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Settlements on Svalbard as sources for emerging contaminants

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Settlements on Svalbard as sources for emerging contaminants

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Sammendrag / Summary
Målsettingen med prosjektet som presenteres her har vært å undersøke om aktive bosettinger på Svalbard kan være kilder til såkalte 'nye' miljøgifter i marint miljø. Prosjektet har fokusert på en rekke nye (og noen gamle) miljøgifter, herunder fosfororganiske flemmehemmere (OPFR), perfluorerte forbindelser (PFAS), polybromerte difenyletere (PBDE), dioksiner/furaner (PCDD/PCDF), bisfenol A, ftalater, nonyl- og okty-fenol, men mer inngående studier har kun blitt gjennomført for de forbindelsene som viste interessante resultater i innledende analyserunder. Det ble innhentet sediment- og biota-prøver fra Adventfjorden og Grønfjorden på Svalbard. I tillegg ble det tatt sedimentprøver på en referansestasjon i Kongsfjorden. Prøvestasjonene ble etablert i områder hvor det var potensielle kilder til miljøgifter, som avfallsfyllinger, kloakkutløp og flyplass. Det ble ikke funnet målbare konsentrasjoner av PCDD/PCDF, bisfenol A, ftalater eller fenoler i sedimentprøver fra Adventfjorden (indre del av fjorden og området ved kloakkutslipp prøvetatt) eller Grønfjorden (området ved en avfallsfylling og området ved kloakkutslipp prøvetatt). Resultatene viste imidlertid at bosettingene Longyearbyen og Barentsburg representerer lokale kilder for OPFR og PFAS. Det ble funnet relativt høye nivå av OPFR i sediment utenfor Barentsburg. Resultater fra en risikoanalyser indikerer likevel at risikoen for giftige effekter på sedimentlevende organismer er lav, med et mulig unntak av PFOS. Det ble målt lave nivå av OPFR i organismer (krabbe og fisk) fra både Adventfjorden og Grønfjorden. Til tross for at nivåene av PFAS i sediment var betydelig lavere enn nivåene av OPFR (spesielt i Grønfjorden), ble det målt noe forhøyde nivå av flere PFAS i organismer. De høyeste nivå og de fleste forbindelser ble målt i prøver fra den indre delen av Adventfjorden. Selv om sedimentkonsentrasjonen av ∑PFAS var noe høyere i Grønfjorden enn i Adventfjorden så var nivåene i organismer lavere. Årsaken til dette kan være at de forbindelsene som var dominerende i sediment fra Grønfjorden bioakkumulerer i mindre grad enn de som dominerte i Adventfjorden, eller at de brytes raskere ned.

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Table of content

Preface

The project reported here received funding from Svalbard Environmental Protection Fund (Svalbard Miljøvernfond) from 2016 - 2017. The project was carried out as a collaboration between Akvaplan-niva, the Norwegian Polar Institute, the Norwegian Institute for Air Research and Lund University in Sweden. A Master thesis, presenting some of the data included in this report, has already been published (Anna Olsson, Lund University). Some text in this report therefore build on the text from the thesis of Olsson.

The authors wish to thank Svalbard Environmental Protection Fund for financial support for an interesting project.

Tromsø 01.06.2018

Anita Evenset

Anita Evenset

1 Summary

Long-range transport is often considered to be the most important source of pollutants for Arctic areas. However, despite small settlements and limited industrial activities in the Arctic region, several studies have shown that also local sources may affect environmental status. In Svalbard it has been documented that, in particular, the Russian settlements Barentsburg and the Pyramid are important sources of polychlorinated biphenyls (PCBs) and certain chlorinated pesticides. There is also a study showing that siloxanes, which is a group of chemicals that is widely used in pharmaceuticals and cosmetics, can be found in elevated concentrations in the marine environment near the settlements Longyearbyen and Ny-Ålesund. The objective of the project presented here has been to investigate whether active settlements in Svalbard may be sources of so-called 'emerging contaminants'.

The project has focused on a number of emerging (and some old) environmental contaminants including organophosphorus flame retardants (OPFR), perfluorinated compounds (PFAS), polybrominated diphenyl ethers (PBDE), dioxins/furans (PCDD/PCDF), bisphenol A, phthalates, nonyl- and octyl-phenols, but more in-depth studies have only been conducted for those compounds that showed interesting results in initial analyzes.

Sediment and biota samples were collected from Adventfjorden and Grønfjorden in Svalbard. In addition, sediment samples were collected at a reference station in the Kongsfjord. Sampling stations were established in areas close to potential local sources for contaminants, such as landfills, sewage outlets and the airport in Longyearbyen. PCDDs/PCDFs, bisphenol A, phthalates or phenols could not be detected in sediment samples from Adventfjorden (inner part of the fjord and an area close to sewage outlet were sampled) or Grønfjorden (area downstream a landfill and area close to sewage outlet sampled). Therefore, further analyzes of these compounds were not performed.

Analyzes of OPFRs in sediments showed interesting results. This compound group was detected in both fjords, but concentrations were significantly higher in sediment from Grønfjorden than in sediment from Adventfjorden, and the levels in Grønfjorden were surprisingly high, considering the low population density in the area. OPFRs were not found in sediment from the reference station in Kongsfjorden. This indicates that local sources has an effect on the environmental status of Adventfjorden and Grønfjorden. However, the sediment from the reference station had lower levels of organic carbon and coarser sediment (lower share of fine-grained materials) than sediment from Adventfjorden and Grønfjorden, and these factors could have contributed to lower levels of OPFRs at the reference station. Therefore, it cannot be concluded that only local sources add OPFRs to the environment outside the settlements. Elevated levels, together with differences in contaminant patterns (relative proportions of different compounds), however, provide a strong indication that local sources are important, especially in Grønfjorden. Still, a risk analysis, based on measured concentrations and literature values for the physicochemical properties of the contaminants, indicates that the risk for sediment-living organisms is low, probably due to low bioaccumulation and/or rapid metabolism in organisms. This is supported by analyzes of OPFRs in organisms. The levels in great spider crabs and fish (Shorthorn sculpin and cod) were low, both in Adventfjorden and Grønfjorden. Thus, the high levels measured in sediment from Grønfjorden were not reflected in elevated levels in organisms. Somewhat elevated levels in organisms collected near the sewage outlet in Barentsburg, compared to other areas, supports the indication from the sediment samples that this may be a local source for OPFRs in Grønfjorden.

The PFAS results were also interesting with respect to potential local sources. No significant differences were found in ΣPFAS between the three sampling areas, although the levels were generally higher in Grønfjorden than in Adventfjorden and lowest at the reference station. Various PFAS-compounds dominated in the three areas, PFOS in Adventfjorden, PFHpA in Grønfjord and 6:2 FTS at the reference station. High concentrations of PFOS has previously been reported in soil-samples from Svalbard aiport (due to past use of PFOS-containing firefighting foam). However, the levels of PFAS were not higher in sediment collected outside the airport than in sediment from other stations in Adventfjorden. PFHxA, PFOS and PFTeA were not found in sediment from the reference station and it is therefore believed that these compounds originate from local sources.

The risk assessment showed that the measured levels of PFOS could pose a risk to sediment-living organisms, but since there is some uncertainty related risk analysis for compounds, such as PFAS, that are neither soluble in water nor in fat, more knowledge is needed to conclude about this. Despite the fact that the levels of PFAS in sediment were significantly lower than the levels of OPFRs (especially in the Grønfjord), elevated levels of several PFAS were measured in organisms. The highest level and the highest number of compounds were measured in samples from the inner part of Adventfjorden. Although the sediment concentration of ΣPFAS was slightly higher in Grønfjorden than in Adventfjorden, the levels in organisms were lower. The reason for this may be that the compounds that dominated in sediment from Grønfjorden are less bioaccumulative than those that dominated in Adventfjorden, or that they are more easily metabolized.

The results from this study show that the settlements Longyearbyen and Barentsburg represent local sources for OPFRs and PFAS. The levels in sediment and organisms are not very high and results from a risk analysis indicate that the risk of toxic effects on sediment-living organisms is low, with a possible exception for PFOS. However, it is important to note that the sedimentation rate in the fjords examined is high due to a large transport of inorganic material from rivers (and glaciers). A high sedimentation rate may camouflage environmental pollutants (dilution in sediment), and it cannot be excluded that the levels would have been higher if the sedimentation rate had been lower.

2 Sammendrag

Langtransport regnes ofte som den viktigste tilførselsveien for miljøgifter til Arktiske områder. Flere studier har imidlertid dokumentert at også lokale kilder kan ha betydning for miljøstatus, til tross for små bosettinger og lite industriell virksomhet. På Svalbard har det bl.a. blitt dokumentert at spesielt de russiske bosettingene Barentsburg og Pyramiden er viktige kilder til polyklorerete bifenyler (PCB) og enkelte klororganiske pesticider. Det foreligger også en studie som viser at siloksaner, som er en gruppe kjemikalier som bl.a. benyttes mye i legemidler og kosmetikk, finnes i forhøyde konsentrasjoner i marint miljø i nærheten av bosettingene Longyearbyen og Ny-Ålesund. Målsettingen med prosjektet som presenteres her har vært å undersøke om aktive bosettinger på Svalbard kan være kilder til såkalte 'nye' miljøgifter.

Prosjektet har fokusert på en rekke nye (og noen gamle) miljøgifter, herunder fosfororganiske flemmehemmere (OPFR), perfluorerte forbindelser (PFAS), polybromerte difenyletere (PBDE), dioksiner/furaner (PCDD/PCDF), bisfenol A, ftalater, nonyl- og okty-fenol, men mer inngående studier har kun blitt gjennomført for de forbindelsene som viste interessante resultater i innledende analyserunder.

Det ble innhentet sediment- og biota-prøver fra Adventfjorden og Grønfjorden på Svalbard. I tillegg ble det tatt sedimentprøver på en referansestasjon i Kongsfjorden. Prøvestasjonene ble etablert i områder hvor det var potensielle kilder til miljøgifter, som avfallsfyllinger, kloakkutløp og flyplass.

Det ble ikke funnet målbare konsentrasjoner av PCDD/PCDF, bisfenol A, ftalater eller fenoler i sedimentprøver fra Adventfjorden (indre del av fjorden og området ved kloakkutslipp prøvetatt) eller Grønfjorden (området ved en avfallsfylling og området ved kloakkutslipp prøvetatt). Det ble derfor ikke utført ytterligere analyser av disse forbindelsene.

Analyser av OPFR i sedimenter viste interessante resultater. Denne stoffgruppen ble påvist i begge fjordområdene, men konsentrasjonene var betydelig høyere i sediment fra Grønfjorden enn i sediment fra Adventfjorden, og nivåene i Grønfjorden var overraskende høye, den lave befolkningstettheten i området tatt i betraktning. OPFR ble ikke funnet i sediment fra referansestasjonen i Kongsfjorden. Dette indikerer at lokale kilder har betydning for miljøtilstanden i Adventfjorden og Grønfjorden. Sedimentet fra referansestasjonen hadde imidlertid lavere nivå av organisk karbon og en lavere finstoffandel enn sedimentet fra Adventfjorden og Grønfjorden, og disse faktorene kan være medvirkende årsaker til lavere nivå av OPFR på referansestasjonen. Det kan derfor ikke konkluderes med at kun lokale kilder tilfører OPFR til miljøet utenfor bosettingene. Forhøyde nivå, sammen med ulikheter i miljøgiftsmønster (relativ andel av ulike forbindelser) gir imidlertid en sterk indikasjon på at lokale kilder er viktige, spesielt i Grønfjorden. En risikoanalyse, basert på målte konsentrasjoner og litteraturverdier for miljøgiftenes fysiokjemiske egenskaper, indikerer likevel at risiko for sedimentlevende organismer er lav, noe som trolig skyldes lav bioakkumulering og/eller rask nedbrytning i organismer. Dette støttes av analyser av OPFR i organismer. Nivåene i krabbe og fisk (ulke og torsk) var jevnt over lave, både i Adventfjorden og Grønfjorden. De høye nivåene målt i sediment fra Grønfjorden ble ikke reflektert i forhøyde nivå i organismer. Et noe forhøyet nivå i organismer samlet inn i nærheten av kloakkutløpet i Barentsburg, sammenlignet med de andre prøvetatte områdene, støtter opp om indikasjonen fra sedimentprøvene om at det er en lokal kilde for OPFR i Grønfjorden.

Også PFAS-resultatene var interessante med tanke på potensielle lokale kilder. Det ble ikke funnet signifikante forskjeller i ∑PFAS mellom de tre prøvetatte områdene, selv om nivåene

generelt var noe høyere i Grønfjorden enn i Adventfjorden og lavest på referansestasjonen. Ulike PFAS-forbindelser dominerte, PFOS i Adventfjorden, PFHpA i Grønfjorden og 6:2FTS på referansestasjonen. Det har tidligere blitt avdekket høye konsentrasjoner av PFOS i grunnen på Svalbard lufthavn (på grunn av tidligere bruk av brannskum som inneholdt PFOS). Det var imidlertid ikke høyere nivå i sediment samlet inn utenfor flyplassen enn i sediment fra andre stasjoner i Adventfjorden. PFHxA, PFOS og PFTeA ble ikke funnet i sediment fra referansestasjonen og det antas derfor at disse forbindelsene stammer fra lokale kilder. Risikovurderingen viste at de målte nivåene av PFOS kan utgjøre en risiko for sedimentlevende organisemer, men det er en del usikkerhet rundt metode for risikoanalyse av slike fluor-forbindelser som verken en løselig i vann eller i fett, så det er behov for mer kunnskap for å kunne konkludere endelig omkring dette. Til tross for at nivåene av PFAS i sediment var betydelig lavere enn nivåene av OPFR (spesielt i Grønfjorden), ble det målt noe forhøyde nivå av flere PFAS i organismer. De høyeste nivå og de fleste forbindelser ble målt i prøver fra den indre delen av Adventfjorden. Selv om sedimentkonsentrasjonen av ∑PFAS var noe høyere i Grønfjorden enn i Adventfjorden så var nivåene i organismer lavere. Årsaken til dette kan være at de forbindelsene som var dominerende i sediment fra Grønfjorden bioakkumulerer i mindre grad enn de som dominerte i Adventfjorden, eller at de brytes raskere ned.

Resultatene fra denne studien viser at bosettingene Longyearbyen og Barentsburg representerer lokale kilder for OPFR og PFAS. Nivåene i sediment og organismer er ikke veldig høye og resultater fra en risikoanalyser indikerer at risikoen for giftige effekter på sedimentlevende organismer er lav, med et mulig unntak av PFOS. Det er imidlertid viktig å være klar over at sedimentasjonsraten i de undersøkte fjordene er høy på grunn av stor tilførsel av uorganisk materiale fra elver (og isbreer). En høy sedimentasjon kan bidra til å kamuflere miljøgifter, og det kan derfor ikke utelukkes at nivåene ville vært høyere dersom sedimentsjonsraten hadde vært lavere.

3 Introduction

Contaminants found in the Arctic are often long-range transported from more densly populated and industrialised areas further south. However, recent studies have shown that even relatively small Arctic settlements can be sources for both legacy and emerging contaminants (Evenset et al. 2006; 2009; Evenset & Christensen 2009; Jartun et al. 2009; Warner et al. 2010). Studies performed in the active and abandoned mining settlements on Spitsbergen, Longyearbyen, Barentsburg and Pyramiden, have shown that soil in and sediment outside the Russian settlements (Barentsburg and Pyramiden) contain elevated levels of PCBs (polychlorinated biphenyls) and some chlorinated pesticides (Evenset et al. 2006; 2009; Evenset & Christensen 2009; Typhoon 2010). The source for these legacy persistent organic pollutants (POPs) are probably old equipment used in mining activities (e.g. transformators, capacitors) and paint on buildings. PCBs have been banned for many years, and there has been a clean-up action on Svalbard focusing especially on this compound group (Lundquist et al. 2011). Therefore, the levels of this compound group are expected to decline in the coming years. However, modern settlements are also sources for other contaminants, and little is known about levels and effects of emerging contaminants in the Svalbard environment (Granberg et al. 2017). On Spitsbergen, local sewage seems to be a source for some environmental contaminants, as there is limited wastewater treatment on the island (Leikvin & Evenset 2010; Evenset et al. 2017). The largest settlements on the island, Longyearbyen (around 2000 inhabitants + in averagearound 500 tourists per day) and Barentsburg (around 500 inhabitants), still emit untreated sewage into Adventfjorden and Grønfjorden, respectively. There has been few studies of local pollution with emerging contaminants from the settlements, but there are indications that sewage is a source for some emerging contaminants. Warner et al. (2010) found concentrations of siloxanes to be higher in the marine environment close to sewage outlets in Adventfjorden (outside Longyearbyen) and in Kongsfjorden (outside Ny-Ålesund) than in more remote, not inhabited, areas on Svalbard. Siloxans are mainly used to produce silicone polymers, but they are also used in personal care and cosmetic products. Siloxanes are for instance important ingredients in deodorants, shampoos, skin creams and hair styling products, and are thus following wastewater streams.

Based on results from e.g. Warner et al. (2010) it is reasonable to believe that also other emerging comtaminants may occur in marine areas outside the local settlements on Svalbard. Different household products may be sources for other emerging contaminants, such as bisphenol A (BPA), phthalates and nonylphenols. Industrial activities, such as mining and transportation, may also add compounds that can pollut the environment. Perfluoroalkyl substances (PFAS) have been widely used as the active ingredients in fire-fighting foams used during fire training at airports (Ahrens et al. 2016), and thus the airports in Barentsburg and Longyearbyen may be sources for these compounds (Kvernland 2017; Kristoffersen 2012). Brominated flame retardants (BFRs) are used in furniture and electronics, from where they can be released to the environment. The past few years a new group of flame retardants, the organophosphorus flame retardants (OPFRs), has received a lot of attention. The use of OPFRs has increased as they are used to replace BFRs in many industrial and consumer products. Both BFRs and PFASs (mainly PFOS, perfluoroktanylsulfonat) have been detected in a few sediment samples collected outside Longyearbyen, Barentsburg and Pyramiden (Evenset et al. 2006; 2009). However, very few samples have been analysed, and a more comprehensive and dedicated sampling outside potential sources is therefore warranted. Thus, the main aim of the project reported here was to examine if selected emerging contaminants can be found close to local sources in the marine environment outside two settlements on Svalbard; Adventfjorden

(Longyearbyen) and Grønfjorden (Barentsburg). A secondary objective was to examine potential environmental risk related to these emerging contaminants, if they were found.

In the first phase of the project, sediment samples were analysed for OPFRs, PFAS and Polybrominated diphenyl ethers (PBDEs). Then, a few sediment samples were analysed for dioxin/furans, bisphenol A, phthalates, nonyl- and octylphenols. Since none of these latter compounds were detected in sediment it was decided to proceed with analyses of OPFRs and PFAS in biota since the first results from analyses of these compounds were very interesting and reqired more investigations in order to achive a better understanding of the environmental status.

3.1 Contaminants that were included in the study

3.1.1 Organophosphorus flame retardants (OPFRs)

Organophosphorus compounds are used as flame retardants and plasticisers in a wide range of products, such as textiles, electronic equipments, polyvinyl chloride (PVC), paint, furnitures and polyurethane foams (Marklund et al. 2003; Leisewitz et al. 2000; Salthammer et al. 2003). The use of phosphorus flame retardants have increased the past few years as they have partly replaced banned brominated flame retardants (Reemtsma et al. 2008; van der Veen and de Boer 2012).

In the Arctic, possible sources for OPFRs are e.g. local settlements (waste dumps and sewage), vessels and cruise ships. OPFRs have been shown to be long-range transported to the Arctic (Hallanger et al. 2015), and are suspected to be persistent and bioaccumulating. Effects in Arctic ecoystems are unknown, but OPFRs have shown possible neurotoxic, genotoxic and reproductively toxic effects (Wei et al. 2015; van der Veen and de Boer 2012), and chlorinated OPFRs are carcinogenic. Some of the congeners, such as triphenyl phosphate (TPhP), tris(2-chloroethyl)phosphate (TCEP) and tricresylphosphate (TCP/TMPP), are considered to be toxic to aquatic organisms.

3.1.2 Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are used as flame retardants in a lot of products, such as furnitures, electronics and textiles (Rahman et al. 2001). Their structure and hence chemical properties and persistence, are similar to PCBs. In the same way as PCBs, they are long-range transported, and PBDEs have therefore over the past two decades been detected in different samples from the Arctic region (Rahman et al. 2001; Evenset et al. 2009; de Wit et al. 2010; Cai et al. 2012). PBDEs are hydrophobic and therefore accumulate in lipids, sediment and soil, where they are largely partitioning to organic carbon (Gouin and Harner 2003; de Wit et al. 2010).

PBDEs have been shown to be endocrine disrupters, to have negative impacts on neurodevelopment, and they are in some cases carcinogenic (McDonald 2002; Darnerud 2008). Because of their toxicity and persistence, the industrial production of some PBDEs is restricted under the Stockholm Convention (Stockholm Convention 2016).

3.1.3 Perfluorinated alkylated substances (PFAS)

Perfluorinated alkylated substances (PFAS) are, due to their physio-chemical properties, both non-polar and polar. They have been used in a wide range of products, such as firefighting foams, textiles, paints, repellents etc. (Kissa 2001; Herzke et al. 2012). Most PFAS released into the environment comes from direct sources, such as production and use of products containing fluorochemicals (Butt et al. 2010). However, releases from indirect sources, such as

degradation of precursor substances, do also occur. The most common PFAS are perfluorooctanoate (PFOA) and perfluorooctane sulfonate (PFOS). Some PFAS have been shown to be persistent and bioaccumulative, and they may act as endocrine disruptors. Changes in lipid metabolism have also been reported to occur in exposed organisms (Lau et al. 2007; Jensen and Leffers 2008).

The compound group was, due to their physio-chemical properties and ability to undergo long-range transport, voluntary phased out by manufacturers around the world. Today, PFOS and its precursors are included in the Stockholm convention (Stockholm Convention 2016).

3.1.4 Dioxines

Dioxins refers to a group of toxic chemical compounds that share certain chemical structures and biological characteristics. The group includes chlorinated dibenzo-p-dioxins (PCDDs), chlorinated dibenzofurans (PCDFs).

PCDDs and PCDFs are not created intentionally, but are byproducts of industrial processes or released from combustion processes, such as waste incineration (commercial or municipal) or from burning fuels (like wood, coal or oil). Natural processes, like forest fires, also produce PCDDs and PCDFs. Dioxins are extremely persistent compounds and break down very slowly. They are highly toxic and can cause cancer, reproductive and developmental problems, damage to the immune system, and can interfere with hormones. On Svalbard, the coal-fired power plants has been suspected to be sources for dioxines in the environment. Previous analyzes of water-discharges from the coal power plant in Longyearbyen have shown that the main emissions were dioxins/furans, hydrocarbons, sulfur, and a variety of metals (e.g. mercury (Hg) and chromium) (Evenset 2002).

3.1.5 Bisphenol A

Bisphenol A (BPA) is an industrial chemical used to make clear plastic such as polycarbonate. Polycarbonates are used in many consumer products, including re-usable water bottles, baby bottles, sport equipments, medical and dental devices, lenses and household electronics. BPA is also found in epoxy resins, which act as a protective lining on the inside of metal-based food and beverage cans. Products containing or made from BPA have been in commerce for more than 50 years. BPA has been demonstrated to be weakly estrogenic (Bolger et al. 1998; Welshons et al. 1999) and causing uterotrophic effects at high doses (200 to 800 mg/kg) in animals (Ashby and Odum 2004). Despite a half-life in the soil of only 1–10 days, its ubiquity makes it an important pollutant. In February 2016, France announced that it intends to propose BPA as a REACH Regulation candidate substance of very high concern (SVHC). The European Chemicals Agency agreed to the proposal in June 2017.

3.1.6 Phtalates

Phthalates are a group of chemicals that were first produced during the 1920s, and have been produced in large quantities since the 1950s, when polyvinyl chloride (PVC) was introduced. Phthalates are used to make plastics more flexible and harder to break. They are often called plasticizers. Phthalates are also found in modern electronics and medical applications such as catheters and blood transfusion devices. They are easily released into the environment, but they do not persist due to rapid biodegradation, photodegradation, and anaerobic degradation. Some types of phthalates have been shown to affect the reproductive system of laboratory animals, but in general they are assumed to have a low toxicity. Some compounds in the group are today regulated, and DEHP (Bis(2-ethylhexyl) phthalate) has been phased out in Europe under REACH and can only be used in specific cases if an authorisation has been granted.

3.1.7 Nonyl- and octyl-phenols

Nonylphenol (NP) and octylphenol (OP) are alkylated phenols that have various uses. Nonylphenols are used in e.g. household products, cleansers, cosmetics and insecticides. They are liphophilic and persistent in the environment. The impact of NP in the environment include feminization of aquatic organisms, decrease of male fertility and reduced survival of juveniles. Octylphenols are mainly used as an intermediate in the production of phenol/formaldehyde resins (98% of use) and in the manufacture of octylphenol ethoxylates (2% use). Octylphenol is very toxic to aquatic organisms, is not easily degraded in the environment and has the potential to cause significant endocrine disruption effects (OSPAR 2006).

4 Materials and methods

4.1 Sampling areas

Sediment sampling was conducted in September 2015 and 2016 in three areas; Adventfjorden, Grønfjorden and Kongsfjorden (reference area). In Adventfjorden and Grønfjorden, samples were collected in areas close to potential local sources.

In Adventfjorden, sampling was conducted close to the sewage outlet where untreated sewage is released into the fjord (L2 and L3), outside Svalbard lufthavn (L4), in the inner part of the fjord (L1) and close to the settlement (L5) (Table 1, Figure 1a). Biota samples were collected in September 2016 in the inner part of Adventfjorden, close to the settlement and close to the sewage outlet in the outer part of the fjord.

In Grønfjorden, outside Barentsburg, four sites were sampled. Also in Grønfjorden, the selected sites are situated close to potential point sources; two landfills (B1, B2, and B3, Table 1, Figure 1b), a stable/greenhouse area (B4, B5) and the sewage outlet (B6, sampled in 2016). The landfills probably contain a wide variety of waste, including electronical waste, and they may therefore be a source for a variety of contaminants. Biota-samples were collected in 2016 close to the sewage outlet in Barentsburg and outside the landfills.

Reference sediment-samples were collected close to Blomstrandhalvøya in Kongsfjorden, about 9 km from the settlement in Ny-Ålesund. The reference site should be virtually free from local contamination and any levels of contaminants found there would probably originate from long-range transport.

4.2 Fieldwork

4.2.1 Sediment sampling

The fieldwork in Adventfjorden and Grønfjorden was performed from a Polarcircle boat and in Kongsfjorden with MS Teisten. Sediment was collected with a small van Veen grab with a volume of about 2 dm^3 in Adventfjorden and Grønfjorden, and with a larger VanVeen in Kongsfjorden (volume of 10 dm^3). Three parallel samples were taken in each sampling area (with some exceptions, see Table 1). In Adventfjorden and Grønfjorden, each sample concisted of sediment from three grabs in order to get enough sediment for analyses. The upper 2 cms were collected from undisturbed grabs and put in Rilsan® (Tub-ex, Denmark) bags or pre-burned glass jars until analysis. All equipment used was rinsed between each sample taken, to avoid contamination. The samples were frozen at -18°C as soon as possible after sampling.

Table 1. Information about sampling areas for sediment samples.

Area	Replicates	Year	Coordinates		Depth	Distance from point source	Comments
L1	3	2015	78°14,182	15°41, 736	25 m	*	Inner part of Adventfjorden
L2	4	2015, 2016	78°14,781	15°38,804	55 m	0 m	Sewage pipe
L3	3	2015	78°14,824	15°38,639	58 m	108 m	Sewage pipe
L4	3	2015	78°15,078	15°30,422	13 m	100 m	Airport
L5	1	2016	78°13,729	15°36,596	10 m	*	Close to settlement and powerplant
B1	3	2015	78°02,871	14°12,721	4 m	50 m	Landfill
B2	3	2015, 2016	78°03,522	14°12,187	17 m	36 m	Landfill
B3	1	2015	78°03,522	14°11,917	60 m	136 m	Landfill
B4	3	2015	78°04,213	14°11,638	10 m	100 m	Greenhouse
B5	1	2015	78°04,213	14°11,392	55 m	200 m	Greenhouse
B6	1	2016	78°03,522	14°12,187	5 m	0 m	Sewage pipe
REF	3	2015	79°00,288	11°57,169	13 m	-	Reference point

*many potential sources in settlement

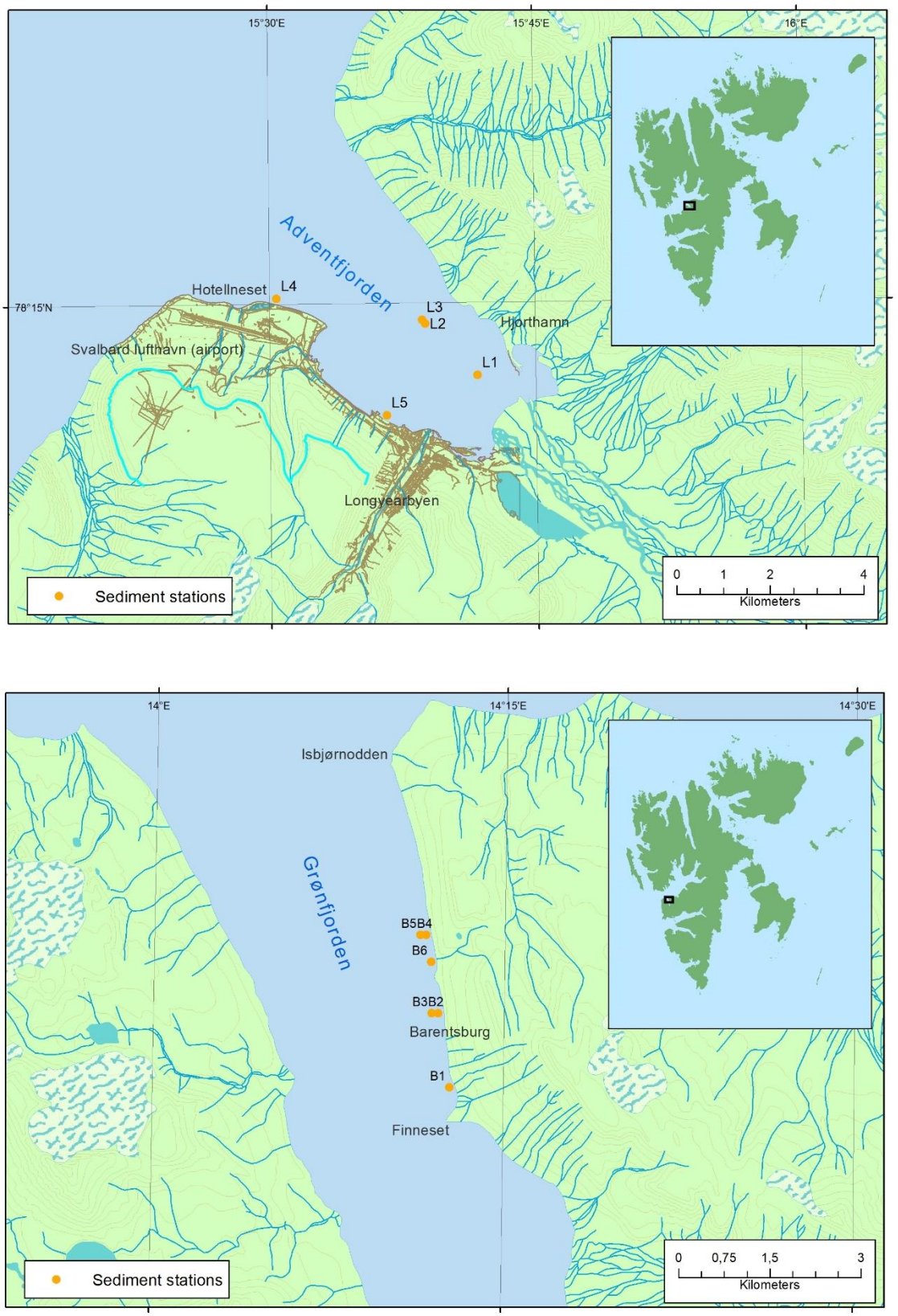

Figure 1. Stations where sediment samples were collected, September 2015 and 2016.

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4.2.2 Biota

Samples of great spider crabs (*Hyas araneus*, Figure 2), fish (Atlantic cod (*Gadus morhua*) and shorthorn sculpin (*Myoxocephalus Scorpius*), were collected at two stations in Adventfjorden and Grønfjorden (Table 2, Figure 3) using multinets. Crabs and sculpins are relatively stationary species and are expected to be affected by local contaminantion sources, while cod is more migratory and will therefore to a larger extend reflect long-range transport as a source. However, as all organisms are expected to move the gillnets were set out to cover 'regions' rather that at specific stations. All biota-samples were directly wrapped in aluminum-foil and zip-lock bags after sampling to avoid contaminantion. Soft-parts of crab (dissected in a clean-cabinet in Tromsø) and whole fish were used for chemical analyses.

Table 2. Stations where biota samples were collected in September 2016.

Station	Area	Coordinates		Depth range	Species caught
Biota A1	Inner Adventfjord	78°13,608	15°38,352	1 – 6 m	Atlantic cod (*Gadus morhua*), shorthorn sculpin (*Myoxocephalus scorpius*), herring (*Clupea haerengus*), tadpole fish (*Raniceps raninus*)
Biota A2	Sewage outlet	78°14,781	15°38,804	3 – 30 m	Thornback ray (*Raja clavata*), Atlantic cod (*Gadus morhua*), polar cod (*Boreogadus saida*)
Biota G1	Landfill	78°02,871	14°12,721	5 - 25 m	Thornback ray (*Raja clavata*), shorthorn sculpin (*Myoxocephalus scorpius*), great spider crab (*Hyas araneus*)
Biota G2	Sewage outlet	78°03,522	14°12,187	3 – 30 m	Thornback ray (*Raja clavata*), shorthorn sculpin (*Myoxocephalus scorpius*), great spider crab (*Hyas araneus*), Atlantic cod (*Gadus morhua*)

Figure 2. Great spider crab (hyas araneus). Photo: Guttorm N. Christensen, Akvaplan-niva.

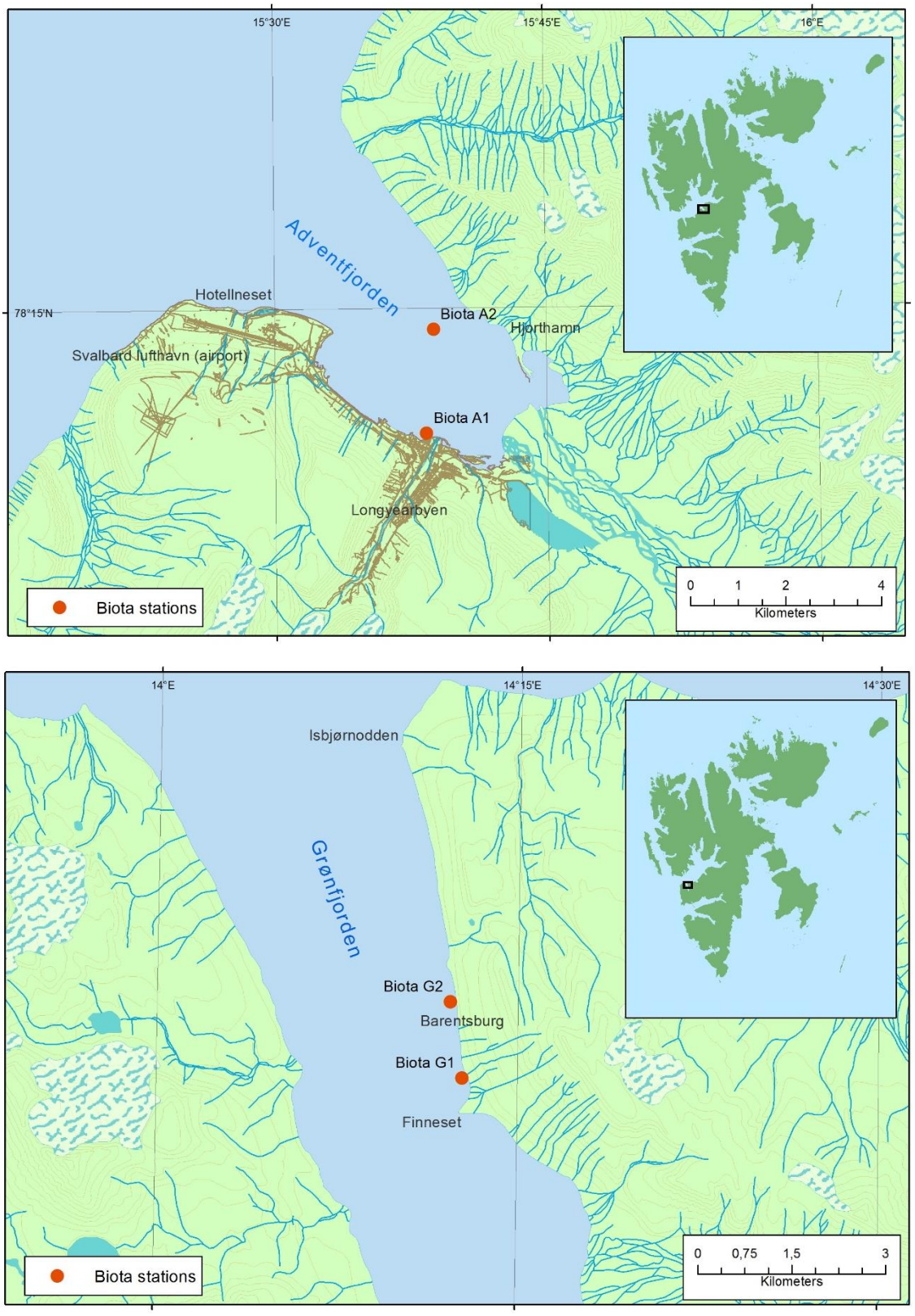

Figure 3. Stations for biota samling, September 2016.

4.3 Chemical analyses of sediment samples

Analyses of OPFRs, PFAS and PBDEs were performed by the Norwegian Institute for Air Research (NILU) in Tromsø. Analyses of dioxins, bisphenol A, phthalates, octyl- and nonylphenols were performed by ALS Laboratory Group. Handling of samples was as far as possible done in a clean-cabinet to avoid contamination. Detailed method descriptions for analyses of OPFRs, PFAS and PBDEs are given by Olsson (2016). Therefore, only brief summaries are given in the following text.

4.3.1 TOC and grain size

Organic contaminants bind to organic matter and fine-grained particles. Therefore, total organic carbon (TOC) and grain size (fraction >< 63 µm) was also measured in the sediment. TOC was determined by measuring released CO_2 with photometric infrared light. The amount of CO_2 is proportional with TOC. The grain size was determined by wet-sieving. More details are available in Appendix 6.

4.3.2 OPFRs

Fourteen OPFRs were quantified in sediment in the present study (Table 3), and all together 26 samples were analysed for these compounds. Prior to extraction, 20 ng of internal standard (PFR I, 1 ng/µL) was added to the samples. Three blank samples (silica burned at 450°C for 8 hours) were analysed together with the samples. OPFRs were extracted from the sediment using acetonitrile. A Solid phase extraction (SPE)-station with an Oasis HLB 6cc (500 mg) LP Extraction cartridge was used to clean-up the samples. The samples were quantified using an ultrahigh pressure liquid chromatography column coupled to a triple quadrupole mass spectrometer (UPLC/MSMS, Vantage, Thermo Scientific) and electrospray ionization (ESI). For more details about analytical method, see Olsson (2016).

Table 3. OPFR-compounds quantified in the sediment- and biota-samples. Compounds in light blue rows were only analysed in biota.

Name	Abbreviation
Butyl diphenyl phosphate	BdPhP
Dibutylphenyl phosphate	DBPhP
2-Etylhexyldiphenylphosphate	EHDP
Tris(2-butoxyethyl) phosphate	TBEP
Tris(2-chloroethyl)phosphate	TCEP
Tricresylphosphate	TCP
Tris(2-chloro-1-methylethyl) phosphate	TCPP
Tris(1,3-dichloro-2-propyl) phosphate	TDCPP
Tris(2-ethylhexyl)phosphate	TEHP
Triethyl phosphate	TEP
Triisobutyl phosphate	TiBP
Tri-n-butyl phosphate	TnBP
Tripropyl phosphate	TPP
Tripropyl phosphate	TPrP
Trixylyl Phosphate	TXP
Tri(isopropylphenyl)phosphate	TIPP
2,4,6-tris(2,4,6-tribromophenoxy)-1,3,5-triazine	TTBPP

4.3.3 PBDEs

Polybrominated diphenyl ethers (PBDEs) were analysed in ten sediment samples. In addition, one blank with silica (burned at 450°C for 8 hours) was analysed. 10 g of dried and crushed sediment (<2mm) and 200 µL of internal standard were added to the extraction thimble. Samples were then extracted using soxhlet with 150 mL of dichloromethane for approximately 20 hours. Clean-up was performed using gel permeation chromatography (GPC). Analysis and quantification was performed using gas chromatography with a quadrupole mass spectrometer (GC/MS, Quattromicro, Waters) using electron ionization (EI). The congeners of PBDE analysed are presented in Table 4. For more details about analytical method, see Olsson (2016).

Table 4. PBDE congeners quantified in sediment-samples.

Name	Abbreviation
2,4-Dibromophenyl 2-bromophenyl ether	BDE 17
2,4,4´-Tribromodiphenyl ether	BDE 28
2,2´,4,4´-Tetrabromodiphenyl ether	BDE 47
2,2′,4,5′-tetrabromodiphenyl ether	BDE 49
2,3′,4,4′-Tetrabromodiphenyl ether	BDE 66
2,3′,4,6′ -Tetrabromodiphenyl ether	BDE 71
3,3′,4,4′-Tetrabromodiphenyl ether	BDE 77
2,2′,3,4,4′-pentabromodiphenyl ether	BDE 85
2,2´,4,4´,5-Pentabromodiphenyl ether	BDE 99
2,2´,4,4´,6-Pentabromodiphenyl ether	BDE 100
2,3',4,4',6-pentabromodiphenyl ether	BDE 119
3,3′,4,4′,5-Pentabromodiphenyl ether	BDE 126
2,2',3,4,4',5'- hexabromodiphenyl ether	BDE 138
2,2',4,4',5,5'-hexabromodiphenyl ether	BDE 153
2,2',4,4',5,6-hexabromodiphenyl ether	BDE 154
2,3,3',4,4',5- hexabromodiphenyl ether	BDE 156
2,2',3,4,4',5',6-heptabromodiphenyl ether	BDE 183
2,2',3,4,4',6,6'- heptabromodiphenyl ether	BDE 184
2,3,3',4,4',5',6- heptabromodiphenyl ether	BDE 191
2,2',3,3',4,4',5,6'-octabromodiphenyl ether	BDE 196
2,3,3',4,4',5',6- heptabromodiphenyl ether	BDE 197
2,2',3,3',4,4',5,5',6- nonabromodiphenyl ether	BDE 206
2,2',3,3',4,4',5,6,6'-nonabromodiphenyl ether	BDE 207

4.3.4 PFAS

PFAS was extracted from 26 sediment samples, as well as in three blanks using the Powley method (Powley et al. 2005). Analysis and quantification was performed using an ultrahigh pressure liquid chromatography column coupled to a triple quadrupole mass spectrometer (UPLC/MSMS, Vantage, Thermo Scientific) and electrospray ionization (ESI). The analysed PFAS-congeners are presented in Table 5. For more details about analytical method, see Olsson (2016).

Table 5. PFAS quantified in sediment and biota samples.

Name	Abbreviation
6:2 Fluorotelomer sulfonate	6:2 FTS
Branched perfluorooctansulfonic acid	br-PFOS
Perfluorobutanoic acid	PFBA
Perfluorobutane sulfonate	PFBS
Perfluorodecanoic acid	PFDcA
Perfluorodecanoic acid	PFDcS
Perfluorododecanoic acid	PFDoA
Perfluoroheptanoic acid	PFHpA
Perfluoroheptane sulfonate	PFHpS
Perfluorohexanoic acid	PFHxA
Perfluorohexane sulfonate	PFHxS
Perfluorononanoic acid	PFNA
Perfluorononane sulfonate	PFNS
Perfluorooctanoic acid	PFOA
Perfluorooctansulfonic acid	PFOS
Perfluorooctane sulfonamide	PFOSA
Perfluoropentanoic acid	PFPA
Perfluoropentane sulfonate	PFPS
Perfluorotetradecanoic acid	PFTeA
Perfluorotridecanoic acid	PFTriA
Perfluoroundecanoic acid	PFUnA

4.3.5 Dioxines

Dioxines were analysed according to US EPA 1613. Four sediment samples (two from Adventfjorden and two from Grønfjorden) were analysed for 7 PCDDs and 10 PCDFs (Table 7). Detection and quantification was performed using HRGC/HRMS. More details are available in Appendix 6.

4.3.6 Bisphenol A

Bisphenol A was analysed according to ISO 14154. Four sediment samples (two from Adventfjorden and two from Grønfjorden) were analysed using GC-ECD. More details are available in Appendix 6.

4.3.7 Phtalates

The phthalates were analysed according to EPA 8061A, CPSC-CH-C1000-09.3, using GC/MS for quantification. The following phthalates were included in the analyses: Dimetylphthalate (DMP), Dietylphthalate (DEP), Di-n-propylphthalate (DPrP), Di-n-butylphthalate (DBP), Di-isobutylphthalate (DIBP), Di-pentylphthalate (DPP), Di-n-oktylphthalate (DNOP), Di-(2-etylheksyl)phthalate (DEHP), Butylbensylphthalate (BBP), and Di-sykloheksylphthalate (DCHP). More details are available in Appendix 6.

4.3.8 Nonyl- and octyl-phenols

Nonyl- and octyl-phenols were analysed according to DIN EN ISO 18857-2. Samples were extracted with n-hexane and quantified with GC/MSD. More details are available in Appendix 6.

4.1 Chemical analyses of biota samples

Biota samples were analysed after the sediment samples, and only compound-groups that were detected in sediments were analysed in biota samples. Therefore, the focus for biota analyses was OPFRs and PFAS.

In order to obtain representative results each biota sample consisted of a pool of 3 – 5 individuals.

4.1.1 OPFRs

Samples of 3-5 small cod, spider crab or sculpin were homogenized in a glass blender and an aliquot of 2g homogenate was homogenized with dry Na_2SO_4. 10 ng internal standard (PFR I, 0.5 ng/uL) was added to sample and let stand for 30 min. Samples was extracted with n-Hexane/Aceton (1/1) by ultrasonication.

Cleanup of the samples was done using solid phase extraction. The sample was eluted using acetonitrile. Analysis was run on a UPLC/MSMS (TSQ Vantage, Thermo Scientific inc) using Ionization was achieved using electrospray ionization (ESI).

4.1.2 PFAS

Internal standard was added to 2 g sample prior to extraction with methanol. After up-concentration samples were cleaned-up with activated carbon before analysis on an ultra high performance liquid chromatograph coupled to mass spectrometer (UPLC-MS/MS).

Quantification was performed using internal standard method. Quality control measures included determination of method detection limits for all analytes on the basis of blank extraction experiments, and control samples.

4.2 Risk analysis

After the sediment samples from 2015 had been analysed a risk analysis for each group (OPFRs, PFAS and PBDEs) and the sum of all substances was performed. A brief description of the method used is given in the following text from Olsson (2016), but a more comprehensive description can be found in Olsson (2016). To assess the risk each substance pose to the marine environment a toxic unit (TU), based on the equation for concentration addition in Könemann and Pieters (1996), was calculated (Equation 1). Concentration addition was used since the congeners of a substance group all exhibit similar mode of action.

$$TU_c = \sum \frac{PEC_{c_i}}{PNEC_{c_i}} \qquad \text{(Equation 1)}$$

TU is the toxic unit, PEC the predicted environmental concentration (ng/L), PNEC the predicted no effect concentration (ng/L), c the compound and i a specific congener of the compound. To estimate the overall risk the sum of toxic units were calculated. The ecosystem is assumed to be affected when TU=>1.

4.2.1 Predicted Environmental Concentration (PEC)

The predicted environmental concentration (PEC) was calculated using the equilibrium partitioning (EqP) theory (Toro et al. 1991). It was assumed that pore water concentrations are

the source of toxicity for sediment-living organisms. However, as the EqP also assumes equilibrium between sediment and pore water, the organisms will be exposed from all phases in the system, i.e. either from respiration in pore water, ingestion of sediment or a mix of both.

PEC was calculated using the measured environmental concentration ($MEC_{sediment}$), achieved from the chemical analysis. PEC represents the dissolved concentration of the substance, i.e. the concentration in pore water ($C_{porewater}$). $MEC_{sediment}$ is the total concentration of the substance in sediment. The concentration in pore water was derived using the partitioning coefficient of sediment-water (K_d) (Equation 2).

$$K_d = \frac{MEC_{sediment}}{C_{porewater}} \quad \text{(Equation 2)}$$

Since the fraction of organic carbon was greater than 0.2%, the organic carbon is the principal phase of sorption in sediment, which is taken into account by equation 3 (Toro et al. 1991).

$$K_p = K_{OC} \times TOC \quad \text{(Equation 3)}$$

K_{OC} is the partitioning coefficient between organic carbon and water (L water/kg organic carbon) and TOC the total organic carbon (kg TOC/kg sediment).

K_{OC} was substituted by equation 4 (Gobas and Morrison, 2000) for OPFR and PBDE, due to lack of literature values for the included congeners of these substance groups.

$$K_{OC} = K_{OW} \times 0.41 \quad \text{(Equation 4)}$$

K_{OW} is the octanol-water partitioning coefficient, obtained from literature. Since PFAS are both hydrophobic and lipophobic the K_{OC} might not give the true partitioning between sediment and water, consequently using only the K_d-value, without correcting for organic carbon might give a more reliable result. However, as the partitioning of PFAS between sediment and water has been shown to be significantly dependent on the organic carbon content of sediment (Ahrens et al. 2011; Ahrens et al. 2010), the K_{OC}-method should not be rejected. Hence, two calculations for PFAS were done, one with K_d-values and one correcting for organic carbon, using K_{OC}-values from literature.

$C_{porewater}$ (ng/L), and hence also PEC, was calculated using equation 5 for OPFR and PBDE, equation 6 for PFAS corrected for organic carbon and equation 2 for PFAS without correction for organic carbon.

$$C_{porewater} = \frac{MEC_{sediment}}{TOC \times K_{OW} \times 0.41} \quad \text{(Equation 5)}$$

$$C_{porewater} = \frac{MEC_{sediment}}{TOC \times K_{OC}} \quad \text{(Equation 6)}$$

The values for MEC and TOC were derived from the chemical analysis, while the K_{OW}- and K_{OC}-values were antilogarithmed from scientific data (see Olsson 2016). If more than one value of K_{OW}, K_{OC} or K_d was found in the literature, the mean was used. For PEC, a 95th-percentile was calculated for each fjord and used to calculate the toxic unit.

4.2.2 Predicted No Effect Concentration (PNEC)

To obtain the predicted no effect concentration (PNEC), EC_{50}- or LC_{50}-values, were collected from scientific literature (see Olsson 2016). If more than one value per substance was found, the 5th-percentile was calculated and used as PNEC to calculate the toxic unit. The 5th-percentile was used in order to reduce the risk of underestimating the PNEC.

Since a lot of toxicity-data on PFOS is available in the literature, a species sensitivity distribution curve was estabilised and a hazard concentration of 5% calculated according to Posthuma et al. (2001). The 5th-percentile was calculated for the species with more than one E(L)C_{50}-value.

5 Results and discussion

5.1 Sediment samples

5.1.1 TOC and grain size

The most fine-grained sediment was obtained from Adventfjorden (67.8 – 96.3 % <0.063 mm). The sediment from Grønfjorden was coarser (10.8 – 80.9 % <0.063 mm), but not as coarse as the sediment from the reference area in Kongsfjorden (0.90 – 25.5 % < 0.063 mm) (Table 6).

Table 6. Total organic carbon (TOC) and grain size in sediment samples.

Station	TOC (g/kg dw)	% < 0.063 mm	% > 0.063 mm
L1-1	22.1	94.9	5.1
L1-2	19.9	95.5	4.5
L1-3	18.1	93.3	6.7
L2-1	20.6	96.3	3.7
L2-2	20.2	95.9	4.1
L2-3	19.2	96.3	3.7
L3-1	19.0	95.9	4.1
L3-2	20.6	95.9	4.1
L3-3	18.4	94.6	5.4
L4-1	9.2	74.3	25.7
L4-2	11.8	73.1	26.9
L4-3	11.6	67.8	32.2
B1-1	13.0	10.8	89.2
B1-2	11.0	13.9	86.1
B1-3	6.85	16.4	83.6
B2-1	35.2	61.0	39
B2-2	32.4	61.5	38.5
B2-3	29.1	66.3	33.7
B3	25.4	80.9	19.1
B4-1	24.6	45.1	54.9
B4-2	20.9	46.9	53.1
B4-3	28.8	54.5	45.5
B5	21.3	66.7	33.3
REF1	3.35	25.5	74.5
REF2	2.78	12.5	87.5
REF3	2.89	0.90	99.1

The TOC-content varied from 9.2 – 22.1 g/kg dw in sediment from Adventfjorden, with the highest levels in sediment collected in the inner part of the fjord and close to the sewage outlet. In Grønfjorden TOC-content varied between 6.85 – 32.4 g/kg dw, with the highest levels at station B2 (outside a landfill), followed by station B3 and B4 (Table 6).

5.1.2 OPFRs

Ten of 14 analysed OPFRs were detected in sediment. In Adventfjorden ΣOPFR (sum of 14 compounds) varied between 0.04 – 10.5 ng/g dry weight (dw) (Appendix 1). The highest concentrations, and the highest number of compounds, were measured in sediments from station L2, which is located close to the sewage outlet in Adventfjorden. TCPP was the dominant compound in the Adventfjord-samples, with an average concentration of 1.62 ng/g dw. BdPhP and TnBP were only detected outside the airport, and DBPhP was measured at the highest concentration at this site (Figure 4). These substances have been used in hydraulic fluids in aircrafts (Solbu et al. 2011; Sundkvist et al. 2010), which can explain the presence of them outside the airport.

In the samples collected in Grønfjorden ΣOPFR (sum of 14 compounds) varied from 6.46 – 74.0 ng/g dw (Appendix 1). The highest levels were measured in sediment collected at station B2, close to a landfill, followed by station B4 and. Also in Grønfjorden, the dominating compound was TCPP (average 12.9 ng/g dw) B5 (Figure 4). The high concentrations of OPFRs at station B2 could be explained by a sewage outlet that is located close to this station. More contamination at B4 and B5 could be explained by point B2-B5 being located right outside the village, while point B1 is situated a bit south of the settlement.

Significant differences between sites were found (Mann-Whitney U test), with higher concentrations in Adventfjorden for DBPhP ($p<0.001$) and in Grønfjorden for TCEP ($p<0.001$), TCP ($p<0.001$), TCPP ($p=0.001$), TEP ($p=0.001$), TnBP ($p<0.001$), TPP ($p<0.001$) and the ∑OPFR ($p<0.001$).

No OPFRs were detected in sediment from the reference station in Kongsfjorden. This indicates that the settlements Longyearbyen and Barentsburg are local sources for these compounds in Adventfjorden and Grønfjorden, respectively, as long-range transport are expected to be equally important in all three fjords. However, as there were significant positive correlations between levels of TOC and several OPFRs (EHDP, TCEP, TCP, TCPP, TnBP and TPP) it cannot be ruled out that low levels of organic carbon (and coarse sediments) on the reference station (Table 6) could be the reason for low concetrations there. Thus, it cannot be concluded that the contamination in Adventfjorden and Grønfjorden is caused only by local pollution. However, elevated levels and differences in the composition (relative abundance) between sites gives clear indications towards local sources.

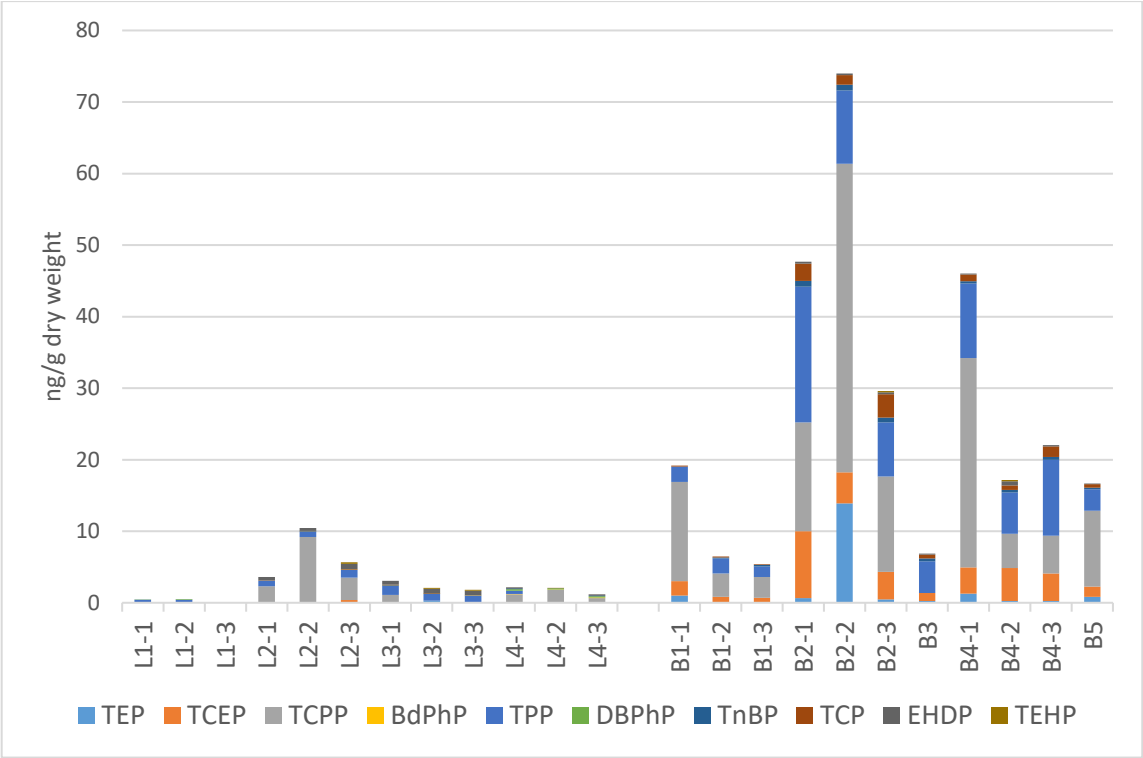

Figure 4. OPFRs in sediment-samples from Adventfjorden (L) and Grønfjorden (B), September 2015. No OFPRs were detected in the reference samples collected in Kongsfjorden.

The OPFR-levels in sediment from Grønfjorden were unexpectedly high, given the limited population in this area. The concentration of the TCPP congener in Grønfjorden varied between <lod – 43.11 ng/g dw. In sediment collected in the marine environment outside wastewater treatment plants at mainland of Norway TCPP-concentrations range between < lod (0.15 ng/g dw) and 54 ng/g dw, with highest concentration found close to Oslo (Leonards et al. 2011). The reason for the relatively high levels measured in Grønfjorden is currently unknown.

5.1.3 PBDEs

Of the analysed PBDEs (23 congeners) only BDE99 could be detected in the sediment samples (Appendix 2). It was detected by the wastewater effluent in Adventfjorden (L2, 26.7-30.8 pg/g dw) and close to the landfills in Grønfjorden (B1: 16.1 - 17.2 pg/g dw, B2: <lod - 22.8 pg/g dw). No PBDEs were detected in sediment from the reference area. There were no significant correlation between grain size or TOC and the concentration of BDE99.

Evenset et al. (2006; 2009) reported BDE99-concentrations of 20.0 pg/g dw and 29.7 pg/g dw in sediment collected close to the previous sewage outlet in the inner part of Adventfjorden in samples 2005 and 2009, respectively. Evenset et al. (2009) also found elevated concentrations of BDE47 and BDE209 in Adventfjorden. It is not unlikely that BDE47 was present also in 2015, but due to high blank values the detection limit was quite high for this compound (35.4 pg/g dw).

Evenset et al. (2006; 2009) also measured PBDE-concentrations in sediment from two stations in Grønfjorden. However, since none of the sampled sites in Grønfjorden from this study overlap with those studied by Evenset et al. (2006; 2009), no direct site-specific comparison can be made. In 2006, the measured concentrations of BDE99 were 20 and 38 pg/g dw, and in 2009 they were 2.84 and 4.03 pg/g dw.

The levels of PBDEs in sediment from Adventfjorden and Grønfjorden are low, and according to the Norwegian classification system (M-608) they are well below the upper level for class II (corresponding to AA-EQS (Annual average – environmental quality standard) in the EU system) which is 62 ng/g dw. Levels below this limit are not expected to cause toxic effects. The low levels and the absence of most congeners indicate that local sources for PBDEs currently are of low importance.

5.1.4 PFAS

Of the analysed PFAS (21 congeners) 9 were detected in sediment: 6:2FTS, PFDcA, PFHpA, PFHxA, PFNA, PFOA, PFOS, PFTeA and PFUnA. Of these PFDcA, PFNA, PFOA and PFUnA were detected at all sites, including the reference site (Figure 5). 6:2FTS was only detected at the reference site. No significant differences in ∑PFAS were found between sampling sites. Sediment from Adventfjorden had significantly higher concentrations of PFHxA ($p<0.000$) and PFNA ($p=0.016$) than sediment from Grønfjorden, while significantly higher concentrations of PFTeA ($p=0.006$) were found in Grønfjorden (Mann-Whitney U test). A significant positive correlation was found between 6:2FTS and PFUnA and grain size, while PFHxA correlated negatively with grain size. Only PFTeA correlated positively with TOC, while significant negative correlations were found for four out of 21 analysed congeners.

In Adventfjorden ∑PFAS varied from 0.06 – 0.45 ng/g dw, in Grønfjorden from 0.08 – 1.00 ng/g dw and at the reference station from 0.16 – 0.45 ng/g dw (Appendix 3). The highest concentration was measured at station B2-1 in Grønfjorden (close to a landfill). PFTeA constituted 93 % of ∑PFAS at this station. PFOS and PFOA are included in in the Norwegian classification system for water, sediment and biota (M-608). The upper limit for class II (good environmental quality) for PFOS (no limit between class I and II given) was only exceeded for one of three samples at station L2 (the L2-3), close to the sewage outlet in Adventfjorden. However, the average for the replicates at this station was 0.19 ng/g dw, corresponding to class II. For PFOA all stations had levels well below the upper limit for class II (71 ng/g dw).

Of the analysed PFAS-congeners, four were detected both close to the settlements and in the reference area; PFDcA, PFNA, PFOA, PFUnA. None of these congeners had significantly higher concentrations close to the settlements, thus it can be assumed that the contamination originated from long-range transport. Four congeners were detected only in Adventfjorden and Grønfjorden; PFHpA, PFHxA, PFOS and PFTeA. Of these PFHpA was only detected in one sample at a concentration close to the level of detection, while the others, such as PFHxA, PFOS and PFTeA, were detected repeatedly throughout the sites, indicating local pollution. Differences in pattern between the two fjords indicate that different chemical mixtures may be used in the Norwegian and the Russian settlement.

Elevated levels of PFOS has previously been measured in soil and water samples collected close to Svalbard Lufthavn (Randolph-Lund 2012; Ahrens et al. 2016). In the present study the highest PFOS-concentration measured outside the airport was 0.15 ng/g dw. This was comparable to or somewhat lower than PFOS-concentrations measured close to the sewage outlet (0.13 – 0.24 ng/g dw), and below the upper limit for class II (0.23 ng/g dw) in sediment (M-608). A lagoon that is situated between the airport and the sea may prevent leakage of PFOS to the fjord, but further investigations are needed to draw firm conclusions. The concentration of PFOS by the sewage outlet is comparable to the concentration measured by Evenset et al. (2009); 0.19 ng/g dw and Evenset et al. (2006); 0.10 ng/g dw in the inner part of Adventfjorden.

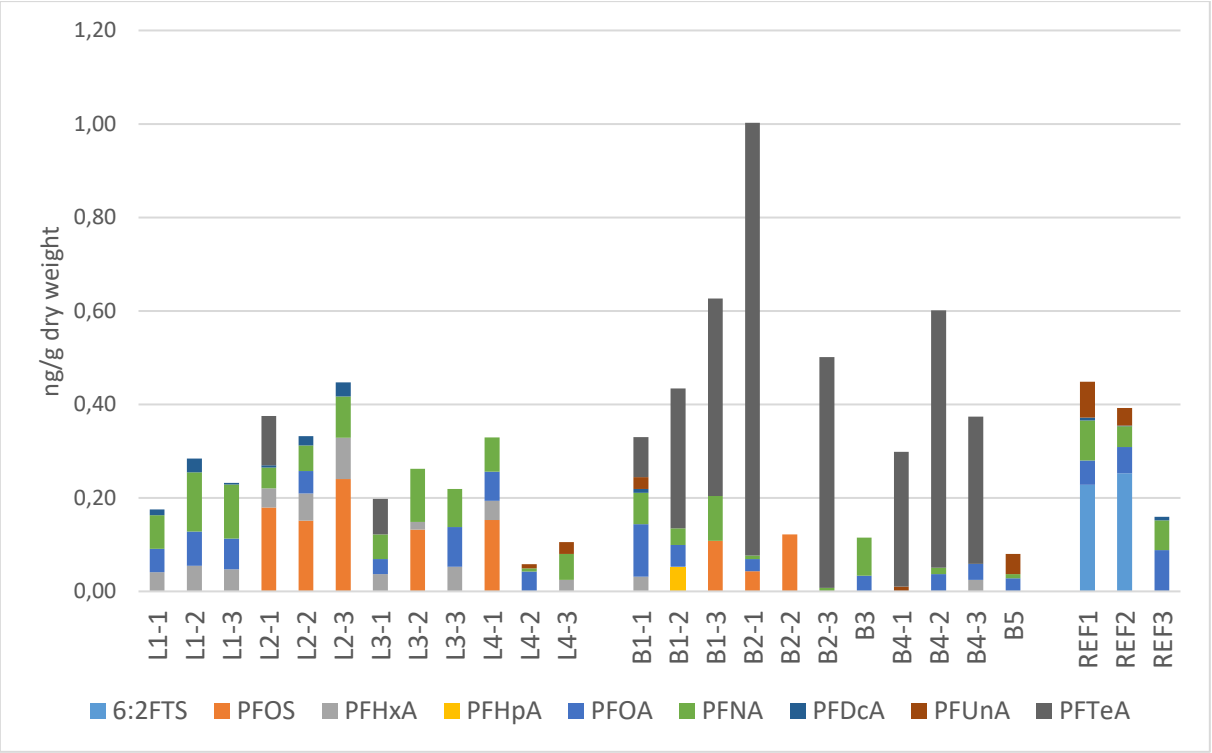

Figure 5. PFAS in sediment-samples from Adventfjorden (L), Grønfjorden (B), and Kongsfjorden (REF), September 2015.

5.1.5 Dioxines/furans

Due to financial limitations, only a few sediment samples were analysed for bisphenol A, phthalates, nonyl- and octyl-phenols and dioxins/furans (Table 7; Appendix 6).

All together 17 PCDDs and PCDFs were analysed in two samples from Adventfjorden (station L2, sewage outlet and station L5, close to settlement) and two samples from Grønfjorden (station B2, close to a landfill, and station B6, close to the sewage outlet). No PCDDs or PCDFs could be detected in any of the samples (Table 7). Thus, there are no indications of any significant local sources for dioxins/furans in Longyearbyen or Barentsburg.

To our knowledge no comprehensive studies of dioxins/furans in sediment samples from Svalbard has been published before. Evenset (2002) analyzed sediment samples from two stations in the Adventfjord for dioxins to assess whether emissions from the energy industry had led to measurable contamination. The conclusion from the survey was that there were low levels of dioxins in sediment from Adventfjorden. Levels were comparable to those measured in open sea areas in the Barents Sea. The results from Evenset (2002) are thus supported by the results from the present study.

Table 7. PCDDs, PCDFs, Bisphenol A, phthalates, nonylphenols, and octylphenols in sediment samples from Adventfjorden and Grønfjorden, September 2016.

Element	Unit	B2	B6	L1	L5
Dry matter (G)	%	56	59	57.5	60.7
Bisphenol A	mg/kg TS	<0.020	<0.020	<0.020	<0.020
Dry matter (E)	%	57.8	57.5	55.5	65.6
Dimethylphthalate (DMP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Diethylphthalate (DEP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-n-prophylphthalate (DPrP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-n-buthylphthalate (DBP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-isobuthylphthalate (DIBP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-pentylphthalate (DPP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-n-okthylphthalate (DNOP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-(2-etylheksyl)phthalate (DEHP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Buthylbesylphthalate (BBP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
Di-syklohexsylphthalate (DCHP)	mg/kg TS	<0.80	<0.80	<0.80	<0.80
4-n-Nonylphenol	mg/kg TS	<0.0020	<0.0020	<0.0020	<0.0020
4-iso-Nonylphenol	mg/kg TS	<0.020	<0.020	<0.020	<0.020
4-t-Okthylphenol	mg/kg TS	<0.0020	<0.0020	<0.0020	<0.0020
2,3,7,8-TetraCDD	ng/kg TS	<1.6		<1.2	
1,2,3,7,8-PentaCDD	ng/kg TS	<1.8		<1.9	
1,2,3,4,7,8-HexaCDD	ng/kg TS	<5.4		<4.9	
1,2,3,6,7,8-HexaCDD	ng/kg TS	<5.4		<4.9	
1,2,3,7,8,9-HexaCDD	ng/kg TS	<5.4		<4.9	
1,2,3,4,6,7,8-HeptaCDD	ng/kg TS	<6.7		<9.5	
Oktachlorodibenzodioxin	ng/kg TS	<15		<13	
2,3,7,8-TetraCDF	ng/kg TS	<1.1		<1.3	
1,2,3,7,8-PentaCDF	ng/kg TS	<1.5		<1.4	
2,3,4,7,8-PentaCDF	ng/kg TS	<1.5		<1.4	
1,2,3,4,7,8-HexaCDF	ng/kg TS	<2.8		<3.8	
1,2,3,6,7,8-HexaCDF	ng/kg TS	<2.8		<3.8	
1,2,3,7,8,9-HexaCDF	ng/kg TS	<2.8		<3.8	
2,3,4,6,7,8-HexaCDF	ng/kg TS	<2.8		<3.8	
1,2,3,4,6,7,8-HeptaCDF	ng/kg TS	<3.7		<4.2	
1,2,3,4,7,8,9-HeptaCDF	ng/kg TS	<3.7		<4.2	
Octachlordibenzofurane	ng/kg TS	<16		<20	

5.1.6 Bisphenol A

Bisphenol A was not detected in any of the sediment samples (Table 7).

5.1.7 Phtalates

No phthalates were detected in any of the sediment samples (Table 7). Unfortunately, the applied lod was rather high.

5.1.8 Nonyl- and octyl-phenols

Neither nonyl- nor octyl-phenols were detected in any of the sediment samples (Table 7).

5.1 Risk assessment based on sediment concentrations

The risk analyses only included the compound groups that occurred in measurable concentrations in the sediment samples (OPFRs, PFAS, PBDEs).

5.1.1 OPFRs

The toxic unit for OPFRs in Adventfjorden is 7.93×10^{-05} and 5.33×10^{-04} in Grønfjorden (Table 8). Thus, the TU is well below 1 for both fjords, indicating low risk to most of the sediment-living organisms. However, it cannot be ruled out that sensitive species are affected or that sub-lethal effects may occur. Few data are available for Arctic species. It is therefore possible that the risk is different for Arctic species, than for species inhabiting temperate regions. Available toxicity data are mainly from species from temperate regions.

Even though the risk analysis gives TUs < 1, the concentration of some of the congeners is not negligible according to Verbruggen et al. (2006). Verbruggen et al. (2006) developed environmental risk limits for nine OPFRs in sediment. Serious risk concentrations are presented for all examined substances, but negligible concentrations and maximum permissible concentrations are not available for TCEP, TCPP and TDCPP. TCPP and TCEP were among the congeners with the highest concentration in the present study. According to Verbruggen et al. (2006) the measured concentrations of TCPP and TCEP in the present study are well below the serious risk concentration (230 and 74 ng/g dw, respectively). Some of the measured TPP-concentrations are, according to Verbruggen et al. (2006), above the negligible concentration (0.95 ng/g dw), but below the serious risk concentration (35 ng/g dw). Also, some of the measured TCP-concentrations are above the negligible concentration (0.090 ng/g dw), but below the serious risk concentration (8.6 ng/g dw).

Table 8. Toxic units (TU) for OPFR compounds.

Congener	TU Adventfjorden	TU Grønfjorden
EHDP	5.22×10^{-07}	2.69×10^{-07}
TBEP	6.27×10^{-06}	7.71×10^{-06}
TCEP	4.93×10^{-06}	4.15×10^{-05}
TCP	2.90×10^{-11}	4.95×10^{-10}
TCPP	2.06×10^{-05}	8.77×10^{-05}
TDCPP	1.41×10^{-06}	1.74×10^{-06}
TEHP	2.02×10^{-11}	2.25×10^{-11}
TEP	7.39×10^{-06}	9.70×10^{-05}
TiBP	3.66×10^{-08}	4.50×10^{-08}
TPP	3.81×10^{-05}	2.97×10^{-04}
∑TU	7.93×10^{-05}	5.33×10^{-04}

5.1.2 PBDEs

Since only BDE99 was detected in the sediment, the risk analyses is quite simple for this compound group. The TU for BDE99 was 7.79×10^{-09} for Adventfjorden and 1.10×10^{-08} for Grønfjorden, i.e. far below 1 for both fjords. In a risk assessment performed by the European Union a PNECsediment 0.31 mg/kg dw and $PNEC_{OC}$-normalised sediment 1.55 mg/kg dw for PBDEs has been calculated (European Union, 2001). The concentrations measured in the fjords on Svalbard are much lower than this, even if BDE 47 is assumed to occur (adding the detection limit to the sum).

5.1.3 PFAS

The TUs for PFAS (with data available) calculated by using K_d and K_{OC} is 1.35×10^{-09} and 225, respectively, for Adventfjorden, and 7.84×10^{-10} and 153, respectively, for Grønfjorden (Table 9). The congener with the highest TU in both fjords is PFOS.

When TUs are calculated using K_d the risk for the ecosystem is assessed to be low, both in Adventfjorden and Grønfjorden. However, if the calculations are made using K_{OC} the risk for negative effects is high. PFOS is the compound that causes the highest risk.

PFTeA could not be included in the risk analysis since data on partitioning or toxicity for this compound is not available in the literature. However, it was the compound with the highest measured concentration, it is therefore possible that this compound might have a negative effect, but more research is needed in order to conclude.

The high toxic unit from the K_{OC}-method is solely dependent of the partitioning of PFOS between sediment and water. It is possible that the K_{OC}-values used to calculate the TU is causing an overestimation of the risk of PFOS while the K_d-method may underestimate the risk.

Both a species sensitivity distribution (SSD) and a distribution with initial, not transformed, values of EC- or LC_{50} were used to obtain the 5th-percentile and to calculate the TU for PFOS. The SSD gives a higher potential risk than the distribution with initial values, which is a result of the SSD giving a lower PNEC than the distribution with initial values. If enough data is available it is more accurate to use the SSD than the distribution with initial values to get the 5th-percentile, since the SSD is giving more attention to the sensitive organisms while the distribution with initial values classify all organisms equal. The toxic unit for the other

investigated compounds are similar for K_{OC} and K_d, and both methods should therefore be appropriate to use.

Table 9. Toxic units for each and the sum of some of the included PFAS, calculated using K_d and K_{OC}.

Congener	TU Adventfjorden	TU Grønfjorden
K_d		
PFOS[a,b]	1.22×10^{-09}	6.77×10^{-10}
PFHxA	8.11×10^{-11}	3.18×10^{-11}
PFOA	9.44×10^{-11}	9.59×10^{-11}
PFNA	1.91×10^{-12}	1.40×10^{-12}
∑TU	1.35×10^{-09}	7.84×10^{-10}
K_{OC}		
PFOS[a,c]	232.43	158.75
PFHxA	9.72×10^{-08}	3.51×10^{-08}
PFOA	1.33×10^{-06}	1.55×10^{-06}
PFNA	2.26×10^{-08}	3.03×10^{-08}
∑TU	225	153

[a]TU calculated using HC_5 from SSD.
[b]$TU_{Adventfjorden}$ 1.92 x 10-10 and $TU_{Grønfjorden}$ 1.07 x 10-10 if 95th-percentile from exponential distribution used.
[c]$TU_{Adventfjorden}$ 36.60 and $TU_{Grønfjorden}$ 24.00 if 95th-percentile from exponential distribution used.

5.2 Biota samples

OPFRs have previously been reported to occur in zooplankton, fish, birds and mammals (Kim et al. 2011: Sundkvist et al. 2010; Brandsma et al. 2015). Little information about their potential to biomagnify is available, but it seems as if PFRs do not biomagnify to any extent to mammals or birds (Hallanger et al. 2015). In the present study the focus was therefore on invertabrates (crabs) and fish.

5.2.1 OPFRs

Only 4 out of 17 analysed OPFRs could be detected in biota samples. TPP was detected in 7 samples, TCPP in 4 samples, TCEP in 3 samples and EHDP in only one sample (Table 10; Appendix 4). Since different species were caught at the different stations direct comparisons were difficult. No OPFRs were detected in any of the samples caught in the inner part of Adventfjorden (Biota A1). TCPP was detected in one and TPP in two cod samples from the sewage outlet area (Biota A2).

In Grønfjorden TPP was detected in shorthorn sculpins caught close to the landfills (Biota G1). The highest detection frequency for OPFRs occurred in the samples collected close to the sewage outlet in Grønfjorden (Biota G2). In this area TCEP, TCPP, TPP and EHDP were detected in shorthorn sculpins, and TCEP and TCPP in one spider crab sample (Table 10). A higher accumulation in sculpins that in cod is in line with previous studies that has shown a higher accumulation in demersal fish than in more pelagic fish (Kim et al. 2011; Sundkvist et al. 2010).

Despite the high levels of OPFRs measured in sediment from Grønfjorden the levels in biota were low. These results are comparable to results from other recent studies that indicate that OPFRs either have a low bioaccumulation potential or are metabolized and excreted rapidly. Elevated levels in organisms caught close to the sewage outlet compared to organisms caught in other areas could indicate that sewage is a local source for the OPFRs measured in sediments, but further studies are required to confirm this.

The results from the risk analyses for sediment-living organisms concluded that the OPFRs pose a low risk in Adventfjorden and Grønfjorden. The results from analyses of biota seems to confirm this, although a continuous exposure combined with rapid metabolism could be a combination that pose a higher risk than can be captured by body concentrations alone.

Table 10. OPFRs (ng/g wet weight) measured in biota samples collected in Adventfjorden (A) and Grønfjorden (G). For station positions see Figure 3 . TEP, TPrP, BdPhP, DBPhP, TiBP, TnBP, TDCPP, TBEP, TCP; TXP, TIPPP, TTBPP and TEHP could not be detected in any of the biota samples. Detection limit for these compunds ranged from 0.01 – 0.60 ng/g wet weight.

Station	Species	n	TCEP	TCPP	TPP	EHDP
Biota A1-1	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD
Biota A1-2	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD
Biota A1-3	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD
Biota A1-4	Cod	5	<LOD	<LOD	<LOD	<LOD
Biota A1-5	Cod	5	<LOD	<LOD	<LOD	<LOD
Biota A2-1	Cod	4	<LOD	0.31	0.20	<LOD
Biota A2-2	Cod	4	<LOD	<LOD	0.22	<LOD
Biota A2-3	Cod	4	<LOD	<LOD	<LOD	<LOD
Biota G1-1	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD
Biota G1-2	Shorthorn sculpin	5	<LOD	<LOD	0.14	<LOD
Biota G1-3	Shorthorn sculpin	5	<LOD	<LOD	0.19	<LOD
Biota G1-4	Spider crab	4	<LOD	<LOD	<LOD	<LOD
Biota G1-5	Spider crab	4	<LOD	<LOD	<LOD	<LOD
Biota G2-1	Shorthorn sculpin	3	<LOD	0.33	0.18	1.10
Biota G2-2	Shorthorn sculpin	4	0.13	0.44	0.44	<LOD
Biota G2-3	Cod	5	<LOD	<LOD	0.13	<LOD
Biota G2-4	Cod	5	<LOD	<LOD	<LOD	<LOD
Biota G2-5	Cod	5	0.14	<LOD	<LOD	<LOD
Biota G2-6	Spider crab	2	0.10	0.34	<LOD	<LOD
Biota G2-7	Spider crab	3	<LOD	<LOD	<LOD	<LOD

Figure 6. Shorthorn sculpin (Myoxocephalus scorpius). Photo: Guttorm N. Christensen, Akvaplan-niva.

5.2.2 PFAS

Despite much lower sediment levels than for OPFRs, elevated levels of PFAS were mesured in organisms. Eight PFAS-compounds were detected in the biota samples (Table 11; Appendix 5). One area differed from the others, both with regard to detection frequency and levels of PFAS, namely the inner part of Adventfjorden (Biota A1). In shorthorn sculpin from this area PFOS, PFOSA, PFNA, PFUnDA and PFTrDA (only in one sample) were detected, and ∑PFAS ranged from 1.74 – 5.02 ng/g ww. In Atlantic cod caught in the same area PFOS, PFOSA, PFNA and PFUnDA were detected and ∑PFAS ranged from 0.29 – 0.63 ng/g ww. PFOSA was the dominating compound in both species, followed by PFOS and PFNA.

In the cod samples obtained close to the sewage outlet PFAS-levels were generally low, i.e. from 0.06 – 0.27 ng/g ww, and only PFOS, PFOA and PFUnA were detected.

In scorthorn sculpin from Biota G2 (landfill) ∑PFAS ranged from 0.16 – 0.51 ng/g ww, and the following compounds occurred in measurable concentrations: PFHpS, PFOS, PFUnA and PFTrA. In spider crabs from the same area, only PFDA and PFUnA were detected, but levels were low. PFOS was the only PFAS-compound that was detected in shorthorn sculpins from the area close to the sewage outlet in Grønfjorden (Biota G1). Cod from the same area had measurable levels of PFOS, PFOA and PFUnA, while PFOA, PFDA and PFUnA were detected in spider crabs (Table 11)

Even though sediment-levels of PFAS generally were somehat higher in Grønfjorden than in Adventfjorden, the levels in organisms were lower. The reason for this could be that the dominant compounds in Grønfjorden are less bioaccumulative and/or more easily metabolized than those dominating in Adventfjorden. PFTeA, which was the dominating compound in sediment from Grønfjorden, was not detected in any of the biota samples.

Table 11. PFAS (ng/g wet weight) measured in biota samples collected in Adventfjorden (A) and Grønfjorden (G). For station positions see Figure 3. The following compounds were not detected in any of the biota samples: 4:2 FTS, 6:2 FTS, 8:2 FTS, PFBS, PFHxS, PFNS, PFDcS, PFHxA, PFHpA, PFDoA, PFTeDa. Detection limit for these compounds ranged from 0.05 – 0.10 ng/g wet weight.

Station	Species	n	PFHpS	PFOSlin	PFOS	PFOSA	PFOA	PFNA	PFDA	PFUnA	PFTrA
Biota A1-1	Shorthorn sculpin	5	<0.05	0.583	0.683	0.808	<0.05	0.198	<0.05	0.050	<0.10
Biota A1-2	Shorthorn sculpin	5	<0.05	1.362	1.589	2.632	<0.05	0.520	<0.05	0.175	0.103
Biota A1-3	Shorthorn sculpin	5	<0.05	0.706	0.877	1.257	<0.05	0.253	<0.05	0.102	<0.10
Biota A1-4	Cod	5	<0.05	0.149	0.149	0.367	<0.05	0.058	<0.05	0.058	<0.10
Biota A1-5	Cod	5	0.053	<0.10	<0.10	0.113	<0.05	0.052	<0.05	0.073	<0.10
Biota A2-1	Cod	4	<0.05	0.112	0.112	<0.10	0.080	<0.05	<0.05	0.080	<0.10
Biota A2-2	Cod	4	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.064	<0.10
Biota A2-3	Cod	4	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.072	<0.10
Biota G1-1	Shorthorn sculpin	5	0.067	0.108	0.202	<0.10	<0.05	<0.05	<0.05	0.170	<0.10
Biota G1-2	Shorthorn sculpin	5	<0.05	0.094	0.094	<0.10	<0.05	<0.05	<0.05	0.070	<0.10
Biota G1-3	Shorthorn sculpin	5	<0.05	0.177	0.277	<0.10	<0.05	<0.05	<0.05	0.113	0.129
Biota G1-4	Spider crab	4	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	0.056	0.155	<0.10
Biota G1-5	Spider crab	4	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.086	<0.10
Biota G2-1	Shorthorn sculpin	3	<0.05	0.101	0.101	<0.10	<0.05	<0.05	<0.05	<0.05	<0.10
Biota G2-2	Shorthorn sculpin	4	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.10
Biota G2-3	Cod	5	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.070	<0.10
Biota G2-4	Cod	5	<0.05	0.123	0.123	<0.10	0.059	<0.05	<0.05	0.109	<0.10
Biota G2-5	Cod	5	<0.05	0.100	0.100	<0.10	<0.05	<0.05	<0.05	0.129	<0.10
Biota G2-6	Spider crab	2	<0.05	<0.10	<0.10	<0.10	<0.05	<0.05	0.050	0.188	<0.10
Biota G2-7	Spider crab	3	<0.05	<0.10	<0.10	<0.10	0.22	<0.05	<0.05	0.085	<0.10

6 Overall conclusion

The results from this study show that the settlements Longyearbyen and Barentsburg represent local sources for OPFR and PFAS. The levels in sediments and organisms are not very high and the results of a risk analysis indicate that the risk for sediment-living organisms is low, with a possible exception for PFOS. However, it is important to be aware that the sedimentation rate in the fjords examined is high due to the large supply of inorganic material from rivers (and glaciers) (see Evenset et al. 2017). A high sedimentation can camouflage environmental pollutants, and it is likely that the levels would be higher if the sedimentation rate had been lower.

Further studies are needed to reveal the source for OPFRs in Grønfjorden. In addition, more detailed studies around Svalbard lufthavn should be carried out to assess potential spreading of PFAS to Adventfjorden.

7 References

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8 Appendix 1 – Analytical results OPFRs in sediment (ng/g dw)

Sample	TEP	TCEP	TPrP	TCPP	TiBP	BdPhP	TPP	DBPhP	TnBP	TDCPP	TBEP	TCP	EHDP	TEHP	Sum
Ref1	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	< 0.4	< 0.01	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0
Ref2	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	< 0.4	< 0.01	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0
Ref3	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	< 0.4	< 0.01	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0
L1-1	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	0,42	0,06	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0,49
L1-2	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	0,43	0,07	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0,51
L1-3	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	< 0.4	0,04	< 0.12	< 0.3	< 5.7	< 0.01	< 0.05	< 0.11	0,04
L2-1	< 0.2	< 0.3	< 0.02	2,30	< 0.08	< 0.01	0,76	< 0.01	< 0.12	< 0.3	< 5.7	0,05	0,49	< 0.11	3,60
L2-2	< 0.2	< 0.3	< 0.02	9,20	< 0.08	< 0.01	0,78	0,03	< 0.12	< 0.3	< 5.7	0,05	0,39	< 0.11	10,45
L2-3	< 0.2	0,37	< 0.02	3,17	< 0.08	< 0.01	1,07	0,03	< 0.12	< 0.3	< 5.7	0,07	0,75	0,22	5,68
L3-1	< 0.2	< 0.3	< 0.02	1,11	< 0.08	< 0.01	1,32	0,03	< 0.12	< 0.3	< 5.7	0,07	0,56	< 0.11	3,09
L3-2	0,28	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	0,94	0,04	< 0.12	< 0.3	< 5.7	0,07	0,62	0,15	2,08
L3-3	< 0.2	< 0.3	< 0.02	< 0.5	< 0.08	< 0.01	0,97	0,04	< 0.12	< 0.3	< 5.7	0,07	0,61	0,13	1,81
L4-1	< 0.2	< 0.3	< 0.02	1,17	< 0.08	0,07	0,45	0,20	0,14	< 0.3	< 5.7	0,05	0,07	< 0.11	2,15
L4-2	< 0.2	< 0.3	< 0.02	1,79	< 0.08	0,07	< 0.4	0,19	< 0.12	< 0.3	< 5.7	0,03	< 0.05	< 0.11	2,09
L4-3	< 0.2	< 0.3	< 0.02	0,67	< 0.08	0,06	< 0.4	0,17	0,13	< 0.3	< 5.7	0,07	0,09	< 0.11	1,19
B1-1	0,25	1,12	< 0.02	< 0.5	< 0.08	< 0.01	4,45	< 0.01	0,38	< 0.3	< 5.7	0,54	0,12	< 0.11	6,86
B1-2	0,84	1,43	< 0.02	10,58	< 0.08	< 0.01	3,00	< 0.01	0,24	< 0.3	< 5.7	0,51	0,07	< 0.11	16,66
B1-3	1,00	2,04	< 0.02	13,86	< 0.08	< 0.01	2,14	< 0.01	< 0.12	< 0.3	< 5.7	0,14	< 0.05	< 0.11	19,17
B2-1	< 0.2	0,85	< 0.02	3,25	< 0.08	< 0.01	2,08	< 0.01	0,14	< 0.3	< 5.7	0,14	< 0.05	< 0.11	6,46
B2-2	< 0.2	0,68	< 0.02	2,91	< 0.08	< 0.01	1,47	< 0.01	0,23	< 0.3	< 5.7	0,11	< 0.05	< 0.11	5,41
B2-3	0,65	9,38	< 0.02	15,20	< 0.08	< 0.01	18,95	< 0.01	0,83	< 0.3	< 5.7	2,39	0,31	< 0.11	47,70
B3	13,88	4,35	< 0.02	43,11	< 0.08	< 0.01	10,28	< 0.01	0,76	< 0.3	< 5.7	1,38	0,23	< 0.11	74,00
B4-1	0,49	3,81	< 0.02	13,36	< 0.08	< 0.01	7,55	< 0.01	0,66	< 0.3	< 5.7	3,27	0,26	0,19	29,61
B4-2	1,26	3,68	< 0.02	29,25	< 0.08	< 0.01	10,45	< 0.01	0,30	< 0.3	< 5.7	0,93	0,15	< 0.11	46,02
B4-3	0,24	4,61	< 0.02	4,77	< 0.08	< 0.01	5,81	< 0.01	0,32	< 0.3	< 5.7	0,66	0,58	0,16	17,16
B5	0,25	3,86	< 0.02	5,25	< 0.08	< 0.01	10,62	< 0.01	0,40	< 0.3	< 5.7	1,50	0,17	< 0.11	22,04

9 Appendix 2 – Analytical results PBDEs in sediment (pg/g dw)

	REF1	REF2	L1-1	L1-3	L2-1	L2-3	B1-1	B1-3	B2-1	B2-3
PBDE 17	<3.4	<3.1	<3	<3.1	<3.1	<3.2	<3.2	<3.1	<3.4	<3.2
PBDE 28	<3.4	<3.1	<3	<3.1	<3.1	<3.2	<3.2	<3.1	<3.4	<3.2
PBDE 49	<3	<2.8	<2.7	<2.8	<2.8	<2.9	<2.9	<2.8	<3	<2.9
PBDE 71	<3.3	<3	<3	<3.1	<3.1	<3.2	<3.2	<3	<3.4	<3.2
PBDE 47	<35.4	<35.4	<35.4	<35.4	<35.4	<35.4	<35.4	<35.4	<35.4	<35.4
PBDE 66	<3.1	<2.9	<2.8	<2.9	<2.9	<3	<3	<2.9	<3.2	<3
PBDE 77	<1.6	<1.4	<1.4	<1.5	<1.5	<1.5	<1.5	<1.4	<1.6	<1.5
PBDE 100	<10.3	<9.4	<9.3	<9.5	<9.6	<9.9	<9.8	<9.4	<10.4	<9.8
PBDE 119	<7.6	<7	<6.9	<7.1	<7.2	<7.3	<7.2	<7	<7.7	<7.2
PBDE 99	<8.3	<7.6	7.9 (<LOQ)	<7.7	26.7	30.8	17.2 (<LOQ)	16.1 (<LOQ)	<8.4	22.8 (<LOQ)
PBDE 85	<8.9	<8.2	<8.1	<8.3	<8.4	<8.6	<8.5	<8.2	<9	<8.5
PBDE 126	<5.6	<5.1	<5	<5.2	<5.2	<5.4	<5.3	<5.1	<5.6	<5.3
PBDE 154	<3.7	<3.4	<3.3	<3.4	<3.4	<3.5	<3.5	<3.4	<3.7	<3.5
PBDE 153	<3.7	<3.4	<3.4	<3.5	<3.5	<3.6	<3.6	<3.4	<3.8	<3.6
PBDE 138	<4.6	<4.2	<4.2	<4.3	<4.4	<4.5	<4.4	<4.2	<4.7	<4.4
PBDE 156	<4.7	<4.3	<4.3	<4.4	<4.4	<4.5	<4.5	<4.3	<4.8	<4.5
PBDE 184	<10.6	<9.7	<9.6	<9.8	<9.9	<10.2	<10.1	<9.7	<10.7	<10.1
PBDE 183	<11.1	<10.1	<10	<10.2	<10.4	<10.6	<10.5	<10.1	<11.2	<10.5
PBDE 191	<10.6	<9.7	<9.6	<9.8	<9.9	<10.2	<10.1	<9.7	<10.7	<10.1
PBDE 196	<8.3	<7.6	<7.5	<7.7	<7.8	<8	<7.9	<7.6	<8.4	<7.9
PBDE 197	<9.8	<8.9	<8.8	<9	<9.1	<9.4	<9.3	<8.9	<9.9	<9.3
PBDE 207	<21.7	<19.9	<19.6	<20.2	<20.4	<20.9	<20.6	<19.9	<22	<20.6
PBDE 206	<47.9	<43.8	<43.3	<44.4	<44.9	<46	<45.5	<43.8	<48.4	<45.5

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10 Appendix 3 – Analytical results PFAS in sediment (ng/g dw)

	6:2FTS	PFOSA	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum
Ref1	0,23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,05	0,09	0,01	0,08	<LOD	<LOD	<LOD	0,45
Ref2	0,25	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,06	0,04	0,001	0,04	<LOD	<LOD	<LOD	0,39
Ref3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,09	0,06	0,01	<LOD	<LOD	<LOD	<LOD	0,16
L1-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,04	<LOD	0,05	0,07	0,01	<LOD	<LOD	<LOD	<LOD	0,18
L1-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,06	<LOD	0,07	0,13	0,03	<LOD	<LOD	<LOD	<LOD	0,28
L1-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,05	<LOD	0,07	0,12	0,004	<LOD	<LOD	<LOD	<LOD	0,23
L2-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,18	<LOD	<LOD	<LOD	<LOD	0,04	<LOD	<LOD	0,04	0,004	<LOD	<LOD	<LOD	0,11	0,37
L2-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,15	<LOD	<LOD	<LOD	<LOD	0,06	<LOD	0,05	0,05	0,02	<LOD	<LOD	<LOD	<LOD	0,33
L2-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,24	<LOD	<LOD	<LOD	<LOD	0,09	<LOD	<LOD	0,09	0,03	<LOD	<LOD	<LOD	<LOD	0,45
L3-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,04	<LOD	0,03	0,05	<LOD	<LOD	<LOD	<LOD	0,08	0,20
L3-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,13	<LOD	<LOD	<LOD	<LOD	0,02	<LOD	<LOD	0,11	<LOD	<LOD	<LOD	<LOD	<LOD	0,26
L3-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,05	<LOD	0,09	0,08	<LOD	<LOD	<LOD	<LOD	<LOD	0,22
L4-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,15	<LOD	<LOD	<LOD	<LOD	0,04	<LOD	0,06	0,07	<LOD	<LOD	<LOD	<LOD	<LOD	0,33
L4-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,04	0,01	<LOD	0,01	<LOD	<LOD	<LOD	0,06
L4-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,02	<LOD	<LOD	0,06	<LOD	0,03	<LOD	<LOD	<LOD	0,11
B1-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,03	0,08	<LOD	<LOD	<LOD	<LOD	<LOD	0,12
B1-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,03	0,01	<LOD	0,04	<LOD	<LOD	<LOD	0,08
B1-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,03	<LOD	0,11	0,07	0,01	0,03	<LOD	<LOD	0,09	0,33
B2-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,05	0,05	0,04	<LOD	<LOD	<LOD	<LOD	0,30	0,43
B2-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,10	<LOD	<LOD	<LOD	<LOD	0,42	0,63
B2-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,03	0,01	<LOD	<LOD	<LOD	<LOD	0,93	1,00
B3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,12	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,12
B4-1	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,01	<LOD	<LOD	<LOD	<LOD	0,49	0,50
B4-2	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,01	<LOD	<LOD	0,29	0,30
B4-3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,04	0,01	<LOD	<LOD	<LOD	<LOD	0,55	0,60
B5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,02	<LOD	0,03	<LOD	<LOD	<LOD	<LOD	<LOD	0,31	0,37

11 Appendix 4 – Analytical results OPFRs in biota (ng/g ww)

	Species	n	TEP	TCEP	TPrP	TCPP	BdPhP	DBPhP	TiBP	TnBP	TPP	TDCPP	TBEP	TCP	EHDP	TXP	TIPPP	TTBPP	TEHP
Biota A1-1	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A1-2	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A1-3	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A1-4	Cod	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A1-5	Cod	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A2-1	Cod	4	<LOD	<LOD	<LOD	0,31	<LOD	<LOD	<LOD	<LOD	0,20	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A2-2	Cod	4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,22	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota A2-3	Cod	4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G1-1	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G1-2	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,14	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G1-3	Shorthorn sculpin	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,19	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G1-4	Spider crab	4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G1-5	Spider crab	4	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-1	Shorthorn sculpin	3	<LOD	<LOD	<LOD	0,33	<LOD	<LOD	<LOD	<LOD	0,18	<LOD	<LOD	<LOD	1,1	<LOD	<LOD	<LOD	<LOD
Biota G2-2	Shorthorn sculpin	4	<LOD	0,13	<LOD	0,44	<LOD	<LOD	<LOD	<LOD	0,44	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-3	Cod	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0,13	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-4	Cod	5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-5	Cod	5	<LOD	0,14	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-6	Spider crab	2	<LOD	0,10	<LOD	0,34	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Biota G2-7	Spider crab	3	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
LOD			0,02	0,0	0,0	0,25	0,0	0,0	0,60	0,2	0,1	0,10	0,2	0,0	0,60	0,0	0,0	0,02	0,5
LOQ			0,04	0,1	0,0	0,50	0,0	0,0	1,40	0,3	0,2	0,20	0,4	0,0	1,60	0,1	0,0	0,04	1,3

12 Appendix 5 – Analytical results PFAS in biota (ng/g ww)

Station	Species	n	4:2 FTS	6:2 FTS	8:2 FTS	PFBS	PFHxS*	PFHpS	PFNS	PFDcS	PFOS	PFOSA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFDoDA	PFUnA	PFTrA	PFTeDA
Biota A1-1	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.683	0.808	<0.10	<0.05	<0.05	0.198	<0.05	<0.05	0.050	<0.10	<0.10
Biota A1-2	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	1.589	2.632	<0.10	<0.05	<0.05	0.520	<0.05	<0.05	0.175	0.103	<0.10
Biota A1-3	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.877	1.257	<0.10	<0.05	<0.05	0.253	<0.05	<0.05	0.102	<0.10	<0.10
Biota A1-4	Cod	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.149	0.367	<0.10	<0.05	<0.05	0.058	<0.05	<0.05	0.058	<0.10	<0.10
Biota A1-5	Cod	5	<0.10	<0.10	<0.10	<0.05	<0.05	0.053	<0.10	<0.10	<0.10	0.113	<0.10	<0.05	<0.05	0.052	<0.05	<0.05	0.073	<0.10	<0.10
Biota A2-1	Cod	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.112	<0.10	<0.10	<0.05	0.080	<0.05	<0.05	<0.05	0.080	<0.10	<0.10
Biota A2-2	Cod	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.064	<0.10	<0.10
Biota A2-3	Cod	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.072	<0.10	<0.10
Biota G1-1	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	0.067	<0.10	<0.10	0.202	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.170	<0.10	<0.10
Biota G1-2	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.094	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.070	<0.10	<0.10
Biota G1-3	Shorthorn sculpin	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.277	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.113	0.129	<0.10
Biota G1-4	Spider crab	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.056	<0.05	0.155	<0.10	<0.10
Biota G1-5	Spider crab	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.086	<0.10	<0.10
Biota G2-1	Shorthorn sculpin	3	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.101	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<0.10
Biota G2-2	Shorthorn sculpin	4	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.10	<0.10
Biota G2-3	Cod	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.070	<0.10	<0.10
Biota G2-4	Cod	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.123	<0.10	<0.10	<0.05	0.059	<0.05	<0.05	<0.05	0.109	<0.10	<0.10
Biota G2-5	Cod	5	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	0.100	<0.10	<0.10	<0.05	<0.05	<0.05	<0.05	<0.05	0.129	<0.10	<0.10
Biota G2-6	Spider crab	2	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	0.050	<0.05	0.188	<0.10	<0.10
Biota G2-7	Spider crab	3	<0.10	<0.10	<0.10	<0.05	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.10	<0.05	0.22	<0.05	<0.05	<0.05	0.085	<0.10	<0.10

13 Appendix 6 - Analytical sertificates from Akvaplan-niva and ALS Laboratory Group

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NORSK AKKREDITERING TEST 061

ANALYSERAPPORT
Sedimentprøver

Kunde: Intern

Kunde referanse: 7874 Nye miljøgifter ved bosettinger på Svalbard

Kontaktperson: Anita Evenset

Adresse: Framsenteret

Postnr./sted:

Tel:

E-post:

Dato: 15.03.2016

Rapport nr.: **7874**
Analyseparameter(e): Splitt-i-to, TOC
Kontaktperson: Ingar H. Wasbotten

Analyseansvarlig: Lisa Todde (sign.)

Underskriftsberettiget: Marita A. Gaski (sign.)

Prøveoversikt finnes på side 2

Prøve id. Lab	Kundens id.	Matrix	Prøvens beskaffenhet ved mottak	Mottatt Lab	Analyseperiode
7874/1	B11	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/2	B12	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/3	B13	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/4	B21	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/5	B22	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/6	B23	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/7	B3	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/8	B41	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/9	B42	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/10	B43	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/11	B5	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/12	L11	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/13	L12	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/14	L13	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/15	L21	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/16	L22	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/17	L23	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/18	L31	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/19	L32	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/20	L33	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/21	L41	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/22	L42	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/23	L43	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/24	REF1	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/25	REF2	sediment	tint	18.02.16	22.02. - 11.03.2016
7874/26	REF3	sediment	tint	18.02.16	22.02. - 11.03.2016

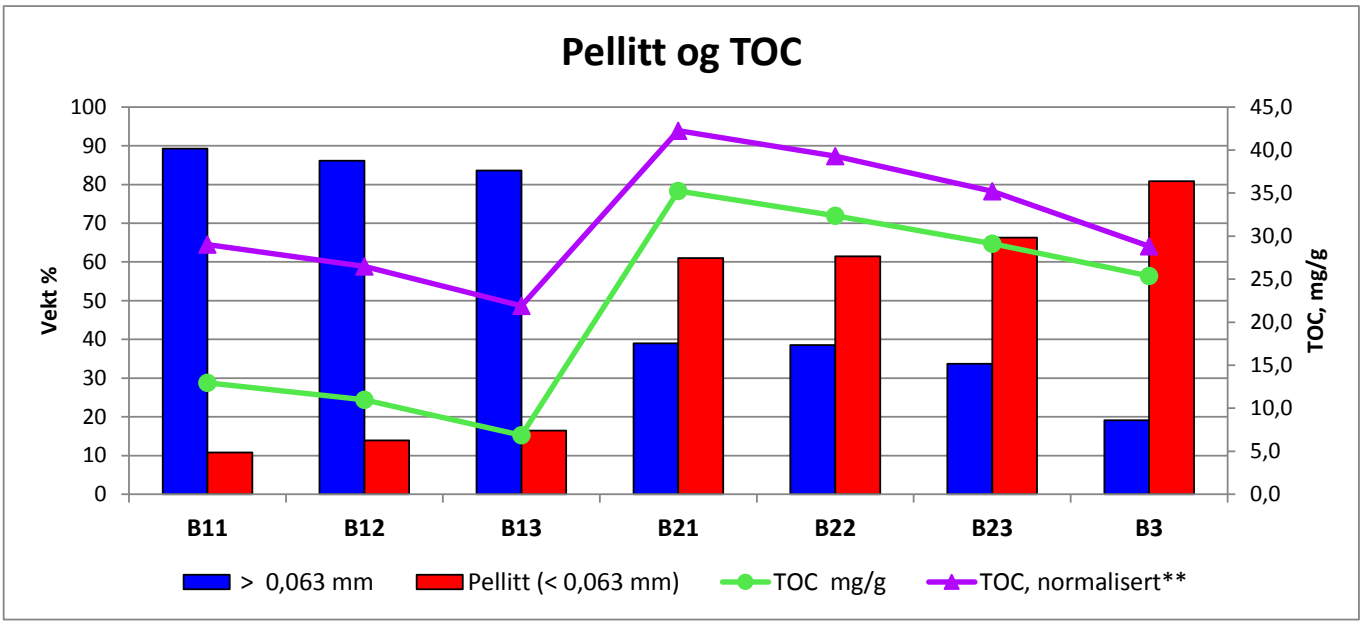
MERKNADER: Prøvene B11 (7874/1) og B22 (7874/5) inneholder stein større enn 15 mm som ikke er inkludert i analysen. Steinen ville utgjøre henholdsvis 2.5 vekt % og 2 vekt % av den totale prøven.

Resultater

Kundens id.:		B11	B12	B13	B21	B22	B23	B3
Parameter	Enhet	7874/1	7874/2	7874/3	7874/4	7874/5	7874/6	7874/7
> 0,063 mm	vekt %	89,2	86,1	83,6	39,0	38,5	33,7	19,1
Pelitt (< 0,063 mm)	vekt %	10,8	13,9	16,4	61,0	61,5	66,3	80,9
TOC	g/kg TS	13,0	11,0	6,85	35,2	32,4	29,1	25,4
TOC, normalisert**	mg/g TS	29,0	26,5	21,9	42,3	39,3	35,2	28,8

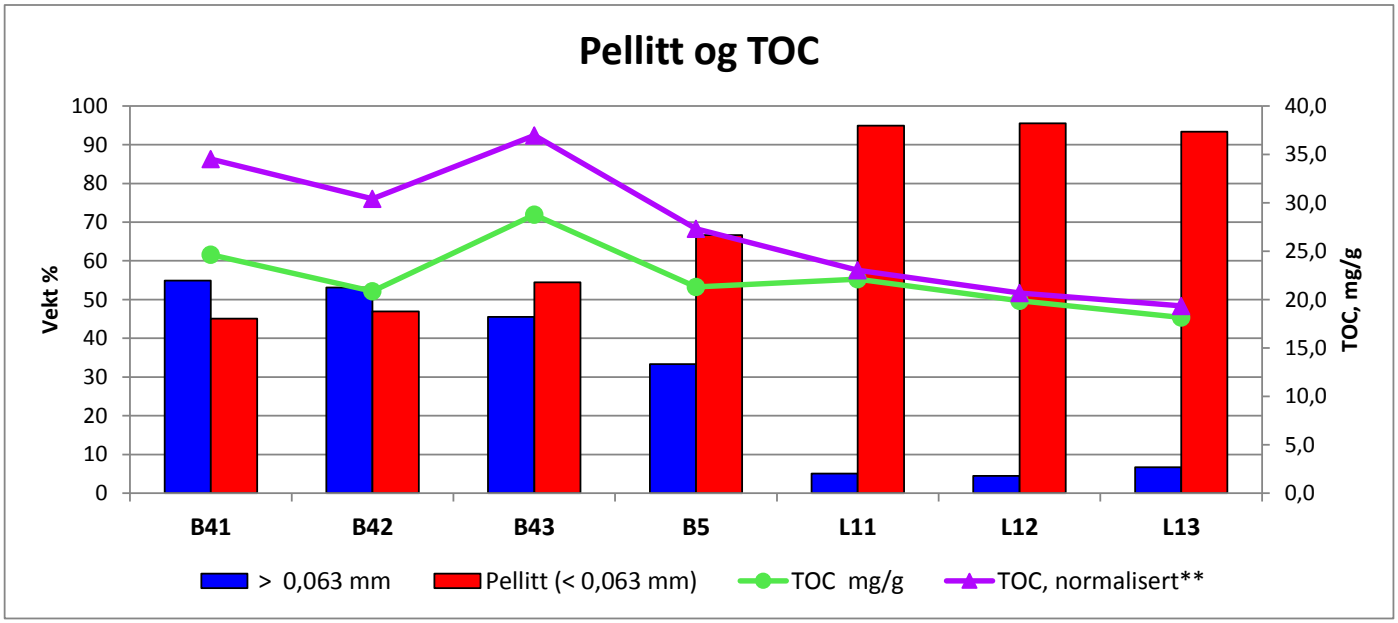
** Uakkreditert beregninger utført av Akvaplan-niva AS

TOC, normalisert = *målt TOC mg/g + 18*(1-F), der F=andel finstoff (pellitt) gitt ved %pellitt/100.*



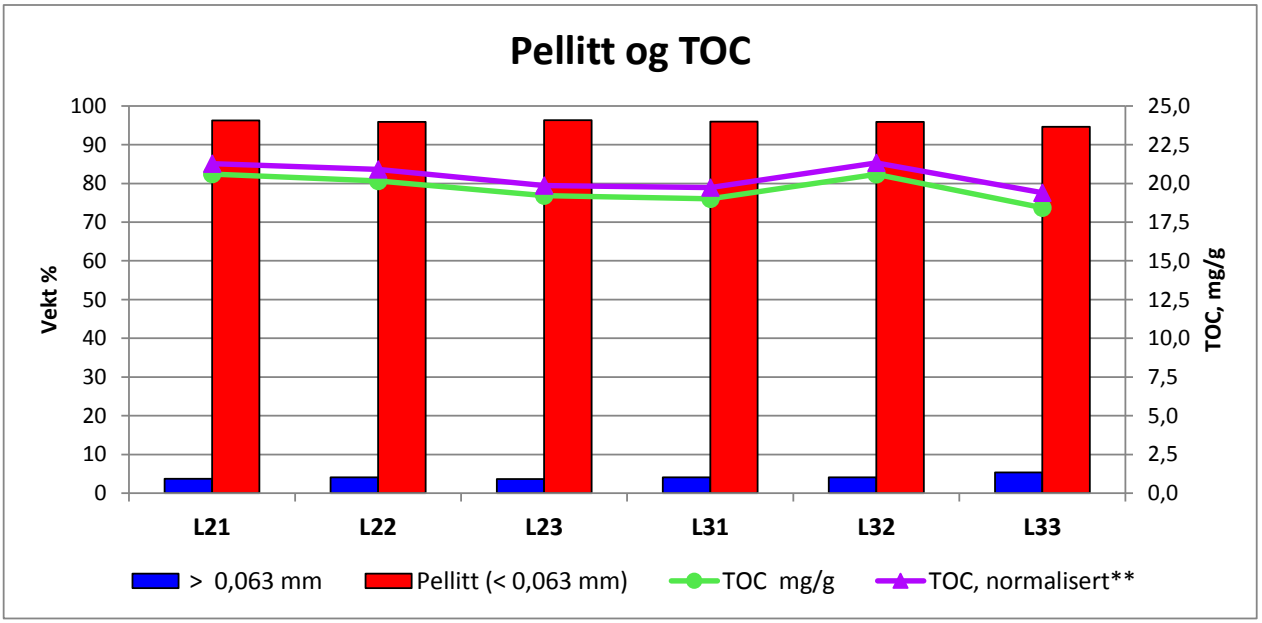
Resultater forts.

Kundens id.:		B41	B42	B43	B5	L11	L12	L13
Parameter	Enhet	7874/8	7874/9	7874/10	7874/11	7874/12	7874/13	7874/14
> 0,063 mm	vekt %	54,9	53,1	45,5	33,3	5,1	4,5	6,7
Pelitt (< 0,063 mm)	vekt %	45,1	46,9	54,5	66,7	94,9	95,5	93,3
TOC	g/kg TS	24,6	20,9	28,8	21,3	22,1	19,9	18,1
TOC, normalisert**	mg/g TS	34,5	30,4	37,0	27,3	23,0	20,7	19,3



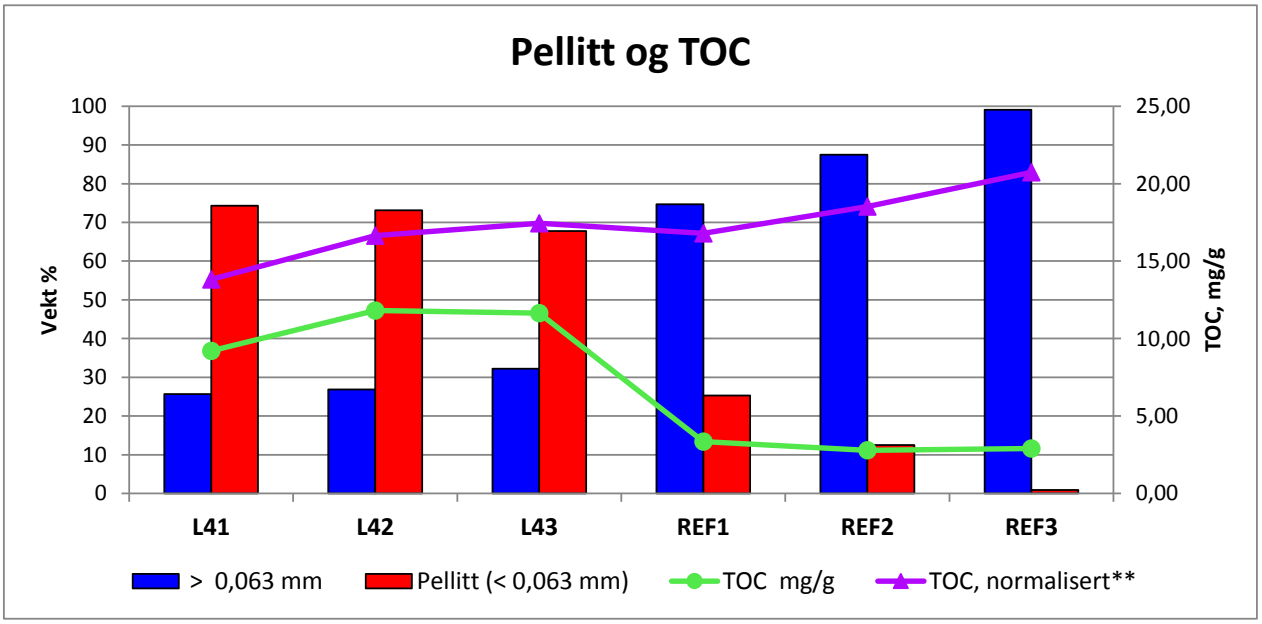
Resultater forts.

Kundens id.:		L21	L22	L23	L31	L32	L33
Parameter	Enhet	7874/15	7874/16	7874/17	7874/18	7874/19	7874/20
> 0,063 mm	vekt %	3,7	4,1	3,7	4,1	4,1	5,4
Pelitt (< 0,063 mm)	vekt %	96,3	95,9	96,3	95,9	95,9	94,6
TOC	g/kg TS	20,6	20,2	19,2	19,0	20,6	18,4
TOC, normalisert**	mg/g TS	21,3	20,9	19,9	19,7	21,3	19,4



Resultater forts.

Kundens id.:		L41	L42	L43	REF1	REF2	REF3
Parameter	Enhet	7874/21	7874/22	7874/23	7874/24	7874/25	7874/26
> 0,063 mm	vekt %	25,7	26,9	32,2	74,7	87,5	99,1
Pelitt (< 0,063 mm)	vekt %	74,3	73,1	67,8	25,3	12,5	0,9
TOC	g/kg TS	9,20	11,8	11,6	3,35	2,78	2,89
TOC, normalisert**	mg/g TS	13,8	16,6	17,4	16,8	18,5	20,7



Rapport

N1721335

E854OWOU69

Mottatt dato **2017-12-06**
Utstedt **2017-12-28**

Akvaplan-niva AS
Ingar H. Wasbotten

Framsenteret
N-9296 Tromsø
Norway

Prosjekt .
Bestnr

Analyse av faststoff

Deres prøvenavn **GF-st 1-waste dump Jord**

Labnummer N00547088

Analyse	Resultater	Usikkerhet (±)	Enhet	Metode	Utført	Sign
Tørrstoff (G) [a ulev]	**56.0**	1.1	%	1	1	NADO
Bisfenol A [a ulev]	**<0.020**		mg/kg TS	1	1	MORO
Tørrstoff (E) [a ulev]	**57.8**	3.50	%	2	2	NADO
Dimetylftalat (DMP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Dietylftalat (DEP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-propylftalat (DPrP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-butylftalat (DBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-isobutylftalat (DIBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-pentylftalat (DPP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-oktylftalat (DNOP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-(2-etylheksyl)ftalat (DEHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Butylbensylftalat (BBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-sykloheksylftalat (DCHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
4-n-Nonylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
4-iso-Nonylfenol (tekn.) [a ulev]	**<0.020**		mg/kg TS	3	1	MORO
4-t-Oktylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
2,3,7,8-TetraCDD [a ulev]	**<1.6**		ng/kg TS	4	2	NADO
1,2,3,7,8-PentaCDD [a ulev]	**<1.8**		ng/kg TS	4	2	NADO
1,2,3,4,7,8-HeksaCDD [a ulev]	**<5.4**		ng/kg TS	4	2	NADO
1,2,3,6,7,8-HeksaCDD [a ulev]	**<5.4**		ng/kg TS	4	2	NADO
1,2,3,7,8,9-HeksaCDD [a ulev]	**<5.4**		ng/kg TS	4	2	NADO
1,2,3,4,6,7,8-HeptaCDD [a ulev]	**<6.7**		ng/kg TS	4	2	NADO
Oktaklordibensodioksin [a ulev]	**<15**		ng/kg TS	4	2	NADO
2,3,7,8-TetraCDF [a ulev]	**<1.1**		ng/kg TS	4	2	NADO
1,2,3,7,8-PentaCDF [a ulev]	**<1.5**		ng/kg TS	4	2	NADO
2,3,4,7,8-PentaCDF [a ulev]	**<1.5**		ng/kg TS	4	2	NADO
1,2,3,4,7,8-HeksaCDF [a ulev]	**<2.8**		ng/kg TS	4	2	NADO
1,2,3,6,7,8-HeksaCDF [a ulev]	**<2.8**		ng/kg TS	4	2	NADO
1,2,3,7,8,9-HeksaCDF [a ulev]	**<2.8**		ng/kg TS	4	2	NADO
2,3,4,6,7,8-HeksaCDF [a ulev]	**<2.8**		ng/kg TS	4	2	NADO
1,2,3,4,6,7,8-HeptaCDF [a ulev]	**<3.7**		ng/kg TS	4	2	NADO
1,2,3,4,7,8,9-HeptaCDF [a ulev]	**<3.7**		ng/kg TS	4	2	NADO

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Deres prøvenavn	**GF-st 1-waste dump** **Jord**
Labnummer	N00547088

Analyse	Resultater	Usikkerhet (±)	Enhet	Metode	Utført	Sign
Oktaklordibensofuran [a ulev]	**<16**		ng/kg TS	4	2	NADO
Sum WHO-TEQ Lowerbound [a ulev]	**0**		ng/kg TS	4	2	NADO
Sum WHO-TEQ Upperbound [a ulev]	**3.5**		ng/kg TS	4	2	NADO
Vedlegg UL [a ulev]	----------		Se vedlegg	4	2	NADO

Deres prøvenavn	**GF-st 2-seawage** **Jord**
Labnummer	N00547089

Analyse	Resultater	Usikkerhet (±)	Enhet	Metode	Utført	Sign
Tørrstoff (G) [a ulev]	**59.0**	1.2	%	1	1	NADO
Bisfenol A [a ulev]	**<0.020**		mg/kg TS	1	1	MORO
Tørrstoff (E) [a ulev]	**57.5**	3.48	%	2	2	NADO
Dimetylftalat (DMP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Dietylftalat (DEP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-propylftalat (DPrP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-butylftalat (DBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-isobutylftalat (DIBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-pentylftalat (DPP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-oktylftalat (DNOP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-(2-etylheksyl)ftalat (DEHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Butylbensylftalat (BBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-sykloheksylftalat (DCHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
4-n-Nonylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
4-iso-Nonylfenol (tekn.) [a ulev]	**<0.020**		mg/kg TS	3	1	MORO
4-t-Oktylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO

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Deres prøvenavn	**LYB Indre Jord**
Labnummer	N00547090

Analyse	Resultater	Usikkerhet (±)	Enhet	Metode	Utført	Sign
Tørrstoff (G) [a ulev]	**60.7**	1.2	%	1	1	NADO
Bisfenol A [a ulev]	**<0.020**		mg/kg TS	1	1	MORO
Tørrstoff (E) [a ulev]	**65.6**	3.97	%	2	2	NADO
Dimetylftalat (DMP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Dietylftalat (DEP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-propylftalat (DPrP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-butylftalat (DBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-isobutylftalat (DIBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-pentylftalat (DPP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-oktylftalat (DNOP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-(2-etylheksyl)ftalat (DEHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Butylbensylftalat (BBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-sykloheksylftalat (DCHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
4-n-Nonylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
4-iso-Nonylfenol (tekn.) [a ulev]	**<0.020**		mg/kg TS	3	1	MORO
4-t-Oktylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO

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Rapport

N1721335

E854OWOU69

Deres prøvenavn	**Utløp Adventfjorden** **Jord**
Labnummer	N00547091

Analyse	Resultater	Usikkerhet (±)	Enhet	Metode	Utført	Sign
Tørrstoff (G) [a ulev]	**57.5**	1.2	%	1	1	NADO
Bisfenol A [a ulev]	**<0.020**		mg/kg TS	1	1	MORO
Tørrstoff (E) [a ulev]	**55.5**	3.36	%	2	2	NADO
Dimetylftalat (DMP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Dietylftalat (DEP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-propylftalat (DPrP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-butylftalat (DBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-isobutylftalat (DIBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-pentylftalat (DPP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-n-oktylftalat (DNOP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-(2-etylheksyl)ftalat (DEHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Butylbensylftalat (BBP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
Di-sykloheksylftalat (DCHP) [a ulev]	**<0.80**		mg/kg TS	2	2	NADO
4-n-Nonylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
4-iso-Nonylfenol (tekn.) [a ulev]	**<0.020**		mg/kg TS	3	1	MORO
4-t-Oktylfenol [a ulev]	**<0.0020**		mg/kg TS	3	1	MORO
2,3,7,8-TetraCDD [a ulev]	**<1.2**		ng/kg TS	4	2	NADO
1,2,3,7,8-PentaCDD [a ulev]	**<1.9**		ng/kg TS	4	2	NADO
1,2,3,4,7,8-HeksaCDD [a ulev]	**<4.9**		ng/kg TS	4	2	NADO
1,2,3,6,7,8-HeksaCDD [a ulev]	**<4.9**		ng/kg TS	4	2	NADO
1,2,3,7,8,9-HeksaCDD [a ulev]	**<4.9**		ng/kg TS	4	2	NADO
1,2,3,4,6,7,8-HeptaCDD [a ulev]	**<9.5**		ng/kg TS	4	2	NADO
Oktaklordibensodioksin [a ulev]	**<13**		ng/kg TS	4	2	NADO
2,3,7,8-TetraCDF [a ulev]	**<1.3**		ng/kg TS	4	2	NADO
1,2,3,7,8-PentaCDF [a ulev]	**<1.4**		ng/kg TS	4	2	NADO
2,3,4,7,8-PentaCDF [a ulev]	**<1.4**		ng/kg TS	4	2	NADO
1,2,3,4,7,8-HeksaCDF [a ulev]	**<3.8**		ng/kg TS	4	2	NADO
1,2,3,6,7,8-HeksaCDF [a ulev]	**<3.8**		ng/kg TS	4	2	NADO
1,2,3,7,8,9-HeksaCDF [a ulev]	**<3.8**		ng/kg TS	4	2	NADO
2,3,4,6,7,8-HeksaCDF [a ulev]	**<3.8**		ng/kg TS	4	2	NADO
1,2,3,4,6,7,8-HeptaCDF [a ulev]	**<4.2**		ng/kg TS	4	2	NADO
1,2,3,4,7,8,9-HeptaCDF [a ulev]	**<4.2**		ng/kg TS	4	2	NADO
Oktaklordibensofuran [a ulev]	**<20**		ng/kg TS	4	2	NADO
Sum WHO-TEQ Lowerbound [a ulev]	**0**		ng/kg TS	4	2	NADO
Sum WHO-TEQ Upperbound [a ulev]	**3.4**		ng/kg TS	4	2	NADO
Vedlegg UL [a ulev]	----------		Se vedlegg	4	2	NADO

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"a" etter parameternavn indikerer at analysen er utført akkreditert ved ALS Laboratory Group Norway AS.
"a ulev" etter parameternavn indikerer at analysen er utført akkreditert av underleverandør.
Utførende laboratorium er oppgitt i tabell kalt Utf.
n.d. betyr ikke påvist.
n/a betyr ikke analyserbart.
< betyr mindre enn.
> betyr større enn.

	Metodespesifikasjon
1	**Bisfenol-A i jord** Metode: ISO 14154 Måleprinsipp: GC-ECD Rapporteringsgrenser (LOQ): 0,010 mg/kg TS Måleusikkerhet: 40%
2	**Ftalater i jord/sediment** Metode: EPA 8061A, CPSC-CH-C1000-09.3 Måleprinsipp: GC/MS Rapporteringsgrenser (LOQ): Enkeltforbindelser: 0,80 mg/kg TS Måleusikkerhet: 30%
3	**Bestemmelse av nonylfenol og oktylfenol i jord** Metode: DIN EN ISO 18857-2 Ekstraksjon: n-Heksan Deteksjon og kvantifisering: GC/MSD Rapporteringsgrenser: 4-tert-Oktylfenol: 0,0010 mg/kg TS 4-n-Nonylfenol: 0,0010 mg/kg TS Iso-Nonylfenol (tech): 0,010 mg/kg TS Relativ måleusikkerhet: 14,80%
4	**Bestemmelse av dioksiner** Metode: US EPA 1613 Deteksjon og kvantifisering: HRGC/HRMS Kvantifikasjonsgrenser: varierer med matriks Måleusikkerhet: For kongenerene enkeltvis: 30% For total WHO-TEQ: 20% Note: Sum PCDD/PCDF er oppgitt som internasjonale toksisitetsekvivalentfaktorer (TEF) der den giftigste forbindelsen, 2,3,7,8-Tetra CDD, har fått "vektfaktor" 1, mens de andre mindre giftige forbindelsene er vektet lavere. Vektfaktorene (WHO 2005 TEF) som er benyttet er i henhold til EU nr 589/2014. «Lowerbound» defineres i samme forskrift som det begrep som krever bruk av kvantifiseringsgrense som bidraget fra hver ikke-kvantifiserbare kongener. «Mediumbound» defineres i samme forskrift som det begep som krever bruk av halvparten av kvantifiseringsgrensen som bidraget fra hver ikke-kvantifiserbare kongener.

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	Metodespesifikasjon
	«Upperbound» defineres i samme forskrift som det begrep der man bruker null som bidrag fra hver ikke-kvantifiserbart kognener.

	Godkjenner
MORO	Monia Alexandersen
NADO	Nadide Dönmez

	Utf[1]	
1	Ansvarlig laboratorium:	GBA, Flensburger Straße 15, 25421 Pinneberg, Tyskland
	Lokalisering av andre GBA laboratorier:	
	Hildesheim	Daimlerring 37, 31135 Hildesheim
	Gelsenkirchen	Wiedehopfstraße 30, 45892 Gelsenkirchen
	Freiberg	Meißner Ring 3, 09599 Freiberg
	Hameln:	Brekelbaumstraße 1, 31789 Hameln
	Hamburg:	Goldschmidstraßse 5, 21073 Hamburg
	Kontakt ALS Laboratory Group Norge, for ytterligere informasjon	
2	Ansvarlig laboratorium:	ALS Laboratory Group, ALS Czech Republic s.r.o, Na Harfě 9/336, Praha, Tsjekkia
	Lokalisering av andre ALS laboratorier:	
	Ceska Lipa	Bendlova 1687/7, 470 03 Ceska Lipa
	Pardubice	V Raji 906, 530 02 Pardubice
	Kontakt ALS Laboratory Group Norge, for ytterligere informasjon	

Måleusikkerheten angis som en utvidet måleusikkerhet (etter definisjon i "Evaluation of measurement data – Guide to the expression of uncertainty in measurement", JCGM 100:2008 Corrected version 2010) beregnet med en dekningsfaktor på 2 noe som gir et konfidensinterval på om lag 95%.

Måleusikkerhet fra underleverandører angis ofte som en utvidet usikkerhet beregnet med dekningsfaktor 2. For ytterligere informasjon, kontakt laboratoriet.

Måleusikkerhet skal være tilgjengelig for akkrediterte metoder. For visse analyser der dette ikke oppgis i rapporten, vil dette oppgis ved henvendelse til laboratoriet.

Denne rapporten får kun gjengis i sin helhet, om ikke utførende laboratorium på forhånd har skriftlig godkjent annet.
Resultatene gjelder bare de analyserte prøvene.
Angående laboratoriets ansvar i forbindelse med oppdrag, se aktuell produktkatalog eller vår webside www.alsglobal.no

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[1] Utførende teknisk enhet (innen ALS Laboratory Group) eller eksternt laboratorium (underleverandør).

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