

REVIEW

History of asbestos related disease

P W J Bartrip

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The first medical article on the hazards of asbestos dust appeared in the *British Medical Journal* in 1924. Following inquiries by Edward Merewether and Charles Price, the British government introduced regulations to control dangerous dust emissions in UK asbestos factories. Until the 1960s these appeared to have addressed the problem effectively. Only then, with the discoveries that mesothelioma was an asbestos related disease and that workers other than those employed in the dustiest parts of asbestos factories were at risk, were the nature and scale of the hazard reassessed. In Britain, America, and elsewhere new and increasingly strict regulations were enacted.

companies, such as Johns–Manville, the American giant that dominated the industry for many years, ran to scores of pages. So asbestos had many “upsides”. Unfortunately, it also has a very significant “downside” in that exposure to its dust can cause three fatal diseases: asbestosis, lung cancer, and mesothelioma of the pleura and peritoneum.

It has long been known that asbestos dust constitutes a danger to health; however, some issues, including the relative hazards of different types of asbestos and whether there is a safe level of exposure to any of them, remain in scientific dispute.^{1,2} Since the 1960s crocidolite has been regarded as a particular hazard, chiefly because of its strong association with mesothelioma. Amosite is widely regarded as scarcely less dangerous. In contrast, some have argued that pure chrysotile “may present little or no carcinogenic hazard” if uncontaminated by amphiboles. As recently as 2000, pure chrysotile was termed “a remarkably safe and valuable natural resource”, which could be used to substantial public health advantage in the Third World.^{3,4} Others dismiss such views and demand an international ban on all forms of asbestos.⁵ Such scientific disputes and policy uncertainties conform to a long standing pattern whereby medical knowledge about the health hazards of asbestos dust has emerged slowly and sometimes falteringly since the early 20th century. As Irving J Selikoff, one of the foremost authorities on asbestos related disease in late 20th century America, once said, nature long held “some secrets ... rather close to its vest”.⁶

Asbestos is the generic term for a number of naturally occurring fibrous minerals. Commercially, the most important of these are the white, blue, and brown varieties, otherwise known as chrysotile (a serpentine asbestos), crocidolite, and amosite (both amphiboles). Asbestos is widely distributed, but the largest deposits are found in Canada and Russia. It possesses amazing characteristics. Uniquely among minerals, it can be spun into a thread and then woven into a cloth. Clothes and soft furnishings can be made from asbestos—even though it is literally a rock. But why make such products out of a mineral except as a curiosity? The answer lies mainly in the material’s unparalleled fireproofing and insulating capabilities. However, asbestos possesses other attractive qualities: it is relatively lightweight (an important consideration when fireproofing naval vessels), abundant, cheap to mine and process, resistant to water and acids (and hence corrosion), durable to the point of indestructibility, electrically non-conductive, and unattractive to vermin. Finally, it can be put to an enormous number of uses (usually when blended with resins, plastics, or other materials). In many respects, therefore, asbestos is the perfect material for an industrialising and electrifying world of heat, combustion, and high speed locomotion. Not surprisingly, it came to be viewed, for the first two thirds of the 20th century, as the “indispensable” and even the “magic” mineral.

By the mid-20th century asbestos was an ingredient in all manner of things, including motor cars (as an ingredient of brakes, clutch linings, and gaskets), buildings (for insulation and fireproofing), warships (also for insulation and fireproofing), domestic products (such as ironing boards), and electrical distribution systems. The product ranges of the largest asbestos

DISCOVERY OF A LINK BETWEEN ASBESTOS AND DISEASE

The sequence of developing knowledge about asbestos and disease has generated historical controversy.^{7–13} Some even maintain that the health hazards of asbestos dust were appreciated in the ancient world; such claims have been convincingly refuted.¹⁴ Those doyens of occupational medicine, Thomas Arlidge and Thomas Oliver, ignored the hazards of asbestos in the late-Victorian and Edwardian periods (though Oliver addressed them subsequently).^{15,16} The first medical paper on the subject appeared in the *British Medical Journal* in 1924.¹⁷ Written by William Cooke of Wigan Infirmary’s department of pathology, it briefly dealt with the illness and death from fibrosis of the lungs and tuberculosis of Nellie Kershaw, who had worked in the spinning room of a Rochdale asbestos factory. Following this case report, other papers soon appeared. These included articles by Oliver, who coined the word “asbestosis”, though most observers have mistakenly attributed the term

Correspondence to:
Dr Peter W J Bartrip,
Centre for Socio-Legal
Studies, Wolfson College,
Linton Road, Oxford OX2
6UD, UK; peter.
bartrip@csls.ox.ac.uk

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Table 1 Raw asbestos consumption in the USA, 1917–77 (10 year intervals)

Year	Consumption (short tons)
1917	135338
1927	226365
1937	316263
1947	616194
1957	723492
1967	720583
1977	671543

US Department of Commerce. *Bureau of Mines Mineral Yearbook*. Consumption peaked at 882 908 tons in 1973. The vast bulk of American consumption (some 96% in 1956) consisted of chrysotile (white asbestos).

to Cooke, who used it in a 1927 paper that further explored the Kershaw case.^{18 19} In 1928, following the discovery of a case of pulmonary fibrosis affecting a Glasgow asbestos worker, Britain's factory inspectorate took up the issue. Edward Merewether, a medical inspector based in Glasgow, was instructed to ascertain "whether the occurrence of this disease in an asbestos worker was merely a coincidence, or evidence of a definite health risk in the [asbestos] industry".²⁰

At 36 years of age, Merewether was comparatively young when he embarked upon this task. He was also a newcomer to the inspectorate, having taken up his appointment only in 1927. Merewether's initial survey was soon followed by a full scale investigation, which he completed in October 1929. He found that occupational exposure to asbestos dust, particularly for prolonged periods at high concentrations, constituted a "definite occupational risk among asbestos workers as a class".²¹ The fibrosis of the lungs that could result might lead to "complete disablement" and death.²¹ His report endorsed a view expressed a few months earlier that a "new" disease, pulmonary asbestosis, had been discovered.²²

Merewether had confirmed the existence of a new fatal disease, but he also believed that this disease was preventable. Dust control, he anticipated, "will cause, firstly, a great increase in the length of time before workers develop a disabling fibrosis, and secondly, the almost total disappearance of the disease, as the measures for the suppression of dust are perfected".²¹ At this point, Merewether's colleague, the engineering inspector of factories, Charles Price, investigated and recommended practical measures to control dust.

Following negotiations between representatives of the asbestos industry, the Trades Union Congress (largely in the person of its eminent medical adviser, Dr Thomas Legge, the first ever medical inspector of factories), individual unions, the factory inspectorate, and senior Home Office officials, the government enacted the Asbestos Industry Regulations, 1931. Implemented in full in 1933, these required the suppression of dust in the dustiest, and hence, apparently, the hazardous, areas of asbestos factories.²³ With these measures in place, and for decades to come, it was widely agreed that the 1931 regulations had solved the problem of asbestosis in British asbestos factories. Thus, in 1955, Richard Doll referred to the infrequency of asbestosis and attributed its rarity to the "great reduction in the amount of dust in asbestos works" since the early 1930s.²⁴ In the same year, Donald Hunter, then one of the leading authorities on occupational health, observed that the legislation had been "effective in controlling the disease" of asbestosis.²⁵ Other distinguished figures, including Georgiana Bonser of Leeds University and Andrew Meiklejohn of Glasgow University, expressed similar views.^{26 27}

All of these opinions referred to the British experience; for years Britain's efforts to prevent asbestos related disease were not replicated elsewhere. In the USA, asbestos was mined, manufactured, and used in large quantities (table 1), but, apart from the patchy industrial hygiene measures established by some states beginning in the 1930s, little regulation pre-dated the federal Occupational Safety and Health Act of 1970. By this time scientific and regulatory attitudes towards asbestos disease had been transformed in several ways. Most significantly, it had been ascertained that asbestosis was not the only disease associated with exposure to asbestos dust.

LINK WITH LUNG CANCER

Suspicion that asbestosis might be linked with lung cancer began to emerge in the 1930s.^{28 29} This link became more persuasive in the 1940s, even though doubts remained.^{30–34} Then, in 1955, Doll established to the satisfaction of most informed observers that a causal association existed between asbestosis and lung cancer.²⁴ He believed, however, that the Asbestos Industry Regulations had greatly reduced the risk of lung cancer for those who worked in Britain's asbestos factories. As he wrote in 1960, "It seems likely that the risk may now be largely eliminated".³⁵

At this time, notwithstanding the discovery of a second asbestos related disease, there was every reason to suppose that the asbestos industry could continue to produce the fireproofing, insulation, and friction materials widely regarded as indispensable to modern life, provided that workers were protected from the heavy and prolonged exposures associated with asbestosis and lung cancer. In 1956, Meiklejohn dismissed the notion of a ban as "completely futile and absurd".²⁷ Such views remained prevalent during the 1970s and even the 1980s. Irving Selikoff, along with the editorial pages of the *Lancet*, *BMJ*, and *JAMA* and other commentators, emphasised precautions over proscription of the mineral.^{36–39}

The 1960s saw several important developments in the story of asbestos and disease. First, a third asbestos related disease, mesothelioma, was discovered. Second, it was shown that the hazards of asbestos dust were not confined to heavily exposed workers in asbestos factories but extended to insulation workers, other users of products containing asbestos, and people who lived close to asbestos factories.^{40–44} There were even suggestions that urban dwellers, even in towns and cities remote from asbestos mines or factories, might face a hazard simply because they lived among buildings and cars containing asbestos.⁴⁵ Third, even in Britain, with its well established and relatively high degree of regulation, some evidence suggested that asbestos related disease had ceased to decline and was possibly increasing.¹² Fourth, in Britain and America at least, asbestos hazards began to attract increased media attention. Between 1964 and 1967, stories about the health hazards of asbestos appeared in such national newspapers as *The Times*, *Sunday Times*, *Daily Herald*, *Guardian*, *Daily Telegraph*, *Morning Star*, *New York Times*, and *Wall Street Journal*, as well as in local and regional papers. In January 1967, the BBC broadcast a film on the subject in its early evening news programme *24 Hours*. Thereafter, asbestos health hazards regularly featured in newspaper and television reports. Fifth, in 1969, the first third party products liability suit claiming personal injury from asbestos was launched in the USA, thereby initiating the process that led to the demise of many large, well established, and successful companies.

LINK WITH MESOTHELIOMA

Cases of pleural mesothelioma were apparently detected in the nineteenth century, but the term itself had not appeared, and its occurrence was "so rare that some pathologists

doubted its existence".⁴⁶ However, during the 1950s, South African researchers J C Wagner, Christopher Sleggs, and Paul Marchand began to identify cases of mesothelioma in the crocidolite mining district of Griqualand West. Curiously, they found no such cases in the vicinity of the Transvaal asbestos mines, even though the asbestos there was the same as in Griqualand West. This discrepancy initially suggested that the mesotheliomas in the Griqualand West district could have had an origin unrelated to asbestos exposure. Wagner, Sleggs, and Marchand first presented their findings at a conference in Johannesburg in 1959. Papers they published between 1960 and 1962 established a "possible association between the development of mesotheliomas of the pleura and exposure to asbestos dust in people living in the Cape asbestos fields".⁴⁷⁻⁵³ As this quotation indicates, the researchers had not established a clear causal association between exposure to crocidolite dust (let alone other forms of asbestos dust) and cases of mesothelioma among people who had never visited the northwest Cape. There was not long to wait. Papers published in 1964 and 1965 resulted in the general medical recognition of mesothelioma as an asbestos related disease.^{40-44 54-60} Scepticism remained in some quarters, but, as a leading article in the *BMJ* later put it, by "the end of 1965 it was clear that asbestos workers are at special risk of developing ... mesothelioma".^{61 62}

Though other causal agents have been identified, for years asbestos dust (at least certain types of it) has been widely considered to be the principal or even the only cause of mesothelioma.⁶³ Recently, however, the longstanding assumption that mesothelioma is solely caused by asbestos exposure has been called into question by the recognition that there are "many cases (>20%) of mesothelioma for which there is little or no known exposure to asbestos".⁶⁴ A causal association between asbestos and mesothelioma is not in dispute, but it has been widely proposed that the disease may also be causally linked with poliomyelitis vaccine contaminated with simian virus 40 (SV40), which was administered to millions of people in Europe and the USA between 1955 and 1963. Mayall *et al* have suggested a "synergistic interaction between asbestos and SV40 in human mesotheliomas".⁶⁵ However, much remains in doubt. Carbone *et al* have warned against premature "conclusions about the possible role of SV40 in mesothelioma development in the general population".⁶⁶ Likewise, Jasani *et al* have observed that the "causal link between SV40 and mesothelioma ... still needs to be examined further".⁶⁷ More recently, Gazdar *et al* have pointed to "considerable evidence that SV40 has a causative role in the pathogenesis of mesothelioma", but caution that "the evidence is still insufficient to distinguish between association and causation".⁶⁸ At present, therefore, it remains unclear whether a causal association exists between SV40 and elevated rates of mesothelioma.⁶⁴⁻⁶⁹

EXTENT OF THE RISKS POSED BY ASBESTOS

Recognition that asbestos related disease was not confined to unprotected workers in the dustiest locations dates from the 1960s and had much to do with the discovery of mesothelioma and the appreciation that relatively brief and light dust exposure could cause the disease years before its manifestation. A few isolated cases of asbestosis in insulation workers were reported in medical journals as early as the 1930s.⁷⁰⁻⁷² Furthermore, as we now know, the US Navy and Maritime Commission appreciated the need to protect heavily exposed shipyard insulation workers in the early 1940s.⁷³ This knowledge was not disseminated to a wider audience, however, and *Asbestos Worker*, the magazine of the US insulation workers' union, accurately noted in 1966 that "probably more attention has been focused on these particular health hazards in the last 3 or 4 years, than in

the previous 30 or 40 years".⁷⁴ The key figure in identifying the dangers of insulation work involving materials containing asbestos and exposure to even intermittent and light dust concentrations was Irving J Selikoff of Mount Sinai Hospital in New York City. Beginning in the early 1960s, with financial support from sources as diverse as the insulation workers' union and (from 1968) the Johns-Manville Corporation, Selikoff and his colleagues produced a stream of publications indicating, among other things, that insulators who worked with asbestos material in the USA faced an "important risk" of contracting asbestosis, lung cancer or mesothelioma, and possibly also gastrointestinal cancer.^{40-42 75 76}

In Britain the emergence of knowledge about mesothelioma and the hazards of insulation work coincided with the first doubts about the 1931 regulations. As a result, the factory inspectorate began revising these regulations in 1964. Five years later, following extensive consultation with business, scientists, and trades unionists, the Asbestos Regulations, 1969 were established. These allowed the continued use of asbestos only if maximum allowable concentrations of dust were not exceeded and if other precautions were observed. The regulations applied to all work sites and not, as previously, to asbestos factories alone. The maximum allowable concentration for crocidolite was set so low that its use was virtually eliminated. In the 1970s, 1980s, and 1990s further restrictions, both voluntary and statutory, were placed on the importation and use of asbestos. At their peak, in 1973, UK asbestos imports stood at some 190 000 tonnes per annum; by 1997, the amount had fallen to 4820 tonnes of chrysotile, by then the only form allowed.¹² Then, in July 1999, with one minor exception, the European Commission announced a European Union ban on all remaining chrysotile use by 1 January 2005. Britain implemented the ban some five years ahead of schedule in October 1999. Other European Union members have also beaten the deadline, and other countries have introduced their own bans.⁷⁷ Elsewhere, including many parts of Africa, Asia, and South America, asbestos use remains widespread.

In the early 1970s, the US Occupational Safety and Health Administration (OSHA) identified asbestos as one of its first regulatory targets and introduced a range of controls. The OSHA reduced permitted exposure limits from 5 ff/ml (time weighted average) in 1972 to 2 ff/ml (time weighted average) in 1976.⁷⁸⁻⁸⁰ As in Britain, stricter measures on the manufacture, importation, and processing of asbestos and products

A chronology of medical discovery

- 1924: W E Cooke publishes the first paper on asbestos related disease.
- 1925: Thomas Oliver coins the term "asbestosis".
- 1930: Edward Merewether confirms that inhalation of asbestos dust can cause a fatal disease.
- 1935: Kenneth Lynch and W Atmar Smith identify a "possible relationship" between pulmonary asbestosis and carcinoma of the lung.
- 1955: Richard Doll finds that certain asbestos workers face a "notably higher risk" of contracting lung cancer than the rest of the population.
- 1960: Wagner, Sleggs, and Marchand publish their first paper indicating a relationship between pleural mesothelioma and asbestos exposure.
- 1964: Selikoff, Churg, and Hammond demonstrate that insulation contract workers face a health hazard resulting from asbestos exposure.

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containing asbestos followed in the 1980s and 1990s. A permitted exposure limit of 0.1 ff/ml (fibres per millilitre) was introduced in 1994.⁸¹ Many of the companies that mined, manufactured, and used asbestos have gone out of business since the early 1980s under the burden of litigation. At present, asbestos use is heavily regulated and banned in most circumstances in the USA. A “comprehensive ban on asbestos in America” is envisaged. However, since exceptions are apparently anticipated if no alternative materials are available and it can be demonstrated that no damage to health or the environment will ensue, it remains to be seen how “comprehensive” this “ban” will be.⁸²

FUTURE OF ASBESTOS RELATED DISEASE

Even if a worldwide ban on asbestos were to be introduced forthwith, past exposures will ensure that death and disease related to asbestos continue for the foreseeable future. Epidemiologists have predicted that the incidence of male mesothelioma in the USA should peak at about 2300 cases per year at the end of the 20th century and will decline to some 500 cases per year by about 2055.⁸³ In 1995, Julian Peto *et al* predicted that male deaths from mesothelioma in Britain will peak at between 2700 and 3300 per year around the year 2020.⁸⁴ A few years later, Peto *et al* forecast some 250 000 male deaths from mesothelioma in Western Europe as a whole by about 2035. Most of these deaths are expected to occur among roofers, plumbers, electricians, carpenters, gas fitters, and others employed in the building trades.⁸⁵ Others anticipate figures as high as 10 000 per year among British males alone by 2020.^{86 87} It appears that the history of asbestos related disease still has some distance to travel.

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