UiT
THE ARCTIC UNIVERSITY OF NORWAY

Faculty of Health Sciences, Department of Community Medicine

Geographic variation of human dietary intake of PCBs from Norwegian coastal fish species and potential health risks of consumption

—

Sia Gerard

HEL-3950 Master's thesis in Public Health; May 2019

Table of Contents

List of Tables

List of Figures

Acknowledgements

I would like to send a warm thank you to several people, without whom I would never have completed this project.

Firstly, I'd like to thank my main supervisor Therese Haugdahl Nøst, who all but held my hand through this experience. Without you I probably wouldn't have finished. Thank you for taking me under your wing after my initial eagerness to do a project with you in your field, and then supporting me through the challenging moments and drafts. I deeply appreciate your guidance and feedback, your flexibility, your ability to cheer me up in particularly stressful times (even while abroad), and especially your kindness and encouragement. I am eternally grateful for your statistical and map making skills.

Second, I'd like to thank my external supervisor Ingjerd Sunde Krogseth at NILU for all of the guidance, coffee breaks, and pep talks. You have inspired me to follow my new (ish) passion in environmental research. Your encouragement to try my best despite not knowing what I was doing (still don't ☺), your friendly approach to supervising, and easy availability made you one of the best assets for getting me through this project. Not to mention the time spent editing and providing detailed feedback on all my drafts. It has really been a pleasure working with you.

I'd like to thank The Fram Centre flagship research program for Hazardous Substances, research theme "Human health and society" - *Evaluating the significance of spatial variability and body mass index (BMI) for human concentrations of persistent organic pollutants (POPs) in northern areas.* (project number: 522018). And everyone at the Norwegian Institute for Air Research (NILU) for providing the support, space, and encouragement while researching and writing.

I would also like to thank Sylvia Frantzen from the Institute of Marine Research (IMR) for providing me with the fish contamination data and Marie Lundblad from Institute of Community Medicine (ISM) at UiT for providing the unpublished Tromsø Study 7 results.

And finally, I'd like to thank the family and friends who supported me through the whole master's program. Without the random ski adventures, coffee and cake breaks, cabin holidays, and supportive phone calls, these two years would have been quite dull.

Sia Gerard

May 2019

Abstract

Today, the majority of human exposure to PCBs and dioxins originates from food consumption. In Norway, most dietary intake of the same compounds comes from fish consumption. This study aimed to investigate if current human dietary intake of PCBs and dioxins demonstrated geographic variation across Norwegian coastal regions. Also, to evaluate if resulting consumption patterns of some Norwegians could be considered unsafe according to current PCB and dioxin TWI thresholds. Coordinates and concentrations of PCBs in cod and salmon samples were used in creating maps of the distribution of concentrations based on their source of origin in the sea around Norway. The maps demonstrated considerable geographic variation across Norwegian northern and southern coastal regions and oceans. An assessment of possible health risk associated with dietary intake of fish was performed for scenario people profiles who represented samples of Norwegians who consume fish. The scenario profiles 'northern Norwegian men', 'northern Norwegian woman', 'average Norwegian man' and average Norwegian woman' exceeded the new TWI rates, whereas those profiles with lower fish consumption ('lean fish Norwegian woman', 'pregnant woman', and 'children') stayed below the new TWI. Consumption patterns revealed the estimated dietary intake rates were influenced most by consumption of fatty fish and liver intake, but also by the overall weekly fish consumption, gender, and region. The results of this study suggest that Norwegians are potentially exceeding a safe weekly intake of PCBs and dioxins due to dietary fish consumption.

KEYWORDS: PCBs, TCDD, dietary intake, tolerable weekly intake, geographic variation, fish consumption.

List of Abbreviations:

Acute: Disease effects that take a very short period of time to show symptoms.

Bioaccumulation: The build-up of concentrated contaminants in the food chain

Chronic: Disease effects that take many years to show symptoms.

95% CI: Confidence interval, values within a 95% interval that are statistically significant

Dioxin: TCDD- 2,3,7,8- Tetrachlorodibenzodioxin

dl-PCBs: dioxin-like polychlorinated biphenyls with only one chlorine atom at the ortho-position (mono-ortho or non-ortho)

EFSA: European Food Safety Authority

FFQ: Food Frequency Questionnaire

Fish tissue type: 3 categories of fish food types, Atlantic salmon muscle, Atlantic cod muscle, and Atlantic cod liver.

LOD: Limit of Detection

Long range transport: Transport of contaminants through water and air currents, and migratory pathways, and river run-off.

Max threshold value: maximum amount of PCB in blood before causing a health effect.

ndl-PCBs: Non- dioxin-like polychlorinated biphenyls

OCs: Organochlorides- organic chlorinated substances

pg TEQ/kg (b.w.): Picograms of toxic equivalents per kilograms of body weight (humans)

pg/g w.w.: Picograms per gram wet weight (fish)

Polyunsaturated fatty acids: Fatty acids eicosatetraenoic acid (EPA), docosahexaenoic acid (DHA) found in fish

POPs: Persistent Organic Pollutants

Risk exposure assessment: assessment of potential risk of exposure to toxic substances

TEF: Toxic equivalency factor (designated by the WHO in 2005)

TEQ: Total toxicity equivalents of a contaminant

Toxic potential: A scientific unit which describes the potential harm a chemical can have on humans.

TWI: Tolerable weekly intake

VKM: Norwegian Scientific Committee for Food and the Environment

µg/kg (OR ng/g) w.w.: micrograms per kilogram (OR nanograms per gram) wet weight (fish)

1 Introduction

1.1 Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are organic environmental contaminants that have been used as industrial use chemicals and in agriculture as pesticides and herbicides, and are formed as unintentional byproducts (1). They persist in the environment and resist degradation over a long period of time. All the while, being transported around the world via atmospheric and oceanic currents, as well as through animal transport from birds, fish, and other marine animals. This long-range transport results in higher concentrations in Arctic and Antarctic ecosystems. POPs then remain in the ecosystem as a result of bioaccumulation and biomagnification; the build-up of concentrated contaminants in the food chain (2). Food chain accumulation results in the highest concentrations of POPs in animals at higher trophic levels and in humans. Further, mother-to-child transferal of POPs leads to exposure even for fetuses and infants. POPs have harmful toxic effects and thus, a number of such compounds have been regulated and are monitored in the environment and in humans.

Since the late 1970s, international and national regulations, like the Stockholm Convention of 2004, have prohibited the production and use of many POPs, called legacy POPs, which have reduced the global burden of these contaminants. By 2012 the convention consisted of 22 POPs and there are regulatory measures to reduce and eliminate them (2). Concentrations of many legacy POPs in the environment have declined as a result of international regulations, but due to their long environmental persistence, especially in the Arctic, factors such as improper disposal practices and leakage into the environment (3), render them a continued concern for human and ecosystem health.

1.2 Dioxins and PCBs

Chlorinated dibenzo-*p*-dioxins (dioxins) were among the first POPs to be identified (4). Dioxins are naturally occurring by-products of forest fires and volcanic activity but are more commonly produced as by-products of incineration of materials containing organochlorine chemicals. They are resilient to break down, where sunlight and high temperatures have a miniscule effect on their degradation. Industrially produced dioxins affect enzyme production due to their interaction with the cellular protein Ah-receptor, which results in both acute and chronic organ toxicity (4). Some effects of this ‘dioxin-like effect’ are chloracne, cancer, diabetes, hypertension, neurotoxicity, atherosclerosis, and immunological and hormonal effects. Historically, dioxin was produced as an herbicide, but most human exposure has originated from industrial accidents or warfare (5).

Polychlorinated biphenyls (PCBs) are some of the oldest man-made POPs that remain in the ecosystem and among the most toxic. They were first synthesized in 1881, and were mass produced for industrial use since the 1930's (4). They were originally used in industrial processes, for example, PCBs were used in heat transfer systems, as cooling and insulating fluids in electrical transformers, paints, plastics, rubbers, and pigments; because they had low heat conductivity, high dielectric constants, and general chemical stability (1,6). PCBs were at their peak production and use in the 1960's and 1970's and have been banned and reduced in use since the 1980s but they still persist in the environment. Some PCB congeners accumulate more than others as a result of their long half-lives and physicochemical properties, such as solubility and number of chlorines in their molecular structure For example, congeners that are more "dioxin-like" have a coplanar structure which results in similar toxicological properties as tetrachlorodibenzo-*p*-dioxin and furans (3).

The toxic potential for PCBs and dioxins varies between congeners. Among the dioxins, 2,3,7,8 tetrachlorodibenzo-*p*-dioxin (TCDD) is the most toxic and is classified as a group 1 human carcinogen by the International Agency for Research on Cancer (7). The chemical structures of dioxins are similar to those of the PCBs. There are 209 PCB congeners that can be divided into two groups based on toxicological properties of their structure, 12 dioxin-like (dl) and 197 non-dioxin-like (ndl) congeners. Both types can be attributed to nervous, immune, and endocrine system disruption, developmental and neurodevelopmental problems, and may impair reproductive function and cause cancer (6). Selected ndl-PCBs are typically grouped together in a grouping of six (sumPCB6) or seven (sumPCB7) congeners- 28, 52, 101, 138, 153 and 180, and the dl-PCB 118 (sumPCB7 only), and used as indicators of patterns of ndl-PCBs found in samples, because they do not have the same toxicological properties as the dl-PCBs. The sum of these six or seven 'indicator PCBs' represents about 50% of total ndl-PCBs in human food sources (3).

Toxic potential of PCBs is based on dioxin toxicity, specifically how close in toxicity a PCB congener is to 2,3,7,8 tetrachlorodibenzo-*p*-dioxin (TCDD). Chemical congeners are assigned a toxic equivalency factor (TEF) based on its similarity to TCDD (TEF=1). Congeners included in this study are, PCB-126 (TEF= 0.1) representing the non-ortho PCBs, PCB-118

(TEF= 0.00003) representing the mono-ortho PCBs, and ndl congeners PCB 28, 52, 101, 138, 153 and 180, which do not have a TEF (8). TEFs are used for calculating the toxic equivalency (TEQ) of a given congener. Where the TEQ is the product of grams of dioxin, furan, or PCB found in a sample and its TEF. TEQs are used to evaluate the level of toxicity in a given amount of chemicals in a sample, to discern if it will have a health effect.

Today, approximately 90 percent of human exposure of both compound groups are from food consumption, mainly from animal fat products due to the lipid-based nature of accumulation of both contaminants (5,6). Use of these contaminants are strictly regulated today or have been phased out completely. However, some old industrial systems, mechanical equipment, paint, and materials still in use contain these chemicals and continue to leak and release POPs into the environment (1). This, in combination with the long environmental half-lives of these contaminants, means they will continue to bioaccumulate and persist in the global ecosystem, and leave a human health impact for years to come. Both compound groups have been the basis for research for many years, as a result, researchers have been able to develop more advanced methods and models for detection and predicting health risk.

1.3 **Dietary Intake of PCBs and Dioxins**

Dietary intake of contaminated foods has been agreed upon as one of the main human exposures to PCBs and other POPs today (1). As a result, the World Health Organization (WHO), European Food and Safety Authority (EFSA), and the Norwegian health authority have all developed and implemented Tolerable Weekly Intakes (TWIs) and maximum level TEQs based on contaminant thresholds found in food, which researchers use as a standard and valid measurement (6,9). Prior to November 2018, the designated threshold level, the concentration dose at which the toxic chemical shows an effect, of dioxin and dl- PCB concentrations in animals and humans was 6.5 ng TEQ/kg, and the maximum toxicity value for dioxins and furans was 3.5 ng TEQ/kg, for concentrations in food items for commercial sale. There was no specific threshold or maximum level specific to fish or fish products. These thresholds are safe for human consumption (9). The 2011 EFSA panel set the tolerable weekly intake of PCBs and dioxins at 14 picograms TEQ/ kilogram (body weight) per week (pg TEQ/kg (b.w.) (*6*). In November 2018, EFSA released a new report setting the new TWI to 2 pg TEQ/kg (b.w.) per week (3).

The 2018 EFSA report analyzed recent research regarding PCBs and dioxins and their effects on human health and found that human exposure to dioxins and dl-PCBs has not changed since the previous report in 2012. The average upper bound exposure to dioxins and dl-PCBs was estimated between about 0.4 to 2.6 pg TEQ/kg (b.w.) per day, in both reports (3,6). Fish, dairy, and meat products remain the highest contributors to human dietary exposures, and infants/toddlers still have the highest exposure to PCB and dioxins. TWI was decreased as a result of new findings from experimental animal and epidemiological studies, which indicated that sensitivity to PCB and dioxin exposure during the postnatal period may also expand into puberty. Some studies found “critical effect” causality between impaired semen quality from moderate exposure (about 7 pg TEQ/ gram of fat in 9-year-old’s) to these contaminants, and a “lower sex ratio in offspring (lower number of boys relative to girls)” from high exposure. Also, that postnatal and childhood exposure was dose-related to tooth enamel defects (3). These findings along with some other casual health effects to the contaminants, lead to the decision to reduce the TWI.

In Norway, most dietary intake of POPs, particularly PCBs, comes from consumption fish and fish products (10). Governmental institutions responsible for public health communication utilize the standardized TWIs to draw comparisons between dietary consumption of contaminated foods and the health problems associated with POPs. Dietary recommendations are then created from of the subsequent human health studies. Current national dietary guidelines recommend a diet of fish 2-3 times per week totaling in 300-450 grams of fish per week, for adults, where 200 grams is fatty fish (11). Due to the considerable change in TWI, and the understanding that fish is a key contributor to PCB and dioxin exposure, a new risk-benefit assessment of fish consumption and PCBs and dioxins has been requested by the Norwegian Food Safety Authority of the Norwegian Scientific Committee for Food and the Environment (VKM) (12).

A previous report by VKM, in 2014 estimated that adults eat approximately an average of 52 grams of fish per day (g/day), pregnant women eat an average of 31g/day, and 2-year-olds eat an average of 16 g/day. As a result, the average exposure to dioxins and dioxin-like PCBs was estimated to be between 1.4-1.7 pg TEQ/kg (b.w.)/week for adults, between 0.75-0.94 pg TEQ/kg (b.w.)/week for pregnant women, and between 2-2.6 pg TEQ/kg (b.w.)/week for 2-year-olds (13). Variation in type of fish consumed also provides weight to these average PCB quantities, where oily or fatty fish contributes the most to total PCB contamination (Figure 1), followed by fish liver, and other marine sources like seagull eggs (14). Both studies in Figure

1 were based on a 14 pg TEQ/kg (b.w.)/week TWI, which means that the risk of human exposures to exceed the TWIs was low. However, as fish are a key contributor to human contamination of PCBs and the TWI has been reduced to 2 pg TEQ/kg (b.w.)/week, these rates need to be revisited.

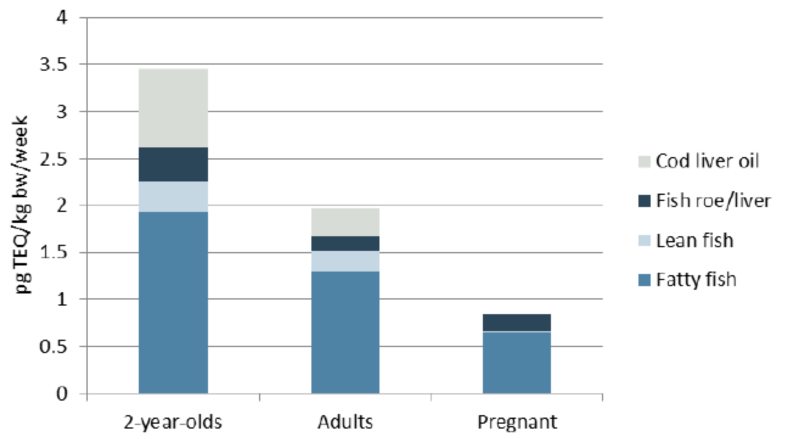


Figure 7.1.4-2 Mean upper bound (UB) exposure to dioxins and dl-PCBs from fish and cod liver oil (including fish oil) in Norwegian 2-year-olds (Småbarnskost 2007), adults (Norkost 3) and in pregnant women (MoBa, not including cod liver oil). Fish is grouped into fatty fish, lean fish and liver/roe.

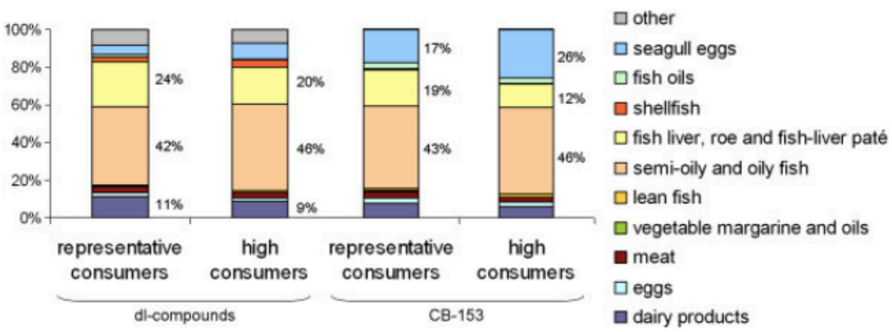


Figure 3. Dietary sources of dl-compounds and CB-153. Mean percentage contributions by the 11 different food groups are shown for the high consumers ($n = 111$) and representative consumers ($n = 73$).

Figure 1- Figure describing fish food type and its dl-PCB contribution to human contamination for infants, adults, and pregnant women (upper panel), and representative consumers and high consumers (lower panel) (12,13).

1.4 **Health effects of sea food consumption**

There are many nutritional benefits from eating fish and sea food. The 2014 Norwegian risk benefit assessment (13), highlighted studies that supported several benefits to eating fish starting from low doses (1-2 times per week), including reduced cardiac mortality and other cardiovascular diseases like ischemic stroke, and increased benefit to children's neurological development. Disease reduction and benefits are a result of the contribution of important protein, vitamins and minerals, like polyunsaturated fatty acids, iodine, vitamin D, and selenium. Fatty acids are especially important to fetal and infant neurological development and reduction in heart disease (13,15). However, the important vulnerable groups such as pregnant women and their children, could be missing out on these benefits because they consume less than what is recommended (13). Also, studies suggest that benefits of fish consumption are complicated because there are other mechanisms mediating the connection between eating fish and the positive health outcomes. For example, Domingo (2016) suggested that the benefits of eating fish are more of a result of other healthy lifestyle choices and eating habits (14).

PCBs and dioxins have certain toxicological effects on humans, some acute, but because human exposure is mainly through food consumption and resulting bioaccumulation, the long-term chronic effects are more of a concern Previous studies have demonstrated that people who eat high fish-diets, like traditional diets, have higher risk of higher exposures to POPs (16,17). Exposure from intake of contaminants through fish food sources have shown long-term neurobehavioral effects, like slower cognitive development among children who were exposed directly and from their mothers (1). Additionally, the 2018 EFSA report found increased negative health effects among the infant and young boys' population from exposure to these contaminants (3). Data suggests contaminant exposure is most detrimental to vulnerable groups such as pregnant women and children (18).

Norway regulates and provides ample information on various seafood sources and nutrition consumption guidelines, through interactive websites and reports provided annually. Regional guidelines are available for commercial fishing and recreational fishing activities, and for fish health and contamination based on local advice (19,20). Sources also give recommendations for fish consumption and sea food safety in regard to specific POP's contamination (21). These guidelines and warnings exist to prevent people from consuming highly contaminated fish in certain highly contaminated areas. For example, Miløjstatus.no provides information about the types of contaminants in different fish, where they can be found around Norway, and who should avoid eating the fish in these populated coastal areas.

In addition to the monitoring of PCBs and dioxins, Norwegian governmental agencies provide national nutritional recommendation reports annually for the whole population (11) and for vulnerable groups (22), as well as reports on how much fish is consumed on a regular basis and the associated nutrition intake (23). National recommendations are difficult to formulate because there are both risks and great benefits to fish consumption and finding the balance is difficult when considering the health of vulnerable groups, high consumers and other dietary consumption categories (24), in addition to the complicated mechanisms of lifestyle choices and cultural traditions which dictate dietary patterns.

Risk benefit assessments have revealed that in general the nutritional benefits outweigh the risks of current levels of contaminants found in fish and recommend moderate consumption of fish (13,15,18). However, in light of the new evidence reducing the TWI of PCBs and dioxins (3), health risks to vulnerable groups such as pregnant women and children may need to be reevaluated in Norway. Especially if the studies show both that pregnant women are not eating enough fish (13), and that the long-term effects of consumption may be worse for health than previously thought (3,15).

1.5 Variability in human exposure to POPs in Norway

Many studies have addressed human health effects related to POP concentrations in humans. Further, many studies have been included in the Arctic Monitoring and Assessment Program, which has been compiling research and assessments in Arctic human biomonitoring since 1997 (25). AMAP has explored studies which describe transport, human exposures, time-trends, and human health outcomes of POPs in the Arctic regions (16). Additionally, there is an abundance of literature addressing dietary intake of PCB and dioxin exposure from human consumption of fish internationally (3,6,16,25), and in Norway (10,14,33,34,17,26–32). Many of these studies address similar issues, that fish consumption and the subsequent contamination levels are primarily a result of dietary and lifestyle patterns, which consist of multiple variables.

A variable that has been considered, but few studies have addressed, is large-scale spatial or geographic variability of human dietary intake of PCBs from Norwegian coastal fish species in Norway. Studies that have shown spatial variability of contamination in fish, have mostly been from biological ecosystem studies (35,36), which do not address human exposure. The few studies that address human exposure in relation to geographic variation, have found that there is likely regional contamination variation within Scandinavia ((14,32,37–39)). These studies show that fish consumption differs between regions, for example between northern Norway and southern Norway (37). Also, the concentrations in the fish species representing the majority of consumption, may also vary and thus dietary recommendations could vary by region of origin of the fish.

Seafood and fish in particular are integral to the Norwegian diet (10) and if there is geographic variability in PCB contamination of fish and other dietary items then there could be spatial variability within human concentrations around Norway as well. While the weekly intakes of POPs may be lower than the safe maximum levels for most of the general population, some communities and vulnerable groups around Norway may be more at risk of exposure than others, such as pregnant women, children, and northern Norwegians. Evaluating the spatial variability of contaminants has the potential to help influence Norwegian nutritional guidelines to more accurately represent the variability in human exposure to PCBs from fish due to differentiation of the population's dietary preference patterns.

This study aims to investigate if human dietary intake of PCBs and dioxins demonstrates geographic variation across Norwegian coastal regions, as a result of both geographic variability in PCB and dioxin concentration in fish and variability in human dietary intake patterns of fish. This study also aims to evaluate if this data could predict whether consumption patterns of some Norwegians could be considered unsafe according to current threshold values for tolerable weekly intakes of PCBs and dioxins.

2 Materials and methods

2.1 Data collection and selection

2.1.1 PCBs and dioxins in commonly consumed fish species and their geographic locations

Data has been provided by the Norwegian Institute of Marine Research (IMR) which included samples of muscle from Atlantic salmon and Atlantic cod, as well as liver from Atlantic cod from between 2006 and 2018. POP concentrations in these samples were reported in micrograms per kilogram wet weight (µg/kg ww). The contaminant congeners included in this study were PCB-153, PCB-118, PCB-126, sum PCB6 (sum of PCBs 28, 52, 101, 138, 153 and 180) and sum PCB7 (sum of PCBs 28, 52, 101, 138, 153, 180 and 118). Also considered are data for the dioxin congener 2,3,7,8-TCDD in the same samples. These congeners were chosen because they are the most frequently detected and tested congeners and best represent generally detectable ndl-PCB and dl-PCB congeners of the mono-ortho and non-ortho types. The sum concentrations of 6 and 7 PCBs and PCB-153 represent ndl-PCBs, and PCB-126 and PCB-118 represent dl-PCBs. Cod and salmon were the only fish species chosen because they represent the most commonly consumed types of lean and fatty fish in Norway and are data-rich species (40). Muscle tissues in addition to cod liver were chosen as those are the parts of the fish that are consumed as part of human diet.

IMR provided fish sample information and the POP concentrations specifically important to this study was imported onto a master spreadsheet for data cleaning and analysis. All congeners were provided in micrograms per kilogram wet weight but was converted to picograms per gram wet weight (pg/g ww) as that unit was the basis for the calculations of the risk estimations. The data on concentrations of selected PCB and dioxin congeners was sorted and tested for normal distribution using the Shapiro-Wilk test. Only those congeners that were detected in more than 30% of samples were considered further. Statistical analyses of normal distribution and outlier examination was performed in IBM SPSS statistical software (IBM Corp. Released 2017. IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY: IBM Corp.).

2.1.1.1 Maps of PCB concentrations in fish

Geographic coordinates were provided for many of the data points for all three sample types and were sorted and re-written in decimal format. The coordinates and PCB concentrations of each sample were used to create maps of the distribution of concentrations in fish based on where they were caught in the Atlantic Ocean and Norwegian sea. The aim of this visualization was to help provide an overview of the variability in levels of fish POP contamination around Norway.

We used the open source statistical software R (R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.), with the following packages: ggmap and googlemaps to create maps with layers of data points representing PCB concentrations in cod muscle, salmon muscle and cod liver. Utilizing these GPS coordinates we created maps to represent geographic variation of PCB concentrations. Samples without location were excluded whereas samples with named locations were looked up to find approximate coordinates for.

2.1.2 Dietary consumption rates of fish in Norway

Data on human dietary intake of fish and fish products in grams per week was collected from various Norwegian reports and academic studies found through a literature search. The studies and reports targeted were recently updated studies from Norway, Scandinavia, and Europe, that provided aggregate data. The aggregate data collected for this study was the most recent information available from these regions. Some older or international studies were excluded because they were not considered especially relevant to this study. These studies and reports had to provide comprehensive information on Norwegian consumption of fish and fish products, as well as provide information about the consumers of fish, such as age, gender, and type of fish consumed. Fish tissue type is defined as the specific categories of fish, namely fatty fish, lean fish, and fish liver. Many of the studies selected were also used as consumption sources for studies on POP exposures, for example the EFSA report on monitoring of PCBs and dioxins (6) or the Norwegian Scientific Committee for Food and the Environment (VKM) risk benefit analysis on fish consumption (13).

Summary statistics and descriptive tables of fish consumption rates were created using IBM's SPSS statistical software (IBM Corp. Released 2017. IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY: IBM Corp.), to describe average and median total consumption for each study and potential group, for example consumption of fish tissue type by age and gender.

2.2 Risk assessment of dietary intake of PCBs in Norway

2.2.1 Scenario People

Based on the available data, selected characteristics of hypothetical persons as average or vulnerable groups, hereafter referred to as scenario people or profile, were selected for the contaminant risk assessment. They were to represent samples of people within the Norwegian population who consume fish. They all represent certain variables that differ between groups, for example, Northerners eat more fish (41), men eat more fish than women (42), pregnant women and children are considered vulnerable groups and thus likely have differing consumption rates (10,43). Body weight was estimated for each group either by the information provided in the studies or from national statistics(44). The seven selected scenario people and their representative profile were as follows:

i. *Average Norwegian man:* This scenario represented a typical Norwegian man from a community between inland and coastal with a normal or typical higher than recommended fish consumption. He represented a man between the ages of 18-70, with a weight of 89 kg. These men consumed a heavier diet in fatty fish and unspecified fish product and only consumed a bit more per week of fish than what is recommended.

ii. *Average Norwegian woman*: This scenario represented a typical Norwegian woman from a location between inland and coastal between the ages of 18-70 with a weight of 72 kg. This woman represented a slightly older population of women (>26) who were overall past the age of fertility. This woman eats within the recommended amount of average weekly fish.

iii. *Average Norwegian woman who consumes more lean fish*: This scenario represented the same characteristics of the average Norwegian woman. However, she eats mostly lean fish and very little special fish like liver. She represented an inland dwelling woman between the ages of 26- 70, who consumes a diet that is lower than the recommended amount of fish.

iv. *Northern Norwegian man*: This scenario represented a Norwegian man between the ages of 20-80 years old from northern Norway, who eats more than the recommended amount of weekly fish and weighs approximately 89 kg. This person represents the a 'high consumer' of fish who lives in a coastal region known for eating more abnormal fish meals like cod liver, roe liver pate' and/ or seagull eggs, which are high in contaminants (41).

v. *Northern Norwegian woman*: A northern coastal living woman who eats fish for more meals than their southern counterpart. She represents a 'high consumer', with similar characteristics as the Northern man scenario person with a weight of 72kg.

vi. *Pregnant woman*: This scenario person represents a typical Norwegian woman between the ages of 18-35 who plans to become pregnant, is pregnant, or has just had a child. She represents a group who is more vulnerable to exposure to contaminants and will pass on contaminants to her children. She eats lower than the average recommended amount of fish per week. A diet consisting of mostly lean fish and no cod liver or especially high contaminated fish. Pregnant women's weight fluctuates but is typically slightly heavier than a non-pregnant woman, so this scenario woman is 77kg, instead of 72kg.

vii. *Child*: This scenario person represents a child between the ages of 9 and 13, who eats a lower than recommended amount of fish a week, and weighs 40kg. It could be a boy or a girl because their weekly consumption is about the same. Children eat a diet higher in fatty fish and fish product and get most of their nutritional fish from bread spread (11). This scenario person represents a vulnerable group, because children are exposed from birth and before to contamination from their mothers and contaminants like PCBs and dioxins are known for causing neurological development problems in children at medium to high exposures.

Scenario populations were chosen based on available fish consumption information. The associated average or median of grams of fish eaten per week were calculated and split into the three fish tissue type categories, salmon muscle representing fatty fish, cod muscle representing lean fish, and cod liver representing a unique food item category. Based on the available information, we calculated percentages of dietary consumption of each fish category, based on the diet of primarily fatty fish and another of primarily lean fish. This was represented as 67% fatty fish intake (approximately 200 grams a week recommended of a dietary intake of 300 grams of fish per week), 32% lean fish intake, 1% liver intake. And also 40% fatty fish (approximately 200 grams a week recommended of a dietary intake of 450 grams of fish per week), 60% lean fish intake, and 1% liver intake. There was enough information from studies on pregnant women, children, and women who eat lean fish to calculate percentages based on observed consumption of lean fish, fatty fish, and fish liver from the available FFQ data.

2.2.2 Calculating PCB and dioxin concentrations

To assess risk, we followed an equation to calculate each scenario person's exposure to PCBs and dioxins:

$$Weekly\ Intake = N\ pg\,\frac{TEQ}{kg\ (b.w)}$$

First, we utilized the PCB and dioxin concentrations available from locations in the Norwegian and Barents Sea (pg/g ww) and multiplied each congener by the weekly estimated human consumption (g/week) of Atlantic cod, Atlantic salmon, and cod liver to calculate the estimated weekly intakes of PCB and dioxin congeners in the chosen populations of the scenario people (pg/week).

Next, we calculated each congeners TEQ by multiplying the congener's WHO-2005 TEF (either 0.00003 or 0.1) by the estimated pg/week from consuming a certain percentage of fish muscle or liver. Congeners included in this study are, PCB-126 (TEF= 0.1) representing the non-ortho PCBs, PCB-118 (TEF= 0.00003) representing the mono-ortho PCBs, and ndl congeners PCB 28, 52, 101, 138, 153 and 180, which do not have a TEF (8). It is important to note that the ndl-PCBs do not have TEFs based on the toxicity estimated from their chemical structure, but we assumed here they would have a similar TEF to the average dl-PCB, which is 0.00003 according to the World Health Organization (8). This rendered these calculations worst-case-assumptions as ndl-PCB's toxicity is likely lower, but there are no equivalent estimations for those PCB congeners that have chemical structures that are less dioxin-like.

Finally, we divided the congener's TEQ by the scenario person's weight to discover each scenario person's estimated weekly exposure to PCBs from the eating the three fish tissue types (pg TEQ/kg (b.w.)). From this information, we produced graphs in order to compare potential PCB exposures to demonstrate potential exposure risk due to variation in human consumption. We compared the EFSA dietary intake of PCB and dioxins recommended TWIs, to the estimated weekly dietary intake exposure of PCBs and dioxins among the scenario persons, to find if these people or representative groups would be at risk of exceeding TWI recommendations. Human dietary TWI PCBs and dioxins has been set by EFSA to 2 pg TEQ/kg (b.w.) per week (3), however it was previously set to 14 pg TEQ/ kg (b.w.) before November 2018. Both of these numbers will be used in the analysis in this study to compare which, if any, consumption rates exceed the past and the new thresholds.

3 Results

3.1 Geographic variation in commonly consumed fish and in human consumption rates of fish

3.1.1 Variation of PCBs and dioxins in commonly consumed fish species

3.1.1.1 Atlantic cod muscle

Between 2010- 2018, the average concentrations of PCB congeners across all samples from Atlantic cod muscle were 107 picograms per gram wet weight (pg/g ww) for PCB-153, 42.8 pg/g ww for PCB-118, 0.11 pg/g ww for PCB-126, 261 pg/g ww for sum PCB 6, and 304 pg/g ww for sum PCB 7 (Table 1). The average lipid content across these samples was 0.64 grams/100grams wet weight (g/100g ww) (95% CI 0.51-0.77) (Appendix 2).

The percentage of PCB concentrations in cod muscle samples below the detection limit (LOD), were 69% for PCB-153 and 77.5% for PCB-118, but only for the samples taken between 2006-2009 (Appendix 1). Only congeners that were detected in 30% or more of samples were considered further, so the samples from these years were excluded from the analysis. Additionally, TCDD was not considered any further for any years because 91% of samples were below LOD.

The 2014 sample provided for PCB analyses in cod muscle was a composite average of all of the samples taken that year. As a result, the descriptive analysis of the 25 samples, where one sample was a composite average of samples taken, was skewed. The Shapiro-Wilk test for normality indicated the samples were not normally distributed and the histograms indicated that none of the PCB concentrations were normally distributed except for PCB-126 (Appendix 1). PCB-126 did not include data from 2014 and was less skewed and considered normally distributed, which may explain why the other congeners were skewed.

Table 1- Concentrations of PCBs (pg/g ww) in Atlantic cod muscle samples that were above LOD. 25P, 75P, and 95P are the 25, 75, and 95 percentiles, respectively.

COD MUSCLE (PG/G WW)		PCB-153	PCB-118	PCB126	SUM PCB 6	SUM PCB 7
ALL YEARS	Mean	107	42.8	0.11	261	304
	25P	38.5	17.5	0.11	95	113
	75P	80	40	0.20	265	310
	95P	183	105	0.34	497	598
2010	Mean	89	52	0.19	296	348
	Median	75	40	0.15	265	310
	25P	67.5	37.5	0.14	220	258
	75P	113	62.5	0.26	338	395
2014*	Mean	118	56.1	.	373	429
	Median	.	.	.	.	.
	25P	.	.	.	.	.
	75P	.	.	.	.	.
2018	Mean	43.1	20.2	0.13	114	134
	Median	39	19.1	0.13	102	121

	25P	32.3	15.3	15.3	32.3	100
	75P	54.3	25.1	25.1	54.3	163
* 2014 CONSISTED OF ONLY ONE COMPOSITE DATA POINT, SO ONLY MEAN COULD BE IDENTIFIED. ALSO, THERE WAS NO DATA FOR PCB-126						

3.1.1.2 Atlantic salmon muscle

The average concentrations of all the Atlantic salmon samples collected in 2012 were; 2477 pg/g ww for PCB-153, 1151 pg/g ww for PCB-118, 5.4 pg/g ww for PCB-126, 7324 pg/g ww for sum PCB 6, and 8478 pg/g ww for sum PCB 7 (Table 2). The average lipid content across these samples was 8.2 g/100g ww (95%CI 7.6-8.5) (Appendix 2).

All samples were above LOD, so they were all included in the analysis. TCDD data samples for salmon muscle was not provided in the IMR provided data. There were some samples that were questioned while cleaning the data because they had high PCB concentrations, but lower fat levels than some others. When testing for outliers, only three samples, out of 152 samples total, did not meet the standardized value of 3.2. Still, they were kept in the dataset when calculating means for each congener as a worst-case approach to including concentrations. It is notable that all three outliers were from Sørfjorden, a fjord in south western Norway near Bergen. After testing for normality, the Shapiro-Wilk test indicated that the samples were not normally distributed, and the histograms agreed but with only minor skew from the few outliers (Appendix 3).

Table 2- Concentrations of PCBs (pg/g ww) in Atlantic salmon muscle. 25P and 75P are the 25 and 75 percentiles, respectively.

Salmon Muscle (pg/g ww)		PCB-153	PCB-118	PCB126	sum PCB 6	sum PCB 7
All years: 2012	Mean	2477	1151	5.4	7324	8478
	Median	2374	1095	5	6993	8050
	25P	1907	910	4.2	5762	6725
	75P	2987	1320	6.3	8741	10075
	Minimum	187	300	1.7	2061	2400
	Maximum	4936	2480	11	14578	16800

3.1.1.3 Atlantic cod liver

The mean of all the Atlantic cod liver samples collected between 2006 and 2018 were; 70.82 nanograms per gram wet weight (ng/g ww) for PCB-153, 26.15 ng/g ww for PCB-118, 168.2 ng/g ww for sum PCB 6, and 194.35 ng/g ww for sum PCB 7 (Table 3). The average lipid content across these samples was 52.3 g/100g ww (95%CI 51.8-52.8) (appendix 2).

There were many extreme PCB concentration values detected, where the maximum values for each congener or group were 3051 ng/g ww, 1532 ng/g ww, 6826 ng/g ww, and 7926 ng/g ww, for PCB-153, PCB-118, sum PCB 6 and sum PCB 7, respectively. Data for PCB-126 and TCDD was not available. The Shapiro-Wilk test indicated that the samples were not normally distributed. The histograms showed a positive skewed distribution where most concentrations were higher than the means (Appendix 4). 47 samples were more than the standardized value of 3.2 when testing for outliers. The 25th and 75th percentile for PCB-153, PCB-118, sum PCB 6 and sum PCB 7 were between, 20 and 72 ng/g ww, 9 and 25 ng/g ww, 56 and 168 ng/g ww, and 65 and 193 ng/g ww respectively.

The mean values included in this study were the unfiltered means, because all data points and their relative geographic locations were important for evaluating spatial variation, so no outliers were excluded.

Table 3- Concentrations of PCBs (ng/g ww) in Atlantic cod liver samples.

Cod Liver ng/g		PCB-153	PCB-118	sum PCB 6	sum PCB 7
All years	Mean	70.8	26.2	168	194
	95% CI	65.6-76	24-28.3	156-180	181- 208
	Median	38.8	15	99	115
	25P	19.9	9	56	65
	75P	72	25	168	193
	Minimum	1.1	0	3	3
	Maximum	3051	1532	6826	7926
Before 2010	Mean	41.9	23.9	117	141
	Median	22	14	70	83
	25P	13	8	42	49
	75P	41	25	120	145
	Minimum	3	2	10	3

	Maximum	3051	1100	6826	3051
After 2010	Mean	80	26.9	185	212
	Median	46	16	110	126
	25P	24	10	62	73
	75P	81	25	182	206
	Minimum	1.1	0	3	3
	Maximum	2789	1532	5661	7192

3.1.2 Visualizations of geographic variation in contaminant concentrations in fish

The maps produced showed both the location of the samples taken and the concentration in pg/g or ng/g ww of the samples for each fish sample group (Figures 2-3). The maps showed that samples were quite extensively distributed around the coast of Norway and in fjord areas located mostly around the Norwegian Sea. These maps displayed the geographic variation in PCB concentrations. There were higher concentrations in the fjords than out in the sea. However, the highest concentrations are found mostly in the southern parts of Norway than in the north.

Maps of contaminant concentrations in cod liver display both the highest concentrations and the most samples, which demonstrated a clearer variation for PCB concentrations geographically, than in cod and salmon muscle (Figure 2). Additionally, there were more cod liver samples taken before 2012, but the PCB concentrations did not differ in the same sample locations across the different years (Figure 3).

For both salmon muscle and cod muscle, there was limited geographic variation in measured concentrations. Concentrations were higher in salmon muscle than in cod muscle. It was difficult to see differences between fish tissue types, especially in the northern samples, where the majority of samples for cod muscle and salmon muscle were taken. Overall geographic patterns were similar across different congeners, concentration levels, and years (Appendix 5)

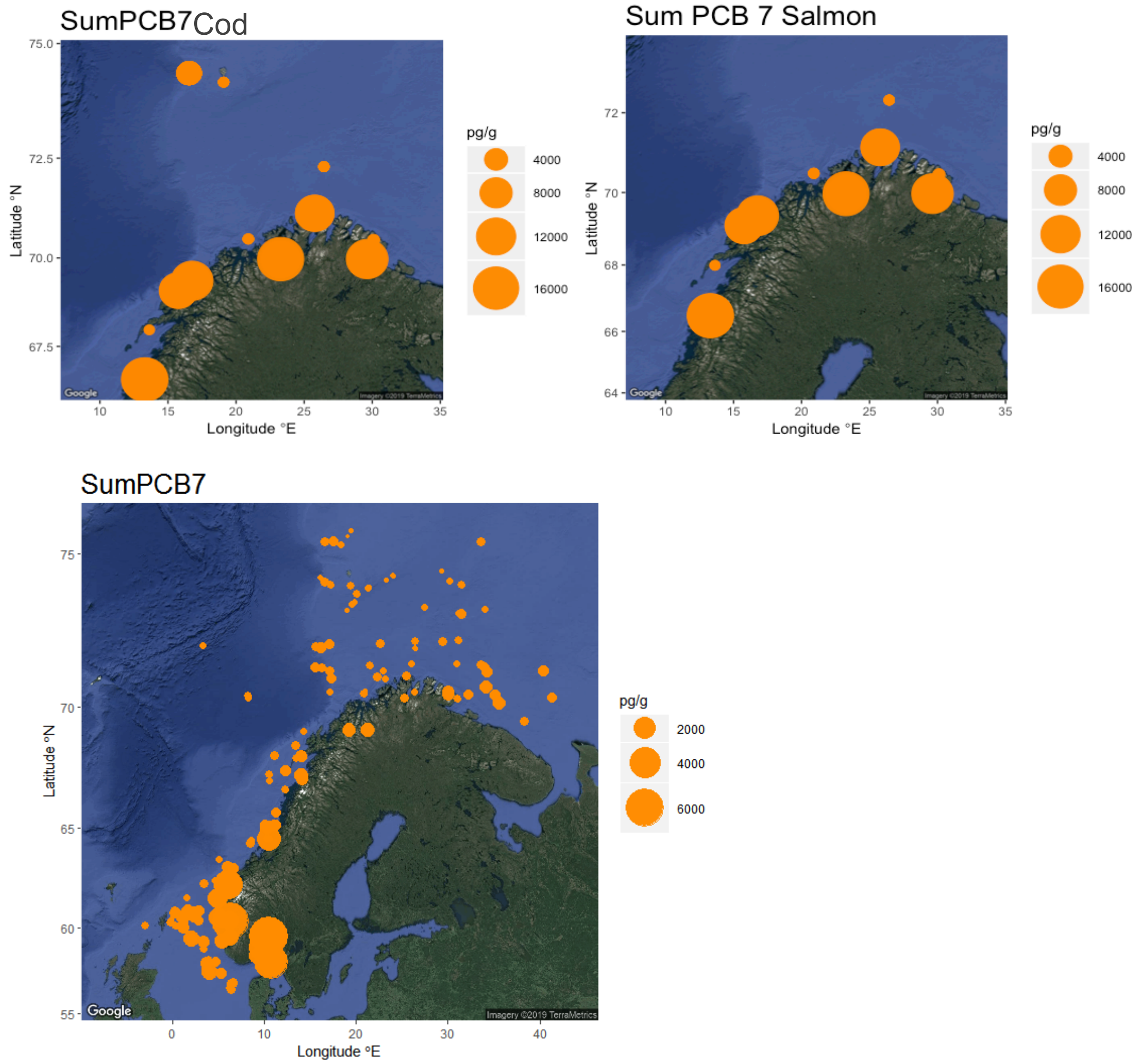


Figure 2- Measured concentrations of sum PCB 7 in cod muscle (pg/g) (top left), salmon muscle (pg/g) (top right), & cod liver (pg/g) (bottom).

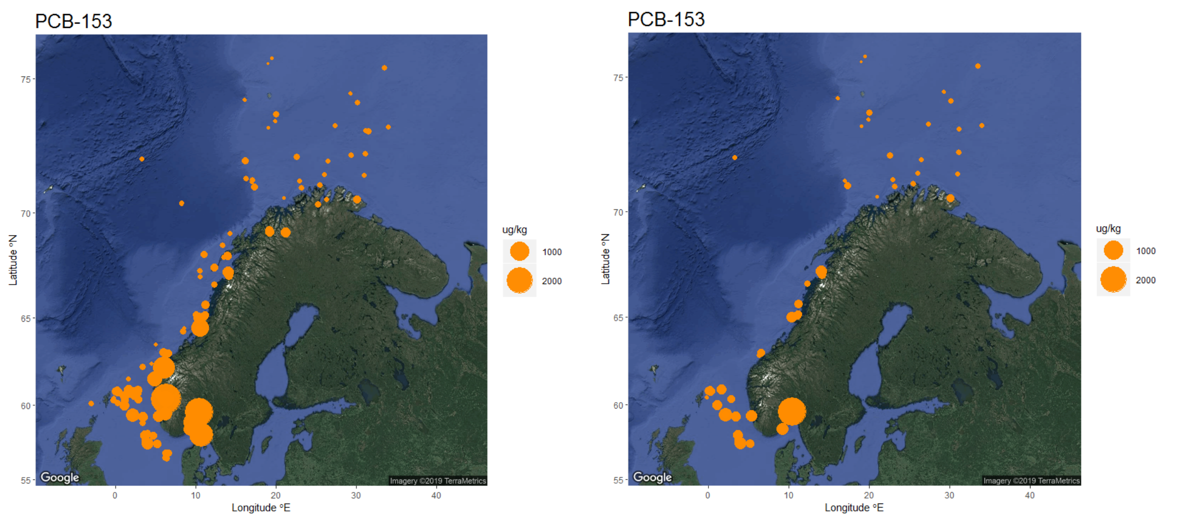


Figure 3- Measured concentrations of PCB 153 (µg/kg) in cod liver samples obtained after 2010 (left), and after 2012 (right).

3.1.3 Human consumption rates of fish

Aggregate dietary intake information was collected from dietary surveys provided in various available human health studies and reports (Table 4). Dietary food frequency questionnaires (FFQs) were collected in all the population-based studies and reports assessed. These questionnaires required participants to answer questions about their daily or weekly dietary consumption of various foods. For this study we only obtained the information about consumption of fish and fish products.

All of these studies provided either an average grams per week or median grams per week, or both, of total consumed fish in the study populations or Norwegian central measures. Some studies provided measures of central tendencies for specific types of fish, for example shell fish, fatty fish, lean fish, fish liver, etc. in addition to total fish consumed. Some studies provided result summaries separated by other categories such as gender and/or age. The data identified is summarized in Table 4 and Appendix 6.

Table 4- Cohort studies and reports used in this study, and the fish consumption information they provide in grams/ week.

Study	Year	N	Age range (years)	Total Fish Consumption:		Total Fish Consumption g/week:	
				Avg g/week	Median g/week	Men	Women
Children							
UNGKOST 3 (43)	2015	636	9-13	168	91	196 (avg)	147 (avg)
Adult- North + South Norway							
NORKOST 3 (41)	2011	1787	18-70	469	N/A	553 (avg)	392 (avg)
NOWAC (Norwegian Women and Cancer Study) (29,45)	2010, 2012	326	48-62	N/A	287	N/A	287 (median)
Adult- North Norway							
Andøya Municipality Study (46)	2009	56	26-60	N/A	677.1	834.3 (median)	655.9 (median)
Tromsø Study 7 (42)	2017	11425	40- >80	N/A	707	802.9 (median)	661.5 (median)
Pregnant Women							
MISA (Northern Norwegian mother-and-child contaminant cohort study) (32)	2012	391	18-43	556.5	504	N/A	
MoBa (Norwegian Mother and Child Cohort)* (10,34,47)	2007, 2011, 2013	83524	<25- >40	252	231	N/A	
*MoBa is a cohort study and thus had slightly different grams/week for every year sampled (Appendix 6 provides more info).							

The 2015 Ungkost 3 study provided fish consumption data for 9-year-old and 13-year- old Norwegian children. This was the third update of a national survey and report which analyzed national dietary consumption and nutritional intake of a variety of foods and beverages. Average fish consumption for both age groups was 168 grams per week. 14g/week were lean fish, and 56 g/week and 70 g/week were fatty fish for 9-year-olds and 13-year-olds, respectively. Boys in both groups ate approximately 40 grams more fatty fish per week then girls (43). These average weekly intakes of fish were used as the scenario profile for the group "children" in the risk assessments presented below.

Information on dietary intake of fish for pregnant women was available from two studies in Norway and were performed within the years of the range in sampled fish. The women in the MISA study were from Northern Norway and were between the ages of 18-40 (32). The women in the MoBa study were from all of Norway and in the same age range. It has been suggested that 58% of all fish intake in Norway, was of lean fish, 31% of fatty fish, and 11% of shellfish (34). The average mean fish consumed was 404.25 g/week and the average median fish consumed was 367.5 g/week, between the two studies. Also, both of the pregnant women studies suggested that pregnant women eat less than 0.1 grams of fish liver per day. The average median weekly intakes of fish were used as the scenario profile for the group "pregnant women" in the risk assessments presented below.

Fish consumption rates for adults were compiled from the Norkost 3 study, NOWAC study, Andøya study, and Tromsø 7 study that together included both genders and adult age groups (29,41,42,45,46). The Andøya study and the Tromsø 7 study data represented the northern Norwegian populations, and the Norkost 3 and NOWAC study represented the whole Norwegian population. All studies except for the Norkost study included participants with age ranges older than 40 years old. The Norkost 3 study was the only study that considered adults under the age of 30. Table 4 provides the consumption totals for each study, however combined the average median fish consumption for northern Norwegian men was 818.6 g/week and for women was 663.7 g/week; and the average consumption for average Norwegian men was 553 g/week; and finally, for average women it was 392 g/week and for women with lower fish consumption it was 287 median g/week. These weekly consumption rates of fish were regarded overall and were used as the scenario profile for the groups "average woman", "average man", "northern woman", "northern man", and "average women who eats more lean fish" in the risk assessments presented below.

The Tromsø study is an on-going health cohort study by the Department of Community Medicine (ISM) at UiT - the Arctic University of Norway. All the other studies have been completed and published. The first health survey in the Tromsø study began in 1974 and the latest one, Tromsø 7 was completed in 2017. Approximately 40000 residents in the Tromsø municipality have participated in at least one of the studies by answering an in-depth questionnaire about their health status, followed by health assessments and blood sample delivery. In 2017, 21083 men and women between the ages of 40-104 participated in Tromsø 7 (48). The data for Tromsø 7 has not been published yet. Fish consumption data was provided to this study by Marie Lundblad from ISM. After cleaning, the Tromsø 7 study data excluded the top and bottom 1% of the energy intake because they were unrealistic energy intakes for participants. Additionally, anyone who answered less than 90 % of the questions in the dietary questionnaire was excluded.

The Norwegian Fish and Game Study (14), was not regarded in this study because the data was older than the other studies included, the sample size low, and it was difficult to find the total aggregate data in the published study. However, the study participants were largely represented by the other studies included. All other included studies provided newer and more extensive information for human consumption rates of fish.

3.2 Risk assessment

3.2.1 Consumption rates of fish for scenario persons

Based on the information compiled from the available studies on consumption rates of fish per week in Norway, several scenario profiles were selected as described above (section 2.2.1). The average pg TEQ/kg (b.w.) per week for each PCB congener and for every scenario person, based on their average total consumption of fish and the pg/ g ww of PCB in salmon muscle, cod muscle, and cod liver are presented in Table 5. Additional information, such as the results from the steps to calculate TEQ and the estimates for percent of fatty fish/lean fish, and fish liver consumption are presented in Appendix 7.

According to the pg of weekly intake for every scenario person who consumed a diet consisting of 67% fatty fish, 32% lean fish, and with a 1% dietary consumption of fish liver, For every scenario person who consumed a diet consisting of 67% fatty fish, 32% lean fish, and with a 1% dietary consumption of fish liver, highest intake rates of sum PCB 7 and PCB-126 were observed for adult men and women from northern Norway with 5.47 and 5.48 pg TEQ/kg (b.w.) / week, respectively, followed by average Norwegian men with 3.69 pg TEQ/kg (b.w.) /week and average Norwegian women with 3.23 pg TEQ/kg (b.w.) /week

(Table 5). The lowest consumption rates were among pregnant women with 1.22 pg TEQ/kg (b.w.) /week, and children with 1.5 pg TEQ/kg (b.w.) /week. A second estimation for women who consumed a mostly lean fish diet was also considered as Norwegian women was also reported to eat a mostly lean fish diet of approximately 44% lean fish and 35% fatty fish (34). The resulting weekly intake rate for these women was 1.38 pg TEQ/kg (b.w.) /week.

Table 5- Resulting TEQ (pg TEQ/kg (b.w.) per week) for PCB congeners 153, 118, and 126, as well as sum PCB 6 and sum PCB 7, for salmon muscle, cod muscle, and cod liver based on the seven scenario people and their weekly fish and fish product consumption (grams/ week) and weight (kilograms). Based on a fatty fish diet.

Scenario People: Fatty Fish diet	**Northern Norwegian Man**	**Northern Norwegian Woman**	**Norwegian Man**	**Norwegian Woman**	**Norwegian Women (lean fish)**	**Pregnant Woman**	**Child 9-13yr**
Weight (kg)	89	72	89	72	72	77	40
g/week total fish consumed	818.6	663.7	553	392	287	367.5	168
TEQ/kg Salmon Muscle 2012:							
PCB 153	0.46	0.46	0.31	0.27	0.10	0.11	0.12
PCB 118	0.21	0.21	0.14	0.13	0.05	0.05	0.05
PCB 126*	3.3	3.3	2.23	1.95	0.75	0.79	0.84
Sum PCB 6**	1.35	1.36	0.91	0.80	0.31	0.33	0.35
Sum PCB 7**	1.57	1.57	1.06	0.93	0.36	0.38	0.40
TEQ/kg Cod Muscle 2010-2018:							
PCB 153	0.01	0.01	0.01	0.01	0.01	0.01	0.001
PCB 118	0.004	0.004	0.003	0.002	0.002	0.004	0.0004
PCB 126*	0.03	0.03	0.02	0.02	0.02	0.03	0.004
Sum PCB 6**	0.02	0.02	0.02	0.01	0.01	0.02	0.003
Sum PCB 7**	0.03	0.03	0.02	0.02	0.02	0.03	0.003
TEQ/kg Cod Liver 2006-2018:							
PCB 153	0.2	0.2	0.13	0.12	0.08	0	0.09
PCB 118	0.07	0.07	0.05	0.04	0.03	0	0.03
PCB 126*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sum PCB 6**	0.46	0.47	0.31	0.27	0.2	0	0.21
Sum PCB 7**	0.54	0.54	0.36	0.32	0.23	0	0.24
Total TEQ/kg of Congeners PCB- 28, 52, 101, 138, 180, 153, 118, & 126:							
Total	**5.47**	**5.48**	**3.69**	**3.23**	**1.38**	**1.22**	**1.50**
All values are "pg TEQ/weight (kg)".							

*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.
** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.

A diet consisting of 60% lean fish, 40% fatty fish, and 1% fish liver was also considered because if Norwegians consume fish on the high end of the weekly recommended amount, about 450 g/week, then 200 grams of fatty fish would only be 40% of the total fish diet. Table 6 indicates the highest intake rates of sum PCB 7 and PCB-126 were observed for adult men and women from northern Norway with 3.55 and 3.56 pg TEQ/kg (b.w.) /week, respectively, followed by average Norwegian men with 2.4 pg TEQ/kg (b.w.) /week and average Norwegian women with 2.1 pg TEQ/kg (b.w.) /week. The lowest consumption rates were among pregnant women with 1.22 pg TEQ/kg (b.w.) /week, and children with 1.5 pg TEQ/kg (b.w.) /week. Norwegian women who reported to eat a mostly lean fish diet had a resulting weekly intake rate of 1.38 pg TEQ/kg (b.w.) /week.

Table 6- Resulting TEQ (pg TEQ/kg (b.w.) per week) for PCB congeners 153, 118, and 126, as well as sum PCB 6 and sum PCB 7, for salmon muscle, cod muscle, and cod liver based on the seven scenario people and their weekly fish and fish product consumption (grams/ week) and weight (kilograms). Based on a lean fish diet.

Scenario People: Lean fish	**Northern Norwegian Man**	**Northern Norwegian Woman**	**Norwegian Man**	**Norwegian Woman**	**Norwegian Women (lean fish)**	**Pregnant Woman**	**Child 9-13yr**
Weight (kg)	89	72	89	72	72	77	40
g/week total fish consumed	818.6	663.7	553	392	287	367.5	168
TEQ/kg Salmon Muscle 2012:							
PCB 153	0.27	0.27	0.18	0.16	0.10	0.11	0.12
PCB 118	0.13	0.13	0.09	0.08	0.05	0.05	0.05
PCB 126*	1.97	1.98	1.33	1.17	0.75	0.79	0.84
Sum PCB 6**	0.81	0.81	0.55	0.48	0.31	0.33	0.35
Sum PCB 7**	0.94	0.94	0.63	0.55	0.36	0.38	0.40
TEQ/kg Cod Muscle 2010-2018:							
PCB 153	0.02	0.02	0.01	0.01	0.01	0.01	0.001
PCB 118	0.007	0.007	0.005	0.004	0.002	0.004	0.0004
PCB 126*	0.06	0.06	0.04	0.04	0.02	0.03	0.004
Sum PCB 6**	0.04	0.04	0.03	0.03	0.01	0.02	0.003
Sum PCB 7**	0.05	0.05	0.03	0.03	0.02	0.03	0.003
TEQ/kg Cod Liver 2006-2018:							

PCB 153	0.20	0.20	0.13	0.12	0.08	0	0.09
Sum PCB 6**	0.46	0.47	0.31	0.27	0.2	0	0.21
PCB 118	0.07	0.07	0.05	0.04	0.03	0	0.03
Sum PCB 6**	0.46	0.47	0.31	0.27	0.2	0	0.21
Sum PCB 7**	0.54	0.54	0.36	0.32	0.23	0	0.24
Total TEQ/kg of Congeners PCB- 28, 52, 101, 138, 180, 153, 118, & 126:							
Totals	**3.55**	**3.56**	**2.40**	**2.10**	**1.38**	**1.22**	**1.50**
All values are "pg TEQ/weight (kg)".							
*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.							
** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.							

3.2.2 Estimated weekly intakes and comparisons with tolerable intake thresholds

Table 5 and 6 and their corresponding graphs in figure 4 and 5, present the results for summed concentrations of 7 PCB congeners, which represent the ndl-PCB congeners (including dl-PCB 118), and also dl congener PCB-126 so as not to repeat congeners in summed concentration estimates. Figure 6 presents the percent of contribution the ndl- congeners (including PCB-118 and PCB-126 contribute to total TEQ.

The calculated pg of weekly intakes of PCB 28, 52, 101, 138, 180, 153, 118, and 126 from dietary consumption of fish as pg TEQ/kg (b.w.) /week is presented in Figure 4 for all scenario profiles. The estimations assumed a diet consisting of 60% fatty fish, 40% lean fish, and with a 1% dietary consumption of fish liver. Pregnant women, children, and women who eat mostly lean fish remain below the TWI of 2 pg TEQ/kg (b.w.) /week threshold, but the other groups exceeded the tolerable threshold estimated by EFSA indicated by the red line in the figure. All scenario intake profiles remained below the previous TWI threshold of 14 pg TEQ/kg (b.w.) /week.

The calculation of pg of weekly intakes of PCB 28, 52, 101, 138, 180, 153, 118, and 126 from dietary consumption of a lean fish diet was also performed for every scenario and are represented in Figure 5. This diet consisted of 60% lean fish, 40% fatty fish, and 1% fish liver. Only the scenario profile for the Norwegian woman's TEQ reduced to a level near the TWI (2.1 pg TEQ/kg (b.w.) /week) when a diet of more lean fish was considered (Figure 5) instead of the fatty fish diet assumption (Figure 4). For the other scenario profiles, an assumption of more lean fish diet did not change whether they exceeded the TWI or not.

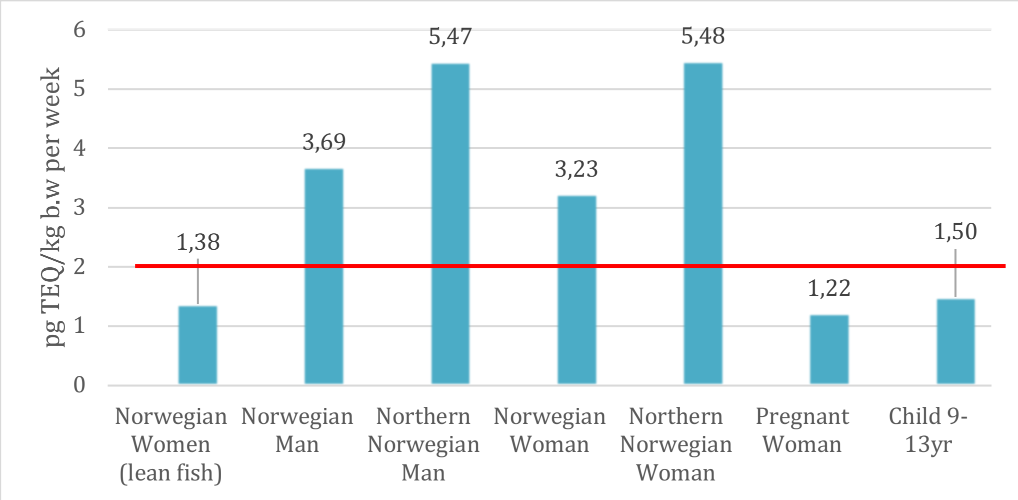


Figure 4- Estimates of weekly intakes of TEQ in pg TEQ/ kg (b.w.) per week based on summed concentrations of eight PCB congeners (PCB 28, 52, 101, 138, 180, 153, 118, & 126) for seven selected scenario profiles representing children, pregnant women and adult men and women in Norway. Based on a fatty fish diet.

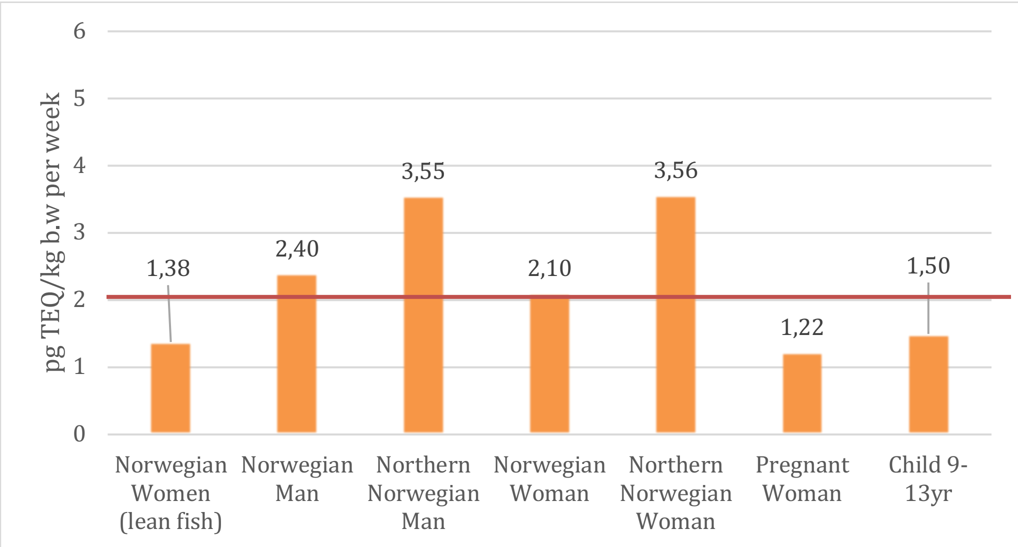
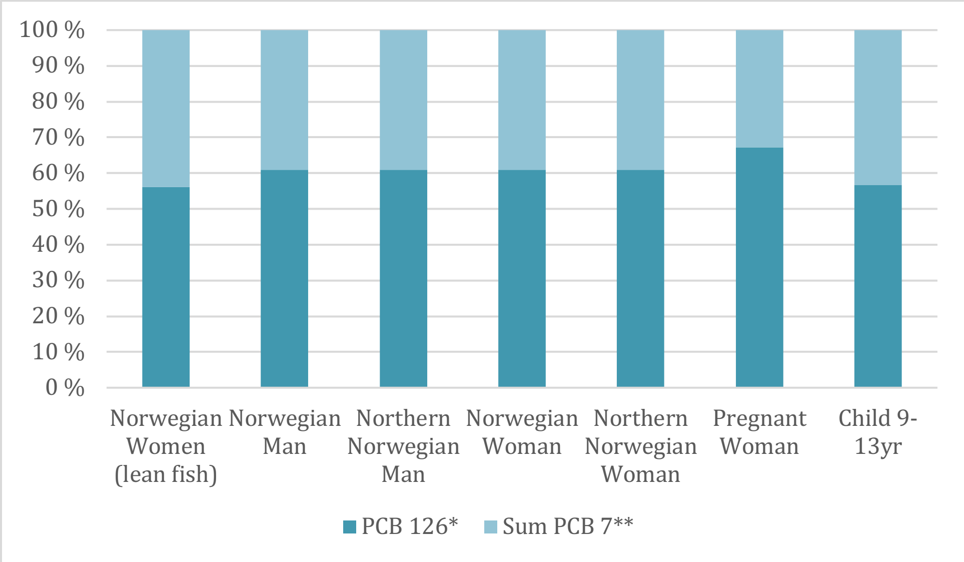


Figure 5- Estimates of weekly intakes of TEQ in pg TEQ/ kg (b.w.) per week based on summed concentrations of eight PCB congeners (PCB 28, 52, 101, 138, 180, 153, 118, & 126) for seven selected scenario profiles representing children, pregnant women and adult men and women in Norway. Based on a lean fish diet.



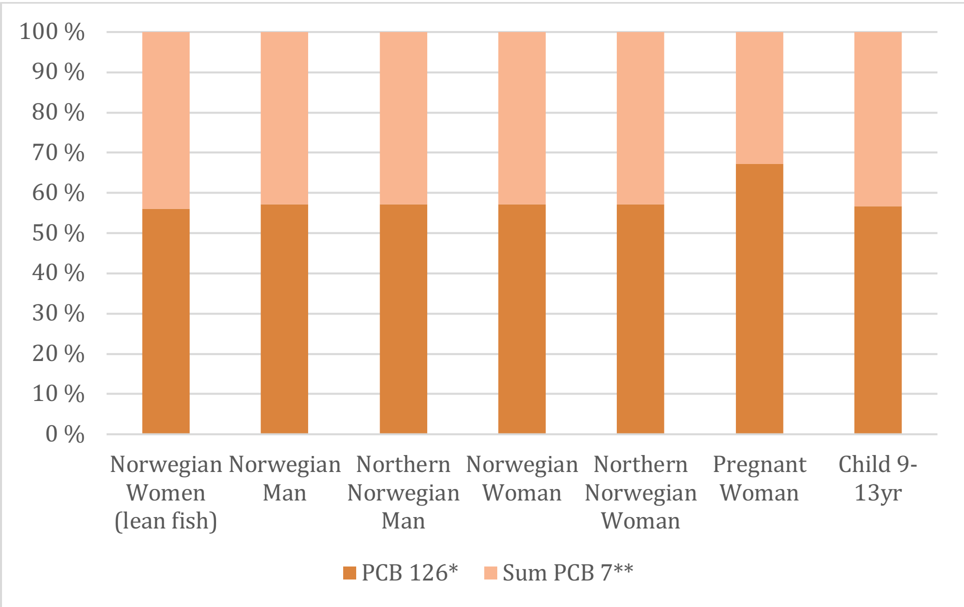


Figure 6- Graphs show the percent the ndl- congeners sum PCB- 28, 52, 101, 138, 180, 153 (including PCB-118) and PCB-126 contribute to the total TEQ of each scenario profile, based on fatty fish diet (top) and lean fish diet (bottom).

4 Discussion

4.1 Main findings

4.1.1 Geographic variation

The available information for concentrations of PCBs in cod and salmon demonstrated considerable geographic variation across Norwegian coastal regions and oceans. The maps presenting geographic location of fish samples demonstrated higher concentrations in fish in fjords and in the southern regions of Norway, and lower concentrations in the north. This agrees with previous studies of geographic variation of concentrations of PCBs and other contaminants in Atlantic cod (49) and marine sediments (50) in Norwegian marine areas. For example, in the Oslo fjord area, cod liver samples exceeded 2000 µg/g ww, whereas in Nordland county and farther north the samples did not exceed 1000 µg/g ww (figure 3). This should imply that the concentrations that humans are exposed to by regionally caught fish are lower in the northern areas. The northern regions where PCB concentrations in fish are lower, correspond with reported maps of catchment areas by the Fiskeridirektoratet (51). They show that the majority of Norwegian fish is indeed generally caught in Nordland county and Møre and Romsdal county, followed by Finnmark and Troms county. Additionally, higher PCB concentrations in cod and salmon across certain Norwegian coastal regions (figure 2), agree with existing guidelines provided by Miljødirektoratet to not eat certain fish from specific fjord and urban areas (19).

There were higher concentrations of PCBs in salmon muscle and cod liver as compared to cod muscle (Table 2,3,4) but the indicated consumption rates of those fish tissue types were lower than those for lean fish among Norwegians (Appendix 6, (13)). The resulting intake rates of PCB (pg TEQ/kg (b.w) among scenario people, were an outcome of both the TEQ concentrations in the fish tissue itself, but also the rates of consumption of the same fish, so the estimated weekly intakes of PCB TEQ represented both these aspects (Table 5 and 6). Notably, this study only included 8 PCB congeners, and to estimate the true dietary intake of PCBs and dioxins through fish consumption for Norwegians, the other congeners should be considered. According to the assessment in this study and the potential inclusion of other contaminants, an exceedance of the new TWI would be inevitable based on these results. However, the detected PCBs were the most prevalent PCBs and represent most of the prevalent PCBs in Norwegians (26). So, it is likely that vulnerable groups, children and pregnant women may remain close to or below the 2 pg TEQ/ weight (kg) TWI.

4.1.2 Estimated TEQ intakes

The information obtained about consumption of fish in children and adults in Norway indicated variation related to several factors. The selected scenario profiles representing Norwegians demonstrated variation of PCB intake rates depending on the geographic location, age, and gender of the person (Figure 4 and 5, Appendix 7). Risk of high intake rates was highest among men who live in the northern regions of Norway, followed by women who live in the north. Higher consumption of fish was found among scenario people who represented an older age group, especially men. This corresponds with population-based studies conducted in Norway, which identify highest consumption among men and women in the north and especially those who live in coastal locations (41,42,46,52).

Women in general had lower consumption of fish and lower TEQ intake rates as compared to men, and especially women who consumed fish within the recommended guidelines for fish intake, namely 300-450 grams fish per week of which lean fish should represent most (Table 4). Biomonitoring studies of blood concentrations have confirmed that women who consumed a diet containing fish high in fats and oils more than lean fish, had higher concentrations of PCBs (10,29), and also that women in the northern counties consume more fish (32,41). This is illustrated among the populations of women in this study. The pregnant younger group and the older non-pregnant group, who do not live in the north, have similar TEQ regardless of their diet of fatty fish or lean fish (Table 5 and 6). However, the scenario person representing the older-aged Norwegian women population still exceeded the new TWI of PCB TEQ, which confirms that there is variation of consumption as a result of age.

None of the men and women who were represented as scenario people in Norway in this study, were close to exceeding the previous PCB and dioxin TWI of 14 pg TEQ /kg (b.w.) per week. Even among the estimated highest consumers, the total weekly intake was about 6 pg TEQ/kg (b.w.) (Figure 4 and 5). This corresponds with literature which describes that the rates of PCB exposures and blood concentrations in Norwegian human populations have decreased since they were banned in the 1970s (26).When considering the new TWI established in November 2018 of 2 pg TEQ/kg (b.w.) per week, the ‘northern Norwegian men’, ‘northern Norwegian woman’, ‘average Norwegian man’ and average Norwegian woman' exceeded, and the lower consumers ('lean fish Norwegian woman', 'pregnant woman', and 'children') of fish stayed at or below the new level according to our estimations (Figure 5).

4.2 Public health context

4.2.1 Dietary consumption of fish tissue types

The estimations of dietary intakes of PCB and dioxin TEQ were based both on reported dietary proportions of lean and fatty fish and on recommended proportions in national guidelines (appendix 7). In this study, the proportions of fish tissue types (fatty, lean, liver) could be calculated only for the diets of pregnant women and children, while all the other scenario categories were based on assumed percentages from dietary recommendations and from dietary reports on total Norwegian consumption. Pregnant women who participated in the MoBa study ate a diet of approximately 58% lean fish, 31% fatty fish, and 11% shellfish, with zero consumption of fish liver (52). As this was a nation-wide study, these percentages of approximate fish tissue type consumed best suited the pregnant woman scenario person. The UNGKOST study (43), provided the grams consumed of each fish tissue type per week (fatty, lean, and liver), among a population of Norwegian children aged 9-13 years old.

The scenario people categories for men and women's weekly intake of the three tissue types of fish was based on a percentage calculated based on dietary recommendations due to the lack of other types of information and the public health relevance of assuming these percentages. Norwegian dietary recommendations advise that fatty fish should amount to about 200 grams per week (11) which would be 44% - 67% of weekly fish intake depending on how many grams of fish one eats in a week of the recommended total 300-450 g. The studies included indicated that most populations of men and women consumed more grams of fatty fish than lean per week (Appendix 6), so scenario individuals' TEQ was calculated with a 67% fatty fish, 34% lean fish diet. However, reported average consumption rates indicated that in general the Norwegian diet consists of more lean fish then fatty fish (13), so scenario TEQs were also calculated with a 60% lean fish and 40% fatty fish diet.

In calculations based on both recommended and reported consumption of lean or fatty fish, cod liver was considered 1% because the average amount of cod liver consumed was below 1% for the majority of the population (30,46). Still, high fish consumer groups, like the northern Norwegian scenario people in this study, are known to seasonally eat highly contaminated foods like seagull eggs and roe liver pate (25,31), but this was not considered in this study due to the insufficient information on this type of consumption.

4.2.2 Considerations for TEQ intakes by fish consumption

When TEQ intakes by fish consumption was assessed for each scenario profile, men exceed the TWI of 2 pg TEQ/kg (b.w.) in both the 'average Norwegian man' category and the 'northern Norwegian man' scenario category (table 5 and 6). This is likely because men in general exceed the weekly recommended dietary intake of fish. The 'average Norwegian woman' scenario ate within the dietary recommendations and still exceeds the 2018 TWI threshold. According to figure 5, a lean fish diet most likely contributes to a decrease in TEQ in both men and women, as does avoiding cod liver ('pregnant women'), as long as they eat within the recommended weekly dietary fish consumption guidelines. This corresponds with the knowledge that eating fatty fish and other special sea food (roe liver pate and seagull eggs) significantly contributes to higher contamination (10,14,29–31,39). 'Children' and the other scenario 'Norwegian women (lean fish)' both eat less than what is recommended, and their TEQ is accordingly below the new TWI. Future assessments should also consider the nutritional benefits of these same consumption rates, when considering nutrition recommendations to these population groups, but that was outside the scope of this study.

Figure 6 shows that the sum of PCB 28, 52, 101, 138, 180, 153, 118 and PCB-126, contributed about the same amount of TEQ for every category. PCB-126 contributed the most, because it has been considered the most toxic of the dl-PCBs (1). It is interesting, though, that PCB-126 contributes the most to the 'Pregnant woman' scenario who did not eat cod liver, and the least to the 'woman who eat a mostly lean fish' scenario diet. This may also indicate that dietary patterns impact specific PCB congener TEQs in humans, but this study does not have enough information to agree or disagree.

4.2.2.1 Women in reproductively active ages or pregnant women

The relevant national guidelines for what pregnant women should eat only concern consumption of food containing toxins and how to avoid certain food items. Specifically, women are advised to eat varied diets consisting of mostly plant-based foods, to avoid eating raw or cured red meats, avoid unpasteurized milk products, less caffeine, no coffee, and finally to avoid wild game meats, large exotic fish / seal, large freshwater fish, fish liver, and certain parts of shellfish (22). Recommendations specific to fish liver explain that fish liver contains toxic pollutants which exceed the EU thresholds (53).

As evaluated in this study, pregnant women meet dietary recommendations for fish intake based on the consumption information from both the MoBa study and the MISA study (10,32). The TEQ of the 'pregnant woman' scenario profile remains beneath the 2 pg TWI in both the fatty and lean fish diet scenarios (Table 5 and 6). The northern Norwegian pregnant women from the MISA study exceed weekly recommended fish consumption, approximately 500 grams per week (Table 4), but the average fish consumption of the MISA and the MoBa study participants was 375 grams of fish per week, well within what is recommended. The MoBa study alone, however, reveals that the consumption of fish by pregnant women from all over Norway is about 250 grams per week, which is lower than weekly fish consumption recommendations. VKM reported that approximately 23% of the MoBa women met the recommended fish intakes overall, and only 6.7% met fatty fish intake recommendations (13).

If the average Norwegian pregnant women are not meeting recommended fish intakes, their dietary intakes of PCB TEQ would probably be lower than if they had met the recommendations, but so would their dietary intakes of vitamins, minerals, and healthy fatty acids. This may pose a health issue, especially since there are no specific grams of fish consumed per week recommendations for pregnant women, only health advisories. Pregnant women may be missing out on important health benefits, as higher fish consumption rates during pregnancy have shown to improve risk of cardiovascular disease and neurodevelopment, as well as reduce risk of preterm birth and increase birthweight (13). This study shows that even with an increased consumption of fish (fatty and lean), pregnant women will likely not exceed the new TWI of PCBs and dioxins. If they are also not meeting recommended fish intake, they are also possibly missing out on the health benefits of eating fish during pregnancy.

4.2.2.2 Children

Children from the VKM analysis had very high PCB TEQ compared the adults. We expected to see similar results to the risk benefit analysis in this study, when in actuality they were one of the lowest consumers of fish. A potential explanation is that the Småbarnkost (2-year-old infants) study contributed this to a high diet of cod liver oil and fatty fish, which are high in PCBs (12). However comparatively, the PCB TEQ from the Småbarkost study and the

UNGKOST study (9-13-year-old children), which represented the 'child' scenario person in this study, were similar 2.6 pg TEQ/kg (b.w.) per week (12) and 1.5 pg TEQ/kg (b.w.) per week (table 5), respectively. So, fish alone is likely not the cause of such high TEQ among infants and children.

Children in this study also consumed less fish than recommended and had a lower PCB TEQ, approximately 1.5 pg TEQ/kg (b.w.). Children remaind below the TWI, based on their fatty and lean fish consumption, however the risk PCBs and dioxins pose to infants and children is mainly from their background exposure from their mothers (10,18). This study does not address this concept, but studies show that children's main exposure to contaminants is through prenatal exposure (18). Prenatal and perinatal exposure can result in neurological and behavioral problems in children, which is addressed by the new EFSA panel, who has identified this kind of exposure as the most important health concern from exposure to PCBs and dioxins (3). These specific exposures were the reason for the reduction in the TWI of PCBs and dioxins by EFSA, also the TWI considered for adults.

4.2.3 Dietary predictors for PCBs

Exposure to PCBs and dioxins comes from many different dietary sources such as different fish species, meat and dairy products (3). Additionally, fish in Norwegian diets consist of a variety of different types of fish and fish products which differ from place to place (14) and between different age and gender groups (27,29,41). Consequently, any results found for PCB exposure in this study will not demonstrate the full picture of an individuals' dietary exposure to dioxins and dioxin-like PCBs, because it does not take into consideration a wide variety of individual types of fish and fish products that contribute to a complete fish diet. Additionally, while fish and marine food consumption may be considered the highest contributing source of exposure to PCBs for Norwegian/Scandinavian populations (14,29,30), the 2018 EFSA report states that when broken down into food groups, the highest contributors for European populations are actually fatty fish (56%), other fish meat (53%), cheese (22%), and livestock meat (34%) (3).

This study evaluated selected scenarios of potential consumption patterns among Norwegians, where the highest contributions to scenario contamination, was through fatty fish and liver intake, grams of total fish consumption, gender, and location. The scenario people in this study demonstrate a combination of several lifestyle factors including weight, age, location, gender, and fish consumption variations, to evaluate examples of potential exposure risks.

These lifestyle factors have been indicated as more predictive of risk of PCB and dioxin exposure than food sources alone (10,14,30–32,39). Dietary patterns especially dominated by higher consumption of food items that have high PCB and dioxin concentrations, fatty fish, seagull eggs, roe liver pate and cod liver (10,30), in combination with lifestyle factors may be the best predictors of PCB and dioxin exposures among Norwegians. Thus, the relative importance of exposure to PCBs from fish is dependent on the study population and the study years (26).

4.2.3.1 Geography as an important dietary predictor

Many of these potential prediction patterns in study populations in Norway also include aspects of geographic variation in PCB concentrations in fish. This study demonstrated geographic variation in the fish concentrations and also in rates of consumption. We have discussed how type of fish consumed also can vary across Norwegian regions as well. Geographic location within Norway may be an important indicator of human dietary exposure to contaminants, which few studies have focused on. Furthermore, to evaluate if fish contamination from certain areas directly effects the human exposure, it would be important to know where the fish intended for consumption comes from.

In this study we calculated human dietary intake of PCBs using average PCB concentrations of all samples for each fish tissue type, independent of geographic origin of the fish. Geographic origin of the fish was not included in the calculations because information on regional distribution of fish into grocery stores is limited. In coastal locations, many people can catch their own fish, especially in the north, but there are only a few studies on habits of recreational fishing for personal consumption in relation to PCB concentrations in blood (37,54), which is not enough to correlate geographic location of caught fish to PCB exposure in this study. We may be able to infer, however, that if people only eat fish from their locality, people in northern Norway would have the same contamination as their southern counterparts. This is because intake of PCBs through fish is less in the north, and northerners eat more fish than southerners.

4.2.4 Current national dietary recommendations

Based on the information available, it appears likely that if Norwegians are consuming diets high in fat, eating dairy, oils, and red meat, in addition to a recommended diet of fish, they would exceed their 2 pg TEQ/kg (b.w.) TWI of PCB. This study did not account for other food types that may contribute to contamination and as the other food items also contain some concentration of PCBs and dioxins it is likely that the new TWIs are exceeded by many Norwegians today. Norwegians may meet the new TWI level if they consume less foods high in fat, including fatty fish and fish liver products, and stay within the dietary recommendations of 300-450 grams of fish per week. Decreasing weekly fatty fish consumption per se would likely reduce the intake of PCB concentrations. As some of the non-vulnerable scenario people exceeded recommended fish consumption guidelines, reducing their fish diet may not affect the health benefits they receive from eating fish, because studies have shown that low consumption of fish still provides enough nutrients (13). The vulnerable groups, pregnant women and children, had the lowest consumption of fish, and hence also the lowest calculated PCB intake rates. These vulnerable scenario people may need to consume more fish to benefit from the nutrients fish provide (12) and have more specific recommendations for their age and gender groups.

Perhaps the nutritional and health benefits of a high fatty fish diet still outweigh the risks of high contamination, as some literature suggests (12). But could this diet keep all Norwegians below the new TWI and still have health benefits for everyone, if consumption and contamination vary geographically and among different dietary consumption patterns? To address this concern, it may be important for public health officials to discover what type of diet, considering both fish and non-fish foods containing contaminants, would best suit the different age groups and sexes. A new risk-benefit assessment of fish in Norwegian dietary habits has been requested by Norwegian health authorities and will be performed by the Norwegian Scientific Committee for Food and Environment (VKM), which will report on this very topic.

Another important aspect to dietary guidelines and recommendations is how the information is disseminated to the population. Norway provides many reports on statistics and nutrition information which are readily available to download, sometimes in summarized form and in Norwegian and English. However, three-hundred-page risk benefit analyses will likely not be read by the everyday consumer, but websites which comment on or release summaries of the information reported will be trusted and recounted by mass media outlets. Trusted sources need to be more accountable for the information they release, especially when delivering public health advise, so as not to cause alarm in the general public.

4.3 **Limitations**

4.3.1 Uncertainties in PCB and dioxin concentrations in fish

There were only 25 cod muscle samples from 2010-2018 that could be included in the analysis because the majority of the samples for PCB congeners 153 and 118 were recorded as below the limit of detection (LOD) and were thus not useful for our calculations. These recent study years were included to avoid the influence of old methods with higher detection limits. The low sample number may have led to uncertainty in average PCB concentrations in cod muscle. However, since the dietary consumption rates of Norwegians for the TEQ calculations were based on average consumption assumptions, a small fish data sample size is not detrimental to calculating TEQ in the scenario profiles.

The samples excluded had PCB and/or dioxin concentrations below LOD. Specifically, the congeners TCDD, PCB-153 and PCB-118 were below LOD in 91%, 69% and 78%, respectively, of all cod muscle samples. When considering the year of sampling, PCB-153 and PCB-118 were above LOD in only 7% of cod muscle samples collected in 2009, in 34.5% (PCB-153) and 3.5% (PCB-118) of samples collected in 2008, in 14% (PCB-153) and 8.5% (PCB-118) of samples collected in 2007, and in 50% of samples collected in 2006. PCB concentrations in cod muscle below LOD is in itself good news for humans and the environment, because it means contaminant concentrations are low in this fish tissue type. However, it does introduce more uncertainty in determining the average PCB concentrations and detecting them in general.

None of the analyzed PCBs were below LOD in samples of salmon muscle and cod liver. However, there were some high outliers, which were not excluded in the analysis. All of the outliers in the salmon muscle dataset were from Sørfjorden, a fjord in western Norway near Bergen. Figure 6 shows that this region had the second highest PCB concentrations among cod liver samples too, after the Oslo fjord area. This high concentration of contaminants in Sørfjorden is because of the zinc smelter which released its metallurgic waste into the fjord until 1986. It is considered one of the most metal-polluted fjords in the world (50).

Cod liver data had two-fold the number of samples than cod and salmon muscle. Larger sample sizes provide more accurate and detailed estimations in the maps. This allowed us to make more specific observations about fish contamination in Norway. Very highly contaminated cod liver samples from urban and port regions where we expected to find high levels of PCB TEQ, were not excluded as outliers and included in the analysis.

Not excluding high concentrations and not including low concentrations, like those in cod muscle below LOD, meant that average means of PCB concentrations in salmon muscle and cod liver could be overestimated, as would the human dietary intake of PCBs through these fish tissue types. However, including them may have provided more realistic averages, when considering the entire population's consumption varies and many people do eat fish from these contaminated locations.

4.3.2 Uncertainties in calculated TEQs

Another consideration is that the food frequency questionnaires (FFQs) used in all of the human studies and reports come with inherent recall bias when they ask people to remember past dietary habits. Bias within these studies and reports was limited by the use of validated FFQs (10,29,32,47). Additionally, selecting assumption values for variables such as body weight, total consumption, portion size, etc. for scenario people was difficult because each variable was based on the available presented aggregate data provided by the human contamination studies and reports. Had we had access to the individual FFQ data, the assumptions could have been more accurate. However, each variable was carefully included to best represent the hypothetical scenario people.

This analysis included only two fish species to represent the three fish tissue types, fatty fish, lean fish, and special sea food. There are other fatty fish and lean fish species which may have provided different estimated TEQs, whether they would result in high concentrations or lower concentrations is hard to predict, but for the purposes of this study, the species included were good enough. This study assumed that the grams/ week used to calculate human dietary intakes of TEQ through consumption of fish were all as close to the truth as possible. It is important to note that median values could underestimate high exposure episodes and mean values could overestimate the average exposure levels, so data should be interpreted with discretion as it could have resulted in biased results.

The estimated TEQ intake rates in this study are likely overall overestimated because we have used mostly average numbers for both consumption of g/week and for PCB concentrations in fish. Also, the estimates likely represent worst-case scenario risk because we assumed higher TEFs for the ndl congeners, which do not have TEFs, resulting in higher TEQs. Higher TEQ intake values likely indicate a worst-case-scenario for the all the populations represented among the scenario person groups. Having a potential worst-case scenario provided us the possibility to evaluate nutrition guidelines and recommendations in a conservative way.

5 Conclusion

This study demonstrated geographic variation in the fish concentrations and also in rates of fish consumption. The results of this study suggest that Norwegians are potentially exceeding a safe weekly intake of PCBs and dioxins due to moderate to high dietary fish consumption, predominantly of fatty fish. Also, that the variation in PCB concentrations in Norwegian fish and variation in human consumption of these fish, results in variations in human exposures to PCBs and dioxins around Norway. Certain groups within Norway may be more at risk of high exposures than others and so dietary recommendations need to be evaluated taking into account varying geographic locations, consumption of contaminated food sources, and the origin of fish and other food items. Monitoring projects and recommended dietary guidelines from governing bodies need to be up to date and synchronized in order to ensure low potential health effects of contaminants among the whole Norwegian population. It is likely that newer or more communication strategies to the vulnerable groups (children and pregnant women) will increase awareness of national guidelines for dietary recommendations.

This study identified several points of interest to be followed up with in future research. There is considerable research on geographic distribution and variation of POPs in fish intended for consumption, however, information on monitoring of where contaminated fish is being distributed for consumption in grocery stores, for export, etc is not easily accessible. More complete information regarding how geographic variation of POP concentrations in fish correlates with human exposure to PCBs from consumption of fish and other food items is needed. Further, concentrations in different foods should be assessed to be able to analyze potential dietary patterns that lead to higher exposures; in order to compile an assessment of the overall dietary exposures to ensure low health risks in vulnerable groups.

Works Cited

1. World Health Organization. General description Polychlorinated biphenyls (PCBs). Air Qual Guid WHO [Internet]. 2000;2(2):1–22. Available from: http://www.euro.who.int/__data/assets/pdf_file/0016/123064/AQG2ndEd_5_10PCBs.PDF

2. Norwegian Climate and Pollution Agency, Authority NFS. Norwegian Implementation Plan For The Stockholm Convention On Persistent Organic Pollutants (POPs). 2015.

3. Waalkens-Berendsen I, Schwerdtle T, Steinkellner H, Zeilmaker M, Binaglia M, Gómez Ruiz JÁ, et al. Risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food. EFSA J. 2018;16(11).

4. European Environment Agency. Late lessons from early warnings: the Precautionary Principle 1896–2000. Environmental issue report. 2002. 1–200 p.

5. Pelclová D, Urban P, Preiss J, Lukáš E, Fenclová Z, Navrátil T, et al. Adverse health effects in humans exposed to 2,3,7,8-tetrachlorodibenzo-p- dioxin (TCDD). Rev Environ Health. 2006;21(2):119–38.

6. European Food Safety Authority. Update of the monitoring of levels of dioxins and PCBs in food and feed. EFSA J. 2012;10(7).

7. Steenland K, Bertazzi P, Baccarelli A, Kogevinas M. Dioxin revisited: developments since the 1997 IARC classification of dioxin as a human carcinogen. Environ Health Perspect [Internet]. 2004 Sep [cited 2019 May 8];112(13):1265–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15345337

8. Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, et al. The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicol Sci [Internet]. 2006 Oct [cited 2019 Apr 11];93(2):223–41. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16829543

9. NIFES- Institute of Marine Research. Dioxins, furans and dioxin-like PCBs [Internet]. 2015 [cited 2018 Oct 10]. Available from: https://nifes.hi.no/en/research-topics/seafood-safety/undesirable-substances-seafood/dioxins-furans-dioxin-like-pcbs/

10. Caspersen IH, Knutsen HK, Brantsæter AL, Haugen M, Alexander J, Meltzer HM, et al. Dietary exposure to dioxins and PCBs in a large cohort of pregnant women: Results from the Norwegian Mother and Child Cohort Study (MoBa). Environ Int [Internet]. 2013;59:398–407. Available from: http://dx.doi.org/10.1016/j.envint.2013.07.001

11. Helsedirektoratet. Utviklingen i norsk kosthold 2018 Rapport [Internet]. Oslo; 2018 [cited 2019 Apr 25]. Available from: https://helsedirektoratet.no/Lists/Publikasjoner/Attachments/1479/Utviklingen-i-norsk-kosthold-2018-IS-2759.pdf

12. Mattilsynet. Utkast til VKM-bestilling: Nytte og risikovurdering av fisk i norsk kosthold | Mattilsynet [Internet]. 15/02/2019. 2019 [cited 2019 May 22]. p. 1. Available from: https://www.mattilsynet.no/mat_og_vann/produksjon_av_mat/fisk_og_sjomat/fiske_og_fangst/utkast_til_vkmbestilling_nytte_og_risikovurdering_av_fisk_i_norsk_kosthold.33864

13. Skåre J, Brantsæter A, Frøyland L, Hemre G-I, Knutsen H, Lillegaard I, et al. Benefit-risk Assessment of Fish and Fish Products in the Norwegian Diet – An Update. Vol. 5, European Journal of Nutrition & Food Safety. 2015. 260–266 p.

14. Kvalem HE, Knutsen HK, Thomsen C, Haugen M, Stigum H, Brantsæter AL, et al. Role of dietary patterns for dioxin and PCB exposure. Mol Nutr Food Res. 2009;53(11):1438–51.

15. Domingo JL. Nutrients and Chemical Pollutants in Fish and Shellfish. Balancing Health Benefits and Risks of Regular Fish Consumption. Crit Rev Food Sci Nutr [Internet]. 2016 Apr 25 [cited 2019 May 25];56(6):979–88. Available from: http://www.tandfonline.com/doi/full/10.1080/10408398.2012.742985

16. Odland JØ, Donaldson S, Dudarev A, Carlsen A. AMAP assessment 2015: Human health in the Arctic. Vol. 75, International Journal of Circumpolar Health. 2016.

17. Gibson J, Adlard B, Olafsdottir K, Sandanger TM, Odland JØ. Levels and trends of contaminants in humans of the Arctic. Int J Circumpolar Health. 2016;75.

18. Genuis SJ. To sea or not to sea: Benefits and risks of gestational fish consumption.

Reprod Toxicol [Internet]. 2008 Oct 1 [cited 2019 May 25];26(2):81–5. Available from: https://www.sciencedirect.com/science/article/pii/S0890623808002074?via%3Dihub

19. Miljødirektoratet. Advarsler mot fisk og sjømat fra forurensede områder | Miljøstatus [Internet]. miljodirektoratet. 2018 [cited 2019 Apr 24]. Available from: https://www.miljostatus.no/tema/hav-og-kyst/miljogifter-langs-kysten/advarsler-mot-fisk-og-sjomat-fra-forurensede-omrader/

20. Mattilsynet- Norwegian Food Safety Autority. Annual Report [Internet]. 2016 [cited 2019 Apr 24]. Available from: https://www.mattilsynet.no/om_mattilsynet/annual_report_the_norwegian_food_safety_authority_2016.26919/binary/Annual report The Norwegian Food Safety Authority 2016

21. Havforskningsinstituttet- Institute of Marine Research. Seafood safety - NIFES [Internet]. 2015 [cited 2019 Apr 24]. Available from: https://nifes.hi.no/en/research-topics/seafood-safety/

22. Helsenorge.no. Mat og drikke gravide ikke bør spise [Internet]. 2019 [cited 2019 May 22]. p. 1. Available from: https://helsenorge.no/gravid/mat-og-drikke-som-gravide-ikke-bor-spise

23. Helsedirektoratet. Anbefalinger om kosthold, ernaering og fysisk aktivitet- Norwegian guidelines on diet, nutrition and physical activity [Internet]. Oslo; 2014 [cited 2019 Apr 25]. Available from: https://helsedirektoratet.no/Lists/Publikasjoner/Attachments/806/Anbefalinger-om-kosthold-ernering-og-fysisk-aktivitet-IS-2170.pdf

24. Rideout K, Kosatsky T. Fish for Dinner? Balancing Risks, Benefits, and Values in Formulating Food Consumption Advice. Risk Anal [Internet]. 2017 Nov 1 [cited 2019 May 25];37(11):2041–52. Available from: http://doi.wiley.com/10.1111/risa.12769

25. Arctic Monitoring and Assessment Programme. AMAP Assessment 2009 : Human Health in the Arctic. 2009.

26. Nøst TH, Breivik K, Fuskevåg OM, Nieboer E, Odland JØ, Sandanger TM. Persistent

organic pollutants in Norwegian men from 1979 to 2007: Intraindividual changes, age-period-cohort effects, and model predictions. Environ Health Perspect. 2013;121(11–12):1292–8.

27. Nøst TH, Breivik K, Wania F, Rylander C, Odland JØ, Sandanger TM. Estimating time-varying PCB exposures using person-specific predictions to supplement measured values: A comparison of observed and predicted values in two cohorts of norwegian women. Environ Health Perspect. 2016;124(3):299–305.

28. Nøst TH, Sandanger TM, Nieboer E, Odland JØ, Breivik K. The impacts of emission trends of POPs on human concentration dynamics: Lessons learned from a longitudinal study in Norway (1979–2007). Int J Hyg Environ Health [Internet]. 2017;220(4):776–81. Available from: http://dx.doi.org/10.1016/j.ijheh.2017.01.015

29. Rylander C, Lund E, Frøyland L, Sandanger TM. Predictors of PCP, OH-PCBs, PCBs and chlorinated pesticides in a general female Norwegian population. Environ Int [Internet]. 2012;43(1):13–20. Available from: http://dx.doi.org/10.1016/j.envint.2012.02.008

30. Berg V, Nøst TH, Sandanger TM, Rylander C. Predicting human plasma concentrations of persistent organic pollutants from dietary intake and socio-demographic information in the Norwegian Women and Cancer study. Environ Int. 2018;

31. Furberg A-S, Sandanger T, Thune I, Burkow IC, Lund E. Fish consumption and plasma levels of organochlorines in a female population in Northern Norway. J Environ Monit [Internet]. 2002 Jan 25 [cited 2019 May 21];4(1):175–81. Available from: http://xlink.rsc.org/?DOI=b106207g

32. Veyhe AS, Hansen S, Sandanger TM, Nieboer E, Odland JØ. The northern Norway mother-and-child contaminant cohort study: Implementation, population characteristics and summary of dietary findings. Int J Circumpolar Health. 2012;71(1).

33. Knutsen HK, Kvalem HE, Haugen M, Meltzer HM, Brantsæter AL, Alexander J, et al. Sex, BMI and age in addition to dietary intakes influence blood concentrations and congener profiles of dioxins and PCBs. Mol Nutr Food Res. 2011;55(5):772–82.

34. Brantsaeter AL, Birgisdottir B, Margrete Meltzer H, Kvalem H, Alexander J, Magnus P, et al. Maternal seafood consumption and infant birth weight, length and head circumference in the Norwegian Mother and Child Cohort Study. Br J Nutr. 2011 Jul 18;107:436–44.

35. Mangano MC, Sarà G, Corsolini S. Monitoring of persistent organic pollutants in the polar regions: knowledge gaps & gluts through evidence mapping. Chemosphere. 2017;172:37–45.

36. Bakke T, Boitsov S, Brevik E, Gabrielsen GW, Green N, Helgason LB, et al. Mapping selected organic contaminants in the Barents Sea 2007 - Kartlegging av utvalgte organiske miljøgifter fra Barentshavet 2007 [Internet]. Norsk institutt for vannforskning; 2008 [cited 2019 Apr 24]. Available from: https://brage.bibsys.no/xmlui/handle/11250/214037

37. Heimstad ES, Grønstøl G, Hetland KT, Alarcon JM, Rylander C, Mariussen E. A survey of dioxin-like contaminants in fish from recreational fishing. Environ Monit Assess. 2015;187(8).

38. Darnerud PO, Atuma S, Aune M, Bjerselius R, Glynn A, Grawé KP, et al. Dietary intake estimations of organohalogen contaminants (dioxins, PCB, PBDE and chlorinated pesticides, e.g. DDT) based on Swedish market basket data. Food Chem Toxicol. 2006;44(9):1597–606.

39. Birgisdottir BE, Brantsæter AL, Kvalem HE, Knutsen HK, Haugen M, Alexander J, et al. Fish liver and seagull eggs, vitamin D-rich foods with a shadow: Results from the Norwegian Fish and Game Study. Mol Nutr Food Res. 2012;56(3):388–98.

40. Norge. Fiskeridirektoratet. Key figures from aquaculture industry, 2002 [Internet]. 2003 [cited 2019 Apr 9]. Available from: http://www.fao.org/fishery/facp/NOR/en

41. Totland TH, Melnaes BK, Lundberg-Hallén N, Helland-Kigen KM, Lund-blix NA, Myhre JB, et al. Norkost 3: nationwide dietary survey among men and women in Norway between the ages of 18 and 70, 2010-11. 2012.

42. Lundblad M. Tromsø 7 (unpublished data). 2018.

43. Hansen L, Myhre J, Johansen A, Paulsen M, Andersen L. UNGKOST 3.

Landsomfattende kostholdsundersøkelse blant elever i 4. -og 8. klasse i Norge, 2015. [Internet]. 2015. Available from: https://www.fhi.no/globalassets/dokumenterfiler/rapporter/ungkost-rapport-24.06.16.pdf

44. Worlddata.info. Average height of men and women worldwide [Internet]. [cited 2019 May 22]. Available from: https://www.worlddata.info/average-bodyheight.php

45. Rylander C, Sandanger TM, Frøyland L, Lund E. Dietary patterns and plasma concentrations of perfluorinated compounds in 315 norwegian women: The NOWAC postgenome study. Environ Sci Technol [Internet]. 2010 Jul [cited 2019 Apr 24];44(13):5225–32. Available from: https://pubs.acs.org/doi/10.1021/es100224q

46. Rylander C, Brustad M, Falk H, Sandanger TM. Dietary Predictors and Plasma Concentrations of Perfluorinated Compounds in a Coastal Population from Northern Norway. J Environ Public Health [Internet]. 2009 Jan 6;2009:268219. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2810450/

47. Meltzer HM, Brantsaeter AL, Ydersbond TA, Alexander J, Haugen M. Methodological challenges when monitoring the diet of pregnant women in a large study: experiences from the Norwegian Mother and Child Cohort Study (MoBa). Matern Child Nutr [Internet]. 2007 Dec 13 [cited 2019 Apr 24];4(1):14–27. Available from: http://doi.wiley.com/10.1111/j.1740-8709.2007.00104.x

48. Arctic University of Norway Tromsø. Tromsøundersøkelsen | UiT- The Tromsø Study [Internet]. Web page. 2019 [cited 2019 May 9]. Available from: https://uit.no/forskning/forskningsgrupper/gruppe?p_document_id=367276

49. Karl H, Kammann U, Aust MO, Manthey-Karl M, Lüth A, Kanisch G. Large scale distribution of dioxins, PCBs, heavy metals, PAH-metabolites and radionuclides in cod (Gadus morhua) from the North Atlantic and its adjacent seas. Chemosphere [Internet]. 2016;149:294–303. Available from: http://dx.doi.org/10.1016/j.chemosphere.2016.01.052

50. Everaert G, Ruus A, Hjermann DØ, Borgå K, Green N, Boitsov S, et al. Additive Models Reveal Sources of Metals and Organic Pollutants in Norwegian Marine Sediments. Environ Sci Technol. 2017 Nov 7;51(21):12764–73.

51. Fiskeridirektoratet. Fangst fordelt på fartøyfylke [Internet]. 2018 [cited 2019 May 27]. Available from: https://fiskeridir.no/Yrkesfiske/Statistikk-yrkesfiske/Fangst-og-kvoter/Fangst-fordelt-paa-fartoeyfylke

52. Jenssen MTS, Brantsæter AL, Haugen M, Meltzer HM, Larssen T, Kvalem HE, et al. Dietary mercury exposure in a population with a wide range of fish consumption - Self-capture of fish and regional differences are important determinants of mercury in blood. Sci Total Environ [Internet]. 2012;439:220–9. Available from: http://dx.doi.org/10.1016/j.scitotenv.2012.09.024

53. Mattilsynet. Ikke spis fiskelever fra selvfangst. 2011 Apr 28 [cited 2019 May 27]; Available from: https://www.matportalen.no/matvaregrupper/tema/fisk_og_skalldyr/ikke_spis_fiskelever_fra_selvfangst

54. NIVA. Miljøgifter i fisk og zooplankton i Mjøsa. Klima- o Forurensnings-Direktoratet. 2009.

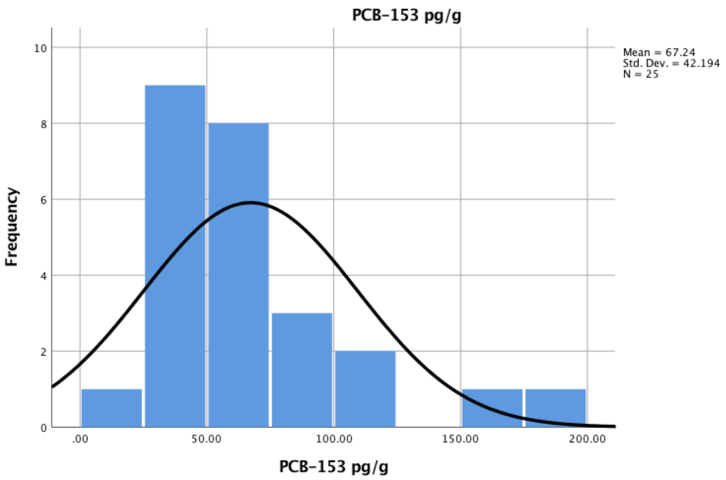
Appendix 1- Atlantic cod muscle

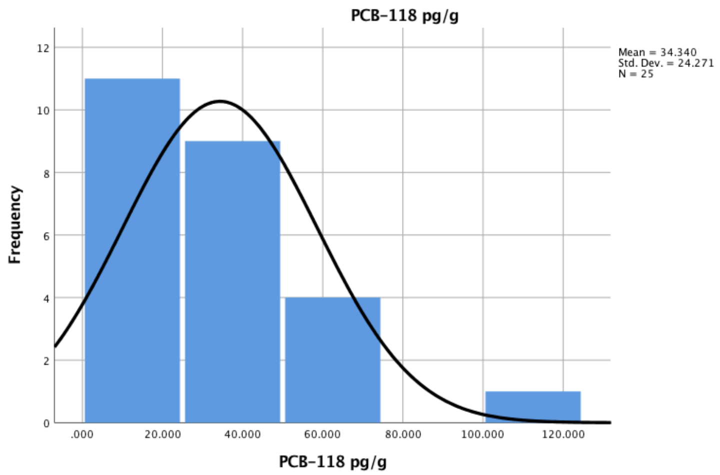
Results of the tests for normality

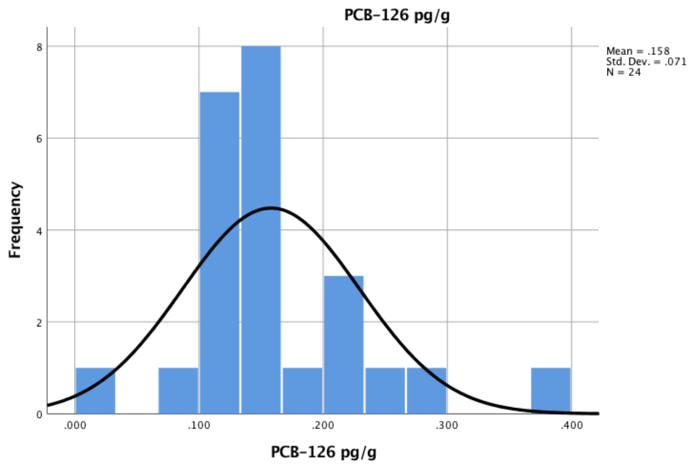
Tests of Normality

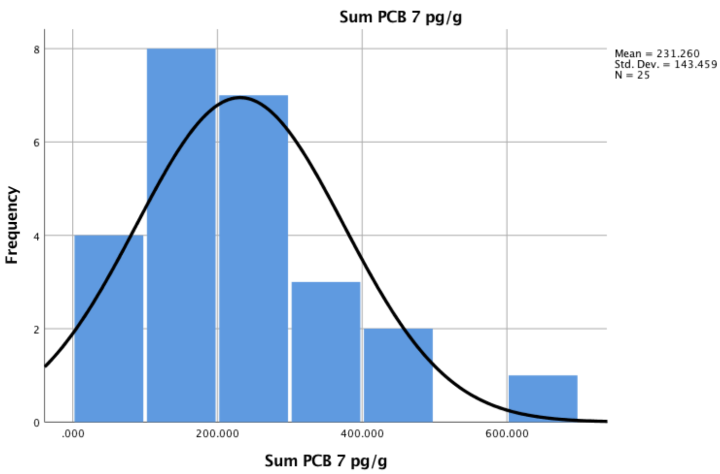
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCB-153 pg/g	.161	24	.109	.889	24	.013
PCB-118 pg/g	.227	24	.002	.811	24	.000
PCB-126 pg/g	.247	24	.001	.901	24	.023
Sum PCB 6 pg/g	.170	24	.070	.891	24	.014
Sum PCB 7 pg/g	.166	24	.087	.880	24	.008

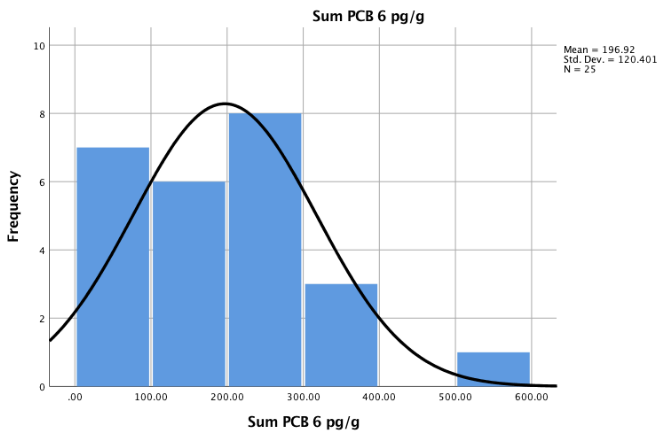
a. Lilliefors Significance Correction











Atlantic cod muscle- Congeners below the detection limit

% Below Detection	PCB-153	PCB-118	TCDD
All Years	69 %	77.5%	91 %
2006	50 %	50 %	N/A
2007	86.1%	91.7%	96 %
2008	66.7%	93.3%	65.5%
2009	93.3%	93.3%	100 %
2010	0	0	100 %
2014	0	0	100 %
2018	0	0	100 %

Appendix 2- Fish species lipid content

Fish Species' Lipid content (g/100g ww)		
	mean	95% CI
Cod Muscle	0.64	0.51-0.77
Salmon Muscle	8.2	7.6-8.5
Cod liver	52.3	51.8-52.8

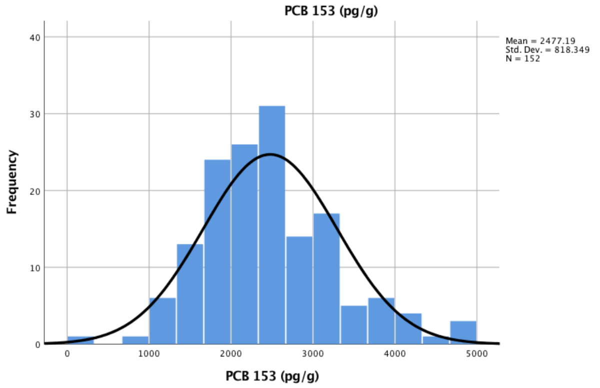
Appendix 3- Atlantic salmon muscle

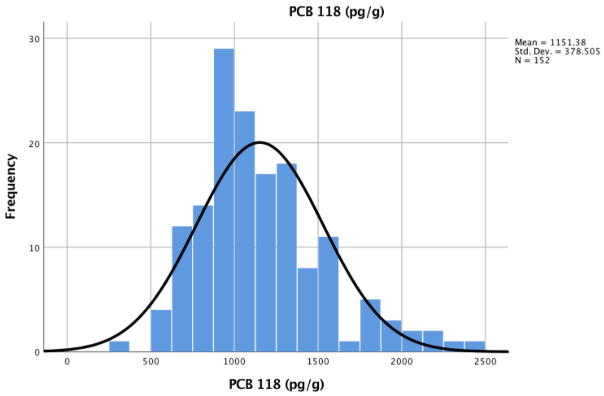
Results of tests for normality

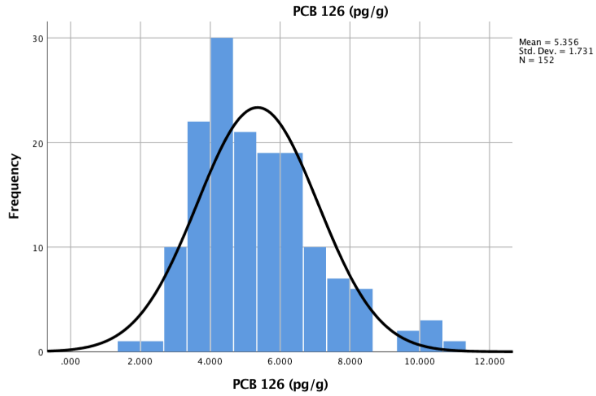
Tests of Normality

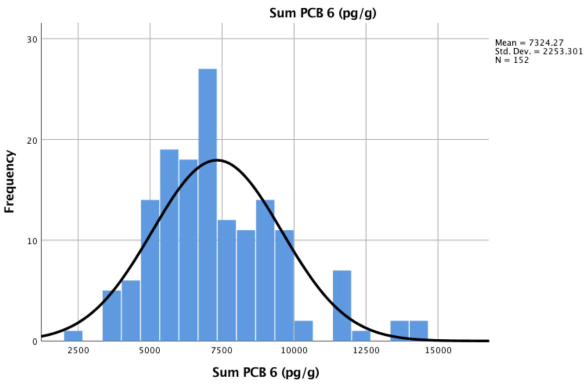
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCB 153 (pg/g)	.082	152	.014	.972	152	.003
Sum PCB 6 (pg/g)	.100	152	.001	.962	152	.000
Sum PCB 7 (pg/g)	.100	152	.001	.958	152	.000
PCB 118 (pg/g)	.108	152	.000	.944	152	.000
PCB 126 (pg/g)	.090	152	.004	.950	152	.000

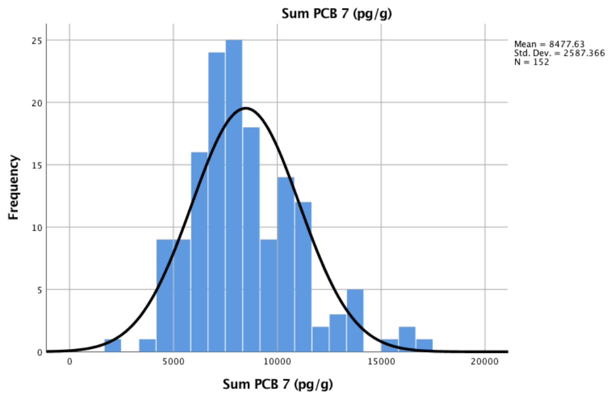
a. Lilliefors Significance Correction











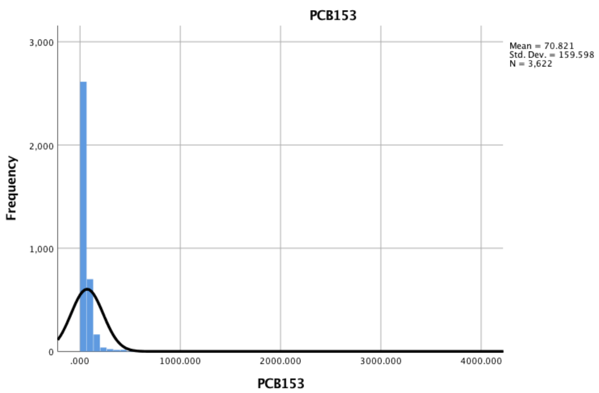
Appendix 4- Atlantic cod Liver

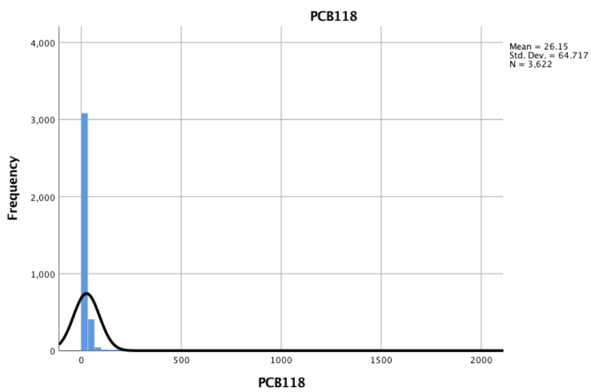
Results of tests for normality

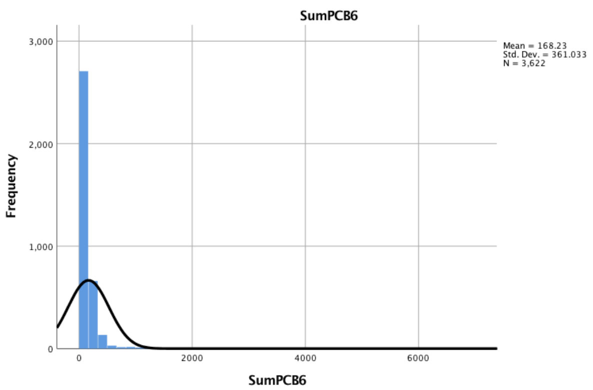
Tests of Normality

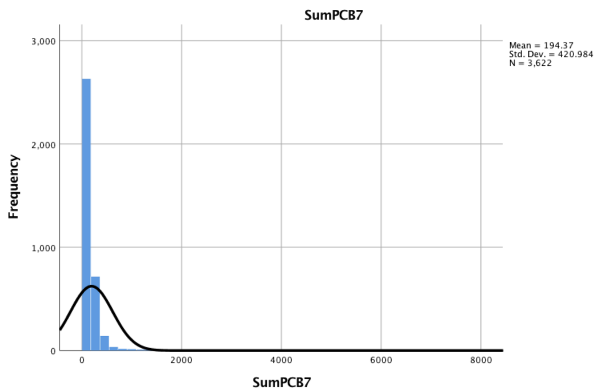
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PCB153	.198	3574	.000	.664	3574	.000
SumPCB62852101138 153180	.185	3574	.000	.664	3574	.000
SumPCB72852101118 138153180	.183	3574	.000	.660	3574	.000
PCB118	.207	3574	.000	.582	3574	.000

a. Lilliefors Significance Correction



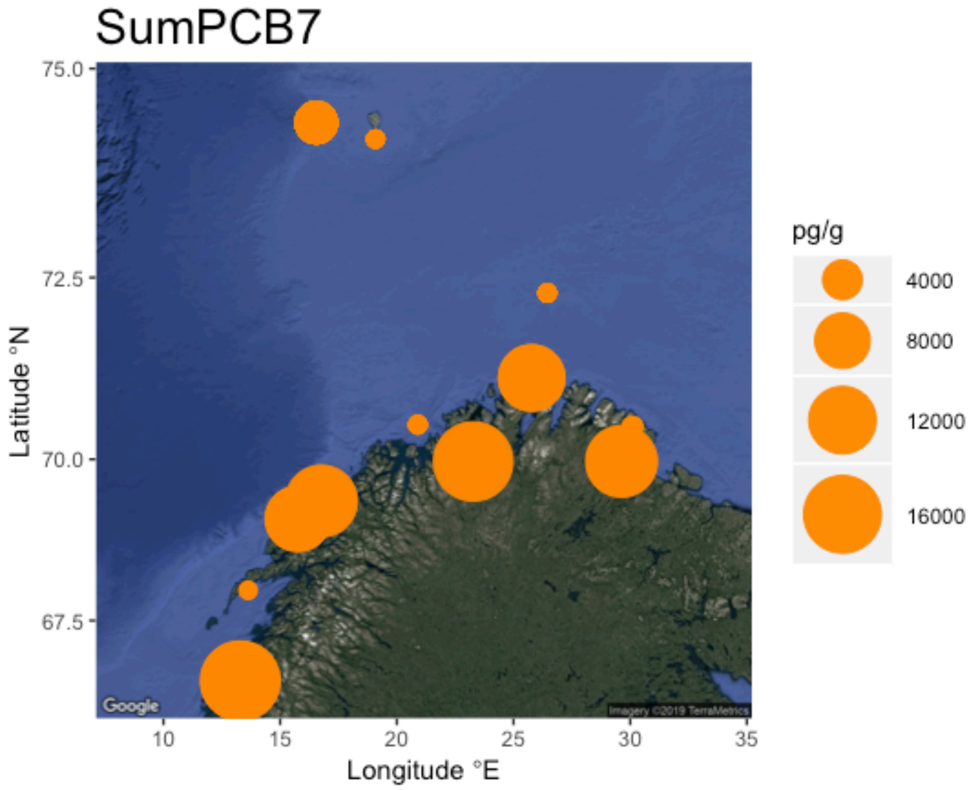


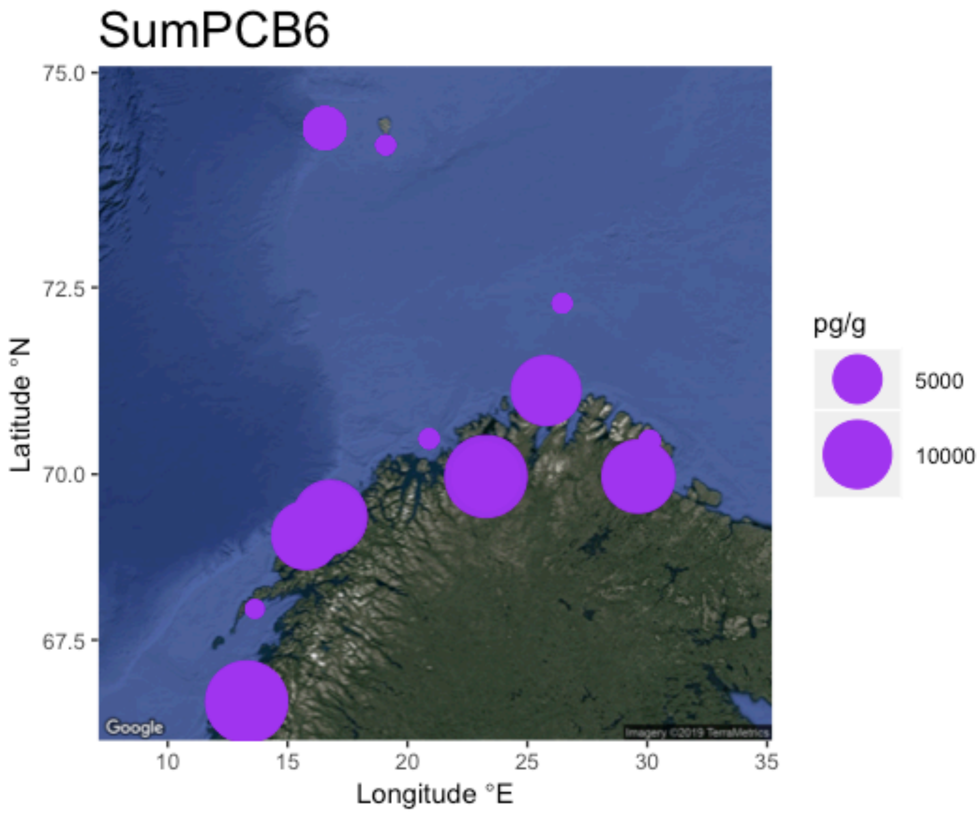




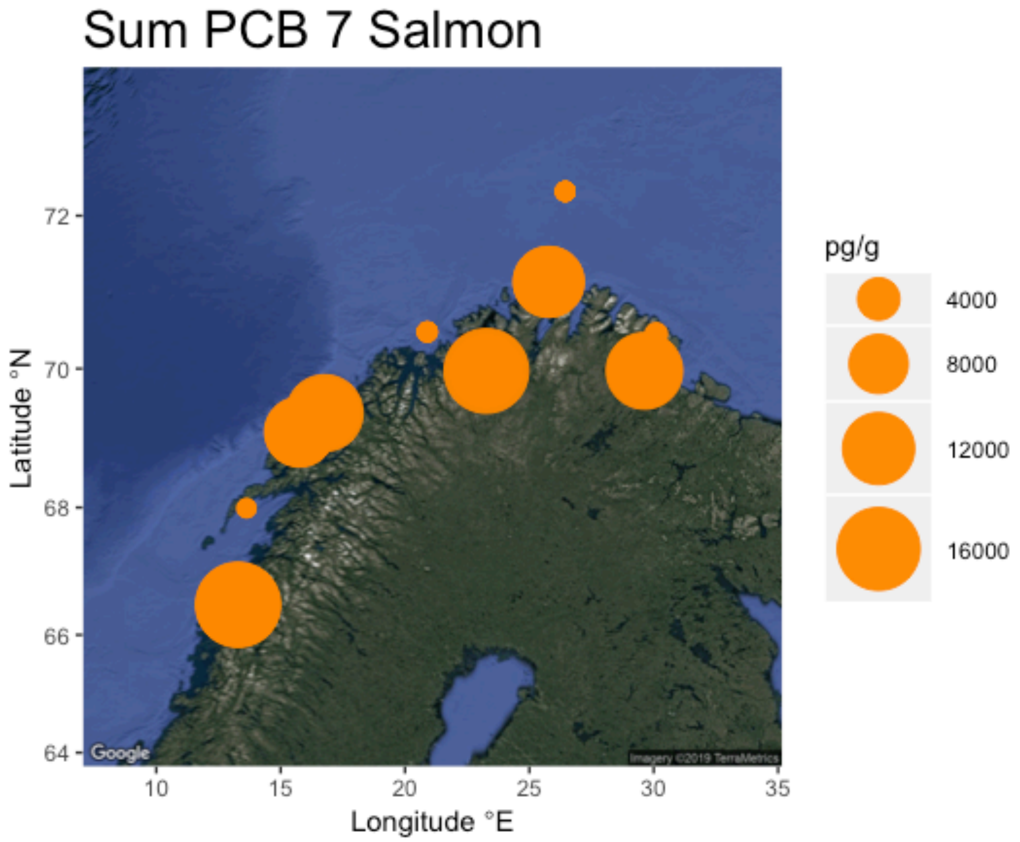
Appendix 5- Maps

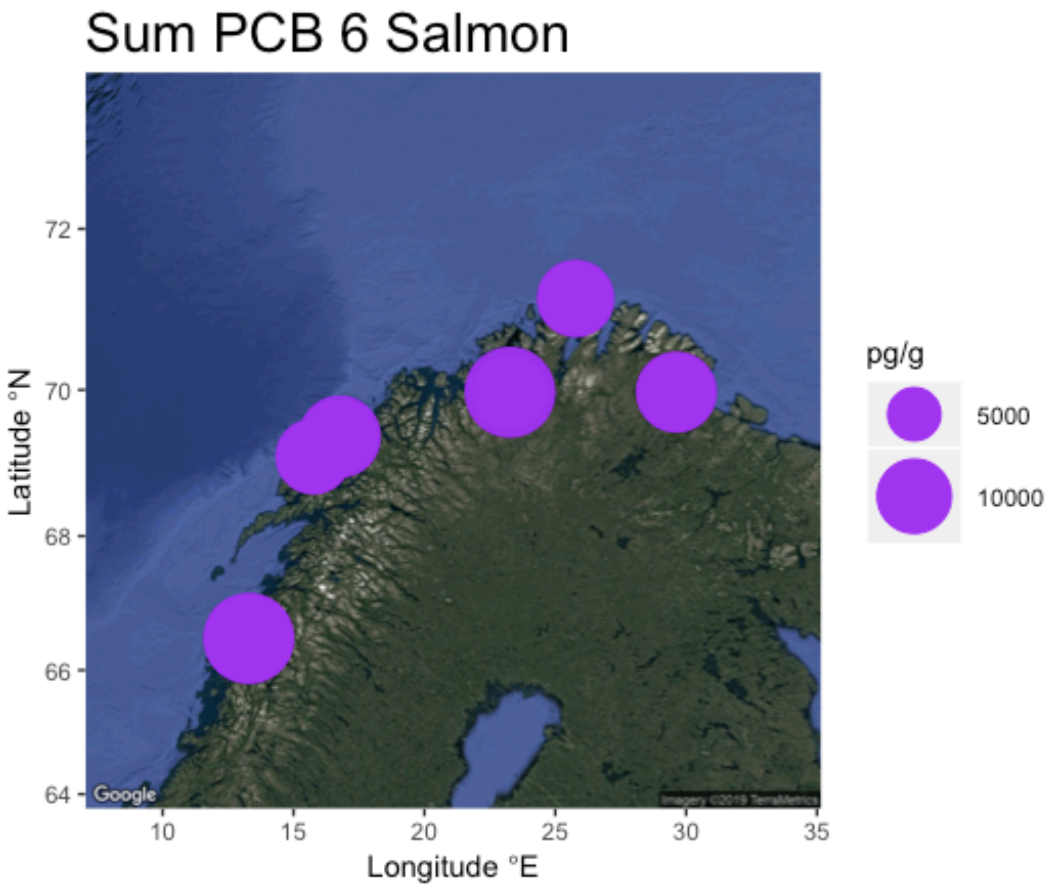
Atlantic cod muscle (2006-2018)



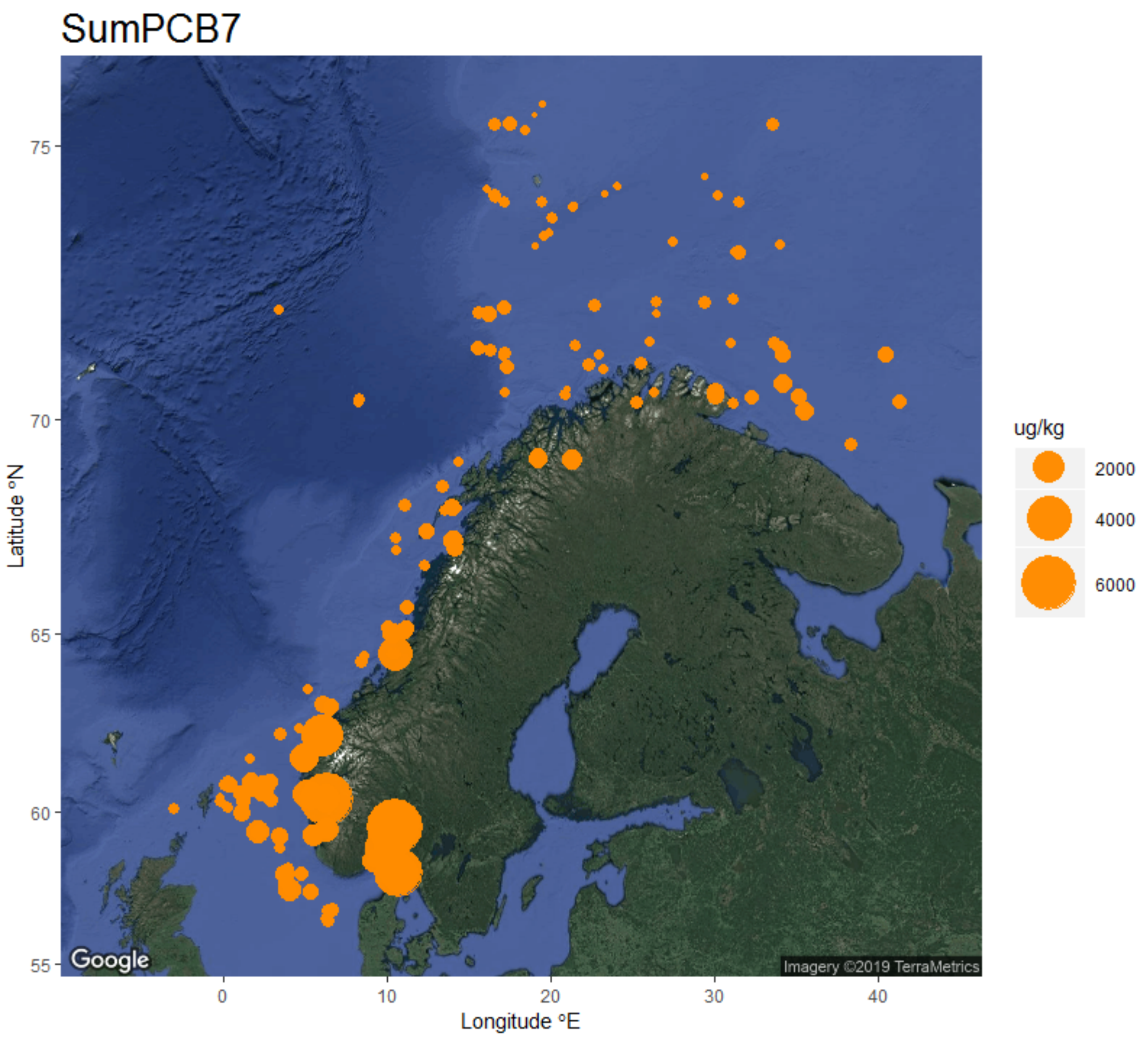


Atlantic salmon muscle (2002)





Atlantic cod liver (All years)



Appendix 6- All included data of human consumption of fish

Study	year collected	N	location	Age/ identifier	Age Category	Gender	fish food type	Avg grams/ day (SD	Median grams/ day	avg g/week	Median g/week
NORKOST	2010	1787	Oslo & Akershus	18-70 years	Adult	Male	Fish and Fish Produ	85 (97)		595	
NORKOST	2010	1787	Sør-Østlandet	18-70 years	Adult	Male	Fish and Fish Produ	72 (97)		504	
NORKOST	2010	1787	Hedmark & Opplan	18-70 years	Adult	Male	Fish and Fish Produ	60 (84)		420	
NORKOST	2010	1787	Agder &Rogaland	18-70 years	Adult	Male	Fish and Fish Produ	74 (96)		518	
NORKOST	2010	1787	Vestlandet	18-70 years	Adult	Male	Fish and Fish Produ	83 (108)		581	
NORKOST	2010	1787	Trøndelag	18-70 years	Adult	Male	Fish and Fish Produ	69 (80)		483	
NORKOST	2010	1787	Nord-Norge	18-70 years	Adult	Male	Fish and Fish Produ	106 (136)		742	
NORKOST	2010	1787	Oslo & Akershus	18-70 years	Adult	Female	Fish and Fish Produ	59 (77)		413	
NORKOST	2010	1787	Sør-Østlandet	18-70 years	Adult	Female	Fish and Fish Produ	48 (63)		336	
NORKOST	2010	1787	Hedmark & Opplan	18-70 years	Adult	Female	Fish and Fish Produ	49 (63)		343	
NORKOST	2010	1787	Agder &Rogaland	18-70 years	Adult	Female	Fish and Fish Produ	50 (69)		350	
NORKOST	2010	1787	Vestlandet	18-70 years	Adult	Female	Fish and Fish Produ	49 (63)		343	
NORKOST	2010	1787	Trøndelag	18-70 years	Adult	Female	Fish and Fish Produ	61 (74)		427	
NORKOST	2010	1787	Nord-Norge	18-70 years	Adult	Female	Fish and Fish Produ	81 (85)		567	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	Fish, Fish product	79 (102)	38	**553**	**266**
NORKOST	2010	862	Norway	18-70 years	Adult	Male	Oily/ Fatty fish	15 (42)	0	105	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	Lean fish	20 (62)	0	140	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	other Fish	6 (29)	0	42	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	fish product	17 (49)	0	119	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	fish pålegg	13 (29)	0	91	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	shellfish	5 (18)	0	35	
NORKOST	2010	862	Norway	18-70 years	Adult	Male	fish dish	3 (22)	0	21	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	Fish, Fish product	56 (72)	29	**392**	**203**
NORKOST	2010	925	Norway	18-70 years	Adult	Female	Oily /Fatty fish	14 (35)	0	98	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	Lean fish	12 (37)	0	84	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	other Fish	5 (22)	0	35	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	fish product	10 (29)	0	70	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	fish pålegg	8 (19)	0	56	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	shellfish	4 (115)	0	28	
NORKOST	2010	925	Norway	18-70 years	Adult	Female	fish dish	3 (26)	0	21	
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	total fish intake	79.5[0-252]	72	**556,5**	**504**
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	Fatty fish	11.5 [0-66.2]	9	80,5	63
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	Lean fish	19.8 [0 – 136]	15.8	138,6	110,6
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	fish products	36.3 [0 – 119]		254,1	
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	Fish Spread	8.6 [0 – 62.3]		60,2	
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	shell fish	1.42 [0 – 4.06]		9,94	
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	roe	0.51 [0 – 5.28]		3,57	
MISA (Northern No	2007-2009	381	Nord-Norge	pregnant	Pregnant	Female	fish liver	0.14 [0 – 3.63]		0,98	
UNGKOST 3	2015	636	Norway	9	Child	Both	Fish and Fish produ	24 (30)	13	**168**	**91**
UNGKOST 3	2015	341	Norway	9	Child	Female	Fish and Fish produ	21 (28)		**147**	
UNGKOST 3	2015	295	Norway	9	Child	Male	Fish and Fish produ	27 (32)		**189**	
UNGKOST 3	2015	636	Norway	9	Child	Both	Lean fish	2 (9)		14	
UNGKOST 3	2015	636	Norway	9	Child	Both	Fatty fish	8 (20)		56	
UNGKOST 3	2015	636	Norway	9	Child	Both	fish product	8 (17)		56	
UNGKOST 3	2015	636	Norway	9	Child	Both	other Fish	3 (11)		21	
UNGKOST 3	2015	636	Norway	9	Child	Both	fish pålegg	2 (6)		14	
UNGKOST 3	2015	636	Norway	9	Child	Both	shellfish	1 (5)		7	
UNGKOST 3	2015	687	Norway	13	Child	Both	Fish and Fish produ	24 (37)	6	**168**	**42**
UNGKOST 3	2015	355	Norway	13	Child	Female	Fish and Fish produ	21 (29)		**147**	
UNGKOST 3	2015	332	Norway	13	Child	Male	Fish and Fish produ	28 (44)		**196**	
UNGKOST 3	2015	687	Norway	13	Child	Both	Lean fish	2 (9)		14	
UNGKOST 3	2015	687	Norway	13	Child	Both	Fatty fish	10 (27)		70	
UNGKOST 3	2015	687	Norway	13	Child	Both	fish product	7 (17)		49	
UNGKOST 3	2015	687	Norway	13	Child	Both	other Fish	3 (13)		21	
UNGKOST 3	2015	687	Norway	13	Child	Both	fish pålegg	1 (5)		7	
UNGKOST 3	2015	687	Norway	13	Child	Both	shellfish	1 (4)		7	

MoBa, 2011	2002-2008	62099	Norway	Pregnant mothers	Pregnant	Female	Total fish intake	36	33	**252**	**231**
MoBa, 2011	2002-2008	62099	Norway	Pregnant mothers	Pregnant	Female	Lean fish	20	19	140	133
MoBa, 2011	2002-2008	62099	Norway	Pregnant mothers	Pregnant	Female	Fatty fish	12	8	84	56
MoBa, 2011	2002-2008	62099	Norway	Pregnant mothers	Pregnant	Female	shellfish	4	2	28	14
MoBa, 2011	2002-2008	62099	Norway	Pregnant mothers	Pregnant	Female	Fish liver	<0,1	<0.1	0,7	<0.1
MoBa, 2007	2002-2009	40108	Norway	Pregnant Mothers	Pregnant	Female	Fish and Seafood	45 (26.6)	42	**315**	**294**
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	Lean fish	.	13,7		95,9
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	semi-oily fish (2-8%	.	2,9		29,3
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	oily fish (except sal	.	2,6		18,2
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	salmon/trout	.	2,9		20,3
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	fish liver	.	0		0
MoBa- Norwegain	2007-2009	83524	Norway	Pregnant Mothers	Pregnant	Female	total seafood	.	31		**217**
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	Fish spread for bread			78	59
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	fish roe			4	4
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	fish liver			1	0
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	shellfish			29	25
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	processed fish products			166	139
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	other kinds of fish not included in lean or fatty fish			28	0
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	Lean fish			183	143
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	Fatty fish			129	100
NOWAC, 2010	2006	315	Norway	48-62 (mean 56)	Adult	Female	fish oil			9	0
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Fish roe	*0,6*	0,6	*4,2*	4,2
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Fish liver	*0*	0	*0*	0
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Processed fish proc	*24*	20	*168*	140
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	shellfish	*4*	4	*28*	28
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	other kinds of fish r	*4*	0	*28*	0
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Lean fish	*26*	20,5	*182*	143,5
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Fatty fish	*18*	12,9	*126*	90,3
NOWAC, 2012	2006	326	Norway	48-62 (mean 56)	Adult	Female	Fish and Fish Produ	.	**41**		**287**
Andøya Study	2009	15	Andenes Municipal	26-60 (mean 44)	Adult	Male	Fatty fish	.	3.4 kg/yr		65,2052
Andøya Study	2009	15	Andenes Municipal	26-60 (mean 44)	Adult	Male	Lean fish	.	18 kg/yr		345,204
Andøya Study	2009	15	Andenes Municipal	26-60 (mean 44)	Adult	Male	Other kinds of fish r	.	2.1 kg/yr		40,2738
Andøya Study	2009	15	Andenes Municipal	26-60 (mean 44)	Adult	Male	fish products	.	20 kg/yr		383,56
Andøya Study	2009	15	Andenes Municipal	26-60 (mean 44)	Adult	Male	shellfish	.	0 kg/yr		0
							sum total fish intak	.			**834,243**
Andøya Study	2009	41	Andenes Municipal	26-60 (mean 44)	Adult	Female	Fatty fish	.	3.1 kg/yr		59,4518
Andøya Study	2009	41	Andenes Municipal	26-60 (mean 44)	Adult	Female	Lean fish	.	14 kg/yr		268,492
Andøya Study	2009	41	Andenes Municipal	26-60 (mean 44)	Adult	Female	Other kinds of fish r	.	2.1 kg/yr		40,2738
Andøya Study	2009	41	Andenes Municipal	26-60 (mean 44)	Adult	Female	fish products	.	15 kg/yr		287,67
Andøya Study	2009	41	Andenes Municipal	26-60 (mean 44)	Adult	Female	shellfish	.	0 kg/yr		0
							sum total fish intake				**655,8876**
Tromsø Study 7 (ur	2017	11425	Tromsø Municipali	>40 yrs	Adult	Both	Fish and Shellfish		101 [113.1455 – 115.3972]		**707**
Tromsø Study 7 (ur	2017	11425	Tromsø Municipali	>40 yrs	Adult	Both	Lean Fish frequency	2,723673	3	19,04	21
Tromsø Study 7 (ur	2017	11425	Tromsø Municipali	>40 yrs	Adult	Both	Fatty Fish Frequenc	2,475522	3	17,3	21
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	>40 yrs	Adult	Female	Fish and Fish Produ	106,5 (104.9 - 108	94.5 (65 – 136.3)	**745,5**	**661,5**
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	>40 yrs	Adult	Male	Fish and Fish Produ	126.5 (124.6 - 128	114.7 (76.7 - 164.4	**885,5**	**802,9**
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	40-49	Adult	Female	Fish and Fish Produ	87.4 (84.8 - 89.9)	76 (49.4 - 111.5)	611,8	
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	50-59	Adult	Female	Fish and Fish Produ	110.3 (107.3 - 113	98.8 (66.9 - 141)	772,1	
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	60-69	Adult	Female	Fish and Fish Produ	117.98 (114.957 -	106.5 (75.6 - 149.3	825,86	
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	70-79	Adult	Female	Fish and Fish Produ	119.9 (115.4 - 124	110 (77.9 - 152.3)	839,3	
Tromsø Study 7 (ur	2017	6104	Tromsø Municipali	>80	Adult	Female	Fish and Fish Produ	108.1 (98.8 - 117.4	99.6 (68.3 - 139.5)	756,7	
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	40-49	Adult	Male	Fish and Fish Produ	103.1 (99.9 - 106.3	93.7 (58.4 - 134.8)	721,7	
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	50-59	Adult	Male	Fish and Fish Produ	125.7 (121.9 - 129	112.3 (74.3 - 165.6	879,9	
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	60-69	Adult	Male	Fish and Fish Produ	140.2 (136.6 - 143	131.1 (89.3 - 177.8	981,4	
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	70-79	Adult	Male	Fish and Fish Produ	142.98 (138.1 - 14	133.3 (93.3 - 177.6	1000,86	
Tromsø Study 7 (ur	2017	5321	Tromsø Municipali	>80	Adult	Male	Fish and Fish Produ	135.9 (124.6 - 147	122 (84.9 - 179.5)	951,3	
								****(25%-75% quartiles)**			

Appendix 7- Calculation table of pg TEQ/kg (b.w.) for each scenario person

Fatty fish diet:

Scenario People + TEQ/kg for each congener	Contaimination pg/g ww	Norwegian Pregnant Woman (≈77kg)		**WEEKLY INTAKE**	Child btw 9-13 (≈33-50kg) (40kg used)		**WEEKLY INTAKE**	Northern Norwegian Man (≈89kg) HIGH Consumer		**WEEKLY INTAKE**	Avg Northern Norwegain Woman (≈72kg) HIGH CONSUMER		**WEEKLY INTAKE**
	g/week fish intake	367,50	-->MoBa Study + MISA		168,00	--> UNGKOST study		818,60	'--> based on avgs of Tromsø study & And		663,70	"--> based on avgs of Tromsø study & And	
		pg/week	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**
Salmon Muscle:		113,93	--> 31% MoBa Study + MISA		63,00	--> UNGKOST study		548,46	≈67%		444,68	≈67%	
PCB 6	7324,27	834417,46	25,03	0,33	461429,01	13,84	0,35	4017083,77	120,51	1,35	3256949,06	97,71	1,36
PCB 7	8477,63	965814,00	28,97	0,38	534090,69	16,02	0,40	4649657,91	139,49	1,57	3769824,03	113,09	1,57
PCB 118	1151,38	131170,97	3,94	0,05	72536,94	2,18	0,05	631488,18	18,94	0,21	511994,51	15,36	0,21
PCB 153	2477,19	282213,87	8,47	0,11	156062,97	4,68	0,12	1358644,58	40,76	0,46	1101554,37	33,05	0,46
PCB 126*	5,36	610,64	61,06	0,79	337,68	33,77	0,84	2939,76	293,98	3,30	2383,48	238,35	3,31
Cod Muscle 2010-2018:		213,15	-->58% MoBa Study + MISA		14,00	--> UNGKOST study		261,95	≈32%		212,38	≈32%	
PCB 6	260,86	55602,31	1,67	0,02	3652,04	0,11	0,00	68332,80	2,05	0,02	55402,49	1,66	0,02
PCB 7	303,63	64718,73	1,94	0,03	4250,82	0,13	0,00	79536,49	2,39	0,03	64486,15	1,93	0,03
PCB 118	42,77	9116,43	0,27	0,00	598,78	0,02	0,00	11203,69	0,34	0,00	9083,66	0,27	0,00
PCB 153	106,69	22740,97	0,68	0,01	1493,66	0,04	0,00	27947,66	0,84	0,01	22659,25	0,68	0,01
PCB 126*	0,11	23,23	2,32	0,03	1,53	0,15	0,00	28,55	2,86	0,03	23,15	2,31	0,03
Cod Liver:		0,00	-->MoBa Study + MISA		1,68	--> UNGKOST study		8,19	≈1%		6,64	≈1%	
PCB 6	168200,89	0,00	0,00	0,00	282577,50	8,48	0,21	1376892,49	41,31	0,46	1116349,31	33,49	0,47
PCB 7	194345,76	0,00	0,00	0,00	326500,88	9,80	0,24	1590914,39	47,73	0,54	1289872,81	38,70	0,54
PCB 118	26144,87	0,00	0,00	0,00	43923,38	1,32	0,03	214021,91	6,42	0,07	173523,50	5,21	0,07
PCB 153	70820,74	0,00	0,00	0,00	118978,84	3,57	0,09	579738,58	17,39	0,20	470037,25	14,10	0,20
PCB 126*	NOT AVAILIABLE												

All values are "pg TEQ/weight (kg)".
*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.
** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.

Scenario People + TEQ/kg for each congener	Contaimination pg/g ww	Avg Norwegian Man (≈89kg)		**WEEKLY INTAKE**	Avg Norwegain Woman (≈72kg)		**WEEKLY INTAKE**	Lean fish women (≈72 kg)		**WEEKLY INTAKE**
.	g/week fish intake	553,00	--> based on avgs of norkost		392,00	'--> norkost avg		287,00	'--> based on median NOWAC	
		pg/week	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**
Salmon Muscle:		370,50	≈67%		262,60	≈67%		101,00	≈35%	
PCB 6	7324,27	2713642,04	81,41	0,91	1923353,30	57,70	0,80	739751,27	22,19	0,31
PCB 7	8477,63	3140961,92	94,23	1,06	2226225,64	66,79	0,93	856240,63	25,69	0,36
PCB 118	1151,38	426586,29	12,80	0,14	302352,39	9,07	0,13	116289,38	3,49	0,05
PCB 153	2477,19	917798,90	27,53	0,31	650510,09	19,52	0,27	250196,19	7,51	0,10
PCB 126*	5,36	1985,88	198,59	2,23	1407,54	140,75	1,95	541,36	54,14	0,75
Cod Muscle 2010-2018:		177,00	≈32%		125,40	≈32%		126,28	≈44%	
PCB 6	260,86	46172,22	1,39	0,02	32711,84	0,98	0,01	32941,40	0,99	0,01
PCB 7	303,63	53742,51	1,61	0,02	38075,20	1,14	0,02	38342,40	1,15	0,02
PCB 118	42,77	7570,29	0,23	0,00	5363,36	0,16	0,00	5401,00	0,16	0,00
PCB 153	106,69	18884,13	0,57	0,01	13378,93	0,40	0,01	13472,81	0,40	0,01
PCB 126*	0,11	19,29	1,93	0,02	13,67	1,37	0,02	13,76	1,38	0,02
Cod Liver:		5,53	≈1%		3,92	≈1%		2,87	≈1%	
PCB 6	168200,89	930150,92	27,90	0,31	659347,49	19,78	0,27	482736,55	14,48	0,20
PCB 7	194345,76	1074732,05	32,24	0,36	761835,38	22,86	0,32	557772,33	16,73	0,23
PCB 118	26144,87	144581,13	4,34	0,05	102487,89	3,07	0,04	75035,78	2,25	0,03
PCB 153	70820,74	391638,69	11,75	0,13	277617,30	8,33	0,12	203255,52	6,10	0,08
PCB 126*	NOT AVAILIABLE									

All values are "pg TEQ/weight (kg)".

*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.

** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.

Lean fish diet

Scenario People + TEQ/kg for each congener		Norwegian Pregnant Woman (≈77kg) WEEKLY INTAKE			Child btw 9-13 (≈33-50kg) (40kg used) WEEKLY INTAKE			Northern Norwegian Man (≈89kg) HIGH Consume WEEKLY INTAKE			Avg Northern Norwegain Woman (≈72kg) I WEEKLY INTAKE		
	g/week fish intake	367,50	-->MoBa Study + MISA		168,00	--> UNGKOST study		818,60	'--> based on avgs of Tromsø study & Andøya medians		663,70	"--> based on avgs of Tromsø study & Andøya medians	
Contaimination pg/g ww		**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x TEF**	**TEQ/ weight (kg)**
Salmon Muscle:		113,93	--> 31% MoBa Study + MISA		63,00	--> UNGKOST study		327,44	≈40%		265,48	≈40%	
Sum PCB 6**	7324,27	834417,46	25,03	0,33	461429,01	13,84	0,35	2398258,97	71,95	0,81	1944447,20	58,33	0,81
Sum PCB 7**	8477,63	965814,00	28,97	0,38	534090,69	16,02	0,40	2775915,17	83,28	0,94	2250641,21	67,52	0,94
PCB 118	1151,38	131170,97	3,94	0,05	72536,94	2,18	0,05	377007,87	11,31	0,13	305668,36	9,17	0,13
PCB 153	2477,19	282213,87	8,47	0,11	156062,97	4,68	0,12	811131,09	24,33	0,27	657644,40	19,73	0,27
PCB 126*	5,36	610,64	61,06	0,79	337,68	33,77	0,84	1755,08	175,51	1,97	1422,97	142,30	1,98
Cod Muscle 2010-2018:		213,15	-->58% MoBa Study + MISA		14,00	--> UNGKOST study		491,16	≈60%		398,22	≈60%	
Sum PCB 6**	260,86	55602,31	1,67	0,02	3652,04	0,11	0,003	128124,00	3,84	0,04	103879,67	3,12	0,04
Sum PCB 7**	303,63	64718,73	1,94	0,03	4250,82	0,13	0,003	149130,91	4,47	0,05	120911,54	3,63	0,05
PCB 118	42,77	9116,43	0,27	0,004	598,78	0,02	0,0004	21006,91	0,63	0,01	17031,87	0,51	0,01
PCB 153	106,69	22740,97	0,68	0,01	1493,66	0,04	0,001	52401,86	1,57	0,02	42486,09	1,27	0,02
PCB 126*	0,11	23,23	2,32	0,03	1,53	0,15	0,004	53,54	5,35	0,06	43,41	4,34	0,06
Cod Liver:	*≈1% (not a recommended*	0,00	-->MoBa Study + MISA		1,68	--> UNGKOST study		8,19	≈1%		6,64	≈1%	
Sum PCB 6**	168200,89	0,00	0,00	0,00	282577,50	8,48	0,21	1376892,49	41,31	0,46	1116349,31	33,49	0,47
Sum PCB 7**	194345,76	0,00	0,00	0,00	326500,88	9,80	0,24	1590914,39	47,73	0,54	1289872,81	38,70	0,54
PCB 118	26144,87	0,00	0,00	0,00	43923,38	1,32	0,03	214021,91	6,42	0,07	173523,50	5,21	0,07
PCB 153	70820,74	0,00	0,00	0,00	118978,84	3,57	0,09	579738,58	17,39	0,20	470037,25	14,10	0,20
PCB 126*	NOT AVAILIABLE												

All values are "pg TEQ/weight (kg)".
*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.
** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.

Scenario People + TEQ/kg for each congener		Avg Norwegian Man (≈89kg) **WEEKLY INTAKE**			Avg Norwegain Woman (≈72kg) **WEEKLY INTAKE**			Lean fish women (≈72 kg) **WEEKLY INTAKE**		
	g/week fish intake	553,00	--> based on avgs of norkost		392,00	'--> norkost avg		287,00	'--> based on median NOWAC	
Contaimination pg/g ww		**pg/week**	**TEQ= pg/week x**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/week x**	**TEQ/ weight (kg)**	**pg/week**	**TEQ= pg/weel**	**TEQ/ weight (kg)**
Salmon Muscle:		221,20	≈40%		156,80	≈40%		101,00	≈35%	
Sum PCB 6**	7324,27	1620128,52	48,60	0,55	1148445,54	34,45	0,48	739751,27	22,19	0,31
Sum PCB 7**	8477,63	1875251,76	56,26	0,63	1329292,38	39,88	0,55	856240,63	25,69	0,36
PCB 118	1151,38	254685,26	7,64	0,09	180536,38	5,42	0,08	116289,38	3,49	0,05
PCB 153	2477,19	547954,43	16,44	0,18	388423,39	11,65	0,16	250196,19	7,51	0,10
PCB 126*	5,36	1185,63	118,56	1,33	840,45	84,04	1,17	541,36	54,14	0,75
Cod Muscle 2010-2018:		331,80	≈60%		235,20	≈60%		126,30	≈44%	
Sum PCB 6**	260,86	86553,35	2,60	0,03	61354,27	1,84	0,03	32946,62	0,99	0,01
Sum PCB 7**	303,63	100744,43	3,02	0,03	71413,78	2,14	0,03	38348,47	1,15	0,02
PCB 118	42,77	14191,09	0,43	0,005	10059,50	0,30	0,004	5401,85	0,16	0,002
PCB 153	106,69	35399,74	1,06	0,01	25093,49	0,75	0,01	13474,95	0,40	0,01
PCB 126*	0,11	36,17	3,62	0,04	25,64	2,56	0,04	13,77	1,38	0,02
Cod Liver:	*≈1% (not a recommended am*	5,53	≈1%		3,92	≈1%		2,87	≈1%	
Sum PCB 6**	168200,89	930150,92	27,90	0,31	659347,49	19,78	0,27	482736,55	14,48	0,20
Sum PCB 7**	194345,76	1074732,05	32,24	0,36	761835,38	22,86	0,32	557772,33	16,73	0,23
PCB 118	26144,87	144581,13	4,34	0,05	102487,89	3,07	0,04	75035,78	2,25	0,03
PCB 153	70820,74	391638,69	11,75	0,13	277617,30	8,33	0,12	203255,52	6,10	0,08
PCB 126*	NOT AVAILIABLE									

All values are "pg TEQ/weight (kg)".
*PCB-126 has a TEF of 0.01, where all other congeners have a TEF of 0.00003.
** Sum PCB 6 includes PCB congeners: 28, 52, 101, 138, 153, 180. Sum PCB 7 also includes PCB-118.