CrossMark

ORIGINAL ARTICLE

Occupational exposure in the removal and disposal of asbestos-containing materials in Italy

Alberto Scarselli[1] · Marisa Corfiati[1] · Davide Di Marzio[1]

Abstract

Purpose A great variety of asbestos-containing materials are present in both residential and work settings because of the widespread use made in the past, and many occupational activities still entail the risk of asbestos exposure in Italy, more than 2 decades after the total national ban, mainly those involved in the removal and disposal of asbestos. The aim of the study was to evaluate the level and extent of asbestos exposure in Italy between the years 1996–2013 in the sector of asbestos abatement.

Methods Data were collected from firm registries of asbestos-exposed workers and descriptive statistics were calculated for exposure-related variables.

Results Overall, 15,860 measurements of asbestos exposure were selected from the national database of registries, mostly referring to the construction sector ($N = 11,353$). Despite the mean exposure levels are low, the air concentration of asbestos fibers measured during these activities may overcome the action level established by the Italian legislation and, in a limited number of cases, can exceed even the occupational limit value. Among occupations at higher risk, there are also garbage collectors and insulation workers.

Conclusions Starting from the analysis of the Italian database of occupational exposure registries, this study outlines the current levels of asbestos exposure in abatement-related sectors, discussing their possible implications for public health policies and surveillance programs.

✉ Alberto Scarselli
   a.scarselli@inail.it

1 Department of Occupational and Environmental Medicine, Epidemiology and Hygiene, Italian Workers' Compensation Authority (INAIL), Rome, Italy

Introduction

Adverse health effects from exposure to airborne asbestos fibers were known since the beginning of twentieth century, even if the first epidemiological evidences of cancer causing came in 1950s. The minerals classified as asbestos by Italian law are: crocidolite (blue asbestos), amosite (brown asbestos), anthophyllite, actinolite, tremolite and chrysotile (white asbestos). These fibrous silicates are widely distributed in the earth's crust and possess unique properties of tensile strength, poor heat conduction and chemical resistance. The biological effects of asbestos fibers depend on their chemico-physical characteristics, such as size, solubility and biopersistence (Boulanger et al. 2014; Berman and Crump 2008). Canada and South Africa were the world's leading producers of asbestos, whereas in Europe, the major producers were Italy, Greece and the Soviet Union. Despite the ban in many countries, asbestos is still widely used in some parts of the world due to its low price and its durability as a construction material; indeed, there is still a very large market for asbestos cement products. Currently, most of the asbestos extracted is used in Asia and Eastern Europe (Stayner et al. 2013; Le et al. 2011).

In Italy, since post-war period up to the ban introduced in 1992, 3,748,550 tons of raw asbestos were produced, with a peak of 160,000 tons per annum between 1976 and 1980. Asbestos was mainly used in the asbestos cement industry, but also for the insulation of buildings, ships and trains (paints and plasters, vinyl flooring and wallpapers, ceramic tiles), in textile products (blankets, ropes and tapes), adhesives and friction materials (Marinaccio et al.

2012). The use of asbestos was banned in Italy in 1992 by Law no. 257, which set the deadline and procedures for ending to all activities involving the processing and extraction of this mineral. After this date, the only permitted work activities involving asbestos exposure are asbestos remediation, insulation removal and disposal. All firms regularly engaged in these activities have to be registered within specific categories in the Italian national registry of environmental managers, held by the Ministry of environment and protection of land and sea.

Asbestos has been widely used in building materials, either in industrial or residential settings, and remains mostly in place, representing a health hazard for workers engaged in their maintenance and abatement, as well as for unaware population groups. A great number of epidemiological studies have been carried out since the 1960s and 1970s on groups of workers occupationally exposed to asbestos. These studies have shown that workers exposed to asbestos have an increased risk of lung cancer, mesothelioma, diffuse interstitial lung diseases and benign pleural abnormalities (acute or chronic pleurisy, pleural plaques, diffuse pleural thickening and round atelectasis). There are also recent evidences that exposure to asbestos is associated with larynx and ovarian cancer and, to a smaller extent, with other cancers (pharynx, stomach and colon) and immune disorders (IARC 2012; Pfau et al. 2014). As well as for asbestosis, a clear dose–response relationship has been demonstrated for neoplastic diseases, such as mesothelioma and lung cancer, but in these cases, no evidence of a threshold exposure level emerges from the scientific literature (Wolff et al. 2015). This is also confirmed by well-documented mesothelioma occurrence from environmental asbestos exposure (Maule et al. 2007; Corfiati et al. 2015). Few studies have measured the level of asbestos exposure in abatement workers and even less in those involved in asbestos-containing material disposal (Lange et al. 1996, 2006, 2008; Miscetti et al. 2014; Bujak-Pietrek and Szadkowska-Stańczyk 2012; Dumortier and De Vuyst 2012; Dufresne et al. 2009; Mlynarek et al. 1996; Price et al. 1992). Risk excesses for mesothelioma and lung cancer were found in construction workers (Consonni et al. 2015; Welch et al. 2015; Järvholm and Englund 2014) as well as in asbestos removal workers (Frost et al. 2008), mainly referring to levels and circumstances of asbestos exposure belonging to the past. The health effects of current exposures in the asbestos removal and disposal are expected to be smaller, also taking into account the enforcement of prevention and protection measures at workplace introduced by the most recent European Union directives no. 2003/18/CE and 2009/148/CE. Nevertheless, these effects may not have been fully evaluated until now because of the long latency of neoplastic diseases and difficulties in conducting large cohort studies. Many epidemiological surveillance systems have also provided the evidence of non-occupational mesothelioma cases occurring during home renovation (Olsen et al. 2011).

In Italy, the workers' compensation authority (INAIL) centrally collects and stores the registries of exposed workers that firms involved in activities entailing the risk of asbestos exposure are obliged to institute by law. The objective of this study was to provide summary statistics on the level and extent of occupational exposures to asbestos fibers in Italy between the years 1996–2013 during the removal and disposal of asbestos-containing materials.

Methods

Data gathering

Data collected by INAIL are stored in a database named SIREP. The SIREP database has been fully described elsewhere (Scarselli et al. 2007). In brief, Italian law requires that employers collect data on workers' exposures to carcinogens and report these information to INAIL every 3 years. Reporting is mandatory for carcinogens classified as 1 and 2 by the European Union (1, substance known to be carcinogenic to humans; 2, substances that should be regarded as if carcinogenic to humans). As regards occupational exposure to asbestos, the notification of registry is mandatory only if exposure level exceeds the value of 0.01 fibers per cubic centimeter of air, i.e., 1/10 of the occupational exposure limit value (OEL). However, some employers (about 49 % of firms that notified the registry) have decided to voluntarily notify the registry, even if the asbestos exposure level was under this action limit. Employers are required to report carcinogen type, personal and occupational data of exposed employees, and exposure levels. The information reported by employers is standardized and includes the firm's economic activity sector and workforce size; workers' personal data and job type; year of measurement and level of exposure (magnitude, frequency and duration). Employers are responsible for the measurement procedures and air sampling methods, to be carried out in accordance with European standards, which provide technical guidance to implement a dust-monitoring strategy (CEN 1995). The Italian law specifies phase contrast optical microscopy (PCOM) and scanning electron microscopy (SEM) as the standard techniques to count airborne asbestos fibers per unit volume (Health Decree Ministry of 6 September 1994).

Data selection

A total of 15,860 measurements of asbestos fibers, representing 6359 exposures (2470 workers in 241 different

firms) between 1996 and 2013 were obtained from the SIREP database and selected for the analysis (3222 exposures were excluded from analysis since the measurement was not specified). The airborne concentration of asbestos fibers for some exposures ($N = 2229$) was measured at least twice between 1996 and 2013. These multiple measurements always refer to the same asbestos form, i.e., actinolite, amosite, anthophyllite, chrysotile, crocidolite or tremolite. Measurements ($N = 4876$) that were below the analytical limit of detection (LOD) were replaced with the LOD value divided by two (LOD/2) (Hornung and Reed 1990). Air sampling measurements were collected over an 8 h work shift. The type of sampling methodology (personal or stationary) was reported in a very limited number of measurements (<5 %), thus not usable for the analysis. In order to increase the precision of the estimates, only sectors and occupations having more than 50 measurements were considered in the descriptive analysis. International standard classifications were used to code firm economic activity sector (NACE Rev. 1) and worker occupation (ISCO-88). To investigate the regional distribution of firms that have notified asbestos exposures to INAIL, the proportion of firms currently involved in its removal and disposal, i.e., those registered in the national registry of environmental managers (in accordance with legislative decree 152/2006), was evaluated and mapped for each Italian region (Italian Ministry of Environment and Protection of Land and Sea 2015). In particular, the registration is required by law for firms whose activities fall into the following categories: category 5, collection and transport of hazardous waste; category 10, remediation of asbestos-contaminated materials.

Descriptive statistical analyses were used to calculate the arithmetic and geometric means (AM, GM) of asbestos exposure levels, in addition to 95 % confidence intervals (CI), arithmetic and geometric standard deviations (SD, GSD) and the 75th percentile. Statistical analysis was performed using SPSS software package v. 22 (SPSS Inc., Chicago, IL), and geographical data were mapped using MapInfo software v. 8 (Pitney Bowes Inc., Troy, NY).

Results

Descriptive statistics

The mean airborne concentration of asbestos fibers in workplaces was 0.025 f/cc ($N = 15,860$, AM = 0.025 f/cc, GM = 0.006 f/cc, GSD = 6.55, 95 % CI 0.0058–0.0061, 75th percentile = 0.0318). In the analysis by mineral type, fiber concentrations were the highest for the anthophyllite ($N = 446$, GM = 0.0093 f/cc, GSD = 5.60, 75th percentile = 0.050) and actinolite ($N = 420$, GM = 0.0088 f/cc,

GSD = 5.54, 75th percentile = 0.050) and lowest for chrysotile ($N = 8403$, GM = 0.0040 f/cc, GSD = 6.46, 75th percentile = 0.011). The analytic method most frequently utilized to count asbestos fibers was the PCOM (57 % of measurements), followed by the SEM technique (2 %). Measurements made by these two main methods of fibers counting (SEM and PCOM) gave the same AM (0.020 f/cc) but different values of GM ($N = 249$, GM = 0.011, GSD = 3.65, 75th percentile = 0.024 for the ones performed by SEM, and $N = 9020$, GM = 0.006, GSD = 7.18, 75th percentile = 0.050 for those by PCOM).

The 37.3 % of measurements was equal or >0.01 f/cc (the action level) while the 4.3 % resulted to be equal or over the OEL. In about 8 % of firms the concentration of asbestos fibers was above the OEL (>0.1 f/cc), and the 5 % of all exposed workers suffered an exposure level upper to this limit. If we limited the analysis only to mandatory exposure reporting, i.e., those exceeding the action limit, the mean asbestos exposure level was 0.066 f/cc ($N = 5521$, GM = 0.045, GSD = 2.11, 75th percentile = 0.060).

The greatest number of measurements occurred in the construction sector ($N = 11,353$), which also showed a higher mean level of exposure (AM = 0.029 f/cc, GM = 0.007 f/cc, GSD = 5.82) than the sewage and refuse disposal sector ($N = 4507$, AM = 0.016 f/cc, GM = 0.003 f/cc, GSD = 7.67). Most of the data were sent by micro (<10 employees)- and small-sized (10–20 employees) firms, corresponding to over 78 % of all measurements, while larger firms are mainly in the sector of collection and disposal of solid waste (46 % of firms with more than 100 employees). The asbestos exposure level by industrial sector is shown in Table 1, and the distribution by occupational group (only male) is provided in Table 2. When only measurements exceeding the action limit (>0.01) were selected, mean levels of exposure resulted even higher for constructions ($N = 4225$, AM = 0.071 f/cc, GM = 0.050 f/cc, GSD = 2.03) than for the sector of sewage and refuse disposal ($N = 1296$, AM = 0.050 f/cc, GM = 0.030 f/cc, GSD = 2.09). The percentage of measurements overwhelming the OEL was 2.86 % in constructions and 1.13 % in the sewage and refuse disposal. The occupational groups showing the highest fraction of measurements above the OEL were insulation workers and building finishers with, respectively, 4.75 and 12.12 %.

As regard the job tasks in men, the first three groups contain more than 75 % of all measurements. These are, in rank order, Eternit removal operators ($N = 9642$, AM = 0.030 f/cc, GM = 0.0058 f/cc, GSD = 7.97, 75th percentile = 0.047), insulation removal operators ($N = 3329$, AM = 0.015 f/cc, GM = 0.0051 f/cc, GSD = 4.02, 75th percentile = 0.014) and asbestos-containing materials disposal workers ($N = 1031$, AM = 0.031 f/cc, GM = 0.0138 f/cc, GSD = 5.08, 75th percentile = 0.050).

Table 1 Descriptive statistics of asbestos exposure by economic activity sector (SIREP, 1996–2013)

Economic activity sector (NACE code)	N	AM	SD	GM	GSD	(95 % CI)	P75
Demolition and wrecking of buildings; earth moving (45.11)	1454	0.005	0.032	0.003	2.31	0.0029–0.0031	0.005
General construction of buildings and civil engineering works (45.21)	986	0.010	0.022	0.004	3.76	0.0039–0.0046	0.010
Erection of roof covering and frames (45.22)	1208	0.045	0.155	0.006	11.30	0.0053–0.0070	0.050
Construction of highways, roads, airfields and sport facilities (45.23)	65	0.004	0.001	0.004	1.07	0.0038–0.0039	0.004
Other construction work involving special trades (45.25)	6650	0.036	0.090	0.011	5.63	0.0108–0.0117	0.050
Insulation work activities (45.32)	725	0.011	0.018	0.006	3.24	0.0052–0.0062	0.009
Other building installation (45.34)	79	0.017	0.019	0.008	3.73	0.0061–0.0109	0.014
Other building completion (45.45)	111	0.009	0.022	0.001	16.63	0.0004–0.0011	0.005
Sewage and refuse disposal, sanitation and similar activities (90.00)	4507	0.016	0.089	0.003	7.67	0.0032–0.0036	0.014
Other activities	75	–		–	–	–	

N Number of 8-h TWA exposure measurements (f/cc), *AM* arithmetic mean, *SD* standard deviation, *GM* geometric mean, *GSD* geometric standard deviation, *CI* confidence interval, *P75* 75th percentile. Only sectors with at least 50 exposure measurements are shown

Table 2 Descriptive statistics of asbestos exposure by occupational group (male only; SIREP, 1996–2013)

Occupational group (ISCO-88 code)	N	AM	SD	GM	GSD	(95 % CI)	P75
Civil engineering technicians (3112)	102	0.127	0.51	0.0128	7.23	0.0087–0.0187	0.050
Safety, health and quality inspectors (3152)	3256	0.022	0.03	0.0072	5.81	0.0068–0.0076	0.050
Bricklayers and stonemasons (7122)	774	0.010	0.02	0.0036	4.15	0.0033–0.0040	0.009
Concrete placers, concrete finishers and related workers (7123)	457	0.003	0.01	0.0016	3.62	0.0014–0.0018	0.002
Carpenters and joiners (7124)	76	0.012	0.02	0.0046	3.94	0.0034–0.0062	0.018
Insulation workers (7134)	5111	0.033	0.09	0.0065	9.55	0.0061–0.0069	0.050
Plumbers and pipe fitters (7136)	55	0.009	0.02	0.0025	3.55	0.0018–0.0035	0.003
Building finishers and related trade workers not elsewhere classified (7139)	504	0.066	0.29	0.0070	6.50	0.0060–0.0083	0.016
Sheet-metal workers (7213)	104	0.036	0.03	0.0189	5.30	0.0137–0.0261	0.060
Cement and other mineral products machine operators (8212)	1351	0.019	0.02	0.0075	5.55	0.0069–0.0082	0.044
Chemical-products machine operators not elsewhere classified (8229)	156	0.017	0.03	0.0086	2.97	0.0072–0.0102	0.012
Garbage collectors (9161)	370	0.047	0.05	0.0105	13.68	0.0081–0.0138	0.100
Building construction laborers (9313)	341	0.009	0.02	0.0032	3.14	0.0028–0.0036	0.005
Manufacturing laborers (9320)	2879	0.014	0.05	0.0046	3.71	0.0044–0.0048	0.011
Other groups	201	–		–	–	–	

N Number of 8-h TWA exposure measurements (f/cc), *AM* arithmetic mean, *SD* standard deviation, *GM* geometric mean, *GSD* geometric standard deviation, *CI* confidence interval, *P75* 75th percentile. Only groups with at least 50 exposure measurements are shown

The distribution of exposure level (AM) and 95 % confidence limits by job task and economic sector of activity is shown in Fig. 1. Again, selecting only measurements exceeding the action limit, mean levels of exposure resulted to be more elevated (Eternit removal operators: $N = 3223$, AM = 0.082 f/cc, GM = 0.053 f/cc; insulation removal operators: $N = 1100$, AM = 0.045 f/cc, GM = 0.032 f/cc; asbestos-containing materials disposal workers: $N = 359$, AM = 0.049 f/cc, GM = 0.047 f/cc).

Regarding the distribution of asbestos exposure level by workforce size, micro firms (<10 employees) had the lowest exposure risk ($N = 1528$, GM = 0.0032 f/cc, 95 % CI 0.0029–0.0035, 75th percentile = 0.015), whereas the highest ($N = 5020$, GM = 0.012 f/cc, 95 % CI 0.0112–0.0123,

75th percentile = 0.050) was found in larger firms (20–50 employees). During the analyzed time period (1996–2013), the highest level of exposure was recorded in 2002 ($N = 333$, AM = 0.098 f/cc, GM = 0.026 f/cc, 95 % CI 0.021–0.032, 75th percentile = 0.15), while the largest number of measurements in 2008 ($N = 2966$, AM = 0.030 f/cc, GM = 0.009 f/cc, 95 % CI 0.0082–0.0093, 75th percentile = 0.05). Figure 2 shows a clear inhomogeneity in the distribution of exposure levels by industry type, workers occupation and time period. Indeed, high exposures (>0.1) are concentrated only in a few situations, especially in the sector of other construction work (NACE code: 45.25), among insulation workers (ISCO-88 code: 7134) and during the 1999–2004 time period.
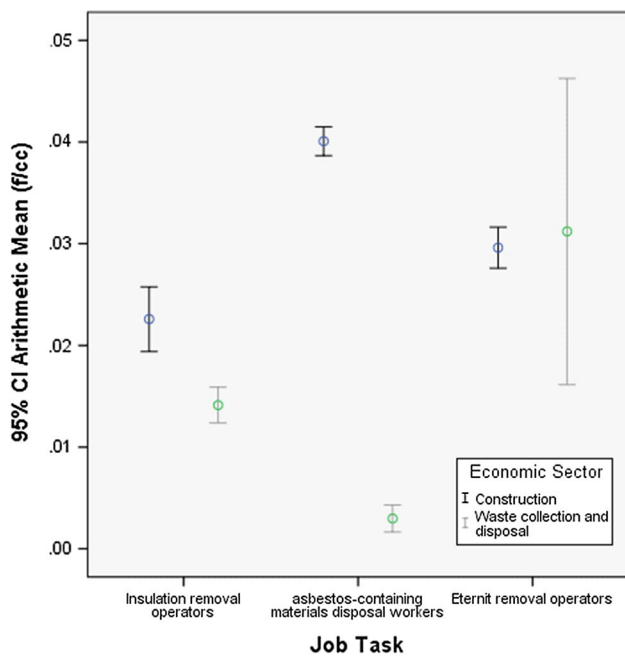
Fig. 1 Distribution of asbestos exposure level (AM) and 95 % CI by job task and economic sector of activity (SIREP, 1996–2013)

In Fig. 3 is illustrated the distribution (%) of firms that have reported data, according to the national registry of environmental managers (Italian Ministry of Environment and Protection of Land and Sea 2015). The central area of Italy (Marche 6.78 % and Umbria 6.19 %) is the one with the highest percentage of firms reporting the registry, while the highest absolute count of firms refers to Lombardy region (N = 61) in the northwest. If only firms reporting air asbestos concentrations higher than the action level are considered (mandatory reporting), 1.6 % of firms in the national registry of environmental managers emerges to have transmitted the workers' exposure register, percentage varying between 0 and 3 across regions.

Discussion

The SIREP system, which tracks data about workers exposed to carcinogens, represents one of the most reliable information sources on current occupational asbestos exposure in Italy. The epidemiological usefulness of such a kind of surveillance system has been acknowledged for planning public health policies either at national and international level (Koné Pefoyo et al. 2014; Arrandale et al. 2014). In particular, by making available a certain amount of standardized data collected from a large territory over time, SIREP was able to compare in space and time the occupational asbestos exposure level, to provide information about the real exposure situation at country level, and indirectly to
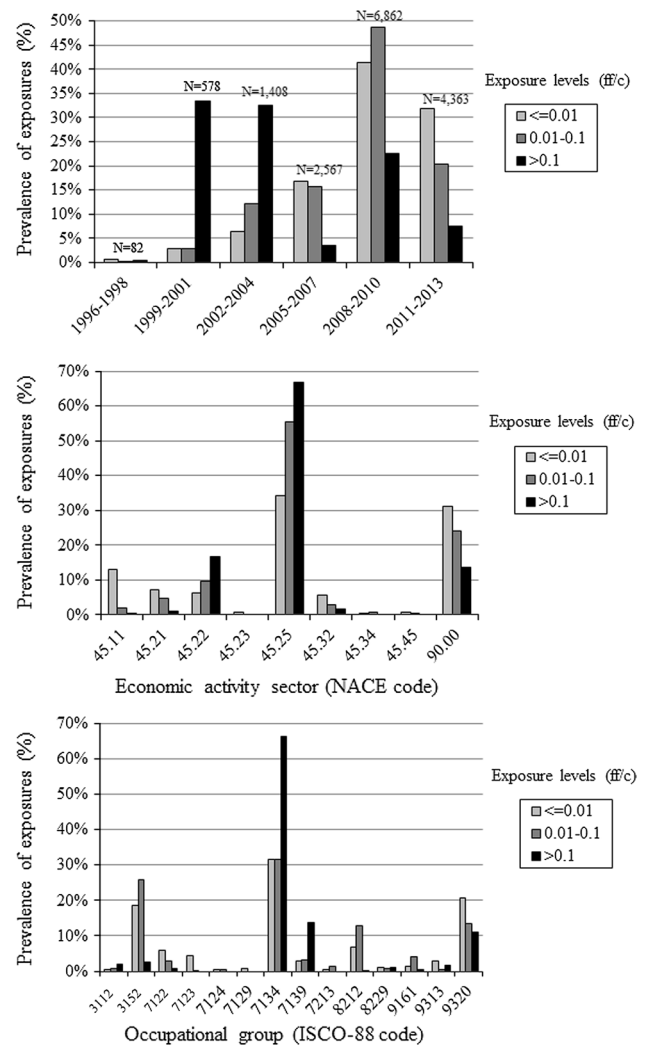

Fig. 2 Distribution of prevalence (%) of asbestos exposure levels (broken down by classes of values) by time period, economic activity sector and occupational group (SIREP, 1996–2013)

monitor the implementation of prevention measures among different Italian regions. This study confirms that currently many construction workers have exposure levels above the action limit established by national legislation (0.01 f/cc), and in a very limited fraction of cases also exceeding the EU limit value (0.1 f/cc). These findings are in line with the most recent studies conducted in United States and European countries in the asbestos abatement sector (Miscetti et al. 2014; Bujak-Pietrek and Szadkowska-Stanczyk 2012; Lange et al. 2008). The vast majority of measurements exceeding the OEL in constructions were actually recorded in 45.25 NACE sector ("Other construction work involving special trades"), which includes most of asbestos abatement specialized firms, confirming the importance of targeted control programs by labor inspection authorities. The measured level of asbestos fibers is lower in the sector of
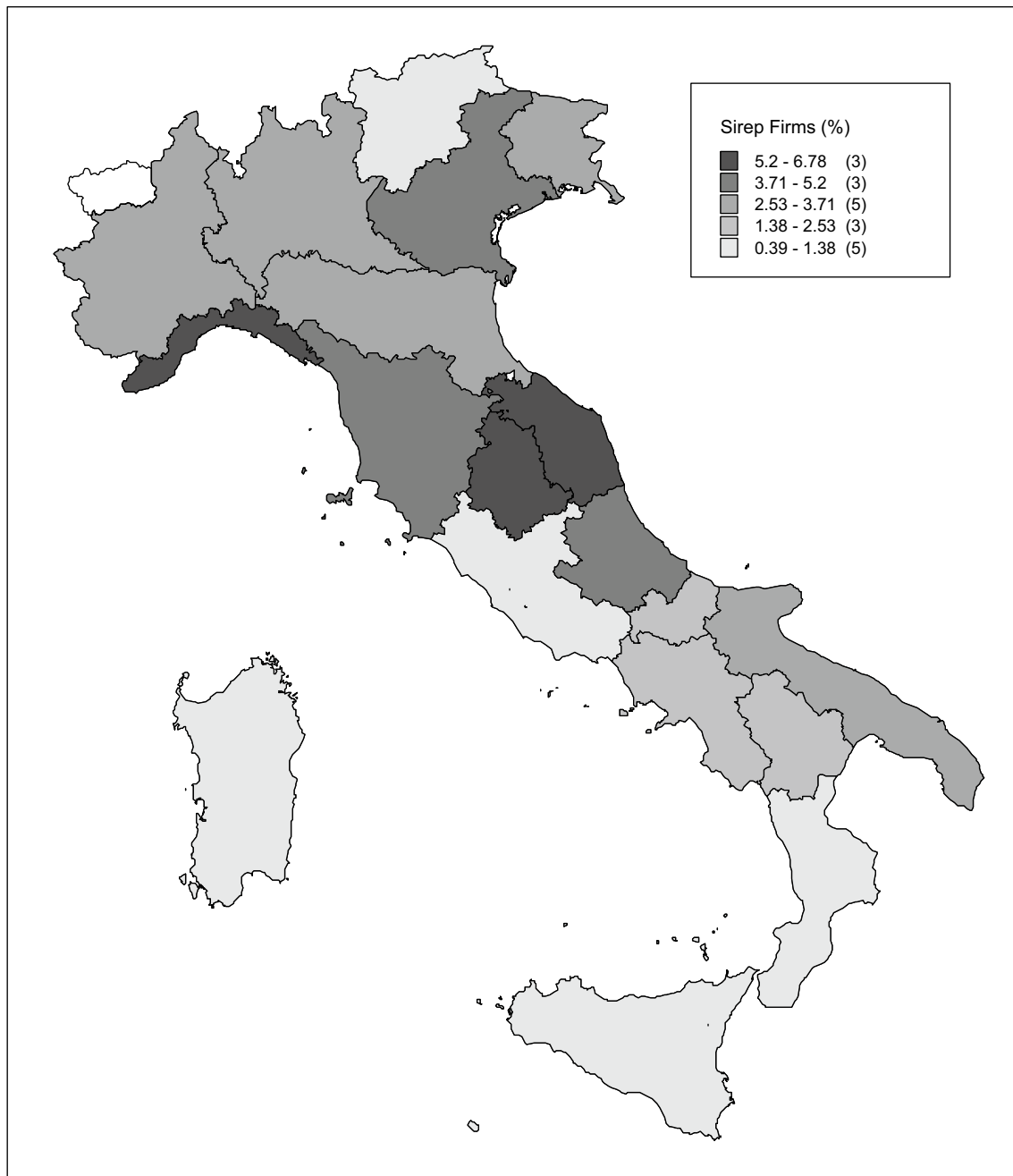
Fig. 3 Distribution of firms (%) that have reported data according to the Italian national registry of environmental managers (SIREP, 1996–2013)

waste collection and disposal with respect to construction. The number of measurements over time reflects the process of implementation of notifying procedures set by law. On the other hand, the temporal trend observed in exposure levels must be interpreted with caution: Beyond the high concentration of asbestos fibers registered between 1999 and 2004, which actually refers to relatively few measurements (12.5 %), no clear change was detectable.

Taking into account the number of firms regularly enlisted in the national registry of environmental managers, i.e., those firms specifically engaged in asbestos removal and disposal, the percentage of firms in the SIREP is low, with a clear difference among territorial areas. As noticed elsewhere, one of the main limitation of SIREP database is the inhomogeneous territorial coverage. This makes it difficult to compare the asbestos exposure among different

Italian regions, despite the influence of the geographical area suggested in our findings. This inhomogeneity is due basically to the fact that the notification of registry is mandatory only if exposure level exceeds the value of 0.01 f/cc. Indeed the main differences refer to firms which voluntary reported lower asbestos fiber levels. Our study could suggest that a small percentage (1–2 %) of firms in asbestos abatement sectors have relevant occupational asbestos exposure levels, but caution is demanded in the interpretation of these data. Small and medium size enterprises (SMEs) are prevalent in asbestos remediation, but micro firms (<10 employees) are generally underreported in the SIREP database, as shown in the comparison with industry census data (0.02 % for this class of firms vs a mean of 0.8 %) (ISTAT 2004). The possibility that firms neither keeping nor transmitting data on exposures have higher exposure levels may have affected our estimates. Coverage or representativeness of a registry is a common issue, since it has been found also in other similar situations such as in the Ontario Asbestos Workers Registry (Koné Pefoyo et al. 2014). However, a recent study on eight registries, while showing limitations and constraints, concluded that registry data can be a valuable tool for epidemiology, as well of usefulness for primary prevention, especially if based on mandatory registration like the SIREP database (Arrandale et al. 2014). A further limitation of this study may rely on differences in air sampling, analytical procedures and sample collection methods (personal or stationary), which are also possible contributing factors to the underreporting. About 40 % of reporting firms do not fully detail the fiber counting method used, and in most of cases, it is not specified whether personal or area sampling was performed. Previous studies showed significant differences between stationary and personal sampling methods, the latter providing significantly higher levels (Miscetti et al. 2014; Dufresne et al. 2009; Lange et al. 1996). The scarcity of information on type of sampling (personal versus stationary) in our dataset did not allow to assess the influence of this variable on data. Similarly, SEM and PCOM analytic techniques of fibers counting are known to give different results. The advantage of using SEM is that it has a better resolution than PCOM, whereas the latter is relatively fast and inexpensive but does not distinguish between asbestos and non-asbestos fibers (ATSDR 2001). Although the PCOM method is still most commonly recommended by international standards, also providing a more direct correlation with risk assessment due to its use in historical epidemiological studies, the possible underestimation of asbestos exposure with this method remains a debated issue. Our analysis failed to find difference in average exposure levels measured by the two analytical methods, but the relative few measurements performed with SEM and the lack of exposures measured with more than one

method made no possible to correctly interpret this aspect. Moreover, no specific laboratory standards and certification procedures were yet stated in Italy, likely causing a certain uncertainty of our estimates. Previous Italian studies actually found poor agreement between asbestos fiber measurements effected by National Health System labor inspection services and those performed by firms (Miscetti et al. 2014). Bias may also have been introduced into the exposure estimate by substituting censored data (measurements below the LOD) with LOD/2. Additionally, due to the wide difference in the number of measurements among different industrial sectors and occupational groups, caution should be used in the interpretation of results especially in the presence of great data variability. In order to increase the precision of estimates, only sectors and occupations having more than 50 measurements recorded were included in the descriptive analysis. A possible misclassification of some variables (e.g., industrial sector or job/occupation) may have also occurred, although its effect is partially reduced by the use of standard international classifications. In reading of Tables 1 and 2, it is important to keep in mind that an occupational group may be transversal among economic sectors of activity. For example, garbage collectors in this study were employed mainly in firms belonging to the construction sector (65.1 %). Great differences between AM and GM together to high values of 75th percentile underline the important asymmetry of some distributions, since the GM is less affected by extreme values.

The occupations at higher risk for asbestos exposure were found to be sheet-metal workers, garbage collectors, civil engineering and cement and other mineral products machine operators, but the highest number of workers exposed (769 male workers) was insulation workers. Moreover, this occupational group showed the higher number of measurements exceeding the OEL, followed by building finishers. Considering the job tasks with asbestos exposure, most of the exposures were associated with removing asbestos cement materials or asbestos insulation. Maintenance activities on asbestos-containing building materials or other insulating products are traditionally at risk for indirect exposure to asbestos fibers, and there are great evidences of occurrence of mesothelioma, lung cancer and asbestosis in the occupational groups involved (Frost et al. 2008; Ulvestad et al. 2004). The more favorable environmental conditions and the use of more adequate respiratory protective equipment make the current asbestos exposure clearly lower than in the past, and thus the expected health effects not easily predictable. Moreover, as it results from our analysis, uncontrolled exposure circumstances may still occur, because of the incomplete compliance with prevention and protection measures recommended by law, as reported elsewhere (Dufresne et al. 2009; Miscetti et al. 2014). Interventions aimed at improving compliance with

prevention and protection standards are recommended to be targeted to specific occupational groups at higher risk, such as insulation workers.

This is the first study, in our knowledge, that provides data on asbestos exposure in waste collecting and processing firms. Despite the low levels of asbestos exposure reported in this sector, the relatively high exposure level recorded in workers engaged in asbestos disposal during abatement within the construction sector suggests the need to specifically consider the activities related with disposal of asbestos-containing materials for health surveillance and education programs. Another job group to consider for such interventions is "safety, health and quality inspectors", which includes, in our database, mostly technicians engaged in industrial waste inspections. These data are mainly useful in countries like Italy where asbestos abatement work is a big business, due to the great number of asbestos products to be removed or treated, and the public economic incentives provided, such as those for the substitution of asbestos roof with photovoltaic panels. Furthermore, it must be borne in mind that the vast majority of firms of asbestos removal and disposal are SMEs, as it also results from our study, likely experiencing more difficulties in the occupational safety and health management.

The findings of this study, overall, support the major contribution of in-place asbestos materials to the current occupational exposures and the need of monitoring air concentration levels in sectors and occupations at risk. It is also strongly recommended to warrant the epidemiological surveillance of mesothelioma and of other asbestos-related cancers among workers exposed also after the ban on the use of asbestos, in order to assess their contribution to the public health burden. Moreover, the dissemination of results on occupational exposure levels to asbestos may be useful as a tool for the exposure monitoring and control, and in improving the system notification.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

References

Arrandale VH, Bornstein S, Demers PA (2014) Exposure registries as a tool for epidemiology. Occup Environ Med 71(Suppl 1):A49

ATSDR (2001) Toxicological profile for asbestos. Agency for Toxic Substances and Disease Registry, Atlanta, GA, pp 187–189

Berman DW, Crump KS (2008) A meta-analysis of asbestos-related cancer risk that addresses fiber size and mineral type. Crit Rev Toxicol 38(Suppl 1):49–73

Boulanger G, Andujar P, Pairon JC, Billon-Galland MA, Dion C, Dumortier P, Brochard P, Sobaszek A, Bartsch P, Paris C, Jaurand MC (2014) Quantification of short and long asbestos fibers to assess asbestos exposure: a review of fiber size toxicity. Environ Health 13:59

Bujak-Pietrek S, Szadkowska-Stańczyk I (2012) Exposure to respirable asbestos fibers at various stage of asbestos removal work. Med Pracy 63:191–198

CEN (1995) Workplace atmospheres-Guidance for the assessment of exposure by inhalation to chemical agents for comparison with limit values and measurement strategy, EN 689. European Committee for Standardization, Brussels

Consonni D, De Matteis S, Pesatori AC, Bertazzi PA, Olsson AC, Kromhout H, Peters S, Vermeulen RC, Pesch B, Brüning T, Kendzia B, Behrens T, Stücker I, Guida F, Wichmann HE, Brüske I, Landi MT, Caporaso NE, Gustavsson P, Plato N, Tse LA, Yu IT, Jöckel KH, Ahrens W, Pohlabeln H, Merletti F, Richiardi L, Simonato L, Forastiere F, Siemiatycki J, Parent MÉ, Tardón A, Boffetta P, Zaridze D, Chen Y, Field JK, 't Mannetje A, Pearce N, McLaughlin J, Demers P, Lissowska J, Szeszenia-Dabrowska N, Bencko V, Foretova L, Janout V, Rudnai P, Fabiánová E, Stanescu Dumitru R, Bueno-de-Mesquita HB, Schüz J, Straif K (2015) Lung cancer risk among bricklayers in a pooled analysis of case-control studies. Int J Cancer 136:360–371

Corfiati M, Scarselli A, Binazzi A, Di Marzio D, Verardo M, Mirabelli D, Gennaro V, Mensi C, Schallemberg G, Merler E, Negro C, Romanelli A, Chellini E, Silvestri S, Cocchioni M, Pascucci C, Stracci F, Romeo E, Trafficante L, Angelillo I, Menegozzo S, Musti M, Cavone D, Cauzillo G, Tallarigo F, Tumino R, Melis M, Iavicoli S, Marinaccio A, ReNaM Working Group (2015) Epidemiological patterns of asbestos exposure and spatial clusters of incident cases of malignant mesothelioma from the Italian national registry. BMC Cancer 15:286

Dufresne A, Dion C, Frielaender A, Audet E, Perrault G (2009) Personal and static sample measurements of asbestos fibres during two abatement projects. Bull Environ Contam Toxicol 82:440–443

Dumortier P, De Vuyst P (2012) Asbestos exposure during uncontrolled removal of sprayed-on asbestos. Ann Occup Hyg 56:49–54

Frost G, Harding AH, Darnton A, McElvenny D, Morgan D (2008) Occupational exposure to asbestos and mortality among asbestos removal workers: a Poisson regression analysis. Br J Cancer 99:822–829

Hornung R, Reed LD (1990) Estimation of average concentration in the presence of nondetectable values. App Occup Environ Hyg 5:46–51

IARC (2012) IARC monographs on the evaluation of carcinogenic risks to humans. A review of human carcinogens: chemical agents and related occupations, vol 100F. International Agency for Research on Cancer, Lyon

ISTAT (2004) Eight data census on industry and services. Italian National Statistics Institute, Rome

Italian Ministry of Environment and Protection of Land and Sea (2015) National registry of environmental managers: online database. http://www.albonazionalegestoriambientali.it. Accessed 27 Feb 2015

Järvholm B, Englund A (2014) The impact of asbestos exposure in Swedish construction workers. Am J Ind Med 57:49–55

Koné Pefoyo AJ, Genesove L, Moore K, Del Bianco A, Kramer D (2014) Exploring the usefulness of occupational exposure registries for surveillance: the case of the Ontario Asbestos Workers Registry (1986–2012). J Occup Environ Med 56:1100–1110

Lange JH, Lange PR, Reinhard TK, Thomulka KW (1996) A study of personal and area airborne asbestos concentrations during asbestos abatement: a statistical evaluation of fibre concentration data. Ann Occup Hyg 40:449–466

Lange JH, Thomulka KW, Sites SL, Priolo G, Mastrangelo G (2006) Personal airborne asbestos exposure levels associated with various types of abatement. Bull Environ Contam Toxicol 76:389–391

Lange JH, Sites SL, Mastrangelo G, Thomulka KW (2008) Exposure to airborne asbestos during abatement of ceiling material, window caulking, floor tile and roofing material. Bull Environ Contam Toxicol 80:10–13

Le GV, Takahashi K, Park EK, Delgermaa V, Oak C, Qureshi AM, Aljunid SM (2011) Asbestos use and asbestos-related diseases in Asia: past, present and future. Respirology 16:767–775

Marinaccio A, Binazzi A, Marzio DD, Scarselli A, Verardo M, Mirabelli D, Gennaro V, Mensi C, Riboldi L, Merler E, Zotti RD, Romanelli A, Chellini E, Silvestri S, Pascucci C, Romeo E, Menegozzo S, Musti M, Cavone D, Cauzillo G, Tumino R, Nicita C, Melis M, Iavicoli S, ReNaM Working Group (2012) Pleural malignant mesothelioma epidemic: incidence, modalities of asbestos exposure and occupations involved from the Italian National Register. Int J Cancer 130:2146–2154

Maule MM, Magnani C, Dalmasso P, Mirabelli D, Merletti F, Biggeri A (2007) Modeling mesothelioma risk associated with environmental asbestos exposure. Environ Health Perspect 115:1066–1071

Miscetti G, Bodo P, Garofani P, Abbritti EP, Lumare A (2014) Levels of exposure to respirable fibres at worksites for abatement of compact and friable asbestos. Med Lav 105:63–73

Mlynarek S, Corn M, Blake C (1996) Asbestos exposure of building maintenance personnel. Regul Toxicol Pharmacol 23:213–224

Olsen NJ, Franklin PJ, Reid A, de Klerk NH, Threlfall TJ, Shilkin K, Musk B (2011) Increasing incidence of malignant mesothelioma after exposure to asbestos during home maintenance and renovation. Med J Aust 195:271–274

Pfau JC, Serve KM, Noonan CW (2014) Autoimmunity and asbestos exposure. Autoimmune Dis 2014:782045

Price B, Crump KS, Baird EC 3rd (1992) Airborne asbestos levels in buildings: maintenance worker and occupant exposures. J Expo Anal Environ Epidemiol 2:357–374

Scarselli A, Montaruli C, Marinaccio A (2007) The italian information system on occupational exposure to carcinogens (SIREP): structure, contents and future perspectives. Ann Occup Hyg 51:471–478

Stayner L, Welch LS, Lemen R (2013) The worldwide pandemic of asbestos-related diseases. Annu Rev Public Health 34:205–216

Ulvestad B, Kjaerheim K, Martinsen JI, Mowe G, Andersen A (2004) Cancer incidence among members of the Norwegian trade union of insulation workers. J Occup Environ Med 46:84–89

Welch L, Dement J, West G (2015) Mortality among sheet metal workers participating in a respiratory screening program. Am J Ind Med 58:378–391

Wolff H, Vehmas T, Oksa P, Rantanen J, Vainio H (2015) Asbestos, asbestosis, and cancer, the Helsinki criteria for diagnosis and attribution 2014: recommendations. Scand J Work Environ Health 41:5–15