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XIV INTERNATIONAL MINERAL PROCESSING AND RECYCLING CONFERENCE

Editors:
Jovica Sokolović
Milan Trumić

May 12-14, 2021, Belgrade, Serbia

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MATERIAL FLOW ANALYSIS OF GLASS PACKAGING WASTE IN THE REPUBLIC OF SERBIA

Angelina Pavlović[#], Goran Bošković, Nebojša Jovičić
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ABSTRACT – Accelerated population growth and economic development cause an increase in the consumption of material goods and an increase in the generated amount of municipal waste. Glass amounts to 5% of total generated waste worldwide. Millions of glass waste pose serious environmental problems every year, which primarily arise due to unharmonized glass waste flows. This paper aims to quantitatively and qualitatively investigate the system of glass packaging waste management in the Republic of Serbia, using the material flow analysis (abbr. MFA) since glass packaging makes up to 85% of the total generated glass waste.

Keywords: MFA, Glass Packaging, Waste, Environment Protection.

INTRODUCTION

Every year, world glass production grows, which is proved by the fact that the global glass manufacturing market size was valued at USD 127.1 billion in 2019 [1]. Following a global trend, the production and consumption of glass in the Republic of Serbia has continuously risen over the past decades. That leads to the generation of large quantities of glass waste that have caused problems related to the environment. In 2019, 2.35 million tons of municipal solid waste (abbr. MSW) were generated in the Republic of Serbia, and glass waste amounts to 4% [2,3]. Globally, most waste is currently dumped or disposed of in some form of a landfill [4]. However, glass can be recycled countless times in 100% [5]. The landfilled glass will never decompose, so disposed glass represents the loss of raw materials.

Glass is a material that is used in numerous applications in daily human lives. In particular, glass represents one of the safest and most suitable materials for packaging [6]. Management of glass packaging and glass packaging waste has a very pronounced environmental, social and economic significance. Today, the largest percentage of total used glass packaging is used for a single-use and the purpose of packaging products for further distribution (food, beverages, pharmaceuticals, etc.), so that is the reason because 85% [7] of the glass in MSW is glass packaging. According to that, the importance of minimizing and recycling glass packaging waste disposal has long been recognized. To improve the glass packaging waste management system, it is essential to identify flows of glass packaging waste that can be easy to improve. Forecasting material flows is essential for sound policymaking on issues relating to waste management [8]. In this paper, the MFA approach was used to assess the flows and stocks of glass waste packaging to understand and quantify sources, pathways and sinks of the analyzed material.

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Considering that this topic is important for improving the quality of the environment, both in the world and in the Republic of Serbia, this paper aims to define measures to improve the system of monitoring the flow of glass packaging waste, based on analysis of inappropriate software – STAN 2.6.

EXPERIMENTAL

A large number of methods have been developed in the world, which are used during decision-making in the field of resource management and environmental protection. One of the methods, which has a wide application and can be said that is the basis for other methods, but also, can be used independently of other methods, is the MFA. During the developing of the MFA method, it was started from the fact that materials behave following the fundamental laws of conservation of mass. MFA is based on the material balance, which means - matter cannot disappear; it can only transform and leave the system in the form of emissions or other by-products [9,10].

In order to create an MFA model, it is necessary to follow the next steps [10,11]:

- analysis of the system and the involved processes and materials (model building stage),
- measurement of the material or mass flows (data collection),
- calculation of material or mass flows, and
- interpretation of the results.

The focus of this paper is the analysis of glass packaging waste flows in the Republic of Serbia, and it is essential to note that by balancing the inputs and outputs of waste streams in one system, the environmental footprint becomes more noticeable, and the sources of environmental pollution are possible to locate. Appropriate measures to improve the current state of the glass packaging waste management system in the Republic of Serbia can be taken based on identifying depletion or accumulation of material stocks in the complete system.

Packaging quickly becomes waste, so data about packaging placed on the market are generally taken as data on the generated amount of glass packaging waste in one year. In this case, MFA can locate material flows, i.e. processes during the life cycle of glass packaging that can be improved by simultaneously reducing the extraction of new raw materials and the total generated amount of packaging glass waste.

In the MFA system building stage, it is necessary to define the analysis's boundaries, which are defined in time and space. Frequently, the MFA's spatial system boundary coincided with the politically defined region (intended as administrative regions such as states) [12]. In this paper, the geographical border is defined by the territory of the Republic of Serbia. The time interval determines processes within the MFA, i.e. the year from which the data were taken. During the analysis, data from 2019 was used; in the case where data are not available for the mentioned year, the last available data was used. The number of flows and processes during one MFA model depends on the analysis's goal and its complexity. For the analysis of glass packaging flows, ten processes are shown by the model that is composed of four phases:

- the first phase comprises two processes: manufactures and industries that use glass packaging (food and beverage industry, the pharmaceutical industry, etc.),

- the second phase includes the only process of glass packaging consumption in households and small businesses,
- the third phase implies four processes that are connected to a different way of collection and treatment of glass waste packaging (collection and transport of MSW by public utility companies, informal waste collection, secondary waste separation and glass packaging recycling), and
- the fourth phase covers three processes that refer to landfilling of glass waste packaging on unregulated (illegal) landfills, controlled landfills and sanitary landfills. All processes in this phase are considered as processes with stocks of materials.

Processes are connected by flows (mass of material per unit time) that can be observed as input and output flows from one process. Flows can be internal and external, depending on whether it exceeds the defined boundary of the system. In the analysis, twenty flows were defined, of which four were defined as external input flows – imported flows, and three were defined as external output flows – exported flows. The remaining flows are internal flows, i.e. input/output flows from defined processes. In the analyzed model, imported flows represent raw materials for production of glass packaging products, imported secondary raw materials, imported glass packaging and imported material goods (products packed in glass packaging). The exported flows represent the export of secondary raw materials, export of products in glass packaging as well as export of glass packaging.

The choice of substances depends on the type of system to be analyzed. In this paper, material goods will be defined without defining substances.

Since there is no record of the amount of glass packaging produced in the Republic of Serbia, it is possible to use different approaches to obtain the necessary data to measure the glass packaging flows.

According to the Environmental Protection Agency data, 2.35 million tons of waste were generated in Serbia in 2019, of which 4% is glass waste [2]. Based on the above, it is concluded that 94,000 tons of glass waste were generated in Serbia during the same year. Since it is known that 85% of glass in municipal waste is glass packaging, it is known that 79,900 t of glass packaging can be identified in the total amount of municipal waste [7].

The total amount of glass packaging placed on the Republic of Serbia market is 61,979.8 [13]. Imported material goods, i.e. products packed in glass packaging used by households and small enterprises, are unknown. However, the data on the differences between glass packaging distributed to the industries that use it and the amount of packaging placed on the RS market is adopted since MFA analyzes material flows on that way, everything that enters one system must leave the same, and that is 17,920 t.

Based on the Glass Alliance Europe's statistical report, it was found that in 2019, 74,743 tons of glass packaging were exported from Serbia, while 16,928 tons were imported [14].

In the Republic of Serbia, concerning the amount of glass produced and in general in circulation, there are few accredited collectors, especially recyclers of this secondary raw material. Of the total amount of glass packaging placed on the market, 27,743.7 t was recycled [13], while 21,691 tons of secondary raw materials from packaging glass were

exported, and 0 tons of secondary raw materials were imported [2]. The amount of secondary raw materials used in glass packaging production is determined as the difference between the total recycled amount of glass packaging waste and the secondary raw material that is exported.

On the other hand, significant amounts of glass packaging waste are irretrievably disposed of in landfills and dumps. Based on data from the Statistical Office of the Republic of Serbia, the amount of generated industrial waste that the processing industry sends to the controlled landfill is 10,437 tons [15]. The quantities of generated glass packaging waste disposed of in unregulated landfills were adopted according to the average MSW collection rates. Therefore, 86.2% is disposed of in controlled and sanitary landfills, while 13.8% is disposed of in illegal landfills [2]. Of the total amount of glass packaging waste generated, about 30% is collected by informal collectors [16].

It is estimated that about 60% of glass packaging waste collected by the public utility company is disposed of in controlled landfills. During 2019, out of the total amount of generated waste, 500,897 t of the generated waste was disposed of at sanitary landfills [2]. That amount represents 21% of total generated municipal solid waste, so the same percentage was adopted to determine the amount of waste sent to sanitary landfills collected by public utility companies. The specific target for recycling glass packaging waste for 2019 was 43%, so the stated coefficient was adopted for the amount of waste that undergoes the process of secondary separation [13].

Based on analyzing collected and assumed data, calculation of glass packaging waste as possible, and interpretation of the results.

It is possible to find much-developed software on the market that are used in the analysis of material flows. The use of appropriate software for the formation of MFA models has various advantages, the most important of which are:

- possibility of graphic modelling with automatic translation into a mathematical model,
- creating a database of collected data, including source documentation,
- calculation of unknown flows and stocks,
- interpretation of the obtained results using SANKEY diagrams and others.

To simulate the flow of glass packaging waste in the Republic of Serbia, software STAN 2.6 was used in this paper. STAN (subSTance flow Analysis) is freely available software (www.stan2web.net) that helps to perform analysis of material flows following the Austrian standard ÖNORM S 2096 [17], which relates to the application of MFA in the field of waste management. After creating a graphical model with predefined elements (processes, flows, system boundaries, text fields), it is possible to enter or import data using STAN software, after which software calculates unknown quantities of material flows according to a predefined mass balance algorithm [17].

RESULTS AND DISCUSSION

Based on the analysis conducted in the STAN software, the amount of imported raw materials for obtaining glass packaging products is estimated at 159,027 tons, while the amount of exports of products in glass packaging is 34,848 tons. The second phase of the model formed in the STAN software includes waste primary glass packaging from

households and small businesses collected and transported by the public utility company, which amounts to 44,904 tons per year, while 11,026 tons are disposed of in uncontrolled (illegal) landfills. Of the total amount of mixed waste collected by the public utility company, 43% is used for secondary separation - 19,309 tons. 3,774 tons of secondary separated fractions are recycled. 21% of total input glass packaging waste in the process of collection and transport of MSW by the public utility company is disposed of in sanitary landfills, i.e. 9,430 tons per year and the remaining amount of 16,165 tons is disposed of in controlled landfills. 30% of the total amount of glass packaging waste generated in households and small business is informally collected, representing 23,970 tons per year, from where the same amount passes into the recycling process. From the secondary separation process, 21% of packaging residues are disposed of in the sanitary landfill, which is 4,055 tons per year, and 11,480 tons in the controlled landfill. In the last phase of the model, the amount of waste deposed in controlled landfills is 38,082 tons per year, while 13,485 tons are disposed of in sanitary landfills. The MFA model of glass packaging waste in the Republic of Serbia for 2019 is shown in Figure 1.

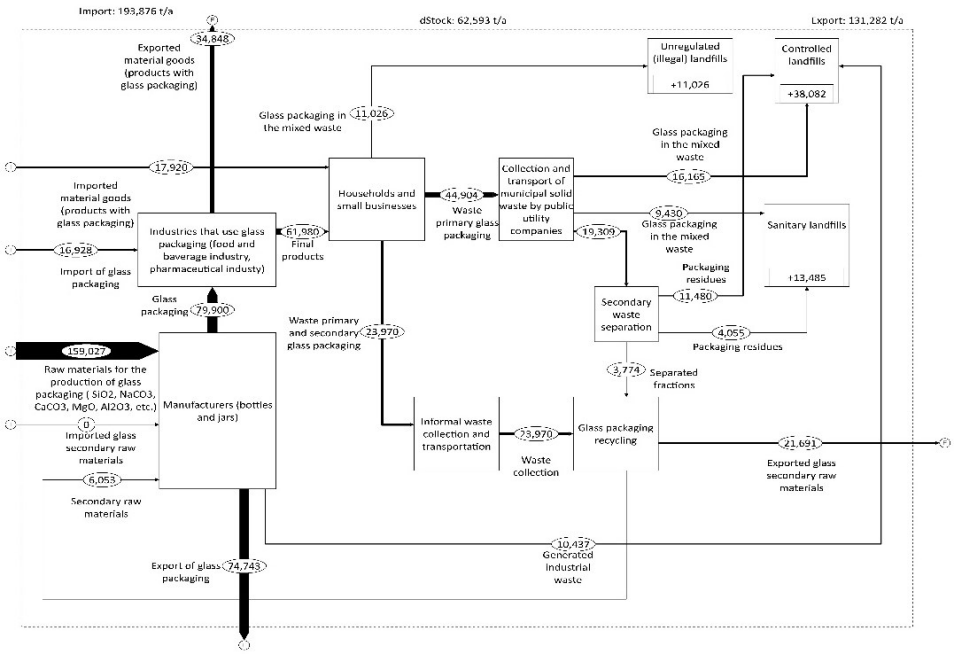

Figure 1 Material flow analysis of glass packaging waste in the Republic of Serbia

The model results are interpreted using diagrams created according to the Sankey principle, where the width of the arrows is proportional to the flow rate.

Based on the above data, which is imported in STAN 2.6, it is concluded that the largest share of glass packaging is disposed of in landfills in Serbia. In order to solve this problem, it is necessary to increase the reuse and recycling of glass. Glass is a material in which products for human consumption can be stored most safely, it can be completely recycled, and the reuse process saves a significant amount of energy and natural

resources, reduces disposal costs and saves landfill space. Organized collection for recycling and reuse of glass can be the only answer to the situation shown by created scenario. Currently, glass recycling in Serbia is unprofitable, which is explained through the price of one kilogram of waste packaging glass from 0.5 to 2.2 Serbian dinars [18], transportation costs are high, and there are insufficient registered recyclers.

CONCLUSION

Since glass was introduced into mass production, and with the exponential growth of its consumption until today, there have been significant problems related to glass packaging waste. The negative consequences caused by glass waste mainly occur due to the long-term decomposition of its components in a natural way. Most of the problems are caused by single-use glass packaging, which has a short lifecycle and it is disposed of immediately after the use phase.

In the recent past, Serbia has witnessed substantial growth in glass packaging consumption and increased glass waste production. So, the Republic of Serbia, as a candidate for EU membership, has to ensure that all packaging on the market will be reusable or recyclable in an economically viable way by 2030 [19] because for the Republic of Serbia, it is necessary to harmonize its legislation with European, which includes the adoption of regulations on waste reduction, utilization, reuse, treatment and disposal of waste in a way which is safe for the human environment.

To analyze the current situation of glass packaging waste management in the Republic of Serbia, the MFA model was formed. An adequately defined MFA model characterizes input, output, and stocks following a system's controlled material balance. The system analyzed in this paper is created from 10 processes, and 20 material flows that are created in the software STAN 2.6. Based on the analysis of the flows of glass packaging, obtained data shows that the most considerable amount of glass packaging waste is currently dumped or disposed of in some form of a landfill – 62,593 tons per year. This amount needs to be reduced as well as the number of raw materials for the production of glass packaging such as SiO_2, $NaCO_3$, $CaCO_3$, MgO, Al_2O_3, etc., for which it is determined that their mass approximates 159,027 tons.

Based on the conducted MFA of glass packaging materials in the Republic of Serbia, in order to improve the complete system, it can be proposed:

- financial investment in domestic glass factories, state assistance to meet the capacity of the factories themselves,
- increase in the number of unique containers and bins for the collection of glass packaging, thereby increasing the citizens awareness about the benefits of recycling as well as reducing the disposal of glass waste in unregulated landfills,
- introduction of separate collection of packaging waste and its use to obtain new raw materials,
- reduction of the imported raw materials for glass products, encourage national recycling,
- investment in better sorting infrastructure,
- definition by law for the working conditions and obligation of authorized collectors and recyclers.

The created MFA model shows that in the Republic of Serbia, it is necessary to decrease the amount of used raw materials used for the glass packaging production process as well as a share of glass packaging waste disposal and increase the share of recycling glass packaging through a new system of technical, organizational and economic arrangements for carrying out stated requirements.

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