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Review

Critical review on challenge tests to demonstrate decontamination of polyolefins intended for food contact applications

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ABSTRACT

Background: As post-consumer recycled plastics may be contaminated with chemical substances, their use for food packaging may raise food safety issues. Recycling technologies should therefore efficiently remove contaminants of concern.
Scope and approach: Usually, the abundant data available for recycled poly(ethylene terephthalate) (PET) are extrapolated to polyolefins. This paper reviews the differences of basic properties and typical contaminants of polyolefins compared to PET. The use of thermal desorption process to remove polyolefin contaminants is discussed.
Key findings and conclusions: It is suggested in this review that this extrapolation is not scientifically justified, on the basis of the comparison between the intrinsic diffusion properties of contaminants of concern in PET and in polyolefins. It is concluded that the scope of contaminants of concern considered for the safety assessment of polyolefins recycling technologies based on thermal desorption should be carefully re-examined.

1. Introduction

As food packaging is a rapidly growing market, the demand for post-consumer recycled plastic packaging materials also grows. However, post-consumer collected materials may be contaminated from the first usage. Contamination often occurs in an uncontrolled and unpredictable way by what is called *a misuse* of packaging by consumers: at the end of the previous life of packaging materials, consumers may re-use the containers to store non-food substances available in their domestic environment. Moreover, plastic waste collection and the recycling technology itself may also be contamination sources for the materials. Therefore, the safety assessment of post-consumer recycled plastics intended for food contact applications requires a careful view of each step of the process, from waste collection to the final recycled plastic output.

In order to ensure that the final material does not contain contaminants of concern, when it comes into contact with food, recycling processes must include a critical decontamination step. Each recycled polymer displays specific contamination and decontamination behaviour governed by physical processes: sorption (contamination), diffusion and migration (release into foodstuff). Overall these properties are related to structure and polarity of the polymer. Considerations underlying the design and efficiency of the decontamination are specific to each polymer to be recycled.

Up to now, recycling of post-consumer plastics into food contact materials (FCM) has focused mainly on PET. It has been shown that the post-condensation steps of PET recycling processes usually require long time high temperature and vacuum or gas flow conditions, which also allow elimination of possible contaminants of concern.

Polyolefins are the most important group of polymers used for food packaging. However only a smaller number of studies has investigated safety issues related to the use of recycled polyolefins.

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Most studies extrapolate to polyolefins the results obtained for PET, which may not be scientifically sound. PET is a glassy polymer at room temperature and in the vast majority of conditions of use. In contrast, polyolefins are rubbery; they display poor functional barrier properties. The diffusion coefficient of a given substance is lower in PET than in polyolefins by orders of magnitude, so that the possible migration of absorbed contaminants is much lower for PET. Furthermore, as polyolefins have a reduced thermal stability, degradation products are formed during the processes (Coulier, Orbons, & Rijk, 2007). Stabilizers, which are used to protect polyolefins from oxidation and degradation during processing also give rise to reaction products. This becomes even more important when the materials are recycled and processed several times. Neoformed substances formed from both polymers and stabilizers may migrate into the packaged food (Nerin, Alfaro, Asnar, & Domeno, 2013).

2. Current approaches for the safety evaluation of recycled polymeric materials intended to come into contact with food

The guidelines of the European Food Safety Authority (EFSA) define the major risks associated to the use of recycled polymeric materials in contact with food. These risks are linked to the possible presence in a recycled plastic of substances, following its previous lifetime, its collection, sorting and recycling processes. These substances may contaminate by migration the food that will be packed in contact with the recycled plastic. Given the variety of sources of contamination, the identity of these contaminants cannot be precisely anticipated. Therefore, categories of contaminants were defined by EFSA (EFSA, 2008; EC, 2009; EC, 2011) depending on the contamination sources.

2.1. Contaminant sources in recycled plastics

Sources of contamination have been divided into three broad categories including the i) input contaminants ii) the chemicals used specifically for the recycling process and iii) the degradation products.

i) *The input contaminants* are incidental contaminants arising from use and misuse of the materials by consumers in the previous life of the container. Misuse happens when consumers re-use the plastic containers to store undesirable or toxic substances (petrol, detergents or domestic pesticides …). Substances from normal use may also contaminate the material (non food use such as cosmetic packaging) or food components which may be transformed into neoformed undesired substances. Such contaminants are not under control as their identity and frequency of use are not predictable. Analytic surveys of post-consumer collected materials were run at international level to give an overview of the possible identity of these contaminants and on frequency and levels of contamination. For PET, misuse constitutes the major source of contamination.

Input contaminants may also be introduced in the input stream by wasted non-food grade plastic containers (containers for mouthwash, detergents, shampoos, household cleaning products, medicines, garden chemicals and DIY “Do It Yourself” home improvement products like paint removers, furniture polish). The composition of these containers may include substances which have not been authorized for food contact applications (EC, 2011). Such containers are often present in collected post-consumer PET. As far as possible, they are removed by the sorting technologies. To have input contaminants under control, business operators set specifications to their suppliers.

ii) *The substances* used in the collection and in the recycling processes, such as detergents, may not be completely eliminated from the recycled plastic and are then possible contaminants.

iii) *The degradation products* of the polymer or of the plastic additives, mainly stabilisers, are neoformed substances. During the various steps of the recycling process, mainly during thermal treatments, the polymeric chain may break down (chain scission) into low molecular weight substances, which may migrate; the original additives may also react and be converted into neoformed substances (Coulier et al. 2007).

In the EU, the target of recycling processes is that the final recycled materials and articles have to comply with the requests set in Commission Regulation EU 10/2011 (EC, 2011). In this Regulation, composition criteria as well as both overall and specific migration limits are set for all materials intended to be in contact with food.

Given that neither the identity nor the presence of the contaminants are anticipated, the recycling technology must include sorting, washing and decontamination steps to efficiently remove contaminants, whether or not they are effectively present. The decontamination efficiency of the process steps are measured for reference surrogate contaminants.

2.2. Contaminants of concern

Contaminants are considered to be of concern if, after a recycling process, (i) they are present in the articles manufactured from recycled materials and (ii) if they can migrate into foodstuffs in levels which endanger human health (AFSSA, 2006). It has been shown for the risk assessment of recycled PET, that one has to consider altogether the decontamination efficiency of the recycled process as well as the intended use of the recycled plastic (EFSA, 2011).

In 2008, EFSA (EFSA, 2008) determined the target for cleaning and decontamination efficiency, by defining an exposure limit (microgram/kg bw day). It has been estimated that the risk associated with a dietary exposure of contaminants below 0.0025 μg/kg bw per day is negligible (EFSA, 2011; EFSA, 2012; EC, 2011). This is the human exposure threshold value for chemicals with structural alerts raising concerns for potential genotoxicity. For the risk assessment of recycled materials, the contaminants are of potential concern when their migration is such that the dietary exposure threshold of 0.0025 μg/kg bw per day is reached.

Among the factors supporting that this level of 0.0025 μg/kg bw per day is conservative, EFSA considered that the presence of genotoxic contaminants in post-consumer waste is unlikely, since such substances are not available to consumers; furthermore, even if they were present at trace levels in wasted containers, they are usually reactive at elevated temperatures such as those of the plastic manufacturing processes and they would not survive during these processes.

Migration and consumption scenarios are then correlated to the dietary exposure threshold of 0.0025 μg/kg bw. The default scenario, when the recycled PET is intended for general use, is that of an infant weighing 5 kg and consuming every day 0.75 l of water coming from a water bottle manufactured from 100% recycled PET. It can be derived that the highest concentration of a substance in water that would ensure that the dietary exposure of 0.0025 μg/kg bw/day is not exceeded, is 0.017 μg/kg food (EFSA, 2011). In the case of the other exposure scenarios for adults and toddlers, the relevant migration criterion are 0.75 and 0.15 μg/kg food respectively.

Contaminants are of concern if their migration may exceed