Chemicals in plastic packaging: Prioritization of hazardous substances

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1. Introduction

Plastic packaging is increasingly used globally, causing rising concerns for the environment and human health from littering, release of microplastic and leakage of hazardous chemicals [1]. Of the global 380 Mt annual plastic production in 2015, an estimated 40% are used for packaging [2]. A large part of packaging is for foods and beverages, but consumer packaging for non-food items can be expected to increase in the "connected world", where many goods are being ordered online and mailed.

Plastic packaging is a source of chemicals which may migrate into foods or the environment during use, disposal, and recycling of the packaging material [3, 4]. Occupational exposure during plastic packaging manufacture is also relevant [5]. Therefore, a detailed look at the chemical composition of plastic packaging is warranted. One of the main obstacles to assessing the risks of chemicals originating from plastic packaging is the absence of information on the materials' exact chemical composition. For plastics intended to package foods, the European Union legislation contains a positive list of additives, monomers and other starting substances [6]. However, this list does not contain all substances which are used in the manufacture of plastic food contact materials (FCMs), or which are present in the final food contact article (FCA). For example, the non-intentionally added substances (NIAS)—comprising impurities, break down products and reaction by-products—are not covered. Further, to our knowledge, no comparable lists exist for non-food contact plastic packaging. The objective of this study is therefore to fill this knowledge gap, by compiling a list of chemicals potentially present in plastic packaging. This list will then allow us to identify chemicals with the highest risk to human and environmental health, and assess substitution options.

2. Materials and methods

We extracted available plastics-relevant information from the Chemical and Product Categories (CPCat) database compiled by the U.S. Environmental Protection Agency (EPA) [7, 8]. We further consulted the scientific literature along with commercial product information sources to identify chemicals that can be expected to be present in finished plastic packaging. Thereby, we focused on starting substances and other chemicals used in plastics manufacture, such as monomers, polymerization aids, solvents or catalysts, along with plastics additives such as pigments, fillers, antioxidants, stabilizers, plasticizers, slip agents and others [9]. We further included selected known NIAS such as impurities, reaction by-products, oligomers, and degradation products [10, 11].

We then ranked the substances in the Chemicals in Plastic Packaging Database (CPP-DB) according to their hazard for human health and the environment. For this, we applied a published methodology [12] based on Classification, Labeling and Packaging (CLP) data on hazard categories established by the European Chemicals Agency (ECHA). We further refined the initial CLP-based hazard ranking by considering endocrine disrupting properties, known and predicted PBT (persistence, bioaccumulative and toxic) characteristics [13], and existing identifications as a relevant hazardous chemical, according to the lists maintained by e.g. ECHA, Occupational Safety and Health Administration (OSHA), or non-government organizations (e.g. Chemsec). Due to the lack of CLP information and/or empirical hazard data for many of the substances in the CPP-DB, we also used in silico tools to bridge data gaps [14].

3. Results and discussion

The CPP-DB we compiled includes 4311 chemicals identified to be potentially present in plastic packaging. Of these, we identified a group of 145 substances having the highest environmental hazard classification based on chronic and/or acute aquatic toxicity. Identifying or confirming a substance's use in plastic packaging applications proved to be challenging due to the lack of comprehensive registries and the restrictions imposed by commercial data sources. Consequently, the actual use or non-use in plastic packaging could be confirmed for several hundred substances only, while for many substances, no conclusions on their use could be made due to insufficient data available. This demonstrates a significant lack of information in the field of chemicals' use and presence in products, even those that are in direct contact with foods and therefore can be assumed to be directly relevant for human exposure on a population scale. For high production-volume products such as plastic packaging articles, which have a significant potential for direct human exposure and release to the environment, the present scarcity of information significantly hampers risk assessment and risk management efforts.

4. Conclusions

In this study, we identified hundreds of compounds that are hazardous for human health and/or the environment, and that are being used in plastic packaging, for various reasons (as additives or monomers), or that are present in plastic packaging as NIAS. Substantial information gaps exist, for example for hazard profiles, which makes ranking of substances of concern problematic. Further, a risk-based ranking of substances of concern is impossible due to the absence of information on use, including exposure concentrations for humans and the environment. For some of the key compounds we have identified in this study we plan to carry out a more detailed evaluation. Furthermore, the apparent use of highly-ranking hazardous compounds in plastic packaging implies a need for alternatives identification which will also be addressed in this study.

References

[1] Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady A, Narayan R, Law KL. 2015. Plastic waste inputs from land into the ocean. Science 347:768-771.
[2] Geyer R, Jambeck JR, Law KL. 2017. Production, use, and fate of all plastics ever made. Science Advances 3.
[3] Hahladakis JN, Velis CA, Weber R, Iacovidou E, Purnell P. 2018. An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. J Hazard Mater 344:179-199.
[4] Hermabessiere L, Dehaut A, Paul-Pont I, Lacroix C, Jezequel R, Soudant P, Duflos G. 2017. Occurrence and effects of plastic additives on marine environments and organisms: A review. Chemosphere 182:781-793.
[5] Montano D. 2014. Chemical and biological work-related risks across occupations in Europe: a review. Journal of occupational medicine and toxicology (London, England) 9:28.
[6] European Union. 2011. COMMISSION REGULATION (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food in: E. Union (Ed.) EU 10/2011, European Union, Brussels.
[7] Dionisio KL, Frame AM, Goldsmith M-R, Wambaugh JF, Liddell A, Cathey T, Smith D, Vail J, Ernstoff AS, Fantke P, Jolliet O, Judson RS. 2015. Exploring consumer exposure pathways and patterns of use for chemicals in the environment. Toxicology Reports 2:228-237.
[8] EPA U. 2017. CPCat: Chemical and Product Categories. http://actor.epa.gov/cpcat in.
[9] Zweifel H, Maier, R., Schiller, M., Plastics Additives Handbook, 6 ed., Hanser Publications, Cincinnati, OH, 2009.
[10] Hoppe M, de Voogt P, Franz R. 2016. Identification and quantification of oligomers as potential migrants in plastics food contact materials with a focus in polycondensates – A review. Trends Food Sci Technol 50:118-130.
[11] Nerin C, Alfaro P, Aznar M, Domeño C. 2013. The challenge of identifying non-intentionally added substances from food packaging materials: A review. Anal Chim Acta 775:14-24.
[12] Lithner D, Larsson Å, Dave G. 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. Sci Total Environ In Press, Corrected Proof.
[13] Strempel S, Scheringer M, Ng CA, Hungerbühler K. 2012. Screening for PBT Chemicals among the "Existing" and "New" Chemicals of the EU. Environ Sci Technol 46:5680-5687.
[14] Raies AB, Bajic VB. 2016. In silico toxicology: computational methods for the prediction of chemical toxicity. Wiley Interdisciplinary Reviews Computational Molecular Science 6:147-172.