WORKING FOR A HEALTHIER FUTURE

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Development of a quantitative Job Exposure Matrix for wood dust in the wood manufacturing industry

Summary of the analysis results

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1 INTRODUCTION

The Institute of Occupational Medicine (IOM) was contracted by the University of Aarhus (AU) to develop a quantitative Job-Exposure Matrix (JEM) for wood dust to be used in general population studies. The work formed part of the ongoing CODUST[1] and DOC*X[2] Danish cohort studies.

CODUST is a register-based study on the effect of organic dust exposure on the development of asthma and chronic obstructive pulmonary disease (COPD). The study population comprises of all Danish subjects born between 1933 and 1977 who have ever held a job in either the wood processing or the farming industries in the period between 1964 and 2007. The study can be divided into 3 parts depending on the source and size of the population included:

a) The internal cohort, a pooled analysis of two smaller cohorts comprising of 4307 furniture industry workers and 225 farm apprentices;
b) The external cohort I, a study on all subjects employed in an agriculture or wood related industry between 1964-2007 as identified from employment statistics (Supplementary Pension Fund; ATP) and;
c) The external cohort II, a study including the total Danish population born between 1933-1995, as identified by the Registers of Statistics in Denmark.

Overall, the study is designed to combine the strengths of quantitative exposure assessment with the detailed information on health and employment status available in the Danish registries in order to explore the effect of occupational organic dust exposure on the incidence of COPD and asthma in greater detail and with more precise and reliable exposure estimates than previously possible. This will be facilitated through the development of quantitative JEMs specific for the two industries involved using the International Standard Classification of Occupations (ISCO 88 revision)[3] and the Danish Industrial Classification (Danish Branch Code, 2007)[4] coding systems.

The Danish Occupational Cohort (DOC*X) is a register based nationwide Cohort, that includes all Danish residents that have been employed in an industry following 1970. It combines data from different registers of Denmark including the Statistics Denmark, The Labour Market Supplementary Pension Fund, and the National Health Data Agency. The study is design to allow examination of health effects across a broad range of subjects by established and integrating state-of-the-art exposure assessment approaches for historical exposures based, to the extent possible, on quantitative measurement data. Exposures of interest include psychosocial factors, light, chemical agents, dusts, heavy lifting and noise.

[1] http://www.codust.com/index.php/en/
[2] http://doc-x.dk/en/
[3] http://www.ilo.org/public/english/bureau/stat/isco/
[4] http://www.dst.dk/en/Statistik/dokumentation/Nomenklaturer/DB

1.1 OBJECTIVES AND WORKING CONCEPT

The overall aim of the present project was to provide the required means for a valid and reliable group-based exposure assessment strategy for wood dust to be enabled and applied within the previously mentioned cohorts (i.e. CoDUST and DOC*X). This was achieved by completing the following objectives:

a) Modelling wood dust exposure and time trends on the basis of actual measurement data while taking into account exposure differences present across branches and occupations within the wood industry.

b) Using the outputs of the elaborated statistical models to establish a quantitative JEM for the retrospective assessment of wood dust exposure at a job title level.

1.2 DATA SOURCES

For developing the JEM Aarhus University (AU) has previously established an exposure database comprising of approximately 35,500 original personal and stationary measurements. The database includes measurements originating mainly from Northern Europe (Denmark, Germany, France, Finland and the UK) and covers a broad range of industries including manufacturing and processing of wood and sub-products as well as education, construction and other relevant industries where wood processing and handling regularly takes place.

For the creation of the dataset the following data sources were used:

a) The personal measurements from the Danish “Wood” epidemiological study comprising of 3572 personal measurements in the furniture industry collected between the years 1997 and 2004. [5]

b) The personal measurements (n=343) from a Dutch study among workers in joineries and furniture factories performed between 1992-1993. [6]

c) The personal easements (n=41) from a measurement survey among Norwegian wood workers performed in 1978 as part of a response from the “Yrkeshygienisk Institute” to health complaints from related workers.[7]

d) The personal measurements (n=399) from a survey in the wood and furniture industries performed from the Danish Working Environment Authority (Arbejdstilsynet) in 1988. [8]

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[5] Schlünssen V, et al. (2008) Determinants of wood dust exposure in the Danish furniture industry—results from two cross-sectional studies 6 years apart. Ann of Occup Hyg 52.4: 227-238.

[6] Scheeper B, et al. (1995) Wood-dust exposure during wood-working processes. Ann Occup Hyg 39:141–154.

[7] Johnsen BK, Pedersen JR. (1978) Teknosk-Hygienisk kartlegging av eksponering for stov, gasser og lose-middeldamper ved granli trevare A/S. Yrkeshygienisk Institute. Oslo, Norway.

[8] Arbejdstilsynet. (1989) Trae – og mobelindustrien traersnitsundersogelse – Exponering. Hellas-Print, Haslev. ISBN: 87-7534-320-7.

e) The raw WOODEX databases.[9] The databases were established on the framework of a research project called ‘Risk assessment of wood dust: Assessment of exposure, health effects and biological mechanisms´ (acronym: WOOD-RISK). In their final form they contained data from Denmark (n=2703), Finland (n=1230), France (n=7881), Germany (n=20828) and Great Britain (n=2665). Following agreements with representatives from the Finnish Institute of Occupational Health (FIOH) and involved parties, AU was provided with:

- All 20828 German measurements available and included in WOODEX. The original source of the German data was the MEGA database.[10]
- All 7881 French measurements available and included in WOODEX. The original source of these data was the COLCHIC database.[11]
- All 1230 Finnish measurements included in WOODEX as well as an additional 272 measurements collected by FIOH in the period after 2002.

The Danish measurements included in WOODEX were also provided but they were not utilised as they most were available from other sources (see above). This excludes 266 measurements from the ATABAS database held by the The National Research Centre for the Working Environment (NRCWE).[12] These measurements though not included in the other sources were excluded a priori as they did not contain any contextual information including among others whether they were personal or stationary. In addition, contact with the Health and Safety Executive (HSE) persons responsible for the British measurements in WOODEX to ask for permission to use the data could not be established. As a consequence these measurements were not made available by FIOH to AU for the establishment of the Database.

Concerning the British data however, contact with the original centres (IOM and HSE) that held the data was re-established outside the WOODEX and they were asked to contribute to the establishment of the database. Both centres responded positively and the following data were provided and include in the database:

- The personal measurements (n=226) from a series of exposure surveys in the wood industry performed and utilised in time-trends analysis by the IOM.[13]
- The personal measurements (n=409) from a 1999/2000 survey by the Health and Safety Laboratory (HSL) to assess exposure levels to WOOD dust and compliance with COSHH within the British wood processing industry.

[9] http://partner.ttl.fi/en/sectors_of_activity/woodrisk/pages/default.aspx
[10] http://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/index-2.jsp
[11] Vincent, R, et al. (2001). COLCHIC-occupational exposure to chemical agents database: current content and development perspectives. App occup environ hyg, 16(2), 115-121.
[12] Breum NO, (1986) ATABAS. Et EDB-register for arbejdshygiejniske malinger. AMI-rapport nr. 24
[13] Galea KS, et al. (2009). Trends in wood dust inhalation exposure in the UK, 1985–2005. Ann Occup Hyg;53(7):657-67.

Relevant job and industry codes were assigned to all measurements included, based on the provided process and/or job descriptions. Specifically, industry codes were assigned according to the ‘Danske branchekoder (DB), 77, 93 and 07’ classifications which is a classification is similar to the Statistical Classification of Economic Activities in the European Community (NACE) and follows its periodical evolvement in relation to version updates. For job titles, codes were allocated according to the ‘International Classification of Occupations (ISCO), 1988’. Data management and processing has been performed at an individual data-source level using, to the extent possible, a standardised approach by a data manager at AU. It needs to be noted though, that at time of delivery of the overall database to the IOM, no quality control of the job- and industry coding assignment was performed, whereas apart from some core variables (i.e. source, file, study, sampling time, year, measured concentration) no further merging or decoding/translation of relevant covariates (e.g. sampling equipment, fraction) across databases was made.

1.3 DEVELOPMENT STRATEGY FOR THE JEM

To achieve the above objectives we intent to utilise the above mentioned database in a JEM developing strategy based on the one used within the SYNERGY project[14]. The SYNERGY methods are described in detail in a previous paper by Peters et al[15]. Briefly, the aim was to establish a JEM with three axes: job title/ISCO code, year and country. Following data management, linear mixed effect regression is applied to assess historical trends in exposure and establish predictions for the exposure across the three axes of the matrix. Predictions are to be based on either the fixed and random effects included in the model, which include confounders of the levels and exposure trends in exposure (e.g. sampling duration, sampling strategy) and JEM parameters (i.e. year, ISCO code, country). In SYNERGY both the ISCO code and the country have been included as random effects whereas fixed effects were the year of measurement, measurement strategy (representative or worst-case approach), the sampling duration, and the exposure rating (low, medium, high) for each job title from an independently developed semi-quantitative JEM, the DOM-JEM[16].

DOM-JEM was included in the model to allow extrapolation of the exposure estimates to occupations/job titles where measurements were not available in the model as well as to overwrite arbitrary model results considering that measurements in otherwise unexposed job-titles (e.g. chief executives, managers and mechanics) may have been included in the data. Since DOM-JEM did not include ratings for exposure to wood dusts, and to achieve the above, we used in our study the exposure ratings from another general population JEM, the ASTHMA-JEM[17].

[14] Olsson AC, et al (2011) Exposure to diesel motor exhaust and lung cancer risk in a pooled analysis from case-control studies in Europe and Canada. Am J of Respir and Crit Care Med.;183(7):941-8.

[15] Peters S, et al (2011) Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies. J Env Monit 13:3262–3268.

[16] Peters S, et al (2011) Comparison of exposure assessment methods for occupational carcinogens in a multi-centre lung cancer case-control study. Occup Env Med 68:148–153.

[17] Moual NL, et al (2016) O46-1 Development of an updated asthma-specific job-exposure matrix to evaluate occupational exposure to 33 specific agents. Occup Environ Med;73:A87.

ASTHMA-JEM is a semi-quantitative JEM which has recently been developed primarily in order to assess exposure within the European Community Respiratory Health Survey. It covers 33 agents relevant towards the development of asthma and including wood dusts, HMW, mites, microbial exposures, LMW, highly reactive chemicals, biocides, irritants. It is coded under the ISCO-88 classification system with each code assigned an agent-specific exposure level from an ordinal scale (i.e. no exposure, medium exposure, high exposure). Exposure assignments were performed by 3 individual experts with any disagreements between them solved by consensus.

2 DESCRIPTION OF THE POOLED DATA / ESTABLISHMENT AND CHARACTERISTICS OF THE DATASET

Upon receipt by the IOM, the data were transferred from a STATA to a Statistical analysis Software format and the data structure and contents were screened. Data management was performed and covariates corresponding to sampling fraction and equipment, sampling time, measurement type (personal vs stationary), limits of detection, sampling reason and strategy were created. Subsequently, a descriptive analysis was undertaken to describe the basic attributes of the complete dataset. This analysis is described in the sections that follow.

2.1 OVERALL POOLED DATABASE DESCRIPTION

The following analyses results describe the basic characteristics of the overall database as provided by Aarhus University. In separate sections that follow descriptions on the applied restrictions on the dataset are provided together with comments and separate analysis for any intermitent subset of as well as for the final dataset used in the analysis.

2.1.1 Basic characteristics of the measurements included in the pooled database

Table 2.1 Distribution of available measurements by dataset

Dataset	n	%
DK-N-NL - retro_exp_5-tablecorr	4355	12.37
Finland - FIN WOODEX FURNITURE- Table	116	0.33
Finland - FIN wood dust measurements 2001-2003_2-table	206	0.59
Finland - FIN_WOODEX BOARD MILLS - NTA	200	0.57
Finland - FIN_WOODEX SAWMILLS AND PLANING MILLS-table	166	0.47
Finland - FIN_WOODEX_WOOD PRODUCTS-table	130	0.37
Finland - Wood dust measurements_FIOH_2001-2007_processed	684	1.94
Frankrig - FRDATAorigs[18]	7881	22.39
GB - HSE 2000 wood dust survey data for sharing-NTA-22.05.2015	409	1.16
GB - IOM wood dust data for Ioannis - NTA coded	226	0.64
Tyskland - WoodexTabelle160802[19]	20828	59.17
Total	35201	100.00

Table 2.2 Distribution of available measurements by country

Country	n	%
1. Denmark	3971	11.28
2. Norway	41	0.12
3. The Netherlands	343	0.97
4. Finland	1502	4.27
5. Great Britain	635	1.80
6. Germany	20828	59.17
7. France	7881	22.39
Total	35201	100.00

[18] The French COLCHIC data
[19] The German MEGA data

Comment: Evidently the vast majority of the data source from the German MEGA and French COLCHIC databases.

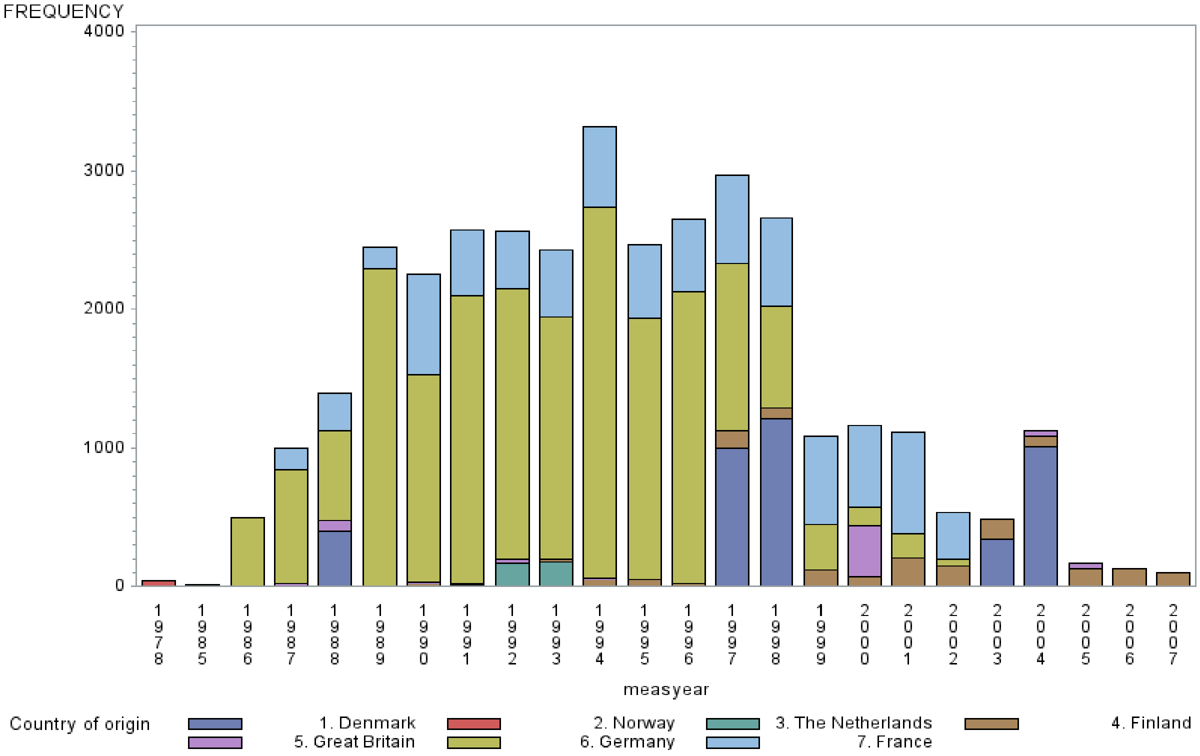
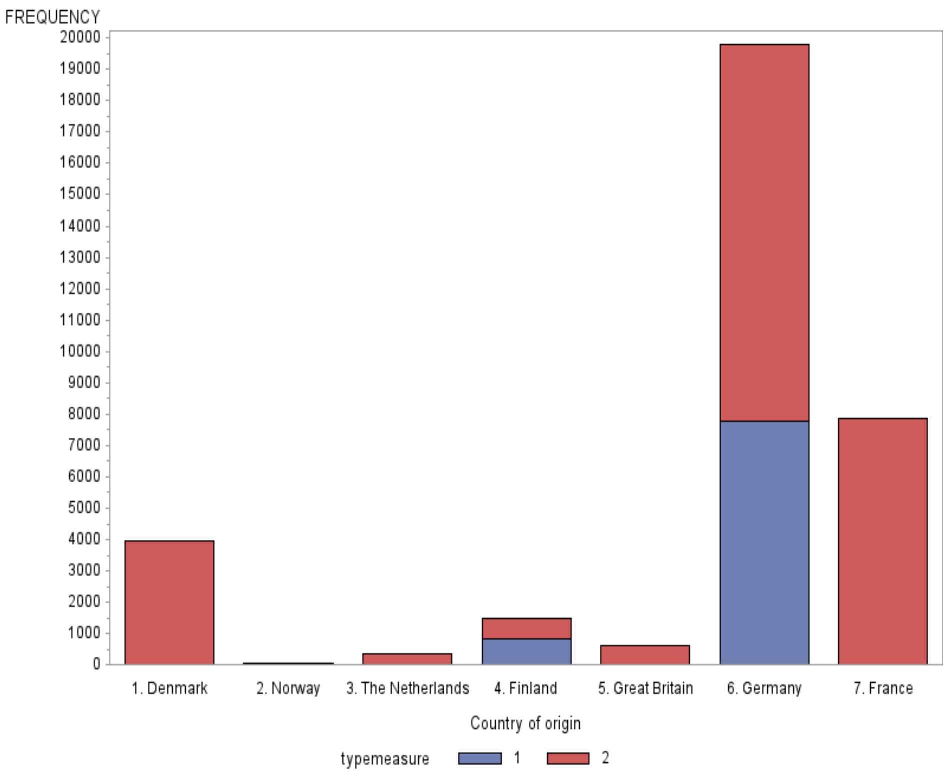


Figure 2.3 Distribution of available measurements across country and year

Comment: Measurement availability reduces sharply after 1998. Evidently this is because of the limited data coming in from the MEGA database (i.e. German data) after this year. The likely explanations of this are related to the way that the data comprising the database were collected – i.e. not directly from the original source but rather through WOODEX - or the finalisation of the "intervention" like program that they have been running for years. In general German measurements were performed in "worst case" settings following an intervention approach: i.e. a high exposed workplace is first measured then an intervention on the ventilation settings is applied and then follow up measurements are made.

Table 2.4 Distribution of available measurements by type (i.e. personal vs stationary)

Type of measurements	n	%
Overall	35,201	100.00
Personal	25,892	73.55
Stationary	9,255	26.29
Unknown	55	<0.01



Legend explanation: 1=stationary; 2=personal

Figure 2.5 Distribution of available measurements by type (i.e. personal vs stationary) and country

Comment: 75% of the included data are from personal measurements. The number of measurements included is sufficient to allow an analysis using only personal measurements. Looking at the distribution of personal measurements across countries, years (see later analyses for distribution characteristics among personal measurements only) and the better representativeness of personal measurements in relation to the workers actual levels of exposure further supports such an approach.

Table 2.6 Distribution of available measurements by sampling device

Sampler	n	%
37mm CFC with 4mm hole	7881	22.39
37mm OFC	797	2.26
7 hole sampler	137	0.39
FAP	2	0.01
GSP	13319	37.84
Gravicon GC25	6471	18.38
Gravicon VC25	31	0.09
IOM sampler	1464	4.16
MPG	6	0.02
Hund	2	0.01
Millipore casette	440	1.25
Other	990	2.81
Passive dust	3572	10.15
Unknown	89	0.25
Total	35201	100.00

CFC=closed faced cassette; OFC=open faced cassette.

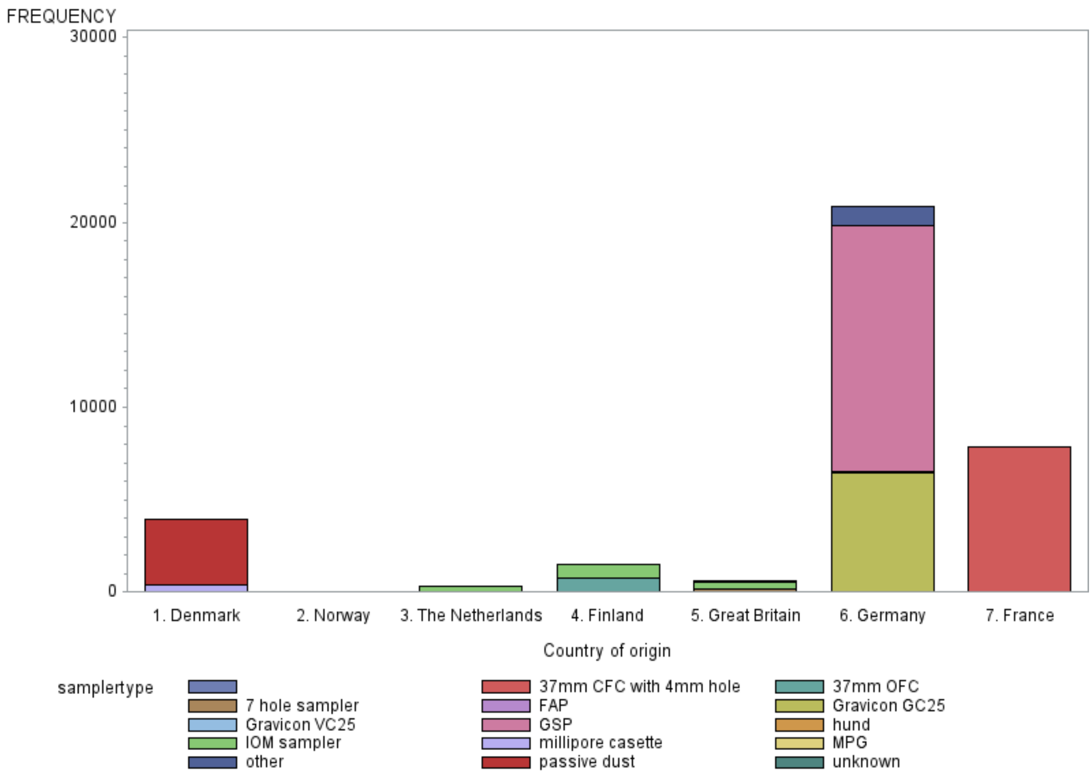


Figure 2.7 Distribution of available measurements by sampling device and country. Colour box with no description indicates missing information.

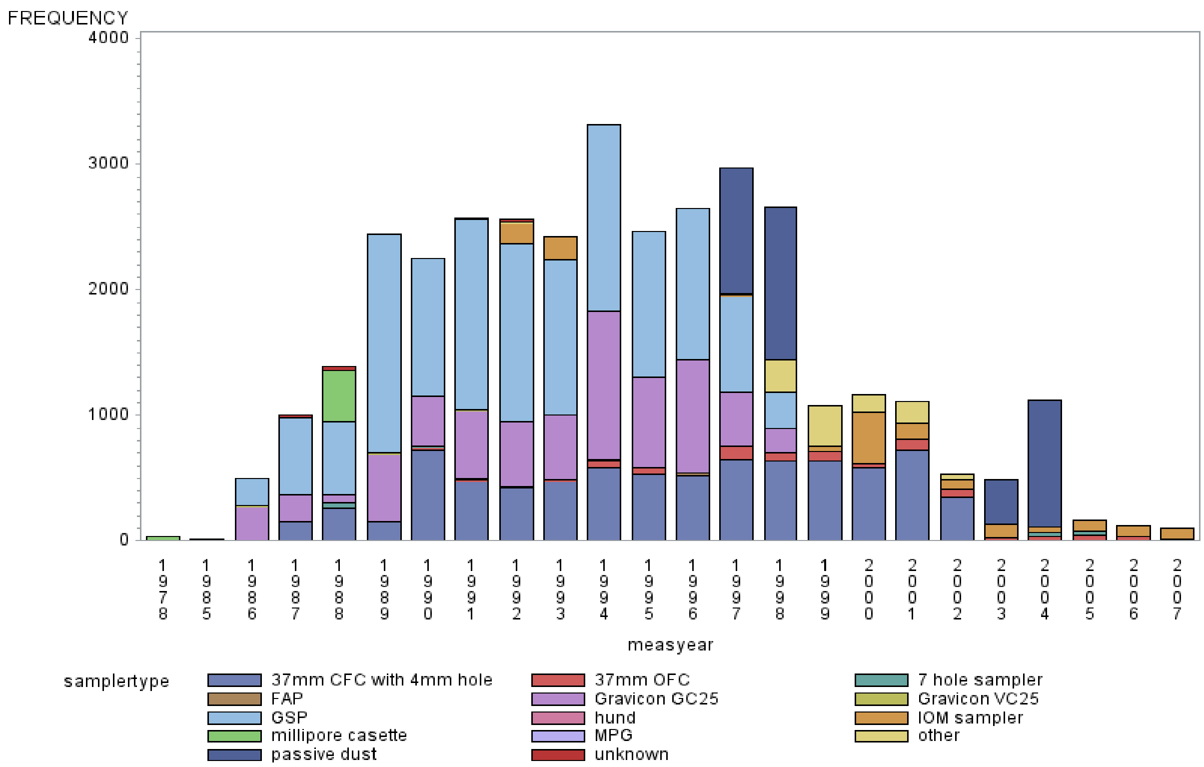


Figure 2.8 Distribution of available measurements by sampling device and year

Table 2.9 Distribution of available measurements by sampling fraction

Sampling fraction	**n**	**%**
Inhalable dust	18574	52.77
other	2	0.01
Respirable dust	33	0.09
Total dust	15595	44.30
Unknown	997	2.83
Overall	35201	100.00

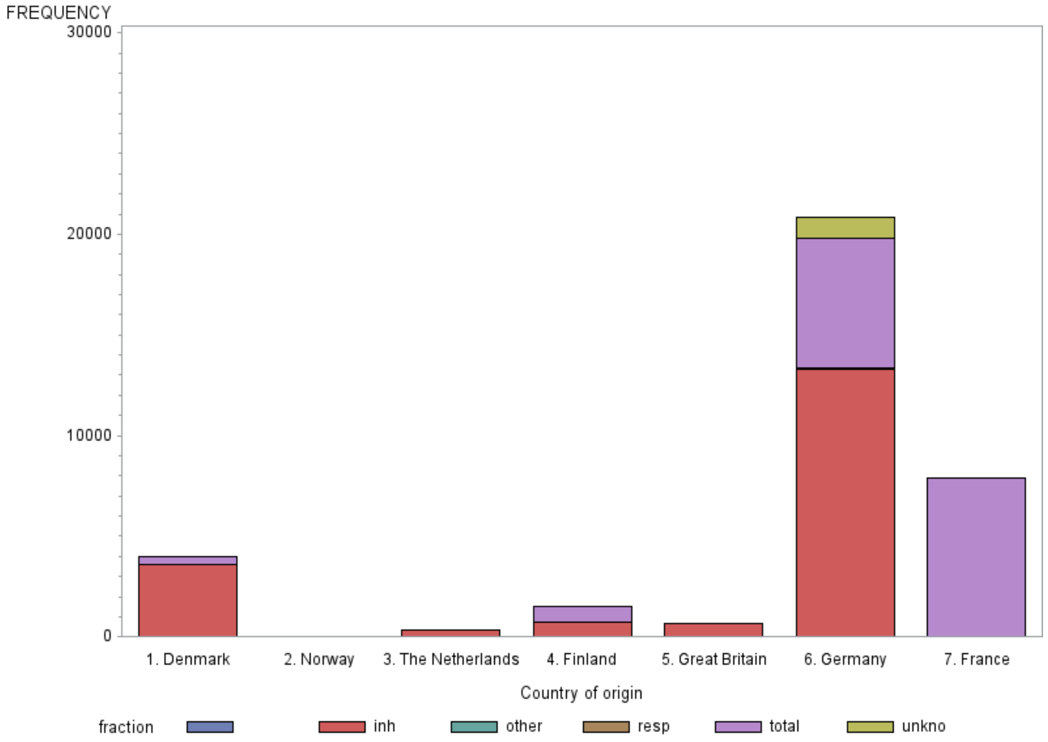


Figure 2.10 Distribution of available measurements by fraction and country. Coloured box with no description indicates missing information; inh=inhalable, resp=respirable,unkno=unknown.

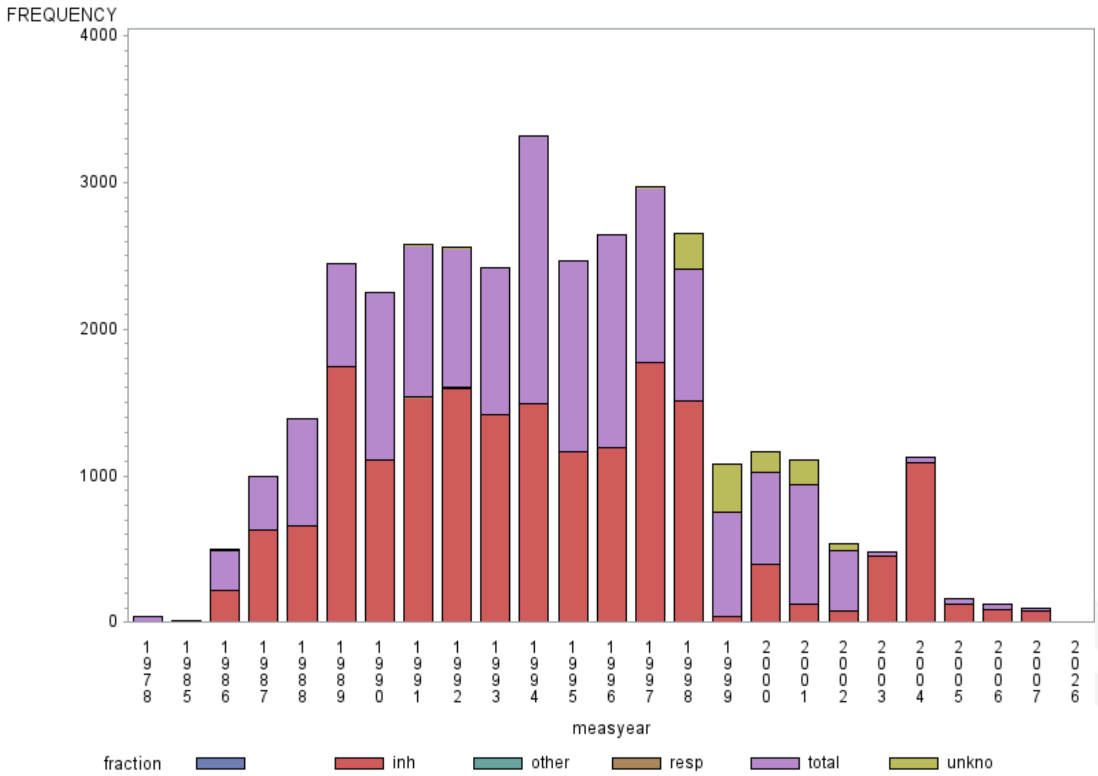


Figure 2.11 Distribution of available measurements by fraction and year. Blue colour indicated measurements with unknown fraction. Coloured box with no description indicates missing information; inh=inhalable, resp=respirable,unkno=unknown.

2.2 DESCRIPTION OF THE CHARACTERISTICS OF ALL PERSONAL MEASUREMENTS INCLUDED

As described above all stationary measurements were excluded from the analysis. In the following the basic attributes of the sub-set of the data comprising of all the personal measurements are described.

2.2.1 Basic attribute of all personal measurements included in the dataset

Table 2.12 Distribution of available personal measurements by dataset.

file	n	%
DK-N-NL - retro_exp_5-tablecorr	4355	16.82
Finland - FIN WOODEX FURNITURE- Table	50	0.19
Finland - FIN wood dust measurements 2001-2003_2-table	103	0.40
Finland - FIN_WOODEX BOARD MILLS - NTA	38	0.15
Finland - FIN_WOODEX SAWMILLS AND PLANING MILLS-table	75	0.29
Finland - FIN_WOODEX_WOOD PRODUCTS-table	65	0.25
Finland - Wood dust measurements_FIOH_2001-2007_processed	321	1.24
Frankrig - FRDATAorigs	7881	30.44
GB - HSE 2000 wood dust survey data for sharing-NTA-22.05.2015	409	1.58
GB - IOM wood dust data for Ioannis - NTA coded	226	0.87
Tyskland - WoodexTabelle160802	12369	47.77
Overall	25,892	100.00

Table 2.13 Distribution of available personal measurements by country.

country	n	%
1. Denmark	3971	15.34
2. Norway	41	0.16
3. The Netherlands	343	1.32
4. Finland	652	2.52
5. Great Britain	635	2.45
6. Germany	12369	47.77
7. France	7881	30.44
Overall	25,892	100.00

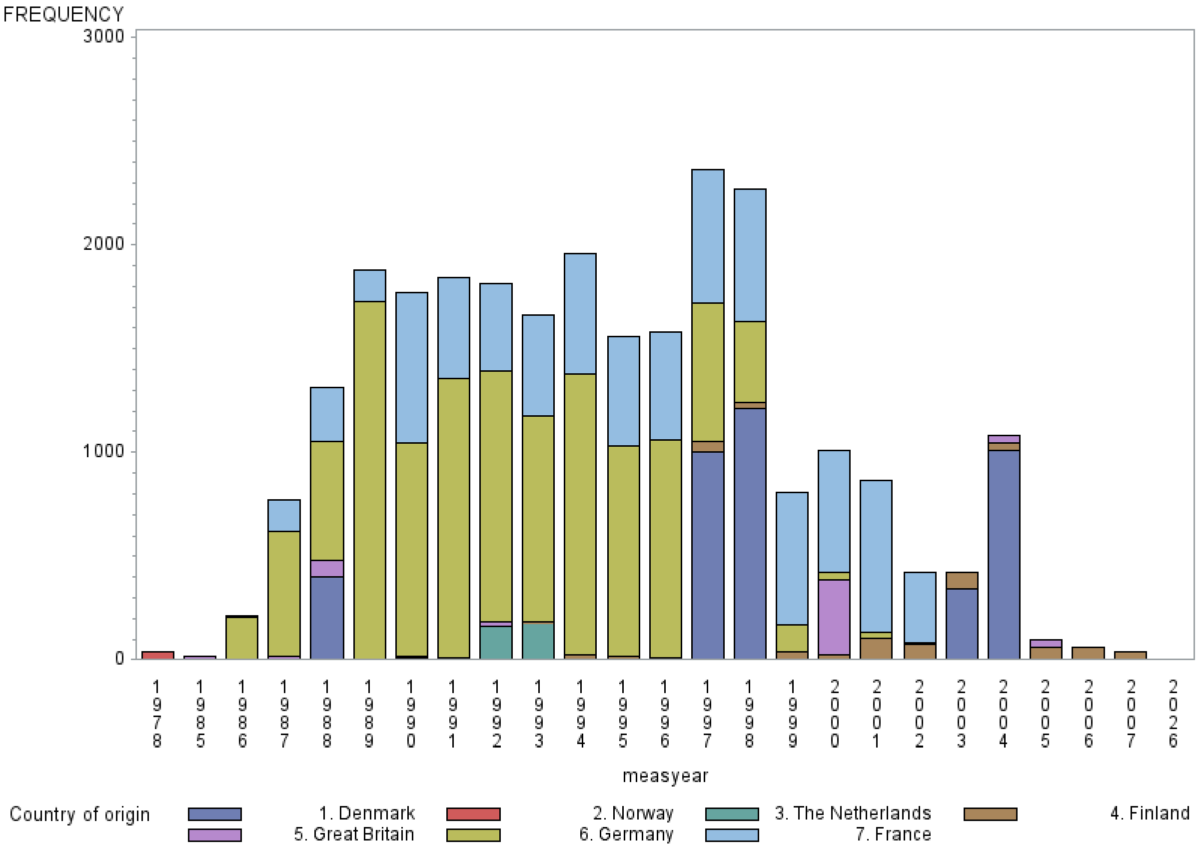


Figure 2.14 Distribution of available measurements across country and year. Coloured box with no description indicates missing information.

Table 2.15 Distribution of available measurements by sampling device

Sampler type	**n**	**%**
37mm CFC with 4mm hole	7881	30.44
37mm OFC	137	0.53
7 hole sampler	137	0.53
FAP	1	0.00
GSP	11984	46.28
Gravicon GC25	39	0.15
IOM sampler	1274	4.92
MPG	2	0.01
hund	2	0.01
millipore casette	440	1.70
other	340	1.31
passive dust	3572	13.80
unknown	83	0.32
Overall	25,892	100.00

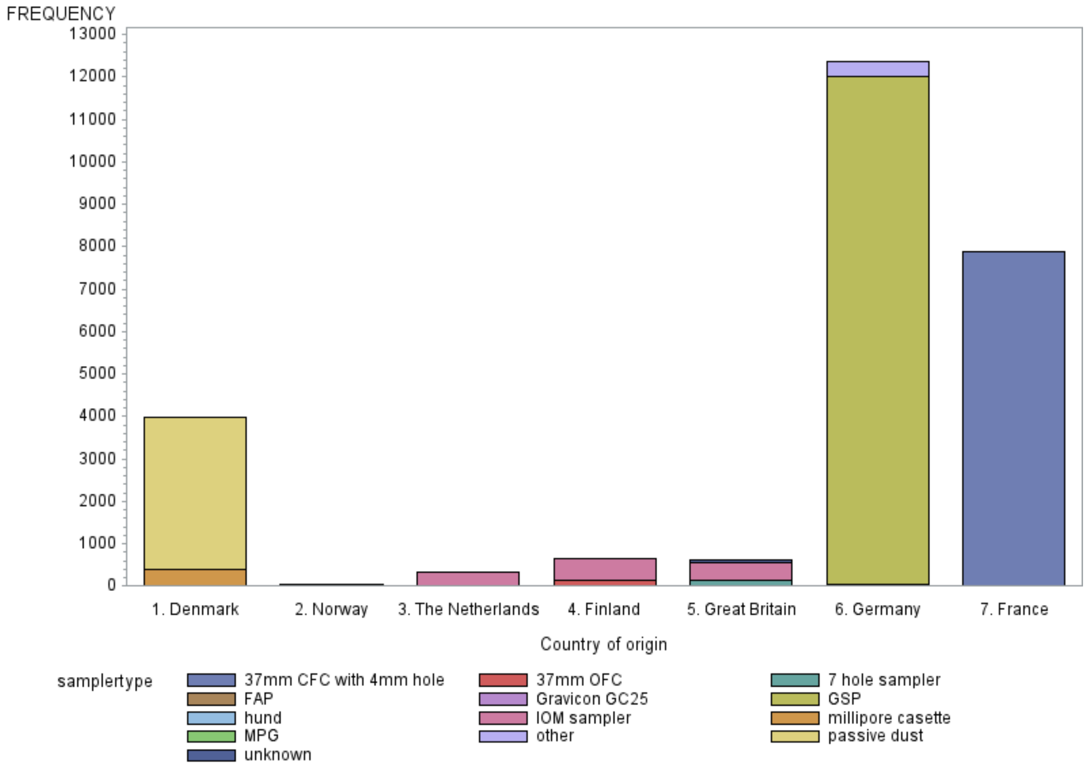


Figure 2.16 Distribution of available measurements by sampling device and country

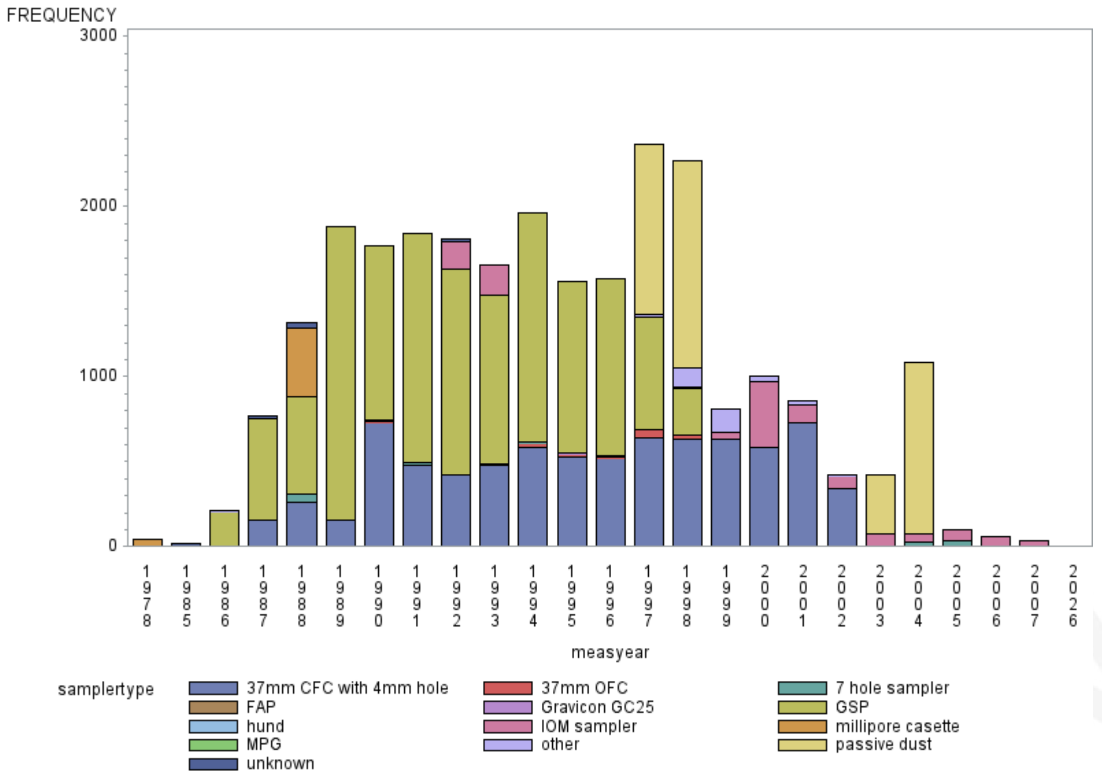


Figure 2.17 Distribution of available measurements by sampling device and year

Table 2.18 Distribution of available measurements by sampling fraction

Sampling fraction	Frequency	Percent
Inhalable dust	17049	65.85
Other	1	0.00
Respirable dust	2	0.01
Total dust	8499	32.82
Unknown	341	1.32

Comment: The single observation in the "other" group represents the results of a dermal exposure measurement. It will be excluded.

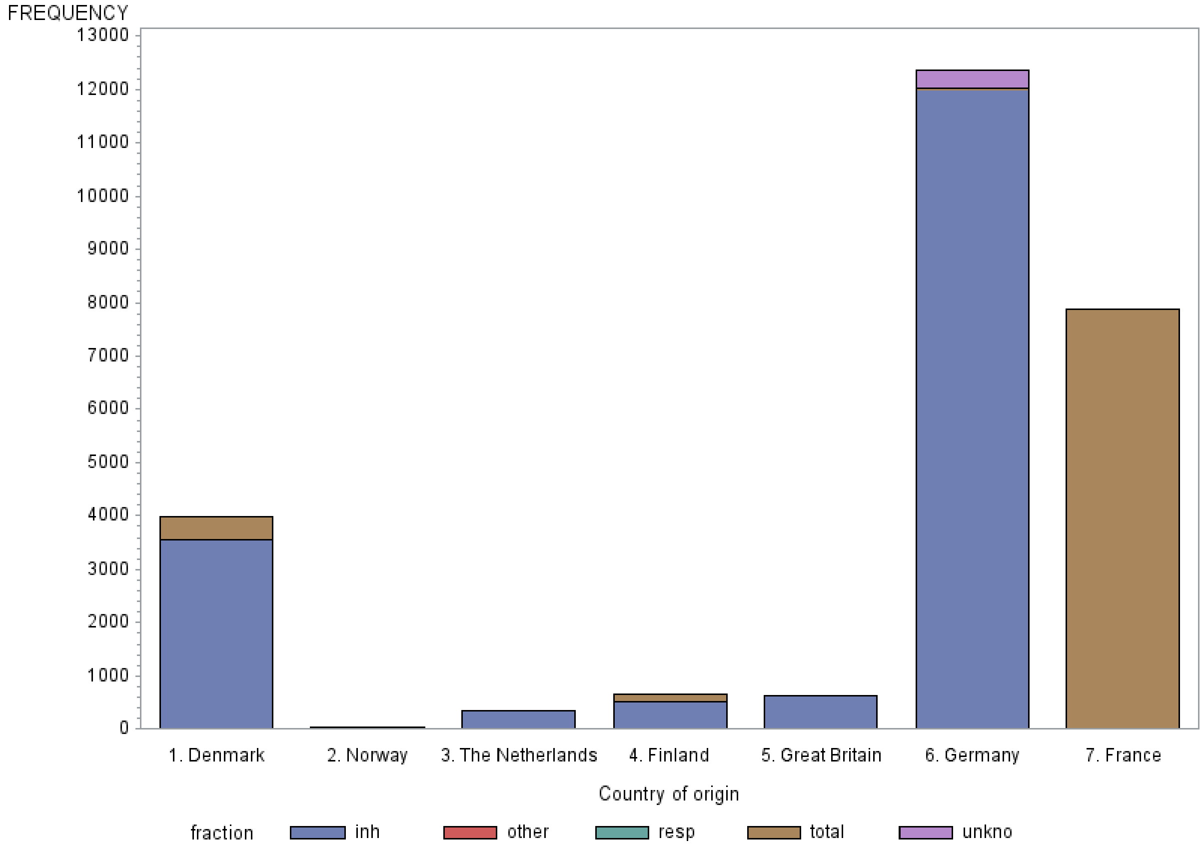


Figure 2.19 Distribution of available measurements by fraction and country. Coloured box with no description indicates missing information; inh=inhalable, resp=respirable,unkno=unknown.

Comment: As can be seen from the above figures and tables most of the personal measurements are collected GSP and CFC cassettes. Evidently errors are also present in the dataset with e.g. high volume samplers refer to as being used for personal monitoring. For a small proportion of measurements the sampling device and/or fraction is unknown. Only a couple of measurements are respirable ones. Restrictions will be applied to clear the data from measurements with improper sampling methods, respirable dust and unknown samplers.

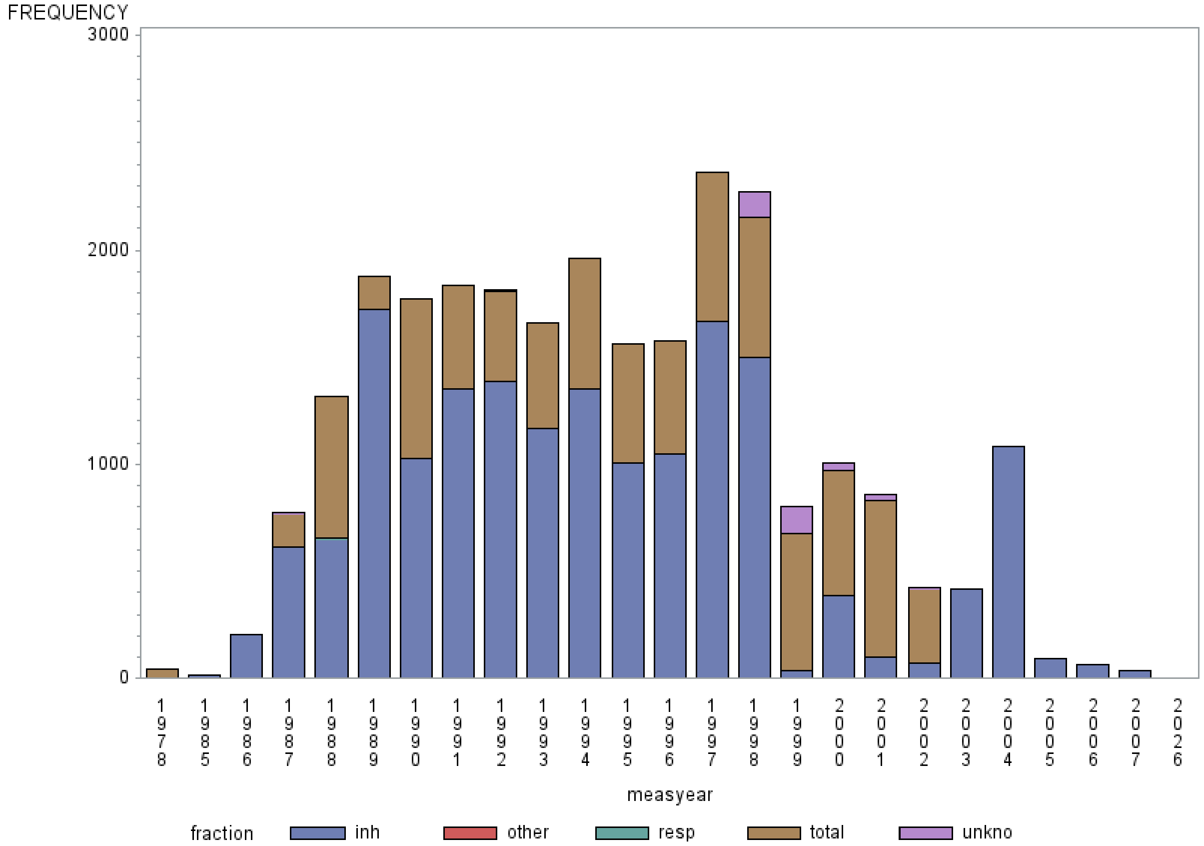


Figure 2.20 Distribution of available measurements by fraction and year. Coloured box with no description indicates missing information; inh=inhalable, resp=respirable,unkno=unknown.

2.2.2 Distribution of sampling time across the available personal measurements

In the following the distribution of the sampling time of the included personal measurements is summarised as output of the SAS software. Results are presented overall as well as for in each of the individual countries

2.2.2.1 SAS output summarising the distribution of sampling time (in minutes) for all personal measurements in the data

The univariate procedure

N	25892	**Sum Weights**	25892
Mean	197.782497	**Sum Observations**	5120984.4
Std Deviation	112.073872	**Variance**	12560.5527
Skewness	1.07462074	**Kurtosis**	0.50047578
Uncorrected SS	1338046350	**Corrected SS**	325205270
Coeff Variation	56.6652124	**Std Error Mean**	0.69650073

Basic Statistical Measures			
Location		Variability	
Mean	197.7825	**Std Deviation**	112.07387
Median	136.0000	**Variance**	12561
Mode	120.0000	**Range**	1178
		Interquartile Range	155.00000

Quantiles (Definition 5)	
Quantile	**Estimate**
100% Max	1183
99%	500
95%	423
90%	371
75% Q3	275
50% Median	136
25% Q1	120
10%	103
5%	81
1%	50
0% Min	5

Extreme Observations			
Lowest		Highest	
Value	**Obs**	**Value**	**Obs**
5	9668	837	12462
8	19009	845	12500
8	12298	921	12498
8	12297	936	12404
8	10131	1183	13689

2.2.2.2 Sampling time characteristics by country

The following tables provide an overview of the characteristic of the distribution of sampling time (in minutes) across the different countries. Detailed results for each of the individual countries are presented in the SAS outputs shown in Appendix 1.

Table 2.21: Summary of the distribution characteristics of sampling time (in minutes) for the included measurements stratified by country of origin

Country	N	AM	SD	Median	Range	Min	Max	5PCT	95PCT
Denmark	3971	318.492	98.072	295	928	8	936	175	470
Norway	41	322.000	101.534	322	471	23	494	162	429
Netherlands	343	475.545	64.189	498	406	165	571	335	527
Finland	652	269.761	81.995	282	424	56	480	120	375
Great Britain	635	246.235	79.135	252	796	8	804	103	367
Germany	12369	127.014	52.614	120	486	9	495	75	184.8
France	7881	225.436	103.748	202	1178	5	1183	75	405

There were 278 measurements (Table 2.22) with missing info in relation to the sampling time involved for the collection of a sample. The distribution of numbers of measurements across different countries is presented in the table that follows. These measurements were assigned a sampling time equal to the median value of the origin country. The corresponding median values used were (summarised also in Table 2.21 above):

Denmark = 295 min
Finland = 282 min
Great Britain = 252 min
Germany = 120 min

Table 2.22 distribution of measurements with missing info on sampling time stratified by country

Country of origin	n	%
1. Denmark	34	12.23
4. Finland	230	82.73
6. Germany	14	5.04

2.2.2.3 *Frequency of measurement below 60 and above 600 min in the dataset*

Measurements with sampling time <60 or >600 measurements are unlikely to be representative of full-shift ones and are to be removed from the analysis. The distribution of the measurements with such characteristics in the data is summarised in Table 2.23 and 2.24 that follow.

Table 2.23 Measurements with a sampling time below 60min across countries

Country of origin	**n**	**%**
1. Denmark	19	5.22
2. Norway	2	0.55
4. Finland	1	0.27
5. Great Britain	9	2.47
6. Germany	157	43.13
7. France	176	48.35

Table 2.24 Measurements with a sampling time above 600 min across countries

Country of origin	**n**	**%**
1. Denmark	9	64.29
5. Great Britain	1	7.14
7. France	4	28.57

Comment: To account for bias resulting from the presence of a large number of measurements with sampling time <240 min we will perform sensitivity analysis by excluding those samples from the modelling process.

2.3 EXCLUSIONS TOWARDS THE DEVELOPMENT OF A DATASET COMPRISING OF ALL PERSONAL MEASUREMENTS

The following measurements were excluded from the database:

- 9,255 non personal measurements.
- 1 measurement from Finland referred to as being skin measurement.
- 1 measurement from the German dataset has a sampling year of 2026.
- 45 measurements for which info on the sampling year were not available
- 54 measurements from the German dataset where it is not known whether they were personal or stationary.
- 56 measurements for which the measurement method is improper or they were not dust measurements (i.e. measurements referred to as being collected with gas probes, silica gel tubes, absorbers etc.).
- 328 measurements for which both the fraction and sampler were unknown
- 83 for which the fraction was known but not the sampler
- 3509 measurements which did not included sufficient information to be coded to ISCO-88 – i.e. they did not bear an ISCO-88 code
- All measurements with sampling time >600 min (n=14) or <60 min (n=290) were also excluded

Note that any deviation between numbers in the list of excluded measurements above and those described in the previous sections as being present in the database strictly reflects to them being excluded for another reason before provided that the approach and descriptions are stepwise. These exclusions resulted in 21,565 personal measurements being available to be used in the analysis.

Following and initial numerical summarisation of these measurements it was realised that coding quality should be re-evaluated across the dataset; a considerable number of mostly German and French measurements seemed to not be related to wood measurements (e.g. Manufacture of plastic, and/or extrusion of plastic materials etc.) whereas evidently, the ISCO codes 9320 and 9322 seemed to have been used as “junk” ones (i.e. whenever coding was related to a certain degree of uncertainty then the measurement was considered as sourcing from a labourer). A re-evaluation of the coding approach applied for the 21,565 measurements available was performed particularly in concern to codes/job titles that are generally considered as unexposed ones (e.g. teachers, mechanics, electricians, labourers etc.). Following the revision/re-evaluation a further 793 measurements were excluded whereas extensive recoding was performed within ISCO88 9322 and 9333 codes. This resulted in a total of 20,772 personal measurements included in the analysis that is described in the section 23.

Overall and effectively the database was restricted to those measurements that were wood dust, personal, had adequate information on sampling devices used, could represent full-shifts, were collected using adequate methodology and could be ISCO-88 coded.

2.4 HANDLING OF MEASUREMENTS WITH LEVELS BELOW THE LIMIT OF DETECTION (LOD)

2.4.1 General description and characteristics of measurements with levels <LOD in the dataset

In the sub-section that follows the handling and characteristics of measurements with levels <LOD is described in detail. It should be noted that measurements with measured levels below the LOD were identified within each of the datasets on the basis of the provided information. Three distinct cases of such measurements were present:

1) Measurements that were reported as below (<) a certain value within the dataset (Type a). In this case the reported/assigned value on the measurement was perceived as the actual LOD concentration.
2) Measurements that were reported as having a concentration of 0 (Type b). For those measurements specific values were neither provided or were available in publications and thereby the actual LOD levels were unknown/missing.
3) Measurements which were reported as a value between 0 and the LOD – e.g. by replacing the measured value with a value e.g. equal to LOD/2 (Type c). The Danish, Norwegian and Dutch data did not contain information identifying samples with measured levels <LODs. For these datasets the LODs were extracted from the relevant publications and used to identify the relevant measurements on the basis of the stated assignment values (e.g. LOD/2) that were used. Following their identification, the assigned values for these measurements were replaced by the reported LOD concentrations on the relevant publication/s.

Based on the above 818 measurements were identified as being <LOD in the dataset comprising of all personal measurements available (Table 2.25). Following the exclusion reported in section 2.3, 703 measurements with levels below remained in the dataset (Table 2.26). These were measurements exclusively from Denmark, Finland, Germany and France (Tables 2.27 and 2.28). No samples with <LOD levels were reported within the UK and Norwegian data, whereas for the Dutch data it seemed that measurements <LOD were either not present among personal measurements or, if present, they were excluded a priori from the provided dataset.
The characteristics and the general handling of these measurements are described in details in the tables that follow. The distribution of measurements <LOD by type and country, as well as ISCO code is provided in tables 2.27 and 2.28, respectively. Descriptions of the LOD value distributions are shown as SAS outputs.

Table 2.25 Distribution of measurements below LOD in the dataset of all personal measurements

Measurement below LOD	n	%
No	24643	96.79
Yes	818	3.21

Table 2.26. Distribution of measurements below LOD in the dataset following exclusions reported in section 1.3

Measurement below LOD	n	%
No	20069	96.62
Yes	703	3.38

Table 2.27. Distribution of measurements below the LOD in the dataset per country

Country of origin	n	%	Type of LOD measurements
1. Denmark	207	29.45	c
2.Norway	0	0	Not relevant
3.The Netherlands	0	0	Not relevant
4. Finland	14	1.99	a/b
5. UK	0	0	Not relevant
6. Germany	249	35.42	b
7. France	233	33.14	a

Table 2.28. Distribution of measurements below the limit of detection across ISCO88 codes

ISCO882	ISCOSTANDARDDESCRIPTION	n	%
2331	Primary education teaching professionals	3	0.43
5220	Shop salespersons and demonstrators	8	1.14
7124	Carpenters and joiners	174	24.75
7131	Roofers	1	0.14
7132	Floor layers and tile setters	1	0.14
7142	Varnishers and related painters	1	0.14
7233	Agricultural- or industrial-machinery mechanics and fitters	1	0.14
7420	Wood treaters, cabinet-makers and related trades workers	18	2.56
7422	Cabinet makers and related workers	33	4.69
7423	Woodworking machine setters and setter-operators	46	6.54
7424	Basketry weavers, brush makers and related workers	2	0.28
8141	Wood-processing-plant operators	162	23.04
8142	Paper-pulp plant operators	4	0.57
8240	Wood-products machine operators	135	19.20
8285	Wood and related products assemblers	95	13.51
8324	Heavy truck and lorry drivers	9	1.28
9141	Building caretakers	6	0.85
9212	Forestry labourers	3	0.43
9313	Building construction labourers	1	0.14

<u>SAS output summarising the overall distribution of LODs (mg/m^3) in the dataset with only personal measurements.</u>

The output below summarises the distribution of reported values in the measurements with levels <LOD. There were 118 different reported LODs on the dataset across 449 measurements. Most individual LOD levels (not measurements) sourced from the French COLCHIC (110 values) dataset. Evidently the 449 measurements with known LOD levels were the ones of type (a) and (c) as reported above. For 254 measurements the LOD level was missing.

The univariate procedure

Variable: conc

Moments			
N	449	**Sum Weights**	449
Mean	0.49399332	**Sum Observations**	221.803003
Std Deviation	0.5518239	**Variance**	0.30450962
Skewness	4.34372869	**Kurtosis**	25.2443247
Uncorrected SS	245.989511	**Corrected SS**	136.420308
Coeff Variation	111.706752	**Std Error Mean**	0.02604218

Basic Statistical Measures			
Location		Variability	
Mean	0.493993	**Std Deviation**	0.55182
Median	0.330000	**Variance**	0.30451
Mode	0.330000	**Range**	5.55400
		Interquartile Range	0.16000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	5.560
99%	2.700
95%	1.500
90%	0.900
75% Q3	0.460
50% Median	0.330
25% Q1	0.300
10%	0.201
5%	0.150
1%	0.010
0% Min	0.006

Extreme Observations			
Lowest		Highest	
Value	**Obs**	**Value**	**Obs**
0.006	4931	2.70	8454
0.010	7850	3.50	9805
0.010	7849	3.60	8543
0.010	7471	4.00	6453
0.010	6438	5.56	5408

Missing Values			
Missing Value	**Count**	**Percent Of**	
		All Obs	**Missing Obs**
.	254	36.13	100.00

The 254 measurements reported as missing in the SAS output above are those of type (b) that have been assigned a value of 0. The distribution of those measurements across country, source project file, and ISCO88 code is shown in Tables 2.29 and 2.30 below.

Table 2.29 Distribution of measurements without a known limit of detection (i.e. type b measurements) across source file/project (as defined by the projectnum variable) and country

Table of projectnum by country			
projectnum(i.e. source dataset)	**country(Country of origin)**		
	6. Germany	**7. France**	**Total**
8	0	5	5
11	249	0	249
Total	249	5	254

Table 2.30. Distribution of measurements without a known limit of detection across ISCO88 codes (i.e. those of type (b) where a value of 0 was originally reported)

ISCO882	ISCOSTANDARDDESCRIPTION	Frequency	Percent
5220	Shop salespersons and demonstrators	1	0.39
7124	Carpenters and joiners	131	51.57
7132	Floor layers and tile setters	1	0.39
7142	Varnishers and related painters	1	0.39
7233	Agricultural- or industrial-machinery mechanics and fitters	1	0.39
7420	Wood treaters, cabinet-makers and related trades workers	11	4.33
7422	Cabinet makers and related workers	26	10.24
7423	Woodworking machine setters and setter-operators	25	9.84
7424	Basketry weavers, brush makers and related workers	2	0.79
8141	Wood-processing-plant operators	45	17.72
8240	Wood-products machine operators	10	3.94

2.4.2 Overall approach on handling of measurements <LOD

Previous research has demonstrated that results which lie below the level of detection require careful handling with imputation methods generally being preferable to the substitution ones. (Ogden., 2010; Flynn et al., 2010)[20] [21] Hence it was decided to have the values for samples <LOD imputed using an approach based on Maximum likelihood estimation (MLE).

As the limits of detection depend among others on the sampling time and the sampler involved it was decided if possible to account for both these factors on the assignment of exposure levels for these samples. To account for variations in LOD levels resulting from differences in sampling durations all the analysis for samples with levels <LOD was performed on the basis of the actual mass of dust collected on the filter (mg) rather than the weighted levels of exposure per volume of sampled air (i.e. mg/m^3). The characteristics of the distribution of the collected mass on the measurements <LOD are summarised on the SAS output that follows. The distribution of the sampled dust masses on the samples >LOD are also provided in table 2.31.

<u>SAS output describing the overall distribution of estimated limits of quantification (in mg of collected dust) in the clean dataset including all personal measurements (n=20772).</u>

The output below summarises the distribution of the limits of quantification for those measurements with <LOD. Evidently the 449 measurements with known LOD levels were the ones of type (a) and (c) as reported above. For 254 measurements their LODs were missing.

[20] Ogden TL (2010) Handling results below the level of detection. Ann Occup Hyg 54.3: 255.
[21] Flynn MR (2010) Analysis of censored exposure data by constrained maximization of the Shapiro-wilk W statistic. Ann Occup Hyg 54(3):263-271.

The Univariate procedure

Moments			
N	449	**Sum Weights**	449
Mean	0.13669286	**Sum Observations**	61.3750932
Std Deviation	0.07438586	**Variance**	0.00553326
Skewness	4.26611374	**Kurtosis**	48.8647655
Uncorrected SS	10.8684353	**Corrected SS**	2.47889843
Coeff Variation	54.4182455	**Std Error Mean**	0.00351049

Basic Statistical Measures			
Location		**Variability**	
Mean	0.136693	**Std Deviation**	0.07439
Median	0.128440	**Variance**	0.00553
Mode	0.174900	**Range**	1.04429
		Interquartile Range	0.07648

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	1.04528
99%	0.31320
95%	0.24900
90%	0.20790
75% Q3	0.17490
50% Median	0.12844
25% Q1	0.09842
10%	0.06336
5%	0.03912
1%	0.00288
0% Min	0.00099

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.00099	5156	0.28200	4516
0.00153	7471	0.28200	4528
0.00181	7849	0.28200	4626
0.00209	7850	0.28200	4642
0.00288	4931	0.28200	4649
0.00301	6438	0.28200	4654
0.00385	9978	0.28254	7475
0.00861	5492	0.29125	10730
0.01130	8900	0.30102	6483
0.01692	4609	0.31152	11148
0.01780	6598	0.31320	8543
0.01920	6599	0.31375	10729
0.02158	5085	0.32800	6453
0.02185	5084	0.33210	8454
0.02460	6600	1.04528	5408

Missing Values			
Missing Value	**Count**	**Percent Of**	
		All Obs	**Missing Obs**
.	254	36.13	100.00

Table 2.31 Distribution of mass of wood dust (in mg) collected in samples above the limit of quantification. Results are stratified by data source as defined by the variable “projectnum”. Data sources with missing levels of quantification are highlighted in colour

projectnum	Data file	n	Arithmentic mean	Standart deviation	Minimum	Maximum	Standart error	5th Percentile	95the Percentile
1	DK-N-NL - retro_exp_5-tablecorr	3910	0.967	1.818	0.050	37.588	0.029	0.235	2.863
2	Finland - FIN WOODEX FURNITURE-Table	102	0.985	1.033	0.104	5.544	0.102	0.176	3.141
3	Finland - FIN wood dust measurements 2001-2003_2-table	50	1.570	2.335	0.113	12.577	0.330	0.169	6.204
4	Finland - FIN_WOODEX BOARD MILLS - NTA	35	0.937	0.931	0.113	3.948	0.157	0.147	3.666
5	Finland - FIN_WOODEX SAWMILLS AND PLANING MILLS-table	73	1.115	1.143	0.034	8.065	0.134	0.169	3.158
6	Finland - FIN_WOODEX_WOOD PRODUCTS-table	60	1.338	4.058	0.056	31.584	0.524	0.141	3.130
7	Finland - Wood dust measurements_FIOH_2001-2007_processed	315	1.036	1.298	0.008	10.728	0.073	0.144	3.612
8	Frankrig - FRDATAorigs	7206	0.924	3.184	0.004	116.105	0.038	0.068	2.854
9	GB - HSE 2000 wood dust survey data for sharing-NTA-22.05.2015	356	2.730	4.933	0.003	55.293	0.261	0.101	10.305
10	GB - IOM wood dust data for Ioannis - NTA coded	143	2.169	4.499	0.046	45.588	0.376	0.128	7.949
11	Tyskland - WoodexTabelle160802	7819	1.685	2.924	0.004	53.575	0.033	0.17363	5.546

For the imputation to work the actual LOD levels (or limits of quantification, due to the back transformation to amount of sampled dust) will need to be known for each of the identified relevant sample. This was straightforward for the samples of type (a) and (c). For the samples from datasets where results below the LOD were reported as 0 (i.e. type b) we identified and used as an LOD the lowest **“reasonable”** measured mass concentration after excluding outliers from the lower end of the distribution of actual measurements within the relevant datasets. The details of these assignments are provided on section 2.4.3 that follows.

The actual distribution of measured mass concentrations (mg) is summarised below (Table 2.31) for each of the data sources including samples <LOD. For the two data sources containing measurements with concentrations <LOD with an unknown limit of quantification further details of the distributions of measured concentrations are provided in section 2.43 that follows. Any samples stated as below the limit of detection with a sampled mass of dust exceeding the 0.2 mg were considered as unrealistic and excluded from the dataset. This applies to 51 measurements from Denmark (n=17), Finland (n=7), and France (n=27). After these exclusions, **20721 measurements remained available for the upcoming analysis** including 652 with measured amounts of collected dust that were <LOD. This dataset comprising of 20721 personal measurements will form the core of the analysis and will for the rest of the document simply be referred to as the **“final dataset”**. The mass concentration values for samples below LOD were imputed using a single imputation method based on Lubin et al, 2004[22] .

2.4.3 Assigning an upper limit to measurements <LOD with an unknown limit of quantification (i.e. type b)

As stated above the 254 measurements with an unknown limit of quantification were assigned a mass equal to the lowest **“reasonable”** measured one within the corresponding dataset. These values corresponded to 0.013860 mg for the German samples and 0.00374 mg for the French samples. The selection of these values is described in further details for each of the two relevant datasets in the sub-sections below.

2.4.3.1 Detailed distribution of collected mass (mg of dust) in samples with measured concentrations in the “Tyskland - WoodexTabelle160802” data file (i.e. German MEGA data).

The UNIVARIATE Procedure

Moments			
N	7819	**Sum Weights**	7819
Mean	1.68469668	**Sum Observations**	13172.6433
Std Deviation	2.92382429	**Variance**	8.5487485
Skewness	7.15718725	**Kurtosis**	80.0234701
Uncorrected SS	89026.0243	**Corrected SS**	66834.1158
Coeff Variation	173.551971	**Std Error Mean**	0.03306554

[22] Lubin JH, Colt JS, Camann D, et al. Epidemiologic evaluation of measurement data in the presence of detection limits. Environmental health perspectives. 2004. 112:1691-6.

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	53.575201
99%	14.158200
95%	5.546163
90%	3.536400
75% Q3	1.769229
50% Median	0.877800
25% Q1	0.453600
10%	0.246330
5%	0.173628
1%	0.071400
0% Min	0.004200

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.004200	20237	26.1082	20448
0.013860	21654	26.1253	19368
0.016800	20284	27.9421	19249
0.016800	17526	31.1595	14793
0.018375	20056	32.6844	22364
0.018375	14389	33.6714	18088
0.018900	22030	37.7211	17303
0.018900	20134	38.5476	17169
0.021000	16606	42.4133	16913
0.021840	16125	43.0416	22363
0.030030	20668	45.5364	19641
0.033600	21523	46.7420	14785
0.033600	19378	48.5184	19036
0.034650	14390	51.8868	19410
0.035280	22020	53.5752	19409

Comment: From the above it is evident that the lowest measured concentration within this dataset is likely an outlier either due to reporting error or issues related to the flow rate or measurement time used to back transform the concentration to mass of collected dust. Consequently the second lowest measured value – i.e. 0.013860 mg is considered as the "reasonable" lowest measured concentration within the specific dataset. This value was assigned and used in the imputation exercise that follows.

2.4.3.2 Detailed distribution of collected mass (mg of dust) in samples with measured concentrations in the "Frankrig – FRDATAorigs" data file (i.e. French COLCHIC data)

The UNIVARIATE Procedure

Moments			
N	7206	**Sum Weights**	7206
Mean	0.92402942	**Sum Observations**	6658.55602
Std Deviation	3.18410514	**Variance**	10.1385256
Skewness	18.6808409	**Kurtosis**	531.457912
Uncorrected SS	79200.7784	**Corrected SS**	73048.0767
Coeff Variation	344.589151	**Std Error Mean**	0.03750941

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	116.105040
99%	11.228800
95%	2.854200
90%	1.674800
75% Q3	0.751500
50% Median	0.336075
25% Q1	0.165880
10%	0.098430
5%	0.068200
1%	0.033460
0% Min	0.003740

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.00374	7848	27.5440	9283
0.00380	7445	27.7608	10542
0.00392	8040	28.4000	11466
0.00395	11495	29.2000	11465
0.00480	10645	30.0437	10003
0.00670	5578	30.3525	6761
0.00670	7865	36.3649	7734
0.00750	5010	41.1336	8735
0.00868	8340	44.9760	10004
0.00930	9492	49.3376	5356
0.00940	8822	51.1820	10802
0.01038	9242	54.9445	10002
0.01188	8339	73.8500	9184
0.01335	12174	112.1714	8734
0.01591	8523	116.1050	8579

Comment: Based on the distribution characteristics summarised above there is no reason to assume that any of the lowest measured concentrations form extreme outliers. Consequently the lowest sampled mass in the dataset of 0.00374 mg was used in the imputations of the few measurements with an unknown limit of quantification within this dataset.

2.4.4 Imputing values for measurements <LOD

The mass concentration values for all samples below LOD were then imputed. A single imputation using the Ludin et al, 2004 method was used. The distribution of the imputed values for measurements to be used in analysis are summarised below both in relation to sampled mass (mg of dust) and estimated (using the volume) measured airborne concentrations (mg/m^3).

2.4.4.1 SAS output summarising the distribution of imputed values of mass (in mg) for samples with levels <LOD in the final dataset with personal measurements (i.e. following all exclusions including those of measurements with an estimated limit of quantification >0.2 mg of dust n=20721)

The UNIVARIATE Procedure

Covariate: mass of collected dust (in mg), Variable name: imp_resp

Moments			
N	652	**Sum Weights**	652
Mean	0.0495558	**Sum Observations**	32.3103815
Std Deviation	0.0451324	**Variance**	0.00203693
Skewness	0.89499332	**Kurtosis**	-0.2688631
Uncorrected SS	2.92721047	**Corrected SS**	1.32604368
Coeff Variation	91.0738992	**Std Error Mean**	0.00176752

Basic Statistical Measures			
Location		**Variability**	
Mean	0.049556	**Std Deviation**	0.04513
Median	0.032591	**Variance**	0.00204
Mode	.	**Range**	0.19110
		Interquartile Range	0.07095

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	0.192001373
99%	0.171241814
95%	0.135541986
90%	0.120148121
75% Q3	0.082657681
50% Median	0.032591494
25% Q1	0.011704052
10%	0.008268294
5%	0.006182920
1%	0.002848343
0% Min	0.000898815

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.000898815	5156	0.173049	2589
0.000969769	7850	0.175778	2661
0.001308200	7471	0.177060	1277
0.001808062	7849	0.187964	2396
0.001897020	4931	0.192001	1181

2.4.4.2 Distribution of imputed estimated concentration (in mg/m3) for samples with levels <LOD in the final dataset (i.e. following all exclusions including those of measurements with an estimated limit of quantification >0.2 mg of dust n=20721).

The UNIVARIATE Procedure

Variable: imputed estimated concentration (in mg/m3), variable: imp_conc1

Moments			
N	652	**Sum Weights**	652
Mean	0.15876387	**Sum Observations**	103.514041
Std Deviation	0.18729263	**Variance**	0.03507853
Skewness	2.93218871	**Kurtosis**	13.820329
Uncorrected SS	39.2704108	**Corrected SS**	22.8361214
Coeff Variation	117.969302	**Std Error Mean**	0.00733495

Basic Statistical Measures			
Location		Variability	
Mean	0.158764	**Std Deviation**	0.18729
Median	0.101474	**Variance**	0.03508
Mode	.	**Range**	1.65621
		Interquartile Range	0.20274

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	1.66016041
99%	0.93012566
95%	0.48466160
90%	0.32542606
75% Q3	0.23166106
50% Median	0.10147409
25% Q1	0.02891813
10%	0.02076306
5%	0.01475848
1%	0.00791184
0% Min	0.00395213

Extreme Observations			
Lowest		Highest	
Value	**Obs**	**Value**	**Obs**
0.00395213	4931	0.996512	7023
0.00464004	7850	1.097916	9970
0.00730344	11496	1.110670	5856
0.00732224	21408	1.486464	8388
0.00745101	17415	1.660160	5089

2.4.4.3 Distribution of measurements below the LOD across ISCO88 codes in the final dataset (i.e. following all exclusions including those of measurements with an estimated limit of quantification >0.2 mg of dust n=20721)

Table 2.32 Distribution of measurements below the LOD across ISCO88 codes on the in the final dataset (n=20721):

ISCO882	ISCOSTANDARDDESCRIPTION	Frequency	Percent
2331	Primary education teaching professionals	3	0.46
5220	Shop salespersons and demonstrators	8	1.23
7124	Carpenters and joiners	168	25.77
7131	Roofers	1	0.15
7132	Floor layers and tile setters	1	0.15
7142	Varnishers and related painters	1	0.15
7233	Agricultural- or industrial-machinery mechanics and fitters	1	0.15
7420	Wood treaters, cabinet-makers and related trades workers	13	1.99
7422	Cabinet makers and related workers	32	4.91
7423	Woodworking machine setters and setter-operators	43	6.60
7424	Basketry weavers, brush makers and related workers	2	0.31
8141	Wood-processing-plant operators	148	22.70
8142	Paper-pulp plant operators	4	0.61
8240	Wood-products machine operators	122	18.71
8285	Wood and related products assemblers	89	13.65
8324	Heavy truck and lorry drivers	7	1.07
9141	Building caretakers	6	0.92
9212	Forestry labourers	3	0.46

2.5 DESCRIPTION OF THE FINAL DATASET

In the following the final dataset of personal measurements established after all previously mentioned exclusions described in sections 2.3 and 2.4.2 above and its attributes are described in detail. These include descriptions of the distributions of measurements and their characteristics across data sources, countries, sampling devices, fractions, and periods.

2.5.1 Basic characteristics

Table 2.33 Distribution of measurements in the final dataset by data source file.

Source file	n	%
DK-N-NL - retro_exp_5-tablecorr	4100	19.79
Finland - FIN WOODEX FURNITURE- Table	50	0.24
Finland - FIN wood dust measurements 2001-2003_2-table	102	0.49
Finland - FIN_WOODEX BOARD MILLS - NTA	35	0.17
Finland - FIN_WOODEX SAWMILLS AND PLANING MILLS-table	75	0.36
Finland - FIN_WOODEX_WOOD PRODUCTS-table	61	0.29
Finland - Wood dust measurements_FIOH_2001-2007_processed	319	1.54
Frankrig - FRDATAorigs	7412	35.77
GB - HSE 2000 wood dust survey data for sharing-NTA-22.05.2015	356	1.72
GB - IOM wood dust data for Ioannis - NTA coded	143	0.69
Tyskland - WoodexTabelle160802	8068	38.94
Overall	20721	100.00

Table 2.34 Distribution of measurements in the final dataset by country.

country	**n**	**%**
1. Denmark	3719	17.95
2. Norway	39	0.19
3. The Netherlands	342	1.65
4. Finland	642	3.10
5. Great Britain	499	2.41
6. Germany	8068	38.94
7. France	7412	35.77
Overall	20721	100.00

Comment: There are only a few measurements in Norway. These will be merged together with the Danish ones in one category named Scandinavia.

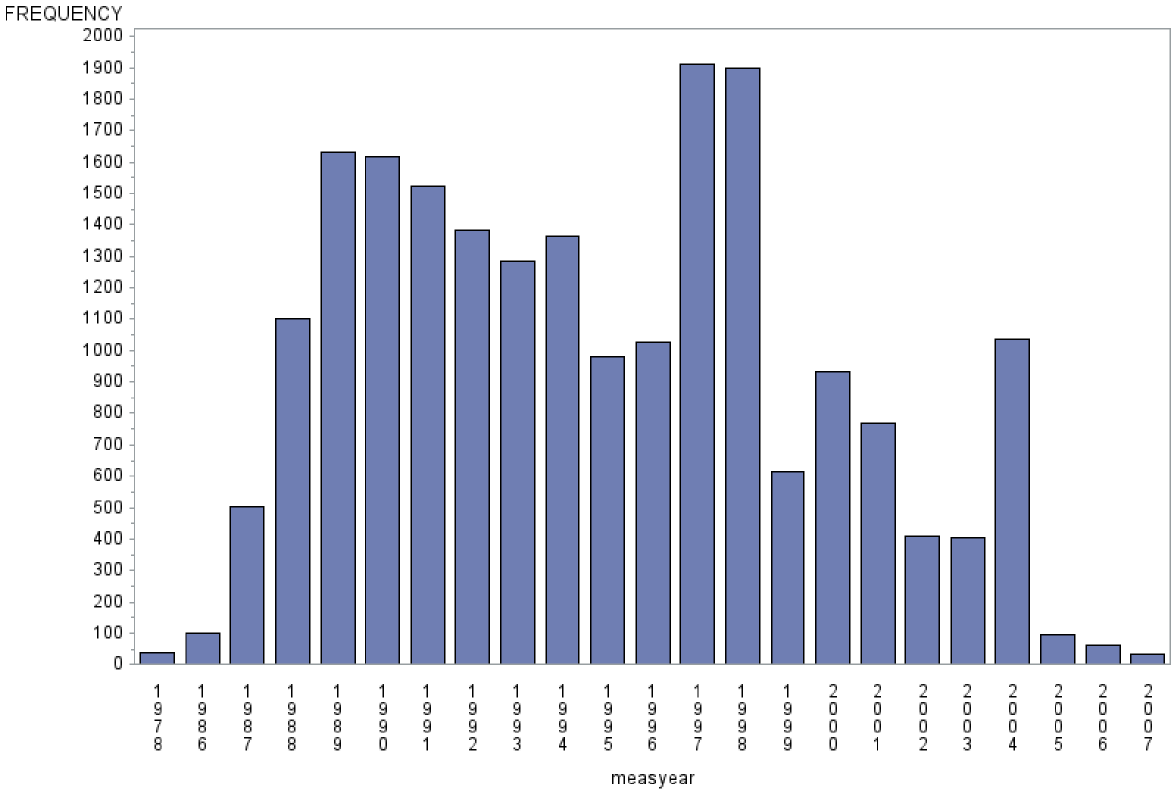


Figure 2.35 Distribution of measurements in the final dataset across year (n=20721)

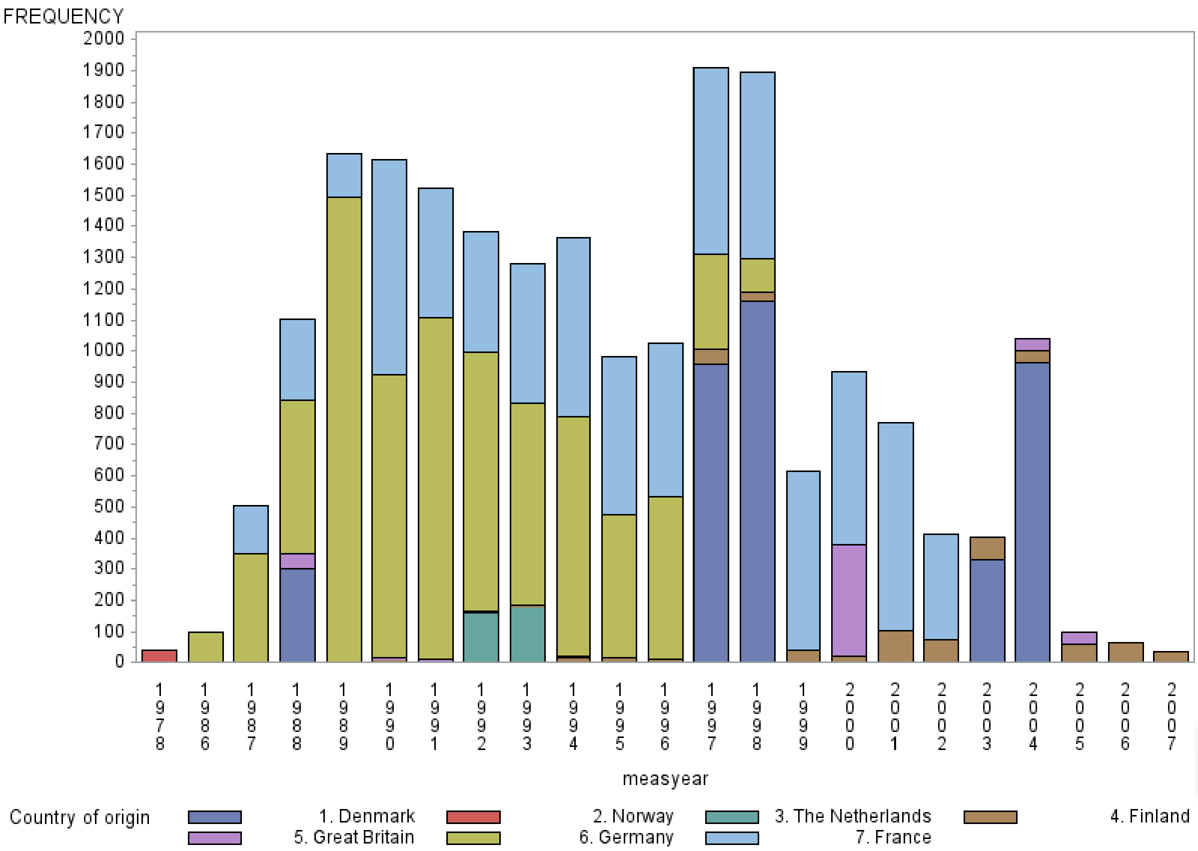


Figure2.36 Distribution of measurements in the final dataset across countries and years (n=20721)

Table 2.37 Distribution of measurements in the final dataset by sampling device

samplertype	n	%
37mm CFC with 4mm hole	7412	35.77
37mm OFC	129	0.62
7 hole sampler	136	0.66
GSP	8068	38.94
IOM sampler	1218	5.88
millipore casette	340	1.64
passive dust	3418	16.50
Overall	20721	100.00

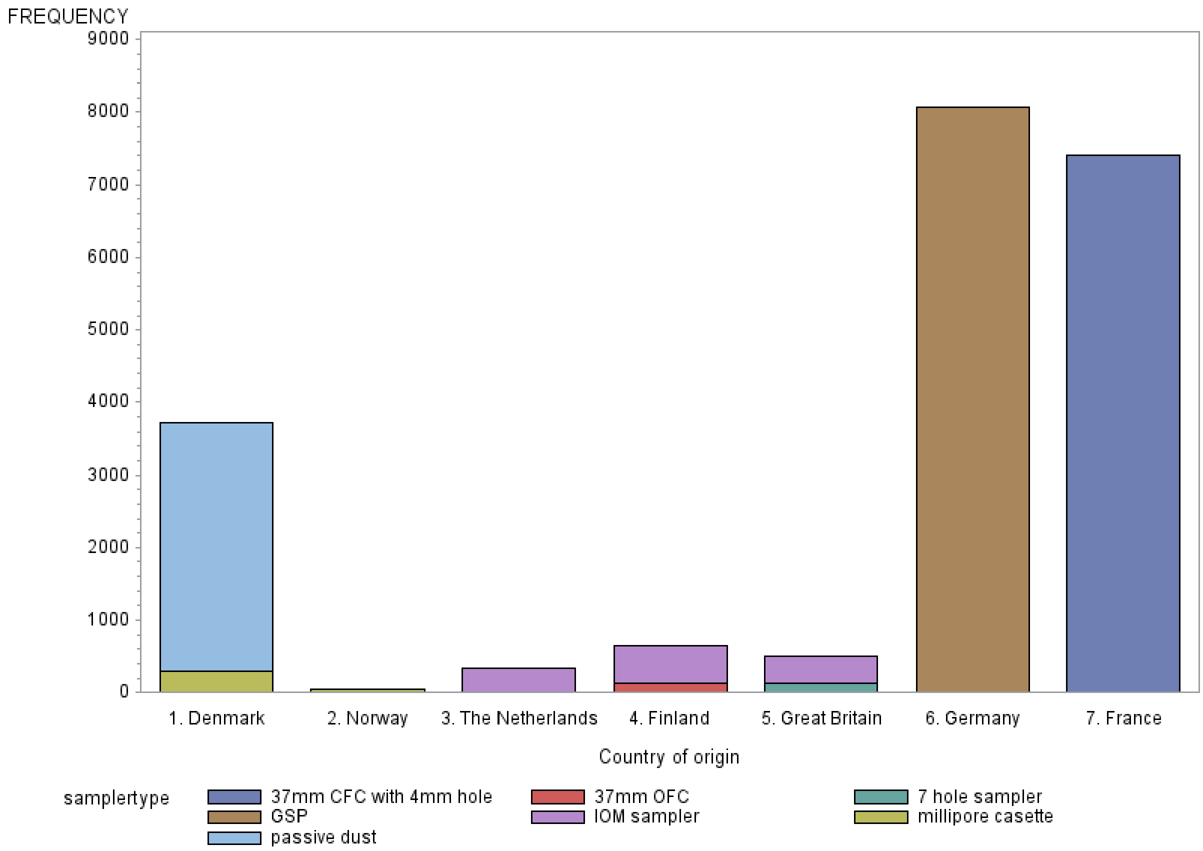


Figure 2.38 Distribution of measurements in the final dataset by sampling device and country (n=20721)

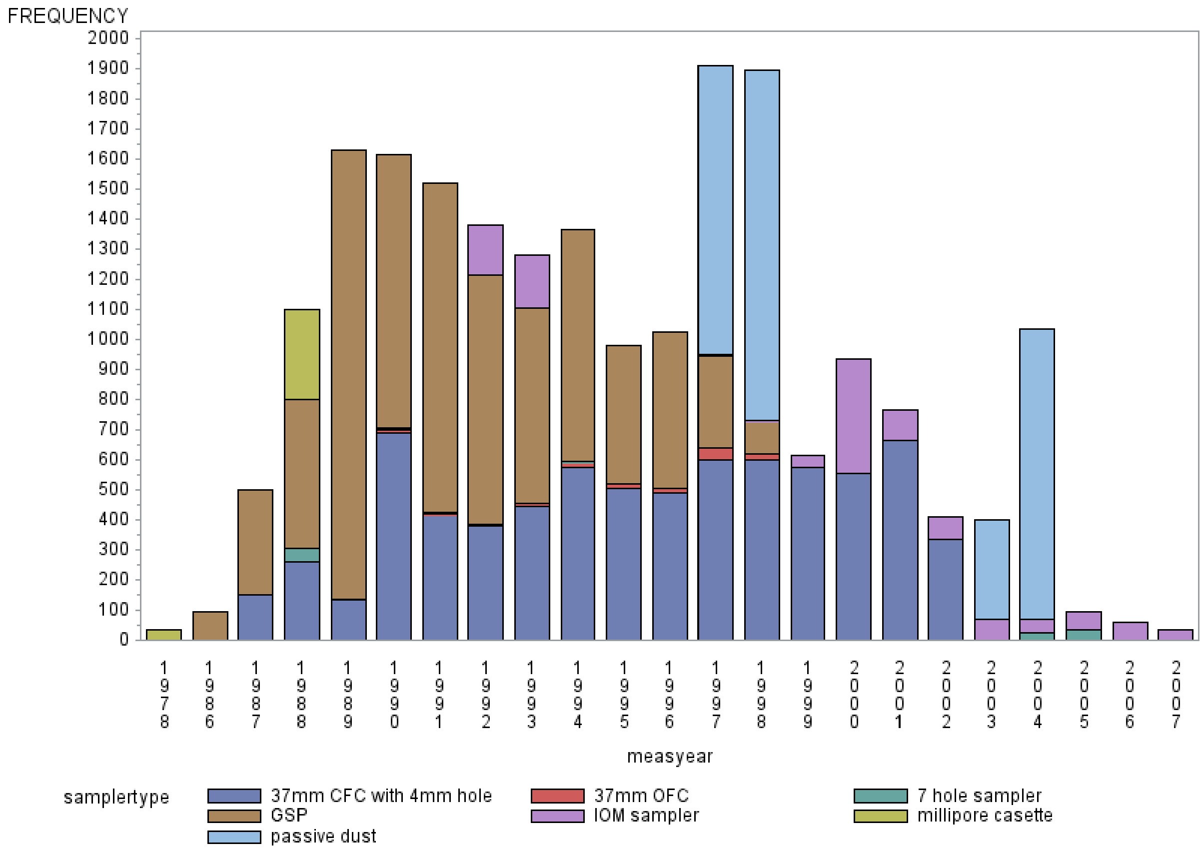


Figure2.39 Distribution of measurements in the final dataset by sampling device and year (n=20721)

Table 2.40 Distribution of measurements in the final dataset by sampling fraction (n=20721)

fraction	n	%
inhalable	12840	61.97
total	7881	38.03

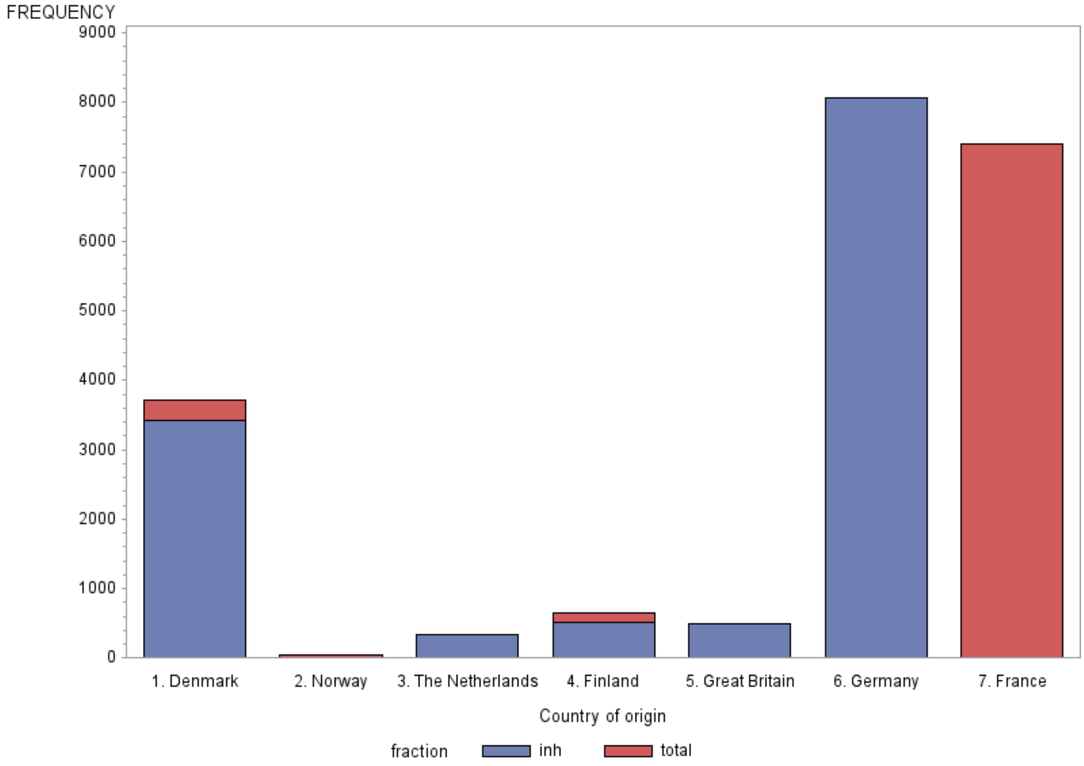


Figure 2.41 Distribution of measurements in the final dataset by sampling fraction and country (n=20721).

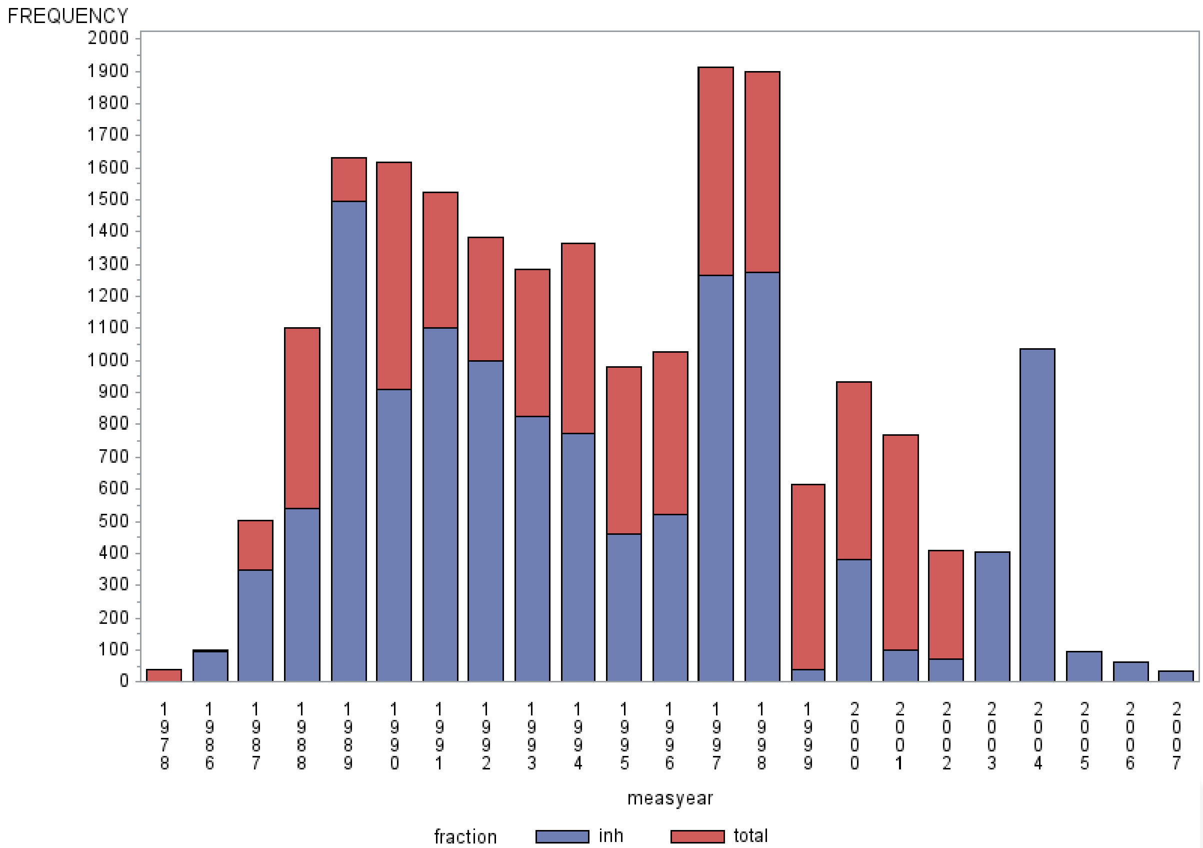


Figure2.42 Distribution of measurements in the final dataset by sampling fraction and year (n=20721).

2.5.2 Distribution of sampling time in the final dataset

The following SAS output summarises the distribution of sampling time in the final dataset (i.e. all personal measurements incl. n=20721) following substitution of the missing values with the corresponding median sampling times (see section 2.2.2 above).

The Univariate procedure

Variable: meastime (Duration of measurement (in minutes))

Moments			
N	20721	**Sum Weights**	20721
Mean	210.20889	**Sum Observations**	4355738.4
Std Deviation	112.556695	**Variance**	12669.0097
Skewness	0.90211472	**Kurtosis**	-0.2564975
Uncorrected SS	1178116812	**Corrected SS**	262501880
Coeff Variation	53.5451643	**Std Error Mean**	0.78192658

Basic Statistical Measures			
Location		**Variability**	
Mean	210.2089	**Std Deviation**	112.55670
Median	169.0000	**Variance**	12669
Mode	120.0000	**Range**	531.00000
		Interquartile Range	165.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	591.0
99%	501.0
95%	435.0
90%	388.0
75% Q3	285.0
50% Median	169.0
25% Q1	120.0
10%	110.0
5%	90.6
1%	64.8
0% Min	60.0

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
60	22318	571	7536
60	22317	574	6609
60	22310	579	7537
60	22290	586	4300
60	22263	591	7535

An overview of the basic characteristics in the distribution of sampling time across the different countries in the full dataset is provided below:

Table 2.43 Basic distribution characteristics of sampling time across countries in the full dataset.

Obs	country	n	AM	STD	Median	min	max	stderr	p5	p95
1	1. Denmark	3719	318.183	93.6479	295.0	65	586	1.5356	175.0	469.0
2	2. Norway	39	336.615	79.6693	336.0	162	494	12.7573	192.0	471.0
3	3. The Netherlands	342	475.532	64.2821	498.5	165	571	3.4760	335.0	527.0
4	4. Finland	642	269.679	82.0347	282.0	60	480	3.2377	120.0	375.0
5	5. Great Britain	499	252.487	69.9193	254.0	75	501	3.1300	140.0	418.0
6	6. Germany	8068	122.822	38.3427	120.0	60	495	0.4269	88.2	139.2
7	7. France	7412	230.248	99.8114	205.0	60	591	1.1593	90.0	405.0
Overall		20721	210.209	112.5567	169.0	60	591	0.7819	90.6	435.0

2.5.3 Distribution of sampling year in the final dataset (n=20721)

The UNIVARIATE Procedure

Variable: year (measyear)

Moments			
N	20721	**Sum Weights**	20721
Mean	1994.73476	**Sum Observations**	41332899
Std Deviation	4.84018855	**Variance**	23.4274252
Skewness	0.22304856	**Kurtosis**	-0.6601708
Uncorrected SS	8.24487E10	**Corrected SS**	485416.251
Coeff Variation	0.24264823	**Std Error Mean**	0.03362458

Basic Statistical Measures			
Location		Variability	
Mean	1994.735	**Std Deviation**	4.84019
Median	1994.000	**Variance**	23.42743
Mode	1997.000	**Range**	29.00000
		Interquartile Range	7.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	2007
99%	2004
95%	2004
90%	2001
75% Q3	1998
50% Median	1994
25% Q1	1991
10%	1989
5%	1988
1%	1987
0% Min	1978

Extreme Observations			
Lowest		Highest	
Value	**Obs**	**Value**	**Obs**
1978	3783	2007	4987

1978	3782	2007	4988
1978	3781	2007	4989
1978	3780	2007	5004
1978	3779	2007	5005

2.5.4 Correction factors

A literature review on relevant studies comparing sampling has been completed previously by the involved researchers as part of the development of another JEM for organic dust and endotoxin. The results of the review were used to extract sampler-specific correction factors used to correct for differences between sampler efficiencies in the included dust measurements.

In a similar fashion the results of the above review were used to identify relevant studies in relation to the relative efficiency of different samplers used for sampling wood dust. Only studies which summarized results including measurements of wood dust were considered. The results were tabulated stratified by study and sampler and suggested correction factors were estimated relatively to the IOM sampler which was used as the reference. Corrections were applied using the median values estimated for each of the samplers included. The results of the review and the applied correction factors are shown in Table 2.44 that follows.

Table 2.44.Literature reported relative efficiencies of different samplers used for sampling of wood dusts. Results are summarised with the IOM sampler as a reference

Type of sampler	**Correction factor**										
	Kromhout et al. 2005[23]	**Tatum et al., 2001**[24]	**Liden et al., 2000**[25]	**Kauffer et al., 2010**[26]	**Vaughan et al., 1990**[27]	**Werner et al., 1996**[28]	**Lee et al., 2011** [29]	**Schlünssen et al., 2001**[30]	**Harper and Muller. 2002**[31]	**Martin and Zalk. 1998**[32]	**Median**
IOM	1	1	1	1	1	1	1	1	1	1	1
Millipore closed faced	2.00	1.85[a]		2.02[a]		1.79[a;] 1.79[b]		1.59	3.35 [a]	5.5	1.92
Millipore open faced	2.21		2.5								2.36
GSP inhalable		1.27					1.01				1.14
7 hole sampler		1.38			1.28[c] 1.36[d]						1.36

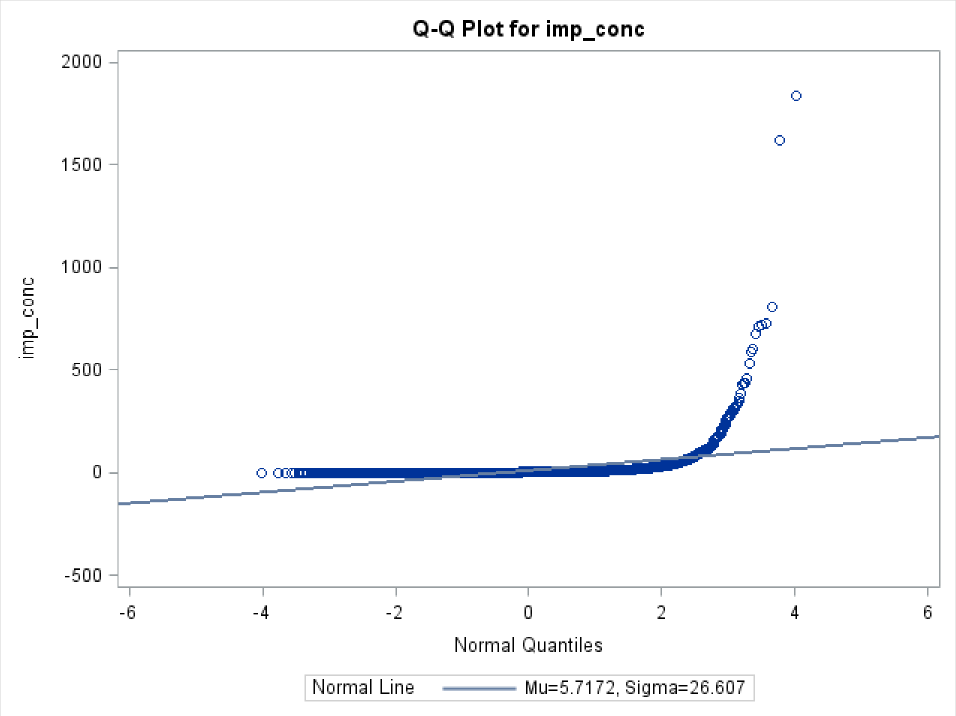
a =4mm orifice; b=5.6 mm orifice; c=casella 7-hole; d=J.S. Holdings 7-hole;

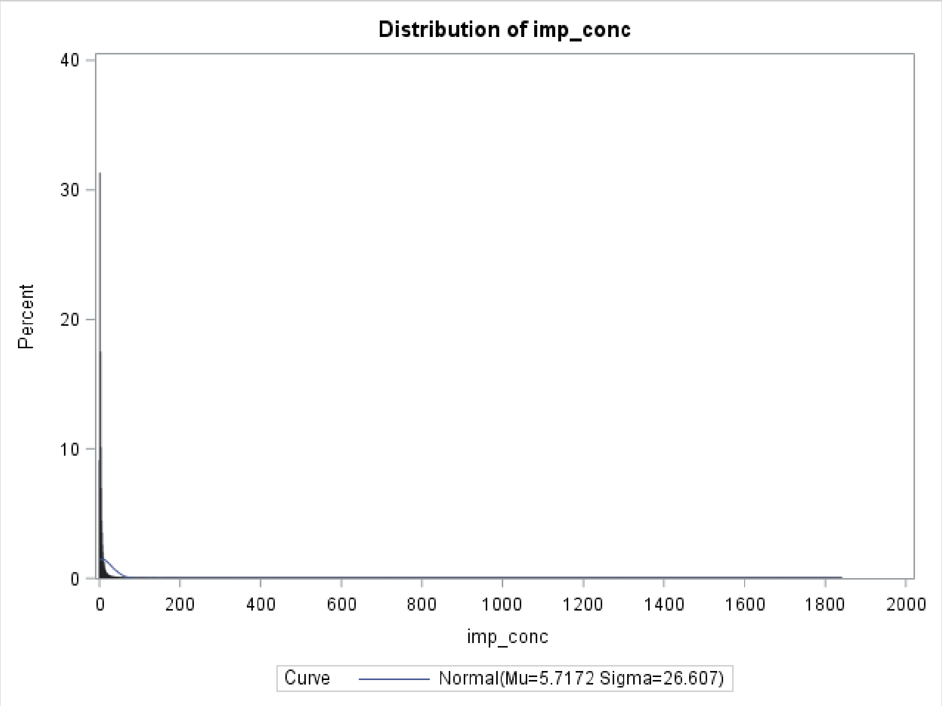
Davies et al., 1999 (AOH; 43;6) was also identified, but excluded as it did not include comparisons against the IOM same. The study includes comparisons of the GSP against 7-hole, CFC and PEM.

[23] Kromhout H, et al (2005) In situ testing of a calibration tool for workplace aerosol samplers (CALTOOL). Unpublished research report.
[24] Tatum VL, et al (2001) The performance of personal inhalable dust samplers in wood-products industry facilities. Appl Occup Env Hyg 16:763–769.
[25] Liden G, et al (2000) Personal sampling in parallel with open-face filter cassettes and IOM samplers for inhalable dust-implications for occupational exposure limits. Appl Occup Env Hyg 15:263–276.
[26] Kauffer E, et al (2010) Site comparison of selected aerosol samplers in the wood industry. Ann Occup Hyg 54:188–203.
[27]Vaughan NP, et al (1990) Field comparison of personal samplers for inhalable dust. Ann Occup Hyg 34:553–573.
[28] Werner MA, et al (1996) Investigation into the impact of introducing workplace aerosol standards based on the inhalable fraction. Analyst 121:1207–1214.
[29] Lee T, et al (2011) Wood dust sampling: field evaluation of personal samplers when large particles are present. Ann of Occup Hyg 55.2: 180-191.
[30] Schlunssen V, et al (2001) Wood dust exposure in the Danish furniture industry using conventional and passive monitors. Ann Occup Hyg 45:157–164.
[31] Harper M, Muller SM (2002) An evaluation of total and inhalable samplers for the collection of wood dust in three wood products industries. J Environ Monitor 4.5: 648-656.
[32] Martin JR, and Zalk DM (1998) Comparison of total dust/inhalable dust sampling methods for the evaluation of airborne wood dust. Appl Occup Env Hyg 13.3: 177-182.

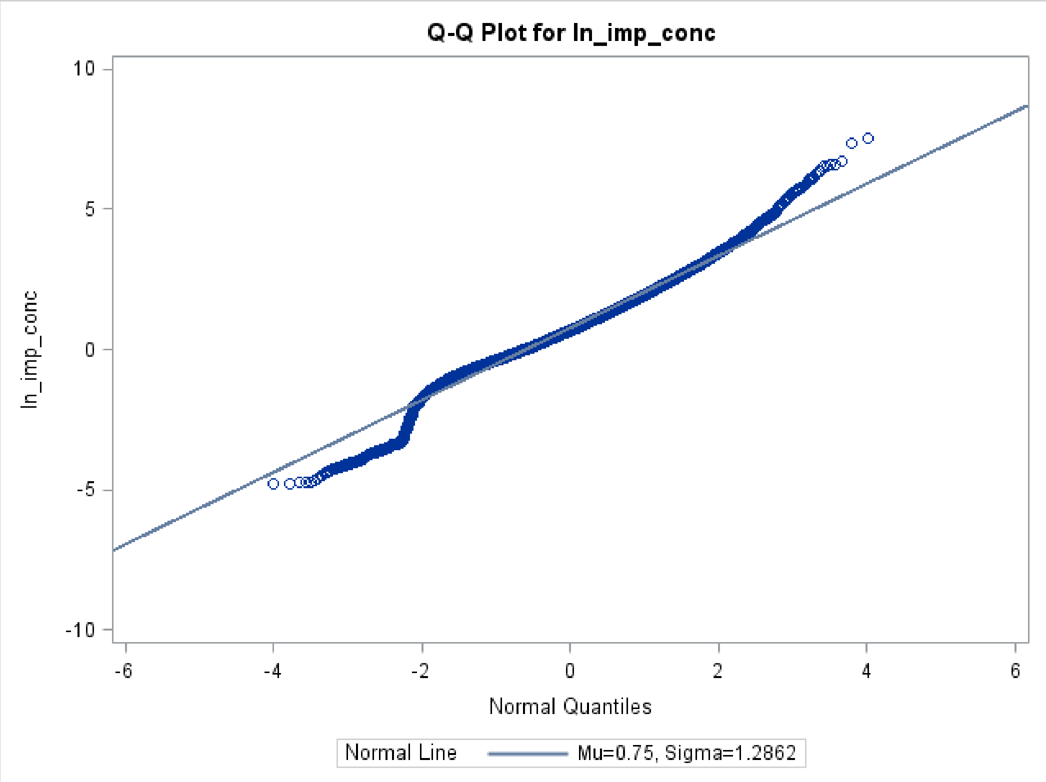
2.5.5 Examining and describing the distribution of exposure levels in the final dataset (n=20721):

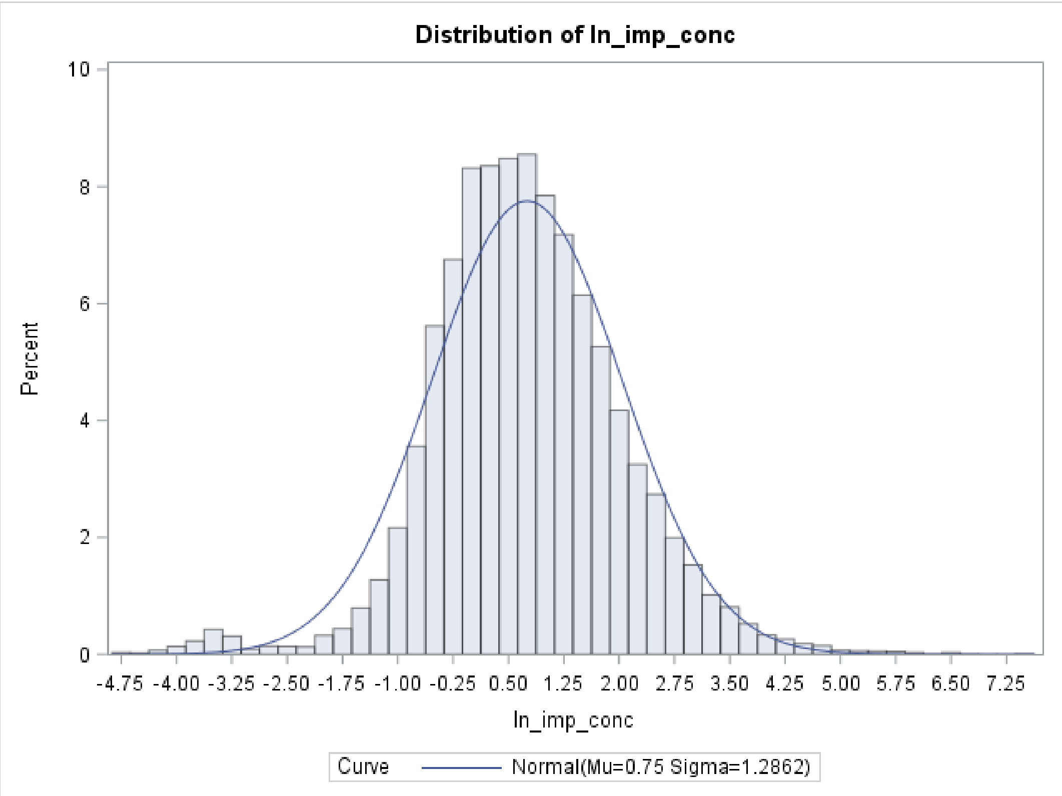
2.5.5.1 Fitting a normal distribution on the data





2.5.5.2 *Fitting a log-normal distribution on the data*





Comment: Data fit better on a log-normal distribution -with though some issues on fit at the left side due to the <LOD levels - and thereby they are be naturally log transformed, and analysed on the log-scale.

2.5.6 Summarising the basic attributes of the distribution of exposure levels in the in the final dataset (n=20721)

In the following the descriptive measures of the distribution of the measured wood dust concentrations are provided in SAS outputs concerning the original and log-transformed levels.

SAS output describing the basic attributes of the measured concentrations in the Original/Normal scale

The UNIVARIATE Procedure

Variable: imp_conc

Moments			
N	20721	**Sum Weights**	20721
Mean	5.71719528	**Sum Observations**	118466.003
Std Deviation	26.6066641	**Variance**	707.914575
Skewness	35.8183074	**Kurtosis**	1947.65938
Uncorrected SS	15345283.3	**Corrected SS**	14667990
Coeff Variation	465.379663	**Std Error Mean**	0.18483537

Basic Statistical Measures			
Location		Variability	
Mean	5.717195	**Std Deviation**	26.60666
Median	1.996800	**Variance**	707.91458
Mode	0.809400	**Range**	1841
		Interquartile Range	3.60420

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	1840.760000
99%	56.920200
95%	17.955000
90%	10.560000
75% Q3	4.550400
50% Median	1.996800
25% Q1	0.946200
10%	0.524400
5%	0.345600
1%	0.035082
0% Min	0.008347

Extreme Observations			
Lowest		Highest	
Value	**Obs**	**Value**	**Obs**
.00834735	21408	719.616	10004
0.00849416	17415	730.176	10003
0.00887247	20409	810.240	9184
0.00890888	7850	1622.976	10002
0.00901950	21906	1840.762	8734

SAS output describing the basic attributes of the measured concentrations in the Log normal scale

The UNIVARIATE Procedure

Variable: ln_imp_conc

Moments			
N	20721	**Sum Weights**	20721
Mean	0.75000966	**Sum Observations**	15540.9501
Std Deviation	1.28622439	**Variance**	1.65437318
Skewness	-0.0048444	**Kurtosis**	1.60988696
Uncorrected SS	45934.475	**Corrected SS**	34278.6123
Coeff Variation	171.494377	**Std Error Mean**	0.00893535

Basic Statistical Measures			
Location		**Variability**	
Mean	0.75001	**Std Deviation**	1.28622
Median	0.69155	**Variance**	1.65437
Mode	-0.21146	**Range**	12.30375
		Interquartile Range	1.57052

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	7.5179347
99%	4.0416503
95%	2.8878686
90%	2.3570733
75% Q3	1.5152151
50% Median	0.6915459
25% Q1	-0.0553013
10%	-0.6455005
5%	-1.0624732
1%	-3.3500765
0% Min	-4.7858108

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
-4.78581	21408	6.57872	10004
-4.76838	17415	6.59329	10003
-4.72480	20409	6.69733	9184
-4.72071	7850	7.39202	10002
-4.70837	21906	7.51793	8734

2.5.7 Distribution of measurements across ISCO88 codes

Table 2.45 Distribution of measurements across ISCO88 codes and assigned Asthma-JEM score in the in the final dataset ((n=20721).

isco88	ISCO STANDARD DESCRIPTION	ASTHMA-JEM score	n	%
110	Armed forces	0	1	0
2310	College, university and higher education teaching professionals	0	3	0.01
2320	Secondary education teaching professionals	0	9	0.04
2331	Primary education teaching professionals	0	78	0.38
2359	Other teaching professionals not elsewhere classified	0	1	0
5220	Shop salespersons and demonstrators	0	146	0.7
7124	Carpenters and joiners	1	6122	29.54
7129	Building frame and related trades workers not elsewhere classified	1	20	0.1
7131	Roofers	1	196	0.95
7132	Floor layers and tile setters	1	13	0.06
7142	Varnishers and related painters	0	20	0.1
7233	Agricultural- or industrial-machinery mechanics and fitters	0	22	0.11
7241	Electrical mechanics and fitters	0	2	0.01
7312	Musical instrument makers and tuners	1	4	0.02
7420	Wood treaters, cabinet-makers and related trades workers	2	643	3.1
7421	Wood treaters	1	35	0.17
7422	Cabinet makers and related workers	2	940	4.54
7423	Woodworking machine setters and setter-operators	2	956	4.61
7424	Basketry weavers, brush makers and related workers	0	24	0.12
7437	Upholsterers and related workers	0	1	0
8141	Wood-processing-plant operators	2	3645	17.59
8142	Paper-pulp plant operators	0	45	0.22
8143	Papermaking-plant operators	0	4	0.02
8161	Power-production plant operators	0	1	0
8172	Industrial-robot operators	0	1	0
8240	Wood-products machine operators	2	5700	27.51
8285	Wood and related products assemblers	1	1335	6.44
8324	Heavy truck and lorry drivers	0	162	0.78
8334	Lifting-truck operators	0	62	0.3
9141	Building caretakers	0	312	1.51
9161	Garbage collectors	0	9	0.04
9212	Forestry labourers	1	14	0.07
9313	Building construction labourers	1	195	0.94

2.5.8 Sampling reason within the measurements comprising the final dataset (n=20721)

The representativeness of the measurements comprising the final dataset was established on the basis of the available information. In particular, information pertaining to the reason behind the measurements were available for the UK (mix of survey, compliance/complain and other reason), Danish (survey data), and part of the Finnish data (survey data). To classify the remaining measurements information was sought from the source documents and/or the data providers. Norwegian data on the basis of description in the report (worst case sampling) were considered as “not-representative”. The Dutch data were classified as survey data based on the information provided by Scheeper et al (1995), and were generally considered as representative. The German data on the contrary included measurements that were collected from workplaces with expected high wood dust concentrations and following interventions on ventilation to reduce the exposures within such workplaces. Both the pre and post intervention measurements were included though with no direct inference on which is which. As a consequence the German data were generally considered as non-representative. The sampling reason was accordingly considered as one of compliance/complain and/or inspection. For the Finnish data with no information the assistance of our Finnish colleagues was sought. Following feedback it was clarified that all Finnish measurements were generally representative. The most common reason for sampling was “workplaces having to know the exposure level and they have ordered the survey” which seems similar to the HSE “local initiative/survey classification”. Consequently Finnish measurements were also considered as representative, however, the sampling reason for the measurements for which there was no info remained unknown. Finally the French data were considered as representative on the basis of the information provided on the WOODEX publications. No sampling reason was assigned here either (i.e. unknown).

3 MODELING EXPOSURE LEVELS AND TIME-TRENDS

3.1 MODELLING APPROACHES FOR STATISTICAL ANALYSIS: METHODS

As described in the introduction the present work aims to establish a Job-exposure matrix with quantitative estimates of exposure by job, year and country (3 axes). This is to be achieved through the establishment of statistical models using Linear mixed effect regression. In these models ISCO-88 codes was the random effect whereas as fixed effects the year, sampling time, country, ASTHMA-JEM score, and sampling strategy (representativeness) or reason for sampling were used. Inclusion of variables was based on the following reasons:

a) Year, ISCO88, and country: these are all parameters of the JEM to be established.
b) Asthma-JEM score: needed to allow extrapolation of estimates to occupations/job titles where measurements have not been available, as well as to overwrite arbitrary results.
c) Sampling strategy, reason and duration (sampling time): these were all included to address potential confounding in time trends and exposure estimates.

Neither sampling devise nor fraction were included as variables in the modelling process because individual measurement results have already been corrected for the presence of systematic variations due to sampler efficiencies (see section 2.5.4 above). The inclusion of country as a fixed rather than a random effect follows the decisions made at the teleconference on early May 2016. This was based on an expected small difference in the actual exposure estimates by application of either of the approaches.

Three models were originally considered:
a) Occupation level (4 digits)
b) Unit level (3 digits)
c) Minor group level (2 digits)

However, because ASTHMA-JEM does not include minor groups assigned an exposure status above 0 only the models (a) and (b) were performed. A forward build approach was used with year a priori included in the models. Predictions for the development of the matrix were based on the model BLUPS for ISCO codes with measurements and on the ASTHMA-JEM score estimates for ISCO codes without measurements.

3.1.1 Measurement availability for exposed according to the Asthma-JEM ISCO88 codes

The following table summarises the available measurements for the exposed occupations according to Asthma-JEM ISCO88 code when all levels of the latter are considered. Evidently there were no measurements for 3 exposed codes i.e. 6141, 7330 and 7331 whereas for another (7312) there are less than 5 measurements available. For ISCO code 6141 the BLUP estimates derived for forestry labourers can potentially be used.

Table 3.1 Measurement availability for exposed according to the Asthma-JEM ISCO88 codes

ISCO88	ISCO STANDARD DESCRIPTION	wood dusts	number of measurements in the overall dataset (i.e. all personal measurements incl. n=20721)
6141	Forestry workers and loggers	**1**	0
7124	Carpenters and joiners	**1**	6122
7129	Building frame and related trades workers not elsewhere classified	**1**	20
7131	Roofers	**1**	196
7132	Floor layers and tile setters	**1**	13
7312	Musical instrument makers and tuners	**1**	4
7330	Handicraft workers in wood, textile, leather and related materials	**1**	0
7331	Handicraft workers in wood and related materials	**1**	0
7420	Wood treaters, cabinet-makers and related trades workers	**2**	2574
7421	Wood treaters	**1**	35
7422	Cabinet makers and related workers	**2**	940
7423	Woodworking machine setters and setter-operators	**2**	956
8140	Wood-processing- and papermaking-plant operators	**1**	3645
8141	Wood-processing-plant operators	**2**	3645
8240	Wood-products machine operators	**2**	5700
8285	Wood and related products assemblers	**1**	1335
9212	Forestry labourers	**1**	14
9313	Building construction labourers	**1**	195

3.2 RESULTS OF THE MODELLING PROCESS

Spearman correlation analysis showed that sampling strategy (representativeness) correlated with the sampling reason whereas very strong correlations were present also between these two variables and the sampling time/duration (Table 3.2). Therefore only the sampling time was included in the modelling process but not the sampling duration or reason.

Table 3.2 SAS output summarising the results of spearman correlation analysis

Spearman Correlation Coefficients, N = 20721 Prob > |r| under H0: Rho=0							
	meastime	**reason1**	**strategy1**	**country**	**wooddusts**	**year94**	**ln_imp_conc**
meastime Duration of measurement (in minutes)	1.00000	0.719 <.0001	-0.682 <.0001	-0.133 <.0001	0.220 <.0001	0.527 <.0001	-0.251 <.0001
reason1 sampling reason, 1=unknown, 0=inspection, 2=survey		1.00000	-0.906 <.0001	-0.241 <.0001	0.264 <.0001	0.596 <.0001	-0.226 <.0001
strategy1 sampling strategy, 1= not representative, 0=representative			1.000	-0.171 <.0001	-0.328 <.0001	-0.5483 <.0001	0.0816 <.0001
country Country of origin				1.000	0.126 <.0001	-0.143 <.0001	0.350 <.0001
wooddusts Asthma JEM score for wood dust, 0=no exposure, 1=low exposure, 2=high exposure					1.000	0.079 <.0001	0.021 0.0027
year94 Measurement year with reference set at 1994						1.000	-0.322 <.0001
ln_imp_conc Ln transformed Concentrations (mg/m3) with imputed LOD levels and corrected for differences in sampler efficiency							1.000

3.2.1 Results of the models using all samples available in the final dataset (n=20721): ISCO88 Occupation level (4 digits)

In the following, the first table (Table 3.3) summarizes the different stages of the model building process whereas in the next pages the full SAS outputs for the final models (naïve and full versions) are presented.

Table 3.3 Results from linear mixed effect regression describing estimated temporal trends in wood dust exposure in the database. Results are based on **20721** personal wood dust measurements collected between 1978 and 2004.

Model	***β* Year (ref 2001)**	***e***	**P-value**	**Annual trend (%)**	**AIC**	**$_{bisco}\sigma^2$**	**$_{wisco}\sigma^2$**
Wood dust							
Naïve					68082.4	0.2282	1.5586
+ year*	-0.07133	0.00192	<.0001	-6.9	66751.9	0.1559	1.4615
+ year, country	-0.07045	0.00215	<.0001	-6.8	64750.4	0.04592	1.3271
+ year, country, sampling time	-0.05931	0.00223	<.0001	-5.8	64458.5	0.04260	1.3076
+ year, country, sampling time, ASTHMA-JEM score	-0.05928	0.00223	<.0001	-5.8	64463.2	0.04945	1.3076

β=regression coefficient for log-transformed exposure data; *e*=standard error; *p*=p-value; annual trend=% of change in exposure per year estimated as 100*(exp(β)-1); $_{bisco}\sigma^2$ = between job variance; $_{wisco}\sigma^2$= within-Job (residual) variance;. Naive estimates are derived from a model without fixed effects.

SAS output summarising the results of the naïve model

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	33	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7241 7312 7420 7421 7422 7423 7424 7437 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	6	2 3 4 5 6 7
wooddusts	3	0 1 2

Number of Observations	
Number of Observations Read	20721
Number of Observations Used	20721
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.2282	0.07359	3.10	0.0010
Residual	1.5586	0.01532	101.72	<.0001

Fit Statistics	
-2 Res Log Likelihood	68078.4
AIC (Smaller is Better)	68082.4
AICC (Smaller is Better)	68082.4
BIC (Smaller is Better)	68085.4

Solution for Fixed Effects								
Effect	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept	0.6956	0.1002	32	6.94	<.0001	0.05	0.4914	0.8997

SAS output summarising the results of the main model (full- 4 digit ISCO88 code)

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	33	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7241 7312 7420 7421 7422 7423 7424 7437 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	6	2 3 4 5 6 7
wooddusts	3	0 1 2

Number of Observations	
Number of Observations Read	20721
Number of Observations Used	20721
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.04945	0.02072	2.39	0.0085
Residual	1.3076	0.01286	101.71	<.0001

Fit Statistics	
-2 Res Log Likelihood	64459.2
AIC (Smaller is Better)	64463.2
AICC (Smaller is Better)	64463.2
BIC (Smaller is Better)	64466.2

Solution for Fixed Effects										
Effect	**Country‡**	**Asthma JEM score***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept			1.6753	0.1041	30	16.09	<.0001	0.05	1.4627	1.8879
year94			-0.05928	0.002231	21E3	-26.57	<.0001	0.05	-0.06365	-0.05490
country1	**2**		-0.9873	0.02944	21E3	-33.54	<.0001	0.05	-1.0450	-0.9296
country1	**3**		-0.08670	0.07096	21E3	-1.22	0.2218	0.05	-0.2258	0.05239
country	**4**		-0.1577	0.0498	21E	-3.16	0.001	0.05	-	-

Solution for Fixed Effects										
1				8	3		6		0.2555	0.05994
country1	**5**		0.09426	0.05439	21E3	1.73	0.0831	0.05	-0.01235	0.2009
country1	**6**		-0.8592	0.02801	21E3	-30.68	<.0001	0.05	-0.9141	-0.8043
country1	**7**		0	.	.	.	.	.	.	.
meastime			-0.00188	0.000107	21E3	-17.62	<.0001	0.05	-0.00209	-0.00168
wooddusts		**0**	-0.04662	0.1310	21E3	-0.36	0.7219	0.05	-0.3034	0.2101
wooddusts		**1**	-0.01131	0.1380	21E3	-0.08	0.9347	0.05	-0.2819	0.2593
wooddusts		**2**	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR
*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
year94	1	21E3	705.82	<.0001
country1	5	21E3	431.85	<.0001
meastime	1	21E3	310.55	<.0001
wooddusts	2	21E3	0.07	0.9293

3.2.2 Results of the models using all samples available in the final dataset (n=20721): ISCO88 unit level (3 digits)

In the following the results from the analysis using the unit level of the ISCO88 coding system are shown started from the distribution of measurements across ISCO88 codes and the Asthma –JEM score (Table 3.4) and followed by the results of the naïve and full mixed effect regression model.

Table 3.4 Distribution of measurements across ISCO88 codes for units (i.e. 3 digits) and assigned Asthma-JEM score in the in the final dataset (n=20721)

ISCO88_ 3digit	ISCO 88 description	Wooddusts 3digit*	n	%
11	Armed forces	0	1	0.00
231	College, university and higher education teaching professionals	0	3	0.01
232	Secondary education teaching professionals	0	9	0.04
233	Primary and pre-primary education teaching professionals	0	78	0.38
235	Other teaching professionals	0	1	0.00
522	Shop salespersons and demonstrators	0	146	0.70
712	Building frame and related trades workers	0	6142	29.64
713	Building finishers and related trades workers	0	209	1.01
714	Painters, building structure cleaners and related trades workers	0	20	0.10
723	Machinery mechanics and fitters	0	22	0.11
724	Electrical and electronic equipment mechanics and fitters	0	2	0.01
731	Precision workers in metal and related materials	0	4	0.02
742	Wood treaters, cabinet-makers and related trades workers	2	2598	12.54
743	Textile, garment and related trades workers	0	1	0.00
814	Wood-processing- and papermaking-plant operators	1	3694	17.83
816	Power-production and related plant operators	0	1	0.00
817	Automated-assembly-line and industrial-robot operators	0	1	0.00
824	Wood-products machine operators	2	5700	27.51
828	Assemblers	0	1335	6.44
832	Motor-vehicle drivers	0	162	0.78
833	Agricultural and other mobile-plant operators	0	62	0.30
914	Building caretakers, window and related cleaners	0	312	1.51
916	Garbage collectors and related labourers	0	9	0.04
921	Agricultural, fishery and related labourers	0	14	0.07
931	Mining and construction labourers	0	195	0.94

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

SAS output summarising the results of the naïve model at the ISCO88 unit level

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO88_3digit	25	11 231 232 233 235 522 712 713 714 723 724 731 742 743 814 816 817 824 828 832 833 914 916 921 931
country1	6	2 3 4 5 6 7
wooddusts	3	0 1 2

Number of Observations	
Number of Observations Read	20721
Number of Observations Used	20721
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO88_3digit	0.2688	0.09970	2.70	0.0035
Residual	1.5673	0.01540	101.74	<.0001

Fit Statistics	
-2 Res Log Likelihood	68178.3
AIC (Smaller is Better)	68182.3
AICC (Smaller is Better)	68182.3
BIC (Smaller is Better)	68184.7

Solution for Fixed Effects								
Effect	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept	0.6102	0.1261	24	4.84	<.0001	0.05	0.3500	0.8705

SAS output summarising the results of the full model at the ISCO88 unit level

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO88_3digit	25	11 231 232 233 235 522 712 713 714 723 724 731 742 743 814 816 817 824 828 832 833 914 916 921 931
country1	6	2 3 4 5 6 7
wooddusts	3	0 1 2

Number of Observations	
Number of Observations Read	20721
Number of Observations Used	20721
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO88_3digit	0.05091	0.02930	1.74	0.0411
Residual	1.3105	0.01288	101.72	<.0001

Fit Statistics	
-2 Res Log Likelihood	64493.7
AIC (Smaller is Better)	64497.7
AICC (Smaller is Better)	64497.7
BIC (Smaller is Better)	64500.1

Solution for Fixed Effects										
Effect	**Country ‡**	**Asthma JEM score ***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept			1.8072	0.1623	22	11.13	<.0001	0.05	1.4706	2.1439
year94			-0.05966	0.002231	21E3	-26.74	<.0001	0.05	-0.06403	-0.05529
country1	**2**		-0.9951	0.02945	21E3	-33.79	<.0001	0.05	-1.0529	-0.9374
country1	**3**		-0.09491	0.07101	21E3	-1.34	0.1814	0.05	-0.2341	0.04428
country1	**4**		-0.1464	0.04968	21E3	-2.95	0.0032	0.05	-0.2438	-0.04904
country1	**5**		0.07653	0.05392	21E3	1.42	0.1558	0.05	-0.02916	0.1822
country1	**6**		-0.9013	0.02723	21E3	-33.10	<.0001	0.05	-0.9547	-0.8479
country1	**7**		0	.	.	.	.	.	.	.
meastime			-0.00189	0.000107	21E3	-17.65	<.0001	0.05	-0.00210	-0.00168
wooddusts		**0**	-0.1295	0.1752	21E3	-0.74	0.4600	0.05	-0.4730	0.2140
wooddusts		**1**	-0.4293	0.2775	21E3	-1.55	0.1218	0.05	-0.9732	0.1145
wooddusts		**2**	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR
*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
year94	1	21E3	715.75	<.0001
country1	5	21E3	467.18	<.0001
meastime	1	21E3	310.74	<.0001
wooddusts	2	21E3	0.02	0.9754

3.3 SENSITIVITY ANALYSIS ON MODELS USING ALL AVAILABLE SAMPLES IN THE FINAL DATASET (N=20721)

To test the robustness of the derived models and associations and series of sensitivity analysis has been performed where models were repeated with restrictions in samples size or in parameters included. In particular, the main models were refitted after:

a) Removing the exposure prior (Asthma-JEM) score from the fixed effects
b) Excluding all measurements with a measured exposure concentration above 50 mg/m3
c) Excluding all measurements with a sampling time <240 min

3.3.1 Fitting the main model without the exposure prior (i.e. asthma-JEM score)

In the following the SAS output from a main model without the exposure prior is shown.

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	33	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7241 7312 7420 7421 7422 7423 7424 7437 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	6	2 3 4 5 6 7

Number of Observations	
Number of Observations Read	20721
Number of Observations Used	20721
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
ISCO882	0.04260	0.01739	2.45	0.0071
Residual	1.3076	0.01286	101.71	<.0001

Fit Statistics	
-2 Res Log Likelihood	64454.5
AIC (Smaller is Better)	64458.5
AICC (Smaller is Better)	64458.5
BIC (Smaller is Better)	64461.5

Solution for Fixed Effects									
Effect	Country ‡	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept		1.6566	0.05671	32	29.21	<.0001	0.05	1.5411	1.7721
year94		-0.05931	0.002230	21E3	-26.60	<.0001	0.05	-0.06368	-0.05494
country1	2	-0.9876	0.02940	21E3	-33.59	<.0001	0.05	-1.0452	-0.9299
country1	3	-0.08693	0.07095	21E3	-1.23	0.2205	0.05	-0.2260	0.05214
country1	4	-0.1593	0.04979	21E3	-3.20	0.0014	0.05	-0.2568	-0.06167
country1	5	0.09417	0.05434	21E3	1.73	0.0831	0.05	-0.01235	0.2007
country1	6	-0.8589	0.02797	21E3	-30.71	<.0001	0.05	-0.9137	-0.8041
country1	7	0	.	.	.	.	.	.	.
meastime		-0.00188	0.000107	21E3	-17.62	<.0001	0.05	-0.00209	-0.00167

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR

Type 3 Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
year94	1	21E3	707.30	<.0001
country1	5	21E3	432.95	<.0001
meastime	1	21E3	310.61	<.0001

Comment: From the above it can be seen that the exclusion of the prior from the model has little effect on the model estimates for the fitted effects. The same can also be concluded when looking on the estimated BLUPs which remained essentially unaffected (not shown).

3.3.2 Fitting the main model after excluding all measurements with a concentration >50 mg/m^3 from the dataset

In the following the SAS output from a main model without the measurements with a concentration >50 mg/m^3 is shown.

The Mixed Procedure

Model Information	
Data Set	X.WOODIMPUTED
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	33	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7241 7312 7420 7421 7422 7423 7424 7437 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	6	2 3 4 5 6 7
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	12
Columns in Z	33
Subjects	1
Max Obs per Subject	20478

Number of Observations	
Number of Observations Read	20478
Number of Observations Used	20478
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.05964	0.02536	2.35	0.0093
Residual	1.1893	0.01176	101.11	<.0001

Fit Statistics	
-2 Res Log Likelihood	61767.9
AIC (Smaller is Better)	61771.9
AICC (Smaller is Better)	61771.9
BIC (Smaller is Better)	61774.9

Solution for Fixed Effects										
Effect	**Country‡**	**Asthma JEM score***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept			1.5320	0.1132	30	13.53	<.0001	0.05	1.3008	1.7632
year94			-0.05313	0.00215	2E4	-24.68	<.0001	0.05	-0.05735	-0.04891
country1	**2**		-0.9371	0.0283	2E4	-33.15	<.0001	0.05	-0.9925	-0.8817
country1	**3**		-0.02556	0.0678	2E4	-0.38	0.7063	0.05	-0.1585	0.1074

country1	4		-0.1448	0.0477	2E4	-3.03	0.0024	0.05	-0.2384	-0.05119
country1	5		0.08200	0.0524	2E4	1.56	0.1176	0.05	-0.02072	0.1847
country1	6		-0.7477	0.0270	2E4	-27.67	<.0001	0.05	-0.8007	-0.6948
country1	7		0	.	.	.	.	.	.	.
meastime			-0.00167	0.0001	2E4	-16.18	<.0001	0.05	-0.00187	-0.00146
wooddusts		0	-0.0658	0.1410	2E4	-0.47	0.6406	0.05	-0.3421	0.2105
wooddusts		1	-0.0238	0.1494	2E4	-0.16	0.8734	0.05	-0.3167	0.2690
wooddusts		2	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR
*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

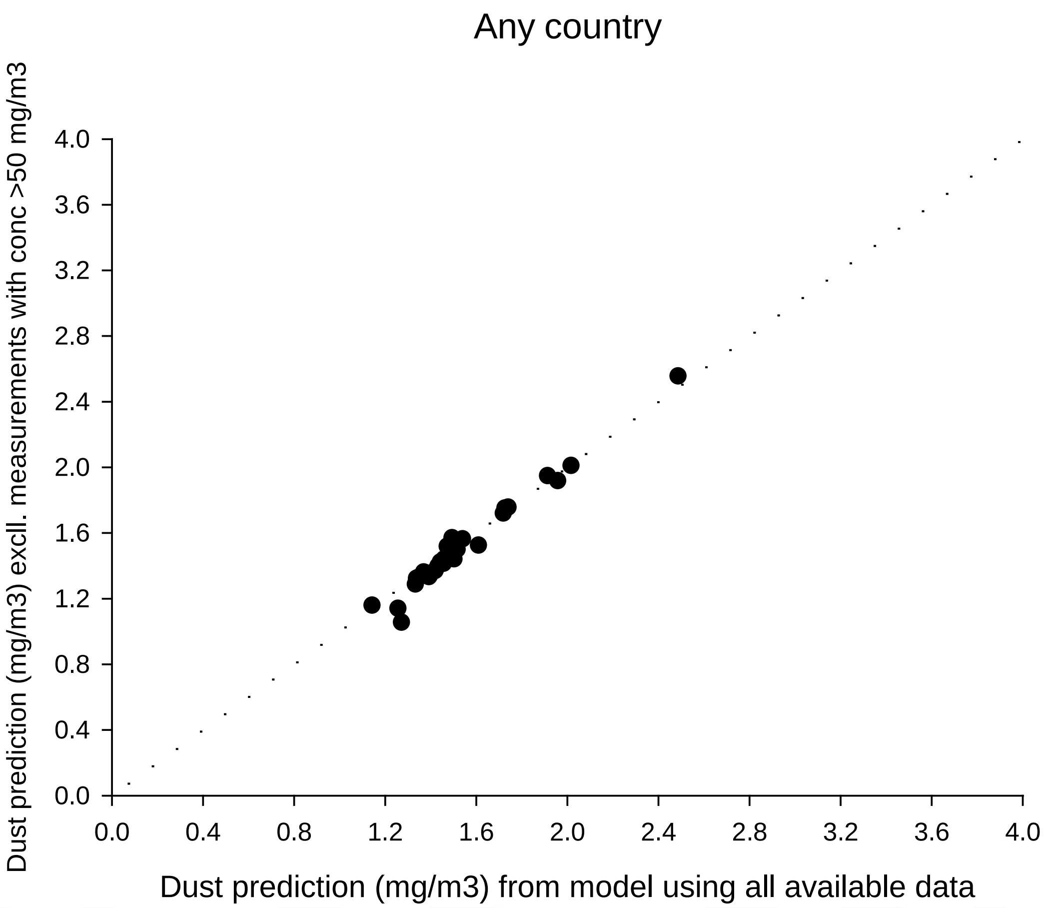


Figure 3.5 Agreement between the non-country specific BLUPs from the model with all measurements and the one excluding measurements >50 mg/m^3. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

Comment: From the above model results and the plots it can be seen that The exclusion of these measurements hardly affects the exposure estimates.

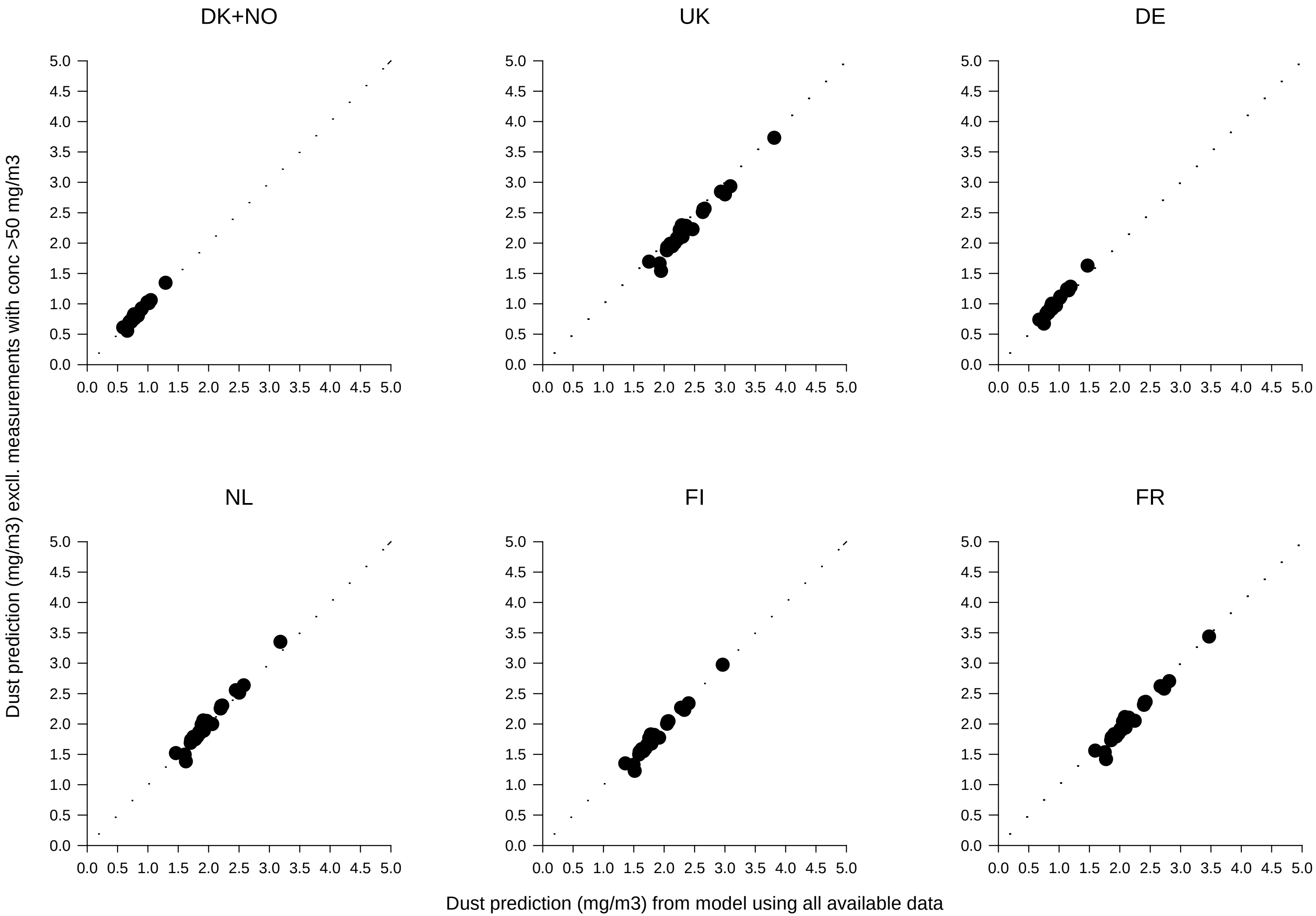


Figure 3.6 Agreement between the country-specific BLUP estimates from model with all measurements and the one excluding measurements >50 mg/m^3. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

3.3.3 Fitting the main model after excluding measurements with sampling time <240 min

One of the sensitivity analysis pertained to the removal of all measurements with a sampling duration below 240 min (4 hr) from the final dataset in order to account for biases resulting from the presence of a substantial number of measurements with duration between 60-240 min. Such measurements have been particularly prevalent in the German data set where the median sampling time was 120 min (range 9 – 495 min). In the following the results of this analysis are summarised.

An overview of the basic characteristics in the distribution of sampling time across the different countries in the final dataset is provided below (Table 3.7) as a reminder of previously presented results (see section 2.5.2):

Table 3.7 Basic distribution characteristics of sampling time across countries in the final dataset.

Obs	country	n	AM	STD	Median	min	max	stderr	p5	p95
1	1. Denmark	3719	318.18	93.65	295.0	65	586	1.5356	175.0	469.0
2	2. Norway	39	336.62	79.67	336.0	162	494	12.7573	192.0	471.0
3	3. The Netherlands	342	475.53	64.28	498.5	165	571	3.4760	335.0	527.0
4	4. Finland	642	269.68	82.03	282.0	60	480	3.2377	120.0	375.0
5	5. Great Britain	499	252.49	69.92	254.0	75	501	3.1300	140.0	418.0
6	6. Germany	8068	122.82	38.34	120.0	60	495	0.4269	88.2	139.2
7	7. France	7412	230.25	99.81	205.0	60	591	1.1593	90.0	405.0
Overall		**20721**	**210.21**	**112.56**	**169.0**	**60**	**591**	**0.7819**	**90.6**	**435.0**

Comment: Evidently from this table it is obvious that a short sampling duration is an issue specifically present among the German measurements. Omitting measurements with a duration <240 min should be expected to severely alter the number of available measurements and reduce study power.

Indeed restricting the analysis on measurements with duration between 240 and 600 min resulted in a much smaller dataset comprising of only 7230 measurements (hereafter called the "restricted dataset"). More than 65% of the available measurements are removed due to the restriction with major impacts in the German, French and UK datasets. The number of available measurements and the resulting reduction on them by the restriction across the different countries is summarised in Table 3.8.

Table3.8 Comparison of available measurements in the full and restricted datasets across countries and overall, and proportion of measurements removed due to the restriction.

country	n		Reduction (%) in available measurements following the exclusion
	Final dataset	Restricted dataset	
1. Denmark	3719	3008	19.1
2. Norway	39	34	12.8
3. The Netherlands	342	338	1.2
4. Finland	642	506	21.2
5. Great Britain	499	324	35.1
6. Germany	8068	179	97.8
7. France	7412	2841	61.7
Overall	**20721**	**7230**	**65.1**

The basic attributes of the distribution of sampling time across the different countries in the restricted dataset is provided in Table 3.10. Some basic information related to the availability of measurements across countries (Figure 3.11) and ISCO codes in the two datasets (Table 3.12 and 3.13 for the final and restricted datasets, respectively) follow.

Table 3.10 Basic distribution characteristics of sampling time across countries in the restricted (i.e. only measurements with a duration between 240 and 600 min are incl.) dataset.

Obs	country	n	AM	STD	Median	min	max	stderr	p5	p95
1	1. Denmark	3008	348.07	76.73	330	240	586	1.40	250	475
2	2. Norway	34	356.18	64.29	365	259	494	11.03	260	471
3	3. The Netherlands	338	478.78	57.16	499	250	571	3.11	355	527
4	4. Finland	506	304.38	48.22	282	240	480	2.14	240	420
5	5. Great Britain	324	288.27	55.09	273	240	501	3.06	243	430
6	6. Germany	179	356.66	26.19	360	256.2	495	1.96	300	379.8
7	7. France	2841	338.32	62.30	340	240	591	1.17	245	450
Overall		7230	**344.86**	**74.71**	**335**	**240**	**591**	**0.88**	**246**	**485**

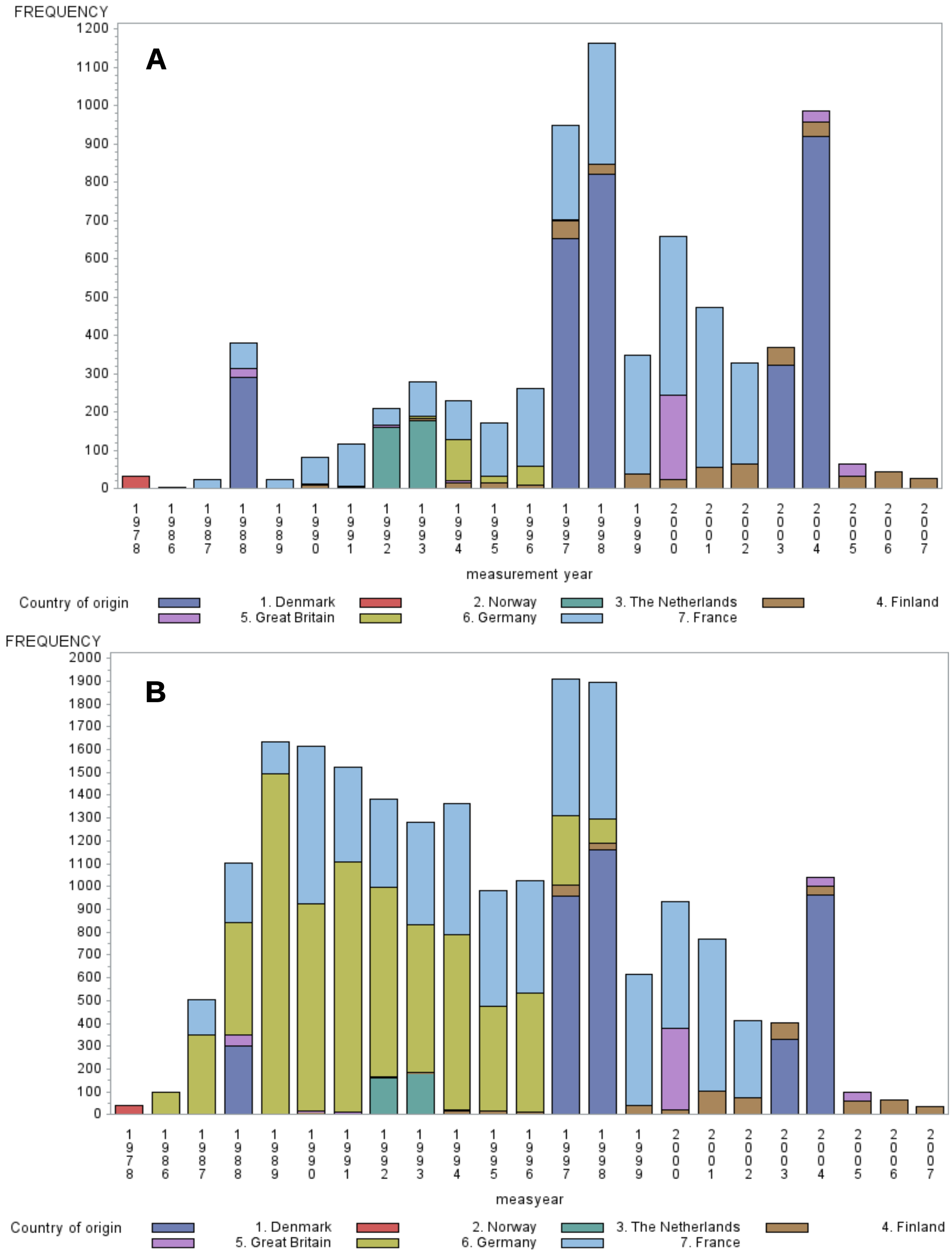


Figure 3.11 Distribution of measurements between countries and years in the restricted (A) and final (B) dataset respectively.

Table 3.12 Distribution of measurements across ISCO-88 codes in the final dataset (n=20721)

isco88	ISCO STANDARD DESCRIPTION	ASTHMA-JEM score	Final dataset (n=20721) n						
			Overall	DK	Netherlands	Finland	UK	Germany	France
110	Armed forces	0	1			**1**			
2310	College, university and higher education teaching professionals	0	3			3			
2320	Secondary education teaching professionals	0	9			7			2
2331	Primary education teaching professionals	0	78			11			67
2359	Other teaching professionals not elsewhere classified	0	1			1			
5220	Shop salespersons and demonstrators	0	146					58	88
7124	Carpenters and joiners	1	6122	205	7	30	76	5066	738
7129	Building frame and related trades workers not elsewhere classified	1	20						20
7131	Roofers	1	196						196
7132	Floor layers and tile setters	1	13					5	8
7142	Varnishers and related painters	0	20				2	18	
7233	Agricultural- or industrial-machinery mechanics and fitters	0	22			7	1	9	5
7241	Electrical mechanics and fitters	0	2					2	
7312	Musical instrument makers and tuners	1	4					1	3
7420	Wood treaters, cabinet-makers and related trades workers	2	643	59		30	12	188	354
7421	Wood treaters	1	35			2	25		8
7422	Cabinet makers and related workers	2	940	81		1	8	840	10
7423	Woodworking machine setters and setter-operators	2	956	49		7	42	702	156
7424	Basketry weavers, brush makers and related workers	0	24				3	21	
7437	Upholsterers and related workers	0	1					1	
8141	Wood-processing-plant operators	2	3645	17		429	212	697	2290
8142	Paper-pulp plant operators	0	45			25			20
8143	Papermaking-plant operators	0	4						4
8161	Power-production plant operators	0	1			1			
8172	Industrial-robot operators	0	1			1			

isco88	ISCO STANDARD DESCRIPTION	ASTHMA-JEM score	Final dataset (n=20721) n						
			Overall	DK	Netherlands	Finland	UK	Germany	France
8240	Wood-products machine operators	2	5700	2095	265	68	84	339	2849
8285	Wood and related products assemblers	1	1335	1092	70	15	32	1	125
8324	Heavy truck and lorry drivers	0	162	160		2			
8334	Lifting-truck operators	0	62			1	2	59	
9141	Building caretakers	0	312						312
9161	Garbage collectors	0	9						9
9212	Forestry labourers	1	14						14
9313	Building construction labourers	1	195					61	134

Table 3.12 Distribution of measurements across ISCO-88 codes in the restricted dataset (n=7230)

isco88	ISCO STANDARD DESCRIPTION	ASTHMA - JEM score	Resticted dataset (i.e. only measurements with sampling duration between 240-600 min are inlc.) n						
			Overall	Skandinavia (DK+NO)	Netherlands	Finland	UK	Germany	France
110	Armed forces	0							
2310	College, university and higher education teaching professionals	0	3			3			
2320	Secondary education teaching professionals	0	2						2
2331	Primary education teaching professionals	0	10			2			8
2359	Other teaching professionals not elsewhere classified	0							
5220	Shop salespersons and demonstrators	0	44						44
7124	Carpenters and joiners	1	601	145	7	24	44	137	244
7129	Building frame and related trades workers not elsewhere classified	1	3						3
7131	Roofers	1	109						109
7132	Floor layers and tile setters	1							
7142	Varnishers and related painters	0	2				2		
7233	Agricultural- or industrial-machinery mechanics and fitters	0	11			7	1		3

isco88	ISCO STANDARD DESCRIPTION	ASTHMA - JEM score	Resticted dataset (i.e. only measurements with sampling duration between 240-600 min are inlc.)						
			n						
			Overall	Skandinavia (DK+NO)	Netherlands	Finland	UK	Germany	France
7241	Electrical mechanics and fitters	0							
7312	Musical instrument makers and tuners	1	2						2
7420	Wood treaters, cabinet-makers and related trades workers	2	217	56		22	4	7	128
7421	Wood treaters	1	27			2	21		4
7422	Cabinet makers and related workers	2	69	59		1	1	8	
7423	Woodworking machine setters and setter-operators	2	172	42		7	30	1	92
7424	Basketry weavers, brush makers and related workers	0	3				3		
7437	Upholsterers and related workers	0							
8141	Wood-processing-plant operators	2	1541	12		341	134	6	1048
8142	Paper-pulp plant operators	0	25			18			7
8143	Papermaking-plant operators	0	4						4
8161	Power-production plant operators	0	1			1			
8172	Industrial-robot operators	0							
8240	Wood-products machine operators	2	2978	1705	261	60	69	1	882
8285	Wood and related products assemblers	1	1037	883	70	15	14		55
8324	Heavy truck and lorry drivers	0	142	140		2			
8334	Lifting-truck operators	0	21			1	1	19	
9141	Building caretakers	0	123						123
9161	Garbage collectors	0	2						2
9212	Forestry labourers	1	14						14
9313	Building construction labourers	1	67						67

It is evident from the above that there is a considerable loss of power across many of the ISCOs with available measurements particularly in relation to the German and French datasets. The number of exposed ISCO codes with no measurements increases to 6 out of 18 available.

A descriptive summary of the measurement results across countries in the final and restricted dataset is provided in tables 3.13 and 3.14 below.

Table 3.13 Distribution characteristics of wood dust levels across countries in the final dataset.

Obs	country	n	AM	STD	GM	GSD	min	max	p5	p95
1	1. Denmark	3719	1.27	2.53	0.88	2.16	0.03	95.68	0.28	3.12
2	2. Norway	39	13.51	23.23	4.51	4.42	0.38	84.29	0.38	80.64
3	3. The Netherlands	342	3.58	3.72	2.54	2.23	0.24	30.15	0.74	10.47
4	4. Finland	642	2.84	6.71	1.48	2.92	0.01	132.16	0.30	8.30
5	5. Great Britain	499	6.02	12.21	2.46	3.74	0.01	118.32	0.29	22.57
6	6. Germany	8068	4.27	6.84	2.16	3.60	0.01	110.69	0.30	14.06
7	7. France	7412	9.81	43.33	3.23	3.68	0.01	1840.76	0.50	30.24

Table3.14 Distribution characteristics of wood dust levels across countries in the restricted (i.e. only measurements with a duration between 240 and 600 min are incl.) dataset.

Obs	country	n	AM	STD	GM	GSD	min	max	p5	p95
1	1. Denmark	3008	1.26	2.75	0.86	2.13	0.03	95.68	0.30	3.00
2	2. Norway	34	11.93	21.64	4.24	4.02	0.38	84.29	0.38	72.19
3	3. The Netherlands	338	3.53	3.66	2.52	2.22	0.24	30.15	0.71	10.47
4	4. Finland	506	2.71	6.95	1.42	2.89	0.01	132.16	0.30	8.30
5	5. Great Britain	324	5.03	10.48	2.38	3.14	0.14	118.32	0.37	16.39
6	6. Germany	179	6.28	8.34	3.51	3.04	0.05	48.47	0.62	22.42
7	7. France	2841	4.78	15.90	1.95	3.26	0.01	592.88	0.35	15.03

Comment: From these tables it can be seen that the exclusion of the short duration measurements have only small downward effects on the level of wood dust for most of the included datasets. For the French data the decline is somewhat much higher than observed for other countries. There could be several reasons behind this trend. For example short-term measurements can be of worst case nature, collected in earlier periods than the long-term ones, or amid a task based approach they are more likely to not include unexposed persons. In contrast to the observed effects for other countries, the exclusion of short duration German measurements results in increase in the average country levels; the GM values for the 197 measurements that remained following the exclusion is higher (3,52 vs 2,16) than the estimated value for all the measurements included. This is a rather unexpected finding as one would expect concentrations to reduce with the exclusion of the short term measurements.

From the available descriptions accompanying the dataset (WOODEX national report for Germany) it is known that Germans sampled where "high concentrations of wood dust gave rise to the improvement or the installation of an exhaust ventilation system. Afterwards wood dust concentrations were measured again. This is why the measurement results are not representative. Measurements were done wherever inspectors expected high concentrations or to prove the result of a technical measure (improvement of the exhaust ventilation)". This indicates some form of a non-random and unspecified intervention. However, the exact size of the issue is not known nor is the exact reason and sampling strategy followed for each of the measurements and hence it is difficult to say something more about these differences.

To examine further the influence of the "intervention" like sampling strategy we looked at the distribution of the ventilation parameters within the German dataset across measurements with (Table 3.15) and without (Table 3.16) a sampling time > 240 min in order to provide us with some clues in relation to the applied sampling strategies and the results observed when short term data are excluded from the sample.

Table3.15 Ventilation characteristics in measurements with duration above 240 min.

luftfhrung (air ducting)	absaugart (Suction type)	n	%
0 (likely means none)	0 (likely means none)	1	1.15
0 (likely means none)	1 = ohne Absaugung (without suction)	1	1.15
1 = keine Luftrückführung (no air recirculation)	0 (likely means none)	12	13.79
1 = keine Luftrückführung (no air recirculation)	1 = ohne Absaugung (without suction)	20	22.99
1 = keine Luftrückführung (no air recirculation)	2 = mit Fänger (with catcher)	37	42.53
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	2 = mit Fänger (with catcher)	2	2.3
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	0 (likely means none)	3	3.45
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	1 = ohne Absaugung (without suction)	8	9.2
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	2 = mit Fänger (with catcher)	3	3.45
Frequency Missing = 92			

From the 92 measurements with missing info on ventilation 74 are carpenters in various industries but with unknown or no specialised tasks (not shown for brevity and need for translations). The missing information is expected to relate to either a mixture of situations or (amid also the inconsistency in the reporting) absence of a ventilation.

Table 3.16 Ventilation characteristics in measurements with a duration below 240 min.

luftfhrung (air ducting)	absaugart (Suction type)	n	%
0 (likely means none)	0 (likely means none)	21	0.28
0 (likely means none)	1 = ohne Absaugung (without suction)	114	1.54
0 (likely means none)	2 = mit Fänger (with catcher)	96	1.3
0 (likely means none)	3 = Saugwand, -tisch (suction wall, table)	4	0.05
0 (likely means none)	5 = Kapsel (capsule)	9	0.12
1 = keine Luftrückführung (no air recirculation)	0 (likely means none)	59	0.8
1 = keine Luftrückführung (no air recirculation)	1 = ohne Absaugung (without suction)	993	13.43
1 = keine Luftrückführung (no air recirculation)	2 = mit Fänger (with catcher)	4182	56.56
1 = keine Luftrückführung (no air recirculation)	3 = Saugwand, -tisch (suction wall, table)	59	0.8
1 = keine Luftrückführung (no air recirculation)	5 = Kapsel	276	3.73
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	0 (likely means none)	1	0.01
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	1 = ohne Absaugung (without suction)	8	0.11
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	2 = mit Fänger (with catcher)	176	2.38
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	3 = Saugwand, -tisch (suction wall, table)	22	0.3
2 = mit Luftrückführung und Filter am Arbeitsplatz (with air return and filter at the workplace)	5 = Kapsel (capsule)	7	0.09
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	0 (likely means none)	12	0.16
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	1 = ohne Absaugung (without suction)	101	1.37
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	2 = mit Fänger (with catcher)	1074	14.53
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	3 = Saugwand, -tisch (suction wall, table)	28	0.38

luftfhrung (air ducting)	absaugart (Suction type)	n	%
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	4 = Naßbearbeitung (Wet processing)	1	0.01
3 = mit Luftrückführung durch Großanlage (with air return through large plant)	5 = Kapsel (capsule)	147	1.99
5 (label not provided)	2 = mit Fänger (with catcher)	3	0.04
5 (label not provided)	3 = Saugwand, -tisch (suction wall, table)	1	0.01
Frequency Missing = 495			

Similarly with the above, from the 495 measurements with missing info on ventilation 407 are carpenters in various industries but with unknown or no specialised tasks (not shown). Again it is presumed that the missing information relates to either a mixture of situations or (amid also the inconsistency in the reporting) absence of a ventilation.

When looking at the distribution of ventilation/LEV characteristics across the two strata (i.e. below and above 240 min measurements) then you can see than in most cases there is some type of LEV for measurements below 240 min. On the contrary most of the measurements with duration >240 min have either no info on LEV or they don't refer to the presence of one. Considering that the vast majority of the cases with missing info (in both strata) are "Schreiners" (i.e. carpenters and trainees) with no specialised tasks one can presume that the information is missing either because LEV characteristics do not apply or because they are exposed to a mixture of conditions. It must be stated that carpenters work across a range of different industries though among the >240 min measurements mostly in "SCHREINEREIs". Therefore these findings could indicate ventilation to, at least partly, be an explanation for the unexpected trend with sampling time in the German data.

A comparison of the results from the models using the final (hereafter called the full model) and the restricted dataset (hereafter called the restricted model) is provided in the table 3.17 below. It can be seen that the estimated annual reduction in exposure levels based on the restricted model is somewhat larger than the one sourcing from the full model utilising the final dataset. Asthma-JEM seems to have a small and non-significant role in both models

Table 3.17 Linear mixed effect results describing the relationships between log-transformed wood dust levels and fixed effects in the model with the final (n=20721;all measurements included, sampling duration 60-600min) and the restricted (i.e. only measurements with sampling time 240 - 600 min included) datasets respectively. Data from all countries are included.

Parameter	Model with full data			Model with restricted data		
	b	e	p	b	e	p
intercept	1.6753	0.104	<.0001	1.1024	0.129	<.0001
Year (ref 94)	-0.05928	0.0022	<.0001	-0.0802	0.003	<.0001
Sampling time, min	-0.0019	0.0001	<.0001	-0.0005	0.0002	0.003
Country						
DK+NO	-0.9873	0.029	<.0001	-0.7306	0.031	<.0001
NL	-0.0867	0.071	0.2	-0.1839	0.063	0.003
FI	-0.1577	0.050	0.002	0.0422	0.047	0.4
UK	0.0942	0.054	0.08	0.3966	0.056	<.0001
DE	-0.8592	0.028	<.0001	0.2956	0.080	0.0002
FR	Ref	.	.	Ref	.	.
Asthma-JEM score						
No exposure	-0.0466	0.131	0.7	-0.0727	0.156	0.6
Low exposure	-0.0113	0.138	0.9	0.0138	0.16	0.9
High exposure	Ref			Ref		
Between ISCO variance (naïve estimates)	0.049 (0.22)	0.020		0.063 (0.27)	0.030	0.02
Within ISCO variance (naïve estimates)	1.31 (1.56)	0.013		0.83 (1.08)	0.014	<.0001

In the following a comparison between the estimated BLUPs from the two models is graphically made both for the general (Figure 3.18) and the country-specific (Figure 3.19) estimates.

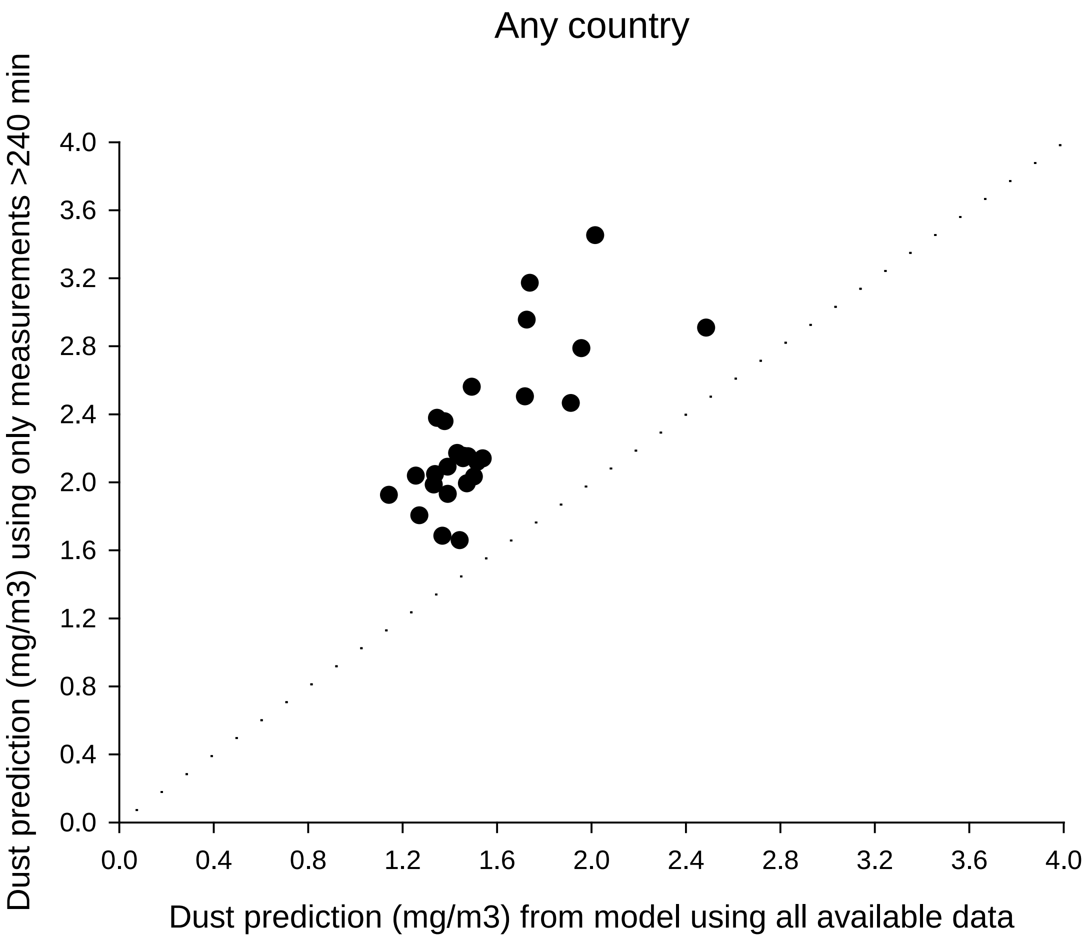


Figure 3.18 Agreement between the non-country specific BLUPs from the restricted and full models. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

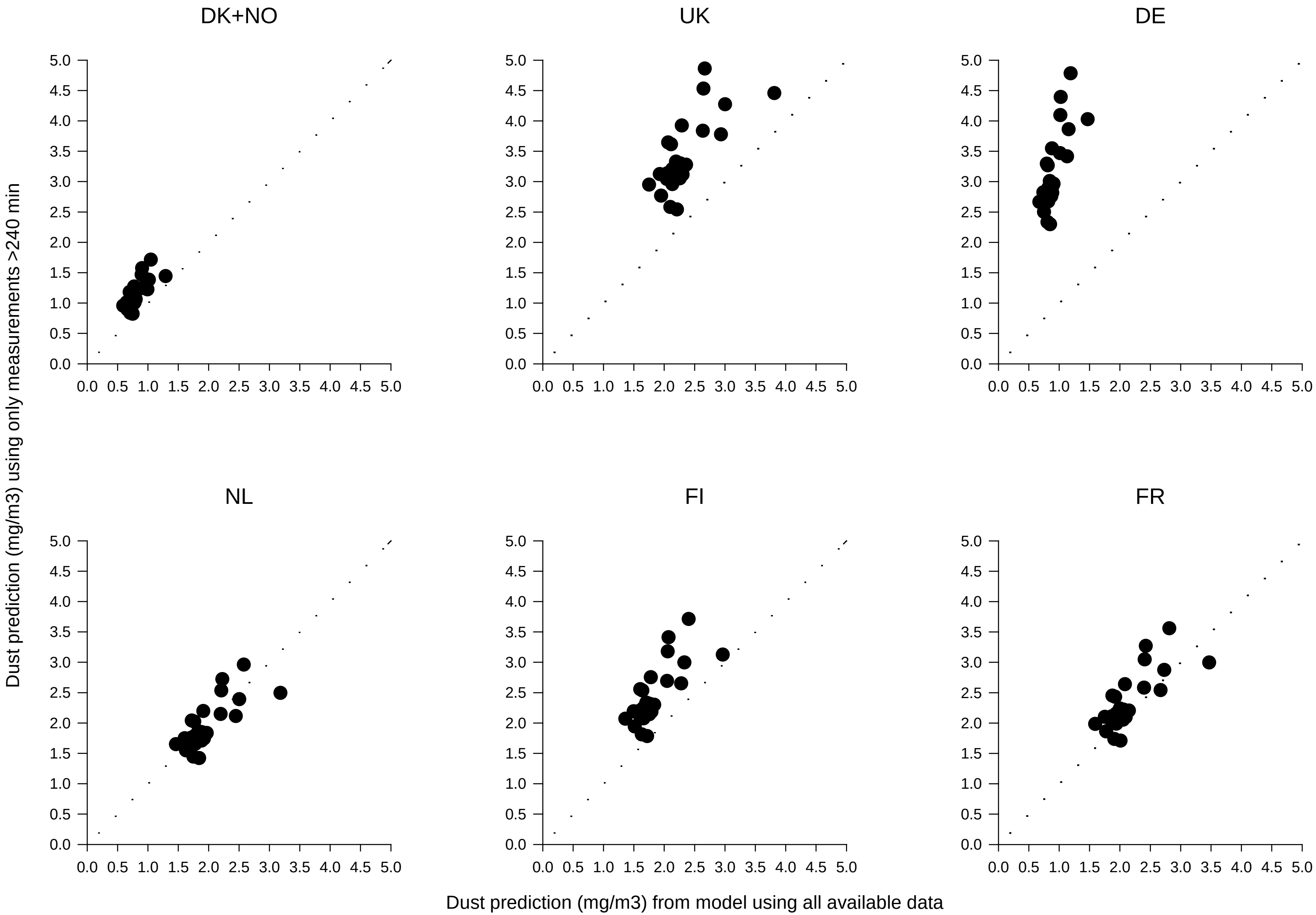


Figure 3.19 Agreement between the country-specific BLUP estimates from the restricted and full models. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

Comment: The above plots clearly indicate that with the exception of the Dutch and (partly) French datasets the predicted exposure estimates by the restricted model are generally higher than those from the full model even though the overall levels of exposure are reduced by the removal. The difference is particularly pronounced for the German data, a finding which is generally not unexpected based on the removal of 97% of the available measurements. Clearly though there are differences in the estimated BLUPs of rather a systematic nature (i.e. – BLUPs from the model using the full dataset are systematically higher than those from the restricted model). This finding, given the results presented in Tables 3.13 and 3.14, is rather difficult to be explained. It could, at least partly, reflect to the intervention nature of the German data, the removal of many "unexposed" (e.g. teachers) measurements especially from Finland and France, and/or a reduced influence of <LOD levels on the results (~70% of such measurements is also removed by the applied restriction). An in depth investigation is likely not possible because of lack of in-depth contextual information on the data. Another question that rises though from these findings is whether the correction by putting sampling time into the model results in an unbiased estimate for the German jobs and how the German data influence the overall and specific estimates for other countries given that they are short-term duration measurements.

3.3.3.1 Repeating the analysis after removing all available German measurements

To assess dependency of the BLUPs on the German measurements and their short sampling duration we have repeated the models (full and restricted ones) after removing all German measurements. The results of these analyses are shown in table 3.20 that follows.

Table 3.20 Linear mixed effect results describing the relationships between log-transformed wood dust levels and fixed effects in the model with the full and the restricted (i.e. only measurements with sampling time >240 min) datasets respectively following exclusion of all German measurements from the analysis.

Parameter	Model with full data			Model with restricted data		
	b	e	p	b	e	p
intercept	1.7129	0.101	<.0001	1.1109	0.122	<.0001
Year (ref 94)	-0.0807	0.002	<.0001	-0.0799	0.003	<.0001
Sampling time, min	-0.0019	0.0001	<.0001	-0.0005	0.0002	0.002
Country						
DK+NO	-0.9121	0.027	<.0001	-0.731	0.031	<.0001
NL	-0.129	0.065	0.05	-0.1788	0.06	0.004
FI	-0.0311	0.045	0.5	0.0393	0.047	0.4
UK	0.1895	0.049	0.0001	0.3941	0.056	<.0001
FR	Ref	.	.	Ref	.	.
Asthma-JEM score						
No exposure	-0.0329	0.133	0.8	-0.1083	0.150	0.5
Low exposure	0.0369	0.134	0.8	0.0179	0.150	0.9
High exposure	Ref			Ref		
Between ISCO variance (naïve estimates)	0.045 (0.34)	0.019		0.054 (0.23)	0.026	0.02
Within ISCO variance (naïve estimates)	1.05 (1.49)	0.013		0.82 (1.06)	0.014	<.0001

Comment: When comparing those findings with the results from the analysis with the German data (Table 3.17) it can be seen that the German data do not confound the effect of sampling duration on exposure. However, the presence of the German data seem to somewhat impact on the effect size of the estimated annual decline in exposure which could though at least partly reflect to the removal of a large part of measurements below LOD levels. A more straightforward comparison can be shown in Table 3.21 where the full models with and without the German data are summarised side by side. From these comparisons it can be seen that there are differences in between the two models regarding the country specific effects of Finland, UK which though confounded remain on the same direction and the within ISCO code variance which generally reduces but only when fixed effects are taken into account.

Table3.21 Linear mixed effect results describing the relationships between log-transformed wood dust levels and fixed effects in the model with the full data and the one without the German data respectively. Measurements with a sampling duration between 60-600 min are used

Parameter	Model with final data (full model)			Model without German data		
	b	e	p	b	e	p
intercept	1.6753	0.104	<.0001	1.713	0.1013	<.0001
Year (ref 94)	**-0.0593**	0.0022	<.0001	**-0.0807**	0.0023	<.0001
Sampling time, min	-0.0019	0.0001	<.0001	-0.0019	0.0001	<.0001
Country						
DK+NO	-0.9873	0.029	<.0001	-0.912	0.0271	<.0001
NL	-0.0867	0.071	0.2	-0.129	0.0645	0.05
FI	**-0.1577**	0.050	0.002	**-0.0311**	0.0453	0.5
UK	0.0942	0.054	0.08	0.190	0.049	0.0001
DE	-0.8592	0.028	<.0001			
FR	Ref	.	.	Ref	.	.
Asthma-JEM score						
No exposure	-0.0466	0.131	0.7	-0.0329	0.133	0.8
Low exposure	-0.0113	0.138	0.9	0.0369	0.134	0.8
High exposure	Ref			Ref		
Between ISCO variance (naïve estimates)	0.049 (0.22)	0.020		0.05 (0.34)	0.018	0.01
Within ISCO variance (naïve estimates)	**1.31** (1.56)	0.013		**1.05** (1.49)	0.013	<.0001

A comparison of the predicted values from the full models with and without the German data is shown in figures 3.22 and 3.23 that they follow.

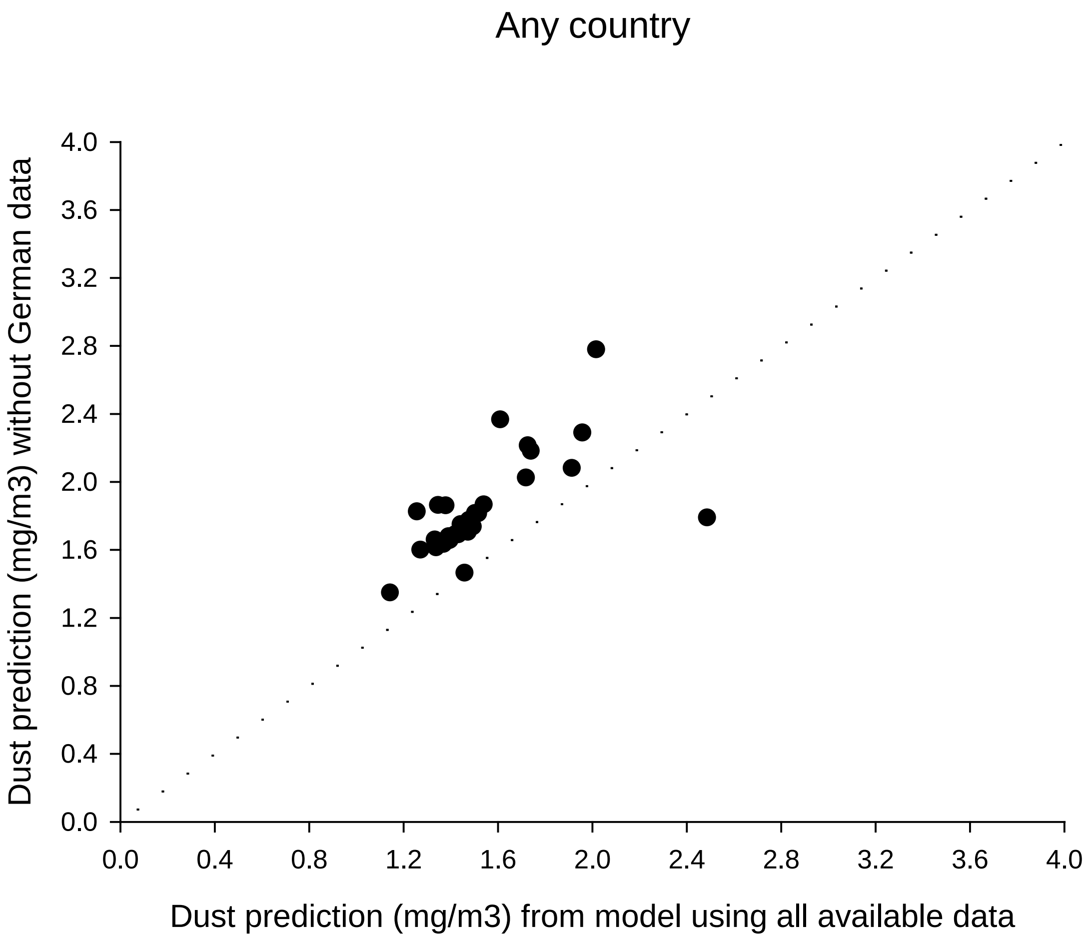


Figure 3.22 Agreement between the non-country specific BLUPs from the model with (full) and without the German data for the reference year (1994). Measurements with a sampling duration between 60-600 min are used. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown

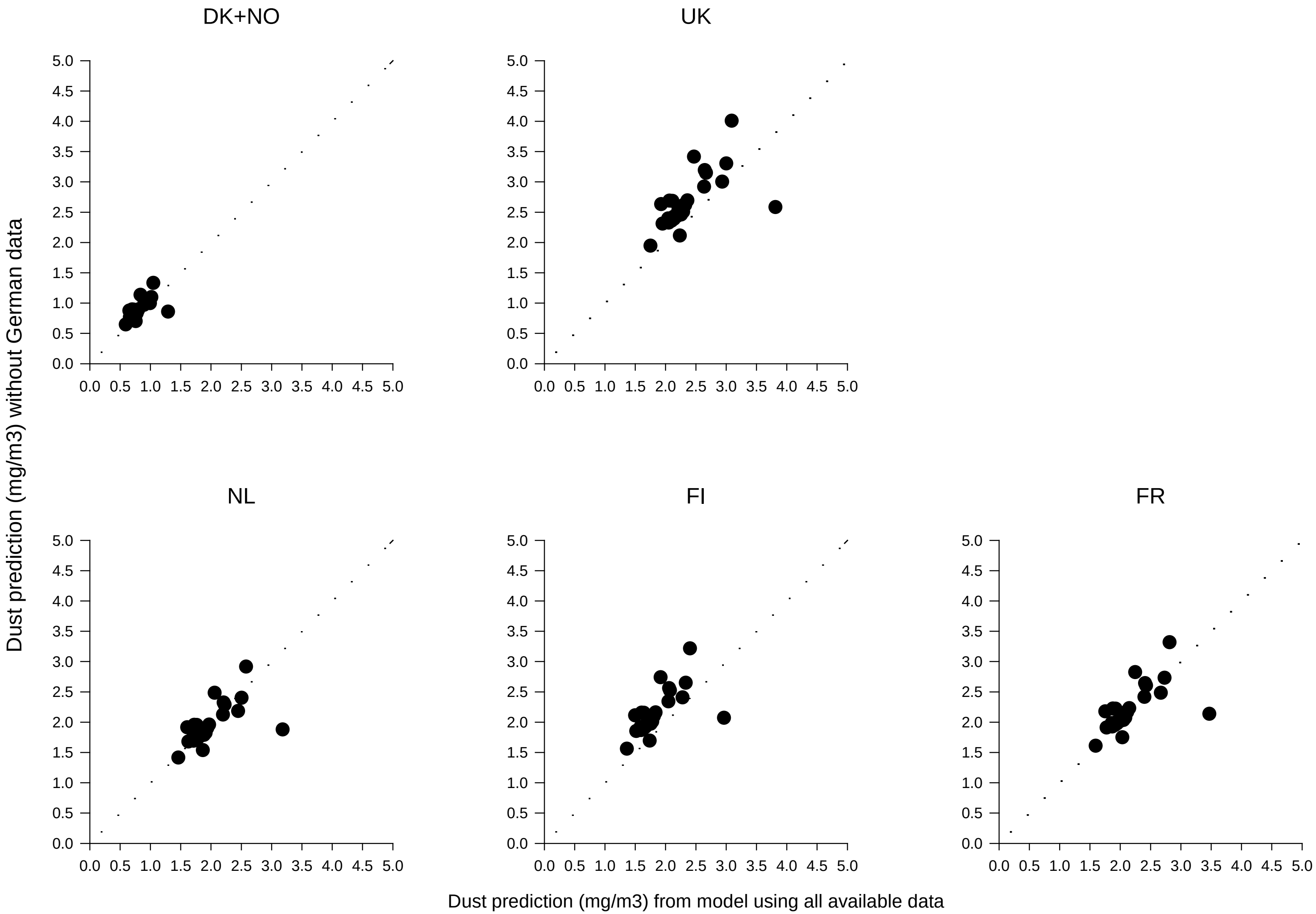


Figure 3.23 Agreement between the country-specific BLUP estimates from the models with (full model) and without the German data for the ref year (1994). Measurements with a sampling duration between 60-600 min are used. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

From the above plots it is evident that exclusion of the German data does not affect the majority exposure estimates for the remaining countries. The non-country specific estimates for the BLUPs for the ref year though seem to be slightly higher whereas the estimated annual decline in exposure levels is also somewhat increased.

3.3.3.2 Examining the German data and their quality in greater detail.

To further explore on the issue we have also run models with the German data alone. The results of those models are summarised in the SAS outputs that follow.

SAS output summarising the results of the model using only the German data (measurements with duration between 60-600min are used)

The SAS System

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD2
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	17	5220 7124 7132 7142 7233 7241 7312 7420 7422 7423 7424 7437 8141 8240 8285 8334 9313
country1	1	6
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	6
Columns in Z	17
Subjects	1
Max Obs per Subject	8068

Number of Observations	
Number of Observations Read	8068
Number of Observations Used	8068
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.03972	0.03414	1.16	0.1223
Residual	1.6275	0.02566	63.44	<.0001

Fit Statistics	
-2 Res Log Likelihood	26871.9
AIC (Smaller is Better)	26875.9
AICC (Smaller is Better)	26875.9
BIC (Smaller is Better)	26877.5

Solution for Fixed Effects									
Effect	**Asthma JEM score***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept		0.5768	0.1056	14	5.46	<.0001	0.05	0.3504	0.8032
year94		0.01684	0.005138	8049	3.28	0.0011	0.05	0.006765	0.02691
meastime		0.001257	0.000378	8049	3.33	0.0009	0.05	0.000517	0.001997
wooddusts	**0**	0.04346	0.1673	8049	0.26	0.7950	0.05	-0.2845	0.3714
wooddusts	**1**	0.07727	0.1774	8049	0.44	0.6631	0.05	-0.2705	0.4250
wooddusts	**2**	0	.	.	.	.	.	.	.

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Comment: Results based on the German data apparently differ from those based on other data sources. For example the exposure levels appear to increase over the years rather than decreasing as was shown for the overall and including only data from other countries. In addition measurement duration has also a positive effect on the measurement results which is rather unexpected. To further examine the reasons behind these results sensitivity analysis was performed including models without the 249 measurements <LOD and with restrictions on the year 1992 as done in WOODEX.

SAS output summarising the results of the model using only the German data but excluding the 249 measurements <LOD

The SAS System

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD2
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	17	5220 7124 7132 7142 7233 7241 7312 7420 7422 7423 7424 7437 8141 8240 8285 8334 9313
country1	1	6
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	6
Columns in Z	17
Subjects	1
Max Obs per Subject	7819

Number of Observations	
Number of Observations Read	7819
Number of Observations Used	7819
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.01396	0.01160	1.20	0.1143
Residual	1.0710	0.01714	62.47	<.0001

Fit Statistics	
-2 Res Log Likelihood	22770.1
AIC (Smaller is Better)	22774.1
AICC (Smaller is Better)	22774.1
BIC (Smaller is Better)	22775.7

Solution for Fixed Effects									
Effect	**Asthma JEM score***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept		0.7352	0.07009	14	10.49	<.0001	0.05	0.5848	0.8855
year94		-0.00804	0.004225	7800	-1.90	0.0572	0.05	-0.01632	0.000246
meastime		0.000872	0.000307	7800	2.84	0.0045	0.05	0.000271	0.001474
wooddusts	**0**	0.09527	0.1164	7800	0.82	0.4130	0.05	-0.1328	0.3234
wooddusts	**1**	0.03460	0.1123	7800	0.31	0.7579	0.05	-0.1855	0.2547
wooddusts	**2**	0	.	.	.	.	.	.	.

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Comment: Eventually the measurements <LOD have a considerable impact on the estimated levels of annual trends in the German data.

SAS output summarising the results of the model using only the German data but excluding all measurements performed before 1993

The SAS System

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD2
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	13	5220 7124 7142 7233 7312 7420 7422 7423 7424 8141 8240 8334 9313
country1	1	6
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	6
Columns in Z	13
Subjects	1
Max Obs per Subject	2804

Number of Observations	
Number of Observations Read	2804
Number of Observations Used	2804
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.01707	0.01593	1.07	0.1420
Residual	1.2209	0.03267	37.37	<.0001

Fit Statistics	
-2 Res Log Likelihood	8551.1
AIC (Smaller is Better)	8555.1
AICC (Smaller is Better)	8555.1
BIC (Smaller is Better)	8556.2

Solution for Fixed Effects									
Effect	Asthma JEM score *	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept		0.7849	0.08424	10	9.32	<.0001	0.05	0.5972	0.9726
year94		-0.1070	0.01442	2789	-7.42	<.0001	0.05	-0.1352	-0.07869
meastime		0.001201	0.000351	2789	3.42	0.0006	0.05	0.000513	0.001889
wooddusts	0	0.09903	0.1575	2789	0.63	0.5294	0.05	-0.2097	0.4078
wooddusts	1	0.04119	0.1395	2789	0.30	0.7678	0.05	-0.2324	0.3148
wooddusts	2	0	.	.	.	.	.	.	.

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Comment: Surprisingly when deleting all pre-1993 measurements from the German dataset then the time trend seems to be closer to the one expected based on the literature and the data from other countries. However this is not accompanied by a similar change in the effect of sampling time which retains its positive effect.

SAS output summarising the results of the model using only the German data but excluding all measurements below 240 min

The SAS System

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD2
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	7	7124 7420 7422 7423 8141 8240 8334
country1	1	6
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	6
Columns in Z	7
Subjects	1
Max Obs per Subject	179

Number of Observations	
Number of Observations Read	179
Number of Observations Used	179

Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
ISCO882	0.9980	1.0231	0.98	0.1646
Residual	1.0699	0.1161	9.22	<.0001

Fit Statistics	
-2 Res Log Likelihood	538.7
AIC (Smaller is Better)	542.7
AICC (Smaller is Better)	542.8
BIC (Smaller is Better)	542.6

Solution for Fixed Effects									
Effect	Asthma JEM score*	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept		0.8541	1.2344	4	0.69	0.5270	0.05	-2.5731	4.2813
year94		-0.2643	0.08093	170	-3.27	0.0013	0.05	-0.4241	-0.1046
meastime		0.001597	0.003250	170	0.49	0.6238	0.05	-0.00482	0.008013
wooddusts	0	0.1833	1.1579	170	0.16	0.8744	0.05	-2.1025	2.4690
wooddusts	1	-0.00753	1.1355	170	-0.01	0.9947	0.05	-2.2490	2.2339
wooddusts	2	0	.	.	.	.	.	.	.

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Comment: When all German measurements below <240 min are excluded from the analysis for the specific country then a stronger annual reduction is estimated, based though on only a limited number of measurements.

3.3.3.3 Conclusions of the sensitivity analysis described above.

In general, the above show that results are sensitive to the inclusion of all or part of the German data into the analysis. It is not entirely clear what caused the unexpected patterns in findings within the German dataset but these could relate to the overall sampling strategy and the fact that they come from an "intervention" type of study. Based on these findings and= the lack of info on exposure affecting factors to account on the analysis it was decided to exclude all German data from the analysis and JEM development. Further detail in the dataset remaining following the exclusion of the German data and its analysis will be provided in the sections that follow.

3.4 DESCRIPTION OF THE (FINAL) DATASET AFTER EXCLUDING THE GERMAN DATASET.

Following the exclusion of the German data there are 12653 measurements that remain and used in the analysis. The basic characteristics of these measurements are summarised below.

3.4.1 Basic characteristics including distribution of measurements per country, dataset, type of sampler and measurement period.

Table 3.24 Distribution of measurements by dataset of origin in the (final) dataset without the German data (n=12653)

File (data source)	n	%	Cumulative frequency
DK-N-NL - retro_exp_5-tablecorr	4100	32.40	4100
Finland - FIN WOODEX FURNITURE- Table	50	0.40	4150
Finland - FIN wood dust measurements 2001-2003_2-table	102	0.81	4252
Finland - FIN_WOODEX BOARD MILLS - NTA	35	0.28	4287
Finland - FIN_WOODEX SAWMILLS AND PLANING MILLS-table	75	0.59	4362
Finland - FIN_WOODEX_WOOD PRODUCTS-table	61	0.48	4423
Finland - Wood dust measurements_FIOH_2001-2007_processed	319	2.52	4742
Frankrig - FRDATAorigs	7412	58.58	12154
GB - HSE 2000 wood dust survey data for sharing-NTA-22.05.2015	356	2.81	12510
GB - IOM wood dust data for Ioannis - NTA coded	143	1.13	12653

Table 3.25 Distribution of measurements by country of origin in the (final) dataset without the German data (n=12653).

country	n	%
1. Denmark	3719	29.39
2. Norway	39	0.31
3. The Netherlands	342	2.70
4. Finland	642	5.07
5. Great Britain	499	3.94
7. France	7412	58.58
Total	12653	100

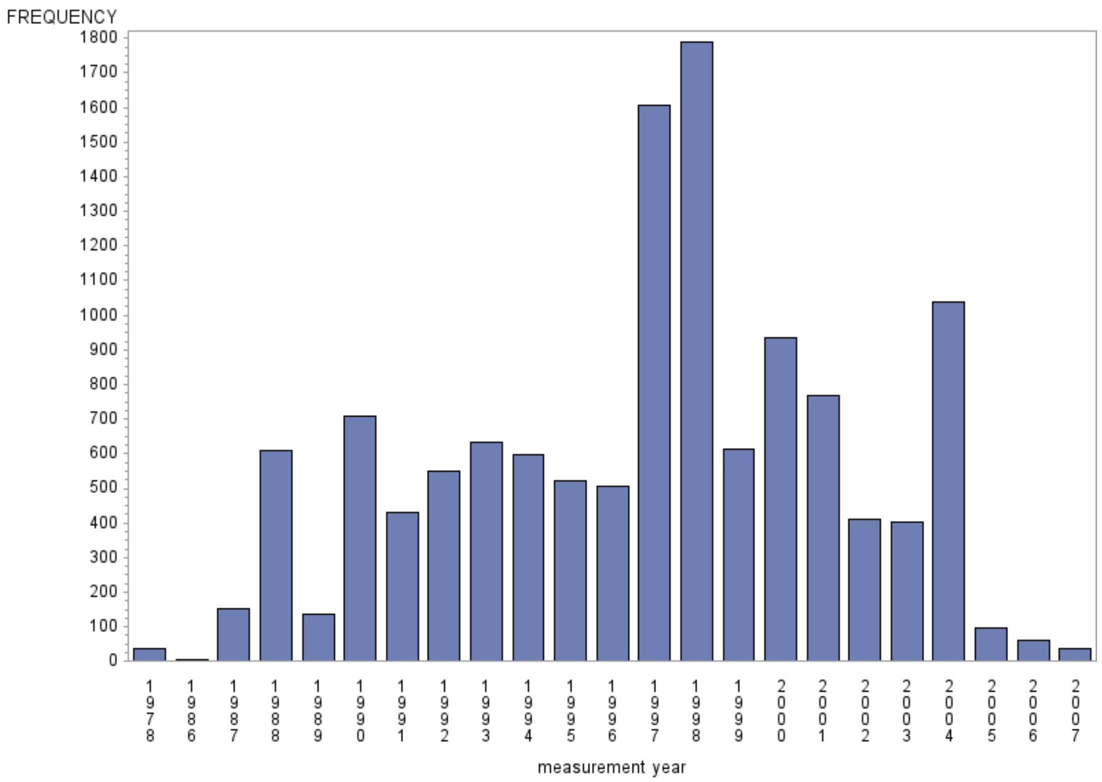


Figure 3.26 Distribution of measurements in the (final) dataset excluding German measurements across years (n=12653).

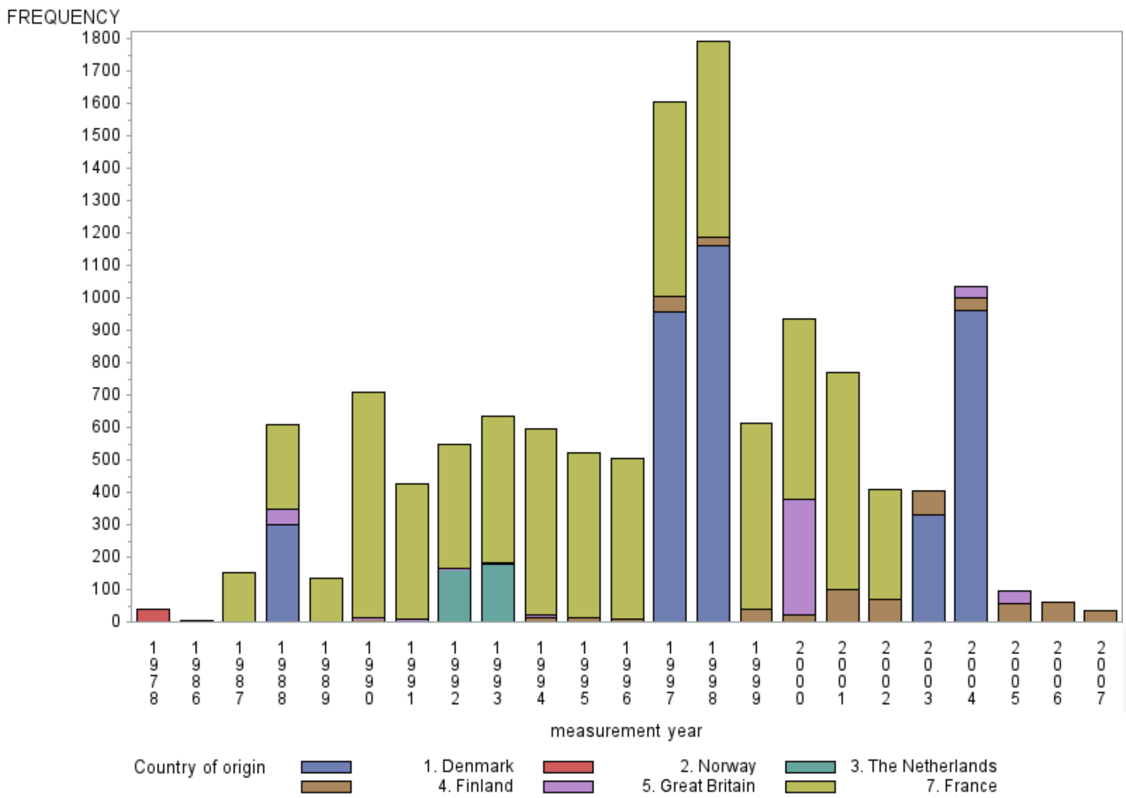


Figure 3.27 Distribution of measurements in the (final) dataset excluding German measurements across years and countries (n=12653).

Table 3.28 Distribution of measurements by sampler type in the (final) dataset without the German data (n=12653).

samplertype	n	%
37mm CFC with 4mm hole	7412	58.58
37mm OFC	129	1.02
7 hole sampler	136	1.07
IOM sampler	1218	9.63
millipore casette	340	2.69
passive dust	3418	27.01

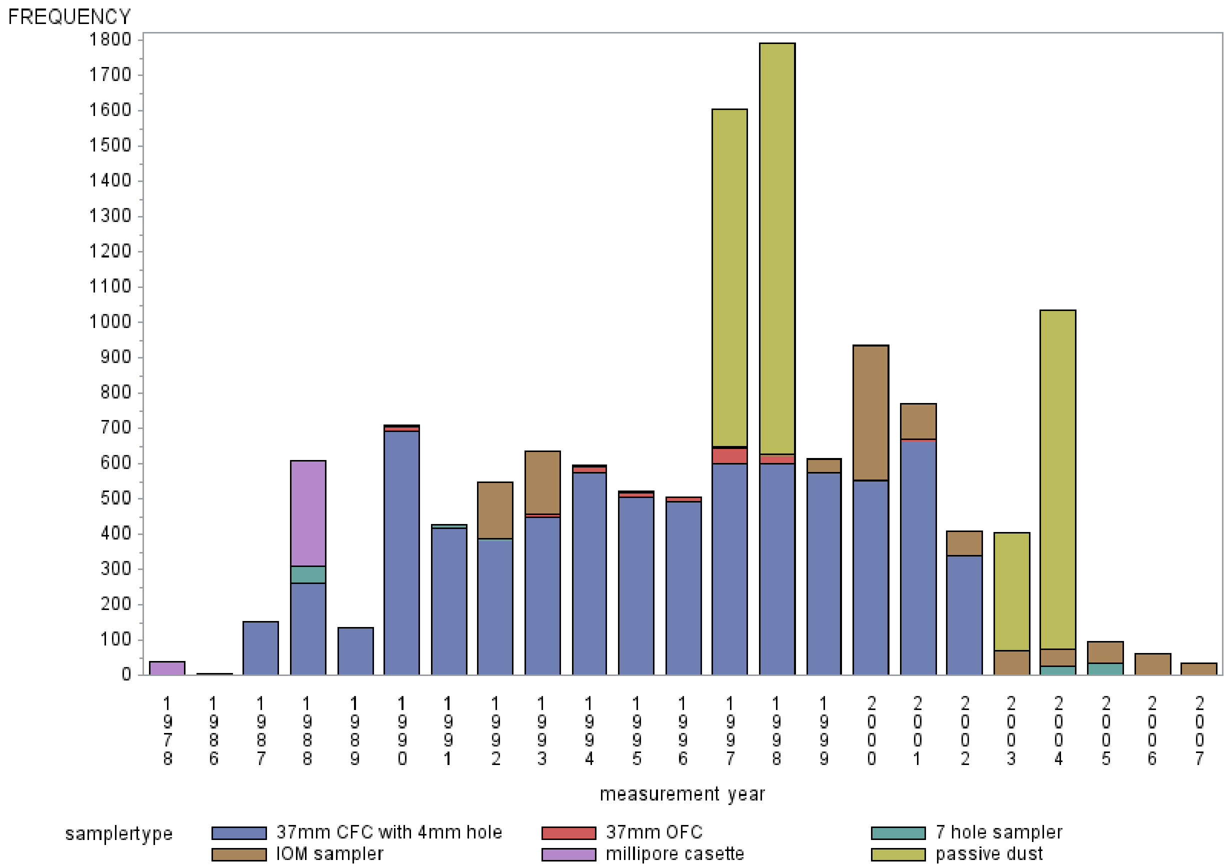


Figure 3.29 Distribution of measurements in the (final) dataset excluding German measurements across years and samplers (n=12653).

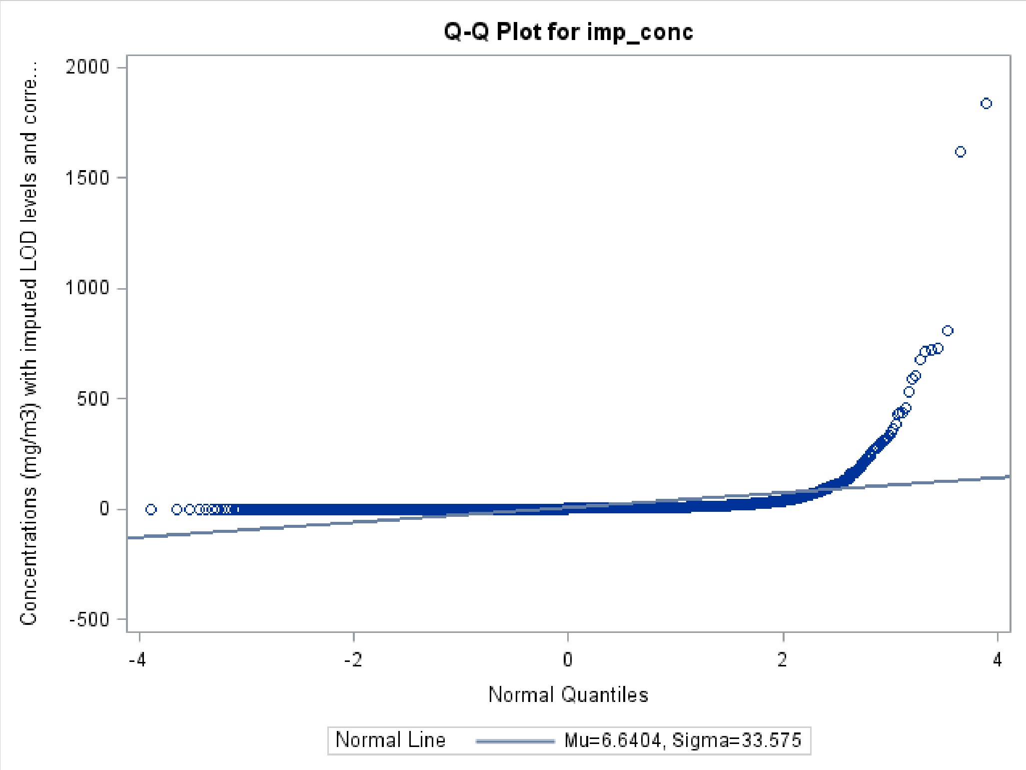


Figure 3.30 Testing for a normal distribution on the (final) dataset excluding German measurements (n=12653)

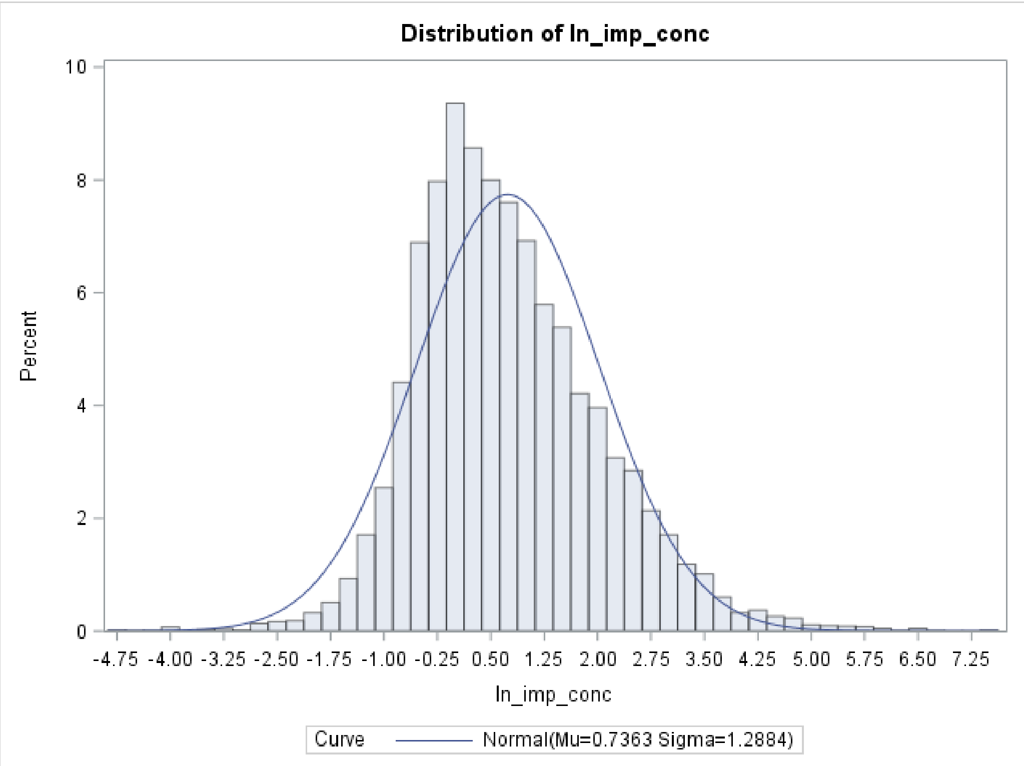


Figure 3.31 Fitting a log-normal distribution on the (final) dataset excluding German measurements (n=12653)

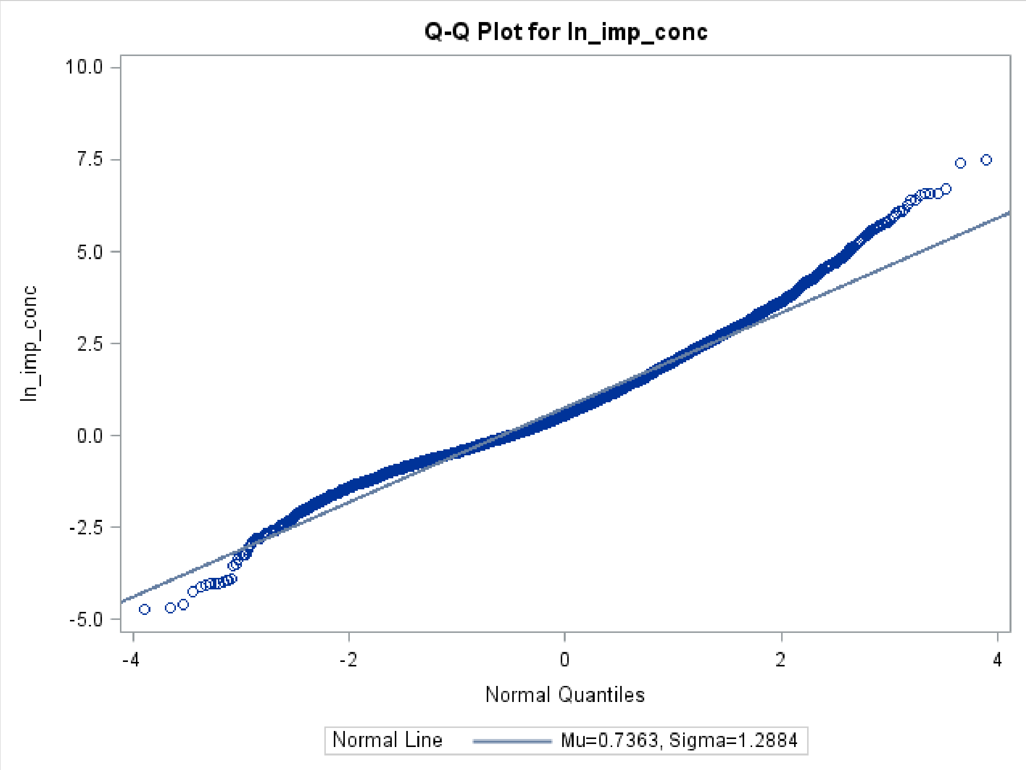


Figure 3.32 Testing a log-normal distribution on the (final) dataset excluding German measurements (n=12653)

Table 3.33 Distribution of measurements across Asthma-JEM scores in the (final) dataset following the exclusion of all German data (n=12653).

Asthma JEM score	n	%
0=no exposure	735	5.81
1=low exposure	2800	22.13
2=high exposure	9118	72.06

Table 3.34 Distribution of measurements across ISCO88 codes for units and assigned Asthma-JEM score in the (final) dataset following the exclusion of all German data (n=12653).

ISCO88	ISCO STANDARD DESCRIPTION	Asthma_JEM score	n	%
110	Armed forces	0	1	0.01
2310	College, university and higher education teaching professionals	0	3	0.02
2320	Secondary education teaching professionals	0	9	0.07
2331	Primary education teaching professionals	0	78	0.62
2359	Other teaching professionals not elsewhere classified	0	1	0.01
5220	Shop salespersons and demonstrators	0	88	0.70
7124	Carpenters and joiners	1	1056	8.35
7129	Building frame and related trades workers not elsewhere classified	1	20	0.16
7131	Roofers	1	196	1.55
7132	Floor layers and tile setters	1	8	0.06

ISCO88	ISCO STANDARD DESCRIPTION	Asthma_JEM score	n	%
7142	Varnishers and related painters	0	2	0.02
7233	Agricultural- or industrial-machinery mechanics and fitters	0	13	0.10
7312	Musical instrument makers and tuners	1	3	0.02
7420	Wood treaters, cabinet-makers and related trades workers	2	455	3.60
7421	Wood treaters	1	35	0.28
7422	Cabinet makers and related workers	2	100	0.79
7423	Woodworking machine setters and setter-operators	2	254	2.01
7424	Basketry weavers, brush makers and related workers	0	3	0.02
8141	Wood-processing-plant operators	2	2948	23.30
8142	Paper-pulp plant operators	0	45	0.36
8143	Papermaking-plant operators	0	4	0.03
8161	Power-production plant operators	0	1	0.01
8172	Industrial-robot operators	0	1	0.01
8240	Wood-products machine operators	2	5361	42.37
8285	Wood and related products assemblers	1	1334	10.54
8324	Heavy truck and lorry drivers	0	162	1.28
8334	Lifting-truck operators	0	3	0.02
9141	Building caretakers	0	312	2.47
9161	Garbage collectors	0	9	0.07
9212	Forestry labourers	1	14	0.11
9313	Building construction labourers	1	134	1.06

Table 3.35 Distribution of measurements based on the underlying sampling reason in the (final) dataset following the exclusion of all German data (n=12653).

reason1	n	%	Cumulative Frequency
0=inspection	160	1.26	160
1=unknown	7759	61.32	7919
2=survey	4734	37.41	12653

Table 3.36 Distribution of measurements based on the underlying sampling strategy in the (final) dataset following the exclusion of all German data (n=12653).

strategy1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0=representative	12471	98.56	12471	98.56
1= not representative	182	1.44	12653	100.00

Comment: Evidently little can be done with the categorisation of strategy in this stage. Only measurements from the UK (n=143) and Norway (n=39) could be identified as not-representative (i.e. WC) with coverage of ISCO codes being rather small (e.g. Norwegian codes cover only 2 ISCOs). However, it is unlikely that these are the only WC and compliance measurements in the dataset. Such measurements should be present also in Finnish and GOLCHIC data provided that representativeness in WOODEX is based on the approach (i.e. intervention vs other) rather than the actual reason for sampling.

Table 3.37 Distribution of sampling time overall and across-countries in the (final) dataset following the exclusion of all German data (n=12653).

Obs	country	n	AM	SD	min	max	median	p5	p95
1	1. Denmark	3719	318.183	93.6479	65	586	295.0	175	469
2	2. Norway	39	336.615	79.6693	162	494	336.0	192	471
3	3. The Netherlands	342	475.532	64.2821	165	571	498.5	335	527
4	4. Finland	642	269.679	82.0347	60	480	282.0	120	375
5	5. Great Britain	499	252.487	69.9193	75	501	254.0	140	418
6	7. France	7412	230.248	99.8114	60	591	205.0	90	405
	Overall	12653	265.930	108.792	60	591	255	105	463

SAS output summarising the year of measurement in the dataset excluding all German data.

The UNIVARIATE Procedure
Variable: year (measurement year)

Moments			
N	12653	**Sum Weights**	12653
Mean	1996.78614	**Sum Observations**	25265335
Std Deviation	4.74386044	**Variance**	22.5042119
Skewness	-0.3804334	**Kurtosis**	-0.1547355
Uncorrected SS	5.04498E10	**Corrected SS**	284723.289
Coeff Variation	0.23757479	**Std Error Mean**	0.04217306

Basic Statistical Measures			
Location		**Variability**	
Mean	1996.786	**Std Deviation**	4.74386
Median	1997.000	**Variance**	22.50421
Mode	1998.000	**Range**	29.00000
		Interquartile Range	7.00000

Quantiles (Definition 5)	
Level	Quantile
100% Max	201E1
99%	201E1
95%	2E3
90%	2E3
75% Q3	2E3
50% Median	2E3
25% Q1	199E1
10%	199E1
5%	199E1
1%	199E1
0% Min	198E1

Extreme Observations			
Lowest		Highest	
Value	Obs	Value	Obs
1978	3783	2007	4987
1978	3782	2007	4988
1978	3781	2007	4989
1978	3780	2007	5004
1978	3779	2007	5005

Comment: The distribution described above pertains that the reference year should be set at the year 1997 which is the median sampling year in the database.

3.4.2 Summary of the distribution of the concentrations in the final dataset after excluding all German data

SAS output summarising the measured concentrations in the original scale within the final dataset after excluding all German data.

The UNIVARIATE Procedure

Variable: imp_conc (Concentrations (mg/m3) with imputed LOD levels and corrected for differences in sampler efficiency)

Moments			
N	12653	Sum Weights	12653
Mean	6.64041482	Sum Observations	84021.1687
Std Deviation	33.5753223	Variance	1127.30227
Skewness	29.0820997	Kurtosis	1253.74797
Uncorrected SS	14820563.7	Corrected SS	14262628.3
Coeff Variation	505.620857	Std Error Mean	0.29848564

Basic Statistical Measures			
Location		Variability	
Mean	6.640415	Std Deviation	33.57532
Median	1.747200	Variance	1127
Mode	2.112000	Range	1841
		Interquartile Range	3.58193

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	1.84076E+03
99%	7.84320E+01
95%	2.08704E+01
90%	1.17120E+01
75% Q3	4.44000E+00
50% Median	1.74720E+00
25% Q1	8.58066E-01
10%	5.02810E-01
5%	3.64800E-01
1%	1.53600E-01
0% Min	8.90888E-03

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.00890888	7850	719.616	10004
0.00932702	4931	730.176	10003
0.01000000	12959	810.240	9184
0.01402261	11496	1622.976	10002
0.01641663	7471	1840.762	8734

<u>SAS output summarising the measured concentrations in the log scale within the final dataset after excluding all German data.</u>

The UNIVARIATE Procedure

Variable: ln_imp_conc

Moments			
N	12653	**Sum Weights**	12653
Mean	0.73628862	**Sum Observations**	9316.25995
Std Deviation	1.28844726	**Variance**	1.66009634
Skewness	0.59208227	**Kurtosis**	1.00124021
Uncorrected SS	27862.9952	**Corrected SS**	21003.5389
Coeff Variation	174.992146	**Std Error Mean**	0.01145434

Basic Statistical Measures			
Location		**Variability**	
Mean	0.736289	**Std Deviation**	1.28845
Median	0.558015	**Variance**	1.66010
Mode	0.747635	**Range**	12.23864
		Interquartile Range	1.64373

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	7.517935
99%	4.362232
95%	3.038332
90%	2.460614
75% Q3	1.490654
50% Median	0.558015
25% Q1	-0.153074

Quantiles (Definition 5)	
Level	**Quantile**
10%	-0.687543
5%	-1.008406
1%	-1.873403
0% Min	-4.720707

Extreme Observations			
Lowest		Highest	
Value	Obs	Value	Obs
-4.72071	7850	6.57872	10004
-4.67484	4931	6.59329	10003
-4.60517	12959	6.69733	9184
-4.26708	11496	7.39202	10002
-4.10946	7471	7.51793	8734

Table 3.38 Distribution characteristics of wood dust levels across countries in the full dataset after excluding all German data.

Obs	country	n	AM	STD	GM	GSD	min	max	p5	p95
1	1. Denmark	3719	1.27	2.53	0.88	2.16	0.03	95.68	0.28	3.12
2	2. Norway	39	13.51	23.23	4.51	4.42	0.38	84.29	0.38	80.64
3	3. The Netherlands	342	3.58	3.72	2.54	2.23	0.24	30.15	0.74	10.47
4	4. Finland	642	2.84	6.71	1.48	2.92	0.01	132.16	0.30	8.30
5	5. Great Britain	499	6.02	12.21	2.46	3.74	0.01	118.32	0.29	22.57
6	7. France	7412	9.81	43.33	3.23	3.69	0.01	1840.76	0.50	30.24
	Overall	12653	6.64	33.6	2.09	3.63	0.01	1840.76	0.36	20.87

3.4.3 Correlations between variables to be used in the modelling process

Table 3.39 Correlation between variable to be tested/entered on the modelling process using the measurements in the final dataset without the German data

Spearman Correlation Coefficients, N = 12653 Prob > |r| under H0: Rho=0								
	meastime	**reason1**	**strategy1**	**country**	**wooddusts**	**Year1997**	**ln_imp_conc**	**imp_conc**
meastime Duration of measurement (in minutes)	1.000	0.379 <.0001	0.007 0.4413	-0.401 <.0001	-0.018 0.0485	0.373 <.0001	-0.403 <.0001	-0.403 <.0001
reason1 sampling reason, 1=unknown, 0=inspection, 2=survey		1.000	-0.225 <.0001	-0.912 <.0001	-0.118 <.0001	0.348 <.0001	-0.444 <.0001	-0.444 <.0001
strategy1			1.000	-	0.008	-0.068	0.036	0.036

Spearman Correlation Coefficients, N = 12653 Prob > |r| under H0: Rho=0								
	meastime	**reason1**	**strategy1**	**country**	**wooddusts**	**Year1997**	**ln_imp_conc**	**imp_conc**
sampling strategy, 1= not representative, 0=representative				0.060 <.0001	0.3770	<.0001	<.0001	<.0001
country Country of origin				1.000	0.120 <.0001	-0.331 <.0001	0.474 <.0001	0.474 <.0001
wooddusts Asthma JEM score for wood dust, 0=no exposure, 1=low exposure, 2=high exposure					1.000	-0.135 <.0001	0.122 <.0001	0.122 <.0001
Year1997 Measurement year with reference set at 1997						1.00000	-0.474 <.0001	-0.474 <.0001
ln_imp_conc							1.00000	1.000 <.0001

Comment: Strategy and sampling reason are included in order to re-evaluate whether the observed correlations before still apply or they should be re-introduced in the analysis. As sampling reason correlates strongly with country it is excluded from the modelling process.

3.4.4 Results of the models using the measurements in the final dataset after exclusion of the German data: ISCO88 Occupation level (4 digits)

Table 3.40 Results from linear mixed effect regression describing estimated temporal trends in wood dust exposure in the database. Results are based on **12653** personal endotoxin measurement collected between 1978 and 2004.

Model	β Year (ref 2001)	*e*	P-value	Annual trend (%)	AIC	${}_{bisco}\sigma^2$	${}_{wisco}\sigma^2$
Wood dust							
Naïve					41069.5	0.3418	1.4943
+ year*	-0.1148	0.00215	<.0001	-10.9	38509.5	0.1778	1.2209
+ year, country	-0.09425	0.00221	<.0001	-9.0	36931.2	0.05424	1.0778
+ year, country, sampling time	-0.08068	0.00229	<.0001	-7.8	36592.1	0.04025	1.0483
+ year, country, sampling time, ASTHMA-JEM score	-0.08065	0.00229	<.0001	-7.8	36596.6	0.04514	1.0483

β=regression coefficient for log-transformed exposure data; *e*=standard error; *p*=p-value; annual trend=% of change in exposure per year estimated as 100*(exp(β)-1); ${}_{bisco}\sigma^2$ = between job variance; ${}_{wisco}\sigma^2$= within-Job (residual) variance;. Naive estimates are derived from a model without fixed effects.

Comment: Sampling strategy did not improve models at any stage and thereby was kept out of the final models.

SAS output summarising the results of the naïve model

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	31	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7312 7420 7421 7422 7423 7424 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	5	2 3 4 5 7
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	1
Columns in Z	31
Subjects	1
Max Obs per Subject	12653

Number of Observations	
Number of Observations Read	12653
Number of Observations Used	12653
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.3418	0.1137	3.01	0.0013
Residual	1.4943	0.01881	79.46	<.0001

Fit Statistics	
-2 Res Log Likelihood	41065.5
AIC (Smaller is Better)	41069.5
AICC (Smaller is Better)	41069.5
BIC (Smaller is Better)	41072.3

Solution for Fixed Effects								
Effect	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept	0.7225	0.1246	30	5.80	<.0001	0.05	0.4681	0.9770

SAS output summarising the results of the main model (full- 4 digit ISCO88 code)

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Dimensions	
Covariance Parameters	2
Columns in X	11
Columns in Z	31
Subjects	1
Max Obs per Subject	12653

Number of Observations	
Number of Observations Read	12653
Number of Observations Used	12653
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.04514	0.01864	2.42	0.0077
Residual	1.0483	0.01319	79.46	<.0001

Fit Statistics	
-2 Res Log Likelihood	36592.6
AIC (Smaller is Better)	36596.6
AICC (Smaller is Better)	36596.6
BIC (Smaller is Better)	36599.5

Solution for Fixed Effects										
Effect	**Country ‡**	**Asthma JEM score ***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept			1.4709	0.1018	28	14.45	<.0001	0.05	1.2624	1.6794
year1997			-0.08065	0.002293	13E3	-35.17	<.0001	0.05	-0.08514	-0.07615
country1	**2**		-0.9121	0.02714	13E3	-33.60	<.0001	0.05	-0.9653	-0.8589
country1	**3**		-0.1290	0.06453	13E3	-2.00	0.0457	0.05	-0.2554	-0.00247
country1	**4**		-0.03113	0.04526	13E3	-0.69	0.4916	0.05	-0.1198	0.05759
country1	**5**		0.1895	0.04900	13E3	3.87	0.0001	0.05	0.09345	0.2855
country1	**7**		0	.	.	.	.	.	.	.
meastim			-	0.00010	13E	-	<.00	0.05	-	-

Solution for Fixed Effects										
Effect	**Country ‡**	**Asthma JEM score ***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
e			0.00194	2	3	19.00	01		0.00214	0.00174
wooddusts		**0**	-0.03290	0.1330	13E3	-0.25	0.8047	0.05	-0.2936	0.2278
wooddusts		**1**	0.03690	0.1337	13E3	0.28	0.7825	0.05	-0.2251	0.2989
wooddusts		**2**	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Solution for Random Effects						
Effect	**updated ISCO88 code with recoded junk codes**	**Estimate**	**Std Err Pred**	**DF**	**t Value**	**Pr > |t|**
ISCO882	**110**	-0.01519	0.2081	13E3	-0.07	0.9418
ISCO882	**2310**	-0.01063	0.2002	13E3	-0.05	0.9577
ISCO882	**2320**	-0.01147	0.1822	13E3	-0.06	0.9498
ISCO882	**2331**	0.001406	0.1230	13E3	0.01	0.9909
ISCO882	**2359**	-0.04566	0.2081	13E3	-0.22	0.8263
ISCO882	**5220**	0.1612	0.1203	13E3	1.34	0.1806
ISCO882	**7124**	0.06377	0.09387	13E3	0.68	0.4969
ISCO882	**7129**	-0.08922	0.1614	13E3	-0.55	0.5804
ISCO882	**7131**	0.1387	0.1066	13E3	1.30	0.1933
ISCO882	**7132**	0.2202	0.1847	13E3	1.19	0.2333
ISCO882	**7142**	0.04947	0.2040	13E3	0.24	0.8084
ISCO882	**7233**	0.02969	0.1732	13E3	0.17	0.8639
ISCO882	**7312**	-0.04523	0.2002	13E3	-0.23	0.8213
ISCO882	**7420**	0.4174	0.1048	13E3	3.98	<.0001
ISCO882	**7421**	-0.1074	0.1461	13E3	-0.74	0.4620
ISCO882	**7422**	-0.1130	0.1225	13E3	-0.92	0.3561
ISCO882	**7423**	-0.2229	0.1093	13E3	-2.04	0.0414
ISCO882	**7424**	0.05071	0.2003	13E3	0.25	0.8001
ISCO882	**8141**	-0.3051	0.09971	13E3	-3.06	0.0022
ISCO882	**8142**	-0.04641	0.1376	13E3	-0.34	0.7359
ISCO882	**8143**	-0.05346	0.1967	13E3	-0.27	0.7858
ISCO882	**8161**	-0.06708	0.2081	13E3	-0.32	0.7472
ISCO882	**8172**	-0.06633	0.2081	13E3	-0.32	0.7499
ISCO882	**8240**	0.2235	0.09906	13E3	2.26	0.0241
ISCO882	**8285**	-0.1630	0.09458	13E3	-1.72	0.0849
ISCO882	**8324**	-0.06465	0.1101	13E3	-0.59	0.5570
ISCO882	**8334**	0.01050	0.2002	13E3	0.05	0.9582
ISCO882	**9141**	0.02518	0.1006	13E3	0.25	0.8024
ISCO882	**9161**	0.05279	0.1821	13E3	0.29	0.7719
ISCO882	**9212**	-0.1708	0.1715	13E3	-1.00	0.3191
ISCO882	**9313**	0.1530	0.1125	13E3	1.36	0.1739

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
year1997	1	13E3	1236.79	<.0001
country1	4	13E3	318.91	<.0001
meastime	1	13E3	360.95	<.0001
wooddusts	2	13E3	0.15	0.8605

3.4.5 Results of the models using the samples available in the (final) dataset after excluding all German data: ISCO88 unit level (3 digits)

Table 3.41 Distribution of measurements across ISCO88 codes for units and assigned Asthma-JEM score in the (final) dataset after excluding all German measurements (n=12653)

ISCO88_3digit	ISCO 88 description	wooddusts*	Frequency	Percent
11	Armed forces	**0**	1	0.01
231	College, university and higher	**0**	3	0.02
232	Secondary education	**0**	9	0.07
233	Primary and pre-primary education	**0**	78	0.62
235	Other	**0**	1	0.01
522	Shop salespersons	**0**	88	0.7
712	Building frame and related	**0**	1076	8.5
713	Building finishers and	**0**	204	1.61
714	Painters, building structure	**0**	2	0.02
723	Machinery mechanics	**0**	13	0.1
731	Precision workers in	**0**	3	0.02
742	Wood treaters, cabinet-	**2**	847	6.69
814	Wood-processing-	**1**	2997	23.69
816	Power-production	**0**	1	0.01
817	Automated-assembly-line	**0**	1	0.01
824	Wood-products	**2**	5361	42.37
828	Assemblers	**0**	1334	10.54
832	Motor-vehicle drivers	**0**	162	1.28
833	Agricultural and other	**0**	3	0.02
914	Building caretakers,	**0**	312	2.47
916	Garbage collectors and	**0**	9	0.07
921	Agricultural, fishery and	**0**	14	0.11
931	Mining and construction	**0**	134	1.06

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

SAS output summarising the results of the naïve model at the ISCO88 unit level

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO88_3digit	23	11 231 232 233 235 522 712 713 714 723 731 742 814 816 817 824 828 832 833 914 916 921 931
country1	5	2 3 4 5 7
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	1
Columns in Z	23
Subjects	1
Max Obs per Subject	12653

Number of Observations	
Number of Observations Read	12653
Number of Observations Used	12653
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
ISCO88_3digit	0.2998	0.1162	2.58	0.0049
Residual	1.5190	0.01911	79.48	<.0001

Fit Statistics	
-2 Res Log Likelihood	41254.9
AIC (Smaller is Better)	41258.9
AICC (Smaller is Better)	41258.9
BIC (Smaller is Better)	41261.2

Solution for Fixed Effects								
Effect	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept	0.6577	0.1388	22	4.74	<.0001	0.05	0.3697	0.9456

SAS output summarising the results of the full model at the ISCO88 unit level

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Dimensions	
Covariance Parameters	2
Columns in X	11
Columns in Z	23
Subjects	1
Max Obs per Subject	12653

Number of Observations	
Number of Observations Read	12653
Number of Observations Used	12653
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	Estimate	Standard Error	Z Value	Pr > Z
ISCO88_3digit	0.01105	0.007578	1.46	0.0723
Residual	1.0552	0.01328	79.48	<.0001

Fit Statistics	
-2 Res Log Likelihood	36654.9
AIC (Smaller is Better)	36658.9
AICC (Smaller is Better)	36658.9
BIC (Smaller is Better)	36661.1

Solution for Fixed Effects										
Effect	Country ‡	Wooddusts*	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept			1.6702	0.08114	20	20.59	<.0001	0.05	1.501	1.8395
Year1997			-0.08159	0.002294	1.30E+04	-35.57	<.0001	0.05	-0.0860	-0.0770
country1	2		-0.9282	0.02661	1.30E+04	-34.88	<.0001	0.05	-0.9804	-0.8761
country1	3		-0.1369	0.06457	1.30E+04	-2.12	0.034	0.05	-0.2635	-0.0103
country1	4		-0.01572	0.04501	1.30E+04	-0.35	0.727	0.05	-0.1039	0.0725
country1	5		0.1466	0.04857	1.30E+04	3.02	0.002	0.05	0.05145	0.2418
country1	7		0	.	.	.	.	.	.	.
meastime			-0.00197	0.000102	1.30E+04	-19.31	<.0001	0.05	-0.0021	-0.0017
wooddusts		0	-0.1614	0.08798	1.30E+04	-1.83	0.0666	0.05	-0.3339	0.01103
wooddusts		1	-0.4953	0.1318	1.30E+04	-3.76	0.0002	0.05	-0.7537	-0.2369
wooddusts		2	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Solution for Random Effects						
Effect	**ISCO88_3digit**	**Estimate**	**Std Err Pred**	**DF**	**t Value**	**Pr > |t|**
ISCO88_3digit	**11**	-0.00457	0.1046	1.30E+04	-0.04	0.9651
ISCO88_3digit	**231**	-0.00491	0.1035	1.30E+04	-0.05	0.9622
ISCO88_3digit	**232**	-0.00968	0.1006	1.30E+04	-0.1	0.9233
ISCO88_3digit	**233**	-0.02992	0.08048	1.30E+04	-0.37	0.7101
ISCO88_3digit	**235**	-0.01223	0.1046	1.30E+04	-0.12	0.9069
ISCO88_3digit	**522**	0.06621	0.07866	1.30E+04	0.84	0.4
ISCO88_3digit	**712**	0.06574	0.04966	1.30E+04	1.32	0.1856
ISCO88_3digit	**713**	0.1294	0.06636	1.30E+04	1.95	0.0513
ISCO88_3digit	**714**	0.01245	0.1041	1.30E+04	0.12	0.9048
ISCO88_3digit	**723**	0.002345	0.0988	1.30E+04	0.02	0.9811
ISCO88_3digit	**731**	-0.01183	0.1035	1.30E+04	-0.11	0.909
ISCO88_3digit	**742**	-0.03839	0.07666	1.30E+04	-0.5	0.6165
ISCO88_3digit	**814**	-2.93E-17	0.1051	1.30E+04	0	1
ISCO88_3digit	**816**	-0.01755	0.1046	1.30E+04	-0.17	0.8667
ISCO88_3digit	**817**	-0.01746	0.1046	1.30E+04	-0.17	0.8674
ISCO88_3digit	**824**	0.03839	0.07666	1.30E+04	0.5	0.6165
ISCO88_3digit	**828**	-0.132	0.0502	1.30E+04	-2.63	0.0086
ISCO88_3digit	**832**	-0.07238	0.07035	1.30E+04	-1.03	0.3036
ISCO88_3digit	**833**	0.001607	0.1035	1.30E+04	0.02	0.9876
ISCO88_3digit	**914**	-0.02896	0.06081	1.30E+04	-0.48	0.6339
ISCO88_3digit	**916**	0.01071	0.1006	1.30E+04	0.11	0.9152
ISCO88_3digit	**921**	-0.05597	0.09838	1.30E+04	-0.57	0.5695
ISCO88_3digit	**931**	0.109	0.07243	1.30E+04	1.5	0.1324

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Year1997	1	13E3	1265.01	<.0001
country1	4	13E3	339.35	<.0001
meastime	1	13E3	372.90	<.0001
wooddusts	2	13E3	7.06	0.0009

3.4.6 Sensitivity analysis on the models without the German data.

In a similar fashion to what is described in section 3.3 and to examine the robustness of the derived model results the models were repeated after:

a) Removing the exposure prior (Asthma_JEM) score from the fixed effects
b) Excluding all measurements with a measured exposure concentration above 50 mg/m^3
c) Excluding all measurements with a sampling time <240 min

3.4.6.1 Removing the exposure prior (Asthma_JEM) score from the fixed effects

In the following the SAS output from a model based on the database excluding the German data and without the exposure prior is shown.

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	31	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7312 7420 7421 7422 7423 7424 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	5	2 3 4 5 7

Dimensions	
Covariance Parameters	2
Columns in X	8
Columns in Z	31
Subjects	1
Max Obs per Subject	12653

Number of Observations	
Number of Observations Read	12653
Number of Observations Used	12653
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.04025	0.01588	2.53	0.0056
Residual	1.0483	0.01319	79.46	<.0001

Fit Statistics	
-2 Res Log Likelihood	36588.1
AIC (Smaller is Better)	36592.1
AICC (Smaller is Better)	36592.1
BIC (Smaller is Better)	36595.0

Solution for Fixed Effects									
Effect	**Country ‡**	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept		1.4732	0.05697	30	25.86	<.0001	0.05	1.3569	1.5896
year1997		-0.08068	0.002292	13E3	-35.20	<.0001	0.05	-0.08517	-0.07619
meastime		-0.00194	0.000102	13E3	-19.00	<.0001	0.05	-0.00214	-0.00174
country1	**2**	-0.9124	0.02711	13E3	-33.66	<.0001	0.05	-0.9655	-0.8593
country1	**3**	-0.1293	0.06452	13E3	-2.00	0.0452	0.05	-0.2557	-0.00279
country1	**4**	-0.03302	0.04515	13E3	-0.73	0.4646	0.05	-0.1215	0.05548
country1	**5**	0.1893	0.04896	13E3	3.87	0.0001	0.05	0.09330	0.2852
country1	**7**	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR

In the following plots a comparison of the BLUPs of the models with and without the Asthma-JEM score are shown. From these plots and the above table it can be seen that the inclusion or not of the scores has little effect to the exposure prediction by the model.

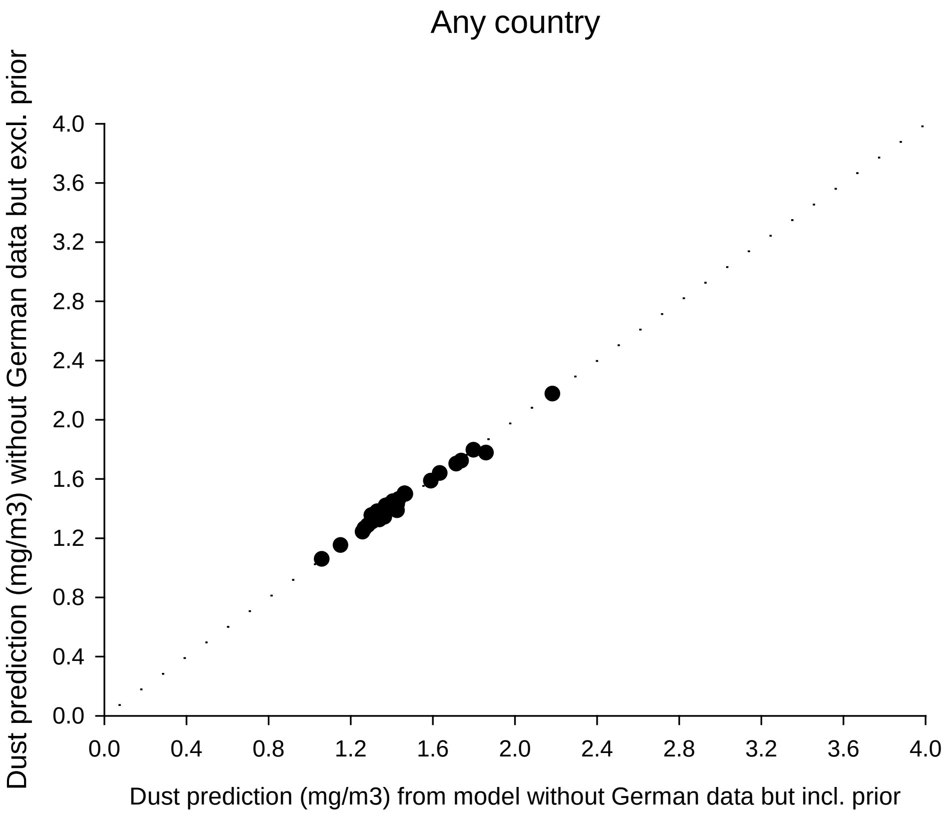


Figure 3.42 Agreement between the non-country specific BLUPs from the model with and without the exposure prior (Asthma-JEM scores) for the reference year (1997). Measurements with a sampling duration between 60-600 min are used and all German measurements are excluded. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

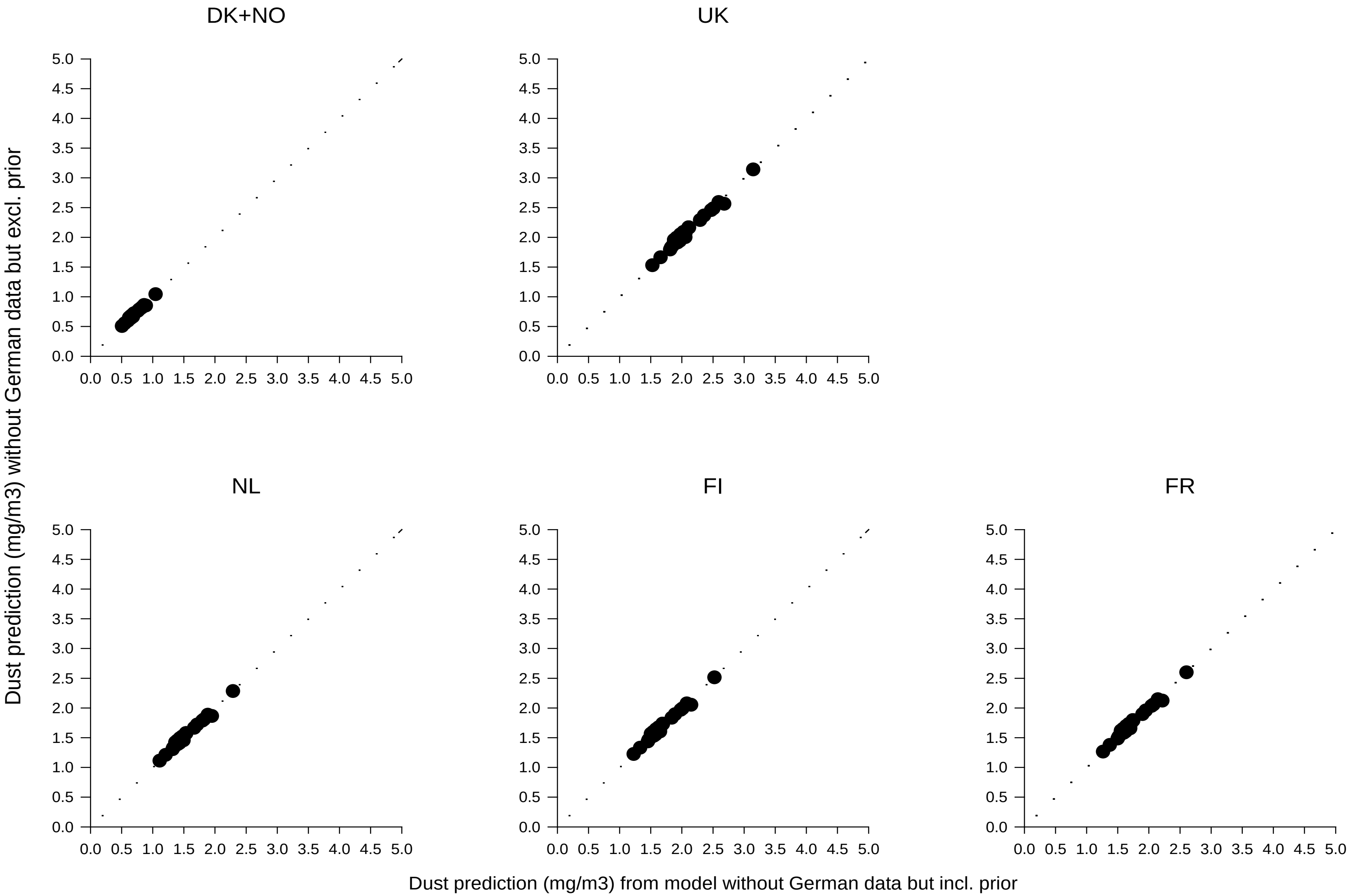


Figure 3.43 Agreement between the country-specific BLUPs from the model with and without the exposure prior (Asthma-JEM scores) for the reference year (1997). Measurements with a sampling duration between 60-600 min are used and all German measurements are excluded. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

3.4.6.2 *Excluding all measurements with a measured exposure concentration above 50 mg/m3*

In the following the SAS output from a model based on the database excluding the German data and without the measurements with concentrations above 50 mg/m3 (i.e. excluding outliers).

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	31	110 2310 2320 2331 2359 5220 7124 7129 7131 7132 7142 7233 7312 7420 7421 7422 7423 7424 8141 8142 8143 8161 8172 8240 8285 8324 8334 9141 9161 9212 9313
country1	5	2 3 4 5 7
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	11
Columns in Z	31
Subjects	1
Max Obs per Subject	12446

Number of Observations	
Number of Observations Read	12446
Number of Observations Used	12446
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.04940	0.02113	2.34	0.0097
Residual	0.8887	0.01128	78.80	<.0001

Fit Statistics	
-2 Res Log Likelihood	33943.7
AIC (Smaller is Better)	33947.7
AICC (Smaller is Better)	33947.7
BIC (Smaller is Better)	33950.6

Solution for Fixed Effects										
Effect	**Country ‡**	**Asthma JEM score ***	**Estimate**	**Standard Error**	**DF**	**t Value**	**Pr > |t|**	**Alpha**	**Lower**	**Upper**
Intercept			1.3593	0.1051	28	12.94	<.0001	0.05	1.1441	1.5745
year1997			-0.07284	0.002142	12E3	-34.01	<.0001	0.05	-0.07704	-0.06865
country1	**2**		-0.8661	0.02518	12E3	-34.39	<.0001	0.05	-0.9154	-0.8167
country1	**3**		-0.05924	0.05959	12E3	-0.99	0.3201	0.05	-0.1760	0.05756
country1	**4**		-0.02973	0.04184	12E3	-0.71	0.4775	0.05	-0.1117	0.05229
country1	**5**		0.1678	0.04557	12E3	3.68	0.0002	0.05	0.07843	0.2571
country1	**7**		0	.	.	.	.	.	.	.
meastime			-0.00174	0.000095	12E3	-18.31	<.0001	0.05	-0.00192	-0.00155
wooddusts		**0**	-0.05656	0.1360	12E3	-0.42	0.6776	0.05	-0.3232	0.2101
wooddusts		**1**	0.01906	0.1378	12E3	0.14	0.8900	0.05	-0.2510	0.2891
wooddusts		**2**	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR
*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

In the following plots a comparison of the BLUPs of the models with and without the measurements with concentration >50 mg/m^3 is made. As it can be seen there is little effect on the predictions due to the inclusion of these measurements.

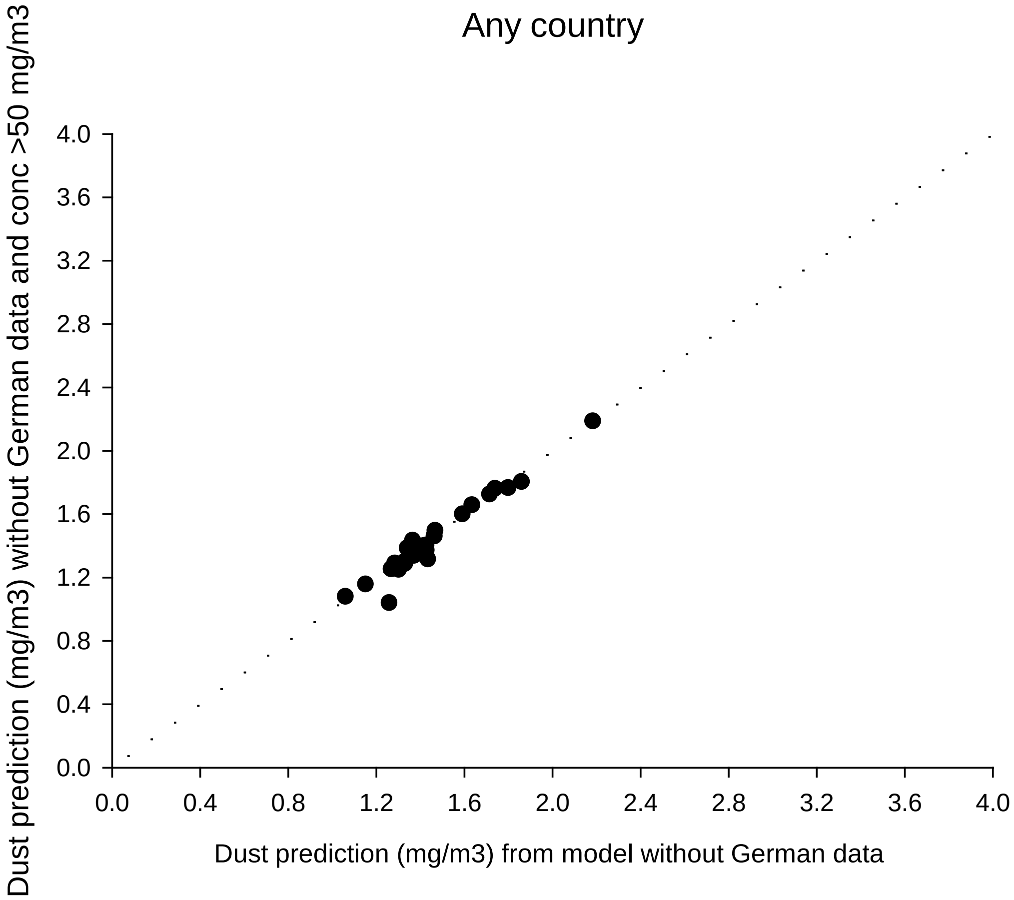


Figure 3.44 Agreement between the non-country specific BLUPs for the reference year (1997) from the model with and without measurements above 50 mg/m³. Measurements with a sampling duration between 60-600 min are used and all German measurements are excluded. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

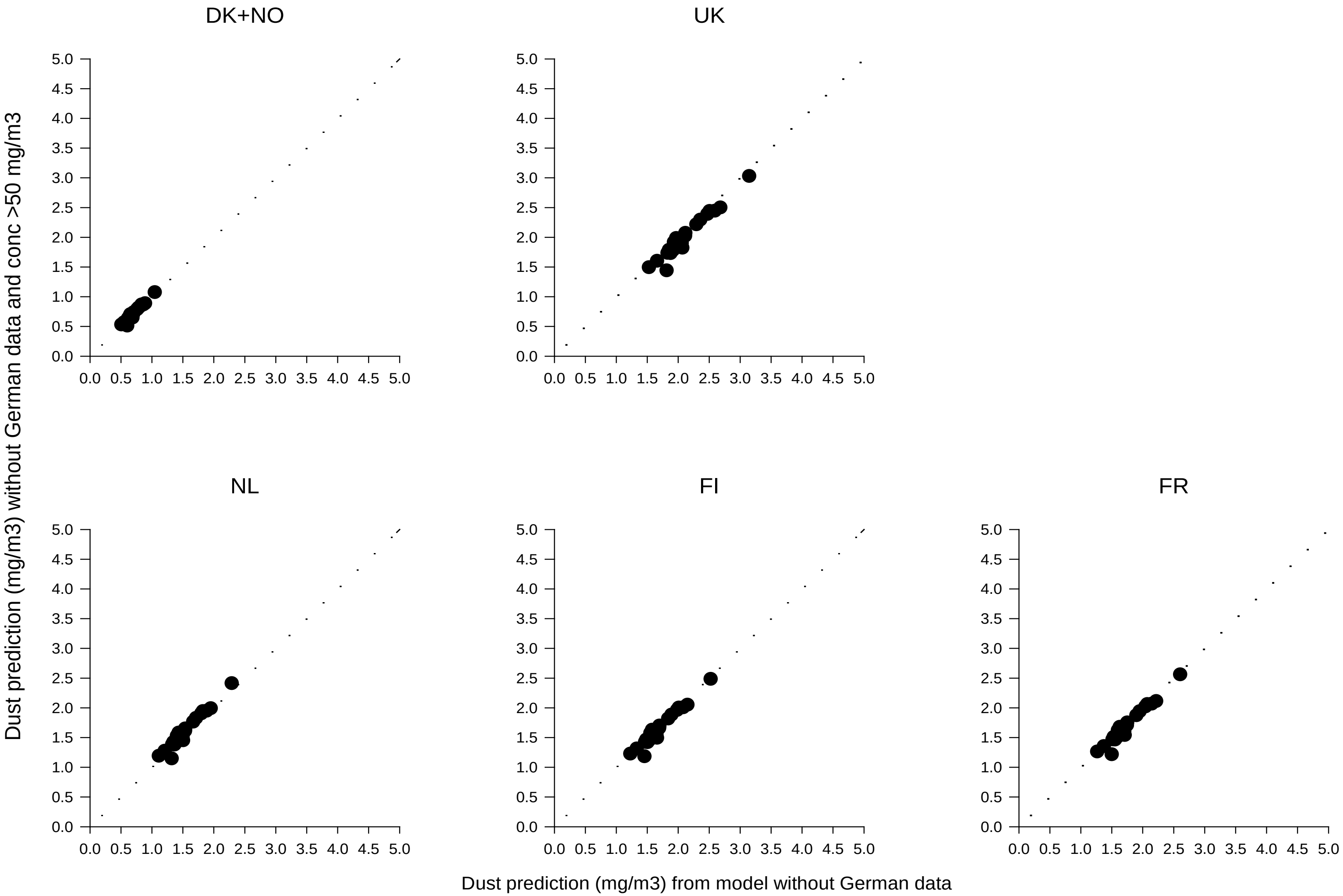


Figure 3.45 Agreement between the country-specific BLUPs for the reference year (1997) from the model with and without measurements above 50 mg/m^3. Measurements with a sampling duration between 60-600 min are used and all German measurements are excluded. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

3.4.6.3 Excluding all measurements with a sampling time <240 min

In the following the SAS output from a model using only measurements with a sampling duration >240 min is shown based on the database excluding the German data. As the model may be considered an alternative to the one with all measurements the BLUP predictions are also provided.

The Mixed Procedure

Model Information	
Data Set	WORK.WOOD1
Dependent Variable	ln_imp_conc
Covariance Structure	Variance Components
Estimation Method	REML
Residual Variance Method	Profile
Fixed Effects SE Method	Model-Based
Degrees of Freedom Method	Containment

Class Level Information		
Class	**Levels**	**Values**
ISCO882	27	2310 2320 2331 5220 7124 7129 7131 7142 7233 7312 7420 7421 7422 7423 7424 8141 8142 8143 8161 8240 8285 8324 8334 9141 9161 9212 9313
country1	5	2 3 4 5 7
wooddusts	3	0 1 2

Dimensions	
Covariance Parameters	2
Columns in X	11
Columns in Z	27
Subjects	1
Max Obs per Subject	7051

Number of Observations	
Number of Observations Read	7051
Number of Observations Used	7051
Number of Observations Not Used	0

Convergence criteria met.

Covariance Parameter Estimates				
Cov Parm	**Estimate**	**Standard Error**	**Z Value**	**Pr > Z**
ISCO882	0.05441	0.02632	2.07	0.0193
Residual	0.8216	0.01386	59.26	<.0001

Fit Statistics	
-2 Res Log Likelihood	18705.7
AIC (Smaller is Better)	18709.7
AICC (Smaller is Better)	18709.7
BIC (Smaller is Better)	18712.2

Solution for Fixed Effects										
Effect	Country ‡	Asthma JEM score *	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept			0.8712	0.1223	24	7.12	<.0001	0.05	0.6188	1.1237
year1997			-0.07990	0.002586	7018	-30.89	<.0001	0.05	-0.08497	-0.07483
country1	2		-0.7310	0.03072	7018	-23.80	<.0001	0.05	-0.7913	-0.6708
country1	3		-0.1788	0.06240	7018	-2.87	0.0042	0.05	-0.3011	-0.05647
country1	4		0.03927	0.04674	7018	0.84	0.4009	0.05	-0.05236	0.1309
country1	5		0.3941	0.05571	7018	7.07	<.0001	0.05	0.2849	0.5033
country1	7		0	.	.	.	.	.	.	.
meastime			-0.00051	0.000165	7018	-3.11	0.0019	0.05	-0.00084	-0.00019
wooddusts		0	-0.1083	0.1503	7018	-0.72	0.4711	0.05	-0.4029	0.1863
wooddusts		1	0.01785	0.1502	7018	0.12	0.9054	0.05	-0.2765	0.3122
wooddusts		2	0	.	.	.	.	.	.	.

‡ Country of data origin defined as 2=DK+NO, 3=NL, 4=FI, 5=UK, 6=GE, 7=FR

*Score for wood dust defined as 0=no exposure, 1=low exposure, 2=high exposure

Solution for Random Effects						
Effect	ISCO88 code	Estimate	Std Err Pred	DF	t Value	Pr > |t|
ISCO882	2310	-0.00115	0.2138	7018	-0.01	0.9957
ISCO882	2320	-0.2293	0.2195	7018	-1.04	0.2963
ISCO882	2331	0.01151	0.1856	7018	0.06	0.9506
ISCO882	5220	0.1552	0.1414	7018	1.10	0.2726
ISCO882	7124	0.05904	0.1088	7018	0.54	0.5874
ISCO882	7129	0.07528	0.2138	7018	0.35	0.7247
ISCO882	7131	0.2896	0.1227	7018	2.36	0.0183
ISCO882	7142	0.08292	0.2196	7018	0.38	0.7057
ISCO882	7233	-0.03776	0.1829	7018	-0.21	0.8365
ISCO882	7312	-0.09308	0.2195	7018	-0.42	0.6716
ISCO882	7420	0.3746	0.1179	7018	3.18	0.0015
ISCO882	7421	-0.1590	0.1567	7018	-1.01	0.3102
ISCO882	7422	-0.2927	0.1361	7018	-2.15	0.0315
ISCO882	7423	-0.08386	0.1199	7018	-0.70	0.4842
ISCO882	7424	0.09230	0.2139	7018	0.43	0.6661
ISCO882	8141	-0.1822	0.1104	7018	-1.65	0.0991
ISCO882	8142	0.02857	0.1577	7018	0.18	0.8563
ISCO882	8143	-0.02136	0.2086	7018	-0.10	0.9184
ISCO882	8161	-0.09560	0.2260	7018	-0.42	0.6723
ISCO882	8240	0.1842	0.1093	7018	1.68	0.0921
ISCO882	8285	-0.1432	0.1079	7018	-1.33	0.1847
ISCO882	8324	-0.04981	0.1206	7018	-0.41	0.6797
ISCO882	8334	0.09513	0.2196	7018	0.43	0.6648

Solution for Random Effects						
Effect	**ISCO88 code**	**Estimate**	**Std Err Pred**	**DF**	**t Value**	**Pr > |t|**
ISCO882	**9141**	-0.02693	0.1210	7018	-0.22	0.8239
ISCO882	**9161**	-0.00370	0.2195	7018	-0.02	0.9865
ISCO882	**9212**	-0.2476	0.1756	7018	-1.41	0.1586
ISCO882	**9313**	0.2189	0.1314	7018	1.67	0.0958

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
year1997	1	7018	954.36	<.0001
country1	4	7018	186.52	<.0001
meastime	1	7018	9.67	0.0019
wooddusts	2	7018	0.43	0.6524

In the following plots a comparison of the BLUPs of the models with and without the measurements with sampling duration <240 min is made. From these plots it can be seen that in principal there is a reasonably good agreement between the predictions of the two models, although there are some deviations mainly when considering the UK data. However, for the other countries little effect is observed and on the whole we consider that the findings support the inclusion of all measurement data on the modelling process and creation of the JEM.

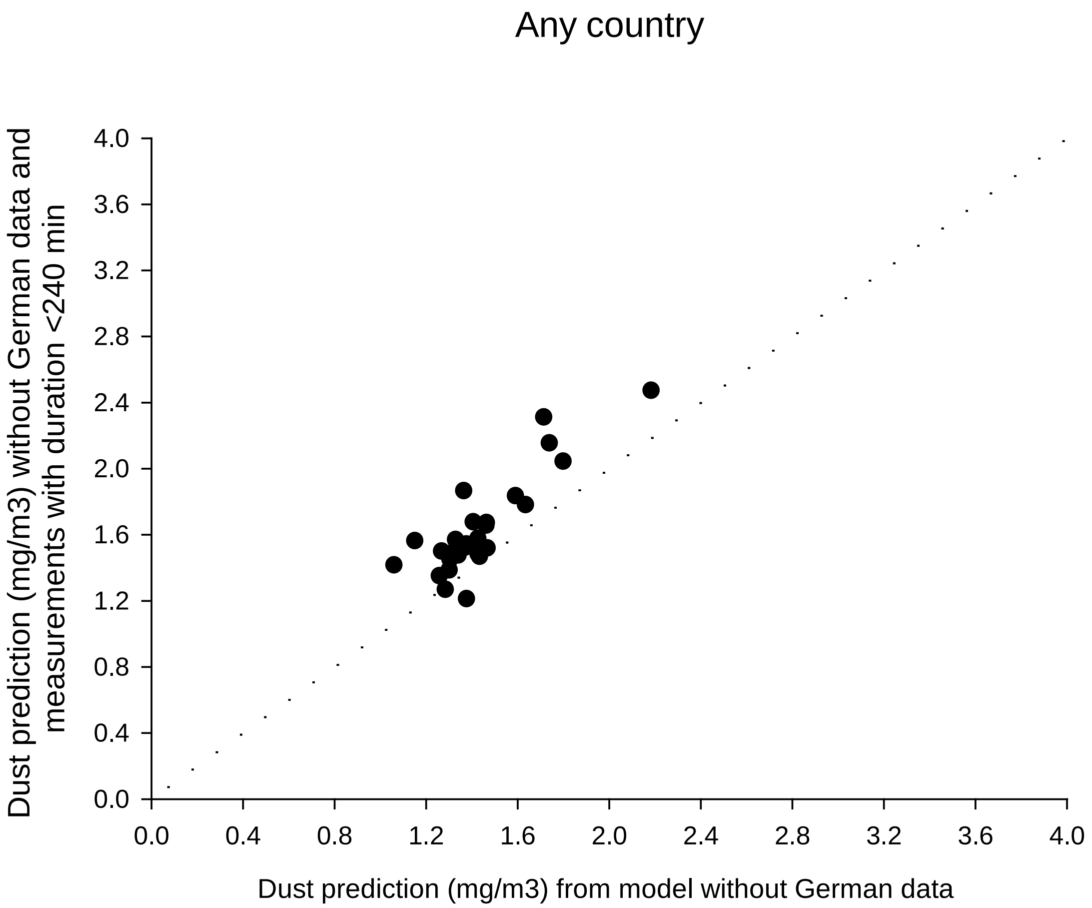


Figure 3.46 Agreement between the non-country specific BLUPs from the model with and without measurements with a sampling duration <240 min. Predictions for the reference year (1997) are shown and analysis excludes all German measurements. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

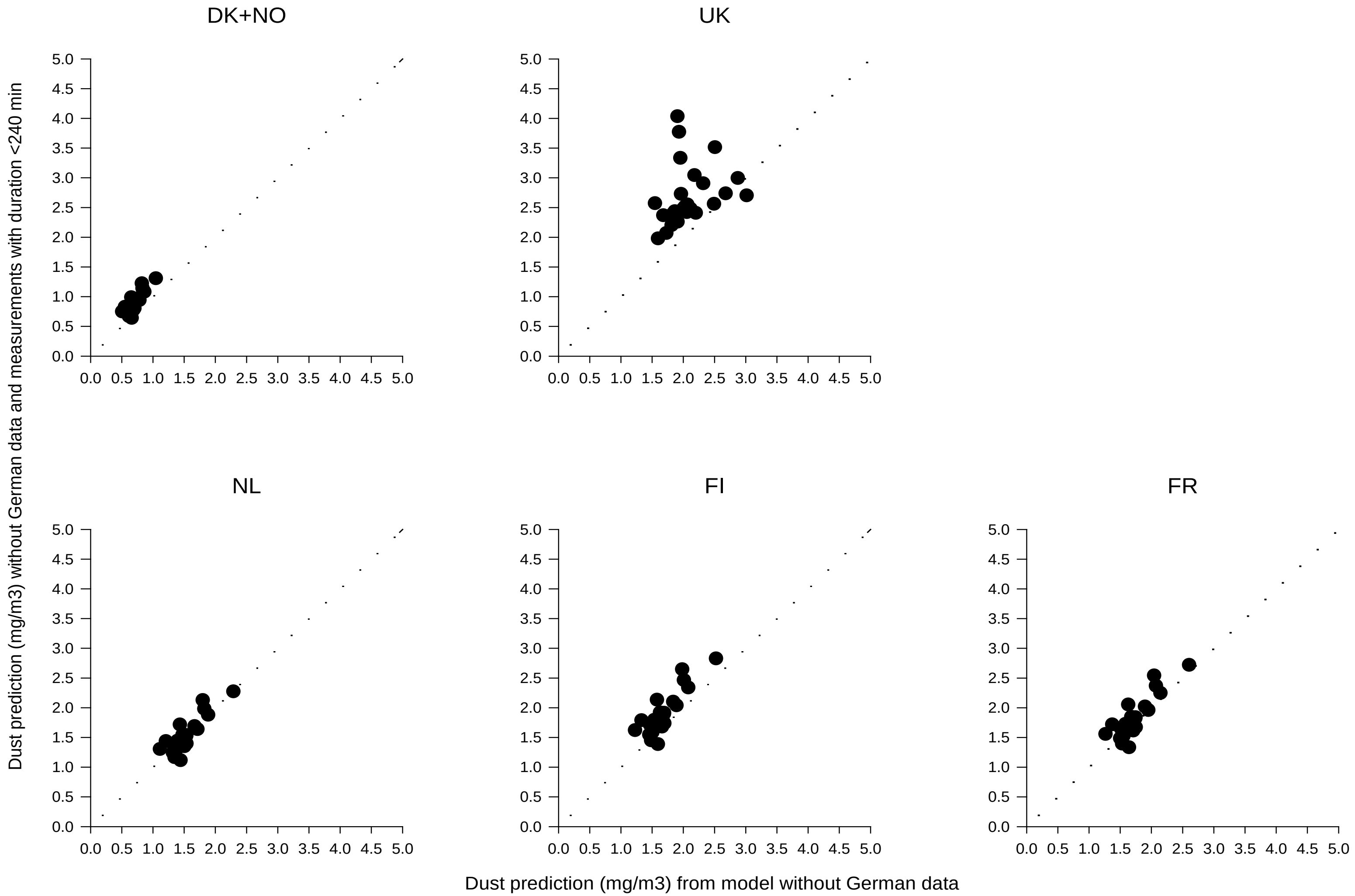


Figure 3.47 Agreement between the country-specific BLUPs from the model with and without measurements with a sampling duration <240 min. Predictions for the reference year (1997) are shown and analysis excludes all German measurements. Dashed line indicates perfect agreement. Only estimates for ISCO codes with measurements in both models are shown.

4 ESTABLISHMENT OF THE JOB-EXPOSURE MATRIX (JEM)

Based on the results summarised on section 3 above and the discussions held between the contributing parties (IOM, IRAS, AU) it was agreed to model exposures to wood dust and establish the JEM using the dataset that excludes all German measurements (see previous sections for details). The specific dataset is summarised in sub-section 3.4.1 to 3.4.3 and the relevant models are presented in section 3.4.4 to 3.4.5. The results of a series of sensitivity analyses suggest the estimates to be rather robust. Consequently the predictions for the BLUPs of these models (sections 3.4.4, 3.4.5) were used to assign exposure estimates for the relevant ISCO-88 codes (i.e. for the establishment of the JEM).

In principle, and as described in section 3.1 the derived exposure estimates originate from linear mixed models with the ISCO88 code as a random effect and the measurement year, sampling duration, country, ASTHMA-JEM score and sampling strategy (representativeness) or reason for sampling as the fixed effects. Measurement year in these models was included as a continuous variable with year 1997 as the reference, whereas sampling time was also a continuous variable. Model building was based on model improvement (i.e. AIC) whereas at the final stage the ASTHMA-JEM ratings (3 levels: no exposure, low exposure, high exposure) for wood dust were included to allow assignment of exposure levels to ISCO codes with no measurements in the database.

As previously discussed (see section 1.3), the approach to establish the JEM follows closely the one used within the “SYNERGY” project.[33] The model with the complete ISCO codes (4 digits) is used to assess temporal trends in exposure and used to provide prediction estimates for the full (4-digit) ISCO codes for which measurements were available in the dataset. This model can also be referred to as the “main” model.

For ISCO codes with no or less than 5 measurements available, we applied different approaches to estimate the level of exposure depending on the involved ISCO detail level and measurement availability. Specifically:

a) For those ISCO codes on the unit level (3-digit) we have re-elaborated our exposure models using fewer digits of the assigned ISCO-codes on the measurements (i.e. measurements were grouped at one level higher).
b) For ISCO codes either at the occupation (4-digit) or unit (3-digit) level for which no or <5 measurements were available we used the model predictions for the ASTHMA-JEM score corresponding to the

[33] Peters S, Vermeulen R, et al. Modelling of occupational respirable crystalline silica exposure for quantitative exposure assessment in community-based case-control studies. J Env Monit 2011;13:3262–8. doi:10.1039/c1em10628g

assigned intensity level for the job title in question. It should be noted however, that these did not appear to be very good predictors of the exposure.

In all cases for the jobs (ISCO-codes) with an ASTHMA-JEM score 0 the model predictions were overruled and assigned an exposure of 0.

The only exception to the above mentioned approach was applied for the ISCO code 6141 (Forestry workers and loggers) where exposure estimates were assigned from the estimated BLUPs for ISCO code 9212 (Forestry Labourers). This was based on the similarity of the activities performed by the two groups.

The derived main model results for the fixed effects suggest an annual trend of -7.8% in exposure significant at the <0.0001 level. This will be used to assign exposure for the period covered by the database (i.e. 1978 - 2004). For previous years before 1978 where no measurements were available it can be assumed that either the exposure was constant (i.e. broken stick model) or that the trend continues. However as the annual reduction is rather large the broken stick option may be more reasonable. Sensitivity analysis to compare the impact of the two options on the results of the epidemiological analysis is however recommended.

An outline of the exposure levels for the exposed codes (both at an occupation and unit level) as assigned by the JEM for the year 1997 is provided in the table that follows. The complete matrix for the same year is also attached as a separate file.

Table 4.1 Measurement availability and predicted levels of wood dust for exposed Job-codes (ISCO88) according to the Asthma-JEM.

ISCO88 code	ISCO STANDARD DESCRIPTION	ASTHMA-JEM score	number of measurements in dataset (N=12,653)	Predicted exposure level for the year 1997 (mg/m^3)						Source of exposure estimate
				Non-country specific	DK+NO	NL	FI	UK	FR	
6141	Forestry workers and loggers	**1**	0	1.26	0.6	1.32	1.45	1.81	1.5	Estimated BLUPs and equation for 9212 from model with 4-digits
7124	Carpenters and joiners	**1**	1062	1.59	0.76	1.67	1.84	2.29	1.9	From 4-digit model
7129	Building frame and related trades workers not elsewhere classified	**1**	20	1.36	0.65	1.43	1.58	1.97	1.63	From 4-digit model
7131	Roofers	**1**	196	1.71	0.82	1.8	1.98	2.47	2.04	From 4-digit model
7132	Floor layers and tile setters	**1**	8	1.86	0.89	1.95	2.15	2.68	2.22	From 4-digit model
7312	Musical instrument makers and tuners	**1**	3	1.49	0.71	1.56	1.73	2.15	1.78	Estimate for corresponding Asthma-JEM from 4-digit model
7330	Handicraft workers in wood, textile, leather and related materials	**1**	0	1.20	0.5	0.43	1.1	1.46	1.26	From 3-digit model
7331	Handicraft workers in wood and related materials	**1**	0	1.49	0.71	1.56	1.73	2.15	1.78	Estimate for corresponding Asthma-JEM from 4-digit model
7420	Wood treaters, cabinet-makers and related trades workers	**2**	460	1.65	0.79	1.73	1.96	2.3	1.99	From 3-digit model
7421	Wood treaters	**1**	35	1.34	0.64	1.41	1.55	1.93	1.6	From 4-digit model
7422	Cabinet makers and related workers	**2**	101	1.28	0.62	1.35	1.49	1.85	1.53	From 4-digit model
7423	Woodworking machine setters and setter-operators	**2**	257	1.15	0.55	1.21	1.33	1.66	1.37	From 4-digit model
8140	Wood-processing- and papermaking-plant operators	**1**	0	1.04	0.5	1.1	1.24	1.46	1.26	From 3 digit model
8141	Wood-processing-plant operators	**2**	2962	1.06	0.51	1.11	1.23	1.53	1.26	From 4-digit model
8240	Wood-products machine operators	**2**	5374	1.78	0.85	1.87	2.11	2.48	2.14	From 3 digit model

8285	Wood and related products assemblers	**1**	1340	1.27	0.61	1.33	1.47	1.83	1.51	From 4-digit model
9212	Forestry labourers	**1**	14	1.26	0.6	1.32	1.45	1.81	1.5	From 4-digit model
9313	Building construction labourers	**1**	135	1.74	0.83	1.82	2.01	2.51	2.07	From 4-digit model

5 TABLES AND FIGURES FOR POTENTIAL USE IN MANUSCRIPT TO BE DRAFTED (NON-EXHAUSIVE LIST)

In the following a list of potential tables and figures to be used on the upcoming manuscript are shown. It has to be noted that these outputs are not final versions and they may be both modified and/or replaced by others that may be of greater relevance.

Table 1. Basic characteristics of wood dust measurements included in the final dataset

Covariates		**Dust** **n (%)**
General characteristics		
Type of measurements	Personal	12,653 (100)
Reason for sampling	Survey	4,734 (37.3)
	Inspection/compliance	160 (1.3)
	Unknown	7,759 (37.4)
Sampling strategy	Representative	12,471 (98.6)
	Not representative	182 (1.4)
ASTHMA-JEM score	Non-exposed	735 (5.8)
	Low-exposed	2,800 (22.1)
	High exposed	9,118 (72.06)
Year of measurement	Years, mean (SD)	1997 (4.7)
Country	Denmark	3,719 (29.4)
	Norway	39 (0.3)
	The Netherlands	342 (2.7)
	Finland	642 (5.1)
	Great Britain	499 (3.9)
	France	7,412 (58.6)
Measurement characteristics		
Sampling duration	Minutes, mean (SD)	265.9 (108.8)
Type of sampler	Closed-faced cassette	7752 (61.3)
	Open faced cassette	129 (1.0)
	7-hole sampler	136 (1.1)
	IOM	4636 (36.6)
Measurements <LOD		403 (3.2)

Table 2. Literature reported relative efficiencies of different samplers used for sampling of wood dusts. Results are summarised with the IOM sampler as a reference.

Type of sampler	**Correction factor**									
	Kromhout et al. 2005	Tatum et al., 2001	Liden et al., 2000	Kauffer et al., 2010	Vaughan et al., 1990	Werner et al., 1996	Schlünssen et al., 2001	Harper and Muller., 2002	Martin and Zalk. 1998	**Median**
IOM	1	1	1	1	1	1	1	1	1	**1**
Millipore closed faced	2.00	1.85[a]		2.02[a]		1.79[a;] 1.79[b]	1.59	3.35 [a]	5.5	**1.92**
Millipore open faced	2.21		2.5							**2.36**
7 hole sampler		1.38			1.28[c] 1.36[d]					**1.36**

a =4mm orifice; b=5.6 mm orifice; c=Casella 7-hole; d=J.S. Holdings 7-hole;

Table 3. Results from linear mixed effect regression describing estimated temporal trends in wood dust exposure in the database. Results are based on 12,653 personal endotoxin measurement collected between 1978 and 2004.

Model	***β*** **Year (ref 2001)**	***e***	**p-value**	**Annual trend (%)**	**AIC**	**biscoσ^2**	**wiscoσ^2**
Wood dust							
Naïve					41069.5	0.342	1.494
+ year*	-0.115	0.002	<.0001	-10.9	38509.5	0.178	1.221
+ year, country	-0.094	0.002	<.0001	-9.0	36931.2	0.054	1.078
+ year, country, sampling time	-0.081	0.002	<.0001	-7.8	36592.1	0.040	1.048
+ year, country, sampling time, ASTHMA-JEM score	-0.081	0.002	<.0001	-7.8	36596.6	0.045	1.048

β=regression coefficient for log-transformed exposure data; *e*=standard error; *p*=p-value; annual trend=% of change in exposure per year estimated as 100*(exp(β)-1); $_{bisco}\sigma^2$ = between job variance; $_{wisco}\sigma^2$= within-Job (residual) variance;. Naive estimates are derived from a model without fixed

Table 4. Linear mixed effect results describing the relationships between log-transformed wood dust levels and fixed effects. Results are based in 12653 measurements collected between 1978 and 2004.

Parameter	*β*	e	p-value
intercept	1.471	0.102	<.001
Year (ref 1997)	-0.081	0.002	<.001
Sampling time, min	-0.0019	0.0001	<.001
Country			
DK+NO	-0.912	0.027	<.001
NL	-0.129	0.065	0.05
FI	-0.031	0.045	0.5
UK	0.190	0.049	<.001
FR	Ref	.	.
Asthma-JEM score			
No exposure	-0.033	0.133	0.8
Low exposure	0.04	0.134	0.8
High exposure	Ref		
Between-ISCO variance (naïve estimates)	0.045	0.019	<.01
Within-ISCO variance (naïve estimates)	1.05	0.013	<.0001
% of explained variance by the model			
Between-ISCO variance	86.8		
Within-ISCO variance	29.8		
Total variance	40.5		

b=beta for log-transformed exposure levels, e=standard error

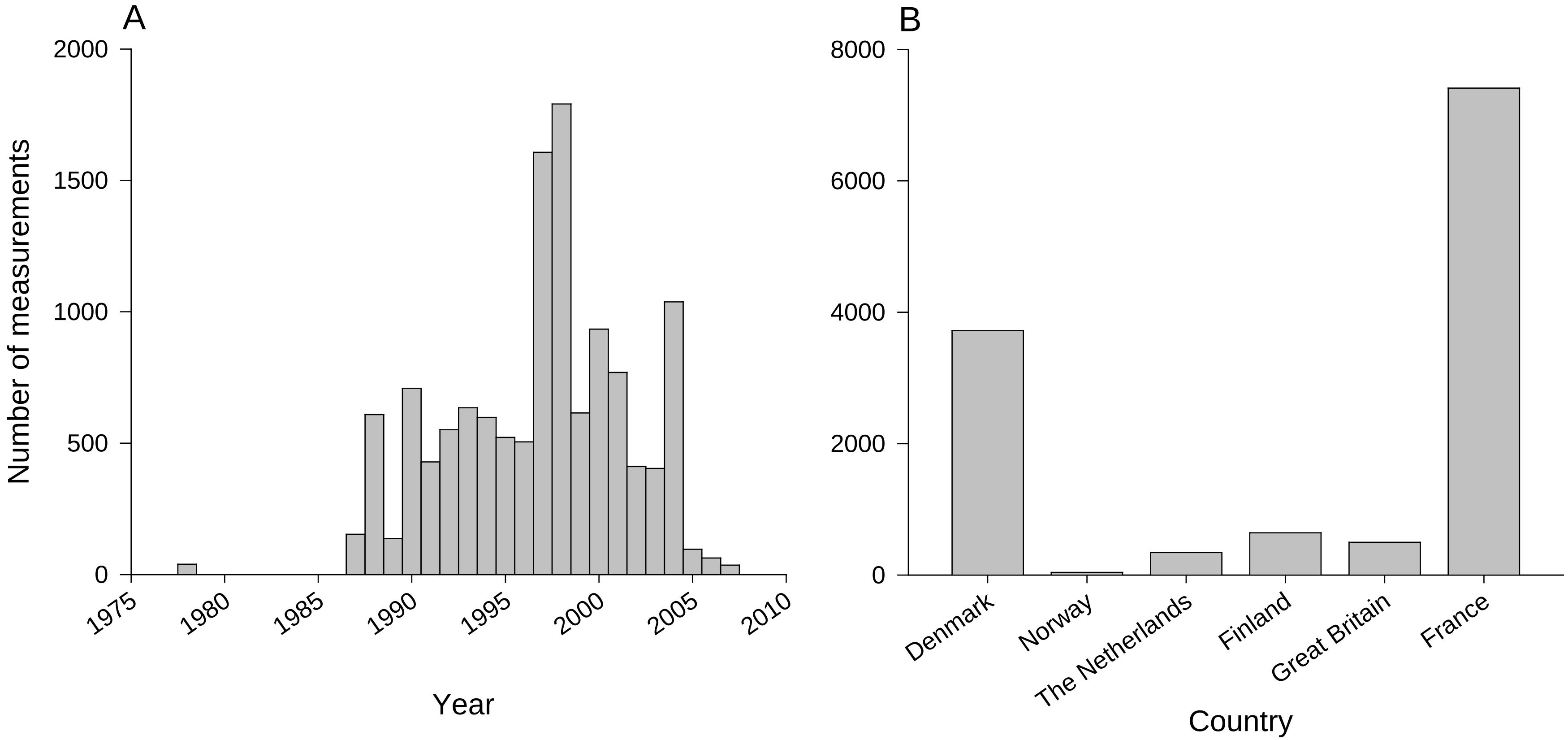


Figure 1. Distribution of measurements in the database across years (A) and countries (B).

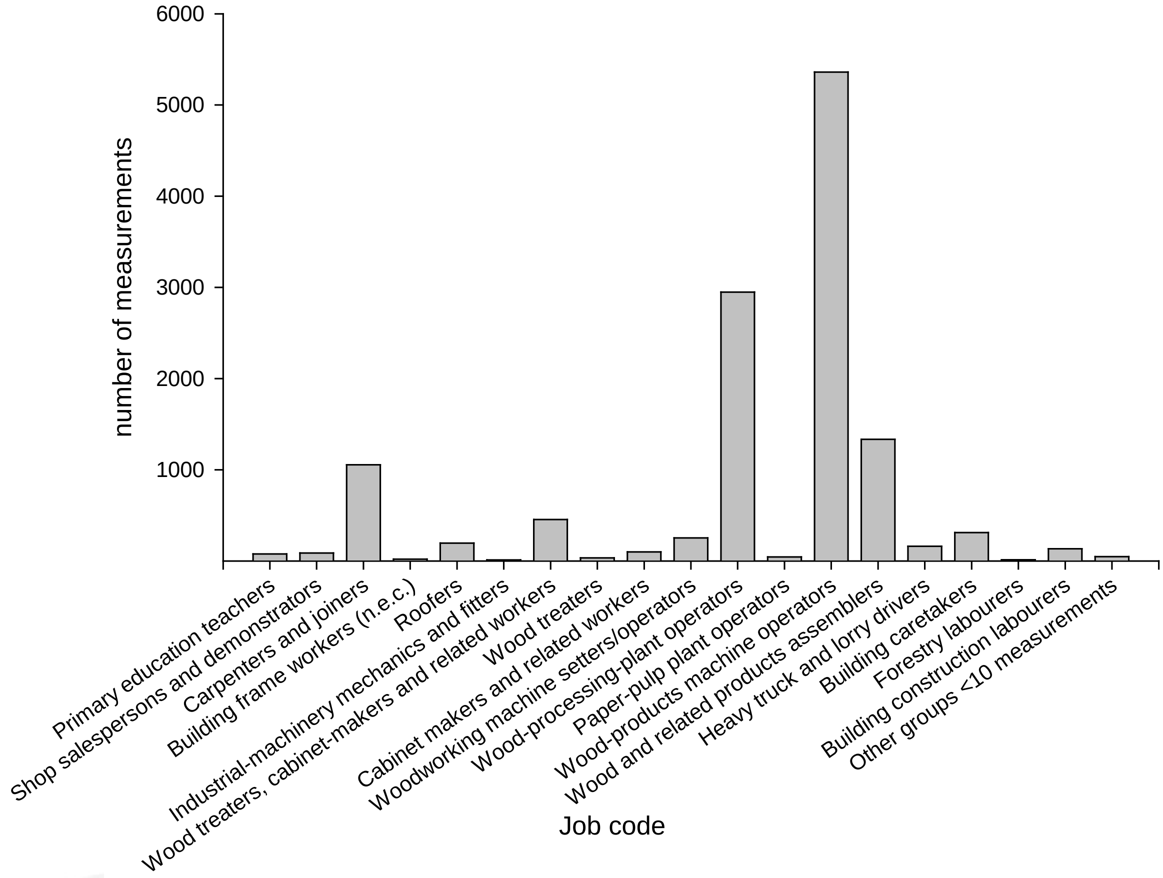


Figure 2. Distribution of measurements in the database across job-titles.

Table 5. Predicted levels of wood dust exposure for the reference year for the 5 highest and lowest exposed job-codes

ISCO88 code	ISCO STANDARD DESCRIPTION	Predicted wood dust level (mg/m^3) for the year 1997	
		Non-country specific estimate	Range of country-specific estimates
Highest exposed codes			
7132	Floor layers and tile setters	1.86	0.89-2.68
8240	Wood-products machine operators	1.78	0.85-2.48
9313	Building construction labourers	1.74	0.83-2.51
7131	Roofers	1.71	0.82-2.68
7420	Wood treaters, cabinet-makers and related trades workers	1.65	0.79-2.30
Lowest exposed codes			
9212	Forestry labourers	1.26	0.60-1.81
7330	Handicraft workers in wood, textile, leather and related materials	1.20	0.5-1.46
7423	Woodworking machine setters and setter-operators	1.15	0.55-1.66
8141	Wood-processing-plant operators	1.06	0.51-1.53
8140	Wood-processing- and papermaking-plant operators	1.04	0.50-1.46

APPENDIX 1. DISTRIBUTION OF SAMPLING TIME (IN MINUTES) ACROSS COUNTRIES.

The following SAS output describes the distribution of sampling time in personal measurements of the overall dataset (n=35201) across the different countries.

Individual country results: Denmark

The univariate procedure

Moments			
N	3971	**Sum Weights**	3971
Mean	318.492319	**Sum Observations**	1264733
Std Deviation	98.0714803	**Variance**	9618.01524
Skewness	0.27531537	**Kurtosis**	0.72020882
Uncorrected SS	440991267	**Corrected SS**	38183520.5
Coeff Variation	30.7924161	**Std Error Mean**	1.5562981

Basic Statistical Measures			
Location		**Variability**	
Mean	318.4923	**Std Deviation**	98.07148
Median	295.0000	**Variance**	9618
Mode	285.0000	**Range**	928.00000
		Interquartile Range	150.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	936
99%	510
95%	470
90%	450
75% Q3	405
50% Median	295
25% Q1	255
10%	195
5%	175
1%	105
0% Min	8

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
8	1525	801	1689
8	1524	837	1690
20	3950	845	1728
25	2801	921	1726
30	2389	936	1631

Individual country results: Norway

The univariate procedure

Moments			
N	41	**Sum Weights**	41
Mean	322	**Sum Observations**	13202
Std Deviation	101.533984	**Variance**	10309.15
Skewness	-0.9926539	**Kurtosis**	1.3828597
Uncorrected SS	4663410	**Corrected SS**	412366
Coeff Variation	31.5322933	**Std Error Mean**	15.8569443

Basic Statistical Measures			
Location		**Variability**	
Mean	322.0000	**Std Deviation**	101.53398
Median	323.0000	**Variance**	10309
Mode	285.0000	**Range**	471.00000
		Interquartile Range	119.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	494
99%	494
95%	429
90%	423
75% Q3	404
50% Median	323
25% Q1	285
10%	206
5%	162
1%	23
0% Min	23

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
23	3988	423	4003
51	4002	425	4004
162	3976	429	3974
192	3990	471	3995
206	3972	494	3998

Individual country results: Netherlands

The univariate procedure

Moments			
N	343	**Sum Weights**	343
Mean	475.54519	**Sum Observations**	163112
Std Deviation	64.1885255	**Variance**	4120.16681
Skewness	-2.1137061	**Kurtosis**	4.67367696
Uncorrected SS	78976224	**Corrected SS**	1409097.05
Coeff Variation	13.4978814	**Std Error Mean**	3.4658546

Basic Statistical Measures			
Location		Variability	
Mean	475.5452	Std Deviation	64.18853
Median	498.0000	Variance	4120
Mode	495.0000	Range	406.00000
		Interquartile Range	34.00000

Note: The mode displayed is the smallest of 2 modes with a count of 21.

Quantiles (Definition 5)	
Level	Quantile
100% Max	571
99%	563
95%	527
90%	520
75% Q3	510
50% Median	498
25% Q1	476
10%	375
5%	335
1%	228
0% Min	165

Extreme Observations			
Lowest		Highest	
Value	Obs	Value	Obs
165	4180	559	4209
190	4217	563	4186
220	4157	564	4264
228	4156	569	4269
250	4182	571	4110

Individual country results: Finland

The univariate procedure

Moments			
N	652	Sum Weights	652
Mean	269.760736	Sum Observations	175884
Std Deviation	81.9947422	Variance	6723.13775
Skewness	-0.5149081	Kurtosis	0.52797668
Uncorrected SS	51823360	Corrected SS	4376762.67
Coeff Variation	30.3953583	Std Error Mean	3.21116193

Basic Statistical Measures			
Location		Variability	
Mean	269.7607	Std Deviation	81.99474
Median	282.0000	Variance	6723
Mode	282.0000	Range	424.00000
		Interquartile Range	60.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	480
99%	480
95%	375
90%	360
75% Q3	300
50% Median	282
25% Q1	240
10%	120
5%	120
1%	60
0% Min	56

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
56	4893	480	4822
60	4975	480	4981
60	4908	480	4982
60	4857	480	4983
60	4855	480	4984

Individual country results: Great Britain

The univariate procedure

Moments			
N	635	**Sum Weights**	635
Mean	246.234646	**Sum Observations**	156359
Std Deviation	79.1344944	**Variance**	6262.2682
Skewness	0.69614191	**Kurtosis**	4.83215013
Uncorrected SS	42471281	**Corrected SS**	3970278.04
Coeff Variation	32.1378392	**Std Error Mean**	3.14035662

Basic Statistical Measures			
Location		**Variability**	
Mean	246.2346	**Std Deviation**	79.13449
Median	252.0000	**Variance**	6262
Mode	273.0000	**Range**	796.00000
		Interquartile Range	72.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	804
99%	476
95%	367
90%	327
75% Q3	277
50% Median	252
25% Q1	205

10%	152
5%	103
1%	58
0% Min	8

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
8	5279	485	5371
22	5300	492	5370
26	5235	500	5368
30	5608	501	5367
48	5334	804	5166

Individual country results: Germany

The univariate procedure

Moments			
N	12369	**Sum Weights**	12369
Mean	127.013776	**Sum Observations**	1571033.4
Std Deviation	52.6142627	**Variance**	2768.26064
Skewness	3.48575294	**Kurtosis**	13.1705146
Uncorrected SS	233780733	**Corrected SS**	34237847.6
Coeff Variation	41.4240598	**Std Error Mean**	0.47308175

Basic Statistical Measures			
Location		**Variability**	
Mean	127.0138	**Std Deviation**	52.61426
Median	120.0000	**Variance**	2768
Mode	120.0000	**Range**	486.00000
		Interquartile Range	3.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	495.0
99%	364.2
95%	184.8
90%	135.0
75% Q3	123.0
50% Median	120.0
25% Q1	120.0
10%	91.2
5%	75.0
1%	49.8
0% Min	9.0

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
9.0	6607	394.2	11205
12.0	7651	405.0	17316

13.2	14956	405.0	17317
15.0	10319	450.0	10638
16.2	14712	495.0	10057

Individual country results: France

The univariate procedure

Moments			
N	7881	**Sum Weights**	7881
Mean	225.435985	**Sum Observations**	1776661
Std Deviation	103.747517	**Variance**	10763.5472
Skewness	0.57907035	**Kurtosis**	0.43123642
Uncorrected SS	485340075	**Corrected SS**	84816752
Coeff Variation	46.0208322	**Std Error Mean**	1.16865695

Basic Statistical Measures			
Location		**Variability**	
Mean	225.4360	**Std Deviation**	103.74752
Median	202.0000	**Variance**	10764
Mode	180.0000	**Range**	1178
		Interquartile Range	152.00000

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	1183
99%	474
95%	405
90%	375
75% Q3	305
50% Median	202
25% Q1	153
10%	102
5%	75
1%	45
0% Min	5

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
5	21609	591	20540
8	18012	623	20941
9	18489	630	20697
11	23561	635	20698
11	21965	1183	22457

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