteen (23%) reported that their symptoms had improved, 25 (35%) that they had stayed the same and 13 (18%) said that their symptoms had got worse. Seventeen subjects reported that their symptoms had started only since arriving in the UK (one of whom provided a date of first symptom occurrence prior to leaving Montserrat).

The 75 individuals with symptoms of breathlessness were subdivided according to whether their symptoms first occurred before coming to the UK (24 subjects; 32%), first occurred after coming to the UK (16 subjects; 21%) or it was unknown or ambiguous when their symptoms first occurred (35 subjects; 47%). Of the 24 subjects whose symptoms first occurred on Montserrat, six (25%) said they had improved since coming to the UK, 12 (50%) said that they had stayed the same and six (25%) said that they had got worse.

5.3.4 Asthma attacks

Respondents to the questionnaire were asked directly whether they had ever had an attack of asthma, and whether they had had an attack of asthma since they came to the UK. Results for the 407 subjects who completed both questions are given in Table 5.6.

Table 5.6 Distribution of study group by attack of asthma ever and attack of asthma since coming to the UK.

Asthma attack ever	Asthma attack since coming to the UK		
	No	Yes	All
No	378	0	378
Yes	9	20	29
All	387	20	407

Most of the respondents (378 subjects; 93%) had never had an attack of asthma. Twenty-nine subjects had ever had an attack of asthma, of whom 20 had had an attack since coming to the UK. (Two additional subjects reported having ever had an attack of asthma, but did not complete the question on asthma attacks in the UK.) Fifteen women (6%) reported having an attack of asthma compared to sixteen men (10%).

The prevalence of an asthma attack ever by age group is shown in Table 5.7. Asthma attacks were much more common among the under-20s in the study group than among the older subjects. Of the 31 subjects with asthma attacks, 26 were non-smokers, two were ex-smokers and one was a current smoker. Two subjects with asthma attacks did not answer the questions on smoking.

Table 5.7 Prevalence of asthma attacks by age group. Each cell contains number *(percentage)* of subjects with asthma attacks. Percentages based on fewer than 10 subjects are given in brackets

	Age Group													
	<16		16-19		20-29		30-39		40-49		50+		All	
Subjects with Asthma Attacks	12	*13*	5	*18*	3	*5*	1	*2*	4	*9*	6	*5*	31	*8*

5.3.5 Chronic bronchitis

Fifty-nine subjects (15% of those completing the relevant questions) reported symptoms of chronic bronchitis, defined as coughing up phlegm for three months or more each year. Prevalence was the same for men (23 subjects; 14%) and women (35 subjects; 14%). The distribution of those with chronic bronchitis by age and smoking group is shown in Table 5.8.

Prevalence of chronic bronchitis was highest among those aged 40 or more, and much higher among current smokers than among non or ex-smokers. More than half of the 23 current smokers who completed the relevant questions, reported symptoms of chronic bronchitis.

Table 5.8 Prevalence of chronic bronchitis by age group and smoking habit. Each cell contains number *(percentage)* of subjects with chronic bronchitis. Percentages based on fewer than 10 subjects are given in brackets.

Smoking Habit	Age Group													
	<16		**16-19**		**20-29**		**30-39**		**40-49**		**50+**		**All**	
Non	7	*8*	1	*5*	4	*8*	5	*9*	8	*21*	15	*17*	40	*12*
Ex	-	-	-	-	0	*(0)*	-	-	-	-	2	*(20)*	2	*18*
Current	-	-	-	-	2	*(67)*	0	*(0)*	2	*(67)*	8	*62*	12	*52*
All	**7**	**8**	1	*5*	6	*11*	5	*9*	10	*24*	25	*22*	54	*14*

Eleven (19%) of the 59 subjects with chronic bronchitis reported that their symptoms had improved since coming to the UK, 22 (37%) that they had stayed the same and 10 (17%) that they had got worse. The remaining 16 subjects reported that their symptoms had first occurred after arriving in the UK (although three of these reported contradictory or missing dates of first symptom occurrence).

The 59 subjects with chronic bronchitis were subdivided according to when their symptoms first occurred:

- For 16 (27%) subjects, the symptoms first occurred prior to coming to the UK
- For 13 (22%) subjects, the symptoms first occurred after coming to the UK
- For 30 (51%) subjects it was not possible to determine whether they had started before or after coming to the UK

Of the sixteen subjects whose symptoms started prior to coming to the UK, six said that their symptoms had improved since coming to the UK, six said that they had stayed the same and four said that the symptoms had got worse.

5.4 ASSOCIATION BETWEEN SYMPTOMS AND EXPOSURE

As described in Chapters 3 and 4, individuals could be exposed to volcanic ash from four principal sources which were residential exposure (from background levels of ash), exposure from domestic cleaning, exposure from heavy ash clearing activities and occupational exposure. The prevalence of respiratory symptoms in relation to each of these exposure sources separately is described in sections 5.4.1 to 5.4.4 below, and associations with total exposure to volcanic ash are described in section 5.4.5.

5.4.1 Respiratory symptoms and residential exposure

For each subject geographical area of residence on the island was recorded for five areas and seven time periods (see section 4.1 for details). The dustiest conditions on the island were during 1997, and during this time period residents of Plymouth and Cork Hill were exposed to the highest levels of ash.

Table 5.9 shows the distribution of the study group by presence of each symptom and by where they lived during 1997. Some subjects lived in more than one area during that time and so are included in the table more than once.

Table 5.9 Distribution of study group by residential area in 1997 and respiratory symptom occurrence. Each cell contains number *(percentage)* of subjects in each cell reporting each symptom

	Residential Area in 1997									
Symptom	**Plymouth**		**Cork Hill**		**Salem**		**Woodlands**		**North**	
Asthma	6	*16*	5	*11*	26	*20*	7	*26*	20	*11*
Breathlessness	7	*17*	8	*18*	29	*23*	7	*27*	29	*17*
Asthma attacks	4	*10*	1	*2*	9	*7*	3	*12*	14	*8*
Chronic bronchitis	4	*11*	4	*9*	19	*16*	2	*8*	28	*16*

There was no indication from these data that individuals who resided in the dustier areas of Montserrat during 1997 were more likely to report respiratory symptoms. Table 5.10 shows similar information for symptoms which were reported to have first occurred while the individual was resident on Montserrat. Again there was no evidence that residents of dustier areas were more likely to report symptoms which occurred while on Montserrat.

Table 5.10 Distribution of study group by residential area in 1997 and occurrence of symptoms which first occurred while on Montserrat. Each cell contains number *(percentage)* of subjects in each cell reporting each symptom

	Residential Area in 1997									
Symptom	**Plymouth**		**Cork Hill**		**Salem**		**Woodlands**		**North**	
Asthma	2	*6*	2	*5*	14	*11*	4	*15*	7	*4*
Breathlessness	2	*6*	2	*5*	11	*9*	2	*9*	11	*7*
Chronic bronchitis	0	*0*	1	*2*	4	*4*	0	*0*	9	*5*

An estimation of cumulative residential exposure in μg.months.m^{-3} was calculated for each individual based on their reported residential histories and estimates of the ash concentrations by time period and geographical area. Table 5.11 shows the mean level of residential exposure for the study group subdivided by presence/absence of respiratory symptoms. Mean residential exposure is also shown for the subgroup who reported symptoms which first occurred on Montserrat.

Table 5.11 Mean level of residential exposure by symptom occurrence (μg.months.m^{-3})

	Occurrence of symptoms		
Symptom	**No**	**Yes**	**On Montserrat**
Asthma	1338	1304	1452
Breathlessness	1369	1302	1415
Asthma attacks	1358	1443	-
Chronic bronchitis	1338	1329	1103

Table 5.11 shows that the mean level of residential exposure was similar for subjects with and without respiratory symptoms. For the few subjects who reported symptoms first occurring on Montserrat, residential exposures were slightly higher for those with asthma and breathlessness and lower for those reporting symptoms of chronic bronchitis. However, none of these differences was significant statistically.

Logistic regression analyses were carried out to examine simultaneously the effects of age, sex, smoking and residential exposure on the occurrence of respiratory symptoms. The results are summarised in Table 5.12. Results are expressed as the odds ratio for the risk of reporting each symptom, and its associated 95% confidence interval. For example an odds ratio of 1.20 represents a 20% increase in the risk of reporting a symptom. A statistically significant effect is seen where the 95% confidence interval for an odds ratio does not include the value one.

For none of the symptoms was there any evidence of an association with residential exposure, after adjustment for age, sex and smoking effects. Similar analyses of symptoms which first occurred on Montserrat also did not show any association between symptom occurrence and estimated residential exposure (results not shown here). For 168 subjects, residential exposure was based on less reliable data, due to missing information on residential area in some time periods. Results from the statistical models, including only those with reliable residential exposure data are shown in Table 5.13. No associations between exposure and symptoms were apparent. Examination of the association between symptoms and residential ash exposure for subjects subdivided by smoking group showed no evidence of a stronger exposure effect among smokers.

Table 5.12 Results from regression analysis of symptoms in relation to residential exposure. Each cell contains estimated odds ratio and 95% CI

	Asthma		**Breathlessness**		**Asthma attacks**		**Bronchitis**	
Age Group (vs <29)								
30-39	1.32	(0.4,4.5)	1.67	(0.7,4.3)	1.50	(0.4,6.1)	3.12	(1.2,8.3)
40-49	3.02	(1.4,6.7)	2.47	(1.2,5.0)	0.81	(0.2,2.7)	2.34	(1.0,5.2)
50+	1.71	(0.7,3.3)	1.15	(0.5,2.7)	2.71	(1.0,7.2)	1.20	(0.4,3.3)
Males (vs Females)	1.31	(0.6,2.7)	0.62	(0.3,1.2)	1.83	(0.8,4.3)	0.65	(0.3,1.4)
Smoking (vs Current)								
Ex	0.55	(0.1,3.7)	0.83	(0.2,4.4)	5.71	(0.4,75.7)	0.34	(0.1,2.2)
Non	0.43	(0.1,1.4)	0.45	(0.1,1.4)	1.65	(0.2,14.2)	0.16	(0.1,0.5)
Residential Exposure (per 1000 units)	1.04	(0.8,1.4)	1.05	(0.8,1.4)	1.20	(0.8,1.7)	1.08	(0.8,1.4)

Table 5.13 Results from regression analysis of symptoms in relation to residential exposure – restricted to subjects with reliable exposure data only. Each cell contains estimated odds ratio and 95% CI

	Asthma		**Breathlessness**		**Asthma attacks**		**Bronchitis**	
Age Group (vs <29)								
30-39	1.28	(0.3,5.1)	2.25	(0.8,6.5)	1.53	(0.3,8.3)	3.81	(1.2,12.4)
40-49	2.04	(0.8,4.9)	2.81	(1.3,6.2)	0.34	(0.1,2.1)	2.66	(1.0,6.9)
50+	1.42	(0.5,3.8)	0.88	(0.3,2.5)	2.43	(0.8,7.1)	1.36	(0.4,4.5)
Males (vs Females)	1.17	(0.5,2.7)	0.57	(0.2,1.3)	2.19	(0.8,5.9)	0.59	(0.2,1.6)
Smoking (vs Current)								
Ex	0.87	(0.1,8.0)	2.66	(0.3,23.5)	*	-	0.13	(0.0,1.6)
Non	0.39	(0.1,1.8)	0.86	(0.2,4.7)	*	-	0.08	(0.0,0.4)
Residential Exposure (per 1000 units)	0.99	(0.6,1.6)	1.06	(0.7,1.6)	1.06	(0.6,2.0)	1.39	(0.9,2.3)

*too few cases, by smoking group, for this term to converge

5.4.2 Symptoms and exposure from heavy ash clearing tasks

Individuals were asked how often they were involved in clearing large quantities of ash from buildings, roads or other surfaces. Table 5.14 shows the distribution of symptoms subdivided by the frequency of ash clearing work.

Table 5.14 Prevalence of respiratory symptoms by frequency of heavy ash clearing. Each cell contains number *(percentage)* with symptoms

Frequency of clearing of ash	Asthma		Breathlessness		Asthma Attacks		Chronic bronchitis	
Never	13	*10*	21	*16*	7	*5*	12	*9*
Once/twice a month	6	*9*	9	*14*	2	*3*	7	*11*
Once/twice a week	9	*10*	17	*19*	8	*9*	13	*16*
Daily (not as job)	22	*28*	18	*24*	8	*10*	18	*23*
Daily (as main job)	6	*26*	5	*23*	2	*8*	6	*27*

Asthma, breathlessness and chronic bronchitis were reported more often by individuals who cleared large quantities of ash daily (whether as a main job or not). Reports of asthma attacks were not as strongly related to the clearing of ash although the prevalence was slightly higher among those who reported clearing ash more than once a week.

Table 5.15 shows the same information for symptoms which first occurred on Montserrat. For asthma the prevalence among those clearing ash daily are around three times as high as among those who cleared ash less frequently. For breathlessness and chronic bronchitis increased prevalence is apparent among those who cleared ash daily, but not as main occupation. This was not the case for the relatively few subjects who cleared ash daily as a main occupation.

Table 5.15 Prevalence of respiratory symptoms first occurring on Montserrat, by frequency of heavy ash clearing. Each cell contains number *(percentage)* with symptoms

Frequency of clearing of ash	Asthma		Breathlessness		Chronic bronchitis	
Never	6	*5*	6	*5*	2	*2*
Once/twice a month	1	*2*	2	*4*	3	*5*
Once/twice a week	4	*5*	5	*6*	3	*4*
Daily (not as job)	10	*14*	9	*13*	6	*9*
Daily (as main job)	3	*15*	1	*5*	1	*5*

Estimated exposure due to heavy ash clearing was calculated from the reported frequency of ash clearing and estimated concentrations experienced during ash clearing tasks by time period. Table 5.16 summarises the mean level of exposure due to ash clearing tasks by presence/absence of symptoms, and for the subgroup whose symptoms started on Montserrat.

Table 5.16 Mean level of exposure due to heavy ash clearing by symptom occurrence ($\mu g.months.m^{-3}$)

	Occurrence of symptoms		
Symptom	No	Yes	On Montserrat
Asthma	5012	7930	10550
Breathlessness	5298	6072	7545
Asthma attacks	5222	7870	-
Chronic bronchitis	5071	8057	7566

For all four symptoms, mean exposure from heavy ash clearing was higher among those with symptoms than among those without; the differences were statistically significant for asthma and chronic bronchitis. For both asthma and breathlessness, the mean levels of heavy ash exposure were higher for those whose symptoms first occurred on Montserrat. For chronic bronchitis mean levels among those whose symptoms occurred on Montserrat were higher than among those without symptoms but no higher than all those reporting symptoms regardless of timescale.

Results from the logistic regression analyses of symptoms in relation to heavy ash exposure are shown in Table 5.17. For all symptoms except breathlessness, there was a statistically significant association between risk of reporting symptoms and estimated exposure to ash from heavy ash clearing activities, after adjustment for age, sex and smoking habit. The odds ratios associated with 1000 μg.months.m^{-3} were small, ranging from increases in risk of 5% (odds ratio 1.05) to 8%.

Table 5.17 Results from regression analysis of symptoms in relation to exposure due to heavy ash clearing tasks. Each cell contains estimated odds ratio and 95% CI

	Asthma		Breathlessness		Asthma attacks		Bronchitis	
Age Group (vs <29)								
30-39	1.44	(0.4,1.9)	1.80	(0.7,4.6)	1.71	(0.4,7.1)	4.51	(1.6,12.8)
40-49	3.36	(1.5,7.6)	2.33	(1.1,4.8)	0.96	(0.3,3.2)	3.44	(1.5,8.1)
50+	1.61	(0.5,4.8)	1.32	(0.5,3.3)	2.97	(0.9,9.4)	1.86	(0.6,6.2)
Males (vs Females)	0.94	(0.4,2.1)	0.57	(0.3,1.2)	1.38	(0.5,3.6)	0.56	(0.2,1.4)
Smoking (vs Current)								
Ex	0.49	(0.1,3.4)	0.72	(0.1,3.9)	5.95	(0.4,80.4)	0.27	(0.0,1.8)
Non	0.27	(0.1,0.9)	0.34	(0.1,1.1)	1.26	(0.1,11.3)	0.09	(0.0,0.3)
Heavy Ash Exposure (per 1000 units)	1.05	(1.00,1.09)	1.01	(0.97,1.05)	1.07	(1.01,1.13)	1.08	(1.03,1.13)

Table 5.18 shows the odds ratios associated with heavy ash exposure for symptoms which first occurred on Montserrat. For breathlessness and asthma the odds ratios increased slightly compared to all reported symptoms, and for breathlessness the association between symptoms first occurring on Montserrat and heavy ash exposure was significant statistically. For chronic bronchitis, the odds ratio for symptoms on Montserrat was lower than for all symptoms and was not statistically significantly associated with heavy ash exposure.

Table 5.18 Results from regression analysis of symptoms which first occurred on Montserrat in relation to exposure due to heavy ash clearing tasks. Results are from statistical models also including terms for age, sex and smoking. Each cell contains estimated odds ratio and 95% CI

	Asthma		Breathlessness		Bronchitis	
Heavy Ash Exposure (per 1000 units)	1.07	(1.00,1.13)	1.05	(0.99,1.11)	1.06	(0.99,1.14)

There was no evidence that the association between heavy ash exposure and respiratory symptoms varied between smoking groups.

5.4.3 Symptoms and exposure from domestic cleaning tasks

Each study participant was asked how often it was necessary to clean ash from inside the building in which they were living, during the three months before they left Montserrat. Table 5.19 shows the prevalence of symptoms by frequency of domestic ash cleaning.

Table 5.19 Prevalence of respiratory symptoms by frequency of domestic cleaning. Each cell contains number *(percentage)* with symptoms

Frequency of domestic cleaning	Asthma		Breathlessness		Asthma attacks		Chronic bronchitis	
Never	12	*11*	11	*10*	7	*6*	12	*11*
Once/twice a month	3	*7*	9	*23*	2	*5*	7	*18*
Once/twice a week	15	*19*	17	*21*	8	*10*	13	*18*
Once a day	6	*10*	11	*19*	4	*7*	7	*12*
More than once a day	20	*22*	22	*25*	6	*7*	17	*19*

There was no apparent trend of symptom prevalence with increasing frequency of domestic cleaning tasks. This was also the case if only symptoms which first occurred on Montserrat were considered (Table 5.20).

Table 5.20 Prevalence of respiratory symptoms first occurring on Montserrat, by frequency of heavy ash clearing. Each cell contains number *(percentage)* with symptoms

Frequency of domestic cleaning	Asthma		Breathlessness		Chronic bronchitis	
Never	4	*4*	3	*3*	3	*3*
Once/twice a month	1	*3*	3	*9*	2	*6*
Once/twice a week	8	*11*	8	*11*	4	*6*
Once a day	3	*5*	2	*4*	2	*3*
More than once a day	9	*11*	7	*9*	5	*5*

Estimated exposure due to domestic cleaning tasks was calculated using the information on frequency of cleaning and the residential histories of where each participant lived on Montserrat during each time period. Mean levels of domestic cleaning exposure by presence/absence of symptoms and for the subgroup whose symptoms first started on Montserrat are given in Table 5.21.

Table 5.21 Mean level of exposure due to domestic cleaning by symptom occurrence ($\mu g.months.m^{-3}$)

	Occurrence of symptoms		
Symptom	**No**	**Yes**	**On Montserrat**
Asthma	540	590	888
Breathlessness	544	610	715
Asthma attacks	573	579	-
Chronic bronchitis	548	642	521

There was little difference in exposure levels between those with and without respiratory symptoms. For asthma and breathlessness, average exposure levels were higher among those whose symptoms first started on Montserrat, but the differences were non-significant statistically.

Results from the logistic regression analyses of symptoms in relation to domestic cleaning exposure are shown in Table 5.22.

Table 5.22 Results from regression analysis of symptoms in relation to exposure due to domestic cleaning tasks. Each cell contains estimated odds ratio and 95% CI.

	Asthma		Breathlessness		Asthma attacks		Bronchitis	
Age Group (vs <29)								
30-39	1.28	(0.4,4.4)	1.66	(0.6,4.3)	1.46	(0.3,6.1)	3.53	(1.3,9.8)
40-49	2.82	(1.2,6.4)	2.28	(1.1,4.7)	0.88	(0.3,2.9)	2.79	(1.2,6.5)
50+	1.39	(0.5,3.8)	1.17	(0.5,2.9)	2.26	(0.8,6.5)	1.35	(0.5,4.0)
Males (vs Females)	0.89	(0.4,2.0)	0.56	(0.3,1.2)	1.48	(0.6,3.7)	0.56	(0.2,1.3)
Smoking (vs Current)								
Ex	0.52	(0.1,3.5)	0.74	(0.1,4.1)	5.31	(0.4,72.0)	0.27	(0.0,1.8)
Non	0.31	(0.1,1.0)	0.36	(0.1,1.2)	1.55	(0.1,13.9)	0.12	(0.0,0.4)
Domestic Exposure (per 1000 units)	1.04	(0.7,1.5)	1.11	(0.8,1.5)	1.19	(0.8,1.9)	1.12	(0.8,1.6)

After adjustment for age, sex and smoking there was no evidence that any respiratory symptoms were significantly related to domestic ash exposure. No associations were found if the analyses were restricted to those with more reliable residential data, nor if only symptoms which first occurred on Montserrat were included in the analysis. Nor was there any evidence that the results varied by smoking group.

5.4.4 Symptoms and occupational exposure

Of the 465 study respondents, 192 had never held any job on Montserrat. Of the remaining 273, 174 had held some jobs on Montserrat and had completed a lifetime occupational history, while for 99 subjects information on occupation was incomplete or missing. Of the 174 subjects who had been in employment on the island, relatively few had ever worked in the dustiest occupations following the eruption of the volcano in 1995 (Table 4.10 in section 4.4). Only nine subjects had worked in the five occupational groups with the highest exposures to volcanic ash – Montserrat Defence Force and Police, Port Workers, Gardeners, Roadworkers and Construction workers.

The prevalence of symptoms subdivided by OG is shown in Table 5.23. Four occupational categories have been used:

- High exposure group - Montserrat Defence Force and Police, Port Workers, Gardeners, Roadworkers and Construction workers
- Medium High exposure group – Utilities, Farmworkers, Drivers, Heliport Workers
- Medium Low exposure group – Housekeepers
- Low exposure group – all other jobs

Where an individual held jobs in more than one of the categories, they have been assigned to the highest exposure category in which they worked.

Table 5.23 Prevalence of symptoms by occupational category. Each cell contains number *(percentage)* with each symptom

Occupational category	Asthma		Breathlessness		Asthma attacks		Chronic bronchitis	
High	0	*0*	2	*25*	0	*0*	1	*14*
Medium High	1	*10*	2	*20*	1	*10*	1	*10*
Medium Low	2	*22*	3	*27*	0	*0*	3	*27*
Low	7	*12*	9	*16*	1	*2*	8	*14*

There was no evidence that individuals with symptoms tended to work in occupations with higher exposures to ash. None of the subjects with symptoms which first occurred on Montserrat had worked in High or Medium High exposure jobs.

An estimated occupational exposure to volcanic ash was calculated for each subject who had been in employment. Table 5.24 shows the mean occupational exposure level by presence/absence of symptoms and for the subgroup whose symptoms first occurred on Montserrat. For asthma and asthma attacks, occupational exposures were lower among those with symptoms than among those without. In contrast, for breathlessness occupational exposures were higher among those reporting symptoms, while for chronic bronchitis exposures were similar in the two groups.

Table 5.24 Mean level of occupational exposure by symptom occurrence (µg.months.m^{-3})

	Occurrence of symptoms		
Symptom	**No**	**Yes**	**On Montserrat**
Asthma	339	117	114
Breathlessness	277	529	207
Asthma attacks	339	91	-
Chronic bronchitis	310	309	197

Table 5.25 summarises the same information for those who had some occupational exposure (i.e. excluding unexposed subjects). Among the exposed individuals, similar patterns were seen as for all those with occupational exposures. For asthma and asthma attacks, exposure levels were lower among those with symptoms, and for breathlessness they were lower among those without.

Table 5.25 Mean level of occupational exposure by symptom occurrence (µg.months.m^{-3}). Subjects with non-zero occupational exposure only

	Occurrence of symptoms		
Symptom	**No**	**Yes**	**On Montserrat**
Asthma	1231	628	608
Breathlessness	1048	1852	1035
Asthma attacks	1201	1140	-
Chronic bronchitis	1212	928	525

The results from the logistic regression analyses of symptoms in relation to occupational exposure are shown in Table 5.26. Results from the regression analyses show that there was an association between risk of reporting breathlessness and occupational exposure with an odds ratio per 1000 µg.months.m^{-3} of 1.39 (95% CI: 1.01,1.90). None of the other symptoms were related to occupational exposure.

Table 5.26 Results from regression analysis of symptoms in relation to occupational exposure. Each cell contains estimated odds ratio and 95% CI.

	Asthma		Breathlessness		Asthma attacks		Bronchitis	
Age Group (vs <29)								
30-39	1.45	(0.3,6.4)	1.07	(0.3,3.5)	*	-	1.22	(0.3,5.0)
40-49	4.53	(1.6,12.4)	2.09	(0.9,5.1)	1.49	(0.4,5.5)	1.43	(0.5,4.4)
50+	1.24	(0.4,3.5)	1.08	(0.4,2.7)	1.88	(0.6,5.5)	1.10	(0.4,3.3)
Males (vs Females)	1.11	(0.5,2.6)	0.45	(0.2,1.1)	2.22	(0.9,5.6)	0.27	(0.1,0.9)
Smoking (vs Current)								
Ex	0.31	(0.0,5.5)	0.06	(0.0,1.1)	0.97	(0.0,22.3)	0.23	(0.2,2.9)
Non	0.34	(0.1,2.1)	0.10	(0.0,0.6)	0.65	(0.1,7.4)	0.02	(0.0,0.2)
Occupational Exposure (per 1000 units)	0.38	(0.11,1.27)	1.39	(1.01,1.90)	0.61	(0.2,1.8)	0.98	(0.60,1.58)

*Did not converge due to sparsity of data

Regression analyses were also carried out for symptoms which first occurred on Montserrat and for subjects with non-zero exposures. The results are summarised in Table 5.27.

Table 5.27 Results from regression analysis of symptoms which first occurred on Montserrat in relation to occupational exposure and results for subjects with non-zero exposures. Results are from statistical models also including terms for age, sex and smoking. Each cell contains estimated odds ratio and 95% CI

	Asthma		Breathlessness		Asthma attacks		Bronchitis	
All exposure: Symptoms first on Montserrat	0.37	(0.1,2.3)	1.07	(0.4,2.6)	-	-	0.88	(0.2,3.9)
Non-zero exposure:								
All symptoms	0.26	(0.0,2.2)	1.51	(0.9,2.5)	0.84	(0.3,2.1)	0.39	(0.1,1.7)
Symptoms first on Montserrat	0.11	(0.0,4.9)	3.35	(0.4,30.7)	-	-	0.34	(0.1,14.6)

For none of the symptoms was there any evidence of an association between occupational exposure (overall, or among those who had non-zero exposures) with risk of reporting all symptoms or symptoms which first occurred on Montserrat, nor of different associations between smoking groups or between men and women.

5.4.5 Symptoms and total exposure to volcanic ash

For just over half of the study group (240; 52%) estimated exposure levels were available for residential, occupational, heavy ash clearing and domestic cleaning tasks. For 59 of these individuals, the residential and domestic cleaning exposures were based on less reliable data. Total exposure to volcanic ash was calculated for these 240 subjects, and ranged from 0 to 34672 μg.months.m^{-3}. The distribution of total ash exposure was strongly dominated by exposures due to heavy ash clearing, and all those with very high total exposures had very high heavy ash clearing exposures. Table 5.28 shows the mean exposure levels by presence/absence of symptoms and for symptoms which first occurred on Montserrat.

Table 5.28 Mean level of total exposure to volcanic ash by symptom occurrence (µg.months.m^{-3})

	Occurrence of symptoms		
Symptom	**No**	**Yes**	**On Montserrat**
Asthma	7393	10715	17766
Breathlessness	7687	9244	12323
Asthma attacks	7803	8689	-
Chronic bronchitis	7656	9234	13023

For all symptoms, total exposure was higher among those with symptoms than among those without, and highest for those with symptoms which first occurred on Montserrat. The differences were statistically significant for asthma only.

Results from the logistic regression analyses of total ash exposure are summarised in Table 5.29. All the odds ratios for the effect of total exposure are greater than one (for all four symptom complexes and for symptoms overall and those which first occurred on Montserrat), but they vary in size and in statistical significance. For all four symptoms, the odds ratios associated with total ash exposure were higher when the analyses were restricted to subjects with reliable data, and were higher for symptoms which first occurred on Montserrat than for all symptoms. For asthma and chronic bronchitis, there was a statistically significant association with total ash exposure for symptoms regardless of timescale, but for the reliable data subset only. For asthma and breathlessness, risk of symptoms which first occurred on Montserrat increased significantly with increasing total ash exposure, in analyses of all subjects and, more strongly, in analyses of subjects with reliable exposure data.

Table 5.29 Results from regression analysis of all symptoms and symptoms which first occurred on Montserrat in relation to total ash exposure. Results are from statistical models also including terms for age, sex and smoking. Each cell contains estimated odds ratio and 95% CI

	Asthma		**Breathlessness**		**Asthma attacks**		**Bronchitis**	
All subjects								
All symptoms	1.03	(0.98,1.08)	1.02	(0.97,1.06)	1.03	(0.97,1.10)	1.04	(0.98,1.10)
Symptoms first on Montserrat	1.10	(1.02,1.19)	1.09	(1.01,1.17)	-	-	1.08	(0.98,1.19)
Reliable data only:								
All symptoms	1.05	(1.00,1.12)	1.03	(0.98,1.09)	1.06	(0.99,1.15)	1.07	(1.00,1.14)
Symptoms first on Montserrat	1.12	(1.03,1.23)	1.13	(1.03,1.24)	-	-	1.10	(0.98,1.24)

More detailed examination of the associations between total exposure to volcanic ash and respiratory symptoms showed no differences between smoking groups.

5.5 SUMMARY OF RESULTS

i. Responses were achieved from 465 individuals, around 25% of the eligible study population. Of these 39% were male and 60% were female (1% did not give information on gender); 22% of the study group were children (aged less than 16).

ii. Most of the study group were non-smokers (91%); prevalence of smoking was higher among men (22%) than women (1%); and higher among older subjects.

iii. Prevalence of symptoms ranged from 7% (asthma attacks) to 18% (breathlessness). Asthma and chronic bronchitis were reported by 14% of the study group. Symptoms were more prevalent in current smokers and among older subjects, with the exception of asthma attacks which were most common in children.

iv. No association was found between risk of reporting symptoms and exposure due to place of residence on the island or due to domestic cleaning of the house in which they lived.

v. Prevalence of asthma, breathlessness and chronic bronchitis were higher among those who carried out heavy ash clearing activities daily. Risk of reporting asthma, chronic bronchitis and asthma attacks were statistically significantly related to exposure from heavy ash clearing tasks. The increases in risk were small (5% to 8% for an exposure of 1000 μg.months.m^{-3}). Risks of reporting these symptoms were increased, but not significant statistically, for symptoms which first occurred on Montserrat.

vi. The risk of reporting breathlessness was significantly increased among those with higher occupational exposures, but this increase was not evident in analyses of the relatively few subjects who reported symptoms of breathlessness which first occurred while they were on Montserrat.

vii. Total exposure to volcanic ash could be calculated for 52% of the study group. Among these individuals, asthma and symptoms of breathlessness which first occurred on Montserrat were significantly associated with increasing total ash exposure in both analyses of all subjects and analyses restricted to subjects with reliable exposure data only. Asthma and chronic bronchitis were significantly related to total exposure, in the subgroup with reliable data only.

6. DISCUSSION

6.1 BACKGROUND TO THE STUDY AND STUDY DESIGN

The volcanic eruptions on the island of Montserrat since July 1995 have resulted in dust deposits throughout the island. The southern area of the island is now uninhabitable, and former residents have moved to the north of the island or have left Montserrat. Many residents of Montserrat who left the island following the eruptions have settled in the UK. Analyses of the volcanic ash to which Montserratians have been exposed shows that the cristobalite content of the ash varied from below 5% to 20%, dependent on the type of volcanic activity, with pyroclastic flows giving rise to much higher proportions of cristobalite than explosions (Baxter *et al*, 1999). Concentrations of dust in the northern part of Montserrat have been similar to those in the UK air and probably close to normal background concentrations on a Caribbean island. Concentrations elsewhere on the island have been much higher and it is possible that a few individuals may have been exposed to sufficient levels of volcanic dust to lead to the onset of mild silicosis (Searl and Nicholl, 1997; Searl, 1998; Searl, 2000; Searl *et al*, in prep). A study has also been carried out of the respiratory health of schoolchildren on the island (Baxter *et al*, 1998), which found that children of under 12 years were more likely to have wheeze and asthmatic symptoms if they had been exposed to ash within the last 12 months.

Further studies were therefore planned to look at the health status of the population of Montserrat more generally. The current study was commissioned to describe the health status and exposure history of Montserratians who had relocated to the UK; a second study describing the health of Montserratians who remained on the island has also been commissioned and will be reported separately. Because of the relatively short timescale since exposure began, and the rate at which disease is likely to develop, it is unrealistic to try to get a full picture of any adverse effects on people's health already. It is timely however to seek early warning or early reassurance about what effects might be expected eventually. The focus of the current study therefore was to obtain early warning of any respiratory ill-health problems of Montserratians in the UK, as a starting point for any more detailed investigations, if appropriate.

Respiratory health of a population can be investigated in a number of ways including radiology, lung function testing and/or a respiratory symptoms questionnaire. In this study we considered that the inclusion of a radiological or lung function survey was unwarranted and impractical at this time for several reasons. Radiology is relevant, because silicosis is a serious disease arising from exposure to crystalline silica. However, given the nature and likely patterns of individuals' exposure to ash, the risks that people in the study group would ever develop silicosis are small; and if silicosis were to occur it could take many more years to become apparent. Also, there are other reasons for early radiological signs (low profusion of small opacities) and any exposure-response associations with ash from the island would be likely to be weak. Finally, the study population is spread throughout the UK and there are enormous practical difficulties, and costs, in surveying in a standardised manner (for both lung function and radiology) a population that is so scattered geographically. The opportunities for studying radiological and lung function effects are much better for people still on the island and this is being done as part of the companion study.

On the other hand, a postal questionnaire is an easy way of accessing the population within a relatively short time period and at a reasonable cost. A questionnaire study would enable the collection of information on symptoms, smoking habits, occupation and other factors relevant to personal levels of exposure to volcanic ash and personal details, which would allow the establishment of baseline levels of self-reported respiratory ill health in the study group, and a first assessment of exposure-response relations. The disadvantages of a questionnaire include possible low response and, because reporting of health outcomes by questionnaire is subjective, aware or unaware biases. Self-administered questionnaires also need to be carefully designed to be comprehensible without anybody being available at time of completion to explain anything that seems unclear or to check for inconsistencies.

All things considered therefore we felt that a postal questionnaire survey was the most relevant and value-for-money option, good enough to meet the aims of the study and efficient of resources.

6.2 STUDY POPULATION

The target study population was all Montserratians who had relocated to the UK. However, as no official records exist of this group, the study was based on Montserratians whose details were known to the Montserrat Community Support Trust. The MCST is a government-funded organisation set up to provide help and advice to Montserratians living in the UK. It is staffed by former residents of Montserrat, and its involvement in and support for the current study was beneficial in easing mistrust of UK officialdom among the Montserratian community. In an attempt to maximise the survey response, the questionnaires were sent out by and returned to the MCST, who were available to answer any general queries about the survey. Information about the study was also published in the community newsletter. In addition, following the mailing of the survey questionnaire, a series of meetings was held across the country where respondents were encouraged to participate in the survey. Nevertheless the response for the current survey was low, with around one quarter of those to whom questionnaires were posted returning completed questionnaires. For this and other reasons, it is important to consider the representativeness of the study participants.

The Montserratians who relocated to the UK are very likely to be different from those remaining on Montserrat. In particular, women, children and those with existing respiratory conditions were encouraged to leave the island after the first serious volcanic eruption, while those employed in occupations directly involved with the consequences of the eruption (e.g. police, roadworkers etc) were more likely to remain on the island. The target study population was therefore not representative of all Montserratians affected by the volcano. While this does not affect the aims of the study, which were specifically targeted at Montserratians who relocated to the UK, it has implications for the generalisation of results to the Montserratian population as a whole. In particular it is possible that the current study population was more susceptible, on average, to respiratory disease, but was likely to have worked for shorter lengths of time in dusty jobs. This is reflected in the very small number of individuals in this study who had worked in any dusty jobs after the eruption in 1995.

The next level of selection involves how representative the Montserratians on the MCST register are of all Montserratians in the UK. There are no data available to examine this directly, and we are unable to draw any conclusions on the representativeness of the MCST database of Montserratians in the UK more generally.

Thirdly, we consider how representative the study respondents are of all Montserratians registered with the MCST. Similarly no direct information is available for those who were sent questionnaires but did not respond. However, many studies of non-response have been reported which include investigation of any relationship between non-response and health status. It might be considered, on general grounds, that individuals who show concern about their health are more likely to participate in surveys pertaining to illness, leading to increased estimates of prevalence. However, if so, this does not necessarily always apply. For example, Walsh (1994) reported no difference in consultation rates for back pain among GP records of responders and non-responders to a postal survey of back pain. Another study of respiratory health in relation to response among US underground coalminers found no association between respiratory symptoms and questionnaire return (Trent and Ames, 1987). Finally a postal survey of a general population sample carried out by the IOM in 1994, using a questionnaire very similar to that used in the present study carried out three rounds of mailings, some time apart, to the study population. Comparisons of responders to the first and second mailings with responders to the third mailing (as the best representatives of the non-responders for whom health data were available) showed few differences. In fact, a small increase in the prevalence of respiratory symptoms (statistically non-significant) among responders to the third mailing did not support the hypothesis of preferential, or early, response among those with ill-health (Cowie *et al*, 1997).

Finally, within the responders, there were some exclusions because of incomplete questionnaire responses, particularly in the estimation of exposure variables. Exposures were estimated for as many respondents as possible, where necessary making estimations based on the incomplete data provided. Key analyses were carried out for the full study population and for the sub-group with reliable exposure data. Differences in the findings were small. In addition comparison of the demographic and health data of those with and without complete exposure data showed that although those with full exposure information were younger on average than those without, there was no evidence of differences in health status between the two groups.

Overall, therefore the identification and low response of the study group may have led to some selection and non-response bias in the estimation of respiratory symptom prevalence. Where such biases have occurred they are more likely to have resulted in an increase in prevalence, because those Montserratians who relocated to the UK were more likely to be susceptible to respiratory illness, and those with respiratory symptoms may have been more likely to respond to the survey questionnaire. However, the selection and non-response effects are less likely to have affected any exposure-response associations (Gauld *et al*, 1988). Exposure-response associations were examined *within* the study group, with respondents with lower exposure levels acting as internal controls. Such calculations should be less affected by selection or response biases. Insofar as they are affected, the combination of higher symptom prevalence and low exposures could over-estimate any effects of ash exposure on respiratory health in the study group compared with the general Montserratian population.

6.3 DATA RELIABILITY

The data analysed in the current study were from two sources – information on symptoms, smoking habit, residential and occupational histories from the postal questionnaire and information on volcanic ash concentrations, by area and time period, from the dust sampling exercises carried out on the island.

An important issue to consider in the interpretation of the data collected using postal questionnaires is the subjectivity of the results, and any potential biases that might result from this. For example an individual who believed his symptoms were caused by exposure to ash might tend to report more respiratory symptoms and higher levels of exposure. To minimise the possibility of bias, the questionnaire was designed to ask indirect questions relevant to exposure levels (notably history of place of residence on Montserrat and detailed occupational history) which were then linked to the dust concentration data to calculate estimated individual exposures to ash. In this way, the exposure of individuals as used in this study was at least in part concealed from the participants. However, some aspects of exposure (in particular, frequency of heavy ash clearing and of domestic cleaning) were reported directly by the participants. The implications of this for the interpretation of the study results are discussed in more detail below (section 6.4). The definition of respiratory symptom complexes depended entirely on the answers to specific questions by the participants and so the prevalences reported are those for self-reported symptoms.

The majority of the study group completed all the health questions with relatively little missing data. Questions on the time period during which the symptoms first occurred were less consistently answered, with ambiguous information provided in a number of cases. Limited information from the few subjects reporting symptoms in the pilot study had not indicated any confusion or misunderstanding with these questions. Analyses of symptoms which first occurred on Montserrat are therefore based on the relatively few subjects, with respiratory symptoms, who answered the timescale questions unambiguously. Consequently much of the analysis reported is based on the presence of symptoms regardless of timescale.

The data provided on symptoms regardless of timescale was on the whole filled in correctly, and associations with age and smoking habit were biologically plausible (prevalence higher in the younger

and older age groups and higher among the relatively few current smokers) providing reassurance on the reliability and accuracy of these data.

6.4 KEY FINDINGS AND THEIR IMPLICATIONS

The prevalence of specific respiratory symptoms ranged from 7% of the study group with asthma attacks, through 14% with asthma symptoms and 14% with chronic bronchitis, to 18% with symptoms of breathlessness. In all, 30% of respondents reported one or more of the defined respiratory symptom complexes.

It is difficult to put the results in context. Comparisons of prevalence with general population figures are difficult and are complicated by differences in factors such as age structure, smoking habits and study methods. Nevertheless, and despite the low proportion of tobacco smokers, results suggest somewhat higher prevalences in the Montserratians in the UK than in the general UK population. Asthma prevalence in the general population in the UK is reported at 5% (Anderson, 1992), although this does not take account of the reported increase in prevalence in young adults over the last decade. Reported prevalence for chronic bronchitis has shown a downward trend in the UK since the 1950s when 20-30% prevalence rates were reported, with currently reported prevalences of up to 8% in men and slightly less in women (Calverley and Pride, 1995). Additionally, results from a survey of a random sample of the general population in West Lothian in Central Scotland, using the same symptom definitions as here, reported a prevalence of 8% for asthma, 5% for asthma attacks and 15% for chronic bronchitis (Cowie *et al*, 1997). While the prevalence of chronic bronchitis is similar in the current study and in the West Lothian study, a higher proportion of the West Lothian study group were current or ex-smokers. Comparisons of prevalence of chronic bronchitis within smoking group show higher levels among the Montserratians for both non-smokers (12% compared to 7% in the West Lothian group) and the relatively few current smokers (52% compared to 32% in the West Lothian group).

There are several reasons why this might have occurred. As discussed previously, the Montserratians who relocated to the UK may represent islanders who were more susceptible to respiratory effects of ash, so that the prevalence reported in the current study is likely to be at the high end of the estimated prevalence among all Montserratians. Other study selection effects may have exacerbated the difference. Also, the current study group had recently been displaced to a new country, with different climate conditions and different population immunities. We had intended to investigate this by finding out information on the timescale of the first occurrence of symptoms. As noted earlier, this was incomplete. However, around 3% to 4% of subjects reported symptoms first occurring after arrival in the UK, and taking account of non-response the true proportion is higher. This gives some support to the view that factors associated with the migration itself played a part.

Another possible explanation is that any excess of respiratory symptoms or disease was at least in part the result of exposure to ash and our principal aim was to get an indication of whether and to what extent this was true. While the comparisons of general prevalence above give some insights – for example with 70% of the study group not reporting any symptom complex, there is not a gross epidemic of respiratory ill-health among Montserratians who now live in the UK – the best information was given by analyses of the occurrence of symptoms in relation to estimated exposure to volcanic ash. These analyses, while still potentially affected by the subjectivity of the questionnaire data, are unlikely to be seriously affected by selection bias.

The exposure-response analyses of symptoms showed the expected relationships with age and smoking habit, and also showed evidence of association between each of the respiratory symptom complexes and exposure due to heavy ash clearing and total exposure to volcanic ash. These findings were apparent for the whole study population and also for those respondents with exposure data which was judged to be most reliable. Similar patterns were also seen for analyses restricted to symptoms which first occurred on Montserrat. Very few of the Montserratians surveyed had worked in the most

dust-exposed jobs on the island and so there was little information available from this study on the effects of occupational exposure.

These results for heavy ash exposure and for total exposure were not independent in that the heavy ash exposures were orders of magnitude higher than exposures due to other factors (e.g. domestic cleaning and place of residence on Montserrat) and as such dominated the total exposure variable. It is important also to note that heavy ash exposure was the most subjective of the exposure measurements estimated, being based strongly on the responses to one question on the frequency of heavy ash clearing, weighted according to the time periods during which the individuals resided on the island.

Nevertheless, an association between heavy ash exposure and respiratory symptoms is biologically plausible. Around a quarter of the study group reported clearing quantities of ash greater than 1mm thickness from buildings, roads or other surfaces daily, and of these a third said that they did not wear a dust mask when clearing ash, or wore one less than half the time. Even among those who did wear dust masks, the masks may not have been fitted properly and may have provided less protection than expected.

Overall, the prevalence of respiratory ill-health among the participants in this study seems somewhat higher than in the general UK population. There are several possible contributing factors. Among these, there is plausible evidence of an association between heavy ash exposure and the occurrence of these symptoms, but no evidence that other exposures increased symptoms occurrence. We think it likely therefore that any increase in the risk of silicosis is small, though we did not investigate silicosis directly. The companion study will help to clarify this.

The study does not provide clear guidance on the need for future studies of the population. If there had been no evidence, or strong evidence, of an excess of symptoms and an association with ash exposure then it would have been clear whether or not a follow-up study was warranted. As it is, we consider that the results of the current study suggest that there may be a case for a follow-up questionnaire study of this group in some years time. The results of the companion study of Montserratians on the island, available in a few months time, will provide additional information which will help in deciding whether further follow-up is justified.

7. REFERENCES

Anderson HR. (1992). Epidemiology of asthma. British Journal of Industrial Medicine; 47: 99-104.

Baxter P, Jarvis D, Potts J (1998). Respiratory health of schoolchildren currently living in Montserrat. In: The health effects of volcanic ash on Montserrat: an emergency response. Edinburgh: Institute of Occupational Medicine.

Baxter PJ, Bonadonna C, Dupree R, Hards VL, Kohn SC, Murphy MD, Nicols A, Nicholson RA, Norton G, Searl A, Sparks RSJ, Vickers BP (1999). Cristobalite in volcanic ash of the Soufriere Hills Volcano, Montserrat, British West Indies. Science; 283: 1142-1145

Calverley PMA, Pride NB (eds.) (1995). Chronic obstructive pulmonary disease. London: Chapman and Hall.

Collett D. (1991). Modelling binary data. London: Chapman and Hall.

Cowie HA, Prescott GJ, Beck J, Hutchison PA, Middleton WG, Miller BG, Ritchie P J, Soutar CA, Wright SC. (1997). Community-based epidemiological study of the relations of asthma and chronic bronchitis with occupation. Final report on HSE contract no. HPD/126/142/93. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/97/01).

Draper NR, Smith H. (1998). Applied regression analysis. 3rd ed. New York: John Wiley.

Gauld SJ, Hurley JF, Miller BG. (1988). Differences between long-term participants and non-responders in a study of coalminers' respiratory health and exposure to dust. Annals of Occupational Hygiene; 32(suppl 1):545-551.

Health and Safety Executive (1997). General methods for the gravimetric determination of respirable and total inhalable dust. Methods for the Determination of Hazardous Substances; 14/2

Health and Safety Executive (1994). Cristobalite in respirable airborne dusts. Methods for the Determination of Hazardous Substances; 76

International Union Against Tuberculosis and Lung Disease. (1986). Bronchial symptoms questionnaire. Paris: IUATLD

Medical Research Council, Committee on Environmental and Occupational Health. (1986). Questionnaire on respiratory symptoms (1986); with instructions to interviewers. London: MRC.

Office for National Statistics. (1997). UK standard industrial classification of economic activities 1992. London: The Stationery Office.

Office of Population Censuses and Surveys. (1990). Standard occupational classification. Vol.1: Structure and definition of major, minor and unit groups. London: HMSO.

Scott AJ, Groat S, Lorenzo S, Waclawski ER, Spankie S, Sewell C, Hurley JF, Hutchison PA. (1993). Cross sectional study of skin complaints and respiratory symptoms in workers in the furniture upholstery industry. Final report on HSE contract 1/HPD/126/275/91. Edinburgh: Institute of Occupational Medicine. (IOM Report TM/93/02).

Searl A, Nicholl A (1997). Assessment of the exposure of the population of Montserrat to volcanic ash containing cristobalite. Unpublished IOM report (P752) prepared for the Department for International Development.

Searl A (1998). Air quality monitoring on Montserrat March-August 1998. Unpublished IOM report (752-400) prepared for the Department for International Development.

Searl A (2000). Survey of personal exposures to volcanic ash on Montserrat. Unpublished IOM report (119-502) prepared for the Department for International Development.

Searl A, Baxter P, Nicholl A (in preparation). Assessment of the exposure of islanders to ash from the Soufriere Hills volcano, Montserrat, British West Indies. submitted to Occupational and Environmental Medicine

Trent RB, Ames RG. (1987). Respiratory health as a predictor of questionnaire return in a sample of United States underground coalminers. British Journal of Industrial Medicine; 44: 407-411.

Walsh K. (1994). Evaluation of the use of general practice age-sex registers in epidemiological research. British Journal of General Practice; 44: 118-122.

8. ACKNOWLEDGEMENTS

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APPENDIX 1 RESPIRATORY SYMPTOMS QUESTIONNAIRE

A SURVEY OF MONTSERRATIANS IN THE UK

HEALTH QUESTIONNAIRE

This section will be removed before the questionnaire is sent to the IOM

ID no:	

PLEASE COMPLETE YOUR DETAILS BELOW**:**

Name:	
Address:	
Date of birth:	

INTRODUCTION

The Institute of Occupational Medicine is an independent charity that carries out research into work-related and environmental health problems.

We are conducting a survey of the health of people who lived on Montserrat and have now moved to the UK. To help us do this, we would be grateful if you would fill in this questionnaire.

One health questionnaire should be filled in for each member of the household (including children). You may help your child fill it in, or complete it for your child if necessary.

All the information you give us will be treated in strict confidence and used only by medical researchers to study health in this group of people.

The Montserrat Community Support Trust fully supports the survey, and will be responsible for the distribution of the questionnaires. **All personal details (name, address, date of birth) will be held only by the Montserrat Community Support Trust and will be removed from the questionnaires before they are passed to the IOM.** At the end of the study the personal details will be transferred to the Health Department of the Montserrat Government

By completing and returning the questionnaire you are indicating that you are willing for MCST to store your data and for the anonymised data to be sent to the Institute of Occupational Medicine. Your answers will be put with others and analysed without any identifying information.

INSTRUCTIONS

1. For most of the questions there is a list of possible answers with a box printed beside each one. Please choose your answer and put a tick in the box beside it, for example:

	Yes	No
	✓	

2. There are instructions after some questions which allow you to miss out certain questions. Please follow these carefully.

3. If you are unsure of the answer to any of the questions, please answer 'No'.

ID Number	

SECTION A: QUESTIONS ABOUT CHEST SYMPTOMS

	Yes	No
1. At any time since you came to the UK have you had wheezing or whistling in your chest?	☐	☐
2. At any time since you came to the UK have you woken up with a feeling of tightness in your chest first thing in the morning?	☐	☐
a. At any time since you came to the UK have you had an attack of shortness of breath that came on during the day when you were not doing anything strenuous?	☐	☐
4. At any time since you came to the UK have you been woken at night by an attack of shortness of breath?	☐	☐

If 'NO' to ALL of questions 1,2,3 and 4 please go to SECTION B ⟶

5. Thinking about your chest symptoms as a whole, what has happened to them since you came to the UK, compared to when you were on Montserrat?

(Please ✓ one box)

- They have improved ☐
- They have stayed the same ☐
- They have got worse ☐
- They have only started since I arrived in the UK ☐

6. In which month and year did you first experience any of these symptoms?

	Month	Year
	☐☐	☐☐

For example June 1997 is ☐☐ ☐☐

SECTION B: QUESTIONS ABOUT BREATHLESSNESS

		Yes	No
7.	Do you get short of breath walking with other people of your own age on level ground?	☐	☐

If 'NO' to question 7 go to SECTION C ⟶

8. Thinking about your shortness of breath, what has happened to it since you came to the UK, compared to when you were on Montserrat?

(Please ✓ one box)

- It has improved ☐
- It has stayed the same ☐
- It has got worse ☐
- It has only started since I arrived in the UK ☐

9. In which month and year did you first experience shortness of breath? Month ☐☐ Year ☐☐

SECTION C: QUESTIONS ABOUT ASTHMA

		Yes	No
10.	Have you **ever** had an attack of asthma?	☐	☐
11.	Have you had an attack of asthma at any time **since you came to the UK**?	☐	☐
12.	Have you ever been told by a doctor that you have asthma?	☐	☐
13.	Are you currently taking medicines for asthma (including inhalers or tablets)?	☐	☐

SECTION D: QUESTIONS ABOUT COUGH AND PHLEGM

		Yes	No
14.	Do you usually cough up mucus from your chest (phlegm) first thing in the morning?	☐	☐
15.	Do you usually cough up mucus from your chest (phlegm) during the day - or at night?	☐	☐

If 'NO' to questions 14 and 15 go to SECTION E ⟶

		Yes	No
16.	Do you cough up mucus from your chest (phlegm) like this on most days for as much as three months each year?	☐	☐

If 'NO' to question 16 go to SECTION E ⟶

17. Thinking about your coughing up mucus from your chest (phlegm), what has happened to it since you came to the UK, compared to when you were on Montserrat?

(Please ✓ one box)

- It has improved ☐
- It has stayed the same ☐
- It has got worse ☐
- It has only started since I arrived in the UK ☐

18. In which month and year did you first experience it?

Month ☐☐ Year ☐☐

SECTION E: QUESTIONS ABOUT SMOKING HABITS

	Yes	No
19. Have you ever smoked as much as one cigarette a day (or one cigar a week or an ounce of tobacco a month) for as long as a year?	☐	☐
20. Do you smoke now?	☐	☐

SECTION F: QUESTIONS ABOUT MONTSERRAT

21. In which month and year did you **first** come to the UK from Montserrat?

Month ☐☐ Year ☐☐

22. Have you ever returned to Montserrat since you first came to the UK?

(Please ✓ one box)

- Never ☐
- For less than one month ☐
- For one month or more ☐

23. Where on Montserrat did you live from July 1995 onwards?

Please tick the place in which you lived for most of the time in each time period

Place name		July to Dec 1995	During 1996	Jan to June 1997	July to Dec 1997	During 1998
Plymouth	*1*					
Cork Hill	*2*					
Salem/Old Towne	*3*					
Olveston/Woodlands	*4*					
St Peters/ Cavalla Hill/ Brades/ Davy Hill	*5*					
St Johns	*6*					
Kinsale / St Patricks	*7*					
Harris/ Spanish Point/Long Ground	*8*					
Not in Montserrat	*9*					

24. Since 1995, how often were you involved in clearing large quantities of ash (greater than 1mm in thickness) from buildings, roads or other surfaces?

(*Please ✓ the box that most applies)*

- Never ☐
- Once or twice a month ☐
- Once or twice a week ☐
- Every day (but not as main occupation) ☐
- Every day as main occupation ☐

If 'NEVER' to question 24 go to question 26 →

25. How often did you use a dust mask when clearing large quantities of ash?

(Please ✓ the box that most applies)

- Never ☐
- Less than half the time ☐
- More than half the time ☐
- Always ☐

26. During the 3 months before you left Montserrat how often was it necessary to clean volcanic dust from inside the building where you were living at the time?

(*Please ✓ the box that most applies)*

- Never ☐
- Once or twice a month ☐
- Once or twice a week ☐
- Once a day ☐
- More than once a day ☐

SECTION G: QUESTIONS ABOUT YOUR WORK

	Yes	No
27. Have you ever been in paid employment?	☐	☐

If 'NO' to question 27 go to SECTION H ⟶

Please could you tell us about all of the (part or full-time) jobs you have ever had in Montserrat or in the UK, giving details as shown in the example. Start with your first job after leaving school and list them in order. Please continue on a separate sheet if necessary.

Date started	Name of Employer	Nature of Employer's Business	Place of work	For IOM use only
March 1994	*Ideal Furniture Ltd*	*Upholstery*	*St Johns*	
Date ended	**Full job title**	**Main things done in job**		**For IOM use only**
June 1996	*Cutter*	*Cutting up fabrics*		

FIRST JOB SINCE LEAVING SCHOOL

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

SECOND JOB

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

THIRD JOB

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

FOURTH JOB

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

FIFTH JOB

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

SIXTH JOB

Date started	Name of Employer	Nature of Employer's Business	Place of work	
Date ended	**Full job title**	**Main things done in job**		

Please continue on a separate sheet if necessary

SECTION H: QUESTIONS ABOUT YOURSELF

Your age in years: ☐ **Your sex - F for female, M for male:** ☐

Today's date: Day ☐☐ Month ☐☐ Year ☐☐

THAT IS THE END OF THE QUESTIONNAIRE. THANK YOU VERY MUCH FOR FILLING IT IN. PLEASE SEND IT BACK IN THE ENVELOPE PROVIDED.

PLEASE REMEMBER TO COMPLETE A QUESTIONNAIRE

FOR EACH MEMBER OF YOUR HOUSEHOLD

APPENDIX 2: CODING OF PLACE NAMES IN MONTSERRAT

01 Plymouth/Glendon/Dagenham

includes:

Dagenham
Richmond
Lovers Lane
Wall Street
Harvey Street
Parliament Square
Church Road
George Street
Groves
Parsons Road
Parson
Amersham

02 Corkhill

includes:

Foxes Bay
Devlins
Belham
Isles Bay
Condominium
Lees
Molyneux
Georges Hill
Weekes

03 Salem/Old Towne

includes:

Friths

04 Olveston/Woodlands

includes:

Palm Loop

05 St Peters/Cavalla Hill/Brades/Davy Hill

includes:

Little Bay
Sweeneys
Cudjoe Head
Nixons
Carrs Bay
Banks

06 St Johns

includes:

Mongo Hill
Gerards

07 Kinsale/St Patricks

includes:

Trials
Gingoes
Reids Hill

08 Harris/Spanish Point/Long Ground

includes:

Bethel
Windyhill
Farrell
Trants
Tuitts

98 Montserrat (non specific)

99 Not Montserrat

APPENDIX 3: VALIDATION OF RESIDENTIAL HISTORIES

Data availability and validity

Each study respondent was asked where they had lived on Montserrat between July 1995 and December 1998. Residence was recorded for eight geographical areas of Montserrat and five time periods (question 23 of the questionnaire – appendix 1). Of the 465 respondents, 230 (49%) provided information for all periods between July 1995 and the date on which they left Montserrat for the UK. A further 84 respondents provided information up to and including the time period before they left Montserrat (e.g. residential information available to June 1997, left Montserrat in October 1997). For these individuals it was assumed that place of residence in the time period during which they left the island was the same as that reported for the preceding time period. In total, therefore, 314 (68%) of respondents had valid residential information.

The remaining 151 respondents had missing or incomplete residential histories. Of these:

- 23 had completely missing residential histories
- 17 had missing or invalid date of leaving Montserrat so validity could not be determined
- 111 had other invalid data

Data imputation

Information on place of residence on Montserrat by time period was necessary for the estimation of several of the indices of exposure to volcanic ash and it was therefore important that data were available for as many respondents as possible. It was decided that, where possible, missing information on residence should be imputed from the available data to maximise the number of respondents for whom exposure estimates could be calculated. Respondents for whom data imputation was done were identifiable in the analyses and the main analyses of symptoms in relation to exposure were carried out both for the whole study group and for the subgroup with non-imputed ('reliable') residential data.

(a) Missing residential histories (23 subjects)

No data imputation was possible for these subjects.

(b) Missing or invalid dates of leaving Montserrat (17 subjects)

- Ten subjects were from family groups, in which full and identical residential data was available for another family member. Date of leaving Montserrat was assumed to be the same as other family members and the residential information used as given.

- Four subjects had valid residential information up to June 1997. It was assumed that they left the island between July and December 1997 when the majority of the study group left. For the calculation of exposure, their leaving date was assumed to be July 1997.

- Three subjects did not provide enough residential data to allow imputation.

(c) Otherwise invalid data (111 subjects)

These subjects were subdivided according to the number of time periods (between July 1995 and date of leaving Montserrat) for which data were missing. Seventeen subjects had one time period missing, 34 two time periods missing, 41 had three time periods missing and 19 had four time periods missing. Imputation of missing data was then done according to the rules summarised in table A3.1.

Table A3.1: Action taken to impute missing data on residential histories

Action[1]	No of subjects
One time period missing:	
Missing data for 95, apparently accurate thereafter; assume that 95 = 96	7
Data for 95, left in 96 but no 96 data, assume that 96 = 95	3
Gap in data, but same place either side of gap, assume gap = either side	3
Not possible to impute missing data	4
Two time periods missing:	
Data for middle period (96, 97a) but not either end (95, 97b or 98). Assume 95 = 96, 97b = 97a or 98 = 97b	12
Missing data for final two time periods before leaving. Assume = last stated time period	11
Missing gaps. Assume = to others given if only one or if the same either side of gap	3
Not possible to impute missing info	8
Three time periods missing:	
Data for 95 but not 96, 97a&b (left 97b). Assume 96, 97a&b = 95	22
Data for 97b (left in 97b), no data for 95,96,97a. Assume 95,96,97a = 97b	6
Data given for middle period only. Assume all other periods = this	3
Not possible to impute missing data	10
Four time periods missing	
One time period given. Assume all = this	14
Not possible to impute missing data	5

[1]Time periods coded as Jul-Dec 1995 (95), Jan-Dec 1996 (96), Jan-Jun 1997 (97a), Jul-Dec 1997 (97b), Jan-Dec 1998 (98)

Following the data imputation, these residential histories were compared to those for other family members who had complete residential histories. Where the two sets of data were based on identical histories (except, of course, for the missing data, now imputed) in all cases the imputed data using the above rules were the same as the complete data. In addition, for two of the subjects where imputation was not possible, it subsequently proved possible to impute data based on family members' data (both missing cases were children and data was taken from a family adult).

APPENDIX 4: RESULTS FROM THE MEASUREMENT SURVEYS

Measured environmental concentrations of volcanic ash

Concentrations of respirable particulate on Montserrat during the course of the eruption have ranged from a few μgm^{-3} to several mgm^{-3}. The cristobalite content of airborne respirable dust in samples collected between September 1996 and June 1997 (Table A4.1) has generally been about 10%, somewhat less than in the original ash (Baxter *et al*, 1999). During 1999, however, the cristobalite content of freshly fallen ash rose from about 15 to 20% to nearer 30% (British Geological Survey, unpublished data). Airborne dust concentrations have been highest in parts of the island closest to the volcano and during periods of elevated volcanic activity and dry weather. Wind direction and strength at different altitudes have been important determinants of how much ash has drifted northwards into occupied parts of the island. The predominant wind is from the east and most of the ash has been blown over Plymouth and out over the sea. A substantial amount of ash has however, found its way northwards across the island and affected areas such as Cork Hill and Salem. Ambient concentrations of respirable dust and PM_{10} in Cork Hill prior to evacuation in June 1997 were frequently in the range of 100-500μgm^{-3} (Tables A4.1 and A4.2). Concentrations in Salem during the same period were generally lower than in Cork Hill, but subsequently rose during the summer to early autumn of 1997. The high concentrations of airborne particulate added weight to the decision to evacuate Salem which was considered to be at an unacceptable risk of death and injury from the growing eruptive activity. About a hundred people are, however, believed to have remained in Salem during the period of official evacuation which lasted until October 1998.

Table A4.1 Mean (range) respirable dust concentrations measured using cyclone samplers between September 1996 and June 1997 ($\mu g.m^{-3}$)

		Plymouth		Cork Hill		Salem		North	
Date of samples		Mean	Range	Mean	Range	Mean	Range	Mean	Range
September 1996	Respirable dust*	153	30-310	183	10-360	76	20-270		
	Cristobalite	11	<10- 19	11	<10- 31	6	<10- 19		
	No of samples	12		12		7			
October 1996-May 1997	Respirable dust*	116	9-544	75	9-956	23	<5- 59	21	<5-40
	Cristobalite	9	< 5- 57	3	<5- 16	3	<5- 10	<5	
	No of samples	53		29		6		4	
June 1997	Respirable dust*	183	107-292	236	55-395	78	16-480	45	25-56
	Cristobalite	16	11- 25	11	<5- 23	<5	< 5- 58	<5	
	No of samples	3		8		26		12	

*BMRC convention approximately PM_5

Table A4.2 Environmental concentrations of PM_{10} (containing approximately 10% crystalline silica) in μgm^{-3} estimated from Dust Trak measurements made between June 1997 and September 1998. The ranges of measured 15 minute (approximate) means at each location are shown in brackets. High ash days are when indoor surfaces are covered with a visible layer of dust

	Low ash days				High ash days (Dry)			
	Wet weather		Dry weather		Wind not from south		Southerly wind	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Plymouth	35		150	70-180	>1000	1000-2000	nm	
Cork Hill	35	19-35	60	35- 75	1000	1000-3500	nm	
Salem	20	15-30	30	90-130	200	55- 500	800	100-1000
North	20	15-25	30	20- 60	50	45- 80	500	

nm = not measured

Concentrations of respirable particulate in ambient air in Salem during 1998 were generally low with a few dustier days when elevated volcanic activity combined with a southerly wind and dry weather led to relatively high dust concentrations (Table A4.3). Official re-occupation of Salem commenced during October 1998. The volcanic activity was much less than during 1997 and the weather was unusually wet, even during the "dry season". During 1999 there were frequent but light emissions of ash from the volcano that contributed to maintaining elevated ash concentrations in the Salem and Cork Hill areas (Table A4.3). In addition, substantial quantities of unconsolidated ash were still being washed across road surfaces during rainstorms and this material was readily made airborne as a result of passing traffic. With time, however, an increasing amount of ash has been washed off the island by surface runoff following heavy rain and the remaining ash in the occupied part of the island has been bound together by grass and other vegetation. Rainfall records kept by the Forestry Development Office on the island suggest that the weather was damp throughout most of 1999 and the early part of 2000. This has probably contributed to the relatively low ash concentrations.

Concentrations of respirable particulate in the northern part of the island have generally been low throughout the eruption. Typical concentrations of PM_{10} have been between 10 and $30\mu gm^{-3}$. Concentrations of PM_{10} exceeded $300\mu gm^{-3}$ on a few days during 1997 when elevated volcanic activity coincided with unfavourable winds. Concentrations were raised on a number of days during 1998 and also during 1999. A major source of airborne particulate in the north of the island has been from construction work arising from the need to rehouse the island's population in this area. Other sources of particulate included road dust, smoke from the landfill site and vehicle emissions.

Table A4.3 Airborne dust monitoring stations on Montserrat 1998-1999. St Johns and Woodlands are in the North of the Island and Isles Bay is within the area classified as Cork Hill in other tables

Location	Period over which measurements made	Mean (s.d) concentration of PM_{10} (μgm^{-3})		Percentage of daily mean measurements > 50 μgm^{-3}
St Johns - MVO[1] (N)	8 March – 30 August 1998	19.9	(16.5)	5 %
"	13 June – 6 August 1999	32.8	(16.1)	21 %
Woodlands	8 March – 22 August 1998	23.6	(19.7)	10 %
Salem - MVO[1] (S)*	8 March - 2 July 1998	24.2	(16.5)	10 %
Salem – central square	20 May - 30 August 1998	39.9	(44.6)	18 %
"	16 May – 6 August 1999	80.9	(100.0)	59 %
Iles Bay*	15 May – 6 August 1999	62.1	(49.5)	56 %
Cork Hill*	16 May – 6 August 1999	56.6	(43.6)	52 %

*area not occupied during measurement period
[1]MVO = Montserrat Volcano Observatory

Rainstorms during the autumn of 1999 removed much of the remaining loose ash from occupied areas of the island and the very limited information available for 2000 suggests that dust concentrations were generally fairly low.

Measured personal exposures to volcanic ash

Table A4.4 shows the measured levels of personal exposure to respirable dust and cristobalite that islanders were exposed to during 1997. These measurements were augmented with Dust Trak measurements of PM_{10}. Overall it was apparent that personal exposures were heavily influenced by both the activities undertaken by individuals and the general dustiness of the environment. Activities such as cleaning, gardening or clearing the roads (under dry conditions), actively disturbed deposited dust such that workers created dust clouds around themselves. Concentrations of PM_{10} associated with mowing grass outside and sweeping inside, for example, were of the order of 10 – 20 mgm^{-3} (10000-20000μgm^{-3}). Vehicles travelling across dry ash-covered roads raised tremendous dust clouds, even when there was only a light dusting of ash on the road surface. Road surfaces also dried out very rapidly in comparison to vegetated areas following any rainfall. Consequently both driving and activities undertaken immediately adjacent to the roadside were associated with relatively high levels of exposure to the ash. Concentrations of PM_{10} within vehicles were of the order of 100-1000 μgm^{-3} throughout any journey and peaks of concentration both within vehicles and at the roadside exceeded 5000 μgm^{-3}. Outdoor levels of exposure to volcanic ash were dependent on the dampness of the weather. Disturbance of wet ash had little effect on airborne dust concentrations.

Table A4.4 Mean (range) personal exposures to respirable dust and cristobalite measured using cyclone samplers during June 1997 (average concentrations measured over 4 to 8 hour shifts)

Occupation	Concentration (μgm^{-3}) Respirable dust* Mean	Respirable dust* Range	Cristobalite Mean	Cristobalite Range	Number of samples
Gardener/Handyman	825	817- 833	41	<5- 82	2
Roadworkers	>20 000	77-71000	Na		6
Police at road checkpoint	373	45- 778	51	<5- 76	3
Housekeeper	442		30		1
Waiter	96		11		1
Office worker	173		18		1
Driver	357	144- 830	32	<5-105	5

*BMRC convention approximately PM_5

Subsequent measurements made during 1998 confirmed that those in the dustiest occupations: housekeepers, gardening, handyman and roadworkers continued to have some high exposures to volcanic ash. For those in outdoor occupations, high exposures were most likely on dry days when the combination of volcanic activity and weather had led to the recent deposition of volcanic ash within the working environment. Housekeepers were repeatedly exposed to high concentrations of ash indoors because it was impossible to keep indoor surfaces completely free of ash, and the main methods of cleaning used were sweeping and dusting. Outdoor exposures to airborne dust during wet weather were very low, and the general prevalence of wet weather during 1998 (MVO records) and 1999 (Forestry Development records) suggest that dust exposures for those in outdoor occupations have been relatively low on a substantial proportion of days.

Measurements made during April 2000 suggest that recent levels of exposure have also generally been very low (Table A4.5). Only one sample contained a measurable amount of cristobalite.

Table A4.5 Summary of exposure concentrations measured in April 2000 (μgm^{-3})

Description	Respirable dust* Mean	Respirable dust* Range	Cristobalite Mean	Cristobalite Range	Number of samples
Background	32	22 - 46	<4	<6	4
Gardener	134	7 - 444	<14	<9-23	6
Hotel housekeeper	41	31 - 52	<14	<15	3
Housekeeper	50	12 - 105	<20	<25	9
Housewife	12		<20		1
IOM	46	16 - 75	<11	<13	2
Maintenance	11	6 - 81	<19	<20	2
Office	39		<19		1
Police	16	4 - 34	<10	<12	10
Public works	54	33 - 85	<11	<11	7
Shopworker	105	83 - 126	<11	<11	2

*ISO convention, approximately PM_4

Institute of Occupational Medicine

WORLD HEALTH ORGANISATION
COLLABORATING CENTRE
FOR OCCUPATIONAL HEALTH

Applying science for a better working environment

The Institute of Occupational Medicine

The IOM is a major independent centre of scientific excellence in the fields of occupational and environmental health, hygiene and safety. We aim to provide quality research, consultancy and training to help to ensure that people's health is not damaged by conditions at work or in the environment. Our principal research disciplines are exposure assessment, epidemiology, toxicology, ergonomics and behavioural and social sciences, with a strong focus on multi-disciplinary approaches to problem solving.

Our beginnings

Our first major research programme began in the 1950s, on respiratory health problems in the coal mining industry. Major themes were quantification of airborne dust concentrations in different jobs, characterisation of types and constituents of the dusts, measurement of health effects, relationships between exposure and disease, and proposals for prevention. This research became an international benchmark for epidemiological studies of occupational health, and was the primary influence on dust standards in mines in the UK, US and other countries.

Current themes

Our current work spans many other industries including asbestos, MMMF, pesticides, chemicals, energy, telecoms, metals, textiles, construction, agriculture as well as the environment. While diseases of the respiratory tract remain a major interest, our scope now extends to many other health outcomes such as mortality, cardiovascular effects, cancer, back pain, upper-limb disorders, hearing loss, skin diseases, thermal stress and psychological stress. Related work includes the development and application of measurement and control systems, mathematical models and survey methods.

Who we work for

Our work in these areas is conducted for a wide range of organisations in the UK, the EU, and the US, including Government departments, international agencies, industry associations, local authorities, charitable organisations, and industrial and commercial companies. The IOM is a World Heath Organisation (WHO) collaborating centre and is an approved institute of the Universities of Edinburgh and Aberdeen, enjoying collaborative research links with NIOSH, IARC, and many other institutes throughout the world.

Publication

We believe that our research findings should be publicly available and subject to the scrutiny of the international scientific community. We publish our findings in the peer reviewed scientific literature and through our own series of Research Reports.

Contact

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