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Final report on Department for International Development contract: 00 1537A

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Since the volcanic eruption on Montserrat in 1995, residents of the island have been exposed to, sometimes high, concentrations of volcanic ash. The aim of this study, funded by the Department for International Development, was to identify any increased risk of respiratory ill health among Montserratian workers which might be associated with volcanic ash exposure. The target study group was all workers from occupational groups with potentially high volcanic ash exposures.

A medical survey was carried out during October 2000, comprising respiratory symptoms questionnaire, lung function tests and chest radiograph. Data on age, sex, smoking habit, occupation and personal exposure to volcanic ash were also collected. A total of 421 subjects attended the survey.

Prevalence of respiratory symptoms was relatively low. Proportionally fewer respiratory symptoms were reported than in a concurrent study of Montserratians who had relocated to the UK. There was no evidence of radiological abnormalities on the chest radiographs. Respiratory symptoms and lung function were both associated with ash exposure; in particular, symptoms were associated with exposure from heavy ash clearing activities and lung function with work as a gardener or roadworker (two of the dustiest occupations on the island). There was no evidence that other exposures (residential, domestic cleaning) affected subjects' health.

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SUMMARY

Background

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. Analyses of the volcanic ash to which Montserratians have been exposed show that the cristobalite content of the ash varied from below 5% to 20%, dependent on the type of volcanic activity, while concentrations of dust in the northern part of Montserrat have been similar to those in the UK air. Possible health risks from the ash 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.

It was decided therefore that a medical survey should be carried out which included those residents with the highest potential exposures to volcanic ash. This study was funded by the Department for International Development. During October 2000 a survey of workers from occupations with potentially high exposures to volcanic ash took place on the island. The occupations were chosen to include workers with the highest potential exposures to ash and to include a wide range of exposure levels. The overall aim of the study was to identify any increased risk of respiratory ill-health among Montserratian workers, which might be associated with exposure to volcanic ash.

Methods

A detailed medical survey was carried out comprising respiratory symptoms questionnaire, lung function tests and a chest radiograph. The symptoms questionnaire was based on that used in a concurrent study of Montserratians who had relocated to the UK, and enabled comparisons to be made between the results of the two studies. Lung function measurements of forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were made and full-size chest radiographs were taken.

Estimated dust concentrations were available for different activities, areas and time periods. These were combined with information on the frequency with which participants carried out heavy ash clearing and domestic cleaning tasks, information on place of residence within Montserrat and full lifetime occupational histories to estimate four types of volcanic ash exposure:

- 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.

Three respiratory symptoms were investigated: asthma, breathlessness and chronic bronchitis. Lung function was summarised as the maximum value of FEV_1 and FVC, and their ratio. The chest radiographs were read, according to the ILO classification, to a standard protocol by three experienced medically-qualified readers. Median profusion of small opacities was the principal response analysed.

Associations between symptoms and exposure were examined using logistic regression methods, and associations between lung function and exposure using linear regression methods. There were too few subjects with radiological abnormalities to be analysed statistically.

Results

A total of 421 subjects participated in the medical survey (321 men, 100 women). Most participants (83%) were non-smokers. The prevalence of respiratory symptoms in the study group was relatively low: 4% of subjects reporting asthma attacks, 7% reporting chronic bronchitis, 8% reporting asthma and 17% reporting symptoms of breathlessness. Most of the symptoms reported by the study participants first occurred after the volcanic eruption in summer 1995. The prevalence of asthma and chronic bronchitis in the study group was considerably lower than among the concurrent study of Montserratians in the UK, consistent with the theory that individuals with respiratory conditions preferentially left the island after the early volcanic eruptions. The prevalence of breathlessness in the two studies was similar.

The risks of reporting symptoms of asthma and breathlessness were statistically significantly associated with exposure due to heavy ash clearing activities. The risks of reporting chronic bronchitis also increased with increasing heavy ash exposure, but the association was less significant statistically. This finding was consistent with the results of the study of Montserratians in the UK, where an association was also found between heavy ash exposure and reporting of respiratory symptoms. No association between respiratory symptoms and other exposure variables was found.

Among men, lung function levels for subjects who had ever worked as gardeners or as roadworkers (two of the dustiest jobs on the island) were statistically significantly reduced compared to subjects who had never worked in these occupations. No other associations were found with occupational or other exposure variables. There were very few signs of radiological abnormalities on the chest radiographs, and those that were apparent were of low profusion of small opacities.

Discussion

The target study population was all workers from the selected occupations, with an estimated total of 300-400 participants. The final study group included slightly more subjects than originally planned (421 participants) and was representative of the target population. There was very little missing data among the 421 survey attenders, and the data collected on volcanic ash exposure and health endpoints was of good quality and reliability.

Taken together, the findings of the study suggest that exposure to volcanic ash has had some mild effect on the respiratory health of the Montserratian workers. The lack of radiological signs in the study group is reassuring in that there is no evidence of an accelerated or severe silicotic reaction to volcanic ash exposure. However the time period between first exposure and the medical survey was short and the possibility of more gradual silicotic changes over the next five to ten years cannot be ruled out at this stage.

Among the more heavily exposed residents the results of the current study, and of the study of Montserratians in the UK, suggest that it is essential that exposure to large amounts of volcanic ash be restricted as far as possible. Where such exposure is necessary, respiratory protection should be readily available and workers should be educated in its use.

There was no evidence from the study of any effect of residential exposure or exposure from domestic cleaning tasks on the health of the study participants, results which are reassuring for the health of the general population of Montserrat. This finding, together with the finding of relatively mild health effects among residents most heavily exposed to volcanic dust, suggest that a medical survey of the general population on the island is not warranted. For the current study group of more heavily exposed Montserratians, a follow-up medical survey in three to five years time would be appropriate, to allow better information on the presence of any radiological changes and to investigate whether the prevalence of symptoms or lung function losses were worsening following further exposure to the ash.

1. INTRODUCTION

The island of Montserrat is situated in the Eastern Caribbean chain of islands, about 27 miles south-west of Antigua, and is dominated by 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. Most of the exodus occurred before the end of 1997, with former residents leaving the island for nearby Caribbean islands, the United States and 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 is cristobalite, a highly toxic polymorph of crystalline silica. Preliminary laboratory studies indicate that the mixed dust is inflammatory and cytotoxic (Wilson *et al*, 2000). 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.

With the main volcanic activity taking place between July 1995 and March 1998, and other volcanic activity subsequently, it was thought important that a study be carried out of the respiratory health of the Montserratians exposed to volcanic ash. At an interval of four to five years from the first eruption, silicotic changes in the lung may have developed sufficiently to be detectable on the chest radiograph, although they may become more pronounced in later years. A health study now would identify any established cases and give warning of any early evidence so far of more slowly developing disease. Such a study would also provide a secure basis of information on the current lung health status of the participants and on whether any effects of dust on lung health can be demonstrated at this stage.

An epidemiological study of workers potentially exposed to volcanic ash in the course of their occupation was therefore funded by the Department of International Development. The study included chest radiography, lung function tests and a questionnaire of respiratory symptoms, smoking history and details of frequency of exposure to volcanic ash. A concurrent study of the respiratory health of Montserratians who relocated to the UK was funded by the Department of Health and has been reported separately (Cowie *et al*, 2001).

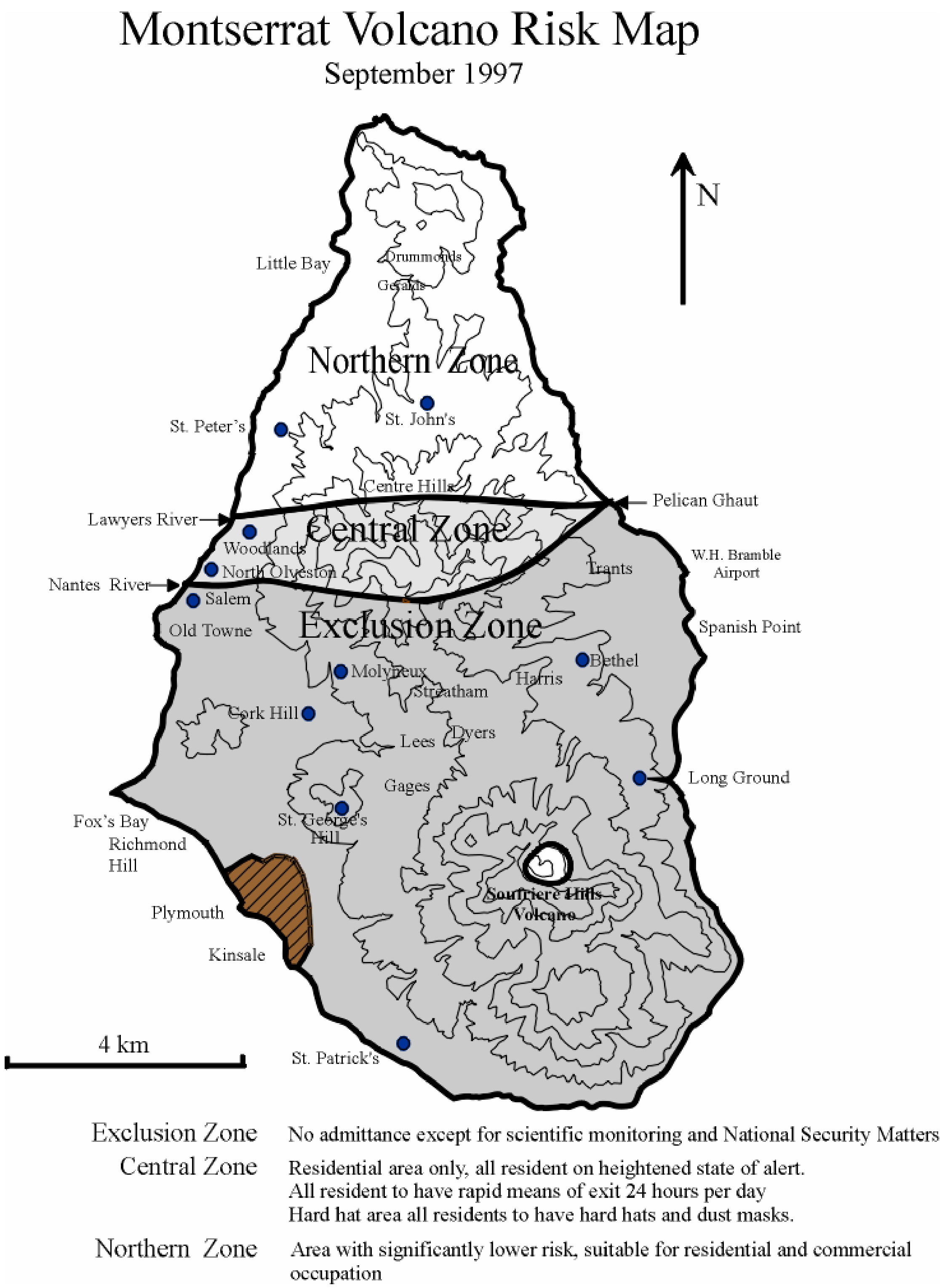

Figure 1: Montserrat risk zones: September 1997

2. AIMS AND OBJECTIVES

2.1 OVERALL AIM

The overall aim of the study was to identify any increased risk of respiratory ill-health among Montserratian workers who have remained on the island following the volcanic eruption, which might be associated with exposure to volcanic dust on Montserrat.

2.2 SPECIFIC OBJECTIVES

The specific objectives of the study were:

i. To identify any established silicosis or minor less specific radiographic abnormalities suggesting possible early silicosis in the study participants.

ii. To identify symptoms of asthma, chronic bronchitis and breathlessness in the study participants.

iii. To identify any lung functional abnormalities in the study participants.

iv. To carry out analyses of any association between respiratory ill-health and volcanic ash exposure, adjusting as necessary for the confounding effects of age, sex, physique and smoking habit.

3. METHODS

3.1 OUTLINE OF STUDY DESIGN

The study was an epidemiological survey of Montserratians currently employed in jobs which entailed exposure to volcanic ash. Individuals eligible to participate in the study were identified in consultation with the Chief Medical Officer on Montserrat, and lists were provided from records of each of the relevant occupational groups. Individuals were invited to attend for medical survey at Glendon Hospital in St John’s where they completed a questionnaire on respiratory symptoms, smoking habits, occupational history and history of exposure to volcanic ash on Montserrat. Each participant also had a chest radiograph and lung function tests. Data from the questionnaires and results from the lung function tests were entered onto computer prior to analysis. The chest radiographs were read epidemiologically by three experienced chest physicians and the results of these readings entered onto computer. Ethical approval for the study was granted by the Multi-Centre Research Ethics Committee for Scotland.

3.2 IDENTIFICATION OF STUDY POPULATION

The target study population was a group of between 300 and 400 workers from specified occupational groups on the island. The occupational groups were selected to include the workers most likely to have been exposed to volcanic ash in the course of their work. All employees in each occupational group were invited to attend the survey to ensure as wide a range of exposures as possible, within workers from similar jobs. Eight principal occupational groups were identified:

- The Royal Montserrat Defence Force
- The Royal Montserrat Police Force (including Fire Officers)
- Public Works Department (including heliport workers)
- Montserrat Water Authority
- Montserrat Electricity Services Limited
- Montserrat Port Authority (including Customs)
- Montserrat Volcano Observatory and Emergency Operations Centre
- Gardeners, Roadside workers and Cleaners

In addition, construction workers, truckers, rice mill workers and cable TV installers were invited to attend the survey.

Lists of workers in the Police Force, Public Works Department, Water Authority, Electricity Industry and Port Authority were provided to the IOM survey team before they went to the island. Workers from the other occupational groups were identified during the course of the medical survey, with assistance from Montserrat residents and staff of the Department for International Development based on the island.

3.3 SURVEY METHODOLOGY

3.3.1 Survey administration

Each identified study subject was sent a letter of invitation to survey which included an information sheet giving details of the medical tests and a patient consent form. Copies of these documents are shown in Appendix 1. All participants in the study signed the consent form before taking part.

The IOM medical survey team was present on the island for three weeks during October 2000. The survey team was led by Marion Russell, a radiographer employed by the IOM who had considerable experience of running similar surveys, and Scott Dempsey an IOM lung function technician. Both IOM team members were very experienced in the collection of data and the administration of questionnaires. During the setting up of the medical survey and the first few days of data collection the team was assisted by Dr Peter Baxter, a consultant of the Department of International Development who had made many previous visits to Montserrat. Dr Baxter was able to set up contacts with residents and medical staff on the island who could assist in the smooth running of the survey. The final member of the survey team was Mrs Katie Buffonge, a nurse who worked at the Hospital on Montserrat. Mrs Buffonge provided invaluable assistance in helping workers with their questionnaires and in identifying other Montserratians from the relevant occupations, who were not on the lists provided prior to the start of survey. Also of assistance was Niall Conlon, a medical student working on the island, who helped with the questionnaire at particularly busy periods.

3.3.2 Chest radiography

Full size (40x40cm) postero-anterior chest radiographs were taken using the facilities of the Glendon Hospital x-ray department, using a moderately high kV technique (up to 125kV). Films were developed immediately after exposure and checked for radiographic technique and film quality, so that a repeat exposure could be made if necessary.

A chest X-ray was repeated if the quality was classed as 'poor' or 'unusable' by the radiographer. In addition, repeat chest X-rays were taken where artefacts, subject movement or poor inspiration were considered to be present. One radiographer performed all the radiography to ensure consistent quality. The radiographer was experienced in taking films for ILO classification purposes and in field survey work.

3.3.3 Lung function testing

Routine lung function spirometry tests were attempted for each subject. These tests were carried out by an experienced physiological measurement technician using standard procedures. Height to the nearest centimetre and weight to the nearest 0.5 kilogram (without heavy clothing or shoes) were measured prior to lung function testing.

The spirometric test consisted of a single forced rapid exhalation to residual volume, following a maximal inhalation of room air. The test is intended to provide evidence of both obstructive and restrictive lung defects. The procedure requires three technically satisfactory maximal forced exhalations to be recorded, unless the subject was physically incapable of performing the test, had limited comprehension, became too breathless to provide satisfactory tests or was otherwise reluctant to continue with the tests. The FEV and the FVC of the three acceptable blows should be within 100ml or 5% (whichever is the greatest) of the best effort. The forced expiratory volume in one second (FEV_1), the forced vital capacity (FVC) and the ratio of the FEV_1/FVC are the main parameters of interest, both for clinical assessment of the test results and for the subsequent analysis.

Spirometric lung function was measured using a Vitalograph 2120 spirometer linked to a laptop computer. This system was operated by a trained and experienced technician using standard procedures. The spirometer meets the requirements of the American Thoracic Society (ATS 1979,1987) and the European Community for Coal and Steel (Quanjer, 1983) criteria for spirometric equipment.

Spirometric data was recorded on PC using the Vitalograph 2170 (version 4.01) software package. A calibration was carried out every day before any measurements were taken. This calibration is stored by the PC and used to accurately interpret data from the spirometer tests. The programme requires the temperature to be input from each session. Additionally each subjects' age, height, weight, sex and race is entered to allow accurate comparison with the tables of normal lung function values.

Additional calibration checks were made if it was deemed necessary. Twice daily biological checks were made by self tests on the spirometer system's technician.

The spirotrac system produced a printout of each subject's results after tests were complete so that a paper record was maintained in case of any computer systems failure. These paper records were also used during the clinical assessment of each subject's results.

3.3.4 Respiratory questionnaire

The respiratory symptoms questionnaire was designed to record personal information, information on respiratory symptom occurrence, smoking habit, factors affecting exposure to volcanic ash on Montserrat, and other occupational exposures. It was based on the postal questionnaire used in the survey of Montserratians who had relocated to the UK, which in turn had been compiled using questions from several standard sources. A copy of the final version of the questionnaire is shown in Appendix 2.

Information requested on the questionnaire comprised:

- Personal details – date of birth and sex. (Questionnaire Section H).

- Questions on chest symptoms (Section A) (IUATLD, 1986) - subjects who answered yes to any of these questions were also asked supplementary questions on the date on which they first had the symptoms.

- Questions on breathlessness (Section B) (MRC, 1986) - for those subjects answering positively, supplementary questions were asked about the date on which they first had breathlessness.

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

- Questions on cough and phlegm production (Section D) (MRC, 1986) – 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 former residents of Montserrat 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 information about place of residence (on Montserrat or elsewhere) since the first volcanic eruption in 1995. 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 elsewhere. 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 CLINICAL REPORTING

Chest radiographs were clinically interpreted by a radiologist. Lung function measurements and respiratory symptoms in association with occupational and smoking history were interpreted by an Occupational Physician. Results from any abnormal cases were also reviewed by an independent Professor of Occupational Medicine. All results were reported to the individual by confidential letter. In the case of abnormal results, brief details were given to the individual with the advice to see his/her general practitioner. Full details of abnormal results were sent to the relevant General Practitioner in confidence, via the Chief Medical Officer on Montserrat. The Department for International Development assisted in the forwarding of correspondence although all letters were sealed in medical confidence and those detailing abnormal results were directed by the Chief Medical Officer.

3.5 EPIDEMIOLOGICAL FILM READING

The radiographs were classified according to the full ILO (1980) classification independently by three experienced, medically-qualified readers. The radiographs were randomised and divided into two batches prior to the reading trial. Each reader then read the radiographs according to a standard protocol, and the classifications made by each reader were recorded on standard forms. A copy of the protocol and recording form are shown in Appendix 3. A full set of ILO standard films was available for reference during the reading trial.

3.6 DATA PROCESSING AND VALIDATION

3.6.1 Data coding and data entry

Each job in the occupational history 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. In addition, each job was coded according to which of the targeted occupational groups (listed in section 3.2 above) it was in.

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 4 for details).

Data from coding exercises and the rest of the questionnaires, personal details, height, weight and lung function test results and the epidemiological film classifications were double-punched by experienced computer operators using a data entry program set up specifically for this purpose.

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, the identification of invalid combinations of answers to specific questions from the questionnaire and the investigation of levels of lung function, height or weight which were unusually high or low. Apparent invalid or inconsistent responses were checked in the study database and, where necessary, on the original questionnaires or recording forms, and data were corrected or set to missing or invalid where appropriate.

3.7 EXPOSURE ESTIMATION

3.7.1 Strategy for exposure estimation

Individual exposures to volcanic ash were estimated using information on the frequency and type of exposure experienced combined with estimated concentration levels to which they were exposed. Data on the subjects' exposure to ash were recorded on the survey questionnaire. This included information on where subjects resided on the island, how frequently it was necessary to clean domestic residences, the frequency of heavy ash clearing activities and the time spent in occupations with potential exposure to volcanic ash.

Data on the levels of volcanic ash on the island were available from a number of dust surveys that had been carried out on the island since the first volcanic eruption (details in Appendix 5). Cyclone samplers were used to collect samples of respirable dust and continuous reading aerosol monitors, the DustTrak, were used to measure concentrations of PM_{10} in real time. The respirable dust samples were also analysed for cristobalite. The surveys were carried out to determine the potential exposure of islanders to volcanic ash containing cristobalite. Measurements were made to determine background environmental concentrations and exposure concentrations associated with different occupations and specific tasks. The measurements were not made specifically for use in this epidemiological study. Nevertheless, the dust concentration data collected have enabled the estimation of average concentrations by area, time period, task and/or occupation which have been combined with the questionnaire data to calculate estimated exposures for the study participants.

Specifically, the dust survey measurement data (combined with other information about weather and volcanic activity) were used to estimate the ash concentrations associated with place of residence, occupation and activities involving cleaning and clearing of the dust (Appendix 5). 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 used in these calculations were 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 DustTrak samplers are calibrated using Arizonian road dust and it is possible that they underestimate levels of PM_{10} on Montserrat.) The values used in the calculations therefore represent our best estimates of respirable dust levels derived from measurements from both sources.

3.7.2 Estimation of individual exposures

For each individual in the study group, four exposure indices were calculated – residential exposure, occupational exposure, heavy ash exposure and domestic cleaning exposure. The estimation of each of these indices is described below.

Residential exposure

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. The 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 and January to October 2000. 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 John's.

For a few individuals, little or no residential information was provided and these were excluded from all analyses in relation to exposure.

Estimates of concentrations associated with place of residence were based on long-term mean concentrations of airborne particulate in different areas of the island. Measurement data were not available for all area-time period combinations. For each time period therefore, an estimate was made of the proportion of days falling into four classifications of dustiness, based on the Department of Health criteria for PM_{10} on the island:

- Alert level (> 300 $\mu g.m^{-3}$)
- Very high (101 – 300 $\mu g.m^{-3}$)
- Raised (50 – 100 $\mu g.m^{-3}$)
- Low (< 50 $\mu g.m^{-3}$)

The proportion of days in each dustiness category in each time period was estimated from PM_{10} measurement, where available, supplemented by information on level of volcanic activity, rainfall data collected by the Forestry Development Office for 1999-2000 and interviews with a range of residents of the island. The estimated proportions of days in each category were used in conjunction with the available measurement data to estimate average concentrations for each area and time period.

Occupational exposure

The occupational exposure index was calculated by combining the information provided in the detailed lifetime occupational histories with concentrations for each occupational group, in the seven time periods listed above. Where the occupational data were comprehensive enough, a cumulative occupational exposure index was calculated for each individual. For a few of the study respondents, the occupational history was completed only sparsely and it did not prove possible to calculate any occupational exposure index. Categorical variables were also created where possible, which indicated whether an individual had ever worked in each of the specified occupational groups, following the volcanic eruption in 1995.

Based on measurement data, a typical concentration was assigned to each occupation. The assignment of different concentrations was based on full shift personal exposure measurements made with the cyclone sampler, and also DustTrak measurements of concentrations associated with specific activities, including surveys of roadworkers and Montserrat Volcano Observatory staff.

Heavy ash clearing and domestic cleaning exposure

Exposures from heavy 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.

Estimated mean concentrations for these activities were based on measurement data from the dust surveys, including surveys of people engaged in ash clearing operations both inside and outside and during wet and dry weather. Specific measurements were made for each type of activity such as sweeping, shovelling, dusting, mopping and beating mattresses. 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.

3.7.3 Other exposure classifications

Each individual was classified according to whether they had ever worked in each of the occupational groups listed in section 3.2, thus allowing comparisons between subjects who had ever worked, for example, as gardeners and subjects who had never carried out gardening work.

In addition, all subjects who had been included in the identification lists supplied prior to the medical survey team travelling to the island were assigned an exposure category of Low, Medium, High or Very High based on personal knowledge of the work carried out by that subject. This information was, however, available for only a subset of those attending survey.

3.8 DATA ANALYSIS

3.8.1 Medical endpoints

The chest radiographs were classified by three experienced medically qualified readers according to the full ILO (1980) classification scheme. The key response from these radiological readings was the profusion of small opacities.

The spirometric recordings of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were summarised as the maximum of, usually three, technically satisfactory blows. FEV_1, FVC and their ratio were included in the analysis.

The symptom responses of particular interest were those representing asthma, breathlessness on exertion and chronic bronchitis, each defined using the respiratory symptoms questionnaire. Some analyses were also carried out for asthma attacks reported directly by the study participants. 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). Question 5 was used to determine when the symptoms first occurred.

Breathlessness: Presence of breathlessness was defined as being short of breath walking with people of your own age on level ground (Q6). This is the definition used in the Medical Research Council questionnaire on respiratory symptoms (MRC, 1986). Question 7 provided information on when the breathlessness first occurred.

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 12: coughing up phlegm first thing in the morning **and/or** question 13: coughing up phlegm during the day or at night **and**

(ii) answered positively to question 14: do you cough up phlegm like this on most days for as much as three months each year.

Question 15 identified when the symptoms first occurred.

Asthma attacks: Presence of asthma attacks was defined by a positive answer to ‘Have you ever had an attack of asthma?’ (Question 8).

3.8.2 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 of reporting respiratory symptoms associated with multiple explanatory variables (Hosmer and Lemeshow, 1989; 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.

Classifications of the radiographs were examined separately in a series of tables. Comparisons of readers' results on the same films were examined and median classifications calculated as appropriate. Variables examined included profusion of small opacities, shape of small opacities, presence of any pleural thickening and presence of pleural plaques. Descriptive tables of key responses by age, sex, smoking habit and summary occupational variables were produced.

The recordings of FEV_1 and FVC were summarised as the maximum of three technically satisfactory blows. Maximum FEV_1, maximum FVC and their ratio were tabulated in relation to age, sex and smoking habits. Scatterplots of each lung function variable against age were produced. Tabulations were made of lung function variables by selected summary occupational indices and associations with exposure indices were represented graphically.

Regression analyses of the lung function variables, which are recorded on a continuous scale, used linear regression methods (Draper and Smith, 1998). The regression models examined their relationship with exposure indices, in the presence of other factors such as age, physique and smoking habit; and interactions between exposure effects and age and smoking were investigated.

4. DESCRIPTION OF INDIVIDUAL EXPOSURES

4.1 RESIDENTIAL EXPOSURE

4.1.1 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 in section 3.7 and Appendix 5. The relatively low concentration in Cork Hill during 1999 and 2000 relative to Salem reflects differences in the level of human disturbance of deposited ash.

Table 4.1 Typical average environmental concentrations (µgm^{-3}) 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	30	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 of the 421 study participants, 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 18 on the questionnaire. Information on place of residence was collected up to October 2000, when the medical survey took place.

Table 4.2 shows the number of subjects reporting residence in each of the five geographic areas on Montserrat, and Not on Montserrat, by time period. Some subjects reported living in more than one area within the same time period and hence are included in the table more than once.

Table 4.2 Reported residence in Montserrat by time period. Each cell contains number of subjects reporting residence in each area/time period.

	Time period							
Area	**1995 Jul-Dec**	**1996 Jan-Dec**	**Jan-June**	**1997 Jul-Dec**	**1998 Jan-Dec**	**Jan-Aug**	**1999 Sept-Dec**	**2000 Jan-Oct**
Plymouth	183	166	27	4	0	0	0	0
Cork Hill	58	89	66	14	10	4	2	2
Salem	52	100	78	73	74	72	64	62
Woodlands	10	30	33	49	40	37	31	31
North	106	189	193	274	306	316	308	315
Not on island	26	31	32	46	45	22	8	6

The number of residents in the Plymouth area declined slowly after the eruption started in 1995 and declined sharply after Plymouth was officially evacuated in April 1996. In Cork Hill and Salem there was an increase in the number of residents between 1995 and 1996, perhaps caused in part by those moving out of Plymouth. Cork Hill was officially evacuated in June 1997 and Salem was officially evacuated in August 1997. About a hundred people are, however, believed to have continued to live in Salem during the period of official evacuation. Salem was re-occupied from October 1998 onwards. The population in Woodlands showed an initial increase between 1995 and 1998, followed by a steady decline from 1998 onwards. Residence in the North area increased steadily between the end of 1995 and the end of 1998. Between 1995 and the end of 1997, the numbers of residents leaving the island increased but the rate of exodus declined from 1998 until completion of the study.

4.1.2 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 402 subjects and ranged from 185 to 5400 $\mu g.months.m^{-3}$. The average residential exposure was 2451 $\mu g.months.m^{-3}$. The distribution of residential exposures is shown in Figure 4.1.

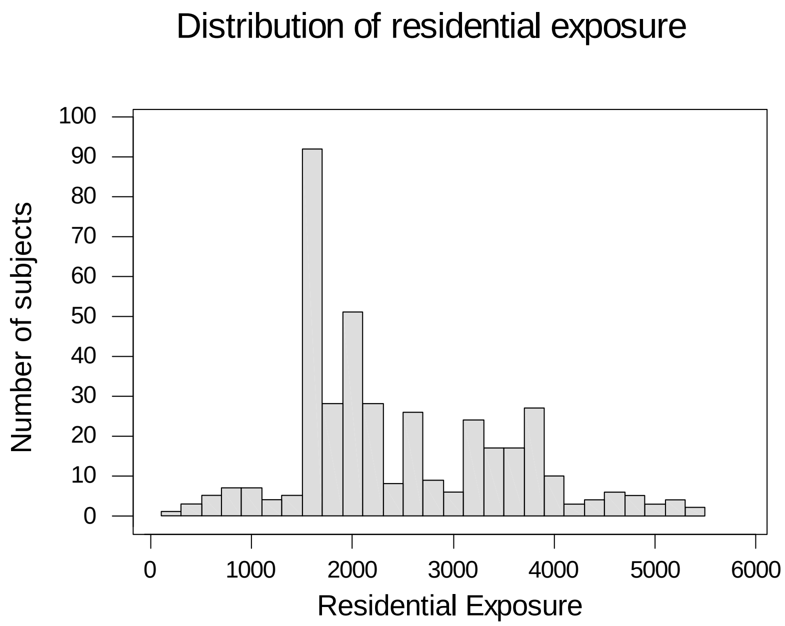

Figure 4.1 Distribution of residential exposure ($\mu g.months.m^{-3}$)

4.2 EXPOSURE FROM HEAVY ASH CLEARING ACTIVITIES

Table 4.3 gives the levels of exposure experienced by individuals carrying out heavy ash clearing tasks. 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 4.3 Estimated exposure to volcanic ash associated with heavy duty ash cleaning ($\mu g.m^{-3}$).

Activity	1996 Jan-Dec	1997 Jan-June	1997 Jul-Dec	1998 Jan-Dec	1999 Jan-Aug	1999 Sept - Dec	2000 Jan-Dec
Heavy duty ash cleaning	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 the amount of time they had spent on the island since the first volcanic eruption. Length of time spent on the island was derived from the residential histories provided by the survey participants.

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 19 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 4.4.

Table 4.4 Calculation of proportion of month spent on heavy ash clearing tasks

	Heavy ash clearing tasks per month		
Response to Q19	**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 tasks was calculated for 400 subjects and ranged from 0 to 41580 $\mu g.months.m^{-3}$, with a mean of 16311 $\mu g.months.m^{-3}$. The distribution of exposure from heavy ash clearing tasks is shown in Figure 4.2. Because the majority of the study participants lived on Montserrat continuously from the date of the eruption until the medical survey, the distribution of heavy ash exposure strongly reflects the four frequencies of heavy ash clearing (never, once or twice a month, once or twice a week, daily).

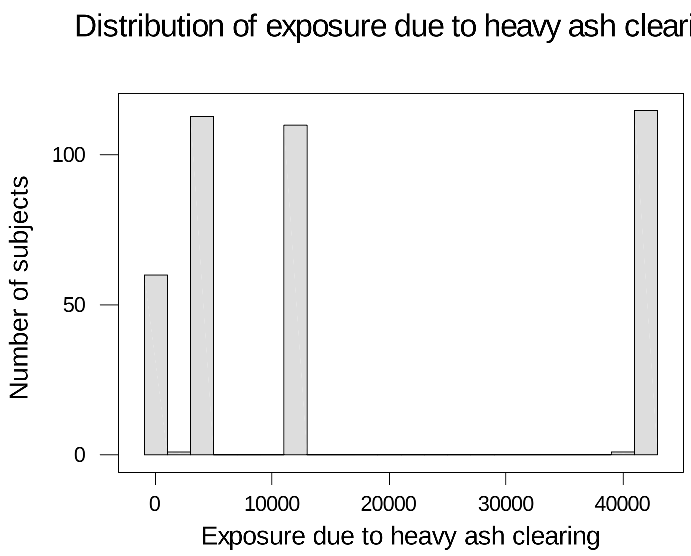

Figure 4.2: Distribution of exposure due to heavy ash clearing tasks ($\mu g.months.m^{-3}$)

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 4.5 shows the estimated increment on 24-hour exposure due to domestic cleaning by time period and area of residence.

Table 4.5 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	na	na	na
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

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 21 on the questionnaire ('During the last three months 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 21, and is summarised in Table 4.6. The exposure levels in Table 4.5 refer to total exposure for the 24 hour period in which the cleaning took place.

Table 4.6 Calculation of proportion of month spent on domestic cleaning tasks

Response to Q21	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 400 subjects, excluding those with relevant data, which was missing or invalid. Exposure from domestic cleaning ranged from 0 to 4100 µg.months.m^{-3}, with a mean level of 237 µg.months.m^{-3}. The distribution of exposure from domestic cleaning is shown in Figure 4.3.

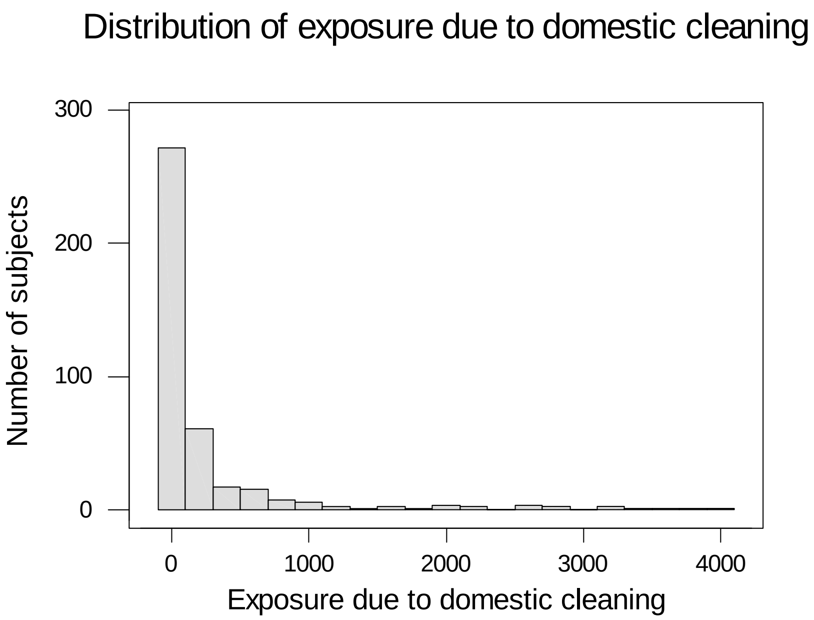

Figure 4.3: Distribution of exposure due to domestic cleaning tasks (µg.months.m^{-3})

4.4 OCCUPATIONAL EXPOSURE

4.4.1 Availability of occupational history data

Occupational exposures for each individual were calculated from the lifetime occupational history as reported in the questionnaire. For 29 (7%) of the 421 study participants the data recorded on occupation was missing or incomplete and occupational exposures were not calculated for these individuals.

4.4.2 Distribution of occupations

Across the 392 subjects with potential occupational exposure, a total of 471 jobs were reported. Table 4.7 shows the number of subjects who ever worked in each occupational group after July 1995 and the percentage of the 392 subjects who have a potential occupational exposure.

Table 4.7 Distribution of occupational groups (OGs) for jobs held on Montserrat. Each cell contains number of subjects and *percentage of study group*

Occupational Group	No. of subjects	
A: MDF, police	70	*18*
B: Port workers	45	*11*
C: Gardeners	27	*7*
D: Roadworkers	56	*14*
E: Housekeepers	32	*8*
F:Utilities, farmworkers, drivers, heliport	116	*29*
G: Construction	7	*2*
H: Other	118	*30*
All	471	

The majority of subjects who worked on Montserrat after the volcanic eruption in July 1995 worked in the ‘other’ category (118; 30%) or in the ‘utilities, farmworkers, drivers, heliport’ category (116; 29%). Of the 392 individuals who had potential occupational exposure, 321 (82%) worked in only one occupational group, 64 (16%) worked in two occupational groups, 6 (2%) worked in three occupational groups, and 1 subject worked in four occupational groups on Montserrat after 1995.

4.4.3 Calculation of occupational exposures

The 392 individuals who worked on Montserrat following the eruption were potentially exposed to volcanic ash in the course of their work. Table 4.8 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 4.8 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 Sep - 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	na	na	na	na	na
Other in Cork Hill	150	400	na	na	na	na	na
Other elsewhere	60	100	100	60	150	50	50

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

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. Total occupational exposure ranged from 20 to 23680 μg.months.m^{-3}, with an overall mean value of 6131 μg.months.m^{-3} among the 392 subjects with occupational exposures. The distribution of the occupational exposures is shown in Figure 4.4.

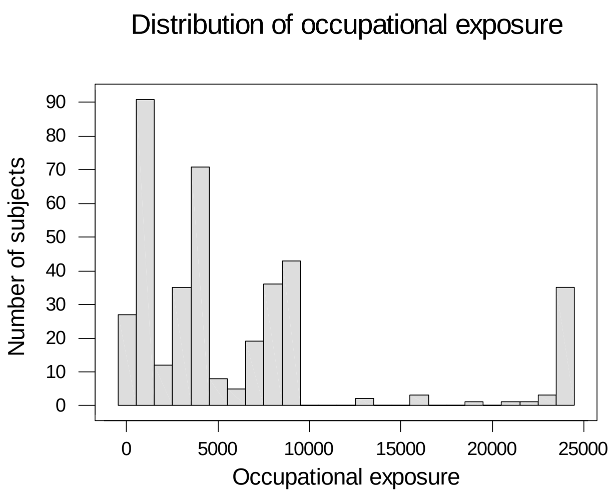

Figure 4.4: Distribution of occupational exposure (μg.months.m^{-3})

Amongst the 392 subjects for whom an occupational exposure was available, the exposure was significantly higher in males (mean: 7196 μg.months.m^{-3}) compared to females (mean: 2560 μg.months.m^{-3}), and higher in the older subjects compared to the younger subjects.

For 180 (43%) of the 421 participants, classification into Low, Medium, High and Very High exposure groups was available, based on personal knowledge of the work carried out by the individual. Of these 180 subjects, 44 (24%) were in the Low exposure group, 19 (11%) in the Medium exposure group, 116 (64%) in the High exposure group and one in the Very High exposure group. In the statistical analyses the subject with Very High exposure was included in the High exposure group.

4.5 SUMMARY OF EXPOSURE AVAILABILITY

Of the 421 study participants, estimated exposures were available as follows:

- 392 subjects had occupational exposure estimates
- 402 subjects had residential exposure estimates
- 400 subjects had heavy ash clearing exposure estimates
- 400 subjects had domestic cleaning exposure estimates

In total, 374 of the 421 study participants (89%) had estimated exposure for all four exposure types.

5. SURVEY RESULTS AND RELATIONS WITH EXPOSURE

5.1 SURVEY PARTICIPATION AND CHARACTERISTICS OF THE STUDY GROUP

Completed questionnaires were received from 421 individuals**.** Of these 421 respondents, 100 (24%) were female and 321 (76%) were male. Table 5.1 shows the distribution of the study group by age group and sex. Little difference was observed in the age distribution for males compared to females.

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

	Age Group								
Sex	**16-29**		**30-39**		**40-49**		**50 +**		**All**
Female	15	*15*	35	*35*	25	*25*	25	*25*	100
Male	72	*22*	89	*28*	75	*23*	85	*26*	321
All	87	*21*	124	*30*	100	*24*	110	*26*	421

Four (4%) females and eight (2%) males did not complete the questions on smoking habit. Of the 96 females who provided information on their smoking status, only two (2%) were current smokers and two (2%) were ex-smokers; the remaining 92 (96%) were non-smokers. Forty one (13%) of the males who completed the questions on smoking habit were current smokers, 24 (8%) were ex-smokers and 248 (79%) were non-smokers. Table 5.2 shows the distribution of the study group by age group and smoking habit.

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

Smoking	Age Group									
Habit	**16-29**		**30-39**		**40-49**		**50 +**		**All**	
Non	79	*92*	105	*88*	74	*78*	82	*75*	340	*83*
Ex	0	*0*	2	*2*	8	*8*	16	*15*	26	*6*
Current	7	*8*	12	*10*	13	*14*	11	*10*	43	*11*
All	86		119		95		109		409	

The prevalence of smoking increases with age. None of the subjects under 30 years old were ex-smokers and 92% of these subjects were lifelong non-smokers. Among subjects aged between 30 and 39 years old, 12% of these subjects were either current or ex-smokers, compared to 22 to 25% of subjects aged 40 years old and above. Both of the females who were current smokers were aged 41 years old.

5.2 SYMPTOM PREVALENCE

5.2.1 Overall prevalence of respiratory symptoms

There were three main symptom complexes of interest, namely asthma, breathlessness and chronic bronchitis (defined in section 3.8.1 above). Some analyses were also carried out for subjects who had ever experienced 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	No. of valid responses	No. of subjects	Percentage of subjects
Asthma	421	34	*8*
Breathlessness	421	70	*17*
Asthma attacks	421	17	*4*
Chronic bronchitis	419	28	*7*

A total of 319 subjects reported none of the above symptoms, 62 reported one symptom, 29 reported two symptoms, seven reported three symptoms and only two reported all four symptoms. Asthma and breathlessness were most often reported together, by 24 study participants, i.e. 71% of those reporting asthma and 34% of those reporting breathlessness. One respondent answered negatively to the question "Do you usually cough up mucus from your chest (phlegm) first thing in the morning?" and positively to the question "Do you usually cough up mucus from your chest (phlegm) during the day or at night?". This same subject, in turn, gave no response to the question "Do you cough up mucus from your chest (phlegm) like this on most days for as much as three months each year?". One individual did not provide an answer to any of these three questions, hence for chronic bronchitis, two subjects (both males) could not be classified.

5.2.2 Asthma

All 421 respondents completed the questions on asthma symptoms. Thirty four (8%) individuals reported asthma, 10 of whom were female and 24 were male. The prevalence of asthma was therefore slightly lower in males (7%) than in females (10%). Table 5.4 shows the prevalence of asthma by age group and smoking habit.

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	Age Group									
Habit	16-29		30-39		40-49		50+		All	
Non	5	*6*	6	*6*	6	*8*	6	*7*	23	*7*
Ex	-	-	0	*(0)*	1	*(12)*	2	*13*	3	*12*
Current	1	*(14)*	2	*17*	0	*0*	3	*27*	6	*14*
All	6	*7*	8	*7*	7	*7*	11	*10*	32	*8*

Overall a larger percentage of current and ex-smokers reported asthma as compared to non-smokers. Current smokers aged 50 or over had the highest prevalence of asthma. The prevalence of asthma was similar in all the age groups for non-smokers. In the younger age groups, the numbers of cases were quite small, so it was difficult to discern any clear patterns in the data. Where the sparse data was available, the prevalence of asthma tended to be lowest in non-smokers.

Subjects were asked to give the date on which they first experienced asthma. Of the 34 subjects who had asthma, 8 (24%) experienced their asthma before the volcanic eruption in July 1995 and 26 (76%) subjects experienced their asthma after this eruption. Of these 26 subjects, 7 (27%) were female and 19 (73%) were male.

5.2.3 Breathlessness

Shortness of breath when walking with people of their own age on level ground was reported by 70 (17%) of the 421 subjects. The prevalence of breathlessness was higher in females (34 subjects; 34%) than in males (36 subjects; 11%). The distribution of subjects with breathlessness by age and smoking habit 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 Habit	Age Group 16-29		30-39		40-49		50+		All	
Non	8	*10*	16	*15*	20	*27*	13	*16*	57	*17*
Ex	-	-	1	*(50)*	0	*(0)*	2	*13*	3	*12*
Current	1	*(14)*	2	*17*	1	*8*	3	*27*	7	*16*
All	9	*10*	19	*16*	21	*22*	18	*16*	67	*16*

Breathlessness was least prevalent in subjects aged between 16 and 29 years old and most prevalent in subjects aged 40-49. Symptoms of breathlessness were least likely to be reported by subjects who were ex-smokers.

All 70 subjects who experienced shortness of breath also gave dates of when they first experienced these symptoms. Nine (13%) of these subjects experienced symptoms of breathlessness before the volcano erupted in July 1995 and 61 (87%) subjects experienced symptoms of breathlessness after this eruption. Of these 61 subjects, 29 (48%) were female and 32 (52%) were male.

5.2.4 Asthma attacks

Study participants were asked directly whether they had ever experienced an attack of asthma and whether they had experienced an attack of asthma in the last 12 months. Results are given in Table 5.6.

Table 5.6 Distribution of study population by attack of asthma ever and attack of asthma at any time in the last 12 months.

Asthma attack ever	Asthma attack at any time in the last 12 months: No	Yes	All
No	404	0	404
Yes	9	8	17
All	413	8	421

Six (6%) females and 11 (3%) males reported having ever experienced an asthma attack. Hence, the prevalence of asthma attacks was twice as high in females as it was in males, but only a small proportion (4%) of the study population had ever experienced an attack of asthma. Table 5.7 shows the prevalence of asthma attacks by age group.

Table 5.7 Prevalence of asthma attacks by age group. Each cell contains number (percentage) of subjects with asthma attacks.

	Age Group 16-29		30-39		40-49		50 +		All	
Subjects with asthma attacks	5	*6*	4	*3*	5	*5*	3	*3*	17	*4*

Of the 17 subjects who had ever experienced an attack of asthma, 13 (76%) were non-smokers and one (6%) was an ex-smoker. Three subjects with asthma attacks did not answer the questions on smoking.

5.2.5 Chronic bronchitis

Chronic bronchitis was defined as experiencing a persistent productive cough for three months or more each year with 28 (7%) subjects reporting such symptoms. The prevalence of chronic bronchitis was fairly similar in females (5 subjects; 5%) and males (23 subjects; 7%) Table 5.8 shows the distribution of subjects with chronic bronchitis by age group and smoking habit.

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 16-29		30-39		40-49		50+		All	
Non	3	*4*	3	*3*	4	*5*	5	*6*	15	*4*
Ex	-	-	1	*(50)*	0	*(0)*	2	*13*	3	*12*
Current	1	*(14)*	4	*33*	4	*31*	1	*9*	10	*23*
All	4	*5*	8	*7*	8	*9*	8	*7*	28	*7*

Overall, the prevalence of chronic bronchitis increases very slightly with age and was highest in current smokers followed by ex-smokers and then non-smokers.

Only 3 (11%) of the 28 subjects who reported chronic bronchitis experienced their first symptoms before the eruption of the volcano in July 1995 and 25 (89%) reported symptoms of chronic bronchitis occurring after the volcanic eruption in July 1995. Of these 25 subjects, 5 (20%) were female and 20 (80%) were male.

5.3 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 5.3.1 to 5.3.4 below. In the statistical regression models reported below, risk of reporting symptoms associated with exposure to volcanic ash has been examined after adjustment for the effects of age, sex and smoking.

5.3.1 Symptoms and residential exposure

For each study participant, geographical area of residence on the island was recorded for five areas and seven time periods. 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.

Symptoms	**Residential Area 1997** **Plymouth**		**Cork Hill**		**Salem**		**Woodlands**		**North**		**Not in Montserrat**	
Asthma	2	*7*	5	*7*	8	*8*	1	*2*	20	*7*	5	*10*
Breathlessness	4	*15*	10	*14*	18	*18*	5	*9*	53	*23*	4	*8*
Asthma attacks	1	*4*	3	*4*	9	*9*	1	*2*	8	*3*	1	*2*
Chronic bronchitis	0	*0*	6	*9*	8	*8*	2	*4*	17	*6*	3	*6*

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.

An estimate of cumulative residential exposure in $\mu g.months.m^{-3}$ was calculated for each individual based on their reported residential histories and estimates of the ash concentrations by time period and geographical area. Table 5.10 shows the mean level of residential exposure for the study group subdivided by presence/absence of respiratory symptoms.

Table 5.10 Mean level of residential exposure by symptom occurrence ($\mu g.months.m^{-3}$)

	Occurrence of symptoms	
Symptom	**No**	**Yes**
Asthma	2460	2339
Breathlessness	2465	2376
Asthma attacks	2438	2828
Chronic bronchitis	2453	2413

As shown in Table 5.10, the mean level of residential exposure was similar for subjects with and without asthma, breathlessness and chronic bronchitis. However, residential exposures were slightly higher for the subjects who reported asthma attacks. This difference was not 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 5.11. 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 1.40 represents a 40% 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.

After adjusting for age, sex and smoking habit, there was no evidence of an association with residential exposure for any of the respiratory symptoms.

Table 5.11 Results from logistic regression analysis of symptoms in relation to residential exposure. Each cell contains estimated odds ratio and 95% CI.

	Asthma		Breathlessness		Asthma Attacks		Bronchitis	
Age (per year)	1.04	(1.0,1.1)	1.03	(1.01,1.06)	0.99	(0.94,1.04)	1.00	(0.98,1.05)
Males (vs Females)	1.03	(0.4,2.7)	0.23	(0.1,0.4)	0.50	(0.1,1.80	1.02	(0.3,2.7)
Smoking (vs Non)								
Ex	1.35	(0.3,5.2)	0.71	(0.2,2.6)	1.48	(0.1,14.5)	0.93	(0.6,9.1)
Current	1.74	(0.6,5.1)	1.26	(0.5,3.3)	*	*	2.26	(2.1,13.7)
Residential Exposure (per 1000 units)	0.74	(0.5,1.1)	0.87	(0.6,1.2)	1.47	(0.8,2.6)	0.95	(0.6,1.4)

Logistic regression analyses were also carried out restricted to symptoms of asthma, breathlessness and chronic bronchitis which first occurred after the first volcanic eruption in 1995. No evidence of an association with residential exposure was apparent.

5.3.2 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 5.12 shows the prevalence of respiratory symptoms subdivided by frequency of ash clearing work.

Table 5.12 Prevalence of asthma, breathlessness, asthma attacks and chronic bronchitis by frequency of clearing large quantities of ash. Each cell contains number *(percent)*.

Clearing of ash	No. in group	Asthma		Breathlessness		Asthma attacks		Chronic bronchitis	
Never	63	3	*5*	10	*16*	2	*3*	3	*5*
Once/twice a month	119	7	*6*	17	*14*	3	*3*	6	*5*
Once/twice a week	115	4	*3*	11	*10*	3	*3*	7	*6*
Daily (not as job)	76	10	*13*	17	*22*	8	*11*	6	*8*
Daily (as main job)	44	10	*23*	15	*34*	1	*2*	6	*14*

The prevalence of asthma and breathlessness was highest in participants who cleared ash daily, in particular in those who cleared ash daily as their main job. Asthma attacks were most prevalent in individuals who cleared ash daily but not as their job and least prevalent in those who cleared ash daily as their main job (one case only). Chronic bronchitis was most prevalent in subjects who cleared ash as their main job.

Table 5.13 summarises the mean level of exposure due to heavy ash clearing tasks by presence/absence of symptoms

Table 5.13 Mean level of exposure due to heavy ash clearing by symptom occurrence (µg.months.m^{-3})

	Occurrence of symptoms	
Symptom	**No**	**Yes**
Asthma	15270	29139
Breathlessness	15167	22547
Asthma attacks	15858	28776
Chronic bronchitis	15892	22358

For all four symptoms, mean exposure from heavy ash clearing was higher among those with symptoms than among those without. These differences were highly statistically significant for asthma, breathlessness and asthma attacks (p-value < 0.001) and were of borderline statistical significance for chronic bronchitis (p-value = 0.053).

Results from the logistic regression analyses of respiratory symptoms in relation to heavy ash exposure are shown in Table 5.14. After adjustment for age, sex and smoking habit, for all symptoms except chronic bronchitis, there was a statistically significant association between the risk of reporting respiratory symptoms and estimated exposure to heavy ash clearing activities. The odds ratios associated with 1000 $\mu g.months.m^{-3}$ were small, ranging from increases in risk of 2% (odds ratio of 1.02) to 4%.

Table 5.14 Results from logistic regression analysis of symptoms in relation exposure due to heavy ash clearing tasks. Each cell contains estimated odds ratio and 95% CI.

	Asthma		**Breathlessness**		**Asthma Attacks**		**Bronchitis**	
Age (per year)	1.03	(0.99,1.06)	1.03	(1.00,1.05)	0.98	(0.93,1.03)	1.02	(0.98,1.05)
Males (vs Females)	1.21	(0.4,3.3)	0.23	(0.1,0.4)	0.61	(0.2,2.2)	1.00	(0.3,2.9)
Smoking (vs Non)								
Ex	1.09	(0.7,12.0)	0.64	(0.2,2.4)	1.45	(0.1,14.1)	2.05	(0.5,8.3)
Current	1.61	(0.5,4.8)	1.20	(0.4,3.2)	*	*	5.06	(2.0,13.0)
Heavy Ash Exposure (per 1000 units)	1.04	(1.02,1.06)	1.02	(1.00,1.04)	1.04	(1.01,1.08)	1.02	(0.99,1.04)

Logistic regression analyses of symptoms of asthma, breathlessness and chronic bronchitis which first occurred after the volcanic eruption in 1995, showed very similar results, with odds ratios per 1000 units exposure of 1.04, 1.02 and 1.01 respectively for the three symptoms.

5.3.3 Symptoms and exposure from domestic cleaning tasks

Each subject was asked how often it was necessary for them to clean ash from inside the building in which they were living. Table 5.15 shows the prevalence of respiratory symptoms subdivided by frequency of domestic ash cleaning.

Table 5.15 Prevalence of asthma, breathlessness, asthma attacks and chronic bronchitis by frequency of cleaning home. Each cell contains number *(percent)*.

Frequency of cleaning home	**No. in group**	**Asthma**		**Breathlessness**		**Asthma Attacks**		**Chronic bronchitis**	
Never	184	12	*6*	25	*14*	9	*5*	8	*4*
Once/twice a month	141	11	*8*	20	*14*	3	*2*	10	*7*
Once/twice a week	50	6	*12*	10	*20*	2	*4*	5	*10*
Once a day	23	4	*17*	10	*43*	2	*9*	2	*9*
More than once a day	20	1	*5*	5	*25*	1	*5*	3	*15*

There was some evidence of an increase in prevalence of asthma and breathlessness with increasing frequency of domestic cleaning (from ‘Never’ to ‘Once a day’), but prevalence among the relatively few individuals who cleaned their homes more than once a day were low.

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 are given in Table 5.16.

Table 5.16 Mean level of residential exposure by symptom occurrence (µg.months.m^{-3})

Symptom	Occurrence of symptoms No	Yes
Asthma	232	302
Breathlessness	221	325
Asthma attacks	233	341
Chronic bronchitis	225	406

Exposure levels were slightly higher among subjects who reported respiratory symptoms.

Table 5.17 shows the results from logistic regression analyses of symptoms in relation to domestic cleaning tasks. There was no evidence of an association with domestic ash exposure for any respiratory symptoms after adjustment for age, sex and smoking habit.

Table 5.17 Results from logistic 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 (per year)	1.03	(1.0,1.1)	1.03	(1.00,1.05)	0.99	(0.92,1.06)	1.02	(0.98,1.05)
Males (vs Females)	0.97	(0.4,2.5)	0.22	(0.1,0.4)	0.57	(0.2,2.0)	0.93	(0.3,2.7)
Smoking (vs Non)								
Ex	1.29	(0.3,5.0)	0.70	(0.2,2.6)	1.62	(0.5,5.1)	2.23	(0.5,9.1)
Current	1.87	(0.6,5.5)	1.30	(0.5,3.4)	*	*	5.44	(2.1,13.9)
Domestic Exposure (per 100 units)	1.01	(0.96,1.07)	1.02	(0.98,1.07)	1.04	(0.97,1.11)	1.04	(0.99,1.09)

Logistic regression analyses of symptoms of asthma, breathlessness and chronic bronchitis which first occurred after the volcanic eruption of July 1995 showed no evidence of an association between risk of reporting symptoms and exposure from domestic cleaning exposure.

5.3.4 Symptoms and occupational exposure

Of the 421 study participants, 392 had held some jobs on Montserrat and had completed a lifetime occupational history, and for 29 subjects information on occupation was incomplete or missing. For 180 of the participants classification into Low, Medium or High exposure group was available based on personal knowledge of the individuals' work. The prevalence of symptoms subdivided by exposure group is shown in Table 5.18.

Table 5.18 Prevalence of symptoms by exposure group. Each cell contains number *(percentage)* with each symptom. Results for 180 subjects with exposure group data only.

Exposure group	Asthma		Breathlessness		Asthma Attacks		Chronic bronchitis	
Low	5	*11*	8	*18*	1	*2*	1	*2*
Medium	1	*5*	2	*11*	1	*5*	2	*11*
High	4	*3*	15	*13*	1	*1*	5	*4*
All	10	*6*	25	*14*	3	*2*	8	*4*

There was no evidence that individuals with higher exposure classifications were more likely to report respiratory symptoms.

An estimated occupational exposure to volcanic ash was calculated for each subject who had been in employment. Table 5.19 shows the mean occupational exposure level by presence/absence of symptoms.

For asthma and chronic bronchitis, occupational exposures were higher in those with symptoms compared to those without symptoms. In contrast, for breathlessness and asthma attacks, occupational exposures were lower in those subjects reporting symptoms compared to those not reporting symptoms.

Table 5.19 Mean level of occupational exposure by symptom occurrence (µg.months.m^{-3})

	Occurrence of symptoms	
Symptom	**No**	**Yes**
Asthma	6093	6648
Breathlessness	6297	5213
Asthma attacks	6204	4302
Chronic bronchitis	6046	7596

The results from the logistic regression analyses of symptoms in relation to occupational exposure are shown in Table 5.20. Results from these analyses show that there was no evidence of associations with occupational exposure and any of the respiratory symptoms after adjusting for age, sex and smoking habit.

Table 5.20 Results from logistic regression analysis of symptoms in relation to occupational exposure. Each cell contains estimated odds ratio and 95% CI.

	Asthma		Breathlessness		Asthma Attacks		Bronchitis	
Age (per year)	1.02	(0.98,1.05)	1.02	(0.99,1.04)	0.99	(0.94,1.04)	1.02	(0.99,1.06)
Males (vs Females)	0.93	(0.3,2.7)	0.25	(0.1,0.5)	1.06	(0.3,4.3)	0.97	(0.3,3.2)
Smoking (vs Non)								
Ex	1.83	(0.5,7.3)	0.76	(0.2,2.8)	1.35	(0.1,12.6)	2.34	(0.6,9.4)
Current	2.33	(0.1,50.0)	1.33	(0.5,3.5)	*	*	7.07	(2.8,18.0)
Occupational Exposure (per 1000 units)	1.01	(0.95,1.07)	1.00	(0.95,1.05)	0.98	(0.88,1.09)	1.01	(0.96,1.07)

Logistic regression analyses of symptoms of asthma, breathlessness and chronic bronchitis which first occurred after the volcanic eruption of July 1995 showed no evidence of an association between risk of reporting symptoms and occupational exposure.

5.4 LUNG FUNCTION LEVELS

Lung function tests were completed satisfactorily by 311 male and 93 female subjects. Table 5.21 shows their distribution by sex, age and smoking habits, and the mean FEV_1 in each subgroup. With only four females ever having smoked, no conclusions can be drawn about the effect of smoking on the lung function of female Montserratians. However, the decline with age is as clear in females as it is in males. Although again the number of smokers is small, there is a suggestion of reduced lung function in older smokers. Patterns in FVC were very similar.

Table 5.21 Lung function by sex, age and smoking habit. Table contains means of maximal FEV_1, *and numbers of subjects.*

Sex	Smoking	Age group 16-29		30-39		40-49		50+	
Male	Non	3.58	*64*	3.44	*71*	3.21	*53*	2.73	*59*
	Ex	-	*0*	3.41	*2*	3.08	*8*	2.77	*13*
	Current	3.62	*7*	3.51	*12*	3.11	*11*	2.31	*11*
Female	Non	2.78	*15*	2.54	*32*	2.17	*20*	1.81	*22*
	Ex	-	*0*	-	*0*	-	*0*	1.99	*2*
	Current	-	*0*	-	*0*	3.13	*2*	-	*0*

5.5 ASSOCIATION BETWEEN LUNG FUNCTION AND EXPOSURE

Lung function variables analysed were FEV_1, FVC and the ratio FEV_1/FVC. Because these are measured on a continuous scale, linear regression models were appropriate. Lung function variables are usually analysed on their original scale of measurement, with adjustment for individual differences in body size and for the known reducing effects of ageing and of tobacco smoking. All the analyses of lung function reported here were adjusted for age, height, weight, Body Mass Index (BMI) and smoking habit. Separate slopes on age (and therefore necessarily separate intercepts) were fitted in each smoking category.

Because the number of female subjects was low, and because males and females usually have quantitatively different relationships between lung function, age and physical measurements, statistical models are reported here only for male subjects.

5.5.1 Lung function and occupational exposure

Initial analyses (not shown) confirmed the usual strong relationships of FEV_1 and FVC with age and height. Coefficients for these terms were similar in magnitude to those used for standardisation of values for European males (Quanjer *et al*, 1983), and also gave similar values for residual variation. The subsequent contributions of weight, BMI and smoking category were much less strong, and all of borderline statistical significance. However, their estimated coefficients had plausible magnitudes and directions, and might have been declared significant in a larger study group. Therefore, they have been retained as adjusting variables in the following models.

The first column of Table 5.22 shows the estimated coefficients for a regression model for FEV_1 with these adjusting variables but with no exposure variables, while the second column adds a coefficient for the estimated occupational exposure to ash, which was negative and small. The 95% confidence interval for this term contains zero, and the term is not statistically significant. The coefficients of the adjusting variables changed very little when occupational exposure was added to the model.

The same analyses for FVC led to very similar conclusions, with the term for occupational exposure not statistically significant. Because both FEV_1 and FVC are related similarly to age and body size, their ratio varies much less, and this is seen in the much lower coefficients for the adjusting variables and for occupational exposure.

Table 5.22 Results of fitting linear regression models to lung function variables, with estimated occupational exposure. Table contains estimated regression coefficients *and selected 95% confidence intervals.*

Source	Variable analysed					
	FEV_1		FVC		FEV_1/FVC Ratio	
Constant (non-smokers)	-12.38	-12.49	-14.24	-14.32	0.875	0.867
Age (non-smokers)	-0.0229	-0.0222	-0.0211	-0.0206	-0.0013	-0.0012
Constant (ex-smokers)	-12.01	-12.02	-13.68	-13.68	0.882	0.882
Age (ex-smokers)	-0.0299	-0.0314	-0.0307	-0.0317	-0.0018	-0.0019
Constant (smokers)	-12.03	-12.14	-13.31	-13.39	0.778	0.771
Age (smokers)	-0.0329	-0.0322	-0.0431	-0.0412	-0.0001	0.0003
Height (cm)	0.0962	0.0969	0.1095	0.1100	0.0003	0.0003
Weight (kg)	-0.0672	-0.0679	-0.0703	-0.0708	-0.0012	-0.0012
BMI	0.1954	0.1979	0.2090	0.2110	0.0021	0.0023
Occupational exposure		-0.0059 *(-0.0144, 0.0026)*		-0.0043 *(-0.0145, 0.0060)*		0.0004 *(-0.0015, 0.0006)*

The results in Table 5.22 provide little evidence for an effect of occupational exposure on lung function. However, it may be questioned whether the index of occupational exposure is equally reliable for all occupational groups; for example, the work patterns of gardeners may be more homogeneous than those of policemen, some of whom may have indoor jobs. To examine this further, additional models were tried, with occupations represented by binary indicator variables that indicated whether each subject had recorded time in each occupational group. A stepwise selection procedure was used, to determine which if any of the OG indicators improved the basic model.

In analyses of FEV_1, after adjustment for other variables, the selection procedure identified roadworkers as a group with reduced average lung function, followed by gardeners (Table 5.23). Both of these selections were statistically significant, even after applying a more stringent significance level to allow for multiple comparisons. For FVC, the same two occupational groups were selected, albeit in reverse order. No occupational groups gave statistically significant relationships in analyses of the FEV_1/FVC ratio.

We conclude that there is evidence that subjects working as roadworkers or as gardeners had, on average and after adjustment for other variables, lower lung function at survey.

Examination of lung function levels among the 180 study participants for whom information was available on Low, Medium or High exposure group, based on personal knowledge of each individuals' work, showed no evidence of lower lung function among the more heavily exposed subjects.

Table 5.23 Results of fitting linear regression models to lung function variables, with indicators of belonging to specific occupational groups. Table contains estimated regression coefficients *and selected 95% confidence intervals.*

	Variable analysed							
	FEV_1				FVC			
Constant (non-smokers)	-12.06		-12.02		-14.23		-13.91	
Age (non-smokers)	-0.0221		-0.0225		-0.0216		-0.0208	
Constant (ex-smokers)	-11.49		-11.36		-13.60		-13.11	
Age (ex-smokers)	-0.0328		-0.0346		-0.0324		-0.0353	
Constant (smokers)	-11.66		-11.68		-13.37		-13.01	
Age (smokers)	-0.0329		-0.0318		-0.0405		-0.0404	
Height (cm)	0.0945		0.0950		0.1102		0.1086	
Weight (kg)	-0.0664		-0.0685		-0.0727		-0.0721	
BMI	0.1922		0.1958		0.2140		0.2110	
Roadworker	-0.198	*(-0.352, -0.044)*	-0.217	*(-0.370, -0.064)*			-0.197	*(-0.382, -0.013)*
Gardener			-0.305	*(-0.532, -0.078)*	-0.342	*(-0.616, -0.068)*	-0.369	*(-0.643, -0.095)*

5.5.2 Lung function and exposure from heavy ash clearing tasks

Table 5.24 shows the results of fitting regression models with the usual adjustments, and with the addition of a variable estimating exposure during heavy ash clearing operations (see section 4.2).

The coefficients for the adjustment variables before the addition of exposure differ from those in Table 5.22 because exposure data were available on a slightly different subset of male subjects. However, they show the same pattern. For FEV_1, when heavy ash clearing exposure was added to the model, its coefficient was small, and its 95% confidence interval included zero, indicating that it was not statistically significant. The same was true in the analysis of FVC. Analysis of the ratio also showed no significant exposure effect (not shown).

We conclude that these data provide no evidence of an effect of exposure from heavy ash clearing activities on lung function. This contrasts with the finding of a positive effect on the risks of reporting respiratory symptoms.

Table 5.24 Results of fitting linear regression models to lung function variables, with estimated exposure from heavy ash clearing tasks. Table contains estimated regression coefficients *and selected 95% confidence intervals.*

Source	Variable analysed			
	FEV_1		FVC	
Constant (non-smokers)	-9.93	-10.10	-11.27	-11.47
Age (non-smokers)	-0.0224	-0.0223	-0.0203	-0.0202
Constant (ex-smokers)	-9.55	-9.738	-10.68	-10.90
Age (ex-smokers)	-0.0300	-0.0294	-0.0339	-0.0303
Constant (smokers)	-9.14	-9.30	-10.13	-10.32
Age (smokers)	-0.0424	-0.0425	-0.0490	-0.0461
Height (cm)	0.0816	0.0827	0.0917	0.0930
Weight (kg)	-0.0499	-0.0513	-0.0503	-0.0520
BMI	0.1457	0.1501	0.1530	0.1580
Exposure from heavy ash clearing		-0.0019 *(-0.0053, 0.0015)*		-0.0023 *(-0.0065, 0.0020)*

5.5.3 Lung function and other exposures

Additional regression models were fitted, with the same adjusting variables, to examine possible relationships of lung function with residential exposures and with exposure from domestic cleaning (see sections 4.1, 4.3). In all cases, the estimated coefficients for these exposures were very small, and fell far short of statistical significance. This was true for FEV_1, FVC and their ratio. The models are not shown here.

We conclude that these data provide no evidence of an effect of residential exposures, nor of exposures from domestic cleaning, on lung function.

5.6 PREVALENCE OF RADIOGRAPHIC ABNORMALITIES

5.6.1 Film quality

All three readers examined radiographs from 414 subjects. Table 5.25 summarises the judgements made by the readers on the technical quality of the radiographs taken. The vast majority of films were of quality grades "Good" or "Acceptable", implying no impediment to further classifications of abnormality. Reader 2 judged no film to be of less than acceptable quality. Reader 1 was the most critical, but rejected only three films as being not possible to classify on grounds of quality. All three of these films were judged by the other two readers to have some technical defects, but not sufficient to prevent classification.

Table 5.25 Judgements of film quality by three readers

Quality	Reader		
	1	2	3
Good	355	396	348
Acceptable	50	18	60
Poor	6	0	6
Unacceptable	3	0	0
Total	414	414	414

5.6.2 Classification of small opacities

The readers classified very few radiographs as showing abnormalities. Table 5.26 shows the distribution of their classifications of profusion of small opacities, and of the consensus reading constructed as the median. In all cases where an assessment was omitted because of poor film quality, the other readings were both 0/0, so the median value 0/0 was allocated.

Table 5.26 Classifications of profusion of small opacities by each reader, and median reading.

Reader	Profusion of small opacities												
	0/-	0/0	0/1	1/0	1/1	1/2	2/1	2/2	2/3	3/2	3/3	3/+	Total
Reader 1	0	390	13	4	2	0	1	0	0	0	1	0	411
Reader 2	0	412	1	0	0	0	0	0	0	0	0	1	414
Reader 3	0	390	19	3	0	0	0	0	0	1	0	0	414
Median	0	407	5	1	0	0	0	0	0	0	1	0	414

All three readers classified the same subject as having abnormalities in the main profusion category 3. The radiograph for this subject was examined clinically and the abnormalities were judged unlikely to have been caused by recent exposure to respirable dust.

In the remaining radiographs, the numbers classified as showing abnormalities was small, and the readers rarely classified these on the same subjects. Reader 1 classified a film as 2/1 that the others classified as 0/0. In the consensus median reading, only one film was classified as 1/0, and only 5 as 0/1. This represents a very low prevalence of small opacities.

5.6.3 Other radiological abnormalities

Other possibly pneumoconiotic abnormalities were extremely rare. No radiographs were judged by any reader to show large opacities. One reader classified one radiograph as having a pleural plaque on the right side, of width over 10mm and extent 1, i.e. less than one quarter the length of the chest wall. No recordings were made of diffuse pleural thickening, of thickening in the diaphragm, or of pleural calcification. Two subjects were classified, each by one reader, as having unilateral costophrenic angle obliteration, usually a sign of past infection.

A number of radiographs were described as having other abnormalities from the list designated by two-letter symbols. The majority concerned cardiac abnormalities, and there were some recorded as suspected tuberculosis markings.

5.7 ASSOCIATION BETWEEN RADIOLOGY AND EXPOSURE

As described above, after exclusion of the individual with significant abnormality, which had been judged not related to ash exposure, there remained five subjects with a median profusion of small opacities of 0/1, and only one with a median profusion of 1/0. This number of positives was not sufficient to attempt regression modelling, and so no models have been fitted. We describe below a small exercise to check whether there was any relationship at all with occupational groups.

5.7.1 Radiology and occupational exposure

Data on profusion of small opacities and on inclusion within occupational groups were printed out in parallel for inspection by eye. Subjects with a median profusion of small opacities 0/1+ were examined, to see whether they might cluster within a single occupation. In fact, they were distributed across the OGs without any apparent pattern.

Thus there was no data to suggest any relationship between small opacities and occupation. Given that opacities of profusion 0/1 are often considered not abnormal, this is not surprising.

5.7.2 Radiology and other exposures

Given the small number of potential positives, no formal statistical modelling was performed.

6. DISCUSSION

6.1 BACKGROUND AND NEED FOR A STUDY

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. Analyses of the volcanic ash to which Montserratians have been exposed show 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 levels of volcanic dust above the current Occupational Exposure Limit for silica, sufficient 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 resident on Montserrat. The possibility of surveying all residents of the island was considered, but it was judged to be unethical medically to carry out chest radiography of the general population. In addition a health survey of such a large number of subjects would be time-consuming and expensive. It was decided therefore that a medical survey should be carried out which included those residents with the highest potential exposures to volcanic ash. During October 2000 a survey of workers from occupations with potentially high exposures to volcanic ash was carried out on the island. If no serious health effects were found among these workers then it would be unlikely that there would be any serious health effects among the less-exposed remainder of the island population. The occupational groups were chosen to include workers with the highest potential exposures to ash and to include a wide range of exposure levels; with the overall aim of identifying any increased risk of respiratory ill-health among Montserratian workers, which might be associated with exposure to volcanic ash.

A detailed medical survey was carried out comprising respiratory symptoms questionnaire, lung function tests and a chest radiograph. The symptoms questionnaire was based on that used in a concurrent study of Montserratians who had relocated to the UK (Cowie *et al*, 2001) which included questions on the three symptom complexes of interest (asthma, chronic bronchitis and breathlessness), and enabled comparisons to be made between the results of the two studies. While the reporting of symptoms by questionnaire is a subjective measurement of respiratory ill-health, lung function tests provide objective measurements of forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). It was acknowledged that the timescale of the study, only five years since the first volcanic eruption, was probably too short to detect silicotic changes in the lung, but chest radiography now would detect any very severe silicotic effects and would provide baseline levels of radiographic changes in the study population. Respiratory symptoms and lung function measurements reflect more acute effects and also provide baseline levels for follow-up, if indicated.

6.2 STUDY POPULATION

The target study population was all workers from the selected occupational groups. For the major occupations (including Police, Utilities, Defence Force, Port Authority workers) comprehensive lists of employees were supplied by the employers prior to the start of the medical survey. For the other occupations (including gardeners, roadworkers and housekeepers), eligible study participants were identified by Montserrat-based members of the medical survey team, with the assistance of other residents on the island. The target survey attendance was 300 to 400 participants.

The medical survey was planned to take place over a four week period in the autumn of 2000. Study advisors with experience of working on Montserrat felt that there might be some antipathy to the study on the island and that it might be difficult to achieve the target participation rate in the allotted time period. In the event, the Montserratian workers were keen to take part in the survey and a total of 421 participants were surveyed in under four weeks, including reasonable coverage of all the selected occupational groups. The final study group therefore included slightly more subjects than originally planned and was representative of the target population.

6.3 DATA COMPLETENESS AND RELIABILITY

6.3.1 Data completeness

There was very little missing data among the 421 survey attenders. All 421 subjects completed the self-administered questionnaire (only two of whom did not fully complete the questions on respiratory symptoms), chest radiographs were available for 414 subjects and lung function tests were completed by 404 subjects. Four different exposure variables were calculated for study participants, based on information recorded on the self-administered questionnaire. Completeness of exposure information ranged from 392 subjects with occupational exposures to 402 subjects with residential exposures; almost 90% of the study group had full exposure information for all four exposure variables.

6.3.2 Data reliability

Medical endpoints

Chest radiography and lung function spirometry are objective measurements of lung health. The vast majority of the chest radiographs for this study were classified as of Good or Acceptable quality by the three experienced epidemiological film readers, with each reader classifying over 80% of the radiographs as quality category one (Good). The variability of the lung function measurements was similar to that found in other studies of working populations, and the expected relationships with age and height were apparent, suggesting that the recorded measurements were reliable.

There was more potential for, aware or unaware, bias in the self-administered questionnaire which was used to collect information on the presence of respiratory symptoms and on potential exposure to volcanic ash. 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. The definition of the respiratory symptom complexes included in the analysis depended entirely on the answers to specific questions by the participants and so the prevalences reported are those for self-reported symptoms. However, associations of symptom presence 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.

Dust exposure

The estimates of concentrations of volcanic ash experienced for different occupations and activities by time period and geographical area were based on measurement data from hygiene surveys. These surveys were not specifically designed as part of this epidemiological study and so were not designed to be comprehensive across time periods or activities. Nevertheless, the measurement data available, supplemented by information on weather conditions and by detailed interviews with residents on the island, allowed the estimation of typical respirable dust concentrations for the relevant activities and time periods for the study. While the estimated concentration levels assigned to each activity and time period are not exact measurements, we are confident that they reflect accurately the relative dustiness of different activities and time periods.

Individuals' exposures to volcanic ash were calculated from information recorded on the self-administered questionnaire on the frequency and type 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.

Individuals' occupational exposures were calculated by combining time spent in each of the selected occupational groups with estimated concentrations for that occupation. The estimated concentrations were typical levels for the occupational group as a whole and did not distinguish between different tasks in the same job (e.g. police officers with more desk-based work and police officers on active duty). Cumulative occupational exposure to ash since the 1995 eruption was calculated for each individual, based on these typical concentrations for each occupational group, and associations between the medical endpoints and these exposures were investigated.

In addition, it is possible that some of the workers on Montserrat worked particularly short or particularly long shifts or held multiple jobs, only some of which may have been recorded on the occupational history. To examine this in more detail, further information was available to classify individuals as High, Medium or Low exposed based on personal knowledge of that individuals' work patterns. This supplementary classification was available for almost half of the study group and selected analyses were carried out for this subset of workers. Statistical analyses were also carried out in relation to whether an individual had ever worked in each of the selected occupational groups. Overall, the exposure data available to the study was sufficient to enable comprehensive analysis of any exposure-response associations in the study group.

6.4 KEY FINDINGS AND THEIR IMPLICATIONS

The prevalence of respiratory symptoms in the study group was relatively low, ranging from 4% of subjects reporting asthma attacks, through 7% reporting chronic bronchitis and 8% reporting asthma to 17% reporting symptoms of breathlessness. Most of the symptoms reported by the study participants first occurred after the volcanic eruption in summer 1995. The prevalence of asthma and chronic bronchitis among Montserratians who had remained on the island was considerably lower than among the concurrent study of Montserratians in the UK (where 14% of participants reported symptoms of asthma and 14% reported chronic bronchitis), a finding consistent with the theory that individuals with respiratory conditions preferentially left the island after the early volcanic eruptions. The prevalence of breathlessness in the two studies was similar (17% on the island and 18% in the UK).

There was no evidence that respiratory symptoms were related to occupational exposures, nor to exposures associated with residence in specific areas of the island during specific time periods ('residential exposure'). However, the risks of reporting symptoms of asthma and breathlessness were statistically significantly associated with exposure due to heavy ash clearing activities. The risk of reporting chronic bronchitis was also increased among individuals with more frequent heavy ash exposure, with the increase in risk of similar magnitude to that for asthma and breathlessness but less significant statistically. This finding was consistent with the results of the study of Montserratians in the UK, where an association was also found between heavy ash exposure and reporting of respiratory symptoms.

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 28% of the study group reported clearing quantities of ash greater than 1mm thickness from buildings, roads or other surfaces daily, and of these almost two-thirds 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.

Levels of lung function (FVC, FEV_1) were strongly associated with age and physique. As expected, these associations differed in men and women and, as there were relatively few women in the study group, statistical analyses were carried out for men only. Among men, lung function levels for subjects who had ever worked as gardeners or as roadworkers were statistically significantly reduced compared to subjects who had never worked in these occupations. Average reductions in lung function for the 27 gardeners in the study group were over 300ml of FEV_1 and FVC, while for the 56 roadworkers average reductions were around 200ml of FEV_1 and FVC. No other associations were found with occupational or other exposure variables. It is likely that gardeners and roadworkers were among the most homogeneous occupational groups, with all workers in the group exposed to high levels of volcanic ash. There were very few signs of radiological changes on the chest radiographs, and those that were apparent were of low profusion of small opacities.

Taken together, the findings of the study suggest that exposure to volcanic ash has had some mild effect on the health of the Montserratian workers. Respiratory symptoms and lung function were both associated with ash exposure; the symptoms with exposure due to heavy ash clearing activities and lung function with work as a gardener or roadworker, two of the most heavily exposed occupations. While the two medical endpoints were related to different aspects of ash exposure, it should be noted that proportionally more gardeners and roadworkers reported clearing heavy ash daily as an occupation than other workers in the study group. It is also possible that subjects who were aware of their respiratory symptoms may have preferentially chosen not to work in the dustiest occupations for fear of exacerbating their condition, whereas individuals with small reductions in lung function would be less likely to have been aware of any discomfort or physical symptoms. The lack of radiological signs in the study group is reassuring in that there is no evidence of an accelerated or severe silicotic reaction to volcanic ash exposure. However, as noted earlier, the time period between first exposure and the medical survey was short and the possibility of more gradual silicotic changes over the next five to ten years cannot be ruled out at this stage.

6.5 CONCLUSIONS

Among the more heavily exposed residents, the results of the current study, and of the study of Montserratians in the UK, suggest that it is essential that exposure to large amounts of volcanic ash be restricted as far as possible. Where such exposure is necessary, respiratory protection should be readily available and workers should be educated in its use. Personal protective measures need to be appropriate for small businesses and self-employed workers, who would probably require pro-active practical help and advice on implementing such measures.

There was no evidence from the study of any effect of residential exposure or exposure from domestic cleaning tasks on the health of the study participants, results which are reassuring for the health of the general population of Montserrat. This finding, together with the finding of relatively mild health effects among residents most heavily exposed to volcanic dust, suggest that a medical survey of the general population on the island is not warranted. For the current study group of more heavily exposed Montserratians, a follow-up medical survey in three to five years time would be appropriate, to allow better information on the presence of any radiological changes and to investigate whether the prevalence of symptoms or lung function losses were worsening following further exposure to the ash.

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9. GLOSSARY

FEV_1	The volume of air (forced expiratory volume) that can be forced out in one second after taking a deep breath.
FVC	The maximum volume of air (forced vital capacity) which can be expired as quickly and forcibly as possible, after a maximum inspiration.
FEV_1/FVC	The ratio of FEV_1 to FVC. In obstructive lung disorders, the forced expiratory volume in 1 second (FEV_1) is usually decreased, the forced vital capacity (FVC) is usually normal and the ratio FEV1/FVC is decreased. In restrictive disorders the FEV_1 and FVC are both decreased, leaving a normal FEV_1/FVC.
PM_{10}	The fraction of inhaled airborne particles that reaches the lung. Particles in the PM_{10} fraction are generally less than 0.01 mm in diameter.
Respirable particles	Respirable particles are those that reach the oxygen exchange region of the lung (unciliated airways or alveolar region). Particles in the respirable fraction are generally less than 0.004 mm in diameter.

APPENDIX 1: SURVEY DOCUMENTS

Letter of invitation to survey:

Institute of Occupational Medicine

Dear Sir/Madam

Health Survey

We are carrying out a survey of the health of workers on the island of Montserrat. The survey is being carried out by the Institute of Occupational Medicine, a research charity based in the UK and is funded by the British Government's Department for International Development. All workers on Montserrat who may have been exposed to ash from the Soufriere Volcano are being invited to take part in a medical survey. An information sheet about the survey is attached.

The medical examination consists of some simple breathing tests and a chest x-ray and you will be asked some questions about symptoms from your lungs (such as cough), about smoking and about the jobs you have done. It would be helpful if you could make some notes about the jobs you have done and when, to bring to the survey. You will also be asked to agree that this information can be used for research purposes.

You will receive a confidential medical report and if there are any significant findings we will, with your permission, send details to a doctor of your choice. All information about individuals will be held in strictest confidence by the research team and will not be given to anybody without your written consent. Results from this research will not identify any individual.

Attendance at this survey is voluntary. The more people who attend, the more reliable the result, but you do not have to agree to participate. Non-participation will not affect any medical treatment you may need in future. I do hope that you will take part and provide information about the health of workers on Montserrat.

You will be contacted by telephone nearer the time to arrange an appointment.

I thank you in advance for your participation

Yours sincerely

Dr Adele Pilkington
Consultant Occupational Physician (IOM)

Information sheet:

Health Survey of Workers on Montserrat

INFORMATION SHEET

A health survey of around 400 workers on the island of Montserrat is being carried out by the Institute of Occupational Medicine (IOM), a research charity based in Edinburgh, UK for the Department for International Development (DfID) of the British Government. The aim of the study is to identify respiratory ill-health, if any, among workers who live on the island and who have been exposed to ash from the Soufriere Volcano over the past five years.

Participants in the study have been selected based on their job on Montserrat, and will be asked to make one visit, lasting no more than one hour, to the medical survey unit which will be on Montserrat during October. You will be asked to sign a form agreeing to take part in the study, and you will be given a copy of that consent form and this information sheet to keep. You will be asked some questions about symptoms from your lungs (such as cough), about your smoking habits and about all the jobs you have held. You may decline to answer any question in the questionnaire without giving a reason. Where necessary, transport will be provided to and from the survey unit. No expenses will be paid.

You will be asked to perform simple lung spirometry (a breathing test). The spirometry test involves blowing out hard and fast, to measure how much air your lungs can hold. A heavy meal or smoking just before this test may affect your results so we ask you please to avoid a heavy meal for one hour before your appointment. If you are a smoker, please would you not smoke for at least an hour beforehand.

A chest x-ray will be taken of each participant, using international standard procedures. This involves a small dose of x-ray radiation to the chest, which is not considered to pose any significant hazard to health. If you have had any x-rays taken in the three months before your appointment, you will not be given a chest x-ray at survey.

There is no guarantee of any direct benefit to the individual participants in the study. No special arrangements have been made for compensation, if you are harmed by taking part in this research project. If you are harmed due to someone's negligence then you may have grounds for a legal action but you may have to pay for it.

Participation in the survey is entirely voluntary and you can decline to participate or withdraw at any time without giving a reason. This will not affect any future care or treatment. The data collected will be held in strictest confidence by the research team and will not be given to anybody without your written consent. With your permission, we will send details of any significant findings to a doctor of your choice. The data will be used only for research purposes and you can ask us to destroy it at any time. Published results from the study will not identify any individual.

If you would like any further advice or information about the survey, please contact either :
Dr Adele Pilkington, IOM, 8 Roxburgh Place, Edinburgh, EH8 9SU, UK
(Tel: 00 44 131 667 5131; Fax: 00 44 131 667 0136;
E-mail: adele.pilkington@iomhq.org.uk)
or
Dr Gordon Amery, Chief Medical Officer, Montserrat

Consent form:

Health Survey of Workers on Montserrat

CONSENT FORM

I understand that the purpose of this health survey is to collect information for research into the health of workers on Montserrat.

I understand that my participation in this health survey is voluntary, and that this will include answering questions about symptoms from the lungs (such as cough), about smoking, about all the jobs I have done, some simple breathing tests and a chest x-ray.

I understand that the information collected will be held in the strictest confidence by the research team and will not be given to anyone else without my written consent.

I understand that I will receive my own brief medical report.

I am willing to participate in this health survey.

Signature .... Date ....

Name (*print*)..

Address ....

....

I agree that abnormal test results will be sent to the doctor I have nominated:

Name of doctor ....

Address of doctor...

.. ……………………………………………………………………………………………………

Signature .... Date ....

APPENDIX 2: RESPIRATORY SYMPTOMS QUESTIONNAIRE

A SURVEY OF WORKERS ON MONTSERRAT

HEALTH QUESTIONNAIRE

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 some of the people who work on Montserrat. To help us do this, we would be grateful if you would fill in this questionnaire.

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.

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 in the last 12 months have you had wheezing or whistling in your chest?	☐	☐
2.	At any time in the last 12 months have you woken up with a feeling of tightness in your chest first thing in the morning?	☐	☐
3.	At any time in the last 12 months 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 in the last 12 months 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. In which month and year did you first experience any of these symptoms?
For example June 1997 is | 0 | 6 | | 9 | 7 |

Month ☐☐ Year ☐☐

SECTION B: QUESTIONS ABOUT BREATHLESSNESS ☐

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

If 'NO' to question 6 go to SECTION C →

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

SECTION C: QUESTIONS ABOUT ASTHMA

		Yes	No
8.	Have you **ever** had an attack of asthma?	☐	☐
9.	Have you had an attack of asthma at any time **in the last 12 months**?	☐	☐
10.	Have you ever been told by a doctor that you have asthma?	☐	☐
11.	Are you currently taking medicines for asthma (including inhalers or tablets)?	☐	☐

SECTION D: QUESTIONS ABOUT COUGH AND PHLEGM

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

If 'NO' to questions 12 and 13 go to SECTION E →

		Yes	No
14.	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 14 go to SECTION E →

		Month	Year
15.	In which month and year did you first cough up mucus from your chest (phlegm)?	☐☐	☐☐

SECTION E: QUESTIONS ABOUT SMOKING HABITS

		Yes	No
16.	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?	☐	☐
17.	Do you smoke now?	☐	☐

SECTION F: QUESTIONS ABOUT MONTSERRAT

18. Where on Montserrat have you lived from July 1995 onwards?

Please enter the dates during which you lived in each place

Place name		Dates of residence
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*	

19. Since 1995, how often have you been 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 19 go to question 21 →

20. 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 ☐

21. During the last 3 months how often has it been necessary to clean volcanic dust from inside the building where you are living?

(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
22. Have you ever been in paid employment?	☐	☐

If 'NO' to question 22 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.

APPENDIX 3: PROTOCOL AND RECORDING FORM FOR EPIDEMIOLOGICAL FILM READING TRIAL

Protocol:

P808 Montserrat Workers Study - Film Reading Exercise

Protocol for Readers

Readers are asked to read this protocol and the attached notes before starting this film reading exercise.

This exercise consists of two batches of 200 films (Batch 1) and 214 films (Batch 2). A set of recording forms will be made available. Please ensure that form filling conventions are being used consistent with ILO and IOM conventions.

The recording forms have the identity number of each film pre-printed in the order in which they appear in each batch. The identity consists of a three digit code for each film.

When you lift a film to the viewing box to read it, you should always first verify that you are looking at the correct film - it is easy to get out of step or for a film in the batch to be out of the correct ordering. The identity number of each film is printed at the bottom of the film. This number should match the number on the recording form.

Every feature in the complete ILO (1980) Classification will be recorded. The features referred to are those described on pages 4-10 and summarised on pages 46-48, of the ILO (1980) "Guidelines". A copy of the Guidelines and a full set of reference films should be available during the reading.

By local convention, if no abnormalities are observed on a film, the 'Normal' column should be recorded with a cross. This saves the reader time in recording and is treated as if the reader had recorded category 0/0 for the small opacities, category 0 for the large opacities and no pleural or other abnormalities. If either small or large opacities, or pleural or other abnormalities are observed then the Normal field must be blank and small and large opacities explicitly recorded.

If the reader wishes to make any comment about the film, other than that allowed for on the form, then add a comment indicator after the last column with an 'X'. The reader should then record their comment on a 'Comments Sheet', taking care to identify the correct film and add their initials.

Thank you for taking part in this reading exercise, without which it would not be possible to complete this important study.

Hilary Cowie
December 2000

Guidelines:

Completion of x-ray film reading forms using ILO guidelines and IOM local conventions

This note is intended to spell out the conventions to be used in the recording of data from this exercise. It is hoped that this will ensure that all readers record their results in the same, standard way which will help to avoid ambiguities.

By way of illustration, a copy of the form is attached. In what follows I will refer to the areas where recording takes place on the form as fields; I have numbered them on the example form attached, for ease of reference here, and numbers in round brackets, e.g. (3) will refer to that numbering.

All references to Left and Right will be with reference to the subject of the film. With a P/A film, the subject's right side is on the reader's left, and the layout of the fields on the form reflects this.

Film Quality (1), (2)

Record the quality of the film as 1, 2, 3 or 4 at (1). This assessment should always be present unless the film is missing from the batch, in which case it (and every other field) should be left blank.

If the quality is scored other than 1, i.e. less than perfect, the defects should be recorded at (2), using the IOM's standard in-house codes; a list of these codes is provided. Up to three defects can be recorded in this way. If the quality is as bad as 4, i.e. unreadable, then fields (3) to (14) will be left blank, but a comment would still be permissible at (15) (see below).

CPA Off (3)

Sometimes a film has been taken in such a position that one or both of the costophrenic angles is below the bottom of the film and therefore not visible. This is really another aspect of the quality of the film. Such an occurrence is recorded at (3) using one of the symbols R, L, B for Right, Left or Both. If both angles are visible leave this field blank.

Film Normal (4)

By convention, if you observe no abnormalities at all on a film, we allow you to record this with an X in field (4). In this case fields (5) to (14) will be left blank, although a comment would still be permissible at (15) (see below). It is important to note that if any abnormality covered by the Classification is observed, then it is not appropriate to use this field.

Small Opacities (5), (6), (7)

This assessment is compulsory unless the film is unreadable. It may only be omitted where an X has been entered at field (4), which will be taken to imply a small opacities profusion score of 0/0.

Enter the profusion score assigned after comparison with the ILO standard films at field (5), using one of the 12 possible codes 0/-, 0/0, 0/1, 1/0, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, 3/+. If the profusion is scored 0/- or 0/0 then fields (6) and (7) will be left blank, otherwise they must be completed.

When a score above 0/0 is assigned, mark the zones involved in diagrammatic form at (6), using x's. If all zones are involved a convenient short cut is to put a large X through the whole box at (6), but in other cases the zones must be marked individually. Enter the alphabetic codes for the predominant and secondary size and shape at (7). Since each can be one of the six letters P, Q, R, S, T, U, there are 36 possible 2-letter codes.

Large Opacities (8)

This assessment is also compulsory unless the film is unreadable. An X entered at (4) will be taken to imply a large opacities category of 0. Otherwise, enter the score for the category at (8) according to the definition in the Classification, using one of the codes 0, A, B, C.

Small and Large Opacities are the only compulsory assessments of abnormality; the remainder are all optional.

Pleural Thickening : Plaques (9)

Assess and record each lung separately. If there are no plaques in a lung then leave the field blank in the recording positions for that lung. If plaques are observed in a lung, their total extent must be recorded as 1, 2 or 3 as defined in the Classification. The section marked FACE ON is used to indicate whether any of the plaques in that lung is seen wholly or partially face-on; if any are face-on then a Y is entered. When all plaques are seen side-on, an N is entered. The maximum width is coded A, B or C as defined in the Classification; it is noted there that if all of the plaques can be seen only face-on, it may not be possible to measure a width, and in this case the section marked WIDTH may be left blank.

Pleural Thickening : Diffuse (10)

Diffuse pleural thickening is assessed for extent, whether or not face-on, and width in exactly the same way as for pleural plaques; the rules for recording are identical to those for (9).

Pleural Thickening : Diaphragm (11)

The occurrence of thickening of the diaphragm is scored and recorded R, L or B, according to whether it is observed on Right, Left or Both lungs.

Costophrenic Angle Obliteration (12)

If obliteration of the costophrenic angle can be seen on Right, Left or Both lungs, record this observation by R, L or B; otherwise leave blank. It is possible that either or both angles may be off the film; that is recorded at (3), but obviously limits the site at which obliteration might be observed.

Pleural Calcification (13)

Pleural calcification is assessed independently for each lung. Record with an X the site(s) where it is observed (chest wall, diaphragm, other) and record the total extent over the whole lung as 1, 2 or 3 as defined in the Classification.

Other Abnormalities (14)

Record the presence of any other abnormalities observed using the 2-letter codes in the standard list (copy provided). You may list up to 6 abnormalities in this way.

Comments (15)

A Comments sheet should be kept for noting features not covered by the Classification. If you write a comment about a film, put an X after the last column. It is always possible to comment, whatever other results have been recorded.

Recording form:

Montserrat medical survey radiographs: IOM epidemiological reading exercise **READER INITIALS:** **Batch: 1** **Date:**

Film ID	Film Quality (1-4)	Quality Defects (see list)	CPA off (R,L,B)	Normal (X)	Small Opacities			Large Opacities (0,A,B,C)	Pleural thickening												Pleural thickening				Pleural calcification								Other abnormalities (see list)
									Chest wall plaques						Diffuse						Diaphragm (Y,N)		Costophrenic angle obliteration (Y,N)		Chest Wall (X)		Diaphragm (X)		Other (X)		Extent (1,2,3)		
					Profusion (0/- to 3/+)	Zones (mark X)	Shape/size (p,q,r,s,t,u)		Face On (Y,N)		Width (a,b,c)		Extent (1,2,3)		Face On (Y,N)		Width (a,b,c)		Extent (1,2,3)														
									R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	
171																																	
191																																	
419																																	
217																																	
141																																	
130																																	
231																																	
299																																	
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251																																	
312																																	
386																																	
97																																	
331																																	
195																																	

APPENDIX 4: MONTSERRAT PLACE NAME CODES

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 5: RESULTS FROM THE MEASUREMENT SURVEYS

A description of the dust measurements and exposure estimation for residents of Montserrat has been reported elsewhere (Searl *et al*, in preparation) and full details have been presented in a series of IOM reports to the Department for International Development; the main points are summarised below.

A5.1 SAMPLING OF VOLCANIC ASH

Composition of the ash

The composition of volcanic ash collected from ash deposits on the island has been investigated using a variety of analytical techniques (Baxter *et al*, 1999). The main method of determination of cristobalite content has been by X-ray diffraction.

Concentrations of dust and cristobalite

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, 2000), 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 DUSTTRAK®, 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, April 2000 and August 2001. 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 DUSTTRAK® 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 DUSTTRAK® 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 DUSTTRAK® monitors in September 1996, June 1997, June 1998, April 2000 and August 2001. Although it is impossible to measure personal exposures precisely using a DUSTTRAK®, 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 in the breathing zone of sampled individuals. 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 DUSTTRAK® monitors. These included surveys of the exposure of school children, roadworkers, gardeners, 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.

A5.2 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 A5.1) was generally 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 A5.1 and A5.2). 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, where there was considered to be 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 that lasted until October 1998.

Table A5.1 Mean (range) respirable dust concentrations measured using cyclone samplers between September 1996 and June 1997 (µg.m^{-3})

Date of samples		Plymouth Mean	Plymouth Range	Cork Hill Mean	Cork Hill Range	Salem Mean	Salem Range	North Mean	North 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 A5.2 Environmental concentrations of PM_{10} (containing approximately 10% crystalline silica) in µgm^{-3} estimated from DUSTTRAK® 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 were when indoor surfaces were 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	20-130	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 A5.3). 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 A5.3). 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.

Table A5.3 Airborne dust concentrations measured with DUSTTRAK® monitors 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

The most recent measurements of dust and cristobalite concentrations in Salem and Old Towne were made in August 2001, about a month after a heavy ash fall on July 29th. Several centimetres of ash had fallen on Salem and Old Towne, but relatively little unconsolidated ash remained a month later. This was due to the combined effects of a massive clean up campaign by the Public Works Department, heavy rainfall and rapid re-establishment of grass. The weather during the one week survey was relatively dry. Environmental concentrations of PM_{10}, respirable dust and cristobalite were similar to those measured during 1998 and 1999 (Tables A5.4, A5.5).

Table A5.4 Background environmental concentrations of respirable dust and cristobalite μgm^{-3} measured on 1/9/01

Sample description	Concentration μgm^{-3} Respirable dust	Concentration μgm^{-3} Cristobalite	Period sampled (minutes)
Salem Police Station front desk	31.3	<7.8	580
Belham Valley (Golf Course)	49.1	<8.2	555
Tradewinds, Old Towne	47.0	<7.8	580
Vue Pointe Hotel, Old Towne	44.7	<7.5	610

Table A5.5 Background environmental concentrations of PM_{10} measured with a DUSTTRAK® sampler between 27th August and 1st September 2001.

Location	Mean concentration of PM_{10} (μgm^{-3})	Total time sampled (minutes)
North of the island	36.4	173
Woodlands	20.8	441
Olveston	40	4
Salem :		
excluding roadside measurement	54.7	246
by ash-covered road	297	97
Old Towne excluding Vue Pointe	45.8	70
Vue Pointe	54.7	246
Belham	123.3	84
Isles Bay	43.6	50
Daytime entry zone	184.2	103

Concentrations of respirable particulate in the northern part of the island have generally been low throughout the eruption (Tables A5.1-A5.5). Typical concentrations of PM_{10} have been between 10 and 30μgm^{-3}. Concentrations of PM_{10} exceeded 300 μgm^{-3} on a few days during 1997 when elevated volcanic activity coincided with unfavourable winds. Concentrations were raised above 50 μgm^{-3} on a number of days during 1998 and also during 1999. A major source of airborne particles 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.

A5.3 MEASURED PERSONAL EXPOSURES TO VOLCANIC ASH

Table A5.6 shows the measured levels of personal exposure to respirable dust and cristobalite that islanders were exposed to during 1997. These measurements were augmented with DUSTTRAK® 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 A5.6 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)

	Concentration (μgm^{-3})				
	Respirable dust*		Cristobalite		Number
Occupation	**Mean**	**Range**	**Mean**	**Range**	**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 and August 2001 suggest that recent levels of personal exposure have generally been low (Tables A5.7-A5.9). In April 2000, only one sample contained a measurable amount of cristobalite. The weather during the week of sampling was extremely wet, but rainfall records kept by the Forestry Department on Montserrat suggested that there had been no prolonged periods of dry weather during the previous 18 months. In August 2001, the combination of recent ashfall and relatively dry conditions is reflected in the slightly higher personal exposure concentrations than measured in April 2000. Exposure concentrations for the gardeners undertaking mowing or weed whacking, in particular, were relatively high (Tables A5.8, A5.9). It was noticeable that the full shift measurements for the gardeners gave much lower personal exposure concentrations than would have been anticipated from the DUSTTRAK® measurements.

Table A5.7 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

Table A5.8 Personal exposure concentrations of respirable dust and cristobalite µgm^{-3}

Sample description	Respirable dust Mean	Respirable dust Range	Cristobalite Mean	Cristobalite Range	Number of samples
Gardeners	418	215-869	39.2	16-122	6
Scientist working in daytime entry zone	931	694-1184	84.6	79-90	2
Public Works, ash clearing (includes >1 hour travelling time)	97.3 (91.5)	11-249	<14.2	<11-23.7	5
Police officers	52 (39)	19-96	<9.5		4
Handyman	42.3		<10.6		1
Housekeeper	30.6	31-328	<10.2	<10-22	2
Office worker	49.4		<9.9		1
Exposure during day spent in Old Towne, Salem and Woodlands	28.9		<3.6		1

Table A5.9 Approximate personal exposure concentrations of PM_{10} associated with specific activities measured using the DUSTTRAK®.

Description	**Mean** μgm^{-3}	**Duration (minutes)**
Old Towne - weed whacking – dust levels particularly high when cutting grass where grass poorly established	7487	30.5
Old Towne – mowing	7 350	18
Old Towne - weed whacking following rain	2702	14.5
Mowing, Woodlands, following rain – exhaust fume gave rise to concentrations of 100-200μgm^{-3}	120	3
Old Towne - Clipping dusty shrubs	110	2
Old Towne -Shovelling wet ash	75	1.5
Housekeepers sweeping and dusting in Old Towne	169	8
Driving up and down main Cork Hill – Plymouth road – outside car at point where Peter taking photographs	2 240	10
Driving in daytime entry zone in air conditioned vehicle	1069	113

Reference

Health and Safety Executive (2000) General methods for sampling and gravimetric analysis of respirable and inhalable dust. Methods for the Determination of Hazardous Substances 14/3.

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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.

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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.

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