ASSESSMENT OF PLASTIC FLOWS AND STOCKS IN SERBIA USING MATERIAL FLOW ANALYSIS

by

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Material flow analysis was used to assess the amounts of plastic materials flows and stocks that are annually produced, consumed, imported, exported, collected, recycled, and disposed in the landfills in Serbia. The analysis revealed that approximately 269,000 tons of plastic materials are directly disposed in uncontrolled landfills in Serbia without any pretreatment, and that significant amounts of these materials have already accumulated in the landfills. The substantial amounts of land-filled plastics represent not only a loss of valuable recourses, but also pose a serious treat to the environment and human health, and if the trend of direct plastic land-filling is continued, Serbia will face with grave consequences.

Keywords: *plastic, material flow analysis, waste, storage*

Introduction

The term plastics covers a range of mostly synthetic or semi-synthetic organic condensation or polymerization products that can be molded or extruded into objects or films or filaments.

These synthetic polymers are shatter-resistant, waterproof, lightweight, durable, and strong, which makes them very attractive to the consumers. Synthetic polymers belong to the most important technical materials of the present time. Apart from serving as substitutes for common materials such as glass, metal, wood, ceramic, *etc.*, growth of their production in the 20th century accelerated the progress of many of other areas of human activities. Plastic materials have become irreplaceable in the domains of packaging, electrical industry, ship building, chemical industry, transportation, car industry, airplane industry, civil engineering,

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as well as in the areas of mass consumption. In the car industry alone, the annual rise of the use of plastic materials amounts to 44% [1].

Since 1950, a global average annual increase in the production and consumption of plastics has been 9%. From 1.5 million tons in 1950, the total global production reached 245 million tons in 2008. [2]. In the USA, the share of plastics in communal waste increased from 390,000 tons in 1960 to 2,417,000 tons in 1999 [3].

Due to the growing consumption of plastic materials, their share in the generated waste is constantly increasing. An appropriate management of this category of waste may significantly reduce the needs for this kind of material as a primary resource, which would also essentially reduce their adverse influence on the environment and human health.

Serbia as a transition country is facing with increasing consumption of all sorts of plastic materials. Annual amounts of imported and exported plastics in Serbia are 610,000 and 300,000 tons, respectively. The material flow analysis (MFA) showed that more than 99% of plastic waste is disposed directly into landfills without any pretreatment, of which the major part ends up in wild landfills.

The increased consumption of plastic materials entails an increase in their stocks in the economy, households, and civil engineering constructions. After a certain period of time, plastic becomes a waste and ends up in the system of waste management. Also, the increased use of plastic leads to the increase in its share in the generated waste. Taking into account the trend of increased consumption of plastic in the world [2] it can be expected that the same trend will also be observed in the Republic of Serbia.

The aim of this study was to identify and quantify the flows of plastic materials in Serbia using the MFA method that is, to assess the amounts of plastic materials that annually imported, exported and stocked in the state economy, with a special emphasis on the amounts that are each year deposited in the landfills. Based on the MFA results concerning the flows of plastic materials and products in 2008, as well as on the projected increase in the consumption of plastic materials due to the rise of the gross domestic product (GDP), an outlook for the future is presented. There is no information that an investigation of this type has ever been undertaken in Serbia.

Materials and methodology

The MFA method [4] was applied to model the flows of plastic materials in Serbia. The method allows the design, study, and evaluation of anthropogenic systems. It is concerned with the systematic assessment of flows and stocks within a system defined in space and time. The system consists of the flows of materials, stocks and processes [5]. The balancing of the system is based on the law of mass conservation. The mass balance assumes the assessment of the overall mass of all inputs to the system as well as all associated outputs, including also the mass that remains stocked in the system (material stock) for the year for which the analysis was carried out

$$\sum_{k_1} \dot{m}_{input} = \sum_{k_0} \dot{m}_{output} + \dot{m}_{storage} \tag{1}$$

The MFA can be effectively used in the management of resources and wastes. The analysis of the flows of materials that are associated with a certain activity enables an early identification of the problem such as the future environmental load and consumption of resources. Also, the material stocks and their changes can be followed over a given period of time [4].

Using the MFA, the main sources and flows of plastic materials were identified and quantified in the framework of one year, and for the present study this was the year 2008, for which reliable data were available for the Republic of Serbia. The data about the amount of disposed plastic materials obtained using the MFA model were compared to the data obtained by a direct analysis of the composition and amount of the municipal solid waste at the country level [6].

The system under investigation consisted of the following processes: production and consumption, recycling, system of waste management and disposal. Because of the lack of data, the production and consumption were defined as one process. All the mentioned processes are connected by the corresponding flows (figure 1). The production and consumption, together with the stocks represent the processes in which accumulation of the analyzed material takes place.

The data about the flows and stocks of plastic materials generated in the last ten years, as well as the prediction of the future quantities were determined on the basis of the influence of the change in the GDP on the extent of consumption [7, 8].

This investigation was motivated by the need to determine the amounts of plastic materials that are every year are stocked through the consumption in the economy and deposited in the landfills in Serbia. Also, the study analyzes the amounts that are currently in stocks and which have been generated in the last ten years, as well as the tendency of the future accumulation of this sort of material that may represent threat to the environment and human health, but also can be a potential resource if it is managed in an appropriate way.

Data

The analysis encompassed the flows of plastic materials in Serbia that are annually imported, exported, consumed, and disposed in landfills. This was performed on the basis of available data of the national statistical organizations [9, 10] about the import and export of plastic materials, as well as of products containing plastic. The determination of the share of plastic in the products was carried out on the basis of the literature data [11], as well as based on the assessments of experts. Taking into account the ubiquitous use of plastic products and products containing plastic, their residence time in the anthropo-sphere may be very different. With the aim of obtaining as clear picture as possible about all plastic flows, the products containing plastic were classified into three categories. Category I consists of the products which remain in consumption up to one year, category II those remaining in consumption up to ten years, and category III consisting of products remaining in consumption more than ten years. The time period during which a given product or material is present in the market is defined by the time by which that product/material becomes a waste and thus enters the waste management system. Bearing in mind that Serbia is a country in transition, and that the lack of data presents a problem in doing investigations of this type, the categorization of plastic products and materials based on their residence time in the economy (production and

consumption) is based on the literature data [12], as well as on the assessments of experts relied on the socio-economic situation in Serbia.

The relationship between the GDP and consumption of all kinds of materials was defined on the basis of the research carried out within the European Economic Area [8], which showed that the increase in GDP for new EU-10 members in the period 2000–2010 of 48% has been accompanied by an increase in the amount of materials in use of 18%. Besides, the projection based on the increase in GDP by 50% in the next 10 years shows that it will bring about an increase in the consumption of plastic materials by 22%.

Based on the analysis of plastic materials flows carried out for the year 2008 (figure 1) and the relationship between the increase in GDP and degree of their consumption in Serbia for the last ten years it is obtained that 397,000 tons of plastic materials have been stocked in the economy, while 2,587,000 tons were disposed in the landfills. If the projection is made for the period 2010–2020, the amount of plastic materials in the country economy stocks will be 475,000 tons and almost 3,100,000 tons deposited in the landfills. However, it should be mentioned that, because of the lack of data, the values for 2008 were taken as the reference for 2010.

Based on the performed analysis it can be concluded that if the current practice of plastic waste management is continued, it can be expected that in the landfills of Serbia will be deposited nearly 5,687,000 tons of different plastic waste, while almost 872,000 tons will be stocked in the economy in the period 2000–2020, exerting thus an additional pressure on the future systems of waste management. At the present, the disposal of all kinds of waste materials in Serbia is carried out in uncontrolled wild landfills, while only part of it is deposited in the controlled municipal landfills. The number of identified wild landfills in Serbia amounts to 3443 (only 512 municipal landfills), with the estimated 40,000,000 m^3 of waste [13]. Additional investigations are needed to quantify the amounts of plastic material wastes that are currently stocked both in the country economy and disposed in landfills all over the country.

Results and discussion

The MFA showed that the annual import of plastic, encompassing plastic materials and plastic share in other products amounts to 81 kg per capita, or 610,000 tons. The overall consumption is about 51% of the imported plastic materials, which makes about 41 kg per capita. Each year, about 269,000 tons of plastic (*i. e.* 36 kg per capita) are land-filled, which is similar to the corresponding data for Austria and Poland, with the respective 30 and 50 kg per capita in 2004 [14]. However, if we consider the percentage of plastic wastes that end up in landfill, Serbia has a far higher share of the deposited plastic (99%) compared to Austria (26%) and Poland (90%). The lower percentage of deposited plastic in Austria came as a consequence of the Austrian Landfill Ordinance, which was implemented in 2004, by which is forbidden to landfill wastes with the content of organic carbon exceeding 5%. In 1994, the share of plastic that was directly land-filled in Austria was 83% [14], whereas in India it was 45% of the total plastic waste generated in 2001 [15].

A significant portion of the overall plastic flow is exported, and this makes 300,000 tons a year, which by seven times exceeds the amount of plastic consumed annually in Serbia

(figure 1). The MFA showed that despite of a significant amount of plastic that is annually land-filled, Serbia is still importing each year 955 tons of plastic waste for the needs of recycling.
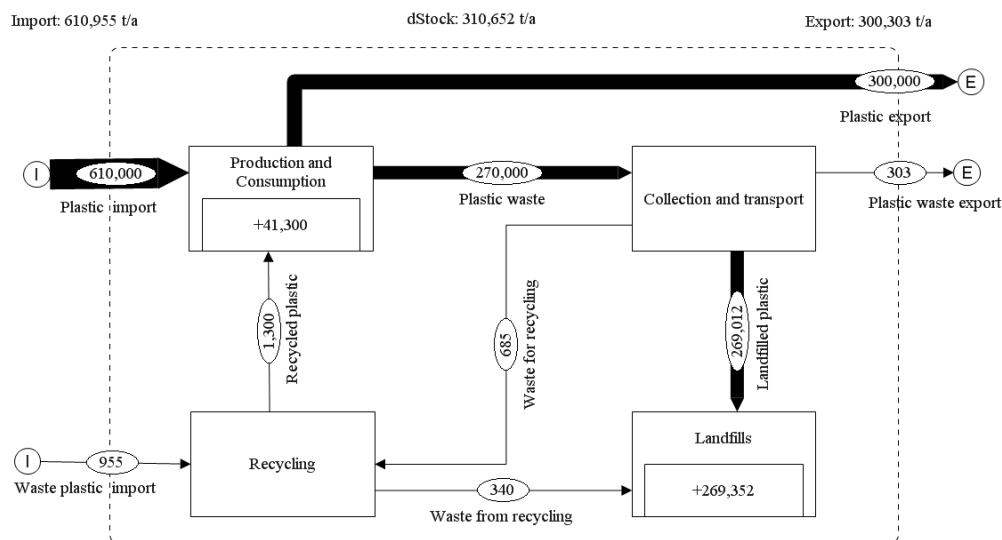

Figure 1. Model of the overall plastic flows and stocks in Serbia in 2008

If the same mode of plastic waste management is continued in the future, Serbia will face serious consequences. The amount of plastic that will end up in landfills (especially in uncontrolled ones), may present a serious threat to the environment and public health. The amounts of plastic that are recycled are small, and by developing an appropriate recycling system in the frame of the system of waste management at the country level it will be possible to reduce significantly the amounts of both the imported and land-filled materials. Thermal treatment of plastic and its use for energy production can also represent one of the strategies aimed at reducing the accumulation of plastic waste in landfills, and thus contribute to the saving of fossil fuels. Difficulties in the investigation presented the lack of information, especially those related to the amounts of plastic materials produced in Serbia and then exported. It is necessary to improve statistical systems, educate companies about the necessity of accessibility of data, as well as introduce such legislative mechanisms that will enable monitoring of plastic flows through the overall economy, and thus lay down the foundation for an appropriate system of management of this kind of material as a valuable resource, and design sustainable systems of waste management.

The Austrian experience showed that by introducing legislative measures that define the waste category that can be disposed can significantly influence the amounts of certain materials (in this case plastic) that are land-filled. Information about the flows of plastic materials may help decision makers in Serbia to define the appropriate strategies as well as

Vujić, G. V., *et.al.*: Assessment of Plastic Flows and Stocks in Serbia Using Material Flow …

S94   THERMAL SCIENCE: Year 2010, Vol. 14, Suppl., pp. S89-S95

legislative measures for waste management. Consumption of plastic materials will certainly continue to rise in the future, which will inevitably lead to an increase in the amount of plastic waste that will end up in the waste management system. It is essential to emphasize that the amounts of plastic that are stocked in cities and households and remain for a longer time in the economy (representing the so-called investment resources) will, after a certain time period, become wastes, which will additionally contribute to the amounts of generated plastic waste. These 'investment resources' contain highest percentage of hazardous additives and toxic substances, and hence, in order to protect the environment and public health it is necessary to design such systems that will prevent dissipation of these substances in the environment [14]. The future investigations must include also the monitoring of the flows of various substances and additives present in plastic materials.

Conclusions

The paper presents the modeling of flows of plastic materials in the Republic of Serbia. It provides the basic framework, assumptions and results of the analysis of plastic materials flows based on the MFA method. The model constructed in this study encompasses the production, import, stocks in economy, export, and amounts of plastic materials that represent wastes that are disposed in the landfills. The obtained results served as the basis for modeling the flows of plastic materials for the period 2000 – 2020, with the aim to point out that the increasing stocks of plastic materials in the market lead to increased accumulation of these materials in economy, which will certainly have a significant influence on the waste management system, bearing in mind that the majority of plastic goods that are in use will become waste. If the plastic waste is considered as a resource, it may represents a remarkable potential in the waste management, which have to be taken into account in designing the future waste management systems. The knowledge of the flows of plastic materials through the economy at the country level may help in defining the priorities in the area of design of sustainable systems of managing these waste flows in the future. The MFA showed that in Serbia more than 99% of plastic materials are directly land-filled without any pretreatment, and mainly in uncontrolled wild landfills. In the case that the trend of the irresponsible management of these flows is continued in the next ten years, Serbia will face serious consequences. Because of the expected increased consumption, the amounts of plastic in stocks will grow, which will directly result in an increase in the generated plastic waste. The MFA results obtained in this work may help authorities to define the priorities in managing this kind of waste, enable early recognition of a potential resource or threat to the environment, as well as prompt application of regulatory mechanisms for establishing a sustainable system for the management of plastic materials flows at the level of the Republic of Serbia.

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