Task 2.1.3 Development of baselines of marine litter - Report on the analysis of compiled data on microlitter in the Baltic Sea

Authors: Outi Setälä

Affiliation of authors: SYKE

Contents

Background

This document compiles information based on the previous data calls on microlitter in the Baltic Sea and other available published information on the topic. Information from the first data call was previously used to produce the first versions of "microlitter in the water column" candidate indicator report in 2016 prepared by Finland and Germany with contribution from Sweden. The table from the candidate indicator report has been further updated for this report.

The first questionnaire on all available data on microlitter (ML) in the Baltic Sea was sent out (6.6.2016) to the HELCOM Expert Network on Marine Litter (EN-Marine Litter). A subsequent data call was sent to the HELCOM EN-Marine Litter in February 2017 (10.2.2017) in the frame of the Theme 2 of the SPICE project, and was further supplemented with a request to report coordinates of the study/survey sites. This report contains a pilot assessment on microlitter in the Baltic Sea and the identification of knowledge gaps based on compiled information from the data calls mentioned.

Availability of data/Responses from the HELCOM countries

Data for ML in ecosystem compartments (water surface, water column, sediment, strandline and biota) were collected in the respective data calls. Altogether over 40 different activities (research and monitoring) were reported. This information however does not cover all studies that have been carried out and published work from reports and scientific journals was sought to complement this data.

An overview of the present activities on microlitter in the Baltic Sea

Microlitter is a new study parameter and data has been collected only for a few years in the Baltic Sea. Based on the information both from data calls and other sources, the earliest sampling for microlitter in the Baltic Sea was done from water surface waters from the Swedish coast (2007). Based on the available data, the earliest studies on microlitter in sediment derive from Denmark (2012), for microlitter on strandline from Germany (2014), and for microlitter in biota from Denmark (2013). Denmark has also analysed historical samples from water column and biota that go back in time as far as into the year 1987, while Sweden has analysed old zooplankton samples from 2007 and 2008. Most of this environmental sampling has been for research purposes and pilot monitoring being so far done for water surface in Estonia, Finland, Sweden and recently also in Poland, while the monitoring of sediment and biota has started in Denmark.

There is great variability in the methods used for sampling and sample analyses. In short: sampling methods and sampling devices vary, also when samples are collected from the same ecosystem compartment. Different devices and extraction protocols are further used to separate ML from the matrices, biological material or sediment, or to digest organic material.

Detailed information on microlitter studies in the Baltic Sea conducted by the HELCOM countries. Data sources: questionnaires and published work not included in the data calls

Although the data call was for microlitter, most of the work has been done to detect plastic polymers from the environmental samples.

Water surface and water column

All countries except Latvia and Lithuania have reported or published studies on microlitter in water surface or water column. Table 1 compiles the reported studies after the data calls and other relevant published work on microlitter/ microplastics in water surface and water column.

Nets

Microlitter in the water column is typically sampled with surface nets or trawls, such as the manta trawl. Manta trawls were used in Denmark, Estonia, Finland, Germany, Poland and Sweden. Germany has also sampled with a Bongo net. Vertical sampling for microlitter from different layers of the water column with zooplankton net or multinet has been carried out by Finland. Historical vertical net tows have been re-used for microlitter analyses by Denmark and Sweden.

Pumps

Two types of pumps have been used. Submersible pumps have a set up where filters can be lowered under the water to eliminate contamination. Finland and Sweden used this method in a study where manta trawl and one such pump were compared. Standard pumps that lift the water which is then driven through different sized filters, or a series of filters have been used in Sweden and recently also in Finland. The volume of water filtered in these studies and the filter mesh sizes varies enormously.

Water samplers

Sweden has also used a Limnos or other type of water sampler for sampling small water volumes which have been consecutively filtered through small mesh size filters (10 µm). Finland used a 30L water sampler in one study and Russia has collected water with Niskin bottles.

Sediment

Microlitter in sediments has been studied in Denmark, Finland, Germany and Sweden. Denmark has used a box corer and Germany a box corer or a Van Veen grab. Sweden has used "various sediment grabs", Finland has used box corers and a twin Gemax corer and Russia a hand-operated dredge. Table 2 compiles the reported, presently on-going and published work on microlitter/microplastics in sediment.

Biota

Studies focused on microlitter in fish from field samples have been reported by Denmark, Finland and Sweden. Methods for catching fish: bottom trawls, seines, line and hook and electronic fishing. Data has been used both for pilot monitoring and method development. Denmark has used historical datasets in this case as well. Other organisms besides fish (invertebrates) are analyzed, mainly during research projects on exposure (ingestion and impacts). These include mostly laboratory work with some incubation *in situ*. No compilation of microplastics in biota is included in this report; however a recent report by Bråte et al. (2017) compiles the studies which have been carried out on microplastics in biota.

Microlitter on strandline

Germany has provided most of the information on sampling microlitter on strandline. The areas studied include four beaches on the isle of Rugen, several beaches along the German Baltic coast in the greater area of Rostock as well as beaches in Lithuania. On the German coast on the isle of Rugen a case study addressing beach sediment microplastics, including method development was carried out. For the analysis, density separation via a glass elutriation column was implemented. In advance, efficiencies were tested for two polymers, being not buoyant in water, and Nile Red staining method used for particle identification. In this study particles between 0.063mm and 5mm were addressed. In spring 2017 Finland started a survey on microlitter on coastal areas where strandline is also included. This survey includes 7 sampling areas where beach sand is collected. One of these areas, close to the city of Kotka in the Gulf of Finland, will be studied more thoroughly. A study on strandline litter was also carried out in the Kaliningrad area, Russia, where the number of macro/meso/microplastics in the upper 2 cm of the sandy sediments was analyzed.

Size fractions and analytical methods for characterizing microlitter materials

In the Commission Decision (EU) 2017/848 all anthropogenic particles in the marine environment which are smaller than 5mm (5000µm) are considered as microlitter. Microplastics are plastic polymers of the same size. The EU Technical Group on Marine Litter noted (Galgani et al. 2013) that within this size fraction (<5mm) the items in the larger end of the spectrum may cause harm to larger organisms such as seabirds while smaller particles may interfere with feeding, digestion and movement. Because of this, microlitter should be divided into size categories between 20µm to 5mm (20-100 µm, 101-200 µm, 201- 300µm etc.), and further categorized by its physical characteristics including size, shape and colour. Particles between 1 and 100 µm should also be further studied with additional microscopy (FTIR or other) to verify materials. When the reported methods of HELCOM data call are investigated, it becomes clear that this guidance has not been followed in all cases.

Size fractions

Water surface and water column sampling has been carried out with various mesh sizes 500, 333, 300, 200, 100, 20, 10µm. Flow meter has been used to evaluate filtered water volumes at least in Denmark, Finland and Sweden , but this information was actually not asked separately, so there may be other countries as well. Mesh sizes of 300µm or 333µm were the most commonly used. Sediment samples have been fractionated with different mesh sizes between 5000 and 20µm. Denmark and Germany have separated different size fractions from the sample. Strandline sampling also includes very detailed fractioning between 5000µm and 63/10µm or simple pre-sieving.

The use of several size fractions somewhat hinders the comparison of the data from different studies. At the moment best comparability is available for water surface studies, since most of them have used manta trawls. It has been shown already in the early work by Magnusson and Norén (2011), and later in the study by Setälä et al (2016), both including data from the Baltic Sea, that data collected with different mesh sizes cannot be compared with each other. The smaller the mesh size, the more litter will be in the sample.

Differences in analytical methods

Samples have been frozen, preserved in formalin or dried. Field collected material usually contains biological or other organic material which must be removed before microscopy can be carried out. Both water samples as well as sediment samples have been treated with different methods.

Water samples have usually been treated with H2O2 with additional digestion with different enzymes. No methods for removing chitin (found in zooplankton and insects) have been presented. Denmark has however treated historical zooplankton samples with a digestion solution (KOH and NaClO).

Sediment and sand samples have been treated both for separating litter (plastics from sediment material) and for digesting organic material. Density separation methods have been used (saturated NaCl, MPSS and sodium polytungstate) with additional digestion (KOH + NaOCl, H2O2 and different enzymes, a multi-step provisional H2O2 over 7d, with NaOCl, and enzymatic digestion).

Most samples have been pre-sorted with stereomicroscopy. Additional material characterization has been done by FTIR, RAMAN, hyperspectral image analysis and digital image analysis.

Table 1. Studies carried out on microlitter/microplastics in water surface and water column.

Ecosystem compartment	HELCOM Sub-basin	Sampling methods applied	Results	Size fractions considered	Reference
Surface water	Gulf of Finland, Northern Baltic proper, Gulf of Riga	Manta trawl	Microlitter <10 items/m^3; microplastics <4 items/m^3	>330 µm	Unpublished, Kati Lind & Inga Lips, data from 2016
Surface water	Gulf of Finland	Manta trawl & Submersible pump	0.3 -2.1 /m^3 (manta), 0–3.4 /m3 (pump 300 µm) and 0–8.2 /m3 (pump100 µm)	>333 µm (manta), >100µm & >300µm pump	Published, Setälä et al. 2016
Surface water	Skagerrak/Kattegat, Baltic sea, Gulf of Bothnia	Large water volumes both for manta trawl and water pump through a filter series, "sandwich"		Manta trawl 330um, Pump: sandwich of 500, 300, 50µm	Unpublished, Kärrman et al., data from 2014
Surface water	Gulf of Finland	Manta trawl	0.3-0.7 particles/m³	300 - 5000µm	Published, Magnusson 2014
Surface water	Gulf of Finland	Pump	0.01-0.65 fibres/L 0.5 9.4 synthetic particles/L	>20 µm, filtered with a sandwich type tower: (20 and 100µm)	Published, Talvitie et al. 2015
Surface water	Gulf of Finland, Bothnian Sea, Archipelago sea Quark, Bothnian Bay	Manta trawl		300 - 5000µm	Unpublished Lehtiniemi & Setälä, data since 2014
Surface water	Central Baltic, Gulf of Riga, Gulf of Finland, Gulf of Bothnia	Manta trawl		300 - 5000µm	Unpublished, Oberbeckmann et al. data from 2015
Surface water	Warnow (Rostock, Germany)	Bongo net		>100µm and >300µm	Unpublished, Oberbeckmann, Labrenz, data from 2014
Surface water	Danish Seas, South Funen Archipelago	Manta trawl		>300µm	Tamminga et al. 2018
Surface water	Kattegat / The Sound / Arkona Basin / Baltic Sea	Plankton net 20 µm	300-1300 fibers/m³ 100-7000 particles/m³	>20 µm -	Published, Norén et al 2009
Surface water	Arkona Basin / Bornholm Basin	Manta trawl	0.0-8.0 particles /m³ 0.0-35.0 fibers /m³	300 - 5000µm	Published, Norén et al. 2015
Surface water		Bulk sampling	710-26 810 particles /m³ 0-1 410 fibers /m³	10 – 5000µm	
Surface waters	Baltic Sea	Manta trawl		≥300 µm and ≥10 µm	Unpublished, K. Norén.
Surface water	Gdańsk Basin, Eastern Gotland Basin, Bornholm Basin	Manta trawl		>330µm	Unpublished, Krzymiński et al., data from 2016
Water column	Northern Baltic Proper (Landsort Deep)	Vertical tows and bulk sampling	10^2-10^4 particles /m³ (mean)	90 – 5000µm	Published, Gorokhova et al. 2015, historical zpl samples
Water column	Gulf of Finland	Vertical tows and bulk sampling		>100µm	Unpublished, Lehtiniemi & Setälä, data from 2016
Water column	From Bothnian Bay to western Gulf of Finland,	Multinet, different water columns		>100µm	Unpublished, Lehtiniemi & Setälä, data from 2017
Water column	Bornholm Basin	Baby-Bongo net		>100µm	Unpublished, Bastian Hüwer historical data since 1987
Water surface – water column	Baltic Sea Proper in 2015–2016	Bulk sampling 10-30-L Niskin bottles	0.07 to 2.6 fibres/L	>174 µm	Published, Bagaev et al 2017
Water surface	Stockholm archipelago, other study close to Visby	Manta trawl and another method with citizen science	Coastal Sweden: 4.2 ×10^5 /km^2, offshore 4.7×10^4 /km^2	335 µm and 80 µm small trawl	Published, Gewert et al. 2017
Water surface	Danish coastal waters	Manta trawl		≥300 µm	Unpublished, Syberg, data since 2015.

Table 2. Studies carried out on microlitter/microplastics in sediment.

Ecosystem compartment	HELCOM Sub-basin	Sampling methods applied	Results	Size fractions considered	Reference
Sediment	Western Baltic Sea, Belt Sea, Sound, Kattegat	Box corer		38, 1000 and 5000µm	Unpublished, Strand, data from 2012-2013
Sediment	Inner Danish waters	Box corer		20 – 38 µm, 38 – 100, 100 – 300, 300 – 1000, 1000 – 5000µm	Unpublished, Strand, data from 2015
Sediment	Danish Seas	Van Veen		(63 - 300, 300 - 630, 630 - 1000, 1000 - 5000µm)	Unpublished, Fisher, data from 2015
Sediment	Warnow (Rostock, Germany)	Van Veen		>500µm	Unpublished, Oberbeckmann, Labrenz, data from 2014
Sediment	Central Baltic, Gulf of Riga, Gulf of Finland, Gulf of Bothnia	Van Veen or Box corer		>500µm	Unpublished, Oberbeckmann, Labrenz, data from 2014
Sediment	Gdańsk Basin, Eastern Gotland Basin, Bornholm Basin, Szczecin Lagoon, Vistula Lagoon	Nemisto corer		<100µm	Unpublished, Krzymiński, data from 2016
Sediment	Gulf of Finland	GEMAX corer		100 – 300, 300 – 1000, 1000 – 5000µm	Unpublished, Lehtiniemi & Setälä, data from 2015
Sediment	Archipelago sea, Bothnian Sea, Bothnian Bay, Quark, Northern Baltic proper	GEMAX corer		100 – 300, 300 – 1000, 1000 – 5000µm	Unpublished, Lehtiniemi & Setälä, data from 2017
Coastal sediments	Finnish coastline, 7 stations between the cities Kotka and Vaasa	Petit ponar grab sampler		100 – 300, 300 – 1000, 1000 – 5000µm	Unpublished, Lehtiniemi & Setälä, data from 2016
Coastline sediments	Bay of Mecklenburg / Arkona Basin (German Baltic coast)	samples were scraped off the surface layer with a stainless steel table spoon either at the drift line or were carefully spooned off the surface of sand ripples under water with the same flat table spoon.	0-7 particles and 2-11 fibers /kg (dw)	63µm – 5mm	Published, Stolte et al. 2015
Coastline sediments	Gulf of Finland	GEMAX corer	average conc. 1.7 fibres and 7.2 synthetic particles/kg (ww); black particles excluded here		Published, Talvitie et al. 2015
Sediments from 3-30m depth	South-Eastern part of the Baltic Sea near the Baltiysk Strait inlet	Hand-operated dredge	Average conc. 34 ± 10 /kg (dw)	>174µm	Published, Zobkov & Esiukova 2017
Shallow coastal and deeper open sea sediments	Polish coast of the Baltic Sea	van Veen grab, top 0.5 – 2.5 cm of the sample.	0.5 – 53 particles/kg (dw)sediment	≤5mm	Published Graca et al 2017
Strandline/Beach sediments	Isle of Rügen	Stainless steel frame	Median abundance of 88.10 microplastic particles/kg (dw) or 2862.56 particles per m2	63µm – 5mm	Published Hengstmann et al. 2017

Spatial coverage

A questionnaire for reporting sampling sites´ coordinates was sent. Separate maps showing spatial coverage of the studies for water surface, water column and sediment according to the information received, and updated with published work, are included in Figures 1 and 2.

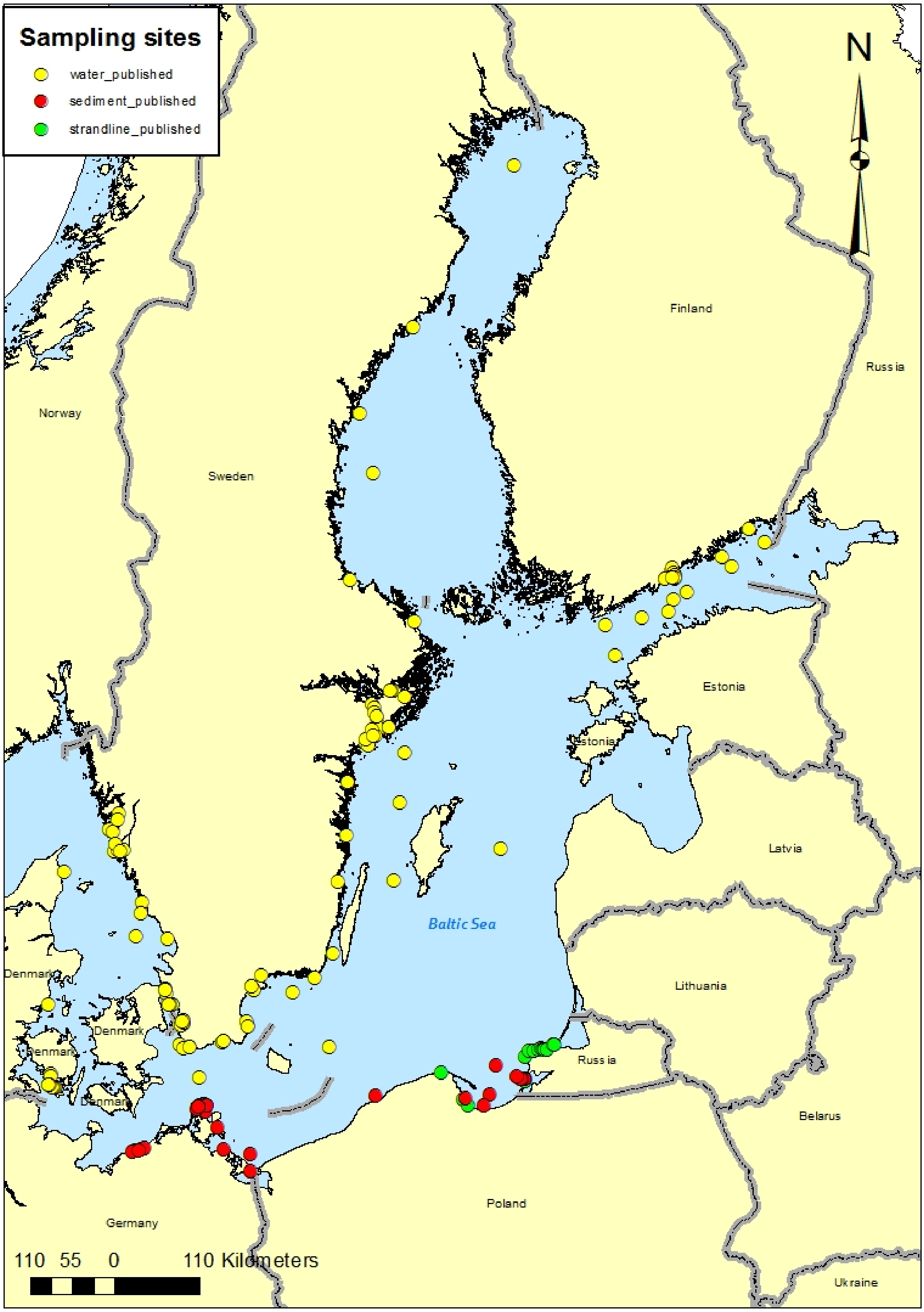

Figure 1. Microlitter sampling sites in the Baltic Sea based on published data (scientific journals and national reports).

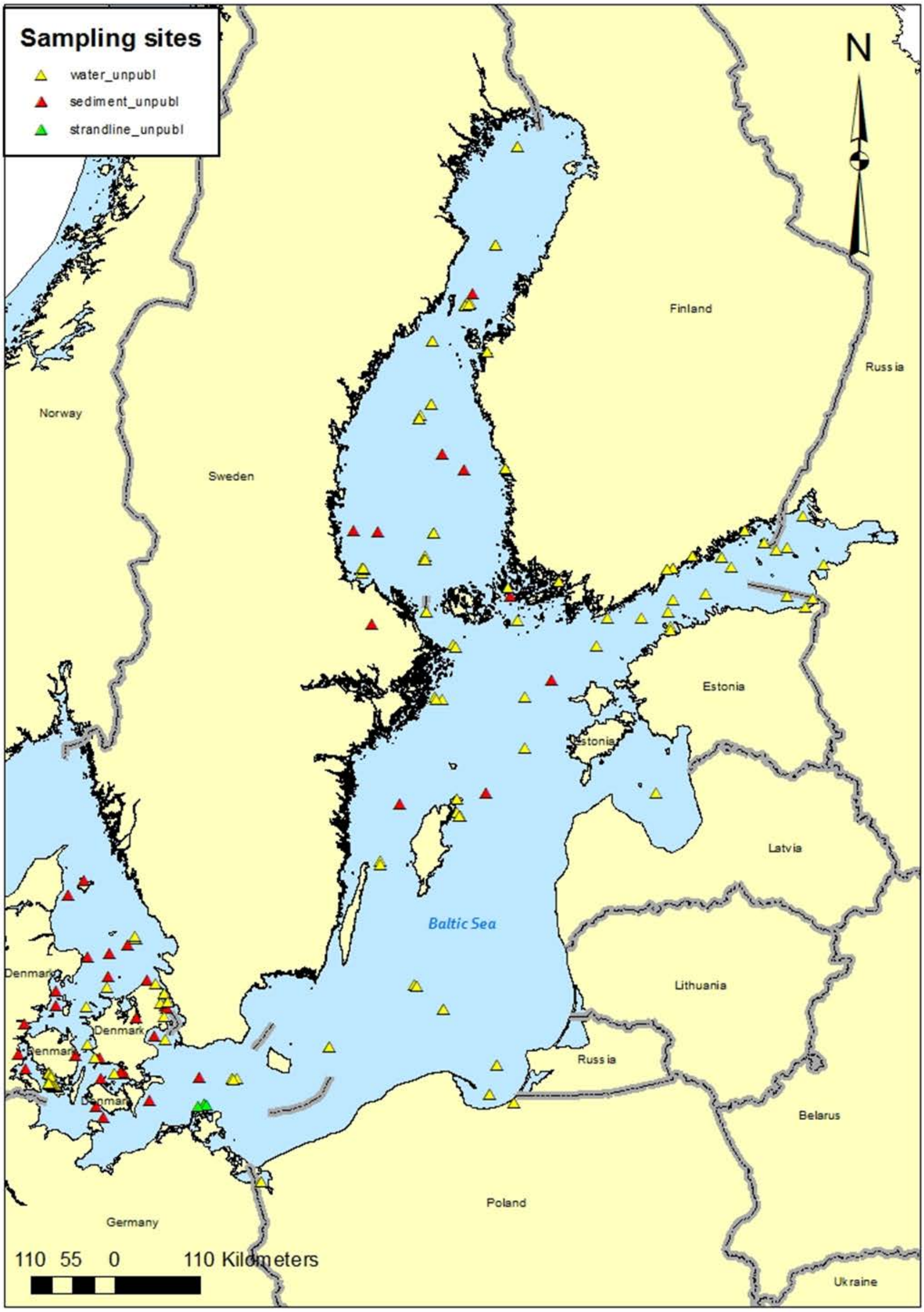

Figure 2. Microlitter sampling sites in the Baltic Sea based on HELCOM data call (unpublished).

Assessment on microlitter and microplastics in the Baltic Sea

From the information available it seems that research and pilot monitoring is very active at the moment in several countries. It can be expected that after 1-2 years significantly more data will be available for assessing ML and MPs in the Baltic Sea environment. However, before this, there are several issues which need to be solved. Most importantly methods for both sampling and analyses must be harmonized and targeted for the Baltic Sea specifically. For the development of a regional database on microlitter and microplastics in the Baltic Sea it is essential to formulate and agree on a common reporting format. The reporting should include metadata (i.e., matrices, sampling stations categories, equipment, etc.) and data on monitored parameters (eg. size and particle shape categories, information on materials and concentrations).

References

Bagaev, A., Mizyuk, A., Khatmullina, L., Isachenko, I., Chubarenko, I. 2017. Anthropogenic fibres in the Baltic Sea water column: Field data, laboratory and numerical testing of their motion. Science of the Total Environment 599–600.

Bråte, I.L.N., Huwer, B., Thomas, K.V., Eidsvoll, D.P., Halsband, C., Carney Almroth, B. & Lusher, A. 2017. Micro- and macroplastics in marine species from Nordic waters. *Nordic Council of Ministers*. 101p. DOI: 10.6027/TN2017–549

Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU

Galgani F., Hanke G., Werner S., Vrees L. De, 2013. Marine litter within the European Marine Strategy Framework Directive. ICES Journal of Marine Science, 70(6), 1055–1064.

Gewert, B, Ogonowski, M, Barth, A & MacLeod, M. 2017. Abundance and composition of near surface microplastics and plastic debris in the Stockholm Archipelago, Baltic Sea. Marine Pollution Bulletin 120(1-2), 292–302.

Gorokhova, E. 2015. Screening for microplastic particles in plankton samples: How to integrate marine litter assessment into existing monitoring programs? Marine Pollution Bulletin 99(1-2), 271–275.

Graca, B., Szewc, K., Zakrzewska, D., Dołęga, A., Szczerbowska-Boruchowska, M. 2017. Sources and fate of microplastics in marine and beach sediments of the Southern Baltic Sea—a preliminary study. Environ Science and Pollution Research International, 24(8), 7650-7661.

Hengstmann, E., Tamminga, M., vom Bruch, C., Fischer, E.K. 2017. Microplastic in beach sediments of the Isle of Rügen (Baltic Sea) - Implementing a novel glass elutriation column. Marine Pollution Bulletin 126 (2018) 263–274.

Johansson, A. 2011. Mikroskopiska antropogena partiklar i marina sediment. [Microscopic antropogenic particles in marine sediments]. BSc Thesis no 548, Department of marine ecology, Göteborg University (in Swedish).

Magnusson, K. 2014. Microlitter and other microscopic anthropogenic particles in the sea around Rauma and Turku, Finland. IVL reports, Report no. U4645. February 2014. 18 pp.

Magnusson, K. & Norén, F. 2011. Microscopic litter in the sea - development of a monitoring method (in Swedish: Mikroskopiskt skräp i havet - metodutveckling för miljöövervakning). Rapport till Naturvårdsverket, Swedish Environmental Protection Agency: 22.

Norén, Fredrik. Small Plastic Particles in Swedish West Coast Waters. N-research, 2007. http://www.kimointernational.org/WebData/Files/Small%20plastic%20particles%20in%20Swedish%20West%20Coast%20Waters.pdf

Norén, F., Johansson, U., Ekendahl, S. 2009. Mikroskopiska antropogena partiklar i svenska hav. Projekt rapport. Lysekil: N-research.

Norén, K., Haikonen, K., Norén, F. 2015. Marint mikroskräp längs Skånes kust. IVL-rapport 2015: C 139. (in Swedish). http://www.ivl.se/download/18.422aa27a15260b0160f3cb/1454412386965/C139.pdf.

Setälä, O., Magnusson, K., Lehtiniemi M., Norén, F. 2016. Distribution and abundance of surface water microlitter in the Baltic Sea: A comparison of two sampling methods. Marine Pollution Bulletin 110(1), 177–83.

Stolte A., Forster, S., Gerdts, G., Schubert, H. 2015. Microplastic concentrations in beach sediments along the German Baltic coast. Marine Pollution Bulletin, 99(1–2), 216–229.

Talvitie, J., Heinonen, M., Pääkkönen, J.P., Vahtera, E., Mikola, A., Setälä, O., Vahala, R. 2015. Do wastewater treatment plants act as a potential point source of microplastics? -Preliminary study in the coastal Gulf of Finland, Baltic Sea. Water Science and Technology 72, 1495–1504.

Tamminga, M., Hengstmann, E., Fischer, E. K. 2018. Microplastic analysis in the South Funen Archipelago, Baltic Sea, implementing manta trawling and bulk sampling. Marine Pollution Bulletin 128, 601–608.

Zobkov, M. & Esiukova, E. 2016. Microplastics in Baltic bottom sediments: Quantification procedures and first results. Marine Pollution Bulletin, 114(2), 724–732.