MICRO/NANO PLASTICS RELEASE FROM FCM DURING THEIR USE

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BACKGROUND & EFSA SELF-MANDATE (EFSA-Q-2025-00139)

Background

- EFSA Scientific Colloquium 25, 2021
- EFSA FCM Working Group
- EFSA FCM Network

Knowledge gaps

- Release during their use
- Publication raising concern: FCM-to-food MPs (teabags, bottles)

Mandate

Establish the **current state of knowledge** on the release of MNPs from FCMs during their use

1. from virgin and recycled plastic FCM
2. the mechanism of formation and degradation of MP and NP in FCM
3. the data and methodological gaps that need to be addressed.

Output: **EFSA Technical Report**

TERMINOLOGIES AND BOUNDARIES

Micro- and nano plastic

- Generally understood as **solid plastic fragments** resulting from the **degradation or mechanical wear of larger plastic materials**. In the context of FCM, such particles could be generated by **deterioration** of the FCM surface due to **physical forces** (e.g. friction, abrasion), to **aging** (e.g. by air/oxidation, heat, UV/light), and/or to **chemical interactions** (e.g. swelling), during the manufacture and use of plastic FCM.
- These particles are expected to **retain the chemical composition of the parent FCM.**
- **Size: MP: 0.1 to 5,000 µm**; **NP: 1 to 100 nm.**

Release from FCM during their use

Both (i) the **generation/production of MNP** and (ii) the **transfer from the FCM to the food of newly generated or existing MNP**. The already existing MNP may be stuck to the surface and originate from the production and handling processes of the FCM. MNP from the environment of FCM or from the food (e.g. environmental contamination during food production, FCM contamination during food processing), the sampling, were treated as **background contamination and excluded from the scope**.

METHODOLOGY: STRUCTURED LITERATURE REVIEW FROM 2015 TO 1/2025

Main Question: **Are there evidences of microplastics/nanoplastics released from Food Contact Materials (FCM) during their use? If so, what are their characteristics?**

Six sub-questions/themes.

Theme	Sub-question (SQ)	Purpose
FCM types and test conditions	SQ1 – What types of FCM have been studied to evaluate whether they release MP or NP, under which conditions, and how representative are these conditions?	Identify the diversity of FCM tested and assess the relevance of experimental conditions.
Analytical methods and particle characteristics	SQ2 – What analytical techniques are used to detect and quantify MP/NP released from FCM, and what are the key characteristics of these particles (e.g. size, shape, composition)?	Evaluate the reliability and scope of analytical methods and reported particle features.
Contamination and carry-over	SQ3 – Are the particles released from FCM potentially from cross-contamination (e.g. air, sampling), food carry-over or manufacturing process, and are they consistent with FCM composition?	Distinguish true release from external contamination or artefacts.
False positives / mimicking substances	SQ4 – Can certain substances (e.g. oligomers precipitate, fatty acids) mimic MP/NP, and how do they impact the interpretation of release data?	Understand sources of misinterpretation and their implications for study validity.
Release mechanisms and influencing factors	SQ5 – What mechanisms drive the release of MP/NP, and how do food type, material ageing, or interactions affect this release?	Identify how release occurs and what factors accelerate or influence it.
Recycled materials	SQ6 – Is there evidence of MP/NP release from mechanically recycled materials, and does recycling influence their release?	Determine whether and how recycling affects MNP release from FCM.

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LITERATURE REVIEW

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Title & abstract screening

1711 Publications

- Link with MNp release from FCM in the **abstract** during their uses

Full text screening

254 Publications

- Focus only on **Article** (Exclusion of Review)
- Link with MNp release from FCM **in the text** during their uses

Data extraction

122 Publications

- **81 publications** extracted with in detailed
- **41 publications** extracted narratively

Note: 8 publication/review were manually added after the extraction

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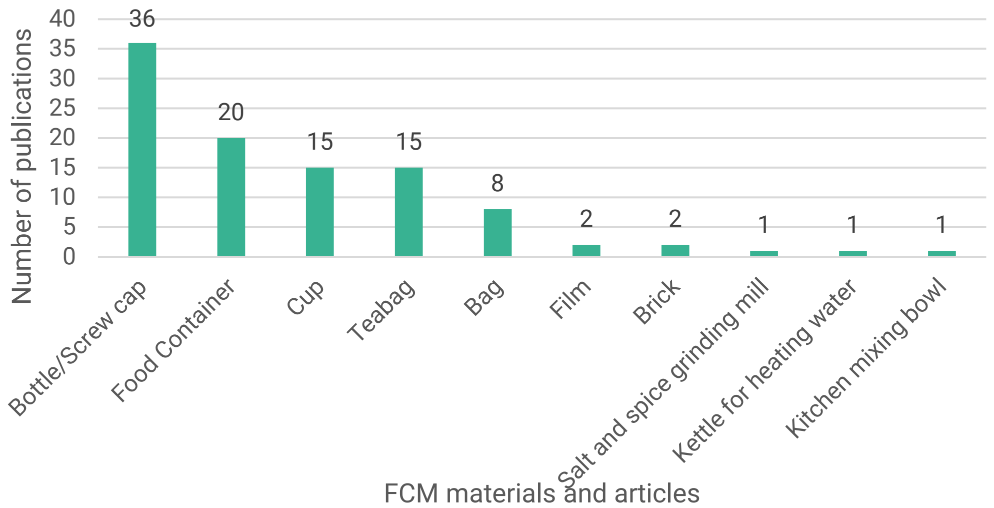
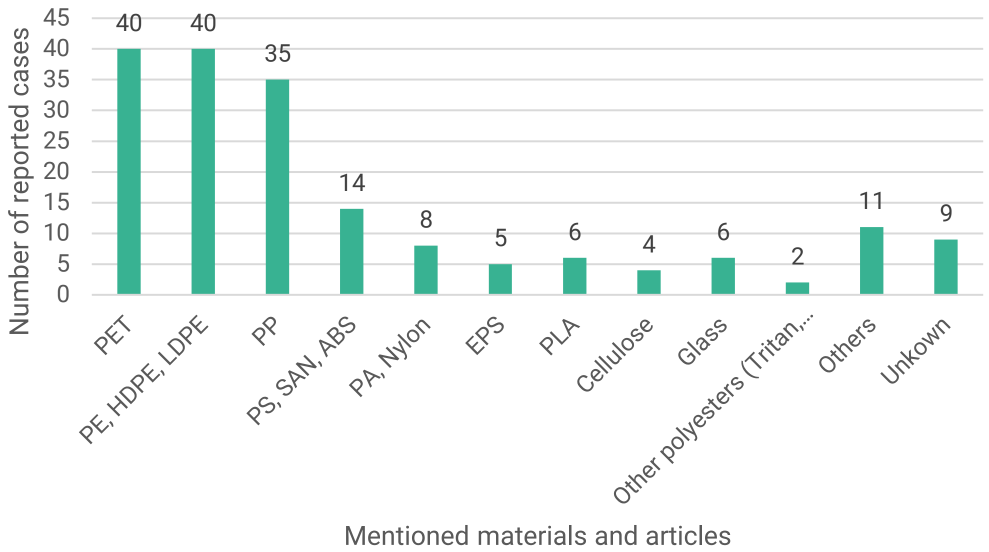
SQ1: FCM STUDIED



Plastic food containers are mostly bowl and boxes for takeaway or not, microwavable or not.



- **Scope & coverage:** 101 FCM samples across 81 studies;
- **Wide range and variety of plastic FCM** food types with preponderance of rigid articles tested and of tea bags, rather than flexible packaging materials. Tested article types and their related **polymers** provided a good picture of materials available to consumers, covering both single and repeated use articles. Overall, the range of plastic FCM studied is judged to be **reasonably comprehensive** at this stage of research and understanding.

SQ1: EXPERIMENTAL TEST CONDITIONS

time/Temperature

- **Largely hot-fill condition and heating** relatively short time (≤ 60mn up to 1 day) and **storage at various time** (< 1 day to >10 days) and temperature (-18 to 60°C)
- **Other treatments**, e.g. repeated boiling, sterilisation, microwaving or hot-plate heating, UV or sunlight , gamma irradiation at high doses and oxidative treatments with H_2O_2… They are expected or foreseeable and may affect the MNP release.

Food type

- **Liquid simulant**: 71% – in 92% it was a water-based simulant; use of water is acceptable in the studies; it was mostly used as a convenient medium for particle suspension.
- **Food** directly tested: 29% - usually directly filtered (water, juice, tea, sodas, energy drinks; rice); Very few publication on solid foods

SQ2: ANALYTICAL TECHNIQUES USED TO DETECT AND QUANTIFY MNP

Main techniques

- **Vibrational spectroscopy:** Raman and µ-Raman, Fourier-transform infrared (FTIR) spectroscopy
- **Electron Microscopy (EM) and imaging:** scanning electron microscopy with energy-dispersive X-ray analysis (SEM-EDX),
- **Fluorescence-based techniques** combined with Nile Red (NR) staining to enhance the visibility of particles

Less used techniques

- **Thermal and mass spectrometry techniques:** pyrolysis–gas chromatography/mass spectrometry (pyr-GC/MS) and dynamic light scattering (DLS), thermal desorption-GC-MS, high resolution-LC-MS
- **Other techniques:** TEM, single-particle inductively coupled plasma mass spectrometry (SP-ICP-MS) and single particle extinction and scattering (SPES) techniques, etc.

SQ2: PARTICLE KEY CHARACTERISTICS

Shape & Size

- May be the total particles, not necessarily MNP
- Particles include all reported shapes e.g. **fragment, bead-like, fibre, film-like** and other, as well as **any colour**.
- **Large variety** of size as reported (without validated chemical information) ranging from **10 nm to 5000 µm;**
- **Size reported link with the technique used:**
  - **µ-Raman** spectroscopy which is limited in resolution to **1-2 µm**
  - **FTIR** spectroscopy minimum sized detected is around **10-11 µm**
  - **Filtration** pore sized were usually around **1-20 µm**

Concentrations

Most studies measured and reported the particle concentrations in a number-basis (i.e. particles/L); a few studies measured or recalculated the particle concentrations in mass-based.

SQ3: CONSISTENCY BETWEEN THE MNP AND TESTED FCM?

Scope

- MNP should **match the FCM polymer composition**.
- MNP from the environment of FCM or from the food (e.g. environmental contamination during food production, FCM contamination during food processing), the sampling, were treated as **background contamination and excluded from the scope**.

Result

- **In 44% of the publications:** majority of the particles reported (≥ 60 out of 100 counted P) -> were judged by the authors to be definitely or likely associated with the FCM polymer type.
- **In 11% of the publications:** particles reported were not of the same polymer type as the FCM.
- **In the remaining :** detection and identification methods used did not allow a conclusion.

SQ3: INCONSISTENCY BETWEEN THE MNP AND TESTED FCM

- In numerous studies, **no sufficient chemical analysis** was carried out to identify the MNP polymer types.
- **Shape and colour** may help in verifying consistency; e.g. fibres have dominated in many reports while not expected from thermoplastics. In contrast, fibres were commonly reported in studies of tea bags and coffee filters (fibrous materials).
- The **incorrect or inconclusive studies** mainly correspond to reports (i) on foods taken from the market with no control samples, and (ii) where the particle identification techniques lacked power (e.g. NR staining used alone) or where the vibrational spectra (FTIR, Raman) were likely misidentified. In many cases, identifications made by the study authors can now be judged to be misidentifications (see SQ4).
- **The most and few reliable studies with conclusive findings** were the well-controlled studies that tested FCM of known provenance, under carefully controlled conditions. **They concern** generation and release from FCM by abrasion, rinsing-off of particles from tea bag tissue (see SQ5).

SQ4: FALSE POSITIVE MNP AND MIMICKING SUBSTANCES

Low solubility substances

They are **present in the food/water or migrating from the plastics** (e.g., fatty acids, slip agents, oligomers, pigments); they **can precipitate** and be retained on filters, **mimicking MNP**.

Most reliable studies

Migrating additives and procedural artefacts can cause **orders-of-magnitude overestimation**. Critical controls are essential, especially after heat treatments.

- **Hot-contact then cold filtration** massively inflates counts; e.g., up to **~ 15 x 10^6 P/L** to **about 2,800 P/L**, often near/below LOD ~1,700 P/L.
- **Solvent rinse** (EtOH/MeOH) dissolves mimics: PE-like counts **dropped from ~26 x 10^6 to ~230 P/L.** GC/MS of the rinse detects slip agents such as stearic acid.
- **Acid/EDTA cleaning** dissolve/trap mineral in bottled mineral water.

SQ5: MECHANISMS DRIVING THE RELEASE OF MP/NP

Physical/mechanical stress by abrasion, friction

- **Screw caps & capping lines:** after 100 opening of PET bottle, HDPE debris on the grooved screw surface of the cap (rather than on the sealing surface): ≈ 63k–1.23M of 1-5 µm in majority, far fewer in water (≈ 148 ± 253 P/L) and not related to the treatment and bottle brand. Automated capping: MP numbers of sizes > 11 µm in the water from uncapped (< LOD of 81 MP/L) to capped bottles (317 ± 257 MP/L) hinting at capping and bottle opening to be the main entry paths.
- **Ziploc® seals (PE bags):** ≈ 5 P per mm along the length released during each closure/opening; clear signs of deformation and fractures on the female rim and scratches on the male rim were seen (SEM) after 10 times close/open.
- **Cutting/handling (boards, packs):** PE boards shed 1–7 P/g into meat/fish (in mass: 0.1 - 1.6 mg P/g) with mean sizes in the range 500 to 2,500 µm. The meat/fish samples were diced rather small (cut into small cubes) and so these results may have a 'worse-case' character.
- **Salt mills (PS/POM/PMMA):** 2,400–76,280 P (PS/POM/PMMA)/g milled salt (average particle size was >10 µm). Unground salt had a background count of 4,230 P of (mainly) PET/g.

SQ5: MECHANISMS AND HOW DO FOOD TYPE, AGEING, OR INTERACTIONS AFFECT THIS RELEASE?

Fibre shedding (open/fibrous structures)

- **Particles already on the surface** likely due to electrostatic and mechanical trapping, then and washed off.
- **Originating** from backgroung contamination and from the FCM (both from manufacturing residues and mechanical breakdown of the fibre matrix).
- **Teabags/filters**: fibres can detach; robust studies report 10- tens of thousands >1 µm per bag identified as MNP; 5.8-20.4 × 10^3 (Busse et al. 2020), ~10–19 fibres per serving (Kim et al. 2022).

Amplifiers

- **Swelling** (food type).
- **Ageing** (e.g., UV embrittlement), might contribute as a mechanism.

SQ6: EVIDENCE OF RELEASE FROM MECHANICALLY RECYCLED MATERIALS?

- Evidence is scarce: **only two targeted rPET studies**; limited power.
- **No signal that rPET releases more MP than PET**; one study found lower counts in rPET (all low overall).
- **Closures matter**: PE from caps shows up in PET, rPET, and even glass → interface is a key source.
- **Refillable** may be higher than single-use (washing/labels), but no evidence.

INSIGHTS AND CONCLUSION

1. **Water** dominate → not worst-case for all plastics; higher T (>100 °C) rare; solid foods little tested.
2. **No evidence for diffusion-driven** particle release from intact matrices, or for de novo surface formation.
3. **MP release occurs during FCM use**, driven by mechanical processes (i. abrasion, friction; ii. fibre shedding from woven and non-woven tissues). Generation prior to food contact may give rise to presence on the surface and conveyed along the FCM and food production chain.
4. **Actual release is much lower** than early high-count reports once artefacts are controlled. **False positives** due to mimics/precipitation (additives/oligomers). Corrected protocols show far lower values (tens to tens of thousands).
5. Available evidence remains **limited concerning characteristics and quantities** of MNP. Needs polymer confirmation, blanks, temperature-matched filtration, solvent rinses, mineral cleanup. **Mass uncertainty:** shape not fully reported; number-to-mass conversions are sensitive to morphology.
6. Data and validated methods **nanoplastics** are **largely missing.**
7. **MNP range** (1 nm- 5 mm) is not covered, and their potential **hazard are unknown**.

RECOMMENDATIONS

It is recommended to fill the identified gaps on:

1. the lack of **validated test protocols** including polymer **MNP standards and recovery tests** using those standards;
2. the paucity of information (and **suitable analytical methods and their combination**) on the release of nanoparticles (< 0.1 µm) and microparticles < 1 µm;
3. the **identification of the composition** of any purported MNP, their size and their quantity (number-based and mass-based);
4. the contact between **non-polar FCM** plastics and **non-polar fatty food/simulants**;
5. the testing of **real foods** (other than water), considering possible mimicking substances;
6. the need to **estimate dietary exposure** to MNP from FCM and **place into perspective** with other exposure sources.

It is recommended to revisit these findings and outcomes as necessary and to **repeat this review in about 5 years**. This timeframe aims allowing sufficient time to provide new data such as the development and use of validated methods and reference materials. Taking into account that most of the usable data recorded in this literature search are from the more recent years, a review in 5 years' time seems to be appropriate because by then one can be reasonably confident to find enough new information to make the (re-)review worthwhile. The FCM WG will be keeping a watching brief on progress in this area and that will inform if 5 years is too long or too short.

Technical Report:

- **Validation on 15th October;**
- **Published on 21th October**

https://www.efsa.europa.eu/en/supporting/pub/en-9733

Thank you for your attention

RESULT TABLE: FOR DISCUSSION

Reference	Particles number / mass in food or water	Size (if mentioned)	Contact type / key conditions
Vega-Herrera et al. (2023)	Mass-based (after dissolution): median 359 ng/L, max 4,700 ng/L	> 20 µm	20 bottled water brands in PET, PP, PE
Hagelskjær et al. (2025)	Recalculated mass from number: ≈ 1–250 ng/L	Measured > 1 µm; 97.5% are < 20 µm; 93.5% are < 10 µm	10 bottled-water brands; number-based counts converted to mass.
Gerhard et al. (2022)	After µ-Raman: one bottle ≈ 2,800 P/L; 7 others < LOD (1,700 P/L). Blanks: 17–1,210 P/L	≥ 80% between 1 and 10 µm	Infant feeding bottles (PP/PA); Identified particles mainly PES (~84%) and silicone (~13%); no PP/PA detected.
Li et al. (2022)	230 P/L	n/r	PP bottles / polyolefins
Winkler et al. (2019)	Bottled water: 148 ± 253 P/L. Cap surface debris: 63,400; 1,225,500; 333,800 P/cap.	Mostly 1-5 µm	PET bottles with HDPE screw cap; for the cap, 100 open/close cycles.
Weisser et al. (2021)	317 ± 257 MP/L (capped) vs < LOD (81 MP/L) (uncapped).	n/r	Automated capping module in a mineral water filling line.
Fang et al. (2024)	≈ 5 (± 1–3) P per mm of zip length per open/close cycle.	n/r	PE Ziploc® bags (no slider); 10 cycles
Schymanski et al. (2020)	2,400–76,280 P/g milled salt; background unground salt ≈ 4,230 P/g.	Average > 10 µm	Plastic salt mills (PS, POM, PMMA)
Busse et al. (2020)	Per tea bag: 122,300–222,800 total P of which 5,800–20,400 identified as MP	> 1 µm	Tea bag brewing
Kim et al. (2022)	≈ 10–19 fibres per serving (> 1 µm).	> 1 µm	Tea bags
Habib et al. (2022a, 2022b)	1-7 P/g in meat cutting (in mass: 0.1-1.6 mg/g)	Mean values 500-2,500 µm	Cutting boards