# CHAPTER 1 EXECUTIVE SUMMARY

## 1.1 Background and Introduction

There is now a substantial body of evidence linking ambient $PM_{10}$ (particulate matter of less than 10 microns diameter) levels with respiratory symptoms, decreased lung function, hospital visits, school absences and other health outcomes (1-8). Previous studies have been concerned with health effects of particulate matter generated by combustion processes of point sources, by vehicle emissions or with general urban background levels of particulate matter.

The current study was initiated in 1993 in response to concerns expressed by community groups about a possible link between living close to opencast coal mining sites and respiratory ill-health and the issue has continued to be raised since then (9-12). At that time there was a lack of scientific evidence to support or refute this concern. A study was designed to compare rural and semi-urban populations exposed to a mixture of background and opencast related $PM_{10}$, i.e. overburden, soil, diesel with populations exposed to similar rural and semi-urban background levels of $PM_{10}$ only.

## 1.2 Aims

The original aims of the study were:
- to compare and characterise particulate levels in communities close to and some distance from opencast sites using quantitative and qualitative monitoring methods,
- to compare the respiratory morbidity of children living in these communities, and
- to investigate the relationship between particulate patterns and respiratory morbidity.

A fourth aim was added following discussions with DOH and DETR: to collect extra site and background information, and to inform the planning process, through the findings of the study.

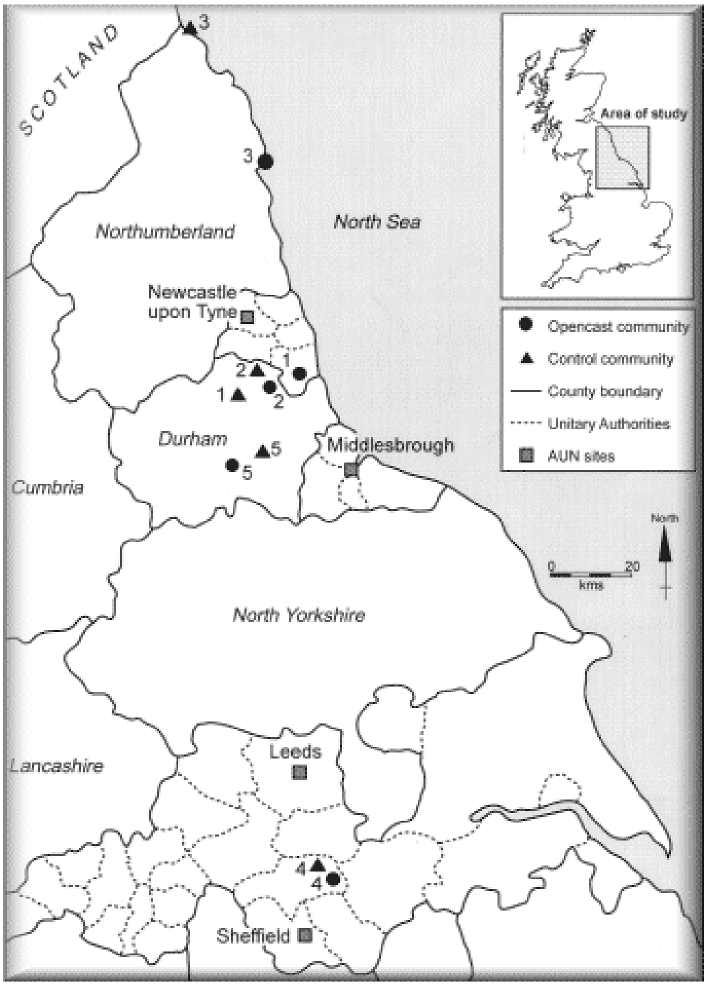
It was not an aim of the study to investigate the effect of coarse or nuisance dust, but only to investigate the health relevant particles of 10 microns and less ($PM_{10}$). The impact of nuisance dust from opencast coal mining had previously been addressed in a 1995 report (13). The study also did not aim to investigate dust dispersion in detail, even though some limited data were collected.

## 1.3 Methods

***Study design*** - The study used 5 Pairs of communities: 5 Communities close to operational opencast sites and 5 paired Control Communities some distance away (see map 1). Study and Control Communities were matched for socio-economic characteristics using Census data, information on urban/rural mix, the distance from the coast and geographic data. Data were collected simultaneously at each Pair in turn, during different seasons, but not during the main summer holiday period.

Each data collection started with a cross-sectional survey of health and family circumstances. Subsequently, longitudinal data on $PM_{10}$ and health outcomes were collected simultaneously: daily health outcomes were collected by daily diaries and the abstraction of GP records. Site operators provided retrospective information on activity at the opencast sites once monitoring had been completed.

**Map 1.1 Pairs of Opencast and Control Communities**




***Study Subjects* -** 4860 children aged 1-11 years, resident within specified geographical areas and registered with a family doctor were identified: 2443 children from 5 Opencast Communities and 2417 from 5 Control Communities. Children of this age group were selected because of their likely susceptibility to pollution-related respiratory events, the absence of active smoking and occupational exposure to pollutants, and because their movements were likely to be within the community. It could therefore be assumed that $PM_{10}$ levels from the community monitor were a fair reflection of community exposure.

***Exposure Assessment* -** Exposure assessment was conducted at different levels. The five communities near opencast sites were chosen by a predefined set of criteria: at least 300 children aged 1-11; less than 750m between the active part of the site and the centre of the community; no major intervening dust sources; and prevailing wind direction from the opencast site to the community. Because at the site selection stage we did not have information to predict operational activity for the time of the monitoring period, sites had to be chosen based on distances between the nearest point of site boundary and centre of community. The approximate distances later established between the community monitor and the first point of operational activity during the monitoring periods were: OC (Opencast Community) 1: 800m, OC2: 750m, OC3: 1300m, OC4: 800m, OC5: 1400m.

$PM_{10}$ was monitored using continuous real-time monitors (TEOM 1400a = tapered element oscillating microbalance), and co-located gravimetric (Partisol) samplers at representative sites in each community. Additionally, a battery operated PQ100 sampler collected $PM_{10}$ samples in the vicinity of site boundaries. TEOM $PM_{10}$ data were collected at 30 minute intervals for 6 weeks (42 days for each pair, 30 weeks in total). In Pair 2, dust data were collected for an extended 24 week period (total dust collection period 48 weeks). Comparative data on hourly $PM_{10}$ concentrations in the cities nearest to the study areas were obtained from the Department of the Environment Transport and the Regions' (DETR) Automated Urban Network (AUN). Wind speed and direction were recorded using standard meteorological instruments at the sampling locations in the Opencast and Control Communities.

152 PQ100 and Partisol samples were collected on an approximately weekly basis to provide sufficient material for physico-chemical analysis. At least 100 particles per sample were characterised by electron microscopy for particle type using the following categories: shale (as an indicator of opencast derived particulates (14-17), soot, flyash, carbon, biological material, quartz, and other. Particle size and number, shape and sphericity were recorded as well as mass. The composition of insoluble $PM_{10}$ particulates was determined by scanning electron microscopy with energy dispersive analysis (SEM-EDS). Water soluble $PM_{10}$ particulates were analysed using graphite furnace atomic absorption spectrophotometry (GF-AAS) and ion chromatography (IC).

Finally, indicative 'enrichment factors' (e) were calculated incorporating the TEOM and Partisol filter weights and the proportional number of shale particles per sample to identify periods when opencasting was likely to have an impact on the community:

e-TEOM = mass TEOM Opencast¸TEOM Control,

e-Partisol = weight Partisol Opencast¸Partisol Control,

e-shale = Proportion shale Opencast¸proportion shale Control.

Sample periods were classified as 'opencast impact periods' if all three ratios were above one. This would indicate additional weight and extra particulate numbers attributable to shale. Shale was chosen as an indicator because it is a component of soil and overburden which is disturbed during opencast operations. Similar enrichment factors were calculated for the soot load to identify local and regional influences. If volatile materials were responsible for additional $PM_{10}$, only the Partisol and possibly the soot load estimate would have been expected to increase.

***Health Outcomes*** **-** Health outcomes covered different levels of severity of illnesses of the respiratory tract, eye and skin over different time periods: ever, past 12 months, past 2 months, 6 week monitoring periods and daily during monitoring periods. A postal questionnaire collected information on the previous and current history of children's respiratory health, their family circumstances and lifestyle factors. Children whose questionnaire had been returned formed the basis for the collection of daily diary and GP data. A respiratory symptom diary was used to collect health information over the 6 week periods concurrently with $PM_{10}$ dust collection. Cough, wheeze, difficulty breathing, visit to GP, fever, absence from school and medication were recorded. Diaries and questionnaires were completed by parents on behalf of their children. General practitioner records were abstracted both retrospectively for the six week periods of $PM_{10}$ monitoring and for the one year period prior to the study. This was one of the measures taken to allow an assessment of whether the six week core study periods were typical for the pattern of consultations in communities. Information on 9980 GP consultations was collected from 193 GPs in 77 GP practices using a tailor-made database. Consultations were categorised as respiratory, skin, eye and other (unclassified).

***Statistical analysis***- The influence of proximity to opencast sites was considered separately for each type of health outcome and for the $PM_{10}$ data. In addition, links between daily $PM_{10}$ levels and daily prevalence and incidence of ill-health were investigated. $PM_{10}$ levels were compared using differences between log($PM_{10}$) on those occasions when paired readings were available in both communities, because of the skewed distribution of the data; mean ratios and geometric means were therefore used as summary statistics. Formal comparisons of $PM_{10}$ levels between Opencast and Control Communities were made using Cochran-Orcuttt regression, which adjusted for serial correlation (18).

Logistic regression was used to compare Opencast and Control Communities on aspects of the questionnaire data. Models were fitted using community (e.g. residence in a community near an opencast site and Pair), and a set of previously defined covariates: sex; age; number of people in the household; smokers and moulting pets in household; population stability; use of polluting fuels to heat or cook; damp problems; housing tenure type; unemployment; family history of atopy; and propensity of parents to worry.

For respiratory diary and the GP consultation data two methods were used to address the issue that children may not be equally likely to develop a particular symptom (between child variation) and the presence of a symptom on one day may be associated with the presence of the same symptom on previous days (serial correlation): logistic regression incorporating extra-binomial variation (19), and logistic regression using generalised estimating equations (GEE) (20). Since the health data showed little evidence of serial correlation, GEE results were not reported.

For the analysis of the link between daily $PM_{10}$ concentrations and daily health outcomes logistic regression models were fitted assuming independent errors and extra binomial variation where necessary. These models included predictors at community level (living near an opencast site and Pair); time varying predictors ($PM_{10}$ levels); and predictors at child level (age, sex, previous asthma and housing tenure). If a significant interaction between community type and $PM_{10}$ levels was found, odds ratios were reported for groups of similar communities.

## 1.4 Results

### *Comparison of $PM_{10}$ levels and $PM_{10}$ characteristics in Opencast and Control Communities -*

Figure 1.1 shows the time-series plot of 24 hour geometric mean $PM_{10}$ concentrations in the five Pairs. Despite a wide range of values (3-54µg/m$^3$), patterns were similar for much of the period, indicative of strong regional contributions to $PM_{10}$ levels. The geometric mean of daily paired differences between Opencast and Control Communities was 2.0mg/m$^3$ with a maximum difference of 35µg/m$^3$. The importance of the regional contribution to daily $PM_{10}$ levels in rural study communities was reinforced by the comparison with urban AUN monitoring stations which also showed similar patterns over time. A total of 14609 paired 30 minute readings in Opencast and Control Communities were recorded (91% data capture) over the 4x6 and 1x24 week monitoring periods. The most common category of differences of paired simultaneous readings of $PM_{10}$ concentrations in Opencast and Control Communities (n=9613) was less than 5mg/m³ in either direction, i.e. levels were slightly higher either in the Opencast or the Control Community. However, overall Opencast Community readings were higher than Control Community readings in 63% of paired readings. This was reflected in an overall geometric mean of 17.0µg/m³ in Opencast Communities (5x6 weeks) and 14.9mg/m³ in Control Communities (see table 1.1).

**Key findings 1 and 2:**

- **The pattern of $PM_{10}$ levels over time were similar in Opencast and Control Communities indicating regional influences**
- **The geometric mean $PM_{10}$ was 17.0µg/m³ in Opencast and 14.9µg/m³ in Control Communities**

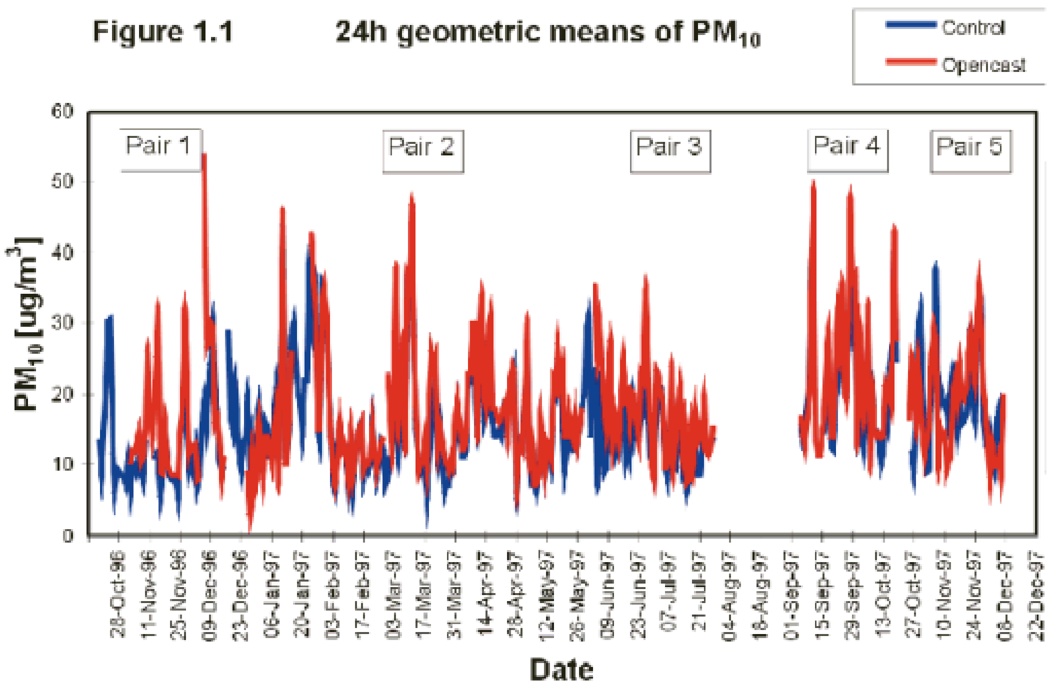



**Table 1.1 30min average $PM_{10}$ levels (TEOM) in Opencast and Control Communities**

| Pair | Duration (weeks) | Geometric mean [µg/m³] O | Geometric mean [µg/m³] C | Mean ratio [O/C] | 95%Cl | Pairs of readings (N) |
|---|---|---|---|---|---|---|
| 1 | 6 | **14.4** | **11.4** | **1.27** | 1.20 - 1.35 | 1871 |
| 2 | 6 | **16.2** | **13.2** | **1.23** | 1.18 - 1.29 | 1975 |
| 2 | 24 | **15.4** | **14.2** | **1.08** | 1.06 - 1.11 | 6970 |
| 3 | 6 | **16.1** | **13.3** | **1.21** | 1.15 - 1.27 | 1999 |
| 4 | 6 | **22.3** | **20.4** | **1.09** | 1.06 - 1.13 | 1784 |
| 5 | 6 | **17.1** | **18.1** | **0.94** | 0.89 - 1.00 | 1984 |
| 1-5 | 30 | O: **17.0** | C: **14.9** | **1.14** | 1.13 - 1.16 | 9613 |

**O**: Opencast Community, **C**: Control Community

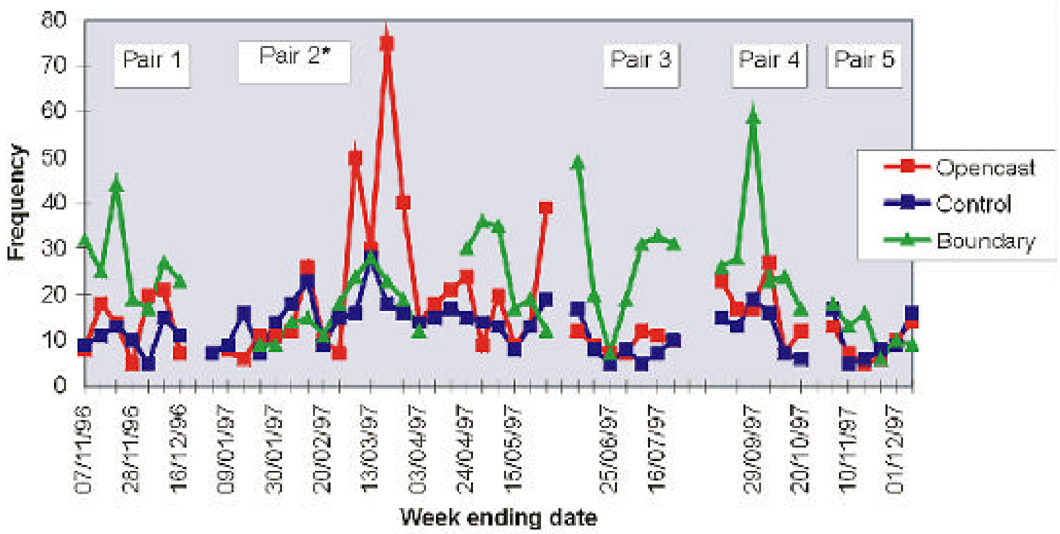
Table 1.1 also shows the ratios of simultaneous $PM_{10}$ readings in Opencast and Control Communities. The geometric mean ratio of 1.14 (95% confidence interval 1.13 to 1.16) shows that overall $PM_{10}$ levels in Opencast Communities were significantly higher than in Control Communities. In Pairs 1-4 Opencast Community readings were on average higher than readings in Control Communities, whereas in Pair 5 this trend was reversed and the Opencast Community experienced lower concentrations than the Control Community.

Further analysis investigated any links between $PM_{10}$ levels and wind speed, wind direction, days of the week, time of the day, and permitted opencast site working hours. $PM_{10}$ levels followed a diurnal pattern typical of rural communities with a gradual build up throughout the day, without the distinctive morning peak seen in urban areas. The differences between Opencast and Control Communities were not found to be greater under conditions when the contribution of site related $PM_{10}$ dust had been expected to be raised, i.e. when the wind was blowing from the site to the community monitor, or during permitted site working hours.

**Key findings 3 and 4:**

- **Opencast Communities had on average 14% higher $PM_{10}$ concentrations than Control Communities**
- **Elevated $PM_{10}$ levels in Opencast Communities were not associated with permitted site working hours or monitored wind direction**

**Figure 1.2** **Frequency of shale (%)**




*Three high proportionate shale contents in Opencast Community 2 were related to local roofing work, not opencast operations

Figure 1.2 shows the proportionate number of shale particles in samples from Opencast and Control Communities and from the site boundaries. The Boundary samples frequently displayed the highest proportion of shale particles and had the largest mean particle size of shale, both indicate that these shale particles were generated on the opencast sites. Four out of five Pairs also showed elevated shale levels in the Opencast Community. The higher proportion of shale in both Boundary and Opencast Community samples indicated that opencast sites were adding to the $PM_{10}$ load in adjacent communities. Fifteen out of thirty-four sampling periods showed an impact of opencast activity based on all three ‘enrichment factors’ of sample weights and proportion of shale.

With the exception of Pair 1, soot levels were not elevated in Boundary samples compared to Opencast Community samples, but were higher in Opencast Communities than in the Control Communities. Flyash, secondary particulate sulphates and nitrates displayed mainly regional trends, even though there were suggestions of variation in source.

**Key findings 5, 6 and 7:**

- **Opencast sites were associated with additional $PM_{10}$ load in adjacent communities**
- **Flyash, nitrates and sulphates showed mainly regional influences; whereas soot, biological material and minerals (including shale) reflected local patterns**
- **15/34 samples showed opencast impact based on all three separate ‘enrichment factors’**

***Response rates for health data* -** Parents of 1639 children in Opencast Communities and 1577 children in Control Communities returned the questionnaire (response rate 69% and 68%). Those returning the questionnaire represented the basis for data collection from GPs and daily diaries. 2572 GP records were accessed (82% in Opencast, 78% in Control Communities for the 6 week periods), and 46% of parents who received a daily diary returned it.

***Comparability and characteristics of study sample* -** The responses to indicators of socio-economic status from the questionnaire survey were compared with data collected from the 1991 Census. Respondents were found to be representative of the general community population, with the exception of access to a car which was more common in the study respondents. The original questionnaire sample, and the sub-sample from which daily diary and GP data were collected, were similar with regard to demographic and lifestyle characteristics. Those who responded to the postal questionnaire survey in Opencast and Control Communities were, overall, well matched for factors linked with the occurrence of respiratory illnesses (see Table 1.2). However, children in Control Communities were more likely to have lived at their present address for most of their lives and to live in a household using polluting cooking fuels: these imbalances were addressed in the analysis of the health outcomes.

**Table 1.2 Comparability and characteristics of study respondents**

| | | Communities | |
|---|---|---|---|
| | | Opencast % | Control % |
| **Household**: | Not owner occupied | 35 | 35 |
| | Unemployed | 12 | 10 |
| | No car access | 18 | 20 |
| | Single adult | 15 | 16 |
| **1+ smokers in household** | | 45 | 43 |
| **1+ indicators of damp** | | 17 | 22 |
| **Polluting heating**[1] | | 66 | 63 |
| **Polluting cooking**[2] | | 44 | 59 |
| **Present address for most of life**[3] | | 85 | 91 |
| **Long term work in dusty industry**[4] | | 17 | 15 |
| No. of respondents | | 1639 | 1577 |

[1]coal or open fire, solid fuel, coke, wood, gas fires/bottles, paraffin, [2] solid fuel, oil, [3]child at present address or within half a mile for most of life, [4]agriculture/gardening, coal industry/ coal delivery (not opencast), cokeworks, opencast coal extraction, potter/ceramics, printing industry, quarrying/stonemasonry, wood/paper industry

**Key findings 8 and 9:**
- **The respondents were representative of the underlying population**
- **Study Pairs were overall well matched for socio-economic indicators and were similar in their lifestyle characteristics**

***Questionnaire data: general health, cumulative prevalence of asthma, wheeze and bronchitis, asthma severity -*** The general health and occurrence of long term illness in children was similar in Opencast and Control Communities: 5% reported their child's health to be poor or fair, and 9% had any long term illness, with asthma being the most common one. Levels of reported illnesses or symptoms that might be affected by particulate matter were very similar in Opencast and Control Communities. This applied to the cumulative prevalence (whether the child had ever had it), the period prevalence over the past 2 months and over the past year, regular symptoms and whether the child had been absent from school. Table 1.3 shows the descriptive statistics for the cumulative prevalence for wheeze, asthma and bronchitis, and for the severity of asthma in the past 12 months amongst those who have asthma. Table 1.4 shows the results of the formal comparisons of these health outcomes between Opencast and Control Communities. Other outcomes analysed were tonsillitis, sinus trouble, hayfever, allergies, glue ear, eczema, eye irritation, diarrhoea, stomach upset and urine infection.

**Table 1.3 Cumulative prevalence of wheeze and asthma, bronchitis and asthma severity and frequency in past year**

| | Study Communities (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **O1** | **C1** | **O2** | **C2** | **O3** | **C3** | **O4** | **C4** | **O5** | **C5** | **O all** | **C all** |
| **ever had:** | | | | | | | | | | | | |
| **Wheeze** | 39 | 38 | 35 | 36 | 38 | 32 | 35 | 40 | 30 | 40 | **36** | **37** |
| **Asthma** | 24 | 24 | 23 | 23 | 24 | 17 | 12 | 14 | 13 | 23 | **21** | **21** |
| **Bronchitis** | 8 | 5 | 7 | 8 | 10 | 5 | 6 | 5 | 4 | 8 | **8** | **6** |
| No. of respondents | 438 | 301 | 338 | 438 | 461 | 370 | 219 | 133 | 183 | 335 | 1639 | 1577 |
| **wheezing attacks in past year have:** | | | | | | | | | | | | |
| **been 12 or more** | 10 | 18 | 5 | 3 | 5 | 7 | 8 | 21 | 3 | 5 | **6** | **9** |
| **woken child at night** | 62 | 70 | 58 | 61 | 66 | 67 | 67 | 63 | 57 | 77 | **62** | **68** |
| **limited speech** | 18 | 24 | 15 | 18 | 16 | 20 | 26 | 13 | 18 | 22 | **18** | **20** |
| **occurred on exercise** | 60 | 63 | 60 | 53 | 65 | 69 | 64 | 70 | 41 | 58 | **60** | **61** |
| No. of respondents (asthmatics) | 82 | 67 | 60 | 88 | 84 | 54 | 39 | 24 | 30 | 60 | 295 | 293 |

**O** = Opencast Community, **C** = Control Community,

**Table 1.4 Odds ratios and 95% confidence intervals comparing proximity to opencast sites for the cumulative prevalence of asthma, wheeze, bronchitis, and asthma severity**

| | **Adjusted odds ratio**[1] | 95% CI |
|---|---|---|
| **Wheeze** | **1.03** | 0.8 - 1.2 |
| **Asthma** | **1.03** | 0.8 - 1.2 |
| **Bronchitis** | **1.3** | 0.99 - 1.8 |
| **12+ wheezing attacks in past year** | **0.5** | 0.2 - 0.93 |
| **wheezing attack has:** | | |
| woken child at night | **0.8** | 0.6 - 1.2 |
| limited speech | **0.9** | 0.5 - 1.4 |
| occurred on exercise | **1.01** | 0.7 - 1.5 |

[1]logistic regression assessed the association with Community type having taken into account the effect of Pairs, and as confounding variables: child's sex; no of people in household; smoking; moulting pets; use of polluting fuel to heat or cook; damp; housing tenure; unemployment; access to transport; child's age; family history of asthma, eczema or hayfever; propensity of parent to worry; population stability.

Overall 36% of children in Opencast and 37% Control Communities had ever wheezed, 21% in all communities reported they 'ever had asthma', and 8% of children in Opencast and 6% in Control Communities had ever had bronchitis. There was little evidence of a significant association between living in an Opencast Community and the cumulative prevalence of wheeze, asthma, or bronchitis. Whereas the prevalence of wheezing did not vary much (30-40%), the cumulative asthma prevalence varied by a factor of two (12-24%), between communities. Asthma and wheeze did not always vary in parallel, thus suggesting possible differences in the use of diagnostic labels between communities. Amongst those children reported as ever having had asthma, 6% in Opencast Communities and 9% in Control Communities had 12 or more wheezing attacks in the past year. The proportions of asthmatic children being woken at night, having had a speech limiting attack and having had an attack on exercise were higher in Control Communities than in Opencast Communities, and regression analysis did not suggest that asthmatic children in Opencast Communities had more or more severe asthma attacks.

**Key finding 10 and 11:**

- **The cumulative or period prevalence of asthma, wheeze, bronchitis and other respiratory illnesses was similar in Opencast and Control Communities**
- **Asthmatic children in Opencast Communities did not have more or more severe asthma attacks than children in Control Communities in the past year**

***Daily diary data -*** Figure 1.3 and Table 1.5 show selected findings of the analysis of the daily diaries. The average daily prevalence of wheeze was 4%, of cough 15% and of other respiratory symptoms 16%. Figure 1.3 illustrates the considerable variation of daily prevalence between communities and to a lesser extent between pairs (i.e. cough 8% - 20%) without a pattern being discernible except for a slight seasonal trend with a higher prevalence in winter than in summer. The regression analysis showed that living near an opencast site was not significantly associated with the daily prevalence of wheeze, cough, or other respiratory symptoms, except for two results in single pairs of communities (one positive, one negative). The use of asthma relievers was not significantly associated with proximity to an opencast site in Pairs 1 and 2, whereas in Pair 3 there was a significant positive association. The precision of the estimates made the results consistent with positive, nil or negative association.

**Figure 1.3 Daily prevalence of self reported respiratory symptoms**

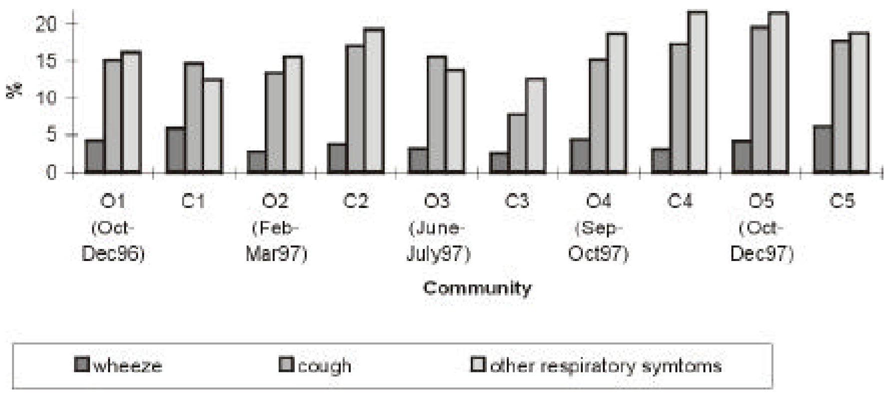



**Table 1.5 Odds ratios and 95% confidence interval from logistic regression for the effect of proximity to opencast sites on the daily prevalence of symptoms**

| Symptom | Pairs | OR[1] | 95% CI | Number of respondents |
|---|---|---|---|---|
| Wheeze | 1-5 | **0.82** | 0.36 - 1.89 | 1405 |
| Cough | 1,2,4,5 | **0.96** | 0.79 -1.16 | 1405 |
| | 3 | **1.99** | 1.31 - 3.01 | |
| Other respiratory symptom[2] | 1,3,4,5 | **1.26** | 0.99- 1.61 | 1405 |
| | 2 | **0.80** | 0.66 - 0.97 | |
| Asthma reliever used[3] | 1,2 | **0.66** | 0.33 - 1.26 | 224 |
| | 3 | **4.32** | 1.12 - 16.7 | |

[1] association with Community having taken into account Pair, sex, housing tenure, age and asthma, [2] sore throat, ear ache, runny ear or nose, [3] numbers in pairs 4 and 5 too small to be analysed

***GP consultations -*** Figures 1.4 and Table 1.6 show selected findings of the analysis of the GP consultation rates per child per person-year for the 6 week monitoring periods. Analysis was also done for the 52 weeks before the study. Consultation rates were overall slightly lower during the 6 week study periods compared to the year prior to the study (2.7 vs. 3.1 per person-year in Opencast and 3.0 vs. 3.3 in Control Communities) and were overall slightly higher in Control Communities than in Opencast Communities. Considerable variation was again observed between communities and pairs, with Control Community 5 showing the highest rates. Rates were reported separately for Pair 5 because there was a significant interaction between the health outcomes and Pair. The difference between summer and winter periods was not as pronounced as for the self reported events.

The logistic regression analysis for GP consultations over the 6 week periods showed no significant association between living in an Opencast Community and the overall rate of consultations for any reason. However, the odds of respiratory, eye and skin consultations, and respiratory consultations alone were 40% and 42% respectively higher in Opencast than in Control Communities in Pairs 1-4, but not in Pair 5. Consultation rates for respiratory, skin and eye consultations were 2.1 per person-year in Opencast Communities 1-4 and 1.5 per person-year in Control Communities 1-4. Consultation rates for respiratory consultations were 1.5 per person-year in Opencast Communities 1-4 and 1.1 in those Control Communities. This finding was not repeated for the 52-week periods, where a more mixed picture emerged (data presented in Chapter 10).

**Table 1.6 GP Consultation rates and logistic regression results comparing proximity to opencast sites over 6 week period (N=2442)**

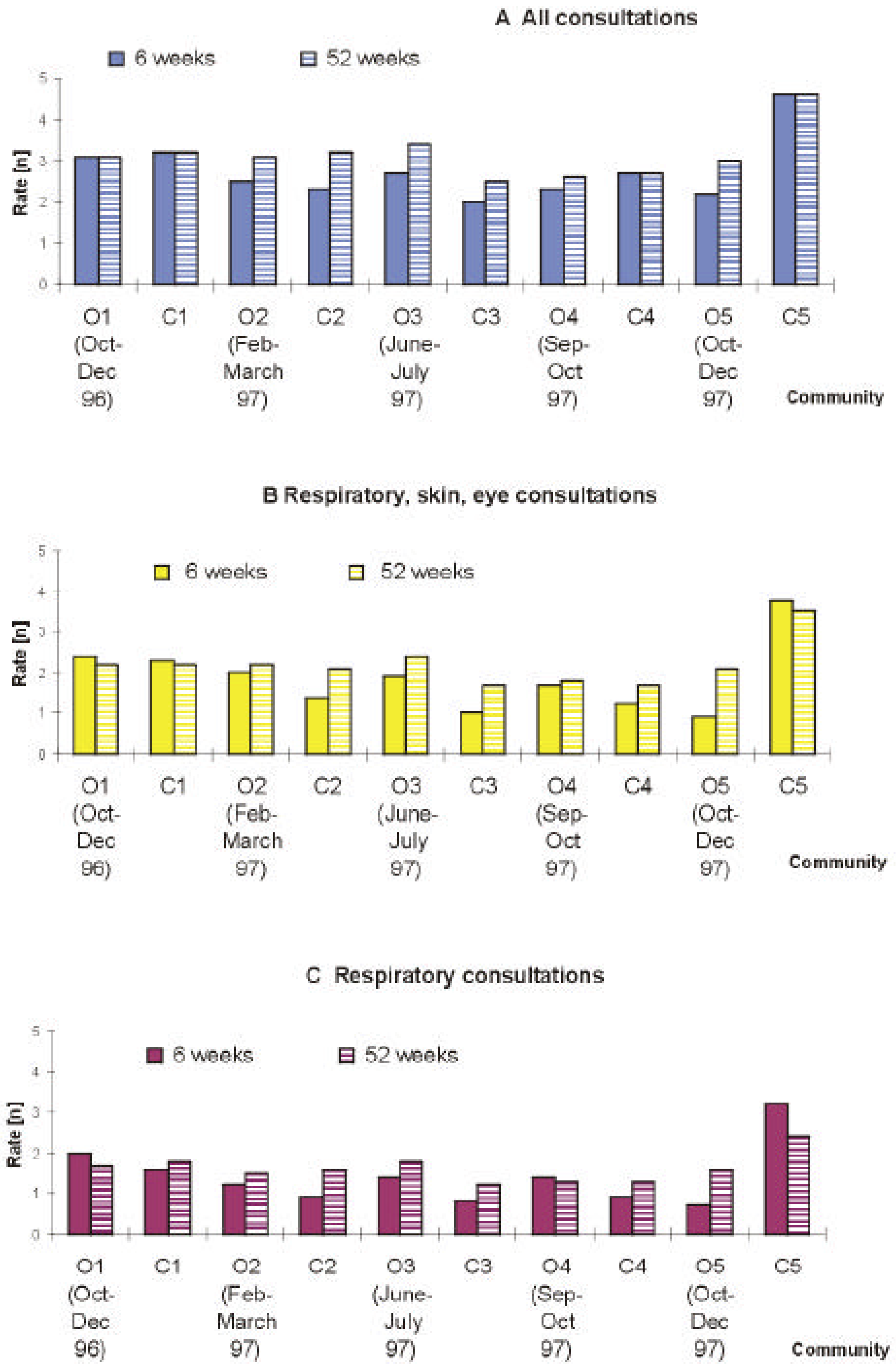
| Consultations | Rates per person -year | | Logistic regression | | |
|---|---|---|---|---|---|
| | O[1] | C[1] | Pairs | OR2 | 95% CI |
| All | **2.7** | **2.4** | 1,2,3,4 | **1.10** | 0.94- 1.29 |
| | **2.2** | **4.6** | 5 | **0.43** | 0.24 - 0.78 |
| Respiratory, skin and eye | **2.1** | **1.5** | 1,2,3,4 | **1.40** | 1.15- 1.70 |
| | **0.9** | **3.8** | 5 | **0.16** | 0.06 - 0.40 |
| Respiratory | **1.5** | **1.1** | 1,2,3,4 | **1.42** | 1.13- 1.79 |
| | **0.7** | **3.2** | 5 | **0.15** | 0.06 - 0.43 |

[1]**O**: Opencast Community, **C**: Control Community [2] association with Community having taken into account Pair, sex, housing tenure, age and asthma

**Key finding 12, 13, and 14:**

- **Parent-reported daily wheeze, cough, other respiratory symptoms, and asthma reliever use over 6 weeks were not significantly different in Opencast and Control Communities, with the exception of single pairs of communities for different items**
- **Children in Opencast Communities 1-4 had 2.1 GP consultations per child per year for respiratory, skin and eye conditions compared to 1.5 in Control Communities (1.5 and 1.1 for respiratory conditions only) for the 6 week periods**
- **The odds on GP consultation for children in Opencast Communities 1-4 were significantly higher - 40% more for respiratory, skin and eye conditions and 42% for respiratory conditions for the 6 week study periods**

**Fig 1.4** GP consultations per person-year



***Associations between daily $PM_{10}$ levels and respiratory events* -** Table 1.7 shows the odds ratios linking both the prevalence of symptoms and GP consultations with a $10mg/m^3$ increase in daily level of $PM_{10}$ on the same day as a typical example of findings. The variation between results in the 10 communities made it necessary to report results in separate groups. Around half of the associations in wheeze, cough and other symptoms were found to be positive and statistically significant, and the precision of the estimates in the remainder meant they were consistent with a zero or positive association. The associations with asthma reliever use and GP consultations were all non-significant, but the precision of the estimates meant that results were also consistent with a small positive or negative association. Similar results were found when the link between respiratory events and lagged $PM_{10}$ levels were explored.

Although the odds ratio estimates varied between some communities there were no consistent differences between Opencast and Control Communities. Such a relationship would have been expected if the constituents of $PM_{10}$ particulate matter in Opencast Communities were more or less likely to provoke respiratory events.

**Table 1.7 Odds ratios and 95% confidence intervals per $10\mu g/m^3$ increase in daily PM for daily diary and GP consultations for the 6 week monitoring periods (N=1405)**

| **Outcome** | **Communities[4]** | | **Odds ratio[1]** | **95% CI** |
|---|---|---|---|---|
| | **Opencast** | **Control** | | |
| **DAILY DIARIES** | | | | |
| Wheeze | 1, 3, 4 | 1, 3, 4, 5 | **1.02** | 0.96 - 1.09 |
| | 2 | 2 | **1.18** | 1.05 - 1.33 |
| | 5 | | **1.59** | 1.23 - 2.06 |
| Cough | 1, 3 | 2, 4, 5 | **1.03** | 0.99 - 1.07 |
| | 2, 4, 5 | | **1.08** | 1.02 - 1.14 |
| | | 1, 3 | **1.28** | 1.16 - 1.42 |
| Other respiratory[2] | 1, 2 | 1, 2, 4, 5 | **1.01** | 0.98 - 1.05 |
| | 3, 4, 5 | 3 | **1.16** | 1.10 - 1.22 |
| Use of asthma reliever[3] | 1, 2, 3 | 1, 2, 3 | **1.00** | 0.94 - 1.06 |
| **GP CONSULTATIONS** | | | | |
| All | 1,2, 3, 4, 5 | 1, 2, 3, 4, 5 | **1.05** | 0.96 - 1.15 |
| Respiratory, skin, eye | 1,2, 3, 4, 5 | 1, 2, 3, 4, 5 | **1.04** | 0.93 - 1.15 |
| Respiratory | 1, 2, 3, 4, 5 | 1, 2, 3, 4, 5 | **1.06** | 0.94 - 1.19 |

**O**: Opencast Communities, **C**: Control Communities, [1] association with $PM_{10}$ level having adjusted for covariates: Pair, sex, housing tenure, age and asthma, [2] sore throat, ear ache, runny ear or nose, [3] numbers in pairs 4 and 5 too few to be analysed, [4] different community groupings as a result of significant interactions found in the statistical analysis. Numbers refer to the Pair number

**Table 1.8** **Comparison between studies of odds ratios for the daily prevalence of wheeze per 10µg/m$^3$ increase in $PM_{10}$ levels on the same or previous day**

| Study[1] | Location | Range of daily $PM_{10}$ [µg/m$^3$] | Age [y] | Adjusted Odds Ratio | | 95% Confidence interval |
|---|---|---|---|---|---|---|
| | | | | **lag0** | **lag1** | |
| Pope 91 | Utah Valley, USA | **11 - 195** | 10-12 | **1.05** | | 1.01 - 1.09 |
| Pope 92 | Utah Valley, USA | **7 - 251** | 10-12 | **1.05**[a] | | 1.01 - 1.08 |
| | | | | **1.02**[b] | | 0.98- 1.07 |
| Roemer 98 | 7 urban, 7 suburban European Centres | **5 - 242** | 6-12 | **0.992** | | 0.984- 1.001 |
| | | | | | **1.000** | 0.991 - 1.009 |
| Hoek 94 | 4 Dutch non industrial cities | **14 - 126** | 7-11 | | **1.02** | 0.99 - 1.04 |
| Boezen 99 | 3 rural and 2 urban Dutch areas | **5-242** | 7-11 | | **1.03**[a] | 1.01-1.05 |
| | | | | | **1.00**[b] | 0.97-1.04 |
| Opencast | 7/10 rural or semi-urban communities, UK | **5 - 58**[2] | 1-11 | **1.02** | | 0.96- 1.09 |
| | | | | | **0.98** | 0.92 - 1.05 |

[1] sources: (2, 4, 5, 7, 28), [2]Daily arithmetic mean - excluding days with unrepresentative very local dust impact near monitor, a: symptomatic, b a-symptomatic

Table 1.8 compares current findings with previous reports on associations between daily $PM_{10}$ levels and wheeze in children. It highlights the similarity between the strength of the associations in locations with a much wider range of daily $PM_{10}$ values in urban settings and different likely sources of $PM_{10}$.

**Key finding 15, 16, 17 and 18:**

- **There were small, but significant positive associations between daily levels of $PM_{10}$ and daily diary events in about half the analyses. The precision of the estimates meant that most others were consistent with either no or a small positive association**
- **Associations between daily $PM_{10}$ levels and both asthma reliever use and GP consultations were not significant, but also consistent with small positive associations**
- **The associations were similar in Opencast and Control Communities suggesting that $PM_{10}$ had a similar link with respiratory ill-health whatever the community type**
- **The magnitude of the associations between daily $PM_{10}$ levels and health outcomes was in line with previous reports on children exposed to ambient particulate matter, even though daily $PM_{10}$ levels were some of the lowest reported**

## 1.5 Does living near opencast coal mining impair children's health?

A detailed discussion of all findings can be found in Chapter 12 of the report and only a summary is provided here. A simple 'Yes' or 'No' answer to the question cannot be given, since not all findings, both on exposure and on health, pointed in the same direction. An important observation affecting many analyses was the considerable level of variation between community and pairs, even though community pairs were well matched for lifestyle and socio-economic factors and were all rural or semi-urban in character.

Exposure to $PM_{10}$ particulate matter and health during the main 6-week data collection periods was investigated using different time scales: half-hourly ($PM_{10}$ monitoring); daily ($PM_{10}$ monitoring, GP consultations, daily diary), and approximately weekly (sample characterisation, enrichment factors, GP consultations, daily diary). Health data were also collected for the period prior to this study (cumulative and period prevalence, GP consultations in year before the study). The particular advantage of the analysis of daily diary entries and events from GP records over the 6-week study periods was that individual information on health outcomes could be linked with simultaneous daily measures of exposure to $PM_{10}$. When health outcomes alone were compared over the 6 week study periods or over other periods, current residence in a community that was then near an opencast site was used as the indicator for exposure: this applied to data on chronic health collected in the questionnaire survey, and for the one year period of GP data where we did not have concurrent exposure data from $PM_{10}$ monitors. Consequently we cannot ascribe any differences in these health outcomes to variation in $PM_{10}$ levels over time.

Even though the temporal pattern of $PM_{10}$ levels in all 10 communities was dominated by regional patterns, similar to those at nearby AUN sites, the paired design of the study picked up a small but statistically significant 14% increase (2.1µg/m$^3$) in $PM_{10}$ levels in Opencast Communities. Shale was identified as a measurable component of $PM_{10}$ in Opencast Communities, indicating an ‘opencast impact’ on communities. However, additional $PM_{10}$ levels in Opencast Communities were not linked to monitored wind direction or times of permitted site activity as had been expected on the basis of previous studies which had investigated the association at distances closer to opencast sites (13, 21, 27). Wind speed and direction were monitored because they were thought to influence $PM_{10}$ levels in communities, and the monitors were sited to best reflect conditions in the children’s community, as with $PM_{10}$ monitoring. This meant that the equipment was not sited in open situations as would have been done if the focus of the study had been the dispersion of $PM_{10}$ created on opencast sites, so local topography might have influenced readings of wind speed and direction in some communities. With regard to site activity, the diaries provided retrospectively by operators varied in the level of detail they included. It was therefore decided to use permitted hours of work as a proxy measure. In summary, both the data for the analysis of the influence of wind direction and times of site activity were not as precise as we would have hoped for. Future detailed work on the dispersion of $PM_{10}$ could be designed to incorporate more monitoring points around opencast sites and at varying distances to investigate this aspect in more detail.

Recent evidence (22, 23) has suggested that there is a fairly good correlation between personal exposure to $PM_{10}$ and ambient $PM_{10}$ levels. Thus the $PM_{10}$ data collected at the community monitoring sites should reflect children’s exposure though there will be some measurement error of individual exposures.

Small but significant associations were found between daily respiratory symptoms and daily $PM_{10}$ levels. The associations sometimes differed between communities, but they were similar in Opencast Communities and Control Communities and also similar to those in previous studies, which were mainly conducted in areas with higher $PM_{10}$ levels than our study communities.

The small associations found between daily health and $PM_{10}$ data indicated that the small ***average*** difference in $PM_{10}$ levels seen between Opencast and Control Communities in this study lead to small ***average*** effects on daily health events. Although differences between Opencast and Control daily $PM_{10}$ levels of around 2µg/m$^3$ were the most common, there were some days when the difference was 10µg/m$^3$, or exceptionally 35µg/m$^3$. To illustrate the size of the predicted effects, the logistic regression parameters were used to predict the prevalence of acute health effects for different $PM_{10}$ levels. Table 1.9 presents the predicted prevalence of wheezing for four levels of $PM_{10}$: 20µg/m$^3$ is a typical daily $PM_{10}$ level, the others are 2, 10 and 35µg/m$^3$ higher with 2mg/m$^3$ representing the typical difference between Opencast and Control Communities in the current study and 35µg/m$^3$ representing the upper end of the spectrum of differences of paired reading of $PM_{10}$ levels. Since the regression model for prevalence depends on many other factors (e.g. age, sex, socio-economic status, and whether or not the child has asthma), predictions are presented, as an example, for a girl aged 5 years from a family who owns their own house in Control Community 1, and are given separately for whether she is an asthmatic or not. These values suggest that the prevalence of wheezing is predicted to change very little when the daily $PM_{10}$ level rises from 20µg/m$^3$ to 22µg/m$^3$, and even for a daily $PM_{10}$ level of 55µg/m$^3$ the predicted daily prevalence of wheeze increased only to 4.1% for non-asthmatics (from 3.8%) and to 16.1% respectively for asthmatics (from 15.1%).

**Table 1.9 Predicted daily prevalence of wheezing* (and 95%CI) for different values of concurrent $PM_{10}$**

| $PM_{10}$ level [µg/m$^3$] | **Non-asthmatics** Prevalence (%) | 95% CI | **Asthmatics** Prevalence (%) | 95%CI |
|---|---|---|---|---|
| 20 | **3.8** | 3.6 - 4.0 | **15.1** | 14.9 -15.3 |
| 22 | **3.8** | 3.6 - 4.0 | **15.2** | 15.0 - 15.4 |
| 30 | **3.9** | 3.7 - 4.1 | **15.4** | 15.2 - 15.6 |
| 55 | **4.1** | 3.7 -4.4 | **16.1** | 15.7 -16.4 |

* Child assumed to be girl , 5 years of age, from family who own their house in Control Community 1

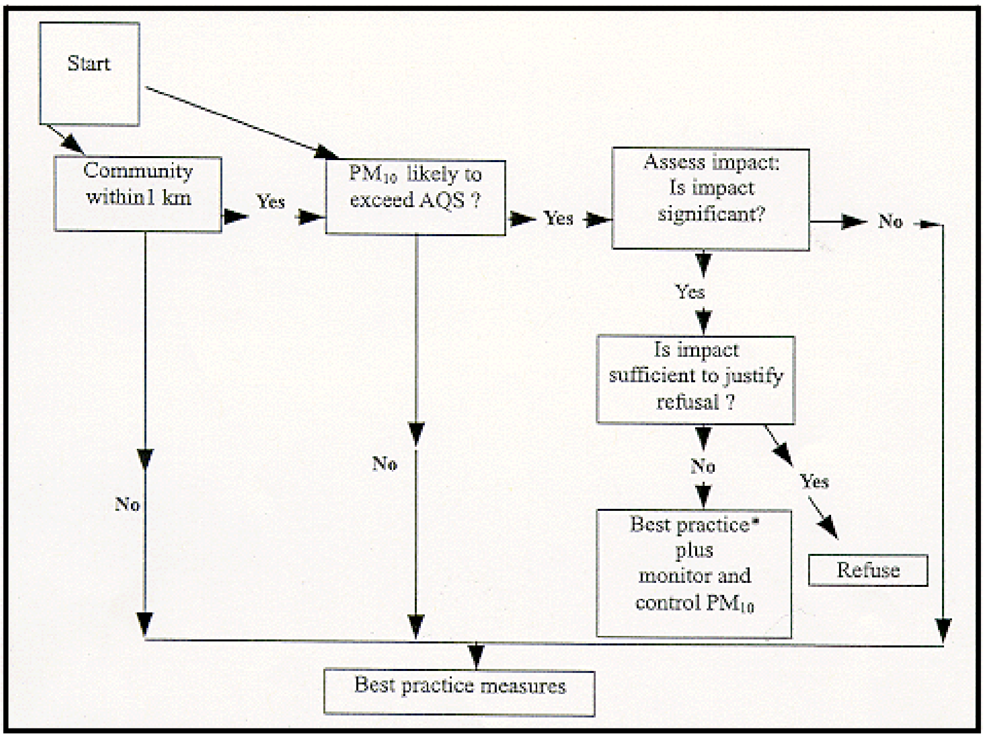
From the small positive associations found between daily levels of $PM_{10}$ and respiratory symptoms we might expect to find very small differences in the analysis of health outcomes over the six week study periods, since the average daily difference in $PM_{10}$ was 2µg/m$^3$. However, the daily analysis does not allow us to predict the effect of a change in the 6-week average of $PM_{10}$. Very few significant associations were found between daily diary symptoms and living near opencast sites. However, significant associations were found between GP consultations for respiratory, skin and eye conditions and living near opencast sites, in four out of five Pairs for over the 6-week period. These are conditions which could be expected to be exacerbated by an increase in levels of $PM_{10}$. It is unlikely that the positive findings on GP consultations were due to changes in behaviour of parents or GPs because they were aware of the study. There are a number of reasons for this: no study material sent to parents or GPs mentioned that opencast mining was the focus of the study; the effect was not observed in daily diary or questionnaire data; the effect was not observed for the overall consultation rate; and finally, consultation rates for the 6 week periods were lower overall than for the year before the study. This pattern in the GP results did not apply to Pair 5 where an unusually high consultation rate was observed in the Control Community but not in the Opencast Community. Consultation with the local health authority did not suggest that a different pattern of primary health care delivery, or other local factors could easily explain the excess in the recorded consultation rates in Control Community 5. Overall, therefore, we found an association between living near an opencast site and health outcomes over the 6 week periods for one type of health outcome but not for the other. It might be argued that this would not be too surprising given the very small magnitude of the effect which could have been expected on the basis of the findings from the analysis of daily $PM_{10}$ and health data.

Data on the cumulative and period prevalence of respiratory events collected from the questionnaire were similar to recent national surveys (24-26), and there was little evidence for a difference between Opencast and Control Communities. We need to be aware, however, that exposure was assessed, for this analysis, by current proximity of residence near an opencast site and these had been operational for varying periods before the survey. We would therefore argue that the fact that positive associations found for daily $PM_{10}$ and for GP consultations for respiratory, skin and eye conditions over 6 week periods with residential proximity to opencast sites does not necessarily contradict the negative findings of the questionnaire survey. Given the small magnitude of the association between daily $PM_{10}$ levels and health outcomes, differences in the sensitivity of exposure and health outcome measures may have contributed to these results. An extrapolation from the daily $PM_{10}$/health link to an estimation of an expected difference in chronic health would not be justified

## 1.6 Implications for planning policy

The town and country planning system regulates the development and use of land in the public interest. Where dust is demonstrated to have the potential to affect the use of land it is capable of being a material consideration. However, material considerations must be genuine planning considerations, i.e. they must be related to the purpose of planning legislation. The considerations must also fairly and reasonably relate to the application concerned. The framework for consideration of pollution issues is found in the Clean Air Acts, Environment Acts, Planning Acts and Mineral Planning Guidance. The analysis of the decision letters and reports from 24 recent Public Inquiries showed that Third Party objectors consistently raised health effects in their objections to proposed opencast coal sites. Without substantive evidence of cause and effect and without an assessment or mitigation methodology this could not be given weight within the planning process. The epidemiological study found that the presence of opencast coal mining was likely to have an impact on communities within 750m of the site (as measured from site boundary to community centre). In looking at the potential impacts both distance and the existing environment will be material. In considering a specific cut off for assessment no definitive maximum distances have been established by this study. The study investigated sites where the site boundary and community centre were within 750m. The distances between actual workings and community monitoring point varied between 750m and 1400m. This information combined with the Arup reference to 1km (13) has led to our proposed distance for assessment purposes of 1km. The study investigated monitored levels of $PM_{10}$ and compared AUN data to background $PM_{10}$ levels, but did not attempt to provide evidence to establish emission standards for opencast coal working. However, it is relevant to consider the contribution of opencast coal sites to $PM_{10}$ levels and whether that contribution is likely to lead to a breach of the established National Air Quality Standards. This will be particularly relevant when a site is proposed to be located in the same vicinity as existing or consented major contributors to the local $PM_{10}$. Figure 1.6 shows the recommended stages in scoping and assessing an opencast coal proposal for $PM_{10}$, starting by identifying the proximity of any community and then considering the background level of $PM_{10}$ and how these relate to the National Air Quality Standard. It is designed to allow consideration of the potential for impact by a number of tests and only proposes full assessment, monitoring and control when appropriate. When $PM_{10}$ impact is found to be likely to be significant in planning terms, but on balance does not merit refusal of an opencast planning application, then procedures to monitor and control $PM_{10}$ should be adopted.

**Figure 1.6 Proposed site assessment flowchart**




* additional control measures will be through monitoring and operational restrictions

## 1.7 Conclusions

Children in Opencast Communities were on average exposed to a small but significant additional amount of $PM_{10}$ on average compared to children in Control Communities (2.1µg/m$^3$, 14%). The chemical and morphological character of the particles as well as enrichment ratios pointed to opencast sites as a measurable contributors to the extra dust. The overall prevalence of asthma, wheeze, and other respiratory illnesses, the severity of asthma amongst those having asthma, daily self reported ill health, and overall rates of GP consultations were largely similar in Opencast and Control Communities. However, GP consultations for respiratory, skin and eye conditions were higher in Opencast than in Control Communities for Pairs 1-4 for the core study period: 2.1 instead of 1.5, and 1.5 instead of 1.1 respectively per child per year). Associations between daily $PM_{10}$ levels and health outcomes were frequently positive, but not always significantly so. The magnitude of the effect was similar in Opencast and Control Communities, and with those seen in previous studies with $PM_{10}$ pollution from point sources or general urban background. This suggested that $PM_{10}$ in Opencast Communities was similar to $PM_{10}$ in Control Communities, in terms of acute health effects to other sources of $PM_{10}$. A framework is recommended to direct scoping and assessment in the planning process. This incorporates distance between site and community, the likelihood of more frequent breaches of the Air Quality Standard and the presence of other major sources of local $PM_{10}$, in addition to best practice.

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