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REVIEW PAPER

ENVIRONMENTAL AND OCCUPATIONAL EXPOSURE TO ASBESTOS AS AN ONGOING CHALLENGE FOR ENVIRONMENTAL AND HEALTH EDUCATION*

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Abstract

Asbestos owes its popularity to its unique features, which include: non-flammability, resistance to chemical and biological agents, high thermal and mechanical resistance, thermal and electrical insulation properties, easy connection with other materials, good sorption and sound-absorbing properties and the possibility of fibre spinning. Asbestos is still used worldwide. Exposure to asbestos dust can cause many respiratory diseases, including: lung cancer, pleural mesotheliomas and peritoneum, asbestosis; it can significantly increase the risk of developing cancers of the larynx, stomach, colon and ovaries. The appearance of pathologies resulting from exposure to asbestos dust depends on the type of exposure. It is estimated that the environmental, occu-

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pational, and para-occupational effects of asbestos kill over 107,000 people each year. Aim of the study: Demonstration of negative health effects of environmental and occupational exposure to asbestos and analysis of literature trends in the field of exposure and health protection of asbestos. Test methods: In this study, bibliometrics was used as a tool to assess the area of research related to environmental and occupational exposure to asbestos fibres. To analyse bibliographic data of the 2020-2021, 21 potentially relevant articles addressing the topic at hand were selected by evaluating the full text of each article. Results: In the area of the analysed scientific works, there is a constant interest in the subject of pleural and peritoneal mesothelioma and asbestos-dependent lung cancer, especially in exposure to asbestos fibres in the environment, which seems to dominate the area of interest of scientists. Conclusions: Diseases caused by occupational exposure to asbestos occur mainly after a long latency period. It is justified and advisable, considering the health effects from the public health perspective, to take actions in the field of environmental and health education in order to minimize them.

Keywords: asbestos, asbestos fibres, occupational exposure, environmental exposure, asbestos-related diseases, occupational diseases, environmental education, health education, bibliometric analysis.

INTRODUCTION

The wide use of asbestos, due to its natural occurrence in the environment, in industrial production of the past and present, taking into account the negative health effects, is a key issue for public health both at the local and global level, both now and in the long term (Paglietti et al. 2016, van Zandwijk et al. 2020, Chmielewski et al. 2020).

Asbestos is a fibrous mineral that occurs in nature (naturally occurring asbestos – NOA). Asbestos is used to denote six naturally occurring silicate minerals belonging to the serpentine (chrysotile) and amphibole (amosite, crocidolite, tremolite, anthophyllite and actinolite) groups. Its largest deposits are in Russia, Canada, South Africa, China, Italy, and Brazil. (Abakay et al. 2015, Pagliwtti et al. 2016, Chmielewski et al. 2020, Ricchiuti et al. 2020, Zacašnik et al. 2022).

The chemical composition of selected NOA-containing minerals is presented in Table 1 (Chmielewski et al. 2020).

Asbestos, as a raw material, has unique physio-chemical properties that make it applicable in various fields of the economy. There are 3,000 applications known in the world. We find Asbestos-Containing Materials (ACMs): in construction as roofing, wall cladding, chimney pipes, water, and sewage pipes, as covers for elevators, installation and ventilation shafts, as road paving material and insulation elements. It was also used, inter alia, in the production of household appliances, e.g., cookers, electric and gas stoves, toasters and hair dryers. It was also used to produce paints, adhesives, lubricants, tiles and floor coverings and fire blankets (Paglietti et al. 2016, Allen et al. 2018, Algranti et al. 2019, Szymańska, Lewadnowska 2019, Chmielewski et al. 2020, Van Zandwijk et al. 2020, Zavašnik et al. 2022).

Table 2 shows the occurrence and use of minerals of industrial importance (Chmielewski et al. 2020).

Table 1

Chemical composition of selected asbestos minerals (modified Chmielewski et al. 2020)

Name of mineral	Chemical name	Chemical formula
Chrysotile	hydrated magnesium silicate	Mg_6 $[(OH)_8$ $Si_4O_{10}]$
Crocidolite	ferric sodium silicate	Na_2 Fe_3 Fe_2 $[(OH)Si_4O_{11}]_2$
Amosite	ferric magnesium silicate	$(Fe,Mg)_7$ $[(OH)Si_4O_{11}]_2$
Anthophyllite	iron-containing magnesium silicate	$(Mg,Fe)_7$ $[(OH)Si_4O_{11}]_2$
Tremolite	calcium magnesium silicate	Ca_2 Mg_5 $[(OH)Si_4O11]_2$
Actinolite	calcium silicate containing magnesium	$Ca_2(Mg)[(OH)Si_4O_{11}]_2$

Table 2

The characteristics of fibrous minerals most frequently used in the industry (modified Chmielewski et al. 2020)

Mineral	Chrysotile	Crocidolite	Amosite
Susceptibility to action in biological environment	soluble	insoluble	moderately soluble
Occurrence	Brazil, Canada, China, Russia, Kazakhstan	South Africa, Canada, Russia	South Africa, India
Application	asbestos-cement, products textile, insulation	sewer pipes, water supply	thermal insulation

The widespread use of asbestos and its application in many industries has resulted in adverse health effects both for workers directly employed in industries using this raw material and for people exposed to asbestos fibres in the environment (Paglietti et al. 2016, Noonan 2017, Allen et al. 2018, Algranti et al. 2019, Barbieri et al. 2020, Chmielewski et al. 2020, Militello et al. 2021, Visona et al. 2021).

Asbestos in the environment

The environment is an important factor influencing health of both individuals and the general population. The importance of environmental factors in the understanding of present epidemiology was already indicated by Hippocrates (460–377 BCE). Environmental health hazards are commonly understood as the negative impact of a contaminated environment on human health. Undoubtedly, economic development, extensive use of natural resources, and waste management significantly affect the degradation of the environment, which means that the number of factors having a negative impact on health and quality of life is increasing in parallel. Health economics shows that the improvement of environmental living and working conditions should be treated as a preventive measure against the negative health effects associated with the impact of ACMs on the body. (Paglietti et al. 2016, Chmielewski et al. 2017, Hankey, Marshall 2017, Li 2017, Chmielewski et al. 2020*a*, Walosik et al. 2021).

Asbestos pollution in the environment is measured by examining the concentration of its fibres in the atmospheric air. The risk related to environmental pollution with asbestos dust, resulting from the presence of asbestos deposits, is estimated to be minimal due to their significant dispersion and occurrence in relatively sparsely populated areas. Due to its properties and durability, asbestos introduced into the environment remains there for an indefinite period of time. This means the nature of the pollution of individual components of the environment is permanent. Asbestos pollution of the environment means air pollution with asbestos dust, especially the respirable fraction that is most dangerous for humans, and pollution of soil and land, which causes re-emission of asbestos dust. The primary source of ACM environmental pollution related to human activity are construction facilities and areas where asbestos-containing waste was produced, warehoused, and stored, wild dumps of asbestos-containing products, devices and installations in which asbestos-containing products are used. Currently, the biggest problem is air pollution caused by the use of asbestos products and fibre emissions due to corrosion of asbestos-cement boards. ACMs during their use, disassembly, storage, and disposal are the source of asbestos fibres emission to the environment, posing a serious threat to health (Brzana et al. 2014, Paglietti et al. 2016, Szymańska, Lewandowska 2019, Chmielewski et al. 2020, Ricchiuti et al. 2020, Militello et al. 2021).

The literature related to exposure to chemical substances provides the basis for demonstrating three types of exposure to asbestos dust: occupational, para-occupational, and environmental. Occupational exposure is related to work in conditions of exposure to asbestos dust. The para-occupational exhibition concerns the inhabitants of the areas adjacent to mines and asbestos processing plants and the families of their employees. In turn, environmental exposure is related to the presence of asbestos in the atmospheric air, soil, drinking water as well as industrial and food products. The assessment of exposure to chemical agents in the air usually consists of measuring or estimating the concentrations of these agents in the air and comparing the measurement results with the adopted criteria. These criteria, also known as hygienic standards, permissible values, and more commonly as just limit values in the English-language literature, define the permissible concentrations of chemical substances in the air depending on the averaging period they refer to (Goswami et al. 2013, Chmielewski et al. 2015, 2017, Pira et al. 2018, Ricchiuti et al. 2020, Chmielewski et al. 2020*b*, 2020*c*, Zunarelli et al. 2021).

The available literature data show that currently about 80% of the world's population live in countries where the use of ACMs is not prohibited.

In contrast, over 85% of the world's ACMs production takes place in Asian and Eastern European industries. The largest consumers of ACMs in the world are China (24%), the Russian Federation (21%), India (10%), Kazakhstan (9%), Brazil, Indonesia, Thailand, Vietnam, and Ukraine. Industrial production in China, Russian Federation, India accounts for more than 60% of annual consumption. Worldwide, it is estimated that 125 million people are exposed to ACMs each year, and more than 107,000 people die each year from lung cancer, mesothelioma and asbestosis related to exposure to asbestos. It is estimated that in the early 21st century, occupational exposure to asbestos caused 43,000 mesothelioma deaths and 7,000 deaths due to asbestosis worldwide (Stayber et al. 2013, Mensi et al. 2015, Paglietti et al. 2016, Vainio et al. 2016, Allen et al. 2018, Algranti et al. 2019, Zunarelli et al. 2021).

The literature shows that there is a risk of asbestos fibres being present in water as a result of the degradation of the inner and outer surfaces of pipes by dissolving or washing out the components. Asbestos fibres are also released from damaged pipes when they are subjected to vibration caused by proximity to roads, railways, construction works, etc. The degradation of asbestos cement pipes can act as a continuous source of asbestos fibre contamination of drinking water. Likewise, the aging of pipes is recognized as an significant source of asbestos in drinking water. Asbestos fibres from drinking water can become airborne as a result of numerous processes such as evaporation during cooking, moistening, spraying, showering or bathing, or when fibres are trapped on clothing during washing and are then released into the atmosphere (Punurai, Davis 2017, Van Laarhoven et al. 2021, Zavašnik et al. 2022).

The presence of asbestos in the soil in selected countries depending on the source of contamination is presented in Table 3 (Ricchiuti et al. 2020). Table 4 displays information about ACMs, taking their asbestos content into account (Chmielewski et al. 2020).

Biological health effects of asbestos exposure

One of the main determinants of the degree of risk that asbestos poses to the human health is its biological persistence. The health effects of inhaling asbestos fibres have been identified and are now well known (Dragani et al. 2018, Chmielewski et al. 2020, Visona et al. 2021, Milietello et al. 2021).

The gradual degradation of ACMs causes the fibres to be released into air, soil and water. Their inhalation, consumption, drinking and accumulation in the human body can cause serious asbestos-related diseases (ARD). The occurrence and type of pathological changes are influenced by the type of asbestos, the size of the fibres and their concentration in the air, as well as the length of exposure time and the type of exposure (Dragani et al. 2018, Szymańska, Lewandowska 2019, Chmielewski et al. 2020, Ricchiuti et al. 2020, Militello et al. 2021, Zunarelli et al. 2021, Zavašnik et al. 2022).

Table 3

Selected data of asbestos-containing soil (modified Ricchiuti et al. 2020)

Place	Fibre type	Source of contamination
Australia	amosite, crocidolite, chrysotile	indirect (ACMs in the soil)
India (Mohanlalganj, Lucknow)	chrysotile	indirect (vicinity to asbestos cement factory)
Italy (Liguria)	tremolite, actinolite, chrysotile	direct (natural occurrences)
Italy (Sicily)	fluoro-edenite	indirect (quarries, dirt roads, use in mortar and plasters)
Korea (Hongseong; Janghang)	chrysotile, tremolite, actinolite	indirect (vicinity to asbestos mine), direct (natural occurrences)
New Caledonia	tremolite	indirect (whitewash, dirt roads)
New Zealand	asbestos fibres	indirect (construction waste)
Turkey (Anatolia)	tremolite, actinolite, chrysotile	indirect (whitewash, stucco, terracotta); direct (natural occurrences)
USA (California)	chrysotile, fibrous amphiboles	direct (natural occurrences)
USA (Nevada)	actinolite, fibrous erionite	direct (natural occurrences)

Table 4

The most important ACMs and their asbestos content (modified Chmielewski et al. 2020)

Product	Asbestos contents (%)	A type of asbestos (mineral)
Friction materials, textiles	65-100	chrysotile, crocidolite
Insulation products including spray insulation	12-100	amosite, chrysotile, crocidolite
Fillers, reinforcements, and products made of them (cardboard boxes, paper, filters, putties, adhesives, protective coatings)	25-98	chrysotile
Connectors and seals	25-85	chrysotile, crocidolite
Plastic products and battery housings	55-70	chrysotile
Fireproof insulation boards	25-40	amosite, chrysotile

The ethology of ARD results from the inhalation of asbestos fibres in the air. Their biological aggressiveness is related to the degree of penetration and the number of fibres in the respiratory system. The diameter of individual fibres is of particular importance, length less so. Fibres smaller than 3 μm in diameter pass through and accumulate in the terminal parts of the respiratory tract, while coarse fibres larger than 5 μm in diameter end up in the upper respiratory tract. Respirable fibres pose the greatest threat to the human body. This is due to the fact that they travel in the air to the alveoli, and from there they can penetrate the lung tissue. All diseases caused by asbestos dust are characterized by long periods of time between the first exposure and the onset of pathological changes, the most common periods being 15-25 years for asbestosis and 20-40 years for cancer (Chmielewski et al. 2020, Militello et al. 2021).

The literature shows that the first case of asbestosis was recorded in a London worker in 1906. In contrast, studies conducted in 1955 showed a correlation between exposure to asbestos fibres and lung cancer (Stayner et al. 2013, Militello et al. 2021).

The largest and most diverse group of carcinogenic or mutagenic factors are chemical substances, including asbestos, which due to its health effects is classified as group I carcinogenic substances for humans. Asbestos is considered one of the most dangerous types of dust for the human health (Satyner et al. 2013, Paglietti et al. 2016, Solbes, Harper 2018, Chmielewski et al. 2020, 2020*d*, La Maestra et al. 2020, Militello et al. 2021).

The 1997 Helsinki Criteria define the conditions for the diagnosis of ARD (Vainio et al. 2016). Exposure to asbestos dust can cause many respiratory diseases, such as pleural fibrosis and plaques, asbestosis, benign asbestos pleural effusion, small cell lung carcinoma, non-small cell lung carcinoma, and malignant mesothelioma, and can significantly increase the risk of developing cancers of the larynx, stomach, colon and ovaries. Exposure to asbestos dust may also be associated with the risk of autoimmune diseases (Goswami et al. 2013, Pfau et al. 2014, Mensi et al. 2015, Paglietti et al. 2016, Dragani et al. 2018, Solbes, Harper 2018, Chmielewski et al. 2020, 2020*d*, Militello et al. 2021).

Occupational and non-occupational asbestos exposure plays a well-known role in the development of asbestosis, deterioration of lung function, lung cancer and mesothelioma (Chmielewski at al. 2020*b*, Zunarelli et al. 2021).

As shown by the data of the Institute of Occupational Medicine in Łódź, which implements the Amianthus program in Poland, an occupational disease was diagnosed among 2,222 out of the 8,329 people participating in the program examined who were examined in 2000-2019. Data analysis shows that asbestosis was diagnosed in 1,880 people (22.6% of respondents), and lung cancer was diagnosed in 121 participants (1.4% of respondents), while pleural mesothelioma was diagnosed in 77 subjects (0.9% of respondents). Pleural radiological changes were found in 3,282 (39.4%) people, and the shadowing of the pulmonary parenchyma appeared in 5,461 (65.6%) people. Asbestos-related diseases were most often found among former employees of asbestos-cement plants (ACP).

MATERIAL AND METHODS

The scope of the scientific content taken from the PubMed database, the English-language online database of the National Library of Medicine, National Institutes of Health, Bethesda, MD, USA (http://www.ncbi.nlm.nih.

gov/PubMed) was analysed, including articles in the field of medicine and biological sciences concerning asbestos-related diseases. The literature published between 2010 and 2021 was reviewed using the advanced search option, based on key words or combinations of keywords: mesothelioma asbestos, asbestos lung cancer, asbestosis, asbestos, occupational exposure asbestos, environmental exposure asbestos and a predetermined time frame. To analyse bibliographic data from the time period 2020-2021, 21 potentially relevant articles addressing the topic at hand were selected by evaluating the full text of each article.

Documents such as opinions, conference materials, letters to the editor, book chapters, and notes from conferences and training courses were excluded from the analysis.

RESULTS AND DISCUSSION

The conducted analysis revealed 14,932 publications in the PubMed scientific base (as of October 12, 2021) concerning health-related issues of asbestos dust exposure written between 2010-2021. Meanwhile, Table 5 presents a quantitative list of publications on health-related issues of asbes-

Table 5

Publications on health-related issues of asbestos dust exposure in the years 2010-2021

Year of publication	Number of publications based on keyword search						
	mesothelioma asbestos	asbestos lung cancer	asbestosis	asbestos	occupational exposure asbestos	environmental exposure asbestos	total
2010	171	107	102	387	161	178	1,106
2011	212	111	97	421	164	184	1,189
2012	210	125	91	438	177	205	1,246
2013	255	168	107	432	160	182	1,304
2014	216	193	70	431	168	204	1,282
2015	219	184	87	444	173	189	1,296
2016	287	236	89	498	197	216	1,523
2017	228	185	81	440	172	177	1,283
2018	256	202	46	447	183	192	1,326
2019	239	204	55	425	154	168	1,245
2020	252	194	74	458	173	165	1,316
2021	176	105	43	321	98	73	816
Total results	2,721	2,014	942	5,142	1,980	2,133	14,932

tos dust exposure in the analysed time period. Of all the 14,932 papers (100% of publications) which appeared in that time, publications on mesothelioma asbestos accounted for 18.20%, papers about asbestos lung cancer represented 13.50%, papers about asbestosis constituted 6.30%, and papers devoted to asbestos accounted for 34.40%, works dedicated to occupational exposure asbestos made up 13.30% of all articles, while 14.30% of all papers dealt with environmental exposure to asbestos.

It is noteworthy how stable the number of publications is, owing to the scientific efforts of many authors around the world dedicated to the issue of exposure to asbestos dust. Overall, 1,200 papers appeared annually in 2012-2020 except in 2016, when 1,523 original papers in this area were published. Since 2010, asbestos consistently dominated the area of interest of scientists. In the research on asbestos fibres exposure, environmental exposure prevailed as the subject until 2019. Globally, it still remains the main area of interest for researchers, amounting to 2,133 publications year, while occupational exposure was raised in 1,980 works in the time period analysed (Table 5). On the other hand, the issue of asbestos exposure dominated in specific categories of publications, both in every year and throughout the entire period.

The analysis has shown that researchers dealing with health problems related to exposure to asbestos worldwide have focused on environmental exposures. In the last two years, there has been a noticeable shift in the interest of researchers dealing with the mentioned health problems due to environmental to occupational exposure to asbestos. Asbestos mesothelioma is still the focus of research interest.

Considering the degradation of ACMs and their widespread presence in the environment, it is expected that the number of ARD cases will increase. This conclusion is supported by two facts: the improved diagnostics of diseases and, on the other hand, the omnipresence of asbestos in the economies of many countries, and thus also in the environment.

Some countries began to partly ban asbestos back in the 1970s. In the mid-1980s, some countries began to impose a complete ban on asbestos, while the European Union prohibited the use of asbestos in all 25 member states in 2005. By 2013, 67 countries had banned asbestos partially or completely. Nevertheless, asbestos deposits in the environment will be a significant source of health risks for many years to come, in terms of both environmental and occupational exposure. We will still have to struggle with the legacy of asbestos due to its present and past use spanning at least 4 decades (Stayner et al. 2013, Mensi et al. 2015, Allen et al. 2018, Szymańska, Lewandowska 2019, Algranti et al. 2019, Ricchiuti et al. 2020, Van Zandwijk et al. 2020).

The literature clearly indicates the need for continuous documentation of the effects of asbestos exposure in the occupational, para-occupational and environmental context. These activities should aim to raise awareness of the health effects of asbestos in local communities, but also among governments of countries that still use it. It is reasonable to undertake close cooperation among all the entities operating in the field of public health, including environmental medicine, occupational medicine, and occupational health protection, in order to develop a common prevention strategy aimed at minimizing negative health effects related to environmental factors. Health education of the society should constitute the foundation of disease prevention. The introduction of various forms of environmental and health education should enable broad social groups to understand what health is in relation to exposure factors, what determines health, why and how to care for it. As far as health education in the workplace is concerned, stimulating methods should play a dominant role. Preventive measures, including extensive education and an appropriate policy in the field of ensuring safe living and working conditions without ACM exposure, should be conducted on the basis of a detailed health risk analysis. The application of broad environmental and health education will allow community members to become involved in the process of creating safe living and safe working conditions (Mensi et al. 2015, Chmielewski et al. 2017, Szymańska, Lewandowska 2019, Chmielewski et al. 2020, 2020*e*, 2020*f*; Van Zandwijk et al. 2020).

CONCLUSIONS

1. In countries where scientific research and epidemiological analysis of the effects of ACMs on the environment are undertaken, the research in question should constitute the basis for an assessment of the health situation of the studied group, as well as the basis for implementing tailored prevention programs.

2. In the area of scientific research and analyses, there is a constant tendency for scientists to focus on the subject of ARD, in terms of both environmental and occupational exposure to asbestos fibres.

3. ACMs exposure has a significant impact on health.

4. The obligation to protect the health of the public against negative effects of ACMs is often insufficiently fulfilled by the authorities.

5. Preventive measures limiting the negative impact of ACMs on the health of the general population should be implemented on many levels, and their effectiveness should be ensured through constant monitoring and supervision at each of those levels.

Conflict of interest

The authors declare no potential conflict of interest with respect to the authorship and/or publication of this article.

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