Evidence of microplastics and nanoplastics in food originating from food packaging: Protocol for a systematic evidence map

Registration

The protocol is registered and uploaded to Zenodo on November 15, 2022, with the digital object identifier (DOI) 10.5281/zenodo.7310760.

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Amendments

In case we will amend this protocol, we will use this section to give the date of each amendment and describe the change and the underlying reasons. Changes will not be incorporated into the protocol.

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Competing Interests

FPF is an independent and charitable foundation dedicated to science communication and scientific research on chemicals in all types of food contact materials and articles. LZ, BG, and JM are employees of FPF. MW is a member of FPF's scientific advisory board. FPF funders and donors had no influence on this study and did not restrict the scientific freedom of the authors to conceptualize this study, nor did they influence protocol writing, study design, and study execution.

Keywords

Microplastics, Nanoplastics, Systematic evidence map, Exposure assessment, Migration, Release, Contamination, Food packaging

Abbreviations

FCA	Food contact article
FCM	Food contact material
IAS	Intentionally added substances
MNP	Micro- and nanoplastics
MP	Microplastic
NIAS	Non-intentionally added substances
NP	Nanoplastic
PA	Polyamide
PC	Polycarbonate
PE	Polyethylene
PECO	Population, exposure, comparator, outcome
PET	Polyethylene terephthalate
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
PU	Polyurethane
PVC	Polyvinyl chloride
rPET	Recycled polyethylene terephthalate
SEM	Systematic evidence map

1 Introduction

1.1 Rationale

Food packaging plays a critical role in the modern food supply. It enables globalized business models, high throughput filling, microbial food safety, food transportation, marketing, and storage. As such, food packaging, especially made of single-use plastics, has become an enabler of today's globalized food systems (Chakori et al., 2021). Food packaging is also an expected source of human exposure to micro- and nanoplastics (MNPs) – plastic particles smaller than 1000 and 1 µm, respectively (Jadhav et al., 2021). The majority of food packaging is made of plastics or includes components made of plastics, or synthetic, organic, polymerized materials (e.g., bottle lid, gasket, inner food contact layer in beverage cartons, varnishes on the inside of food and beverage cans) (Costa et al., 2020). Normal use of food packaging, such as bottle opening, can lead to the abrasion of small plastic particles and their transfer into food or beverages (Winkler et al., 2019). Microplastics have been detected in several types of food, including table salts, honey, fruits and vegetables, and seafood, as well as beverages, including mineral water and milk (Da Costa Filho et al., 2021; Katsara et al., 2022; Makhdoumi et al., 2022; Oliveri Conti et al., 2020; Schymanski et al., 2018b; Smith et al., 2018; Yang et al., 2015). Humans ingest these plastic particles together with their foods and drinks (Jadhav et al., 2021). Currently available data suggest that dietary exposure to MNP may result in adverse effects (World Health Organization, 2022; Yang et al., 2022). Taken together, this evidence illustrates that food contact materials (FCMs) are likely a relevant source of dietary exposure to MNPs. As consequence, there is a need for an overview of MNPs present in foodstuffs, originating from FCMs, and their sources (e.g., a certain type of food packaging) need to be identified as a prerequisite to reduce exposures.

Therefore, we will compile a systematic evidence map (SEM), with the aim of systematically documenting the available scientific evidence on MNPs that are generated by the normal and intended use of food packaging or other food contact articles (storage containers, filling lines, processing equipment, etc.) and thereby are released into foodstuffs or food simulants.

Here, we present the protocol for this SEM. The selection of the SEM method was based on James et al. (2016) and is deemed suitable since we aim to (i) describe the current state of knowledge (ii) discover the available evidence, and (iii) identify knowledge gaps for primary research on the topic, as well as the fact that (iv) our scope is likely to collate very heterogeneous studies. Ultimately, we aim to generate a reliable, science-based resource on MNP from food packaging that will be useful to diverse stakeholders and that can be updated as new evidence emerges.

1.2 Objectives

The overall objective of our SEM is to evaluate the available scientific information on MNPs generated by the intended use of FCMs or food contact articles (FCAs) with plastic or plastic-like composition and their migration into food or food simulant.

The specific objectives of the SEM are the following:

- provide an overview of the current knowledge base for food packaging as a source of MNPs in foodstuffs which can be updated by using the developed methodology
- identify pertinent knowledge gaps in scientific evidence and provide recommendations for future research
- identify if study designs and applied methods allow for robust evidence that MNPs originate from an FCM/FCA
- propose a methodology for investigating the migration of MNPs from food packaging

Identifying the key elements of the research question helps to structure the question of an SEM, the eligibility criteria, and the data extraction categories (James et al., 2016). According to Aiassa et al. (2015), questions in the area of food and feed safety focusing on exposure assessment can best be structured in the two key elements population (P) and outcome (O). Under this framework, P is represented by the food commodity of interest and O can represent the prevalence of a condition, the occurrence or quantity of the chemical of interest. We applied this structure to our research question as indicated in Table 1.

Table 1. Structure of our research question in key elements.

Question	Population (P)	Outcome (O)
What is the evidence for MNPs, that originated from an FCA, detected in food?	Food or food simulant	Presence of MNP originating from an FCA

1.3 Definitions

Here, we provide a list of terms and definitions we use in our SEM and throughout this protocol.

Food: Solid or liquid non-medicinal product intended for human consumption by any age group, including beverages.

Food contact articles (FCAs): Products or items which intentionally come into contact with food, such as packaging, storage containers, tableware, cooking utensils, tubes, and processing equipment.

Food contact materials (FCMs): Any material that is intended for use in the manufacture of an FCA and that is typically in direct contact with food. Materials that are not in direct contact with the food but may be a source of chemicals migrating into food (e.g., printing inks) are also considered FCMs.

Food simulant: Liquid or solid substance or mixture that is well-defined and used in extraction or migration experiments. Food simulants may include those defined in European Union (EU) or United States (US) regulations (EU, 2011; Food and Drug Administration, 2007).

Mesoplastics: Plastic particles of any shape and with a size between 1 and <10 mm following the definition of Hartmann et al. (2019).

Microplastics (MPs): Plastic particles of any shape and with a size between 1 and <1000 µm following the ISO/TR21960:2020 (ISO, 2020).

Migration: Transfer of a chemical or a chemical mixture from an FCM or FCA into food or food simulant under realistic, intended-use, and foreseeable conditions. We also include the migration of a small-sized solid (i.e., a particle such as a micro- or nanoplastic) under that definition which is

traditionally not covered but should be considered in our opinion. Particle migration further includes abrasion - the process of MNPs splitting off a plastic FCM or FCA. The migration of a chemical, chemical mixture, or small-sized solid into food may result in human exposure through food consumption.

Migration study: Experimental setup measuring the transfer of a chemical or particle from an FCM/FCA into food or food simulant.

Nanoplastics (NPs): Plastic particles of any shape and with a size of <1 µm following the ISO/TR21960:2020 (ISO, 2020).

Non-intentionally added substance (NIAS): Chemicals present in the final article without having a technical function. NIAS includes impurities in the starting substances for FCM manufacture, contaminants, side products (oligomers) of processing, and break-down products.

Intended use of food packaging: Handling of food packaging as suggested (i.e., intended) by the packaging manufacturer during the food packaging process, transportation, storage, and consumption.

Normal use of food packaging: Handling of food packaging as perceived as appropriate (i.e., normal) by the person handling the packaging.

Particle: A small-sized solid form suspended in a medium of interest (e.g., food, food simulant) <10 mm.

Plastic-like materials: Organic synthetic materials which are polymerized including elastomers (i.e., rubbers (Hartmann et al., 2019)), adhesives, as well as polymeric coatings, binders, pigments, and varnishes. Silicones are also considered under this category. These are inorganic synthetic polymers with an inorganic polysiloxane backbone and with organic units added as side chains. Silicones also contain chemical additives.

2 Methods

This protocol was developed using the Preferred Reporting Items for Systematic Reviews and Meta-analysis Protocols (PRISMA-P) guideline according to the PRISMA-P 2015 checklist and the associated elaboration and explanation (Shamseer et al., 2015). In addition, we conducted a pilot study to test and optimize our search and data extraction strategies, help with further SEM protocol planning, and set up the research team (see 2.4) (James et al., 2016).

2.1 Core team, reviewers, and their contributions

Two groups of experts contributed to the establishment of this SEM protocol. For one, the core team developed and drafted the protocol. Then, the reviewers carefully read the final draft and provided feedback which the core team integrated into the protocol.

The core team consists of the authors of this protocol: LZ, BG, AMD, AD, MW, and JM. LZ, BG, and JM developed the concept and methodology of the protocol. LZ and BG performed a pilot study and refined the literature search as well as the data extraction strategy. AMD, AD, and MW validated the protocol and provided constructive input to improve the protocol. LZ wrote the first draft. BG, JM, AMD, AD, and MW reviewed and edited the draft.

The reviewers are independent scientific experts in the MNP research field (Christoph Schür from Eawag, The Swiss Federal Institute of Aquatic Science and Technology) and with expertise in SEMs, (Verena Schreiner from the University of Basel, Switzerland).

2.2 Eligibility criteria

Eligibility criteria were developed according to the PO statement and are shown in detail in Table 2. In our study, we only include research articles written in English for which full texts are available. Reviews, book chapters, dissertations, conference abstracts, presentations, comments, and other editorial material will be excluded. Moreover, we will exclude studies that present FCAs/FCMs which are novel or in development since they are most probably not yet on the market.

Table 2. Eligibility criteria for outcomes of PO.

PO element	Description	Inclusion criteria	Exclusion criteria
Population	- Food or food simulant	- Plastic particle analyzed in food/food simulant	
Outcome	- MNP	- Analyzed particle is reported to be made of plastic - Particle size < 10 mm*	- Analyzed particle is not reported to be made of plastic - Particle size > 10 mm
	- Plastic FCM/FCA	- At least one part of the FCM or FCA is reported or assumed** to be made of plastic and/or plastic-like material	- It is not reported nor assumed that any part of the FCM or FCA is made of plastic/plastic-like material

*This means we include particles falling into the size range of nano-, micro-, and mesoplastics. We made this decision since, currently, there is no standardized definition of MNPs (e.g., while we define MP particles <1mm, others also include larger particles) and since we aim to capture all plastic particles.

** In the eligibility screening, we will also include studies on FCMs/FCAs that are not reported but only assumed to include a plastic/plastic-like material based on the typical composition of the reported food packaging. This ensures that all potentially relevant studies will be screened thoroughly in data extraction and avoids creating a bias during eligibility screening. In fact, it might not always be reported at all or only very subtly (e.g., as a sub-clause in the discussion) whether an FCM/FCA includes a plastic component. Examples of FCAs assumed to include a plastic component include glass bottles since they are likely to have a plastic or plastic-coated closure, glass jars since their lids usually have a plastic coating and/or plastic gasket, as well as cans, beverage cartons, and cardboard cups since they are likely to have an inner plastic-like coating.

2.3 Information sources

To search for relevant indexed scientific articles we will consult the following bibliographic databases which are openly accessible to us:

- PubMed
- Web of Science Core Collection (WoS) all editions
- ScienceDirect

Moreover, we identified additional relevant reports from authoritative sources (intergovernment or government agencies) on MNPs in foodstuffs. Since these reports combine (i.e., reference) primary

scientific articles, we will examine their references by backward snowballing to identify potential additional studies to be subjected to eligibility screening. The following reports will be included:

- Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment, 2019. Overarching statement on the potential risks from exposure to microplastics. Report TOX/2019/62. London. 80 pp.
- EFSA Panel on Contaminants in the Food Chain (CONTAM), 2016. Presence of microplastics and nanoplastics in food, with particular focus on seafood. EFSA Journal 2016;14(6):4501. https://doi.org/10.2903/j.efsa.2016.4501
- Food and Agriculture Organization of the United Nations (FAO). Lusher, A. et al., 2017. Microplastics in fisheries and aquaculture - Status of knowledge on their occurrence and implications for aquatic organisms and food safety. Rome, 2017. ISBN 978-92-5-109882-0
- German Federal Institute for Risk Assessment (BfR), Shopova, S, et al., A, 2020. Risk assessment and toxicological research on micro- and nanoplastics after oral exposure via food products. EFSA Journal 2020;18(S1):e181102. 12 pp. https://doi.org/10.2903/j.efsa.2020.e181102
- GESAMP, 2015. Sources, fate and effects of microplastics in the marine environment (Part 1). IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. GESAMP Reports and Studies No. 90. 96 pp. ISSN 1020-4873
- GESAMP, 2016. Sources, fate and effects of microplastics in the marine environment: part two of a global assessment. IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/ UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. GESAMP Reports and Studies No. 93. 220 pp. ISSN 1020-4873
- Health Canada, 2020. Draft science assessment of plastic pollution. Environment and Climate Change Canada, Ottawa. 153 pp.
- Norwegian Scientific Committee for Food and Environment (VKM), Skåre, J. U., et al. 2019. Microplastics; occurrence, levels and implications for environment and human health related to food. Scientific opinion of the Scientific Steering Committee of the Norwegian Scientific Committee for Food and Environment. VKM, Oslo, Norway, VKM report 16. 175 pp. ISBN 978-82-8259-332-8
- Science Advice for Policy by European Academies (SAPEA), 2019. A scientific perspective on microplastics in nature and society. SAPEA, Berlin. 167 pp. https://sapea.info/topic/microplastics/
- United Nations Environment Programme (UNEP), 2016. Marine plastic debris and microplastics: Global lessons and research to inspire action and guide policy change. UNEP, Nairobi. ISBN 978-92-807-3580-6
- World Health Organization (WHO), 2022. Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. WHO, Geneve. 154 pp. ISBN 978-92-4-005460-8
- WHO. 2019. Microplastics in drinking-water. WHO, Geneva. 110 pp. ISBN 9789241516198

2.4 Pilot study

We performed a pilot study to test our search strategy, its sensitivity and specificity (James et al. 2016), to optimize the data extraction, to refine the development of the protocol, and to get an overview of the available literature on the topic. The latter facilitated deciding on the number of people needed for data extraction and, therefore, the set of the research team.
We optimized our search strategies by testing different terms, groups, and combinations thereof in PubMed, WoS, and ScienceDirect. To evaluate the sensitivity and specificity of our searches, we screened a subset of the search results at the title and abstract levels. Furthermore, we examined whether five seed studies on the topic (i.e., studies we identified as relevant before starting the pilot searches) were actually identified by our search approach. The seed studies include Hernandez et al., 2019; Karami et al., 2018; Kedzierski et al., 2020; Liebezeit and Liebezeit, 2015; Schymanski et al., 2018a. This revealed that four of the five seed studies were indeed retrieved as expected. The fifth seed study could only be found at the expense of a great loss of specificity (by not including search terms on "packaging" and "FCAs"). Since this study and comparable ones are included in the references of the above-listed reports, we could ensure that they will be identified and assessed for eligibility, nevertheless. We conclude that our final search strategy (see 2.5) is indeed specific enough to keep the number of studies within manageable limits and sensitive enough to identify all seed studies.

In addition to a pilot reference search, we performed a pilot to refine the data extraction strategy. To test whether the data categories and terms, as well as their organization, allow us to extract the relevant information, data extraction on three of the above-mentioned studies (i.e., Hernandez et al., 2019, Kedzierski et al., 2020, and Schymanski et al., 2018a) was performed by two core team members in parallel. By comparing the results and discussing the challenges of the initial procedure, the data extraction was refined.

2.5 Database search strategy

To identify the relevant literature in PubMed, WoS, and Science Direct, we will apply four groups of search terms (Table 3). Terms within one group will be connected with the Boolean operator 'OR'.

Table 3. Search terms grouped by topic.

Search number	Topic/Group	Search terms
1	Particle	nanoplastic OR nano plastic OR nano-sized plastic OR nano sized plastic OR microplastic OR micro plastic OR micro-sized plastic OR micro sized plastic OR plastic particle OR plastic fragment OR plastic sphere OR plastic bead OR plastic pellet OR plastic foam OR synthetic particle OR plastic microparticle OR plastic nanoparticle OR polyethylene terephthalate particle OR polyethylene particle OR polyvinyl chloride particle OR polypropylene particle OR polystyrene particle OR polycarbonate particle OR polyamide particle OR polylactic acid particle
2	Food/food simulant	food OR drink OR beverage OR foodstuff OR nutrition OR mineral water OR tap water OR bottled water OR bottled drinking water OR soda OR beer OR wine OR tea OR coffee OR milk OR seafood OR fish OR mollusc OR mollusk OR mussel OR

		sardine OR bivalve OR meat OR chicken OR rice OR pasta OR noodle OR flour OR bread OR sandwich OR soup OR stew OR chocolate OR candy OR sugar OR honey OR salt OR fruit OR vegetable OR salat OR cereal OR nut
3	Packaging	packaging OR packing OR packaged OR canned
4	FCA (including terms related to food processing and transport)	bottle OR container OR shrink film OR foil OR wrap OR wrapping OR bag OR plate OR glass OR cutlery OR cup OR gasket OR closure OR cap OR lid OR jar OR tableware OR food container OR frying pan OR cookware OR food processing equipment OR pipe OR hose OR storage tank OR valve OR pump OR barrel

Groups #1 and 2 cover terms related to plastic particles and the food/food simulant (i.e., the content of the packaging). Searches #3 and 4 cover terms related to packaging in general or the FCA specifically. For searches #3 and #4, only one term of either one of the groups needs to be mentioned in the searched literature. Therefore, they were connected with an 'OR' Boolean operator. All other groups were connected with an 'AND' Boolean operator, meaning that for each of the groups # 1 and #2 and #(3 or 4) at least one of the terms needs to be present in the searched literature. The complete developed search string is the following: #1 AND #2 AND (#3 OR #4).

Since advanced searches vary between databases, individual terms and settings are adapted accordingly. In contrast to PubMed and WoS, ScienceDirect only allows entering eight search terms in the full-text search. Therefore, a simplified string was developed for searching that database. The full text is searched for the string ((food OR beverage OR drink) AND (packaging OR packaged OR packing) and the title, abstract, or author-specified keywords for the string (microplastic OR nanoplastic OR "plastic particle" OR "synthetic particle"). Full search strings for each database, as well as the number of hits at the search date, will be published together with the manuscript.

Depending on the number of hits and the expenditure of time for the literature screening, we may also identify additional relevant articles through forward snowballing (i.e., identify new literature based on those papers citing the paper being examined) and/or backward snowballing (i.e., identify older literature referenced in the examined paper).

2.6 Literature assessment and data extraction

2.6.1 Study selection

References identified in the bibliographic search will be imported into Citavi 6.12 and uploaded into CADIMA (https://www.cadima.info/index.php/area/evidenceSynthesisDatabase). CADIMA is a freely available online tool published by the Julius Kühn-Institut - Federal Research Centre for Cultivated Plants which will be used to manage the literature as well as to facilitate literature screening for eligibility criteria. First, duplicates will be removed. Subsequently, the core team will screen titles and abstracts for eligibility. Clearly irrelevant studies will be excluded. Of all other studies, the full text will be evaluated for eligibility. If a study is excluded, the reason(s) for exclusion will be documented in CADIMA. The latter will allow us to identify study designs and methodological approaches associated with a lack of evidence that MNPs detected in food originated from the food packaging.

At least 10% of the references will be assessed for eligibility by two members of the core team in a blinded manner to verify whether they independently derive the same conclusion (i.e., extract the same data). CADIMA allows checking for inconsistency, e.g. if two core team members derive a

different decision on study inclusion/exclusion. In that case, the disagreement will be resolved bilaterally by consensus. In cases where eligibility screening is only performed by one core team member, a second opinion will be requested when there is a lack of clarity on at least one of the criteria. For each reviewed reference, the person(s) assessing it, the person's decision of in- or exclusion, the final decision of in- or exclusion, as well as the reasons for exclusion, where appropriate, will be documented.

2.6.2 Data extraction

The core team members will extract the data from eligible studies in two consecutive steps.

Step 1: Collection of data

Step 1 aims to collect all the information on one sample and record it as one database entry. One sample corresponds to one experimental setup, i.e., the combination of one FCA, one food/food simulant and associated MNP(s). A single database entry will ideally provide answers to the following questions: What plastic was the FCA made of? If the FCM is made of a different material than plastics, can it nevertheless be assumed that the food in the packaging came into contact with plastic, e.g., during processing? What food was packaged by the FCA? Which approach was applied to study the migration of MNPs from food packaging into food? What type of MNPs were measured in the food or food simulants? Which concentrations of MNPs were measured? Information collected in step 1 will be grouped into the following categories:

- Bibliographic information (e.g., first author, publication year, journal name, DOI)
- Experimental design (e.g., conditions to study migration, controls, MNP detection method)
- Food/food simulant (e.g., type)
- FCA studied (e.g., article type, polymer type, color)
- MNPs detected in the food/food simulant (e.g., polymer type, color, size, quantity)

For some data categories multiple key terms may apply, for example, if more than one MNP detection method was applied. These will all be combined into one entry. Depending on the study design and the information provided in a publication, it might also be the case that no data are provided for one or more categories, in which case the respective field is left blank.

Step 2: Rating the level of evidence

The subsequent step 2 aims to determine the evidence for MNPs detected in food/food simulant to have originated from an FCM (Table 4) rather than being a contamination from another source, e.g. environmental exposure.

Table 4: Study design or details provided on the object of analysis and resulting levels and ratings of evidence that the MNP(s) originated from an FCM.

Study design or details provided on the FCM and MNP	Evidence	
	Level	Rating
Kinetic study design: MNP levels increase in the food/food simulant over time or by usage e.g., with the duration of food exposure to an FCM, with temperature, or by certain handling such as (cycles of) bottle opening.	1	strong
Spatial study design: Higher concentrations of MNPs are detected in parts of the food/food simulant that are in closer contact with the FCM/FCA compared to parts that are further away from the FCM/FCA.	1	strong

Common characteristic of MNP and plastic FCM: At least one specific characteristic of the MNP type corresponds to the characteristic of the plastic FCM, e.g., polymer type, color.	2	medium
Reported plastic FCM (part): The FCM is reported to be made of plastic but the polymer type of the FCM and/or the polymer type of the MNPs are not specified.	3	low
Assumed plastic FCM (part): The FCM is assumed (but not reported) to include a plastic/plastic-like material based on expert knowledge and MNPs are detected in food/food simulant.	4	possible
The authors of the paper only hypothesized that the MNPs detected in the food/food simulant originated from an FCM/FCA without providing any of the above-mentioned evidence to prove it.	no	no
The location of the MNPs in the food/food simulant makes it unlikely that they originated from the packaging/makes another source more likely. For instance, the MNP detection in the gut but no other tissue of a packaged fish makes it likely that the MNP was already in the fish (ingested) before it was packaged but did not originate from the packaging.	no	no

Depending on the study, a single reference can generate one or several database entries in steps 1 and 2 (Figure 1).

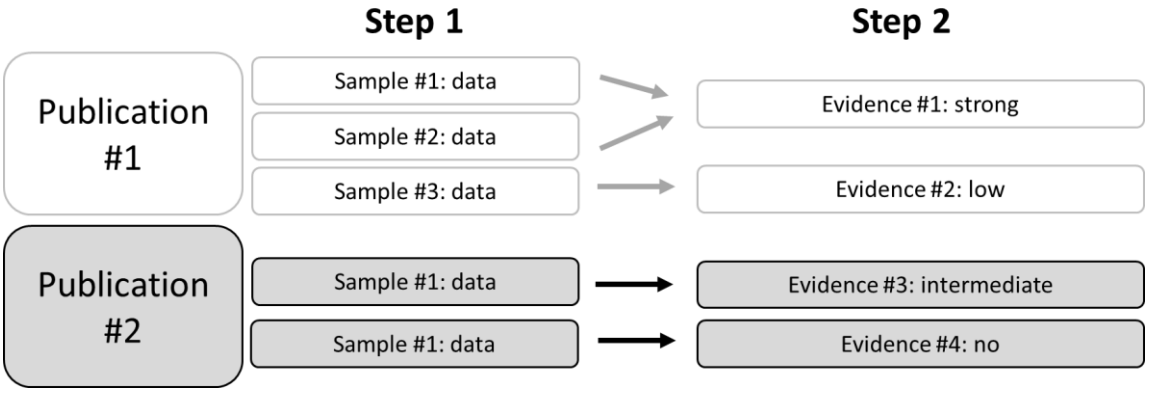

Figure 1. Examples of entries one publication can create in steps 1 and 2 of the data extraction. For instance, if a reference reports on more than one sample, the respective information is recorded separately. Furthermore, either one entry or several entries (e.g., kinetic study design) in step 1 may result in one database entry in step 2.

The main objective of our SEM is to identify, collect and organize knowledge to provide an overview of the State of Science. However, we will also evaluate a study`s level of QA/QC to avoid and quantify sample contamination. Furthermore, we will assess the level of confirmation of polymers based on the MNP detection method applied.

As a quality control measure of the actual data extraction, data recording will partly (at least 10%) be conducted by two core team members individually. Disagreements will be resolved bilaterally by consensus. For studies only screened by one core team member, a second opinion can be requested whenever there are doubts about the interpretation of the study.

2.6.3 Data management

Either MS Excel or SciExtract will be used to extract and record the data. SciExtract is a computational tool developed when compiling the database on migrating and extractable food contact chemicals (FCCmigex) (Geueke et al., 2022). It helps to select and store information, as well as to extract data in a systematic and semi-automated manner. For instance, categories of data that shall be extracted (e.g., polymer type of the FCM) can be set together with key terms to select from (e.g., polyethylene, polystyrene), results can be exported, and utilized in other software tools (e.g. for data analysis). Data categories (sorted by their P and O statements) and associated key terms have already been defined and can be chosen from drop-down lists but controlled addition of key terms will be allowed as needed. For data categories that are very specific to a certain study, only the free-text option is available (e.g., particle quantities).

2.7 Data analysis and visualization

All data recorded in the systematic evidence mapping will be compiled in a database/repository of MNPs from FCMs. The database allows us to meet our objective of documenting the knowledge base on MNPs present in food and generated by the intended use of FCMs or FCAs entirely or partly made of plastic or plastic-like material. Specifically, we will evaluate the evidence base on the following questions:

- How many studies have analyzed MNPs in (plastic) packaged food?
- What detection methods have been used to analyze MNPs in food/food simulants?
- Did the studies include QA/QC measures?
- What has been analyzed more often, migration of MNPs into food or food simulant?
- In what type of foods have MNPs been analyzed and detected?
- For which type of FCA (e.g., bottle, container) and which polymer type (e.g., polystyrene) have most studies been performed?
- What is the size (range) of plastic particles most frequently detected?
- What characteristics (e.g., color, polymer type) do MNPs have that were reported to migrate from an FCA into a food/food simulant?
- What quantities of MNPs have been detected in food/food simulant?
- Which type of FCA has been found to release the highest number of MNPs into food/food simulant?
- Which polymer type of FCA has been found to release the highest number of MNPs into food/food simulant?
- Is there a difference between single- and repeated-use FCAs concerning levels of MNP release?
- How many studies that have analyzed MNPs in plastic packaged food do or do not provide sufficient evidence that MNPs originated from the FCM/FCA?

GraphPad Prism 9 (https://www.graphpad.com/scientific-software/prism/) will be used to analyze and visualize the extracted data. We will choose the graphic types that most accessibly and effectively communicate our findings to the reader. Tables and flow charts will be created in MS Excel, Word, or PowerPoint files to provide an overview of certain study outcomes.

2.8 Data Reporting

The collected information will be summarized and discussed in a manuscript submitted for peer review in a scientific journal. The manuscript will further specify the reason for choosing an SEM, the methodology used for the mapping, the main findings including potential knowledge gaps, and recommendations for future research derived thereof. The compiled data will be made openly available and updated regularly.

3 References

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