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Asbestos cement materials: impacts on the use and waste generation in Brazil

Materiais de cimento — amianto: impactos no uso e geração de resíduos no Brasil

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ABSTRACT

This article updates data on consumption of chrysotile (white asbestos), in the global and national context, and presents an estimate of the amount of MCA in use in the country; discusses situations of risk to health and the environment, due to the release of chrysotile fibers, and proposes warnings for their use; questions waste disposal routes at the end of life. For the global update, the evolution of the market and ban were researched, by collecting data on domestic consumption of chrysotile, from 1998 (period of permission to use) to 2017 (year of ban), the generation of asbestos-cement waste (RCA) (2012 to 2017), as well as the percentage of fibers per composite and durability factor. There was a significant difference between the average annual production of MCA (1.38 million t) and the generation of RCA (17 thousand t), evidencing a large amount in use and that the installed capacity of class I landfills in the country is below the projected RCA demand. Considering aspects of reuse, maintenance, pollution, and climatic actions, in addition to situations associated with the construction characteristics of low-income housing with asbestos-cement tiles (TCA), hazards were identified for residents due to the possibility of inhaling asbestos fibers. These situations require adequate management of the MCA and RCA, with routes for treatment and recovery, mapping of areas of use, monitoring and preventive actions, such as measuring the concentrations of fibers/cm³ in the environment, and creating technical instructions for training the hands of work for safe removal and disposal with a view to reducing risk to the health of the exposed population.

Keywords: asbestos-cement waste; waste management; chrysotile; health impacts; asbestos exposure.

RESUMO

Este artigo atualiza dados de consumo de crisotila (amianto branco) nos contextos global e nacional e apresenta estimativa da quantidade de materiais de cimento-amianto (MCA) em uso no país; discute situações de risco à saúde e ao ambiente, pela liberação das fibras de crisotila, propondo alerta sobre seu uso; e questiona rotas de destinação dos resíduos no fim de vida. Para a atualização global foi pesquisada a evolução de mercado e banimento, foram levantados dados de consumo interno de crisotila de 1998 (período de permissão de uso) até 2017 (ano do banimento), a geração de resíduos de cimento-amianto (RCA) (2012 a 2017), assim como o percentual de fibras por compósito e o fator durabilidade. Constatou-se significativa diferença entre a média anual de produção de MCA (1,38 milhões t) e a geração de RCA (17 mil t), revelando grande quantidade em uso e mostrando que a capacidade instalada dos aterros classe I no país está aquém da demanda projetada de RCA. Considerando-se aspectos de reúso, manutenção, poluição e ações climáticas, além de situações associadas às características construtivas de moradias de baixa renda com telhas de cimento-amianto, perigos foram identificados aos moradores pela possibilidade de inalação de fibras de amianto. Essas situações requerem gestão adequada dos MCA e RCA, com rotas para tratamento e recuperação, mapeamento das áreas de uso, monitoramento e medidas preventivas como medição das concentrações de fibras/cm³ no ambiente, bem como criação de instruções técnicas para a capacitação de mão de obra para a remoção e destinação seguras, visando à redução de risco à saúde da população exposta.

Palavras-chave: resíduos de cimento-amianto; gerenciamento de resíduos; crisotila; impactos na saúde; exposição ao amianto.

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Introduction

A lot has been discussed about asbestos and its danger in all phases of its life cycle: extraction, fiber processing, and the use of products. With the realization of risks to human health, represented by respiratory problems resulting from the inhalation of asbestos-cement fibers, this material has been banned in several parts of the world. In Brazil, the banning of asbestos commercialization in the domestic market, as of 2017, definitely gives room for new products and technologies in the civil construction sector, a sector characterized by the high use of fiber cement composites.

Studies that proved the danger of asbestos, the classification of all asbestos as carcinogens (WHO, 2017) and the emergence of diseases caused by the inhalation of fibers in human health have provided changes in the asbestos market worldwide. The trade has changed in various parts of the world, including bans in several countries. In the United States, where asbestos consumption has been declining for decades, it has dropped from a record 803,000 tons in 1973 to around 450 tons (0.06%) in 2020 (USGS, 2021).

On the other hand, the market was opened up to less dangerous alternatives such as composites produced with white asbestos, whose fibers are surrounded by adherent materials such as cement, which acts as a fixative of the chrysotile fibers to the composite. These materials meet very well the expectations of the civil construction market regarding thermal, mechanical (traction) performance and good acoustic insulation (Paglietti et al., 2016), in addition to being durable, with an estimated time of use of 50 years. (Marques et al., 2016). Even with the advent of substitutes, such as synthetic fibers, MCA remain highly sought after in markets open to their use, such as India, Mexico, and Indonesia, where there is extensive demand for infrastructure works (Virta, 2005). They were also widely marketed in Brazil from 1940 (beginning of their production) to 2017, the year of their ban by determination of the Federal Supreme Court.

However, a broader discussion regarding MCA should consider, in addition to these aspects, the issue of waste generated and its disposal at the end of life, considering that, for more than 70 years (Brasilit, 2021), MCA were marketed and are still in use in the country.

Asbestos-cement waste (RCA) is classified as hazardous (CONAMA 307/2002) due to the detachment and dispersion of chrysotile fibers that can be inhaled, representing a risk to human health. When improperly discarded, under the action of the weather on the cement matrix, over time, fibers are released into the environment, compromising water resources, the soil, by its absorption (Malinconico, et al., 2022), and especially the atmosphere. In this sense, such waste must have specific management with adequate destination for treatment, or for disposal in hazardous waste landfills (Class I), as is the most common practice in a large number of countries. The appreciation and proper destination of RCA are in line with the Sustainable Development Goals (UN, 2015), contributing to urban sustainability and the promotion of public health.

According to Kim and Hong (2017), there are few studies on asbestos waste, which cover the quantification of generation, the cost of disposal and the degree of danger involved, so this is a knowledge gap that this study aims to address. In this sense, the purpose of this article is to update data on chrysotile consumption in the global and national context, and to present an estimate of the amount of MCA in use in the country, in order to discuss the risk situations to the environment caused by the detachment of chrysotile fibers, during episodes of maintenance, environmental pollution, or climate action, as well as alerting to the need of creating mechanisms for managing the RCA and routes to sustainable disposal, considering the possibility of adequate treatment and the return to the consumer market.

Characteristics of asbestos fibers

Asbestos is the generic name given to a heterogeneous set of mineral fibers basically composed of hydrated magnesium silicates, belonging to the group of fibrous silicates, found in abundance in nature.

Although there are about thirty asbestiform minerals commercially known, the term asbestos encompasses two main groups: serpentines and amphiboles. Chrysotile (white asbestos) belongs to the serpentinite group, while amosite (brown asbestos), crocidolite (blue asbestos), and tremolite and anthophyllite fibers belong to the amphibole group (Gualtieri, 2017), as can be seen in the diagram of Figure 1.

Because they have different characteristics and properties, such as straight and cylindrical fibers (DNPM, 2017), the amphibole group is considered as the best quality asbestos. Crocidolite (blue asbestos), found mainly in South Africa and Australia, has a low melting point and high resistance to acids, while brown asbestos (amosite) has shiny fibers, excellent thermal and mechanical resistance, and good elasticity, being found in mines in South Africa (Mendes, 2001). Anthophyllite consists of normally weak and short fibers, with high resistance to heat, acids, and chemical substances in general, with main deposits in Finland and Brazil (Jiramatia, Alagoas), both deactivated. On the other hand, tremolite has long, silky fibers that are not very resistant to traction, as well as actinolite, which has brittle fibers, is rarely found in fibrous form, and is present in small amounts in amosite and chrysotile reserves. The amphibole asbestos group has been banned worldwide, and is practically banned from the market.

Among asbestos fibers, chrysotile (hydrated magnesium silicate) is the most abundant in nature and causes the least impact on the airways due to the geometry and size of its fibers, being less biopersistent in the lungs than amphiboles (Scherpereel et al., 2020). It is presented in the form of flexible, fine, and silky fibers, with a length that varies from less than 1 to 40 mm; one kilogram of this fiber can produce up to 20 thousand meters of yarn. As they are resistant to heat and strong alkalinity, these fibers can be easily woven, but they become unstable in the presence of acids (Mendes, 2001).

Production of asbestos fibers in Brazil and in the world

The commercial exploitation of asbestos began in 1878, in the region of Quebec, Canada, but world consumption increased sharply during the Second Industrial Revolution due to its widespread use in the industry (Ebert, 2019).

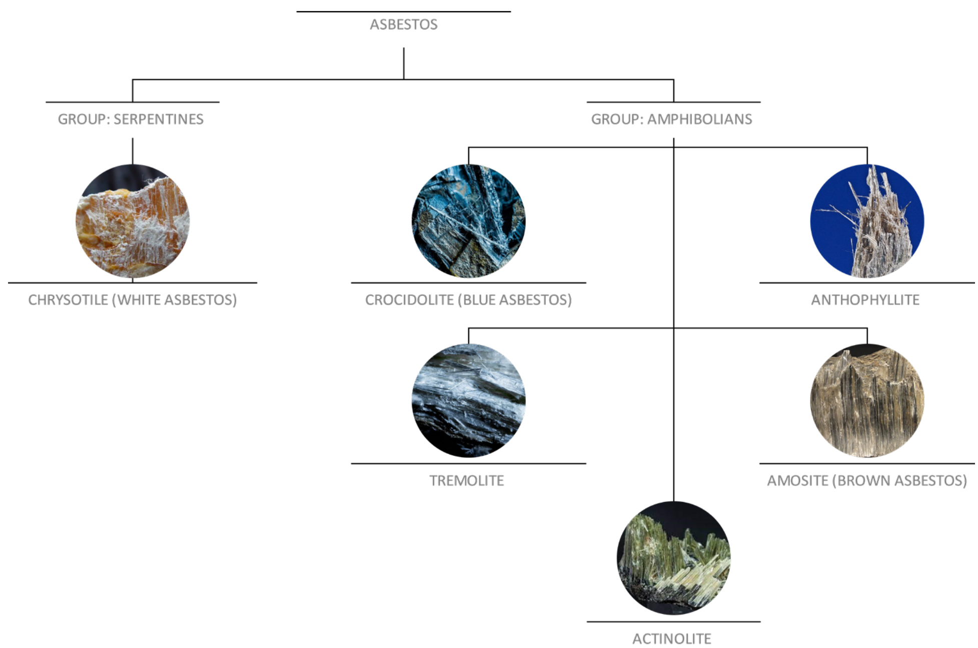

Figure 1 – Main commercial types of asbestos, its mineral representation.

In Brazil, until the end of the 1930s, all asbestos consumed were imported. In the 1940s, small coal beds were discovered, but with insufficient production for the domestic market: Pontalina, south of Goiás; São Félix, municipality of Poções, Bahia; São João, Piauí; and Batalha, Alagoas. This scenario changed with the discovery of the Cana Brava coal bed (1962), in the municipality of Minaçu, Goiás, whose reserve provided self-sufficiency to the sector, with a perspective for consumption for approximately 50 years (TST, 2012). Globally, in 1950, Canada stood out as the main producer of asbestos fibers, with more than 60.0% of the world market, followed by the Soviet Union with 16.9%, and South Africa with 6.1% (IBAS, 2017).

Studies on the impacts of asbestos on human health, the adoption of banning policies, and the discovery of new coal beds around the world are factors that have changed this scenario. In 2010, the main producer became Russia (1 million tons/year), responsible for more than half of the world production. 2015 was the peak of the world production, but in 2019 and 2020 there was a significant reduction in three main producers, Russia, China, and Brazil, with the exception of Kazakhstan, which remained constant (Figure 2).

In 2019, there was a significant reduction in the production of asbestos in the country, as a result of the decision of the Federal Supreme Court (*Supremo Tribunal Federal* — STF) (2017) for its banishment in the national territory. However, asbestos continues to be exploited in Minaçu, northern Goiás, supported by State Law No. 20,514, enacted in July 2019, which caused the increase in production for export in 2020.

Consumption of asbestos fibers and manufactured products

Exports of Brazilian chrysotile fiber are mainly destined for developing countries with large populations and in a process of increasing urbanization, which justifies the use of fibers as raw material in the manufacture of large-scale products aimed at low-income populations, such as tiles, water tanks, and pipes for water supply and sewage network infrastructure. In 2015, the main buyers of domestic asbestos fibers were: India (USD 40.70 million), Indonesia (USD 16.36 million), Colombia (USD 5.32 million), Mexico (USD 4.65 million), and Thailand (USD 2.25 million) (DNPM, 2015). On the other hand, products manufactured with asbestos have a differentiated purchase profile, with the main destination countries being: United States (31%), Germany (21%), Argentina (7%), Paraguay (4.6%), and Mexico (4.6%) (DNPM, 2017).

The evolution of world consumption of chrysotile fibers from 2000 to 2019 is shown in Figure 3. It is observed that, in this period, Russia, China, and India maintained consumption above 10,000 tons/year. Other countries such as Australia and Egypt banned the use of asbestos fibers in 2015, as did Spain and Japan, despite having appeared as major consumers in 2000. In South America, Chile and Argentina banned the use in 2001, and Uruguay in 2002 (IBAS, 2022).

In 2000, Brazil was a major consumer of chrysotile, as shown in Figure 3. However, from 2017 onwards, the Brazilian scenario changed significantly with the ban on consumption in the national territory, even though the country continued to produce chrysotile fibers for export.

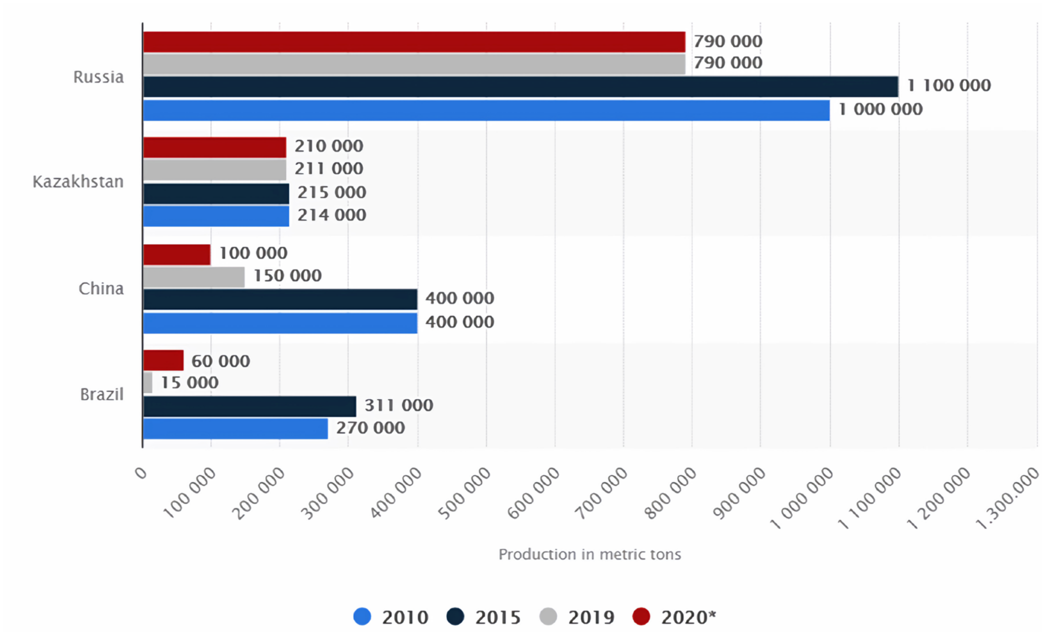

Figure 2 – Evolution and distribution of world asbestos production, from 2010 to 2020.
Source: Statista (2021).

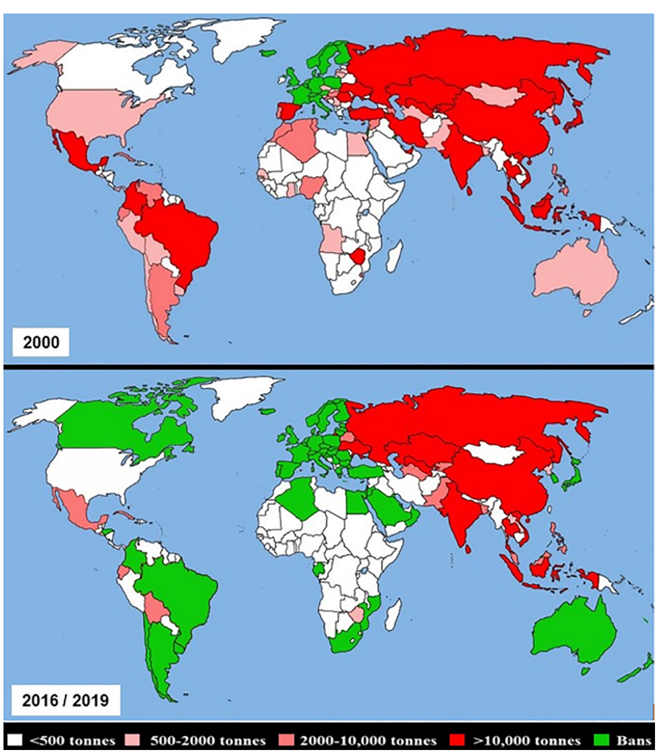

Figure 3 – World mapping of apparent consumption, years 2000 and 2016, and banning in 2000 and 2019.
Source: IBAS (2022).

In Figure 3, the quantities in the legend (in tons) represent the apparent consumption of fibers, which is defined as production plus imports, discounting the quantities exported in the same period, for each country.

Asbestos-cement as an element of civil construction

Composites in general are associations of materials from two or more insoluble and chemically distinct phases, whose properties and performance are superior to those of the constituents when acting alone (Gutiérrez et al., 2014). Composites aim to achieve properties not provided by the separate materials, uniting characteristics of each item of the composition (Pacheco et al., 2018); however, not all composites can be evaluated exclusively for their innovation and competitiveness, as they also include those that cause harmful impacts on human health.

The asbestos-cement material (ACM), or simply asbestos-cement (AC), is the result of the association of Portland cement with chrysotile fibers. For Bentur and Mindness (1990), asbestos fibers can be used in large volumes due to their high mechanical strength and high modulus of elasticity, which can exceed 10% in volume. For Douguet et al. (1997), the AC contains a proportion corresponding to approximately 10% of asbestos fibers, incorporated in 90% of cement.

The AC belongs to the group of composites that involve and adhere to the asbestos fibers, internal to the piece, referred to as Cement Bonded Asbestos, distinguished from the friable materials, the Asbestos

Insulation Board, which have a greater degree of danger, requiring other forms of care for handling, collection, transport, and disposal due to the ease with which the fibers detach from the material and disperse in the environment (HPA, 2021). AC has been widely used in ducts, flat sheets, corrugated tiles, and insulation boards, products that represent 80% of the global asbestos production (Bordebeure, 2017).

For domestic consumption, in 2014, 181,000 tons of chrysotile fibers were sold (USGS, 2017). Sales were mainly intended for the production chain of fiber cement artifacts for the civil construction industry, such as tiles, water tanks, and pipes, which corresponded to 98.86% of the total sold. In addition to these, the fibers were also used to manufacture parts for brakes (0.85%) and for chlor-alkali products (0.29%) (DNPM, 2015).

Degradation of asbestos-cement materials due to bad weather

Like most fiber cement composites, its matrix is subject to deterioration by aggressive chemical agents, similar to other Portland cement-based products such as concrete and mortar (Dias et al., 2008). Damage can occur in transport, installation, and during use from exposure to moisture, wind, and rain. Leaching in composites whose matrix is Portland cement can further weaken the material (Taylor, 1997). In the case of AC tiles, due to their small thickness with market variations from 4 to 10 mm, the effects of corrosion, even if of smaller proportions in relation to depth, can generate significant impacts on the bending force of the tiles (Dias et al., 2008), weakening the material.

According to Campopiano et al. (2009), sulfuric and nitric acids react with the chemical structure of cement, by displacing silicic acid, causing the transformation of calcium silicate, insoluble in water, into calcium sulfate or nitrate, soluble in aqueous medium. As a result, surface corrosion with erosive removal of the subsequent layers of dissolved cement may occur, which leads to the release of asbestos fibers. Wasserbauer et al. (1988) showed that nitrifying bacteria such as *Nitrosomonas* and *Nitrobacter* increase the porosity of AC roofs and reduce strength due to the production of nitrous and nitric acid.

The danger inherent to AC is the large amount of fibers that, when detaching from the composites and being released into the environment, become inhalable. For Ervik et al. (2021) the release of fibers in AC roofs occurs mainly due to weathering. Another determining factor for the degradation of AC composites is exposure to acid rain, resulting from the degradation of air quality in urban areas (Fornaro, 2006).

Not only do tiles represent problems, AC ducts, generally used in water distribution systems, can suffer corrosion resulting from the action of slime-forming bacteria and heterotrophic aerobic bacteria, a phenomenon that leads to corrosion of the internal surface of these ducts, due to acid production arising from bacterial metabolism (Wang et al., 2011).

However, the action of time does not always bring negative impacts to the composites. Roofs in AC tiles are often colonized by lichens, whose 25% lichen layer modifies the physical and chemical properties of the tiles, forming a physical barrier to the detachment of asbestos fibers (Favero-Longo et al., 2009).

Asbestos and health impacts

The study of respiratory diseases related to asbestos began with the expansion of the use of fibers in England, a pioneer country in the regulation of this type of product.

In the 1960s, researchers established a reliable correlation between fiber exposure time and lung cancer, with asbestosis being the first disease described, followed by lung cancer, benign pleural changes, and serous mesothelioma, mainly pleura and peritoneum (Mendes, 2001).

The danger of asbestos fibers, including chrysotile, applied to asbestos-cement composites is recognized around the world and by several entities. According to the International Agency for Research on Cancer (IARC, 1997), all types of asbestos are classified as carcinogenic to humans, and for the World Health Organization (WHO) there is no safe exposure limit to the carcinogenic risk. For Van Zandwijk et al. (2020), the safe use of chrysotile is unjustified, so it cannot be used safely. The danger is not just for individuals who have come into contact with asbestos fibers. According to Marinaccio et al. (2018), cases of mesothelioma due to non-occupational exposure to asbestos in women are relevant, and the disease is also diagnosed in wives or relatives of exposed workers.

It is estimated that exposure to asbestos, both in occupational and environmental areas, causes approximately 255,000 deaths annually worldwide (Furuya et al., 2018). On the other hand, exposure to asbestos via water receives less attention, despite the increased risks of stomach cancer due to ingested asbestos (Fortunato and Rushton, 2015).

In Brazil, there is a representative portion of informal workers, mainly in civil construction, working in activities such as renovations, demolitions, and self-constructions, where roofing tiles and AC reservoirs are found, with risk of inhaling chrysotile fibers, and who are outside the public policies on workers' health. Algranti (2001) estimated that mesothelioma cases in the country would continue to grow, and should reach a peak between 2021 and 2026.

Destination and blanketing of asbestos-cement

In Brazil, CONAMA Resolution 307/2002 classifies asbestos-cement waste (ACW) as dangerous, so its disposal in the environment without control represents an environmental risk. The appropriate destination is the landfill for hazardous waste (class I), which requires care in its execution and operation, for the safe confinement of such waste in the soil. However, despite all the technical criteria in the execution, operation and closure of hazardous waste landfills, the destination of ACW in class I landfills does not totally reduce the risk of fiber release, since the occurrence of damages in the disposal in these landfills can potentiate the release of asbestos fibers into the surrounding environment (David et al., 2021). In addition, although they represent safe confinement, class I landfills occupy areas that could have nobler uses, and become degraded areas and environmental liabilities.

Another method of disposing of asbestos fiber cement waste is incineration, but the thermal process of blanketing of asbestos fibers requires high temperatures and prolonged treatment, which demands high energy consumption (Spasiano and Pirozzi, 2017). Changes in the material microstructure and morphology of the asbestos fiber strongly depend on the applied temperature (Iwaszko, 2019). Thermal treatment already has consolidated technology and, in the end, results in a reduced amount of tailings, being blank to most chemical or biological agents, which allows final disposal in landfills (Paolini et al., 2018). The microwave oven treatment is an alternative to thermal blanketing as ACW has low thermal conductivity (Yoshikawa et al., 2015).

In addition to heat treatment, others such as solidification, vitrification, chemical, mechanical and biological treatments are also used in the blanketing of ACW (Spasiano and Pirozzi, 2017), but with an impact on processing costs.

Method

In this article, the updating of the consumption data of chrysotile fibers was carried out based on information from the National Department of Mineral Production (DNPM) and on international mineral production and trade market sites, in addition to information collected from the International Ban Asbestos Secretariat (IBAS), an organization that provides channels for the exchange of information on global asbestos prohibitions and bans.

The criterion for delimiting the time frame of the research, for the quantitative calculation, was the regular period of exclusive use of chrysotile in the country, which involved the year 1998 — the year following the approval of Decree No. 2,350/1997, which vetoed the extraction, production, industrialization, use and sale of brown and blue asbestos, allowing only the use of chrysotile (white asbestos) — until 2017, the year in which the STF judicially decreed the ban on the production of white asbestos in the domestic market.

Calculation of the estimated amounts of asbestos fibers was carried out using data on apparent consumption in Brazil, obtained from the website of the United States Geological Research Institute — U.S. Geological Survey (USGS) and Mineral Commodity Summaries, considering apparent consumption as the result of production plus fiber imports, minus exports (USGS, 2021).

Institutions and companies of trade and production of fiber cement materials in Brazil were also researched: ETERNIT S.A. and BRASILIT-SAINT GOBAIN.

Calculation of the chrysotile fibers

The estimate for calculating the amounts of apparent consumption of chrysotile fibers used for the production of MCA (QFMCA) was obtained according to the basis and Equation 1:

Baseline: Percentage of commercialization of fibers according to their purpose, considering that 98.86% of the commercialization of asbestos fibers in the national market are destined for the production of fiber cement materials (DNPM, 2015).

$$QFMCA = QFC \times PFC \quad (1)$$

Where:
QFMCA = Amount of apparent consumption of chrysotile fibers destined for the production of MCA in tons;
QFC = Amount of apparent consumption of chrysotile fibers in Brazil in tons;
PFC = Percentage of chrysotile fibers, intended for the production of MCA, being = 98.8%

Calculation of asbestos-cement materials

The estimated production of MCA for the domestic market was based on the properties of the asbestos fiber cement composites, on the expected useful life and on the percentages of fibers in its composition, and the calculation of the quantities of production of MCA (QMCA) was obtained according to the basis and Equation 2:

Baseline: On average, ACM contains 10% chrysotile fibers and 90% Portland cement in the asbestos-cement composition (Bentur and Mindess, 1990; Douguet et al., 1997).

$$QMCA = \frac{QFMCA}{PFCCA} \quad (2)$$

Where:
QMCA = Amount of production of MCA in tons;
QFMCA = Amount of apparent consumption of chrysotile fibers intended for the production of MCA in tons;
PFCCA = Percentage of chrysotile fibers, in the composition of the MCA, being =10%.

The RCA generation data were obtained from the IBAMA website, through the waste generation panel (PGR), a tool that allows the search for information by productive activity, type of waste generated and the National Corporate Taxpayers' Registry (CNPJ) of the reporting companies, based on information from more than 60,000 companies available in the Report on Potentially Polluting Activities and Users of Environmental Resources (RAPP).

Results and Discussion

Quantity of chrysotile fibers consumed in Brazil from 1998 to 2017

The calculation of the amount of chrysotile fibers sold in the national market, in the period, was 2.798 million tons, with an annual average of 139,935 t, as shown in Table 1.

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Application of Equations: (E1) resulted in the sum of 2.765 million tons of chrysotile and an annual average of 138,256 t of asbestos destined for the fiber cement industry, and (E2) resulted in the sum of 27.65 million tons of MCA and an average annual production of 1.38 million tons.

For better visualization, Figure 4 provides the annual quantities consumed in the country from 1998 to 2017, highlighting the year 2011 with 189,000 t, the highest amount consumed in the period, as well as the annual average of 139,935 t.

Table 1 – Apparent consumption of fibers and MCA, Brazil, 1998 to 2017.

Consumption Year	Quantity (t)		
	chrysotile fibers (QFC)	Fibers intended to the MCA (QFMCA)	MCA (QNCA)
1998	174,859	172,761	1,727,607
1999	172,598	170,527	1,705,268
2000	172,560	170,489	1,704,893
2001	149,540	147,746	1,477,455
2002	123,735	122,250	1,222,502
2003	78,403	77,462	774,622
2004	66,900	66,097	660,972
2005	139,000	137,332	1,373,320
2006	134,000	132,392	1,323,920
2007	93,800	92,674	926,744
2008	131,000	129,428	1,294,280
2009	140,000	138,320	1,383,200
2010	171,000	168,948	1,689,480
2011	189,000	186,732	1,867,320
2012	168,000	165,984	1,659,840
2013	165,000	163,020	1,630,200
2014	181,000	178,828	1,788,280
2015	163,000	161,044	1,610,440
2016	120,000	118,560	1,185,600
2017	65,300	64,516	645,164
total	2,798,695	2,765,111	27,651,107
Annual average	139,935	138,256	1,382,555

Source: adapted from USGS (2021).

The method for estimating the amounts of MCA based on the consumption of chrysotile fibers is unprecedented in the country. In countries where the asbestos removal process is more advanced, records of the use of TCA by the population and public buildings have already been carried out. In these countries, qualitative methods are used, through remote sensing and aerial photos, in order to analyze the state of conservation of installed asbestos cement tiles (Cilia et al., 2015).

ACW generation in Brazil from 2012 to 2017

According to the Waste Generation Panel (PGR) in Brazil, contained on the IBAMA website (the Solid Waste Generation in Brazil panel was produced based on information, as of 2012, from more than 60,000 companies available in the Report on Potentially Polluting Activities and Users of Environmental Resources — RAPP), 103,180 tons of ACW were generated and registered in Brazil, in the period from 2012 to 2017, with an annual average of 17,200 tons, as shown in Table 2.

In the period from 2012 to 2017, which can be compared by data availability, when verifying the potential of MCA production and the generation of ACW declared in the IBAMA Panel, there is a significant lag in all years, with a downward trend in production of MCA from 2014, as shown in Figure 5. It appears that the production of MCA reaches millions of tons/year, with the peak in 2014, while the generation of ACW ranged from 4,530 to 36,800 tons/year, with a peak in 2016.

The average annual production of MCA was 1.42 million tons and the average annual generation of ACW was 17,200 tons, revealing a great difference between the two. Following this trend of average declared ACW generation, it would take 83 years to equate the amount of waste with the average annual production of MCA. It is worth mentioning that the IBAMA hazardous waste generation panel is a recent instrument, in place since 2012, whose records are still incomplete and whose data reflect partial records of hazardous waste disposal, even with the obligation to register the generator in the Technical Registry of Potentially Polluting Activities, according to Normative Instruction No. 13, of August 23, 2021. On the other hand, activities classified as renovation, demolition, and even self-construction, that is, informal activities for the generation of civil construction waste, which as a rule may contain discarded AC tiles or water tanks, are outside this control, as they are not registered in the system. These are activities that are likely to lead to improper disposal of asbestos waste into the environment.

Table 2 – ACW generation, Brazil, 2012 to 2017.

ACW generation (tons)	Year						Period
	2012	2013	2014	2015	2016	2017	Total
	31,940	5,530	6,180	4,530	36,800	18,200	103,180

Source: IBAMA (2021).

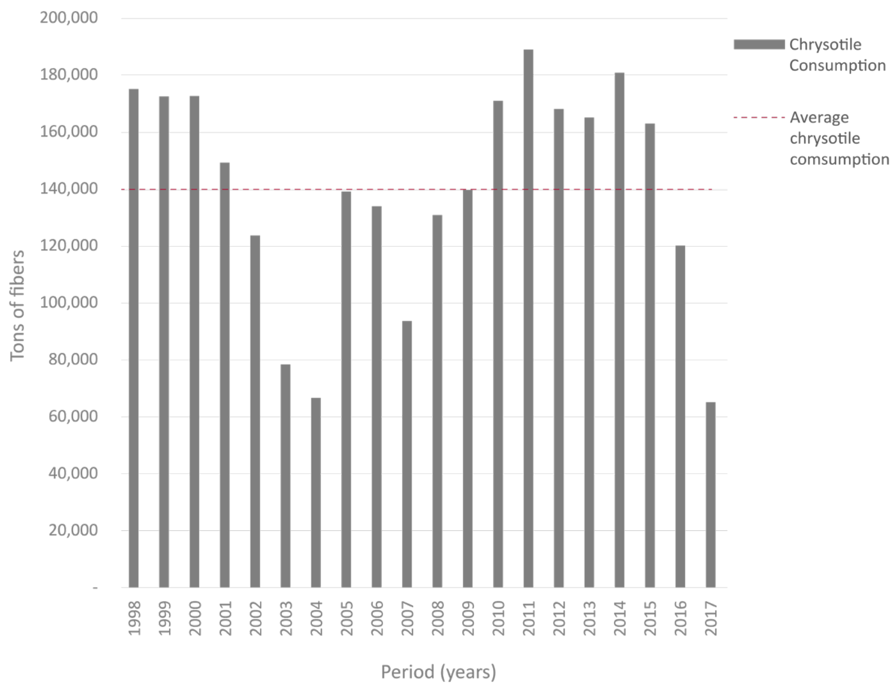

Figure 4 – Amount of chrysotile fibers consumed, Brazil, 1998 to 2017.

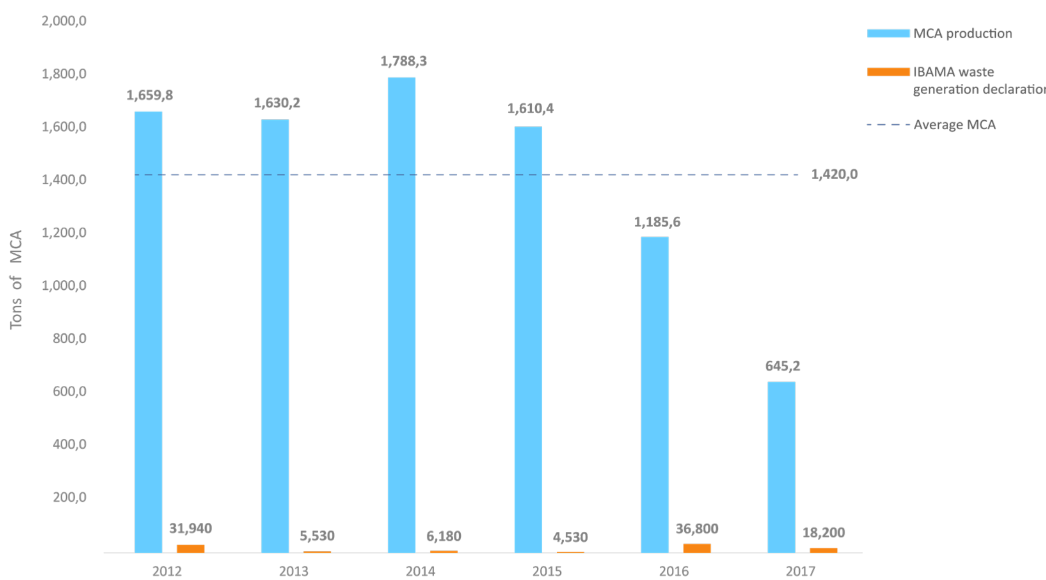

Figure 5 – MCA production and RCA generation, Brazil, 2012 to 2017.

It is observed that the amount of MCA production in 2017 (645,200 tons) is below the values of previous years, a reflection of the process of banning asbestos in the country, in addition to the fall in production due to the wearing image of the product with public opinion. and the consumer market.

The great difference between the MCA production data and the declared amount of waste generation indicates a large stock of MCA in use in residential housing, commerce, services, industries, and infrastructure in the country. This inventory in use represents a contingent of ACW to be discarded in the future, from the end of the product life or disposal for replacement in renovation or demolition works; therefore, it represents a future liability, for which there is a need for attention and public policy for an environmentally safe destination.

In terms of analysis of environmental impacts generated in demolition of roofs with asbestos-cement tiles, it is important to emphasize that deconstruction methods (disassembly that prioritizes maintaining the integrity of materials) mitigate the impacts of air pollution by reducing the use of equipment and vehicles (Anuranjita et al., 2018), the generation of waste, areas for disposal in landfills and consumption of natural resources (Spadotto et al., 2022) and result in greater use of labor, generating employment and income. For the handling of asbestos-cement tiles, in addition to strictly following occupational safety standards with the use of PPE and EPRs, deconstruction reduces the release of fibers into the environment, minimizes tile debris and impacts to the surroundings, compared to conventional demolition.

Differentiated collection and shipment for disposal in landfills for hazardous waste (class I) is the preferred route that is environmentally appropriate and has the lowest cost. According to technical information from ABETRE, in 2021 there were 21 industrial landfills in operation in the country, duly licensed by state environmental agencies, with a predominance of installation in the south and southeast regions. This number of suitable disposal sites is below the projected demand for RCA (reaching millions of tons for the next years), considering that the estimated receipt of hazardous materials in a medium-sized industrial landfill, according to information provided by Candiani in an informal conversation, is between 18,000 to 22,000 tons/year. The geographic distribution of these landfills and the possibility that not all of them are licensed to receive ACW should also be considered, factors that further restrict the offer of environmentally adequate reception areas.

Considering several aspects of the future scenario of ACW:

- the long period of manufacture of MCA and its time on the market: from 1940 to 2017;
- the large amount of MCA in use;
- the process of degradation of the cement matrix of the composites that tend to accelerate by the time of use and climatic actions;
- the number of maintenance interventions increasingly necessary due to the aging of MCA;
- the most used places for their destination: Class I landfills with characteristics such as: demand for large spaces; environmental restrictions such as distance from the water table and from urbanized areas; in addition to the residue being stored in a landfilled area and not returning to the production cycle, there is an urgent need to improve the management of these residues.

The management model to minimize risks and promote sustainability will require an appropriate system of deconstruction, collection and disposal for large demands for ACW disposal, characterized by diffuse flows and in small quantities. It will also be necessary to invest in technologies for processing and blanketing the fibers in order to mitigate their impact on the environment and also allow for a return to the production chain, in addition to investigating the risks of degradation of these composites and possible relationship with the contamination of surrounding areas and human health.

As the greatest use of AC is focused on the manufacture of roofing tiles, greater attention is paid to this segment. In 2012, there were more than 25 million households covered with asbestos-containing fiber cement tiles in the country (Eternit, 2012). Considering that the average size of financed home ownership in the country (in 2013) was approximately 58 m², according to the Fundação Instituto de Pesquisas Econômicas (FIPE) in 2018, and adopting the average area of coverage per dwelling as 50 m², it results in an estimate of 1.25 billion m² of AC tiles, just for 2012. This value tends to increase until 2017, due to the following factors:

- the production of tiles in AC until the ban on asbestos in 2017;
- the durability of the product;
- the degree of reuse;
- the average amount of ACW declared in the period.

Therefore, this estimate of the area covered with asbestos-cement tiles reinforces the fact that there are large amounts of MCA still in use in the country, which will be transformed into future waste.

On the other hand, the use of fiber cement roofing tiles, in general, affects self-built housing located in low-income communities and settlements, due to its durability and low cost (Castro, 2021). Therefore, this type of tile is found in areas with high population density, high rates of construction and occupation per m², factors that, added to the time of use, the frequent maintenance due to the degradation of the cement matrix and the frequent reuse of the material, increase the risks for residents to be exposed to chrysotile fibers dispersed in these environments. Most of the asbestos fiber cement tiles discarded in CDW collection buckets in public areas are removed and reused by the population (Castro, 2021), often used with other constructive functions such as partitions, fences, and doors.

This overview of the issue of MCA, the conditions of use and the possibility of degradation raise the need to investigate the danger that the degradation of AC tiles represents during its use, as well as the level of dispersion of the fibers and the conditions of their surroundings. In this regard, some recommended measures are:

- mapping of the degradation of AC tiles associated with the characteristics of use, construction and occupation;
- measurement and monitoring of the amounts of fiber concentration in suspension in the air by volume, according to the tolerance limit for respirable chrysotile asbestos fibers;
- reassessment of the exposure limit value index (ELV) applied in Brazil of 2.0 fiber/cm³ in accordance with NR15, a value 20 times greater than the tolerance limit adopted in European Union countries such as Portugal (0.1 fiber/cm³) where legislation is more advanced.

For the ACWs, it is worth reinforcing the need to implement a management system for hazardous waste resulting from the disposal of asbestos-cement tiles at the end of their useful life, which involves appropriate instruments and the provision of technical instructions for the training of manpower to handling, packaging, stocking, collecting, transporting, and disposing of them in an environmentally appropriate and safe way for the worker and others exposed.

Conclusion

The use of asbestos fibers is proven to be a dangerous activity throughout its life cycle, whether in extraction, processing, use as a product, as well as in the disposal of its waste. The risk in the use of asbestos-containing materials, even in composites, arises mainly from their handling, maintenance, and repair, when there is a risk of rupture in the cement matrix. It is also noted that, silently, there is also the wear of the MCA over time due to climatic actions, atmospheric pollution, and acid rain, which cause corrosion in the cement matrix, increasing the risk of chrysotile release.

In this study, the value obtained as potential production of MCA in Brazil, in the period from 1998 to 2017, was 27.65 million tons, mostly made up of tiles, followed by water tanks and pipelines. Considering the period of production and commercialization of these materials in Brazil for more than 70 years, the estimated useful life of these composites in 50 years and the great difference between the production of MCA and the generation of ACW, it is possible to conclude that it is an important future challenge to have the sustainable management of the large amount of these hazardous wastes (ACW) when they are discarded, with a view to minimizing risks and valuing them with the return to the production chain. In this sense, they become important public policies for the sector.

Regarding the technological routes to absorb the ACW, considering only the proper destination in class I landfills, the main destination in the country, it appears that the current installed capacity does not meet, and will not meet in the future, the demand for generating these waste materials, being necessary to establish new routes to absorb the estimated potential and that contemplate recovery, within the principle of Circular Economy.

In the country, the high projection of residential area covered with asbestos-cement tiles and the use profile, represented by housing generally self-built in low-income communities and settlements, with a high rate of construction per m² and high occupancy density, added to the maintenance and the practice of reusing discarded tiles, are factors that intensify the risk of residents exposed to chrysotile fibers dispersed in these environments.

Therefore, it is urgent to insert the sustainable management of ACW in a safe way in the agenda of environmental and health public policies, through the creation of technical instructions for the training of manpower for the handling, packaging, stock, collection, transport and destination of small volumes. It is also recommended the mapping of areas of use of ACM in the country, as well as the application and monitoring of preventive measures, such as measuring the concentrations of fibers/cm³ in the environment, a risk factor to the health of the exposed population.

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LOMBARDI FILHO, P.: Conceptualization; Methodology; Writing — original draft; Writing — review & editing. GÜNTHER, W. M. R.: Supervision; Writing — original draft; Writing — review & editing. VIANA, E.: Writing — review & editing.

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