Vitenskapskomiteen for mat og miljø
Norwegian Scientific Committee for Food and Environment

Microplastics; occurence, levels, and implications for the environment and human health related to food. An opinion from VKM

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Introduction

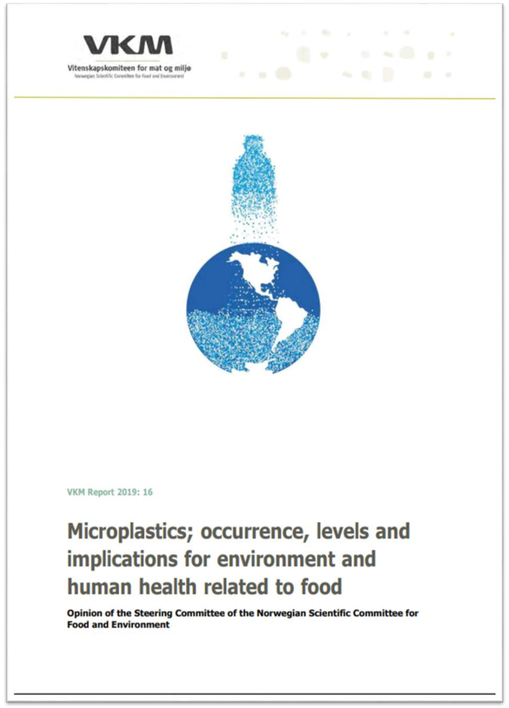
In 2017, The Norwegian Scientific Committee on Food and Environment (VKM) self-initiated a mandate for an opinion on microplastics (MPs) and nanoplastics (NP) in food and environment. The opinion were to be based on recently published international and/or national reports, complemented with peer-reviewed literature from December 2016 to February 2019.

Three international reports were identified as the basis for our assessment.

- **A statement from the EFSA Panel on Contaminants in the Food Chain (CONTAM) on the presence of nano- and microplastics in food, with particular focus on seafood (EFSA, 2016)**
- **A technical paper on the status of knowledge on microplatics in fisheries and aquaculture from Food and Agriculture Organization of the United Nations (FAO, 2017)**
- **Science Advice for Policy by European Academies (SAPEA), a scientific perspective on microplastics in nature and society, which was the basis for recommendations by Europe's Chief Scientific Advisors (SAPEA, 2019).**

VKM had noted a growing public and scientific concern and a corresponding demand for information and interpretation. Furthermore, possible national implications for food resources, environment and human health effects had not been assessed. Thus, VKM considered it necessary to provide a summary of the state of the science on microplastics and their potential implications for the environment and food safety in Norway.

The mandate included a summary of the state of knowledge on the presence of MPs in the environment and the implications for the ecosystem, terrestrial and aquatic organisms, food production and human health.



VKM published their opinion in October 2019. The opinion summarises and discusses analytical, experimental and sampling methods, describes levels of MPs and NPs in various environments, as well as sources, transport, distribution and fate of MPs. It also includes a chapter on biofilms and rafting, in addition to the hazard identification and characterisation, exposure assessment and risk characterisation. Uncertainties in each step of the assessment were described, and knowledge gaps identified.

Microplastics definition

In line wiht EFSA, FAO and SAPEA the VKM pinpoint that there is no international agreed upon definition of microplastics, and the field lacks a common terminology

VKM supports the following definition of microplastics (suggested by Hartmann et al., 2019):

Plastic debris can be defined as objects consisting of synthetic or heavily modified natural polymers as an ingredient that, when present in natural environment without fulfilling an intended function, are solid and insoluble in water at 20°C

VKM intended to do both a **human** and an **environmental** risk assessment

The opinion from VKM also summarised knowledge on

- Sources & fate
- Biofilm & rafting

Sources and fate of microplastics in the environment

Mapping and understanding the sources, transport, distribution and fate of microplastics in the environment is essential to be able to reduce microplastic pollution, and its impact on nature, including humans. Microplastics in the environment is a major source for MP in food and drinking water.

VKMs summary of knowledge shows that researchers are still far from understanding the sources, transport processes and sinks of nano- and microplastics on land. This is also true from the transfer of plastics from terrestrial to aquatic systems. Marine systems still appear to be the ultimate sink for microplastics in the environment. However, as this will happen on geological time scales freshwater and terrestrial systems are also important recipients and reservoirs of microplastics pollution.

Research efforts should focus on terrestrial and freshwater systems to increase knowledge similar to that of the marine systems. Microplastics in terrestrial and freshwater systems may be important sources for MP in food other than seafood.

Biofilms and rafting

Plastic debris can act as a substrate for diverse microbial communities, including pathogens (EFSA, 2016 and FAO 2017).

VKM found in their summary of knowledge that microplastic biofilms have unique microbial community structures compared to the surrounding environments, and microplastics can serve as vectors for microorganisms that are potentially pathogenic to humans, animals or plants. Opportunistic human pathogens have been found to be enriched in microplastic biofilm. Microplastics biofilms are considered possible hotspots for horizontal gene transfer. Also, several studies have suggested that the plastisphere may contribute to the spread of antibiotic resistance.

However, VKM concluded that the available information on microplastic biofilms did not provide sufficient basis to characterize potential effects on human health.

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Methodology used in the opinion

Knowledge based on the assessments done by EFSA (2016), FAO (2017) and SAPEA (2019) was summarized for each theme covered in the opinion.

In order to gather all updated knowledge and data, a systemic literature search was performed for the period December 2016 to May 2018, with an updated search performed in February 2019. These searches resulted in 2116 unique papers. After screening and quality assessment 252 papers were included from the original search (see flow chart in Figure 1), and 17 from the updated search. These were used as basis for both the human and the environmental risk assessments, as well as for the knowledge summaries on levels of MP, sources and fate of MP and biofilms and rafting.

Two sets of quality criteria were developed for papers on occurrence/levels and on toxicology, respectively. The criteria are shown in the boxes to the left. For each criterium that was met, 1 point was awarded. Papers that scored less than 3 in total were then excluded. Some papers scoring >3 points were also excluded based on justified expert judgement. In these cases the reason for exclusion were reported in the opinion.

VKM performed a systematic literature review

Publications published after December 2016 (EFSA CONTAM Panel's search) up to February 2019 were reviewed

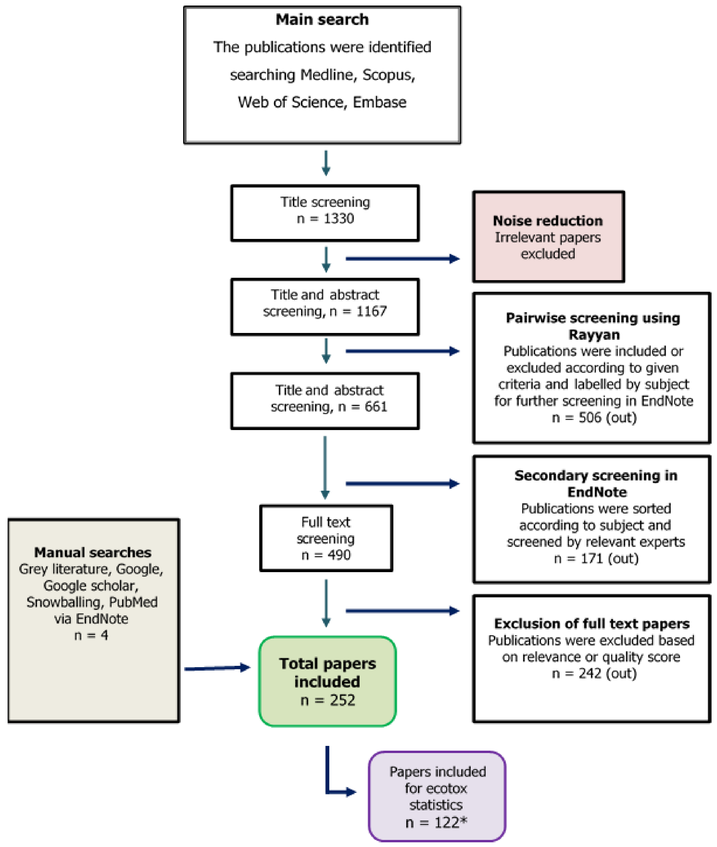

Figure 1. Flowchart for the systematic literature search on microplastics performed in May 2018. *) The 122 papers included for ecotox statistics were exclusively from the library-search (≠ manual searches), 15 were from the updated search performed in February 2019

Quality criteria – occurence

For the papers included in the occurrence and levels chapters, full text papers were assessed and given a quality score. The quality score was based on the following seven criteria:

1. **Chemical validation of visual results**
2. **Appropriate sample size and/or number of replicates**
3. **Procedural controls were used, such as blanks or airbourne particle moniotring**
4. **Extraction efficiencies of methods, where methods were tested for processing ability (i.e. spiking a sample with a known microplastic and reporting the recovery rates), or where methods were tested for their effects on known plastics (i.e. degradation)**
5. **Results corrected based on procedural blanks**
6. **Calculations of uncertainties/confidence levels, such as limit of detection/limit of quantifications (LOD/LOQs)**
7. **Consideration of uncertainties by authors, including but not limited to:**
   - **Understanding of sampling bias**
   - **Sample location**

Quality criteria – toxicology

For the papers included in the ecotoxicology category, full text papers were screened and given a quality score. The quality score was based on the following six criteria (based on Connors et al., (Connors, 2017)):

1. **Use of appropriate control (reference particle other than plastic)**
2. **Are the particles well-characterised (size distribution, surface charge, confirmation of polymer type by e.g., FT-IR, if commercial plastic was used)?**
3. **Was the particle preparation technique and stability of suspensions reported?**
4. **Has sedimentation of dense particles been considered when filter-feeding organisms have been used? For example, by use of e.g., a rotating plankton wheel?**
5. **Analytical verification of test concentrations?**
6. **Have findings been interpreted accurately, without conjecture beyond experimental limits ("overselling")?**

The systematic literature review – LESSION LEARNED

About 50 % of the papers identified and included based on inclusion- and exclusion criteria were later excluded due to poor quality.

As we are striving to get more data on human toxicology and toxicokinetics of microplastics, we need to ensure that the quality of the research is sufficiently high so that the results are useful for risk assessors.

One of the qulity criteria for toxicity studies that was most often failed was the claim for use of an apropriate control, i.e. a reference particle other than plastic. It is important to demonstrate if microplastics cause impacts that differ from those caused by natural particles.

Definition of microplastics includes particles composed of different polymers with different chemical compositions and morphologies and containing a variety of chemical ingredients. Still many studies treat microplastics as one contaminant group, leading to uncertain conclusions, and making high quality risk assessments challenging.

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Results and discussion

Hazard Identification → Hazard Characterisation → Exposure Assessment → Risk Characterisation

Human hazard and exposure assessment

For the human hazard assessment VKM only addressed oral exposure via the gastrointestinal tract

Only one study was identified by VKM that was relevant for toxicokinetics. Reinholz *et al.* found that most nanoparticles will be trapped inside intestinal cells and excreted by normal cell shedding (*Reinholz et al., 2018*)

For human toxicity four studies were identified. Three were *in vivo* studies, one *in vitro.* All used pristine nano- and microparticles. Micro- and nano-sized particles present in food are generally not pristine, and the relevance of studies on pristine particles for toxicity of weathered particles present under natural exposure conditions is unknown.

VKM concluded that the available knowledge and data do not provide sufficient basis to characterize potential toxicity in humans

For the human exposure assessment VKM affirmed that still very limited data of acceptable quality are available on levels of nano- and microplastics in foods, in line with EFSA, FAO and SAPEA

EFSA (2016): quantitative data are lacking

FAO (2017): microplastics have been found in many species intended for human consumption. However, there is still insufficient knowledge of microplastics in aquatic organisms consumed as food

SAPEA (2019): there is sufficient published evidence to say that microplastics occur in bottled water and foodstuff. However, the actual levels are uncertain, and the human exposure to microplastics cannot be assessed due to the lack of data

VKM concluded that an exposure assessment for human exposure to nano- and microplastics could not be done

Environmental hazard assessment

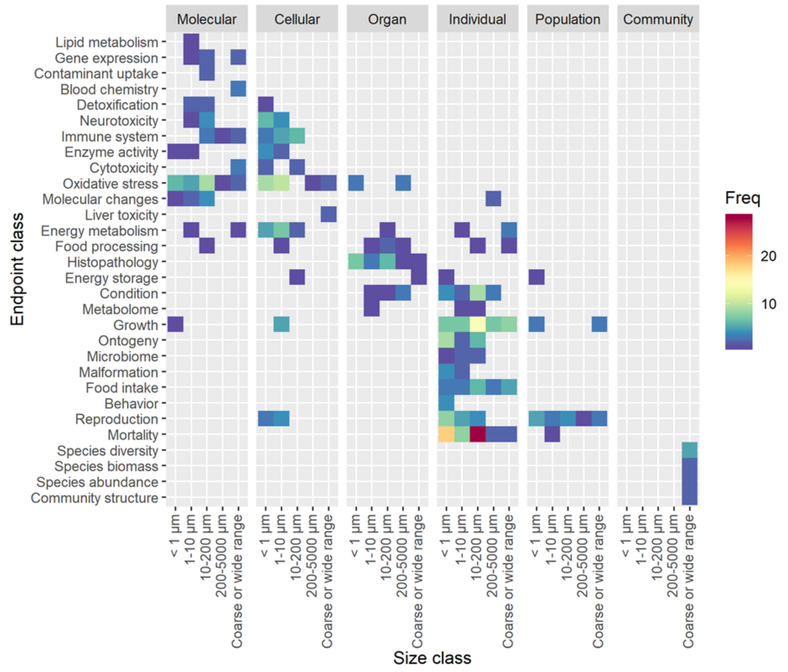

Figure 2. Heatmap showing the frequency of observed effects per endpoint class divided by particle size class and level of biological organisation. One observation is equal to a measured biological endpoint for a unique set of experimental conditions. There can be more than one endpoint and several experimental conditions within a particular study. For example, if mortality and growth effects have been observed for two different microplastics in two different organisms, then there would be 2 x 2 x 2 = 8 observations at the individual level in that study.

For the environmental hazard assessment toxicity data from 122 peer-reviewed publications were extracted. Parameters like experimental concentrations, lowest observed effect concentration (LOEC), polymer type, shape, size and endpoint were collected. Generally, the data extraction for a particular study was performed factorially, meaning that LOEC data for a particular endpoint was retrieved for each combination of particle shape, particle size, polymer type and exposure duration.

The LOECs were used to construct species sensitivity distributions (SSDs). VKM decided to make use of most available data by pooling all species and endpoints, and the SSDs were constructed from 63 studies covering 39-40 species.

For the environmental hazard assessment VKM derived a predicted no effect concentrations (PNEC) for nano- and microplastics of 0.14 µg/L (95% confidence interval: 0.04-0.64 µg/L) for mass-based concentrations and 71.6 particles/L (95% confidence interval: 3.45-1991 particles/L) for numerical concentrations. The PNECs were based on the SSDs, and were set at the hazard concentration 5% level.

Although the environmental hazard assessment has a number of limitations, the PNEC estimates should be relatively robust.

An essential finding in the environmental hazard charcterisation was the tremendous heterogeneity in endpoints measured, combined with a similar heterogeneity in microplastics tested. This was a challenge for the risk assessment. Even though there were relatively many results, there were still only a small *n* for most combinations, as illustrated in the heatmap in Figure 2.

VKM acknowledges that many different approaches are used to study microplastics depending on the matrix of interest. While this is inherent to an evolving field of research, this also poses a challenge to risk assessment as data comparability is limited.

Thus as the field of microplastic research evolves, the need for toxicity studies that can be used for both human and environmental risk assessment should be acknowledged.

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Conclusions, data gaps and future perspectives

Human risk assessment

VKM concluded that no human risk assessment was possible due to lack of occurrence data and lack of human toxicity knowledge

Data gaps specifically relevant for human risk assessment

- Data is lacking to provide a basis for characterisation of the potential toxicity of microplastics to humans. There is a general lack of information on the toxicokinetics of nano- and microplastics in humans. There is a lack of experimental data relevant to human toxicity
- Data is lacking to perform human exposure assessment. There is a lack of data on the precence of microplastics in food and drinking water. Importantly, many relevant food categories (meat, vegetables, dairy products) have not been investigated at all
- Knowledge is lacking on the role of microplastics as vectors for organic pollutants and biofilms on plastic debris. This knowledge is important to map possible devastating effects of microplastics other than direct toxicity of the microplastics itself

Environmental risk assessment

VKM concludes that on a global scale, the environmental risks are low and only for the 6 % most heavily polluted locations a risk is implied

However, the attempted risk characterisation must be considered provisional due to large data gaps. Moreover, it was only performed for aquatic ecosystems.

Data gaps specifically relevant for the environmental risk assessment

- Although a lot more data exist on environmental toxicity compared to human toxicity, data are still missing. Many experimental studies use relatively short exposure periods. Data on long-term effects are therefore lacking
- The effect of microplastics in the environment is often investigated in relation to their size and concentration only. It is important to demonstrate if microplastics cause impacts that differ from those caused by natural particles

Data gaps relevant for both risk assessments

- Most experimental studies use polystyrene particles. Polystyrene particles are not commonly found in environmental samples or in food, and therefore more studies investigating the effects of particles similar to those found in the environment, or in food, are encouraged
- There is limited knowledge about the effects of particle aging and fragmentation on the interaction with chemicals. Surface functional groups, size, shape, surface charge, buoyancy, and hydrophobicity may influence microplastics uptake

Future perspectives

- ✓ Currently, a lot more is known about environmental hazard than human hazard from microplastics, but researchers in the field of human toxicity has a possible advantage in learning from experiences made in the environmental field
- ✓ Challenges related to standardiasation and harmonisation needs to be adressed. There is a need for an internationally agreed upon definition of microplastics, and a common terminology within the field. Moreover, methods for sampling and analysis needs to be standardised
- ✓ For all risk assessments a general challenge exists related to transparent and good quality reporting including sufficient detail as well as evaluating uncertainties

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