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Safety assessment of the process “ExtruPET”, based on Starlinger IV+[®] technology, used to recycle post-consumer PET into food contact materials

EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids (CEF)

Abstract

This scientific opinion of the EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids deals with the safety evaluation of the recycling process ExtruPET (EU register number RECYC0124), which is based on the Starlinger IV+[®] technology. The input of the process is hot caustic washed and dried poly(ethylene terephthalate) (PET) flakes originating from collected post-consumer PET containers, containing no more than 5 % of PET from non-food consumer applications. In this technology, washed PET flakes are dried and crystallised in a reactor, then extruded into pellets which are further crystallised in a second reactor. Crystallised pellets are then pre-heated in a third reactor and fed to the solid state polycondensation (SSP) reactor. Having examined the challenge test provided, the Panel concluded that the three steps, drying and crystallisation, extrusion and crystallisation and SSP are the critical steps that determine the decontamination efficiency of the process. The operating parameters that control their performance are well defined and are the temperature, the gas flow and the residence time for the drying and crystallisation step, and the temperature, the pressure and the residence time for the extrusion and crystallisation step and the SSP step. Under these conditions, it was demonstrated that the recycling process is able to ensure that the level of migration of potential unknown contaminants into food is below a conservatively modelled migration of 0.1 µg/kg food. Therefore, the Panel concluded that the recycled PET obtained from this process intended to be used up to 100 % for the manufacture of materials and articles for contact with all types of foodstuffs for long-term storage at room temperature, with or without hotfill, is not considered of safety concern. Trays made of this recycled PET are not intended to be used, and should not be used in microwave and conventional ovens.

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Keywords: Starlinger IV+, ExtruPET, food contact materials, plastic, poly(ethylene terephthalate) (PET), recycling process, safety assessment

Requestor: Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, Germany

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

Recycled plastic materials and articles shall only be placed on the market for food contact if they contain recycled plastic obtained from an authorised recycling process. Before a recycling process is authorised, EFSA's opinion on its safety is required. This procedure has been established in Article 5 of the Regulation (EC) No 282/2008¹ of the Commission of 27 March 2008 on recycled plastic materials intended to come into contact with foods and Articles 8 and 9 of the Regulation (EC) No 1935/2004² of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food.

According to this procedure, the industry submits applications to the Member States competent Authorities which transmit the applications to EFSA for evaluation.

In this case, EFSA received, from the Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, Germany, an application for evaluation of the recycling process ExtruPET, EU register No RECYC0124.

EFSA is required by Article 5 of Regulation (EC) No 282/2008 of the Commission of 27 March 2008 on recycled plastic materials intended to come into contact with foods to carry out risk assessments on the risks originating from the migration of substances from recycled food contact plastic materials and articles into food and deliver a scientific opinion on the recycling processes examined.

According to Article 4 of Regulation (EC) No 282/2008, EFSA will evaluate whether it has been demonstrated in a challenge test, or by other appropriate scientific evidence, that the recycling process ExtruPET is able to reduce any contamination of the plastic input to a concentration that does not pose a risk to human health. The PET materials and articles used as input of the process as well as the conditions of use of the recycled PET make part of this evaluation.

2. Data and Methodologies

2.1. Data

Each application is supported by a technical dossier submitted by industry following the EFSA guidelines for the submission of an application for the safety evaluation of a recycling process to produce recycled plastics intended to be used for the manufacture of materials and articles in contact with food, prior to its authorisation (EFSA, 2008). Applications shall be submitted in accordance with Article 5 of the Regulation (EC) No 282/2008. The following information on the recycling process was provided by the applicant:

- General information:
 - general description
 - existing authorisations
- Specific information:
 - recycling process
 - characterisation of the input
 - determination of the decontamination efficiency of the recycling process
 - characterisation of the recycled plastic
 - intended application in contact with food

¹ Regulation (EC) No 282/2008 of the European parliament and of the council of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods and amending Regulation (EC) No 2023/2006. OJ L 86, 28.3.2008, p. 9–18.

² Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC. OJ L 338, 13.11.2004, p. 4–17.

- compliance with the relevant provisions on food contact materials and articles
- process analysis and evaluation
- operating parameters.

2.2. Methodologies

2.2.1. The principles of the evaluation scheme

The risks associated with the use of recycled plastic materials and articles in contact with food come from the possible migration of chemicals into the food in amounts that would endanger human health. The quality of the input, the efficiency of the recycling process to remove contaminants, as well as the intended use of the recycled plastic, are crucial points for the risk assessment (see guidelines on recycling plastics: EFSA, 2008).

The criteria for the safety evaluation of a mechanical recycling process to produce recycled poly(ethylene terephthalate) (PET) intended to be used for the manufacture of materials and articles in contact with food are described in the scientific opinion developed by the EFSA Panel on Food Contact Materials, Enzymes, Flavourings and Processing Aids (EFSA CEF Panel, 2011). The principle of the evaluation is to apply the decontamination efficiency of a recycling technology or process, obtained from a challenge test with surrogate contaminants, to a reference contamination level for post-consumer PET, conservatively set at 3 mg/kg PET for contaminants resulting from possible misuse. The resulting residual concentration of each surrogate contaminant in recycled PET (*C_{res}*) is compared with a modelled concentration of the surrogate contaminants in PET (*C_{mod}*). This *C_{mod}* is calculated using generally recognised conservative migration models so that the related migration does not give rise to a dietary exposure exceeding 0.0025 µg/kg bw per day (i.e. the human exposure threshold value for chemicals with structural alerts for genotoxicity), below which the risk to human health would be negligible. If the *C_{res}* is not higher than the *C_{mod}*, the recycled PET manufactured by such recycling process is not considered of safety concern for the defined conditions of use (EFSA CEF Panel, 2011).

3. Assessment

3.1. Introduction

The European Food Safety Authority was asked by the Bundesamt für Verbraucherschutz und Lebensmittelsicherheit, Germany, to evaluate the safety of the recycling process ExtruPET, European Union (EU) register No RECYC0124. The request has been registered in EFSA's register of received questions under the number EFSA-Q-2015-00003. The dossier was submitted on behalf of Extrupet (Pty) Ltd, South Africa.

3.2. General information

According to the applicant, the recycling process ExtruPET is intended to recycle food grade PET containers to produce recycled PET pellets using the Starlinger IV+[®] technology. The recycled pellets are intended to be used up to 100 % for the manufacture of recycled materials and articles. These final materials and articles are intended to be used in direct contact with all kinds of foodstuffs for long-term storage at room temperature, with or without hotfill.

3.3. Description of the process

3.3.1. General description

The recycling process ExtruPET produces recycled PET pellets from PET containers, coming from post-consumer collection systems (kerbside and deposit systems). The recycling process comprises the four steps below. The first step is performed in house by the applicant.

Input

- In step 1, post-consumer PET containers are sorted and processed into hot caustic washed and dried flakes, which are used as the input of the process.

Decontamination and production of recycled PET material

- In step 2, the flakes are dried and crystallised in a reactor under inert gas or desiccant air flow at high temperature.
- In step 3, the flakes are extruded under vacuum at high temperature and then crystallised.
- In step 4, the crystallised pellets are pre-heated before being handled in a continuous running solid state polycondensation (SSP) reactor at high temperature and under vacuum.

The operating conditions of the process have been provided to EFSA.

Recycled PET pellets, the final product of the process, are checked against technical requirements on intrinsic viscosity, colour, black spots, etc. Recycled PET pellets are intended to be converted by other companies into recycled articles used for hotfill and/or long-term storage at room temperature, such as bottles for mineral water, soft drinks, juices, beer, sauces and condiments. The recycled pellets may also be used for sheets, which are thermoformed to make food trays. Trays made of this recycled PET are not intended to be used in microwave and conventional ovens.

3.3.2. Characterisation of the input

According to the applicant, the input material for the recycling process ExtruPET is hot caustic washed and dried flakes obtained from PET containers, mainly bottles, previously used for food packaging, from post-consumer collection systems (kerbside and deposit systems). However, a small fraction may originate from non-food applications, such as soap bottles, mouthwash bottles, kitchen hygiene bottles, etc. According to the applicant, the amount of this non-food container fraction depends on the re-collection system. On the basis of market share data, the applicant estimated that this fraction is below 5 %.

Technical data for the washed and dried flakes are provided, such as information on residual content of poly(vinyl chloride) (PVC), glue, polyolefins, cellulose, metals, polyamides and physical properties (see Appendix A).

3.4. Starlinger IV+[®] technology

3.4.1. Description of the main steps

To decontaminate post-consumer PET, the recycling process ExtruPET uses the Starlinger IV+[®] technology as described below and for which the general scheme is reported in Figure 1.

- Drying and crystallisation (step 2): In this step the flakes are dried and crystallised at high temperature in a reactor under inert gas or desiccant air flow, in a continuous process.
- Extrusion and crystallisation (step 3): The flakes from the previous step are fed into an extruder under high temperature and vacuum for a predefined residence time. Further decontamination occurs in this step. The extruded pellets are then crystallised at high temperature in a further reactor under atmospheric pressure.
- SSP (step 4): The crystallised pellets are continuously pre-heated in a reactor before being introduced into the SSP reactor running under vacuum at a predefined high temperature and for a predefined residence time.

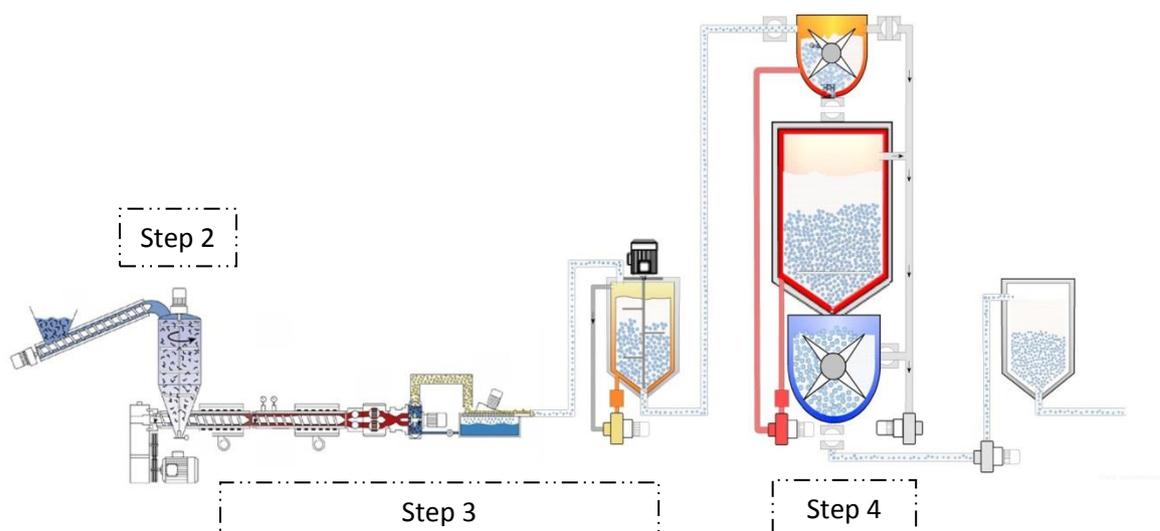


Figure 1: General scheme of the Starlinger IV+[®] technology

The process is operated under defined operating parameters of temperature, pressure, gas flow and residence time.

3.4.2. Decontamination efficiency of the recycling process

To demonstrate the decontamination efficiency of the recycling process, a challenge test on the Starlinger IV+[®] technology was submitted to EFSA.

PET flakes were contaminated with selected chemicals, toluene, chloroform, phenylcyclohexane, benzophenone and lindane, used as surrogate contaminants. The surrogates were chosen in agreement with EFSA guidelines and in accordance with the recommendations of the US Food and Drug Administration. The surrogates include different molecular weights and polarities to cover possible chemical classes of contaminants of concern and were demonstrated to be suitable to monitor the behaviour of PET during recycling (EFSA, 2008).

For the preparation of the contaminated PET flakes, conventionally recycled³ green PET flakes were soaked in a heptane/isopropanol solution containing the surrogates and stored for 14 days at 40 °C. The surrogates solution was decanted and PET flakes were rinsed with water and then air dried. The concentration of surrogates in this material was determined.

The Starlinger IV+[®] technology was challenged in Starlinger facilities in a pilot plant scale and using only contaminated flakes. The contaminated flakes were introduced directly in the drier (step 2) then sampled after each step (2–4) of the process. The samples (flakes then pellets) were analysed for their residual concentrations of the applied surrogates. Instead of being processed continuously, the SSP reaction was run in batch mode. In both batch and continuous modes of operation the surrogates diffuse through the pellets to the surface and they are constantly eliminated by the vacuum applied. Therefore, continuous working processes will result in the same cleaning efficiencies as batch processes, as long as the same temperature, pressure conditions and residence time are applied.

The decontamination efficiency of the process was calculated taking into account the amount of the surrogates detected in washed contaminated flakes before drying and crystallisation (before step 2) and after SSP (step 4). When not detected, the limit of detection was considered for the calculation of the decontamination efficiency. The results are summarised below in Table 1.

³ Conventional recycling includes commonly sorting, grinding, washing and drying steps and produces washed and dried flakes.

Table 1: Efficiency of the decontamination of the Starlinger IV+[®] technology in the challenge test.

Surrogates	Concentration of surrogates before step 2 (mg/kg PET)	Concentration of surrogates after step 4 (mg/kg PET)	Decontamination efficiency (%)
Toluene	563	< 0.8 ^(a)	> 99.9
Chloroform	1 900	< 0.5 ^(a)	> 99.9
Phenylcyclohexane	538	< 0.3 ^(a)	> 99.9
Benzophenone	694	10.8	98.4
Lindane	373	33.9	90.9

(a): Not detected at the limits of detection given.

As shown above, the decontamination efficiency ranged from 90.9 % for lindane to more than 99.9 % for toluene, chloroform and phenylcyclohexane.

3.5. Discussion

Considering the high temperatures used during the process, the possibility of contamination by microorganisms can be discounted. Therefore, this evaluation focuses on the chemical safety of the final product.

Technical data, such as information on residual content of PVC, glue, polyolefins, cellulose, metals, polyamides and physical properties, are provided for the input materials (washed and dried flakes (step 1)) for the submitted recycling process. The input materials are produced from PET containers previously used for food packaging collected through post-consumer collection systems. However, a small fraction may originate from non-food applications, such as soap bottles, mouthwash bottles, kitchen hygiene bottles, etc. According to the applicant, the amount of this non-food container fraction depends on the re-collection system and, on the basis of market share data, it is below 5 %, as recommended by the EFSA CEF Panel in its "Scientific opinion on the criteria to be used for safety evaluation of a mechanical recycling process to produce recycled PET intended to be used for manufacture of materials and articles in contact with food" (EFSA CEF Panel, 2011).

The process is well described. The production of washed and dried flakes from collected containers (step 1) is conducted by the applicant and, according to the applicant, this step is under control. The following steps are those of the Starlinger IV+[®] technology used to recycle the PET flakes into decontaminated PET pellets: drying and crystallisation (step 2), extrusion and crystallisation (step 3) and SSP (step 4). The operating parameters of temperature, pressure, residence time and gas flow have been provided to EFSA.

A challenge test was conducted at a pilot plant scale on process steps 2 to 4 (drying, extrusion and crystallisation, and SSP reactors) to measure the decontamination efficiency. The operating parameters of these steps in the process are at least as severe as those operated for the challenge test. The Panel considered that the challenge test was performed correctly according to EFSA guidelines (EFSA, 2008). Although the fourth step is expected to be the most critical step for the decontamination, drying and crystallisation (step 2) and extrusion (step 3) are relevant too. Therefore, the Panel considered that the three steps (drying and crystallisation, extrusion and crystallisation, and SSP) are the critical steps for the decontamination efficiency of the process. Consequently, the temperature, the gas flow and the residence time for the drying and crystallisation (step 2), and the temperature, the pressure and the residence time for extrusion and crystallisation (step 3) and SSP (step 4) should be controlled to guarantee the performance of the decontamination. These parameters have been provided to EFSA.

The decontamination efficiencies obtained for each surrogate contaminant from the challenge test, ranging from 90.9 % to above 99.9 %, have been used to calculate the residual concentrations of potential unknown contaminants in pellets (*C_{res}*) in accordance with the evaluation procedure described in the "Scientific opinion on the criteria to be used for safety evaluation of a mechanical recycling process to produce recycled PET" (EFSA CEF Panel, 2011; Appendix B). By applying the decontamination efficiency percentage to the reference contamination level of 3 mg/kg PET, the *C_{res}* for the different surrogates is obtained (Table 2).

According to the evaluation principles (EFSA CEF Panel, 2011), the *C_{res}* value should not be higher than a modelled concentration in PET (*C_{mod}*) corresponding to a migration, after one year at 25 °C, which cannot give rise to a dietary exposure exceeding 0.0025 µg/kg bw/day, the exposure threshold below which the risk to human health would be negligible⁴. Because the recycled PET is intended for general use for the manufacturing of articles containing up to 100 % recycled PET, the most conservative default scenario for infants has been applied. Therefore, the migration of 0.1 µg/kg into food has been used to calculate *C_{mod}* (EFSA CEF Panel, 2011). The results of these calculations are shown in Table 2. The relationship between the key parameters for the evaluation scheme is reported in Appendix B.

Table 2: Decontamination efficiency from challenge test, residual concentration of surrogate contaminants in recycled PET (*C_{res}*) and calculated concentration of surrogate contaminants in PET (*C_{mod}*) corresponding to a modelled migration of 0.1 µg/kg food after one year at 25 °C

Surrogates	Decontamination efficiency (%)	<i>C_{res}</i> (mg/kg PET)	<i>C_{mod}</i> (mg/kg PET)
Toluene	99.9	0.004	0.09
Chloroform	99.9	0.001	0.10
Phenylcyclohexane	99.9	0.001	0.14
Benzophenone	98.4	0.047	0.16
Lindane	90.9	0.273	0.31

The residual concentrations of all surrogates in PET after decontamination (*C_{res}*) are lower than the corresponding modelled concentrations in PET (*C_{mod}*). Therefore, the Panel considered that the recycling process ExtruPET using Starlinger IV+[®] technology is able to ensure that the level of migration of unknown contaminants from the recycled PET into food is below the conservatively modelled migration of 0.1 µg/kg food at which the risk to human health would be negligible.

4. Conclusions

The CEF Panel considered that the process is well characterised and the main steps used to recycle PET flakes into decontaminated PET pellets have been identified. Having examined the challenge test provided, the Panel concluded that the three steps (drying and crystallisation, extrusion and crystallisation, and SSP) are the critical steps for the decontamination efficiency of the process. The operating parameters to control its performance are the temperature, the gas flow and the residence time for the drying and crystallisation (step 2) and the temperature, the pressure and the residence time for extrusion and crystallisation (step 3) and SSP (step 4). Therefore, the Panel considered that the recycling process ExtruPET is able to reduce any foreseeable accidental contamination of the post-consumer food contact PET to a concentration that does not give rise to concern for a risk to human health if:

- i) it is operated under conditions that are at least as severe as those obtained from the challenge test used to measure the decontamination efficiency of the process; and
- ii) the input of the process is washed and dried post-consumer PET flakes originating from materials and articles that have been manufactured in accordance with the EU legislation on food contact materials containing no more than 5 % of PET from non-food consumer applications.

Therefore, the recycled PET obtained from the process ExtruPET intended to be used up to 100 % for the manufacture of materials and articles for contact with all types of foodstuffs for long-term storage at room temperature, with or without hotfill, is not considered of safety concern. Trays made of this

⁴ 0.0025 µg/kg bw/day is the human exposure threshold value for chemicals with structural alerts raising concern for potential genotoxicity, below which the risk to human health would be negligible (EFSA CEF Panel, 2011).

recycled PET are not intended to be used, and should not be used in microwave and conventional ovens.

5. Recommendations

The Panel recommended periodic verification that the input to be recycled originates from materials and articles that have been manufactured in accordance with the EU legislation on food contact materials and that the proportion of PET from non-food consumer applications is no more than 5 %. This adheres to good manufacturing practice and the Regulation (EC) No 282/2008, Article 4b. Critical steps in recycling should be monitored and kept under control. In addition, supporting documentation should be available on how it is ensured that the critical steps are operated under conditions at least as severe as those in the challenge test used to measure the decontamination efficiency of the process.

Documentation provided to EFSA

1. Dossier "ExtruPET". March 2015. Submitted on behalf of ExtruPET (Pty) Ltd.

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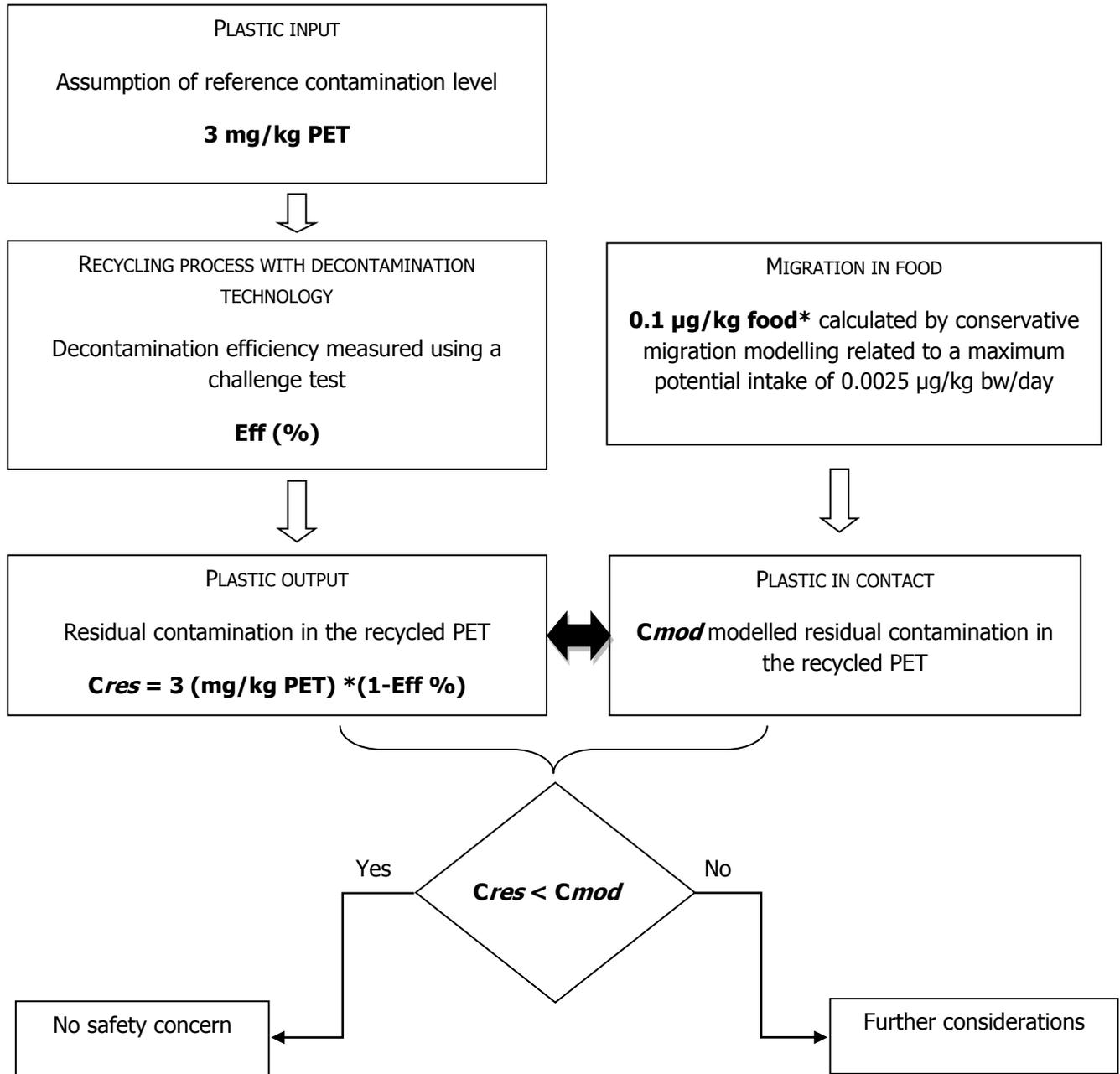
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Appendix A – Technical data of the washed flakes as provided by the applicant

Parameter	Value
Moisture maximum	1.0 %
Bulk density	> 280 kg m ⁻³
Material temperature	10–60 °C
Material temperature variation	± 10 °C h ⁻¹
PVC maximum	50 ppm
Glue maximum	500 ppm (inclusive flakes)
Polyolefins maximum	20 ppm
Metals maximum	20 ppm

Appendix B – Relationship between the key parameters for the evaluation scheme (EFSA CEF Panel, 2011)



*Default scenario (infant). For adults and toddlers, the migration criterion will be 0.75 and 0.15 µg/kg food, respectively.

Abbreviations

bw	body weight
CEF	Food Contact Materials, Enzymes, Flavourings and Processing Aids
<i>C_{mod}</i>	modelled concentration in PET
<i>C_{res}</i>	residual concentrations in PET
EC	European Commission
EFSA	European Food Safety Authority
PET	poly(ethylene terephthalate)
PVC	poly(vinyl chloride)