PROBLEM OF UTILIZATION OF ASBESTOS-CEMENT SHEETS IN POLAND

Malgorzata Ulewicz, Wieslaw Liszewski
Czestochowa University of Technology, Poland
malgorzata.ulewicz@pcz.pl , wieslaw.liszewski@pcz.pl

Abstract. The management of construction and demolition waste in individual EU countries is very diverse, especially the management of asbestos waste. In Poland, asbestos-cement products until 1997 were a commonly used roofing material for both residential and farm buildings, especially in rural areas. Due to the harmfulness of this product, a ban on its production and use has been introduced in European countries. Poland, as the only country in the European Union, introduced in 2002 the "Programme for the removal of asbestos from the country for the years 2009-2032", which defines activities related to the removal and disposal of asbestos products. The paper analyzes the level of generated asbestos construction waste for individual voivodeships, and the degree of its development, together with the identification of obstacles in the effective process of disposal. It has been shown that the asbestos disposal process is very slow and impossible to implement within the assumed time limit. The cover replacement costs are high (net from EUR 54.71 to EUR96.60 per 1 m^2 of roof surface; calculated for the first quarter of 2023). The costs of replacing the asbestos-cement roofing with an environmentally safe one, made for a farm building with an area of 180 m2, are very high and range from EUR 11,135.54 to EUR 18,774.47. Currently, in Poland more than 60% of inventoried asbestos waste awaits disposal. The management of dismantled asbestos-cement coverings by depositing them in landfills is not an effective way of using this material, but only shifts the problem of its actual disposal in time.

Keywords: asbestos-cement products, construction waste, utilization, waste management.

Introduction

In recent years, a lot has been said and written about the harmful effects of asbestos containing products on human health [1; 2]. Asbestos is the commercial name of a specific group of minerals, that occur naturally in the form of fibres and belong to hydrated silicates containing mainly magnesium, sodium, calcium, and iron. These minerals, both morphologically and chemically diverse, can be basically divided into two groups depending on the morphology of the fibres: serpentine (softer fibres, e.g. chrysotile) and amphibole (stiffer fibres, e.g. crocidolite and amosite) [3]. In commercial products are used minerals as: chrysotile, crocidolite, amosite, anthophyllite asbestos, tremolite asbestos and actinolite asbestos. The largest amount of asbestos (chrysotile and amphibole) was used in the production of materials used in construction, such as flat and corrugated asbestos-cement boards, pressure pipes, stone cladding, facade panels, and insulate [4; 5]. As asbestos turned out to have carcinogenic properties (it is included in group 1 by the International Agency for Research and Cancer (IARC), the production of asbestos-containing materials has been banned or limited in many countries [6]. In Poland, a ban on the production of asbestos products, including asbestos-cement boards, was introduced on June 19, 1997 (Dz.U. 1997, No101, 628), and since March 28, 1999, a ban on trade in asbestos and products containing asbestos has been in force. While in the European Union, a total ban on asbestos was introduced on January 1, 2005 (Directive 1999/77/WE). The exception is, in accordance with the Regulation 2016/1005/EC, asbestos materials used for diaphragms for electrolytic installations (they can be used in EU until December 31, 2025).

Currently in the EU countries, a large number of both residential and commercial buildings covered with asbestos-cement boards require modernization [7]. According to the Quality Function Deployment (QFD) method, the investment process should be oriented not only on the investor (client) but also on the environment [8]. It is important both to remove environmentally harmful asbestos-cement products from buildings, as well as to carry out thermal modernization works allowing for energy savings [9; 10]. In addition, it is important in the construction sector to implement the principles of the circular economy by using waste and recycled materials to produce new building materials [11-16]. Attention should be paid to the quality of building materials, the reduction of the costs of the investment process and the safety of use of the building [17-19]. Unfortunately, the cost of replacing cement-asbestos coatings with environmentally safe materials is high, and the subsidy (in Poland) that an investor can obtain is very low [20].

The article analyzes the amount of asbestos products used for roofing in Poland in particular voivodeships. The costs of modernization of the asbestos-cement covering for an exemplary farm building were analyzed and different approaches to the methods of product management were compared.

Inventoried and neutralized asbestos roofing in Poland

At present, Poland is the only country in the European Union that has adopted the program of complete removal of asbestos from the country. The long-term program under the name of "Asbestos abatement in Poland 2009-2032" was adopted on July 29, 2009 [21]. The program has three main objectives: (1) removal and disposal of products containing asbestos; (2) minimizing the negative health effects contacting with asbestos fibres; and (3) elimination of the negative effect of asbestos on the environment. These activities are carried out at the central, regional and local (district and municipalities) levels. As part of the programme, a tool "Asbestos Database" was developed for collecting and processing information obtained from the inventory of asbestos-containing products, which is available to all local government units. The data entered into the Asbestos Database come from the owners and users of properties with asbestos-containing materials, including roofing. The data collected in the database are the basis for local government units in planning activities aimed at effective management and utilisation of these materials and are also the basis for real estate owners to apply for funds for the removal of asbestos-containing products.

Currently, over 8.5 million Mg (tons) of asbestos-containing products have been identified in Poland (Table 1), of which only over 1.5 million tonnes have been subjected to the neutralization process, and still over 6.9 million tonnes are waiting for disposal. Compared to 2019, the number of identified products is higher by 3.8% (8 208 722 198 kg) and the number of products that need to be neutralized is lower by only 2.8% (7 190 450 032 kg). Some asbestos products have still not been identified and entered into the asbestos database. Out of 2,477 Polish municipalities, only 2,464 municipalities (99%) provided data on natural persons, and only 2,365 municipalities (91%) provided data on legal persons. Compared to 2019, this is a slight increase in the amount of reported data [22].

Table 1

Mass of all asbestos products in Poland, kg (February 2023), [22]

Condition	Natural persons	Legal persons	Total
Inventoried	7 740 859 371	779 213 138	8 520 072 509
Neutralized	1 372 061 219	155 221 664	1 527 282 883
Remaining to be neutralized	6 368 826 193	623 991 474	6 992 817 667

For many years, most asbestos was used for roofing. Therefore, among the various asbestos-containing products, they pose the greatest threat to people and the environment. In 2023, 684,682,420 kg of flat asbestos-cement boards and 7,594,723,730 kg of corrugated asbestos-cement boards were inventoried in Poland. The amount of inventoried used corrugated asbestos-cement coverings for disposal, broken down by voivodeships, is presented in Table 2. Currently, a total of 6,294,160,717 kg of flat asbestos-cement boards and 485,806,006 kg of corrugated asbestos-cement boards are still waiting for neutralization in all voivodeships. The most products for neutralization are located in Mazovian and Kuyavia-Pomerania voivodships. Unfortunately, the actual amount of accumulated asbestos products may be higher, because, according to the audit carried out by the Supreme Audit Office [23], the data contained in the Asbestos Database do not fully reflect the actual state of affairs in terms of the amount of inventoried, neutralized and other products intended for disposal. The reason for this is non-compliance by natural persons who are not entrepreneurs and use the products containing asbestos from the obligation to annually provide information on the quantities, types and locations of these products. The reliability of the data contained in this database is also influenced by errors related to its operation or omissions of employees responsible for entering data. According to the the Supreme Audit Office report, discrepancies as to the amount of asbestos included in the Asbestos Database in relation to the data held in this respect by local government units occurred in 18 out of 23 municipalities (which is 78.2%). The timeliness of submitting reports also affects the statistics of the collected data. In addition, 10 out of 23 (43%) of the audited municipalities did not submit the reports on time, and in extreme cases the delays amounted to nearly four years [23]. Thus, the data from the database may be

helpful, but they are not a fully reliable source of knowledge in planning the management of these products.

Table 2

List of identified corrugated asbestos-cement boards used in construction in Poland by voivodeship (February 2023), in kg, [22]

Voivodeship	Inventoried	Neutralized waste	Remaining for disposal
Lower Silesia	167 587 286	51 579 603	108 435 315
Kuyavia-Pomerania	536 611 799	85 395 313	442 575 485
Lublin	1 122 383 255	143 328 604	976 561 177
Lubusz	105 232 093	43 439 974	58 449 205
Lódź	748 690 474	88 275 786	658 667 973
Lesser Poland	345 086 125	91 778 278	250 464 762
Mazovian	1 530 606 255	218 921 112	1 301 052 770
Opole	77 245 902	15 654 970	59 496 760
Subcarpathia	317 642 960	59 444 825	256 458 387
Podlasie	560 978 928	71 206 049	487 966 948
Pomerania	240 033 726	35 275 755	200 491 110
Silesia	181 891 254	33 492 569	135 074 752
Świętokrzyskie	514 811 832	89 407 771	424 073 091
Warmia-Masuria	226 971 638	39 808 736	183 918 076
Greater Poland	751 591 092	120 760 141	620 936 448
West Pomerania	165 844 860	32 748 167	129 551 658

Management of asbestos-cement waste

In Poland, the only acceptable method of asbestos-cement waste management is its utilization by depositing it in hazardous waste landfills or in separate parts of non-hazardous and inert waste landfills. Before depositing, the material should be tightly wrapped in polyethylene foil with a minimum thickness of 2 mm [24]. According to this Act, it is not possible to use dismantled asbestos-cement products, nor is their recycling carried out. The literature shows that for many years research has been carried out to develop an effective and at the same time safe for the environment and people method of disposing of used asbestos products. These methods aim at destroying the harmful fibrous structure and transforming the waste into a material with an amorphous structure. For this purpose, chemical methods (e.g. dissolution in inorganic, organic acids or concentrated alkalis) and thermal (e.g. vitrification) methods are most often used. Asbestos fibres lose their properties at temperatures above 700 °C. The process of neutralizing asbestos fibres, in laboratory tests, was also the use of microwave radiation or mechanical and chemical treatment with a high-energy grinding process [25-30]. The use of microwave technology to break down asbestos fibres in waste has been described in many publications [31; 32]. On the other hand, a combination of mechanical and thermal treatment, i.e. MTT technology (Microwave Thermal Treatment) was patented by the Polish engineer Ryszard Parosa (Aton HT SA company, patent S20120024990A1). This process is competitive compared to traditional thermal treatment technology, due to time reduction and energy savings needed to carry out the process. The processing temperature of asbestos fibers can also be shortened by adding appropriate fluxes. However, according to the research [33], this may result in incomplete utilization of asbestos fibres.

Despite the fact that in the literature one can find many methods of disposal of asbestos fibres, asbestos-cement roofing in Poland for many years was only removed and deposited on waste landfills. In the United States, however, other methods of reducing asbestos-related risks are very popular. These methods consist in coating asbestos-cement products installed in buildings with paints, without dismantling them. Structural elements are painted with asbestos-free preparations, which increases their mechanical strength and resistance to erosion. Urethane preparations, latex, or preparations containing powdered metal are most often used for this purpose. However, a significant disadvantage of this method is the limited lifetime of the insulation materials that protect the asbestos products from erosion [34].

Despite this, if it is not possible to modernize old roofs covered with asbestos cement, even such a short-term solution is important. Because, according to the research [35], with the increase in the degree of damage to asbestos-cement boards, externally applied on buildings or in walls, a linear increase in the concentration of asbestos fibres in the air is observed. The concentrations of asbestos fibres in case of products in good technical state were in the range of < 300 to about 500 fibres·m^{-3} (f·m^{-3}). In case of damaged products inside the building they were above 1000 f·m^{-3}.

Also in Poland, many companies offer paints to protect asbestos products. This solution is temporary and results from the needs of the market (the legislator did not foresee such action in the act). There are polymer facade paints available on the market (e.g. acrylic, preparation Emulbit; preparation acrylic-silicone Aksibet) or based on silicone resin (e.g. StoSilico Color G preparation). However, the use of these preparations seems advisable, because due to the high costs of disassembly of asbestos products and roof modernization, asbestos-cement roofing is still present on the Polish (and European) market.

Analysis of roofing replacement costs on a farm building

The cost of replacing the asbestos-cement roof covering with an environmentally safe covering includes both the costs of disassembly of the unsafe roofing, the cost of purchasing a new material and its placement on the building as well as the cost of disposing of the dismantled asbestos product. Many municipalities offer various types of subsidies for the dismantling and disposal of the asbestos products, but the remaining costs are borne by the owner of the building.

For the subject replacement of the roof of the livestock building with external dimensions of 9.00 m x 20.00 m and the angle of the roof slope of 45° with the perimeter eave 0.50 m extended beyond the building projection, the normative base of the Cost Estimated Standards of Physical Expenditures was used. To facilitate a quick calculation, a unit cost of 1.00 m^2 was established for the replacement of the roof, including its demolition, the implementation of a new roof truss structure and a new variant cover as below:

- simple gable roof in the system of collar beam construction, the roof is covered with glazed cement tiles,
- simple gable roof in the system of collar beam construction, roofing with tile-like sheet,
- simple gable roof in the system of collar beam construction, roofing with trapezoidal sheet,
- simple gable roof in the system of collar beam construction, roofing with heat-weldable roofing felt.

For the detailed calculation, at the level of net prices, price-forming components were adopted at the level of the first quarter of 2023, based on the Intercenbud price list database, and the computer software supporting the costing process Zuzia (C) DataComp license No. 4693 was used to enable numerical calculations:

- Indirect costs *Kp* for general construction works (R, S) – 68%,
- Purchase costs of *Kz* for general construction works (M) – 6.8%,
- Calculation profit *Z* for general construction works (Kp, R, S) – 11.5%,
- Man-hour *R* for general construction works – EUR 8.01,
- Material *M* – average market price,
- Equipment *S* – average market price.

Net unit prices for the analyzed variants are presented in Table 4. According to the data, the cost of replacing the roofing for a farm building in the most expensive variant (No. 1) is EUR 96.60 per 1 m^2, and in the cheapest variant (No. 4) EUR 54.71 per 1 m^2. Which in the case of an outbuilding with an analyzed area of 180 m^2 gives the amounts of EUR 17,397.07 and EUR 10,310.69, respectively. The tax (8% VAT) should be added to the given prices, which will increase the prices of replacing the roof structure. For variants 1 and 4, the gross prices will be EUR 18,774.47 and EUR 11,135.54, respectively (total cost without subsidies). The cost of replacement with a subsidy depends on the municipality (with the subsidy slightly lower). Details of the subsidy are presented in the article [19].

Table 4

Estimated costs of dismantling the truss and new roofing in 4 variants in gross amounts

Rafter flaming structure and roof covering	Cost of 1 m^2, EUR
Simple gable roof with collar beam structure, roof covering with glazed cement tiles, double covering	96.60 EUR·m^{-2}
Simple gable roof with collar beam structure, roof covering with a tile-like sheet	74.89 EUR·m^{-2}
Simple gable roof with collar beam structure, roof covering with trapezoidal sheets	70.57 EUR·m^{-2}
Simple gable roof with collar beam structure, roof covering with heat-weldable roofing paper	54.71 EUR·m^{-2}

Public support for the removal of asbestos products

In Poland in 2016-2021 for dismantling, export and disposal of asbestos-containing products, the National Fund for Environmental Protection and Water Management allocated 15,171.62 EUR. The least was spent in 2018 (892.12 EUR) and the most in 2020 (4,168.28 EUR) [23]. The financial resources provided by the Organization in the years 2016-2021 for this purpose, broken down by province, are presented in Table 5. Since the rules of the co-financing program provide for co-financing only for works related to the cost of dismantling the roofing by a professional company and the cost of asbestos disposal, and do not cover the cost of purchasing a new roofing or assembly works, this results in low interest among Poles in replacing the asbestos roofing [20]. The Agency for Restructuring and Modernization of Agriculture tried to help farmers in this difficult task in 2022. In the last quarter of 2022 (from October 15 to November 15), it announced a competition in which, in addition to the costs of removing asbestos and its disposal, it also co-financed part of the purchase price of the roofing. The condition for receiving financial support from ARMA is the replacement of the roof on the entire building, but the limit per applicant is 500 square meters, and the aid rate is EUR 8.87 per m^2 [36]. For now, it is not known whether another competition will be launched and whether farmers who did not submit an application in the first competition will be able to apply for such aid.

Table 4

Financial resources provided by the National Fund for Environmental Protection and Water Management in 2016-2021 for dismantling, export and disposal of products containing asbestos, broken down by voivodeships, [23]

Voivodeship	Financial means, in thou. EUR	Voivodeship	Financial means, in thou. EUR
Lower Silesia	1245.90	Subcarpathia	1629.27
Kuyavia-Pomerania	2027.05	Podlasie	696.01
Lublin	1262.31	Pomerania	838.80
Lubusz	815.30	Silesia	378.49
Lódź	267.63	Świętokrzyskie	1569.18
Lesser Poland	25.50	Warmia-Masuria	692.68
Mazovian	1520.62	Greater Poland	1052.11
Opole	493.35	West Pomerania	679.60

The postulates for the creation of new instruments, mechanisms and support measures for owners of real estate where asbestos-containing products are located are included in the position of ZGWRP (Association of Rural Communities of the Republic of Poland) on the Program for removing asbestos from the country for the years 2009-2032. One of the instruments would be the introduction of refunds (compensation) from the state budget for communes with rural areas for agricultural tax relief related to investments in the field of asbestos removal on farms. In addition, it calls for the introduction of investment reliefs, deductible from the income tax base, expenses related to asbestos removal and replacement of roofing materials. ZGWRP also points to the need to recreate communal and

environmental protection funds, which, acting locally, would support government and regional programs in the field of asbestos removal from residential and commercial buildings [42].

Conclusions

The analysis shows that the costs of replacing the asbestos-cement roofing on an environmentally safe carried out for a 180 m^2 farm building are very high (from EUR 11,135.54 to EUR 18,774.47). The cost of replacing the roofing increases significantly with the increase in the amount of material used on the roof surface and the type of the selected material solution. Considering that the investor, in addition to replacing the roofing on an outbuilding, sometimes has to consider replacing the roofing on a residential building, these costs will be even higher. The amount of financial support offered by municipalities and voivodeships for asbestos removal is small, which does not make it easier for the investor to decide on the modernization of roofs. After inspections by the Supreme Audit Office, in only five voivodeships, it seems that the Asbestos Removal Program 2009-2032 will not be implemented on time. The literature analysis clearly shows that the use of disposal of asbestos products by depositing them in landfills is not the best solution for the environment.

Author contributions

Conceptualization (M.U); methodology (MU, W.L.) software (W.L.); formal analysis (M.U. and W.L.); data curation (M.U. and W.L.).; writing-original draft preparation (M.U.); writing-review and editing (M.U.) All authors have read and agreed to the published version of the manuscript.

References

[1] Krówczyńska M., Wilk E. Environmental and occupational exposure to asbestos as a result of consumption and use in Poland. Int. J Environ Res Public Health. vol. 16, 2019, 2611.
[2] World Health Organization. Asbestos [online] [18.03.2023] Available at: https://www.who.int/teams/environment-climate-change-and-health/chemical-safety-and-health/health-impacts/chemicals/asbestos
[3] Łuniewski S. The removal of asbestos and asbestos - containing products as the component of waste management, Ekonomia i Środowisko (Polish), vol. 3, 2017, pp. 146-158.
[4] Pyssa J., Rokita G. M. The asbestos - occurrence, using and the way of dealing with asbestic waste material. Min. Res. Manag., vol. 23, 2007, pp. 49-61.
[5] Brycht N. Recycling of asbestos-cement waste – An opportunity or a threat?" System Safety: Human - Technical Facility - Environment, vol. 4, 2022, pp.10-18.
[6] National Asbestos Bans [online] [18.03.2023] Available at: http://ibasecretariat.org/alpha_ban_list.php
[7] Maduta C., Kakoulaki G., Zangheri P., Bavetta M. Towards energy efficient and asbestos-free dwellings through deep energy renovation, Publications Office EU, Luxembourg, 2022
[8] Jagusiak-Kocik M., Ulewicz, R. Implementation of the QFD method in a construction industry company [in]: Blikharskyy Z. (eds), Proceedings of EcoComfort 2022. EcoComfort 2022. Lecture Notes in Civil Engineering, vol 290. 2023, Springer, Cham.
[9] Lis A. The efficiency of energy saving activities in the process of thermal modernization of multifamily buildings, Construction of Optimized Energy Potential (CoOEP), vol. 8, 2019, pp.107-116.
[10] Zhelykh V., Furdas Y. The optimal insulation thickness determined for modular buildings according to multi-criteria analysis, Construction of Optimized Energy Potential (CoOEP), vol. 10, No 1, 2021, pp. 43-51.
[11] Mohajerani A., Vajna J., Cheung T. H. H., Kurmus H., Arulrajah, A., Horpibulsuk S. Practical recycling applications of crushed waste glass in construction materials: A review, Constr. Build. Mater, vol. 156, 2017, pp. 443-467.
[12] Pietrzak A., Ulewicz M. Influence of post-consumer waste thermoplastic elastomers obtained from used car floor mats on concrete properties. Materials, vol. 16, 2023, 2231.
[13] Ulewicz M., Pietrzak A. Properties and structure of concretes doped with production waste of thermoplastic elastomers from the production of car floor mats, Materials, vol. 14, 2021, 872. Jura J., Ulewicz M. Assessment of the possibility of using fly ash from biomass combustion for concrete, Materials, vol. 14, 2021, 6708.

[14] Dębska B., Krasoń J., Lichołai L. The evaluation of the possible utilization of waste glass in sustainable mortars, Construction of Optimized Energy Potential (CoOEP), vol. 9, 2020, pp. 7-15.
[15] Givi A.N., Rashid S.A., Aziz F.N., Salleh M.A. Contribution of rice husk ash to the properties of mortar and concrete: a review. J. Am. Sci. vol. 6 (3), 2010, pp. 157-165.
[16] Krynke M., Mielczarek K. Problems concerning product quality enhancement, Production Engineering Archives, vol. 10, 2016, pp. 17-20.
[17] Tomov M., Velkoska C. Contribution of the quality costs to sustainable development. Production Engineering Archives, vol. 28 (2), 2022, pp.164-171.
[18] Lis T., Nowacki K. Pro-ecological possibilities of using metallurgical waste in the production of aggregates. Production Engineering Archives, vol. 28, 2022, pp. 252-256.
[19] Ulewicz M. Liszewski W. Influence of public financial support on the process of roof covering replacement and safety of civil structures, System Safety: Human - Technical Facility - Environment, vol.2, no.1, 2020, pp.259-267.
[20] M.P. 2009, no 50, position. 735 - Announcement of the Minister of Economy of July 29, 2009 on the adoption by the Council of Ministers of a resolution on the establishment of a long-term program under the name "Program for the Cleanup of the Country from Asbestos for the years 2009-2032" (in Polish).
[21] Asbestos database [online] [18.03.2023] Available at: https://bazaazbestowa.gov.pl/pl/
[22] Report by the Supreme Audit Office, Warsaw, 2022, No. 108/2022/P/22/072/LOL
[23] M.P. 2004, no 71, position. 649 - Regulation of the Minister of Economy, Labor and Social Policy of 2 April 2004 on the methods and conditions of safe use and removal of asbestos-containing products (In Polish)
[24] Gualtieri A.F., Giacobbe C., Sardisco L., Saraceno M., Gualtieri M. L., Lusvardi G., Cavenati C., Zanatto I. Recycling of the product of thermal inertization of cement–asbestos for various industrial applications, Waste Management, vol. 31, 2011, pp. 91-100.
[25] Kusiorowski R., Zaremba T., Piotrowski J., Jung, T. Zastosowanie odpadów azbestowych w masach ceramicznych do produkcji ceramiki budowlanej (in Polish), Materiały Ceramiczne, vol. 66, 3, 2014, pp. 245-252.
[26] Bernasconi A., Pellegrino L., Vergani F., Campanale, F. Marian M.N., Galimberti L., Perotti M., Viti C., Capitani G. Recycling detoxified cement asbestos slates in the production of ceramic sanitary wares, Ceramics International, vol. 49, 2023, pp. 1836-1845,
[27] Nam S. N., Jeong S., Lim H., Thermochemical destruction of asbestos-containing roofing slate and the feasibility of using recycled waste sulfuric acid, J. Hazard. Mater. vol. 265, 2014, pp. 151-157.
[28] Gualtieri A., Tartaglia A., Thermal decomposition of asbestos and recycling in traditional ceramics, J. Eur. Ceram. Soc. vol. 20, 2020, pp. 1409-1418
[29] Yoshikawa, N., Kashimura, K., Hashiguchi, M., Sato, M., Horikoshi, S., Mitani, T., Shinohara N., Detoxification mechanism of asbestos materials by microwave treatment, J. Hazard. Mater., vol. 284, 22015.
[30] Leonelli C., Veronesi P., Boccaccini D. N., Rivasi M. R., Barbieri L., Andreola F., Lancellotti I., Rabitti D., Pellacani G. C. Microwave Thermal Inertisation of Asbestos Containing Waste and its Recycling in Traditional Ceramics, J. Hazard. Mater., vol. 135, 2006, pp. 149-155.
[31] Obmiński A. Asbestos waste recycling using the microwave technique – Benefits and risks, Environmental Nanotechnology, Monitoring & Management, vol. 16, 2021, 100577.
[32] Pawełczyk A., Bożek F., Grabas K., Chęcmanowski J., Chemical elimination of the harmful properties of asbestos from military facilities, Waste Management, vol. 61, 2017, pp. 377-385.
[33] Obmiński A. Asbestos in building and its destruction, Constr. Build Mater., vol. 249, 2020, 118685.
[34] Restructuring Agency and Modernization of Agriculture [online] [18.03.2023] Available at: https://www.gov.pl/web/arimr (In Polish)
[35] Local government portal [online] [18.03.2023] Available at: https://samorzad.pap.pl/kategoria/aktualnosci/zgwrp-apeluje-o-wprowadzenie-zmian-w-programie-usuwania-azbestu (In Polish)