Survey of microscopic anthropogenic particles in Skagerrak
Lysekil and Flødevigen 2010-11-20
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1.1 Summary

The main task in this pilot project on presences of microscopic anthropogenic particles was to establish whether such particles were present in Norwegian waters (Skagerrak), amount of particles, and testing of methods for monitoring of such particles. During two pelagic surveys on along the fixed transect between Arendal and Hirtshals, the concentration of potential anthropogenic particles was measured using a new sampling method for monitoring purposes. The improved sampling strategy is suitable for routine monitoring of particles between 10-500 µm. At all stations potential anthropogenic particles in size range of 10 – 500 µm were present and quantified with the following main results:

1. The concentration of textile fibers and microscale plastic particles could not be qualitatively distinguished to the control samples that were analyzed or be excluded as contamination.

2. A large number of black particles were found (median 41 lit⁻¹, max: 779 lit⁻¹, min: 8 lit⁻¹). A measurable amount could be anthropogenic particles such as rubber particles, road wear etc. The proportion organic particles were 86% and the inorganic/mineral proportion was 14%, based on analysis of 14 black particles in SEM-EDX. One suspicious anthropogenic particle type that was found was the round black particles that partially were dissolved in an organic solvent indicating that that those particles partly consist of an oil fraction.

The sampling method used is optimal for particles <300 µm. However, the fraction of particle larger than 300 µm is not intercept in a content way. The method can easily be modified for sampling of plastic particles larger than 0,3mm by using a larger pump in the sampler and a wider mesh (333/450 µm).
1.2 Background

Marine macroscopic litter is of well known concern and has been studied for several decades. Today both national and intergovernmental organizations work to minimize the littering, such as IMO regulations and UN programs.

The littering by microscopic plastic particles is of more novel interest, even if there were some research on the topic in the 1970’s, such as Carpenter et al. (1972) and Colton et al. (1974). Articles by e.g Thompson et al. (2004), Lattin et al. (2004) and More et al. (2001) received strong response from both governments, media, and researchers. In their studies they found concentrations of plastic particles in the range of ~0,01 – 1 – (20) plastic particle per m$^3$ (see Table 1). It should be pointed out that these studies used zooplankton net to collect particles. The mesh sizes in the nets are between 180 µm to 450µm, capturing somewhat larger particles and excludes particles smaller than those study in this pilot project.

Table 1 Summary of some research results on marine microscopic litter.

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

One of the hazards with microscopic plastic pollution in the sea is that animals such as filter-feeders, fish and sea birds ingests the plastic causing them harm, sometime even lethal.

Another problem is the transport of organic pollutants such as PAH, PCB etc. on the surface of the particles which also is well known Mato et al. (2001), however, the actual uptake into the animals has not been quantified.

During 2007 KIMO, Sweden (Kommunenes Internasjonale Miljøorganisasjon) performed a study to explore if the same amount of particles that Thompson et al (2004) found around Great Britain was found in Swedish waters. They assigned N-research which performed the study using a phytoplankton net as sampler in parallel with a zooplankton net (450 µm).

During the investigation we discovered a hitherto unstudied fraction of anthropogenic particles, with a size distribution from 10µm to 500µm. The particles consisted of polyethylene pellets, textile fibers etc, and was in the order of thousand times higher than previously reported (Table 1 values). This led to further studies in Swedish waters on the behalf of Swedish Environmental Protection Agency (Norén et al. 2009). The study used the same phytoplankton net as sampler and the results was consistent with the 2007 KIMO report (i.e. concentrations of anthropogenic particles (fibers included) in the range 1000-100000 per m$^3$).

During that project the concentration of black particles was estimated for the first time and their hypothetical origin was suggested as road and rubber wear. This was based on the fact that ~100.000 tons of asphalt roads wears every year in Sweden alone and ~10.000 tons of rubber tires together with the striking morphological similarity with particles from road side snow-melt (Fig. 1). This lead to a focus on the black particles due to the fact that the oil constituent in asphalt roads, bitumen, is rich in toxic hydrocarbons such as PAH:s and rubber particles has been shown to be toxic to aquatic animals (Wik and Dave 2006). So one ongoing project, with high priority, is to discriminate between sources of marine black particles:
Naturally degraded organic particles, peat, volcanic ash, black mineral particles, such as biotite and amphibolite, together with anthropogenic sources as asphalt/bitumen particles, rubber tire wear, oil-spill droplets and fly ash. It is of utmost importance that we analyze the particle origin before we can assess the environmental risk of the anthropogenic particles. To our knowledge there is no such studies conducted before, but several studies has studied the concentrations of PAH:s in marine environment (e.g. (Broman 1988) where the PAH concentration in marine waters is coupled to urban areas. During the following period Swedish EPA has granted more research funding for improvement of the sampling methodology and analysis of both environmental concentrations and material composition and one conclusion is that contamination of the samples is a serious threat for overestimation of particle concentrations. Due to contamination problem, previous reported concentrations should be handling with care and are not reliable.

One of the large challenges during sampling, handling, and analyses for microscopic anthropogenic particles is to reduce the risk of contamination of the samples. With all kind of sampling there is a risk of contamination of the samples. This problem is often solved by adding control samples (used as zero line) in the sampling program. The access to contamination free sampler is important as control. Due to the impracticality of using a clean-room technique in routine monitoring we have weighed the need for low contamination with an easy to use method. The methods use during this pilot project lets us take control samples on board. Those controls can be seen as blanks. During the development of the sampler and sampling routines used in this actual KLIF cruise, at least seven different samplers has been tested and rejected due to impracticability or high contamination. We see the sampler used today as still under development, even if we are currently satisfied with the main principle: placing the sampling filter directly in contact with sea water and the use of controls.
1.3 Material & Methods

1.3.1 Area
During two cruises with the research vessel G. M. Dannevig (Institute of Marine Research), the concentration of microscopic anthropogenic particles was assessed. The sampling of microscopic particles was added to the sampling program along the fixed transect between Arendal and Hirtshals. The first cruise was 2010-10-05 and the second was 2011-11-12. See Fig 2 for route and location of sampling stations.

![Map showing the cruise line and stations along the transect Arendal-Hirtshals. Red color showing the stations selected for sampling of microscopic anthropogenic particles.](image)

1.3.2 Sampling
The sampling equipment used was principally a submersible water pump (12V) inside a water proof case (Pelicase) with the sampling filter located directly to the sea. See Figure 3 for a schematic drawing of the sampling equipment and Figure 4 for a photo. The Pelicase was of orange color and the filter holder was a modified stainless pressure filter holder from Sterlitech (#304700). The modification consisted in constructing a new outlet fitting (1/2”') and a new larger inlet was lathed with a smooth surface and a semi-enclosed volume before the filter to avoid resuspension on the filter from wave turbulence. From the submersed pump a water hose (enhanced polyester hose i.d. 10mm) lead to the ship deck, where it was connected to an electronic flow and volume meter (Great Plains Industries). The sampler was hold 2 meter outside the broadside using a metal bar. The sampler was attached to the bar with a white polyester rope. The sampler was hold in position in the surface water at approximately 0,5 meters depth. However, due to large waves at both cruises the sampling depth ranged from 0,1 to 1,5 meter.

1.3.3 Filter handling
The filters used were polycarbonate hydrophobic pore filters with a defined pore size of 10 µm (Sterlitech #PCTF10047100). A 30 µm square mesh nylon filter was used as a supporting filter (this enhanced the filtration capacity of the 10µm filter). Before and after filtration the filters were placed in protective filter holders (Millipore Petrislides #PD1504700) which reduced the risk of contamination from airborne dust. The microscope analysis was performed without taking the filter out of the holder. The pump was started before the sampling device was submersed and shut off after the filter had been removed from the filter holder. This latter procedure was done to keep the filter dry and onto the filter holder.

The procedure of filter handling during the sampling is crucial for avoiding airborne contamination (see Results & discussion). As control samples for contamination, two kinds of controls were taken during the sampling. The first control was to evaluate contamination from the filterholder and filter handling itself, and was done by filtering 25 liters of MilliQ water on deck using the same filter handling techniques as during sampling in sea. This control was performed in duplicate on the second cruise. The second control was performed to reveal if there was airborne contamination when pumping air thought the filter after taken out of the sea. This control was done by placing a wet filter in the filter holder and let the pump work for 3-5 minutes. Except from not submersing the sampler into the water, the filter was handled the same way as an ordinary sample.

To keep the sampler clean, all the material that was removable from the filter holder was cleaned before sampling in a heated ultra wave cleaner (60° C, manufacturers strong detergent] and stored in clean petridishes before use.

During the sampling, purple nitrile gloves was used and fibrous textiles was avoided by the sampler (i.e no fleece- or wool clothes was used).

1.3.4 Analysis

The filters were analyzed in the laboratory using a metallurgical Olympus BHM microscope (reflected light) at 100x to 200x magnification. To get an illumination that showed the natural colors and surface morphology of the particles, extra white light was used (cold light, fiber optics). All samples were taken in duplicate and the variation in concentration could be estimated as the mean value and the variation thereof. For the second survey only one of the two samples has been analyzed, due to the short time between survey and report.
All particles that had certain properties were counted. The properties aimed to exclude natural particles such as unicellular protists and multicellular zooplankton as well as natural debris, both organic (e.g. detrital particles) and inorganic (e.g. various minerals). The focus was to count anthropogenic particles, which in the microscope was distinguished by the combination of colour and texture (morphology). Particles that had unnatural colours were counted, e.g. blue, red, yellow etc. and particles that had a “man made” structure such as plastic or textile fibers.

In addition to microscopic particles samples were collected for chemical analyses and phytoplankton abundance (not included in this report) as well as physical parameters. Hydrographical data was obtained using a Neil Brown CTD sensor as vertical profiles.

1.3.5 Material analysis
To elucidate if the particles were of mineral/organic or natural/anthropogenic origin analyzes were conducted with SEM-EDX (Scanning electron microscope with energy dispersive X-ray spectroscopy). The SEM-EDX analytical procedure could be used to distinguish between organic and mineral black particles, and if possible tell us what kind of mineral the particle consist of.

Black particles from two samples from the November survey was micropipetted over to an aluminum foil on an SEM holder. The particles were analyzed at SP - Technical Research Institute of Sweden, Borås, on a JEOL JSM-5310LV scanning electron microscope equipped with an X-ray dispersive energy system (EDX).
1.4 Results & Discussion

The adaptation that has been done in the sampling strategy has improved the sampling both in terms of reducing the risk of contamination and adapting to monitoring particles between 10 and 300 µm. The sampler was located approx. 2 meters away from the ship hull to avoid potential contamination. Between the first and the second cruise some improvements in the methodology was conducted: 1) the volume was measured with the electronic flow meter with good result. 2) the filters was immediately placed in the Millipore filter holders 3) the use of ultrasonic cleaning of the filter apparatus.

This survey used a 10 µm polycarbonate filter as sampling filter and the method was designed to study the abundance of particles in the size range of 10-500 µm, with > 95% of the particles in the range of 10-100 µm. We argue that this fraction is important to study based on 1) the size of those particles are in the same dimension as phytoplankton and hence can be ingested by filter feeding animals and hence can be incorporated into the food-chain 2) All persistent organic pollutants (POP) is absorbed on particle surfaces, and the surface per volume quota of an particle increases with smaller size leading to smaller particles transports much more POPs than the larger particles previous studied 3) Plastic in itself is not very toxic (a simplification – e.g. except for plasticizers and other additives) but oil particles and rubber particles is toxic in themselves due to the cancerogenicity of e.g the high PAH constituent.

We do not exclude the need for monitoring larger particles. This can be done by using the same kind of zooplankton net as other studies use (WP-2 or manta trawl) or use a modification of the sampler used in this study with a larger pump and wider mesh openings (333 µm). By using the latter method the constant risk of contamination could be minimized and measured using controls. The use of controls is not manageable when using a large zooplankton net as has been used on other studies, but this is manageable when using the submersible pump system.

1.4.1 Controls

The number of particles in controls taken on board before sampling is summarized in Table 2. The fact that there was lower number of particles in the control the second survey could be explained by overall improvement of methodology mentioned above. Notable is that there is fibers in the control. This implies that there could be a constant airborne contamination from clothes or other sources that is hard to avoid during ordinary sampling. By constant improvement of the technique this could be lowered. The necessity for this is that the concentration of textile fibers in the water samples is slightly higher than the control concentration – so we cannot say if this slightly higher concentration reflects a real abundance in the water or if all fibers come from contamination. For coming surveys we will recommend that at least three controls are made in the beginning and in the end of each survey. Another explanation for the particles/fibers in the control water could be impure control water or impure storage cans – it is very easy that just some fibers are contaminating the process.
Table 2 Summary of control samples

<table>
<thead>
<tr>
<th></th>
<th>Black particles (lit⁻¹)</th>
<th>Blue particles (lit⁻¹)</th>
<th>Fibers (all colours) (lit⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control survey #1</td>
<td>7.0</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>Control survey #2</td>
<td>0.4</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Control for air</td>
<td>9 pieces</td>
<td>0 pieces</td>
<td>0 fibers</td>
</tr>
</tbody>
</table>

*Only air was filtered in this control and hence no concentrations are given. The pump was filtering air for 3-5 minutes at the same place as ordinary sampling.*

1.4.2 Particle concentrations
Several kinds of particles were found in the samples that had anthropogenic origin.

1.4.2.1 Fibers
Since we suspect that fibers easily contaminate the samples we have to be cautious in the interpretations of concentrations found. By comparing only the number of fibers on each sample filter we cannot distinguish between samples and controls in each survey. The number of controls is too few for making any statistical test between samples and controls. For all stations during survey #2 the number of fibers on the control filter ranged between 0 and 7 independent on the volume filtered and the concentrations ranged from 0 – 1.2 lit⁻¹ (mean 0.6 lit⁻¹ and median 0.4 lit⁻¹) By including the fact that there were 20 fibers on the control filter in the first survey and there was 4 fibers on the filter after filtering 25 liters MilliQ in the second survey we conclude that we can’t separate the control concentrations from the sample concentrations. For statistical analyses of the number of fibers in seawater a higher counting number is necessary, e.g. larger sample volume has to be taken or that less contamination are found in the controls.

The fibers found in this survey were textile fibers - clearly coloured polyester like and cotton/wool like and as such similar to fibers found in earlier studies.

In comparison with earlier studies from Swedish waters, the numbers of anthropogenic fibers are much lower in this study. Concentrations in Swedish waters ranged from 3-10 lit⁻¹ (study year 2008) compared to this study median value of 0.6 lit⁻¹.
1.4.2.2 Blue particles

Blue particles with dimensions from 10 µm to 300 µm was found in 15 out of 17 samples. The same kind of particles has been recorded from earlier investigations from Swedish waters. During this survey the particles was compared to small samples of paint from G.M. Dannevig. The particles found in the samples were structural identical with the paint samples, see Fig 5. A first conclusion of this finding is that the particles could be contamination and hence excluded from further analysis. In next step a FTIR spectra will be made for the paint and the samples for a chemical identification as well. Earlier FTIR analyses on blue particles from surveys in Swedish waters did show that the blue particles were epoxy-based blue paint. Interestingly we found blue particles in samples where no blue-painted ship was used, such as samples from the harbor of Lysekil and the sampling with the Swedish research vessel Argos (a white painted ship). So even if we exclude the blue particles in this study, it is too early to exclude them as microscopic marine litter origin from ship painting.

Figure 5 a. Reference particle from hull paint b. Particle from sample, size approx. 30*70µm
1.4.2.3 Black particles - abundance

The number of black particles ranged from 799 lit$^{-1}$ to 8 lit$^{-1}$ with the median value of 41 lit$^{-1}$. There was a difference in concentrations as well as geographic distribution, between the two surveys as shown in Figure 6. At both occasions the highest concentrations was found close to land, either Danish side (November) or Norwegian coast (October). The week before and during the cruise in November there were strong winds from north – east. Strong onshore wind will transport pelagic component (e.g. phytoplankton and particles) into the Norwegian coast. Such transport could explain the high concentration at the Norwegian coast. The low salinity (not showed) at the Norwegian side in November reflect the high precipitation at the time. Due to the observed coastal distribution pattern, and low salinity in November, lead to the speculation that the black particles could come from rivers and natural particles therein. An addition samples was taken from a rivulet, unaffected by traffic and discharges. The concentrations of black particles in the rivulet were 170 per liter, well above the average number but within the range of particles in the sea water samples. This result led us further to compare the black particles found with photos of minerals of different kind, such as biotit, amphibolit and volcanic ash and the similarity was striking. As well were photos for natural degraded organic matter (such as peat and similar material). The high number of particles at the Norwegian coast in November could be due to accumulation due to wind transport into the coast and contribution from local run-off. The October maximum at the Danish side could however not be explain by river run off or wind generated accumulation. The water masses at these stations in November were of North Sea origin (salinity 34 psu).

![Figure 6 Summary of concentrations of black particles.](image_url)
1.4.2.4 Black particles - composition

The SEM-EDX analysis on 14 black particles showed that 2 particles (14%) were of inorganic composition, probably mineralogenic and 12 particles (86%) were of organic composition. Based on their high relative composition of C, O, Na, Mg, P, K, Ca, and Fe (see Table 3 and Fig 11 for summary and spectra). The inorganic proportion is lower than expected since we subjectively thought that shiny black particles with high reflectance in epi-illumination were mineral particles (see Fig. 12a and b for this observation, where the same particle is epi-illuminated in 12b).

The organic particles could be further grouped into categories based on their relative atomic composition, see text in Fig 11. But any certain interpretation of possible origin is impossible at this stage. Possible origins are:

1. Road wear particles (where the black particles could be asphalt, bitumen or mineral fillers).
2. Rubber tire debris
3. Fly ash from combustion of organic material
4. Natural degraded particles such as peat
5. Oil spill particles

The SEM-EDX has been used in studies of road wear particles with some success and methodology are used from that field of knowledge (e.g. Gustavsson et al. 2005). Even so a review paper by (Thorpe 2008) states “It is concluded that … unequivocal identification of particles from other sources [than brake dust particles] is likely to prove extremely difficult”. We have the same problem, in that the particles change chemical profiles during transport in marine environment and the samples are minute small.

KLIF will be updated on further analysis on the black particles found in this study when an appropriate literature study are conducted.
1.4.2.5 **Black round particles**

One kind of black particle that always is observed in all samples is the conspicuous round black particles, see Fig. 7. The same kind of particles has also been found in most of the previous samples from Swedish surveys, see Fig. 10. They are even found in sediment samples (Stefan Agrenius pers. com and in our own studies) but then in larger dimensions (~0.5 mm).

![Figure 7 Round black particles (diameters from 10 to 50 µm)](image)

During survey two (November) the concentration of those particles were ranging from 2 to 22 particles per litre, see Figure 7. Which, based on subjective memory, is the highest records of those particles found. The material composition of the particles will be further elucidated at SP (Swedish Technical Research Institute, Borås) where the particles can be tested with SEM-EDX and FTIR. As a first microscopical analysis THF (tetrahydrofuran) was added. THF is known to dissolve bitumen and other organic substances. In 6 out of 7 analyzed particles the black colour was dissolved by THF after 10-30 second, see Figure 9. A preliminary interpretation of this intimated that the particles origin from oil products, but this will be further discussed with material experts at SP. The preliminary SEM-EDX analyses of the Norwegian material and swift literature study could imply that the round black particles are fly ash particles from combustion (see. sample PM121:E4 is located in the fourth column in Fig 11). This is something that we will continue to look into.
Figure 8 Summary of black round particles found in survey two.

Figure 9 Black round particle, Ø 10µm. a. Original particle on sampling filter b. After THF addition.
Figure 10 Black particles from earlier surveys in Swedish waters. Note the round black particle bottom most to the right. The round black particle has a diameter of 10µm.
Table 3 Summary of SEM-EDX analysis. Blue cells are atomic peaks that are dominant in the spectrum.

<table>
<thead>
<tr>
<th>Location</th>
<th>Sample</th>
<th>Black particle</th>
<th>Mineraloid</th>
<th>Organicoid</th>
<th>Rubberoid</th>
<th>Extra notes</th>
<th>Morphology</th>
<th>EDX - visible peaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Black shiny</td>
<td>C O Na Mg (Al) Si - S - K Ca Ti - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brownish, sharp edges</td>
<td>C O Na - (Al) - S - - - - - -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Black - became brownish with H2O</td>
<td>C O Na Mg (Al) Si - S - K Ca Ti - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Metallic in epi-illumination</td>
<td>- O - - - - - - - Ti Mn Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Deep black</td>
<td>C O Na Mg (Al) Si - S - Ca - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Black flake</td>
<td>C O Na Mg (Al) Si - S - K Ca - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Black, Became brownish with H2O</td>
<td>C O Na Mg (Al) Si - S - K Ca - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Black. Grains</td>
<td>C O Na Mg (Al) Si P S - K Ca - Fe -</td>
</tr>
<tr>
<td>52Nm</td>
<td>MP108</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Black. Grains. Became brownish with H2O</td>
<td>C O Na Mg (Al) Si P S - K Ca - Fe -</td>
</tr>
<tr>
<td>Raydypet</td>
<td>MP121</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td>Black shiny</td>
<td>C O Na Mg (Al) Si - S - Ca - Fe -</td>
</tr>
<tr>
<td>Raydypet</td>
<td>MP121</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Black shiny</td>
<td>- O Na Mg (Al) Si - - K Ca Ti Mn Fe -</td>
</tr>
<tr>
<td>Raydypet</td>
<td>MP121</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>Rubber morphology</td>
<td>C O Na Mg (Al) Si P S Cl K Ca - Fe Zn</td>
</tr>
<tr>
<td>Raydypet</td>
<td>MP121</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Misshapen black round (sausage)</td>
<td>C O Na Mg (Al) Si - S K Ca - Fe -</td>
</tr>
</tbody>
</table>

Notes 1: Na, Cl could be salt crystals. Al was excluded since the Aluminium foil was support material.

Notes 2: 14 particles were analyzed. 2 salt crystals were excluded in the summary.
Figure 11 SEM-EDX spectrum showing relative atomic composition. The 14 spectra are grouped in 4 columns based on similarities in relative composition.

Figure 12. The same groupings as in Fig 11 with the particles analyzed in SEM-EDX (a,b,c = Column 1 in Fig 11)
Conclusion
During the two cruises we have managed to improve the sampling methods so that it is more adapted for monitoring purposes, by reducing the ship time at stations and using equipment that is easier to handle and in large degree standardizing the sampling. The improvement has also reduced the risk of contamination. However, the method will not collect large particle (>300 µm) in the same way as the former methods and is best adapt for particles between 10 and 300 µm. The sampling equipment could be further developed to include larger particles. However, the existing method is suitable to capture the size fraction that is most likely ingested by filter feeders and could result in accumulation of environmental harmful substances.

The sampling along the transect Torungen – Hirtshals shows that microscopic litter (paint from boats, oil component and ash particles) is present across the Skagerrak and within the Norwegian coastal current. The concentrations of particles vary between stations and time of covering (October and November). Based on this pilot study it is not possible to state (statistical) if the concentrations of such particles is lower or higher in this part of the Skagerrak compared to former studies in the east part. Neither could we determined, whether this problem is mainly a coastal or mid-ocean problem. The observed increase in particles in the coastal water in this study could be explained by the dominating wind and/or freshwater run-of. There is still need for more information regarding the origin of the particles (anthropogenic or natural component), identification of the particles and possible negative effect or/and accumulation in marine organism. We also see that there is a need for more information regarding concentrations of such particle, if there is “seasonality” in the presence of particle or if there is any “hot spots” of such particle due to currents or discharge.
1.4.3 References
Moore, C. J., G. L. Lattin, et al. (2005). Density of Plastic Particles found in zooplankton trawls from Coastal Waters of California to the North Pacific Central Gyre. The Plastic Debris Rivers to Sea Conference, Redondo Beach, California, USA.

Sammendrag – summary: The main task in this pilot project on presences of microscopic anthropogenic particles was to establish whether such particles were present in Norwegian waters (Skagerrak), amount of particles, and testing of methods for monitoring of such particles. During two pelagic surveys on along the fixed transect between Arendal and Hirtshals, the concentration of potential anthropogenic particles was measured using a new sampling method for monitoring purposes.

4 emneord: Mikropartikler, Skagerrak, målmetoder, overvåkning

4 subject words: Microscopic particles, Skagerrak, measuring methods, monitoring.
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Om Klima- og forurensningsdirektoratet

Klima- og forurensningsdirektoratet (Klif) er fra 2010 det nye navnet på Statens forurensningstilsyn. Vi er et direktorat under Miljøverndepartementet med 325 ansatte på Helsfyr i Oslo. Direktoratet arbeider for en forurensningsfri framtid. Vi iverksetter forurensningspolitikken og er veiviser, vokter og forvalter for et bedre miljø.

Våre hovedoppgaver er å:
- redusere klimagassutslippene
- redusere spredning av helse- og miljøfarlige stoffer
- oppnå en helhetlig og økosystembasert hav- og vannforvaltning
- øke gjenvinningen og redusere utslippene fra avfall
- redusere skadevirkningene av luftforurensning og støy

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