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Background

Development work on the candidate indicator on 'Microlitter in the water column' has in 2015 and 2016 been taken forward by Lead and co-Lead Countries and communicated to and reviewed by the Contracting Parties through the HELCOM Expert Network on Marine Litter (HELCOM EN-Marine Litter). Overall coordination is taking place by the HELCOM State and Conservation Working Group.

Work on the microliter candidate indicator has been led by Finland, with Denmark and Germany as co-lead countries.

The HELCOM EN-Marine Litter has held six online working meetings (18.03.2016, 20.05.2016, 22.06.2016, 22.09.2016, 03.10.2016 and 07.10.2016) addressing, among other issues, the improvement of the microliter indicator report. Memos of those working meetings are available in the beach litter pre-core indicator folder of the marine litter workspace.

This document contains the HELCOM candidate indicator 'Microlitter in the water column' as proposed by the HELCOM EN-Marine Litter. The draft candidate indicator report has been prepared by Finland and Germany. Contributions and feedback has been received from Sweden.

Action requested

The Meeting is invited to take note of the progress of work.

HELCOM candidate core indicator report
October 2016

Microlitter in the water column

Key message

Marine microlitter is an emerging issue that is currently being intensively studied globally. Preliminary field and experimental studies as well as pilot monitoring on microlitter have very recently been also carried out in the Baltic Sea, but these studies do not yet provide enough information to make an evaluation of distribution, concentrations and impacts of microlitter. In order to progress towards the development of an environmental target and to define reliable threshold values the current situation still needs to be better understood and larger datasets are required.

Relevance of the candidate indicator

Microlitter in principle is described as particles that are smaller than 5 mm (GESAMP 2015). Microlitter can be further divided into different size-categories large (1-5mm), small (0.3/0.5-1mm) and very small <0.5/0.3mm litter particles (Imhof et al. 2013; Arthur et al. 2009; Andrady 2011). Most available data focus on microplastics (see Table 1), while data on overall microlitter concentrations is scarce (Setälä et al. 2016). Microlitter includes both synthetic and non-synthetic particles of different shapes (e.g. fibers, flakes, fragments) and materials (e.g. plastic, cellulose, cotton, wool, rubber, metal, glass, combustion particles). These particles are divided into primary and secondary particles, based on their origin: primary particles are intentionally already microscopically small while secondary particles are derived from larger litter items. Microlitter originates from various land-based and sea-based sources and may be found on the water surface, within the water column, on the sea floor and strandline, as well as inside marine organisms. The distribution of microlitter in the environment is amongst other things affected by prevailing environmental conditions like water circulation and winds. Different litter items have different buoyancy, some float, while some sink. Through the incorporation of microplastics in marine snow, or as a result of biofouling, also plastic particles with low density like the common plastic types, polyethylene and polypropylene sink to the sea floor. Some microlitter is long-lived in the marine environment while some degrade relatively fast. Presently, to our knowledge, there is no method being used for evaluating the age of microplastics in the environment. However, aging affects e.g. physical characteristics of the particles, such as the surface topography and morphology as well as coloration. Degradation of microlitter and microplastics depends on the environment. For plastics, exposure to UV-light, oxygen, elevated temperatures and mechanical stress accelerates the process, but no precise estimates are given for the degradation time of long-lived synthetic polymers.

Most of the environmental harm of microlitter has been linked to microplastics although other microlitter materials/types such as combustion particles may also be important. The proposed environmental harm is mostly due to the ingestion of microlitter. Ingestion of microplastics by a variety of animals has been shown by laboratory and field studies. Although the database on impacts of microlitter/microplastics on marine food webs is constantly growing, more data on actual impacts is needed.

Policy relevance of the core indicator

	BSAP Segment and Objectives	MSFD Descriptors and Criteria
Primary link	• Concentration of hazardous substances close to natural levels	D. 10 Marine Litter 10.1 Characteristics of litter in the marine and coastal environment
Secondary link	• Thriving and balanced communities of plants and animals	D. 10 Marine Litter 10.2 Impacts of litter on marine life
Other relevant legislation:		

Cite this indicator

HELCOM, [2016]. Microlitter in the water column. [HELCOM candidate core indicator report]. Online. [Date Viewed], [Web link].

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Results and confidence

The spatial distribution of microlitter in the sea is highly variable both vertically and horizontally because of environmental factors. Moreover, human activities create seasonal and geographical hot spots for the pressure “microlitter input” to the sea. The proportion of synthetic versus non-synthetic microlitter in the Baltic Sea has not been assessed. It is however likely, that plastic polymers form the majority of all microlitter particles, as they do for larger marine litter. In the Baltic most surveys on microlitter include sampling from the water surface, or a little below the surface, while net hauls from the whole water column are few. Studies on the sediment are also being launched.

Table 1 presents results from different studies that have been carried out in the HELCOM region on the amount of marine microlitter/microplastics.

Ecosystem compartment	HELCOM Subdivision	Sampling methods applied	Results	Size fractions considered	Reference
Surface water and water column	Northern Baltic Proper (Landsort Deep)	Vertical tows and bulk sampling	102-104 particles /m^3 (mean)	90 µm - 5 mm	Gorokhova et al. 2015
	Gulf of Finland	Manta trawl	0.3-2.1 particles /m^3	300 µm -5 mm	Setälä et al. 2016
		Submersible pump	0.0-8.2 particles /m^3	100 µm - 5 mm	Setälä et al. 2016
Surface water	Kattegat, Great Belt, Kiel Bay, Arkona Basin (North and Baltic Sea)	Manta trawl	No concentrations provided (only total numbers for both North and Baltic Sea)	300 µm -5 mm	Oberbeckmann et al. 2014
	Kattegat / The Sound / Arkona Basin / Baltic Sea)	Manta trawl	0.6-4.0 particles /m^3 (means)	300 µm - 5 mm	Magnusson & Norén 2011
	Arkona Basin / Bornholm Basin	Manta trawl	0.0-8.0 particles /m^3 0.0-35.0 fibers /m^3	300 µm -5 mm	Norén et al. 2015
		bulk sampling	710-26810 particles /m^3 0-1410 fibers /m^3	10 µm - 5 mm	
	Gulf of Finland	Manta trawl	0.3-0.7 particles/m^3	300 µm-5 mm	Olsson & Magnusson 2014
Seabed sediment	Kattegat	Box corer	96-1044 particle /l (mean)	10 µm-5 mm[1]	Johansson 2011
Coastline sediments	Bay of Mecklenburg / Arkona Basin (German Baltic coast)	Uppest sediment layers of the drift line	0-7 particles and 2-11 fibers /kg dry weight	63 µm - 5 mm	Stolte et al. 2015

Table 1 – Compilation of results from different studies carried out in the HELCOM region on the amount of marine microlitter/microplastics.

[1] To be verified.

Ecosystem compartment	HELCOM Subdivision	Sampling methods applied	Results	Size fractions considered	Reference
Coastline Sediments	Kattegat / Great Belt / The Sound / Kiel Bay / Arkona Basin (Danish waters; including North Sea and Skagerrak)	Not indicated	120-380 particles /kg dry sediment (means)	38 µm - 5 mm	Strand et al. 2013
	Gdansk Basin (Kaliningrad)	Uppest sediment layers (2 cm) of the drift (wrack) line	1.3-36.3 particles /kg dry sediment	0.5 - 5 mm	Esiukova 2016
Biota - Fish	To be specified (North and Baltic Sea)	Gastrointestinal tracts of demersal: cod, dab and flounder, and pelagic: herring, mackerel	5.5 % of all individuals,	To be specified	Rummel et al. 2015
Wastewater Treatment Plant Effluents	Skagerrak / Gulf of Finland	Bulk sampling	8-43 particles/m³ in effluent water.	300 µm - 5 mm	Magnusson et al. 2016
Wastewater Treatment Plant Effluents	Gulf of Finland	Bulk sampling	8600 particles /m³ and 4900 fibres /m³	300 µm - 5 mm	Talvitie et al. 2015

Table 1 – Compilation of results from different studies carried out in the HELCOM region on the amount of marine microlitter/microplastics (cont.)

Major outcomes and conclusions from these studies cover the following:

- Gorokhova et al. 2015 suggest the integration of samples for zooplankton monitoring for microplastic investigations. Their results reveal no differences between microplastic concentrations of coastal and open sea areas and furthermore show a very heterogeneous vertical distribution coinciding with zooplankton abundances.
- Setälä et al. 2016 compared two different sampling methods for microlitter in surface water both resulting in concentrations of <10 particles per m³ especially dominated by fibers.
- Rummel et al. 2015 - investigated the gastrointestinals of 290 individuals of demersal and pelagic fish finding 5.5% of all investigated fishes having ingested plastics and pelagic feeders to ingest significantly more particles than submersals.
- Stolte et al. 2015 – measured the largest microplastic contaminations at the Peene outlet into the Baltic Sea and in the North Sea Jade Bay. City discharges, industrial production sites, fishing activity and tourism are the most likely sources for the highest microplastic concentrations.
- Strand et al. 2013 found microplastic particles throughout shoreline sediments of Danish waters. Results indicate strong correlations between microplastic concentrations with TOC (total organic carbon) and the fine size fractions of sediment (<63 µm).
- Both Norén et al. (2014) and Setälä et al. (2016) show how the filter mesh size has a large impact on the results (concentration of anthropogenic particles in water).

Confidence of the indicator evaluation

The confidence of the indicator cannot be evaluated since there is only a limited amount of data. The indicator is at the beginning of its development, and presently there is a lack of verified and harmonized methods and guidelines for assessing the amount and types (synthetic vs. non-synthetic) of microlitter, especially in the smaller size fractions. Therefore also no harmonized data exists. Information both on the amount and the harm of microlitter, especially microplastics, to marine ecosystems is being rapidly generated because of the studies that are presently on-going globally. HELCOM countries are also actively performing research on marine microlitter in the different marine compartments and biota and will produce valuable data. At present the datasets that have been collected from the Baltic Sea represent a snapshot of the area and cannot be used to build a baseline for the state of the Baltic Sea regarding microlitter.

Good Environmental Status

The overarching aim to be achieved on microplastics in the HELCOM area is part of the 2013 HELCOM Ministerial Declaration (HELCOM, 2013) commitment to achieve a significant quantitative reduction of marine litter by 2025, compared to 2015, and to prevent harm to the coastal and marine environment.

A 6-year running mean may be considered appropriate to provide a baseline in terms of an average level of pollution, given the variability of litter data, which is influenced greatly by season, weather conditions and water currents. Evaluation of whether the good environmental status has been reached is initially proposed to be evaluated against the baseline using the mean level of input during a 6-year period. For microlitter no baseline for this evaluation is available, and further work on the evaluation on the progress towards Good Environmental Status (GES) is needed.

Assessment protocol

The assessment of microlitter shall be done in congruence with the Marine Strategy Framework Directive (2008) taking into account regional specific criteria.

The spatial distribution of monitoring sites shall be carried out close to discharge sites/point sources, when feasible, and at selected reference sites (e.g. open sea areas).

For future assessments basic criteria for frequencies / statistical assessment / trend analysis / threshold values confidence intervals need to be developed.

Relevance of the indicator

Policy Relevance

The 2013 HELCOM Ministerial Declaration (HELCOM 2013) agreed that a regional action plan on marine litter should be developed by 2015 at the latest. Such an action plan should allow the development of common indicators and associated targets related to quantities, composition, sources and pathways of marine litter. The Plan includes a section on monitoring and assessment where the need for the development of common indicators and associated targets related to quantities, composition, sources and pathway of marine litter is laid down. Where possible, harmonized monitoring protocols based on the recommendations of the EU TG ML are to be used. Microplastic litter is a candidate indicator for the OSPAR area (OSPAR). The adequacy of this indicator is under consideration by the Working Group 40 (WG-40) of the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (GESAMP, 2015). The Commission Decision (2010/477/EU) concerning MSFD criteria for assessing good environmental status is currently under review and revised version is to be developed for each descriptor, among which is marine litter.

Effects of microlitter in the ecosystem

World annual plastic production has increased drastically from 1.7 million metric tons in the 1950s to over 300 million metric tons in 2014 (PlasticsEurope 2015). Most plastics are discarded within a year of their production (Hopewell 2009) and up to 10% of all the plastics produced have been estimated to enter the oceans (Barnes et al 2009). Available data especially from beach litter monitoring for the different regional seas demonstrate that the proportion of plastic among total marine litter ranges from 60 to 80% (e.g. OSPAR beach litter monitoring in the Southern North Sea for the years 2002-2008), in some locations even up to a higher percentage (e.g. 83% ICC-campaign in the Mediterranean for the years 2002-2006).

Studies on the harm of microlitter to the ecosystem in general deal on bioaccumulation, desorption and toxicity of pollutants, leaching and toxicity of additives and monomers and transport of alien species. Overall, studies on marine organisms mostly deal with the ingestion of microplastics. This uptake could be through direct exposure (ingestion or other, like gills) of microplastics from water or sediment (e.g. Thompson et al. 2004, Besseling et al. 2013, Watts et al. 2014). Ingested microparticles may clog the digestive tract, or cause problems due to the co-contaminants of the particles (harmful additives or accumulated hazardous substances. It has been proposed that various organic contaminants (PCBs, PAHs, DDT, PBDEs, and BPA) bioaccumulate in plastic-ingesting organisms, with unknown wider consequences to themselves or to the food web (Mato et al. 2001, Endo et al. 2005, Rios et al. 2007; Karapanagioti & Klontza 2008, Teuten et al. 2009, Bowmer & Kershaw 2010, Frias et al. 2010, Rochman et al. 2015). Moreover, according to a study on the accumulation patterns of metals to plastics (Rochman et al. 2014), generally various types of plastics (PET, HDPE, PVC, LDPE) tended to accumulate relatively similar concentrations of metals and accumulation was greater the longer plastics remained at sea.

To summarize: the extent to which microlitter and especially microplastics represent a significant risk is a knowledge gap. However, this field is presently under extensive study, and new information is being generated rapidly.

Human pressures linked to the indicator

Marine microlitter comes from a variety of sources like traffic (abrasion from tires, road paints), constructions in the sea (bridges, piers, etc.) industry, fragmentation of larger plastic particles and sewage treatment plants, merchant shipping, ferries and cruise liners, commercial and recreational fishing vessels, tourism, recreation, military fleets and research vessels, pleasure craft, offshore installations, drilling rigs, aquaculture, local business, industry, unprotected waste disposal etc. Processed municipal wastewaters contain e.g. synthetic textile fibers from washing of clothes and abrasive plastic fragments from cleaning agents (Browne et al 2011).

Monitoring requirements

Monitoring methodology

There is no harmonized methodology available for the assessment of marine microlitter. MSFD TSG Marine Litter 2013 has produced guidelines for marine litter surveys and analyses that also include microlitter methodology. There are currently on going method development in several research projects which will provide essential information for developing the guidelines for harmonized methods. HELCOM members sample microplastics from the environment with different methods (Table 2).

From the data obtained so far it can be concluded that harmonized sampling methods must be developed.

	Water surface	Water column, other than surface	Sediment	Biota
Sampling methods /organism	Manta trawl (EE, FI, DE, SE, PL), trawl of Bongo net (DE), pumping of water through 300 µm filter (SE), water sampler (SE), suction filtration over 10 µm filter (SE)	Plankton samples collected with Baby-Bongo net (DK) (Ø 20 cm, mesh size 150 µm), WP (100µm net), 30L water sampler+ filtration (FI), 90µm zpl net (SE, historical samples)	Box corer (DK, DE), GEMAX (FI), Van Veen Grab (DE, FI), Nemisto corer (PL), Various sediment grabs (SE)	Sprat, herring, whiting, herring, cod & plankton (DK, in separate studies), small fish, e.g. roach, perch herring, blue mussels, seals (all field samples)(FI), plankton, littoral invertebrates(experimental work) (FI), Fish & several invertebrate species (SE)
Analytical methods	None (FI, SE), provisional H2O2 over 7d (EE, DE), fraction <500µm: digestion with H2O2 and different enzymes (DE), being tested (PL)	2 ml digestion solution (KOH and NaOCl) per ml of zooplankton sample (DE), enzyme digestion (FI).	KOH+NaOCl (DK), not decided/under development (FI/SE), multi-step provisional H2O2 over 7d, NaOCl, enzymatic (DE), MPSS + sodium polytungstate; fraction <500µm: +H2O2 and enzymes (DE)	A digestion solution of KOH and NaOCl (DK), chemical + enzymatic (under development) (FI)
Size fractions	>330 µm,1x>100µm + 1x>500µm, Several size classes between ≥10µm and ≥300µm, ≥300 µm and ≥10 µm, >500µm	>100µm (DK, FI))	38,1000 and 5000 µm (DK), 20 – 38 µm, 38 – 100, 100 – 300, 300 – 1000, 1000 – 5000µm (DK), >100µm (FI), >63 µm , (63-300, 300-630, 630-1000, 1000-5000 µm) (DE), Several size classes between ≥20µm and ≥300µm (SE)	Shape and color (>100µm)(DK), shape, color and size (>500 µm)(DK), shape, color and size (>100µm)(DK), >(10-20µm)(FI)
Basic microscopy /sorting with	Stereomicroscope (EE, FI, DE, DK, SE) , digital image analysis (DE)	Light microscopy with hot needle test (DK) (x 50 magnification), Stereomicroscope (FI)	Light microscopy (10 - 100x magnification)(DK, DE, SE), n.a. (FI), digital image analysis (DE)	Light microscopy (stereo)(DK,FI)
Additional microscopy/ testing	FTIR and Raman on subsamples (SE, GE)		FT-IR on few representative particles (DK), FTIR and/or Raman on a subset of samples (DE), all samples: FTIR and Raman (DE), FTIR and/or Raman on a subset of samples(SE)	Raman spectroscopy for some in one study DK), Hot needle test (DK), being planned (FI)
Reference unit	area and volume, volume, (EE, FI, DE), others not defined	density/m³ (DK, FI)	Wet and dry weight and TOC(DK), vol & wet weight(FI), vol & dry weight(DE), wet and dry weight(DE), dry weight(SE)	

Table 2. Methods used for collecting microlitter samples (sampling from strandline not included).

Current monitoring

Microlitter is a new parameter to be studied from the marine environment. Data has been collected for a few years and is mostly being used for testing of sampling and analytical methods. Sampling has included different environments combined with various methods focusing on different size-fractions (Tables 1 & 2)

Analytical methods vary from microscopy to the use of Raman and FTIR. Water surface has been a priority element for sampling. Other work has included experimental work on microlitter uptake by organisms and purification efficiency of STTPs. Based on a data call sent to the HELCOM members the following information was collected.

Microlitter in the water column

Microlitter in the water column is typically sampled with surface nets/trawls. Manta trawl from open water areas was used to sample microlitter from the water surface by Finland, Germany, Estonia and Poland. Size fraction collected with manta was either >330 or >500. Germany has also sampled by a Bongo net a smaller fraction >100µm. In Sweden data has been collected from the shore by a submersible pump (10 and 300µm mesh size filters). Earliest samples are from Sweden (2011). No country is using the data as part of their monitoring program.

Microlitter in sediment

Sampling and analysis of microlitter in sediments are most advanced in Denmark, Germany and Sweden. Methods vary somewhat (see Table 1). Denmark has carried out bot research by sampling with box corer and collected three different size fractions, carried out multistep digestion and light microscopy with some FTIR. In Germany a box corer or a Van Veen grab is used for sampling ("Danish Seas", Central Baltic, Gulf of Riga, Gulf of Finland, Gulf of Bothnia, Rostock), and samples are divided into several size fractions (63-300, 300-630, 630-1000, 1000-5000 µm). Different density separation methods has been used with additional chemical and enzymatic digestion. Also material characterization to separate synthetic and non-synthetic microlitter has been done with FTIR in some cases. Sweden has carried out studies on MPs in sediment mostly in the North Sea area. Finland has taken pilot sediment core samples from the Bay of Bothnia and Gulf of Finland, and Poland has sampled with Nemisto corer.

Microlitter on strandline

Only Germany has provided information on microlitter sampling on strandline. The areas studied include the isle of Rugen, several beaches along the German Baltic coast in the greater area of Rostock as well as beaches in Lithuania. Naked eye was used to identify >2mm particles (2mm mesh) collected from an area of 9m². No results are yet available.

Microlitter in the water column, other than surface

Denmark is carrying out a study based on historical data where the ingestion of microlitter ingestion by pelagic fish (sprat and herring) is done based on old data of fish and corresponding plankton samples (>150µm) from Bornholm basin. Sweden (Gorokhova 2015) has published a work on microplastics in historical zooplankton net samples at two stations on the Swedish coast. Results reveal concentrations several magnitudes higher than what has been found previously in manta net samples. Finland has recently collected 100µm net samples from water column below thermocline and halocline in the Gulf of Finland.

Microlitter in biota

Danish published data for microlitter in fish (DTU Aqua) finds that the digestion mixture recommended in the ICES guideline is too "harsh". In Finland, samples for assessing the amount of microplastics in small fish (Herring, roach etc.) have been collected from the coast of Helsinki and from the river Vantaanjoki in the southern part of the country. Herring for microplastics analysis have also been collected during a monitoring cruise in open water areas in 2015 in Bothnian Sea and Archipelago Sea. A digestion method is also being developed. So far no results are available.

Description of optimal monitoring

Optimal monitoring follows the basic criteria: objectivity, representativeness in space and time, validity (of applied methods, of achieved results) and reliability / reproducibility (comparability of methods used for sampling and analysis). Low-density polymers which are common in marine environments (PE; PP; EPS) float on the water surface, while polymers with higher density sink out from the very surface of the water. During time the floating particles are covered with biofilm and increase in density and eventually should sink. If this is the case, surface microlitter might represent more or less the continuous plastic flow to the environment while the seabed sediment would serve as the accumulation area (long-term sink). Additional sampling of selected indicator species being representative for the whole Baltic region will furthermore enable an evaluation of biota response to microlitter exposure and possible harm.

Monitoring of microlitter in the water column should be done according to selected investigation sites covering all HELCOM sub-basins of the Baltic Sea and representing high risk areas e.g. close to discharge sites/point sources, and selected reference sites representing mean background levels.

Monitoring programmes for microplastics are under development. The results of currently on-going research projects in the Baltic Sea area, together with the findings of the most updated studies worldwide, will support the definition of the optimal monitoring for the Baltic Sea area.

Optimal monitoring of microlitter amounts and distribution may include sampling from water surface, seafloor (sediment), biota and optional coastline (sediment).

Description of data and up-dating

Access and use

The data and resulting data products (tables) on this report can be used freely given that the source is cited as follows: HELCOM, [2016]. Microlitter in the water column. [HELCOM candidate core indicator report].

Metadata

Some HELCOM members provided updated information on their microlitter monitoring activities in the frame of the HELCOM EN-Marine Litter. Such information is compiled in Tables 1 and 2.

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