Material Recovery of the Glassy Slag Produced from Asbestos Containing Waste

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Abstract**—***The present article deals with the option of high-temperature processing of asbestos-cement roof tiles in a plasma reactor. It describes the process of melting this type of waste in a plasma reactor which is aimed at obtaining the resulting product in the form of vitreous slag of the inert nature. The article also briefly comments on the potential recovery of the formed slag which may be used as the secondary material for further manufacture processes.*

Keywords**—*****asbestos, glassy slag, ceramic foam.***

I. INTRODUCTION

Converting materials into material values and increasing their life standard are associated with many problems which affect, to various extents, the natural environment and consequently also humans. One of the apparent human interventions in the natural environment is the production of waste and the persisting existence thereof in the environment. It may be assumed that the amount of waste will grow and this will also increase the number of problems regarding the waste disposal. This means that most waste types, categorised depending on their characteristics and environmental hazard, will have to be recycled in future, not only because of the potential to recover certain desired components (e.g., metals), or because of their energy potential, but mainly because of the environmental protection [3].

A special waste category is the hazardous waste which includes the asbestos-containing waste. The disposal of this kind of waste must be paid special attention as this waste possesses hazardous properties.

At present, the disposal of asbestos-containing waste is divided into seven waste disposal categories. In terms of the environmental protection, important disposal methods are the methods categorised under numbers 01 to 03, i.e., material recovery, energy recovery, and other. The percentage of the recovered hazardous waste is still insignificant due to its hazardous properties.

The removal of asbestos materials from buildings is subjected to the permit issued by the Public Health Authority of the Slovak Republic pursuant to Act No 355/2007 Coll. on the Protection, Support and Development of Public Health. The yearly production of asbestos-containing waste in the period from 2010 to 2015 is shown in Fig. 1 [1].

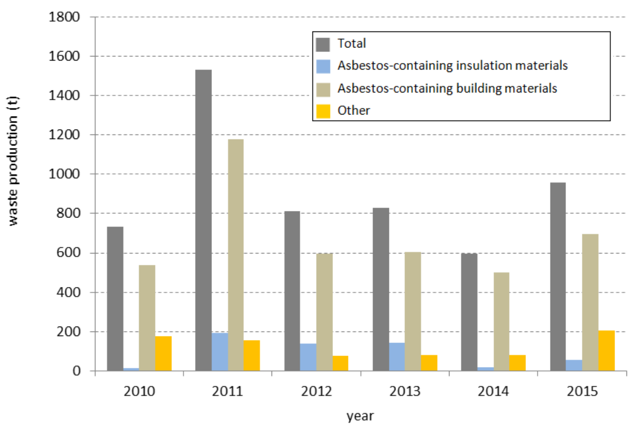


FIGURE 1: Production of asbestos-containing waste in years 2010 – 2015

The 17 06 05 waste category represents an important item in the total amount of the produced asbestos-containing waste. The highest amount of this type of waste, 1,179.65 tons, was produced in 2011 and the lowest amount in 2014 in the quantity of 498.79 tons. These quantities represented 77 % of the total amount of produced asbestos-containing waste in 2011 and approximately 84 % in 2014. The proportion thereof in years 2010 to 2015 ranged from 73 % to 84 %. The proportion of asbestos-containing waste in the total production of hazardous waste in the SR is depicted in Fig. 2 [1].

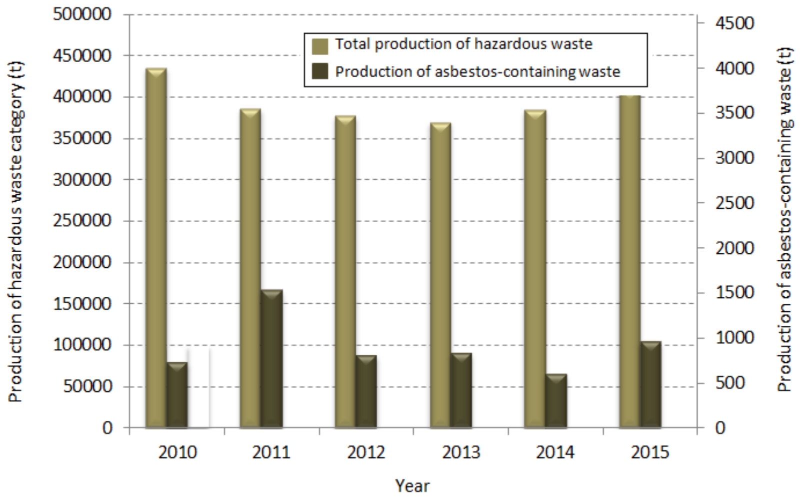


FIGURE 2: Proportion of asbestos-containing waste in the total production of hazardous waste in the SR

Asbestos-containing materials belong to the category of waste typically stored at landfills with controlled regimes. This disposal method represents only a temporary solution, even regarding the potential further use of the material potential inherent in such waste.

In respect of the above mentioned facts, new methods of disposal of asbestos-containing products are being searched. Newly proposed processing methods are expected to meet the requirement for the recovery of even those products that are the results of the waste reprocessing.

II. HIGH-TEMPERATURE PROCESSING OF ASBESTOS-CEMENT ROOF TILES

Probably an efficient method how to dispose of asbestos fibres contained in the waste of various categories is to reprocess it through a thermal process [2, 3]. The effects of high temperatures and chemical reactions running during the process cause that asbestos fibres contained in the waste are subjected to various stages of transformation and phase transitions.

Asbestos waste originating from a disassembled roof of a family house was processed in a plasma reactor at the temperature of 1,470 °C. Free chrysotile fibres on the surface of the roof tiles are depicted in the images made by the Scanning Electron Microscope – SEM (Fig. 3). The images show poorly bound fibres of chrysotile on the surface of the tiles and at the place where the tile was broken.

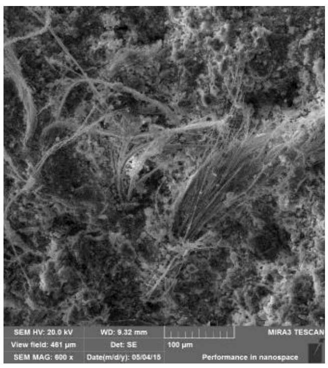


FIGURE 3: Detail of the surface of the used ACRT prior to the experiment waste in the SR

As the melting point of asbestos-cement roof tiles as such is high, it may be reduced by adding an acidic flux. In this particular case, such flux was the fly ash from fluidised-bed combustion chambers. The process of melting the asbestos-cement roof tiles together with the fly ash may also be applied to recover the energy potential of the fly ash. The unburned material contained in the fly ash, weighing > 10 wt.%, will be used in the plasma melting as the reducing agent.

Melting the mixture of ACRTs and fly ash from fluidised-bed boilers, mixed in the 1 : 1 ratio, was carried out in a plasma reactor in reducing conditions. More detailed information on the boundary conditions and on the course of the melting process are provided in [2, 4].

III. DISCUSSION

The two main resulting products of the high-temperature melting of the mixture of ACRTs and fly ash from fluidised-bed boilers with a high content of unburned material were the synthesis gas and the vitrified slag [2, 5]. The proportions of the light ash and of the reduced metals were both low and they were untraceable during the laboratory experiment because the slag became mixed with microscopic inclusions of the reduced metals which could not sediment as a separate metal phase during the melting process because their amount and volume were low.

The energy of the produced synthesis gas, when cleaned, may be recovered for example in the charge drying process or for the production of electric energy in a cogeneration unit in form of auxiliary fuel [6]. The utilisation of the synthesis gas energy is conditioned primarily by the gas being cleaned of undesired components, such as sulphur dioxide.

Slag, as the main product of the high-temperature melting of fly ash and asbestos-cement products, represents the polycomponent system comprising metal oxides and non-metallic components which combine and form chemical compounds and solutions. In addition to the above mentioned components, slag may contain, depending on the course of waste melting and tapping process, also sulphides of metals, gaseous components, droplets of the reduced metal component, etc.

In the first stage of the experiment evaluation, the attention was paid mainly to the produced slag. Its density was approximately 2,850 $kg \cdot m^{-3}$. The waste weight reduction represented 21.5 wt.% and the volume reduction was as much as 79 vol.%. The analyses of the water extract and ecotoxicity confirmed that the product was environmentally acceptable [2, 4].

For melting the mixture of asbestos-cement roof tiles and fly ash from fluidised-bed boilers at the average temperature of 1,470 °C it is also assumed that despite the high melting point of pure chrysotile fibres (1,521 °C) [2] they would decompose as a result of chemical reactions running in the melt. The decomposition process is also significantly affected by the temperature at the site where the arch discharge is maintained; this temperature is significantly higher than the temperature of the melt on the bottom of the reactor. The absence of chrysotile fibres in the slag was confirmed by the finding of ground particles of the slag on the electron micro analyser which did not confirm the presence of chrysotile fibres in vitrified slag (Fig. 4).

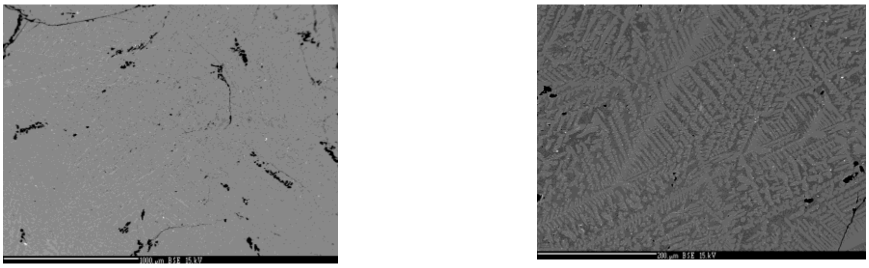
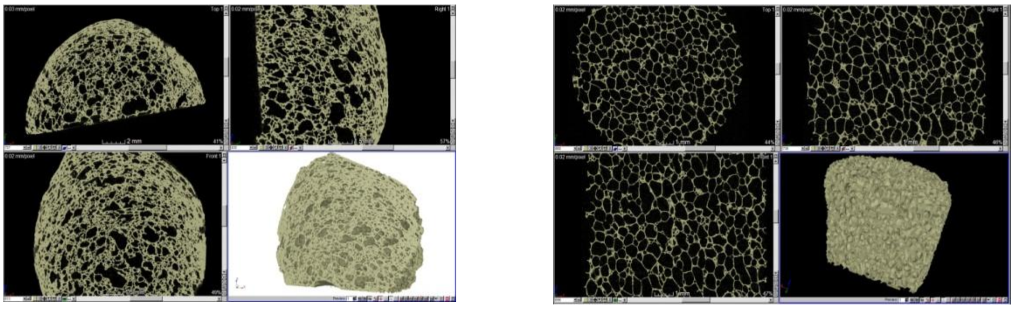


FIGURE 4: Images of the vitrified slag made by the electron micro analyser

The analysis of mechanical properties of the slag confirmed that they are similar to those of silica glass. The dominant phase in the collected slag specimens was gehlenite (DSC analysis).

Considering the technological procedure of waste processing (high-temperature melting), it is possible to discuss the potential of using the liquid slag in the production of mineral wool. The chemical composition of the slag that would be appropriate for the production of foam glass may be achieved by minor modification of its composition. Another method how to recover the vitrified slag produced in the process of thermal processing of fly ash and asbestos-cement roof tiles is the production of porous building materials with low thermal conductivity coefficient, such as foam glass (glass-ceramic foam). The specimen of the glass-ceramic foam was obtained by shock-heating the mixture of the ground melted slag and 1 wt.% of $CaSO_4$ at the temperature of 1,030 °C. The sizes and morphology of pores in the structure of the obtained material (Fig. 5a) are considerably different from the porosity of the commercial foam glass (Fig. 5b). Unlike the commercial product manufactured from the recycled glass applying the well-established technology, the walls of pores in the prepared specimen of the vitrified slag were unevenly thick and the size-based distribution of pores and their shapes changed significantly towards the edge of the specimen. These structural differences may be caused by insufficient homogenisation of the input mixture and by thermal processing. More detailed information on the research on the production of glass-ceramic foam is provided in [2, 4].



a) glass-ceramic foam b) commercial foam glass

FIGURE 5: Structure of pores

IV. CONCLUSION

The comprehensive evaluation of the waste management level in the Slovak Republic indicates that the waste disposal is the segment that has been neglected for a long period of time, as to the technology level and the development the market relationships, and nowadays this segment experiences dynamic development. Novel legislation and the incorporation of the European regulations into the laws of the Slovak Republic created the fundamental regulatory and control conditions for further development of this segment.

In terms of the environmental protection, the purpose of the manufacturing segment is to produce products which may be used as the sources of secondary materials or energy after being decommissioned. Achieving this goal, especially in the segment of manufacture and processing of the products possessing hazardous properties, is often difficult. A potential solution for the recovery of waste containing asbestos fibres is to remelt it applying the high-temperature melting process. In addition to obtaining the inert slag, the resulting slag may be used as the secondary material after slightly modifying its composition. The production of ceramic material will result in the product which may be regarded as 100% recyclable after its service life elapses. In addition to this factor, another advantage is that even the hazardous waste, i.e., asbestos-cement roof tiles, will be recovered and disposed of.

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