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The leaching of mercury and other elements from asbestos-cement sheets in various environmental conditions

Introduction

Asbestos-cement corrugated sheets or 'diamond' type panels situated on building roofs and façades as well as asbestos-cement water supply and sewerage pipes are the most frequently used elements that contain asbestos in Poland. The issue of the application of asbestos-containing products and hazards resulting from its improper use, dismantling and removal have been the subject of numerous papers (e.g. Pyssa and Rokita 2007; Szeszenia-Dąbrowska and Sobala 2010; Szeszenia-Dąbrowska et al. 2015). The use of asbestos-containing products ceased in 1998 pursuant to the Act on Prohibition of Asbestos Containing Products Use of 19 June 1997 (i.e. Dz.U. of 2020, item 1680 with amendments). Thereby, the widespread and long-lasting process of the removal of such materials from the

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territory of the whole country commenced. In accordance with the waste catalogue (Dz.U. of 2020, item 10), each asbestos-containing product automatically becomes group 17 hazardous waste during its removal from a building. Asbestos removal in Poland is performed on the basis of the Programme of Country Cleaning from Asbestos for the years 2009–2032 (Programme of Asbestos Abatement... 2002; Programme of Country Cleaning... 2009). The removal and disposal of the asbestos-containing products (waste) that have accumulated in Poland and worldwide is a huge project (e.g. Klojzy-Karczmarczyk and Staszczak 2020, 2022; Thives et al. 2022). The analysis of data (Asbestos Database 2022) shows that this process will not be completed in accordance with assumptions for the territory of Poland by the end of 2032. On the basis of the current pace of removal of asbestos-containing products, such products will disappear from the territory only within 30 to 190 years, depending on the voivodeship. An average pace of removal, given for the country scale, allows us to state that eighty-three years are needed for the total removal of asbestos products (Klojzy-Karczmarczyk and Staszczak 2022).

Asbestos is a general term for fibrous minerals from the amphiboles and serpentines group, which are hydrated iron-magnesium aluminosilicates, sometimes containing other elements. Asbestos is a mineral featuring exceptional properties, both chemical and physical. It is resistant to high temperatures, has good heat insulating and noise absorbing properties, good tensile strength and flexibility as well as being resistant to acids, alkalis and sea water (e.g. Więcek 2004; Pyssa and Rokita 2007). The asbestos dusts released to the air have an undoubtedly negative impact on human health (e.g. Szeszenia-Dąbrowska and Sobala 2010; Szeszenia-Dąbrowska et al. 2015; Krówczyńska and Wilk 2018a, 2018b). While there are no studies on the significance of the leaching of individual components from the asbestos-cement material, both from roofing as well as from water supply or sewerage pipes. Opinions on the harmful effects of asbestos-cement pipes are divided. However, asbestos is considered to be resistant to the action of atmospheric precipitation, water, and sewage. There are no studies on or evidence of any harmful effect of asbestos minerals contained in water on human health (Klemczak and Biegańska 2009; Pyssa and Rokita 2007). The World Health Organization considers that there is no requirement for the identification of permissible concentrations of this substance in water (WHO Drinking Water Guidelines 2004). Asbestos is known as a carcinogen when it enters the organism through the respiratory tract. The available epidemiological studies have not confirmed a hypothesis that there is an increased risk of a pathogenic process resulting from drinking potable water containing asbestos fibers (Asbestos in Drinking-water 2003, 2020). For asbestos concentrations in the air, the maximum allowable concentrations (MAC) are given, which are expressed by the number of asbestos fibers in 1 cm^3 and by the amount of total dust in mg/m^3. In the case of asbestos concentration in soils, there are no set criteria specifying permissible pollution levels.

In the available literature, there are no studies on the leachability of individual elements from asbestos-cement building materials, and in effect, asbestos-containing waste. Asbestos-cement building materials were selected for studies and are commonly referred to as eternit, which was frequently used to produce roofing and façade components as well as sewerage pipes. The performed studies are a continuation of the analysis started by the authors under conditions of static leaching with the use of deionized water (Klojzy-Karczmarczyk et al. 2021). However, in reality, the atmospheric precipitation frequently shows an acidic nature, thus the leachability of individual metals or metalloids under such conditions can be different. The paper compares the results of studies performed on mercury and other elements leaching under conditions simulating a neutral environment and an acidic environment.

1. The selection of samples for analysis and research methodology

The leaching was carried out on fragments of asbestos-cement sheets, random selected in the area of Poland, which are ultimately asbestos-containing waste. The fragments of corrugated sheets were collected from the surface of the ground. Determining the age of the removed sheets is a difficult issue. Their shades indicate that they may differ in chemical composition.

The five samples from various locations in the area of Lubelskie, Podkarpackie, Kujawsko-Pomorskie, Mazovian, and Lesser Poland Voivodeships were selected for analysis. They were marked as: Corrugated Sheet 1 – Corrugated Sheet 5 (Table 2). The leachability of metals from these sheets, with the use of a neutral medium, was the subject of a 2021 paper (Klojzy-Karczmarczyk et al. 2021).

The analyzed material consisted of removed asbestos-cement products that had been deposited on the ground surface as hazardous waste. The analysis of the leaching of pollutants comprised so-called hard products with densities > 1000 kg/m^3. All of the analyzed samples originate from asbestos-cement sheets (eternit) used mainly as roofing (popular corrugated sheets), which is widely used in domestic construction. The asbestos-cement products used in the construction industry contain 10 to 15% of asbestos. Asbestos-cement water supply and sewerage pipes contain a comparable amount of asbestos, of around 12–15% (Więcek 2004; Indulski 1990).

The leachability test under static conditions was performed for all collected samples of asbestos-containing waste. In the eluate, the following metals and metalloids were determined: aluminum, boron, barium, cadmium, chromium, copper, iron, nickel, lead, strontium, zinc and mercury. A number of testing methods may be used in the laboratory practice which enable the identification of the amount of leachability in the solution (in mg/dm^3) and thus leaching from solid samples (in mg/kg DM). The selection of an appropriate method for leachability studying is a significant element of environmental hazard assessment. Classical leachability tests under static conditions, which are most frequently applied in the laboratory work, use distilled water as the leaching medium. This enables the determination of the amount of individual pollutants leaching, initially in a neutral environment. However, in reality, the existing conditions are definitely different from neutral. The asbestos-cement products are frequently exposed to the effect of atmospheric precipitation, which is often acidic in nature. Normal rain has pH of approx. 5.6. Instead, acidic rains usually show pH between 4.2 and 4.4 (What is Acid Rain? 2022; Du et al. 2014). Such conditions are favorable for heavy metals release.

The paper presents static leachability tests performed in the acidic environment, where pH values of the leaching solution were reduced to approx. 3 (Table 1). The leachability tests under acidic conditions (a solution acidified with acetic acid is the leaching medium for tests 1–20) were performed pursuant to guidelines of the TCLP (*Toxicity Characteristic Leaching Procedure*) method. Such a leaching procedure reflects the process under the conditions of acidic atmospheric precipitation (acid rains). Leachability under conditions close to neutral (the leaching medium – distilled water, tests 1:10) was performed in accordance with guidelines of the standard PN EN 12457/1-4 (*Characterization of waste – Leaching – Compliance test for leaching of granular waste materials and sludges*). It should be emphasized that the assumed pH applies to solutions in the initial stage of the leaching process. After the completed process, the pH values of solutions are on a stabilized level, which is specified in detail in Table 4. The assumptions of each applied method were adapted to instruments held by the MEERI PAS laboratory, in which the studies were performed. The extraction was executed in one stage. Table 1 provides the list of basic principles used in the research process.

Table 1. Parameters of the applied methodology to study the leachability of metals from the asbestos-containing waste (fragments of asbestos-cement sheets)

Tabela. 1. Parametry zastosowanej metodyki badania wymywalności metali z odpadów zawierających azbest (fragmenty płyt azbestowo-cementowych)

Parameter	Leaching in a neutral medium (batch test)	Leaching in a acidic medium (batch test)
Basic assumptions	PN-EN 12457/1-4 method	TCLP method
Sample weight	100 g	100 g
Material's particle size	<10 mm	<9.5 mm
L/S (liquid/solid) ratio	10/1 (1:10 test)	20/1 (1:20 test)
Leaching liquid	Distilled water: pH 7.49	Acetic acid solution: pH 3.15
Shaking method	Laboratory shaker	Laboratory shaker
Shaking time	24 h ± 0.5	18 h ± 2
Type of filter	Membrane filter Pores Ø 0.45 μm	Membrane filter Pores Ø 0.45 μm
Determination of Al, B, Ba, Cd, Cr, Cu, Fe, Ni, Pb, Sr, Zn content	Inductively Coupled Plasma – Optical Emission Spectrometers, ICP-OES method (PN-EN ISO 11885:2009)	
Determination of Hg content	Atomic absorption spectrometer AMA 254	

Methodology adapted to the research equipment of MEERI PAS laboratory.

The values of pH for solutions were determined by the potentiometric method.

To determine aluminum, boron, barium, cadmium, chromium, copper, iron, nickel, lead, strontium, and zinc, atomic emission spectrometry with excitation in inductively coupled plasma method (ICP-OES) was used. The limits of quantification (LOQ) for the analysis of metals in samples are: 0.01 mg/dm^3 (Al, Ba, Cd, Cr, Fe, Pb, Zn), 0.1 mg/dm^3 (B), 0.05 mg/dm^3 (Ni), 0.2 mg/dm^3 (Sr), and 0.005 mg/dm^3 (Cu).

To determine the mercury content, an Altec AMA 254 atomic absorption spectrometer was used. The applied analytical method gives the result of mercury determination as a sum of all mercury forms existing in the sample. High-temperature mineralization and the application of an appropriate catalyst enables good results to be obtained for the majority of mercury instances co-existing in environmental samples. Two determinations of mercury content were made and an arithmetic mean was given for each case. The limit of quantification (LOQ) for Hg analysis in liquid samples is 0.0005 mg/dm^3. The limit of detection (LOD) is 0.00015 mg/dm^3.

Results of the analytical determinations of the eluate are given in mg/dm^3 and are specified in Table 2. The determined concentrations of individual components were then con-

Table 2. Results of metal and metalloid leachability from asbestos-containing waste obtained during the experiment with the use of the TCLP method (tests 1:20)

Tab. 2. Wyniki wymywalności metali i metaloidów z odpadów zawierających azbest uzyskane w trakcie eksperymentu z zastosowaniem metody TCLP (test 1:20).

Parameter	Unit	Sample name				
		Corrugated Sheet 1	Corrugated Sheet 2	Corrugated Sheet 3	Corrugated Sheet 4	Corrugated Sheet 5
pH of the eluate	–	7.94	8.43	8.21	8.52	8.30
Aluminium, Al	mg/dm^3	0.149 ±0.010	0.232 ±0.016	<0.01	0.172 ±0.012	0.127 ±0.009
Boron, B	mg/dm^3	0.116 ±0.011	0.221 ±0.020	0.133 ±0.012	0.147 ±0.014	0.133 ±0.012
Barium, Ba	mg/dm^3	0.425 ±0.050	0.081 ±0.009	0.255 ±0.030	0.366 ±0.043	0.262 ±0.031
Cadmium, Cd	mg/dm^3	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium, Cr	mg/dm^3	0.064 ±0.004	0.064 ±0.004	0.013 ±0.001	0.101 ±0.006	0.036 ±0.002
Copper, Cu	mg/dm^3	0.042 ±0.003	<0.005	0.0056±0.0004	<0.005	<0.005
Iron, Fe	mg/dm^3	0.070 ±0.004	0.036 ±0.002	0.021 ±0.001	0.010 ±0.001	0.061 ±0.004
Nickel, Ni	mg/dm^3	<0.05	<0.05	<0.05	<0.05	<0.05
Lead, Pb	mg/dm^3	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium, Sr	mg/dm^3	5.35 ±0.33	1.43 ±0.09	4.74 ±0.30	1.78 ±0.11	2.19 ±0.14
Zinc, Zn	mg/dm^3	0.221 ±0.014	0.108 ±0.007	0.011 ±0.001	<0.01	0.109 ±0.007
Mercury, Hg	mg/dm^3	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

Table 3. Averaged measured values of leaching from asbestos-containing waste and the limit values for individual metals

Tabela 3. Uśrednione wartości pomierzone wymywania z odpadów zawierających azbest oraz wartości graniczne dla poszczególnych metali

Parameter	Measured values			Limit values	
	min – max (mg/dm^3)	mean		permissible values for industrial sewage* (mg/dm^3)	permissible values of leaching for inert waste**
		mg/dm^3	mg/kg DM		
Al	<0.01–0.232	0.138	2.76	3.0	–
B	0.116–0.221	0.15	3.00	1.0	–
Ba	0.081–0.425	0.278	5.56	2.0	20
Cd	<0.01	<0.01	<0.20	0.07	0.04
Cr	0.013–0.101	0.055	1.10	0.1	0.5
Cu	<0.005–0.042	0.013	0.26	0.5	2
Fe	0.010–0.070	0.040	0.80	–	–
Ni	<0.05	<0.05	<1.00	0.1	0.4
Pb	<0.01	<0.01	<0.20	0.1	0.5
Sr	1.43–5.35	3.10	62.00	–	–
Zn	<0.01–0.221	0.092	1.84	2.0	4.0
Hg	<0.0005	<0.0005	<0.01	0.03	0.01

* Regulation of the Minister of Maritime Economy and Inland Navigation of 12 July 2019 on substances especially hazardous to the water environment and conditions to be met when introducing sewage to waters or ground, and also at discharging rainwater or thaw water to waters or water equipment (Dz.U. of 2019, item 1311).

** Regulation of the Minister of Economy of 16 July 2015 on allowing the waste to be landfilled (Dz.U. of 2015, item 1277).

– no determined limit values.

The gray fields – above the limit values.

verted into the released amount of the pollutant in relation to the dry weight of the sample and also provided in mg/kg DM. The obtained results, together with averaged values, are specified in Table 3.

2. Results and discussion

The presented paper contains analysis of leachability test results for five samples of asbestos-containing waste of corrugated sheet type, previously used as roofing. In the process of leaching with an acetic acid solution (pursuant to the rules of TCLP method), after the experiment performance and stabilization of conditions (after approx. 24 hours), the pH of the obtained solutions ranged from 7.94 to 8.52 (Table 4). So there was a definite increase in the alkalinity of eluates with respect to the initial pH of the leaching medium (3.15). Thus, during the experiment, the acidity was neutralized and the reaction grew towards alkaline. At the stage of experiments performed for asbestos-cement products, it transpired that it was not possible to maintain constant leaching conditions in relation to the pH of the leaching solution. This results from the chemical composition and admixtures in asbestos-cement sheets. Such a process results from the significant share of cement in the material and its leaching.

Table 4. Specification of the results of mercury studies in the process of leaching under various environmental conditions

Tabela 4. Zestawienie wyników badań rtęci w procesie wymywania w różnych warunkach środowiska

Sample name	Hg^d total content (mg/kg DM)	Leaching of Hg in neutral medium (1:10 test)**		Leaching of Hg in acid medium (1:20 test)**	
		Leachability (mg/dm^3)	pH of eluate***	Leachability (mg/dm^3)	pH of eluate***
Corrugated Sheet 1	0.00516	<0.0005 (0.00014)*	8.79	<0.0005 (0.00010)*	7.94
Corrugated Sheet 2	0.00298	<0.0005 (0.00009)*	9.20	<0.0005 (0.00012)*	8.43
Corrugated Sheet 3	0.00161	<0.0005 (0.00008)*	8.54	<0.0005 (0.00010)*	8.21
Corrugated Sheet 4	0.00167	<0.0005 (0.00005)*	9.11	<0.0005 (0.00005)*	8.52
Corrugated Sheet 5	0.00293	<0.0005 (0.00008)*	8.22	<0.0005 (0.00006)*	8.30

* The measured values around the limit of detection (LOD = 0.00015 mg/dm^3; LOQ = 0.0005 mg/dm^3).
** pH of distilled water 7.49 (neutral medium); pH of an acetic acid solution 3.15 (acid medium).
*** pH of eluate measured after completed process of leaching (approx. 24 hours).
Hg^d total – Total content Hg on dry matter.

In general, the low leachability of metals and metalloids under the planned and determined conditions is observed (Table 2 and 3, Figure 1). It should be emphasized that leachability under acidic conditions occurs only in the initial period of the experiment, followed by a change of the eluate reaction into alkaline. With the application of the TCLP method, low leachability was found for barium (0.116–0.221 mg/dm^3), copper (<0.005–0.042 mg/dm^3), and iron (<0.010–0.070 mg/dm^3). No introduction of such metals as cadmium, nickel and lead to solutions was observed among the analyzed elements (Table 3). Compared with

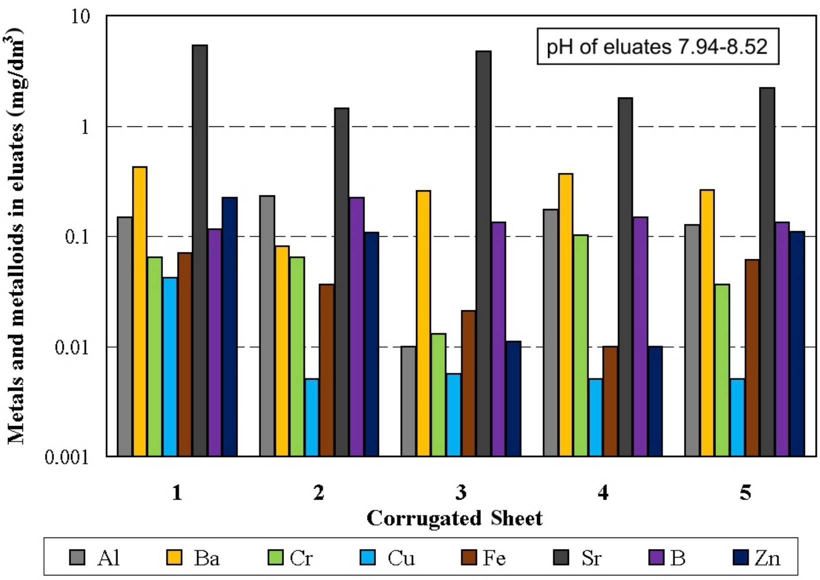

Fig. 1. Specification of metal and metalloid leachability from samples of asbestos-cement sheets (Corrugated Sheets) with the use of the TCLP method (tests 1:20)

Rys. 1. Zestawienie wymywalności metali i metaloidów z próbek płyt azbestowo-cementowych (płyta falista) przy zastosowaniu metody TCLP (test 1:20)

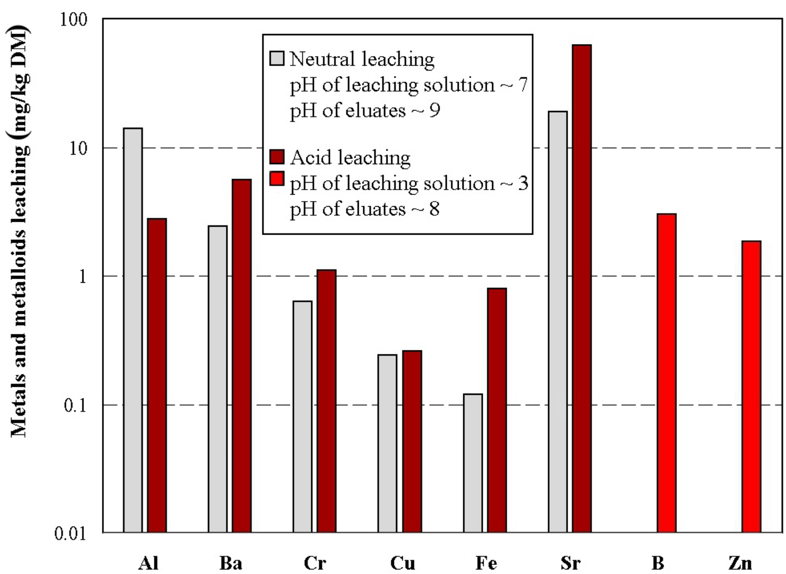

Fig. 2. Averaged values of leaching for individual metals and metalloids from asbestos-cement sheets under various environmental conditions (leaching in a neutral medium based on Klojzy-Karczmarczyk et al. 2021)

Rys. 2. Uśrednione wielkości wymywania poszczególnych metali i metaloidów z płyt azbestowo-cementowych w różnych warunkach środowiska (wymywanie w warunkach obojętnych na podstawie Klojzy-Karczmarczyk i in. 2021) leaching by means of a solution with neutral pH, in this case, boron (0.116–0.221 mg/dm^3) and zinc (<0.01–0.221 mg/dm^3) were additionally introduced to the solution (Figure 2). The leachability of chromium is also low (0.013–0.101 mg/dm^3), but in individual cases, the values exceed the value permissible for drinking water.

The determined values of the leachability of metals and metalloids from asbestos-cement waste by means of the TCLP method is double to a few times as high in comparison to the values obtained with the use of distilled water (Klojzy-Karczmarczyk et al. 2021). This confirms observations reported in the literature for other waste, extraction waste and metallurgical waste or contaminated soil (Du et al. 2014; Kicińska 2020; Król et al. 2020; Klojzy-Karczmarczyk and Mazurek 2021). Cadmium, nickel and lead are the exception. No increased leachability of these elements is observed under acidic conditions.

Among the analyzed group of metals, low leachability was found for mercury. Actually, the mercury leachability is lower than the limit of quantification (LOQ), both with the use of distilled water and an acetic acid solution. However, the obtained values fall around the limit of detection (LOD), which for the applied analytical method is 0.00015 mg/dm^3 (Table 4). The results obtained in this way should be treated with great caution. However, one can assume that there is no significant leaching of mercury from asbestos-cement products irrespective of the existing conditions. For identification purposes, the total mercury was determined in the sample weight. The total mercury content was identified in the asbestos-cement waste to be at an average level of 0.00287 mg/kg DM (Table 4). This value is much lower than its content in extraction waste or casting waste (Klojzy-Karczmarczyk and Mazurek 2021; Bożym and Klojzy-Karczmarczyk 2021).

The highest values of leachability were found for strontium and aluminum, as in the case of leaching with distilled water (Klojzy-Karczmarczyk et al. 2021). The leachability of strontium with the use of the TCLP method ranged from 1.43 to 5.35 mg/dm^3, at a mean value of approx. 3.10 mg/dm^3. The presence of strontium compounds and their leachability from asbestos-cement waste probably resulted from the existence of cement in the material. Strontium compounds were widely used also in the ceramics production in the second half of the twentieth century (Uliasz-Misiak 2016). As compared with leaching by means of distilled water, in this case the leachability of strontium increases three fold with the use of an acetic acid solution.

Slightly lower leachability values were obtained for aluminum. The leachability of aluminum ranged from <0.01 to 0.232 mg/dm^3, at a mean value of approx. 0.138 mg/dm^3. Asbestos-cement materials feature a high degree of firmness, obtained due to a substantial share of a binder (most often just cement binder); they also feature a low asbestos percentage in flat and corrugated asbestos cement sheets (10–15%). As a result of this, it is possible to presume that pollutants characteristic of cement will mainly be present in products of leaching. Therefore, aluminum in the eluate probably results from this element leaching from cement, which is the basic component of the asbestos-cement material according to widely available information (e.g. Portland cement... 2022; Król 2006;Kalarus et al. 2016a, 2016b). As compared with leaching by means of distilled water (Klojzy-Karczmarczyk et al. 2021), in this case the leachability decreases seven fold with the use of an acetic acid solution. Such an effect may be explained by the inhomogeneity of the analyzed samples or changes related to properties of the metal itself. Aluminum is a metal of amphoteric properties, reacting with both acids and bases. The obtained results show increased leachability of aluminum in environmental conditions changing from neutral to highly basic. The leachability of aluminum in environmental conditions changing from acidic to basic is probably slightly lower.

The highest values of leachability were found for strontium. However, strontium is not an element for which permissible limit values are set for drinking waters, industrial sewage or leachate, determining the possibility of storage for landfills of a given type.

The results obtained relating to the leaching of individual elements from waste material provide the basic criterion for determining the possibilities to landfill specific waste on specific types of landfill. In accordance with the requirements specified in the Regulation of the Minister of Economy of 16 July 2015 on *allowing the waste to be landfilled* (Dz.U. of 2015, item 1277), the results of the analyzed leaching of metals and metalloids obtained in the study enable classification of asbestos cement waste as a neutral waste group. Only the chromium content, as with the case of leaching with distilled water, exceeded the permissible values for neutral waste and fell within the limits set for waste other than hazardous and neutral.

It is difficult to compare the leachability (amount of leaching) for the analyzed metals and metalloids from asbestos-containing waste of corrugated sheets with studies of other authors due to the lack of studies on leaching from the waste material of such characteristic available in the literature. There have been no studies performed with the use of both the PN-EN 12457/1-4 method and the TCLP method. The total content and studies on leaching are the subject of the work of various authors for other waste groups generated in the area of Poland (e.g. Bożym 2017, 2022; Bożym and Klojzy-Karczmarczyk 2020, 2021; Kicińska 2021; Kosa-Burda and Kicińska 2016; Król 2006; Król et al. 2020; Szlugaj 2020). In comparison with other waste, the leachability of the analyzed metals and metalloids from asbestos-cement waste is definitely lower.

Conclusions

Thus far, all of the studies on asbestos dust in the air and in water and its impact on human health have been related to the importance of asbestos fibers. In foreign literature, there are no studies whatsoever on the process of the leaching of individual components from the asbestos-cement material, both from roofing as well as from water supply or sewerage pipes. It is therefore difficult to determine the value of leachability (amount of leaching) for mercury and the other analyzed metals and metalloids from asbestos-cement products, which as a consequence become asbestos-containing waste based on the hitherto literature.

The five samples of asbestos-containing wastes from various locations were selected for analysis. The analyzed material consisted of removed asbestos cement products (used for roofing) and deposited on the ground surface as hazardous waste of low asbestos content (approx. 10–15%). The process of leaching was performed using the TCLP method. A solution of acetic acid with a pH of 3.15 was applied as the leaching medium. The maintaining of constant leaching conditions proved to be impossible at the stage of the experiment. After the stabilization of the conditions, the pH range for the obtained solutions grows to an average value of 8.3. Low leachability of individual metals under the planned conditions was observed. In general, no introduction to solutions of such metals as cadmium, nickel, and lead was observed. The mercury content in eluates is below the quantification limit, but the obtained values fall around the detection limit. Compared with leaching with the use of distilled water (Klojzy-Karczmarczyk et al. 2021), zinc and boron additionally appear in eluates. The determined value of leachability for individual analyzed elements increases from double to a few times with the use of with the use of the TCLP method. The value of leaching for barium is on average 5.56 mg/kg, for chromium it is 1.10 mg/kg, for copper 0.26 mg/kg, and for iron 0.80 mg/kg. In addition, the leaching of boron of around 3.00 mg/kg and of zinc 1.84 mg/kg was found. Higher leachability values were found only for strontium and aluminum. The leaching of strontium is on average around 62 mg/kg. While the leaching of aluminum is lower as compared with the previous studies of the authors (Klojzy-Karczmarczyk et al. 2021) with the use of distilled water and is around 2.76 mg/kg. Products of leaching contain mainly pollutants that are characteristic of cement (aluminum, strontium, and iron).

Based on the results obtained for asbestos-cement materials (waste) of corrugated roofing sheets, one can think that the introduction of the analyzed metals and metalloids to the water supply network is of marginal importance. The only concern is raised by aluminum and strontium. The study has shown by testing that they may be introduced to the water supply network and to the sewage system.

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THE LEACHING OF MERCURY AND OTHER ELEMENTS FROM ASBESTOS-CEMENT SHEETS IN VARIOUS ENVIRONMENTAL CONDITIONS

Keywords

leachability, metals and metalloids, asbestos, asbestos-cement products

Abstract

The leachability of pollutants from asbestos-containing waste, previously used for roofing was investigated. Laboratory tests were performed under static conditions (tests 1–20) in accordance with the TCLP methodology (with the use of acetic acid as the leaching medium, initial pH = 3.15). The maintaining of constant leaching conditions proved to be impossible at the experimental stage. Following the stabilization of conditions, the pH range for the obtained solutions increased to an average value of 8.3. Aluminum, boron, barium, cadmium, chromium, copper, iron, nickel, lead, strontium,

zinc, and mercury were identified in the eluate. The low leachability of individual metals under the planned conditions was observed. In general, no leaching of such metals as cadmium, nickel, and lead was observed. The mercury content in the eluates is below the quantification limit, but the obtained values fall to around the limit of detection for the element. As compared with leaching with the use of distilled water (Klojzy-Karczmarczyk et al. 2021), zinc and boron additionally appear in eluates. The determined value of leachability for the individual analyzed elements increases from double to a few times with the use of the TCLP method. The value of leaching for barium is on average 5.56 mg/kg, for chromium it is 1.10 mg/kg, for copper 0.26 mg/kg, and for iron 0.80 mg/kg. In addition, the leaching of boron of around 3.00 mg/kg and of zinc 1.84 mg/kg was found. Higher leachability values were found only for strontium and aluminum. The leaching of strontium is on average around 62 mg/kg. While the leaching of aluminum is lower than values identified in the previous tests with the use of distilled water and is around 2.76 mg/kg. Products of leaching contain mainly pollutants characteristic of cement (aluminum, strontium, and iron).

WYMYWANIE RTĘCI I INNYCH PIERWIASTKÓW Z PŁYT AZBESTOWO-CEMENTOWYCH W RÓŻNYCH WARUNKACH ŚRODOWISKA

Słowa kluczowe

wymywalność, azbest, wyroby azbestowo-cementowe, metale i metaloidy

Streszczenie

Przeprowadzono badania wymywalności zanieczyszczeń z odpadów zawierających azbest, stosowanych wcześniej jako pokrycia dachowe. Przeprowadzono badania laboratoryjne w warunkach statycznych (test 1:20) zgodnie z metodyką TCLP (przy udziale roztworu kwasu octowego, jako medium ługujące, pH początkowe 3,15). Na etapie eksperymentu okazało się niemożliwe utrzymanie stałych warunków ługowania. Po ustabilizowaniu warunków zakres pH dla uzyskanych roztworów wzrasta do średniej wartości 8,3. W eluatach oznaczano glin, bor, bar, kadm, chrom, miedź, żelazo, nikiel, ołów, stront, cynk oraz rtęć. Obserwowana jest niska wymywalność poszczególnych metali w założonych warunkach. Nie obserwuje się generalnie wprowadzania do roztworów metali takich jak kadm, nikiel, ołów. Zawartość rtęci kształtuje się w eluatach poniżej granicy oznaczalności, ale uzyskane wartości mieszczą się w okolicach granicy wykrywalności tego pierwiastka. W porównaniu do ługowania z zastosowaniem wody destylowanej (Klojzy-Karczmarczyk i in. 2021) pojawia się w eluatach dodatkowo cynk oraz bor. Stwierdzona wielkość wymywania dla poszczególnych analizowanych pierwiastków wzrasta od 2 do kilku razy przy zastosowaniu metody TCLP. Wielkość wymywania dla baru wynosi średnio 5,56 mg/kg, chromu 1,10 mg/kg, miedzi 0,26 mg/kg, żelaza 0,80 mg/kg. Dodatkowo stwierdzono wymywanie boru na poziomie 3,00 mg/kg i cynku 1,84 mg/kg. Wyższe wartości wymywalności stwierdzono jedynie dla strontu i glinu. Wymywanie strontu kształtuje się na średnim poziomie 62 mg/kg. Natomiast wymywanie glinu jest niższe w porównaniu do wcześniejszych badań z zastosowaniem wody destylowanej i jest na poziomie 2,76 mg/kg. W produktach wymywania obecne są głównie zanieczyszczenia charakterystyczne dla cementu (glin, stront, żelazo).