APPENDIX A

Table 1. General population studies informing on COPD and symptoms of chronic bronchitis in construction workers.

Odds ratios and other risk estimates in this table relate to construction workers and were based on comparison with non-dust exposed reference groups, usually office workers, and were all adjusted for age and smoking. See main text for further details of individual studies. Studies were all prevalence surveys unless stated otherwise.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
Hnizdo et al (2002)	United States (n = 9823) 493 construction workers	30-75 years	COPD defined as FEV1<80% predicted and FEV1/FVC <0.7	ORs for construction by industry: 1.3 (95% CI 0.8 –2.3) all subjects 3.5 (95% CI 0.9-14) never smokers ORs for construction by occupation: 1.2 (95% CI 0.6-2.5) all subjects 3.4 (95% CI 1.1-10.5) never smokers	Relative increase in COPD more apparent in never-smoking construction workers compared to never-smoking office workers.
Fishwick et al (1997)	New Zealand (n=1132) 18 construction workers	20-44 years	Symptoms of cough, phlegm, and shortness of breath. Mild airway obstruction FEV1/FVC<75%	OR for cough and phlegm 2.7 (95% CI 0.7-10.2) No increase in mild airway obstruction in construction workers.	Age range too young and group size of construction workers too small for study of COPD.
Lebowitz (1977)	Tucson Arizona (n=1132) 140 construction workers	Not stated	Abnormal lung function defined as FEV1<75% FEV1/FVC <80%	Prevalence of abnormal lung function 11.9% in construction workers and 6.5% in non-dust exposed reference group.	Exposures to sawdust and silica were associated with COPD.
Vermeulen et al (2002)	Doetinchem, Netherlands (n=1104)	20-59	Symptoms of cough and phlegm daily >3 months.	OR for chronic bronchitis symptoms	Case-control design

	42 construction workers		Breathlessness while walking on flat.	3.38 (95% CI 1.02-11.27)	
Study	**Country and sample size**	**Age-range**	**Endpoint**	**Results**	**Comment**
IOM 1997	Scotland (n=16,900)	16-64 years	Cough and phlegm for most days for at least 3 months of the year	OR for chronic bronchitis in construction workers 1.96 (95% CI 1.07-3.61)	Case-control design Among construction workers there were 100 cases of chronic bronchitis and 61 controls selected for case-control analysis.
Zock et al (2001)	14 industrialised countries mostly European. (n=13,253) Total no of construction workers not stated	20-44 years	a) Phlegm most days for at least 3 months of year. b) Cough and phlegm most days for at least 3 months of year. c) Pulmonary function testing.	Prevalence ratios for phlegm, and for cough with phlegm, in never-smoking construction workers 2.2 (95% CI 0.8-61) 1.8 (95% CI 0.2-14) Adjusted for age, gender and country Lung function results showed no differences compared to non-dust exposed matched controls	Cross-sectional prevalence survey. Age range rather young for investigation of COPD and chronic bronchitis.
Heederik et al (1989)	Zutphen Netherlands (n=828) 28 construction workers	65-84	Chronic non-specific lung disease (CNSLD) with assessment by physician.	Cough & phlegm: OR 2.6 ($p < 0.05$) Shortness of breath: OR (2.2) CNSLD: OR (2.26) Treated for chronic bronchitis or emphysema: OR (1.99)	Study used a job exposure matrix to investigate exposure and symptoms. Small group size of construction workers.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
				Latter 3 ORs were not statistically significant.	
Study	**Country and sample size**	**Age-range**	**Endpoint**	**Results**	**Comment**
Heederik et al (1990)	Zutphen, Netherlands (n=804) 60 construction workers	40-59 yrs	CNSLD monitored with regular medical examinations	Incidence density ratio for CNSLD in construction workers 2.3 (95% CI 1.44-3.67) Adjusted for age, smoking, calendar period	Longitudinal study with 25 yr follow-up. Cohort overlapped with study above.
Krzyzanowski and Jedrychowski (1990)	Cracow, Poland (n=2370) no of construction workers not stated	19-60 yrs	Epidemiological definition of chronic bronchitis	Attacks of breathlessness more common in construction workers than in other occupational groups (p=0.05)	Study focused on effects of dust, temperature and chemical exposure on chronic bronchitis with no detail on occupational status.
Petersen and Zwerling (1998)	United States 312 construction workers 1716 blue collar workers 2064 white collar workers	51-61 yrs	Physician diagnosis of chronic bronchitis or emphysema.	COPD prevalences in construction, blue collar and white-collar workers of 9.6%, 7.3% and 5.1%. COPD prevalence in non-smoking construction workers 10.4% versus 3.7% in never smoking blue collars. OR 3.2 (95% CI 1.04-10.05) COPD of greater severity in construction workers compared to other blue-collars.	Findings imply that construction workers who smoke leave employment earlier (self-select out of workforce) compared to never-smokers. Study was part of Health and Retirement Survey.

Table 2. Mortality studies in construction workers

Authors and country	Type of study	Results	Comments
Bergdahl et et (2004) 317,629 Swedish construction workers	Longitudinal study with follow-up from 1971-1999. Aim was to investigate role of dust/irritant exposure as a cause of mortality from COPD in construction workers.	RR of death due to COPD of 1.12 (95% CI 1.03-1.22) in exposed versus unexposed construction workers. RR of death from COPD in never smokers was 2.72 (95% CI 1.31-3.68) in exposed versus unexposed workers.	Fraction of COPD mortality attributable to exposure to dusts/irritants was 10.7% in all construction workers and 52.6% in never smokers.
Robinson et al (1995) US construction workers	PMR study based on 876,731 deaths between 1984-1986.	PMR for COPD: 122 (95% CI 113-131) PMR for silicosis: 327 (95% CI 149-620)	Analysis based on deaths in men under age 65. Smoking status not taken into account.
Wang et al (1999) North Carolina, US construction workers	PMR study based on 29,554 deaths between 1988-1994	For *non-malignant respiratory disease including COPD*, PMR in all construction workers 111 PMR in carpenters 114 PMR in labourers 118 PMR in painters and plasterers 152 PMR in insulators 218 For *emphysema* PMR in heavy equipment operators and operating engineers 191 All PMRs were statistically significant ($p < 0.05$)	The deaths from non-malignant respiratory disease may include asbestosis, particularly in the insulators. Not possible to identify if there was an excess mortality specifically from COPD. Smoking status not taken into account.
Bang et al (1995) US population	Data obtained from silicosis mortality surveillance scheme between 1968-1990	Of 13,744 deaths from silicosis, 10% were in construction workers	
Wong et al (1985) 3,243 deaths in heavy equipment	Cohort mortality study on workers who had worked in the construction industry between	SMR for emphysema of 165 (95% CI 136-198) For employment of <5, 5-9, 10-14, 15-19, ≥20 years, SMRs for emphysema: 99, 107, 158, 194,	Duration of union membership suggested as surrogate for exposure to diesel engine exhaust emissions. Did not take smoking into account. Lung cancer mortality not raised.

Authors and country	Type of study	Results	Comments
operators	1964-1978 and died by end 1978.	174. Emphysema SMR rose to 277 in “normal” retirees.	
Stern et al (1997a) US construction heavy equipment operators	PMR study of 15,843 heavy equipment operators who died between 1988-1993	PMR for emphysema: 137 (95% CI 120-155) PMR for pneumoconioses and other respiratory diseases including COPD: 111 (95% CI 104-119)	.
Burstyn et al (2003) Pooled analysis of European cohort studies of 58,562 asphalt workers assembled by IARC.	Study examined the relative risk of mortality from obstructive lung disease in relation to exposures in asphalt workers using a specific job exposure matrix.	Results showed statistically significant positive associations with PAHs, particularly in pavers, and mortality from obstructive lung diseases. Similar results were obtained for coal tar. Associations with bitumen exposure were positively but not statistically significantly linked to mortality from obstructive lung disease. Exposures to silica, diesel exhaust and asbestos showed no association with mortality.	The use of coal tar in asphalt appeared to be the main source of PAH exposure, but the use of coal tar is now discontinued in Europe in asphalt work. The relevance of the findings to contemporary asphalt work in the UK is therefore uncertain, although the authors could not rule out bitumen fume exposure as being causally related to the excess mortality from obstructive lung disease.
Stern et al (2000) US roofers and waterproofers	PMR study based on 11,144 deaths between 1950-1996	PMR for non-malignant respiratory disease including COPD and pneumoconioses 115 (95% CI 103-128). PMR for bronchitis 123 (95% CI 85-172) PMR for emphysema 119 (95% CI 99-139)	These trades may be at risk from asbestosis and the PMR for non-malignant respiratory disease may partly be a reflection of this.
D’Errico et al (2002) Italian road construction and maintenance workers	PMR study based on 863 deaths in workers claiming compensation for work-related disability.	PMR for silicosis of 307 (95% CI 166-567) Based on 10 silicosis deaths among this worker population.	
Stern et al (1995) US construction labourers	PMR study based on 11,685 deaths in labourers between 1985-1988.	PMR for emphysema of 112 (95% CI 92-136)	Smoking not taken into account.
Stern et al (2001) US plasterers and	PMR study based on 12,873 deaths in plasterers between 1972-1996	PMR for non-malignant respiratory diseases including COPD: 109 ($p < 0.05$) PMR for silicosis: 179 (based on 4 deaths)	

Authors and country	Type of study	Results	Comments
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Robinson et al (1996) US construction carpenters	PMR study based on 27,362 deaths between 1987-1990	PMR for emphysema; 115 (95% CI 102-130) PMR for silicosis; 112 (95% CI 31-288), based on 4 deaths.	Smoking status not taken into account.
Stern et al (1997b) US construction iron workers	PMR study based on 13,301 deaths between 1984-1991	PMR for non-malignant respiratory disease including COPD and pneumoconioses of 111 (95% CI 103-120) PMR for emphysema of 122 (95% CI 104-143)	Smoking status not taken into account.
Robinson et al (1999) US electricians	PMR study based on 31,068 deaths in electricians employed in the construction industry between 1982-1987	PMR for emphysema of 130 (95% CI 110-151)	Smoking status not taken into account.
Salg and Alterman (2005) US bricklayers	PMR study based on 10,921 deaths between 1986-1991	PMR for emphysema of 133 (95% CI 111-157) PMR for non-malignant respiratory disease including COPD and pneumoconioses 119 (95% CI 110-129)	Smoking status not taken into account although smoking is not a confounder for pneumoconiosis mortality.
Finkelstein and Verma (2005) Ontario bricklayers	Cohort mortality study based on 836 deaths.	SMRs and 95% CIs for obstructive lung disease for 10-19, 20-29 and ≥30 years since start of union membership: 91 (37-190), 120 (62-210) and 86 (46-150).	There was no increase in deaths from respiratory disease but not a large-scale study.
Steenland and Palu (1999) US construction painters	Cohort mortality study of 42,170 construction painters followed for 15 years during which time there were 18,259 deaths.	SMR for emphysema of 113 (95% CI 99-128) SMR for non-malignant respiratory disease including COPD and pneumoconioses 107 (95% CI 99-114)	Smoking not taken into account.

Table 3. Cross sectional studies informing on COPD, symptoms of chronic bronchitis and silicosis/mixed-dust pneumoconiosis in construction workers.
See main text for further details of individual studies.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
Studies in various groups of construction workers					
Arndt et al (1996) Rothenbacher et al (1997)	Germany 4958 construction workers of various professions.	40-64 years	Chronic respiratory disease identified by a) Presence of clinical findings on lung auscultation; b) FEV_1 < 70% and 80% of predicted in Rothenbacher et al (1997) and in Arndt et al (1996) respectively; c) Medical diagnosis of COPD	Higher prevalence of chronic respiratory disease in most occupations of the construction industry when compared with white-collar employees. For clinical findings on lung auscultation: prevalence of 2.9% in white-collar employees vs 12.6% in unskilled workers. For reduced FEV_1 (<70% of predicted): prevalence of 4.5% in white-collar employees vs 12.9% in unskilled workers. For medical diagnosis of COPD: prevalence of 3% in white-collar employees vs 9.1% in unskilled workers. Statistically significant age-adjusted PRR for reduced FEV_1 (< 80% of predicted) in unskilled workers compared to white-collar workers of 1.5 (95% CI 1.01-2.22).	Smoking status and socio-economic differences were not accounted making the evidence weak.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
Dement et al (2003)	United States 2602 construction workers employed at nuclear weapons sites for facility construction, maintenance and renovation.	58 ± 12.7 years	Chronic respiratory symptoms; Abnormal spirometry classified according to an obstructive pattern (FEV_1/FVC<95%CI of the predicted value and FVC≥95%CI of the predicted value) and a restrictive pattern (FVC<95%CI and FEV_1/FVC≥95%CI); Pneumoconiosis by chest X-ray (ILO score ≥ 1/0).	Prevalences: Pneumoconiosis – 2.2% Obstructive lung disease – 12.2% Restrictive lung disease – 20.5% Mixed obstructive/restrictive disease – 10% Chronic cough – 21.1% Chronic phlegm – 28.7% Grade 2+ dyspnoea – 35% Age- and smoking-adjusted ORs of 3.6 (95% CI 1.1-11.6) for pneumoconiosis and duration of employment, and of 1.6 (95% CI 0.9-2.8) for pneumoconiosis and reporting of regular past exposure to silica	No comparison group to put these prevalences into context. Association between pneumoconiosis and duration of employment.
Pham et al (1972)	France 200 construction workers.	40-60 years	Chronic bronchitis (productive cough for at least 3 months/year for at least 2 years); Airways obstruction defined as FEV_1/VC<65%.	Prevalences: Chronic bronchitis - 21% Airways obstruction – 22% 34% of workers with symptoms of chronic bronchitis had airways obstruction	Small group size. No comparison group to put these prevalences into context. No relationship between chronic bronchitis and perceived workplace exposures was identified.
Studies informing on silicosis/mixed-dust pneumoconiosis					
Nij et al (2003b and c)	The Netherlands 1339 construction workers of various	42 ± 7.8 years	Chronic respiratory symptoms; Mixed-dust	Prevalences: Mixed-dust pneumoconiosis (ILO score ≥1/0) – 10.2% Mixed-dust pneumoconiosis (ILO	Low participation rate (32%). The limited nature of the exposure assessment and the

Study	Country and sample size	Age-range	Endpoint	Results	Comment
	professions with expected high exposure to respirable quartz. Also reference population of 1350 blue-collars.		pneumoconiosis (ILO score ≥ 1/0 and ≥ 1/1 of small opacities irregularly shaped); Silicosis (ILO score ≥ 1/0 of rounded small opacities); Abnormal lung function measured by spirometry.	score ≥1/1) – 2.9% Silicosis – 0.77% Association between mixed-dust pneumoconiosis (ILO score ≥1/1) and a proxy for cumulative exposure to quartz was found (PR of 4.69, 95%CI 1.3-16.9). Chronic cough – 13% Chronic cough with phlegm – 10% Shortness of breath during normal activity – 9% Frequent wheeze – 10% Significantly lower average lung function compared to the reference group after correction for smoking (age- and height-corrected FEV_1 – 120ml lower FVC – 130ml lower PEF – 225ml lower), but no association with exposure to quartz.	lack of information on past exposure question the validity of the observed dose-response relationship between mixed-dust pneumoconiosis and cumulative exposure to quartz.
Ng et al (1987)	Hong Kong 118 caisson workers (74 underground, 44 surface workers).	20-62 years. Mean age 40 years.	Silicosis assessed by chest X-ray.	Prevalences: Silicosis – 16% in underground workers 0% in surface workers 8h-TWA respirable silica levels exceeded 0.1 $mg.m^{-3}$ in 65% of the	Caisson: cylindrical foundation which after excavation is concreted in place.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
				samples, and a median concentration as high as 6.1 $mg.m^{-3}$ (8h-TWA) was found for dry drilling inside the caisson.	
Law et al (2001)	Hong Kong 1056 workers attending the pneumoconiosis clinic between 1995-99 for compensation assessment. Of these, 648 were confirmed as cases of silicosis.	Mean age of silicosis cases was 57.4 years.	Silicosis defined by an occupational history involving significant exposure to silica-containing dust and by the presence of round and/or irregular opacities with profusion greater than 1/0.	80% of the confirmed cases of silicosis worked in the construction industry and a high proportion of these were caisson workers or stone splitters.	Retrospective cross-sectional study. No information on the silica and dust exposure levels.
Dement et al (2003)	United States 2602 construction workers employed at nuclear weapons sites for facility construction, maintenance and renovation.	58 ± 12.7 years	Pneumoconiosis by chest X-ray (ILO score ≥ 1/0).	Prevalence of pneumoconiosis – 2.2% Age- and smoking-adjusted ORs of 3.6 (95% CI 1.1-11.6) for duration of employment, and of 1.6 (95% CI 0.9-2.8) for the reporting of regular past exposure to silica.	Millwrights, sheetmetal workers and ironworkers were found to have a higher prevalence of pneumoconiosis compared to other trades.
Valiante et al (2004)	United States 576 silicosis cases reported to NIOSH (1993-97).	No information	Silicosis	8% of all cases of silicosis reported to NIOSH (1993-7) were construction workers and 27% of these were involved in heavy construction such as road and highway construction/repair.	

Study	Country and sample size	Age-range	Endpoint	Results	Comment
				Silica exposure levels (8h-TWA) in this industry (52 personal samples from 9 highway sites) were above 0.05 $mg.m^{-3}$ and a mean concentration as high as 1.07 $mg.m^{-3}$ (8h-TWA) was found for milling concrete.	
Albin et al (1992)	Sweden 5898 construction workers.	No information	Pneumoconiosis (ILO score ≥ 1/1)	Prevalence of pneumoconiosis was 4.4%	Study was not designed to assess the relationship between dust exposure and health effects.
Tornling et al (1992)	Sweden 271 construction workers involved in concrete work for more than 20 years.	No information	Silicosis	Prevalence of silicosis was 1.5%.	Small retrospective cross-sectional study.
Studies in insulation workers					
Clausen et al (1993)	Denmark 340 male insulation workers. Reference group of 166 bus drivers.	22 - 64 years. Mean age 42 years.	Lung function measured by spirometry	Significantly lower FEV_1 values in insulation workers compared to bus drivers. Also a significantly greater annual decline in FEV_1 (from the longitudinal component of the study) in the insulation workers compared to the bus drivers.	Former exposure to asbestos was not associated with lung function. Age and height were not corrected for but the mean age and height were similar in the two groups.
Albin et al (1998)	Sweden 45,716 construction	Median age 22 years	Lung function measured by spirometry and assessment of respiratory	Exposure to insulation wool was associated with persistent cough (OR 2.59 95% CI 2.19-3.06) but not with	Age of subjects limited the ability to detect an effect of exposure on lung function.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
	workers.		symptoms.	impaired lung function after adjustment for smoking and other occupational exposures.	
Engholm and von Schmalensee (1982)	Sweden 135,000 male construction workers.		Chronic bronchitis (chronic productive cough almost every day for at least 3 months every year).	In non-smokers the rate ratio of chronic bronchitis in workers exposed to MMMF for at least 3 years compared to non-exposed workers was 2.68.	Difficult to assess whether chronic bronchitis was associated with MMMF or other exposures including asbestos.
Kennedy et al (1991)	Canada 88 construction insulation workers with high exposure to asbestos.		Airflow obstruction	Prevalence for airflow obstruction (FEV_1 and FEV_1/FVC below the lower 95% CI of the predicted values) of 35%.	Likely to be associated with asbestos, and so outside the scope of this review.
Studies in painters					
White and Baker (1988)	United States 225 male construction painters.	Mean age 41 years	Lung function measured by spirometry and assessment of respiratory symptoms.	Prevalences: 1.1% small airways disease 1.6% restrictive disease 4.9% mixed restrictive/obstructive disease 16.8% obstructive disease 24.9% chronic bronchitis 17.9% shortness of breath Multiple regression analysis showed a significant association between years worked as a painter and a mean decline in FEV_1 of 11 ml in excess of the age-related loss for each year.	No comparison to a reference group. 37% participation rate

Study	**Country and sample size**	**Age-range**	**Endpoint**	**Results**	**Comment**
				The prevalence of chronic bronchitis was associated with increased use of spray application methods.	
Schwartz and Baker (1988)	United States 118 construction painters. Reference group of 314 sheet metal workers.	Mean age 42 years (painters) 46 years (sheet metal workers).	Lung function measured by spirometry; Pneumoconiosis (ILO score ≥ 1/0) by chest X-ray; Respiratory symptoms by questionnaire.	Prevalence of pneumoconiosis was similar in painters and sheet metal workers. Respiratory symptoms (cough, wheeze and dyspnoea) were more common in painters, even though there were fewer smokers. Lung function was poorer in those painters with at least 15 years in the trade.	Only 29% participation rate but assessment of selection bias showed reasonable comparability between participants and non-participants.
Studies in asphalt workers					
Randem et al (2004)	Norway 64 male asphalt workers. Reference group of 195 male outdoor construction workers.	Mean age 36 years (asphalt workers) 40 years (outdoor workers).	Lung function measured by spirometry; Respiratory symptoms assessed by questionnaire; COPD defined by a FEV_1/FVC ratio <0.7 combined with a history of chronic productive cough, breathlessness and/or wheezing.	Age- and smoking-adjusted ORs (95% CI) in the asphalt workers were significantly greater than in the reference group for: Chest tightness – 2.8 (1.3-5.9) Shortness of breath on exertion – 4.1 (1.3-13) Wheeze – 2.6 (1.4-4.9) COPD – 2.8 (1.2-6.5) FEV_1/FVC was significantly decreased in the asphalt workers compared to the outdoor construction	A very comparable reference group in terms of education, socioeconomic status and selection for employment.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
				workers.	
Studies in electricians					
Hessel et al (1998)	Canada 100 male electricians. Reference group of 100 male telephone workers.	Less than 65 years and with at least 20 years of union member-ship.	Respiratory symptoms assessed by questionnaire; Lung function assessed by spirometry; Radiographic changes (pleural abnormalities or parenchymal small opacities).	Age- and smoking-adjusted ORs (95% CI) in the electricians were higher than in the reference group for: Chronic phlegm – 2.74 (1.13-6.6) Shortness of breath – 2.26 (1.1-4.67) Radiographic changes – 5.03 (1.06-23.93. No differences in lung function Chronic phlegm and chest tightness were significantly associated with at least 5-year exposure to fumes in industrial construction.	80% and 73% participation rates for electricians and telephone workers respectively.
Studies in carpenters					
Lipscomb and Dement (1998)	United States 10,938 active union carpenters		Respiratory diseases, as defined by ICD-9 diagnoses on medical insurance claims (either private health insurance claims or workers' compensation claims).	Among the 931 cases of lung disease identified, 90 (9.7%), 51 (5.5%) and 22 (2.4%) were cases of COPD, chronic bronchitis and emphysema, respectively.	It is unclear whether or not these claims were work-related. Also there is no information on smoking. Therefore, no conclusions on the risk of COPD/chronic bronchitis/emphysema in carpenters can be drawn from this study.
Studies in tunnel workers					
Ulvestad et al (2001a)	Norway 29 non-smoking male	Mean age 44 years (tunnel	Airway inflammation measured by acoustic rhinometry, nasal and	Prevalence of respiratory symptoms were higher in the tunnel workers compared to the reference group;	The group size was very small Exposures had only taken place for 1 year.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
	tunnel concrete workers. Reference group of 26 non-smoking male outdoor concrete workers.	workers) 39 years (outdoor workers)	exhaled nitric oxide, spirometry and respiratory symptom questionnaire.	Congested nose – 76% vs. 42% Sore throat – 65% vs. 23% Productive cough – 38% vs. 0% Chest tightness with wheeze – 38% vs. 0% Exhaled nitric oxide was also higher in tunnel workers – 8.4 vs. 5.6 ppb. Spirometry results were comparable. Exposures to total dust (8h-TWA of 5.4 vs 1.0 $mg.m^{-3}$), respirable dust (1.61 vs 0.21 $mg.m^{-3}$), quartz (0.087 vs 0.003 $mg.m^{-3}$) and nitrogen dioxide (0.9 ppm vs n.d.) were higher in the tunnel workers compared to the outdoor workers.	
Ulvestad et al (2000)	Norway 212 male tunnel construction workers. Reference group of 205 other male construction workers.	Mean age 41 years (tunnel workers) 40 years (other)	Airflow limitation assessed by spirometry; Respiratory symptoms assessed by questionnaire. COPD defined by a FEV_1/FVC ratio <0.7 combined with a history of chronic productive cough, breathlessness and/or wheezing.	Significantly higher prevalence of respiratory symptoms (cough, shortness of breath on exercise, chest tightness and wheezing) in the tunnel workers compared to the reference group, with age- and smoking-adjusted ORs ranging from 1.94 to 3.47. COPD prevalence was 14% vs. 8% (tunnel workers vs. reference group). FEV_1 and FVC (% of predicted) in	100% participation rate. A very comparable reference group in terms of education and socioeconomic status. Exposures to total dust (8h-TWA of 3.6 vs 1.05 $mg.m^{-3}$), respirable dust (1.2 vs 0.21 $mg.m^{-3}$), quartz (0.034 vs 0.003 $mg.m^{-3}$), oil mist (0.5 vs 0.12 $mg.m^{-3}$) and nitrogen dioxide (0.5 ppm vs n.d.) were higher in

Study	Country and sample size	Age-range	Endpoint	Results	Comment
				tunnel workers decreased significantly with years of employment. A linear multiple regression model predicted that FEV_1 would additionally decrease by 17 ml for each year of exposure to tunnel work.	the tunnel workers compared to the reference subjects.
Ulvestad et al (2001b)	Norway 96 tunnel construction workers, a subgroup of the original Ulvestad et al (2000) cohort. Reference groups of 178 outdoor construction workers and 71 white-collar workers.	Mean age 39-41 years at start of study.	Airflow limitation assessed by spirometry; Respiratory symptom questionnaire; Radiographic changes indicative of pneumoconiosis.	Over the 8-year follow up period tunnel workers had a significantly larger decrease in FEV_1 (age and smoking adjusted) compared to the 2 reference groups, with an annual decline at least double the normal age-related loss. Te decrease in FEV_1 was associated with cumulative exposure to respirable dust and quartz. The occurrence of respiratory symptoms was higher in the tunnel workers compared to that in the reference subjects. None of the tunnel workers had radiographic signs of pneumoconiosis.	This study was of longitudinal design with an 8-year follow-up. 83% participation rate. Cumulative exposures to respirable dust and quartz were shown to be the main contributors of the observed airflow limitation. Mean cumulative exposures to respirable dust ranged from 9.6 (drillers) to 25.4 $mg.y.m^{-3}$ (shotcreters), and mean cumulative exposures to quartz ranged from 0.13 to 0.35 $mg.y.m^{-3}$.
Bakke et al (2004)	Norway	Mean age 39-41	Airflow limitation assessed by spirometry.	Over the 6-year follow up period the tunnel workers (except the tunnel	This study was of longitudinal design with a 6-year follow-up.

Study	Country and sample size	Age-range	Endpoint	Results	Comment
	209 tunnel construction workers (115 drill and blast workers, 69 concrete workers, 22 shotcreting operators and 3 tunnel boring machine workers). Overlap with Ulvestad et al (2001b) cohort. Reference/low exposure group of 220 outdoor concrete workers, 67 foremen and 155 engineers.	years.		borers) revealed a clear accelerated annual decline in FEV_1 at least double the normal age-related loss. Multiple linear regression analyses in relation to each exposure variable adjusted for age and smoking showed that all airborne contaminants investigated (total dust, respirable dust, quartz, VOC, oil mist, oil vapour, formaldehyde, nitrogen dioxide and carbon monoxide) were statistically significantly associated with the annual declines in FEV_1. However, cumulative exposures to nitrogen dioxide showed the strongest association.	Peak exposures to nitrogen dioxide were not considered.
Oliver et al. (2001)	United States 231 tunnel workers Reference group of 158 operating engineers.	Mean age 41.4 years	Obstruction was defined by an FEV_1<80% of predicted and an $FEV_1/FVC<0.7$. Restriction was defined by an FVC<80% of predicted and an $FEV_1/FVC \geq 0.7$. Respiratory symptom questionnaire.	Obstruction was found in 4.3% of the tunnel workers and in 3.8% of the operating engineers and within the operating engineers it was more common among the journeymen (mean age 46.7 years) than among the apprentices (mean age 30.6 years) (6.1% vs 0%). Restriction was more common among the operating engineers than among the tunnel workers (3.8% vs 1.7%).	Unsuitable reference group.

Study	**Country and sample size**	**Age-range**	**Endpoint**	**Results**	**Comment**
				The risk of chronic bronchitis was significantly increased in the tunnel workers compared to the operating engineers (age- and smoking-adjusted OR=7.50, 95% CI 1.49-37.37).	
Kessel et al. (1989)	Germany 30 tunnel workers working with shotcrete under compressed air	Mean age 32 years.	Post-shift spirometric changes.	A full shift exposure to shotcrete under compressed air resulted in a statistically significant increase (by 10%) of the airway resistance and in a statistically significant decrease of the FVC (by 3%) and FEV_1 (by 4%). In addition, the PEF and the MEF_{75} decreased by 6% and 8% respectively. Total dust concentrations during a working shift correlated with the lung function data. Employment for about two years did not lead to a substantial difference in FVC and FEV_1 even though MEF_{25} and MEF_{50} were significantly decreased (by 22% and 18% respectively).	Included a 2-year follow-up investigation. Total dust concentrations ranged from 3.2 to 62.1 $mg.m^{-3}$ (8h-TWA) depending on the particular task. The 2-year changes in MEF_{25} and MEF_{50} raise concern for the development of chronic respiratory disease.
Bakke et al. (2001)	Norway 24 tunnel workers with high peak exposures to nitrogen dioxide (up to 20		Lung function assessed by spirometry.	Over an 11-day period a 3% decrease in FVC, a 7% decrease in FEV_1 and an 8% decrease in FEF_{25-75} were observed among these tunnel workers. The lung function values returned to	There was no reference group. The relevance of these short-term changes in lung function to the development of chronic respiratory disease is unclear.

Study	**Country and sample size**	**Age-range**	**Endpoint**	**Results**	**Comment**
	ppm).			the baseline levels after an exposure-free period of 10 days.	