Fraunhofer IVV

Test report

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Challenge test on a recycling process for post-consumer Polypropylene

Commissioning party:	Versalis S.p.A. Viale Alcide De Gasperi, 2 20097 San Donato Milanese (MI) Italy
Project number:	PA-1371a-25 rev2
Start of project:	23.05.2025
Samples:	23.05.2025 (PP virgin pellets for contamination) 21.05.2026 (challenge test samples) 10.07.2026 (challenge test samples)
Date of report:	28.10.2026

The results refer solely to the tested samples.

1 Background and objectives

The customer wants to recycle post-consumer PP into new packaging applications. The decontaminated post-consumer recyclate will be in direct contact to food. The most important parameter of the recycling concept is the cleaning efficiency of the applied recycling process towards potential post-consumer substances.

Aim of the study is the determination of the cleaning efficiency of the investigated PP super-clean process.

2 Model contaminants (surrogates)

Table 1 gives details of the model contaminants that were used.

Table 1: Model contaminants used for the challenge test with details of their molecular weight, functional groups and physical properties

Substance	M_W[a]	Functional groups	Properties
Toluene	92.1	Aromatic hydrocarbon	volatile, non-polar
Chlorobenzene	112.6	Aromatic hydrocarbon, halogen-containing	volatile, polar
Limonene	136.2	Aliphatic hydrocarbon	volatile, non-polar
Phenylcyclo-hexane	160.3	Aromatic hydrocarbon	low volatility, non-polar
Benzophenone	182.2	Aromatic ketone	low volatility, polar
Butyl salicylate	194.2	Aliphatic ester	non-volatile, non-polar
Methyl palmitate	270.5	Aliphatic ester	non-volatile, medium-polar
Diethylhexyl adipate DEHA	370.6	Aliphatic ester	non-volatile, medium-polar
Tris(ethylhexyl) trimellitate TEHTM	546.8	Aromatic ester	non-volatile, medium-polar
Ethylhexyl triazone (Uvinul T150)	823.1	Aromatic ester	non-volatile, medium-polar

[a]Molecular weight in g/mol

3 Contamination procedure

100 kg of PP virgin pelets were contaminated according to the following procedure: The 100 kg of post-consumer washed pellets were filled into 4 barrels (25 kg each). To each of the barrels, a mixture of 25 ml toluene, 25 ml, chlorobenzene, 25 ml limonene, 25 ml phenyl cyclohexane, 25 g benzophenone, 25 ml butyl salicylate, 25 g methyl palmitate, 25 g diethylhexyl adipate, 25 g tris(ethylhexyl) trimellitate and 25 g ethylhexyl triazone (Uvinul T150 dissolved in 25 ml ethyl acetate) was given. Subsequently the barrels were sealed and stored for 7 d at 50 °C. The sealed barrels were turned/rolled each day. Subsequently. After contamination the pellets were rinsed with 10% ethanol in order to remove contaminants from the surface of the pellets. The pellets were combined into 4 barrels and shipped to the customer.

4 Samples

The commissioning party made available the samples listed in Table 2.

Table 2: Description of the investigated samples

Sample	Sample description
Sample 1i	Input before decontamination test 1
Sample 1o	output after decontamination test 1
Sample 2i	Input before decontamination test 2
Sample 2o	output after decontamination test 2
Sample 3i	Input before decontamination test 3
Sample 3o	output after decontamination test 3
Sample 4i	Input before decontamination test 4
Sample 4o	output after decontamination test 4
Sample 5i	Input before decontamination test 5
Sample 5o	output after decontamination test 5
Sample 6i	Input before decontamination test 6
Sample 6o	output after decontamination test 6

5 Extraction method

5.1 Quantification challenge test samples

In each case a 1.0 g sample was weighed into a headspace-vial and extracted with 10 ml dichloromethane for 3 d at 40°C. The extracts were then analyzed by

gas chromatography. Gas chromatograph: Agilent 6890, column: ZB 1 MS - 20 m - 0.18 mm i.d. - 0.18 µm film thickness, temperature program: 50°C (2 min), heat at 5°C min^{-1} to 340°C (10 min), Split: 10 ml min^{-1}. The FID signals of the model contaminants in the gas chromatogram were integrated. The concentrations of the respective contaminants were determined from calibration graphs obtained using external standards.

5.2 Quantification ethylhexyl triazone (Uvinul T150)

1.0 g of the polymer sample were extracted with 10.0 ml dichloromethane for 2 days at 40 °C. An aliquot of the dichloromethane extracts was evaporated to dryness under a stream of nitrogen. The residue was re-dissolved in the same amount of 95% ethanol. The ethanolic solutions were used for HPLC analysis: HPLC equipment: Column: Xbridge (150 x 3 mm, 5 µ; Phenomenex); eluent: 95% methanol to 100% methanol (gradient); mobile phase flow rate: 0.5 ml/min, column oven: 40 °C. Quantification was achieved by coupling the HPLC to a mass spectrometer (Thermo LTQ). For detection, the molecular mass of trimethylolpropane was selected in single reaction monitoring (SRM) mode and the characteristic daughter fragment was detected. The calibration was performed in dichloromethane handled like the samples. All analyses were performed in duplicate.

5.3 Detection limits

Table 3: Detection limits of the applied method for the surrogates

Surrogate	Detection limit [mg/kg, ppm]	
	samples 1-5	sample 6
Toluene	0.1	0.1
Chlorobenzene	0.7	0.3
Limonene	0.2	0.2
Phenyl cyclohexane	0.2	0.2
Butyl salicylate	2.9	3.6
Benzophenone	0.7	0.7
Methyl palmitate	0.3	0.3
Diethylhexyl adipate DEHA	0.1	0.2
Tris(ethylhexyl)trimellitate TEHTM	0.3	0.3
Ethylhexyl triazone (Uvinul T150)	1.4	1.4

6 Results

The results of the quantification of the surrogates in the investigated challenge test samples are summarized in Table 4. Example gas chromatograms of the dichloromethane extracts are shown in Figure 1 to Figure 13.

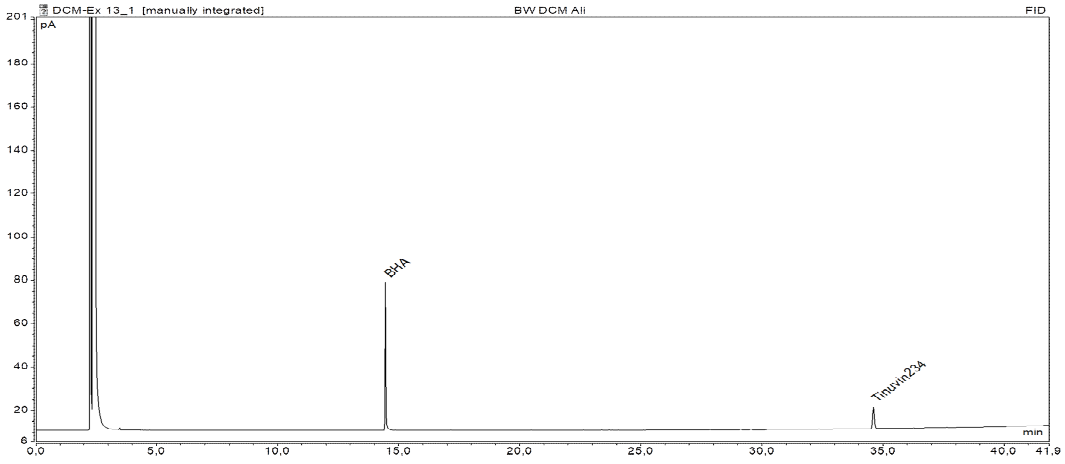


Figure 1: Gas chromatogram of the extract of solvent used for extraction (blind)

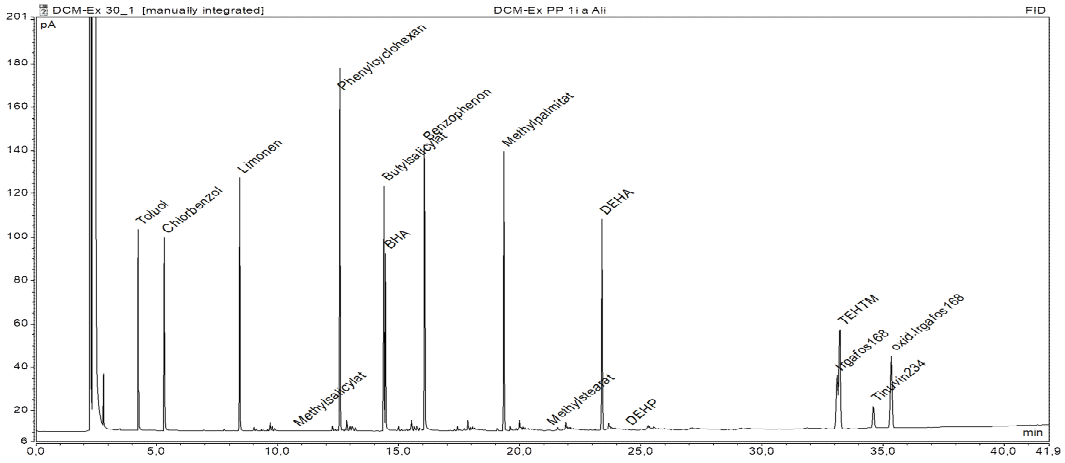


Figure 2: Gas chromatogram of the extract of sample input 1i

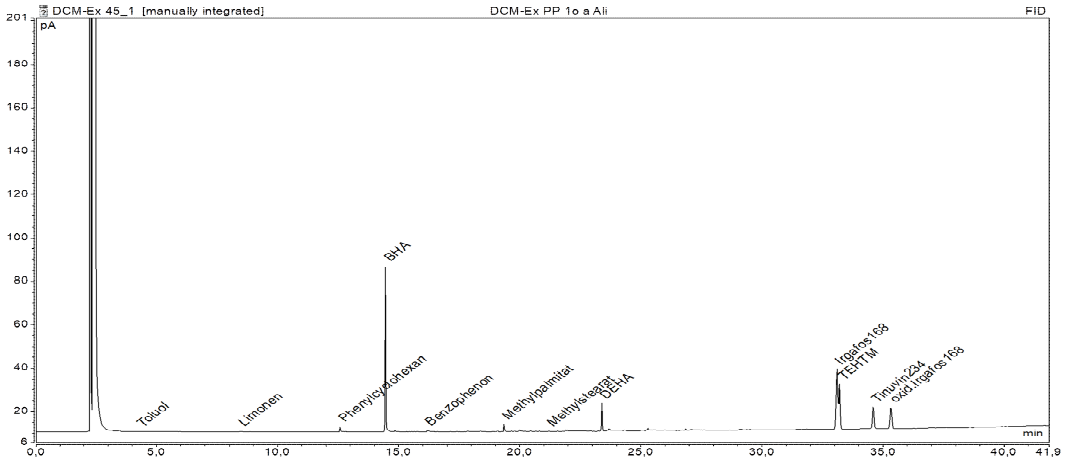


Figure 3: Gas chromatogram of the extract of sample output 1o

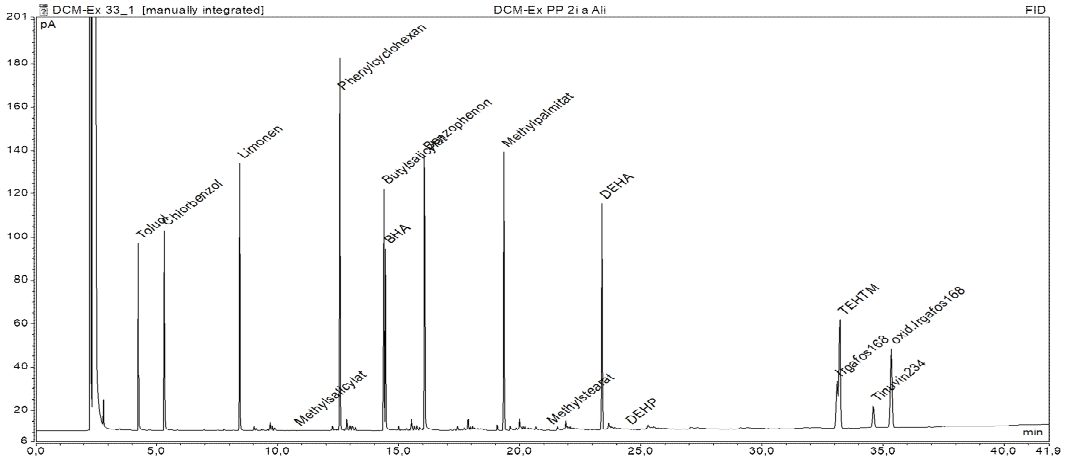


Figure 4: Gas chromatogram of the extract of sample input 2i

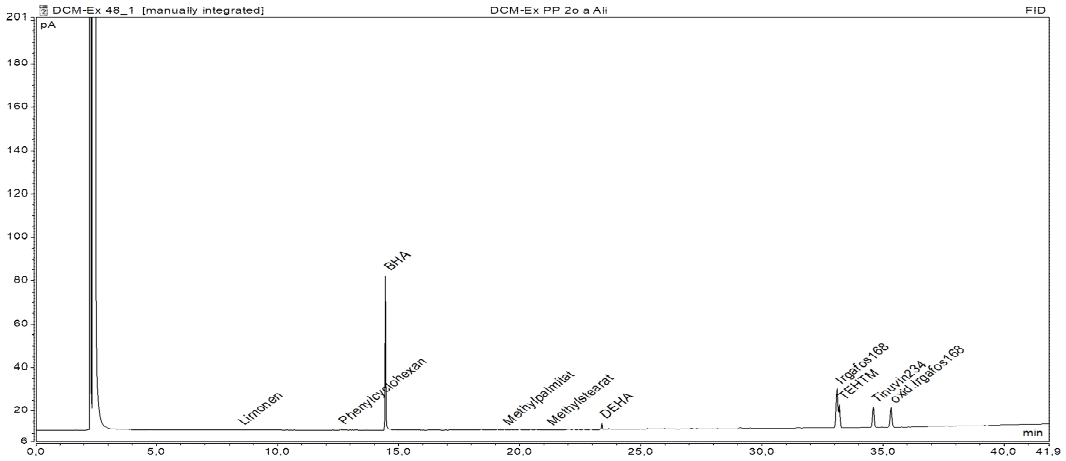


Figure 5: Gas chromatogram of the extract of sample output 2o

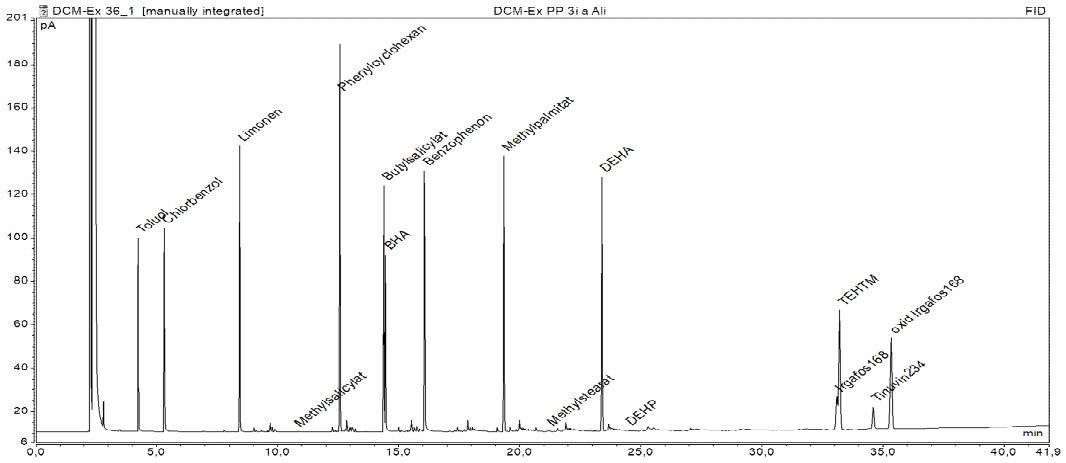


Figure 6: Gas chromatogram of the extract of sample input 3i

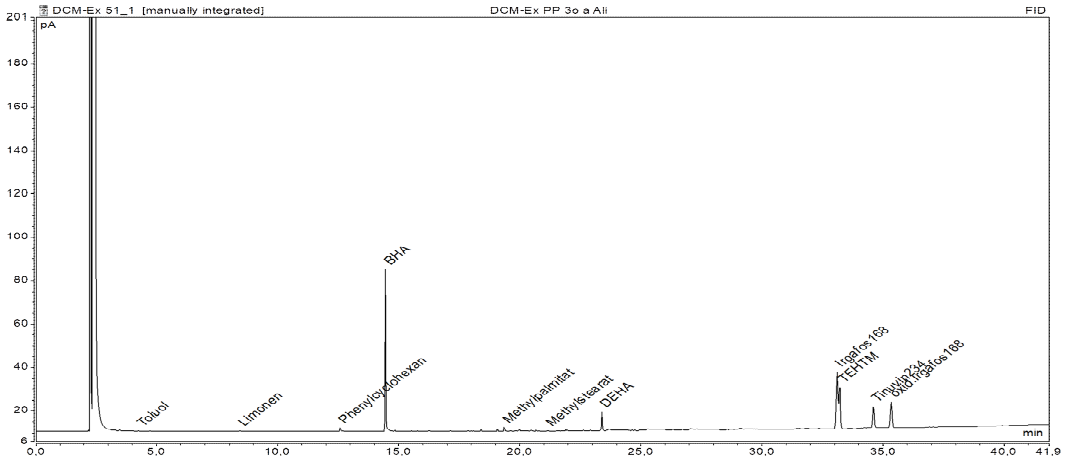


Figure 7: Gas chromatogram of the extract of sample output 3o

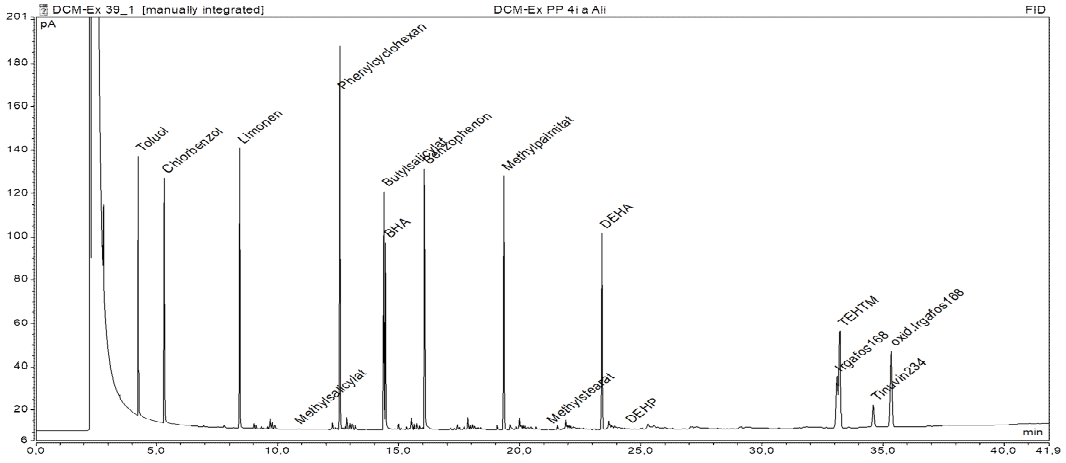


Figure 8: Gas chromatogram of the extract of sample input 4i

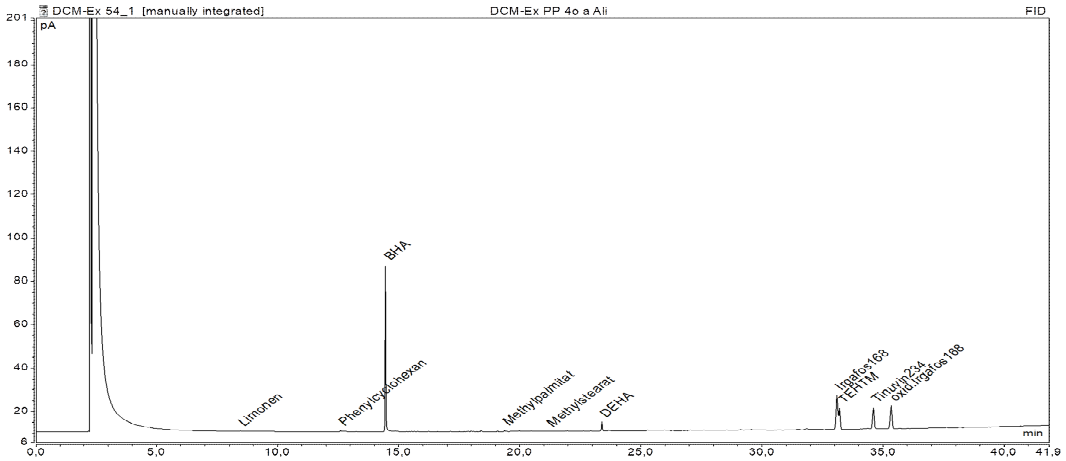


Figure 9: Gas chromatogram of the extract of sample output 4o

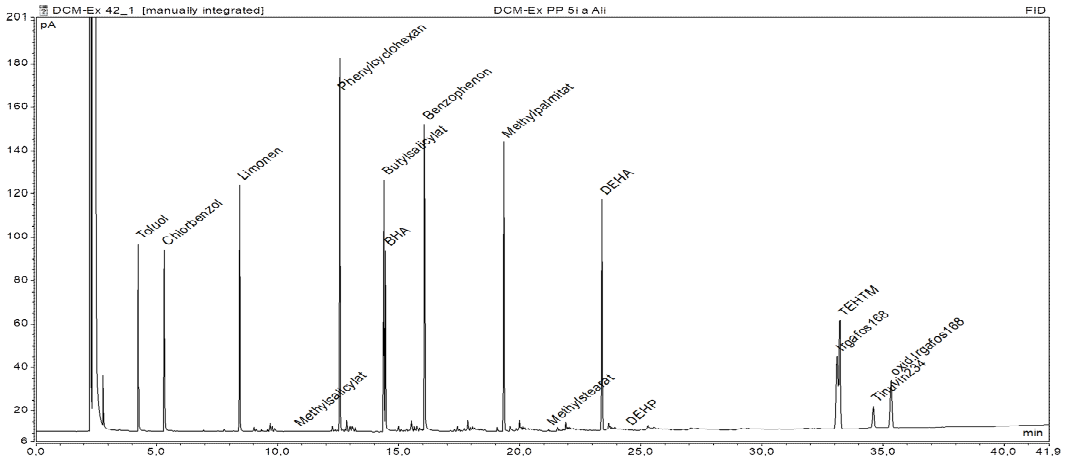


Figure 10: Gas chromatogram of the extract of sample input 5i

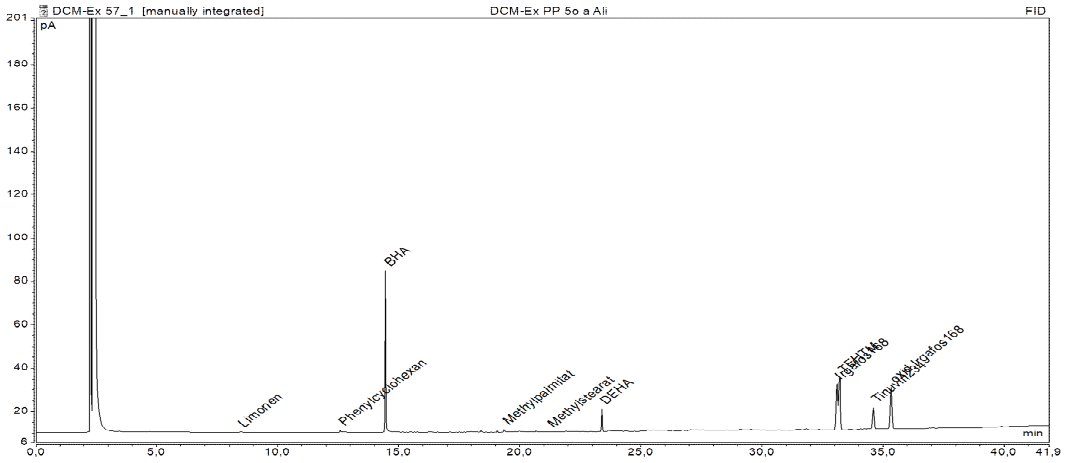


Figure 11: Gas chromatogram of the extract of sample output 5o

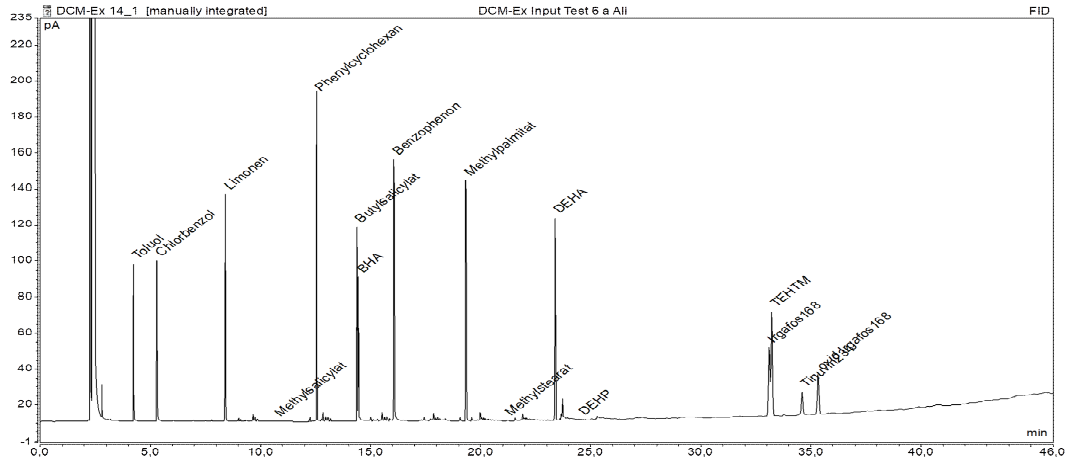


Figure 12: Gas chromatogram of the extract of sample input 6i

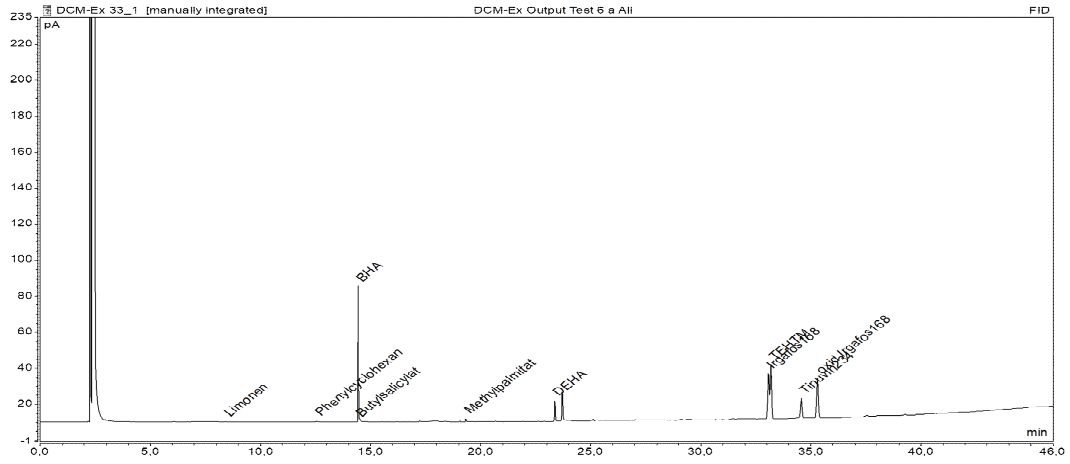


Figure 13: Gas chromatogram of the extract of sample output 6o

Table 4: Concentrations of the model contaminants in the PP material

Sample	Concentration [mg/kg, ppm] (cleaning efficiency)									
	Toluene	Chloro-benzene	Limonene	Phenyl cyclo hexane	Butyl salicylate	Benzo-phenone	Methyl palmitate	DEHA	TEHTM	Uvinul T150
1i a	506.9 ±8.5	697.1 ±10.2	658.1 ±4.7	744.5 ±1.1	717.7 ±1.2	609.3 ±2.3	705.0 ±3.8	633.8 ±4.1	693.3 ±8.5	376.8
1i b	558.1 ±7.6	772.0 ±11.6	720.0 ±7.9	799.7 ±1.0	766.7 ±0.5	655.6 ±8.9	754.5 ±2.6	680.4 ±0.7	715.6 ±10.4	646.4
1i c	549.5 ±1.6	762.5 ±1.0	714.1 ±3.4	795.6 ±2.6	764.9 ±7.6	659.7 ±4.2	746.6 ±6.9	685.5 ±4.8	722.4 ±1.6	622.5
2i a	485.5 ±1.6	728.1 ±2.2	695.4 ±4.4	767.6 ±7.4	710.9 ±6.5	604.7 ±0.9	737.2 ±0.7	691.2 ±3.0	719.2 ±4.8	662.9
2i b	480.9 ±0.3	724.9 ±2.8	698.8 ±2.8	770.4 ±2.7	704.3 ±2.2	583.0 ±10.0	713.8 ±5.2	677.7 ±2.4	721.7 ±9.7	681.1
2i c	497.6 ±27.7	744.3 ±42.6	720.7 ±33.4	792.7 ±25.3	727.0 ±20.3	606.2 ±27.9	756.0 ±18.0	726.0 ±12.8	754.0 ±15.5	632.0
3i a	492.0 ±0.7	740.0 ±0.2	727.0 ±1.7	803.4 ±1.5	729.9 ±1.7	591.7 ±0.9	741.6 ±0.6	719.4 ±2.1	758.9 ±1.6	631.7
3i b	483.1 ±6.1	724.7 ±5.0	702.9 ±7.4	798.6 ±10.6	740.7 ±12.4	582.0 ±3.3	778.8 ±9.9	776.5 ±3.8	839.9 ±4.7	727.1
3i c	490.1 ±3.4	731.4 ±1.2	686.9 ±0.4	755.7 ±2.8	696.9 ±2.8	560.0 ±10.4	695.9 ±2.6	612.4 ±0.3	643.4 ±4.5	512.1
4i a	576.5 ±44.5	799.4 ±67.6	686.0 ±56.1	733.8 ±49.3	667.6 ±39.5	554.6 ±16.3	643.4 ±22.4	595.1 ±11.2	623.1 ±4.4	479.9
4i b	558.9 ±2.7	772.9 ±1.8	675.1 ±3.6	719.6 ±2.7	653.7 ±5.0	541.1 ±5.0	628.3 ±2.8	606.2 ±3.6	634.6 ±2.5	540.6
4i c	546.7 ±0.6	757.2 ±1.0	671.8 ±3.6	736.7 ±0.5	675.1 ±2.0	568.4 ±10.0	680.3 ±3.2	634.7 ±4.2	634.7 ±2.1	500.9

Sample	Concentration [mg/kg, ppm] (cleaning efficiency)									
	Toluene	Chloro-benzene	Limonene	Phenyl cyclo hexane	Butyl salicylate	Benzo-phenone	Methyl palmitate	DEHA	TEHTM	Uvinul T150
5i a	490.0 ±2.4	671.2 ±5.8	644.4 ±9.8	763.3 ±8.4	739.4 ±6.2	659.3 ±5.8	748.4 ±1.1	682.2 ±2.0	700.2 ±5.5	591.8
5i b	482.7 ±7.0	663.6 ±12.2	624.6 ±7.7	716.3 ±10.9	683.1 ±10.5	606.9 ±7.9	678.0 ±5.5	632.3 ±1.2	655.2 ±4.5	632.8
5i c	485.7 ±1.6	668.9 ±2.6	649.9 ±2.6	779.3 ±4.1	764.1 ±1.9	687.5 ±12.1	791.6 ±3.8	754.1 ±0.8	766.8 ±12.1	677.1
6i a	486.1 ±1.0	690.5 ±3.1	673.1 ±1.7	789.8 ±8.1	690.2 ±3.2	700.7 ±4.1	738.5 ±5.8	739.7 ±5.1	809.3 ±14.7	675.5
6i b	487.5 ±8.3	692.8 ±8.6	678.2 ±9.6	803.4 ±2.4	716.8 ±3.2	699.0 ±3.0	763.5 ±0.6	733.2 ±1.4	767.1 ±6.8	595.7
6i c	499.1 ±8.2	710.5 ±10.0	687.1 ±9.7	803.3 ±9.7	725.8 ±7.9	696.8 ±10.5	758.8 ±9.2	754.2 ±6.5	819.6 ±3.1	728.6
mean input	**508.7 ±32.5**	**725.1 ±39.2**	**684.1 ±28.1**	**770.8 ±30.1**	**715.3 ±33.4**	**620.4 ±53.5**	**725.6 ±45.4**	**685.3 ±56.2**	**721.1 ±66.2**	**606.4 ±92.4**
1o a	0.7 ±0.1	<0.7	3.4 ±0.2	15.5 ±1.9	<2.9	4.4 ±0.3	23.7 ±0.1	83.4 ±2.1	273.3 ±20.7	508.7
1o b	1.1 ±0.1	<0.7	3.9 ±0.1	14.1 ±0.8	<2.9	4.8 ±0.1	25.4 ±0.1	88.8 ±0.7	285.2 ±0.9	394.0
1o c	1.2 ±0.2	<0.7	4.0 ±0.2	15.1 ±0.9	<2.9	5.3 ±0.3	28.5 ±0.4	95.7 ±1.2	292.3 ±0.5	396.9
mean output 1o	**1.0 ±0.3 (99.8%)**	**<0.7 (>99.9%)**	**3.8 ±0.3 (99.4%)**	**14.9 ±0.7 (98.1%)**	**<2.9 (>99.6%)**	**4.8 ±0.5 (99.2%)**	**25.9 ±2.4 (96.4%)**	**89.3 ±6.2 (87.0%)**	**283.6 ±9.6 (60.7%)**	**433.2 ±65.4 (34.4%)**

Sample	Concentration [mg/kg, ppm] (cleaning efficiency)									
	Toluene	Chloro-benzene	Limonene	Phenyl cyclo hexane	Butyl salicylate	Benzo-phenone	Methyl palmitate	DEHA	TEHTM	Uvinul T150
2o a	<0.1	<0.7	1.2 ±0.2	3.7 ±0.9	<2.9	<0.7	3.2 ±0.1	23.3 ±1.6	144.8 ±1.9	360.6
2o b	<0.1	<0.7	1.2 ±0.2	4.4 ±0.4	<2.9	<0.7	3.6 ±0.3	25.2 ±0.8	145.1 ±3.1	420.1
2o c	<0.1	<0.7	1.1 ±0.1	3.3 ±0.2	<2.9	<0.7	3.2 ±0.3	22.8 ±1.5	142.4 ±0.8	382.3
mean output 2o	**<0.1 (<99.9%)**	**<0.7 (>99.9%)**	**1.2 ±0.1 (99.8%)**	**3.8 ±0.6 (99.5%)**	**<2.9 (>99.6%)**	**<0.7 (99.9%)**	**3.3 ±0.2 (99.5%)**	**23.8 ±1.3 (96.7%)**	**144.1 ±1.5 (80.0%)**	**387.7 ±30.1 (41.3%)**
3o a	0.3 ±0.2	<0.7	2.9 ±0.2	10.1 ±0.1	<2.9	<0.7	13.1 ±0.3	59.1 ±1.5	262.8 ±4.7	462.7
3o b	0.2 ±0.1	<0.7	2.6 ±0.1	10.5 ±1.2	<2.9	<0.7	12.4 ±0.1	54.8 ±1.5	255.4 ±2.0	501.8
3o c	0.2 ±0.1	<0.7	3.0 ±0.3	12.0 ±0.7	<2.9	<0.7	13.7 ±1.4	59.2 ±5.6	259.2 ±18.5	471.6
mean output 3o	**0.2 ±0.1 (>99.9%)**	**<0.7 (>99.9%)**	**2.8 ±0.2 (99.6%)**	**10.9 ±1.0 (98.5%)**	**<2.9 (>99.6%)**	**<0.7 (99.9%)**	**13.1 ±0.7 (98.2%)**	**57.7 ±2.5 (92.1%)**	**259.1 ±3.7 (64.1%)**	**478.7 ±20.5 (27.5%)**
4o a	<0.1	<0.7	1.0 ±0.2	4.5 ±0.4	<2.9	<0.7	5.9 ±0.1	27.8 ±0.8	140.2 ±1.5	493.7
4o b	<0.1	<0.7	1.1 ±0.3	4.4 ±0.1	<2.9	<0.7	5.8 ±0.1	28.7 ±0.8	144.9 ±1.5	492.1
4o c	<0.1	<0.7	1.3 ±0.1	3.6 ±0.9	<2.9	<0.7	6.0 ±0.4	28.6 ±0.3	147.5 ±5.6	524.3
mean output 4o	**<0.1 (<99.9%)**	**<0.7 (>99.9%)**	**1.1 ±0.2 (99.8%)**	**4.2 ±0.5 (99.4%)**	**<2.9 (>99.6%)**	**<0.7 (99.9%)**	**5.9 ±0.1 (99.2%)**	**28.4 ±0.5 (96.1%)**	**144.2 ±3.7 (80.0%)**	**503.4 ±18.1 (23.7%)**

Sample	Concentration [mg/kg, ppm] (cleaning efficiency)									
	Toluene	Chloro-benzene	Limonene	Phenyl cyclo hexane	Butyl salicylate	Benzo-phenone	Methyl palmitate	DEHA	TEHTM	Uvinul T150
5o a	<0.1	<0.7	2.1 ±0.2	6.8 ±0.6	<2.9	<0.7	10.7 ±0.1	70.2 ±2.0	342.4 ±7.5	402.7
5o b	<0.1	<0.7	2.2 ±0.1	6.7 ±2.4	<2.9	<0.7	11.5 ±0.1	70.0 ±0.4	347.3 ±2.7	381.4
5o c	<0.1	<0.7	1.7 ±0.1	8.3 ±3.0	<2.9	<0.7	11.3 ±0.1	69.4 ±1.5	352.7 ±3.3	404.3
mean output 5o	**<0.1 (<99.9%)**	**<0.7 (>99.9%)**	**2.0 ±0.3 (99.7%)**	**7.3 ±0.9 (99.0%)**	**<2.9 (>99.6%)**	**<0.7 (99.9%)**	**11.2 0.4± (98.4%)**	**69.9 ±0.4 (90.3%)**	**347.5 ±5.2 (51.8%)**	**396.1 ±12.8 (40.0%)**
6o a	<0.1	<0.3	1.0 ±0.1	4.4 ±0.2	<3.6	<0.7	12.6 ±0.1	74.3 ±1.1	430.7 ±3.9	438.3
6o b	<0.1	<0.3	1.3 ±0.1	5.1 ±0.1	<3.6	<0.7	10.4 ±0.1	62.3 ±0.5	374.6 ±4.5	512.1
6o c	<0.1	<0.3	1.3 ±0.1	5.3 ±0.1	<3.6	<0.7	12.2 ±0.3	68.9 ±0.5	396.5 ±14.8	519.6
mean output 6o	**<0.1 (>99.9%)**	**<0.3 (>99.9%)**	**1.2 ±0.2 (99.8%)**	**4.9 ±0.5 (99.3%)**	**<3.6 (99.5%)**	**<0.7 (99.9%)**	**11.7 ±1.2 (98.4%)**	**68.5 ±6.0 (90.6%)**	**400.6 ±28.3 (44.4%)**	**490.0 ±44.9 (25.8%)**

7 Food law compliance evaluation

Diffusion models provide a scientific tool for establishing a correlation between the migration into contact media and the corresponding concentration $C_{P,0}$ of a migrant (surrogates) in the PP packaging or pellets as the final product of the super-clean recycling process. In this way maximum surrogate concentrations in PP can be established which would not lead to exceeding a certain migration value of interest.

7.1 Closures for mineral water bottles

Evaluation criteria for mineral water closures with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing closures for mineral water in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.019 µg/kg (1300 ml consumption of mineral water for an infant with 5 kg bw, overestimative factor of 2 similar to HDPE). This exposure scenario is applied by EFSA for infants and for mineral water. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume bottle and with an inner surface area of the closure of 3.2 cm^2 (data provided by the customer). The thickness of the closure was assumed to 1250 µm. This maximum concentration corresponds to the assumed migration limit of 0.019 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 365 d at 25 °C with initial contamination levels of 3 mg/kg (similar to PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 14 to Figure 16.

Based on the challenge test results a recyclate content of 100% (initial contamination level 1 mg/kg) , 62.0% (initial contamination level 1 mg/kg) and 20.7% (initial contamination level 3 mg/kg) is possible.

[1] Scientific Guidance on the criteria for the evaluation and on the preparation of applications for the safety assessment of post-consumer mechanical PET recycling processes intended to be used for manufacture of materials and articles in contact with food, EFSA Journal 2024, 22, 8879

[2] F. Welle, Recycling of post-consumer HDPE bottle caps into new caps for food contact, Recycling, 2025, 10(6), 197; https://doi.org/10.3390/recycling10060197

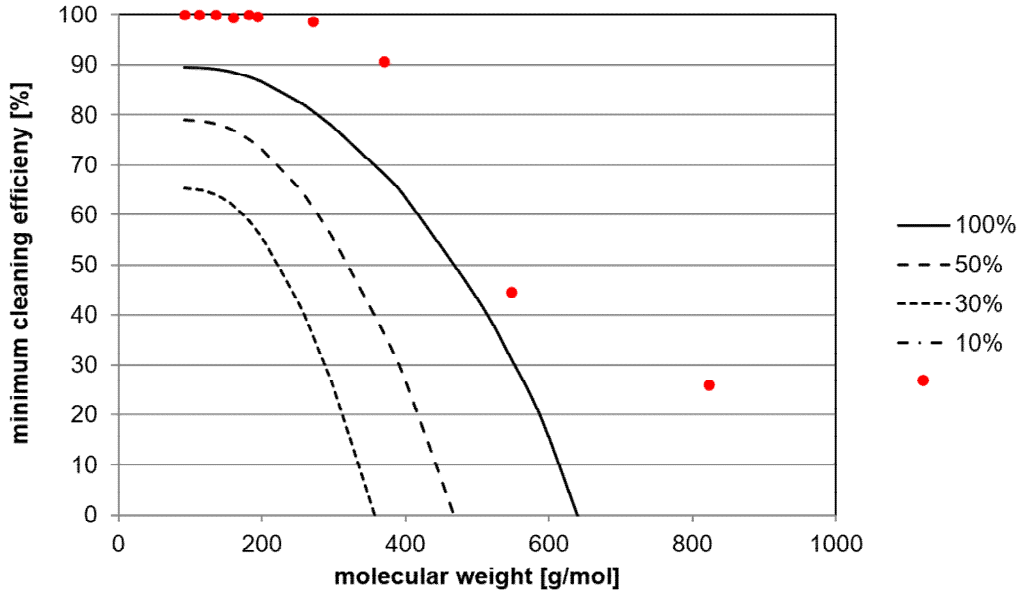


Figure 14: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for mineral water bottles, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

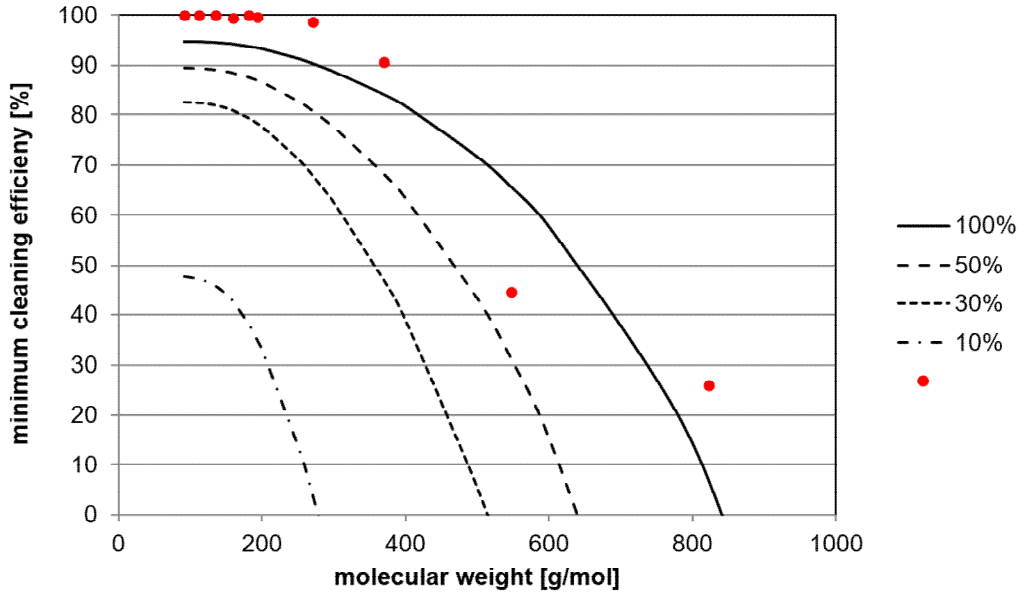


Figure 15: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for mineral water bottles, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

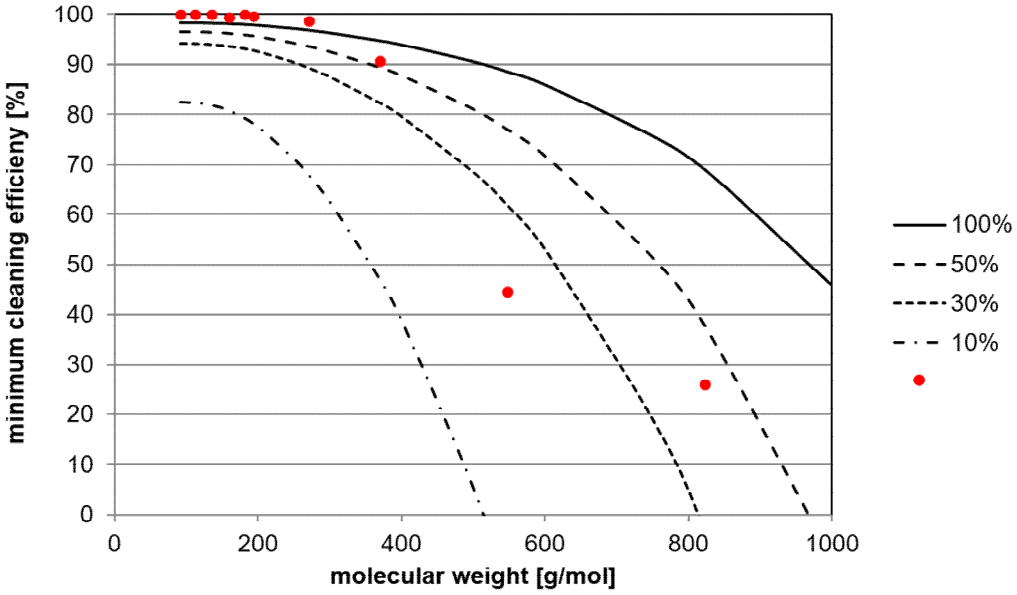


Figure 16: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for mineral water bottles, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.2 Closures for softdrink bottles

Evaluation criteria for softdrink closures with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing closures for softdrink bottles in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.0626 µg/kg (960 ml consumption of softdrink for a toddler with 12 kg bw, overestimative factor of 2 similar to HDPE). Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume bottle and with an inner surface area of the closure of 3.2 cm^2 (data provided by the customer). The thickness of the closure was assumed to 1250 µm. This maximum concentration corresponds to the assumed migration limit of 0.0626 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 365 d at 25 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 17 to Figure 19.

Based on the challenge test results a recyclate content of 100% (initial contamination levels 0.5 mg/kg and 1 mg/kg) and 67.4% initial contamination level 3 mg/kg) is possible.

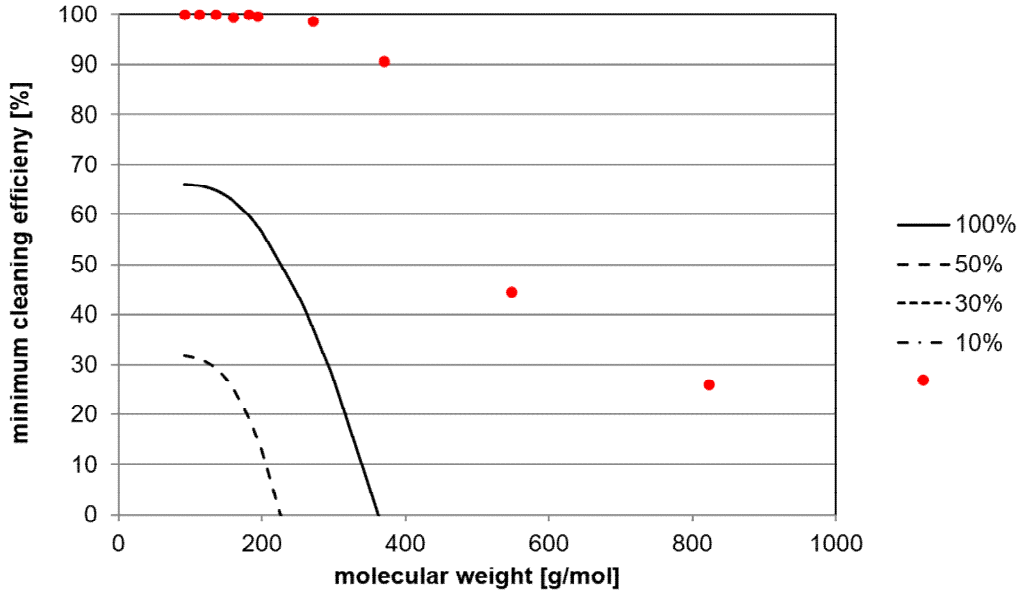


Figure 17: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for softdrink bottles, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

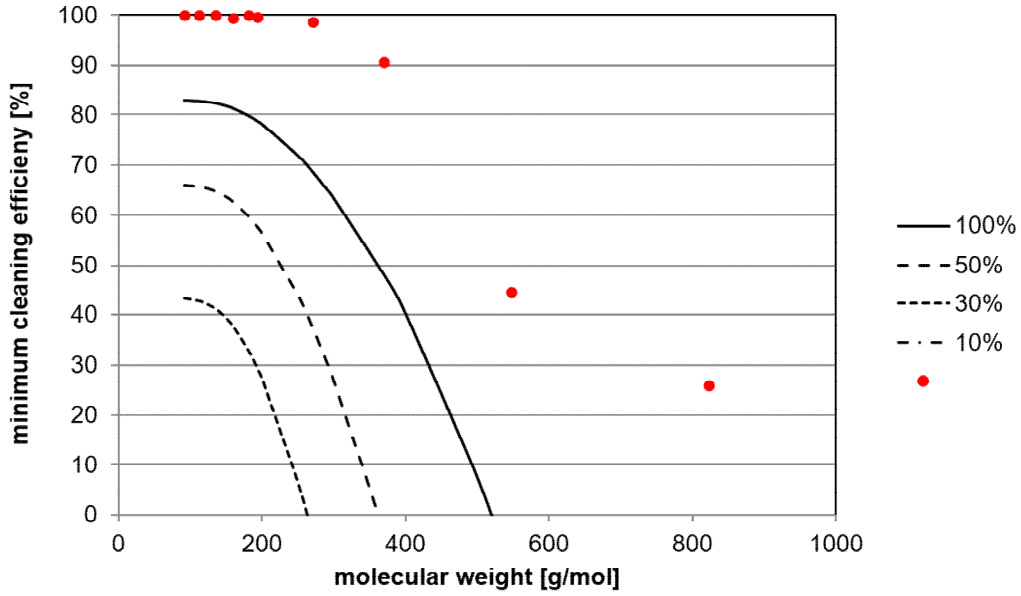


Figure 18: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for softdrink bottles, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

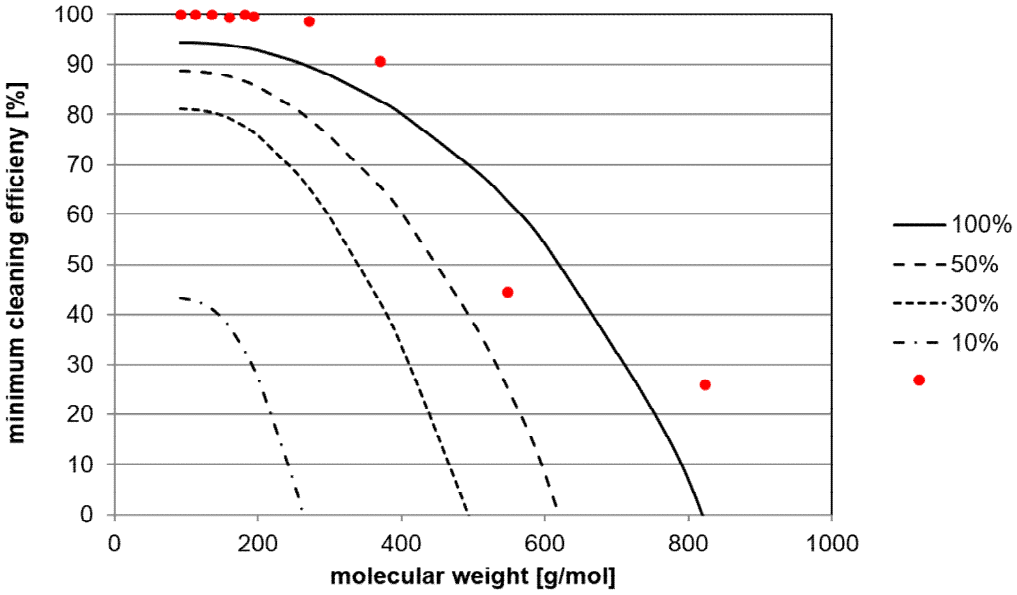


Figure 19: Cleaning efficiencies of surrogates in the challenge test (sample 6o), closures for softdrink bottles, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.3 Packaging for solid and liquid food, 40 days at 6 °C (960 ml)

Evaluation criteria for packaging for solid and liquid food with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing packaging in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.0626 µg/kg (960 ml consumption of food for a toddler with 12 kg bw, overestimative factor of 2 similar to HDPE). Using migration models, the maximum concentration of substances of different molecular weights can be calculated using A_P' = 13.1 and τ = 1577 K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.0626 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food}$ = 1) at conditions of 40 days at 6 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 20 to Figure 22.

Based on the challenge test results a recyclate content of 25.8% ((initial contamination level 0.5 mg/kg), 12.9% (initial contamination level 1 mg/kg) and 4.3% (initial contamination level 3 mg/kg) is possible.

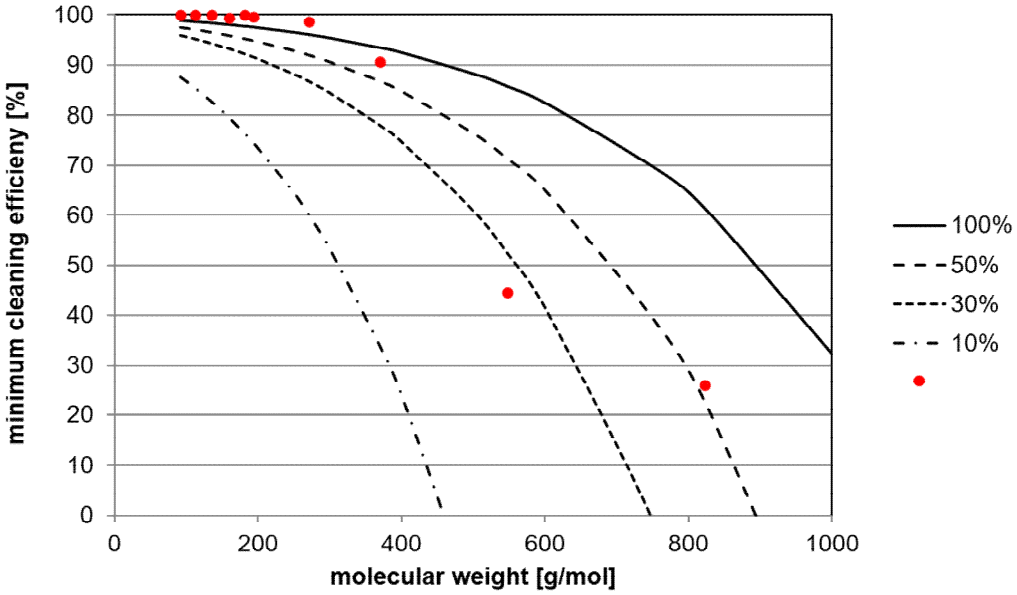


Figure 20: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 960 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

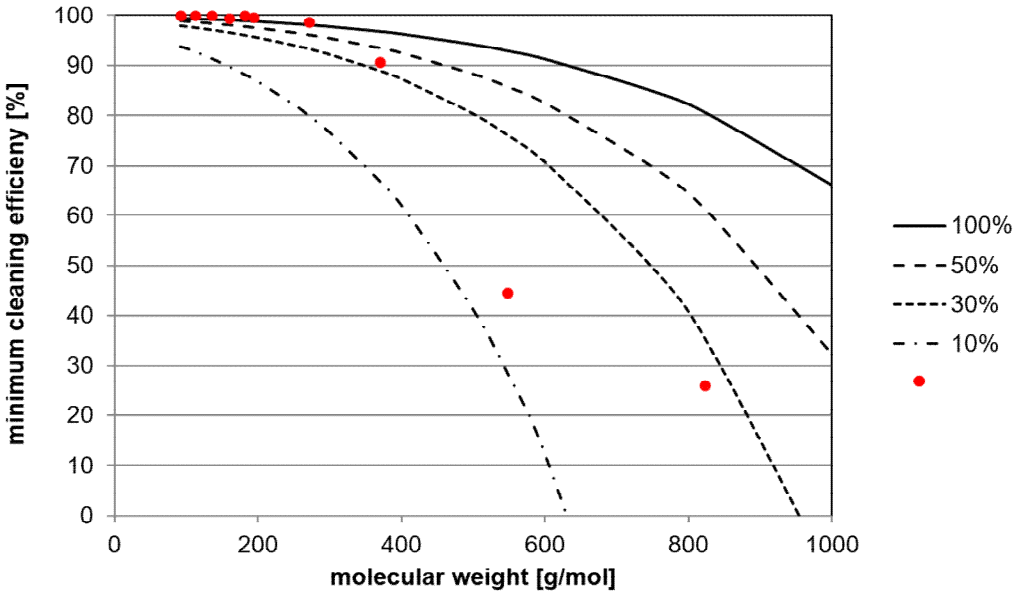


Figure 21: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 960 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

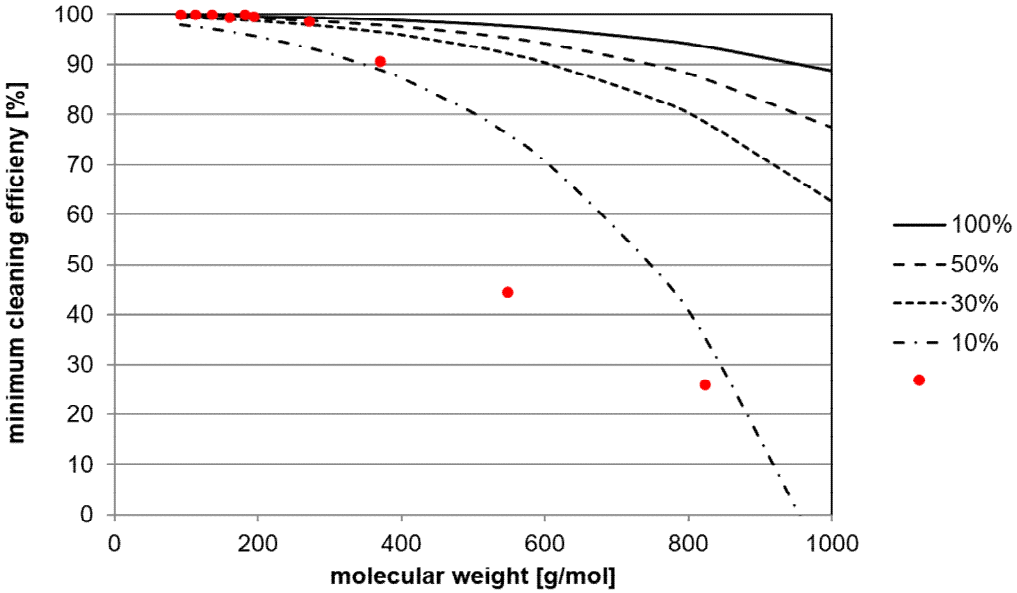


Figure 22: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C, with 960 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.4 Packaging for solid and liquid food, 40 days at 6 °C (500 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 500 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.120 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.120 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 40 days at 6 °C with initial contamination levels of 3 mg/kg (similar for PET) 1 mg/kg, and 0.5 mg/kg. The results are given in Figure 23 to Figure 25.

Based on the challenge test results a recyclate content of 49.7% (initial contamination level 0.5 mg/kg), 24.8% (initial contamination level 1 mg/kg) and 8.3% (initial contamination level 3 mg/kg) is possible.

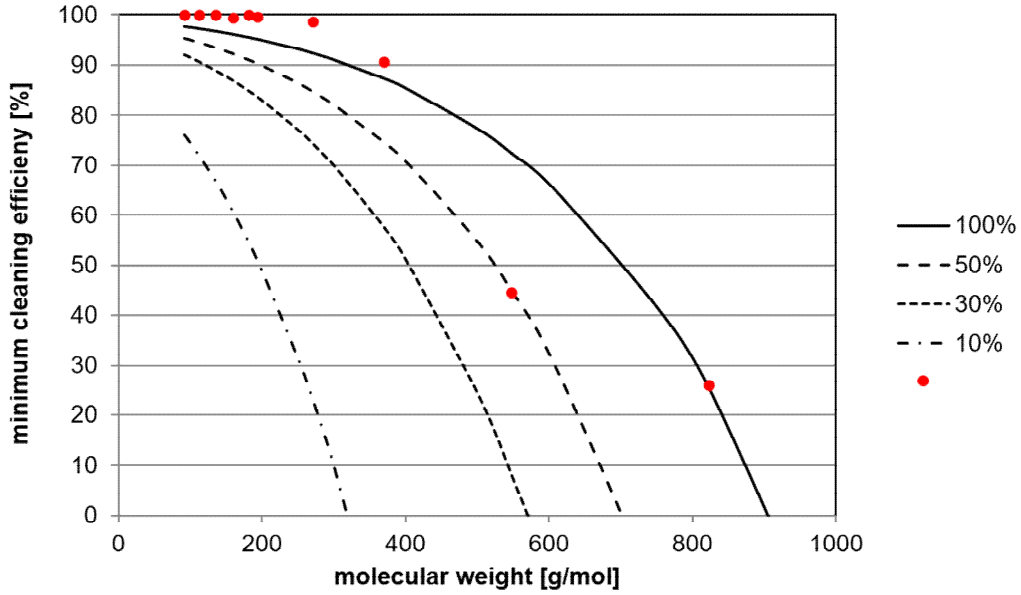


Figure 23: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 500 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

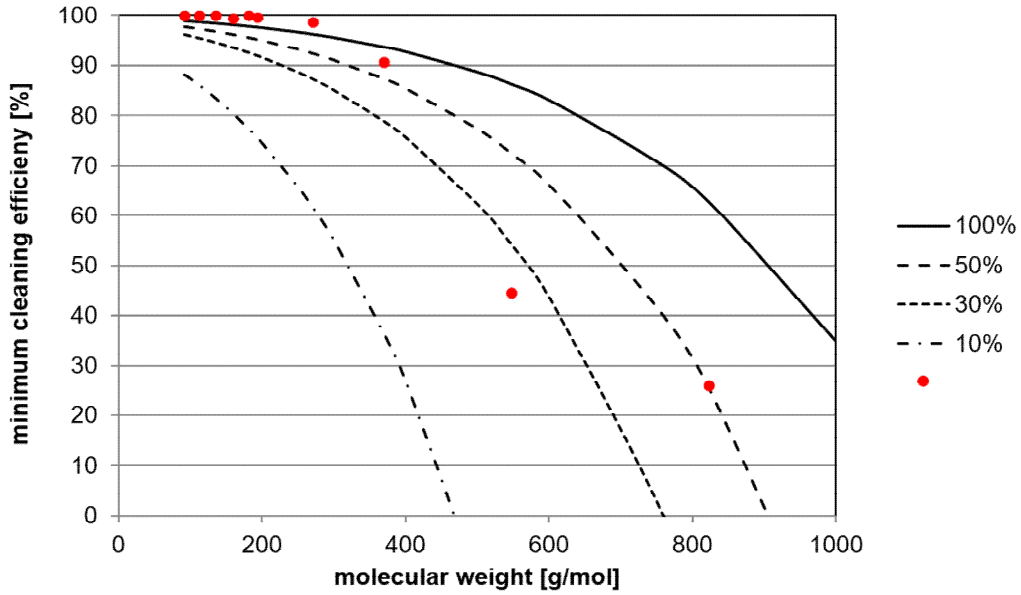


Figure 24: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 500 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

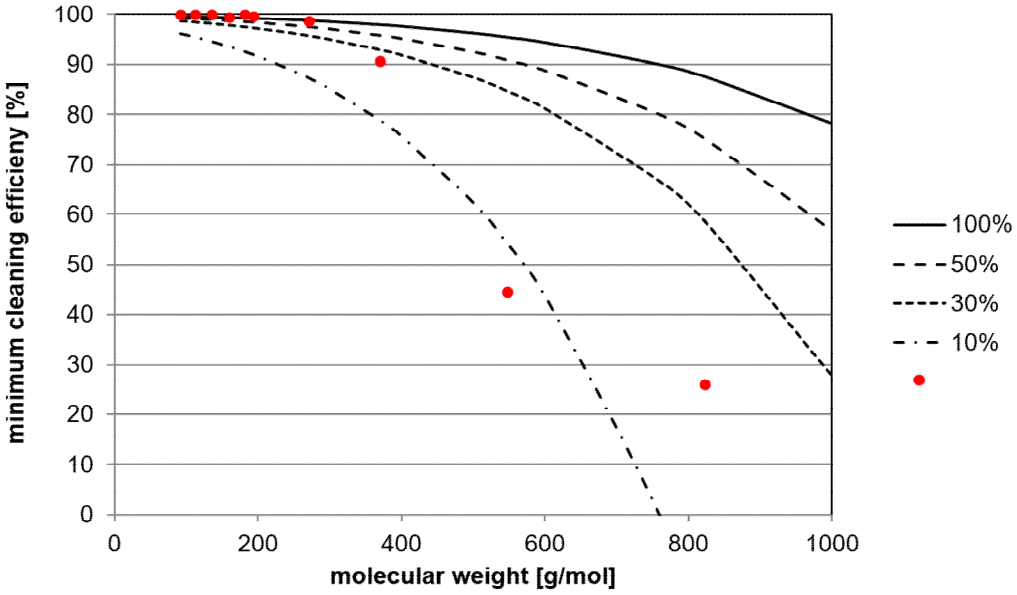


Figure 25: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C, with 500 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.5 Packaging for solid and liquid food, 40 days at 6 °C (350 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 350 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.171 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.171 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 40 days at 6 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 26 to Figure 28.

Based on the challenge test results a recyclate content of 70.4% (initial contamination level 0.5 mg/kg), 35.2% (initial contamination level 1 mg/kg) and 11.7% (initial contamination level 3 mg/kg) is possible.

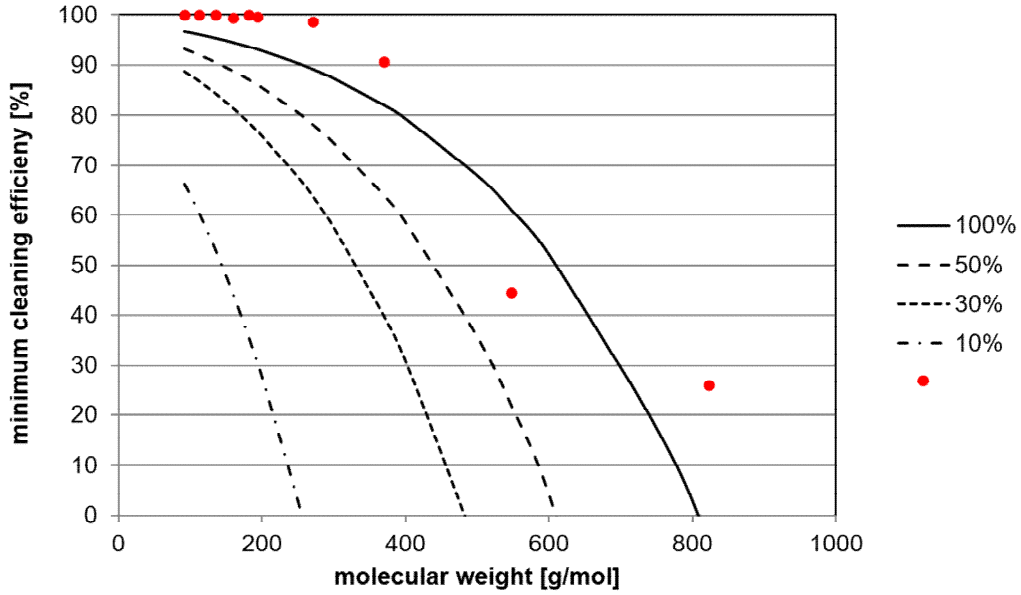


Figure 26: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 350 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

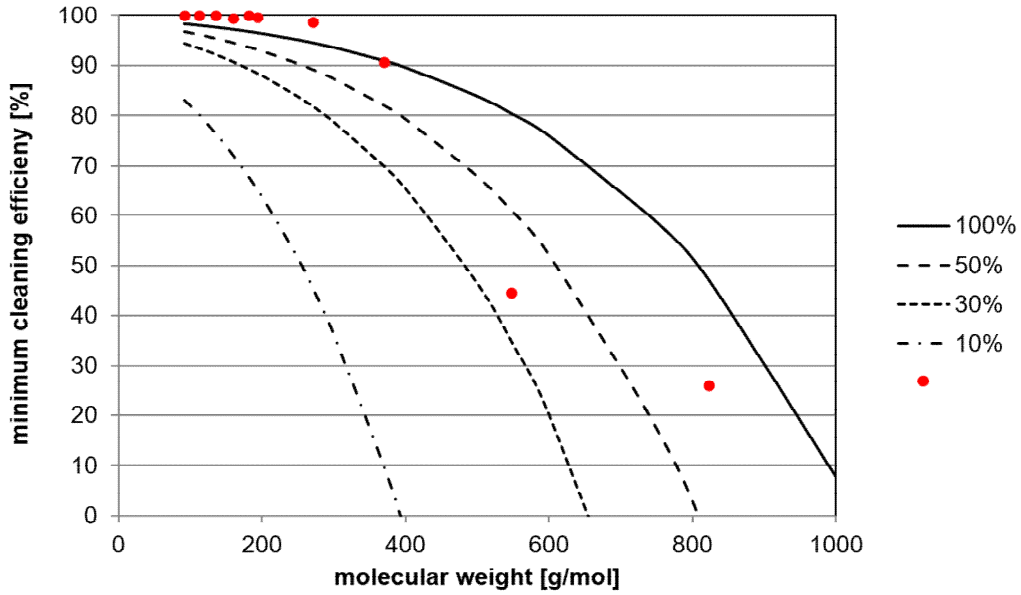


Figure 27: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 350 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

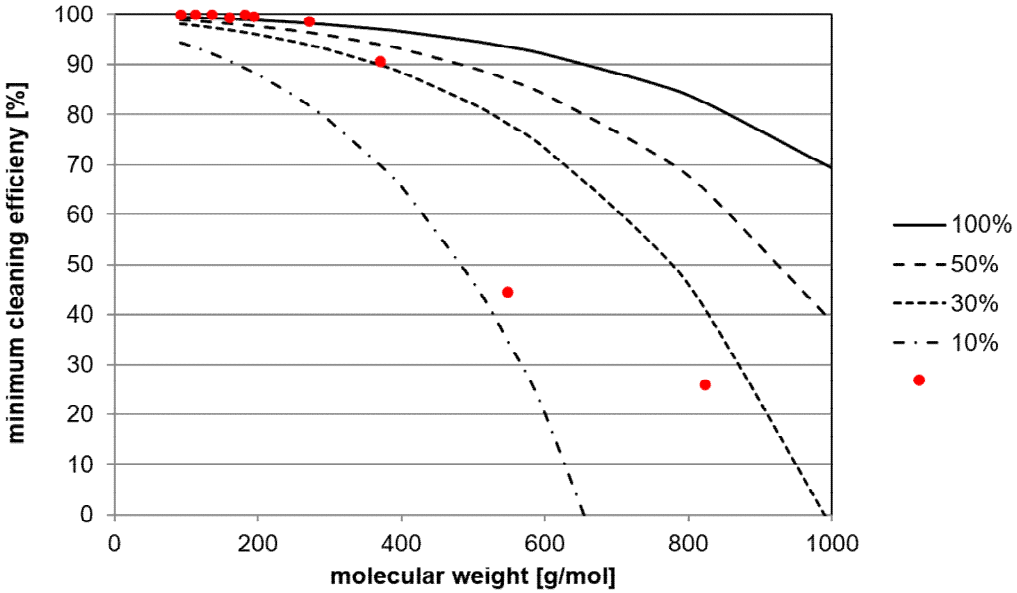


Figure 28: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C, with 350 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.6 Packaging for solid and liquid food, 40 days at 6 °C (250 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 250 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.240 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.240 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 40 days at 6 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 29 to Figure 31.

Based on the challenge test results a recyclate content of 98.8% (initial contamination level 0.5 mg/kg), 49.4% (initial contamination level 1 mg/kg) and 16.5% (initial contamination level 3 mg/kg) is possible.

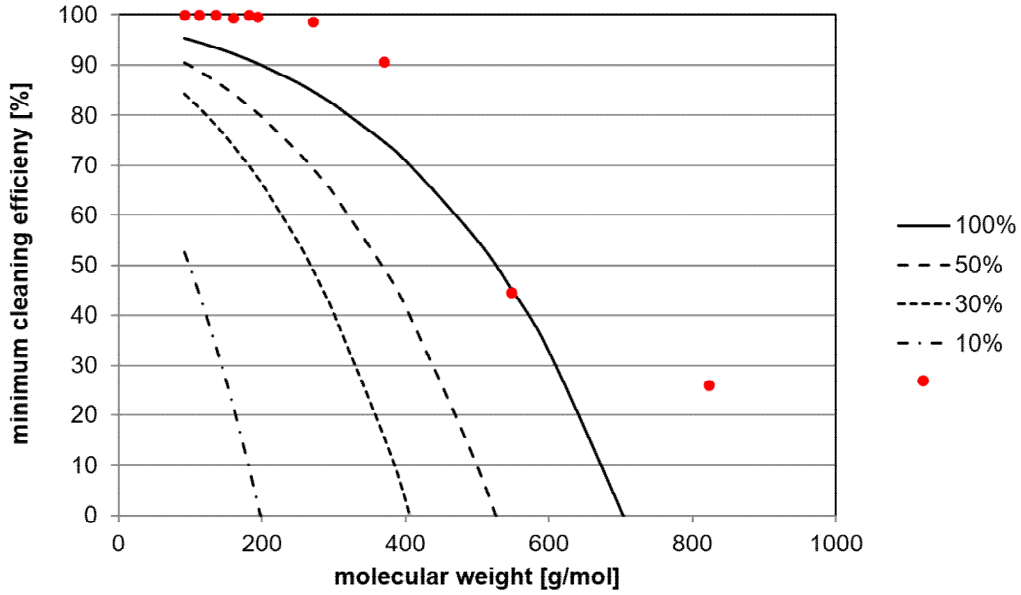


Figure 29: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 250 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

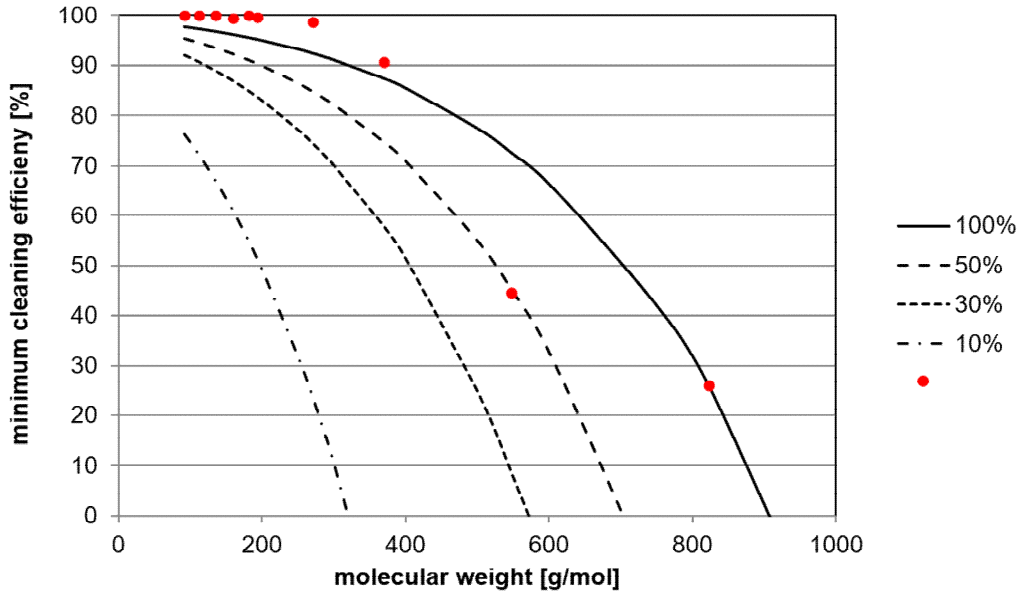


Figure 30: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C with 250 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

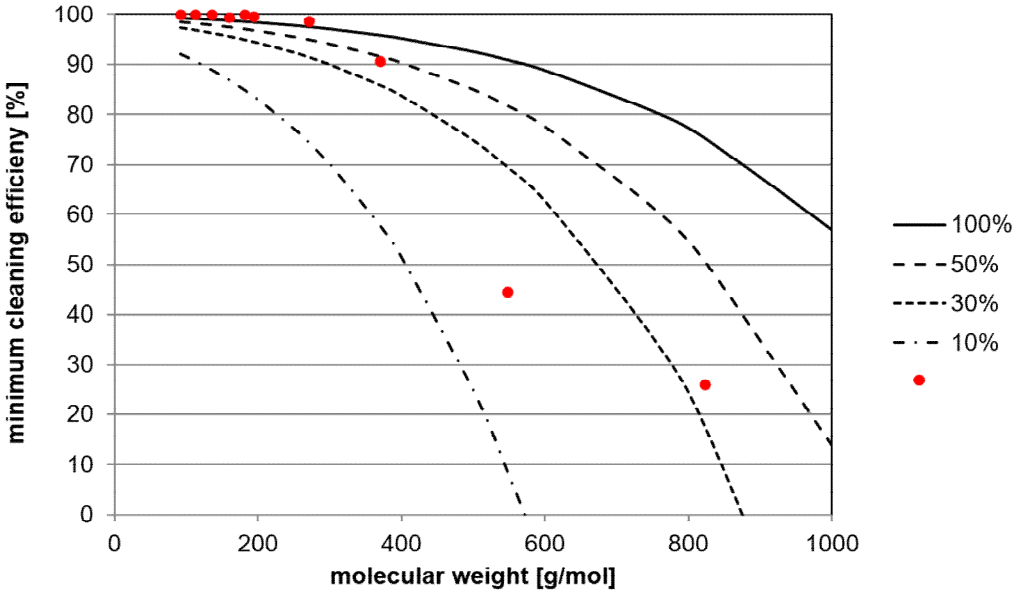


Figure 31: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 40 days at 6 °C, with 250 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.7 Packaging for solid and liquid food, 10 days at 20 °C (960 ml)

Evaluation criteria for packaging for solid and liquid food with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing packaging in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.0626 µg/kg (960 ml consumption of food for a toddler with 12 kg bw, overestimative factor of 2 similar to HDPE). Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.0626 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 20 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 32 to Figure 34.

Based on the challenge test results a recyclate content of 18.4% (initial contamination level 0.5 mg/kg), 9.2% (initial contamination level 1 mg/kg) and 3.1% (initial contamination level 3 mg/kg) is possible.

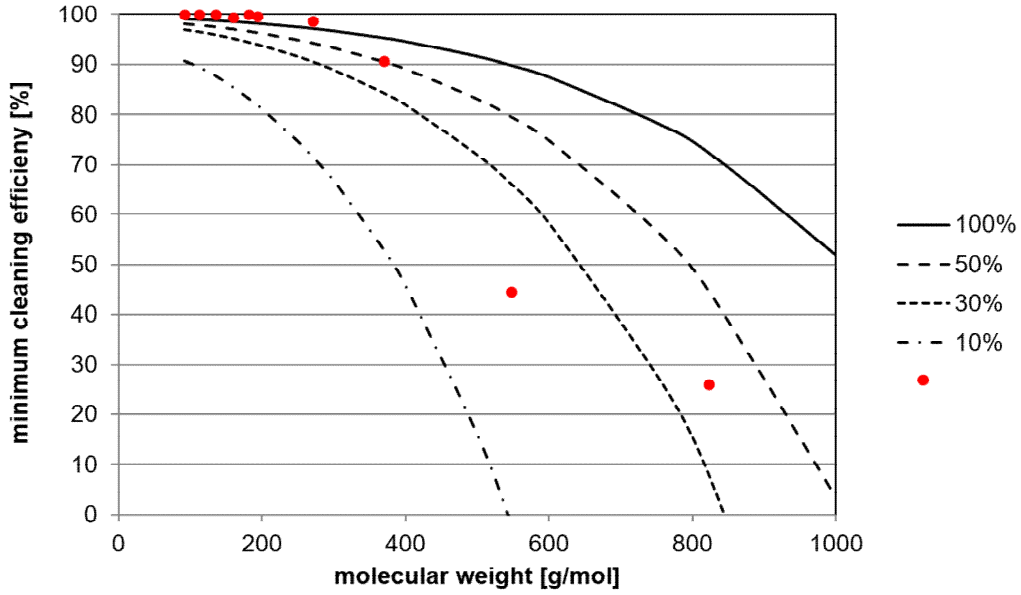


Figure 32: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 960 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

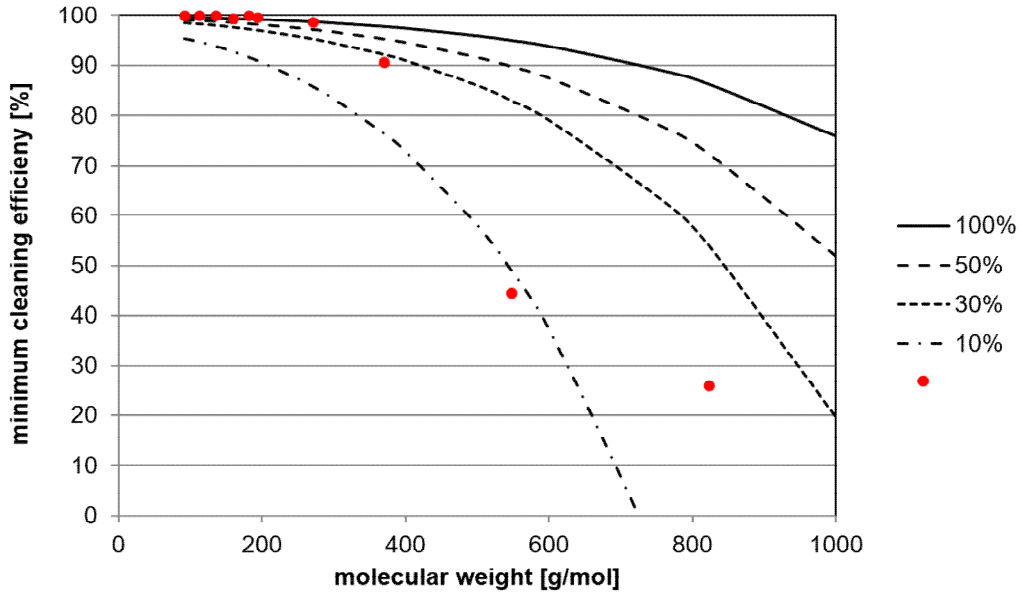


Figure 33: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 960 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

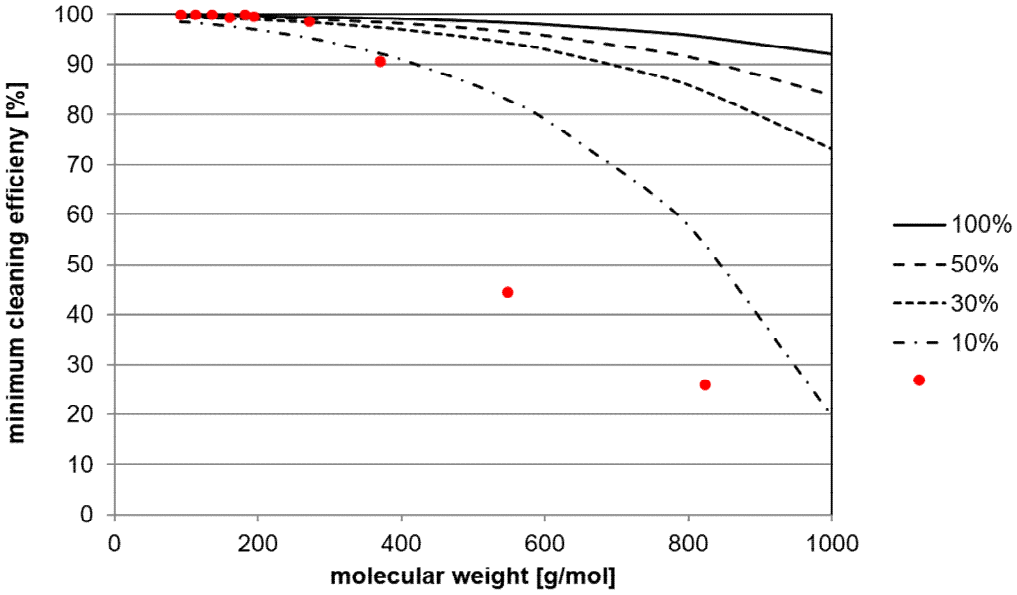


Figure 34: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 960 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.8 Packaging for solid and liquid food, 10 days at 20 °C (500 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 500 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.120 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.171 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 20 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 35 to Figure 37.

Based on the challenge test results a recyclate content of 35.3% (initial contamination level 0.5 mg/kg), 17.6% (initial contamination level 1 mg/kg) and 5.9% (initial contamination level 3 mg/kg) is possible.

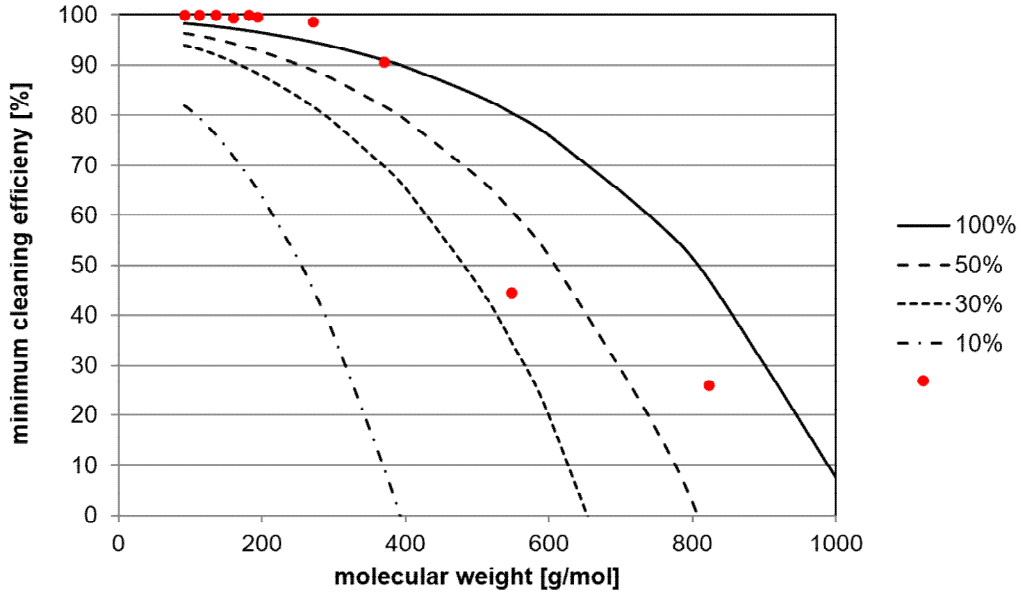


Figure 35: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 500 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

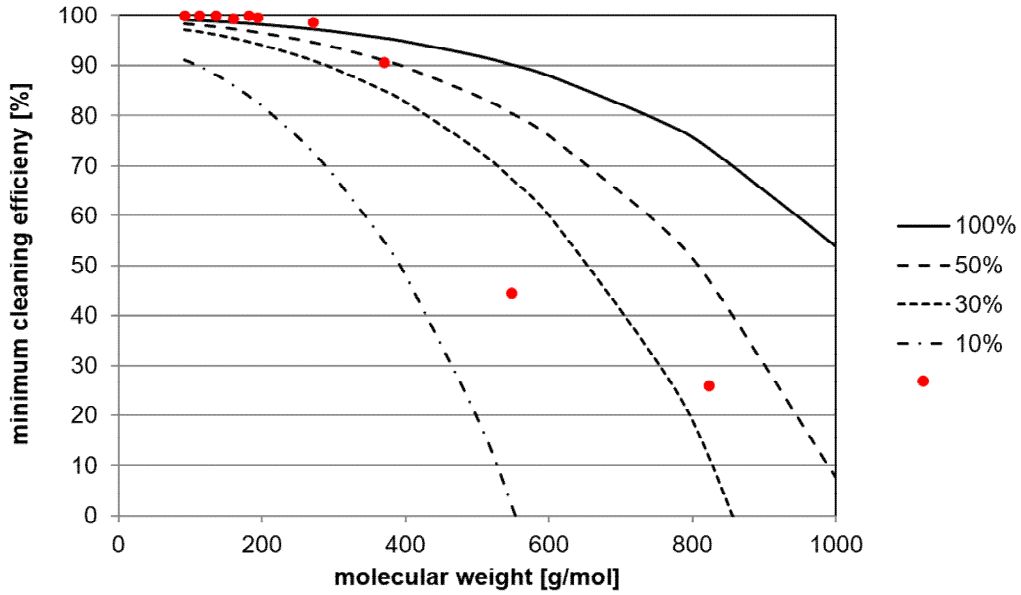


Figure 36: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 500 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

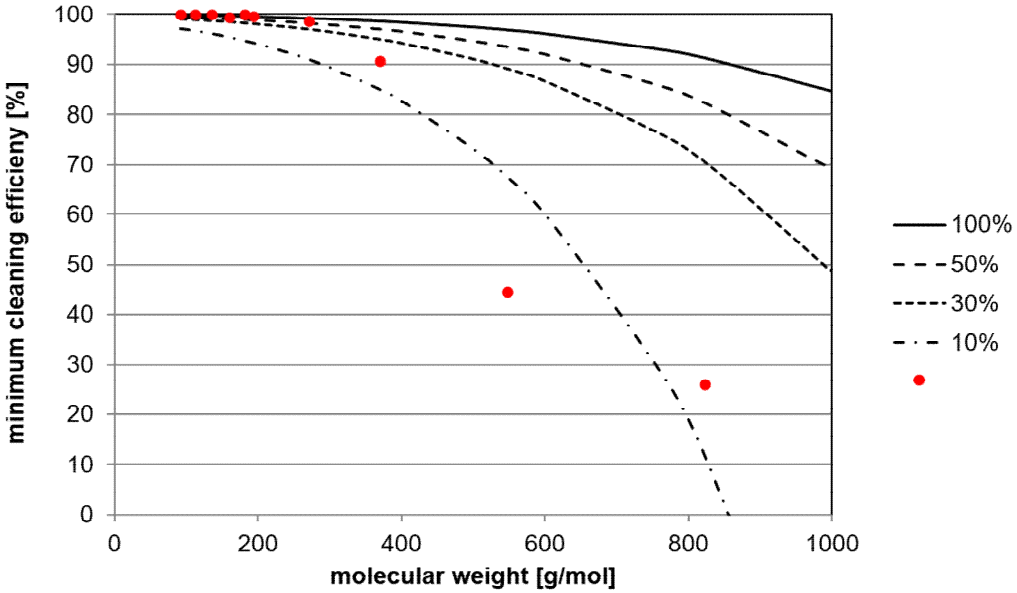


Figure 37: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 500 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.9 Packaging for solid and liquid food, 10 days at 20 °C (350 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 350 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.171 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.171 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 20 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 38 to Figure 40.

Based on the challenge test results a recyclate content of 50.3% (initial contamination level 0.5 mg/kg), 25.1% (initial contamination level 1 mg/kg) and 8.4% (initial contamination level 3 mg/kg) is possible.

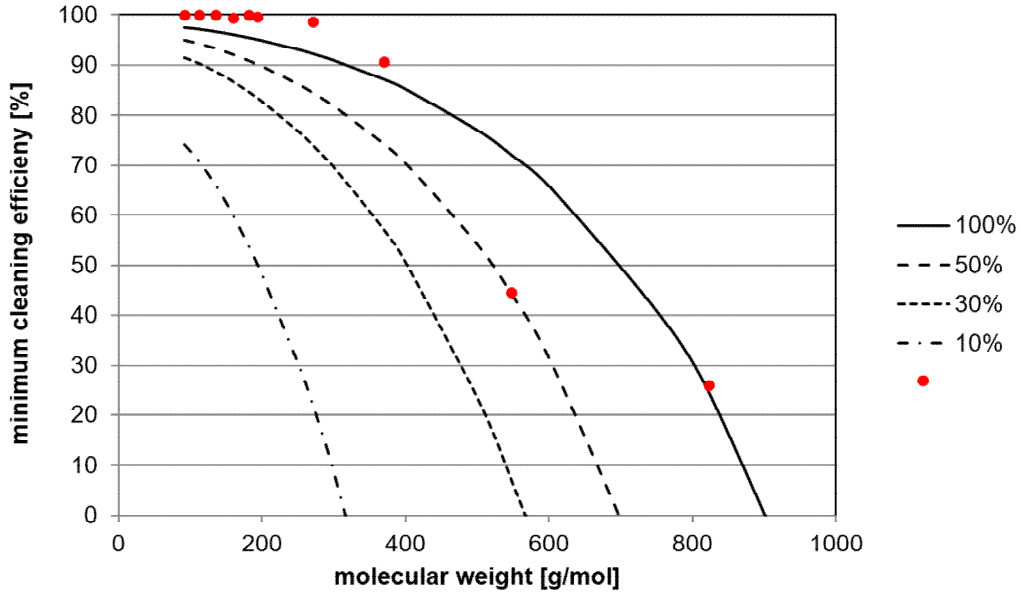


Figure 38: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 350 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

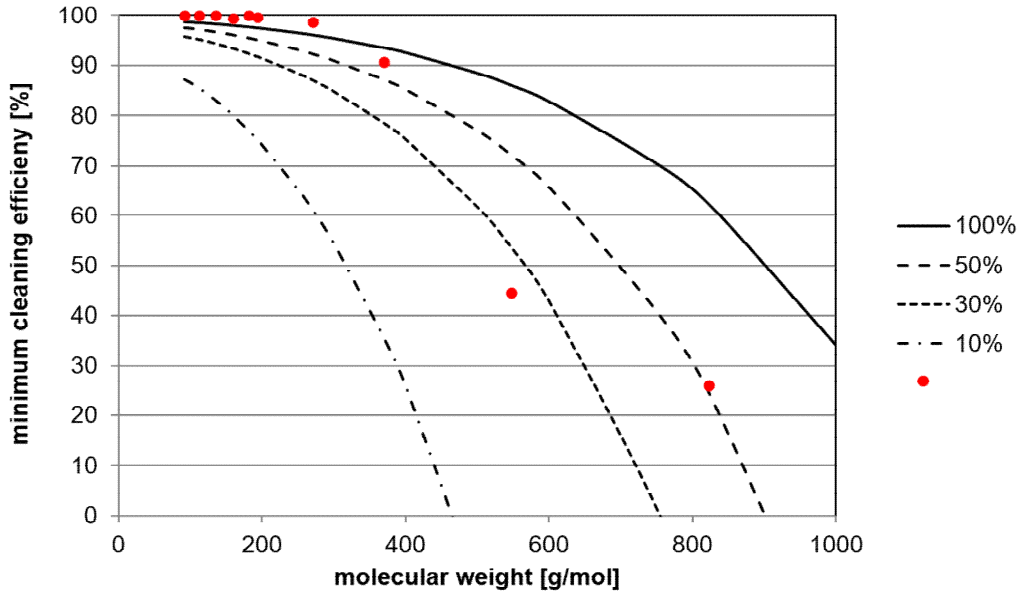


Figure 39: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 350 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

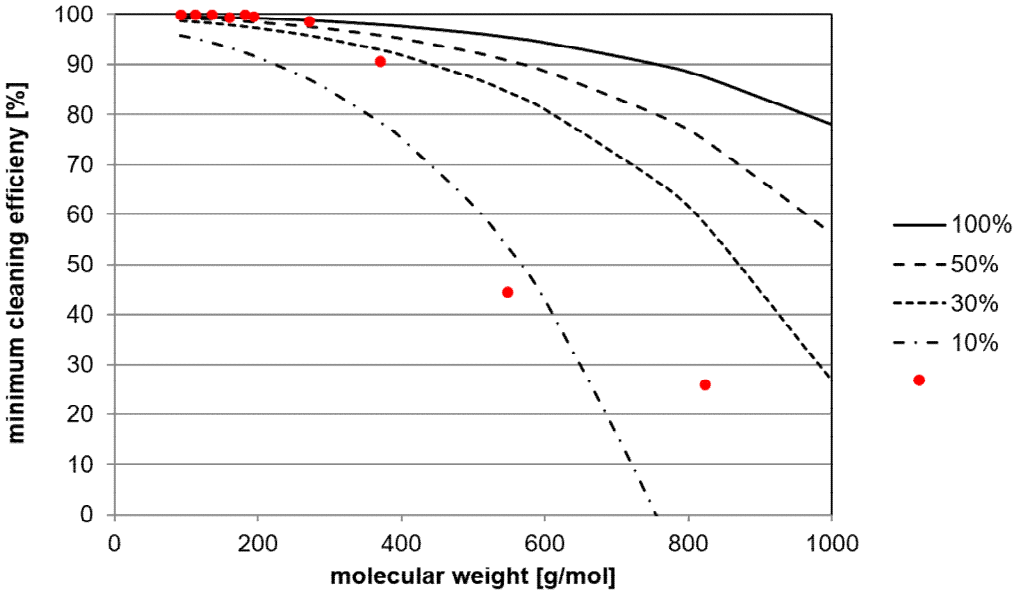


Figure 40: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 350 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.10 Packaging for solid and liquid food, 10 days at 20 °C 250 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 250 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.240 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.240 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 20 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 41 to Figure 43.

Based on the challenge test results a recyclate content of 70.6% (initial contamination level 0.5 mg/kg), 35.3% (initial contamination level 1 mg/kg) and 11.8% (initial contamination level 3 mg/kg) is possible.

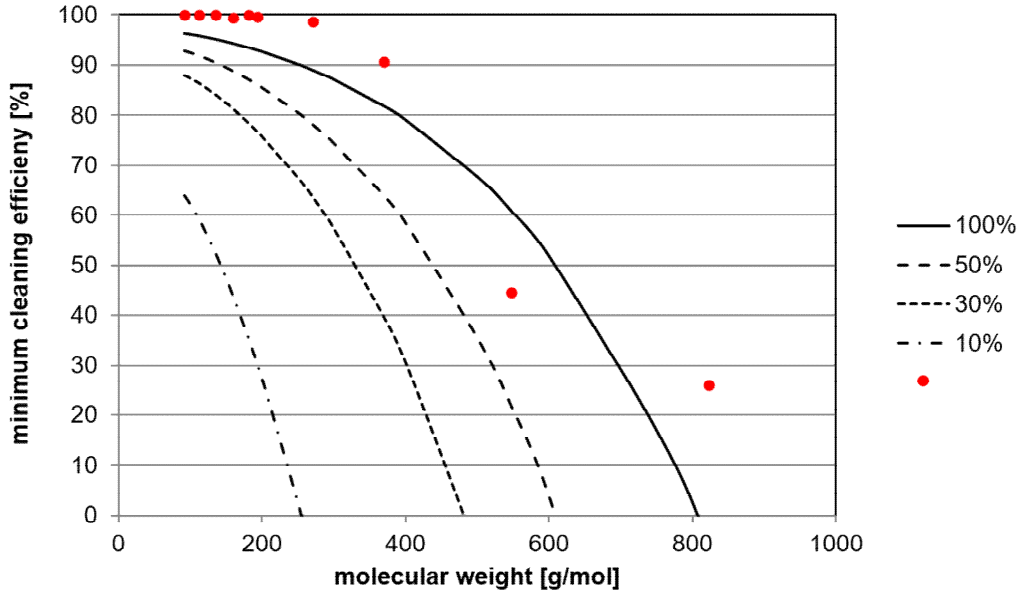


Figure 41: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 250 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

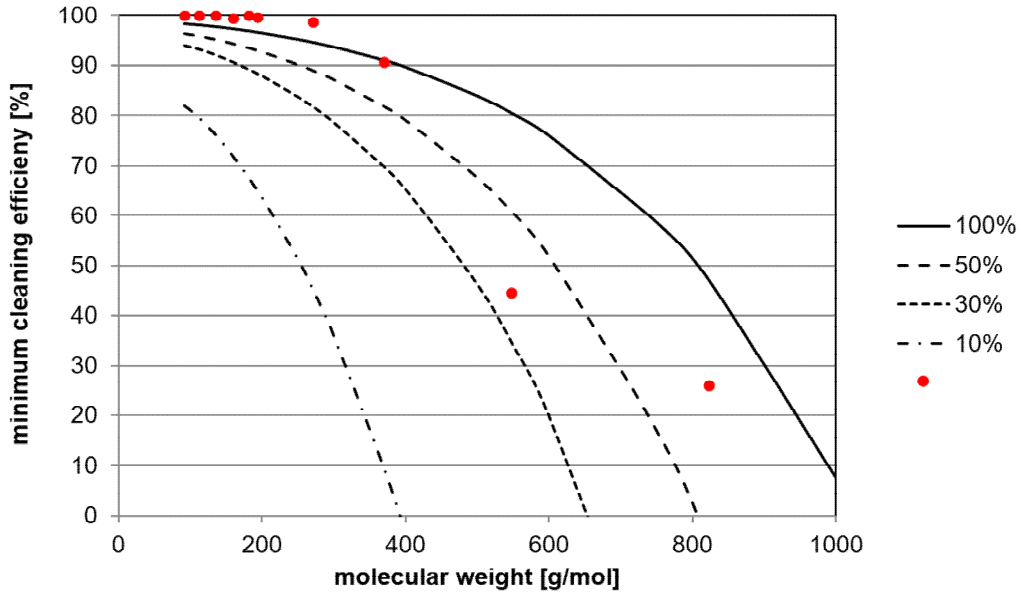


Figure 42: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C with 250 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

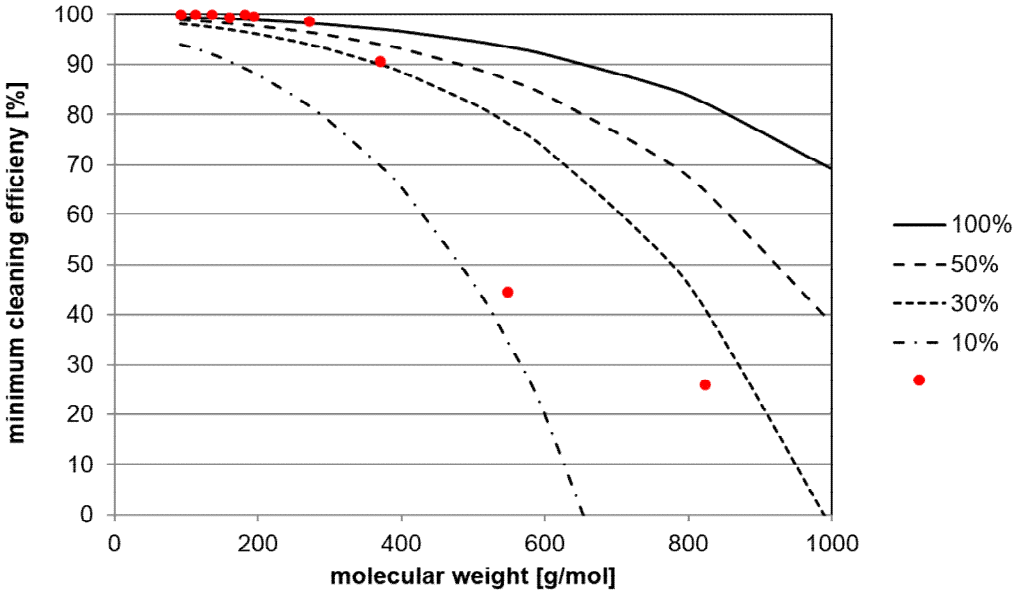


Figure 43: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 20 °C, with 250 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.11 Packaging for solid and liquid food, 10 days at 40 °C (960 ml)

Evaluation criteria for packaging for solid and liquid food with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing packaging in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.0626 µg/kg (960 ml consumption of food for a toddler with 12 kg bw, overestimative factor of 2 similar to HDPE). Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.0626 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 40 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 44 to Figure 46.

Based on the challenge test results a recyclate content of 5.0% (initial contamination level 0.5 mg/kg), 2.5% (initial contamination level 1 mg/kg) and 0.8% (initial contamination level 3 mg/kg) is possible.

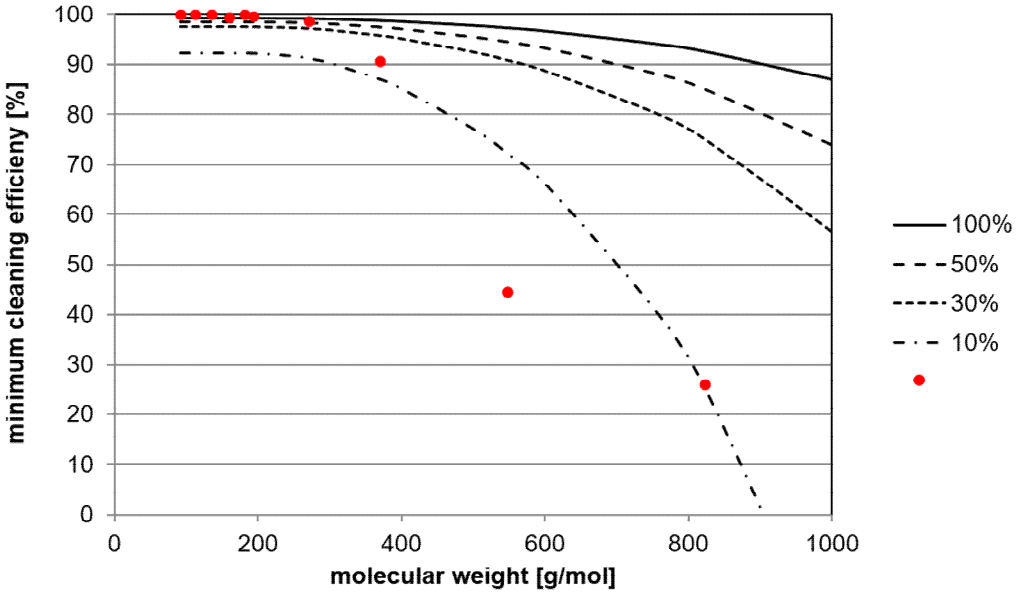


Figure 44: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 960 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

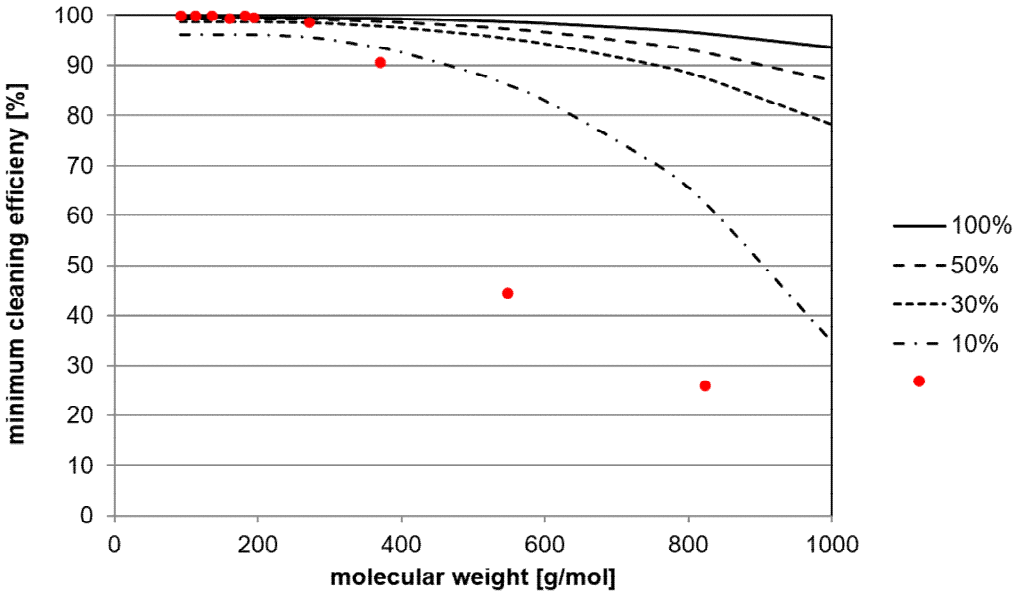


Figure 45: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 960 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

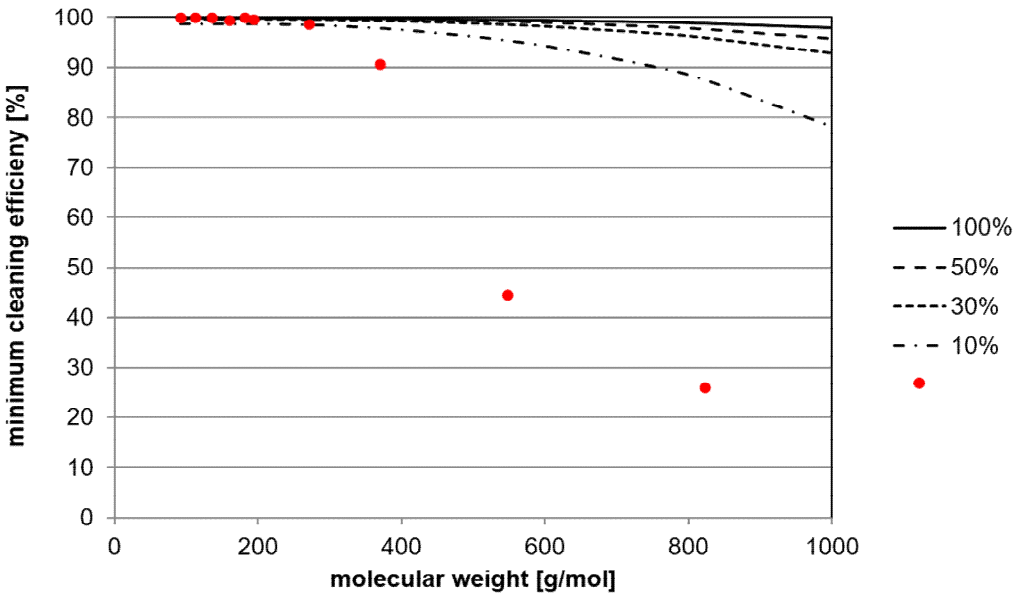


Figure 46: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 960 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.12 Packaging for solid and liquid food, 10 days at 40 °C (500 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 500 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.120 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.171 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 40 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 47 to Figure 49.

Based on the challenge test results a recyclate content of 9.5% (initial contamination level 0.5 mg/kg), 4.8% (initial contamination level 1 mg/kg) and 1.6% (initial contamination level 3 mg/kg) is possible.

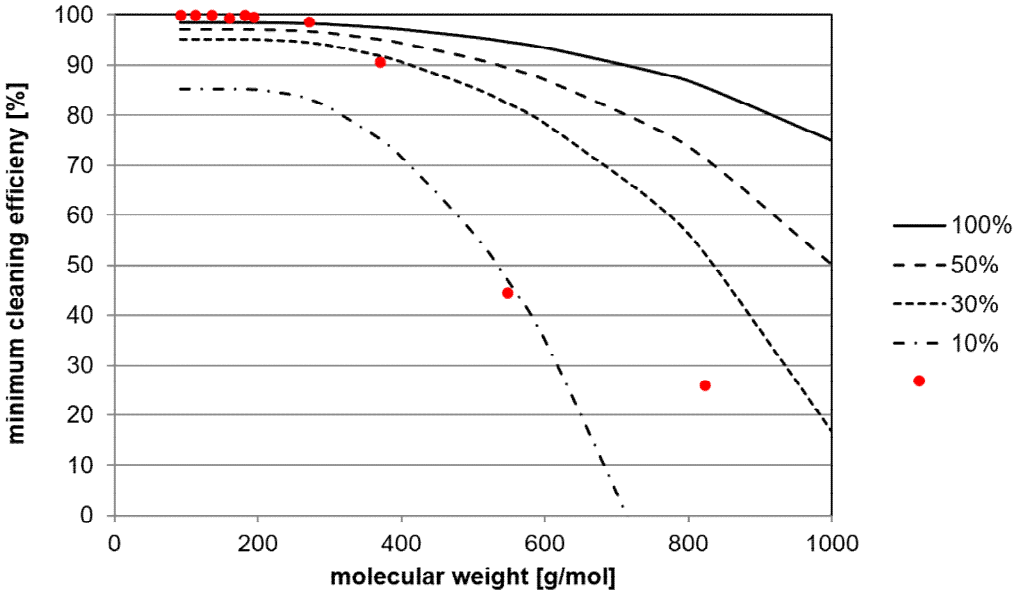


Figure 47: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 500 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

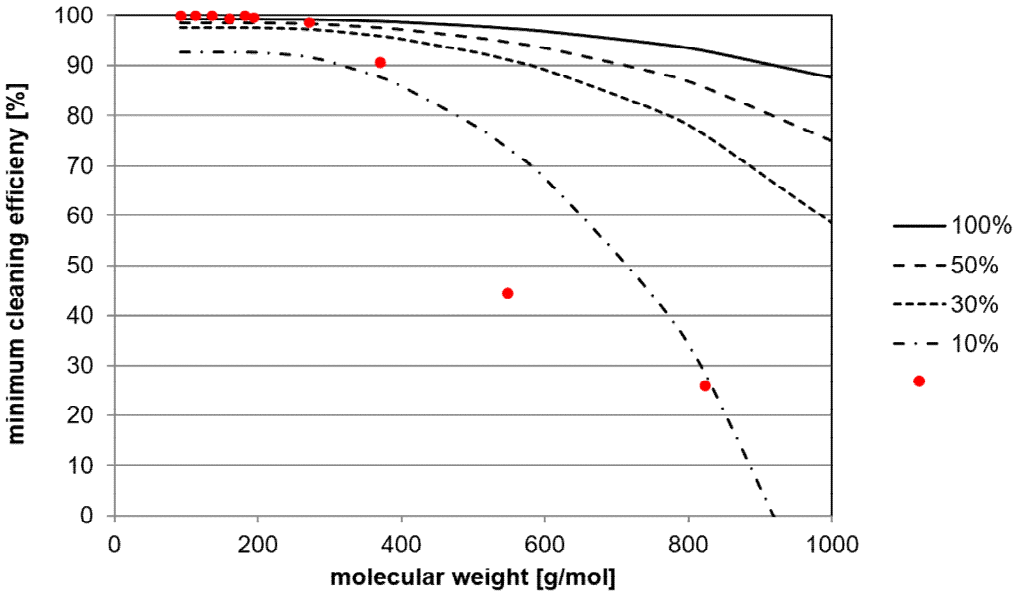


Figure 48: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 500 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

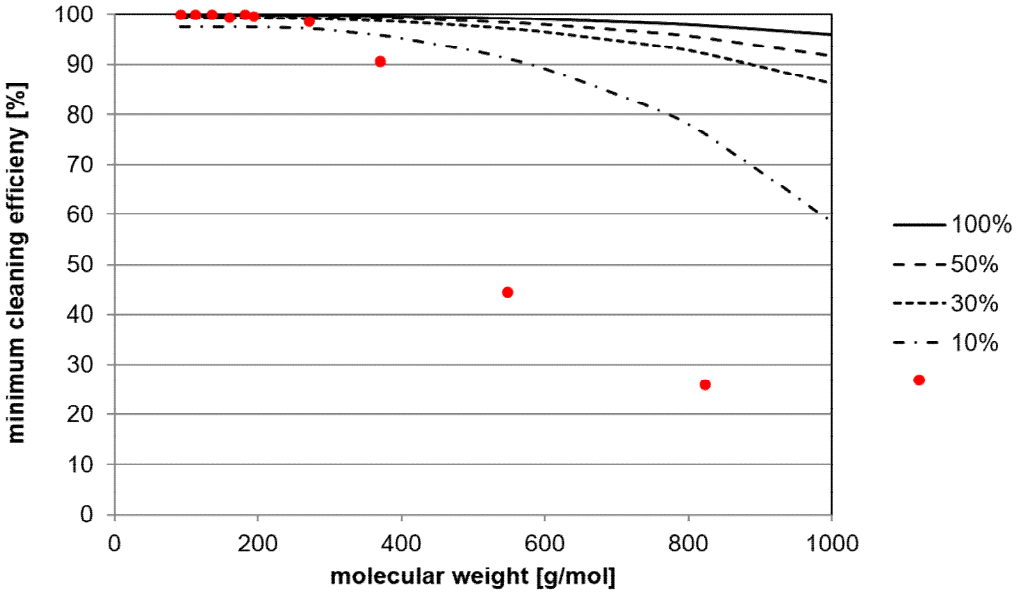


Figure 49: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 500 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.13 Packaging for solid and liquid food, 10 days at 40 °C (350 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 350 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.171 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.171 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 40 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 50 to Figure 52.

Based on the challenge test results a recyclate content of 13.6% (initial contamination level 0.5 mg/kg), 6.8% (initial contamination level 1 mg/kg) and 2.3% (initial contamination level 3 mg/kg) is possible.

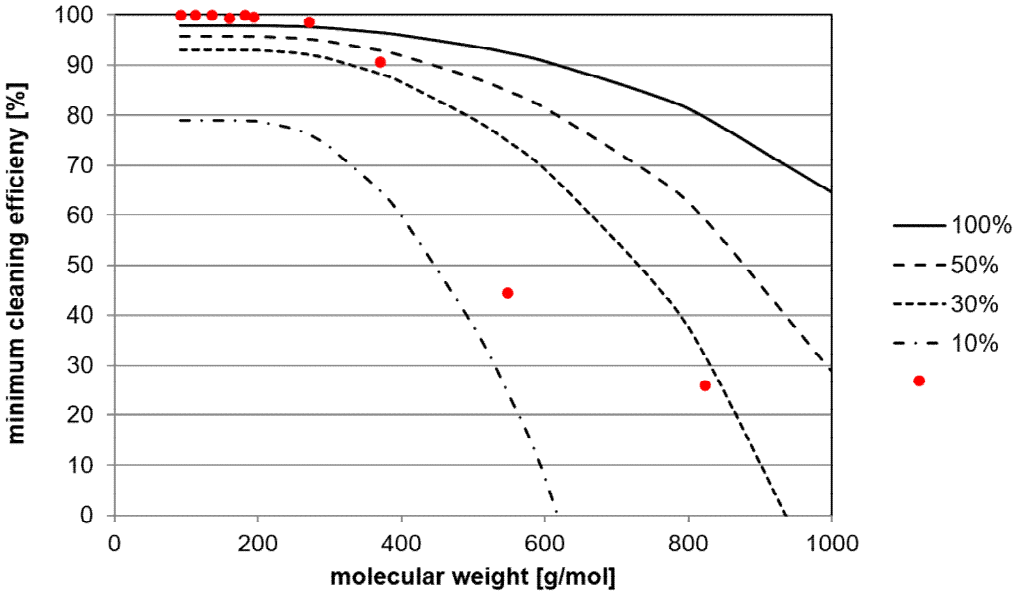


Figure 50: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 350 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

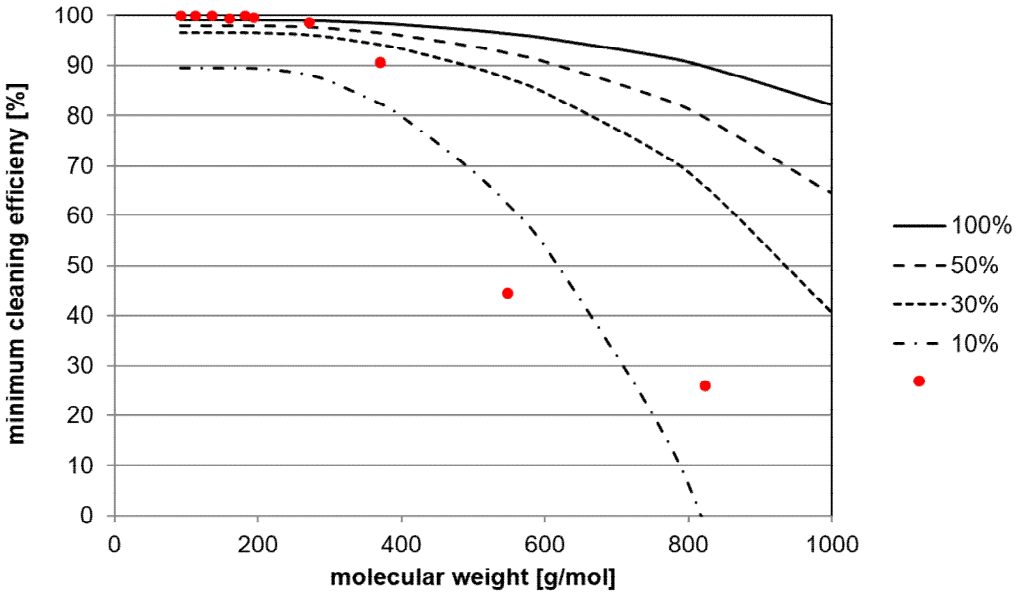


Figure 51: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 350 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

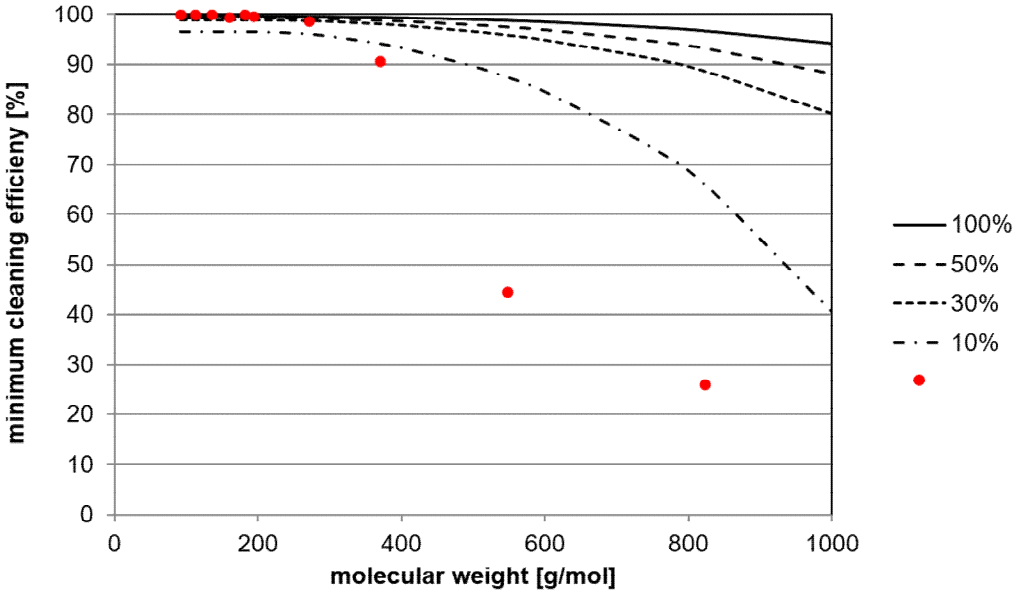


Figure 52: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 350 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.14 Packaging for solid and liquid food, 10 days at 40 °C 250 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 250 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.240 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.240 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 10 days at 40 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 53 to Figure 55.

Based on the challenge test results a recyclate content of 19.1% (initial contamination level 0.5 mg/kg), 9.5% (initial contamination level 1 mg/kg) and 3.2% (initial contamination level 3 mg/kg) is possible.

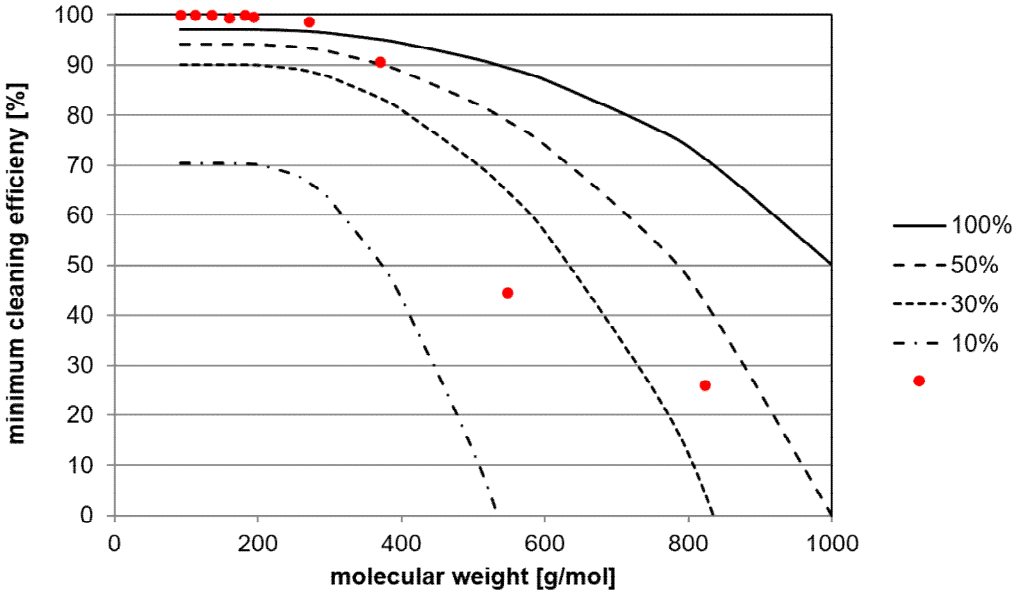


Figure 53: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 250 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

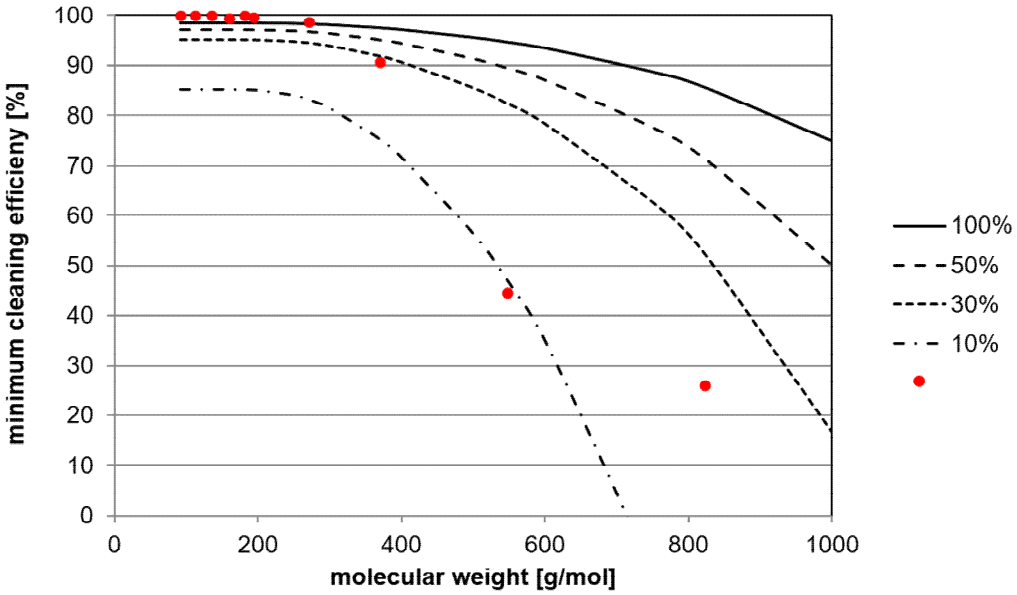


Figure 54: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C with 250 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

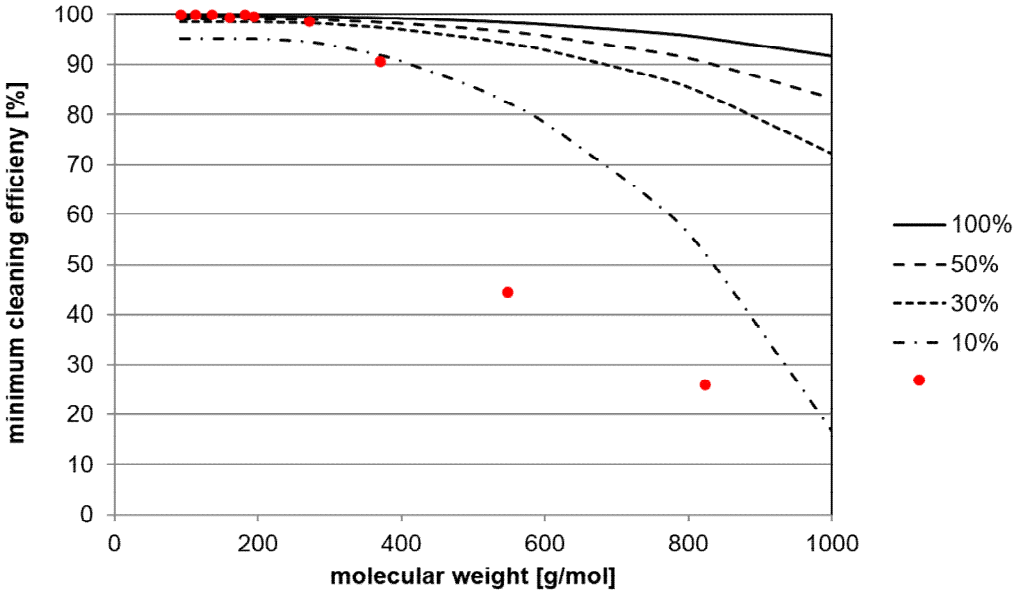


Figure 55: Cleaning efficiencies of surrogates in the challenge test (sample 6o), packaging for solid and liquid food, 10 days at 40 °C, with 250 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.15 Cups for hot drinks, 2 h at 70 °C (960 ml)

Evaluation criteria for cups for hot drinks with post-consumer recyclates are not published till now. It should be noted here that EFSA might evaluate the recyclate containing cups for hot drinks in a different way.

According to the EFSA criteria published for PET mineral water bottles[1], the maximum migration of compounds from the post-consumer materials should be below of 0.0626 µg/kg (960 ml consumption of food for a toddler with 12 kg bw, overestimative factor of 2 similar to HDPE). Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.0626 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 2 h at 70 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg. The results are given in Figure 56 to Figure 58.

Based on the challenge test results a recyclate content of 10.2% (initial contamination level 0.5%), 5.1% (initial contamination level 1 mg/kg) and 1.7% (initial contamination level 3 mg/kg) is possible.

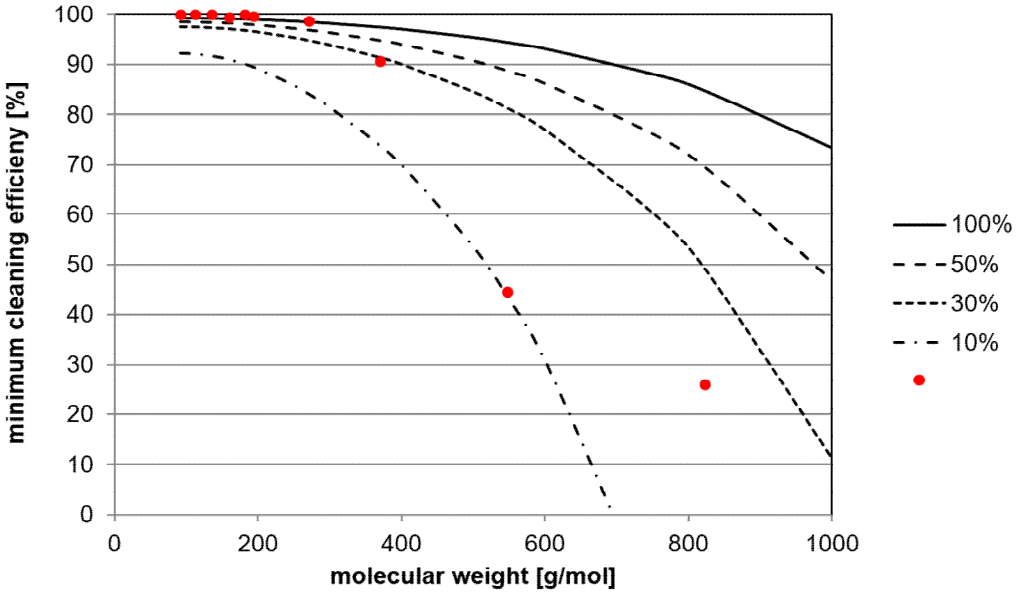


Figure 56: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C, with 960 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

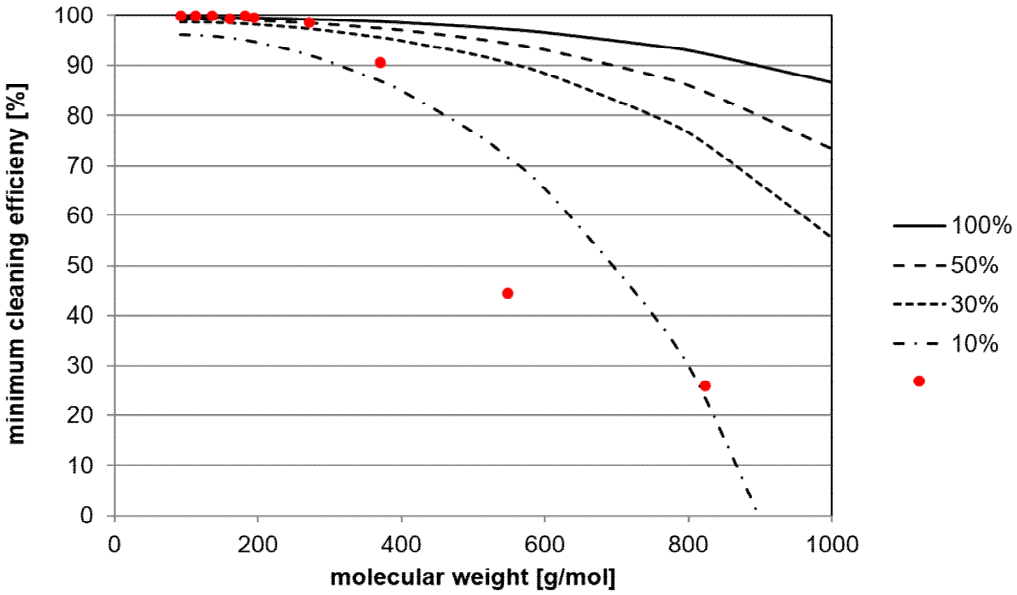


Figure 57: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C, with 960 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

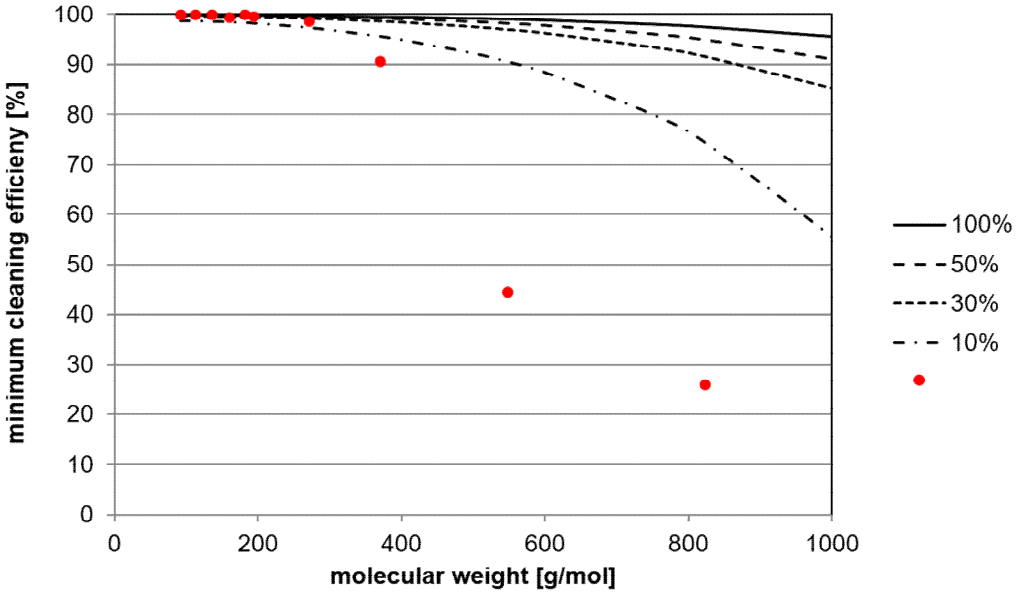


Figure 58: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C, with 960 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.16 Cups for hot drinks, 2 h at 70 °C (750 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 750 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.080 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.080 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 2 h at 70 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 59 to Figure 61.

Based on the challenge test results a recyclate content of 13.0% (initial contamination level 0.5 mg/kg), 6.5% (initial contamination level 1 mg/kg) and 2.2% (initial contamination level 3 mg/kg) is possible.

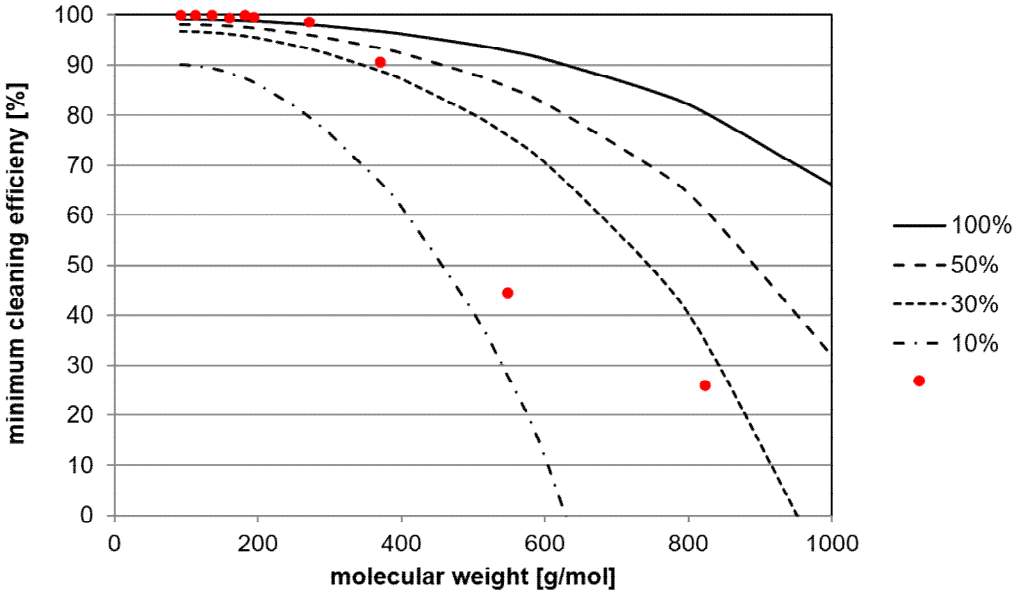


Figure 59: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 750 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

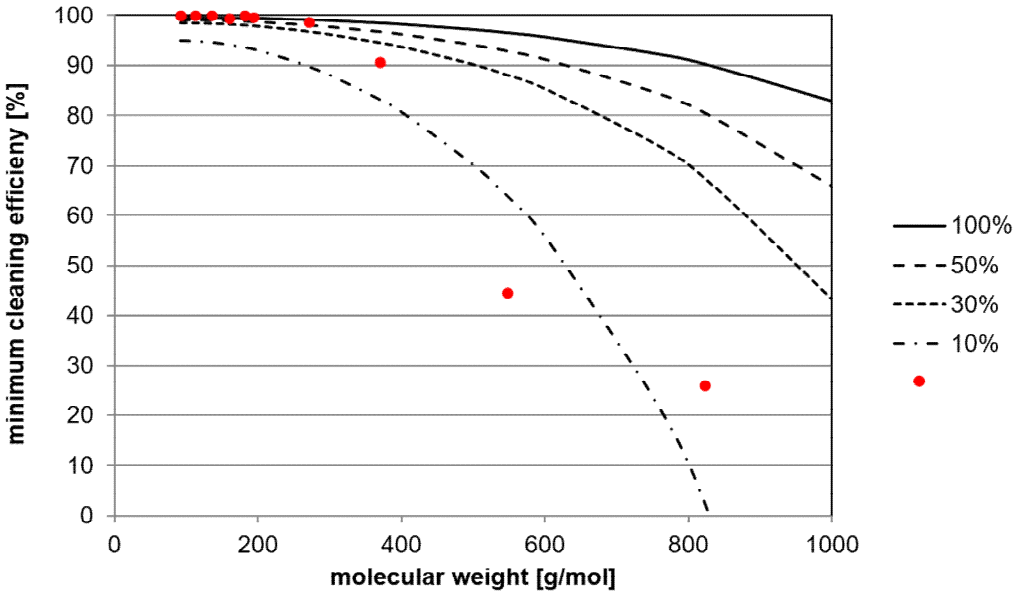


Figure 60: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 750 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

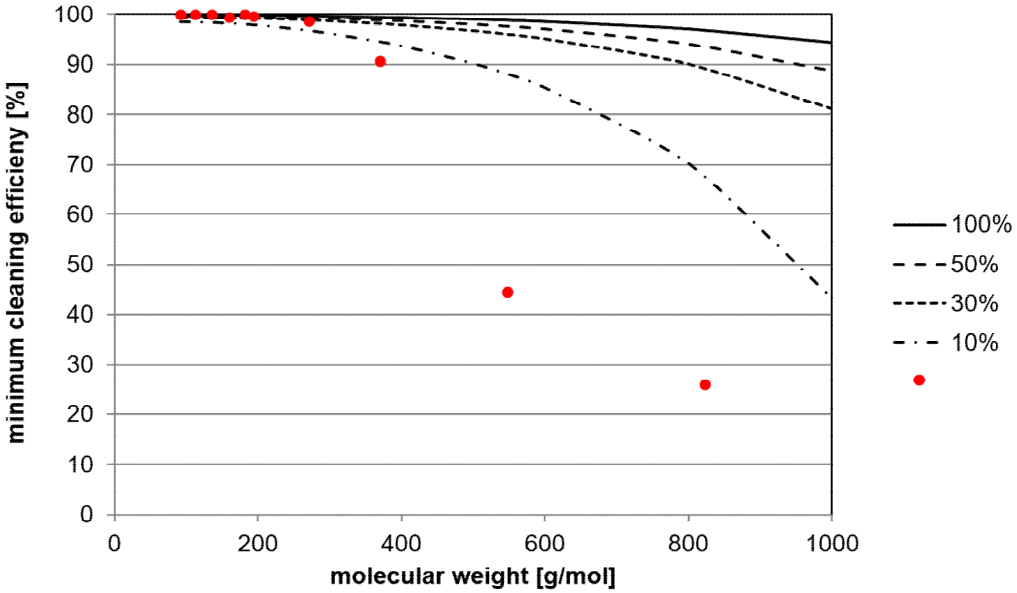


Figure 61: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 750 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.17 Cups for hot drinks, 2 h at 70 °C (500 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 500 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.120 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.240 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 2 h at 70 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 62 to Figure 64.

Based on the challenge test results a recyclate content of 19.6% (initial contamination level 0.5 mg/kg), 9.8% (initial contamination level 1 mg/kg) and 3.3% (initial contamination level 3 mg/kg) is possible.

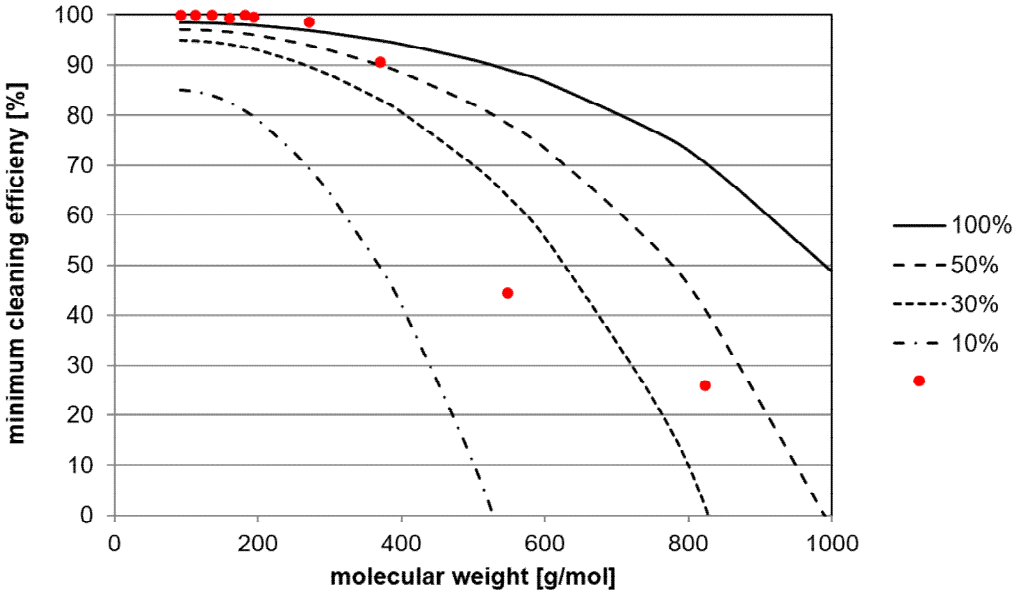


Figure 62: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 500 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

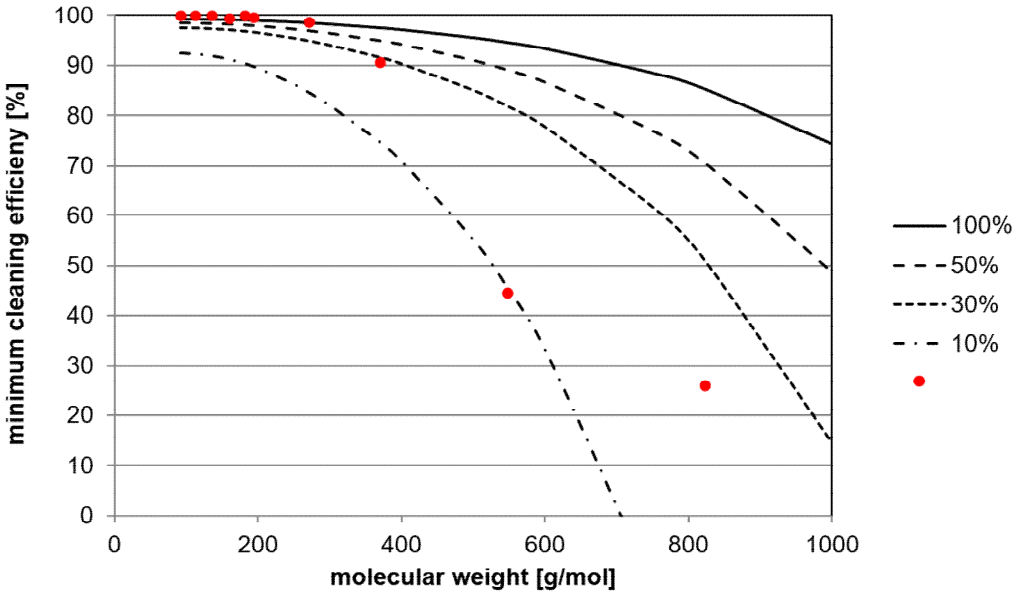


Figure 63: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 500 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

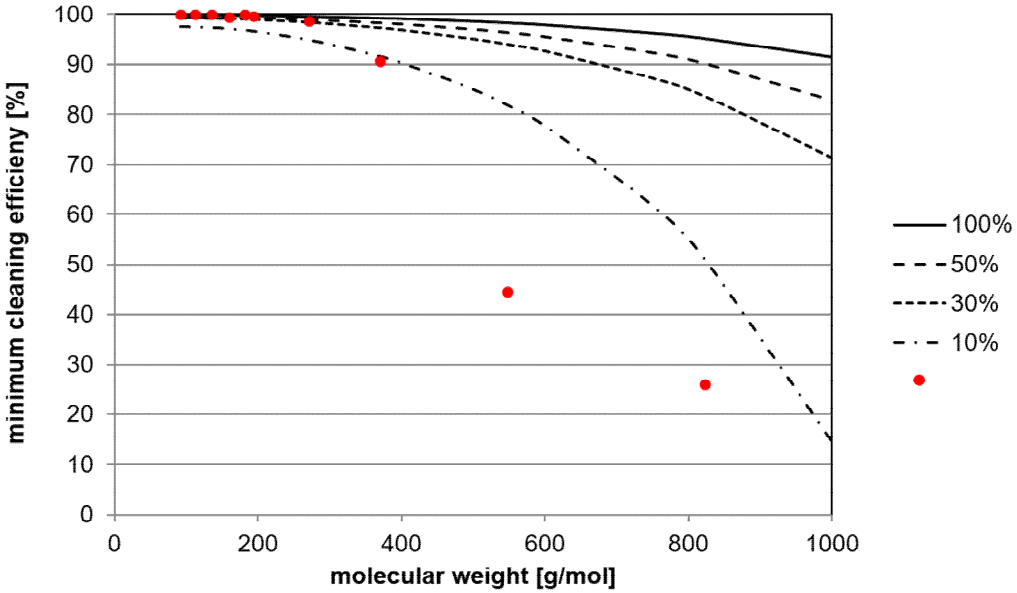


Figure 64: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 500 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

7.18 Cups for hot drinks, 2 h at 70 °C (250 ml)

The EFSA's food consumption is very high, which consequently limits the potential use of recycled materials in direct contact with food. At the client's request, lower food consumption figures were therefore also calculated. When using 250 ml food consumption instead of 960 ml, the maximum migration of compounds from the post-consumer materials should be below of 0.240 µg/kg. Using migration models, the maximum concentration of substances of different molecular weights can be calculated using $A_P' = 13.1$ and $\tau = 1577$ K. The maximum concentrations C_{mod} of the applied surrogates were calculated for a food package with 1 l volume package and with an inner surface area of 6 dm^2. The thickness of the packaging was assumed to 300 µm. This maximum concentration corresponds to the assumed migration limit of 0.240 µg/kg in food. The calculation was done for a food with high solubility for the surrogates (partition coefficient $K_{Polymer/Food} = 1$) at conditions of 2 h at 70 °C with initial contamination levels of 3 mg/kg (similar for PET), 1 mg/kg and 0.5 mg/kg[2]. The results are given in Figure 65 to Figure 67.

Based on the challenge test results a recyclate content of 39.0% (initial contamination level 0.5 mg/kg), 19.5% (initial contamination level 1 mg/kg) and 6.5% (initial contamination level 3 mg/kg) is possible.

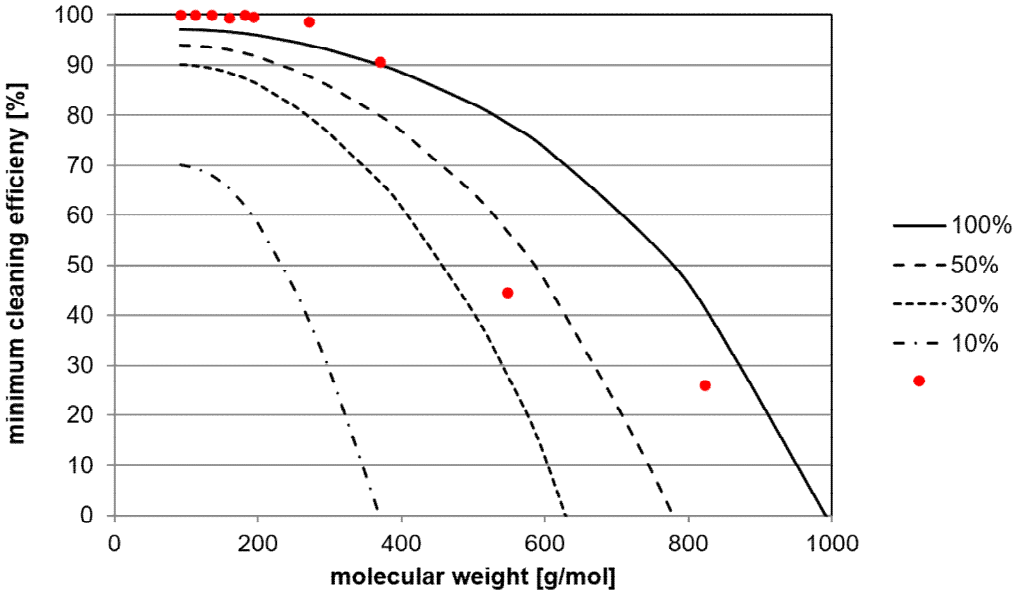


Figure 65: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 250 ml food consumption, initial contamination level **0.5 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

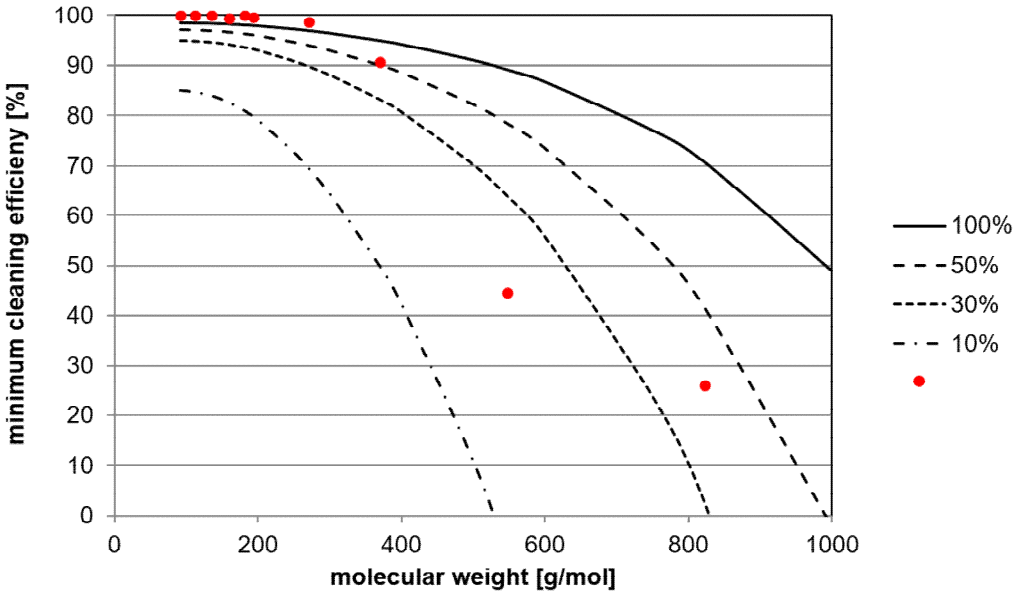


Figure 66: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 250 ml food consumption, initial contamination level **1 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

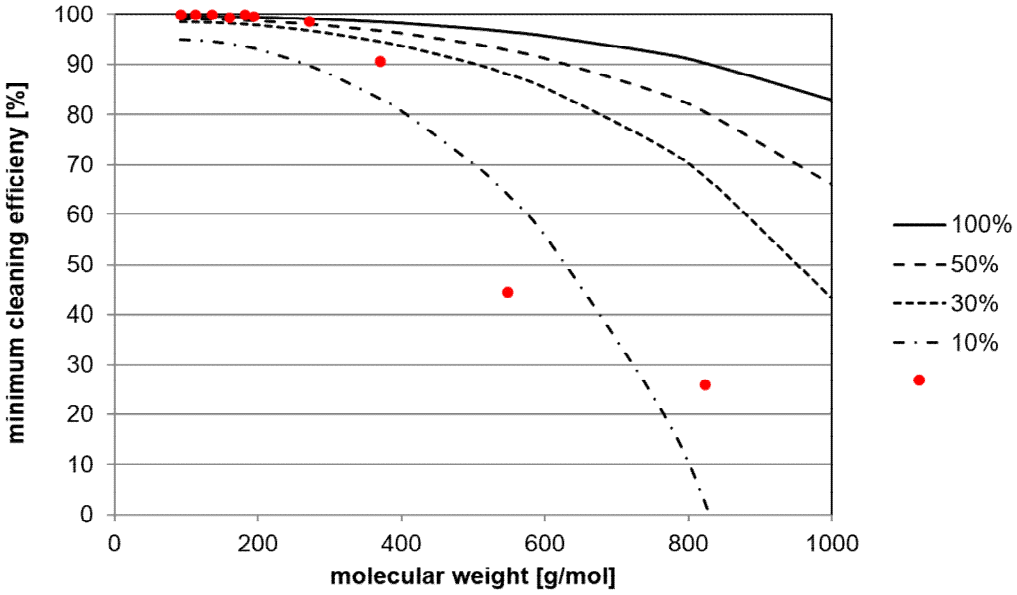


Figure 67: Cleaning efficiencies of surrogates in the challenge test (sample 6o), cups for hot drinks, 2 h at 70 °C with 250 ml food consumption, initial contamination level **3 mg/kg**). Lines: Minimum cleaning efficiency, red dots: experimental data

8 Conclusions

Within the study, a challenge test with artificially contaminated PP material was performed in order to determine the cleaning efficiency of the investigated PP super-clean recycling process.

The challenge test data were evaluated according to the published EFSA opinions. In addition, further applications e.g. closures for mineral water and softdrink bottles as well as packaging for solid and liquid food were evaluated. For these applications, however, evaluation criteria are not published by EFSA till now. The evaluation criteria applied in this study, were therefore derived from two EFSA opinions on PET mineral water bottles as well as on HDPE milk bottles. This is under the assumption that EFSA will evaluate post-consumer PP recyclates in a similar way. In addition, the calculations are based on an input contamination level of 0.5 mg/kg, 1 mg/kg and 3 mg/kg (similar to PET) in post-consumer PP.

As expected, the high molecular weight substances are the most-challenging substances for the investigated super-clean recycling process. Sample 6o was used for the evaluation regarding assumed EFSA criteria for closures, packaging for packaging for solid and liquid food, and cups for hot drinks.

The percentages of PP recyclates, which can be applied under the investigated storage conditions are given in Table 5.

Table 5: Percentages of PP recyclates in the investigated applications

application	storage conditions	Food consump-tion [g/kg bw day]	initial contamination level		
			0.5 mg/kg	1 mg/kg	3 mg/kg
closures for mineral water	365 days at 25 °C	260	100%	62.0%	20.7%
closures for softdrinks	365 days at 25 °C	80	100%	100%	67.4%
packaging for solid and liquid food	40 days at 6 °C	80	25.8%	12.9%	4.3%
		41.7	49.7%	24.8%	8.3%
		29.2	70.4%	35.2%	11.7%
		20.8	98.8%	49.4%	16.5%
packaging for solid and liquid food	10 days at 20 °C	80	18.4%	9.2%	3.1%
		41.7	35.3%	17.6%	5.9%
		29.2	50.3%	25.1%	8.4%
		20.8	70.6%	35.3%	11.8%
packaging for solid and liquid food	10 days at 40 °C	80	5.0%	2.5%	0.8%
		41.7	9.5%	4.8%	1.6%
		29.2	13.6%	6.8%	2.3%
		20.8	19.1%	9.5%	3.2%
cups for hot drinks	2 h at 70 °C	80	10.2%	5.1%	1.7%
		62.5	13.0%	6.5%	2.2%
		41.7	19.6%	9.8%	3.3%
		20.8	39.0%	19.5%	6.5%

The most challenging substances are the high molecular weight substances DEHA and TEHTM. It should be noted that the calculations were done with a partition coefficient of K = 1 which represents good solubility of the substances in the

contact media. This approach was used by EFSA for all calculations on PET and HDPE. However, for high molecular weight substances good solubility in the contact media is most unlikely. Lower solubility will result in higher partitioning coefficients, which will increase the maximum recyclate amounts in the closures and other packaging applications. On the other hand, realistic data on solubility of the applied surrogates in water, softdrinks and food as well as realistic partitioning coefficients are rare in the scientific literature. Therefore, the worst-case approach with K = 1 was applied in this study.

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Freising, October 28, 2026

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Annotation: This report replaces the Fraunhofer test report PA-1371a-25 rev from 09.10.2026. Minor changes were made and errors were corrected.