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Integrated Analysis and Assessment of the Hungarian Regions in Terms of Health Problems and Waste Management Challenges caused by Asbestos

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Nowadays, more information is available regarding the health problems and waste management challenges caused by asbestos, and the research directions that focus on alternative agents, transport processes and mobilization routes of asbestos have gained ground. Only in recent years has the published research on the subject begun to deal more intensively with the development of evaluation methods that would ensure the consistent numerical qualification of individual territorial units. This paper examines the exposure of certain regions of Hungary along the lines of asbestos-related waste management and health aspects. After that, the individual relationships were identified and explored based on the specific patterns of the formed groups. The methodology of this paper is the calculation of an internationally applied integral index, the advantage of which is that it enables the comparison of numerical values with different dimensions. The focus of research is not the development of a new scientific methodology, but rather an exploration of the situation and regional comparability of asbestos exposure that is much more multidisciplinary, complex and multidimensional than the previous viewpoints. The value of the calculated integral index was 0.310±0.155 in 2005, while 0.339±0.170 in 2020. The rate of change in the value of the asbestos involvement and exposure integral index shows an increase of +28.5 % between 2005 and 2020. Based on the results, there are significant differences between the individual regions of Hungary along the values of the calculated multidimensional integral indices.

1. Introduction

How does the asbestos prevalence of a settlement, a region or a country, the population's exposure to asbestos over time, affect the risk ratio of malignant tumors and the opportunities for the waste hierarchy and the circular economy to gain ground? The approach to the problem cannot be defined only along the lines of waste management, environmental monitoring and epidemiological data, a complex, interdisciplinary approach to these aspects is important. At the same time, asbestos is an area of environmental protection for which there is neither environmental monitoring, nor permanent background pollution testing, nor public risk assessment (Gray et al., 2016). The problem is a given, the risks are known, but at the same time, asbestos contamination can still be considered a not analyzed environmental protection topic. Asbestos is a hydrated silicate of magnesium, iron, calcium and sodium, divided into two fiber groups, serpentines (chrysotile) and amphiboles (amosite, crocidolite, tremolite, anthophyllite and actinolite (Castro et al., 2003). The characteristic properties of asbestos are high fire resistance and low temperature and microbiological resistance to contact with bacteria or fungi (Kusiorowski et al., 2023). Important advantages of asbestos fibers include high tensile strength, abrasion resistance (Iwaszko et al., 2018), and resistance to acids and alkalis (Malinconico et al., 2022). Good thermal insulation, sound absorption (Park et al., 2012), and high electrical they are characterized by resistance (Santana et al., 2023). Most asbestos minerals also have high mechanical strength (Virta, 2005). Only three of the asbestos minerals are widely used commercially, especially in the construction industry. These include chrysotile (white asbestos), crocidolite (blue asbestos) and amosite (brown asbestos). Chrysotile accounts for

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90-95% of asbestos mined in the world (L. Frank and Joshi, 2014). Asbestos and asbestos cement products now have a historical legacy (Bolan et al., 2023) in the built environment worldwide (Obmiński, 2021). Their use has been typical since the era of industrialization (Janela and Pereira, 2016). More widely, these products have been used in the construction industry throughout history, mainly as insulators and as structural stabilizers for various materials such as various cement or plastic products (Virta, 2005), hence today more than 3,000 different commercial products contain or may contain asbestos in varying concentrations. (Harris and Kahwa, 2003). More than 50.0 % of asbestos sold worldwide was used in Europe between 1920 and 2000 (Paglietti et al., 2016). According to Ramazzini (2010), more than 90.0 % of the asbestos used was used in the form of various asbestos cement products, sheets, roofing materials and pipes. The first asbestos-related health cases were reported in the 1950s, mainly among miners and factory workers dealing with asbestos (Jung et al., 2021). A study conducted in the 1960s identified asbestos as a carcinogen and stated that the health diseases caused by it cause malignant mesothelioma and lung cancer with a latency period of approximately 20-50 years (Mossman et al., 1996). As a result of these health effects, the use of asbestos has gradually declined since the 1970s, and some countries have banned or restricted its use by law since the 1990s (Bahk et al., 2013). The greatest danger and risk are fibers penetrating the alveoli of the lower respiratory tract. These are so-called respirable fibers, fibers with a diameter of less than 3 μm and a length of more than 5 μm (WHO, 1986).

In Hungary, the new use of asbestos has been prohibited since 2005, but the regulation does not cover the prohibition, restriction or regulation of the further use of previously installed products. Pursuant to the European directive (148/2009), the maximum permissible level of asbestos in the air at workplaces is 100 f/l (fibers/liter) (WHO, 1986). According to Li et al. (2014), all asbestos in use in the world today is chrysotile, also known as white asbestos. As the main health risk, scattered asbestos insulation came into focus, for which an exemption and removal program was launched several times. At the same time, the asbestos cement products used in buildings, on the other hand, were not considered to be directly harmful to health (Bornemann and Hildebrandt, 1986), since the asbestos fibers are bound by a strong layer of cement, but at the same time, as a result of weather conditions and erosion and degradation over time, asbestos fibers are released into the surrounding atmosphere, which can reach up to 3.00-5.00 g/m^2 can be (Brown, 1987). At the same time, asbestos fibers can also be released directly as a result of much occupational safety (Gyenes and Wood, 2016) and household accidents (pipe breaks). The verification of the presence of asbestos should be conducted, where discovered its presence, there should be a clearance, or, in the best of conditions, continuous monitoring (Cecchini et al., 2017). Consequently, the environmental and health problems associated with asbestos cement in these buildings are potentially strongly associated with asbestos cement roofing (Zhang et al., 2022). Malignant mesothelioma has been diagnosed in several cases in residents of properties using asbestos cement roofing (Jung et al., 2006). A survey on the use of asbestos-cement roofing in areas with poor living conditions is therefore essential to manage the associated risks (Zhang et al., 2022). At the same time, such a series of surveys is extremely expensive, given their widespread use.

Several methods can be used to determine asbestos exposure and involvement, which also have different advantages and disadvantages. The first is conducting on-site field visits and surveys in order to count the number of properties and buildings with asbestos-cement roofing (Kim et al., 2010), thus establishing the involvement of a given area (Zhang et al., 2022). At the same time, this process is extremely time- and human-resource-intensive. The second option is modeling (Kim et al., 2016); based on the type (Zhang et al., 2016) and area data on roofing found in the building register (Zhang et al., 2022). At the same time, the data in the register is not public, and in many cases, the data in the register does not reflect reality. Monitoring can also be done using drones, which are based on the first method (Lee et al., 2016), also requiring high resources. In recent years, situational studies have also been published that established the involvement of a given area or settlement through satellite images, with particular regard to the state of erosion of individual asbestos cement sheets. Management and risk assessment tools can also be applied, which infer the involvement of certain territorial units through the continuously collected secondary data. Such data may include waste generation, waste management, health and discharge data. At the same time, this process is greatly influenced by the quality and quantity parameters of individual input data, as well as their actual existence. For this reason, in this study, the impact assessment of Hungary's NUTS-2 regions was chosen as a basis. The purpose of this research is to use an alternative indexing method that relies on currently available indicators directly related to asbestos. The results may provide insight into an alternative asbestos involvement assessment approach based on the applied health and waste generation values.

2. Materials and methods

The aim of the research is to calculate an alternative index value to determine the asbestos involvement of Hungarian regions (NUTS-2). The used taxonomic index formation method is a procedure suitable for the uniform handling of multidimensional data, which results in a dimensionless value between 0.00 and 1.00.

During the calculation, indicators were used that are directly related to the topic of asbestos and asbestos cement. However, it must be emphasized that the amount of public, directly accessible data in this regard is minimal, and extremely insignificant. The range of indicators used consisted of the following: mesothelioma (*Mesothelioma malignum*) incidence values collected and treated by the Hungarian Cancer Registry (2023); the data of the Waste Management System Module of the National Environmental Protection Information System (2023) regarding regional waste generation along the waste types 170605 - asbestos-containing construction material and 170601 - asbestos-containing insulation material. During the analysis, waste disposal data were not used, due to the regional differences in distribution and waste management. The examined period is between 2005 and 2020, and the examined years are 2005, 2010, 2015 and 2020. The elements of the taxonomic assessment used to determine the integral index of asbestos involvement were the same as Oliinyk et al. (2023) with the method used.

Eq(1) Standardization of initial data with different units and dimensions in order to reduce them to a single metric scale, using the following formula: Eq(1), where: Z_{ij} is the standardized value of the i-th indicator of the j-th NUTS-2 region ($i = \overline{1,n};\ j = \overline{1,m}$); x_{ij} the arithmetic mean value of the i-th indicator of the j-th NUTS-2 region; σ_i is the standard deviation value of the i-th indicator.

$$Z_{ij} = \frac{x_{ij} - \bar{x}_{ij}}{\sigma_i}, \tag{1}$$

Eq(2) Creation of reference point Z_{0i} ($Z_{01}, Z_{02}, \ldots Z_m$), which means comparing the values of the NUTS-2 regions to the maximum value of the given value series.

$$Z_{0i} = \max z'_{ij}\ i \in I, \tag{2}$$

Where: I is the set of indicators.

Eq(3) Determination of the Euclidean distance, which shows the distance of the indicators relative to a given reference point, where: d_{0i} is the Euclidean distance of the indicator value from the reference point.

$$d_{0i} = \sqrt{\sum_{i,j=1}^{n,m} (Z_{ij} - Z_{0i})^2}, \tag{3}$$

Eq(4) Calculation of the taxonomic index of the asbestos involvement integral index, which reflects the alternative measure of asbestos involvement of the Hungarian NUTS-2 regions (K_i) with formula (Eq(4)), where: K_i is the picture of the given level of asbestos involvement in each Hungarian NUTS-2 region; $\overline{d_0}$ is the arithmetic mean of the corresponding Euclidean distance; σ_0 is the standard deviation of the corresponding Euclidean distance.

$$K_i = 1 - \frac{d_{0i}}{d_0},\ d_0 = \overline{d_0} + 2 \cdot \sigma_0, \sigma_0 = \sqrt{\frac{\sum (d_{0i} - \overline{d_0})^2}{n}}, \tag{4}$$

3. Results

There is no uniform methodology available for the interdisciplinary assessment of asbestos involvement, so the analysis summarized in this paper was also based on a pre-selected group of indicators. After sorting the data, it was categorized and standardized. Through the data formed into a unified system, the Euclidean distance values were also determined which was followed by the calculation of the alternative, dimensionless asbestos involvement index values (Table 1). According to the primary and secondary data obtained by the taxonomic analysis, the Hungarian NUTS-2 regions were characterized by a varied but at the same time stable situation during the four relevant years of the examined period. During the analysis, the value of the calculated index between 2005 and 2020 was a significant increase. The average value of the calculated index value was 0.3098 in 2005, 0.2377 in 2010, 0.2612 in 2015, and 0.3389 in 2020, which represents a low level at the national level, but at the same time, it should be emphasized that a growth rate was experienced in the examined period. The reason for this is the fluctuating but ever-increasing tendentious increase in the incidence of mesothelioma, as well as the increased amount of asbestos-containing waste generated in certain regions. The average rate of change between 2005 and 2020 was a +28.5 % increase, which in the first third of the examined period (between 2005 and 2010) was a -18.0 % decrease, in the second third (between 2010 and 2015) +24.5 % increase, while in the last third (between 2015 and 2020) there was already a +33.2 % increase.

Table 1: Results of Euclidean distance and integral index calculation

Code	NUTS-2	Euclidean distance: 2005	Euclidean distance: 2010	Euclidean distance: 2015	Euclidean distance: 2020	K_i: 2005	K_i: 2010	K_i: 2015	K_i: 2020
HU11	Budapest	2.72	3.46	2.77	1.84	0.512	0.395	0.474	0.615
HU12	Pest	3.97	3.74	4.46	3.74	0.286	0.346	0.153	0.218
HU21	Central Transdanubia	2.61	4.06	2.92	2.45	0.530	0.289	0.446	0.487
HU22	Western Transdanubia	4.93	5.20	4.21	3.24	0.114	0.090	0.200	0.322
HU23	Southern Transdanubia	4.44	5.01	4.52	3.68	0.202	0.123	0.140	0.231
HU31	Northern Hungary	4.47	4.90	4.02	3.96	0.197	0.143	0.235	0.172
HU32	Northern Great Plain	4.28	3.75	3.82	2.44	0.231	0.344	0.274	0.489
HU33	Southern Great Plain	3.31	4.74	4.38	3.93	0.406	0.171	0.167	0.177

Data from: own calculated, own edited

The results of the analysis showed that, based on the trend between 2005 and 2020, there are significant regional differences between the individual Hungarian NUTS-2. During the entire study period, Western Transdanubia (HU22) showed the largest increase (+182.9 %). Similarly, the Northern Great Plain (HU32) region showed an increase of over 100.0 % (+111.5 %). In contrast, the biggest decline (-56.3 %) was experienced in the case of the Southern Great Plain (HU33). An increase in four of the eight regions (Budapest-HU11, Western Transdanubia-HU22, Southern Transdanubia-HU23, Northern Great Plain-HU32), in four (Pest-HU12, Central Transdanubia-HU21, Northern Hungary-HU31, Southern Great Plain-HU33) and a reduction was experienced. In the first third of the examined period (2005-2010), the largest increase could be detected in the case of the Northern Great Plain (+48.7 %), while the largest decrease was observed in the examination of the Southern Great Plain (-57.9 %). In the second third (2010-2015), Western Transdanubia (+122.2 %) showed the largest increase. The largest decline was experienced in Pest (-55.9 %). Against all this, in the last third (2015-2020), Northern Great Plain (+78.6 %) and Northern Hungary -27.0 % were the two endpoints of the change interval.

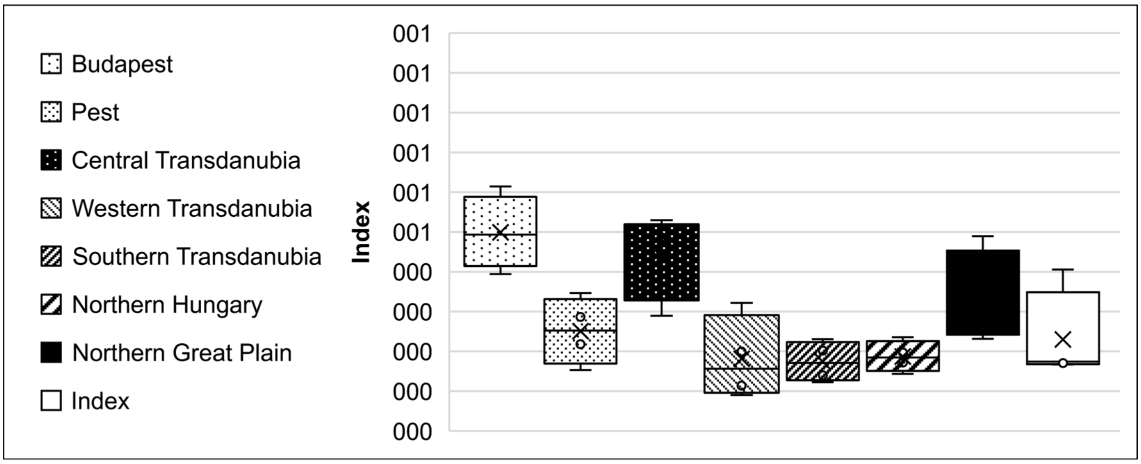

Figure 1: Comparison of calculated asbestos involvement index values in NUTS-2 regions. Data from: own calculated, own edited

Based on the obtained results, it can be concluded that the involvement of asbestos can also be characterized by multidimensional analysis, and the phenomenon can be quantified along the existing indicators. At the same time, it is important to emphasize that if the range of available indicators expands, the values can be continuously refined. If the above results and the inequalities of their territorial distribution were taken into account, Hungary could be classified as moderately affected. The diagram in Figure 1 compares the index values characteristic of each region through the quartiles for the period between 2005 and 2020. It can be concluded that a wide interval was experienced in some regions, with significantly higher index values (Budapest, Central Transdanubia, Northern Great Plain). On the other hand, this is not fulfilled in the case of two regions, the index value showed a low variation spectrum, typically with low values below 0.30 (Southern Transdanubia, Northern Hungary). Pest and Western Transdanubia had a low, but at the same time significantly variable index value.

4. Conclusions

This paper examines the situational picture of asbestos involvement along different indicators in order to highlight regional disparities in mesothelioma incidence and asbestos-containing waste generation. Asbestos involvement can be approached in many ways, but at the same time, there is no uniform, large-scale risk assessment or situational assessment procedure available. The simplest way of assessment is to perform an analysis based on indicators that are directly related to the topic of asbestos. The problem is that the scope of such data and indicators is extremely narrow, and in many cases incomplete. This data can also be health or waste management data. *Mesothelioma malignum*, as a malignant neoplastic disease, is the primary cause of persistent, long-term involvement with asbestos, and its incubation period can be 10-40 years. The other two investigated indicators are the amount of waste generated by the different asbestos cement products and the dusting, dispersed asbestos insulation. During the analysis, a taxonomic method was used whose decisive part element is the number and quality of the indicators used. Based on the results, it can be confirmed that asbestos involvement is indeed a detectable phenomenon following an increasing trend in the NUTS-2 regions of Hungary during the period under review. The results show that there are significant differences between the individual regions, while in some regions the level of asbestos involvement is high, while in others it is typically low. During the entire study period, Western Transdanubia (HU22) showed the largest increase (+182.9 %) in the value of the complex index, while in contrast, the biggest decline (-56.3 %) was experienced in the case of the Southern Great Plain (HU33). The average value of the calculated integral index was 0.310 ± 0.155 at the national level in 2005. In contrast, this value was 0.238 ± 0.119 in 2010, 0.261 ± 0.131 in 2015 and 0.339 ± 0.170 in 2020. The rate of change in the value of the integral index shows an increase of +28.5 % between 2005 and 2020, based on the average of regional values. The research should be continued, the exploration of the asbestos involvement situation is a gap-filling, current topic, which unfortunately depends to a large extent on the quality, quantity and availability of the collected indicators and data. The current results are applicable to environmental scientists and can serve as a starting point for future research.

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