Towards improved deodorization of post-consumer plastic waste: Identifying the industrial hurdles

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Introduction

Household post-consumer plastic waste is typically heavily loaded with odorous constituents, with in total more than 400 identified odour compounds (Cabanes et al., 2020). These odour compounds belong to various chemical groups and have a very wide range of polarities, molecular weights and volatilities, which makes their efficient removal very challenging. Consequently, regranulated plastic waste has typically an unpleasant smell, which is one of the reasons why they are currently mostly processed in bulk (outdoor) applications with a limited market potential, such as plant trays, compost bins, street or garden benches, etc. Since the European recycling targets for plastic packaging are ambitious, aiming for a recycling rate of 50% by 2025 and 55% by 2030 (European Commission, 2015), improving washing procedures for plastic waste is a main priority for European plastic recycling plants. However, only little fundamental research is performed in this field and most studies focus on the identification of odour compounds rather than their removal during washing. Therefore, the objective of this presentation is to highlight the main hurdles towards improved deodorization based on the learnings of our previous work in the field of deodorization of plastic waste (Demets et al., 2020; Roosen et al., 2020).

Materials and Methods

We have first evaluated the efficiency of a currently applied industrial recycling plant for a mixed plastic film fraction (Demets et al., 2020). In the recycling plant, the plastic film waste was washed by means of a friction washer and sink-float system, all using tap water. The film material was then flash dried using hot air. Finally, these materials were regranulated using an extruder at 200°C with vacuum degassing.

As a next step, a more fundamental study was performed to gain more insights in the deodorization kinetics of plastic films (Roosen et al., 2020). In this study, plastics were washed with various washing media, including water, caustic soda, a detergent, and a combination of caustic soda and a detergent at 25, 45, and 65 °C. Subsequently, different kinetic models were fitted to the experimental data and statistically evaluated.

In a third study, different types of plastic packaging (i.e., poly(ethylene terephthalate) (PET) bottles, PET trays, polyethylene (PE) bottles, PE films, polypropylene (PP) bottles, PP trays, and polystyrene (PS) rigids) were washed with different washing media, including water, caustic soda, different types of detergents, and a combination of caustic soda and a detergent, in order to investigate the influence of packaging type on deodorization efficiencies.

Characterization of odour compounds was done by applying various sampling techniques (i.e., solid-phase micro-extraction, adsorption on activated charcoal tubes, and adsorption on Tenax-TA tubes), followed by gas chromatography-mass spectrometry analysis, as described by Demets et al. (2020). The removal of the analysed odour compounds was calculated based on the ratio of the relative peak area before and after washing. The average deodorization efficiency is calculated by averaging the deodorization efficiency of all analysed odour compounds, giving equal weights to all odour compounds.

Results and Discussions

The industrial washing of mixed plastic films indicated that the most polar compounds (with an octanol-water partition coefficient lower than two) are relatively efficiently removed, but that the more apolar compounds are still present in significant concentrations after washing and regranulation.

The effect of polarity was also highlighted in the kinetic study, showing again that the apolar odour compounds are not efficiently removed after a water wash with only average removal efficiencies around 55% at 25 °C. At least a detergent should be added to form micelles around the odour compounds and, hence, to stabilize them. Hence, it is feasible to increase the average deodorization efficiency up to more than 70%.

The study also showed that the kinetics of deodorization of plastic films are best described by a reversible first order model. This implicates that not only desorption, which is thus deodorization, but also adsorption of odour

compounds from the washing water to the plastic films can take place. This is of course an unwanted phenomena during the washing of plastics. Yet, with the high water recirculation rates that are currently applied in industry (in some cases even more than 90%), maximum deodorization efficiencies of only around 20 to 30% can be achieved. This obviously has a significant impact on the washing process of plastics and is an important conclusion of this work, as it indicates that proper management of the applied washing medium is key during the washing process.
As a next step, we compared the washing of different packaging types with various washing media. It was shown that the type of polymer and the application for which it is used strongly determine the types of odour compounds (and thus their physicochemical properties) that are present on the material. PET bottles contain, for instance, more terpenes, which are used as flavour substances in soft drinks, where PP trays contain more oxygenated compounds which are stated to be thermal oxidation products of PP. This has an influence on the average deodorization efficiencies that are achieved with different washing media. Figure 1 indicates that PET bottles, for instance, are relatively well deodorized with caustic soda compared to PE films, where adding a detergent seems more essential.

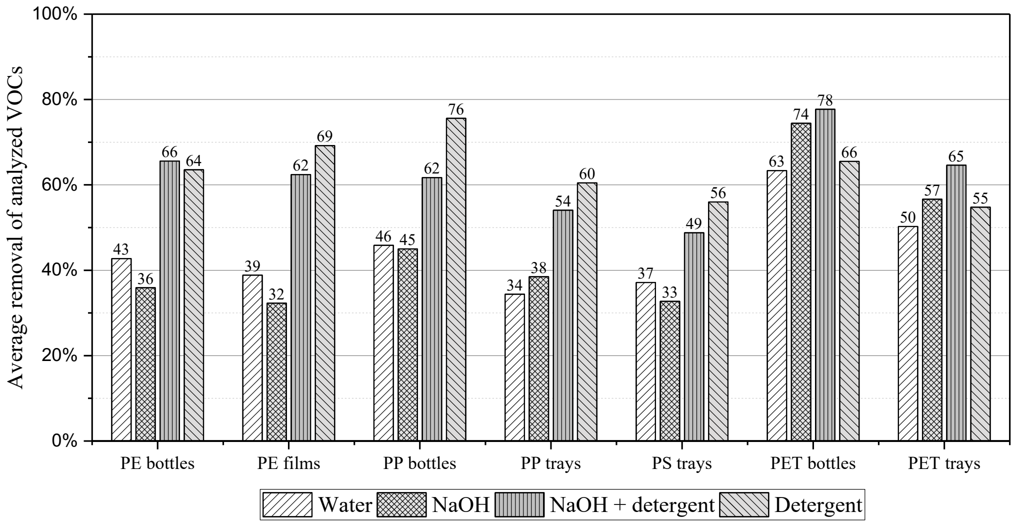

Figure 1: Average removal efficiencies of analysed odour compounds achieved with different washing media at 25 °C and under continuous stirring with a batch-wise lab-scale setup.

The results of the performed studies show that optimizing washing processes tailored on the type of packaging and the physicochemical properties of the washing media and odour compounds is key towards efficient deodorization. Moreover, also the post-treatment of the washing medium in order to avoid saturation is key to further improve the deodorization of plastic waste, and, hence, to move towards a more circular economy for plastics.

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