

Master's thesis



Deposits from historic events in the
Aurlandsfjord, Western Norway, over the
last 40 years
The pollution record

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Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.



Martine Venneman

Abstract

Flåm at the Aurlandsfjord, Western Norway, is a popular destination for cruise tourism. The main attraction of Flåm is the Flåmbane, a railroad that runs between Flåm and Myrdal. The railroad attracted 920.000 tourists in 2016 and 171 cruise ships will arrive at Flåm in 2017. The prediction is that *The growth of the cruise ship industry increases the risk of pollution in the Aurlandsfjord*. To investigate this, sediments cores were taken and investigated from three marine basins near Flåm. These basins are the Cruise Ship Harbor at 37 m, the Kistadypet at 64 m, and at Stampa at 60 m water depth. The assumption was made that an increased amount of cruise ships would have led to an increased amount of sediment pollution. The sediments were dated using sediment signals of local building activity (completion of the cruise ship quay in 1985) and the century flood of 2014, resulting in a linear sedimentation rate from 0,27 to 0,75 cm/year. Samples from the sediment surface and from about 10 cm sediment depth were compared regarding the contents of PAHs, PCBs, TBT, Cu, Cr, Ni, Zn, Hg, Cd, Pb and As. The results showed that the sediments in the Cruise Ship Harbor were polluted with up to 5,6 µg/kg TBT, falling in Class V 'Heavily Polluted' of the Norwegian Environmental Directorate sediment classification of 2016. No TBT was detected in the Kistadypet and at Stampa. All other contaminants in the sediments of the Cruise Ship Harbor, the Kistadypet and at Stampa fell in Class II 'Good'. No major changes were detected between the surface subsample and the 10 cm subsample at either station and the sedimentation rates increased by a factor of 2,78. The use of TBT has been completely prohibited since 2008 and terms of site management, this indicates that action against TBT pollution should be taken in the Flåm Cruise Ship Harbor. Further studies need to be done on the TBT to gathering more information and monitoring the conditions of TBT in the Aurlandsfjord.

I dedicate this work to my parents whose unrelenting support brought me where I am today. You taught me to believe in myself, my hopes and dreams. And to my brother who became my living example of what willpower, talent, and luck can achieve.

Foreword

This thesis was written in collaboration with the 'From mountain to Fjord' minor and the bachelor theses in progress by Mulelid et al. (2017) and Midttømme et al. (2017) at the Western Norway University of Applied Sciences. The samples were taken in the Aurlandsfjord and the data were partly gathered by the international From Mountain to Fjord students. The data gathered were processed in three theses each focusing on a different aspect of the Aurlandsfjord: Part I. The Sediment Record, Part II. The Geochemistry Record, and this master thesis being Part III. The Pollution Record.

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1 Introduction

In the southern part of the Aurlandsfjord, Norway (Figure 1) lies the village of Flåm consisting of 350 inhabitants (Helseth, 2014). Flåm is a tourist destination because of the Flåm railway which goes from Flåm to Myrdal. The Flåm railway is world famous and has won various awards for its scenic beauty. Myrdal is connected to the national rail net through the Oslo – Bergen rail line. (Visit Flam, 2016). Flåm is a cruise destination and received harbor received 88 in 2000 and 161 in 2016. Flåm is a cruise destination and received harbor received 88 in 2000 and 161 in 2016. In 2016, the Flåm railway attracted 920.000 cruise tourists in 2016 (Stedje, 2016). One of the reasons why tourists go to Flåm is because the Aurlandsfjord is part of the UNESCO “West Norwegian Fjords” Natural and Cultural World Heritage Site of the “Western Norwegian Fjords”. The main reason why the site got on the World Heritage list was because of the scenic beauty of the landscape. The site has been evaluated to be „able to cope with great influxes of tourists without losing any of their qualities” (UNESCO, 2004). In spite of this evaluation, there are various threats to the area due to tourism.

The focus of this thesis lies on the potential impact of cruise ships on the degree of pollution in the sediments of the Aurlandsfjord. There is a distinct difference in definition between contamination and pollution: contamination means that there is an elevated concentration of substances. Elevated concentrations do not have to be harmful for the environment and/or humans. If there is pollution, then it means that the concentrations of contaminants are high enough to be hazardous to humans and/or the environment (FAO, 1999).



Figure 1 Map of the local environment featuring Flâm, Aurlandsvangen (or Aurland), Gudvangen, Stalheimskleiva and Myrdal. Map made in ArcGis 10.2 (ERSI 2017a) revised by Venneman, E (2017)

Cruise ships have the potential to become a pollution source bringing in challenges such as sewage treatment and air pollution (FOE, 2009). The sewage of cruise ships is not an issue within Flåm because cruise ships are not allowed to dump their sewage in the fjords (Johnsen & Stedje, 2016). The potential impact of air pollution could be severe, as exhaust gasses can contain polycyclic aromatic hydrocarbons (PAHs) (PCE, 2003) which can cause cancer in humans (National Research Council (US), 1983). In addition to this, hulls of ships (and cruise ships) are painted with antifouling paint that keeps the hull clean from organisms. Various types of antifouling have different impacts on the environment (Price & Readman, 2013). These impacts include a severe disruption in the ecosystem due to the use of antifouling agents like for example Tributyltin (IMO, 2000). Another risk contaminant that is dangerous to humans are polychlorinated biphenyls (PCBs) which can be found in paint, electrical equipment, metal coatings, pesticides, among other. PCBs influence the hormone system and disrupts the entire human body (ATSDR, 2015). Because of the potential danger of PCBs, the use of PCBs is restricted (which started in 1967) but has not been completely banned (HELCOM, 2001). The situation in Flåm unique is because of the many cruise ships coming to Flåm which can remain idle in the fjord for over 12 hours. The exhaust gasses expose the local community, ecosystem and waters to exhaust gasses, containing PAHs and sulfur oxide (Stenersen, 2010).

1.1 Objectives

The study at hand is the first contamination research performed in sediments of the Flåm harbor area. The goal of this thesis is to document possible impacts of pollution on the Aurlandsfjord environment. The focus lies on the potential impact of contamination originating from cruise ships. A number of 2.301 cruise ships visited Flåm between the years 2000 and 2016. To test the environmental impact of these cruise ships, the following model was developed:

“The growth of the cruise ship industry increases the risk of pollution in the Aurlandsfjord”

This leads to the following hypothesis:

H_0 The increasing cruise ship industry did not increase the risk of pollution in Aurlandsfjord sediments

H_1 The increase of the cruise ship industry did increase the risk of pollution in Aurlandsfjord sediments

In order to test the hypothesis, the following research questions were formulated:

1. Do the sediments of and around the Flåm cruise ship harbor contain contaminants (PAHs, PCBs, TBT, Cu, Cr, Ni, Zn, Hg, Cd, Pb, As) above background concentrations?
2. Is it possible to relate the contaminant distribution in the sediments to their sources and source areas?
3. Is it possible to reconstruct the timing of changes in the contaminant concentration?
4. Would the findings regarding the contaminant concentration and their distribution in the sediments have an influence on the environmental management of the area?

1.2 Research question elaboration

The research questions were formulated to answer the hypothesis on whether or not the increasing cruise ship industry influenced the sediments in the Aurlandsfjord. The following paragraphs provide a short explanation on what the research questions mean and which methods were applied. The methods will be described in more details in the 'Materials and Methods' chapter.

Research question 1: Do the sediments of and around the Flåm Cruise Ship Harbor contain contaminants (PAHs, PCBs, TBT, Cu, Cr, Ni, Zn, Hg, Cd, Pb, As) above background concentrations?

The chosen organic and inorganic contaminants are standard contaminants used in contamination investigation for marine coastal sediments in Norway, using standard methods (Miljødirektoratet, 2016). The concentrations are thus directly comparable to sediment investigations from other Norwegian coastal, harbor and fjord regions. Contaminant concentrations are compared between surface sediment levels and concentrations at around 10 cm sediment depth. The idea is to include a time resolution of the contaminant sedimentation by comparing two different time horizons. The method used for estimating the timing of these horizons will be explained in the third research question.

Research question 2: Is it possible to relate the contaminant distribution in the sediments to their sources and source areas?

Finding the sources of contaminants is of importance to adjust the management in the Aurlandsfjord. However, contaminants can have multiple sources and thus pinpointing source areas can be challenging. The approach will involve the use of findings of sources from related sediment parameters (grain sizes, particulate organic and inorganic matter fractions, and diatom analysis; Midttømme et al. 2017), and from related element and image analyses (XRF, magnetic susceptibility, and digital and x-ray imaging; Mulelid et al. 2017).

Research question 3: Is it possible to reconstruct the timing of changes in the contaminant concentration?

The dating is important because (a) it might indicate when certain contaminants arrived in the fjord system and (b) it might be used for the calculation of sedimentation rates in cm/year. The plan is to use the ^{210}Pb dating method and the recognition of horizons of ^{137}Cs fallout from the radioactive accident at Chernobyl (Paetzel & Schrader, 1991) and from the world wide maximum fallout from nuclear weapon testing in 1963 (Pennington, et al., 1973). Also, the use of sediment signals from local events (historically documented slide etc.) might give some time information in Norwegian fjords (e.g. Paetzel & Schrader, 1992; Paetzel & Dale, 2010).

Research question 4: Would the findings regarding the contaminant concentration and their distribution in the sediments have an influence on the environmental management of the area?

The answers of the previous questions provide a view of the current status of the contamination in the Aurlandsfjord. Knowledge on the contaminant distribution in the Flåm harbor area of the Aurlandsfjord is not available prior to the thesis at hand. Thus, sediment contamination is not part of management concerns in the Flåm harbor per today. The findings of this thesis might thus contribute to the involvement of contamination issues into future management plans of the Flåm harbor and fjord area, including the future management of the World Heritage Site.

1.3 Environmental setting

1.3.1 Hydrography

In 2007, the Aurlandsfjord is an oxic fjord with oxygen levels varying between 7,55 mlO₂/l and 7,90 mlO₂/l at the water surface and between 6,45 mlO₂/l and 6,79 mlO₂/l at a 20 m water depth. The salinity in the fjord changes with water depth; the surface water salinity varies between 7,20 psu and 9,14 psu but sharply increases to between 30,49 and 29,98 psu at around 10 m water depth, the depth of change depending on the season (shallower in winter) (Vassenden, 2007). Hydrographic data taken during the research at hand confirm the findings of 2007 at least for the locations in the cruise harbor, the Kistadypet, and at Stampa.

1.3.2 Bathymetry

The Aurlandsfjord branches from the Sognefjord approximately 150 km inland, stretching from the north to the south (Vassenden, 2007). Flåm lies at the southernmost edge of the Aurlandsfjord (Figure 1), consisting of three sediment basins (Figure 10): (a) the open Cruise Ship Harbor in the south with a maximum depth of 37 meters, leading 1,5 km towards the northeast into (b) the 65 m deep open Stampa basin; (c) the basin of the semi-enclosed Kistadypet is located directly to the north of the Cruise Ship Harbor and to the west of the Stampa basin, with a maximum depth of 64 m. Figure 1 shows a map of the broader location of the Sognefjord, Aurlandsfjord and Nærøyfjord. The length of the entire Aurlandsfjord is 29 km and the narrowest point is 800 m wide. The maximum depth of the Aurlandsfjord 774 m and the fjord has three main basins. The Nærøyfjord splits from the Aurlandsfjord in a southwest direction after 11km.

1.4 Geological setting

1.4.1 Bedrock geology of Aurland

Rocks originating from the Caledonian orogeny dominate the landscape of the inner Sognefjord. Fossen et al. (2008) describe in detail the formation of the Caledonian mountain chain during the Silurian time period (500-405 million years ago). During the main phase of the orogeny (488-415 million years ago), the land masses of the tectonic plates of the continents Laurentia (in the west) and Baltica (in the east) were moving towards each other and were finally colliding. The collision closed the ocean of the Iapetus Sea, which lied between Laurentia and Baltica, (440 million years ago) when Laurentia was trusted upon Baltica. As this process continues, the land- and seafloor in between were pushed up into what would become the Caledonian mountain chain (440 to 415 million years ago).

The sediments of this ocean were thrust onto the new continent block, forming metamorphic phyllitic rocks which can be found in the Aurland municipality as well. The phyllitic rocks can be found in the southeast of the municipality (Figure 2; green color, phyllite and mica schist). In addition to the phyllites, the collision of the continents pressed magmatic rocks upward to form anorthositic rocks on the new continent surface. Anorthosite can also be found in the northern part of the municipality (Figure 2; light brown color, mangerite to gabbro, gneiss and amphibolite).

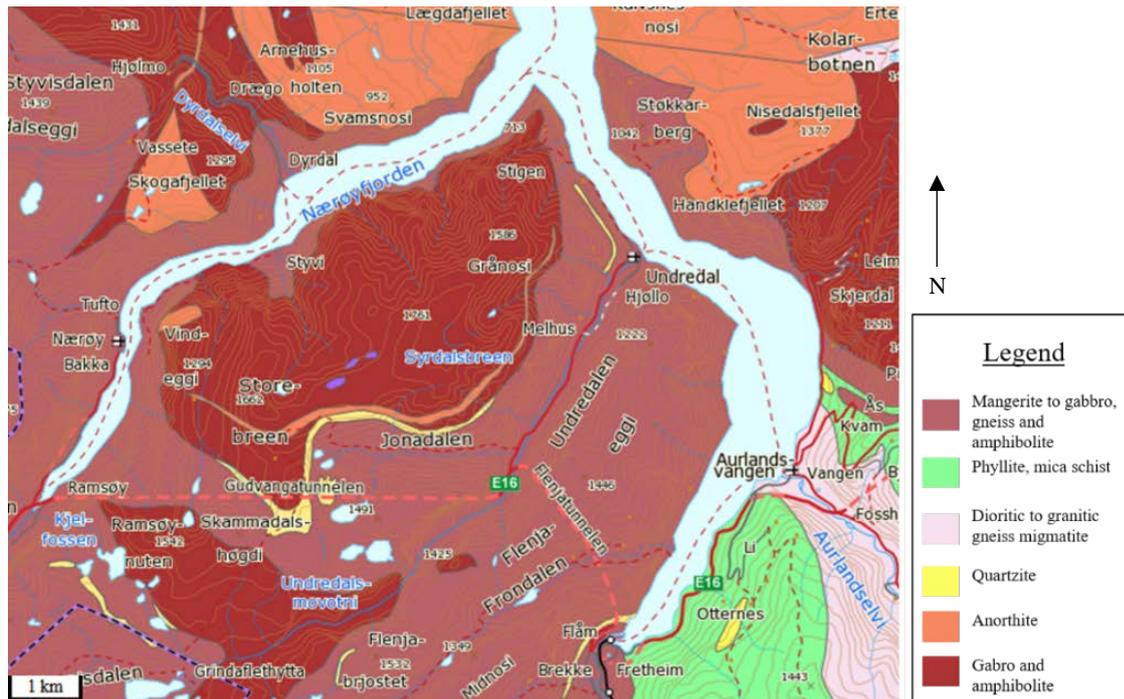


Figure 2 Geological map of the Nærøyfjord area. The map shows the differences in rock type between the Aurlandsfjord and the Nærøyfjord (NGU, 2017).

1.4.2 Fjord formation

The surface of the Norwegian landscape was mostly formed during the Quaternary time period which started around 2 million years ago. The surface has been heavily influenced by glaciers during glaciations (Kessler, et al., 2008). A glacier is an extended mass of ice formed from snow falling and accumulating over the years. Glaciers are potent eroders (Kessler, et al., 2008) and during the Quaternary time period up to 23 glacial/interglacial cycles took place in Scandinavia (Fredin, 2002). A glacial is a period where the temperatures are lowered all over the globe. These cold periods are followed by short, warmer periods between glacials, also called interglacials. A glacial cycle is defined as the process of a glacial period turning into an interglacial and back into a glacial (NOAA, 2017). In the Quaternary period glaciers

moved from mountain areas down to the coasts of Scandinavia and further to the northern part of middle Europe (Fredin, 2002). As a consequence, the glaciations impacted the landscape at different northern European locations during the different glacial periods (Kessler, et al., 2008).

Fjord formation is a slow process which requires multiple glaciations. A fjord is the result of a glacier cutting through the bedrock below sea-level (Lyså, et al., 2009). Glacier valleys originate from the deepening of original river valleys. In fjords, these valleys have been over-deepened below sea level (Lyså, et al., 2009). The process of over-deepening is thus the consequence of glacial erosion which eroded valleys deeper than water erosion alone (Oxford Dictionaries, 2017). In the Sognefjord, the deepest point is located at 1.308 m below sea level (Manzetti & Stenersen, 2010). Roughly 7.600 km³ of bedrock was eroded away due to glacial erosion and over-deepening processes of the Quaternary time period (Nesje, 2017).

1.5 Historical setting

Around the Nærøyfjord at least 28 archeological sites of human settlement were found. The first traces of people living in the area go back until the late Stone Age (ca. 3000 – 2000 BC). There are 668 buildings left in the Nærøyfjord area which were made between the 17th and the 20th century. Most of these buildings were related to farming and all are considered monuments which add value to the landscape (UNESCO, 2004).

1.5.1 Development of tourism in the 19th century

Tourism started to develop in the 19th century with the opening of the Stalheim hotel at Stalheimskleiva (Figure 1). It was built between 1842 and 1846 and was used to improve the postal road between Oslo and Bergen and thus provided a link to Flåm and Aurland (UNESCO, 2004). In 1871, the first plans were made for a railroad between Bergen and Stockholm via Oslo, passing Myrdal (Figure 1). In 1908, the Norwegian parliament included the Myrdal–Flåm route in the National Railway Plan. Construction of the railroad started in 1924 and was finished in 1940. After the completion of the railroad, the number of visitors saw a steady increase. Between 1953 and 1969 the Flåmsbana had around 115.000 passengers each year. The number of passengers increased to 781.427 passengers in 2015 (Vist Flam, N.D) and 920.000 in 2016 (Stedje, 2016). Another important development that stimulated tourism was the opening of the Gudvangen tunnel (UNESCO, 2004).

1.5.2 Recent development of tourism in Norway

In recent years, the tourism in Norway also has seen growth. In 2015, there were 31,6 million guest nights which was 4% more than in 2014. During the same year, Norway attracted 1,2 billion international tourists spending 151,5 billion NOK (17 billion EU). The tourism industry also supplies jobs: About 7% of the Norwegian working stock work in the tourism industry. Growth can also be seen on a longer term: between 2009 to 2015, the total amount of foreign commercial guest nights has increased from 7.482.000 to 8.154.400. The cruise ship industry has grown as well. Between 2009 and 2013, the number of port calls increased from 1.570 to 2.190. However, the cruise ship industry started to decline after 2013 to 1.790 in 2015 (Innovation Norway, 2015).

1.5.3 Events of the last 50 years

The building of the cruise ship harbor

The shape and the size of the Cruise Ship Harbor has changed over the years. Figure 3 shows aerial photographs of the harbor in 1971 (Statens kartverk, 1971) on the left and in 2014 on the right (Statens kartverk, 2014). The photo taken in 2014 shows the change of the river outlet due to the building of a new deep water quay on the old river delta, the overall increase of buildings, and the straightening of the riverbed compared to 1971. In 1985, the building of the quay was completed. The assumption is made is that this event somehow left traces in the sediment record.



Figure 3 A comparison between the aerial pictures of 1971 (Statens kartverk, 1971) and 2014 (Statens kartverk, 2014)

The 2014 flood

Flåm has been flooded at least three times throughout the last 50 years. Figure 4 shows the discharge of water in the Flåm River between 1910 and 2016 in m^3/sec . Major floods happened in 1973, 1985, and in 2014 (Haflidason & Eide, 2016b). The flood in 2014 showed the highest amount of water discharge of the century and was considered to be a 200 to 500 year flood (DSB, 2014). The flood led to an increased sedimentation rate in the riverbed as in one day 30 cm of material was deposited (Eide, 2016). It was estimated that 180.000 m^3 of sediment material was used to rebuild the infrastructure after the flood. As a consequence, the impact of the flood could still be seen in the sediment load in 2016 (Haflidason & Eide, 2016)

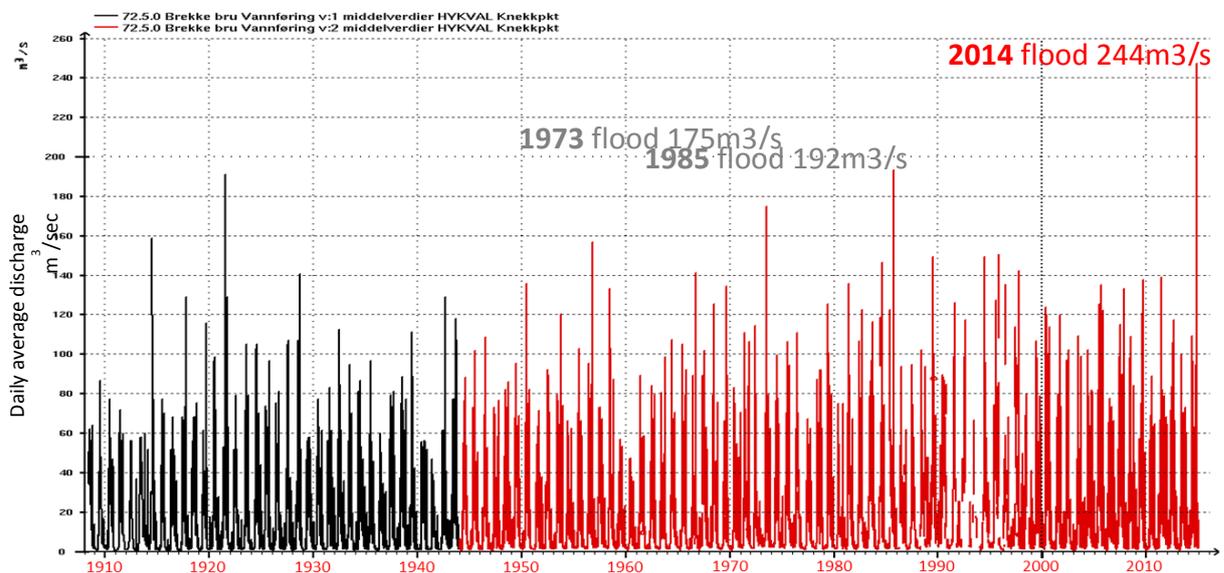


Figure 4 The daily discharge of the Flåm river between 1910 and 2016. The graph shows the various floods and the amount of discharge of water in m^3/s . The flood of 2014 had the highest water discharge since measurements started in 1910. Graph made by NVE (2015) revised by Paetzel (2016).

1.6 Scientific setting

When it comes to contaminant research in the Aurlandsfjord, only one quantitative study exists (Vassenden, 2007). In this study, one contamination sample was taken from sediments of the inner Aurlandsfjord at 411 m water depth (Location Au1, Figure 5). On this location, the sediment was tested for lead, cadmium, copper, chromium, mercury, zinc, tributyltin, PAH16 and ΣPCB_7 . The results of this study were that all the tested contaminants are considered background values (Vassenden, 2007).

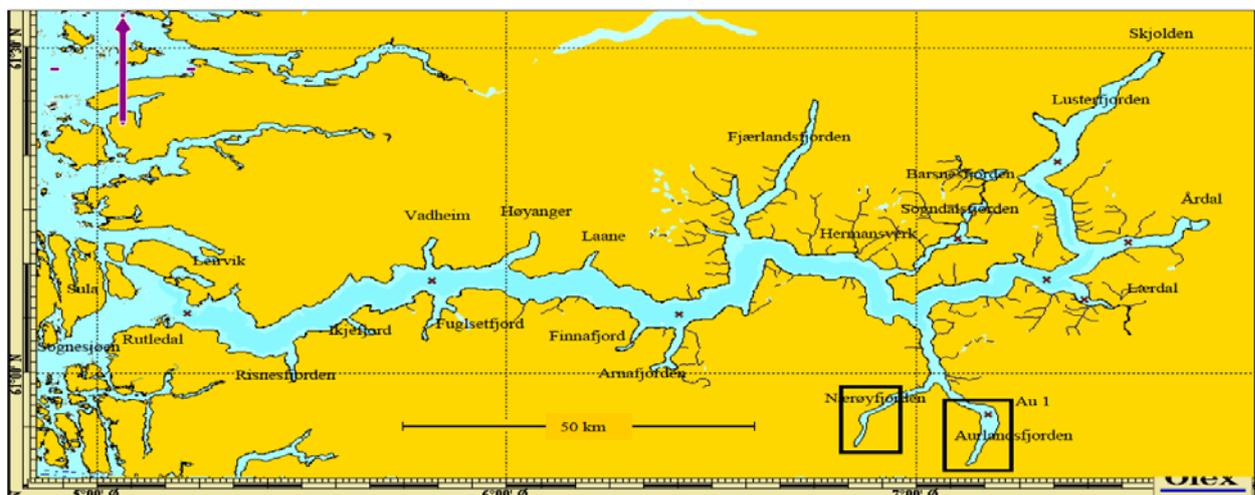


Figure 5 Contaminant sample of Vassenden (2007) taken at Au 1 at 411 m water depth.

The majority of the scientific research in the Aurlandsfjord was performed on the bedrock geology (Bryhni, et al., 1983; Rye & Faugli, 1994; Blikra, et al., 2006). The study of Bryhni, et al. (1983) focused on the division of the Jotun Nappe Complex. The study found a division in the lower and upper allochthon in the mountains between the Aurlandsfjord and the Nærøyfjord. Rye et al. (1994) focused on the water shed and the impacts of the hydroelectric power plant in Aurland and the study of Blikra et al. (2006) focusses avalanches and the mechanisms that trigger them. Avalanches are considered to be serious hazards as the last 100 years more than 170 people died in western Norway because of them.

The Aurlandsfjord has also been studied with regard to landscape planning. The study of Clemetsen & Laar aimed to be regional planning tool for Europe on how ecological agriculture can contribute to a better landscape quality. The study of Clemetsen et al. (2007) used the Aurland community as a case study on how local entrepreneurs can benefit from the tourist industry. This paper promotes a bottom up approach based participatory research methods to stimulate ideas, cooperation and a common framework.

1.7 Historic Norwegian contaminant classifications

The first standards for the classification of the environmental state of the Norwegian fjord and coastal waters were published in 1993 and 1994. In 1997, the system of 1993/1994 was revised and extended (Bakke, et al., 2010). In 2007, the classification of seawater and soft sediments was revised to focus on ecotoxicology of contaminant levels (SFT, 2007). In 2016, the classification was again revised and is now based on both the Annual Average Environmental quality standards (AA EQS) and the Maximum Annual Concentration Environmental quality standards (MAC EQS) (Miljødirektoratet, 2016). All the revisions had a common structure: each had five different classes of concentration intervals ranging between “Background” and “Very bad” (Bakke, et al., 2010).

1993/1994

The standards were published in a series of guiding documents which focused on environmental conditions, pollution degree, eutrophication, and contaminant levels. The classification was developed based on the analysis of water, sediment and organisms. The goal of these documents was to serve as a base line for authorities, industries and environmental consultants which would allow to establish environmental aims, prioritize sites which need mitigation measures, and assess the success of such measures by accepted criteria (Molvær, et al., 1997).

1997

The classes of 1997 were defined on the frequency distribution of 18 contaminants from the upper 0-5 cm in soft sediments. The frequency distribution contained data gathered from national monitoring programs in fjords and coastal waters, surveys for industries, and local authorities. The classes used were developed in comparison with background values originating from the same or similar environments and material (Molvær, et al., 1997). The use of expert judgement in addition to measured effects made the classes difficult to use (Bakke, et al., 2010).

2007

In 2007, the guideline for environmental and health-driven risk assessment for marine sediments was revised. The new guidelines covered 50 compounds and compound groups (Bakke, et al., 2007) and was harmonized with the classifications for seawater. Major changes happened in the classification system (SFT, 2007). The new classification was developed

based on ecotoxicology and follows the principles of contaminant risk assessment of the European Community (Bakke, et al., 2010).

Figure 11 shows the different contamination classes and a brief description of each class. Class I is considered to include background values. The class borders of the contaminants which were used in 1997 are still the same. Class borders of contaminants which were introduced after 1997 were determined by Norwegian screening surveys (OSPAR, 2005; Fjeld, et al., 2005). Classes II to V represent different degrees of damage done to the ecological communities in the free water column and the sediments by defined amounts of the component in question. This data was gained by laboratory tests on acute and chronic toxicity (Bakke, et al., 2010).

2015

In 2015, new contaminants were added to the European priority list of contaminants. In addition to this, the existing environmental quality criteria were updated (Euractiv, 2014). These criteria affect class II and III as these classes are based on the Annual Average Concentrations and the Maximum Annual Concentration. As a consequence, the content of the classes of the Norwegian standards changed (Miljødirektoratet, 2016).

1.8 Contaminant groups

Within this master thesis four groups of contaminants have been investigated in the Flåm harbor sediments: Polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), Tributyltin (TBT) and Inorganic pollutants (Arsenic, Copper, Zinc, Cadmium, Lead, Chromium, Mercury and Nickel) .

1.8.1 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are a diverse group of chemicals which are naturally occurring in ecosystems. They can originate from oil seeps (Pampanin & Sydnes, 2013) but more commonly they are from anthropogenic origin (OSPAR, 2009). Examples are the incomplete burning of PAHs in for example engines, waste incinerators and combustions plants. PAHs have a molecule structure made out of benzene rings (ATSDR, 1995) and Figure 6 shows the molecule structure of a benzene ring. The left shows a benzene ring which exists out of 6 carbon and 6 hydrogen atoms. The basic structure is often simplified visualized as shown on the right (Barbalace, 2003).

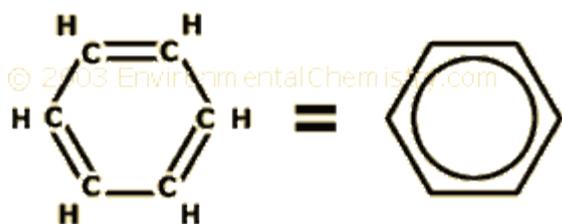


Figure 6 Left: The structural formula of a benzene ring which shows how the 6 carbon and 6 hydrogen atoms are structured. Right: a simplified version of a benzene ring which is often used in illustrations (Barblace, 2003). A special thanks to Barblace for allowing the use of the figure for general reference.

The molecule structure of PAHs varies between two fused benzene rings and structures containing up to 10 rings in total (ATSDR, 1995). Examples on how the molecule structures of PAHs look like can be found in Figure 7 (Zhang, et al., 2012).

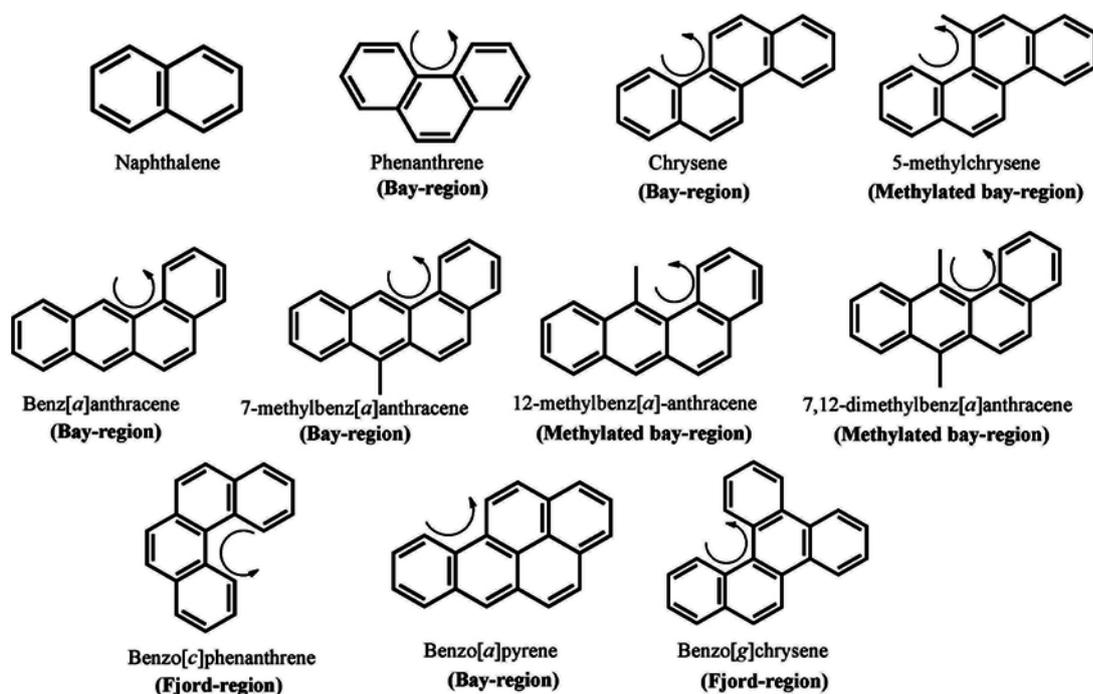


Figure 7 Examples of the molecule structures of PAHs (Zhang, et al., 2012)

There are over 100 different types of PAHs which often occur in complex mixtures and not as singular components. PAHs can be found in a wide range of products as working components such as medicine, dyes, plastics and pesticides but also in substances as crude oil, roofing tar and coal (ATSDR, 1995). There are natural sources of PAHs but human activity has been elevating the levels of PAHs by incinerating processes. Nearly every incineration process produces a mixture of PAHs and all fossil fuels contain PAHs in a certain degree (Neff, 1979).

PAHs in the environment

PAHs can end up in marine systems four different ways. They can be produced by organisms (biogenic), incineration processes (pyrogenic), fossil fuels (petrogenic) and from transformation processes within sediments (diagenic). These processes produce different kinds of PAHs, meaning it could be possible that by looking at the single chemical composition its source can be determined (Neff, 1979).

The ways PAHs can move around in the environment depend on the property of the chemical. Since there is a great variation between the group of PAHs, their ability varies to solve in water or to evaporate. In general, PAHs do not easily solve and are often adsorbed on clay and dust particles; clay particles and silt particles have a higher sorption rate than sand. Sediments which are rich in organic carbon can store more PAHs than sediments which are poor in organic carbon. For example, marshlands retain contaminants, such as anthracene 4 times better than sand. When particles become airborne they can travel for long distances which is proven to be a successful transportation mechanism (ATSDR, 1995).

Toxicology

PAHs are mostly known for their toxicity and for the fact that they slowly break down in the natural environment (OSPAR, 2009). In the natural environment, PAHs break down under the influence of sunlight within days or weeks. In soils and water, the PAHs can break down in weeks or months due to the activity of microorganisms (ATSDR, 1995). Because of the slow breakdown, PAHs bio-concentrate and thus, the concentration of PAHs becomes higher further up in the food chain. Because of their toxicity, OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) has put PAHs in their action plan for reduction of environmental contaminants (OSPAR, 2009).

PAHs is a diverse group of chemicals that contains over a hundred different chemicals and every chemical has an individual effect. Thus, for analysis usually a group of 16 representative PAHs is chosen (Table 1).

Table 1 The 16 representative PAHs. These PAHs were chosen based on the amount information available, toxicity, greater exposer risk and highest abundance (Lerda, 2011).

Acenaphthene	Dibenzo[a,h]anthracene
Acenaphthylene	Phenanthrene
Anthracene	Fluoranthene
Benzo[a]anthracene	Fluorene
Benzo[a]pyrene	Indenol[1,2,3-cd]pyrene
Benzo[fluoranthene	Chrysene
Benzo[ghi]phenylene	Naphthalene
Benzo[k]fluoranthene	Pyrene
Acenaphthene	Dibenzo[a,h]anthracene

The PAHs were chosen was because of the following properties: the information available, their toxicity, the greater risk of exposure to humans, and the risk of exposure from hazardous waste sites where these contaminants were identified at the highest concentrations. The list from Table 1 originates from EPA (United States Environmental Protection Agency) and the sediments of this study were tested for these PAHs. (Lerda, 2011).

Impact on the human body

There are three ways for PAHs to enter the human body. The first way is by inhaling aerosols or particles. The second way is by ingesting contaminated food or water. The third way is by absorption through the skin at direct contact.

Once inside the body, any level of PAHs is significant and detectable amounts can be found in nearly all organs. PAHs are lipophilic (meaning they dissolve in fats) and thus fatty organs can serve as depots that gradually release PAHs. Results from animal studies show that PAHs are not stored in the body for a long time. In addition to this, PAHs can be metabolized by the human body. The results of this process, the metabolites, can be potent mutagens (causing DNA damage) and carcinogens (causing cancer) (ATSDR, 1995). The most significant health effects can be found in the lungs (lung cancer) after inhaling PAHs (Kim, et al., 2013)

Sources

The review paper of Hylland (2006) stated that the main sources of PAHs in the marine environment come from the offshore industry and the smelter industry. It was estimated in 2001 that a total of 184 tons of PAHs were released of which about 50% comes from the smelter industry. Road traffic is also a potential source of PAHs. One car can produce up to 16,8 grams of PAHs per year (Napier, et al., 2008). Run off from roads can end up in aquatic systems where they can have a considerable impact (Lee, et al., 2004).

Possible sources in Flåm

PAHs can enter the marine environment in two different ways: either they are deposited by precipitation and dry deposition, or the particles have been transported by the movement of water (Douben, et al., 2003). Within the Sognefjord the primary threats for the ecosystem are considered to come from hydro power plants, aluminum smelters and cruise ships (Manzetti, 2011). The primary sources of contamination within Flåm would include:

- Urban development
- Industry
- Road use
- Outside sources

In the recent history of the Aurland municipality, of which Flåm is a part of, the population has declined but not changed drastically, from 1.833 people in 2000 to 1.738 in 2015 (City population, 2016). What has changed was the building of tunnels with a total length of 36 km within the Aurland municipality. The leftover material from the tunnel construction was dumped in the Aurlandsfjord. Also, a new cruise ship quay was built in Flåm in 1985. (Manzetti & Stenersen, 2010).

Industry

In 2015, 130 cruise ships visited the harbor of Flåm transporting 180.196 tourists (Cruise Europe, 2015). With a population of 1.738 inhabitants in the entire municipality (City population, 2016), it can be concluded that the tourist industry does have an impact on the area.

A potential source of contamination relates to cruise ships entering the Aurlandsfjord. Due to the shape of the fjord the exhaust gasses cannot easily leave the area. Thus, the area is prone to local smog which also makes it likely that these exhaust gasses make their way into the

fjord (Manzetti & Stenersen, 2010). The exhaust gasses include bromoform, cyanide, naphthalene, fluoranthrene, carbon tetrachloride, and toluene (Loehr, et al., 2006) and gaseous PAHs (PCE, 2003).

Road use

According to literature, car emissions, the wear and tear of tires, and the tearing effect from spiked winter tires on the upper layer of asphalt are sources of PAHs. During rainfall, these contaminants are washed directly from the roads into the fjord (Brown & Peake, 2006). The main attraction in Flåm is the Flåm rail line which attracts many tourists a year (Visit Flam, 2016). About 920.000 tourists took the train in 2015, of which 150.000 came from cruise ships. This means that at least 770.000 tourists came by road (Johnsen & Stedje, 2016). Considering the number of local population, the amount of impact of tourism traffic on the environment seems to be significant but there are no numbers available on the road use in the area.

Outside sources

There are two main ways in which PAHs travel: either the contaminant get transported by air and enter soils/sediments by precipitation or dry deposition or the contaminant travels by water (Douben, et al., 2003). One of the major sources of PAHs is the aluminum smelter industry which also plays a role in the Sognefjord (Manzetti, 2011). One of the aluminum smelters is located in the Årdalsfjord (figure 8).

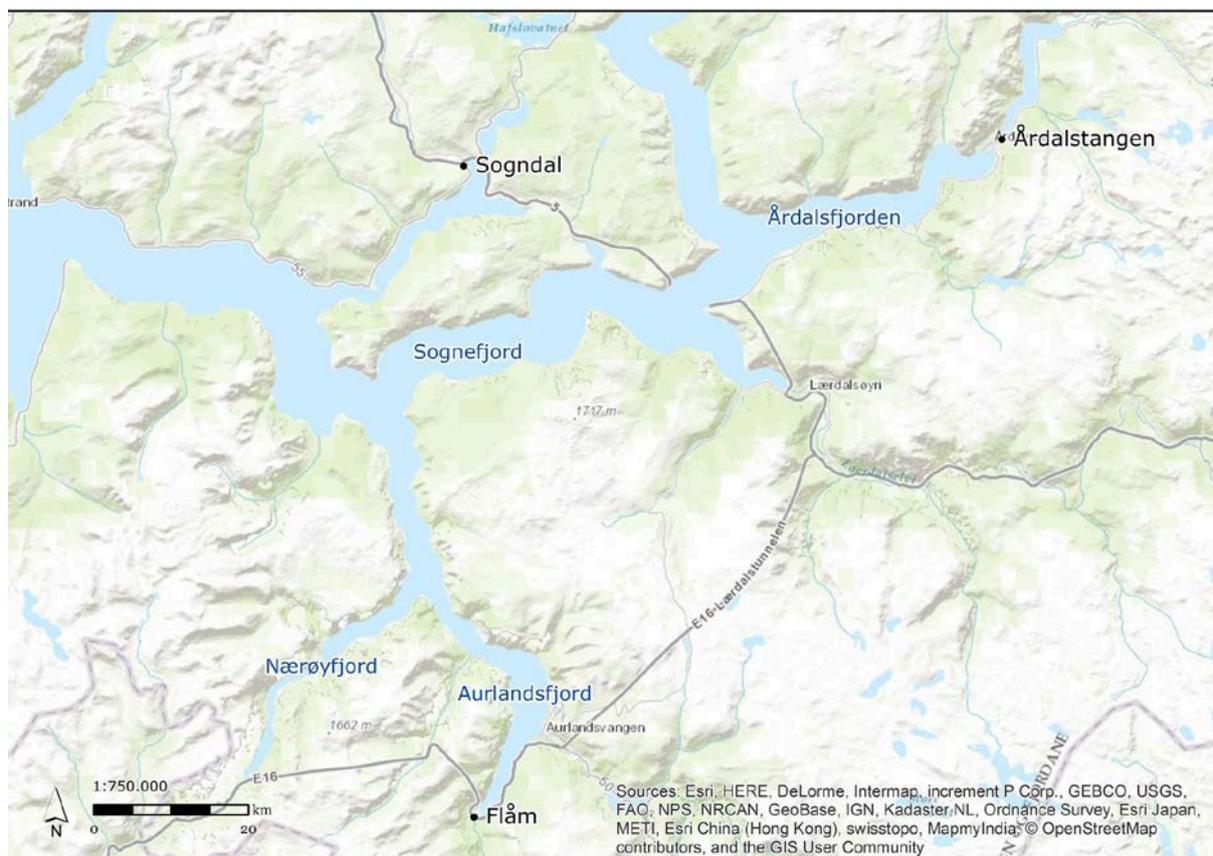


Figure 8 Map area Flåm and Årdal. Map made by using ArcGis 10.2 from ERSI, revised Venneman, (2017c).

Elevated levels of PAH have been documented in the Årdalsfjord in the period from 1980 to 1984. The details of the spreading of these PAHs is still unresolved (Manzetti & Stenersen, 2010). The reason for this could be that fjords act as basins which could lead to an accumulation of PAHs in the sediments; on the other hand, fjord circulation patterns might lead to a widespread transport of contaminants (Manzetti, 2011). The PAHs might thus spread with the fjord current system and end up in different parts of the Sognefjord such as the Aurlandsfjord, which in addition is located relatively nearby (Dale, 2016).

1.8.2 Tributyltin (TBT)

Tributyltin (TBT) was used as an effective antifouling paint for the hulls of ships from the 1960s until the 1980s. TBT rose in popularity due to its cost efficiency when combatting fouling. The reason why TBT is effective, is because it is a toxic and self-polishing paint. The paint exists out of a layer of organotin (active component based on tin) and polymers. The paint is hydrophobic making the paint water resistant and only the outer layer can react with seawater. When the outer layer is used and polished away, the layer underneath becomes exposed, becoming the new outer layer. The process is a continuous chemical reaction which

leads to a constant output of TBT into the environment. Because of the constant output, it became possible for ships to go without repainting for 60 months. The effectiveness and the durability made TBT a popular choice in the 1970s (IMO, 2002). The main downside to TBT is that the toxic components are not only active in the hull but also in the environment. Well known effects of TBT on the environment, is the deformation of oysters (Alzieu, 1991) and imposex in dog whelks (Blabers, 1970)

Toxicology

The danger of TBT can best be summarized in the following quote of Evans (1995): “The most toxic substance ever deliberately introduced into the marine environment”. TBT combats a wide variety of organisms and was used as fungicide, bactericide, insecticide, and as a preserver of wood. The use of TBT as a wood preserver started in the 1950s when it was applied on the hulls of wooden boats and used on high value crops (Woodruff, et al., 2010). TBT is persistent in the food chain and is known to bio-accumulate within organisms (IMO, 2002). TBT is lipophilic and thus bind themselves to organic material instead of staying in the water column. In addition to this, TBT degrades from **tri**-butyltin to **di**-butyltin (DBT) and to **mono**-butyltin (MBT), until tin and organic molecules are left. As TBT degrades, the resulting components are reduced in toxicity compared to the previous product (Maguire, et al., 1983).

Impact on humans

Studies have shown that TBT has an impact on the human body. Shipyard workers who had been exposed to TBT vapors and dust reported skin irritation, breathing problems, flu, headaches, dizziness, fatigue and stomach aches (EPA, 1985). Chronic effects from TBT are not clear. However, it is suggested that prolonged contact can impact the liver and kidneys (Occupational Health Services, 1992).

The impact of TBT in seafood on human health is also difficult to determine. Various studies have been done but the results are inconclusive. The study of Cardwell (1999) revealed that there was TBT in the seafood of the US but estimated that the levels found were not harmful to humans. A different study done by Belfroid (2000) concluded that the average intake of TBT could lead to negative health effects. The main obstacles with these studies are the differences in methods but also in the lack of overall research (Santillo, et al., 2001).

Impact on the environment

The popularity of TBT was mainly due to its effectiveness on keeping antifouling at bay. TBT has severe downsides, though. The use of TBT also affects other species than the intended target species. The effects on non-target species include malformed shells of the oyster species *Crassostrea gigas* (IMO, 2000). The oysters at the west coast of France were impacted by TBT contamination, leading to high mortality in larvae and malformed shells. The malformed shells were unmarketable and it was estimated that between 1979 and 1983 the total loss of revenue was 44 million euros (not corrected for inflation) (Alzieu, 1991). Other example is the imposex of gastropods. It was first observed in the UK in 1970 when the occurrence of imposex of *Nucella lapillus* increased around harbors (Blabers, 1970). The cause was not found at the time. In the 1980s the analytical methods improved and it became possible to connect imposex to TBT (Santillo, et al., 2001).

Banning of TBT

1988 the IMO was asked to consider the legal instruments to restrict the use of TBT on seagoing vessels because of the negative effects of TBT on the environment. In 1998, the use of TBT was restricted with the desire to completely ban the use of TBT on the long term. In the same year, a draft was approved that would completely prohibit the use of TBT (and other organotin compounds) worldwide on January 1st 2008 (IMO, 2002).

Sources

It is well known that TBT comes from anthropogenic sources since it has no known natural sources. TBT has varied uses as it is an effective biocide against a whole range of organisms. Potential sources of TBT are: the textile industry, fishnets, buoys, ships and has industrial appliances in cooling towers and paper mills. The main ways TBT can leak into the environment is by the gradual release of TBT from TBT treated materials, the production of TBT, the appliance of TBT, and the transport and storage of TBT (SEPA, 1999). There is a potential that there are secondary sources as well. These sources include reemission from contaminated locations and disposal sites for dredged material (HELCOM, 2009).

Sources in Flåm

The harbor of Flåm had received 953 port calls between 2009 and 2015 (Cruise Europe, 2015). A potential source of TBT such as shipyards, as seen in Drammen, is not found in the surroundings of the Aurlandsfjord (Ship to Yard, 2017). Since TBT was mostly used as an antifouling on ships (IMO, 2002), the most potential source of TBT within Flåm are the many ships that come and go, including but not limited to cruise ships.

1.8.3 Polychlorinated biphenyls (PCB)

Polychlorinated biphenyls (PCB) is a group of manmade organic chemicals and has, like PAHs, a structure of carbon rings. Every PCB exists out of biphenyl that has been chlorinated to a degree. The basic molecule structure of a PCB can be found in Figure 9. The carbon structure of PCBs is the same but the location and the amount of chlorine can vary. The numbers shown in Figure 9 indicate the location where a hydrogen can be removed and the chlorine can be attached.

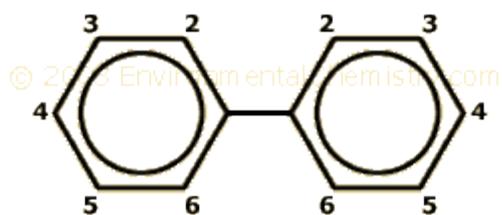


Figure 9 The basic molecule structure of a PCB exists out of 2 fused benzene rings. A PCB contains chlorine and the numbers indicate the possible locations where the chlorine can be attached (Barbalace, 2003) A special thanks to Barblace for allowing the use of the figure for general reference.

PCBs have congeners which means that PCBs have the same molecule formula but have a different chemical formula (Kakareka & Kukharchyk, 2005). PCBs look like oily liquids or solids even though there are some volatile PCBs that exist as a vapor. The color they can have is either none (colorless) or light yellow and have no known taste or smell. PCBs use to have a wide variety of products varying between paint, pesticide extenders, technical applications, metal coatings, and isolators (ATSDR, 2000). Because of these wide appliances, the production of PCBs has been estimated to be around 1.324 million tones between 1930 and 1993 (Breivik, et al., 2002). The use of PCBs has decreased over years, starting with the restriction of use in 1976 by the Helsinki conference (HELCOM, 2001). Over the years, restrictions on the use of PCBs were increased, but they are still produced as an unintentional byproduct in for example paints. Even as a byproduct, PCBs are persistent and can show up in air, water, soil and sediment. The reason for the restriction of PCBs is that PCBs were proven to be toxic and posed a treat for man and environment (Grossman, 2013).

In this study, the sediments were tested for seven PCBs: 8, 52, 101, 118, 153, 138 and 180. These seven PCBs are known as 'PCB₇' or 'ICES-7 PCBs' and are implemented as a

mandatory part of the monitor programs of OSPAR (The Convention for the Protection of the Marine Environment of the North-East Atlantic). The seven PCBs are used as indicators and were recommended by European Union Community Bureau of Reference. The recommendation was based on the abundance in technical mixtures and their wide chlorine range (Webster, et al., 2013).

PCBs in the environment

PCBs belong to a group of chemicals called Persistent Organic Pollutants (POP). The main property of a POP is that they are not biodegradable in the natural environment and thus bioaccumulate. Once volatile, PCBs can travel for long distances and the lighter the chemical, the further it can travel. Because of this, chemicals such as PCBs can cycle between air, soil and water (EPA, 2015). PCBs can enter the environment in five ways (Kakareka & Kukharchyk, 2005):

- Production of PCBs and equipment which contain PCBs
- The use of products containing PCBs
- The utilization of PCBs and the materials that contain PCBs
- Polluted reservoirs
- Thermal processes

Due to the phasing out of PCBs, the production of PCBs is limited but PCBs are still used in closed systems such as cooling fluids. When these closed systems get out of commission, they are either recycled or dumped. When PCBs end up in the environment and change medium, e.g. from soil to water, this medium acts as a secondary PCB source. Finally, PCBs can be created by either chemical process involving carbon and chlorine or an incomplete combustion of a PCB impurity in fuel (Kakareka & Kukharchyk, 2005).

PCBs are non-biodegradable and can exist in all media such as soil, water and organic material. Because PCBs absorb in organic material, they can be found in every component of the environment (Tanabe, 1988). When PCBs arrive into the water column they attach themselves to organic particles allowing them to sediment. This would mean that the sediment acts as a trap for PCBs where the PCBs can accumulate. Various factors influence the distribution of PCBs within the sediment. These factors are: (a) the sources of the PCB; (b) if the sediment is reworked or suspended; (c) the hydrography; (d) physical and biological mixing of the sediment; (e) the chemical properties of the pollutants. PCBs often occur in

combination with other contaminants such as polyaromatic hydrocarbons (PAHs), polychlorinated dibenzofurans (PCDFs), polychlorinated dibenzo-*p*-dioxins (PCDDs), pesticides, and trace metals (National Academy of Sciences, 2001).

The ability to bio-accumulate and degrade depends on the type of chemical. The composition of chemicals in the environment is thus different from the original industrial mixtures (Zell & Ballschmiter, 1980). Generally, PCBs that contain less chlorine are more volatile, dissolve better in water, and are thus more likely to biodegrade. PCBs with a high amount of chlorine are more resilient but also adsorb more to particulate matter. Depending on the structure of the molecule, PCBs can influence the metabolism of animals (National Academy of Sciences, 2001). Considering the toxicity, persistency and the long term impact, PCBs have the potency to be dangerous. Because of this, PCBs, among others, are monitored. In 2012, the Norwegian Institute for Water Research (NIVA) carried out a monitoring program along the coast of Norway, testing for contaminants such as PCBs.

Toxicology

PCBs belong to the group of POPs and are known to be toxic. The toxicology of PCBs is complex since the toxicology varies per chemical. This includes how they interact with the body but also with other toxins. In addition to this, PCBs often occur in mixtures that add to its complexity. Studying the toxicology of singular chemicals may either overestimate or underestimate the impact of the chemical. Instead, two mixtures of PCBs are studied: a mix of commercial PCBs and an experimental mix which represents the chemicals found in breastmilk (ATSDR, 2000).

Impact on the human body

As with PAHs, there are three ways for PCBs to enter the body. The first way is by inhaling aerosols or particles. The second way is by ingesting contaminated food or water. The third way is by absorption in direct contact with skin. The other similarity with PAHs is that PCBs have an affinity to fatty substances. PCBs tend to accumulate in fatty tissues such as the liver and in breastmilk (ATSDR, 2000). The main influence of PCBs on the human body lies in PCBs influencing the hormone system. PCBs cause simulation and stimulation of hormones in organs such as the gut, skin, kidneys and lungs. The change of hormones leads to a changed metabolism that can cause secondary diseases and interfere with medical therapy. PCBs have a low potential of causing acute effects (Letz, G, 1983) and no study reports acute lethality by exposure. The group of PCB₇ can have negative effects on the human body. It can effects the

immune system, reproduction, hormone system, gastrointestinal system and metabolism (ATSDR, 2000).

In the past, there were cases of humans being poisoned by PCBs. One of the most notable cases was the Yusho incident where PCBs were consumed through contaminated fish and other products. These products were heated, resulting in relatively high concentrations of a PCB mixture. The mixture contained another type chemical, chlorinated dibenzofurans (CDFs). It was suspected that the CDFs were the main contributor of the health effects though it is suggested that certain PCBs act in a similar manner. The effect of other PCBs are subtler (ATSDR, 2000). The poisonings showed that the PCB mixture affects the gastrointestinal system in a wide variety. Loss of appetite, intolerance to fatty food and weight loss were reported at the Yusho incident. Other effects reported at the Yusho incident were: cancer, increased respiratory problems, liver problems, problems within urogenital system, skin problems such as chloracne, alternation in the immune system, neurophysiological effects, negative impacts on male and female reproduction and negative effects on newborns (ATSDR, 2000).

Sources

There are various ways that PCBs can enter the environment: By the production, the leakage of PCBs from products containing PCBs, reemission from contaminated waste sites and as a product of thermal processes. The greatest potential source of PCBs is seen as electrical equipment. An example of this was that APARG (1995) that 90% of the PCBs from the UK came from leaks from transformers, capacitors and fragmentizing operations. Other sources include incineration of waste and metal smelters. These numbers should be used as an indication, not as absolute facts (Kakareka & Kukharchyk, 2005).

Possible sources in Flåm

The greatest potential sources of PCBs are not apparent in Flåm, i.e. old electrical equipment and incineration. Cruise ships are not allowed to burn waste within the fjords (Mattilsynet, 2011) and no waste disposal sites are located in Aurland (Stedje, 2016). The other potential source for PCBs, the aluminum smelter in Årdal, was not tested for PCBs and thus no information is available (NIVA, 2011). The Aurlandsfjord area contains none of the sources which were identified by literature. Considering the toxicity, persistency and the long-term impact it was still considered to be relevant in this study.

1.8.4 Inorganic pollutants

The testing in Flåm also included the analysis of inorganic contaminants. The contaminants sampled can be found in Table 2. The contaminants can be classified into 2 groups: heavy metals and metalloids. According to Kibria et. Al. (2010) the group heavy metals is defined by their atomic weight (> 20) and similar electron distribution. A metalloid has properties of metals and non-metals. Metalloids such as arsenic and silicone behave as semiconductor which means that they can carry an electrical charge (Elemental Matter, 2017). From here onward the group of inorganic contaminants, including Arsenic, will be referred to as ‘heavy metals’.

Table 2 List with all inorganic contaminants tested. Nearly all of the analyzed inorganic contaminants can be qualified as heavy metals (Kibria, Haroon, Nugegoda, & Rose, 2010) with the only exception of arsenic (Bentor, 2012).

Arsenic	Metalloids	lead	Heavy metal
Copper	Heavy metal	Chromium	Heavy metal
Zinc	Heavy metal	Mercury	Heavy metal
Cadmium	Heavy metal	Nickel	Heavy metal

Heavy metal can appear naturally in freshwater and marine ecosystems in low and non-hazardous concentrations. Human activities such as industry, agriculture and acid rain are contributors to the increase of these chemicals in the environment (Ansari, et al., 2004). The major industries that contribute to the release of heavy metals in the environment include coal burning, petroleum combustion, nuclear power stations, high power lines, plastics and paper production plants (Tchounwou, et al., 2012).

Not all the heavy metals that were sampled are inheritably dangerous. Heavy metals such as copper and zinc are essential for the metabolism of organisms but become toxic when meeting certain thresholds. Other metals such as lead and cadmium have no biological function and thus provide no benefit (Ansari, et al., 2004).

Toxicology

The main issue with the heavy metals and metalloids that were tested is the fact that they accumulate within organisms. The higher the organisms occur in the food chain, the higher

the metal concentrations become and thus the more dangerous the metals are. As a result, the analyzed heavy metals are known to cause human health hazards (Ansari, et al., 2004). How dangerous heavy metals are depends on a complex set of various factors. These factors include (but not exclude) influences such as the type of exposure, oxidation, solvability, dose, duration, species, age and gender (Tchounwou, et al., 2012). There are also different biological factors which determine the influence of heavy metals on species. These factors include: trophic levels, and the ability to adapt to changes in the physical and chemical environment (Verkleji, 1997). It is important to note that every metal has unique features and a chemical signature that makes the impact of them different from the other (Tchounwou, et al., 2012).

Many studies have been performed on the impact of heavy metals on humans. In general, heavy metals influence the workings within a cell. They can interfere with DNA and proteins within cells which could influence the inner workings of the cells. Arsenic, lead, mercury, chromium and cadmium are known to cause damage to multiple organs even when lower amounts are applied (Tchounwou, et al., 2012). Studies were done on the priority heavy metals which are arsenic (Tchounwou, et al., 2004; Yedjou & Tchounwou, 2006; Yedjou & Tchounwou, 2007), lead (Yedjou & Tchounwou, 2008; Tchounwou, et al., 2004), mercury (Sutton & Tchounwou, 2007; Sutton, et al., 2002), cadmium (Tchounwou, et al., 2001), and chromium (Patlolla, et al., 2009; Patlolla, et al., 2009b) .

Heavy metals become toxic when they enter cells within organisms. The metals can enter bodies of aquatic animals in different ways (Solomon, 2008):

- By skin and gills
- Eating contaminated sediments and drinking contaminated water
- Eating contaminated food

There are similar pathways for heavy metals to enter the human body. This can be through the skin and lungs, drinking contaminated water and eating contaminated food (Solomon, 2008). Once heavy metals are within the body, they interact with the cells of the organism and become toxic. The toxic material affects various organelles of the cells, and they affect some enzymes which are involved in metabolism, detoxification and damage repair (Wang & Shi, 2001). In addition to this, heavy metals such as lead and cadmium have a half-life time of 20

years within the human body. Because of this, the human body is not able to get fully rid of these materials (Solomon, 2008).

The reason why these metals are so dangerous, is because they produce reactive oxygen within cells (Tchounwou, et al., 2012). The production of reactive oxygen within cells causes oxidative stress, which is an imbalance between reactive oxygen and the ability of the body to recover from this. Oxidative stress can be the cause of many different disorders such as Parkinson's disease and Alzheimer's disease, gene mutations, cancer, heart and blood disorders, heart failure, and heart attacks (Mandal, 2015).

Copper is, like the heavy metals, dangerous to aquatic life. It has proven itself to be a potent antifouling and is one of the most toxic metals to aquatic organisms and ecosystems (Solomon, 2009). Copper negatively affects growth, reproduction and alters the blood chemistry, enzyme activity, brain function and the metabolism of organisms (EPA, 2016). What is important to state, is that algae are 1.000 times more sensitive to the effects of copper than mammals (Solomon, 2009).

Impact on the environment

As stated before, trace metals have unique features and chemical behavior (Tchounwou, et al., 2012). The impact of heavy metals within ecosystems can be wide since the entire ecosystem is targeted. The biggest impacts of heavy metals can be expected in the higher trophic levels, even if the metal is not found in the water column. Mercury is a heavy metal that biomagnifies (Wren, et al., 1983) and the older organisms such as fish get, the more they accumulate. The impact of mercury poisoning is a decreased number of hatchlings in fish, waterfowl and bird eggs, which can cause major changes within ecosystems. A common impact of heavy metals on the environment is that there are negative effects on individuals and populations that negatively impact the ecosystem. The type of impact would depend on the exact heavy metal in the system (Solomon, 2008).

Copper has a different impact on the environment than heavy metals have. Copper is used as an antifouling, and blue-green algae species are especially sensitive (Wright & Welbourn, 2002). Copper attacks the gills of aquatic life forms which causes problem with their osmotic regulation. In addition to this, copper has the potential to reduce the sense of smell of fishes by 50%, which could strongly impact the behavior of fish. Other impacts on their behavior

include: altering of swimming, change in migration, and an altering of the brain in addition to acute lethality (Woody & O'Neill, 2012).

Sources

Heavy metals can have natural as anthropogenic causes. However, heavy metal contamination is most common around point source areas such as mining, foundries and smelters, and other metal-based industrial operations. Other sources come from agriculture, metal corrosion, domestic use, resuspension, volcanic activity, combustion, plastic manufacture, textiles, microelectronics, wood preservation and paper processing plants (Tchounwou, et al., 2012).

Sources within Flåm

Within the Aurland community there are many possibilities of heavy metals leaking into the marine system, although the local population of the Aurland municipality does not exceed the number of 2.000 in 2015 (City population, 2016). The tourist industry attracts many tourists to the community: in 2015, a total of 920.000 tourists visited the Flåm railway of which 150.000 came from cruise ships (Stedje, 2016).

Sewage

A potential source of heavy metals within Flåm is related to sewage. Untreated sewage is problematic because the nutrients within the sewage can disturb ecosystems and the sewage is related to increased concentrations of the heavy metals cadmium, lead, chrome and copper (Manzetti & Stenersen, 2010).

Cruise ships

Combustion also represents a possible source of heavy metals (Tchounwou, et al., 2012) meaning that the cruise ships entering Flåm could be a major source of heavy metals. Since 2000, the Flåm cruise harbor has received 2.301 port calls and because to the shape of the fjord the exhaust gasses cannot easily leave the area (Manzetti & Stenersen, 2010). This would imply that the exhaust gasses would stay in the fjord and the heavy metals could precipitate in the area.

Antifouling

Copper has been used to replace TBT as antifouling. Though copper is toxic to the environment when it occurs in excess, it is considered to be 1.000 times less harmful than TBT (IMO, 2002). This is not in line with the SFT (Norwegian Pollution Control Authority)

(2007) which states that pollution at copper starts at 55 mg/kg and TBT at 0,00016 mg/kg. The implication of this is that TBT becomes dangerous 343.000 times lower than copper.

Since 2000, over 2.301 cruise ships have entered the Cruise Ship Harbor of Flåm (Stedje, 2017) In addition to this, there is also a marina for leisure ships (Aurland Havn, 2017). This could also make a significant contribution to the amount of copper in the area.

Road use

Combustion from cars would also release heavy metals (Tchounwou, et al., 2012), making the traffic in the Aurlandsfjord a potential source. In addition to this, and in a similar way as PAHs, the wear and tear of tires and the upper layer of asphalt also releases heavy metals. During rainfall, these contaminants are washed away and can end up in estuarine systems. The main metals released are: copper, lead and zinc (Brown & Peake, 2006).

Outside sources

A potential outside source of heavy metals is the aluminum smelter in Årdal (Tchounwou, et al., 2012). NIVA (2011) has tested the sediments and the local fauna for Arsenic, cadmium, chrome, copper nickel, lead, zinc, mercury, cobalt, molybdenum and vanadium. The results were that the heavy metal concentrations decrease with increasing distance from the point source. As with the PAHs, it is possible that heavy metals were transported with the current into the Aurlandsfjord (Dale, 2016).

2 Material and methods

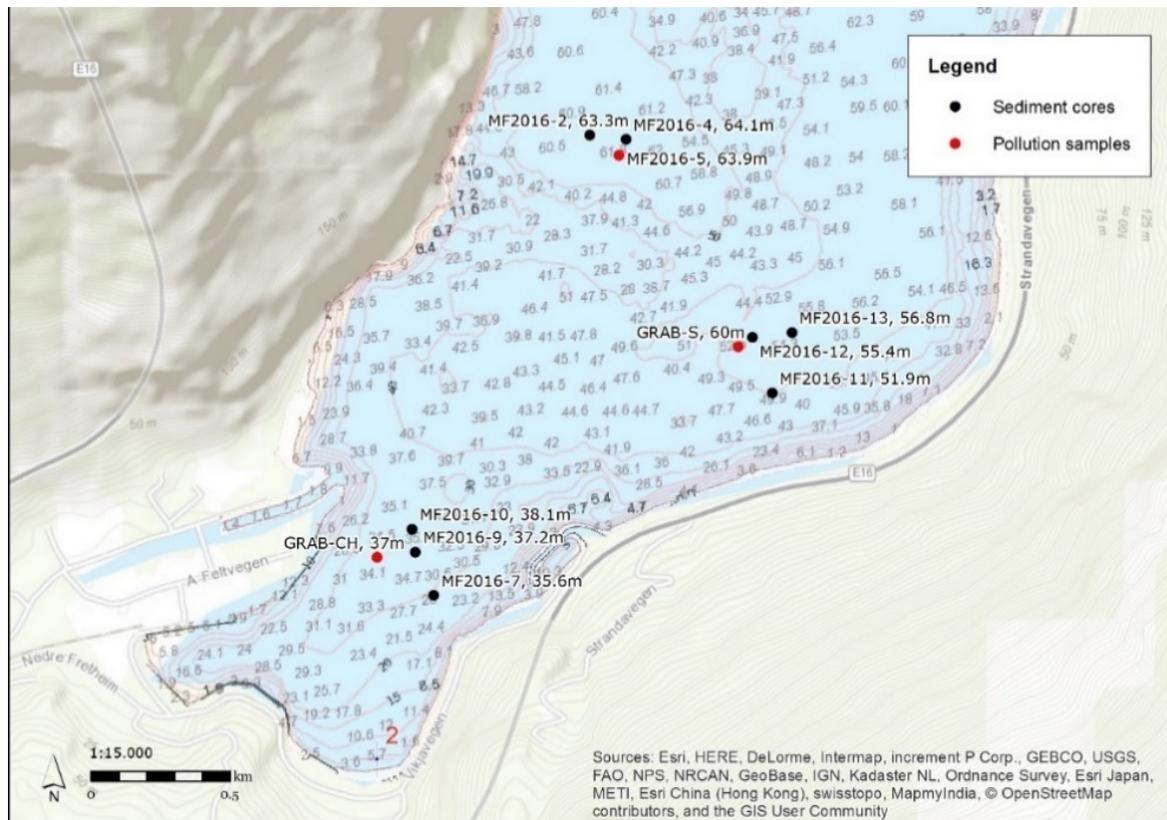
2.1 Field methods

The coordinates of the samples, together with the depths of the subsamples can be found in Table 3.

Table 3 Locations at which the samples tested for contaminants were taken are indicated in. The contamination samples (indicated in red) also show the depth of the subsamples. The location of the samples in degrees and minutes.

Location	Station No.	Longitude E		Latitude N		Water depth (m)	Sub-sample Shallow (cm)	Sub-sample Deep (cm)
		Degrees	Minutes	Degrees	Minutes			
Cruise Harbor basin	MF2016-7	7	7,415	60	51,809	35,6		
	MF2016-9	7	7,379	60	51,850	37,2		
	MF2016-10	7	7,373	60	51,872	38,1		
	GRAB	7	7,305	60	51,845	37,0	0 - 2	8 - 10
Stampa	MF2016-11	7	8,070	60	52,001	51,9		
	MF2016-12	7	8,032	60	52,054	55,4		
	MF2016-13	7	8,109	60	52,057	56,8		
	GRAB	7	8,005	60	52,045	60,0	0 - 2	8 - 10
Kistadypet	MF2016-2	7	7,717	60	52,246	63,3		
	MF2016-4	7	7,787	60	52,242	64,1		
	MF2016-5	7	7,774	60	52,227	63,9	0 - 7	7 - 13,5

The Kistadypet sample is located about 1.3 km north of Flåm, the Stampa sample about 1.0 km north east of Flåm, and the Cruise Ship Harbor sample about 0.4 km north of Flåm.



Aurland is located 6.5 km north of Flåm (Figure 10).

Figure 10 Map of the locations where the samples were taken. The red dots indicate the location of where the samples tested for contaminants were taken. The black dots show the locations of where the samples were taken for the background information. The samples which have the MF2016 labels indicate Niemistö (1974) gravity cores and the samples with the ‘GRAB’ label were taken with a van Veen (1933) grab. GRAB-CH stands for grab sample taken at Cruise Ship Harbor and GRAP-S stands for grab sample taken at Stampa. The equidistance between red water depth lines is five meter. Map made by using ArcGis 10.2 (ERSI 2017b), revised by Venneman, E (2017).

Every sample has two subsamples and the subsamples weighted 700 grams each. The samples were taken using two different sediment samplers: a modified Van Veen (1933) grab and a modified Niemistö (1974) gravity corer. The grab can sample a maximum volume of 0,2 m², and the gravity corer had a maximum penetration depth of 70 cm and a core diameter of 6,7 cm. The surface sediment subsamples were taken in the field from 0 to 2 cm sediment depth and the deep sediment subsamples from 8 to 10 cm sediment depth. In Kistadypet a sediment

core was used to collect the samples tested for contaminants due to technical issues. Subsamples were taken between 0 to 7 cm and 7 to 13,5 cm. The reason why these subsamples deviate from the subsamples take from the grab sample, is because the grab sample contained more material which made it easier to collect 700 grams of material between 0 – 2 cm and 8 – 10 cm.

In addition to this, three gravity cores of 20 cm sediment recovery were taken at the same locations and investigated for grain sizes, particulate organic and particulate inorganic matter, foraminifera, diatoms, redox, and element chemistry. These investigations are further explained and interpreted by the Bachelor theses of Mulelid et al. (2017) and Midttømme et al. (2017).

The thesis at hand will focus on the possible sediment pollution. The locations in which the samples were taken, are shown in Figure 10. On the map, black dots represent the samples which were taken to provide background data. The red dots represent the locations where the samples tested for contaminants were taken. The samples were taken in the Cruise harbor at 37m, in the Kistadypet at 60m and at Stampa at 60m water depth.

2.2 Laboratory methods

2.2.1 Subsamples laboratory

The pollution subsamples of the Cruise Ship Harbor and at Stampa were taken directly from the box corer in the field, while the pollution subsamples at Kistadypet were taken after opening the gravity in the laboratory. The gravity core was opened in the laboratory and sliced into two halves. From one of these halves subsamples were taken from 0 to 7 cm and from 7 to 13,5 cm. The larger subsample thickness of 7 cm (compared to 2 cm of the box cores) is explained by the small diameter of the gravity core and the comparably high amount (700 g) of material needed for the chemical analyses.

2.2.2 Chemical analyses

Organic and inorganic contaminants were analyzed using the PMM 57 contaminant package at Eurofins (Eurofins, 2016). For the chemical analyses the amount of 700g wet sediment was needed. Table 4 summarizes the contaminants included in the PMM57 package.

Table 4 Contaminants tested by Eurofins according to package PMM 57

Contaminants of the PMM57 package at Eurofins	
Copper (Cu)	
Chromium (Cr)	
Nickel (Ni)	
Zinc (Zn)	
Mercury (Hg)	
Cadmium (Cd)	
Lead (Pb)	
Arsenic (As)	
Tributyltin (TBT)	
PCB 7	PCB 28
	PCB 52
	PCB 101
	PCB 118
	PCB 153
	PCB 138
	PCB 180
PAH 16	Acenaphthene
	Acenaphthylene
	Anthracene
	Benzo[a]anthracene
	Benzo[a]pyrene
	Benzo[fluoranthene
	Benzo[ghi]phenylene
	Benzo[k]fluoranthene
	Dibenzo[a,h]anthracene
	Phenanthrene
	Fluoranthene
	Fluorene
	Indenol[1,2,3-cd]pyrene
	Chrysene
	Naphthalene
	Pyrene

Eurofins has used three different techniques to analyze the samples (Table 5). The PAHs, PCBs and TBT were analyzed using a Gas Chromatography Mass Spectrometry analysis (GC-MS). The heavy metals were analyzed by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and CV-AFS (cold vapor atomic absorption spectroscopy) was used for mercury (Lundberg, 2016).

Table 5 Contaminant groups which were tested, including the techniques used to measure the contamination concentration in the samples and the limit of quantification (Eurofins, 2016b)

Analyzed group	contaminant	Analyze technique used	Limit quantification	of Method
PAH		GC-MS	0.01mg/kg	ISO 18287
PCB		GC-MS	0.0005mg/kg	ISO 16167
TBT		GC-MS	1 µg/kg	Internal Standard
Inorganic metals		ICP-MS	Cu 0,5 mg/kg	ISO 11885
			Cr 0,3 mg/kg	ISO 11885
			Ni 0,5 mg/kg	ISO 11885
			Zn 2 mg/kg	ISO 11885
			Cd 0,01 mg/kg	ISO 17294-2
			Pd 0,5 mg/kg	ISO 17294-2
			As 0,5 mg/kg	ISO 17294-2
Mercury		CV-AFS	0.001mg/kg	ISO 12846

Gas Chromatography Mass Spectrometry analysis (*GC-MS*)

Gas Chromatography Mass Spectrometry analysis exists out of gas chromatography (GC) which is coupled to mass spectrometry (MS). During the gas chromatography, the sample is first volatilized and then led through a capillary column by using a carrier gas (EAG, 2016). The capillary column is a narrow tube with a coating which is used to separate the components. The components are separated by how fast the volatile sample reacts with the coating. When components react with the coating they are slowed down and the sample is separated as different compounds travel at a different speed (Steele, 2015). After the compounds leave the gas chromatograph, they are fragmented by electron impact (EAG, 2016). The results of the mass spectrometry analysis were given as the time the component takes to pass through the column of the gas chromatograph. The time used is called ‘retention time’ and can be used to identify components (EAG, 2016).

The mass spectrometry analysis was applied after the gas chromatography by fragmenting the produced compounds (EAG, 2016). The result of the fragmentation include charged fragments which can be detected and are used to identify the compounds. The MS measures the ratio between mass of the mass of the molecule and the charge of the fragment (Waters, 2017). Compounds such as certain PAHs are more difficult to separate in GC columns because they show the same mass fragmentation. These PAH pairs can still be identified due to the different resident time of each compound (Kuipers, et al., 2010). Chromatograms visualize the results of the MS which allow the identification of the compounds, even in complex mixtures (Robbat, et al., 1999)

Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Inductively Coupled Plasma Mass Spectrometry is an analyze technique used to determine the elements in a sample. The analysis is divided into two parts which are connected to each other and exists out of the inductively coupled plasma and mass spectrometry (USGS, 2013). The inductively coupled plasma analysis (ICP) is performed by placing a solution into a core of argon plasma. Argon plasma is extremely hot (~8.726 °C) and is used to evaporate and ionize the solution. The ions are then led to a mass spectrometer where the sample is analyzed. Mass spectrometry uses the products of the ICP, performing elemental as well as isotopic analysis on the ions. ICP-MS has a high sensitivity for a wide range of elements (AEG, 2016).

The Cold Vapor Atomic Absorption Spectroscopy Analysis (CV-AAS)

The Cold Vapor Atomic Absorption Spectroscopy analysis is one of the primary techniques used for analyzing mercury. Mercury is known to be volatile, even at room temperature, meaning that furnace techniques are not recommended for measuring mercury. The CV-AAS makes use of the volatility of mercury. To use the CV-AAS, the sample is first put in an acid solution containing stannous chloride (SnCl_2). The stannous chloride causes the mercury to become volatile and a carrying gas helps to release the vapor. The mercury vapor is then led to an optical sensor because mercury absorbs light of 253.7 nm in logarithmic proportion to the actual concentration. The amount of mercury in a sample is then calculated by using the appropriate software (Seibel, 2016).

2.2.3 Dating

Fjord sediments record the impact of natural and human induced events. To recognize these events, the sediment must accumulate undisturbed and *in situ*. If identified in the sediment,

events like historically documented floods, landslides or slumps can be used as dating horizons, as illustrated in Norwegian fjords by e.g. Paetzel & Schrader (1992). In this way, sedimentation rates can be acquired.

A more common method to determine sedimentation rates is dating the sediment using radiometric dating methods or radiometric markers. The mostly used radiometric dating method is the ^{210}Pb dating method, first used in lake sediments by Koide et al. (1972).

An example of a well-known radiometric marker is the ^{137}Cs radioactive isotope released by the fallout of the accident of Chernobyl in 1986 (first used in Norwegian fjords by Paetzel & Schrader, 1991) and the fallout from the world wide nuclear bomb testing in 1959 and 1963 (first used in lake sediments by Pennington et al. 1973).

Dating the sediments of the Aurlandsfjord

It was the ambition to date the Aurlandsfjord sediments using a combination of the ^{210}Pb dating method, the ^{137}Cs radiometric markers, and event dating. Due to technical problems, this ambition could not be met. Only the event dating was performed in the Aurlandsfjord sediments using the impact of environmental events that took place around Flåm. Possible candidates for the event dating are the completion of the Cruise Ship Harbor in 1985 (Stedje, 2016) and the expected sediment record of the century flood of 2014. Such events are supposed to have left characteristic traces in the sediment record that are useful as dating horizons. Sediment gravity cores and grab samples of the Kistadypet and the Cruise Ship Harbor offer the opportunity of analyzing such events. Core-to-core correlation of recorded events would increase the quality of the event dating, at least within sediments recovered at the same location.

The radiometric dating will still be performed and the results are expected in August 2017. The radiometric dating is expected to confirm the findings of the event dating.

2.3 Interviews

A series of unstructured interviews were held to interpret the results of the contamination with regard to their possible sources, e.g. the cruise ship tourism. The interviews were held with Erling Oppheim, managing director of Nærøyfjord world heritage park, John Erik Johnsen, port manager, and Jon Olav Stedje, Assistant Port Manager. The interview with Erling Oppheim was held in person and the interview with John Erik Johnsen and Jon Olav Stedje was held by Skype due to unforeseen circumstances with transportation. In addition to interviews, there

was an exchange of E-mails with Tormod Selen Lundberg, now former Eurofins employee, Jon Olav Stedje and Tobjorn Dale, marine biologist. Their names were used in correspondence with the said people.

Unstructured interviews are a method to gather qualitative data and allows the responded to elaborate on the addressed topics. The responders all had the same interview questions which allowed a deeper understanding of the perspective of the responded (McLeod, 2014). The questions which were used and the answers that were given can be found in Appendix A.

3 Results

3.1 The social setting in Flåm

There are different strategies in place to decrease the impact of tourism on the environment within the UNESCO World Heritage Site of the “Western Norwegian Fjords”. According to the harbor authorities, there is a maximum amount of 5.000 cruise ship tourists allowed to visit Flåm per day. Still, 920.000 tourists took the train of the Flåmsbanen in 2016. In addition to this, there is a cruise ship season of six months that starts in March and ends in September meaning that the potential impact is spread over half a year. The sewage of cruise ships is not an issue within Flåm because cruise ships are not allowed to dump their sewage in the fjords. They are only allowed to discharge their sewage 12 nautical miles from the nearest land or to deliver it to the harbor authorities. However, according to the UNESCO site manager no holistic management plan available.

According to the UNESCO site manager, the perception of pristinity is the main asset of the heritage site. He considers the main threats are the visual pollution such as smog and the sewage released into the fjords by the small boats. The issue of the air pollution is addressed by the harbor authorities. In the UNESCO area, the limit of 0,1% sulfur is also enforced and in addition to this, LNG (Liquid Natural gas) ships are being promoted to improve the environmental friendliness (Johnsen & Stedje, 2016). LNG has the advantage that it emits hardly any particulate matter, less emissions and thus a cleaner fuel (LNG for Shipping, 2015) Another threat according to the site manager site lies in the livability of the site. It should not be forgotten that the site is the home of people and should be preserved for future generations as well.

3.2 Contaminants

The results of the samples tested for contaminants taken in cruise ship harbor, Stampa and Kistadypet are given in Table 6, 7, 8 and 9 and can also be found in Appendix B. The tables were separated by the contaminant type and will be discussed separately. In addition to this, the tables contain the amount of the contaminant and the samples and subsamples taken at the

various locations. The individual cells are colored and colors used in the table are the same colors as used in the Norwegian sediment contaminant classification scheme (Figure 11) of 2016 (Miljødirektoratet, 2016) to indicate the degree of contamination in natural coastal and marine environments. The concentration of contaminants is given in amount of contaminant/dry weight sediment.

I Background	II Good	III Moderate	IV Bad	V Very bad
Background levels	No toxic effects	Toxic effects following chronic exposure	Toxic effects following short term exposure	Severe acute toxic effects

Figure 11 The contaminant classification for seawater and sediments in Norway (Miljødirektoratet, 2016).

3.2.1 Inorganic contaminants

Table 6 shows that all analyzed inorganic contaminants. All contaminants except arsenic, lead and zinc have a concentration at background levels. The elevated levels of Arsenic fall into the “good” Class were only found in the shallow subsample of Stampa. Lead and Zinc concentrations were found in the “good” Class in both the Stampa and the Kistadypet samples (Miljødirektoratet, 2016). There is no major difference or trend visible between the deep samples and the shallow samples.

Table 6 The concentrations of inorganic contaminants were given in mg/kg of each sub sample. The colors and categorizing in the table are according to the classification system for seawater and sediments (Miljødirektoratet, 2016).

Contaminants tested for	Cruise harbor shallow	Cruise harbor deep	Stampa shallow	Stampa deep	Kistadypet shallow	Kistadypet deep
Arsenic (As) (mg/kg)	17	13	18	14	14	14
Cadmium (Cd) (mg/kg)	0,130	0,200	0,140	0,095	0,220	0,160
Chromium (Cr) (mg/kg)	28	29	30	31	30	34
Copper (Cu) (mg/kg)	58	49	61	56	71	58
Mercury (Hg) (mg/kg)	0,026	0,030	0,028	0,033	0,045	0,048
Nickel (Ni) (mg/kg)	35	36	40	41	39	40
Lead (Pb) (mg/kg)	22	20	26	26	25	29
Zinc (Zn) (mg/kg)	130	120	140	140	140	140

3.2.2 PCBs

No PCBs were detected in the sediment subsamples which can be seen in Table 7.

Table 7 PCBs which were tested in the sediment samples. N.D. indicates “Not Detected”.

Contaminants tested for	Cruise harbor shallow	Cruise harbor deep	Stampa shallow	Stampa deep	Kistadypet shallow	Kistadypet deep
Σ 7 PCB (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 28 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 52 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 101 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 118 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 153 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 138 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
PCB 180 (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

3.2.3 PAHs

The results of the PAH compounds can be found in Table 8. The results show that nine out of sixteen contaminants were found at concentrations above background levels. All the contaminants which were above background level fell into the ‘good’ Class (Miljødirektoratet, 2016).

The Cruise Ship Harbor contained the most contaminants, but according to the classification of SFT (2007) the total sum of PAH (16) falls into the ‘good’ Class in both the deep and the shallow subsample. In the Kistadypet there is a notable difference between the sum of PAH (16) in the deep and shallow samples but the levels are below background. Though both

concentrations are classified as background values, the shallow sample is at 180 µg/kg whereas the deep sample shows noticeably higher concentrations at 280 µg/kg. At Stampa, the PAH concentrations stay at about the same level at the surface and at depth.

Table 8 The number of PAHs given in µg/kg of each subsample. The colors and categorizing in the table are according to the classification system for seawater and sediments (Miljødirektoratet, 2016). * ΣPAH (16) was categorized by using SFT (2007).

Contaminants tested for	Cruise harbor shallow	Cruise harbor deep	Stampa shallow	Stampa deep	Kistadypet shallow	Kistadypet deep
ΣPAH(16)* (µg/kg)	380	390	130	140	180	280
Acenaphthene (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Acenaphthylene (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Anthracene (µg/kg)	12	N.D.	N.D.	N.D.	N.D.	N.D.
Benzo[a]anthracene (µg/kg)	33	28	10	11	12	18
Benzo[a]pyrene (µg/kg)	35	36	14	15	13	27
Benzo[fluoranthene] (µg/kg)	41	44	19	24	20	40
Benzo[ghi]phenylene (µg/kg)	32	33	14	21	14	38
Benzo[k]fluoranthene (µg/kg)	12	12	N.D.	N.D.	N.D.	N.D.
Dibenzo[a,h]anthracene (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Phenanthrene (µg/kg)	15	15	N.D.	N.D.	11	15
Fluoranthene (µg/kg)	73	75	28	29	45	51
Fluorene (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Indenol[1,2,3-cd]pyrene (µg/kg)	45	58	14	20	17	32
Chrysene (µg/kg)	27	21	11	N.D.	13	17
Naphthalene (µg/kg)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Pyrene (µg/kg)	56	66	22	21	33	44

3.2.4 TBT

TBT was only found in the Cruise Ship Harbor samples as can be seen in Table 9. The amount of TBT found in both shallow and deep samples fall into the Class V ‘Very bad’ and have thus acute and severe toxic effects on the environment. For this reason, the sediments in the Cruise Ship Harbor are considered polluted (Miljødirektoratet, 2016).

Table 9 The deep and shallow samples of the Cruise Ship Harbor contain amounts of TBT which fall in the Class V ‘Very bad’. For this reason, the cruise harbor sediments are considered polluted (Miljødirektoratet, 2016).

Contaminants tested for	Cruise harbor shallow	Cruise harbor deep	Stampa shallow	Stampa deep	Kistadypet shallow	Kistadypet deep
TBT (µg/kg)	3,2	5,6	N.D.	N.D.	N.D.	N.D.

3.3 The sediment record as basis for the dating

In order to place the results from the contaminants into context, it is important to date the sediments. A sedimentation dating provides an estimate on when the contaminants found in the subsamples entered the environment. This would show if banning of contaminant had effect or not.

The ambition was to date the Flåm harbor sediments using radiometric dating. The radioactive isotopes used would have been ^{210}Pb dating method, and the recognition of radioactive events in the sediments (e.g. ^{137}Cs released by the Chernobyl accident in 1986). However, due to instrumental problems of the dating laboratory, the radiometric dating will not proceed before August 2017. As an alternative, this thesis uses the sediment record of regional events to estimate the timeframe of the deposition as earlier suggested. Examples of event datings can be found in Paetzel & Schrader (1991) and Paetzel & Dale (2010).. A confirmation of this event dating is expected by the radiometric dating carried out beyond this thesis later in 2017.

For raw data, please refer to the Bachelor theses of Midttømme et al. (2017) and Mulelid et al. (2017). Midttømme et al. (2017) and Mulelid et al investigated the sediment record of the Flåm harbor for particulate inorganic and organic matter, microorganisms (diatom and foraminifera), organic matter (LOI), redox potential, magnetic susceptibility, and element geochemistry (XRD). In the following, the sediment analyses were interpreted for both Cruise Ship Harbor and Kistadypet.

3.3.1 The sediment parameters of the Cruise Ship Harbor

The Cruise Ship Harbor sediments of cores MF2016-9 and MF2016-10 revealed significant changes in sediment parameter composition at around 8 to 9 cm sediment depth. Figure 12 indicates the sediment record of the benthic foraminifera, the general freshwater diatom species, and the redox conditions.

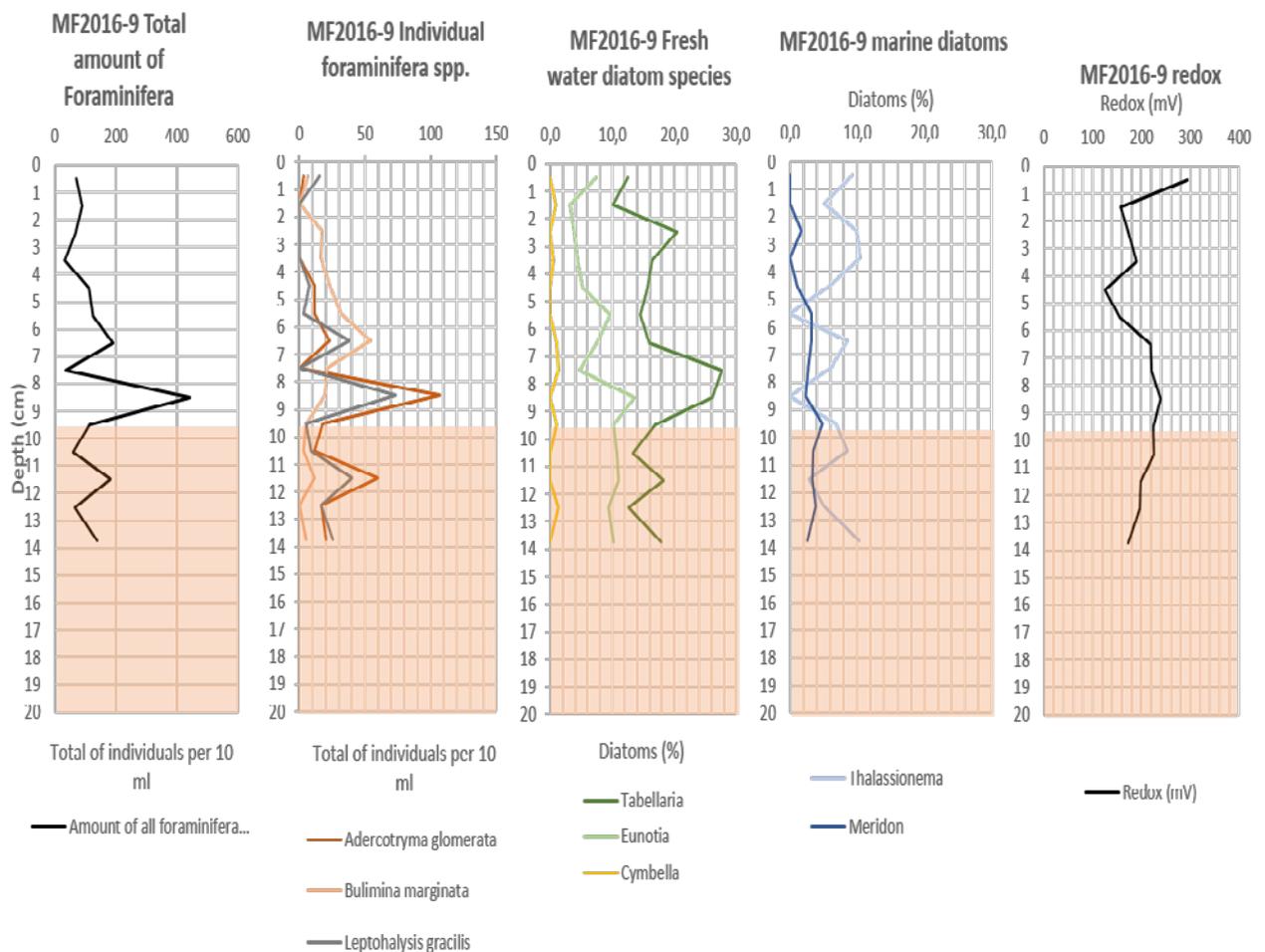


Figure 12 Foraminifera, fresh water diatoms and redox from core MF2016-9 (The orange block indicates the sediment conditions before an overall change happened above 8 to 9 cm sediment depth. Raw data from Midttømme et al. (2017).

Figure 13 indicates the sediment record of the relative bromine (Br) concentration and the relative iron (Fe) concentration compared to the coherence/incoherence ratio of the sediment.

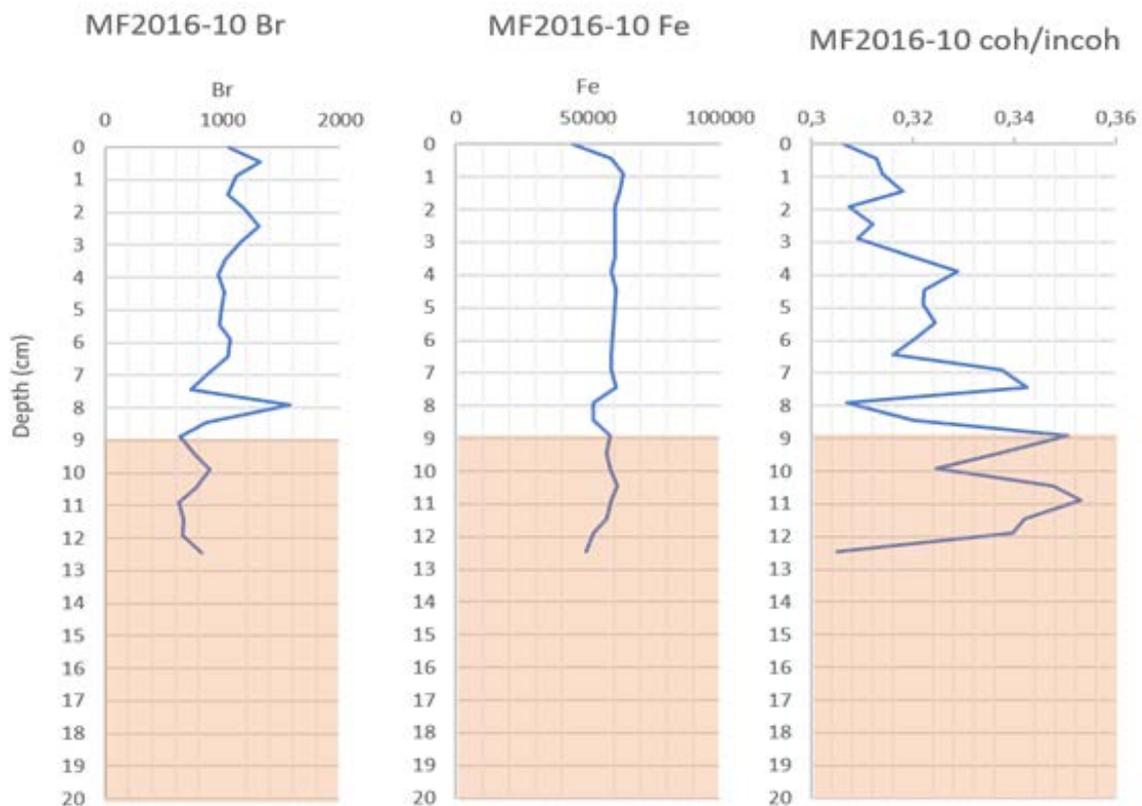


Figure 13 Bromine (Br) relative concentrations, iron (Fe) relative concentrations, and the coherence/incoherence ratio in the Cruise Ship Harbor sediments of core MF2016-10. sediment conditions before an overall change happened above 8 to 9 cm sediment depth. Raw data from Midttømme et al. (2017).

Below the sediment depth of 8 to 9 cm (in the orange block), benthic foraminifera and general freshwater diatoms are abundant in the marine sediments and marine diatoms show a lower abundance compared to the fresh water species. The redox conditions decrease continuously from around 238 mV at 8,5 cm to around 170 mV between 13 and 14 cm sediment depth as shown in Figure 12. In addition, the relative abundance of the elements Br and Fe showed their minimum concentrations below 9 cm sediment depth, and the coherence/incoherence ratios are at their maximum.

At the sediment depth of 8 to 9 cm (1 cm above the orange block) the maximum abundance occurs of benthic foraminifera and the freshwater diatom species. The redox conditions show a slight increase before stabilizing until 6 cm. In the parallel core (Figure 13), the relative Br concentrations are at their highest, while the Fe concentrations remain stable and the coherence/incoherence ratio is at its lowest.

In Figure 12, above 7 cm sediment depth the abundance of the benthic foraminifera and the freshwater diatom species decreases towards the sediment surface, while the percentage of marine diatoms increases. The redox condition pattern varies between 120 and 180 mV, reaching their upper sediment maximum of 298 mV at the surface subsample; note that this high value might have been influenced by the exposure of the sediment surface to air during the opening of the sediment cores. In Figure 13 core, above 7 cm sediment depth, Br and Fe increase continuously, while the coherence/incoherence ratio decreases continuously towards the sediment surface. Only the very surface subsample seems to deviate from this trend, which is likely to be an artificial effect during measurement.

A first general summary allows to point out the following trends above the time horizon related to the sediment depth of 8 to 9 cm: (a) The water conditions in the Cruise Ship Harbor turned from more influenced by freshwater to more influenced by marine water; (b) The redox conditions turned from continuously increasing to heavily varying conditions; and (c) The organic matter fraction (related to the relative Br concentrations (Mayer, et al., 2007)) increases while the mineral fraction (related to the coherence/incoherence ratio) decreases in grain size and/or grain amount.

3.3.2 The sediment parameters of the Kistadypet

Again, for the raw data please refer to the Bachelor theses of Midttømme et al. (2017) and Mulelid et al. (2017). The Kistadypet sediments of cores MF2016-2 and MF2016-5 revealed significant differences in sediment parameter composition across the upper 0 to 8 cm sediment depth compared to the sediment parameter composition below 8 cm sediment depth. This trend is visual in both cores. Figure 14 indicates the sediment record of the redox conditions, the general freshwater diatom record, the mineral matter fraction, and the terrestrial organic matter fraction.

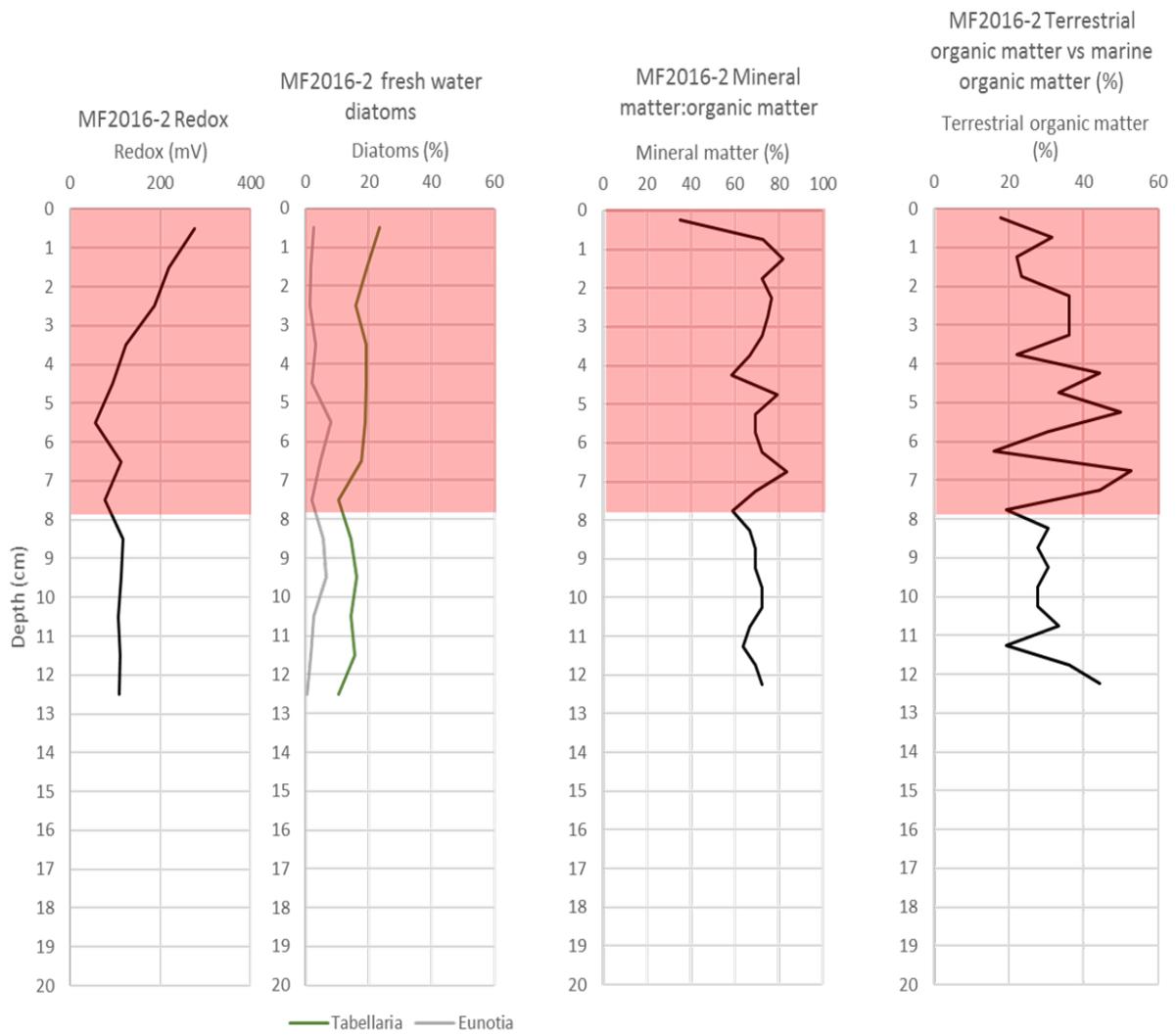


Figure 14 Core MF2016-2 was analyzed for redox conditions, freshwater diatoms, terrestrial organic matter and the mineral fraction. The red block indicates the upper 8 cm of increased terrestrial influence on the sedimentation at Kistadypet

Figure 15 indicates the sediment record of the relative bromine (Br) concentration compared

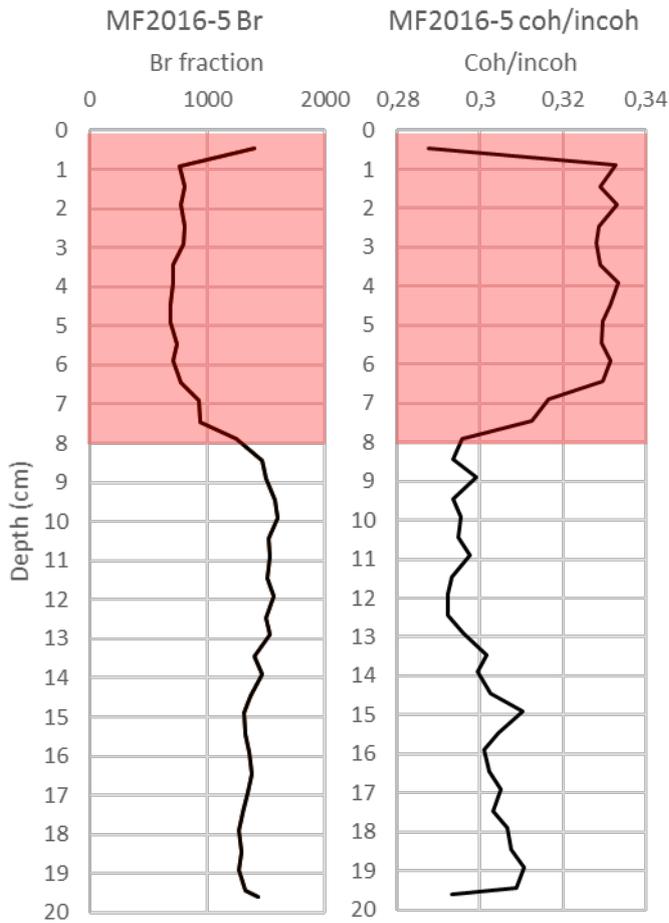


Figure 15 Core MF2016-5 was analyzed for bromine fraction and coherence/incoherence. The red block indicates the upper 8 cm of increased terrestrial influence on the sedimentation at Kistadypet to the coherence/incoherence ratio of the sediment.

Figure 14 shows that between 0 and 8 cm sediment depth, the freshwater diatom record, the percentage of mineral matter, and the percentage of terrestrial organic matter reach their overall maximum values. All parameters show a clear deviation between 0 to 8 cm (the red block) and 8 to 12 cm (below the red block). Figure 15 shows that coherence/incoherence ratios show the same trend and have their overall maximum appearance between 0 to 8 cm, while the relative Br concentrations are lowered to their absolute minimum between 0 to 8 cm.

A first general summary allows to point out the following trends across the sediment depth between 0 and 8 cm: (a) The sediments between 0 and 8 cm sediment depth are influenced by an overall terrestrial impact consisting of a combination of mineral matter, terrestrial organic matter and freshwater diatoms (that only occur in freshwaters of rivers and lakes at land). In addition, the relative Br concentrations indicate low amounts of organic matter together with high amounts of the mineral fraction (grain size or absolute amount) as indicated by the coherence/incoherence ratio. This supports the interpretation of a massive terrestrial impact across the upper 8 cm of the Kistadypet sediments.

4 Discussion

4.1 Dating

Paetzel & Dale (2010) demonstrated in a recent paper the possibility of replacing radiometric dating method with event dating in recent Norwegian Barsnesfjord sediments, using proxies. These proxies consisted of historically documented slide events, the counting of seasonal laminae (see also Paetzel & Schrader (1992B)), and the correlation of freshwater diatoms with the local precipitation pattern (Paetzel & Dale, 2010). Their approaches allow the conclusion that event dating alone might be used as a reliable dating method. However, they also used radiometric dating methods to confirm their approach of event dating. In case of this thesis, this confirmation will take place in August 2017, when the radiometric dating finally will be conducted.

4.1.1 Event: The sediment record of the quay construction in 1985

The sediments of the Cruise Ship Harbor were used to date these sediments in relation to the sediment signals released as a consequence of the harbor quay construction in 1985. During the quay building, the delta of the Flåmselvi River was filled up with land masses, blocking the river from draining across the delta towards the east into the Cruise Ship Harbor basin. Instead, the water was channelized and is draining towards the north since 1985 (Figure 16).



Figure 16 A comparison between the aerial pictures of 1971 (Statens kartverk, 1971) and 2014 (Statens kartverk, 2014). The picture from 1971 shows the river delta and shows that the waterflow changed from a stream that spread between the northeast (main current) and the south east (smaller stream) to a singular stream towards the north west, straight towards Kistadypet.

This process led to a decrease in the main freshwater supply into the Cruise Ship Harbor basin. Thus, the signal of freshwater diatoms should decrease, and the production of marine diatoms should increase in the harbor basin due to less turbidity from the river waters. This increasing primary production would also explain the increase in the organic matter fraction as indicated by bromine. In addition, the decreasing influence from the Flåmselvi River should diminish the supply of terrestrial mineral matter into the harbor as indicated by the coherence/incoherence ratios and the change in sedimentation is also visible in Figure 16.

Another argument for the timing of this event is the record of the foraminifera. The foraminifera species *Adercotryma glomeratum*, *Leptohalysis gracilis*, *Bulimina marginata* together with the freshwater diatom species *Tabellaria flocculosa* increased all after the same point between 8 and 9 cm sediment depth. The importance in this increase lies in the functional behavior of foraminifera species *Adercotryma glomeratum* and *Leptohalysis gracilis*.

Adercotryma glomeratum is a species which has a wide tolerance as it can be found in estuaries, shelf environments and the deepest parts of the ocean. It is most common when

there is no competition of calcareous species. It is most commonly found in estuaries with a stable salinity and high amounts of organic matter (Scott, et al., 2001). *Leptohalysis gracilis* is known to thrive in fjords which with amounts of organic material, and is known for its tolerant to anoxic conditions (Alve, et al., 2009). *Leptohalysis gracilis* and *Adercotryma glomeratum* show a spike at 8,5 cm sediment depth, indicating a rapid change in living conditions.

Conclusion on the sediment record of the quay construction event in 1985

The sediment cores of MF2016-9 and MF2016-10 show an increase in plant material at around 8,5 cm sediment depth which makes it likely that they both are influenced by the same process. The foraminifera species *Leptohalysis gracilis* and *Adercotryma glomeratum* peak both on 8,5 cm sediment depth and both species are known to tolerate a wide set of environmental conditions. Based on their wide tolerance on environmental conditions and the fact that *Adercotryma glomeratum* peaks when there is little competition and that they both peak once, indicate that they are most probable r-strategists. R-strategists create a high amount of offspring, thrives in unstable conditions, and their numbers fluctuate, showing a “boom and burst” pattern (Matthews & Matthews, 2010). In addition to this, the fresh water diatoms, redox, bromine fraction, iron fraction and coherence all show a clear “before and after” pattern of the event at 8,5 cm sediment depth.

The most probable explanation for the change is the building of the quay construction in 1985 (Figure 16). The building of the key in combination with the change of the currents could have led to a redistribution of nutrients which caused a growth spike of foraminifera. Thus, the sediment horizon between 8 and 9 cm sediment depth in the Cruise Ship Harbor sediment cores can be attributed to the year 1985, thus dating the sediments of the Cruise Ship harbor. Linear sedimentation rates between 1985 and the sediment surface would be 8,5 cm over the past 31 years, leading to a linear sedimentation rate of 0,27 cm/year. This number needs to be corrected for the sedimentation from the century flood of 2014 which is suggested to occur between 3,5 and 1,5 cm sediment depth. This is interpreted from the benthic foraminifera record declining to zero across this depth.

The sedimentation rate of 0,27cm/year seems to be reasonable when compared to the similar (though less oxic) fjord settings in other fjords of the area, that is 0,5 cm/year in the anoxic Nærøyfjord (Dybo, et al., 2016) and 0,4-0,5 cm/year in the partly oxic of the Barsnesfjord (Paetzel & Dale, 2010).

4.1.2 Event: The sediment record of the century flood of 2014

The evidence of the century flood of 2014 can be found mainly in the Kistadypet sediment cores. As indicated above, the water outflow current of the Flåmselvi river was changed from an eastern direction into an outflow direction straight to the north in 1985 (Figure 16). During the century flood of 2014, the water masses of the flood where thus led directly into the direction of the Kistadypet. A massive deposition of the terrestrial matter transported with the flood would thus be expected in the direction of the basin of the Kistadypet.

The terrestrial organic matter and the mineral matter fraction both are elevated across the upper 8 cm of the Kistadypet sediment core. The bromine fraction shows a clear, steep decrease, indicating low amounts of organic matter across the upper 8 cm of the Kistadypet sediments. The coherence/incoherence ratio shows the opposite pattern, indicating a strong mineral input above 8 cm sediment depth. In combination, these parameters suggest a dominating terrestrial impact with a massive sedimentation during the duration of this event. Sedimentation rates of 8 cm during one day, including continuous high supply of terrestrial material during the following two years (due to the re-building of the infrastructure of the Flåmselvi River valley) are estimated (Eide, 2016)

Conclusion on the sediment record of the century flood of 2014

Sediments of the century flood of 2014 are prevalent in the upper 8 cm of the Kistadypet sediment cores. All investigated sediment parameters indicate a massive terrestrial impact across the upper 0-8 cm of the Kistadypet sediments. Considering the rapid change in all parameters, especially in the bromine fraction and in the coherence/incoherence ratio, deposition from the century flood is strongly supported. The leveling out of the terrestrial organic matter between 4 cm sediment depth and the sediment surface suggests that these are the sediments brought in after the flood. This would imply that the upper four cm represent two years. In terms of dating, the year 2014 would be located at 8 cm of the Kistadypet sediment cores, and sedimentation rates of the last two years would be 2 cm/year. These sedimentation rates are an order of a magnitude higher than estimated for the sediments of the Cruise Ship harbor. On the other hand, sedimentation rates of 2 cm/year have been found in the oxic part of the Barsnesfjord close to the delta of the Årøy river (Paetzl & Schrader, 1992).

Also, the sediments deposited above 1,5 cm sediment depth at the Cruise Ship Harbor are interpreted as being deposited during the two years after the century flood of 2014. Thus,

sedimentation rates the Cruise Ship Harbor were increasing from 0,27 cm/year to 0,75 cm/year during this period. The near three-doubling of the sedimentation rates at the sediment surface of the Cruise Ship Harbor is in the same way suggested to relate to the post-flood rebuilding of the valley as in the cores from the Kistadypet (Eide 2016).

4.1.3 Consequences of the flood on the total amount of contamination

The flood had a major influence on the sedimentation rates as mentioned previously. The amount of sediment deposited and the change in sedimentation also have an impact on the contamination. In the Cruise Ship Harbor the sedimentation rates increased by at least a factor 2,78. Most of the contaminants do not show any major change between the shallow and the deep sample. The TBT which decreased by 42% in the shallow sample. The lack of overall change can be explained if the total input of contaminants increased at roughly the same rate as sedimentation rate. In the case of the example of TBT, it leads to the absolute increase of TBT by factor 1,58 (= (1-0,43) *2,78)) from the deep sample to the shallow sample. A possible explanation of the reduced increase of TBT (compared to the other contaminants), is the reduced input of TBT. It is a banned substance and this banning should at least have some effect on the amount that is entering the fjord.

4.2 The consequences of the re-classification

In 2016 a new version of the Norwegian classification system came out. The new system had severe impact on the degree of contamination/pollution of the sediments (Miljødirektoratet, 2016), especially the Cruise Ship Harbor sediments, depend on which classification is applied. The classifications of both 2007 and 2016 can be found in Appendix C. Table 10 clearly the difference in standards regarding TBT.

Table 10 The TBT classes from 2007. The differences between the effect based category and management category runs over three orders of magnitude management classes (SFT, 2007)

Classes	I	II	III	IV	V
TBT (µg/kg)— effects based	<1	0,002	0,002-0,016	0,016-0,032	>0,032
TBT (µg/kg)—for management	<1	1-5	5-20	20-100	>100

The effect based scale is three orders of magnitude lower than the management scale (SFT, 2007). In the re-classification of 2015 only the effect based scale was used which means that the Cruise Ship Harbor sediments are according to the newest classification Heavily Polluted with TBT (Miljødirektoratet, 2016), while they were not polluted at all according to the management scale of SFT (2007).

The reclassification also affected the interpretation of copper, lead, zinc and PAHs. In the case of copper, Class II was widened from 35-51 µg/kg (SFT, 2007) to 20 – 84 µg/kg (Miljødirektoratet, 2016). As a consequence, copper falls no longer in Class IV/V (Bad and Very Bad conditions) but in Class II (Good conditions). This is also the case for lead and zinc. The entry value for lead of Class II changed from 30-83 µg/kg (SFT, 2007) to 25-150 µg/kg (Miljødirektoratet, 2016). This means that the amount that is considered background value is lowered but that the amount that is considered to be ‘good’ has been pushed upward. The zinc Class II changed from 150-260 µg/kg (SFT, 2007) to 90-139 µg/kg (Miljødirektoratet, 2016). According to this, the amount of zinc that is considered background is lower than it was, and also less zinc is allowed in the ‘Good’ class. The PAHs were changed more thoroughly. In 2015, the category ΣPAH (16) has been removed and Class II was widened. Because of this, all the PAHs fall in either in Class I or in Class II.

The discussion will focus further on the consequences of TBT. This is because the other contaminants do not form a threat to the environment, they have many potential sources (see chapter 1.7 for further details on the potential sources) and none show clear difference between the shallow and deep sample.

4.2.1 Norwegian TBT classification

The 2007 classification has two TBT categories: management TBT and effect based TBT as can be seen in Table 10. Until 2015, two different criteria were used for TBT. There were the criteria at which the TBT had an effect on the environment, and there were the criteria which is used for ‘management proposes’ (Statens forurensningstilsyn, 2007). The reason for the removal of the management category is not evaluated in the criteria handbook. As only the effect based category is still being used, the amount of TBT found in the Cruise Ship Harbor is enough to fall in Class V of the effect based classification.

Beside its toxicity, a secondary problem with TBT is the fact that it is persistent in the environment. How persistent it is, depends mostly on oxygen conditions and temperature (Viglino, et al., 2004).

4.3 Limit of Quantification

The LOQ is the lowest amount of the researched analyte in a sample that can be quantitatively determined with accuracy (Bernal, 2014). The Limit of Quantification or LOQ, of the contaminants that were tested were given in Table 5. There are two outcomes on when contaminants are not detected: the contaminant does not appear in the sediments or the LOQ is too high.

4.3.1 LOQs and TBT

The LOQ values of TBT lied at 1 µg/kg (Eurofins, 2016b) and in the sediment classification of 2007, Class II ‘Good’ ranged between 1 and 5 µg/kg (Table 10). Everything below 1 µg/kg was considered Class I ‘Background’ (SFT, 2007) and thus of lesser importance. The sediment classification of 2016 was released after the samples were tested at Eurofins. The bench mark for Class V is 100 µg/kg in 2007 (SFT, 2007) compared to 0,032 µg/kg in 2016 (Miljødirektoratet, 2016). Due to the lowered benchmark, it was not possible to differentiate between the classes of 2016.

4.3.2 LOQs and PCBs

There were no PCBs were detected in either of the subsamples. A possible explanation is, is that the LOQ of all individual PCBs was 5 µg/kg (Eurofins, 2016b). The LOQ matches with the sediment classification of 2007 where the benchmark for ΣPCB_7 Class 1 ‘Background’ was less than 5 µg/kg. Still, background values could be interesting as PCBs persistent and thus not likely to break down during natural processes (Grossman, 2013). This means that trends can be revealed about the production and transportation of the PCBs. Svalbard is an example of a location where PCBs are found which originate from elsewhere. Trends regarding PCBs are visible in the in all the media in Svalbard, including marine sediments. (Kallenborn, et al., 2011).

PCBs on Svalbard - Kallenborn et al. (2011)

On Arctic archipelago of Svalbard PCBs are a well-studied chemical. The largest input of new PCBs on Svalbard does not originate from Svalbard itself were transported over long distances towards the archipelago. Due to climatic conditions, PCBs travel from industrialized

areas, e.g. Europe, USA, Asia and Russia, towards Svalbard by air, ocean and ice. As a consequence, PCBs are found in all media on Svalbard, including marine sediments (Kallenborn, et al., 2011). The study of Ivanov (2006) showed that the marine sediments around Svalbard had elevated levels of PCBs. The results of various surveyed showed that an amount of PCBs between 0,2 µg/kg and 1,1 µg/kg was found in the marine sediments around Svalbard. The report of Kallenborn et al. (2011) also compiled studies about PCBs in fjords through time. The highest amount of ΣPCB₇ were found in Billefjorden and increased between 2005 and 2009. It went from 13 µg/kg in 2005 to 20 µg/kg in 2009. However, time trends are also visible at other locations in the Billefjorden. There was an increase of 2 µg/kg to 7,5 µg/kg between 2005 and 2009. If the samples were tested with a LOQ value of 5 µg/kg, a number of trends would have been lost.

4.3.3 Conclusion on PCBs

It is likely that there are PCBs in the sediments of the Aurlandsfjord. Even if there are no emission sources of PCBs in the Aurlandsfjord itself, it is possible that they are transported in. The report of Kallenborn et al. (2011) showed that PCBs can travel for long distances and that there are trends visible in the marine sediments. If the sediments of the Aurlandsfjord are tested with more sensitive tests, it would be likely that PCB trends can be found as well.

4.4 The persistency of TBT

The half-life time of TBT depends on the local conditions and can lie between 1 years (Arp, et al., 2014) and 87 years (Viglino, et al., 2004). One of the conditions that play a role when it comes to the breaking down of TBT, is the degree in which the sediments are oxidized. Another factor is the temperature of the water: warm waters speed up the process at which TBT (**tributyltin**) transforms into DBT (**dibutyltin**). Examples of these studies can be found in Table 11 (Hwang, et al., 1999; Arp, et al., 2014; Viglino, et al., 2004).

Table 11 The half-life time of TBT in different locations. Table altered after (Hwang, et al., 1999; Viglino, et al., 2004; Arp, et al., 2014).

Study	Sediment type	Half-life time (years)
De Mora et al. (1989)	Marine (New Zealand)	1 – 4
Waldock et al. (1990)	Estuarine (UK)	2
Dowson et al. (1993)	Estuarine + fresh (UK)	1 – 5
Kilby and Bately (1992)	Riverine (Australia)	4
Astruc et al. (1989)	Marine (France)	> 8 – 15
Hwang et al. (1999)	Marine (Korea)	7
Arp et al. (2014)	Estuarine (Norway)	1 - 2
Viglino et al. (2004)	Estuarine (Canada)	8 - 87

The studies of Arp et al. and Viglino et al. will be explained in further detail in the following paragraphs. The reason why these studies were chosen were because their uniqueness: Arp et al. (2014) deals with very high amounts of TBT where Viglino et al. (2004) studied TBT in a remote, sub-arctic area.

Arp et al. (2014) – The Drammensfjord, Norway

An example of estimating TBT pollution can be found in the Drammensfjord, Norway. The harbor of Drammen contains various industrial activities such as anchor places, dry docks, and waste treatment plants. To measure the contamination, 30 sediment cores were taken on eight different locations and three reference locations. These samples were taken in 2008 and 2011. The sample locations can be found in Figure 17. The highest concentrations were measured at the Tangen Drydock which is indicated on the map at Number 7.

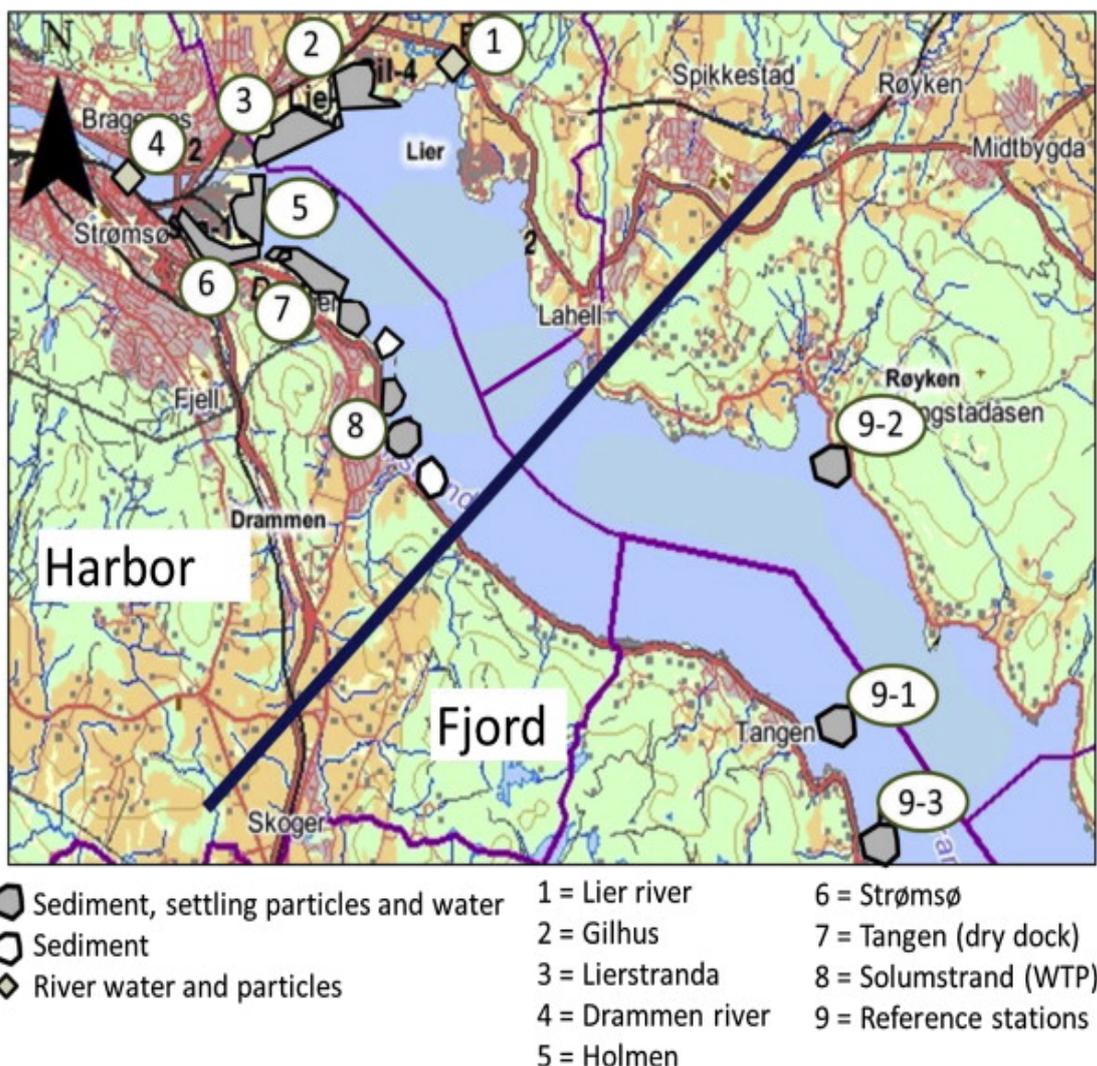


Figure 17 Map of the sampling locations at Drammen. The map shows the 8 different locations which were tested for TBT and the 3 reference stations.

In 2005, the amount of TBT measured at Tangen was 33.600 µg/kg and the harbor had an average concentration of TBT 1781 µg/kg (Arp, et al., 2014). To put the result in perspective, the management scale was applied. The bench mark for severe pollution lies at 100µg/kg (Statens forurensningstilsyn, 2007) meaning that the amount of TBT found is 336 times the benchmark for severe pollution on the management scale.

Arp et al. (2014) sampled multiple locations and Tangen was clearly a ‘hot spot’. The average TBT levels in the harbor was 19 times lower than at the highest location. In addition to this, a model was produced to estimate on how long the TBT needs to break down. If their model is correct, it is expected to reach the ‘good environmental status’ of the management scale in 2025. According to their model, in 2025 concentrations of TBT in the harbor are estimated at 16.5 µg/kg. This means that between 2008/2011 (depending on the sample) and 2025 the

amount of TBT would decrease by 99.99%. Their graphs also showed that the half-life of TBT lies between 1 and 2 years.

Viglino et al. (2004) – The Saguenay Fjord, Canada

The Saguenay Fjord is located in Northern Quebec, Canada and has been studied regarding the degradation of TBT in a semi-enclosed environment with no major shipping routes. The area suffered from a flash flood in 1996 which led to a local increase of 50 cm of sediments in a matter of hours. In the study, they used the concentration of TBT found in the sediment pre flood and post flood. The amounts of TBT found varied between their cores and within their cores: the range of TBT found lied between 0,004 and 0,206 µg/kg. Core 9 and core 16 both showed values at around 0,2 µg/kg on top where the values of core 5 and core 30 have values between 0,002 and 0,005 µg/kg. In addition to this, it was estimated that the amount of TBT entering the fjord was 197 kg. The results showed that in the top layer of the sediment (0-5 cm) the half life time of TBT was 8±5 years. In the anoxic sediment, TBT had a half life time of 87±17 years. The reasons why the degradation rate is so low in the anoxic sediments was most likely due to the cold water (~2°C) and because degradation is mostly caused by aerobic biological processes (Viglino, et al., 2004).

4.4.1 Comparing the Cruise Ship Harbor to Saguenay and Drammensfjord

The amount of TBT found in the Cruise Ship Harbor was compared to both an extremely polluted site in the Drammensfjord, Norway with former heavy shipping industry and a pristine site in the Saguenay Fjord, Canada with no major shipping routes. The results are summarized in Table 12 with the purpose of adding perspective to the numbers.

Table 12 Compares the results of the TBT of this study with the studies from Arp et al. (2014) who studied the Drammensfjord and Viglino, et al. (2004) who studied the Saguenay Fjord.

Location	Amount of TBT (µg/kg)	Half-life (years)
Cruise Ship Harbor, Norway	3,2 - 5,6	Unknown
The Drammensfjord, Norway	230 - 33.600	1-2
Saguenay Fjord, Canada	0,004 - 0,206	8-87

The lowest value in the Saguenay Fjord falls in Class III, ‘Moderately Polluted’ where all the other values fall in Class V ‘Heavily Polluted’. The table compares two extreme scenarios and

though the sediments in the Cruise Ship Harbor are polluted, it is not nearly as polluted as in Drammen. In addition to this, at Kistadypet and at Stampa no TBT was detected.

As shown in Table 12, the half life time of TBT varies between 1 year under optimal conditions (oxygen rich sediments and biological activity) and 87 years under unfavorable conditions (anoxic sediments, cold water and little biological activity). The amount of TBT found in the Cruise Ship Harbor was 3,2 µg/kg in the surface sample and 5,6 µg/kg in the deep sample. If the half-life of TBT is constant and the most favorable half-life found in literature (1 year) is applicable, it will take 11 years for the surface TBT to be degraded to background level (0,00015 µg/kg) but it is highly unlikely that the most favorable conditions persist during these 11 years.

The original amount of TBT in the deep subsample is even more difficult to determine with the current information. According to the model of Arp et al. (2014) stated that the amount of TBT will decrease with 99% in the Drammen fjord in 20 years. Assuming that the deep sample was taken at around 1985, this would mean that the amount that was found, 5,6 µg/kg would only be a small portion of what was there originally. However, more research on TBT is needed to make a statement on the decay of TBT in the Aurlandsfjord.

4.4.2 Spreading of the TBT

The paper of Arp et al. (2014) show that the highest value is 19 times higher than the average value. Differences were also found in the cores of Viglino et al. (2004) between the samples of Core 9 and core 16 both showed values at around 0,2 µg/kg on top where the values of core 5 and core 30 have values between 0,002 and 0,005 µg/kg. This suggests that there are major local differences between samples. It is not unlikely that the Cruise Ship Harbor is a TBT hot spot and the TBT spreads in the environment. Even if the average TBT concentration in the sampling area in the Aurlandsfjord is 100 times lower, it would still mean that the locations within this area, Kistadypet and Stampa, are heavily polluted ($3,2/100 = 0,032$ µg/kg, the bench mark for Class V). The reason why no TBT was detected at Kistadypet and Stampa, was due to the limit of quantification. The limit of quantification (LOQ) used in the methods of Eurofins lies at 1 µg/kg (Eurofins, 2016b). The methods used at Eurofins were not sensitive enough to detect the different classes according to the 2016 classifications (Miljødirektoratet, 2016).

Summary on the use of TBT classification scales

The amount of TBT found in the Cruise Ship Harbor was 3,2 µg/kg in the surface sample and 5,6 µg/kg in the deep sample. TBT was not detected in the other samples could be because the methods at Eurofins was not sensitive enough: the LOQ used was 1 µg/kg where the bench mark for heavy pollution is 0,032 µg/kg. This means that Kistadypet and Stampa could be heavily polluted but we were unable to detect it.

TBT is also very persistent: if the half-life of TBT is constant and the most favorable half-life found in literature (1 year) is applicable, it will take 11 years for the surface TBT to be degraded to background level (0,00015 µg/kg). As the conditions change through time and the surface sediments of today will be covered and become more anoxic, the process will most likely take even longer. It is not known what the half-life of TBT is in the Aurlandsfjord is. In addition to this, new TBT is most likely entering the system, making it unlikely that the sediments will fall into the good conditions of Class I or II in the near future.

4.5 Scope of the samples tested for contaminants

There are advantages and disadvantages to the two subsamples taken of each contamination sample. The main disadvantage of only two subsamples per location is the fact that it is difficult to determine trends based on two data points alone, especially in combination with an unconventional primary dating method. However, the subsamples that were taken were analyzed for a wide range of contaminants and thus provide valuable information on the distribution of these contaminants.

The results of this study showed that only the Cruise Ship Harbor sediments were polluted with TBT. The study of Viglino et al. (2004) focused exclusively on TBT. Four cores were taken in the Saguenay Fjord and subsamples of every core were taken continuously on every centimeter down-core. The result was a detailed record on the amount of TBT at a certain location. This information was used to determine the half-life time of TBT and to calculate the amount of TBT entering the fjord.

The study at hand shows that the Cruise Ship Harbor is polluted with TBT. A more detailed study should be done on the development of the TBT over time. In ideal circumstances the research methods of Viglino et al. (2004) could be applied in the Aurlandsfjord. Detecting these changes over time could also be used to evaluate management and monitoring strategies.

4.6 Management aspects

Re-classification of sediment quality criteria brings in challenges, especially when it comes to time series. A large number of contaminated sites have to be sampled on a regular basis to monitor such changes. Changing the quality criteria in the middle of a time series would lead to a disruption and has thus to be avoided. Because of this, both, the 2007 and the 1997 criteria were used in Norway in 2010 (Bakke, et al., 2010). Because of this, when individual sites are being compared to each other, the amount of contamination should be compared, and not the classifications.

The contaminant standards of Norway differ from the European ones. One of the differences is the fact that PCBs are not on the European classification list and are under review. Even though the European standards consider PAHs to be a 'priority substance', there are less individual PAHs on the list compared to the Norwegian standards. In addition to this, the European classification only mentions concentrations in surface waters, and the classifications mentioned are not the same as the Norwegian fresh water standards (European Parliament; Council of the European Union, 2008).

The samples were taken in an UNESCO site and the sediments of the Cruise Ship Harbor are classified according to the latest standards as 'Heavily Polluted' due to the TBT. The total increase of TBT by a factor 1,58 can be considered problematic as the use of TBT has been prohibited worldwide since 2008. Because of this, it is recommendable that the issue of the existing marine sediment pollution is monitored and taken up in the future management plan for the area.

5 Conclusion

According to the latest Norwegian sediment classification, the deep sample and the shallow sample of the Cruise Ship Harbor fall into Class V 'Very bad' of the TBT pollution. In addition to this, the TBT samples taken at Kistadypet and Stampa fall in the Class II 'Good'.

The sediments taken in the Kistadypet and in the Cruise Ship Harbor basin were dated by using the events completion of the Cruise Ship Harbor in 1985 and the century flood of 2014. The shallow samples of Kistadypet and Cruise Ship Harbor are both heavily influenced from the flood: in the harbor the upper 1,5 cm were deposited after the flood corresponding to a sedimentation rate of 0,75 cm/year after the flood vs. 0,27 cm/year before the flood. At Kistadypet, the upper 8 cm of the sediments were influenced by the century flood and after-flood deposits.

Considering the increased sedimentation at both locations, it is likely that the amount of contamination was diluted due to the sediments brought in by the flood and the increased sedimentation after the flood. In the Cruise Ship Harbor the sedimentation rates between the surface sample and the deep sample changed by a factor 2,78. As the absolute contamination did not show signs of change, with the exception of TBT, it could be concluded that the amount of contamination has increased at the same rate as the sedimentation rate by a factor 2,78. According to the dating, 5,6 µg/kg of TBT found in the deep sample had around 30 years' time to break down. It is unknown how much TBT there was originally deposited in the deep sample but it is very likely that it was much higher than the amount that was found.

Only two contamination subsamples per location were taken. Future research could elaborate on the finer details on the development of the TBT pollution and on the trends of PCBs in the sediments of the Aurlandsfjord. The main reason for this is the fact that TBT is polluting the Cruise Harbor sediments but since the LOQ of TBT lied at 1 µg/kg, it is possible that the sediments at Kistadypet and Stampa are also heavily polluted. PCBs were expected but were not found due to the high LOQ values. This means that

In terms of management, it can be recommended that the area of the area is researched in more detail on TBT. In ideal circumstances, the research method of Viglino et al. (2004) could be applied on multiple locations such as the Cruise Ship Harbor, Kistadypet and

Stampa. By taking multiple cores in the same area and testing a continuous succession of subsamples per core for TBT only, a more detailed sequence can be created. Sampling on more locations and with more subsamples can help with determining the spreading of the TBT and how the TBT developed over time.

In addition to this, it is recommendable to determine the exact sedimentation rate by using radiometric dating, determine the half life time of the TBT and calculate the total flux of TBT into the fjord sediment in regards for future management but also on the amount of TBT that used to be in the sediments but was broken down over time. Detecting these changes over time could also be used to evaluate management strategies. Taken into account the worldwide ban on the use of TBT, it is recommended that the existing marine sediment pollution is discussed in the management as it is a threat to the marine environment.

Based on the current knowledge it cannot be said for certain if the model: *“The growth of the cruise ship industry increases the risk of pollution in the Aurlandsfjord”* is rejected or not. Further studies need to be done on the TBT and how much there originally was in the sediment. Gathering more information and monitoring the conditions of TBT in the Aurlandsfjord, might help to take measures for reducing the concentration and impact of TBT on the Aurlandsfjord sediments.

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Appendix A

Interview questions

Flâm

Main goal interview:

What are the management objectives of the UNESCO world heritage site?

Questions Management

1. What does it mean to manage an UNESCO site?
2. What role does the municipality and county have when it comes to managing the site?
 - a. Top down or bottom up?
3. Are there evaluation systems in place at your site but also on municipality/county level?
4. How do you determine if the management you applied is successful or not?
 - a. Monitoring programs
 - b. What should stay the same?
 - c. What should change?
5. No documents have been published on the evaluation of the site. When will one be published?
6. What are the management goals for future for of Flâm?
 - a. How does a short tourist season fit into this?
 - b. How does the protection of the underwater landscape fit into this?
 - c. How does the pollutants of the cruise ships fit in?
7. Do you communicate with the other UNESCO sites regarding management strategies?

Harbor authority

1. What does it mean to be the harbor authority? What do you do exactly?
2. The harbor authority gave the college university money for fjord research. What role do you fulfil in the municipality/county?
 - a. Do you collaborate with other harbor authorities in for example Geiranger?
3. Are you connected to the UNESCO site?
 - a. Collaborate?

4. How many cruise ships have arrived throughout time?
 - a. Any thoughts on the amount?
5. Where do the cruise ships anchor and how do they do that?
6. The Flatheim shallows are supposed to be removed, why is this necessary?
 - a. Is the underwater landscape not part of UNESCO?
 - b. If it were to be removed, what will happen with the derbies?
7. What are your major challenges as a harbor authority?
8. What are your goals for the future?

Appendix B

Results Eurofins



Høgskulen i Sogn og Fjordane
And. for ing. og naturfag
Røyrgt. 6
6856 SOGNDAL
Attn: Torbjørn Dale

Eurofins Environment Testing Norway
AS (Moss)
F. reg. 955 141 618 MVA
Møllebakken 50
NO-1538 Moss

Tlf: +47 69 00 52 00
Fax: +47 69 27 23 40

AR-16-MM-019344-01



EUNOMO-00148692

Prøvemottak: 20.09.2016
Temperatur:
Analyseperiode: 20.09.2016-06.10.2016
Referanse: Ref: 2405 TD

ANALYSERAPPORT

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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Prøvenr.:	439-2016-09200151	Prøvetakingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvetaker:	Torbjørn Dale
Prøvemerkning:	1. Sted: Cruisehavn, Dyp: 37m Sediment dyp: 0-2m	Analysestartdato:	20.09.2016

Analyse	Resultat	Enhet	LOQ	MU	Metode
b) Arsen (As)	17	mg/kg TS	0.5	30%	NS EN ISO 17294-2
b) Bly (Pb)	22	mg/kg TS	0.5	40%	NS EN ISO 17294-2
b) Kadmium (Cd)	0.13	mg/kg TS	0.01	25%	NS EN ISO 17294-2
b) Kobber (Cu)	56	mg/kg TS	0.5	30%	NS EN ISO 11885
b) Krom (Cr)	28	mg/kg TS	0.3	30%	NS EN ISO 11885
b) Kvikksølv (Hg)	0.026	mg/kg TS	0.001	20%	NS-EN ISO 12846
b) Nikkel (Ni)	35	mg/kg TS	0.5	30%	NS EN ISO 11885
b) Sink (Zn)	130	mg/kg TS	2	25%	NS EN ISO 11885
b) PCB(7)					
b) PCB 28	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005		EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005		EN 16167
b) Sum 7 PCB	N.D.			25%	EN 16167
b) PAH(16)					
b) Naftalen	< 0.010	mg/kg TS	0.01		ISO 18287, mod.
b) Acenaftalen	< 0.010	mg/kg TS	0.01		ISO 18287, mod.
b) Acenaften	< 0.010	mg/kg TS	0.01		ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01		ISO 18287, mod.
b) Fenantren	0.015	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Antracen	0.012	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Fluoranten	0.073	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Pyren	0.056	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Benzo[a]antracen	0.033	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Krysen/Triferylen	0.027	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Benzo[b]fluoranten	0.041	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Benzo[k]fluoranten	0.012	mg/kg TS	0.01	30%	ISO 18287, mod.
b) Benzo[a]pyren	0.035	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.045	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Dibenzof[a,h]antracen	< 0.010	mg/kg TS	0.01		ISO 18287, mod.
b) Benzo[ghi]perylene	0.032	mg/kg TS	0.01	25%	ISO 18287, mod.
b) Sum PAH(16) EPA	0.38	mg/kg TS		25%	ISO 18287, mod.
b) Tørrestoff	49.8	%	0.1	5%	EN 12880
a) Finstoff <63 µm	15.0	% (w/w)	1		ISO 11277 mod
Tributyltinn (TBT)	3.2	µg/kg TS	1	45%	Intern metode
Totalt organisk karbon (TOC)	1.2	% TS	0.1	20%	Internal Method 1
a) Finstoff <2 µm (Leire)	7.7	% TS	1		ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5		EPA 5021
b) THC >C8-C35					
b) THC >C8-C10	<5.0	mg/kg TS	5		ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5		ISO 16703 mod

Technisk forklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
 <: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
 Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N.D.	30%	Kalkulering

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
< Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 3 av 13



Prøvenr.:	439-2016-09200152	Prøvetakingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvetaker:	Torbjørn Dale
Prøvemerking:	2. Sted: Cruisehavn, Dyp: 37m Sediment dyp: 8-10m	Analysestartdato:	20.09.2016
Analyse	Resultat	Enhet	LOQ MU Metode
b) Arsen (As)	13	mg/kg TS	0.5 30% NS EN ISO 17294-2
b) Bly (Pb)	20	mg/kg TS	0.5 40% NS EN ISO 17294-2
b) Kadmium (Cd)	0.20	mg/kg TS	0.01 25% NS EN ISO 17294-2
b) Kobber (Cu)	49	mg/kg TS	0.5 30% NS EN ISO 11885
b) Krom (Cr)	29	mg/kg TS	0.3 30% NS EN ISO 11885
b) Kvikksølv (Hg)	0.030	mg/kg TS	0.001 20% NS EN ISO 12846
b) Nikkel (Ni)	36	mg/kg TS	0.5 30% NS EN ISO 11885
b) Sink (Zn)	120	mg/kg TS	2 25% NS EN ISO 11885
b) PCB(7)			
b) PCB 28	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005 EN 16167
b) Sum 7 PCB	N.D.		25% EN 16167
b) PAH(16)			
b) Naftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafilylen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafiten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fenantren	0.015	mg/kg TS	0.01 25% ISO 18287, mod.
b) Antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoranten	0.075	mg/kg TS	0.01 25% ISO 18287, mod.
b) Pyren	0.066	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[a]antracen	0.028	mg/kg TS	0.01 25% ISO 18287, mod.
b) Krysen/Trifenylen	0.021	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[b]fluoranten	0.044	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[k]fluoranten	0.012	mg/kg TS	0.01 30% ISO 18287, mod.
b) Benzo[a]pyren	0.036	mg/kg TS	0.01 25% ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.058	mg/kg TS	0.01 25% ISO 18287, mod.
b) Dibenzo[a,h]antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[ghi]perylen	0.033	mg/kg TS	0.01 25% ISO 18287, mod.
b) Sum PAH(16) EPA	0.39	mg/kg TS	25% ISO 18287, mod.
b) Tørrstoff	47.3	%	0.1 5% EN 12880
a) Finstoff <63 µm	11.7	% (w/w)	1 ISO 11277 mod
Tributyltinn (TBT)	5.6	µg/kg TS	1 45% Intern metode
Totalt organisk karbon (TOC)	1.8	% TS	0.1 20% Internal Method 1
a) Finstoff <2 µm (Leire)	5.9	% TS	1 ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5 EPA 5021
b) THC >C8-C35			
b) THC >C8-C10	<5.0	mg/kg TS	5 ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5 ISO 16703 mod

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
 <: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
 Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).



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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N D.	30%	Kalkulering

Teqnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet

<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.

Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 5 av 13



Prøvenr.:	439-2016-09200153	Prøvelaksingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvetaker:	Torbjørn Dale
Prøvemerkning:	3. Sted: Stampa, Dyp: 60m Sediment dyp: 0-2m	Analysedato:	20.09.2016
Analyse	Resultat	Enhet	LOQ MU Metode
b) Arsen (As)	18	mg/kg TS	0.5 30% NS EN ISO 17294-2
b) Bly (Pb)	26	mg/kg TS	0.5 40% NS EN ISO 17294-2
b) Kadmium (Cd)	0.14	mg/kg TS	0.01 25% NS EN ISO 17294-2
b) Kobber (Cu)	61	mg/kg TS	0.5 30% NS EN ISO 11885
b) Krom (Cr)	30	mg/kg TS	0.3 30% NS EN ISO 11885
b) Kvikksølv (Hg)	0.028	mg/kg TS	0.001 20% NS-EN ISO 12846
b) Nikkel (Ni)	40	mg/kg TS	0.5 30% NS EN ISO 11885
b) Sink (Zn)	140	mg/kg TS	2 25% NS EN ISO 11885
b) PCB(7)			
b) PCB 28	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005 EN 16167
b) Sum 7 PCB	N.D.		25% EN 16167
b) PAH(16)			
b) Naftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafilylen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafiten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fenantren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoranten	0.028	mg/kg TS	0.01 25% ISO 18287, mod.
b) Pyren	0.022	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[a]antracen	0.010	mg/kg TS	0.01 25% ISO 18287, mod.
b) Krysen/Trifenilylen	0.011	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[b]fluoranten	0.019	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[k]fluoranten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[a]pyren	0.014	mg/kg TS	0.01 25% ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.014	mg/kg TS	0.01 25% ISO 18287, mod.
b) Dibenzo[a,h]antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[ghi]perylene	0.014	mg/kg TS	0.01 25% ISO 18287, mod.
b) Sum PAH(16) EPA	0.13	mg/kg TS	25% ISO 18287, mod.
b) Tørrestoff	54.2	%	0.1 5% EN 12880
a) Finstoff <63 µm	18.2	% (w/w)	1 ISO 11277 mod
Tributyltinn (TBT)	<1	µg/kg TS	1 Intern metode
Totalt organisk karbon (TOC)	1.3	% TS	0.1 20% Internal Method 1
a) Finstoff <2 µm (Leire)	6.2	% TS	1 ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5 EPA 5021
b) THC >C8-C35			
b) THC >C8-C10	<5.0	mg/kg TS	5 ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5 ISO 16703 mod

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
 < Mindre enn > Større enn nd. Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
 Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N.D.	30%	Kalkulering

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet

<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.

Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

Side 7 av 13



Prøvenr.:	439-2016-09200154	Prøvetakingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvetaker:	Torbjørn Dale
Prøvemerking:	4.Sted: Stampa, Dyp: 60m Sediment dyp: 8-10m	Analysestartdato:	20.09.2016
Analyse	Resultat	Enhet	LOQ MU Metode
b) Arsen (As)	14	mg/kg TS	0.5 30% NS EN ISO 17294-2
b) Bly (Pb)	26	mg/kg TS	0.5 40% NS EN ISO 17294-2
b) Kadmium (Cd)	0.095	mg/kg TS	0.01 25% NS EN ISO 17294-2
b) Kobber (Cu)	56	mg/kg TS	0.5 30% NS EN ISO 11885
b) Krom (Cr)	31	mg/kg TS	0.3 30% NS EN ISO 11885
b) Kvikksølv (Hg)	0.033	mg/kg TS	0.001 20% NS-EN ISO 12846
b) Nikkel (Ni)	41	mg/kg TS	0.5 30% NS EN ISO 11885
b) Sink (Zn)	140	mg/kg TS	2 25% NS EN ISO 11885
b) PCB(7)			
b) PCB 28	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005 EN 16167
b) Sum 7 PCB	N.D.		25% EN 16167
b) PAH(16)			
b) Naftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafylen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fenantren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoranten	0.029	mg/kg TS	0.01 25% ISO 18287, mod.
b) Pyren	0.021	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[a]antracen	0.011	mg/kg TS	0.01 25% ISO 18287, mod.
b) Krysen/Trifenylen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[b]fluoranten	0.024	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[k]fluoranten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[a]pyren	0.015	mg/kg TS	0.01 25% ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.020	mg/kg TS	0.01 25% ISO 18287, mod.
b) Dibenzo[a,h]antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[ghi]perylen	0.021	mg/kg TS	0.01 25% ISO 18287, mod.
b) Sum PAH(16) EPA	0.14	mg/kg TS	25% ISO 18287, mod.
b) Tørrestoff	54.5	%	0.1 5% EN 12880
a) Finstoff <63 µm	15.6	% (w/w)	1 ISO 11277 mod
Tributyltinn (TBT)	<1	µg/kg TS	1 Intern metode
Totalt organisk karbon (TOC)	1.6	% TS	0.1 20% Internal Method 1
a) Finstoff <2 µm (Leire)	5.5	% TS	1 ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5 EPA 5021
b) THC >C8-C35			
b) THC >C8-C10	<5.0	mg/kg TS	5 ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5 ISO 16703 mod

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
 <: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
 Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).



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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N.D.	30%	Kalkulering

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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Prøvenr.:	439-2016-09200155	Prøvetakingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvetaker:	Torbjørn Dale
Prøvemerking:	7. Sted: Kistadypet, Dyp: 60m Sediment dyp: 0-7m	Analysestartdato:	20.09.2016
Analyse	Resultat	Enhet	LOQ MU Metode
b) Arsen (As)	14	mg/kg TS	0.5 30% NS EN ISO 17294-2
b) Bly (Pb)	25	mg/kg TS	0.5 40% NS EN ISO 17294-2
b) Kadmium (Cd)	0.22	mg/kg TS	0.01 25% NS EN ISO 17294-2
b) Kobber (Cu)	71	mg/kg TS	0.5 30% NS EN ISO 11885
b) Krom (Cr)	30	mg/kg TS	0.3 30% NS EN ISO 11885
b) Kvikkselv (Hg)	0.045	mg/kg TS	0.001 20% NS-EN ISO 12846
b) Nikkel (Ni)	39	mg/kg TS	0.5 30% NS EN ISO 11885
b) Sink (Zn)	140	mg/kg TS	2 25% NS EN ISO 11885
b) PCB(7)			
b) PCB 28	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005 EN 16167
b) Sum 7 PCB	N.D.		25% EN 16167
b) PAH(16)			
b) Naftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafylen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenafien	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fenantren	0.011	mg/kg TS	0.01 25% ISO 18287, mod.
b) Antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoranten	0.045	mg/kg TS	0.01 25% ISO 18287, mod.
b) Pyren	0.033	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[a]antracen	0.012	mg/kg TS	0.01 25% ISO 18287, mod.
b) Krysen/Trifenylen	0.013	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[b]fluoranten	0.020	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[k]fluoranten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[a]pyren	0.013	mg/kg TS	0.01 25% ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.017	mg/kg TS	0.01 25% ISO 18287, mod.
b) Dibenzo[a,h]antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[ghi]perylen	0.014	mg/kg TS	0.01 25% ISO 18287, mod.
b) Sum PAH(16) EPA	0.18	mg/kg TS	25% ISO 18287, mod.
b) Tørrstoff	62.1	%	0.1 5% EN 12880
a) Finstoff <63 µm	13.3	% (w/w)	1 ISO 11277 mod
Tributyllinn (TBT)	<1	µg/kg TS	1 Intern metode
Totalt organisk karbon (TOC)	1.1	% TS	0.1 20% Internal Method 1
a) Finstoff <2 µm (Leire)	6.0	% TS	1 ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5 EPA 5021
b) THC >C8-C35			
b) THC >C8-C10	<5.0	mg/kg TS	5 ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5 ISO 16703 mod

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet

<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N.D.	30%	Kalkulering

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet

<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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Prøvenr.:	439-2016-09200156	Prøvetakingsdato:	19.09.2016
Prøvetype:	Sedimenter	Prøvelaker:	Torbjørn Dale
Prøvemerkning:	8. Sted: Kistadypet, Dyp: 60m Sediment dyp: 7-13,5m	Analysestartdato:	20.09.2016
Analyse	Resultat	Enhet	LOQ MU Metode
b) Arsen (As)	14	mg/kg TS	0.5 30% NS EN ISO 17294-2
b) Bly (Pb)	29	mg/kg TS	0.5 40% NS EN ISO 17294-2
b) Kadmium (Cd)	0.16	mg/kg TS	0.01 25% NS EN ISO 17294-2
b) Kobber (Cu)	58	mg/kg TS	0.5 30% NS EN ISO 11885
b) Krom (Cr)	34	mg/kg TS	0.3 30% NS EN ISO 11885
b) Kvikksølv (Hg)	0.048	mg/kg TS	0.001 20% NS-EN ISO 12846
b) Nikkel (Ni)	40	mg/kg TS	0.5 30% NS EN ISO 11885
b) Sink (Zn)	140	mg/kg TS	2 25% NS EN ISO 11885
b) PCB(7)			
b) PCB 28	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 52	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 101	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 118	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 153	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 138	< 0.00050	mg/kg TS	0.0005 EN 16167
b) PCB 180	< 0.00050	mg/kg TS	0.0005 EN 16167
b) Sum 7 PCB	N.D.		25% EN 16167
b) PAH(16)			
b) Naftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenaftalen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Acenaften	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoren	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fenantren	0.015	mg/kg TS	0.01 25% ISO 18287, mod.
b) Antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Fluoranten	0.051	mg/kg TS	0.01 25% ISO 18287, mod.
b) Pyren	0.044	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[a]antracen	0.018	mg/kg TS	0.01 25% ISO 18287, mod.
b) Krysen/Trifenylene	0.017	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[b]fluoranten	0.040	mg/kg TS	0.01 25% ISO 18287, mod.
b) Benzo[k]fluoranten	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[a]pyren	0.027	mg/kg TS	0.01 25% ISO 18287, mod.
b) Indeno[1,2,3-cd]pyren	0.032	mg/kg TS	0.01 25% ISO 18287, mod.
b) Dibenzof[a,h]antracen	< 0.010	mg/kg TS	0.01 ISO 18287, mod.
b) Benzo[ghi]perylene	0.038	mg/kg TS	0.01 25% ISO 18287, mod.
b) Sum PAH(16) EPA	0.28	mg/kg TS	25% ISO 18287, mod.
b) Tørstoff	50.0	%	0.1 5% EN 12880
a) Finstoff <63 µm	21.6	% (w/w)	1 ISO 11277 mod
Tributyltinn (TBT)	<1	µg/kg TS	1 Intern metode
Totalt organisk karbon (TOC)	1.8	% TS	0.1 20% Internal Method 1
a) Finstoff <2 µm (Leira)	6.8	% TS	1 ISO 11277 mod
b) THC >C5-C8	< 5.0	mg/kg TS	5 EPA 5021
b) THC >C8-C35			
b) THC >C8-C10	<5.0	mg/kg TS	5 ISO 16703 mod
b) THC >C10-C12	<5.0	mg/kg TS	5 ISO 16703 mod

Tegnforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måtesikkerhet
 <: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om målesikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
 Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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b) THC >C12-C16	<5.0 mg/kg TS	5	ISO 16703 mod
b) THC >C16-C35	<20 mg/kg TS	20	ISO 16703 mod
b) Sum THC (>C5-C35)	N.D.	30%	Kalkulering

Utførende laboratorium/ Underleverandør:

- a) DIN EN ISO/IEC 17025:2005 D-PL-14081-01-00, Eurofins Umwelt Ost GmbH (Jena), Lößstedter Strasse 78, D-07749, Jena
b) ISO/IEC 17025 SWEDAC 1125, Eurofins Environment Sweden AB (Lidköping), Box 887, Sjöhogsg. 3, SE-53119, Lidköping

Moss 06.10.2016-----
Stig Tjomsland

ASM/Bachelor Kjemi

Teamforklaring:

* Ikke omfattet av akkrediteringen LOQ: Kvantifiseringsgrense MU: Måleusikkerhet
<: Mindre enn >: Større enn nd: Ikke påvist

Opplysninger om måleusikkerhet og konfidensintervall fås ved henvendelse til laboratoriet.
Rapporten må ikke gjengis, unntatt i sin helhet, uten laboratoriets skriftlige godkjenning. Resultatene gjelder kun for de(n) undersøkte prøven(e).

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Appendix C

Norwegian environmental standard 2007

Veileder for klassifisering av miljøgifter i vann og sediment (TA-2229/2007)

Tabell 7 a Klassifisering av tilstand ut fra innhold av metaller og organiske stoffer i vann.

	I	II	III	IV	V
	Bakgrunn	God	Moderat	Dårlig	Svært dårlig
Metaller					
Arsen (µg As/L)	<2	2 - 4.8	4.8 - 8.5	8.5 - 85	>85
Bly (µg Pb/L)	<0.05	0.05 - 2.2	2.2 - 2.9	2.9 - 28	>28
Kadmium (µg Cd/L)	<0.03	0.03 - 0.24	0.24 - 1.5	1.5 - 15	>15
Kobber (µg Cu/L)	<0.3	0.3 - 0.64	0.64 - 0.8	0.8 - 7.7	>7.7
Krom (µg Cr/L)	<0.2	0.2 - 3.4	3.4 - 36	36 - 360	>360
Kvikksølv (µg Hg/L)	<0.001	0.001 - 0.048	0.048 - 0.071	0.071 - 0.14	>0.14
Nikkel (µg Ni/L)	<0.5	0.5 - 2.2	2.2 - 12	12 - 120	>120
Sink (µg Zn/L)	<1.5	1.5 - 2.9	2.9 - 6	6 - 60	>60
PAH					
Naftalen (µg/L)	<0.00066	0.00066 - 2.4	2.4 - 80	80 - 160	>160
Acenaftylen (µg/L)	<0.00001	0.00001 - 1.3	1.3 - 3.3	3.3 - 33	>33
Acenaften (µg/L)	<0.000034	0.000034 - 3.8	3.8 - 5.8	5.8 - 58	>58
Fluoren (µg/L)	<0.00019	0.0019 - 2.5	2.5 - 5	5 - 50	>50
Fenantren (µg/L)	<0.00025	0.00025 - 1.3	1.3 - 5.1	5.1 - 10	>10
Antracen (µg/L)		<0.11	0.11 - 0.36	0.36 - 3.6	>3.6
Fluoranthen (µg/L)	<0.00029	0.00029 - 0.12	0.12 - 0.9	0.9 - 1.8	>1.8
Pyren (µg/L)	0.000053	0.000053 - 0.023	0.023 - 0.023	0.023 - 0.046	>0.046
Benzo[a]antracen (µg/L)	<0.000006	0.000006 - 0.012	0.012 - 0.018	0.018 - 0.18	>0.18
Chrysen (µg/L)		<0.07	0.07 - 0.07	0.07 - 0.14	>0.14
Benzo[b]fluoranten (µg/L)	<0.000017	0.000017 - 0.03	0.03 - 0.06	0.06 - 0.6	>0.6
Benzo[k]fluoranten (µg/L)		<0.027	<0.027 - 0.06	0.06 - 0.6	>0.6
Benzo(a)pyren (µg/L)	<0.000005	0.000005 - 0.05	0.05 - 0.1	0.1 - 0.5	>0.5
Indeno[123cd]pyren (µg/L)	<0.000017	0.000017 - 0.002	0.002 - 0.003	0.003 - 0.03	>0.03
Dibenzo[ah]antracen (µg/L)		<0.03	0.03 - 0.06	0.06 - 0.6	>0.6
Benzo[ghi]perylen (µg/L)	<0.00001	0.00001 - 0.002	0.002 - 0.003	0.003 - 0.03	>0.03
Andre organiske					
EDDT ¹⁾ (µg/L)		<0.001	0.001 - 0.025	0.025 - 0.25	>0.25
Lindan (µg/L)		<0.02	0.02 - 0.04	0.04 - 0.2	>0.2
HCB ²⁾ (µg/L)		<0.013	0.013 - 0.05	0.05 - 0.47	>0.47
Pentaklorbenzen (µg/L)		<1	1 - 2	2 - 10	>10
Triklorbenzen (µg/L)		<4	4 - 50	50 - 100	>100
Hexaklorbutadien (µg/L)		<0.44	0.44 - 0.59	0.59 - 5.9	>5.9
SCCP ³⁾ (µg/L)		<0.5	0.5 - 1.4	1.4 - 2.8	>2.8
MCCP ⁴⁾ (µg/L)		<0.10	0.10 - 0.59	0.59 - 1.2	>1.2
Pentaklorfenol (µg/L)		<0.35	0.35 - 1	1 - 2	>2
Oktylfenol (µg/L)		<0.12	0.12 - 0.27	0.27 - 1.3	>1.3
Nonylfenol (µg/L)		<0.33	0.33 - 2.1	2.1 - 4.1	>4.1
Bisfenol A (µg/L)		<1.6	1.6 - 11	11 - 110	>110
TBBPA ⁵⁾ (µg/L)		<0.052	0.052 - 0.9	0.9 - 9	>9
PBDE ⁶⁾ (µg/L)		<0.53	0.53 - 1.4	1.4 - 2.8	>2.8
HBCDD ⁷⁾ (µg/L)		<0.31	0.31 - 1.1	1.1 - 2.2	>2.2
PFOS ⁸⁾ (µg/L)		<25	25 - 72	72 - 360	>360

Veileder for klassifisering av miljøgifter i vann og sediment (TA-2229/2007)

Diuron (µg/L)		<0.2	0.2 - 1.8	1.8 - 3.6	>3.6
Irgarol (µg/L)		<0.008	0.008 - 0.05	0.05 - 0.25	>0.25

Grenseverdier for TBT					
TBT-ion (µg/L) - effektbasert		<0.0002	0.0002 - 0.0015	0.0015 - 0.003	>0.003

- 1) DDT: Diklordifenyiltrikloretan. ΣDDT betegner sum av DDT og nedbrytningsproduktene DDE og DDD
- 2) HCB: Heksaklorbenzen
- 3) SPCC: Kortkjedede (C10-13) polyklorerte paraffiner
- 4) MPCC: middelkjedede (C14-17) polyklorerte paraffiner
- 5) TBBPA: Tetrabrombisfenol A
- 6) PBDE: Pentabromdifenyleter
- 7) HBCDD: Heksabromsyklododekan
- 8) PFOS: Perfluorert oktylsulfonat
- 9) TBT: Tributyltinn

Tabell 7 b Klassifisering av tilstand ut fra innhold av metaller og organiske stoffer i sedimenter.

	I	II	III	IV	V
	Bakgrunn	God	Moderat	Dårlig	Svært dårlig
Metaller					
Arsen (mg As/kg)	<20	20 - 52	52 - 76	76 - 580	>580
Bly (mg Pb/kg)	<30	30 - 83	83 - 100	100 - 720	>720
Kadmium (mg Cd/kg)	<0.25	0.25 - 2.6	2.6 - 15	15 - 140	>140
Kobber (mg Cu/kg)	<35	35 - 51	51 - 55	55 - 220	>220
Krom (mg Cr/kg)	<70	70 - 560	560 - 5900	5900 - 59000	>59000
Kvikksølv (mg Hg/kg)	<0.15	0.15 - 0.63	0.63 - 0.86	0.86 - 1.6	>1.6
Nikkcl (mg Ni/kg)	<30	30 - 46	46 - 120	120 - 840	>840
Sink (mg Zn/kg)	<150	150 - 360	360 - 590	590 - 4500	>4500
PAH					
Naftalen (µg/kg)	<2	2 - 290	290 - 1000	1000 - 2000	>2000
Acenafylen (µg/kg)	<1.6	1.6 - 33	33 - 85	85 - 850	>850
Acenafthen (µg/kg)	<4.8	2.4 - 160	160 - 360	360 - 3600	>3600
Fluoren (µg/kg)	<6.8	6.8 - 260	260 - 510	510 - 5100	>5100
Fenantren (µg/kg)	<6.8	6.8 - 500	500 - 1200	1200 - 2300	>2300
Antracen (µg/kg)	<1.2	1.2 - 31	31 - 100	100 - 1000	>1000
Fluoranthen (µg/kg)	<8	8 - 170	170 - 1300	1300 - 2600	>2600
Pyren (µg/kg)	<5.2	5.2 - 280	280 - 2800	2800 - 5600	>5600
Benzo[a]antracen (µg/kg)	<3.6	3.6 - 60	60 - 90	90 - 900	>900
Chrysen (µg/kg)	<4.4	4.4 - 280	280 - 280	280 - 560	>560
Benzo[b]fluoranten (µg/kg)	<46	46 - 240	240 - 490	490 - 4900	>4900
Benzo[k]fluoranten (µg/kg)		<210	210 - 480	480 - 4800	>4800
Benzo(a)pyren (µg/kg)	<6	6 - 420	420 - 830	830 - 4200	>4200
Indeno[123cd]pyren (µg/kg)	<20	20 - 47	47 - 70	70 - 700	>700
Dibenzo[ah]antracen (µg/kg)	<12	12 - 590	590 - 1200	1200 - 12000	>12000
Benzo[ghi]perylen (µg/kg)	<18	18 - 21	21 - 31	31 - 310	>310
PAH16 ¹⁾ (µg/kg)	<300	300 - 2000	2000 - 6000	6000 - 20000	>20000
Andre organiske					
PCB7 ²⁾ (µg/kg)	<5	5 - 17	17 - 190	190 - 1900	>1900
PCDD/F ³⁾ (TEQ) (µg/kg)	<0.01	0.01 - 0.03	0.03 - 0.10	0.10 - 0.50	>0.50
ΣDDT ⁴⁾ (µg/kg)	<0.5	0.5 - 20	20 - 490	490 - 4900	>4900

Veileder for klassifisering av miljøgifter i vann og sediment (TA-2229/2007)

Lindan (µg/kg)		<1.1	1.1 - 2.2	2.2 - 11	>11
Heksaklorbenzen (HCB) (µg/kg)	0.5	0.5 - 17	17 - 61	61 - 610	>610
Pentaklorbenzen (µg/kg)		<400	400 - 800	800 - 4000	>4000
Triklorbenzen (µg/kg)		<56	56 - 700	700 - 1400	>1400
Hexaklorbutadien (µg/kg)		<49	49 - 66	66 - 660	>660
SCCP ⁶⁾ (µg/kg)		<1000	1000 - 2800	2800 - 5600	>5600
MCCP ⁷⁾ (µg/kg)		<4600	4600 - 27000	27000 - 54000	>54000
Pentaklorfenol (µg/kg)		<12	12 - 34	34 - 68	>68
Oktylfenol (µg/kg)		<3.3	3.3 - 7.3	7.3 - 36	>36
Nonylfenol (µg/kg)		<18	18 - 110	110 - 220	>220
Bisfenol A (µg/kg)		<11	11 - 79	79 - 790	>790
TBBPA ⁸⁾ (µg/kg)		<63	63 - 1100	1100 - 11000	>11000
PBDE ⁹⁾ (µg/kg)		<62	62 - 7800	7800 - 16000	>16000
HBCDD ¹⁰⁾ (µg/kg)	<0.3	0.3 - 86	86 - 310	310 - 610	>610
PFOS ¹¹⁾ (µg/kg)	<0.17	0.17 - 220	220 - 630	630 - 3100	>3100
Diuron (µg/kg)		<0.71	0.71 - 6.4	6.4 - 13	>13
Irgarol (µg/kg)		<0.08	0.08 - 0.50	0.5 - 2.5	>2.5

Grenseverdier for TBT					
TBT ¹²⁾ (µg/kg) - effektbasert	<1	<0.002	0.002-0.016	0.016-0.032	>0.032
TBT ¹²⁾ (µg/kg) - forvaltningsmessig	<1	1-5	5 - 20	20 - 100	>100

- 1) PAH: Polysykliske aromatiske hydrokarboner
- 2) PCB: Polyklorerte bifenyler
- 3) PCDD/F: Polyklorerte dibenzodioksiner/furaner
- 4) DDT: Diklordifenyiltrikloretan. ΣDDT betegner sum av DDT og nedbrytningsproduktene DDE og DDD
- 5) HCB: Heksaklorbenzen
- 6) SCCP: Kortkjedede (C10-13) polyklorerte paraffiner
- 7) MCCP: middelkjedede (C14-17) polyklorerte paraffiner
- 8) TBBPA: Tetrabrombisfenol A
- 9) PBDE: Pentabromdifenyleter
- 10) HBCDD: Heksabromsyklododekan
- 11) PFOS: Perfluorert oktylsulfonat
- 12) TBT: Tributyltinn

vedlegg VII i Veileder for håndtering av sedimenter (M-350|2015) for mer informasjon om prøvetaking ved undersøkelser og overvåking.

1. Grenseverdier for klassifisering av prioriterte stoffer og vannregionspesifikke stoffer under vannforskriften

1.1 Miljøkvalitetsstandarder For prioriterte stoffer og prioritert farlige stoffer i ferskvann og kystvann.

Miljøkvalitetsstandarder i vann er angitt i µg/l

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
1	Alaklor	15972-60-8	0,3	0,3	0,7	0,7
2	Antracen ^A	120-12-7	0,1	0,1	0,1	0,1
3	Atrazin	1912-24-9	0,6	0,6	2,0	2,0
4	Benzen	71-43-2	10	8	50	50
5	Bromerte difenyletere ^{A 5}	32534-81-9			0,14	0,014
6	Kadmium og kadmiumforbindelser ^{A 6} (avhengig av vannets hardhet)	7440-43-9	≤ 0,08 (klasse 1) 0,08 (klasse 2) 0,09 (klasse 3) 0,15 (klasse 4) 0,25 (klasse 5)	0,2	≤ 0,45 (klasse 1) 0,45 (klasse 2) 0,6 (klasse 3) 0,9 (klasse 4) 1,5 (klasse 5)	≤ 0,45 (klasse 1) 0,45 (klasse 2) 0,6 (klasse 3) 0,9 (klasse 4) 1,5 (klasse 5)
7	Kortkjedete klorparafiner (C10-13) ^{A 7}	85535-84-8	0,4	0,4	1,4	1,4
8	Klorfenvinfos	470-90-6	0,1	0,1	0,3	0,3
9	Klorpyrifos	2921-88-2	0,03	0,03	0,1	0,1
10	1,2-Dikloretan	107-06-2	10	10	Ikke oppgitt	Ikke oppgitt

vedlegg VII i Veileder for håndtering av sedimenter (M-350|2015) for mer informasjon om prøvetaking ved undersøkelser og overvåking.

1. Grenseverdier for klassifisering av prioriterte stoffer og vannregionspesifikke stoffer under vannforskriften

1.1 Miljøkvalitetsstandarder For prioriterte stoffer og prioritert farlige stoffer i ferskvann og kystvann.

Miljøkvalitetsstandarder i vann er angitt i µg/l

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
1	Alaklor	15972-60-8	0,3	0,3	0,7	0,7
2	Antracen ^A	120-12-7	0,1	0,1	0,1	0,1
3	Atrazin	1912-24-9	0,6	0,6	2,0	2,0
4	Benzen	71-43-2	10	8	50	50
5	Bromerte difenyletere ^{A 5}	32534-81-9			0,14	0,014
6	Kadmium og kadmium-forbindelser ^{A 6} (avhengig av vannets hardhet)	7440-43-9	≤ 0,08 (klasse 1) 0,08 (klasse 2) 0,09 (klasse 3) 0,15 (klasse 4) 0,25 (klasse 5)	0,2	≤ 0,45 (klasse 1) 0,45 (klasse 2) 0,6 (klasse 3) 0,9 (klasse 4) 1,5 (klasse 5)	≤ 0,45 (klasse 1) 0,45 (klasse 2) 0,6 (klasse 3) 0,9 (klasse 4) 1,5 (klasse 5)
7	Kortkjedete klorparafiner (C10-13) ^{A 7}	85535-84-8	0,4	0,4	1,4	1,4
8	Klorfenvinfos	470-90-6	0,1	0,1	0,3	0,3
9	Klorpyrifos	2921-88-2	0,03	0,03	0,1	0,1
10	1,2-Dikloretan	107-06-2	10	10	Ikke oppgitt	Ikke oppgitt

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
11	Diklorometan	75-09-2	20	20	Ikke oppgitt	Ikke oppgitt
12	Di(2-etylheksyl)ftalat (DEHP) ^A	117-81-7	1,3	1,3	Ikke oppgitt	Ikke oppgitt
13	Diuron	330-54-1	0,2	0,2	1,8	1,8
14	Endosulfan ^A	115-29-7	0,005	0,0005	0,01	0,004
15	Fluoranten	206-44-0	0,0063	0,0063	0,12	0,12
16	Heksaklorbenzen ^A	118-74-1			0,05	0,05
17	Heksaklorbutadien ^A	87-68-3			0,6	0,6
18	Heksaklor- sykloheksan ^A	608-73-1	0,02	0,002	0,04	0,02
19	Isoproturon	34123-59-6	0,3	0,3	1,0	1,0
20	Bly og blyforbindelser	7439-92-1	1,2 ^B	1,3	14	14
21	Kvikksølv og kvikksølv forbindelser ^A	7439-97-6			0,07	0,07
22	Naftalen	91-20-3	2	2	130	130
23	Nikkel og nikkelforbindelser	7440-02-0	4 ^B	8,6	34	34
24	Nonylfenoler (4-nonylfenol) ^{A 9}	84852-15-3	0,3	0,3	2,0	2,0
25	Oktylfenol 4-(1,1,3,3-tetrametylbutyl)fenol ¹⁰	140-66-9	0,1	0,01	Ikke oppgitt	Ikke oppgitt
26	Pentaklorbenzen ^A	608-93-5	0,007	0,0007	Ikke oppgitt	Ikke oppgitt
27	Pentaklorfenol	87-86-5	0,4	0,4	1,0	1,0
28	Polyaromatiske hydrokarboner (PAH) ^{A 11}	Ikke relevant	Ikke oppgitt	Ikke oppgitt	Ikke oppgitt	Ikke oppgitt
	Benzo(a)pyren	50-32-8	1,7x10 ⁻⁴	1,7x10 ⁻⁴	0,27	0,027
	Benzo(b)fluoranten	205-99-2	Se fotnote 11	Se fotnote 11	0,017	0,017

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
	Benzo(k)fluoranten	207-08-9	Se fotnote 11	Se fotnote 11	0,017	0,017
	Benzo(g,h,i)perylene	191-24-2	Se fotnote 11	Se fotnote 11	8,2x10 ⁻³	8,2x10 ⁻⁴
	Indeno(1,2,3-cd)pyren	193-39-5	Se fotnote 11	Se fotnote 11	Ikke oppgitt	Ikke oppgitt
29	Simazin	122-34-9	1,0	1,0	4,0	4,0
30	Tributyltinn forbindelser (tributyltinn kation) ^A	36643-28-4	0,0002	0,0002	0,0015	0,0015
31	Triklorbenzener	12002-48-1	0,4	0,4	Ikke oppgitt	Ikke oppgitt
32	Triklormetan (Kloroform)	67-66-3	2,5	2,5	Ikke oppgitt	Ikke oppgitt
33	Trifluralin ^A	1582-09-8	0,03	0,03	Ikke oppgitt	Ikke oppgitt
34 ¹²	Dicofol ^A	115-32-2	1,3 x 10 ⁻³	3,2 x 10 ⁻⁵	Ikke oppgitt ¹³	Ikke oppgitt ¹³
35 ¹²	Perfluoroktylsulfonat og dets derivater (PFOS) ^A	1763-23-1	6,5 x 10 ⁻⁴	1,3 x 10 ⁻⁴	36	7,2
36 ¹²	Quinoxifen ^A	124495-18-7	0,15	0,015	2,7	0,54
37 ¹²	Dioksin og dioksinlignende forbindelser ^A	Se fotnote 14			Ikke oppgitt	Ikke oppgitt
38 ¹²	Aklonifen	74070-46-5	0,12	0,012	0,12	0,012
39 ¹²	Bifenox	42576-02-3	0,012	0,0012	0,04	0,004
40 ¹²	Cybutryne	28159-98-0	0,0025	0,0025	0,016	0,016
41 ¹²	Cypermethrin ¹⁵	52315-07-8	8 x 10 ⁻⁵	8 x 10 ⁻⁶	6 x 10 ⁻⁴	6 x 10 ⁻⁵
42 ¹²	Diklorvos	62-73-7	6 x 10 ⁻⁴	6 x 10 ⁻⁵	7 x 10 ⁻⁴	7 x 10 ⁻⁵

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
	Benzo(k)fluoranten	207-08-9	Se fotnote 11	Se fotnote 11	0,017	0,017
	Benzo(g,h,i)perylene	191-24-2	Se fotnote 11	Se fotnote 11	8,2x10 ⁻³	8,2x10 ⁻⁴
	Indeno(1,2,3-cd)pyren	193-39-5	Se fotnote 11	Se fotnote 11	Ikke oppgitt	Ikke oppgitt
29	Simazin	122-34-9	1,0	1,0	4,0	4,0
30	Tributyltinn forbindelser (tributyltinn kation) ^A	36643-28-4	0,0002	0,0002	0,0015	0,0015
31	Triklorbenzener	12002-48-1	0,4	0,4	Ikke oppgitt	Ikke oppgitt
32	Triklormetan (Kloroform)	67-66-3	2,5	2,5	Ikke oppgitt	Ikke oppgitt
33	Trifluralin ^A	1582-09-8	0,03	0,03	Ikke oppgitt	Ikke oppgitt
34 ¹²	Dicofol ^A	115-32-2	1,3 x 10 ⁻³	3,2 x 10 ⁻⁵	Ikke oppgitt ¹³	Ikke oppgitt ¹³
35 ¹²	Perfluoroktylsulfonat og dets derivater (PFOS) ^A	1763-23-1	6,5 x 10 ⁻⁴	1,3 x 10 ⁻⁴	36	7,2
36 ¹²	Quinoxifen ^A	124495-18-7	0,15	0,015	2,7	0,54
37 ¹²	Dioksin og dioksinlignende forbindelser ^A	Se fotnote 14			Ikke oppgitt	Ikke oppgitt
38 ¹²	Aklonifen	74070-46-5	0,12	0,012	0,12	0,012
39 ¹²	Bifenox	42576-02-3	0,012	0,0012	0,04	0,004
40 ¹²	Cybutryne	28159-98-0	0,0025	0,0025	0,016	0,016
41 ¹²	Cypermethrin ¹⁵	52315-07-8	8 x 10 ⁻⁵	8 x 10 ⁻⁶	6 x 10 ⁻⁴	6 x 10 ⁻⁵
42 ¹²	Diklorvos	62-73-7	6 x 10 ⁻⁴	6 x 10 ⁻⁵	7 x 10 ⁻⁴	7 x 10 ⁻⁵

Nr	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
43 ¹²	Heksabromsyklododekan (HBCDD) ^A	Se fotnote 16	0,0016	0,0008	0,5	0,05
44 ¹²	Heptaklor og heptakloreposid ^A	76-44-8/1024-57-3	2 x 10 ⁻⁷	1 x 10 ⁻⁸	3 x 10 ⁻⁴	3 x 10 ⁻⁵
45 ¹²	Terbutryn	886-50-0	0,065	0,0065	0,34	0,034

- CAS- Chemical Abstracts service.
- Den gjennomsnittlige årlige verdien. Hvis ikke annet er oppgitt svarer denne verdien til totalkonsentrasjonen av alle isomere.
- Ferskvann innbefatter elver, innsjøer og sterkt modifiserte ferskvannsføremønstre.
- Den maksimalt tillatte verdien. Der hvor denne verdien ikke er oppgitt er den gjennomsnittlige årlige verdien ansett til også å beskytte mot kortvarige utslipp av forbindelsen.
- I gruppen av bromerte flammehemmere kalt polybromerte difenyletere inngår kongener med numrene 28, 47, 99, 100, 153 og 154. Kun Tetra, Penta, Hexa og Heptabromdifenyletere er inkludert som prioritert farlige stoffer (henholdsvis CAS-nr 40088-47-9, 32534-81-9, 36483-60-0, 68928-80-3).
- For kadmium og kadmiumforbindelser er miljøkvalitetsstandardene avhengig av vannets hardhet. Miljøkvalitetsstandardene er derfor delt inn i fem klasser (klasse 1: < 40 mg CaCO₃ /l, klasse 2: 40 til < 50 mg CaCO₃ /l, klasse 3: 50 til < 100 mg CaCO₃ /l, klasse 4: 100 til < 200 mg CaCO₃ /l og klasse 5: ≥ 200 mg CaCO₃ /l).
- Det er ikke gitt noen standard på hvilke av stoffene i denne gruppen det skal analyseres på. Det er derfor opp til laboratoriene å velge ut hvilke av klorparafinene som skal analyseres.
- Miljøkvalitetsstandarden gjelder den biotilgjengelige konsentrasjonen av stoffet.
- Nonylfenol (CAS 25154-52-3) inkludert isomerene 4-nonylfenol (CAS 104-40-5) og 4-nonylfenol (forgrenet) (CAS 84852-15-3).
- Octylfenol (CAS 1806-26-4) inkludert isomer 4-(1,1',3,3'-tetrametylbutyl)-fenol (CAS 140-66-9).
- For Polyaromatiske hydrokarboner (PAH) refererer miljøkvalitetsstandardene for årlig gjennomsnitt til konsentrasjonen av benzo(a)pyren. Benzo(a)pyren kan betraktes som en markør for de andre PAHene, og det er kun benzo(a)pyren som må overvåkes for å sammenligne med årlig gjennomsnitt.
- Disse stoffene trer i kraft som prioriterte stoffer ved utgangen av 2018, og skal frem til den tid ikke telle med i evalueringen av kjemisk tilstand.
- Utilstrekkelig datagrunnlag for å kunne sette maksimal verdi.
- Dette omfatter følgende stoffer: 7 polyklorerte dibenzo-p-dioksiner (PCDDer): 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8- H6CDD (CAS 39227-28-6), 1,2,3,6,7,8- H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9) 10 polyklorerte dibenzofuraner (PCDFs): 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8-P5CDF (CAS 57117-41-6), 2,3,4,7,8-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918-21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0) 12 dioksin-lignende polyklorerte bifenyler (PCB-DL): 3,3',4,4'-T4CB (PCB 77, CAS 32598-13-3), 3,3',4',5-T4CB (PCB 81, CAS 70362-50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS 65510-44-3), 3,3',4,4',5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3',4,4',5,5'-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5'-H7CB (PCB 189, CAS 39635-31-9).
- CAS 52315-07-8 omfatter en blanding av isomerer av cypermethrin; alpha-cypermethrin (CAS 67375-30-8), beta-cypermethrin (CAS 65731-84-2), theta-cypermethrin (CAS 71697-59-1) og zeta-cypermethrin (52315-07-8).

16 Dette omfatter 1,3,5,7,9,11-Heksabromcyclododekan (CAS 25637-99-4), 1,2,5,6,9,10-Heksabromcyclododekan (CAS 3194-55-6), α -Heksabromcyclododekan (CAS 134237-50-6), β -Heksabromcyclododekan (CAS 134237-51-7) og γ -Heksabromcyclododekan (CAS 134237-52-8).

A Prioritert farlige stoffer

1.2 Miljøkvalitetsstandarder for prioriterte stoffer og prioritert farlige stoffer i organismer

Miljøkvalitetsstandarder i organismer er angitt i $\mu\text{g}/\text{kg}$ våtvekt.

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i organismer ²
1	Antracen ^A	120-12-7	2400
2	Bromerte difenyletere ^A	32534-81-9	0,0085
3	Kortkjedete klorparafiner (C10-13) ^A	85535-84-8	6000
4	Di-(2-etylheksyl)ftalat (DEHP) ^A	117-81-7	2900
5	Endosulfan ^A	115-29-7	370
6	Fluoranten	206-44-0	30
7	Heksaklorbenzen ^A	118-74-1	10
8	Heksaklorbutadien ^A	87-68-3	55
9	Heksaklor- sykloheksan ^A	608-73-1	61
10	Kvikksølv og kvikksølvforbindelser ^A	7439-97-6	20
11	Naftalen	91-20-3	2400
12	Nonylfenol (4-nonylfenol) ^A	84852-15-3	3000
13	Oktylfenol 4-(1,1,3,3-tetrametylbutyl)fenol	140-66-9	0,004
14	Pentaklorbenzen ^A	608-93-5	50
15	Pentaklorfenol	87-86-5	180
16	PAH		
	Benzo(a)pyren	50-32-8	5
	Benzo(b)fluoranten	205-99-2	Se fotnote 4.
	Benzo(k)fluoranten	207-08-9	Se fotnote 4.
	Benzo(g,h,i)perylene	191-24-2	Se fotnote 4.
	Indeno(1,2,3-cd)pyren	193-39-5	Se fotnote 4.
17	Tributyltinnforbindelser (tributyltinn kation) ^A	36643-28-4	150
18	Triklorobenzener	12002-48-1	490

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i organismer ²
19	Dicofol	115-32-2	33
20	Perfluoroktylsulfonat og dets derivater (PFOS) ^A	1763-21-1	9,1
21	Dioksin og dioksinlignende forbindelser ^A	Se fotnote 14 i del A i dette vedlegg.	Sum av PCDD+PCDF+PVB-DL 0,0065 µg/kg TEQ ⁵
22	Heksabromsyklododekan (HBCDD) ^A	Se fotnote 16 i del A i dette vedlegg.	167
23	Heptaklor og heptakloreposid ^A	76-44-8/1024-57-3	6,7x10 ⁻³

¹ CAS- Chemical Abstracts service.

² Miljøkvalitetsstandardene gjelder for fisk både i ferskvann og marine områder. Alternativ taksa eller matriks kan benyttes dersom miljøkvalitetsstandarden gir samme beskyttelsesnivå. For fluoranten (stoff nr. 6) og PAH (stoff nr. 16) gjelder miljøkvalitetsstandarden for krepsdyr og bløtdyr. Overvåking av fluoranten og PAH i fisk er ikke hensiktsmessig for å evaluere kjemisk tilstand. For dioksiner og dioksinlignende forbindelser (stoff nr. 21) gjelder miljøkvalitetsstandarden i fisk, krepsdyr og bløtdyr.

³ For Polyaromatiske hydrokarboner (PAH) refererer miljøkvalitetsstandardene i organismer til konsentrasjonen av benzo(a)pyren. Benzo(a)pyren kan betraktes som en markør for de andre PAHene, og det er kun benzo(a)pyren som må overvåkes for å sammenligne med EQS i organismer.

⁴ PCDD: polyklorerte dibenzo-p-dioksiner; PCDF: polyklorerte dibenzofuraner; PCB-DL: dioksinlignende polyklorerte bifenylter TEQ: toksisitetskvivalenter i følge Verdens helseorganisasjon 2005 Toxic Equivalent Factors

^A Prioritert farlige stoffer

1.3 Miljøkvalitetsstandarder for prioriterte stoffer og prioritert farlige stoffer i sediment

Miljøkvalitetsstandarder i sediment er angitt i mg/kg tørrstoff.

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i sediment (kystvann) ²	Miljøkvalitetsstandard i sediment (ferskvann) ²
1	Alaklor	15972-60-8	0,0003	
2	Antracen ^A	120-12-7	0,0046	
3	Bromerte difenyletere ^A	32534-81-9	0,062	0,31
4	Kadmium og kadmiumforbindelser ^A	7440-43-9	2,5	
5	C 10-13 kloralkaner ^A	85535-84-8	0,8	
6	Klorfenvifos	470-90-6	0,0005	

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i sediment (kystvann) ²	Miljøkvalitetsstandard i sediment (ferskvann) ²
7	Klorpyrifos	2921-88-2	0,0013	
8	Di-(2-etylheksyl)ftalat (DEHP) ^A	117-81-7	10	
9	Endosulfan ^A	115-29-7	0,00007	
10	Fluoranten	206-44-0	0,40	
11	Heksaklorbensen ^A	118-74-1	0,017	
12	Heksaklorbutadien ^A	87-68-3	0,049	
13	Heksaklor- sykloheksan ^A	608-73-1	0,000074	0,00074
14	Bly og blyforbindelser	7439-92-1	150	66
15	Kvikksølv og kvikksølvforbindelser ^A	7439-97-6	0,52	
16	Naftalen	91-20-3	0,027	
17	Nikkel og nikkelforbindelser	7440-02-0	42	
18	Nonylfenol ^A	84852-15-3	0,016	
19	Oktylfenol	140-66-9	0,0003	0,003
20	Pentaklorbenzen ^A	608-93-5	0,4	
21	Pentaklorfenol	87-86-5	0,014	
22	PAH ^A			
	Benzo(a)pyren	50-32-8	0,18	
	Benzo(b)fluoranten	205-99-2	0,14	
	Benzo(k)fluoranten	207-08-9	0,14	
	Benzo(g,h,i)perylene	191-24-2	0,084	
	Ideno(1,2,3-cd)pyren	193-39-5	0,063	
23	Tributyltinn forbindelser (tributyltinn kation) ^A	36643-28-4	0,000002	
24	Triklorbenzener	12002-48-1	0,0056	
25	Trifluralin ^A	1582-09-8	1,6	
26	Perfluoroktylsulfonat og dets derivater (PFOS) ^A	1763-23-1	0,00023	0,0023
27	Dioksin og dioksinlignende PCB ^A	Se fotnote 14 i tabell A i dette vedlegg.	8,6 x 10 ⁻⁷ TEQ	

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i sediment (kystvann) ²	Miljøkvalitetsstandard i sediment (ferskvann) ²
28	Heksabromsyklododekan (HBCDD) ^A	Se fotnote 16 i tabell A i dette vedlegg.	0,034	0,17

1 CAS- Chemical Abstracts service.

2 Miljøkvalitetsstandarder i sediment er ikke absolutte. Ved overskridelser av miljøkvalitetsstandarder i sediment bør stedsspesifikke undersøkelser og risikovurderinger gjennomføres.

A Prioritert farlige stoffer

1.4 Miljøkvalitetsstandarder for andre EU-utvalgte stoffer i vann.

Miljøkvalitetsstandarder i vann er angitt i $\mu\text{g/l}$.

Nr.	Navn på substans	CAS-nr. ¹	Årlig gjennomsnitt ² for ferskvann ³	Årlig gjennomsnitt for ² for kystvann	Maksimal verdi ⁴ for ferskvann ³	Maksimal verdi ⁴ for kystvann
1	DDT totalt ⁵	Ikke relevant	0,025	0,025	Ikke oppgitt	Ikke oppgitt
	para-para-DDT	50-29-3	0,01	0,01	Ikke oppgitt	Ikke oppgitt
2	Aldrin	309-00-2	$\Sigma = 0,01$	$\Sigma = 0,005$	Ikke oppgitt	Ikke oppgitt
3	Dieldrin	60-57-1	$\Sigma = 0,01$	$\Sigma = 0,005$	Ikke oppgitt	Ikke oppgitt
4	Endrin	72-20-8	$\Sigma = 0,01$	$\Sigma = 0,005$	Ikke oppgitt	Ikke oppgitt
5	Isodrin	465-73-6	$\Sigma = 0,01$	$\Sigma = 0,005$	Ikke oppgitt	Ikke oppgitt
6	Karbondotetraklorid	56-23-5	12	12	Ikke oppgitt	Ikke oppgitt
7	Tetrakloretylen	127-18-4	10	10	Ikke oppgitt	Ikke oppgitt
8	Triklloretylen	79-01-6	10	10	Ikke oppgitt	Ikke oppgitt

¹ CAS- Chemical Abstracts service.

² Den gjennomsnittlige årlige verdien. Hvis ikke annet er oppgitt svarer denne verdien til totalkonsentrasjonen av alle isomere.

³ Ferskvann innbefatter elver, innsjøer og sterkt modifiserte ferskvannsforkomster.

⁴ Den maksimalt tillatte verdien. Der hvor denne verdien ikke er oppgitt er den gjennomsnittlige årlige verdien ansett til også å beskytte mot kortvarige utslipp av forbindelsen.

⁵ DDT total består av summen av isomerene 1,1,1-trikloro-2,2 bis (p-klorofenyl) etane (CAS nummer 50-29-3); 1,1,1-trikloro-2 (o-klorofenyl)-2-(p-klorofenyl) etane (CAS nummer 789-02-6); 1,1-dikloro-2,2 bis (p-klorofenyl) etylen (CAS nummer 72-55-9); og 1,1-dikloro-2,2 bis (p-klorofenyl) etan (CAS nummer 72-54-8).

1.5 Miljøkvalitetsstandarder for andre EU-utvalgte stoffer i organismer og sediment

Miljøkvalitetsstandarder i sediment er angitt i mg/kg tørrstoff.

Nr	Navn på substans	CAS-nr. ¹	Miljøkvalitetsstandard i organismer (µg/kg våtvekt)	Miljøkvalitetsstandard i sediment (mg/kg tørrvekt)
1	DDT totalt ²	Ikke relevant	609	0,015
	para-para-DDT	50-29-3		0,006

¹ CAS- Chemical Abstracts service.

² DDT total består av summen av isomerene 1,1,1-trikloro-2,2 bis (p-klorofenyl) etane (CAS nummer 50-29-3); 1,1,1-trikloro-2 (o-klorofenyl)-2-(p-klorofenyl) etane (CAS nummer 789-02-6); 1,1-dikloro-2,2 bis (p-klorofenyl) etylen (CAS nummer 72-55-9); og 1,1-dikloro-2,2 bis (p-klorofenyl) etan (CAS nummer 72-54-8).

1.6 Miljøkvalitetsstandarder for vannregionspesifikke stoffer i vann, sediment og biota

Nr	Navn på substans	CAS-nr. ¹	Ferskvann		Kystvann		Sediment EQS _{sed} mg/kg TS	Biota Q5- biota, hh µg/kg biota
			Årlig gjennomsnitt ² for ferskvann ³ µg/l	Maksimal verdi ⁴ for ferskvann ³ n ³ l µg/l	Årlig gjennomsnitt ² for kystvann µg/l	Maksimal verdi ⁴ for kystvann µg/l		
1	Bisfenol A	80-05-7	1.5	11	0.15	11	0.0011	
2	TBBPA (Tetrabromobisfenol A)	79-94-7	0.254	0.9	0.254	0.9	0.108	
3	Dekametyl syklopentasiloksan (D5)	541-02-6	1.7	17	0.17	1.7	0.044	15217
4	Klorparafiner (mellomkjedete)	85535-85-9	0.05		0.05		4.6	170
5	PFOA	3825-26-1. flere	9.1	Ikke oppgitt	9.1	Ikke oppgitt	0.071	91.3
6	Trikloran	3380-34-5	0.1	0.28	0.1	0.28	0.009	15217
7	TCEP (tris(2-kloretyl)fosfat)	115-96-8	65	510	6.5	510	0.0716	7304

Nr	Navn på Navn substans	CAS-nr. ¹	Ferskvann		Kystvann		Sediment	Biota
8	Dodecylfenol med isomere	121158-58-5, 27193-86-8	0.04	0.17	0.004	0.017	0.0044	
9	Diflubenzuron	35367-38-5	0.004	0.1	0.004	0.1	0.000184	730
10	Teflubenzuron	83121-18-0	0.0025	0.12	0.0025	0.012	0.0000004	609
11	Trifenylytin	892-20-6, 900-95-8, 76-87-9, 639-58-7	0.0019	0.035	0.0019	0.035	3.61E-05	152 (med 100% TDI)
12	PCB7	1336-36-3	2.4E-06		2.4E-06		0.0041	1
13	Kobber	7440-50-8	7.8	7.8	2.6	2.6	84	
14	Sink	7440-66-6	11	11	3.38	6	139	
15	PAH							
	Acenaftylen	208-96-8	1.28	33	1.28	3.3	0.033	
	Acenaften	83-32-9	3.8	3.8	3.8	3.8	0.10	
	Fluoren	86-73-7	1.5	33.9	1.5	6.8	0.15	
	Fenantren	85-01-8	0.5	6.7	0.5	6.7	0.78	
	Pyren	129-00-0	0.023		0.023		0.084	
	Benzo(a) antracen	56-55-3	0.012	0.018	0.012	0.018	0.06	304
	Krysen	218-01-9	0.07	0.07	0.07	0.07	0.28	
	Dibenso(ah)antracen	53-70-3	0.0006	0.014	0.0006	0.014	0.027	
16	Arsen	7440-38-2	0.5	8.5	0.6	8.5	18	
17	Krom	7440-47-3 (Cr metall);	3.4	3.4	3.4	35.8	660	

¹ CAS- Chemical Abstracts service.

² Den gjennomsnittlige årlige verdien. Hvis ikke annet er oppgitt svarer denne verdien til totalkonsentrasjonen av alle isomere.

³ Ferskvann innbefatter elver, innsjøer og sterkt modifiserte ferskvannsførekoster.

⁴ Den maksimalt tillatte verdien. Der hvor denne verdien ikke er oppgitt er den gjennomsnittlige årlige verdien ansett til også å beskytte mot kortvarige utslipp av forbindelsen.

2. Tilstandsklasser for Prioriterte- og vannregionspesifikke stoffer i ferskvann, kystvann og sediment

2.1 Tilstandsklasser for ferskvann ($\mu\text{g/l}$)

Nr	Navn på Navn substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
		Bakgrunn	AA-EQS	MAC-EQS		Omfattende akutt tox eff.
1	Kadmium	0.003	Fotnote 1	Fotnote 2	Fotnote 3	Fotnote 3
2	Bly	0.02	1.2	14	57	> 57
3	Nikkel	0.5	4	34	67	> 67
4	Kvikksølv	0.001	0.047	0.07	0.14	> 0.14
5	TBT		0.0002	0.0015	0.003	> 0.003
6	Bromerte difenyletere		4.9E-08	0.14	0.28	> 0.28
7	Heksaklorbensen		0.013 ⁴⁾	0.05	0.47	> 0.47
8	Heksaklorbutadien		0.003	0.6	5.9	> 5.9
9	Heksaklorsykloheksan		0.02	0.04	0.26	> 0.26
10	C10-13 kloralkaner		0.4	1.4	2.8	> 2.8
11	Pentaklorbenzen		0.007	2	10	> 10
12	Pentaklorfenol		0.4	1	2	> 2
13	Triklorbenzen		0.4	50	100	> 100
14	Naftalen	0.00066	2	130	650	> 650
14	Antracen	0.004	0.1	0.1	1	> 1
14	Fluroanten	0.00029	0.0063	0.12	0.6	> 0.6
14	Benzo(b)fluoranten	0.000017	0.017	0.017	1.28	> 1.28
14	Benzo(k)fluoranten	0.000017	0.017	0.017	0.93	> 0.93

Nr	Navn på Navn substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
14	Benzo(a)pyren	0.000005	0.00017	0.27	1.54	> 1.54
14	Indeno(1,2,3-cd)pyren	0.000017	0.0027	0.0027	0.1	> 0.1
14	Benzo(g,h,i)perylene	0.000011	0.0082	0.0082	0.14	> 0.14
15	Nonylfenol		0.3	2	4	> 4
16	Oktylfenol		0.1	0.27	1.3	> 1.3
17	Alaklor		0.3	0.7	1.3	> 1.3
18	Klorfenvinfos		0.1	0.3	0.63	> 0.63
19	Klorpyrifos		0.03	0.1	0.3	> 0.3
20	Endosulfan		0.005	0.01	0.13	> 0.13
21	Trifluralin		0.03	0.88	8.8	> 8.8
22	DEHP		1.3	-	-	-
23	HBCDD	0 (LOD 0.001)	0.0016	0.5	5.2	> 5.2
24	PFOS		0.00065	36		
25	Dioksiner		1.9E-08			
26	DDT (p,p'-DDT)		0.025 (0.01)	0.0265 (0.0265)	0.265	> 0.265
27	Bisfenol A	0	1.5	11	110	> 110
28	TBBPA		0.25	0.9	9	> 9
29	D5		1.7	17	-	-
30	Klorparafiner (mellomkjedete)		0.05	0.59	1.2	> 1.2
31	PFOA		9.1			
32	Trikloran		0.1	0.28	2.8	> 2.8
33	TCEP		65	510	5100	> 5100
34	Dodecylfenol med isomere		0.04	0.17	1.7	> 1.7
35	Diflubenzuron		0.004	0.1	1	> 1
36	Teflubenzuron		0.0025	0.12	1.2	> 1.2
37	Trifenyltin		0.0019	0.035	0.35	> 0.351
38	PCB7		-	-	-	-

Nr	Navn på Navn substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
39	Kobber	0.3	7.8	7.8	15.6	> 15.6
40	Sink	1.5	11	11	60	> 60
41	PAH					
	Acenaftylen	0.00001	1.3	33	330	> 330
	Acenaften	0.000034	3.8	3.8	382	> 382
	Fluoren	0.00019	1.5	34	339	> 339
	Fenantren	0.00025	0.51	6.7	67	> 67
	Pyren	0.000053	0.023	0.023	0.23	> 0.23
	Benzo(a)antracen	0.000006	0.012	0.018	1.8	> 1.8
	Krysen	0.000056	0.07	0.07	0.7	> 0.7
	Dibenso(ah)antracen	0.000001	0.00061	0.014	0.14	> 0.14
42	Arsen	0.15	0.5	8.5	85	> 85
43	Krom	0.1	3.4	3.4	3.4	> 3.4

- 1) Klasse II Cd verdier avhengig av vannets hardhet: ≤ 0.08 (< 40 mg CaCO₃/L); 0.08 (40 - <50 mg CaCO₃/L); 0.09 (50 - <100 mg CaCO₃/L); 0.15 (100 - <200 mg CaCO₃/L); 0.25 (≥ 200 mg CaCO₃/L)
- 2) Klasse III Cd verdier avhengig av vannets hardhet: ≤ 0.45 (< 40 mg CaCO₃/L); 0.45 (40 - <50 mg CaCO₃/L); 0.60 (50 - <100 mg CaCO₃/L); 0.9 (100 - <200 mg CaCO₃/L); 1.5 (≥ 200 mg CaCO₃/L)
- 3) Klasse IV Cd verdier avhengig av vannets hardhet: ≤ 4.5 (< 40 mg CaCO₃/L); 4.5 (40 - <50 mg CaCO₃/L); 6.0 (50 - <100 mg CaCO₃/L); 9.0 (100 - <200 mg CaCO₃/L); 15 (≥ 200 mg CaCO₃/L). Verdier over tilhøre til klasse V.
- 4) HCB AA-EQS basert på human helse er 0.0002 µg/L, men BCF er usikker

2.2 Tilstandsklasser for kystvann (µg/l)

Nr	Navn på Navn substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
		Bakgrunn	AA-EQS	MAC-EQS		Omfattende akutt tox eff.
1	Kadmium	0.03	0.2	Fotnote 1	Fotnote 2	Fotnote 2
2	Bly	0.02	1.3	14	57	> 57
3	Nikkel	0.5	8.6	34	67	> 67
4	Kvikksølv	0.001	0.047	0.07	0.14	> 0.14

Nr	Navn på Navn substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
5	TBT		0.0002	0.0015	0.003	> 0.003
6	Bromerte difenyletere		2.4E-09	0.014	0.28	> 0.28
7	Heksaklorbensen		0.013 ³⁾	0.05	0.47	> 0.47
8	Heksaklorbutadien		0.003	0.6	5.9	> 5.9
9	Heksaklorsykloheksan		0.002	0.02	0.26	> 0.26
10	C10-13 kloralkaner		0.4	1.4	2.8	> 2.8
11	Pentaklorbenzen		0.0007	2	10	> 10
12	Pentaklorfenol		0.4	1	2	> 2
13	Triklorbenzen		0.4	50	100	> 100
14	Naftalen	0.00066	2	130	650	> 650
14	Antracen	0.004	0.1	0.1	1	> 1
14	Fluroanten	0.00029	0.0063	0.12	0.6	> 0.6
14	Benzo(b)fluoranten	0.000017	0.017	0.017	1.28	> 1.28
14	Benzo(k)fluoranten	0.000017	0.017	0.017	0.93	> 0.93
14	Benzo(a)pyren	0.000005	0.00017	0.027	1.5	> 1.5
14	Indeno(1,2,3-cd)pyren	0.000017	0.0027	0.0027	0.1	> 0.1
14	Benzo(g,h,i)perylene	0.000011	0.00082	0.00082	0.14	> 0.14
15	Nonylfenol		0.3	2	4	> 4
16	Oktylfenol		0.01	0.27	1.3	> 1.3
17	Alaklor		0.3	0.7	1.3	> 1.3
18	Klorfenvinfos		0.1	0.3	0.63	> 0.63
19	Klorpyrifos		0.03	0.1	0.3	> 0.3
20	Endosulfan		0.0005	0.004	0.04	> 0.04
21	Trifluralin		0.03	0.88	8.8	> 8.8
22	DEHP		1.3	-	-	-
23	HBCDD	0 (LOD 0.001)	0.0008	0.05	5.2	> 5.2
24	PFOS		0.00013	7.2		
25	Dioksiner		1.9E-09			>

Nr	Navn på substans	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
26	DDT (p,p'-DDT)		0.025 (0.01)	0.0265 (0.0265)	0.265	> 0.265
27	Bisfenol A		0.15	11	110	> 110
28	TBBPA	0	0.25	0.9	9	> 9
29	D5		0.17	1.7	17	> 17
30	Klorparafiner (mellomkjedete)		0.05	0.059	1.2	> 1.2
31	PFOA		9.1			
32	Trikloran		0.1	0.28	2.8	> 2.8
33	TCEP		6.5	510	5100	> 5100
34	Dodecylfenol med isomere		0.004	0.017	0.17	> 0.17
35	Diflubenzuron		0.004	0.1	1	> 1
36	Teflubenzuron		0.0025	0.012	1.2	> 1.2
37	Trifenylytin		0.0019	0.035	0.35	> 0.35
38	PCB7		-	-	-	-
39	Kobber	0.3	2.6	2.6	5.2	> 5.2
40	Sink	1.5	3.4	6	60	> 60
41	PAH					
41	Acenaftylen	0.00001	1.3	3.3	330	> 330
41	Acenaften	0.000034	3.8	3.8	382	> 382
41	Fluoren	0.00019	1.5	6.8	339	> 339
41	Fenantren	0.00025	0.51	6.7	67	> 67
41	Pyren	0.000053	0.023	0.023	0.23	> 0.23
41	Benzo(a)antracen	0.000006	0.012	0.018	1.8	> 1.8
41	Krysen	0.000056	0.07	0.07	0.7	> 0.7
41	Dibenso(ah)antracen	0.000001	0.0006	0.014	0.14	> 0.14
42	Arsen	0.15	0.6	8.5	85	> 85
43	Krom	0.1	3.4	36	358	> 358

1) Klasse III Cd verdier avhengig av vannets hardhet: ≤ 0.45 (< 40 mg CaCO₃/L); 0.45 (40 - <50 mg CaCO₃/L); 0.60 (50 - <100 mg CaCO₃/L); 0.9 (100 - <200 mg CaCO₃/L); 1.5 (≥ 200 mg CaCO₃/L)

- 2) Klasse IV Cd verdier avhengig av vannets hardhet: ≤ 4.5 (< 40 mg CaCO₃/L); 4.5 (40 - < 50 mg CaCO₃/L); 6.0 (50 - < 100 mg CaCO₃/L); 9 (100 - < 200 mg CaCO₃/L); 15 (≥ 200 mg CaCO₃/L). Verdier over tilhøre til klasse V.
- 3) HCB AA-EQS basert på human helse er 0.0002 µg/L, men BCF er usikker

2.3 Tilstandsklasser for sediment

Nr	Navn på Navn substans	Enhet	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
			Bakgrunn	AA-EQS	MAC-EQS		Omfattende akutt tox eff.
1	Kadmium	mg/kg TS	0.2	2.5 (Ferskvann : 1.5)	16	157	> 157
2	Bly	mg/kg TS	25	150 (Ferskvann :66)	1480	2000	2000-2500
3	Nikkel	mg/kg TS	30	42	271	533	> 533
4	Kvikksølv	mg/kg TS	0.05	0.52	0.75	1.45	> 1.45
5	TBT	µg/kg TS		0.002	0.016	0.032	> 0.032
6	Bromerte difenyletere	µg/kg TS		62 (Ferskvann : 310)	79 (Ferskvann:790)	1580	> 1580
7	Heksaklorbens en	µg/kg TS	0	17	61	610	> 610
8	Heksaklorbuta dien	µg/kg TS	0	49	66	660	> 660
9	Heksaklorsyklo heksan	µg/kg TS	0	0.074 (Ferskvann : 0.74)	0.74 (Ferskvann: 1.5)	9.8	> 9.8
10	C10-13 kloralkaner	µg/kg TS		800	2800	5600	> 5600
11	Pentaklorbenzen	µg/kg TS	0	400	800	4000	> 4000
12	Pentaklorfenol	µg/kg TS	0	14	34	68	> 68
13	Triklorbenzen	µg/kg TS	0	5.6	700	1400	> 1400
14	Naftalen	µg/kg TS	2	27	1754	8769	> 8769
14	Antracen	µg/kg TS	1.2	4.6	30	295	> 295
14	Fluroanten	µg/kg TS	8	400	400	2000	> 2000

Nr	Navn på Navn substans	Enhet	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
14	Benzo(b)fluoranten	µg/kg TS	90	140	140	10600	> 10600
14	Benzo(k)fluoranten	µg/kg TS	90	135	135	7400	> 7400
14	Benzo(a)pyren	µg/kg TS	6	183	230 (Ferskvann: 2300)	13100	> 13100
14	Indeno(1,2,3-cd)pyren	µg/kg TS	20	63	63	2300	> 2300
14	Benzo(g,h,i)perylen	µg/kg TS	18	84	84	1400	> 1400
15	Nonylfenol	µg/kg TS	0	16	107	214	> 214
16	Oktylfenol	µg/kg TS	0	0.27 (Ferskvann : 2.7)	7.3	36	> 36
17	Alaklor	µg/kg TS		0.3	0.78	1.5	> 1.5
18	Klorfenvinfos	µg/kg -ts		0.5	1.4	3.0	> 3.0
19	Klorpyrifos	µg/kg TS		1.3	4.44	13	> 13
20	Endosulfan	µg/kg TS		0.073	0.6	6	> 6
21	Trifluralin	mg/kg TS		1.6	1.6	16	> 16
22	DEHP	mg/kg TS	0	10	100	1200	> 1200
23	HBCDD	µg/kg TS	0	34 (Ferskvann : 172)	34 (Ferskvann: 229)	2382	> 2382
24	PFOS	µg/kg TS		0.23 (Ferskvann : 2.3)	72 (Ferskvann: 360)		
25	Dioksiner	µg/kg TEQ TS		8.6E-04	3.6E-03 TEQ (Ferskvann: 8.8 E-03 TEQ)	0.5	> 0.5
26	DDT	µg/kg TS		15 (p,p'-DDT: 6)	165	1647	> 1647
27	Bisfenol A	µg/kg TS		1.1 (Ferskvann : 11)	79	790	> 790
28	TBBPA	µg/kg TS		108	383	3830	> 3830

Nr	Navn på Navn substans	Enhet	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
29	D5	mg/kg TS		0.044 (Ferskvann :0. 44)	2.6	26	> 26
30	Klorparafiner (mellomkjedete)	mg/kg TS		4.6	27	54	> 54
31	PFOA	µg/kg TS		71 (Ferskvann : 713)			
32	Triklosan	µg/kg TS		9.3	26	260	> 260
33	TCEP	µg/kg TS		72	562	5620	> 5620
34	Dodecylfenol med isomere	µg/kg TS		4.4	18.7	187	> 187
35	Diflubenzuron	µg/kg TS		0.2	4.6	46	> 46
36	Teflubenzuron	µg/kg TS		0.0004	0.02 (Ferskvann: 0.2)	2	> 2
37	Trifenyltin	µg/kg TS		0.036	0.67	6.7	> 6.7
38	PCB7	µg/kg TS	-	4.1	43	430	> 430
39	Kobber	mg/kg TS	20	84 (fv:210)	84 (Ferskvann:210)	147 (Ferskvann: 400)	> 147 (Ferskvann: 400)
40	Sink	mg/kg TS	90	139	750	6690	> 6690
41	PAH						
41	Acenaftalen	µg/kg TS	1.6	33	85	8500	> 8500
41	Acenaften	µg/kg TS	2.4	96	195	19500	> 19500
41	Fluoren	µg/kg TS	6.8	150	694	34700	> 34700
41	Fenantren	µg/kg TS	6.8	780	2500	25000	> 25000
41	Pyren	µg/kg TS	5.2	84	840	8400	> 8400
41	Benzo(a)antracen	µg/kg TS	3.6	60	501	50100	> 50100
41	Krysen	µg/kg TS	4.4	280	280	2800	> 2800
41	Dibenso(ah)antracen	µg/kg TS	12	27	273	2730	> 2730
42	Arsen	mg/kg TS	15	18	71	580	> 580

Nr	Navn på Navn substans	Enhet	Klasse I	Klasse II	Klasse III	Klasse IV	Klasse V
43	Krom	mg/kg TS	60	660 (Ferskvann : 112)	6000 (Ferskvann: 112)	15500 (Ferskvann: 112)	15500-25000 (Ferskvann: 112)

a) Hardhet: < 40 mg CaCO₃/L



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