Small Plastic Particles in Coastal Swedish Waters

Presented by KIMO International

The document outlines the results of a study by KIMO Sweden into the prevalence of microscopic plastic particles in Swedish coastal waters.

Background

1. In the summer of 2007 KIMO Sweden hired *N*-research to undertake a pilot project to assess the abundance of small, microscopic, plastic particles in Swedish west coast waters. *N*-research took water samples from nineteen locations, both planktonic and from benthic sediments, and conducted analyses to identify the prevalence of particles in both.
2. The study found that when using an 80µm mesh to concentrate the water samples there is a considerably higher amount of small plastic particles. Concentrations of small plastic fibres up to 100,000 times higher were retained on a 80µm mesh compared to a 450µm mesh
3. The result of the sampling with an 80µm net demonstrates that there is a large amount of small plastic particles in the sea. No previous studies have estimated such high concentrations of microscopic plastic particles since previous studies always have used a zooplankton net with a mesh size exceeding 333µm.
4. The highest concentration, 102 000 per m^3, of plastic particles (diam. ~0.5 -2mm) was found locally in a harbour area outside a polyethene production plant. This is most likely associated with losses during loading.
5. These particles have also been reported to be ingested by filter-feeding invertebrates (Thompson et al. 2004) and possibly bioaccumulate in higher trophic levels of the food chain. Given the fact that organic pollutants accumulate on the plastic particles (Mato et al. 2001), this amount of small particles is extremely serious since the area/volume quota of the particles increases with smaller particle volume (a large amount of small plastic particles may be a larger vector of organic pollutants than fewer large ones).

Action Requested

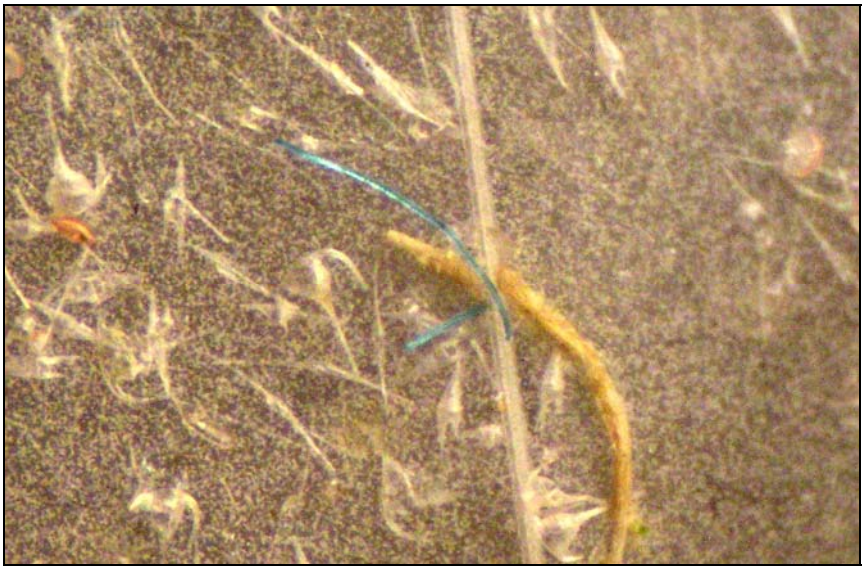
BDC is requested to:

a) Take note of the findings of the report.

b) Consider and discuss what action it would be appropriate for BDC undertake.

Small plastic particles in

Coastal Swedish waters.



Blue plastic fibre, diameter ~20µm

KIMO Sweden

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Summary

KIMO Sweden has given *N*-research an assignment to perform a pilot-study to assess the abundance of small, microscopic, plastic particles in Swedish west coast waters. *N*-research has taken water samples from nineteen locations, both planktonic and from benthic sediments, and conducted analyses thereof.

In this pilot study we found:

- There is a considerably higher amount of small plastic particles when using an 80µm mesh to concentrate the water samples. Up to 100 000 times higher concentrations of small plastic fibers was retained on a 80µm mesh compared to a 450µm mesh
- The amount of plastic particles, concentrated with a 80µm mesh net, was in the range of 150 – 2400 per m^3
- The amount of plastic particles, concentrated with a 450µm mesh net, was in the range of 0,01 – 0,14 per m^3 which is comparable to earlier surveys (0,01 – 7 per m^3).
- A very high concentration, 102 000 per m^3 of plastic particles (diam. ~0.5 - 2mm) was found locally in the harbour outside a polyethene production plant.

If you have further questions on this report, please contact:
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Introduction

KIMO Sweden has given *N*-research an assignment to perform a pilot-study to assess the abundance of small, microscopic, plastic particles in Swedish west coast waters. *N*-research have sampled and analyzed nineteen water samples and three samples from bottom sediments along the Swedish west coast, from Gothenburg and 120km northwards.

Earlier investigations has shown that the number of small, microscopic, plastic particles has increased in number in recent time and correlating to increased production of plastic materials (Thompson et al. 2004). Further, the plastic particles are vectors for organic pollutants (Mato et al. 2001; Takada 2006; Rios et al. 2007) and are a lethal threat to seabirds (Ryan 1987), fish (Vlietstra and Parga 2002) and invertebrates (Thompson et al. 2004).

The abundance of larger plastic debris has been more extensively assessed than their microscopic counterparts and this survey aims, for the first time, to quantify the concentration of microscopic plastic particles in the sea.

Methods

Earlier investigations have been performed, generally, in two ways; by using a plankton net in order to concentrate the plastic particles from surface water or by washing low-density particles from sediment samples. In order to enable comparison with previous studies, this pilot study was performed using similar methods (Thompson et al. 2004). The methodology was also extended by sampling with a net with finer mesh to include smaller plastic particles (<450µm).

Sampling sites

Sixteen sites along the Swedish west coast were chosen for sampling in such a way that a distribution was achieved between outer and inner archipelago as well as between localities influenced and not influenced by harbours. See table 1.

Table 1 Sample locations during the pilot study

Sampling site	Notes	Sample device / type
Lysekil, Southern harbour	Many leisure boats in the harbour during the sampling.	80µm mesh
Lysekil, Southern harbour	Sample from the innermost harbour, Much litter in the water. Sheltered site.	80µm mesh
Lysekil, Southern harbour	Not the same water package as in the major harbour, but "cleaner" Gullmar Fjord water.	80µm mesh
Lysekil, Släggö (Island outside Southern harbour)	Gullmar Fjord water	80µm mesh
Björkö harbour	A windy day with good water exchange.	80µm mesh
Björkö ferry	Clear water	80µm mesh
Tjuvkils huvud, harbour	Small harbour, sampling in sheltered part of harbour.	80µm mesh, sediment
Stenungsund, location 3	Industrial area, samples from the inner part of bay with seaweed vegetation	80µm mesh, sediment
Stenungsunds harbour	Harbour outside shopping center	80µm mesh
Stenungsund, location 4	Industrial area, sampled from the rocks	80µm mesh
Stenungsund, industry harbour	The official industrial harbour of Stenungsund	80µm mesh, sediment
Lysekil, Gäven-Byxeskär	Between Gäven and Byxeskär (1 – 1.5 nautical miles west of Lysekil)	80µm mesh
Lysekil, Gäven	South of Gäven (2.5 nautical miles west of Lysekil)	80µm mesh
Lysekil, Gullmar fjord, Blåbergsholmen	West of Blåbergsholmen	450µm mesh
Lysekil, Islandsberg, sample 1	West of wave energy park	450µm mesh
Lysekil, Islandsberg, sample 2	East of wave energy park	450µm mesh

Metods used in previous studies

In order to quantify the amount of plastic particles in the water mass a plankton net trawl, intended for fish egg and larvae (1x2 meter with 0.947mm mesh), was trawled

at five knots for ten minutes (Colton et al. 1974). In other studies a "Manta trawl" (0.9x0.15m, with 333µm mesh) was used and the trawling distance varied between 5 km and 19 km, which yields an approximate volume of 675m^3 to 2565m^3 (Moore et al. 2001; Lattin et al. 2004).
In order to quantify the amount of plastics in sediment samples a trowel and Ekman sampler was used in order to collect the samples. The sediment was then stirred in high salinity water solution (1 kg NaCl/l), the supernatant was filtered an examined for plastic particles (Thompson et al. 2004).
In the most recent studies plastic particles were qualitatively determined as a specific plastic polymer by the use of FTIR (Fourier Transformation Infra Red Spectrometry) combined with a microscope (Thompson et al. 2004).

Plastic particles in surface water

Two methods were used;

A. A known volume of surface water was poured from a 5 litres measuring jug (unknown plastic) into a phytoplankton net of nylon fabric (rectangular meshes, 80µm, Fig. 1c) into a collection container of polypropylene. The surface water was sampled from 0-0.3 meter depth. The concentrate was filtered onto a 2.0µm filter (ø45mm, polycarbonate, Osmonics Inc.). The filter was rinsed with 100 ml tap water in order to avoid salt crystals and left to dry for at least 24h., before examination under a stereo microscope (20x/40x) or fluorescence microscope (100x/200x/400x). In order to facilitate the analysis and enable partial sampling, the filter was divided into eight equally sized parts. The entire filter was analysed for all samples except the one with the highest amount of plastic particles. For this sample only two eighth parts were analysed and the average value was used as an estimate of the concentration (249 and 263 particles). A control was performed where 20 litres of tap water was concentrated and analysed in the same way as the sea water samples in order to see if any plastic material in the sampling equipment could have ended up in the samples. No plastic fibres/particles were found in this control.

Figure 1. Microscopes and plankton net (80µm) used in the survey

B. A zooplankton net with mesh-size 450µm was dragged, just below the surface, behind a small motor boat making 1-2 knots for about 10 minutes. A speed log inside the net was measuring the flow of water inside the net in order to calculate the amount of water volume filtered. The concentrate from the net, 0.5 litres was poured into a storage container (PVC) and brought to the laboratory for analysis.

The samples were poured into petridishes and analysed with reference to plastic particles, which were sorted out with tweezers and a Pasteur pipette for examination under a stereo microscope and microscope.

Following criteria were used to define a plastic particle (see fig 2 for an example);

- No cellular or organic structures are visible in the plastic particle/fibre
- If the particle is a fibre it should be equally thick, not taper towards the ends and have a three-dimensional bending (not entirely straight fibres which indicates a biological origin)
- Clear and homogeneously coloured particles (blue, red, black and yellow)
- If it is not obvious that the particle/fibre is coloured, i.e. if it is transparent or whitish, it shall be examined with extra care in a microscope under high magnification and with fluorescence microscopy in order to exclude an organic origin.

In the analyses the particles were examined conservatively and only particles that complied with the above criteria were included as plastic particles. The main consequence of this is that transparent fibres were not included because of their similarity to antennae and fibres from different organisms (animals, plants and protists). This can have led to an underestimation of white/transparent plastic fibres. Red fibres were also scrutinized with extra care, because of their similarity to young algae sprouts. These were discriminated by studying the fibre in a microscope under higher magnification and with fluorescence microscopy, making the chloroplasts of the red algae clearly visible.

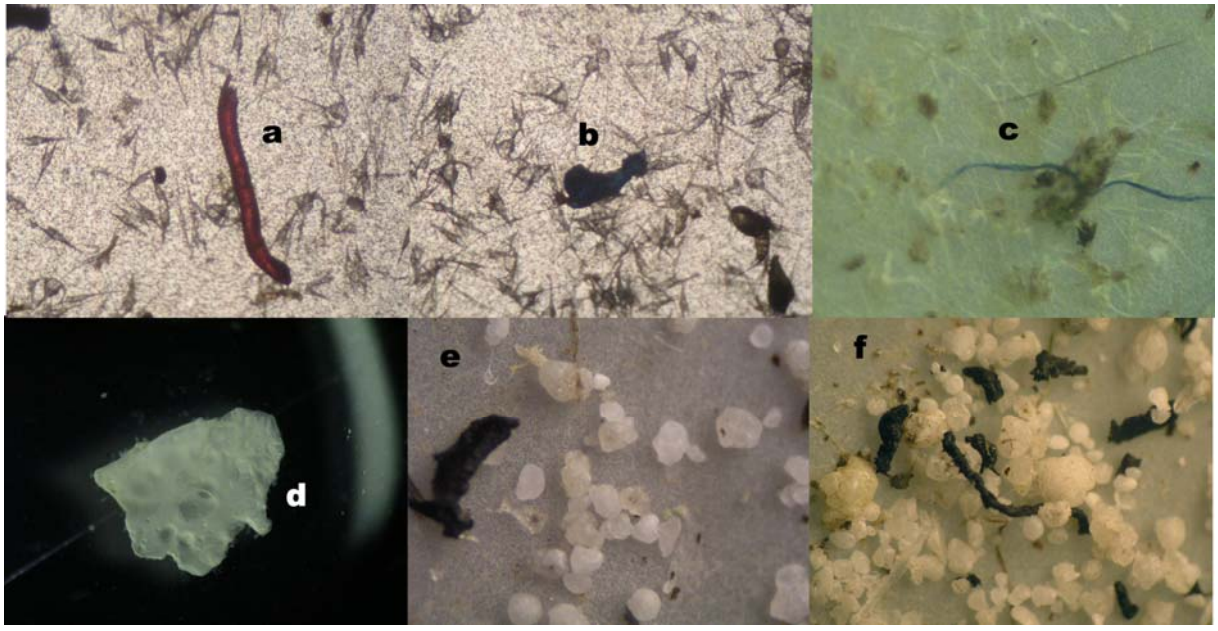

Figure 2 Different plastic particle in the water. A. Red plastic fibres (diam. ~70µm) B. Blue plastic particle C. Blue plastic fibre (diam~100µm) D. White/transparent plastic film, 1*1,5cm E. Milky-white plastic spheres, diam. ~0,4-2mm F. Milky-white plastic spheres and suspected tar particles.

Plastic particles in sediments

A high-saline solution (about 20 % salinity) was prepared. The 100 ml sediment samples were poured into the saline solution, was stirred for about a minute and left for at least 20 minutes before decanting and filtering the supernatant through a 2µm filter. Filtration and analysis was performed with the same methods that were used for analysis of plastic particles in surface water (described above).

Results & discussion

The pilot study presents some remarkable results;

1. The plastic fibres concentrated in the 80µm mesh net are much more numerous (~1000 times more) than the reported number of plastic particles with 333/450 µm mesh nets (see table 2 and 3). This indicates that the number of small plastic particles passing through a zooplankton net might be a considerably larger source of pollution than realised before. These particles have also been reported to be ingested by filter-feeding invertebrates (Thompson et al. 2004) and possibly bioaccumulate in higher trophic levels of the food chain. Given the fact that organic pollutants accumulate on the plastic particles (Mato et al. 2001), this amount of small particles is extraordinarily serious since the area/volume quota of the particles increases with smaller particle volume (a large amount of small plastic particles may be a larger vector of organic pollutants than fewer large ones). **We recommend** continued studies of plastic particles in this size fraction and studies of bottoms sediments in order to examine historical occurrence or these particles. Have they increased in correlation to the production of plastics?
2. There seems to be a local emission of plastic particles at Stenungsund with the highest amount of plastic particles around the loading port for the plastic producing plants. The amount of small plastic particles reached over 100,000 per m^3. **We recommend** more detailed and extensive studies of the area at Stenungsund, with more sampling sites, that determination of plastic species with the aid of FTIR microscopy is performed and that the sampling methodology is developed further (for instance by using plastic free sampling equipment). Since this is a pilot study we do not want to name the industry outside which the sampling has been done.
3. The amount of plastic particles concentrated with the 450µm mesh net is less than reported from other sea areas, see table 3. **We recommend** further sampling along the Bohus Coast, both in the inner and outer parts of the archipelago and in the known litter areas further out where different currents meet. Furthermore, the net mesh should be in the same size as in previous studies i.e. 333µm, in order to exclude differences in result depending on mesh size.

Plastic particles in the surface water

A. The result of the sampling with an 80µm net demonstrates that there is a large amount of small plastic particles in the sea. We have not found any previous study estimating concentrations of such microscopic particles since previous studies always have used a zooplankton net with a mesh size exceeding 333µm.
The number of plastic particles differed between sites. In the harbour of Lysekil, which is well frequented by leisure boats, a large amount of plastic fibres were found that might come from wearing on ropes. In the waters outside the Lysekil harbour, at Björkö and at Tjuvkil the number of plastic particles was lower.

In the harbour of Stenungsund a very special type of plastic particles is found (see figure 2 E & F). The occurrence might originate from careless handling in connection with loading of plastic pellets from the plastics industry in Stenungsund. We are however very careful about commenting on the source of this pollution until more qualified studies have been made in the area. In the laboratory, the particles showed the following properties: They were not dissolved in ethanol, acetone or xylene. The particles melted after having been heated gently on a microscope slide with a spirit burner. They emitted a distinct smell of plastics, as they were melting (smell of melted plastic rope end). Furthermore the plastic resolidified after having cooled and could easily be scratched with a sharpened glass needle.

Table 1 Number of plastic particles concentrated with 80µm plankton net

	The amount of particles in number per m^3					
	Red fibres	**Blue fibres**	**Black / transp.**	**Milky-white spheres**	**Σ particles per m^3**	**+/- sd**
Lysekil, Southern harbour	50	1 900	450	0	2 400	
Lysekil, Southern harbour, inner harbour	100	550	500	0	1 150	
Lysekil, Southern harbour, nrthern Släggö	50	350	200	0	600	
Lysekil, outer Släggö	50	100	50	0	200	
Björkö harbour, mean of 2 samples	0	400	250	0	450	283
Björkö ferry,mean of 3 samples	0	200	100	0	167	126
Tjuvkils huvud, harbour	50	200	0	0	250	
Stenungsund, location 3	25	0	25	1 575	1 625	
Stenungssunds leisure-boat harbour	50	150	50	850	1 100	
Stenungsund, location 4	50	300	50	750	1 150	
Stenungsund, industrial harbour	0	150	0	102 400	102 550	
Lysekil, Gäven-Byxeskär	80	120	320	40	560	
Lysekil, Gäven	70	160	80	0	310	

B. The result of the samplings with a 450µm mesh net indicates that the amount of plastic particles in any case is not alarmingly higher than in other sea areas, compare tables 2 and 3. The sampling with the 450µm was performed within a small geographic area (outside Skaftö in the water system of the Gullmar Fjord) which does not give us an indication on the regional occurrence since different currents can contain different amounts of plastic particles. As plastic particles drift and floats with the currents it is important to study the number of plastic particles in different water packages and not only at a geographical site. We used a 450µm net while previous studies have used a 333µm net, a consequence of this difference could be that we have underestimated the number of small plastic particles. We also have not filtered as large volumes as previous studies did (they filtered ~10 times larger volumes).

Table 2 Number of plastic particles concentrated with 450um zooplankton net

	Particles	Colour	Size (mm)	Sum	Sample volume (m^3)	Number per m^3
Sample 1	1 plastic film	Milkywhite / transp.		1	130	0.01
Sample 2	2 extruded.polystyrene	white	2*3	10	72	0.14
	2 extruded polystyrene	white	1*1			
	1 hard plastic particle	white	3*3*1			
	5 plastic film	milkwhite/transparent	3*4			
Sample 3	1 plastic particle	white	2*3*2	5	141	0.04
	1 plastic particle	white/transparent	5*5*1			
	1 plastic particle	white/transparent	2*2*1			
	1 plastic particle	white	2*3*2			
	1plastic film	grey/transparent	30*20*1			

Table 3 Results from previous studies

Reference	Particle concentration (per m^3)	Sea	Sample type
(Moore et al. 2005)	0.43 – 2.23	North Pacific	Offshore, surface
-II-	5.0 – 7.25	North Pacific	Inshore, surface
-II-	0.017	North Pacific	Offshore, subsurface
(Thompson et al. 2004)	0.01 – 0.06	Scottland-Shetland	
(Lattin et al. 2004)	0.5 – 18	Kalifornien	Inshore, surface
(Carpenter et al. 1972)	0.01 – 2.6	USA north east	Coastal waters

Plastic particles in sediments

The result of the studies of plastic particles in sediments also shows that there is a local littering source at Stenungsund. In other respects, the number of particles from the harbour at Tjuvvik was consistent with the number of particles found in sediments along the English coast (Thompson et al. 2004), i.e. between 1 and 10 particles per 100ml sediment.

Tabell 4 Number of plastic particles concentrated from sediment samples

Site	Sample volume	Particles	Colour	Size (mm)
Tjuvkils harbour	100ml	2 plastic	Milkwhite/transparent	7*1*1
		5 plastic	Milkwhite/transparent	1*1*1
Stenungsund, industrial harbour	100ml	332 plastic spheres	Milkwhite/transparent t	0,5-1mm diam.-
Stenungsund, location 3	100ml	34 plastic spheres	Milkwhite/transparent	0,5-1mm diam.

Referenser

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