Circular economy as possible solution for asbestos burden

B Zoraja¹, M Živančev¹, D Ubavin¹ and B Nakomčić-Smaragdakis¹

¹University of Novi Sad, Faculty of Technical Sciences, Department of Environmental Engineering and Occupational Safety and Health, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia

E-mail: bojanazoraja@uns.ac.rs

Abstract. Asbestos has been used worldwide in a large number of products throughout the 1970s and 1980s. After the proven influence of asbestos materials on diseases that could have a fatal outcome was confirmed, bans on the use and production of these materials began. However, there are still significant quantities of asbestos waste and materials in the environment and there is a need for safe and permanent solution. As a support to sustainable development by minimizing waste production and harmful emissions as well as by reducing the consumption of natural resources, the circular economy (CE) is recognized in the EU as a leading solution. The main meaning of CE in waste management field is to turning waste into a resource. Considering above-mentioned, this paper presents how to resolve a problem of asbestos waste that is currently and will continue to be present. Instead of occupying the space, which is also a valuable resource, with landfills that also raise cost, asbestos can be used in construction material industry. Paper presents estimated amounts of asbestos waste, proposal for appropriate waste collection, treatment and market placing of a new product in Serbia. The conclusion of the paper is that the presented model of circular economy for asbestos in Serbia is feasible, in this way it would be possible to achieve some incomes from material selling and, also, releasing some space. In addition, for the implementation of this model of asbestos management, it is necessary to have Government involvement through investment in infrastructure and improvement of legislation.

1. Introduction
The phrase asbestos indicates a range of silicate minerals, which are naturally found in form of fibers and were commercially very usable. Asbestos minerals separate into two main groups based on crystalline structures: serpentine and amphibole, figure 1. [1] The first group refers to chrysotile, hydrated magnesium silicate materialized in the serpentine stones. Has the small-scale asbestos fiber frequently used in asbestos-textile industry (braids, fleece, etc.). Amphiboles are second group and refers to: actinolite, anthophyllite, tremolite, and commercially very used crocidolite and amosite. [2].
Diverse asbestos has various source and configuration, accordingly different physical attributes. Every asbestos has vast specific surface, so contamination can appear all along the production and preparation processes of the fibers. Raw asbestos may also hold certain content of oil, and traceable metals such as chromium, cobalt, nickel, manganese, well known for their biological activity. [4].

Asbestos usage began over 4500 years ago, but the modern asbestos industry originated from the exploitation of large sites in Russia, Canada, New Zealand, Italy, Australia, Africa, etc. The initiative came from the cotton industry with the goal of producing durable, non-flammable fabric. The main use was for the preparation of cement, plastic fillers, materials for insulation, textile, and brake products. In the golden period of asbestos consumption, thousands types of asbestos-containing products were used in schools, clinics, movie theaters and industrial facilities, etc. [5]. Some asbestos usages are noted in table 1.

Table 1. Usage of asbestos fibers [6]

| Category of asbestos products | Asbestos bonded with other materials | Asbestos as textile fiber | Asbestos used as loose fiber mixtures |
|------------------------------|-------------------------------------|--------------------------|--------------------------------------|
| Percent of total asbestos usage | >98%                                 | <1%                      | <0.1%                                |
| Preparation method           | with inorganic materials            | roving’s, yarn           | mixtures with inorganic materials    |
| Main products                | Portland cement, hydrous calcium silicate, basic magnesium carbonate | oils, tars, elastomers, plastics, resins | woven, plaited cement, gypsum, hydrous calcium silicate, basic magnesium carbonate, diatomaceous earth |
| Main uses                    | pipelines, flat sheets, corrugated roof sheeting and fencing, insulation boards | roofing products, caulking, joining, packings, gaskets, floor tiles, reinforced plastic sheets, friction materials, thermoplastics, thermosets | cloth, webbing, tubing, jointing’s, heat, electrical or sound insulation products |
spread around the world. Despite all its positive characteristics, asbestos has been recognized as dangerous to human health and life. Today, well-known diseases are associated with risks of exposure to asbestos fibers, such as asbestosis of the lungs, malignant respiratory and abdominal diseases, and others. After it was determined that asbestos is extremely dangerous, countries have begun to prohibit the use and production of asbestos-containing materials. There are currently more than 50 countries, including the European Union, that have banned asbestos completely [7]. The danger posed by asbestos-containing products is related to the inhalation of asbestos from the air. [8-12] It has been estimated that about 125*10^6 people are occupationally exposed to asbestos, and it has been stated that asbestos-related illnesses cause 1.07*10^6 deaths per year [5].

1.1. Significance of CE
Circular economy (CE) in comparison to linear economy, that is present, values raw materials differently, it is designed with aim to utilize the maximum value of resources [13]. Materials and products are designed with waste prevention in mind, and they are re-used, recycled, or recovered. New products should have long lifecycle and they can have alternative use also. Effective functionality of the circular economy demands adaptation of market conditions and policy in all sectors. Increasing resource efficiency, reducing cost and environmental effects are goals that demand changing of governments and businesses views. CE generates economic and business opportunities and provides environmental and social benefits. Circular economy in comparison to linear economy is more resilient, innovative, and productive, and finally it would last for longer time.

Three principles are important for circular economy, new product design without pollution and waste, preservation of natural resources and keep material and products in use as much as possible. Strategies like reuse, repair, remanufacture or recycling are key element, in technical cycles, for recovering and restoring materials, components and products. [14].

The aim of this paper is to propose the strategy of CE model in Serbia for asbestos waste and thus eliminate waste by recycling materials within the system and to put a new product on the market.

2. Methods
2.1. Asbestos in Serbia
Data for asbestos quantities, manipulation or waste in Serbia are difficult to access. There is no systematically organized database on the quantities of asbestos produced and used, asbestos inventories or the register of asbestos-related diseases in accordance with European regulations. Calculated quantities of asbestos used in Serbia are shown in figure 3.

In practice, the most common method of storing asbestos waste is in specially prepared landfills. This solution is very debatable, because when asbestos is disposed of, the landfill surface loses any communal value and requires constant investments for its supervision and maintenance. In many countries, such as Poland, storage is the only way to manage asbestos waste that is allowed by law. In the United States, methods are used that consist of coating asbestos elements installed in existing facilities, without removing and damaging the asbestos object. The construction elements are painted, sealed, or covered with a non-asbestos product. Such methods that use coatings increase the mechanical strength and erosion resistance of the asbestos product. [8].

In Serbia possibilities for management of asbestos containing waste are:
- Storage until the moment of export to treatment;
- Treatment, like hazardous waste inertization using Mid - Mix technology with the addition of CaO, or other;
- Landfilling on landfills with permission, municipal landfills, and open dumps.

Treatment product is usually packed in bags and mostly disposed at landfills (not all treatments guarantee there is no more free asbestos fibers).

Problem represents an amount of asbestos that end up in landfills that are not designed for it, such as municipal landfills (not sanitary) and illegal dumping sites. This is particularly characteristic for small settlements, in which minor construction works (repairs, renovation, etc.) are less controlled. Quantities
that are believed to be significant, being deferred without control to landfills where immediately represent a danger to the environment.

In accordance with the published data of the Statistical Office of Serbia and the SEPA (Serbian Environmental Protection Agency) for the period 2010-2018, table 2. shows the official quantities of asbestos containing waste generated, deposited, and treated in Serbia [18, 20, 24].

**Table 2. Official quantities that are generated, deposited, and treated in Serbia for 2010-2018 year**

| Year | Generated (t/y) | Landfilled (t/y) | Treatment (t/y) | Export of asbestos (t/y) |
|------|----------------|-----------------|----------------|------------------------|
| 2010 | 516.6          | 1,034.9         | -              | -                      |
| 2011 | 141            | 0               | 310            | 315                    |
| 2012 | 240.24         | 306             | 43,025         | -                      |
| 2013 | 191.83         | 279             | 30.47          | -                      |
| 2014 | 1542.2         | 1,647           | 27.54          | -                      |
| 2015 | 185.49         | 287             | 28             | -                      |
| 2016 | 216            | 963             | -              | -                      |
| 2017 | 189            | 495             | -              | -                      |
| 2018 | -              | 246             | -              | -                      |

These are the only available official data, but author’s ongoing research on estimated quantities of generated asbestos waste show that these amounts are probably far greater. The highest expected amounts of asbestos waste will be generated in the next ten years, as asbestos installed in buildings during the 1970s and 1980s will be ready for replacement due to decay [17]. These differences indicate the probable existence of larger quantities of waste than officially registered waste, which end up in inappropriate places (unsanitary landfills, stored in households, etc.).

As can be seen in Table 2, landfilling is the most common way of managing asbestos waste in Serbia. The problem is that these landfills were not usually sanitary and were not equipped to receive this specific type of hazardous waste. Of particular concern is that landfilling runs counter to the idea of sustainable land use, recycling and closing the material cycle [6].

2.2. The state of CE in Serbia

The advantages for implementation of CE in Serbia are that part of the legislation is already in line with the acquis communautaire, a process has been started to enable green public procurement to become a standard and innovation has been recognized as a driving force in the introduction of the green economy. One of the strengths is the well-developed IT sector, with exports of services worth almost one billion euros in 2018. Weaknesses have been identified as poor waste management, because of the 12 million tons of waste generated annually, only three percent of municipal waste is recycled, legislation is insufficiently developed, and inspection is ineffective. Energy consumption is also inefficient, 260 grams of waste is generated for each euro of gross domestic product, consumes 4.6 kilowatt hours of electricity, and generates 0.7 kilograms of carbon dioxide (CO2). Uncontrolled imports of inert and hazardous waste, large imports of short-lived old vehicles, poor penalties and inefficient incentive policies are also aggravating circumstances [21].

Although legislation exists, the CE in Serbia has not been sufficiently investigated. Obstacles to full implementation of Serbia's circular economy are poor waste management, wild landfills, lack of infrastructure and slow procedures.
2.3. MID-MIX technology

MID-MIX® TECHNOLOGY is a patented technology that has been applied since the late 1980s and scheme is shown in figure 2. This technology is one of the approved and recommended technologies in Europe BATNEEC (Best Available Technology that does not involve excessive costs). Belongs to the order with the best available technologies that does not involve excessive waste management costs and does not pollute the environment with industrial waste after treatment. Waste treatment plants using this technology are installed in many European countries such as Slovenia, Spain, Austria, Italy, Poland, Croatia, France, Portugal, Serbia, etc. These plants can be mobile and stationary, and are used for inertization of various types of waste from industries such as refineries, petrochemicals, chemistry, pharmacy, food industry, etc. Incurred solidificare and condensed water from evaporation are the final products of the process and do not have a harmful effect on people and their environment. The solidificare created here is a powder of white thick to grey-brown colour with exceedingly hydrophobic attributes. At the end, this solidifier is an inert, non-hazardous material that can be further processed [21, 22].

This powder can be stored in large bags and silos, pressed into briquettes that take up about three times less volume than the initial one, as well as disposed of in landfills for non-hazardous waste. According to EU regulations, solid residue of this process can be further used in the construction industry (concrete blocks), construction waterproofing, road construction (alignment), energy (additive for solid fuels), process industry (additive for industrial fuels), cement industry, asphalt production, etc. [21, 22]

![Figure 2. MID-MIX® mobile plant for waste treatment, schematic diagram [21]](image)

2.3.1. Preparation of asbestos mash. I phase - Crushing asbestos waste. Shredding waste for easy insertion into a grinding mill.

II phase - Starting up of the plant. Delivery of prepared asbestos waste, start-up of the plant and release of water.

III phase - Milling of asbestos waste. Dosage of asbestos waste into a mill, grinding, wetting, and obtaining asbestos slurry. During milling, water is wetted, and an asbestos slurry is prepared which is
ready for MID-MIX inertization. The wetting prevents the asbestos particles from floating in the air, inhaling them, and creating the necessary conditions for the chemical process to take place.

The process of inerting asbestos waste is carried out by the MID-MIX technological process, which involves complex physical-chemical-thermal processes of dissociation, vacuum encapsulation, and primary solidification of waste.

2.3.2 Processing of asbestos mash. The process begins with the introduction of the waste mixture into the mixer, which homogenizes the waste mixture with process additives (sand, calcium hydroxide and calcium oxide), after which it enters the MID-MIX reactor. The process of primary solidification of the waste mixture takes place in the reactor. The neutral is drained from the reactor, with a bucket elevator, into a silo, in which secondary solidification (ripening) occurs - the completion of a chemical reaction and the permanent transfer of waste into environmentally inert material.

Therefore, after preparation of the asbestos slurry, the slurry is inerted on the MID-MIX plant. The end result is an inert, eco-friendly material - NEUTRAL. The neutral, obtained by the MID-MIX process, is powdered, light in color, odorless and in its chemical composition is a mixture of organocalcium water-soluble salts. Neutral derived from asbestos waste has the following characteristics:

- White to gray powder with zero granulation;
- Lighter than water - swims on water;
- Hydrophobic (does not absorb water);
- Odorless;
- Specific gravity 0.85 kg / dm³;
- Moisture content below 5% ;
- Excellent hydro and thermal insulation properties.

The neutral is packed in jumbo bags of 1000 liters or directly into the cistern and transported to its final destination (cement plants, landfill, concrete plants)

3. Results
In Serbia use of asbestos strats at the beginning of the twentieth century. Quantities of asbestos fibers used in Serbia are shown in figure 3. [16, 17]

![Figure 3. Use of asbestos fibers in Serbia 1930-2000 [18]](image)

Figure 3 shows the trend of asbestos use for the period 1930 to 2000. The total amount consumed for this period was 480,123 tons. [18] As it can be seen on figure 3 period of large asbestos usage in Serbia was during 70s and 80s of the 20th century. In Serbia, asbestos was widely used in the construction of buildings, pipelines, and roof coverings, as well as for the insulation of ships. Asbestos products were produced by the companies: "Jugoazbest" from Belgrade and the company "Fiaz" from Prokuplje. [17] During the 1990s, Serbia was under sanctions and war, which evidently led to a decline in asbestos use.
After that, the use of asbestos never returns to the previous quantities. At the same time, the use of asbestos was already banned in some parts of Europe, to be completely banned in 2005. In Serbia, asbestos is partially banned in 2011, while in 2015 it is completely banned for production and use. [18]

An important reason for significant use of asbestos is the case that Serbia was a big producer and had six asbestos mines, two of them large chrysotile mines Korlance and Stragari. The vicinity of an asbestos production plant has a significant impact on the estimated amount of asbestos use. As can be expected, a consequential large amount of asbestos waste will arise in the next ten to twenty years due to the end of life periods for asbestos-containing materials that were built in [16].

Table 3 shows the number of companies that have licenses and in which cities they are located. Licenses are for landfilling and treatment of different asbestos wastes according to waste catalogue number. Data on permits are downloaded from the SEPA website (11.02.2020).

| Waste catalog number for asbestos | Landfilling permission in city | Treatment permission in city |
|----------------------------------|-------------------------------|----------------------------|
| 06 13 04*                        | Belgrade, Kikinda             | Belgrade (2), Kikinda       |
| 17 06 01 *                       | Belgrade, Kikinda             | Indija, Belgrade (2)        |
| 17 06 05*                        | Belgrade, Kikinda             | Indija, Belgrade (2)        |
| 15 01 11*                        | -                             | Sabac, Belgrade (5)         |
|                                  |                               | Kikinda (2), Nis, Valjevo   |
| 16 02 12*                        | -                             | Kikinda, Belgrade,          |
|                                  |                               | Valjevo                     |
| 16 01 11*                        | -                             | Kikinda, Belgrade (2)       |
| 06 07 01*                        | -                             | Kikinda, Belgrade           |
| 10 13 10                         | -                             | Sabac, Kikinda, Ada,        |
|                                  |                               | Valjevo (2), Ub, Kragujevac,|
|                                  |                               | Belgrade (2)                |
| 10 13 09*                        | -                             | Kikinda, Belgrade           |

It can be concluded that only two companies in two different cities have permits for landfilling asbestos waste, and that is only for two types of asbestos waste. On the other hand, several companies have permits for any kind of treatment, for each of asbestos waste type. In addition, there is no data on the type of treatment or the exact quantities that these companies treat annually. According to the Decree on the disposal of waste in landfills in Serbia, the disposal of construction waste containing asbestos and other asbestos waste that meets the requirements in accordance with special regulations is possible. For such landfills, it is necessary to keep a plan of locations with precisely indicated places of cassettes in which asbestos is deposited, even after the cessation of operation of these landfills. Storage of waste containing asbestos is possible under strictly controlled conditions for a maximum of one year. In practice, this deadline is usually extended. [19]

Contrary to the existing legislation on waste management, there are so-called illegal landfills (dumps) in Serbia where construction material that is generated during the demolition/renovation/maintenance of private residential buildings is quite usual.

Steps for implementation of CE solution for asbestos in Serbia:

- Rising public awareness about asbestos waste. When citizens encounter possible asbestos waste, they should contact companies with specific work permits. In order to do this, companies with specific permits should be recognizable and accessible.
- Organized waste collection and transportation to be established. Asbestos waste will be transported to a nearest temporary storage place or directly to treatment facility.
Treatment of asbestos waste. In this step MID-MIX technology would be applied, transforming asbestos into inert, non-dangerous material. Due to its characteristics, it is used in construction and road construction - production of precast concrete elements, brick products, asphalt, road substrates. Concrete and brick products that come with the addition of neutrals are lighter than classic products. This addition material should decrease consumption of natural resources, that are commonly used.

There are several benefits of commercial applying CE for solving of asbestos problem:

- Asbestos waste is collected and treated properly and there is no need for additional space for waste landfilling.
- Obtained material is used as a resource, for production of a new concrete blocks, that can be used in road construction.
- Eco labelling is a possible solution for putting this new product on market. With the help of government in form of decreasing taxes and promoting this kind of production, problem of asbestos waste would be on a good track to final solution. New product will be long-lasting and at the end of life it could be considered in CE model for construction and demolition waste, that is already supported by EU.
- The economic benefits for the one who applies this principle are twofold, the first is charging for waste disposal, the second is reducing the cost of procuring raw materials.

The negative aspects of commercial application would be cost and exceptional health risk if not treated adequately. Aspects of CE that this paper covers are adequate waste management as well as strengthening the secondary raw materials market. In this way, the following goals are achieved: the recycling rate is increased and, in this way, valuable materials are returned to the economy, and lower consumption of natural resources is also achieved.

4. Conclusions

There are some types of asbestos waste treatment in Serbia, it is questionable how much is treated and processed, and what is done with the remains in the end. Whether a particular treatment is appropriate for the region and the conditions, or for that exactly type and amount of asbestos waste generated can be assessed and determined based on several criteria. There are criteria and limitations related to the price, process efficiency, sustainability, and the material output in the end (is there still activity of fibers).

In paper we have presented one solution for asbestos problem in Serbia in general. Thinking about asbestos waste through the concept of circular economy is feasible with inclusion of all interested parties. The advantages and disadvantages of the commercial application of this asbestos management principle are also presented. For further research, it is planned to conduct sustainability and cost-effectiveness analysis for this model of asbestos waste management.

To implement this model of asbestos waste management, it is necessary for the state of Serbia to invest in infrastructure and to strengthen the implementation of existing regulations. Due to public health effects of asbestos, it is necessary to constantly inform citizens about the state of asbestos waste management.

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