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IN-DEPTH ANALYSIS OF PLASTIC FLOWS AND STOCKS IN AUSTRIA

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Abstract

In this study, the plastics household for Austria in 2010 is investigate through a material flow analysis, to track the flows and stocks throughout the system, from the production of the primary polymers up to and including the treatment of the waste streams produced. About 1.1 million tonnes primary plastics were produced in Austria in 2010, and with additional trade of polymers and semi-finished and final products, 1.3 million tonnes plastic products are used for Austrian consumption. This consumption is distributed over ten consumption sectors, of which packaging (24%), non-plastic products (20%), building and construction (18%), and others (13%) are the most important ones. After the use phase, around 53% of the waste material is incinerated with energy recovery, one third of the plastics waste flow is recycled mechanically, and roughly 11% is used for feedstock recycling. Only minor fractions of the waste flow are landfilled or reused. These results highlight the most relevant streams, which can help to focus time and resources on the main processes or sectors, especially for waste management, to guide the current and future waste flows to the most ecologically and economically optimal treatment process.

Keywords: *plastics, recycling, MFA, Austria*

1. Introduction

Plastics have been the most used man-made material in the world since 1900, being applied in virtually all consumption sectors, both in applications with very short lifespans (such as packaging), and very long lifespans (such as piping in building infrastructure) [1, 2]. In 2013, the global plastics production reached 299 million tonnes [3]. The big success of plastics in a wide range of applications is explained by the various unique properties they possess: they can be used at a very broad temperature range, are resistant to chemicals, are light but still strong and tough, although they can be worked easily as a hot melt. This range of properties is in part reached by the use of additives to enhance the performance, as plastics are rarely used in pure form. These additives include among others inorganic fillers, thermal or UV stabilizers, plasticizers, and fire retardants. Additionally, the appearance of the plastic product can be influenced as well, through colorants or matting agents [4].

The use of many different polymers, combined with the various above mentioned additives, makes that plastics in general form a highly complex material stream. This leads to large and highly diverse material flows into the anthropogenic stocks, which needs to be managed well, as the production and use of plastics result in a number of environmental concerns. 90% of plastics are completely derived from non-renewable fossil fuels, resulting in the fact that around 4% of the annual petroleum production us converted into plastics, with an additional 3-4% needed for energy consumption during production. On the other end of the life-cycle, waste plastics form a significant and complex waste stream, part of which accumulates in the natural environment due to the high durability of the polymers, resulting in environmental damage. Recycling is thus a method to reduce both the environmental impact and the resource consumption of the life cycle of plastics products [2, 5].

To achieve this recycling efficiently, detailed knowledge about the different plastics streams flowing through society should be established, but only fragmented data of plastic waste generation are available. To overcome this, a Material Flow Analysis (MFA) can be performed, which balances all material inputs and outputs into society. This allows the anthropogenic resources to be identified and characterized, in order to optimize the management of existing plastic flows, and predict future waste streams. Therefore, in this study an MFA is performed for the Austrian plastics household of 2010, to identify the key processes, stocks and flows, and to serve as a basis for further research into the dynamic modelling of this plastics household.

The methodological background of MFA will be discussed in Section 2, as well as a description of the household model for plastics and the data sources used. In Section 3, the results are presented and discussed, followed by the conclusions in Section 4.

2. Materials and Methods

2.1 Material Flow Analysis

The method of material flow analysis can be used to systematically assess the flux of different materials trough a certain system which is defined in space and time, in this case for plastic flows in Austria in 2010. This method aims to connect the sources (e.g. imports), the pathways (e.g. transfer coefficients from manufacturing to consumption) and the intermediate (e.g. consumption) and final sinks (e.g. waste management) of materials, based on the law of conservation of matter. In this study, the method is applied according to Brunner and Rechberger [6], and the software STAN (freely available under http://www.stan2web.net) is used for the calculations [7].

2.2 Plastics Household Model and Data Sources

For this study, to model the total material household of plastics in Austria different processes were used. First, in the chemical industry process, primary polymers are synthetized and traded. In Austria, the main producer of polymers is Borealis, and they directly provided production data for this project. Furthermore, production quantities of other production plants are derived from annual reports and other publicly available information. Data on the import and export of primary polymers are acquired from the Austrian statistical office [8].

Next, the polymers coming from the chemical industry process are molded into semi-finished products such as sheets and films, and then further converted into final products in the manufacturing and preparation process. During this process, additional additives are used for achieving the required properties of the product. Data on imports and exports of semi-finished products are again obtained from the Austrian statistical office [8].

The final products are subsequently used by consumers in the consumption process. This process is subdivided into ten sub-processes, representing the various consumption sectors:

- Packaging
- Building and Construction
- Transport
- Electronics
- Furniture
- Agriculture
- Medicine
- Household Goods
- Others
- Non-plastic Applications

No data were available on the distribution of the plastic products into the various consumption sectors in Austria, so data from a German study were used [9], assuming that the distribution pattern is similar for both countries. For the transport sector, the number of vehicles entering the consumption market was obtained from WKO [10]. Data from the Austrian statistical office [8] were used again for the import and export of plastic products. In contrast to the processes discussed previously, the consumption processes have stocks that are built up during the use phase of the respective products, due to the longer lifespans of many products.

After the use phase of the products, they are disposed of to the waste management process. Different data sources are available to determine the size of the output flows from the respective consumptions sectors. Information on sectors with extensive regulation is generally available in reports from public authorities or related organizations [11-15], while data on smaller waste streams can be obtained from specialized companies or stakeholders [16-20]. The data form these various sources were subsequently combined to determine the total amount of plastic wastes produced in Austria in 2010.

2.3 Estimation of the Uncertainty

In MFA, data from various and potentially very different sources (such as measurements, reports, and scientific papers) are gathered to complete the total balance of the studied system. These sources can have varying qualities, and thus differing associated uncertainties, arising from different sources, such as statistical variation, variability, subjective judgement, and approximations [21]. In this study, the approach by Laner et al. [22] is used to characterize this uncertainty quantitatively.

3. Results and Discussion

The material flow analysis is computed using STAN, and a Sankey flow scheme of the plastics household in Austria for 2010 is produced. This flow scheme is presented in Figure 1.

3.1 Chemical Industry and Manufacturing and Preparation

In total, the chemical industry in Austria produced 1,112 kilotonne (kt, 1x10^6 kg) of primary plastics in 2010, consisting of 877 kt polyolefins, 175 kt polystyrenes and 60 kt resins. An extra net import of 24 kt polymers, 47 kt rubbers, an export of 17 kt additives and the addition of 128 kt regranulates results in a total of 1,294 kt primary plastics available for the manufacturing of semi-finished and final products.

This amount is reduced by a net export of 60 kt semi-finished products and a production waste of 101 kt, while 35 kt additives are added to achieve the desired properties of the final product. A total of 1,168 kt final plastics products is thus brought onto the consumption market.

The relatively low uncertainty ranges for these values indicate that the data sources are relatively reliable. The exception are the additives, for which rather little information is available due to confidentiality, as these substances have a large impact on the properties of the product. Furthermore, wide ranges of plastics contents for the semi-finished products increase the associated uncertainty as well.

3.2 Consumption

The domestic production of plastic products is supplemented by imports and exports. Two consumption sectors report a net export balance: packaging with 74 kt and non-plastics with 49 kt. The other sectors have a net import, amounting in total to 188 kt. The resulting total amount of plastic products brought on the Austrian market is distributed to the consumption sectors according to Lindner [9], as presented in Table 1.

Table 1: Transfer coefficients of the plastic products to the various consumption sectors

Consumption sector	Transfer Coefficient (%)	Consumption sector	Transfer Coefficient (%)
Packaging	23.88	**Agriculture**	3.40
Building & Construction	18.40	**Medicine**	1.33
Transport	5.84	**Household**	3.73
Electronic	6.47	**Others**	12.56
Furniture	4.39	**Non-Plastic Products**	20.00
		Total	100.00

This shows that around 75% of all products are consumed in the packaging, non-plastic products, building and construction, and others sectors. The packaging sector consists of plastic applications with a short lifetime, as opposed to the building and construction sector, where the products such as piping and isolation materials have lifetimes of several decades, as reflected by the high increase in the stock of this sector. The sector of non-plastic products contains among others lacquers, adhesives and coloring pigments on a polymer basis. These are not recyclable, and are thus not relevant with respect to waste management, so this sector is not further considered and modelled as an export flow.

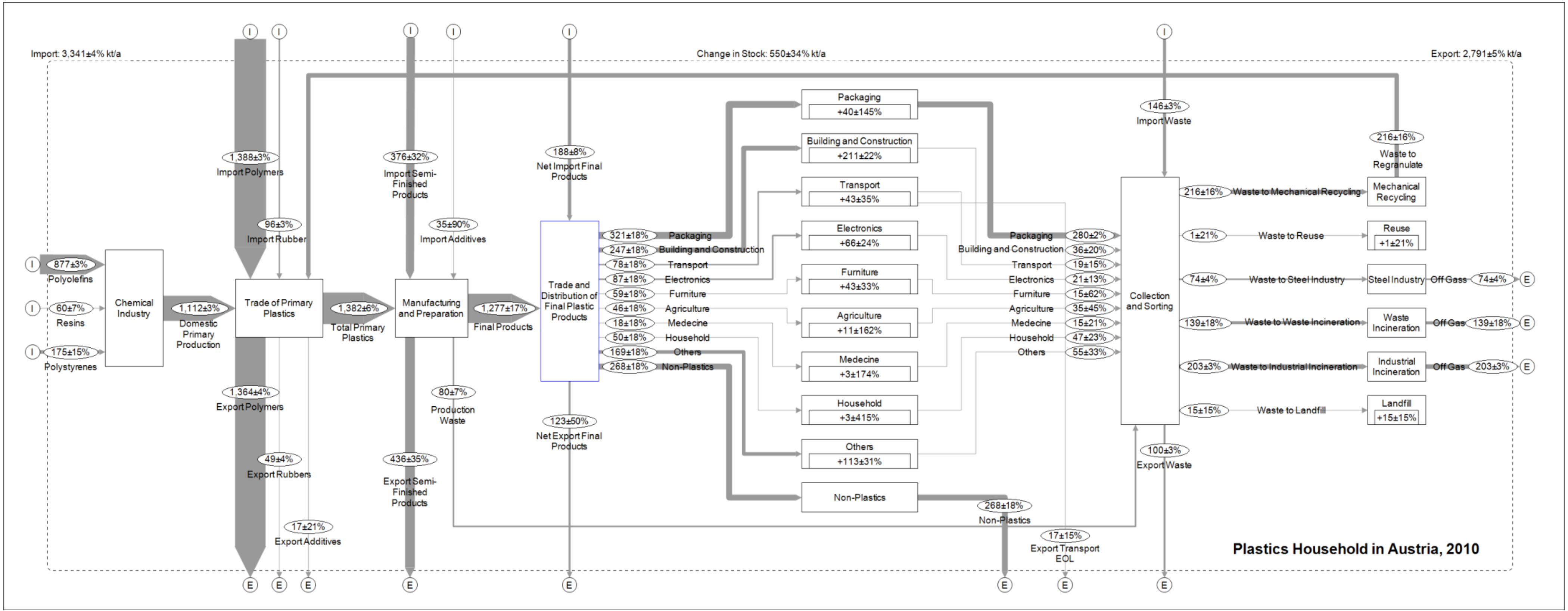

Figure 1: Flow scheme of the plastics household in Austria for 2010

3.3 Waste Management

The outputs of the consumption sectors are waste flows covered by the aggregated collection and sorting process. Due to the large input into the consumption process and the short lifetimes, the packaging sector produces by far the largest waste stream of all consumption sectors. It is clear as well that sectors with an established strong regulation, such as packaging and electronics, have the smallest associated uncertainty, as substantial documentation of the waste flows are required to be collected by the waste management stakeholders.

For the treatment of the plastics waste stream, six main categories of waste management processes can be distinguished. First, mechanical recycling produces regranulate, which is returned to the manufacturing and preparation stage to be used to produce new plastic products. This recovery accounts for 18% of the total treated waste stream. Next, about 1 kt (0.1%) of waste plastic products is reused, which is a negligible amount. Around 11% of the waste flow is used as a reducing agent in the steel industry, thus replacing conventional fossil fuels, so this process can be considered as feedstock recycling. Roughly 44% of the waste plastics ends up in the municipal solid waste and is incinerated with energy recovery, whereas around 25% is used in industrial incineration as a refuse-derived fuel (RDF) in the cement industry. Finally, the remaining 15 kt (2%) is landfilled.

4. Conclusions

The Austrian plastics household is characterized by a domestic production of around 1.1 million tonnes. After trade of primary polymers and semi-finished and final products, around 1.2 million tonnes plastic products are used for Austrian consumption. Here, packaging (24%), non-plastic products (20%), building and construction (18%), and other products (13%) are the most important consumption sectors. These products then contribute to the anthropogenic stock, in relation with the lifespan of the product, which can be used as a source for materials in the waste management process. Around 69% of the waste material is incinerated with energy recovery, 18% of the plastics waste flow is recycled mechanically, and roughly 11% is used for feedstock recycling. Only minor fractions of the waste flow are landfilled or reused. However, as these results are part of an ongoing investigation, the obtained values could further change in the future.

This kind of result can be used for multiple objectives. Policy changes can be highlighted with successive investigations. One illustration is the share of waste plastics which is landfilled. Similar studies on the plastics household in Austria were made by Fehringer and Brunner [23] and Bogucka and Brunner [24] for the years 1994 and 2004 respectively. From these results, the effect of the landfill ban in 2004 is clear, as the amount of waste plastics landfilled went down from around 80% in 1994 [23], over around 30% in 2004 [24], to the 2% obtained for 2010 in this study.

Furthermore, making a full overview of the total flows of plastics in a region highlights the most relevant streams, which can help to focus time and resources on the main processes or sectors. Especially for waste management, it is crucial to know what kind of waste streams are generated, on a qualitative and quantitative basis. In connection with the stocks and lifespans of the various products, predictions for future waste quantities can be made, and efforts can thus be focused on the largest and most relevant (ecologically and economically) waste streams.

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