Chapter 5
Communities at High Risk in the Third Wave of Mesothelioma

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Abstract In this chapter, we describe and discuss communities that have a high incidence of mesothelioma. These communities are part of a third wave of asbestos exposures and consequent asbestos-related diseases (ARD). Many of the current paradigms applied to ARD arose to address the first and second waves associated with mining and the industrial use of asbestos, respectively. We examine the lessons from a number of communities where there is an elevated risk of mesothelioma not restricted to specific occupations: Wittenoom, Western Australia, where crocidolite was mined; Libby Montana where amphibole asbestos contaminated vermiculite was mined and processed; Broni Italy, and Ambler Pennsylvania where asbestos-cement products were manufactured; and Karain in Cappadocia Turkey where the asbestiform mineral erionite occurs naturally. In these communities, in addition to occupational exposures, paraoccupational, residential, and environmental lifestyle asbestos exposures appear to contribute to the mesothelioma burden. Finally, we discuss a number of issues germane to non-occupational community mesothelioma risk: age and gender distribution of non-occupational mesothelioma; prevention appropriate to the third wave; shortcomings of the regulatory definition of asbestos; vulnerable groups in the community; diffuse administrative responsibility; diverse community attitudes to risk and prevention; difficulties in quantifying exposures and justifying remediation actions; surveillance, diagnostic and care requirements in high-risk communities; legal responsibilities and compensation for nonoccupational ARD; the application of epidemiology to third wave high-risk communities; differing expressions of ARD from community exposures; and estimating the magnitude of the third mesothelioma wave.

Keywords Mesothelioma • Risk factors • Epidemiology • Waves of asbestos exposure/disease • High-risk communities • Remediation • Prevention • Asbestos definition • Asbestos-related diseases

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5.1 Waves of Asbestos Exposure and Disease

As a result of the long latent period of 30 to 50 or more years between asbestos exposure and the occurrence of mesothelioma, the peak expression of adverse effects occurs long after the peak exposure. This characteristic delay underscores the importance of recognizing and eliminating or minimizing exposures long before clinical disease is apparent. Understanding this delay also allows us to define several waves of ARD.

The *first wave* was recognized in countries with significant asbestos mining operations in those occupationally exposed through mining, milling, and packaging asbestos. A *second wave,* also industrial and predominantly occupational, resulted from manufacturing various asbestos containing products and from the use of asbestos in construction. From small beginnings in the 1890s the use of asbestos in industrial fabrication, including asbestos cement products, structural insulation, shipbuilding and a multitude of miscellaneous uses, rapidly increased to reach a maximum in the mid-twentieth century (Henderson and Leigh 2012). This resulted in a wave of occupational asbestos-related disease, including lung cancer and mesothelioma whose effects continue to the present. During these first two waves it became apparent that ARD, particularly mesothelioma, were not confined to workers but could also be seen in family members who resided with asbestos workers and were exposed to asbestos bought home on the clothes, footwear, skin and hair of workers, and spread within the home through laundry, dusting and sweeping. These exposures have been variously described as familial, domestic, or "paraoccupational," we will use the latter in this chapter, since this effect is not necessarily confined to family members but could affect others who share a domicile with an asbestos worker. Mesothelioma was also described in connection with residing near an asbestos-manufacturing site (Newhouse and Thompson 1965). In many developed countries the exposures that bought on the first two waves were bought to a halt in the late twentieth century, initially by strict regulations controlling occupational and environmental exposures associated with mining, industrial use, and construction, and later by a total ban on the import or use of asbestos. However elsewhere asbestos use continues, greatest in the BRIC countries: Brazil, Russia, India, and China (Algrantia et al. 2015). For these countries, action to ban the use of asbestos appears imperative.

However, even where there is a ban on asbestos use we can still confront a *third wave* of asbestos exposure and ARD resulting from the previous dissemination of asbestos and asbestos-containing products or from exposure to naturally occurring asbestos. Initially the third wave concept was applied to what was termed asbestos-in-place, particularly asbestos in buildings (Landrigan 1991). Concern was particularly directed at exposures and ARD in groups of workers who had not customarily been considered as at risk from asbestos, such as railroad workers (Maltoni et al. 1991) and merchant seamen (Greenberg 1991). Wide dissemination of asbestos was also recognized. For example, asbestos bodies could be found in the lungs of children living in urban settings (Haque et al. 1991). More recently, there has been increased recognition that the third wave includes communities that are hotspots for ARD including mesothelioma. These include sites where asbestos was mined or used in manufacturing, where there is substantial asbestos-containing waste, where asbestos fibers or products using asbestos have been widely disseminated, and where asbestos fibers occur naturally. In Australia, third wave ARD has been found in non-professional do-it-yourself home renovators who cut and repair or demolish asbestos cement products in home renovation or maintenance. Family members present during these activities are at risk (Olsen et al. 2011; Gordon and Leigh 2011). These types of community third wave exposures raise new issues for which the existing prevention paradigms developed for industrial and occupational exposures are not always adequate, as will be discussed in the final section of this chapter.

Although asbestos use has been banned in many countries there is emerging concern that we may need further action to prevent a *fourth wave* of ARD. For regulatory purposes the term asbestos applies to six types of mineral fibers that were used in commerce at the time of the first and second waves of ARD. However there are other asbestiform minerals that have the same deleterious carcinogenic and other toxic properties that are not regulated because they were not used commercially when the current regulatory definition was developed. Consequently, these carcinogenic, but unregulated fibers, which share some of the useful properties that made asbestos use popular in the early twentieth century could legally be incorporated into materials that could legally be imported into countries where regulated asbestos fibers are banned, e.g., for use in construction. This creates a risk that legally acceptable exposure to such fibers could in turn inadvertently cause a *fourth wave* of exposure and ARD, despite a "ban" on asbestos. This issue will be discussed further in the final section of this chapter.

5.2 Lessons from Exposed Communities

The third wave of asbestos-related events has been recognized and studied most intensively in certain communities where exposure and effect are more concentrated. We will next address the lessons being learned in a number of these high-mesothelioma risk communities around the world.

5.2.1 Libby, Montana

Libby, MT is a small town (2010 census population: 2628) on the Kootenay River in a mountainous area of Western Montana, USA. On July 17, 2009, the U.S. Environmental Protection Agency (EPA) declared the first US Public Health Emergency, using the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), in Libby as a result of documentation of hundreds of ARD over the past several years (USEPA 2009). The declaration also covered neighboring Troy, Montana (2010 census population: 938). About 10,000 people live in a 10-mile radius of Libby including many former workers at the Libby vermiculite mine and processing operations. In addition, the EPA estimated as many as 80,000 individuals were exposed during the life of the mine.

Citizens and workers of these communities had been exposed to high levels of asbestos from vermiculite mines. Vermiculite was discovered by gold miners in 1881. In the 1920s, the Zonolite Company began to mine, mill, screen, exfoliate, process, and ship the ore in Libby, transporting both milled and raw vermiculite from Libby by way of the Kootenay River. In 1963, the mine was purchased by WR Grace and production expanded greatly. Using regulations for asbestos introduced in the 1970s, EPA, NIOSH, and state inspections in the 1980s found that asbestos fiber counts in downtown Libby exceeded allowable limits. Additionally, WR Grace lost its largest customer, Scotts Company in Marysville, Ohio in the 1980s, when ARD were found in workers in their processing plant. Vermiculite production ceased in 1990. Two separate but parallel cohort studies showed excess mortality from lung cancer, mesothelioma, and non-malignant respiratory disease among Libby vermiculite miners (Amandus et al. 1987; Amandus and Wheeler 1987; McDonald et al. 1986). A cross sectional community study showed that radiologic pleural abnormalities related to asbestos were most common in former workers with vermiculite, but also occurred in household contactants (paraoccupational) and those with environmental exposures (Peipens et al. 2003). Libby was added to the National Priority List as a "superfund site" in 2002. It is estimated that the Libby mine was the source of over 70% of all vermiculite sold in the United States from 1919 to 1990 (USEPA 2009).

The presence of asbestiform fibers in the mined vermiculite was not acknowledged at first. The contaminant, a unique mixture of amphiboles now known as Libby Amphibole Asbestos (LAA), consists of winchite, richterite, lesser amounts of tremolite and trace amphiboles (Meeker et al. 2003). LAA could be present in high concentrations; in some locations, it comprised nearly 100% of the ore, and produced abundant, extremely fine fibers on gentle abrasion or crushing. Although winchite and richterite appear to have similar toxicologic and carcinogenic properties to tremolite, because of a legacy regulatory definition from the days of the first and second waves of asbestos disease, only tremolite was officially considered to be a health risk at the time of the plant closure.

Studies of LAA exposure illustrate the complexity of evaluating and reconstructing historic pathways of asbestos exposures in community settings. The most comprehensive analysis, by Noonan et al. (2015), evaluated four categories of exposure: occupational, sharing a household with a worker, residence in Libby or Troy, and environmental pathways.

5.2.1.1 Occupational Exposures

Occupational exposures occurred directly to employees or contracted workers for Zoolite or WR Grace. For this group, quantifiable cumulative exposures could often be reconstructed based on years worked, job categories, and when available, workplace air monitoring data. A second potential occupational exposure group had exposures from disturbing dust-containing vermiculite or LAA through local work at construction, demolition or excavation sites, the Montana railroad industry, work with commercial boilers or incinerators, agriculture or silviculture, cleaning residences or businesses, logging, plywood manufacturing, and other wood processing or finishing. A third potential occupational exposure group included those previously identified in the literature as having an increased risk of exposure to asbestos not necessarily mined at Libby (such as working with brake or clutch linings, high temperature gaskets, cement sheets, pipes or heat-resistant panels, insulation, electric cloth wrap or high-temperature wiring, fire-proofing materials, heat-protective clothing such as gloves, aprons or coats, joint compounds and sheetrock/drywall, heating and ventilation ducts or duct connecting materials, roofing materials, thermal taping compounds, and heat-resistant plastic parts such as Bakelite).

5.2.1.2 Household Contact (Paraoccupational) Exposure

These exposures occurred from sharing a household with Zonolite/WR Grace employees. Elements contributing to the extent of exposure included whether the worker wore visibly dusty clothes at home or in the household car, time spent by adults in the laundry/utility room, and the job classification of the worker. WR Grace had no formal industrial hygiene program to control take-home asbestos exposure.

5.2.1.3 Residential Exposure

Cumulative exposure estimates were developed for Libby and Troy residents using soil and dust sampling at various properties, and limited activity-based sampling to estimate air levels of LAA fibers associated with activities. Geospatial approaches were used to predict soil and dust concentrations at residences that had not been sampled; however, these did not provide useful additional predictive quantitative information to explain ARD phenomena and were not used further.

5.2.1.4 Environmental Exposure Pathways

Eleven potential pathways of environmental exposure were identified based on activity-based sampling and any other available data. Each pathway was categorized as having high (4), medium (3), or low (2) exposure potential. Table 5.1 lists the pathways identified for Libby and the assigned exposure potential. This methodology appears applicable to other communities with non-occupational exposures.

Using this array of exposure estimates for 3031 persons seen at the Center for Asbestos Related Diseases (CARD) clinic in Libby, MT, significant but small or modest correlations with ARD including pleural disease were seen for 22 of 28

Table 5.1 Example of environmental exposure pathway survey for Libby, MT[a]

Questionnaire language	Description of pathway impact	Weight factor
Shoveling and/or hauling vermiculite outside of work?	Ore piles were always available and local citizens were encouraged to take what they needed	4
Playing in or around the vermiculite piles?	Children played in the piles all of the time	4
Handling vermiculite insulation outside of any job?	Many people installed their own insulation because it was easy to get	4
Fishing on the Kootenai River near the mouth of Rainy Creek?	Near a poorly covered conveyor belt that leaked asbestos-containing dust	3
Heating vermiculite ore to make it expand or pop?	Raw ore was used during science lessons	3
Cutting or collecting firewood near Rainy Creek Road?	Common area to gather firewood but very close to the mine	3
Gardening in soil that was observed or known to contain vermiculite?	Vermiculite was free and readily available for gardening use	3
Using the Libby Middle School track beyond scheduled gym classes?	Historically, vermiculite ore was used to cover the track	2
Playing in or watching games at the downtown ballfields?	Plant was adjacent to the fields and they were highly contaminated	2
Recreational activities (hunting, hiking, etc.) along Rainy Creek Road?	Dusty public access road used by trucks containing uncovered vermiculite	2
Burning firewood in your home?	Wood is used as a primary heat source and much of the firewood was found to be contaminated	n/a

[a]Modified from Noonan et al. (2015), from a survey used at Libby, MT to help determine the extent to which residents near the mine and factory were exposed to asbestos from lifestyle environmental exposures. The weight factor helped estimate the impact of the exposure for a study participant

studied estimates, with three of the four higher correlations seen within the household contact exposure pathways. Overall, men had the highest estimates for occupational exposures, whereas women had the highest estimates for household contact exposure, being almost twice that of men. Estimates for environmental exposure pathways were not significantly different by age or gender. Such detailed community exposure analyses help elucidate the importance of specific exposure pathways and enhance risk assessments that can support rational decisions about this superfund site and other similar community exposure situations.

Work at WR Grace and/or residence in Libby has now been associated with mesothelioma (Dunning et al. 2012; Whitehouse et al. 2008), progressive pulmonary disease (Whitehouse 2004; Black et al. 2014), and asbestos-related mortality (Naik et al. 2016). There may be distinctive features of ARD from LAA, compared with ARD in populations occupationally exposed to chrysotile. LAA is associated with an increased frequency of antinuclear autoantibodies (ANA) (Pfau et al. 2005; Pfau et al. 2015), and an increased risk of systemic autoimmune disease (Noonan et al. 2006) not described to date in other asbestos-exposed groups. Furthermore, LAA induces mesothelial cell autoantibodies (MCAA), which induce collagen deposition by mesothelial cells both in vitro (Serve et al. 2013) and in vivo (Gilmer et al. 2016), and is associated with radiographic changes in the pleura (Marchand et al. 2012). In contrast, chrysotile does not induce autoantibodies in mice or humans, MCAA occur with less frequency, and is not associated with pleural disease (Pfau et al. 2011; Pfau et al. 2015).

Following a study showing greatly increased mortality from asbestosis (ATSDR 2002), the Libby community founded CARD in 2000 with a local Board of Directors to provide community health screening, patient care, and social service support and counseling to individuals and families. With significant U.S. Federal Government funding, CARD now operates out of a modern purpose-built facility in Libby. Since 2009, medical records have been electronic, and the population regularly followed now exceeds 5000. CARD activities have engendered remarkable community acceptance and local support.

5.2.2 Broni, Italy

Broni is a small town (approximately 10,000 inhabitants) in Lombardy, Italy. The second oldest and largest asbestos cement factory (Fibronit) in Italy is about 600 m west of the historic town center (Mirabelli et al. 2010). The factory produced asbestos cement pipes and sheets from 1932 to 1993, initially about 8000 ton (metric tons; each equivalent to ~2200 pounds) per year, but increasing in the 1960s up to 100,000 ton/year. Chrysotile, crocidolite, and smaller quantities of amosite were added to the cement in proportions of 10–15% in sheets and up to more than 30% in pipes (Mensi et al. 2015). About 2741 men and 714 women were employed overall at Fibronit. As of the1970s, several tasks were performed manually, there were no ventilation systems, and work hygiene was generally poor without personal protection or change of clothes or showering after shifts. In the late 1970s, air filtration units were installed and automated processes introduced (Oddone et al. 2014). Asbestos use ceased by 1993 following Italian Law 257/1992 banning asbestos (Mensi et al. 2015). The factory continued cement production until 1997 without any remediation work, and closed in 2000. In 2002, Broni was included in a government list of environmentally contaminated sites (Siti di Interesse Nazionale, SIN) under Italian law 388/2000 (Pirastu et al. 2011).

Oddone et al. (2014) investigated 1296 workers (1254 men, 42 women) who had been working in the Broni factory in 1970 or were hired subsequently: the standardized mortality ratio (SMR) for pleural cancer was 18 in males (26 observed vs. 1.45 expected) and 69 in women (2 observed, 0.03 expected). Seven men (SMR 10) died from peritoneal or retroperitoneal cancers and asbestosis, and three deaths from asbestosis (SMR 130), with no deaths in women from these causes.

Mensi et al. (2015) were able to quantify the total impact of asbestos on mesothelioma incidence in Broni for workers employed at the Broni factory (occupational); familial exposure arising from fibers on the workers' clothes or hair (paraoccupational); and residential exposure in Broni and surrounding towns (environmental exposure arising from outdoor pollution related to the factory). Mesothelioma cases were obtained from the Lombardy Mesothelioma Registry, a component of the National Register of Malignant Mesotheliomas, in Italian "Registro Nazionale dei Mesoteliomi" (ReNaM), which collects information on all cases of mesothelioma of the pleura, peritoneum, pericardium, and tunica vaginalis of testis diagnosed either in Lombardy (currently almost 10 million inhabitants) and or from a hospital outside Lombardy (Mensi et al. 2007). The registry record includes information on occupational exposures, domestic cohabitants, residential history including proximity to asbestos sources, and lifestyle including domestic and leisure-time activities involving potential asbestos exposure, all collected from interviews of patients or next-of-kin by trained personnel using a standardized questionnaire (Nesti et al. 2003). From 2000–2011, 147 mesothelioma cases (17.45 expected) were attributable to occupational, familial, or environmental asbestos exposure from the Broni factory. The absolute and relative mesothelioma excess was greater in women (87 cases; 7.6 expected) than in men (60 cases; 9.9 expected). There were 138 pleural and 9 peritoneal mesotheliomas but no mesothelioma of the pericardium or testicular tunica vaginalis.

Where individuals had experienced multiple types of exposures the cause was assigned using Italian national guidelines in the order: occupational > familial > certain environmental > potential environmental (Nesti et al. 2003). Applying this rubric, 38 cases were designated occupational (32 men, 6 women), 37 were paraoccupational (5 men, 32 women), and 72 were environmental, of which 48 were in Broni (20 men, 28 women) and 24 in surrounding towns within ~10 km. Among the occupationally exposed, and when both occupational and paraoccupational exposure groups were combined, the standardized incidence ratios for men and women were similar. Community epidemiologic studies based on registries recording the site of residence at the time of diagnosis may underestimate the true disease burden resulting from past exposures; however, the authors believed this effect would be modest for Broni because of limited outmigration.

Although there were some historical records of intermittent measurements of exposure within the Fibronit factory, there was no data on exposure levels sustained by workers families. Some airborne fiber counts were available for Broni from 1991–1993 (median fiber counts up to ~0.6 f/L); however, at that time production output was rapidly declining and measures to reduce fiber dispersion had been introduced, so that no useful information concerning community or residential exposures is available for the vast majority of the production period.

The Mensi et al. (2007) study of Broni underlines the importance of assessing the impact of asbestos exposure for the community at large. Overall, approximately half the mesothelioma cases in Broni and surrounding towns were attributable to environmental exposure, a quarter to occupational exposure, and a quarter to paraoccupational exposure.

5.2.3 Non-Occupational Asbestos Exposure and Disease Elsewhere in Italy

One of the earliest non-occupational cohort studies of mesothelioma was of wives of asbestos workers employed at the "Eternit" plant in Casale Monferrato (Italy) from 1950 to 1986, when the plant closed: published by Magnani et al. (1993) and later updated (Ferrante et al. 2007). Eternit, one of the largest asbestos cement manufacturing facilities in Italy, used chrysotile and crocidolite to make high-pressure pipes, plain and corrugated sheets, chimney tubes, and other products (Magnani et al. 1996). The factory had no laundry facilities, so work clothes were taken home for cleaning. Wives were tracked through Registrar's Office records, kept in every Italian town, of vital and marital status for each resident and allowed tracking movement to another town. Women who had worked at the plant, and who had no domestic exposure (e.g., married after worker's employment at the plant terminated) were excluded. The final cohort of 1740 women was followed until 2003, when 67% were still alive, 32.3% dead, and 0.7% lost to follow-up. Mortality from pleural mesothelioma over the period 1965 to 2002 was markedly increased (21 observed vs. 1.2 expected; SMR = 18.00; 95% CI 11.14–27.52), whereas mortality from lung cancer was not increased. Most of the mesothelioma was reported in more recent years with 12 cases over the period 1990–2001.

Marinaccio et al. (2015) used mesothelioma incidence data from ReNaM, which covers 98.5% of the Italian population, to examine non-occupational mesothelioma across Italy for the 1993–2008 period. Excluding occupational exposure, mesotheliomas were categorized as caused by familial (paraoccupational) exposures, environmental (residence near a source of asbestos pollution without occupational or familial exposure) and leisure activities (without occupational familial or environmental exposure). For the period 1993 to 2008, 15,845 cases of mesothelioma were identified, of which 93% were pleural, 6.4% peritoneal, and 0.3% pericardial or testicular. The male/female ratio was 2.6 for pleural mesothelioma, 1.4 for peritoneal, and 1.9 for pericardial. The mean age at diagnosis was 68.3 years (SD ±10.6) in men and 69.8 (SD ±11.6) in women. Age less than 45 was rare: 2.4% of all cases. The exposure source could be characterized in 12,065 instances: most were occupational, but 530 (4.4%) had familial (paraoccupational) exposure, 514 (4.3%) had environmental exposure through living near a source of asbestos pollution, and 188 (1.6%) were exposed through hobby-related or other leisure activities. For 2466 cases (20.4%), no asbestos exposure could be found. Females predominated in nonoccupational cases overall (female to male ratio 2.3:1), and particularly for paraoccupational cases (5.9:1). The mean age at diagnosis was slightly, but statistically significantly, lower for nonoccupational cases at 67.2 vs. 68.1 years, $p < 0.01$).

Nonoccupational cases were not distributed uniformly across Italy. Distinct geographic clusters were observed in areas where asbestos-cement plants had operated (Broni, Casale Monferrato, and Bari), areas of shipbuilding and repair (Monfalcone, Trieste, La Spezia, Genova, Castellammare di Stabia, Livorno, and Taranto) and in Biancavilla, Sicily, where the asbestiform amphibole fluoroedenite was used in

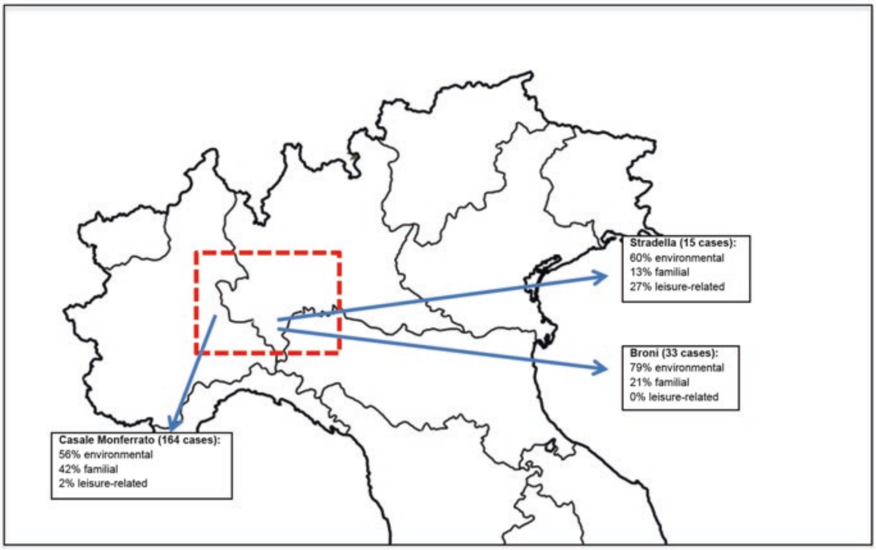

Fig. 5.1 Mesothelioma cases in three communities in Italy (2008–2013). Map highlighting the variation in community exposure within a small area of Italy. Mesothelioma cases were tracked in the Italian National Mesothelioma Register (ReNaM) between the years of 2008 and 2013. Modified from Marinaccio et al. (2015)

large amounts in construction and road paving. Different towns had quite different proportions for the categories of nonoccupational exposure, environmental (residential), familial (paraoccupational, and leisure-related (environmental pathways)). Figure 5.1 displays this variation for the three Northern Italian towns of Broni, Stradella, and Casale Monferrato. The authors commented on the need for a framework to deal with compensation rights for mesothelioma cases induced by nonoccupational asbestos exposure.

5.2.4 Wittenoom, Western Australia

Wittenoom is a remote inland community in Western Australia, approximately 1000 miles north of the state capital of Perth. Rocks exposed in Wittenoom Gorge are remarkable for narrow bands of crocidolite (blue asbestos), averaging about 2.5 in. in width about 25 ft apart. In the 1930s, the seams were worked by hand using primitive methods, and bags of asbestos were carried by donkey to outside the gorge. High prices for crocidolite in 1937–1938 bought a rush of prospectors to the area. Production increased from 1943 to 1966 when ABA (Australian Blue Asbestos) took over the leases and operated a mine and mill in the gorge. Milling was particularly problematic: it consisted of dry mechanical crushing, grinding, and aspiration with persistent problems with dust control, ventilation, fiber purity, and abrasive hard host rock (ironstone). All mining and milling areas were very extensively contaminated with asbestos dust; work conditions were very hot and dusty with almost no use of respirators. A new, somewhat improved, mill built in 1958 still had problems from dustiness. The only adequate industrial hygiene survey made during 1966, the final year of the plant's operation, found fiber levels above 100 f/ml in many areas of the plant (Musk et al. 1992), subsequent reevaluation suggests that these levels were underestimated possibly by several orders of magnitude (Rogers 1990). No asbestos standard was in place in Western Australia until 1978, long after the mine had closed, although standards were in place elsewhere in Australia. The entire operation was only profitable from 1955 to 1960 when there was an export contract to the USA (Musk et al. 1992).

Originally the town settlement was in the Gorge, about a mile from the mine; later a township was built at the entrance to the Gorge about 12 miles away by the state government with an agenda of developing the north subsidized housing and transport (Musk et al. 1992). In 1961, the population was 671 males and 309 females. Tailings from the mine were used in and around the town to pave roads and parking lots, reduce dust and mud in backyards and the school playground and also for the airport runway; tailing uses continued to the mid-1960s. Vehicle movement over the roads produced so much dust that airline pilots claimed to identify Wittenoom from considerable distances by a blue haze on the horizon (Reid et al. 2008). Cumpston (1978, 1979) reported on measured ambient environmental exposures with levels of 0.01–0.21 f/ml. No non-work indoor air exposure measurements from Wittenoom have been reported.

The sociologist Layman (1983) described the community. Wittenoom was a typical company-dominated mining town except for a high degree of both geographic and interpersonal isolation, and an apathetic rather than conflicted community with a high turnover. Although the maximum workforce at any time was about 500, approximately 6500 men and 500 women in total worked for ABA from 1943 from to 1966. Most employees were unskilled; many were migrants from Italy lured by 2-year contracts. Forty-four percent of workers stayed in the community less than 3 months, and only 22% stayed longer than 1 year. About 50% of the workers were in their 20s and only 16% were over 40 years of age. Most desired to make money and leave. Single males lived in particularly squalid conditions. Families were mostly young couples with small children; most women were dismayed by the isolation and primitive conditions with the hotel and alcohol too central to the way of life. The young demographic perversely provided residents with a long time period in which to experience mesothelioma, because of the long latency.

The Western Australian state government began decommissioning the town in the 1980s, by 1992 all government-owned buildings were demolished and new residents officially discouraged (Graham 1994). The town was virtually abandoned when it was degazetted by the state government in 2007, with 150,000 tons of raw, exposed asbestos fibers remaining at the site (Bennett 2016). As of 2015 three remaining residents of the town refused to leave (Daily Telegraph 2015). Cleanup is contemplated (Moulton 2015).

The first case of mesothelioma among ex-Wittenoom workers was detected in 1961 (McNulty 1962), and numerous cases were recognized by 1967 (Elder 1967). Mortality studies of workers (Hobbs et al. 1980; Armstrong et al. 1988) found excesses of many diseases, including cancers of the trachea, bronchus and lung, mesothelioma, pneumoconiosis, mental disorders and alcoholism, cirrhosis of the liver, and injuries and poisonings.

Hansen et al. (1993) examined the risks of non-occupational exposure to crocidolite in a cohort of 4890 residents of Wittenoom during the period 1943–1993, who had never worked for ABA but had lived at Wittenoom for at least 1 month. The cohort was assembled using a wide variety of records: electoral rolls, local school records, hospital and medical records, church records, birth certificates, employment lists for employers other than ABA, answers to a 1979 questionnaire to workers, and participants in a Vitamin A cancer prevention trial, in all 18,553 individual sources of information. Comparison between records suggested that the cohort was complete. Mesothelioma was identified from State and Australia-wide Mesothelioma registries. Wittenoom residents included families of ABA workers, government employees (teachers, hospital staff, police, etc.), employees in agriculture or mining for other companies who used Wittenoom as a base camp, self-employed individuals and families of those people. Almost all had little chance of exposure to asbestos elsewhere. Fifty-five percent were families of workers, 55% women, 50% children of whom 43% were first at Wittenoom when aged <10; 51% of the entire cohort lived at Wittenoom for less than 2 years. As of 1993 the whereabouts of 71.4% of the cohort was known (Hansen et al. 1998). Twenty-seven subjects had developed mesothelioma, the majority since 1989. There was an excess of females: 18 vs. 9 males. Paraoccupational exposures predominated: 12 wives, 11 children, and 1 brother. The mean duration of Wittenoom residence was 60 months (range 2 months to 17 years). Compared with the rest of the cohort, mesothelioma cases had stayed longer at Wittenoom (64.8 months vs. 32.8 months, p 0.001), had a higher estimated intensity of exposure (mean 0.8 f/ml vs. 0.5 f/ml; $p < 0.001$), and a higher estimated cumulative exposure to crocidolite (mean 16.3 f/mly vs. 5.4 f/mly; $p < 0.001$). Nine of the 27 subjects (33%) were younger than 40 at the time of diagnosis. However, there was no significant effect of age after adjustment for time since first exposure and duration of residence; the high number of early-age cases at Wittenoom was simply a result of larger proportions of exposed children compared with other populations. Reid et al. (2008) further examined the causes of death for women in the Wittenoom non-occupational cohort up to 2004 finding significantly increased mortality rates from all causes, all neoplasms, mesothelioma, lung cancer, and pneumoconiosis (asbestosis).

5.2.5 Karain, Turkey

Karain is a village in Cappadocia, Turkey, which had a population of around 2000 in 1950, but more recently less than 150. Residents of Karain and of the nearby villages of Tuzkoy and Sarihidir have very to extremely high rates of mesothelioma

(Baris et al. 1978; Artvinli and Baris 1979). Mesothelioma is responsible for more than 50% of deaths in Karain. Significant numbers of villagers had also migrated to Stockholm, studies of 162 emigrants from Karain found 18 deaths, at least 14 of which were from mesothelioma (Metintas et al. 1999). Around Karain, erionite, a fibrous zeolite, occurs naturally in volcanic rocks in zeolite-rich layers. Stones containing zeolite with deposits of fibrous, whitish, soft and friable erionite were quarried from the nearby mountain and river and used to build houses in these three villages (Carbone et al. 2007). Erionite is found in the air of these villages (Baris et al. 1987) and in the lungs of residents (Sebastien et al. 1981). Experimentally, erionite is a highly potent cause of mesothelioma in rats (Wagner et al. 1985).

However, some villages nearby, including Karlik 3 km away did not experience epidemic proportions of mesothelioma, despite having similar stone in the houses. Pedigree studies of Karain residents found that mesothelioma was concentrated in some families but not others (Roushdy-Hammady et al. 2001). Moreover, members of high-risk families who were born and lived outside Cappadocia did not develop mesothelioma. Current evidence indicates that the extraordinary rates of mesothelioma in Karain, Tuzkoy, and Sarihidir are due to the interaction of genetic predisposition and environmental erionite exposure (Dogan et al. 2006).

Beginning around 2005, a new village has been constructed in Tuzkoy using erionite-free bricks and cement and with asphalt roads. Free radiology screening and medical treatment for mesothelioma are now available through the Turkish Directorate of Cancer Control. Free biomonitoring screening was made available, and approximately 50% of villagers accepted this opportunity; others believed that screening would be useless unless there was effective treatment to offer (Carbone et al. 2007).

5.2.6 Ambler, Pennsylvania

Ambler, located in the suburbs of greater Philadelphia, was at one time home to the world's largest asbestos cement manufacturing operation (Quattrone 2004). Asbestos-containing products were produced in Ambler from the late 1890s; activity peaked before the Great Depression and was very substantial in both World Wars. Mainly chrysotile was used; much imported from a Canadian mine the facility owned. The wide variety of products included piping, electrical insulation, millboard, brake linings, roofing shingles, cement siding, asbestos paper, conveyer belts, laboratory bench tops, and many others. Production was largely discontinued in the 1970s coinciding with stricter occupational health and environmental laws, with the last operations ceasing in 1988. A company town, Ambler was largely built for workers and their families who primarily came from Italy and Virginia. Many residents worked in the asbestos plant. Family members recall that workers would return home covered in so much white dust as to be barely recognizable. Workers houses extended up to the boundary of the plant. Particularly noticeable were the "White Mountains," which consisted of large piles of asbestos-containing waste

Fig. 5.2 Family photograph from around 1963, showing children in proximity to Ambler, PA asbestos-containing waste piles. Photographer: Joe Marincola with permission from Greg Marincola

material from the plants where children and adolescents played extensively. Figure 5.2 is a family photograph from around 1960 showing family members alongside some of these piles.

Initially very prosperous, Ambler underwent a period of unemployment and urban decay after the plants closed, but a renaissance starting in the 1990s resulted in a currently desirable place to live with substantial family-friendly amenities and a thriving restaurant scene. Since the plant closure, attention has focused on two large accumulations of asbestos-containing waste material, both adjoining residential areas. The first, a 24-acre, 30-foot high asbestos-containing waste area, was remediated by the EPA in the 1980s and 1990s by covering with soil and geotextile, grading, and erecting an 8-foot fence to eliminate access and use (USEPA 1988, 1989). The second site of approximately 28 acres known as Bo-Rit is currently designated as a superfund site: hazard reduction activities have been undertaken and a final decision on further remediation is imminent. Decisions on future access and use for the area are complex because of the many parties involved, as discussed later in this chapter.

Using data for 1992–2008 from the Pennsylvania Cancer Registry, the incidence of mesothelioma in residents of the Ambler zip code was found to be 2.7 times that of Pennsylvania as a whole for men and 4.5 times higher for women, both statistically significant, while there was no increase in surrounding zip codes (Pennsylvania Department of Health 2011). The previous manufacturing operations and the Bo-Rit site are both located within the Ambler zip code. Studies are continuing to help determine the excess attributable to past occupational, paraoccupational, residential, and environmental exposures.

To understand the views of Ambler community stakeholders about asbestos hazards, we conducted community surveys and semi-structured in-depth interviews with a purposive sample of diverse Ambler residents from different socio-economic and professional backgrounds (e.g., real estate agent, property developer, environmental scientist, local business owner, urban planner, and others) and officials from different governmental agencies. Attitudes and perceptions were grouped according to a number of themes including: time, space, activities resulting in asbestos exposure, community input and Community Advisory Group, attitudes toward asbestos and risk, choice of remediation remedy, lessons for other communities from Ambler, and research needs and information gaps. There was a high concordance of views amongst community members in most thematic areas. Interviewees were uniformly quite well informed about the hazards of asbestos and all could identify at least one individual who had died as a result of ARD. Community attitudes had changed dramatically from the earlier remediation in the 1980s when attitudes were characterized as "clean it up and get out, we don't want the stigma" to the 2010s "sustainability and future use are important," "it is no longer acceptable just to fence off about 65 acres in the center of town." Residents now question the long-term effectiveness of the 1980s remediation because whitish waste (presumably asbestos-containing) is visible on eroded slopes and near the roots of fallen trees and animal burrows. Despite the similarity of views on most topics, there are widely divergent views in the community and sometimes within the same family about the risk posed by asbestos and the preferred remediation remedy. Interviewees saw limitations in seemingly rigid EPA risk assessment processes in dealing with this complexity.

5.3 Distinctive Features of Third Wave Mesothelioma in Communities

As we address the issue of disease and exposure in communities, we need to think outside the prevailing exposure effect and prevention paradigms appropriate to the first and second waves associated with industrial and mining operations that resulted in occupational disease. In the *third wave*, we face more diffuse, complex and in many ways more difficult situations. To help address this novel situation we will discuss 12 distinctive aspects of non-occupational asbestos exposures and ARD in present-day communities.

5.3.1 Appropriate Prevention for the Third Wave, Banning Asbestos Use is Not Enough

The only known effective measure for preventing mesothelioma is to prevent asbestos exposure. Banning the import, export, and use of asbestos will end the first and second waves of asbestos-related disease. The ILO has called for national bans on asbestos: for example, the Resolution of the 95th Convention June 1, 2006 promotes the elimination of future use of all forms of asbestos and asbestos containing materials in all member states (ILO 2006). As of September 2015 at least 57 countries had instituted such bans (International Ban Secretariat 2015), mostly industrialized nations. There is an undeniable and urgent need for other countries to follow suit.

However, even effective bans on asbestos importation and use will not necessarily eliminate third wave exposures such as those from asbestos-containing products in building and construction, waste sites and communities contaminated with asbestos, exposure to "natural" asbestos fibers, and the like. Preventing these exposures requires additional actions and especially awareness.

5.3.2 *Shortcomings of the Regulatory Definition for Asbestos*

Preventing a fourth wave may also require an expanded regulatory definition of asbestos. Asbestos is a generic term describing a number of silicate minerals that produce thin, flexible fibers when crushed and which have high tensile strength and resistance to heat and chemicals. Six types of asbestos are regulated: the serpentine mineral chrysotile and five amphibole minerals, crocidolite (mineralogically fibrous riebeckite), amosite, tremolite, actinolite, and anthophyllite (USDOL 1975), the choice based on commercial use as of 1975. All are carcinogenic (International Agency for Research on Cancer 2012). For the purposes of U.S. EPA, U.S. OSHA and WHO, fibers of each of these types are regulated if they are longer than 5 μm and have a length to width (aspect ratio) of at least 3:1 (Case et al. 2011). There is no strict minerologic definition to correspond to this regulatory definition (Lowers and Meeker 2002).

Although this definition may have been appropriate for controlling occupational workplace exposures to asbestos in industrial operations, it is inappropriate to many community exposures as exemplified by exposures to erionite (fibrous zeolite) in Cappadocia, and exposures predominantly to winchite and richterite in LAA. For both erionite (Emri et al. 2002; Baris and Grandjean 2006; Carbone et al. 2007) and LAA, there is strong evidence of carcinogenicity from both laboratory animal and human epidemiologic studies.

Ideally regulations for both occupational and environmental health exposures should address all fibers capable of producing mesothelioma and other asbestos-related diseases. Revising the definition of asbestos for regulatory applications will involve toxicologic, minerologic, and analytic considerations and could require a protracted process. If this proves difficult, at the very least the regulatory definition should be extended to include winchite, richterite, and erionite.

5.3.3 *Age and Gender Distribution of Nonoccupational Mesothelioma*

As discussed with specific communities, third wave pleural mesothelioma from community exposure is characterized by a higher proportion of females, and sometimes by cases arising at a younger age than those from occupational exposures.

The younger age distribution appears to be a result of younger age at first exposure so that at any given age there has been greater opportunity to have accrued the characteristically long latent period. This effect is greatest where exposure started in very early childhood. However, mesothelioma risk still rises with age and the rate of mesothelioma still increases 50 years after exposure (Reid et al. 2013). Apart from this exposure-cohort effect, children have not been shown to be more vulnerable to mesothelioma than adults. Peritoneal mesothelioma is uncommon from most community exposures, as is asbestosis; both are more strongly associated with characteristically higher occupational exposures (Reid et al. 2014).

5.3.4 Vulnerable Groups in the Community

Familial clustering of cases of mesothelioma occurs as a direct consequence of paraoccupational exposures to those who are domiciled with asbestos workers, an effect that could be potentially related to shared residential neighborhood and lifestyle-dependent environmental exposures. There is also a strong possibility the familial clustering could reflect an additional or even primary genetic component. De Klerk et al. (2013) have estimated the additional genetically derived familial risk of mesothelioma in the Wittenoom cohort, after allowing for common exposures. This required fitting a statistical survival model to all the data, based on time from first exposure, duration and intensity of exposure and age, which allowed estimation of the expected number of mesotheliomas in family groupings. Of 369 families with at least one case of mesothelioma, 25 mesotheliomas were found in relatives vs. 12.9 expected. The risk ratio for blood relatives after this adjustment was 1.9 (95% CI 1.3 to 2.9, $p = 0.002$). This suggested an important though not dominant genetic component at Wittenoom. A larger genetic component was estimated by Roushdy-Hammady et al. (2001) for mesothelioma resulting from exposure to erionite in the Cappadocia region of Turkey.

An important social vulnerability occurs in those who are unknowingly exposed to asbestos by any pathway. This has been an important characteristic of residents of several high-risk communities in the past. Ignorance of asbestos exposure and effects appears more likely to be associated with non-occupational exposure at present, at least in developed countries, as asbestos awareness is generally high in employers, in the skilled trades, and amongst unionized employees. The role of socioeconomic factors in the risk of mesothelioma does not appear to have been studied even though there appear to be significant environmental justice concerns in the distribution of risk.

General population exposure can include exposures to groups of people who are not usually in the workforce such as those with serious diseases as well as the very young and aged. There is no convincing evidence that there is any increased predisposition to mesothelioma in any such group or amongst different ethnic groups, although it remains a possibility.

5.3.5 Diffuse Administrative Responsibility

For the first and second waves of exposure, the lines of administrative responsibility to protect workers' health were clear, i.e., a responsible party, the employer, and a single enforcing agency. In the USA, the general duty clause of the Occupational Safety and Health Act of 1970, enforced by OSHA, states that "each employer (1) shall furnish to each of his employees a place of employment which is free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees and (2) shall comply with occupational safety and health standards promulgated under this Act." Asbestos has its own standard with detailed requirements for permissible exposures, risk identification and assessment, engineering controls, work practices and respiratory protection, proper hazard communication, demarcation of areas where there are risks, separate decontamination and luncheon areas, training requirements, medical surveillance, and record keeping. Most other countries have similar regulations.

In contrast in many non-occupational exposure situations such as asbestos exposures in residences, asbestos encountered during lifestyle activities, or environmental exposures the chain of responsibility can be very complex. For example for the Bo-Rit Superfund site in Ambler, PA is an area of approximately 25 acres with much asbestos-containing material and potentially contaminated surrounding areas including creeks and parkland. The U.S. EPA is responsible for the cleanup on the site itself but does not even have automatic right of access to surrounding private properties where additional contamination is possible. Present or future use and control of access to potentially contaminated areas is, or will be, variously controlled by several different landowners, the Pennsylvania Department of Environmental Protection, four different local municipalities, the County Planning Department, other important stakeholders including neighborhood residents and businesses, the State Health Department, and a federal health agency (Agency for Toxic Substances and Disease Control). In other community sites, the parties involved may vary but responsibility is likely equally diffuse. When there is a shared common appreciation of risks and commitment to working with others, satisfactory and sustainable control of long-term risks acceptable to at least a majority of stakeholders may be obtainable. Where there are sufficiently divergent views amongst major stakeholders, achieving appropriate hazard control can be contentious, prolonged, and potentially ineffective.

5.3.6 Diverse Community Attitudes to Risk and Prevention

The stakeholders we interviewed regarding Ambler's asbestos-containing waste sites had wide divergence within a community expressed widely divergent views about risk and the appropriate future use of potentially contaminated areas. Interviewees also cited marked changes in community attitudes to asbestos risks over recent decades with increasing importance now given to long-term sustainability. More research is needed to understand how these different views are generated. We need methodology to help communities develop consensus around acceptable solutions, especially in third wave exposure situations where collaborative efforts involving many different parties are necessary to reduce or remove risks in a sustainable manner.

5.3.7 Quantifying Nonoccupational Exposures, Justifying Remediation and Action

In general the data quantifying non-occupational community exposures is sparse and often sporadic or absent. This is true for paraoccupational exposures (Goswami et al. 2013), residential exposures and the various pathways for environmental and lifestyle exposures. Moreover, individuals often sustain multiple exposure pathways: those with occupational exposures may have additional non-occupational exposures. Thus it is difficult or impossible to study the outcomes from a single exposure pathway in isolation. Furthermore, the cumulative "dose" from non-occupational asbestos exposures is likely to be site-specific and not easily extrapolated from one community to another: for example, ambient exposures in a wet temperate climate may differ markedly from those from a dry dusty tropical climate, and all will be affected by the local culture, lifestyle, and activities. Much information about community exposures is based on subjective historical recollection and relates to exposures and practices many years ago that are not readily reconstructed; and past measurement may have had very serious methodologic limitations (Rogers 1990). These inherent limitations in the exposure database pose difficulties for the types of quantitative risk assessments preferred by the U.S. EPA and similar agencies to support decisions as to remediation and prioritization of hazards.

We should be cautious not to overly discount the potential for risk of mesothelioma given the apparent dose response relationship with no known threshold and, in contrast to other ARDs, demonstrable risk from very low exposures. Limitations in our ability to recognize potentially carcinogenic exposures are illustrated by the findings of Leigh and Driscoll (2003): 19% of subjects with mesothelioma in the Australian Mesothelioma Registry gave no known history of any asbestos exposure; however, when lung tissue was analyzed for fibers, 81% of this group had fiber counts >200,000 fibers/g dry lung, and 30% had more than 10^6 fibers/g >2 μm, including "long" (>10 μm) fibers, suggesting that nearly all had been exposed to asbestos but could not recall or had never recognized the exposure.

5.3.8 Surveillance/Early Diagnosis in High-Risk Communities

Any enthusiasm for surveillance of those with previous exposure to asbestos must be tempered by the dismal prognosis once the disease is recognized. Using national U.S. Surveillance, Epidemiology and End-Results (SEER) data from 1973 to 2009, Taioli et al. (2015) found no significant improvement in the mean survival time for pleural mesothelioma over four decades. However, in Australia (Soeberg et al. 2016) and the Netherlands (Damhuis et al. 2012) modest improvements (in the order of a few months increased survival for pleural mesothelioma) have been noted during the last few years, largely corresponding with the introduction of new chemotherapeutic regimes. Furthermore, currently no evidence-based interventions are able to reduce the incidence or prognosis of cancers in those who have been exposed other than smoking cessation, which might help prevent lung cancer but does not influence mesothelioma outcomes. This grim picture emphasizes the need for primary prevention through elimination of exposure rather than secondary or tertiary prevention. Perhaps this situation will change. There is close surveillance of some high-risk community populations such as in Libby, MT, so that more data will become available on any benefits of close follow-up. Efforts to find biomarkers of early effects and to develop effective chemoprevention and treatments continue, so that more optimistic scenarios may emerge.

Importantly, high-risk communities need services to ensure prompt diagnosis and treatment of those ARD that do occur and to provide sociologic and psychologic support. Many high-risk communities contain a substantial number of former asbestos workers. In the USA, current Occupational Health and Safety Regulations are not particularly helpful for retired workers, as employers are required to provide periodic medical evaluations while working with asbestos, but no systematic surveillance or other follow-up after leaving that job. Yet, due to the long latent period for mesothelioma, the greatest risk occurs after work with asbestos has ceased.

Khatab et al. (2014) have developed a risk-based tool to predict which former asbestos workers would benefit most from participation in prospective surveillance for ARD. Risk factors include age, exposure duration, time since first exposure, age at first exposure, and job (partly as a proxy for degree of exposure). Since the primary target of their model is lung cancer where the benefit of early detection on mortality is demonstrated, smoking is included in the risk model. Should the prognosis of treated mesothelioma improve, a model specifically directed at mesothelioma risk might help identify both high-risk communities and individuals within a community who would have the greatest benefit from surveillance.

5.3.9 Legal Responsibility and Compensation for Non-Occupational ARD

The assignment of responsibility and legal recourse for compensation for mesothelioma and other "injury' suffered as a result of exposure was relatively straightforward during the first and second waves of ARD. As a base, Workers Compensation Insurance would apply, although in many countries including the USA, third-party suits against the supplier of asbestos were successful and resulted in much greater monetary settlements for plaintiffs. Community non-occupational exposures have the potential for new legal challenges, particularly where a single responsible party is difficult to identify. For example, in Italy, Marinaccio et al. (2015) have reported concern about insurance and welfare protection for mesothelioma sufferers and note that different pathways of non-occupational exposure to asbestos pose different concerns with respect to the welfare protection framework. They argue that a suitable framework needs to incorporate economic, ethical, and insurance points of view. Environmental exposure to natural asbestiform fibers may pose the greatest challenge.

Gordon and Leigh (2011) cite third wave risks to non-professionals who cut and fix asbestos cement products in home renovation or maintenance and other do-it-yourself activities. They maintain that manufacturers of asbestos-containing products have a continuing duty of care to inform such users about asbestos risks. They see major issues of controversy as the claimant's ability to prove that the manufacturer could, and should, have taken steps that would (before the time of exposure) have drawn the risk to the user's attention; and proving, more probably than not, that the exposure in such limited circumstances was the cause of, or made a contribution to, the mesothelioma manifesting many years later.

5.3.10 Epidemiology for Communities at High Risk for Mesothelioma

National Mesothelioma Registries have been invaluable for discovering trends in mesothelioma incidence and uncovering effects of third wave exposures. These registries overcome weaknesses in other systems that include underreporting of data, uncertain diagnosis, poor elucidation of occupational and environmental exposures, and less than comprehensive coverage (Ferguson et al. 1987). Mesothelioma Registries operate in Italy, France, and Australia. In Italy, ReNaM has recorded mesothelioma cases and collected information on asbestos exposure from 1993 to the present, although as of 2015 some regional data was still not available (Marinaccio et al. 2005; Marinaccio et al. 2015). A French National Registry has operated since 1998 (Goldberg et al. 2006; Galateau-Sallé et al. 2014). In Australia, national data on mesothelioma has been collected under two successive schemes: the Australian Mesothelioma Surveillance Program (1979–1985) and the Australian Mesothelioma Register (1986–2002), the latter operated by the National Occupational Health and Safety Commission (NOHSC) up to 2001 (Leigh and Driscoll 2003). As a consequence of funding cutbacks and interpretations of privacy legislation preventing comparisons with state cancer registries, data was incomplete from 2001 to 2010, when the registry was reconstituted. All Australians diagnosed with mesothelioma who consent to an asbestos exposure assessment complete questionnaires for the registry to record their residential and occupational history, any tasks outside paid work and other circumstances likely to have exposed them to asbestos (Australian Mesothelioma Registry 2014).

Mesothelioma registries have important characteristics for addressing third wave exposures including standardized diagnostic criteria, collection of exposure data that enables trends in the incidence attributable to different exposure types to be monitored, ability to track trends in different regions, and the ability to identify communities with clusters of mesothelioma.

The very long latency period between exposure and effect and the short median survival time after mesothelioma diagnosis pose methodological issues for conventional case-control and cohort studies of communities. In many modern communities, few people reside in the same location 40 or more years later, so that the studies of survivor populations may greatly underestimate the risk from past exposures. Short survival periods allow a brief window to question the patient about exposures, and next-of-kin may be ignorant of exposures many years ago. Occupational studies have used lists of past employees or in some cases union membership to identify cohorts of workers exposed to asbestos (Selikoff et al. 1965; Selikoff and Seidman 1991). Cohorts of children exposed to asbestos (Reid et al. 2013) and of spouses of asbestos workers (Ferrante et al. 2007; Reid et al. 2008) have contributed comprehensive information on long-term effects of exposure to those groups. Cohort studies following an entire community exposed to asbestos are rare; however, studies of former Wittenoom residents show they are possible through innovative methods and exhaustive follow-up.

5.3.11 Estimating the Magnitude and Timing of Third Wave Mesothelioma

Driscoll et al. (2005) estimated a global annual burden of 43,000 deaths and 564,000 disability-adjusted life years (DALYs) from mesothelioma assuming that virtually all mesothelioma is caused by exposure to asbestos. In some countries, mesothelioma incidence appears to have reached a plateau. Soeberg et al. (2016) analyzed the incidence and survival trends for pleural and peritoneal mesothelioma for Australia from 1982–2009. Very high asbestos consumption levels peaked from 1970–1979 and declined rapidly thereafter. Overall, mesothelioma incidence rates appeared to have reached maximum levels in the early 2000s, consistent with the earlier predictions based on consumption patterns (Leigh et al. 1997), but there were differences over time by age, gender, and tumor location. During 2003–2009, the incidence for men aged <65 was declining by about 5% per year, whereas for women and men aged >75 the incidence was increasing by about 5% per year. Although data for peritoneal mesothelioma were sparse, the incidence appeared to be slowly rising over the entire period studied.

Reid et al. (2014) pooled data from Italy and Australia using six cohort studies of exposed workers and two cohorts with residential exposure. Both the rate and risk of pleural mesothelioma increased until 45 years after first exposure and then appeared to increase at a slower rate. The authors commented that while the rate of increase appears to start to level out after 40–50 years, no one survives long enough for the excess risk to disappear. The rate of increase for peritoneal mesothelioma continued to increase over the entire 50 years of study. Women appeared to have a longer latent period than men and mostly obtained their asbestos exposure from paraoccupational, residential, or environmental sources which tend to be associated with lower exposures levels than occupational settings. Lower exposures appear associated with longer latency in other studies. Amongst Turkish emigrants to Sweden lower asbestos exposure was associated with a longer latency period (Metintas et al. 1999), and Wittenoom women who worked for the asbestos company had a shorter latency period than those with only residential exposure (Reid et al. 2008).

Predicting the magnitude of third wave ARD is difficult because of the paucity of good non-occupational exposure data. However, in countries with mesothelioma registries that record both exposure and diagnosis, we are already able to discern third wave mesothelioma from non-occupational exposures, including those in Italian communities with mesothelioma clusters (Marinaccio et al. 2015) and Australian home do-it-yourself renovators (Olsen et al. 2011) mentioned earlier in this chapter.

5.3.12 Varying Expressions of ARD in Different Communities

The pattern of ARD in an affected community can be influenced by amount of exposure, age at exposure, fiber type, and genetic predisposition. The highest exposures, seen predominantly in occupational groups, are associated with excess lung cancer and asbestosis and a higher proportion of peritoneal mesothelioma in addition to pleural mesothelioma; for the lower exposures experienced by non-occupational exposure groups, pleural mesothelioma predominates (Reid et al. 2014). Follow-up of the cohort of children (aged <15 years) exposed at Wittenoom found in addition to a very great excess of mesothelioma, excesses in other cancers including ovarian and brain cancers in women as well as leukemia, prostate, brain, and colorectal cancers, and mortality from "all causes" in men (Reid et al. 2013). With respect to fiber type: the association of LAA with more marked pleural changes and autoimmune manifestations is discussed in the section of this chapter dealing with Libby, MT.

5.4 Conclusion

Mesothelioma caused by asbestos has largely been considered and dealt with as an occupational disease. However recent research demonstrates an elevated incidence in a number of communities where there are important contributions not only from occupational exposures but also from non-occupational exposures. These include paraoccupational, residential, and lifestyle/behaviorally determined exposures. Although these exposures can be clearly identified, they are seldom accurately quantifiable. Genetic vulnerabilities may be important and can play a major role.

Each community cluster appears to have unique characteristics and a distinctive local history. Collectively prevention and attribution of ARD from non-occupational community exposures can be more complex and raise additional and different issues compared with prevention of occupational asbestos exposure. Their issues have been discussed in this chapter.

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