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Environmental pollutants in the terrestrial and urban environment

Foreword

On behalf of the Norwegian Environment Agency, NILU - Norwegian Institute for Air Research in collaboration with NINA – Norwegian Institute for Nature Research have analysed biological samples from a terrestrial urban region for various inorganic and organic contaminants. Selected compounds and sampled species (i.e., PCBs, brominated flame retardants, perfluorinated alkylated substances and metals) were chosen by the Norwegian Environment Agency. Thanks are due to all who have participated in this project and especially to:

Torgeir Nygård, Silja Sletten, Erik Framstad, Svein Erik Sloreid, John Atle Kålås, Arnstein Staverløkk
Norwegian Institute for Nature Research (NINA)

Eldbjørg S. Heimstad, Hilde Uggerud, Linda Hanssen, Arntraut Götsch, Silje Winnem, Camilla Bakken Aas, Athanasios Katsogiannis; Mikael Harju
Norwegian Institute for Air Research (NILU)

Helene M. Lampe, Prof.
Dept. of Biosciences, CEES,
University of Oslo

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Dorte Herzke
Senior Researcher, Project Coordinator

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Forfatter(e)
Dorte Herzke, Torgeir Nygård, Eldbjørg S. Heimstad, Hilde Uggerud, Linda Hanssen, Arntraut Götsch

Tittel - norsk og engelsk

Miljøgifter i det terrestre bynære miljø
Environmental pollutants in the terrestrial urban environment

Sammendrag – summary
On behalf of the Norwegian Environment Agency, NILU - Norwegian Institute for Air Research in collaboration with NINA – Norwegian Institute for Nature Research analysed biological samples from terrestrial urban regions for various inorganic and organic contaminants. Stable isotope analysis for nitrogen and carbon was carried out by the Institute for Energy Technology (IFE). Sample collection was carried out by the Norwegian Institute for Nature Research (NINA) and others. The purpose of this report is to provide an updated assessment of pollution present within the terrestrial urban environment in Norway. In the case of earthworms, urban sites were compared with reference sites.

Eggs of the terrestrial bird species golden eagle and pied flycatcher as well as liver from urban brown rats and urban and rural earthworms were investigated in this study.

4 emneord	4 subject words
POP, PFOS, kvikksølv, kongeørn	POPs, PFOS, mercury, golden eagle

Summary

On behalf of the Norwegian Environment Agency, NILU - Norwegian Institute for Air Research in collaboration with NINA – Norwegian Institute for Nature Research analysed biological samples from terrestrial urban regions for various inorganic and organic contaminants. Stable isotope analysis for nitrogen and carbon was carried out by the Institute for Energy Technology (IFE). Sample collection was carried out by the Norwegian Institute for Nature Research (NINA) and others. The purpose of this report is to provide an updated assessment of pollution present within the terrestrial urban environment in Norway. In the case of earthworms, urban sites were compared with reference sites.

Eggs of the terrestrial bird species golden eagle and pied flycatcher as well as liver from urban brown rats and urban and rural earthworms were investigated in this study.

When comparing the concentrations of the different pollutants, the following interspecies differences of the contribution of the measured pollutants could be observed (on a wet weight basis):

- Golden eagle eggs: sumPCB > Toxic metals > sumPFAS > sumPBDE
- Pied flycatcher: sumPCB > sumPBDE
- Rats: Toxic metals >> sumPCB > sumPFAS > sumPBDE
- Earthworms: Toxic metals >> sumPFAS > sumPCB

Of all the organisms/tissues measured in the study, golden eagle eggs had the highest overall average concentration of sum of all organic pollutants measured, followed by rat liver > pied flycatcher eggs > earthworms (on a wet weight basis). In golden eagle eggs, PCBs contributed with more than 80% on a wet weight basis, followed by Hg and PFAS with ca. 10 and 5%. For comparison, in earthworms Hg and PFAS constituted 90% of the overall pollutant load, followed by PCBs. The liver concentration of brown rats were comparable to the golden eagle eggs with PCBs representing approximately 50%, followed by PFAS and Hg. From the measured congeners in the organic pollutant groups, PBDE 47 dominated in the golden eagle eggs of the PBDE pattern in 1995, but decreased to less than 25% in 2005-2011. PBDE 153 and 154 were the dominating PBDEs in the latter period. In brown rat liver, PBDE 100 was the dominating PBDE. For PCBs, PCB 153 and 180 together contributed with approximately 60% to the sumPCB load in golden eagle eggs. No change over time was observed in the PCB composition. In pied flycatcher eggs, PCB 138 and 153 contributed the most. The same congeners were dominating in the earthworms collected at the reference and the urban site. For PFAS, PFOS was the main congener observed in all tissues, but long-chained PFCA could be detected in golden eagle eggs, brown rats and earthworm in similar magnitudes too.

Changes of contaminant concentrations over time in golden eagle eggs show decreasing concentrations of PCB and a stable trend for PBDE and PFAS. Overall, the results show that PCB continues to remain an important environmental pollutant in biota in Norway even many decades after it was banned. The contribution of the other environmental pollutants is also significant with different pollutant patterns emerging in the different species reflecting species differences in exposure, trophic position and metabolic capabilities. In comparison with available data from terrestrial studies carried out in Norway or Europe, concentrations of PCB, PBDE and PFAS in this study have to be considered low. Samples from Oslo show slightly elevated concentrations of the pollutants compared to the reference sites. To provide additional insight into the pollutant load in organisms living in an urban environment, we recommend further studies on contaminant transfer along natural food chains; i.e. involving species more representative of a terrestrial food chain habiting a Norwegian urban ecosystem.

Combined risk of the measured pollutants (MEC) was evaluated with a first tier conservative concentration addition (CA) approach using predicted no effect concentration for predators (PNECpred) as reference values. A PNECpred value for PCBs and PFOA and other PFAS except

PFOSwas not available. As a results, only some metals, PBDEs and PFOS with available reference values could be included in the combined risk assessment leading to a possible underestimation/ prediction of risk in particular in birds where PCB is the dominant pollutant. Based on the relatively few compounds with available reference values, the results gave no initial possible reason for concern for the species investigated. Earthworm from the Oslo area showed a Sum (MEC/PNECpred) > 1 ranging between 5.9 and 12.6, indicating a risk for other and not here investigated predators with earthworm as an important food item. The present mixture risk assessment for the species should only be considered as an initial step in a mixture assessment and an evaluation of the applicability of PNEC values as reference values for these investigated compounds and species. The mixture risk assessment may underestimate risk due to unavailable PNECpred values for PCBs and PFOA and other not investigated contaminants. Moreover, it is at present not clear how relevant the selected effect concentrations are for mixture risk assessment of bird egg concentrations. Long term effect studies might be needed in order to establish the lacking reference values.

For future studies, a real coherent terrestrial food chain is recommended, preferentially including earthworms, due to their elevated risk indication, bird species feeding on earthworms, and raptors as goshawk or sparrow hawk. Favorably, all sampling should be carried out in the same location, during a short time period on non-migrating species.

Norsk sammendrag

På oppdrag av Miljødirektoratet analyserte NILU – Norsk institutt for luftforskning og NINA – Norsk institutt for naturforskning en lang rekke uorganiske og organiske miljøgifter i dyrearter fra bynært og terrestrisk miljø. Institutt for energiteknikk (IFE) analyserte stabile isotoper til $\delta^{15}N$ og $\delta^{13}C$. Norsk institutt for naturforskning (NINA) var ansvarlig for innsamling av ørneeggene og meitemark. Miljødirektoratet var ansvarlig for innsamling av de andre prøvene. Formålet med studien var å kunne gi en oppdatert vurdering av forurensningssituasjonen i det terrestriske miljøet i bynære områder samt se på samlet effekt av miljøgifter.

Egg fra terrestriske fuglearter som kongeørn og svarthvit fluesnapper, i tillegg til rottelever og meitemark fra by- og mer avsidesliggende områder, ble analysert for metaller, PCB, PBDE og PFAS.

Ved vurdering av samlet eksponering av miljøgifter i de ulike artene ble følgende trender observert på våtvektbasis:

- Kongeørn: sumPCB > sum giftige metaller > sumPFAS > sumPBDE
- Svarthvit fluesnapper: sumPCB > sumPBDE
- Rotte: sum giftige metaller >> sumPCB > sumPFAS > sumPBDE
- Meitemark: sum giftige metaller >> sumPFAS > sumPCB

Kongeørnegg hadde høyeste gjennomsnittlige sumkonsentrasjon av alle organiske miljøgifter etterfulgt av lever fra brunrotte, egg fra svarthvit fluesnapper, og meitemark. I kongeørn egg, bidro PCB med mer enn 80% på våtvektbasis, etterfulgt av Hg og PFAS med ca. 10 og 5%. For sammenligning, Hg og PFAS utgjorde 90% av den samlede forurensende belastning i meitemark, etterfulgt av PCB. Nivåene i brunrottelever var sammenlignbare med kongeørnegg med PCB som utgjorde ca 50%, etterfulgt av PFAS og Hg. I PBDE-gruppen dominerte PBDE 47 i kongeørnegg i 1995, men ble redusert til mindre enn 25% i perioden 2005 til 2011 da PBDE 153 og 154 dominerte. PBDE 100 var den dominerende PBDE kongeneren i brunrotte. PCB153 og 180 bidro tilsammen med ca 60% til sumPCB belastning i kongeørnegg og ingen endring over tid ble observert. PCB138 og 153 bidro mest til sumPCB i svarthvit fluesnapper. De samme kongenere var dominerende i meitemark fra både referanselokalitet og bynære områder. PFOS var dominerende kongener for PFAS gruppen i alle arter, men langkjedete PFCA ble også påvist, der sumkonsentrasjon var sammenlignbar med mengde PFOS i kongeørn, brunrotte og meitemark.

Over tid har mengden av miljøgifter i kongeørn vært avtagende for PCB, men for PBDE og PFAS er trenden stabil. Resultatene viser at PCB fortsatt er den dominerende miljøgiften i norsk biota selv flere tiår etter forbud. Bidraget fra de andre miljøgiftene er også av betydning og viser ulike mønstre i de ulike artene som reflekterer artsforskjeller, ulike eksponeringer, trofisk nivå og metabolisme. Fremtidige studier av arter i terrestrisk bymiljø bør etterstrebe studier av arter som inngår i en næringskjede. Til sammenligning med data fra andre terrestriske studier som er utført i Norge og Europa så er nivåene av PCB, PBDE og PFAS i dette studiet relativ lave. Prøvene fra Oslo viser litt høyere nivåer av miljøgifter sammenlignet med de andre prøvetakingsstedene.

En evaluering av kombinert risiko av målte miljøgifter (MEC) ble undersøkt med en innledende konsentrasjonaddisjonstilnærming med predikert ikke-effekt konsentrasjon (PNECpred) som referanseverdi. En stor svakhet med risikovurderingen var utelatelsen av PCB gruppen på grunn av manglende PNECpred data. Kun metaller, PBDE og PFOS med tilgjengelige referanseverdier ble inkludert i beregningen av kombinert risiko. Beregningene indikerte ingen uakseptabel risiko der sum (MEC/PNECpred) var mindre enn 1 for alle artene. For andre fugler og dyr enn de som er undersøkt i dette studiet og med meitemark som viktig føde, så viste derimot beregningene en viss risiko med sum(MEC/PNECpred) verdier fra 5,9 til 12,6 for områder i Oslo. Risikoevalueringen for artene må kun vurderes som en innledende estimat og mer som en vurdering av PNEC som egnet referanseverdi. Det er stor usikkerhet i samlet risikovurdering siden PCB, PFOA er utelatt i tillegg til andre ikke undersøke stoffer, potensiell usikkerhet i PNEC referansedata, og spesielt med hensyn til bruk av PNEC data som referanseverdi for

konsentrasjoner i fugleegg. Videre økotoksikologiske studier kan være nødvendige for å etablere manglende referanseverdier.

For fremtidige studier anbefales det å inkludere en reell terrestrisk næringskjede, gjerne inkludert meitemark siden beregningene viste en viss risiko for predatorer, inkludert meitemarkspisende fuglearter og rovfugl som spurvehauk og hønsehauk.

Abbreviations

CA	concentration addition
EI	electron impact ionization
ESI	electrospray ionization
EAC	ecotoxicological assessment criteria
EQS	environmental quality standard
GC-HRMS	gas chromatography – high resolution mass spectrometry
GC-MS	gas chromatography – mass spectrometry
ICP MS	inductive coupled plasma – mass spectrometry
LC-MS	liquid chromatography – mass spectrometry
LOD	limit of detection
MEC	measured environmental concentration
NCI	negative chemical ionization
NOEC	no observed effect concentration
NP-detector	nitrogen-phosphorous detector
PCA	principal component analysis
PCI	positive chemical ionization
PEC	predicted environmental concentration
PNEC	predicted no effect concentration
$PNEC_{pred}$	predicted no effect concentration for predator
PSA	primary/secondary amine phase
SSD	species sensitivity distribution
SIR	selective ion reaction
SPE	solid phase extraction
STU	sum toxic unit
UHPLC	ultra high pressure liquid chromatography

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1. Introduction

1.1 Background and objectives

The main objective of this monitoring study was to investigate the concentrations of selected organic and inorganic pollutants and their bioaccumulation in species living in a terrestrial and urban ecosystem. The terrestrial urban ecosystem investigated, covers the land-based urban region of the city of Oslo. To establish background concentrations, earthworm samples were also collected at remote location in Åmotsdalen, Oppdal i Sør-Trøndelag fylke. The results from this study will feed into the evaluation of potential environmental hazard, and ongoing regulatory work at both national- and international level. The project had the following key goals:

- Report concentrations of chosen environmental pollutants in several levels of the terrestrial food chain
- Evaluate the bioaccumulation potential of pollutants in the terrestrial food chain
- Evaluate the combined exposure and mixture risk assessment of pollutants in terrestrial animals
- Evaluate how land-living species are exposed to a variety of pollutants

For that purpose, terrestrial species residing on different trophic concentrations were selected.

1.2 Investigated species

Golden eagle (*Aquila chrysaetos*).
The golden eagle is the second largest bird of prey in Europe, and has a wide circumpolar distribution in the Northern Hemisphere. In Norway, it is distributed all along the mountain regions, and also in the upper regions of forested valleys and in the fjord landscape. The Norwegian population is estimated to between 1200 and 1500 pairs (Heggøy and Øien 2014). The golden eagle feeds mainly on hare *Lepus, timidus,* and different grouse species, *Tetraonidae,* but also feed on ungulates such as reindeer, *Rangifer tarandus,* and sheep, *Ovis aries* (Gjershaug 1981; Fremming 1982; Gjershaug and Nygård 2003; Johnsen et al. 2007) The species has been monitored for concentrations of organohalogens and mercury in their eggs within Programme for monitoring of the terrestrial environment (TOV) since early 1990s (Nygård et al. 2001; Framstad et al. 2003; Nygård et al. 2006; Gjershaug et al. 2008; Nygård 2012; Nygård and Polder 2012), and data on DDE, PCB and mercury concentrations in eggs of golden eagle in Norway are available in published papers (Holt and Norheim 1975; Frøslie et al. 1986). Estimated trophic level 3-4 (Hui et al. 2012).

Pied flycatcher (*Ficedula hypoleuca)*
The pied flycatcher is a small passerine bird that has a wide distribution in Norway; from city gardens to the mountain birch-forests. It is one of Norway's most common birds, which breeds in nest-holes in trees, and readily occupies nest-boxes. It lays a clutch of 5-7 eggs (Haftorn 1971). It is a migratory species, with its presumed main wintering-area in tropical West-Africa and passes through western Europe through Spain and Portugal on its way north and south (Bakken et al. 2006). Only limited data on pollutants in the pied flycatcher exists (Kålås et al. 1995; Kålås and Jordhøy 1995). Estimated trophic level 3 (Hui et al. 2012).

Earthworms (*Lumbricidae)*
Earthworms are animals commonly living in soil feeding on live and dead organic matter. Its digestive system runs through the length of its body. It conducts respiration through its skin. An earthworm has a double transport system composed of co-elomic fluid that moves within the fluid-filled coellom and a simple, closed blood circulatory system. Earthworms are hermaphrodites, having both male and female sexual organs. Earthworms form the base of

many food chains. They are preyed upon by many species of birds (e.g. starlings, thrushes, gulls, crows), mammals (e.g. bears, foxes, hedgehogs), and invertebrates (e.g. ground beetles and other beetles, snails, slugs). They are found almost anywhere in soil that contains some moisture (Macdonald 1983). In our samples, two species were the most common: *Lumbricus terrestris* and *Apporectodea caliginosa* (Åmotsdalen). Estimated trophic level 2 (Hui et al. 2012).

Brown rat (*Rattus norvegicus)*
It is a brown or grey rodent with a body up to 25 cm long, and a similar tail length; the male weighs on average 350 g and the female 250 g. It is the dominant rat in Europe and much of North America. With rare exceptions, the brown rat lives wherever humans live, particularly in urban areas. It is a true omnivore, but cereals seems to be preferred. The gesteation period is only 21 days, and it can produce a litter of 14. It is often considered a pest species, and is often controlled by using rat poisons such as antigoagulants (Warfarin, Brodifacoum, Difethialone and others), metal phosphides (e.g. zinc phosphide) and calciferols (e.g. cholecalciferol), and other poisons (e.g. strychnine barium and thallium) (Meehan, 1984). Rats have a rapid excretion of ingested metals; between 20 and 50 % of copper, thallium, bismuth, lead, cesium, gold, zink, mercury, selenium and chromium were excreted in the course of four days (Gregus and Klaassen 1986). Estimated trophic level 2-3.

1.3 Investigated pollutants

In this study a total of 50 compounds was investigated, consisting of 11 metals, 7 PCBs, 16 PFAS, 14 PBDEs and stable isotopes $\delta^{15}N$ and $\delta^{13}C$. An overview over the analysed compounds is given in Table 1.

Table 1: Overview over analysed compounds

Parameters	Abbreviation	CAS number
Metals		
Chromium	Cr	
Cobalt	Co	
Nickel	Ni	
Copper	Cu	
Zinc	Zn	
Arsenic	As	
Silver	Ag	
Cadmium	Cd	
Lead	Pb	
Methyl Mercury	Me-Hg	
Total-Mercury	Hg	
Polychlorinated biphenyls (PCB)		
2,4,4'-Trichlorobiphenyl 28	PCB-28	7012-37-5
2,2',5,5'-Tetrachlorobiphenyl 52	PCB-52	35693-99-3
2,2',4,5,5'-Pentachlorobiphenyl 101	PCB-101	37680-73-2
2,3',4,4',5-Pentachlorobiphenyl 118	PCB-118	31508-00-6
2,2',3,4,4',5'-Hexachlorobiphenyl 138	PCB-138	35065-28-2
2,2',4,4',5,5'-Hexachlorobiphenyl 153	PCB-153	35065-27-1
2,2',3,4,4',5,5'-Heptachlorobiphenyl 180	PCB-180	35065-29-3
Per- and polyfluorinated substances (PFAS)		
Perfluorinated hexanoic acid	PFHxA	307-24-4
Perfluorinated heptanoic acid	PFHpA	375-85-9
Perfluorinated octanoic acid	PFOA	335-67-1
Perfluorinated nonanoic acid	PFNA	375-95-1

Perfluorinated decanoic acid	PFDcA	335-76-2
Perfluorinated undecanoic acid	PFUnA	2058-94-8
Perfluorinated dodecanoic acid	PFDoA	307-55-1
Perfluorinated tridecanoic acid	PFTriA	72629-94-8
Perfluorinated tetradecanoic acid	PFTeA	376-06-7
Perfluorinated butan sulfonate	PFBS	375-73-5
Perfluorinated pentan sulfonate	PFPS	
Perfluorinated hexan sulfonate	PFHxS	355-46-4
Perfluorinated heptan sulfonate	PFHpS	375-92-8
Perfluorinated octan sulfonate	PFOS	2795-39-3
Perfluorinated nonan sulfonate	PFNS	
Perfluorinated decan sulfonate	PFDcS	67906-42-7
Polybrominated diphenylethers (PBDE)		
2,2',4,4'-Tetrabromodiphenylether 47	BDE-47	5436-43-1
2,2',4,4',5-Pentabromodiphenylether 99	BDE-99	60348-60-9
2,2',4,4',6-Pentabromodiphenylether 100	BDE-100	189084-64-8
3,3',4,4',5-Pentabromodiphenylether 126	BDE-126	366791-32-4
2,2',4,4',5,5'-Hexabromodiphenylether 153	BDE-153	68631-49-2
2,2',4,4',5,6'-Hexabromodiphenylether 154	BDE-154	207122-15-4
2,2',3,3',4,5',6-Heptabromodiphenylether 175	BDE-175	
2,2',3,4,4',5',6-Heptabromodiphenylether 183	BDE-183	207122-16-5
2,3,3',4,4',5,6- Heptabromodiphenylether 190	BDE-190	189084-68-2
2,2',3,3',4,4',5,6'-Octabromodiphenylether196	BDE-196	446255-38-5
2,2',3,3',5,5'6,6'-Octabromodiphenylether 202	BDE-202	
2,2',3,3',4,4',5,5',6-Nonabromdiphenylether 206	BDE-206	63936-56-1
2,2',3,3'4,4',5,6,6'-Nonabromodiphenylether 207	BDE-207	
Decabromodiphenylether 209	BDE-209	1163-19-5

1.3.1 Metals including Hg

Mercury (Hg), Lead (Pb) and Cadmium (Cd) are metals that are toxic and have adverse effects on environment and health, even at very low concentrations. Best studied is the uptake of metals from soil to invertebrates (Heikens et al. 2001). The impact these metals have on humans and animals are well known, and all three metals are considered as environmental hazard compounds (Latif et al. 2013). Recently, there has been an increased use of silver as nanoparticles. Nanotechnology makes it possible to combine silver with other materials than earlier, such as different polymers. As a result, Ag now can be found in a variety of new products, which again lead to alteration of emission sources and patterns. Adsorbed silver may have long residence time in the organism (Rungby 1990). Arsenic is also known as a toxic metalloid (Casarett and Doull 2007). Among the different metals determined in the present work, Pb and Cd have a potential to bioaccumulate (Conell et al. 1984; Latif et al. 2013). However, Hg (as methyl-mercury (MeHg)) is the only metal with high bioaccumulation potential through food-chains.

1.3.2 Polychlorinated biphenyls

Polychlorinated biphenyles (PCBs) have been used in a variety of industrial applications since the 1930s. PCBs were used in Norway until the 1980s, in cooling agents and isolation fluids, as plasticizers, lubricant oils, hydraulic fluids and sealants among others. Use of PCBs was banned in Norway in 1980. They are known to degrade very slowly in the environment, are toxic, may bioaccumulate and undergo long-range environmental transport (Gai, et al. 2014). As a results, PCBs are recognized as persistent organic pollutants and regulated under the Stockholm Convention. They are widely distributed in the environment and can be found in air, water, sediments and biota. Most PCBs are only poorly water soluble but dissolve efficiently in lipid-rich parts of organisms (hydrophobic and lipophilic). They can affect the reproduction success, result in a reduced immune response and can cause defect on the genetic material. PCBs can be metabolized in organisms and form metabolites causing hormonal disturbances.

1.3.3 Polybrominated diphenylethers

Polybrominated diphenylethers (PBDEs) is a group of additive flame retardants with a wide variety of uses in plastics/ polymers/composites, textiles, furniture, housings of computers and TVs, wires and cables, pipes and carpets, adhesives, sealants, coatings and inks. There are three commercial PBDE products, technical or commercial penta-, octa and decabromodiphenyl ether. These are all technical mixtures containing different PBDE congeners. Tetra-, penta-, hexa- and heptaBDE congeners were listed in the Stockholm Convention in 2009, due to being persistent, bioaccumulative and toxic chemicals that can undergo long-range environmental transport (Darnerud, 2003; Law et al., 2014)). As a results, the commercial penta- and octa-PBDE mixtures were globally banned. The use of commercial decaBDE was banned in Norway in 2008. In the same year a restriction on the use of commercial decaBDE in EE-products entered into phase. Globally, commercial deca-BDE is still widely used and remains a high production volume chemical. In North-America voluntary agreements with the industry have led to reduced consumption of decaBDE.

The tetra- and pentaBDE congeners BDE 47 and 99, which were the main components of commercial pentaBDE mixtures, are among the most studied PDBEs. The early documentation of congeners of the technical mixtures penta- and octa-BDE detected in the Arctic was one of the main reasons to ban production, import, export, sales and use of products with more 0.1 % (by weight) of penta-, octa- and deca-BDE in Norway. The regulation and banning of the PBDEs, and most probably a better waste handling, have resulted in a decrease for most BDEs, except BDE 209, the main component of commercial decaBDE, over time (AMAP 2009; Helgason et al. 2009). Spatial trends of PBDEs in arctic seabirds and marine mammals indicate that Western Europe and eastern North America are important source regions of these compounds via long range atmospheric transport and ocean currents. The tetra - hexaBDEs biomagnify in arctic food webs while results for the fully brominated PBDE congener, BDE 209 or decaBDE, are more ambiguous. BDE 209 is found to bioaccumulate in some species, but is generally suggested to show either only low or no biomagnification. However, in the environment and biota, BDE 209 can debrominate to lower PBDE congeners that are more persistent, bioaccumulative and toxic PBDE concentrations are lower in terrestrial organisms and higher in marine top predators (de Wit et al. 2010 and references herein).

1.3.4 Per- and polyfluorinated alkyl substances

Per- and polyfluorinated alkylated substances (PFASs) have been widely used in many industrial and commercial applications. The chemical and thermal stability of a perfluoroalkyl moiety, which is caused by the very strong C-F bond, in addition to its hydrophobic and lipophobic nature, lead to highly useful and enduring properties in surfactants and polymers. Polymer applications include textile stain and water repellents, grease-proof, food-contact paper and other food contact materials used for cooking. Surfactant applications that take advantage of the unparalleled aqueous surface tension–lowering properties include processing aids for fluoropolymer manufacture, coatings, and aqueous film-forming foams (AFFFs) used to extinguish fires involving highly flammable liquids. Numerous additional applications have been described, including floor polish, ski waxes, and water proof coatings of textile fibers. Since they are so persistent and hardly degrade in the environment, and du to their widespread use, PFASs have been detected worldwide in the environment, wildlife, and humans. Scientific questions focus on how these substances are transported in the environment, and to what extent and how humans and wildlife are exposed and potential toxic effects (Butt et al. 2010; Jahnke et al. 2007; Kannan et al. 2005; Stock et al. 2007; Taniyasu et al. 2003; Trier et al. 2011; DeWitt et al. 2012). Among others, long range transport of PFAS has been suggested by Barber et al 2007, and Cousins et al. 2011. Toxic effects on biological organisms and human where for example discussed by Gai et al. 2014, Hagenaars et al. 2008, Halldorsson et al. 2012, Newsted et al. 2005, and Whitworth et al. 2012. PFOS, its salts and PFOSF are listed in the Stockholm Convention and are recognized as persistent organic pollutants. However globally, use of PFOS, its salts and PFOSF is still allowed for certain applications.

1.3.5 Stable isotopes

Stable isotopes of carbon and nitrogen can be used to define the trophic position of an organism as well as assess the carbon sources in the diet of the organism (Peterson and Fry 1987) . The isotope ratio of carbon results in a unique signature which is propagated upwards to the predators (DeNiro and Epstein 1978. The differentiation between terrestrial and marine diet is possible as well (Hobson and Sealy 1991). Predators, feeding mostly on marine organisms will show a higher accumulation of ^{13}C than predators from the terrestrial food chain. The comparison of carbon signatures of organisms from the same food chain will also give the possibility to identify their diet. The enrichment of the heavier ^{15}N-isotope in relation to the lighter ^{14}N-isotope in the predators, compared to the prey, gives the opportunity to define the relative position in a food chain of an organism. The correlation between concentrations of pollutants relative to their trophic concentration can be used to estimate biomagnification (Kidd et al. 1995).

2. Methods

2.1 Sampling

The main objective of the project was to assess the pollution present in the terrestrial urban environment in Norway, together with an evaluation of the combined risk of these pollutants and to assess the bioaccumulation. The different species were selected to represent different trophic concentrations, from primary consumers (earthworm) via secondary consumers (pied flycatcher) to a top predator (golden eagle). In addition, an omnivore generalist representing a truly urban environment, the brown rat, was chosen. Golden eagle eggs were used in this study to give insights in how a terrestrial top predator is affected by background pollution levels. Additionally, golden eagle eggs can give a general idea of changes over time due to the analyses of eggs collected in the period between 1995 and 2011. An overview over the analysed samples is given in Table 2. Caused by the limited availability of species within the project period, no real terrestrial food chain could be sampled, hampering bioaccumulation assessments.

Table 2 Location and selection of samples

Sample type	*No. Sample*	*Location*	*Date*	*Sampling strategy*
Golden eagle (*Aquila chrysaetos)*	36 eggs from 30 clutches	Norway, various sites	1995 - 2011	Unhatched eggs
Pied flycatcher (*Ficedula hypoleuca)*	21	Oslo	2013	Unhatched eggs
Earthworms (*Lumbricidae*)	18	Oslo and Åmotsdalen (reference)	2013	Pool of 5 individuals
Brown rat (*Rattus norvegicus*)	15	Oslo	2013	Individual liver samples

Golden eagle (*Aquila chrysaetos)*.
Within this project we analysed golden eagle eggs collected in a period between 1995 and 2011 (n=23), partly through the Programme for terrestrial monitoring (TOV), led by the Norwegian Institute for Nature Research (NINA), and partly by local ornithologists. To add statistical power to the dataset, previous analytical data for 13 additional eggs were included. These eggs were earlier analysed by the Norwegian Veterinary Institute (VI), also as part of TOV. We have shown previously that PCB and PBDE data analysed in the labs of NILU and VI are comparable. Stable isotope measurements were done in all eggs during this project. The eggs originated from 30 different clutches, located in all over Norway (Figure 1).

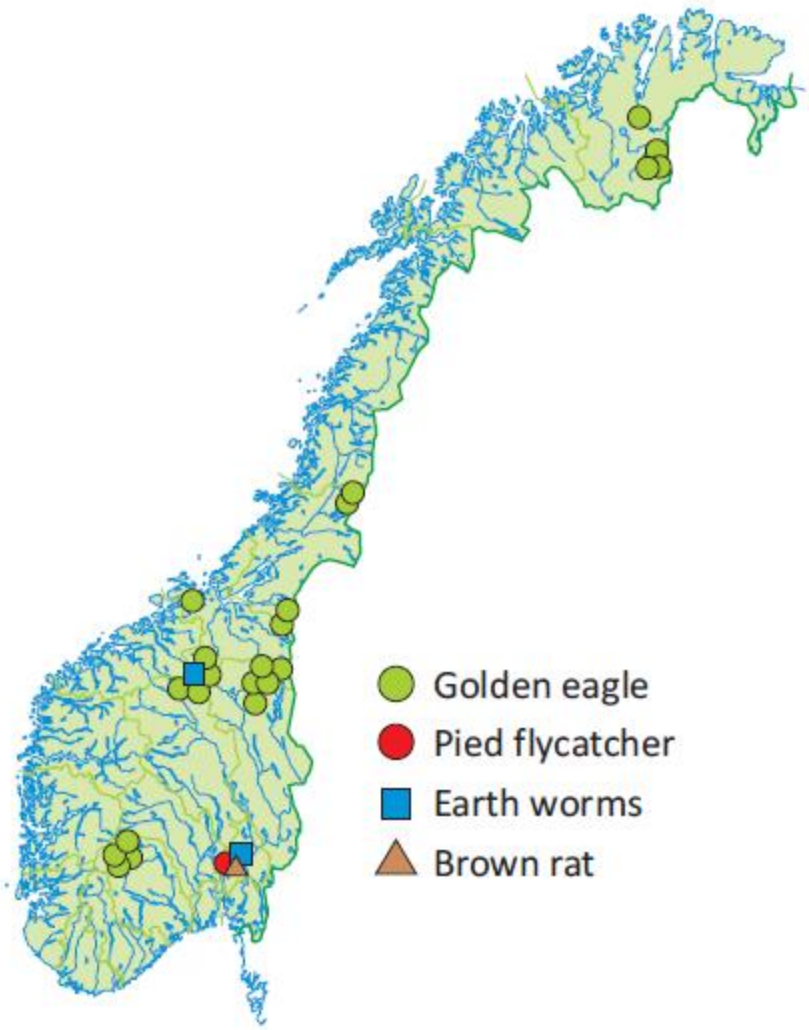


Figure 1. Sampling stations. Green circles = Golden eagle, red circle = Pied flycatcher, Blue squares = earthworms, Brown triangle = brown rat.

Pied flycatcher (*Ficedula hypoleuca)*.
The sampling of unhatched eggs from the pied flycatcher was organized by the Norwegian Environment Agency (Miljødirektoratet). The University of Oslo collected all eggs in 2013 in the same geographical area (north of Bogstadvannet, Oslo) in a period between 6th and 25th of June 2013. Twenty one unhatched eggs from fourteen nests were collected. The majority of the samples contained partly developed embryos. Usually, one egg was collected per nest, but in two cases, two eggs were collected and in one case six eggs.

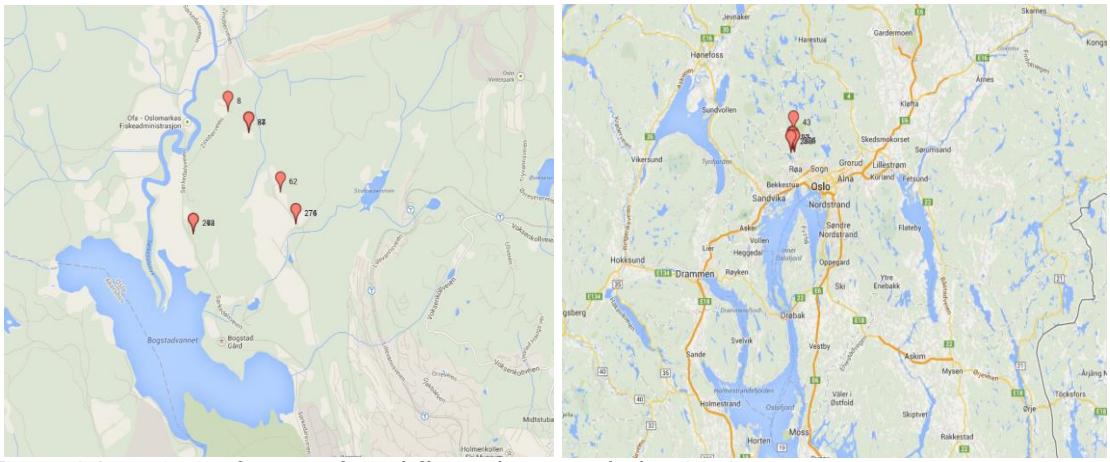


Figure 2 Locations of nests of pied flycatcher sampled in 2013

Figure 3: Illustration of pied flycatcher nests sampled in 2013

Earthworms (*Lumbricidae)*.

Earthworms were collected by NINA at two main sites; Åmotsdalen in Oppdal (reference site), and at five different sites in Oslo, to represent different local pollutant loads. All pooled samples consisted of up to 10 individuals. Three parallel pools per location were provided, resulting in 18 samples, plus one additional sample from the reference location, containing a second species. Reference sample 1, 3 and 4 consisted of the species *Lumbricus rubellus* and sample 2 contains *Apporectodea caliginosa*. The earthworms collected in parks in Oslo could not all be identified to species, because of some decay. The following abbreviations will be used further to refer to the sampling locations: *parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken; : Ref.:Åmotsdalen, Dovre*.

Figure 4: Soil profile sampled for earthworms in Åmotsdalen, Dovre Mountains, 2013.

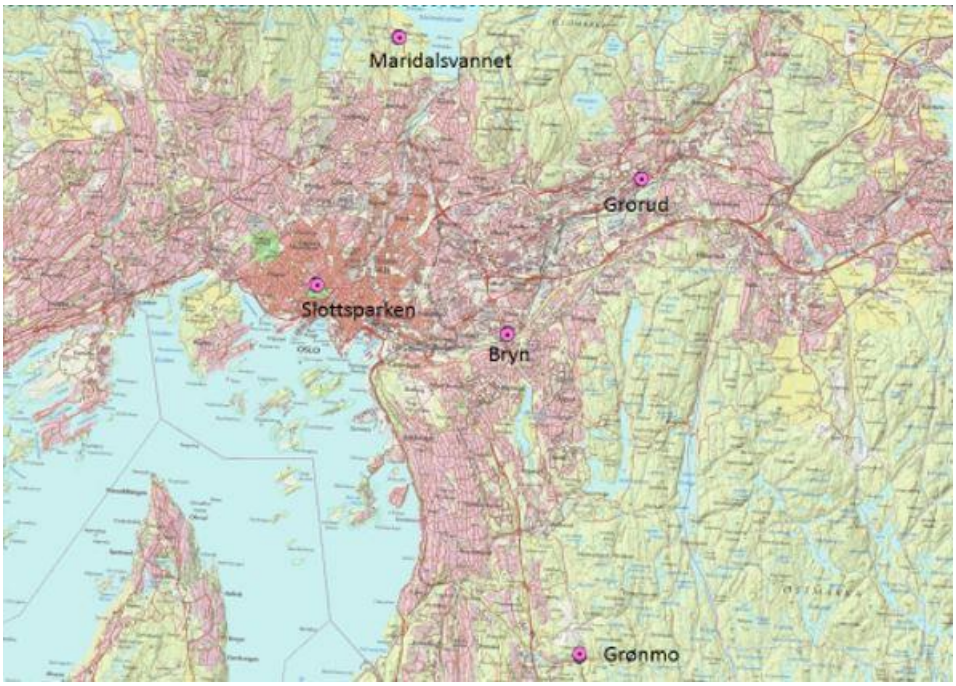


Figure 5a: *Map of sampling sites for earthworms in Oslo.*

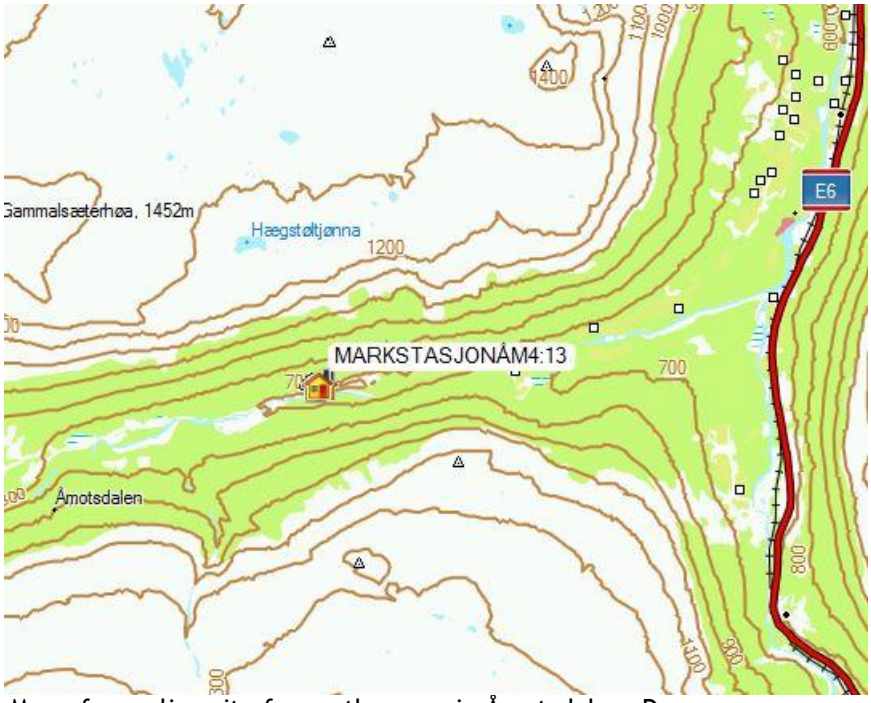


Figure 5b:. Map of sampling site for earthworms in Åmotsdalen, Dovre.

Brown rat (*Rattus norvegicus)*.
Rats were collected near Brugata in the center of urban Oslo. The rats were taken by clap-traps by a professional vermin control company. Among the sampled rats, we collected 8 males, 6 females and one of indeterminate gender. The bodyweight varied between 53 and 177 g.

2.2 Quality assurance

NINA and NILU are certified to both ISO 9001 and 14001. In addition, the "Guidelines for field work in connection with environmental monitoring" were followed. Moreover, special precautions were taken to prevent contamination of samples during field work. Sample collection manuals tested and adapted to special conditions so as to avoid materials which may contain PFAS and BFRs during sampling, handling and storage, were followed. Sampling materials as bags, containers, knives, scalpels, gloves etc. were supplied by NILU, in all cases pre-cleaned or for disposable use. In addition, emphasis was placed on the use of disposable gloves, disposable knives and as little processing of the samples as practical and general cleanliness. Most samples were prepared in the same laboratory for the same compound group which minimized sample handling, shipment, repeated freezing and thawing, etc. to ensure minimum variation in sample quality in all steps and at the same time improves comparability of results.

Sample preparation and analysis
Preparation of golden eagle eggs
Length and width of eggs were measured with a vernier calliper to the nearest 0.1 mm. The eggs were weighed before emptying. A hole was drilled at the equator, and the contents were transferred to a glass container and sealed with sheets of aluminium foil. As the golden eagle egg were not taken fresh, but as unhatched eggs after the breeding season was completed, a desiccation index (Di) value was calculated for each egg as a measure of water loss through the shell (Helander et al., 2002). This index was used to back-calculate the measured values of pollutants to those of a fresh egg (fw), by relating the egg weight (with content) to its volume given by its measurements ($V = 0.51 * length * (breadth)^2$).

Chemical analysis
Due to the differing physicochemical properties of the pollutants of interest, several sample preparations methods were applied. Lipophilic compounds as PBDEs and PCBs were analyzed together. PFAS and metals required a dedicated sample preparation each. Together three different sample preparation methods were applied.

PBDEs and PCBs. All biological samples were prepared in a similar manner. Briefly, 3-4 grams of sample were mixed and homogenized with a 20 fold amount of dry Na_2SO_4. The homogenate was extracted using a mixture of Acetone/ Cyclohexane (1/1 v/v). The organic extract was evaporated and treated 2-4 times with 3-4 mL of concentrated sulfuric acid to remove the lipids.

PFAS. Samples were extracted with acetonitrile and treated with emulsive clean-up prior to analyses with LC/MS/MS.

Metals. All biological samples were prepared in a similar manner. The samples were digested by microwave-assisted mineralization using an UltraClave. About 0.5-0.75 grams of sample were weighed in TFM tubes and 5 ml of diluted supra pure nitric acid was added. The samples were submitted to a four-step program with 220ºC as maximum temperature. After digestion, the samples were split in two aliquots, where concentrated HCl were added to the aliquot used for Hg determination

PBDEs were analyzed using GC/EI-HRMS while PCBs were analysed using GC/EI-MS/MS. PFAS compounds were analyzed using UPLC/MS/MS in ESI(-) mode. Metals were analysed applying an ICP-MS.

Quality control
All chemical analyses followed international requirements for quality assurance and control (QA/QC), e.g., recommendations of the Arctic Monitoring and Assessment Programme (AMAP) and the requirements in the European quality norm EN 17049. The QA/QC of the sample preparation and analysis was assured through the use of mass labeled internal standards for the BFRs (^{13}C DBDPE), PCBs (^{13}C PCBs) and PFAS (^{13}C PFAS). Quality of sample preparation and analysis was achieved through the use of certified reference materials and laboratory blanks. For each batch of either 10 samples, one standard reference material (SRM; NIST 1945 for PCBs and PBDEs and PERFOOD intercal 2012 for PFAS) and one blank sample was prepared. Only analytes with concentrations above the detection limit are presented in tables and figures.

Stable isotopes and other supporting information
Stable isotopes were analysed by the Institute for Energy Technology (IFE), Kjeller, Norway. Lipids were determined using a gravimetric method. All data are listed in the Appendix.

2.3 Mixture risk assessment

An initial mixture risk assessment based on the simple sum of MEC/PNECs were performed where MEC was the median measured concentration of contaminants in the various organisms and PNEC the predicted no-effect concentration of predators in terrestrial environment (Backhaus and Karlsson, 2014, Petersen et al, 2013; Backhaus and Faust, 2012). PNEC values were adopted from previous assessed and reported values (KLIF, 2012). The single MEC/PNEC was calculated and summed up to assess if the sum exceeded 1 or not. The methodology was applied with the presumption that the available PNEC values (KLIF, 2012) were protective and assessed for the most sensitive predator species, in accordance to the guidelines for deriving PNEC values (ECHA, 2008).

3. Results

Of the 50 compounds that were analysed, 40 could be detected. In general the highest concentrations of halogenated organic pollutants were found in golden eagle eggs, followed by livers of brown rat, eggs of the flycatcher and the earthworms. PFAS compounds were measured in flycatcher egg. In contrast, heavy metals were found in highest concentrations in earthworms, followed by brown rat and golden eagle. Flycatcher eggs were not analysed for heavy metals. Since 5 of the 30 golden eagle eggs originated from coastal regions, and therefore are possibly affected by marine food items, these were not include in the calculations of mean, median and statistics. We do however include these data in the further discussion to assess differences within the golden eagle population.

3.1 PCBs

3.1.1 Golden eagle eggs

36 golden eagle eggs were available for analysis. In some instances, two eggs from the same nest were available. In such cases, average concentrations were used in order to avoid pseudoreplication. The total number of units used in the calculations were therefore reduced to 30, and in cases when coastal birds were omitted, the number was 25. The detailed results are shown in Table 3.

Table 3 Concentrations of PCB congeners in golden eagle eggs 1995–2011 in ng/g fw. Zero values indicate values below LOD or LOQ. Five clutches were excluded from the sample as they were from coastal sites.

Year		PCB28	PCB52	PCB99	PCB101	PCB105	PCB118	PCB138	PCB153	PCB180	SumPCB
1995	N	2	2	2	2	2	2	2	2	2	2
	Mean	0.05	0.22	<LOD	0.71	<LOD	15.6	113	138	129	398
	Median	0.05	0.22	<LOD	0.71	<LOD	15.6	113	138	129	398
	Min	<LOD	<LOD	<LOD	<LOD	<LOD	14.7	59.7	110	105	292
	Max	0.09	0.45	<LOD	1.43	<LOD	16.5	167	167	153	504
1997	N	1	1	1	1	1	1	1	1	1	1
	Mean	<LOD	<LOD	<LOD	<LOD	<LOD	10.1	32.8	68.3	38.9	150
	Median										
	Min										
	Max										
1998	N	3	3	3	3	3	3	3	3	3	3
	Mean	0.14	<LOD	19.5	0.95	9.65	36.4	124	202.0	137	501
	Median	<LOD	<LOD	11.7	0.98	5.5	19.5	47.7	84.7	63.5	215
	Min	<LOD	<LOD	8.53	<LOD	3.96	17.1	41.3	84.0	38.9	182
	Max	0.43	<LOD	38.2	1.88	19.4	72.5	283.0	437.0	311	1106
2000	N	4	4	4	4	4	4	4	4	4	4
	Mean	0.19	<LOD	8.62	0.82	6.12	27.12	63.5	121.4	111	324
	Median	0.19	<LOD	2.13	0.63	0.92	6.31	23.9	52.4	62.5	145
	Min	0.1	<LOD	<LOD	0.2	0	2.75	11.1	30.6	39.9	85
	Max	0.25	<LOD	30.2	1.83	22.6	93.1	195	350	280	920
2003	N	3	3	3	3	3	3	3	3	3	3
	Mean	18.4	<LOD	2.92	0.64	1.29	6.83	19.4	52.3	49.7	138
	Median	0.17	<LOD	3.7	0.53	1.32	4.91	15.8	49.8	54.0	125
	Min	0.13	<LOD	0.85	0.35	0.33	1.81	6.4	17.7	20.6	74
	Max	54.9	<LOD	4.2	1.04	2.23	13.8	36.0	89.4	74.4	214
2005	N	1	1	1	1	1	1	1	1	1	1
	Mean	<LOD	0.29	3.5	0.43	0.97	4.32	21.0	66.3	95.7	188
	Median										
	Min										
	Max										
2006	N	3	3	3	3	3	3	3	3	3	3
	Mean	<LOD	<LOD	3.92	0.34	0.73	5.23	15.8	41.0	44.7	107
	Median	<LOD	<LOD	2.98	0.47	0.51	3.5	11.5	44.1	45.7	104
	Min	<LOD	<LOD	2.63	<LOD	<LOD	2.79	11.5	24.4	39.0	98
	Max	<LOD	<LOD	6.15	0.55	1.68	9.4	24.4	54.6	49.5	119
2007	N	6	6	6	6	6	6	6	6	6	6
	Mean	0.61	<LOD	3.6	0.65	0.99	7.68	20.0	65.0	53.7	148
	Median	<LOD	<LOD	3.81	0.54	1.15	8.39	19.5	63.4	56.7	141
	Min	<LOD	<LOD	0.49	<LOD	0.13	2.4	7.1	21.1	25.7	56
	Max	2.44	<LOD	6.2	1.68	1.65	12.2	36.1	102	81.7	217

Table 3 continued.

Year		PCB28	PCB52	PCB99	PCB101	PCB105	PCB118	PCB138	PCB153	PCB180	SumPCB
2009	N	1	1	1	1	1	1	1	1	1	1
	Mean	0.29	1.99	<LOD	4.17	<LOD	7.38	21.1	39.3	36.9	111
	Median										
	Min										
	Max										
2011	N	1	1	1	1	1	1	1	1	1	1
	Mean	0.06	0.26	<LOD	0.32	<LOD	10.1	27.2	49.8	41.4	129
	Median										
	Min										
	Max										
Total	N	25	25	25	25	25	25	25	25	25	25
	Mean	2.42	0.12	5.55	0.77	2.66	14.5	47.2	90.5	77.4	232
	Median	0.06	<LOD	2.98	0.47	0.97	9.4	24.4	54.6	53.3	150
	Min	<LOD	<LOD	<LOD	<LOD	<LOD	1.81	6.4	17.7	20.6	56
	Max	54.9	1.99	38.3	4.17	22.6	93.1	283	437	311	1106

In Figure 6, the average PCB concentrations by year of sampling are shown (mean value per four-year -period of sampling, based on clutch averages on a fresh weight basis). Five egg clutches were excluded from the sample as they were collected from sites close to the coast, as it has been shown that food items from marine food-chains can contribute to higher concentrations of organic pollutants in coastal breeding golden eagles (Nygård and Gjershaug 2001). Elevated PCB concentrations were found in a number of eggs, with a maximum concentration of sumPCB of ca. 1106 ng/g fresh weight (fw) of sumPCBs in 1998. When comparing average sumPCB concentrations of the collected years, we see a decreasing trend over years (Spearman rank correlation R `= - 0.47, P = 0.018). The concentrations seem to have leveled off after 2000, but only one sample from 2009 and 2011 is available, limiting further estimations of changes over time. Only eggs from terrestrial inland locations were included in the assessment of the changes over time, showing low inter-sample variation within years and similar $d^{15}N$ concentrations. However, since locations of egg sampling differed between the years, the time trend has to be treated with caution.

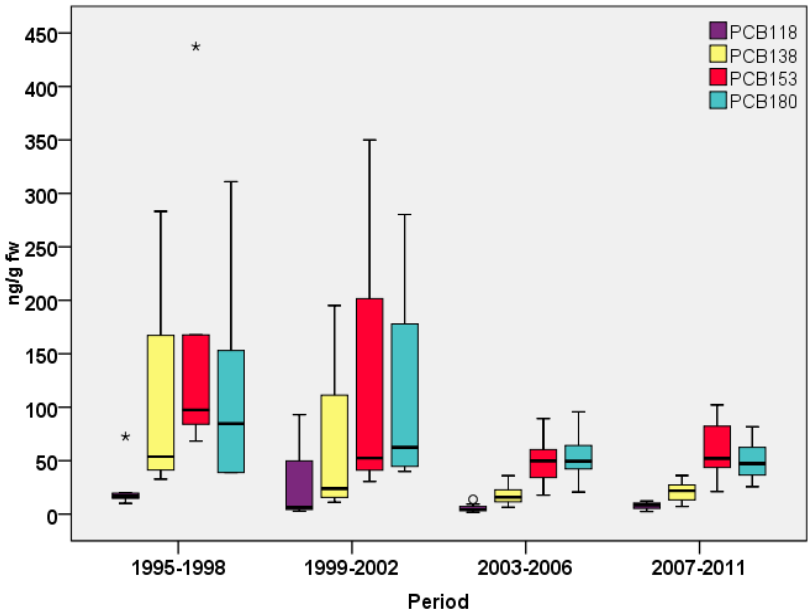


Figure 6: Main congener distribution by period of sampling in eggs of golden eagle (ng/g fw). The band inside the boxes represents the median, while the bottom and the top of the box are the first and third quartiles. The **whiskers** extend to 1.5 times the height of the box or, if no value in that range, to the minimum or maximum values. Points and asterisks are **outliers**. These are defined as values that do not fall within the whiskers. The same is valid for all boxplots in this report

As shown in *Figure 7*, sumPCB concentrations have decreased steadily since 1995. There is a lot of variance in the set, which can be explained partly by various sampling sites and the diet at that particular site. When we assign the eggs as coming from a coastal or inland site, it is evident that eggs from coastal sites have much higher PCB concentrations than those from the inland (see discussion, cf. Nygård and Gjershaug 2001). The coastal pairs are more exposed to PCBs, due to a diet consisting of prey items of mostly marine origin.

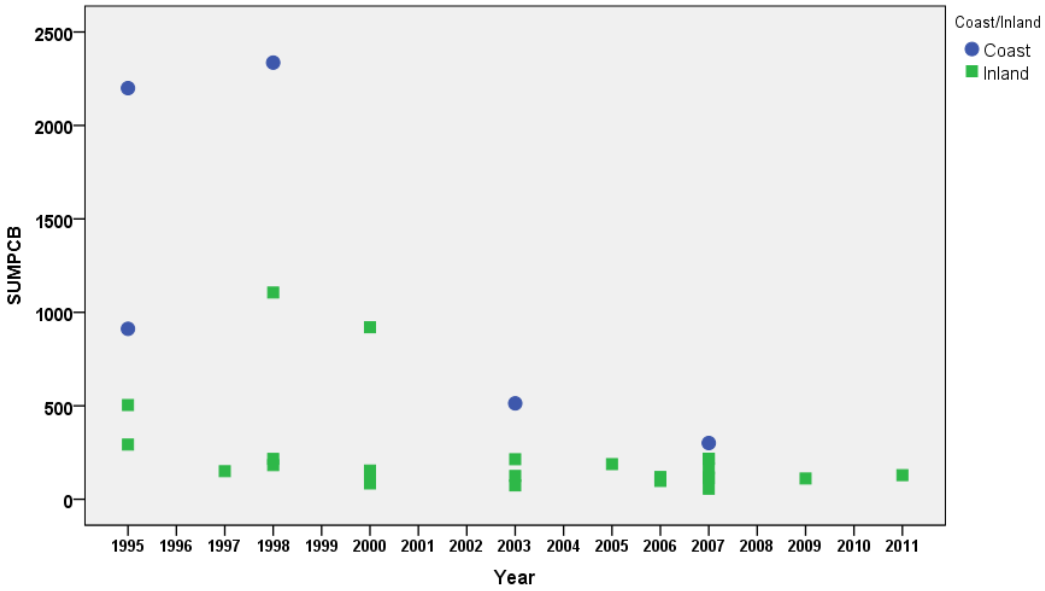


Figure 7: *SumPCBs in eggs of golden eagle sampled between 1995 and 2011 in ng/g fw, clutch averages, divided by geographic origin.*

Figure 8 illustrates the change over time of the relative distribution of PCB congeners in golden eagle eggs. No clear change in PCB congener pattern can be seen in the observed eggs, indicating no change in exposure.

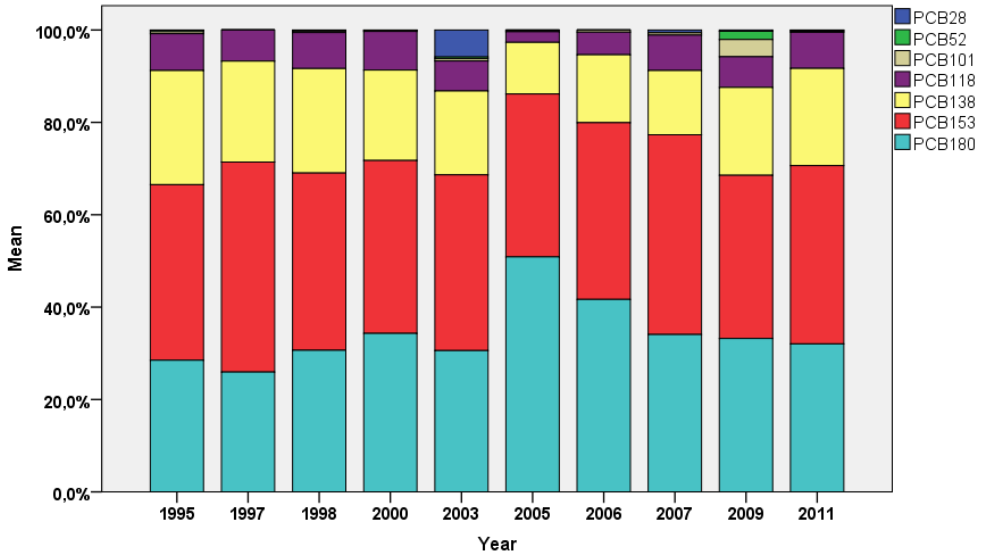


Figure 8: Relative distribution of average PCB concentrations to golden eagle eggs

3.1.2 Pied flycatcher eggs

All seven PCBs could be detected in the flycatcher eggs. SumPCB concentrations (clutch mean) varied between 14 and 96 ng/g ww, with an average of 36 ng/g ww sumPCB. The highest sumPCB concentrations found in flycatcher egg was higher than the lowest sumPCB concentrations found in golden eagle eggs during the period (56 ng/g fw). A summary of values are given in Table 4.

Table 4: PCB congener concentrations at different sampling sites in pied flycatcher eggs from 2013 in ng/g ww.

Site		PCB101	PCB118	PCB138	PCB153	PCB180	SumPCB
Bogstad	N	6	6	6	6	6	6
	Mean	0.22	1.50	7.58	9.89	8.66	27.8
	Median	<LOD	1.22	6.19	8.36	6.80	21.7
	Min	<LOD	<LOD	4.27	4.86	3.67	14.0
	Max	1.21	2.84	14.7	17.3	15.7	51.7
Øgarden	N	6	6	6	6	6	6
	Mean	0.27	0.96	9.39	10.7	7.97	29.2
	Median	<LOD	<LOD	9.47	10.1	7.67	29.6
	Min	<LOD	<LOD	5.09	6.19	4.66	16.3
	Max	1.60	3.08	15.5	16.2	12.8	44.3
Sørkedalen	N	2	2	2	2	2	2
	Mean	0.75	5.24	20.4	28.4	25.5	80.3
	Median	0.75	5.24	20.3	28.4	25.5	80.3
	Min	<LOD	4.53	17.5	24.6	16.8	64.9
	Max	1.50	5.96	23.3	32.1	34.2	95.6
Total	N	14	14	14	14	14	14
	Mean	0.32	1.80	10.2	12.9	10.7	35.9
	Median	<LOD	1.22	9.20	10.7	8.39	30.5
	Min	<LOD	<LOD	4.27	4.86	3.67	14.0
	Max	1.60	5.96	23.3	32.1	34.2	95.6

In Figure 9, the boxplot shows the major PCB congeners by location of the nests sampled. Sørkedalen shows higher concentrations than the other two locations (Figure 9).

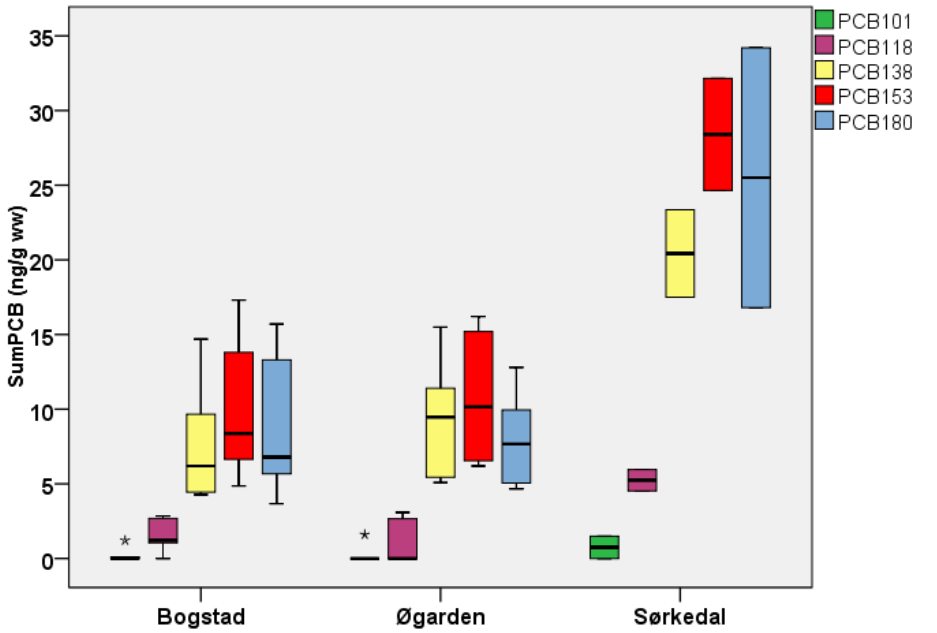


Figure 9: Boxplot of the main PCB congeners in pied flycatcher eggs divided into sampling locations (ng/g ww).

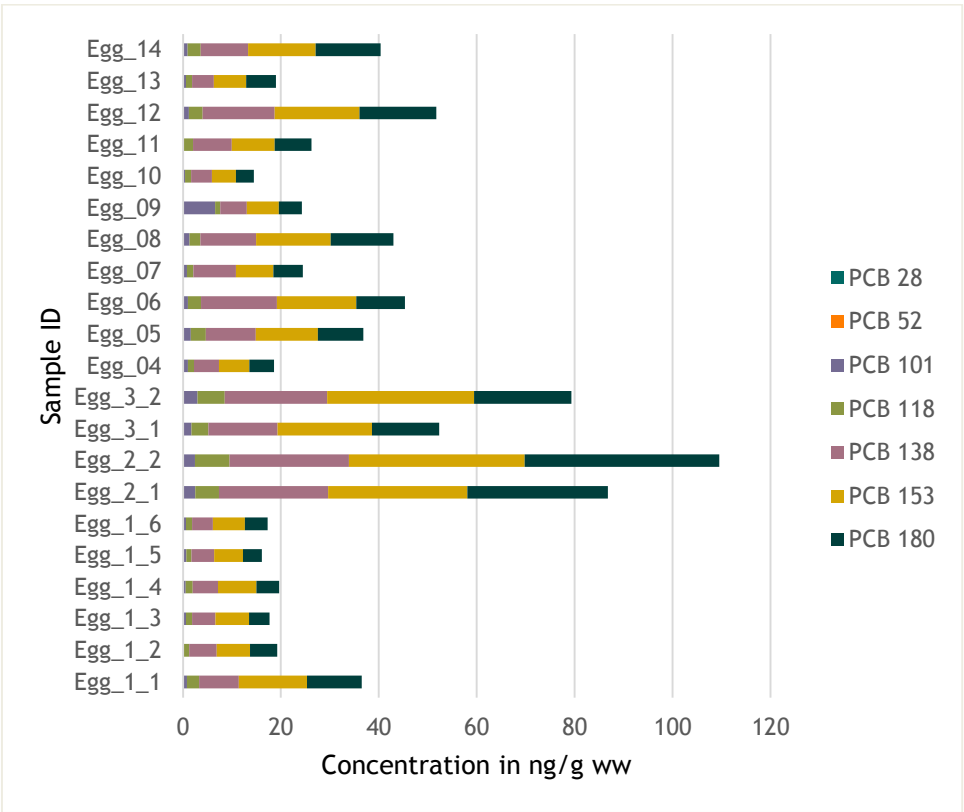


Figure 10: PCB concentrations in single eggs from pied flycatcher in ng/g ww

When comparing eggs from the same nest, similar sumPCB concentrations can be found, indicating that the order of egg-laying is not important for the concentrations of PCBs found in flycatcher eggs (samples nest 1_1-6, nest 2_1-2, nest 3_1-2). This is important information for future sampling campaigns, indicating that for studies on PCB concentrations in flycatcher eggs, only one egg per nest is necessary (Figure 10*)*. When comparing the PCB congener pattern in the flycatcher eggs, a similar conclusion can be drawn regarding intra-nest variation. The investigated PCBs were similarly distributed in all eggs from same nests as well as within the sample set. PCB 138, 153 and 180 dominate the PCB pattern found (up to ca. 90%), typical for terrestrial ecosystems and similar to the eggs from golden eagle (Figure 11). Median concentrations of the dominating PCBs are 9.2, 10.7 and 8.4 respectively (range: 4.3 – 23.3, 4.9 – 32.1 and 3.7 – 34.2 ng/g ww).

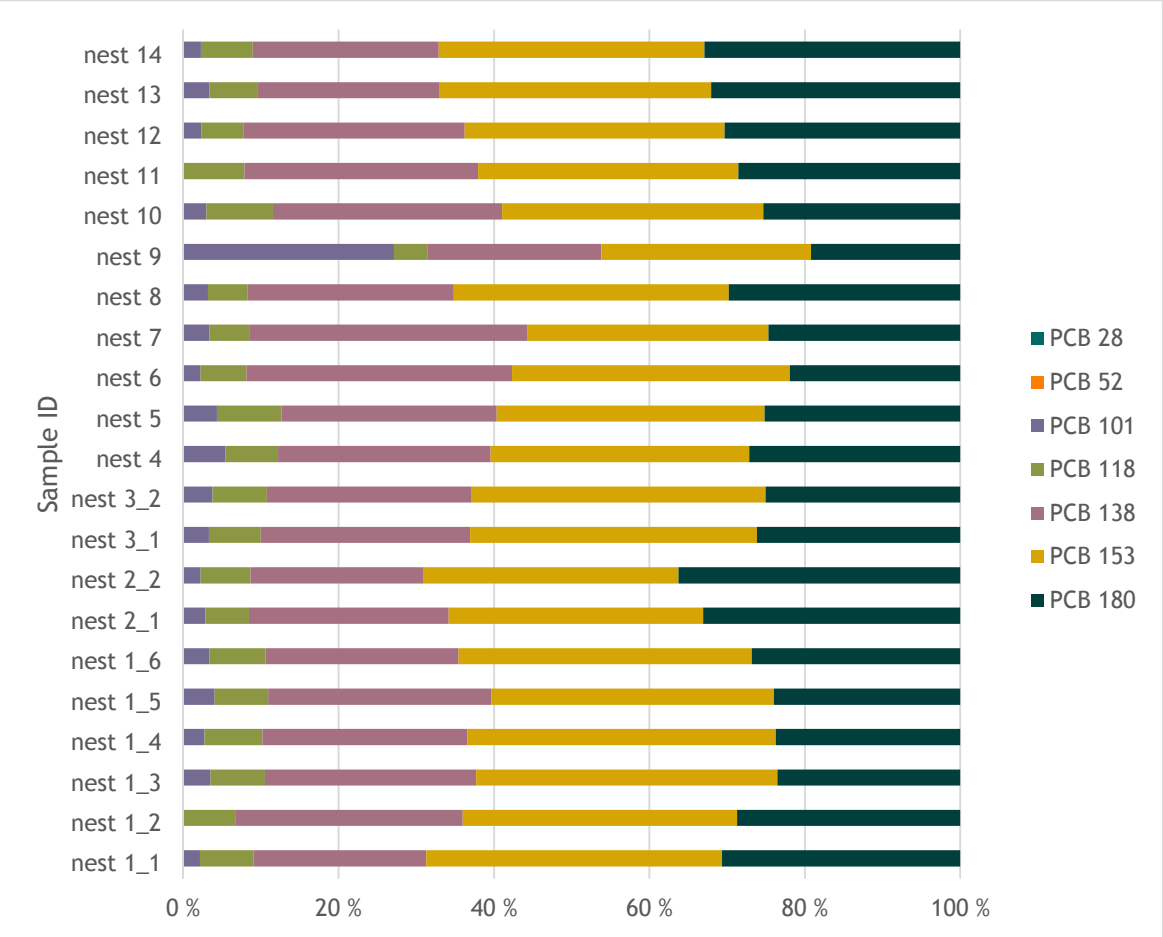


Figure 11: Relative PCB concentrations in eggs from pied flycatcher

3.1.3 Earthworms

As figure 12 illustrates, PCBs could not be detected in all samples also within the same sampling location. On the other hand, PCBs could be detected in all samples of the reference location, independent on subspecies (sample 1 from Åmotsdalen consisted of *Lumbricus rubellus*, while the others contained *Apporectoda caliginosa)*. SumPCB concentrations varied largely between 1.2 ng/g ww (from Bryn) and 33.1 ng/g ww in one sample from Groruddalen. The average sumPCB concentration was 3.3 ng/g ww. Even though sumPCBs concentrations were not much different in urban and background samples (in three out of five sites), the main contributing PCBs in Oslo, PCB 138 and 153, were considerably lower in the reference site Åmotsdalen (average of 1.44 ng/g ww for PCB 138 in Oslo, and 0.38 in Åmotsdalen, and 1.22 ng/g ww for PCB 153 in Oslo, and 0.40 in Åmotsdalen). See *Figure 13* for the distribution of congeners between sites. The detailed results are shown in Table 5.

Table 5: PCB congener concentrations at different sampling sites in Lumbricidae (earthworms) from 2013 in ng/g ww.

Site		PCB 28	PCB 52	PCB101	PCB118	PCB 138	PCB 153	PCB 180	SumPCB
Bryn	N	3	3	3	3	3	3	3	3
	Mean	<LOD	0.17	0.11	0.15	0.69	0.51	0.19	1.83
	Median		0.17	0.11	0.15	0.69	0.51	0.19	1.83
	Min		<LOD	<LOD	<LOD	<LOD	0.37	<LOD	1.46
	Max		0.17	0.11	0.15	0.92	0.64	0.19	2.20
SLO	N	3	3	3	3	3	3	3	3
	Mean	<LOD	<LOD	0.64	0.50	1.23	0.99	0.64	4.02
	Median			0.64	0.50	1.35	0.99	0.64	4.13
	Min			0.49	0.37	0.95	0.61	0.38	2.82
	Max			0.80	0.62	1.38	1.39	0.90	5.10
MAR	N	3	3	3	3	3	3	3	3
	Mean	<LOD	<LOD	0.19	0.30	0.83	0.64	<LOD	1.97
	Median			0.19	0.30	0.86	0.64		1.97
	Min			<LOD	<LOD	0.63	0.48		1.61
	Max			0.10	0.30	1.04	0.79		2.33
GRO	N	3	3	3	3	3	3	3	3
	Mean	<LOD	0.40	0.21	1.63	4.44	3.98	5.96	16.6
	Median		0.40	0.21	1.63	0.76	0.75	5.96	9.70
	Min		0.11	0.16	0.08	0.26	0.22	5.96	6.81
	Max		0.69	0.28	3.17	12.3	11	5.96	33.4
GRM	N	3	3	3	3	3	3	3	3
	Mean	<LOD	0.33	0.29	0.17	0.54	0.36	0.07	1.79
	Median		0.33	0.28	0.14	0.39	0.23	0.07	1.47
	Min		0.27	0.14	0.11	0.26	0.20	<LOD	1.07
	Max		0.38	0.46	0.26	0.97	0.65	0.07	2.83
REF	N	4	4	4	4	4	4	4	4
	Mean	<LOD	0.31	0.22	0.14	0.39	0.39	0.30	1.79
	Median		0.28	0.18	0.14	0.39	0.39	0.30	1.71
	Min		0.15	0.18	<LOD	0.28	0.22	0.30	1.29
	Max		0.54	0.31	0.14	0.51	0.58	0.30	2.41
Total	N	19	19	19	19	19	19	19	
	Mean	<LOD	0.32	0.30	0.53	1.37	1.17	1.30	5.01
	Median		0.27	0.22	0.20	0.63	0.58	0.34	2.27
	Min		0.11	0.11	0.08	0.26	0.20	0.07	0.85
	Max		0.69	0.8	3.17	12.3	11	5.96	33.9

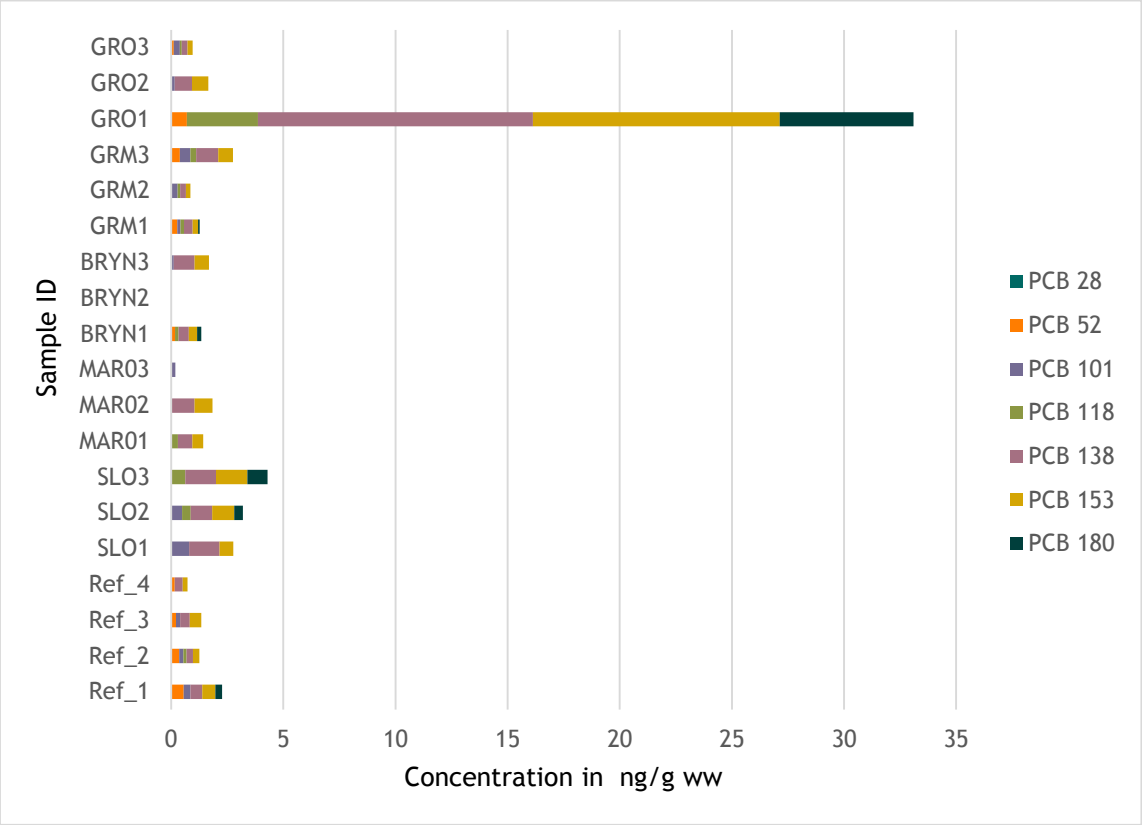


Figure 12: PCBs in Lumbricidae collected in parks in Oslo and Åmotsdalen as reference location (locations: parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken, REF: Åmotsdalen) in ng/g ww

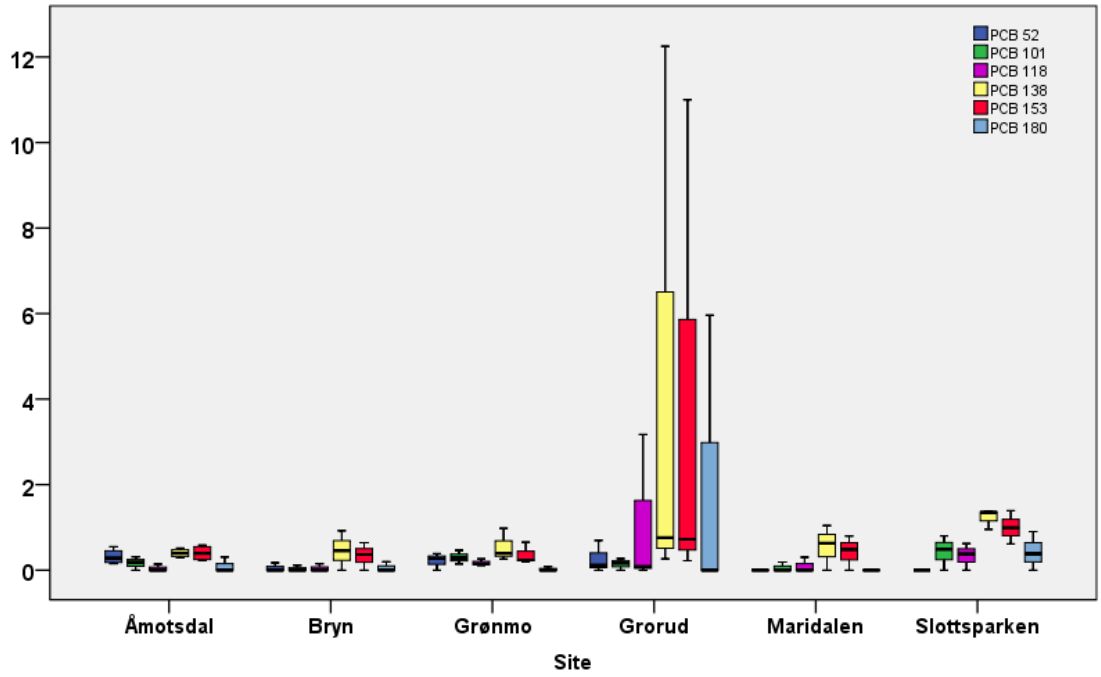


Figure 13: Boxplot of the main PCB congeners in in earthworms at different sites in Oslo (ng/g ww)

As shown in *Figures 13 and* Figure 14, the PCB pattern in parks in Oslo was different compared to the reference location in Åmotsdalen. Whilst we can mostly find PCB 138 and 153 in Lumbricidae from Oslo at varying concentrations, the distribution between the different congeners in the reference area in the Dovre mountains is more even.

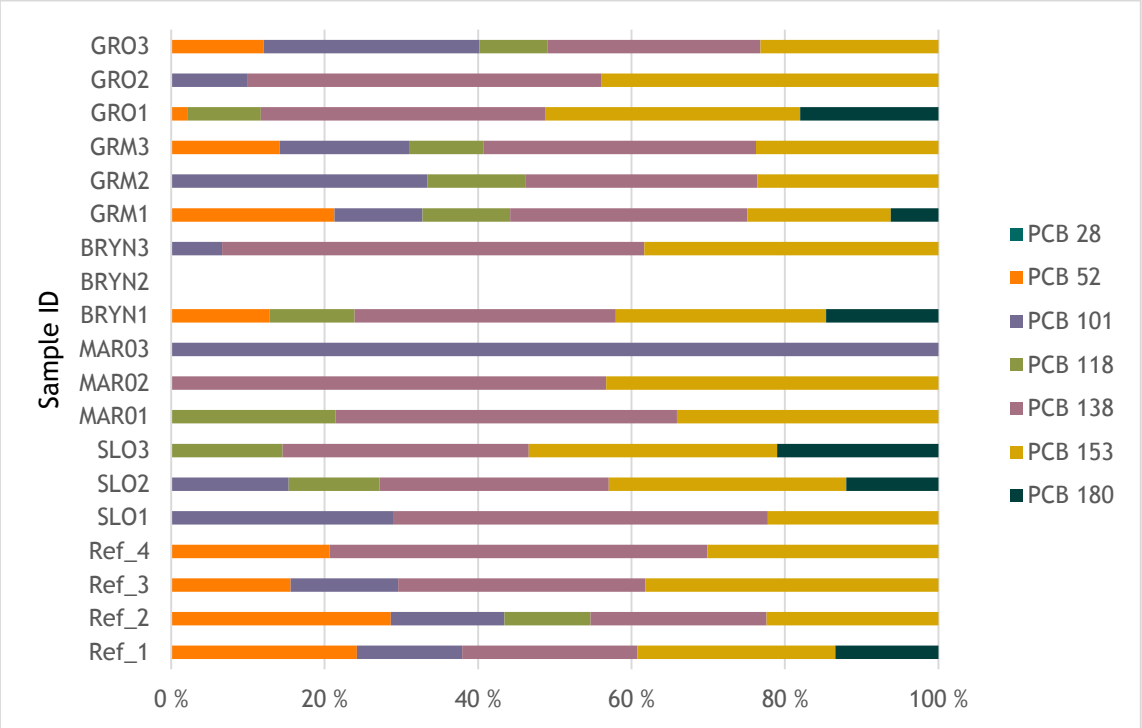


Figure 14: Relative PCB distribution in Lumbricidae (locations: parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken, REF: Åmotsdalen)

3.1.4 Rat liver

In all, 15 livers of rats were analysed for PCBs. They were all from the same site in Oslo (Brugata), and were caught in clap-traps. Eight of them were classified as males, and six of them female, one was undetermined. Females showed almost twice as high concentrations as the males, with PCB 105, 118, 138 and 153 being the dominant congeners (Figure 15*)* One rat liver contained a high concentration of PCB 153; 62 ng/g wet weight. The difference between males and females was not significant when tested for sumPCB (Mann-Whitney U, P = 0.8). A summary of values are given in Table 6.

Table 6: PCB congener concentrations in rat liver from 2014 in ng/g ww.

	PCB 28	PCB 52	PCB101	PCB118	PCB 138	PCB 153	PCB 180	SumPCB
N	15	15	15	15	15	15	15	15
Mean	1.05	0.33	0.55	4.15	7.35	5.80	3.83	23.1
Median	0.73	0.32	0.55	1.76	3.16	2.62	4.04	13.2
Minimum	0.12	0.13	0.20	0.52	1.06	0.24	0.45	2.7
Maximum	2.51	0.610	0.93	12.3	21.1	20.4	9.71	67.6

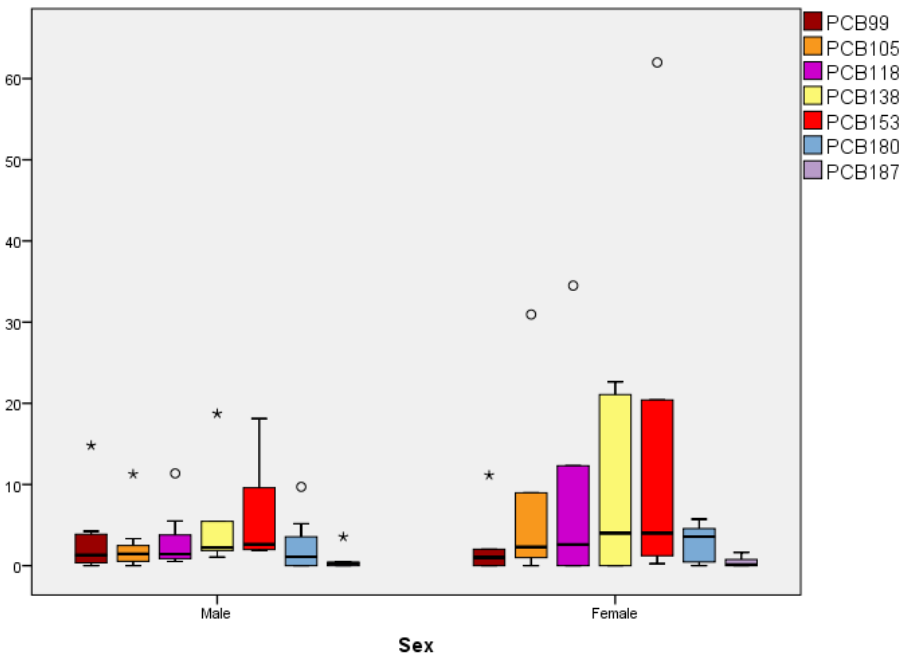


Figure 15: Boxplot of the main PCB congeners in brown rat livers divided by sex (ng/g ww).

No relation between body weight and PCB concentrations were found (Figure 16), indicating that young rats have the same concentrations at adult animals, given that weight is a proxy for age.

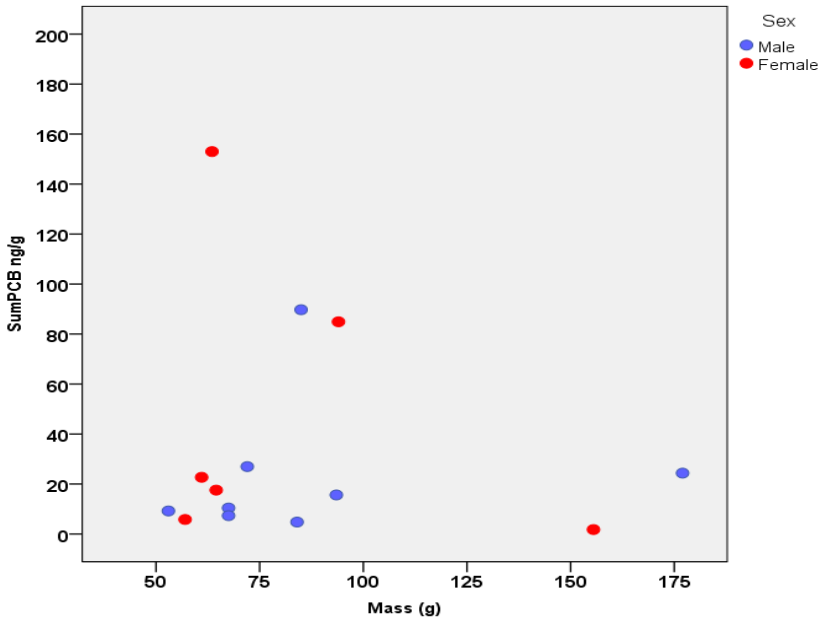


Figure 16: Sum PCB concentrations in brown rats vs body mass and sex (ng/g ww).

3.2 PBDEs

3.2.1 Golden eagle eggs

Of all analysed PBDEs, PBDE 126, 190, 196, 202, 206 and 207 were only detected at very few occasions or not at all. The highest PBDE concentrations were detected in one egg from 1998 with sumPBDE concentrations up to 15.6 ng/g fw. Figure 17 shows the average PBDE concentration of the most dominant congeners grouped into four-year periods (ng/g fresh weight). Eggs from coastal sites are omitted, but the effect of region is discussed later, see *Figure 56*. The detailed results are shown in Table 7.

Table 7: PBDE congener values in golden eagle eggs 1995-2011 in ng/g fw. All clutches are included

Year		PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154	PBDE 175/183	PBDE 206	PBDE 207	PBDE 209	SumPBDE
1995	N	5	5	5	5	5	5	5	5	5	5
	Mean	36.2	8.19	8.98	5.43	3.58	<LOD	0.10	<LOD	<LOD	62.5
	Median	11.1	4.73	4.03	4.22	3.02	<LOD	0.10	<LOD	<LOD	27.2
	Minimum	2.95	1.95	1.56	0.260	1.57	<LOD	0.09	<LOD	<LOD	8.4
	Maximum	81.9	16.6	20.1	13.0	6.27	<LOD	0.12	<LOD	<LOD	138.0
1998	N	5	5	5	5	5	5	5	5	5	5
	Mean	22.2	6.70	8.89	5.64	4.48	3.57	<LOD	<LOD	0.08	51.6
	Median	1.61	3.02	3.61	3.14	3.53	3.57	<LOD	<LOD	0.09	18.6
	Minimum	0.76	0.36	0.44	0.09	1.29	3.57	<LOD	<LOD	0.07	6.6
	Maximum	105	20.4	27.9	21.4	10.7	3.57	<LOD	<LOD	0.09	189
2000	N	4	4	4	4	4	4	4	4	4	4
	Mean	1.57	1.01	0.97	1.23	0.83	1.21	3.30	<LOD	0.06	10.2
	Median	0.93	0.95	0.71	1.43	0.52	1.21	3.30	<LOD	0.06	9.1
	Minimum	0.45	0.45	0.41	0.17	0.27	1.09	3.30	<LOD	<LOD	6.2
	Maximum	3.98	1.63	2.02	1.89	2.03	1.32	3.30	<LOD	0.06	16.2

Year		PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154	PBDE 175/183	PBDE 206	PBDE 207	PBDE 209	SumPBDE
2003	N	5	5	5	5	5	5	5	5	5	5
	Mean	9.24	2.27	2.96	1.78	0.71	1.89	0.100	<LOD	0.070	19.0
	Median	1.58	0.91	0.90	2.18	0.43	1.84	0.10	<LOD	0.07	8.0
	Minimum	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.1
	Maximum	0.49	0.39	0.28	0.63	0.13	1.09	0.10	<LOD	0.02	3.1
2005	N	1	1	1	1	1	1	1	1	1	1
	Mean	1.14	1.1	0.83	0.91	0.37	<LOD	<LOD	<LOD	0.08	4.4
	Median										
	Minimum										
	Maximum										
2007	N	1	1	1	1	1	1	1	1	1	1
	Mean	0.34	0.32	0.3	2.36	3.99	2.34	<LOD	<LOD	<LOD	9.7
	Median										
	Minimum										
	Maximum										
2009	N	1	1	1	1	1	1	1	1	1	1
	Mean	2.32	2.22	0.83	0.33	3.35	0.42	<LOD	<LOD	<LOD	9.5
	Median										
	Minimum										
	Maximum										
2011	N	1	1	1	1	1	1	1	1	1	1
	Mean	3.04	0.75	0.77	2.92	3.38	2.78	<LOD	<LOD	<LOD	13.6
	Median										
	Minimum										
	Maximum										
Total	N	23	23	23	23	23	23	23	23	23	
	Mean	15.3	4.12	4.63	3.19	2.53	1.91	0.90	<LOD	0.07	32.6
	Median	2.32	1.80	1.23	1.78	2.24	1.84	0.11		0.08	11.4
	Minimum	0.34	0.32	0.28	0.09	0.13	0.42	0.09		0.02	1.69
	Maximum	105	20.4	27.9	21.4	10.7	3.57	3.30		0.12	192

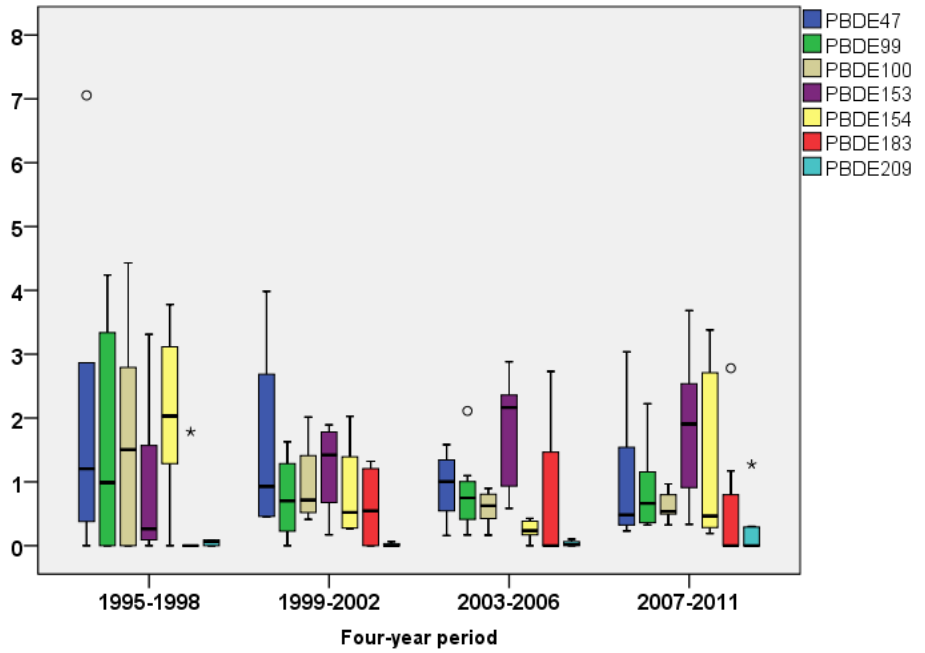


Figure 17: Average concentrations of different PBDEs in eggs of golden eagle (ng/g fw).

Between 1995 and 2003, eggs with elevated sumPBDE concentrations were identified. After that period only low concentrations of PBDEs were found. Some change in PBDE composition can be seen in the golden eagle eggs over time. PBDE 47, 99, 100 and 154 dominate the PBDE pattern with up to ca. 80% in the samples from 1995-1998. In the later years, higher brominated PBDEs as the PBDE 153 and 183 increase in importance, decreasing the PBDE 47, 99 and 100 contribution. The relative contribution of the single PBDEs to the overall PBDE load changed for PBDE 47 from more than 50% in 1995 to less than 25% in the time-period 2005-2011. However, when comparing average sumPBDE concentrations of the collected years, there is a change over time of sumPBDE concentrations. There was a negative correlation with year of sampling, indicating a decrease of overall PBDE concentrations in golden eagle eggs (Spearman rank correlation, R = -0.43, P = 0.019).

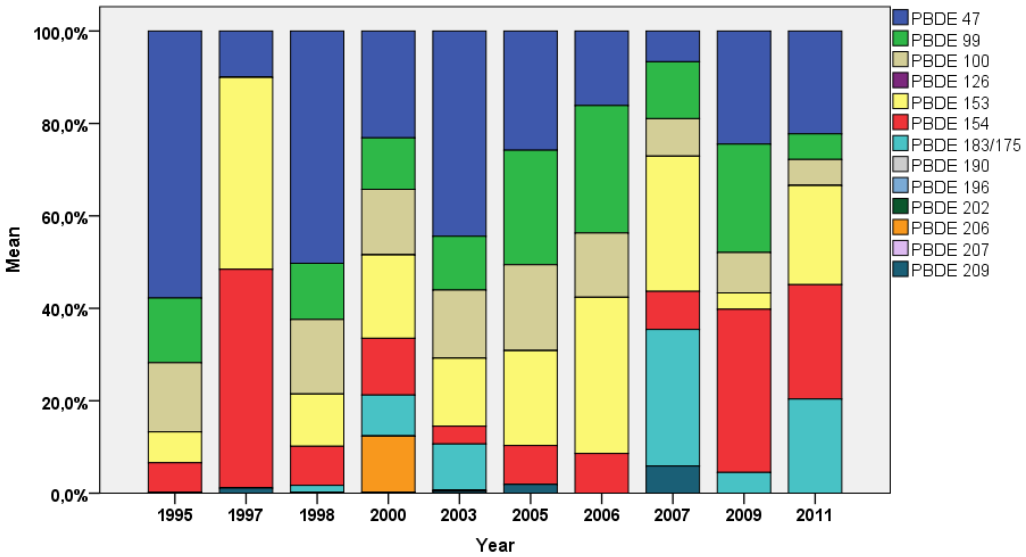


Figure 18: *Average relative PBDE distribution in golden eagle eggs 1995-2011.*

3.2.2 Pied flycatcher eggs

As for the golden eagle, not all PBDEs that were analysed for could be detected (PBDE 126, 183/175, 190, 196 and 202). The concentrations of the detected PBDEs were in general low, with PBDE 153 being the most often detected one (100% detection rate). PBDE 47 and 209 were the dominating PBDEs in most eggs (Table 8). As Figure 19 shows, eggs from the same nest differentiate in PBDE content, unlike to the PCBs. Not only did the sumPBDE concentration vary but the PBDE composition as well. However, the eggs with the highest sumPBDE belonged to the same nest, egg nest1_1 and 1_5 with 13.0 and 20.4 ng/g ww. In general, the sumPBDE on a single egg concentration varied between 0.16 and 20.4 ng/g ww with an average of 4.8 ng/g ww. On average sumPBDE concentrations in flycatcher eggs comparable to golden eagle eggs from the years 2006/7 on a lipid weight basis.

Table 8: Values of individual congeners of PBDE in pied flycatcher eggs at the different sites (ng/g ww).

Site		PBDE47	PBDE99	PBDE100	PBDE153	PBDE154	PBDE183	PBDE206	PBDE207	PBDE209	Sum PBDE
Bogstad	N	6	6	6	6	6	6	6	6	6	6
	Mean	0.55	0.98	0.14	0.54	0.27	0.03	0.01	0.01	1.67	4.20
	Median	0.25	0.77	0.04	0.36	0.09	<LOD	<LOD	<LOD	1.58	4.46
	Minimum	0.13	<LOD	<LOD	0.15	0.04	<LOD	<LOD	<LOD	<LOD	0.80
	Maximum	2.12	2.18	0.54	1.82	1.06	0.12	0.09	0.08	4.96	8.18
Øgarden	N	6	6	6	6	6	6	6	6	6	6
	Mean	0.47	0.77	<LOD	0.27	0.12	0.02	<LOD	<LOD	0.28	1.94
	Median	0.39	0.75	<LOD	0.23	0.11	0.02	<LOD	<LOD	<LOD	1.56
	Minimum	<LOD	<LOD	<LOD	0.15	0.08	<LOD	<LOD	<LOD	<LOD	0.34
	Maximum	1.46	2.00	<LOD	0.46	0.19	0.06	<LOD	<LOD	1.65	4.10
Sørkedalen	N	2	2	2	2	2	2	2	2	2	2
	Mean	1.52	1.95	<LOD	0.84	0.32	0.25	<LOD	<LOD	1.24	6.11
	Median	1.52	1.95	<LOD	0.84	0.32	0.25	<LOD	<LOD	1.24	6.11
	Minimum	1.31	1.51	<LOD	0.55	0.25	0.17	<LOD	<LOD	0.00	5.10
	Maximum	1.74	2.38	<LOD	1.14	0.39	0.32	<LOD	<LOD	2.47	7.13

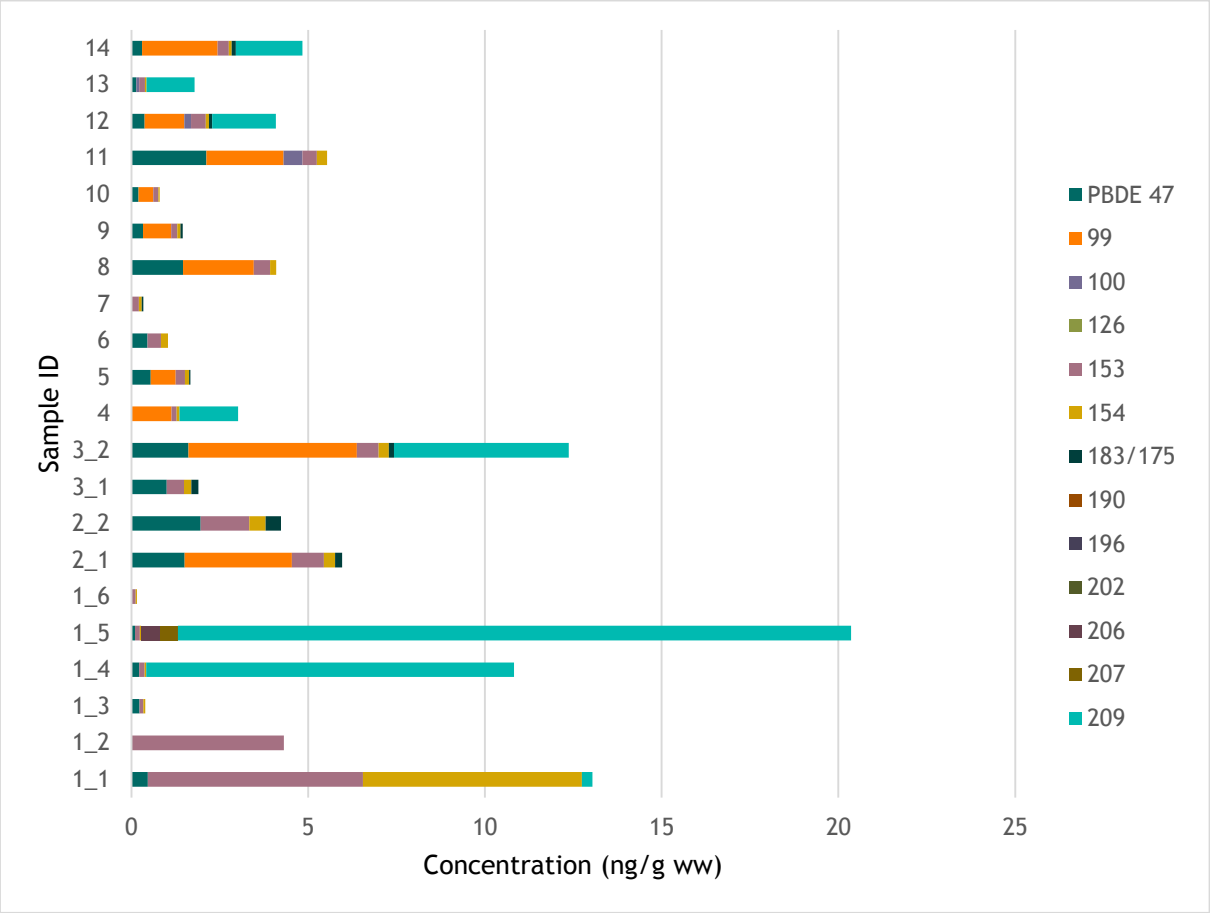


Figure 19: PBDE concentrations in eggs of pied flycatcher in ng/g ww.

When comparing the different sites of collection, it was somewhat surprising that the eggs collected at Sørkedalen had on average the highest PBDE concentrations (Figure 20). The reason for this remains unclear. The relative distribution between the main PBDE congeners is shown in Figure 21. PBDE congeners 47, 99, 153, and 209 were the main congeners, but there were large variations between sites. Sum PBDEs was highest in Sørkedalen, with 6.1 ng/g, while Bogstad had 4.2 and Øgarden had 1.9 ng/g ww.

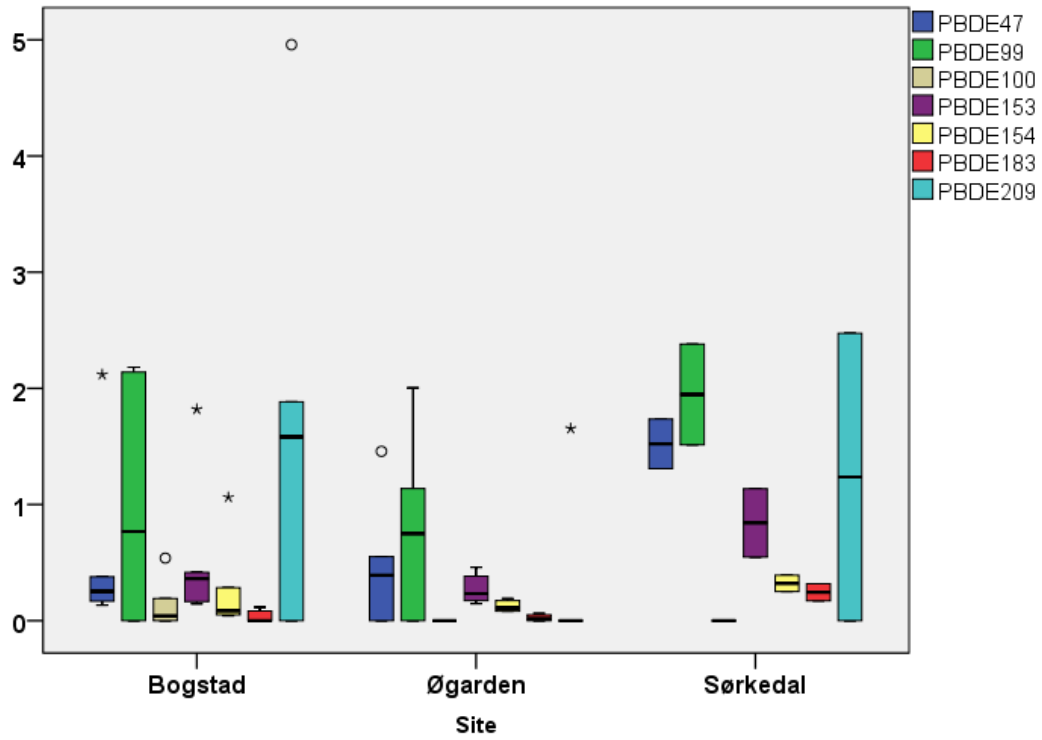


Figure 20: Relative distribution between the main PBDE congeners at the different sites (ng/g ww).

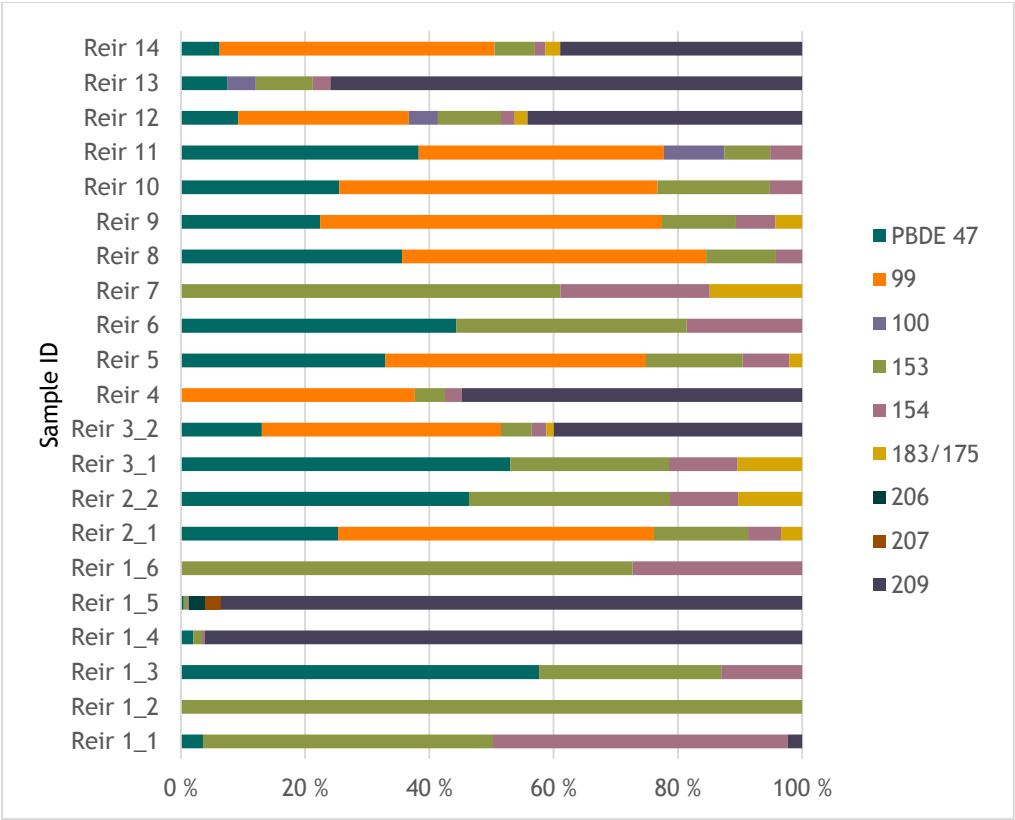


Figure 21: *Relative PBDE contribution in eggs of pied flycatcher*

3.2.3 Rat liver

Of the analysed PBDEs only PBDE 47, 100 and occasionally 183 was detected in quantifiable amounts. PBDE 100 was the dominating PBDE with an average concentration of 2.7 ng/g ww followed by PBDE 47 and 183 with 0.16 and 0.19 ng/g ww on average respectively. The PBDE pattern in rat liver sampled in Oslo differs from the PBDE pattern found in pied flycatcher eggs and golden eagle eggs by being dominated by the pentabrominated PBDE 100 (PBDE 47 and 99 in pied flycatcher eggs and PBDE 153 and 154 in golden eagle eggs) (Figure 22 *and 23*).

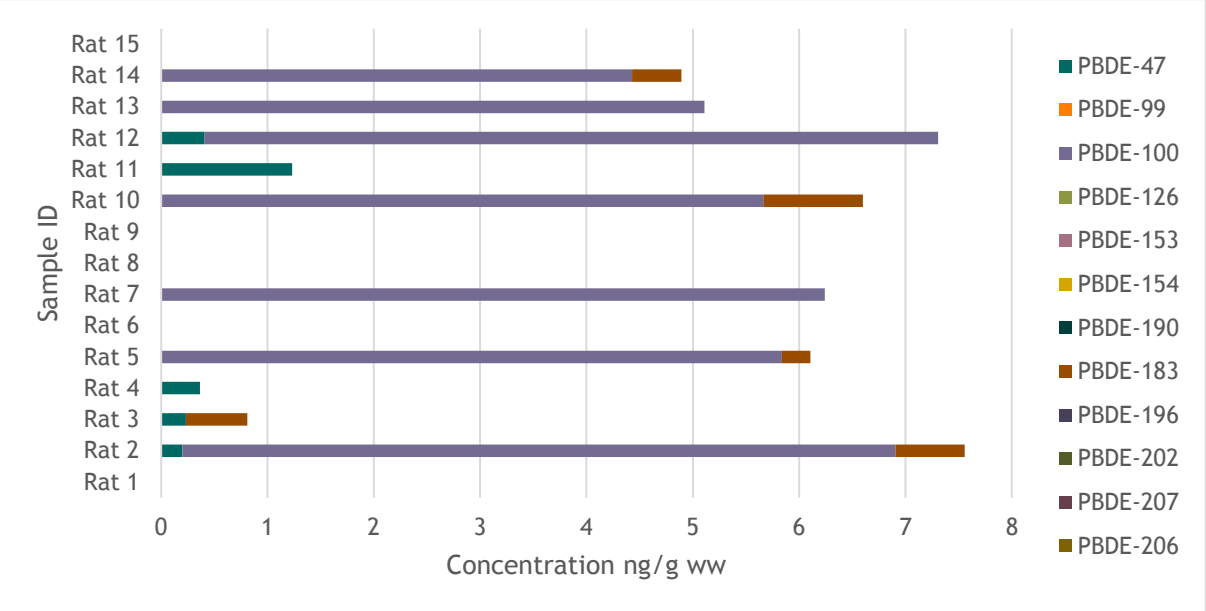


Figure 22: PBDE concentrations in rat liver from Oslo city in ng/g ww

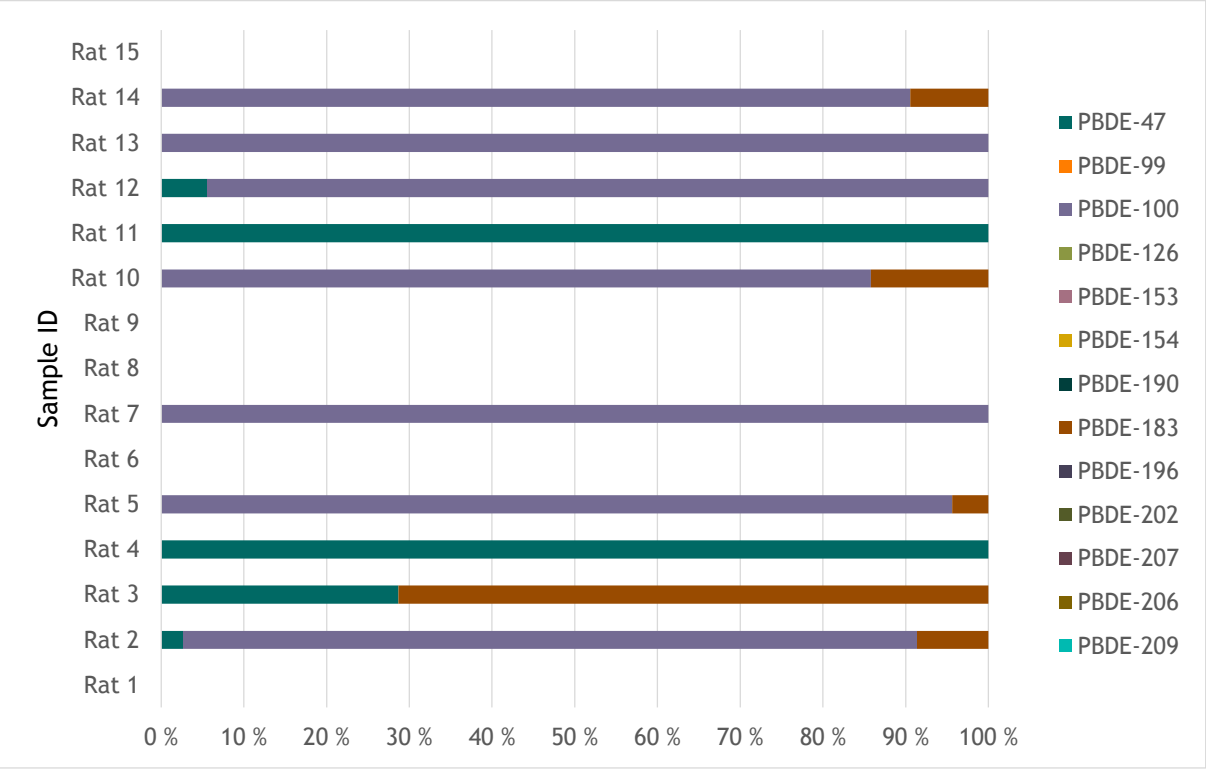


Figure 23*: Relative PBDE concentrations in rat liver from Oslo city*

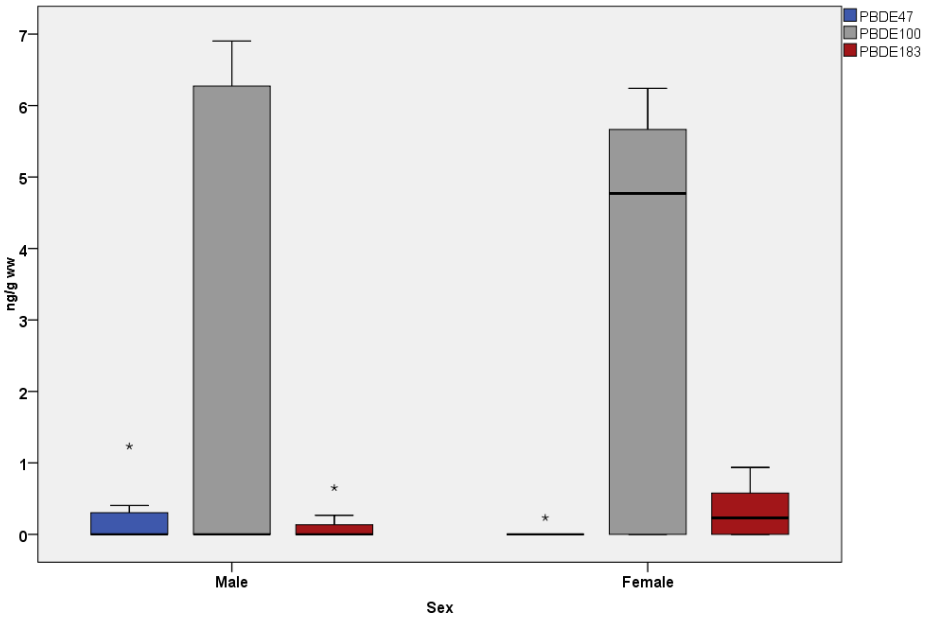


Figure 24: The relative distribution of PBDE congeners in liver of female and male rats from Oslo city (ng/g ww)

3.2.4 *Earthworms*

No PBDEs could be detected inearthworms (Lumbricidae).

3.3 Per-and polyfluoroalkyl substances (PFASs)

3.3.1 Golden eagle eggs

PFAS do not accumulate in the lipids (proteinophilic). It is therefore only appropriate to report wet weight (ww) or fresh weight data (fw). Within this project golden eagle eggs (n=23) were collected in the years 1995 to 2011.The highest sumPFAS concentration of 36 ng/g fw, with eggs from coastal sites excluded, was found in an egg collected in 2003. Data from the years 2006 and 2007 were taken from earlier studies. The detailed results are shown in Table 9.

Table 9: Detected PFAS congener values in golden eagle eggs 1995-2011 in ng/g fw. Five clutches were excluded from the sample as they were from coastal sites.

Year		PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	SumPFAS
1995	N	2	2	2	2	2	2	2	2	2
	Mean	6.88	<LOD	0.09	0.18	0.62	0.50	1.07	0.14	9.49
	Median	6.88	<LOD	0.09	0.18	0.62	0.50	1.07	0.14	9.49
	Min	6.52	<LOD	0.08	0.16	<LOD	<LOD	0.98	<LOD	9.06
	Max	7.24	<LOD	0.09	0.20	0.62	0.50	1.17	0.28	9.92
1997	N	1	1	1	1	1	1	1	1	1
	Mean	5.37	<LOD	0.13	0.25	0.68	0.45	0.71	0.14	7.73
	Median									
	Min									
	Max									
1998	N	3	3	3	3	3	3	3	3	3

Year		PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	SumPFAS
	Mean	4.72	<LOD	0.20	0.40	0.89	0.42	0.87	0.16	7.66
	Median	5.57	<LOD	0.18	0.31	0.73	0.40	0.44	<LOD	6.30
	Min	3.50	<LOD	0.18	0.30	0.61	0.32	0.31	<LOD	5.54
	Max	6.10	<LOD	0.24	0.57	1.34	0.53	1.86	0.49	11.13
2000	N	4	4	4	4	4	4	4	4	4
	Mean	6.82	0.02	0.16	0.33	0.95	0.58	3.47	0.73	13.11
	Median	4.00	<LOD	0.13	0.29	0.72	0.34	0.65	<LOD	6.74
	Min	3.90	<LOD	0.10	0.29	0.72	0.33	0.73	<LOD	6.51
	Max	8.86	0.10	0.22	0.41	1.41	1.08	10.20	2.36	22.23
2003	N	4	4	4	4	4	4	4	4	4
	Mean	10.0	<LOD	0.16	0.40	1.42	0.59	1.48	0.05	14.2
	Median	4.33	<LOD	0.15	0.42	1.31	0.54	1.07	<LOD	7.36
	Min	2.48	<LOD	0.11	0.25	0.64	0.34	0.65	<LOD	5.71
	Max	29.0	<LOD	0.21	0.50	2.43	0.96	3.12	0.19	36.4
2005	N	1	1	1	1	1	1	1	1	1
	Mean	3.74	<LOD	0.09	0.26	1.01	0.68	5.34	1.18	12.3
	Median									
	Min									
	Max									
2006	N	3	3	3	3	3	3	3	3	3
	Mean	4.46	<LOD	1.85	<LOD	<LOD	<LOD	<LOD	<LOD	2.87
	Median	3.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.12
	Min	2.77	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.61
	Max	7.54	<LOD	5.55	<LOD	<LOD	<LOD	<LOD	<LOD	6.51
2007	N	4	4	4	4	4	4	4	4	4
	Mean	2.87	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	2.87
	Median	1.96	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	3.12
	Min	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.61
	Max	6.51	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	6.51
2009	N	1	1	1	1	1	1	1	1	1
	Mean	6.19	0.08	2.84	4.25	8.93	1.72	2.64	<LOD	26.6
	Median									
	Min									
	Max									
2011	N	1	1	1	1	1	1	1	1	1
	Mean	1.44	<LOD	0.26	0.40	1.60	0.92	<LOD	<LOD	4.64
	Median									
	Min									
	Max									

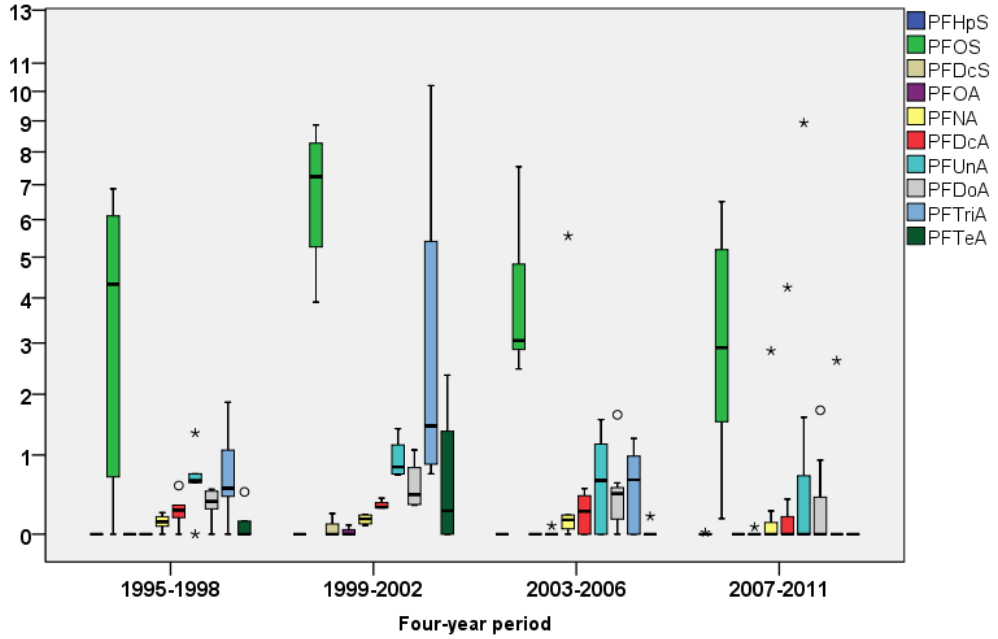


Figure 25: PFAS concentrations (ng/g fw) in eggs of golden eagle during the period 1995-2011, clutch averages. Eggs from coastal sites are excluded.

The PFAS composition in the investigated eggs is presented in Figure 25. PFOS is the dominating compound in the majority of the egg samples, however there is also an increase in the relative abundance of the long chain carboxylic acids visible for the investigated time-period (PFNA to PFTeDA). On average, PFOS contributed with 54% to the sumPFAS load compared to 2.5, 4.6, 11.9, 5.2, 16.9 and 2.8 % for PFNA to PFTeA respectively.

Comparing single PFAS concentrations in time periods of three years, the change of concentrations over time can be assessed. However, PFAS time-trends are impacted by changes of use patterns and amounts in recent years. After 3M phased-out the production of perfluoroalkyl chains containing 6, 8 and 10 carbons, including PFOA in 2002 (contributing with 80% to the worldwide production), other companies continued to manufacture PFOA mainly through the telomerization process which produces only linear isomers. For a thorough description of the sources of PFCA homologues and their precursors see the reviews of Prevedouros et al. (2006), Wang et al. (2014b) and Wang et al. (2014c). In 2006, eight major PFCA, fluoropolymer and fluorotelomer manufacturers joined the US EPA 2010/15 Stewardship Program to work towards the elimination of long-chain PFCAs and their precursors from emissions and products by 2015(US EPA, 2006). Further, PFOA, its ammonium salt (APFO), and C11–C14 PFCAs were included in the Candidate List of Substances of Very High Concern under the European chemicals regulation, REACH (ECHA, 2014). Although long-chain PFCAs are being stepwise phased out by the major manufacturers and heavily regulated in Japan, Western Europe and the United States (US) (3M, 2000; Ritter, 2010; US EPA, 2006), new manufacturers (largely in continental Asia) have begun to produce long-chain PFCAs and their precursors. Regarding PFOS and congeners, the EU adopted a Marketing and Use Directive (2006/122/EC) that bans the use of PFOS in semi-finished products (maximum content of PFOS: 0.005% by weight) as of summer 2008. In 2009, PFOS and related substances based on perfluorooctane sulfonyl fluoride (POSF) were listed under Annex B (restriction of production and use) of the Stockholm Convention on Persistent Organic Pollutants. After 2000, China filled the created gap between global demand and supply of PFOS as well as PFAA containing products.

When assessing the PFAS concentrations in eggs of golden eagle over time, only weak decreases in the case of PFOS or no change over time for the PFCAs can be observed. When the total data are split between coastal and inland sites (Figure 26*)*, PFOS concentrations are stable in eggs from inland birds (Spearman rank correlation, R = -0.16, P = 0.45). More samples from the

recent past (from 2005 until today) need to be included in order to be able to assess possible changes ongoing today. The high concentrations found in coastal eggs are clearly connected with influence from the marine environment, and these values will confound the averages, as they tend to be from earlier part of the period.

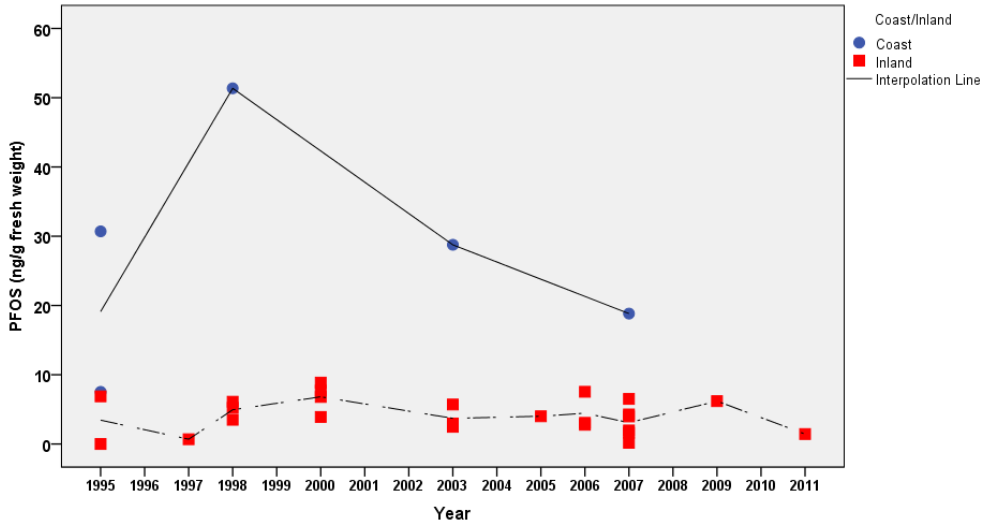


Figure 26: Changes over time of PFOS in eggs of golden eagle in ng/g fw

3.3.2 Rat Liver

As illustrated in Figure 27, PFAS could be detected in all rat liver samples. SumPFAS concentrations ranged from 1.8 to 17 ng/g ww. Linear PFOS was the dominating PFAS in all samples, followed by PFDcA and in some cases 8:2 FTS. That is an uncommon pattern, deviating from the more often found pattern of PFOS > PFNA> PFUnA >PFTrA (Bustnes *et al.*, 2013, Jaspers *et al.*, 2013, Taniyasu *et al.*, 2013, Vestergren *et al.*, 2013). The uncommon PFAS pattern can be explained by exposure to direct PFAS sources as PFAS containing waste (food packaging), degradation of PFDcA precursors or PFAS spills.

Table 10: PFAS in brown rat livers from Oslo city (ng/g ww).

Sex		PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum PFAS
Male	N	8	8	8	8	8	8	8	8	8.00
	Mean	2.97	0.11	0.29	0.80	0.50	0.20	0.29	0.17	5.77
	Median	2.14	0.11	0.22	0.59	0.36	0.11	0.05	<LOD	3.58
	Minimum	1.08	<LOD	<LOD	0.16	0.08	<LOD	<LOD	<LOD	1.38
	Maximum	7.28	0.22	0.92	2.10	1.26	0.64	1.56	0.94	14.6
Female	N	6	6	6	6	6	6	6	6	6
	Mean	2.42	0.08	0.19	0.39	0.25	0.05	<LOD	<LOD	3.62
	Median	2.24	<LOD	0.17	0.29	0.27	0.04	<LOD	<LOD	3.51
	Minimum	0.82	<LOD	0.08	0.22	0.14	<LOD			1.49
	Maximum	5.08	0.34	0.37	0.70	0.30	0.12			6.34

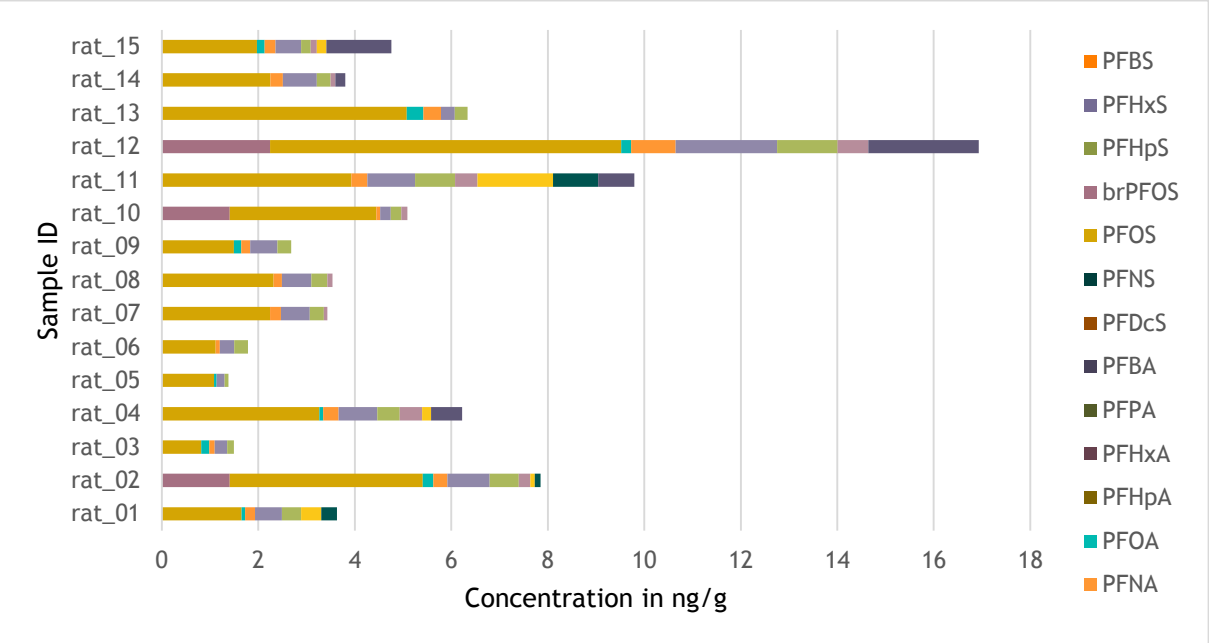


Figure 27: PFAS concentrations in rat liver from City of Oslo, Norway in ng/g ww

Figure 28 shows the relative contribution of the detected PFAS in all samples illustrating the uncommon pattern. PFOA was only detected in a limited number of individuals, varying between <LOD and 0.342 ng/g ww. There was no significant difference between male and female rats.

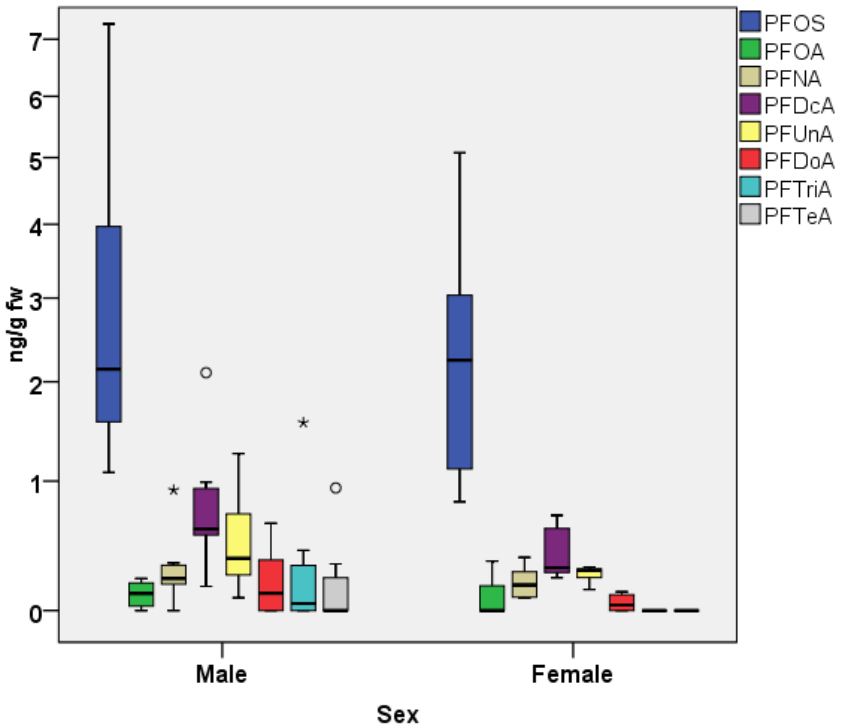


Figure 28: Relative contribution of the detected PFAS in liver of brown rats

3.3.3 Earthworms

As illustrated in Figure 29, PFASs were present in every sample, except for one reference sample where the concentrations were below LOD. The sumPFAS concentrations ranged from <LOD to 37.3 ng/g ww, with PFOS representing as 54% followed by PFDoA, PFTrA and PFTeA WITH 10, 13 AND 16%. PFOS was the predominant compound in the majority of the samples. In addition, PFTrDA was detected in the majority of samples. In one sample from Groruddalen, PFDS was detected, and this sample also had the highest average PFAS concentrations (37.3 ng/g ww), the same sample exhibiting elevated PCB and PBDE content too. In general, variations within the sampling location are considerable, confirming the need of sampling several subsamples in one location as done in this study.

Table 11: PFAS data for earthworm collected in Oslo and reference location in ng/g ww.

Site		PFHxS	PFHpS	PFOS	PFDcS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	SumPFC
Åmotsdalen/ Dovre	N	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Mean	<LOD	2.63	0.20	<LOD	0.27	<LOD	0.82	0.20	0.13	0.28	0.29	1.16	0.42	6.41
	Median	<LOD	1.12	0.18	<LOD	<LOD	<LOD	0.94	0.23	0.14	0.26	0.23	0.99	0.44	6.70
	Min	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
	Max	<LOD	8.29	0.44	<LOD	1.10	<LOD	1.40	0.34	0.26	0.58	0.70	2.66	0.82	12.2
Bryn	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Mean	<LOD	0.09	4.88	<LOD	<LOD	0.72	0.50	0.15	0.08	0.24	0.57	0.63	1.00	8.86
	Median	<LOD	<LOD	6.58	<LOD	<LOD	0.50	0.40	0.20	<LOD	0.30	0.62	0.66	0.93	10.7
	Min	<LOD	<LOD	1.03	<LOD	<LOD	0.18	0.12	0.03	<LOD	0.03	0.24	0.26	0.46	2.60
	Max	<LOD	0.26	7.04	<LOD	<LOD	1.48	0.97	0.23	0.23	0.38	0.84	0.98	1.61	13.2
Grønmo	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Mean	<LOD	<LOD	2.40	<LOD	<LOD	0.19	0.24	0.03	<LOD	0.12	0.20	0.79	0.57	4.54
	Median	<LOD	<LOD	2.42	<LOD	<LOD	0.22	0.17	0.05	<LOD	0.11	0.13	0.57	0.32	3.69
	Min	<LOD	<LOD	1.77	<LOD	<LOD	<LOD	0.07	<LOD	<LOD	<LOD	<LOD	0.42	0.24	3.34
	Max	<LOD	<LOD	3.00	<LOD	<LOD	0.35	0.47	0.06	<LOD	0.25	0.48	1.39	1.14	6.60

Site		PFHxS	PFHpS	PFOS	PFDcS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	SumPFC
Grorud	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Mean	2.76	2.09	9.60	1.40	<LOD	0.67	1.15	0.70	0.75	1.24	2.95	2.94	4.78	31.0
	Median	3.23	2.43	9.11	<LOD	<LOD	0.83	0.59	0.55	0.58	1.25	2.88	3.07	4.01	33.0
	Min	<LOD	<LOD	8.68	<LOD	<LOD	<LOD	0.33	0.28	0.49	1.09	2.26	2.42	3.98	22.7
	Max	5.06	3.84	11.00	4.21	<LOD	1.17	2.54	1.27	1.18	1.38	3.70	3.34	6.36	37.3
Maridalen	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Mean	0.18	<LOD	7.07	<LOD	<LOD	0.41	0.57	0.77	0.32	0.65	0.71	1.28	0.50	12.4
	Median	<LOD	<LOD	6.51	<LOD	<LOD	0.38	0.64	0.38	0.23	0.25	0.60	1.65	0.54	10.4
	Min	<LOD	<LOD	4.57	<LOD	<LOD	0.13	<LOD	0.19	<LOD	0.12	0.16	0.47	<LOD	8.03
	Max	0.55	<LOD	10.13	<LOD	<LOD	0.72	1.08	1.74	0.72	1.57	1.37	1.71	0.94	18.9
Slottsparken	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	Mean	0.09	0.46	4.11	<LOD	<LOD	0.29	0.23	0.07	0.06	0.25	0.96	0.97	1.70	9.19
	Median	<LOD	<LOD	4.51	<LOD	<LOD	0.34	<LOD	0.05	<LOD	0.15	0.57	0.98	1.83	8.62
	Min	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.02	<LOD	0.06	0.22	0.27	0.62	1.18
	Max	0.27	1.37	7.83	<LOD	<LOD	0.54	0.68	0.16	0.19	0.54	2.07	1.65	2.66	17.7

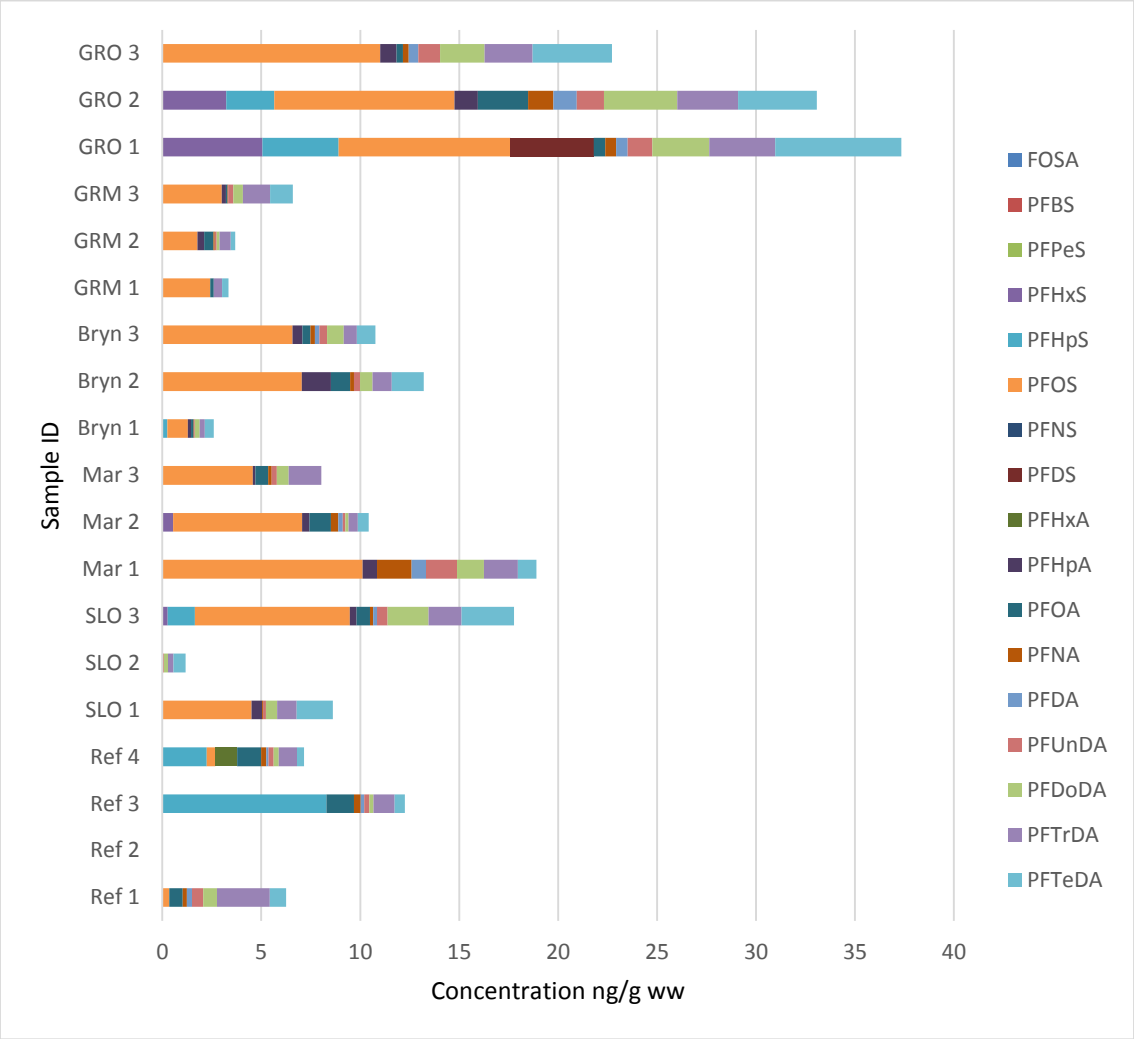


Figure 29: PFAS concentrations (ng/g ww) in Earthworms (Lumbricidae). (locations: parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken, , Ref: Åmotsdalen)

Figure 30 shows the average data of PFAS concentrations found at every location, identifying Grorud as the location with highest PFAS concentrations found in earthworms in Oslo parks.

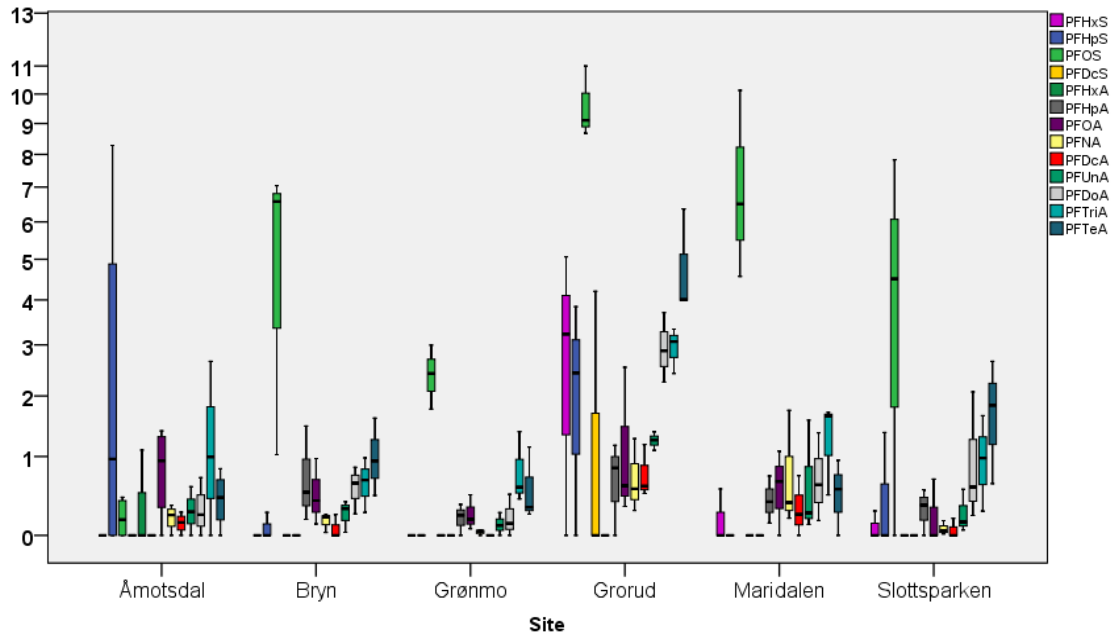


Figure 30: PFAS concentrations in earthworms collected at different locations in Oslo City and reference location (ng/g ww)

In *Figure 30,* the PFAS composition of the single pools from the different areas is presented. There is a difference in PFAS compositions between the reference and urban samples. The average relative abundance of PFOS was below 10% in the reference area in the mountains, while in urban samples, the relative PFOS abundance ranged from 23-73%.

3.4 Metals

3.4.1 Golden eagle eggs

The golden eagle eggs analyzed within this project were collected in a period between 1995 and 2011 (n=23). All samples were analyzed for the content of the following 9 metals: Cr, Ni, Cu, Zn, As, Cd, Pb, Ag and total-Hg (both organic and inorganic forms of mercury). In addition, the concentration of methylmercury (MeHg) was determined. The sum of metals determined varied between 5 000 and 24 000 ng/g. Two samples from 1995 and 1998 respectively, contained all the metals. Cu, Zn, total-Hg and MeHg were found in all samples. The concentration of MeHg determined were for most samples close to the concentration of total-mercury, indicating that mercury is mostly present as MeHg in golden eagle eggs. This is in line with results published by Ackerman et al (2013). Zn was the most predominant metal and accounted for between 73-96% of the sum of metals determined. The concentration of Zn found in golden eagle eggs where in the range of values found in Audouins's gull *Larus audouinii* (Morera 1997), and Cory's shearwater *Calonectris diomedea* (Renzoni 1986). Cu concentrations found where in agreement with results obtained for *Larus audouinii* (Morera 1997). The number of different metals determined is lower in the period 2007-2011 compared with eggs from 1995-2005. During this period, only Hg and Pb were found in addition to Cu and Zn. Since Cu and Zn are physiologically regulated in birds (Richards and Steele 1987), Hg, Pb, Cd and As can prove toxic at concentrations that can be found in the environment (Depledge et al. 1998).

Table 12: Toxic metals in golden eagle eggs 1995-2011, by four-year periods, excluding coastal sites (ng/g ww)

Four-year period		Hg	Cd	Pb
1995-1998	N	5	3	5
	Mean	20.5	0.10	3.98
	Median	14.5	0.10	3.48
	Minimum	6.4	0.09	2.33
	Maximum	45.9	0.12	6.32
1999-2002	N	4	1	4
	Mean	60.6	0.14	3.35
	Median	52.9	0.14	3.17
	Minimum	18.0	0.14	1.91
	Maximum	118.8	0.14	5.17
2003-2006	N	7	1	4
	Mean	22.5	0.13	6.96
	Median	11.2	0.13	5.32
	Minimum	7.10	0.13	4.12
	Maximum	67.0	0.13	13.1
2007-2011	N	8		2
	Mean	19.8		2.68
	Median	13.9		2.68
	Minimum	6.77		2.43
	Maximum	57.3		2.92

When adding data from earlier analyses, following changes over time can be observed for Hg, Pb and Cd, Figure 31and Cu and Zn in Figure 32.

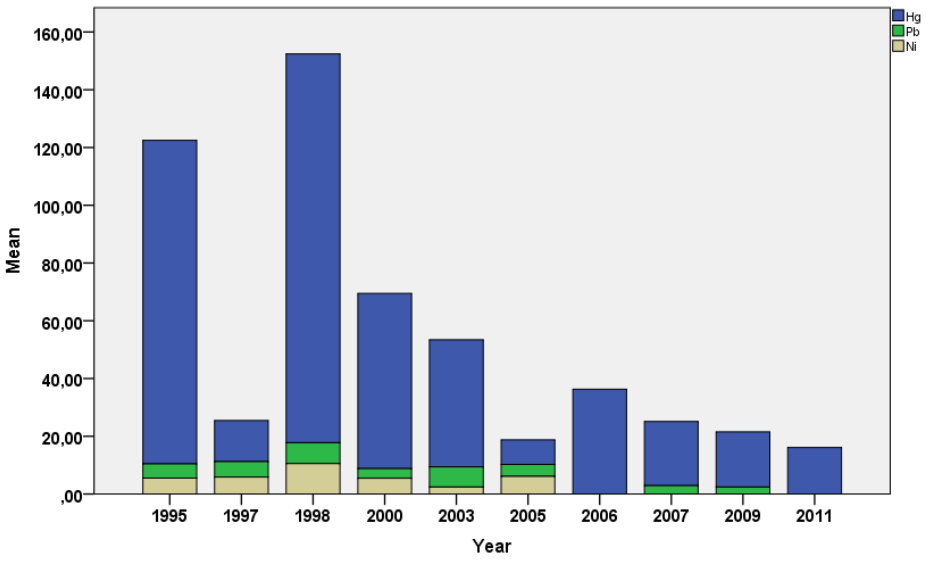


Figure 31: Concentration of Hg, Pb and Ni over time in golden eagle eggs (ng/g fw)

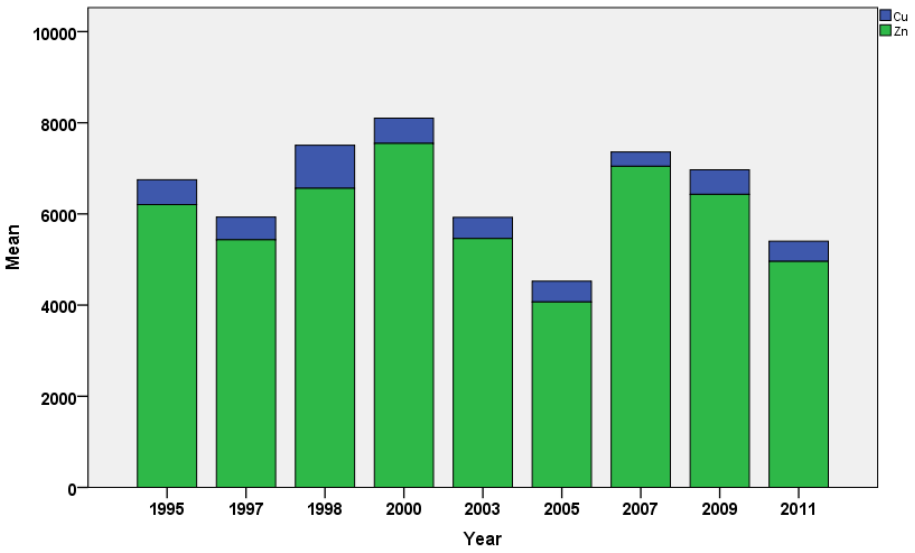


Figure 32: Concentration of Cu and Zn in golden eagle eggs (ng/g fw).

When assessing the metal concentration without the dominating Zn, the minor metals can be compared as well. Following decreasing contribution becomes visible for the main metals found in golden eagle eggs: Zn >> Cu > Hg. Figure 33 shows that there is no significant trend in concentrations of mercury and lead over time. The high concentrations of mercury in the period of 1999-2002 remain unexplained, but may have to do with individual food-choice of the eagles.

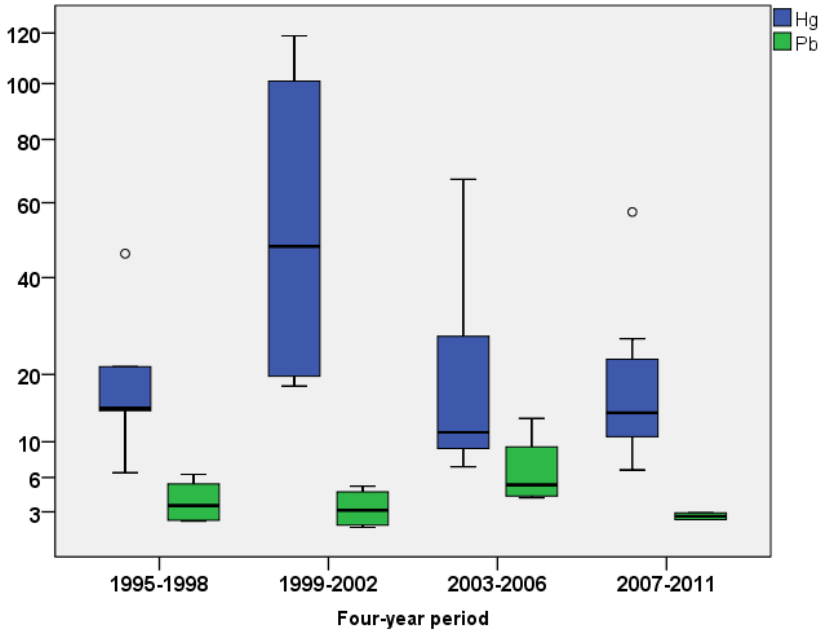


Figure 33: Change over time of mercury and lead concentrations in golden eagle eggs (ng/g)

Some of the metals were correlated with each other (Pearson corr., $P < 0.05$). Cd and As correlated with no other metals. Only Hg showed any significant change over time (negative) ($P = 0{,}047$, $R = -0{,}37$, Pearson correlation, two-tailed).

3.4.2 Earthworm

The metals to be determined in earthworms were as follows: Cr, Ni, Cu, Zn, As, Ag, Cd, Pb and tot-Hg. In addition, all samples were analyzed for the content of methyl mercury. Regrettably, no metal analyses were made for the samples from the reference area, due to limited sample material available. All 9 metals were detected in all samples. The sum of the metals determined varied between 90 000-496 000 ng/g ww. Zn was by far the most dominating element, with a content varying between 85-98% of the sum of the determined metals, with concentration ranging between 76 000 ng/g and 485 000 ng/g. Mean and median values were 175 000 ng/g and 145 000 ng/g, respectively. As shown in *Figure 33* comparable Zn concentrations were found, both within and between sampling sites. However, two samples with Zn concentration a factor of 2 and 3 higher than median was sampled at Bryn and Grorud, respectively. However, as Zn has important physiological functions in all organisms, the concentrations cannot be regarded in a toxicological context.

Table 13: Metals in earthworms from different sites in Oslo, in ng/g ww.

Site		Hg	Ag	Cd	Pb	Cu	Zn	Cr	Ni	As
Bryn	N	3	3	3	3	3	3	3	3	3
	Mean	78	33	1586	355	3424	221345	341	351	627
	Median	47	29	1517	458	3556	172237	317	371	648
	Minimum	39	28	1404	104	3006	156378	41	120	532
	Maximum	150	41	1836	504	3709	335418	665	563	701
Grønmo	N	3	3	3	3	3	3	3	3	3
	Mean	80	171	1645	2938	1925	110122	62	141	412
	Median	68	30	1949	245	1780	113432	64	145	408
	Minimum	67	22	934	237	1739	76100	46	105	228
	Maximum	103	461	2050	8331	2255	140834	76	173	600
Grorud	N	3	3	3	3	3	3	3	3	3
	Mean	88	24	1949	375	2635	261291	654	572	1034
	Median	86	20	957	333	2512	170250	698	626	1061
	Minimum	49	13	891	216	2392	128549	370	382	648
	Maximum	129	39	3997	576	3000	485073	893	708	1393
Maridalen	N	3	3	3	3	3	3	3	3	3
	Mean	78	21	1390	5208	2139	136476	310	382	601
	Median	48	16	1365	1858	1921	145605	129	131	565
	Minimum	45	13	1042	1764	1541	85188	72	124	497
	Maximum	140	33	1762	12001	2955	178635	730	891	741
Slottsparken	N	3	3	3	3	3	3	3	3	3
	Mean	176	50	774	2397	3871	147856	1599	1097	878
	Median	129	51	750	1592	3761	129879	1474	978	833
	Minimum	108	26	696	1297	2390	119749	1109	835	817
	Maximum	291	72	875	4302	5461	193940	2215	1479	985
Total	N	15	15	15	15	15	15	15	15	15
	Mean	100	60	1469	2255	2799	175418	593	509	710
	Median	86	29	1365	576	2512	145605	370	382	648
	Minimum	39	13	696	104	1541	76100	41	105	228
	Maximum	291	461	3997	12001	5461	485073	2215	1479	1393

Possible harmful effects caused by the concentration concentration of certain metals may be difficult to assess, as this seems to be species- and site specific (Lock and Janssen 2001). Even so, Zn concentrations in the earthworm species *E. fetida*, has been found to be physiological regulated to a relatively constant concentration of 100-200 µg/g independent of Zn concentration in the surrounding soil (Lock and Janssen 2001). Other authors report findings of higher body burdens, even at fairly low contaminated sites (Lukkari 2003; Kenette et al. 2002). Of the 15 samples analysed in the present study, one sample collected at Grorud and one sample from Bryn showed values above 200 µg/g.

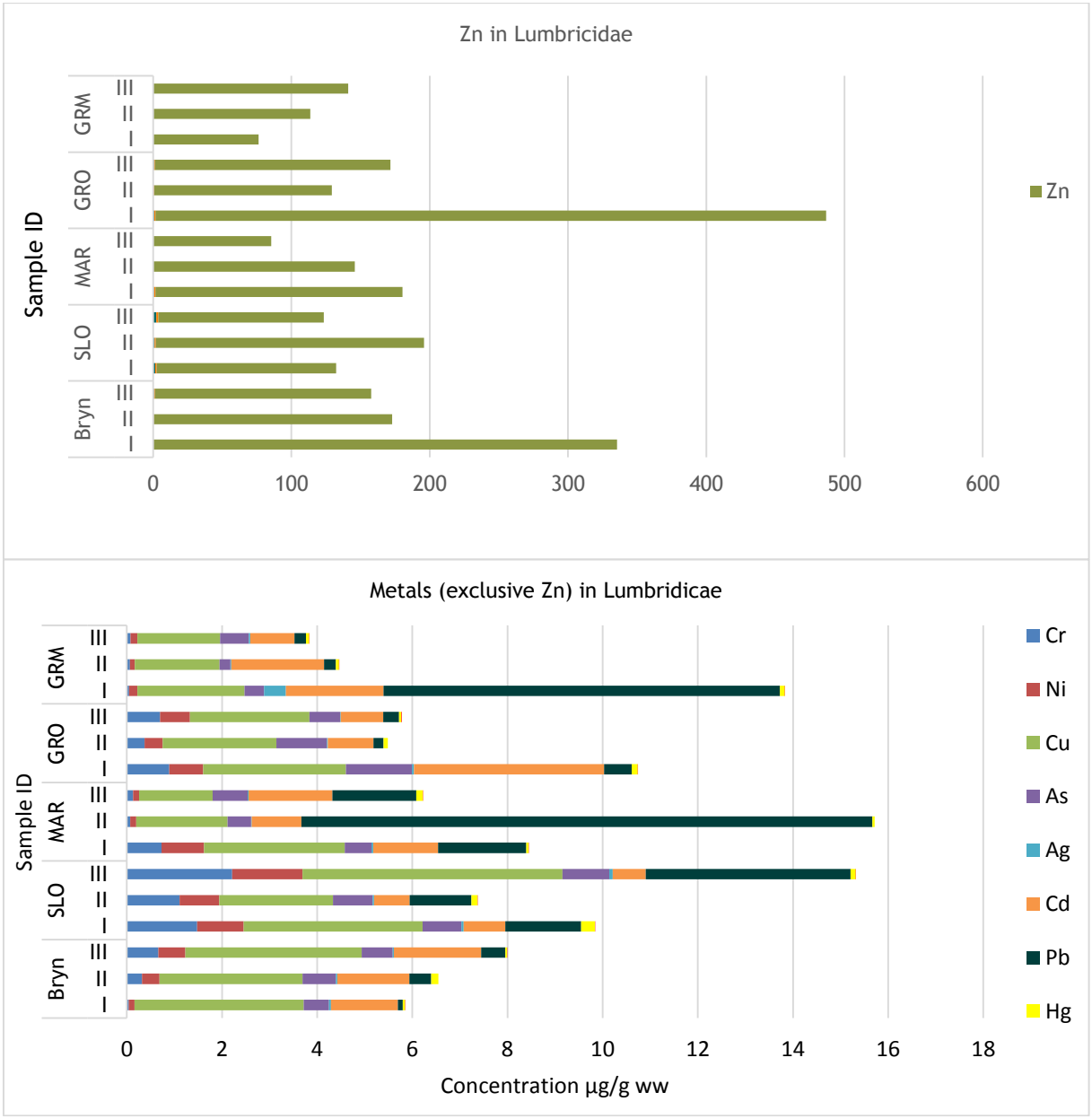


Figure 34: Metal concentrations in Earthworms (Lumbricidae) in µg/g ww (locations: parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken)

Lead was found in highest concentrations at Grønmo, Maridalen and Slottsparken, while cadmium was highest at Bryn and Grorud. Arsenic had relatively high concentrations at Grorud and Slottsparken. Mercury had low concentrations at all sites, but highest in Slottsparken. The next most abundant metal, although far less dominating compared to Zn, was Cu. The Cu

content constitutes between 1.7-4% of the sum of the determined metals. Zn and Cu are physiologically regulated (Lukkari et al. 2004).

The concentration of Pb varied considerably both within and between sampling sites. Minimum value of 100 ng/g was found at Bryn and maximum value of 12000 ng/g was found in a sample from Maridalen. Variation within and between sampling sites were also observed for Cr. Minimum concentration (41 ng/g) was determined in a sample from Bryn, and maximum concentration (2200 ng/g) was obtained in a sample from Slottsparken. Methylmercury was detected in 12 of 15 samples. The concentration concentrations found are low and there are small variations both within and between sampling sites. The ratio of methylmercury to tot-mercury varies between 0.1-0.17. This shows that mercury in earthworms mainly is present as inorganic forms.

In Figure 35, Zn is excluded to make the other elements more visible. Quite similar accumulation patterns within sample-site is observed for Bryn, Slottsparken and Grorud, while samples from Maridalen and Grønmo showed larger variations. Slottsparken differ from Bryn and Grorud with higher accumulation concentrations of Cr, Ni, Pb and lower for Cd.

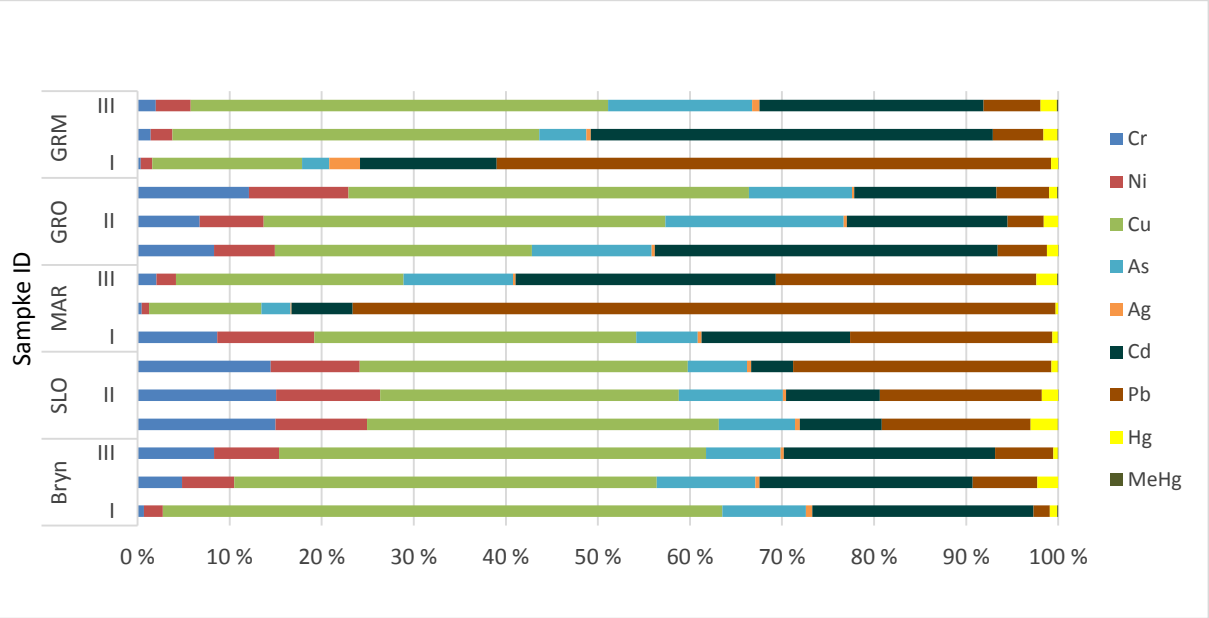


Figure 35: Relative distribution of metals (Zn excluded) in Lumbricidae (locations: parks in Oslo: GRO: Grorud; GRM:Grønmo, BRYN:Bryn, MAR:Maridalen, SLO: Slottparken)

Figure 36 illustrates the difference in metal concentrations found at the different Oslos locations for Cr, Ag, as and Hg, showing no clear difference between the parks except Slottsparken with a high contribution of Chromium and Grønmo with elevated concentrations of silver.

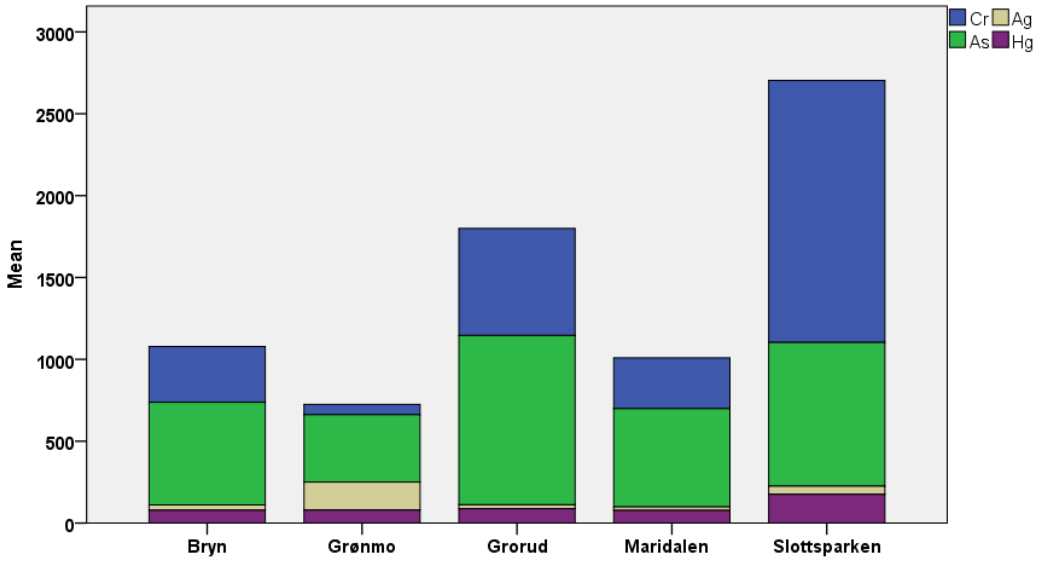


Figure 36: Mean concentrations of non-toxic metals (except Zn) at the different collection-sites in Oslo (ng/g ww).

3.4.3 Rat liver

Due to limited sample material available only five samples of rat liver were analysed for the content of the following 8 heavy metals: Cr, Ni, Cu, Zn, As, Ag, Cd, Pb see Table 14. Due to lack of sample material tot-Hg was only determined in two of the samples (rat 006 and rat 011). The concentration of MeHg was determined in all five samples. Zn was the dominating metal with concentrations varying from 20 000 ng/g to 41 000 ng/g, followed by Cu with a concentration at 3 645-4 296 ng/g. Of the other elements determined, only As and Pb were found in concentration concentrations above 100 ng/g. Concentrations of MeHg in rat livers were found to be low and one sample gave value below LOD. The two results obtained for tot-Hg are in a concentration within the method uncertainty of the methylmercury results. As illustrated in Figure 37 *and* Figure 38, all five liver samples have similar distribution pattern.

Table 14: Metals in livers of rats from Oslo city, divided by sex (ng/g ww).

Sex		Hg	MeHg	Ag	Cd	Pb	Cu	Zn	Cr	Ni	As
Males	N	1	2	3	3	3	3	3	3	3	3
	Mean	6.70	3.10	3.63	13.19	670	3722	41616	13.2	12.9	728
	Median		3.10	3.13	6.60	788	3715	28391	15.2	10.4	672
	Min		2.10	1.11	5.87	394	3645	21885	4.8	9.4	484
	Max		4.10	6.66	27.09	827	3805	74574	19.6	19.0	1027
Females	N	1	2	2	2	2	2	2	2	2	2
	Mean	7.60	1.10	3.65	16.77	1455	4167	35316	20.2	22.1	380
	Median		1.10	3.65	16.77	1455	4167	35316	20.2	22.1	380
	Min		1.00	1.89	15.12	1113	4066	29243	15.2	20.2	219
	Max		1.20	5.42	18.42	1796	4269	41388	25.2	23.9	541
Total	N	2	4	5	5	5	5	5	5	5	5
	Mean	7.15	2.10	3.64	14.62	984	3900	39096	16.0	16.6	589
	Median	7.15	1.65	3.13	15.12	827	3805	29243	15.2	19.0	541
	Min	6.70	1.00	1.11	5.87	394	3645	21885	4.8	9.4	219
	Max	7.60	4.10	6.66	27.09	1796	4269	74574	25.2	23.9	1027

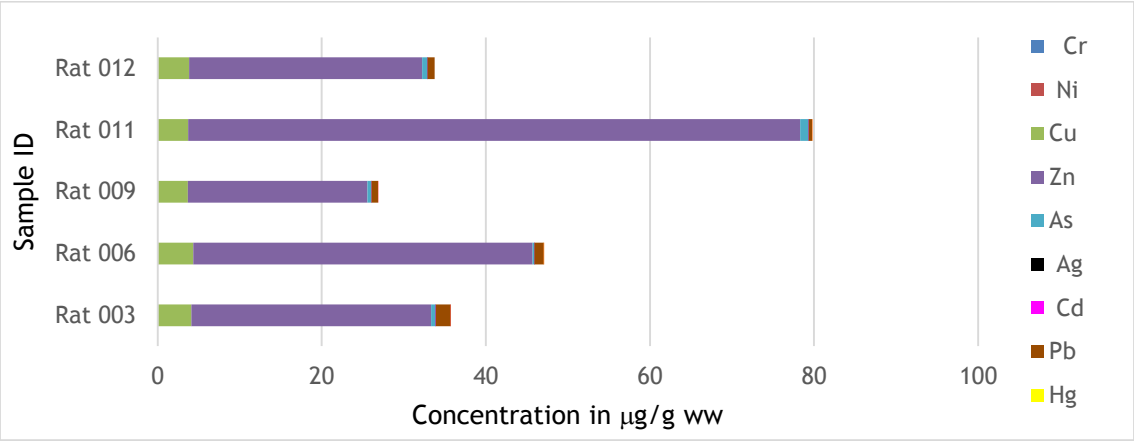


Figure 37: Metal concentrations in liver from rat in µg/g ww.

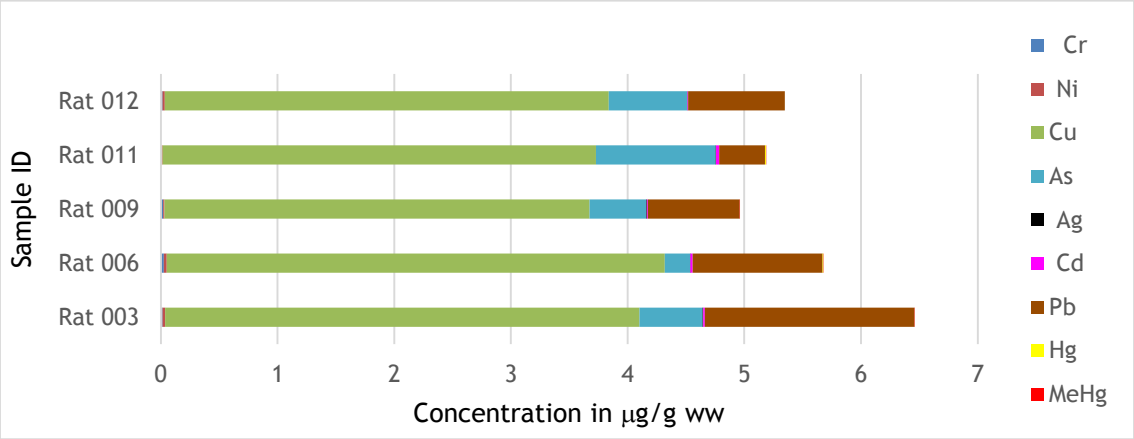


Figure 38: Metal concentrations (exclusive Zn) in liver from rat in µg/g ww.

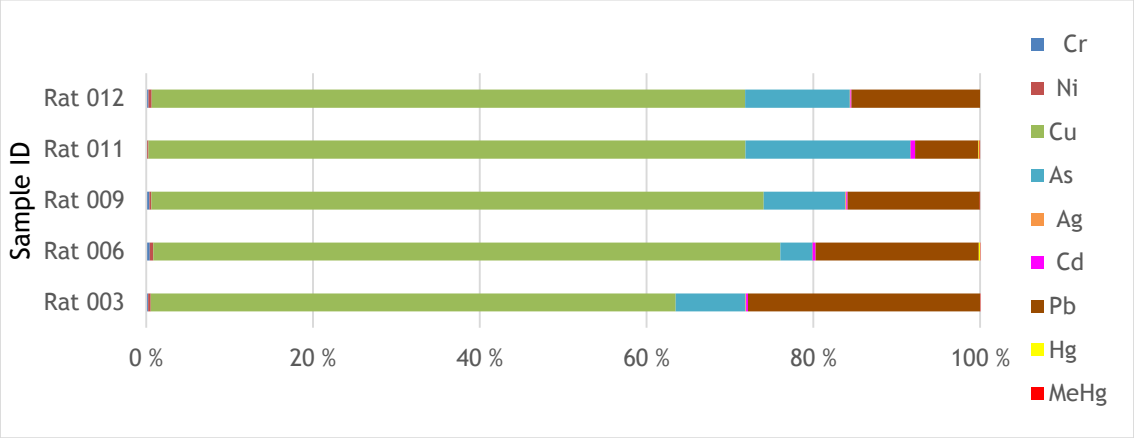


Figure 39: Relative distribution of metals (except Zn) in liver from rat.

3.5 Combined exposure assessment

In the following chapter we will assess the overall exposure of all measured pollutants in the species investigated in this study. The main aim is to compare the contribution of the investigated pollutants per species to be able to identify the main contributors to contamination. In addition, we will assess the correlation between pollutant groups to better understand exposure routes. Interspecies comparison will be discussed as well, improving the understanding of uptake and accumulation of pollutants in urban terrestrial environments. The risk for toxic/biological effects will then be considered in chapter 2.7.

3.5.1 Golden eagle eggs

The summary of all analysed pollutants in golden eagle eggs is shown in Figure 40 (in ng/g ww). Only the metals Hg, Pb, Cd and As are known to be toxic at concentrations that can be found in the environments and are therefore included in the combined exposure assessment. Based on wet weight, PCBs were the most important group, followed by Hg. (sumPCB: 402 ng/g ww, Hg: 56 ng/g ww, sumPBDE: 19 ng/g ww, sumPFAS: 12 ng/g ww, As: 7, Pb: 5, and Cd: 0.1 ng/g ww, excluding Zn) (Figure 40).

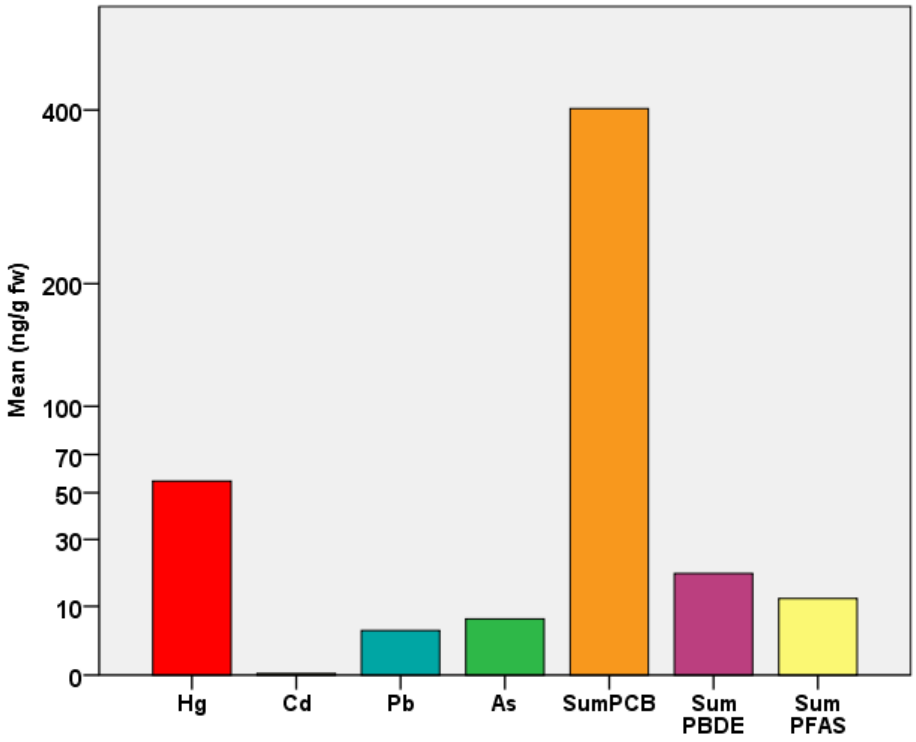


Figure 40: Combined exposure in eggs of golden eagle in ng/g fw

The correlation of sumPCB to sumPBDE reveals a very strong positive relationship as shown in *Figure 41*, indicating similar sources of exposure to the mother birds and/or similar modes of mother-egg-transfer caused by their molecular similarity and subsequent similar physical-chemical properties.

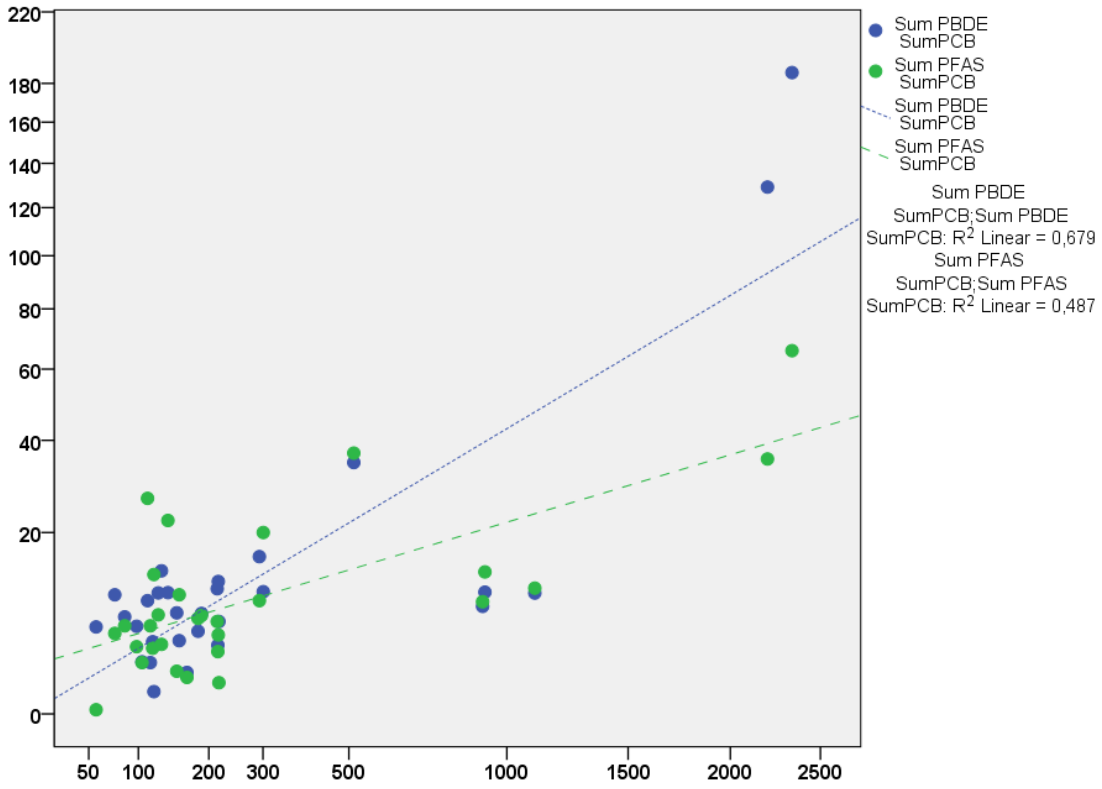


Figure 41: The correlation between sumPBDE (blue) and sumPFAS (green) (Y axis) and sumPCB (x-axis) in golden eagle eggs (ng/g fw.

The correlation between sumPFAS and sumPCB shows a much weaker relationship than between sumPBDE and sumPCB, indicating different bioaccumulation properties of PFAS (weaker correlation coefficient and lower slope) compared to PBDE (*Figure 41*). The relative distribution between the major pollutants over time has not changed considerably, but there is a weak trend for PFAS to be more prevalent over time, relative to the other pollutants (Figure 42). Nevertheless, PCBs are dominating, followed by Hg. It is, however, important to note that many organic pollutants were not analysed for, especially DDE, but also chlordanes and HCH would probably have made considerable additions to the total load (Nygård and Polder 2012). When comparing all measured pollutant concentrations on a wet weight basis, we can see that the major change over time is caused by the decrease of PCB exposure, while PBDE, PFAS and mercury exposure have stayed relatively stable (Figure 42*)*.

The changes over time of the relative contribution of all pollutants analysed for are shown in Figure 42, showing no clear evidence for changes over time in eggs of golden eagle.

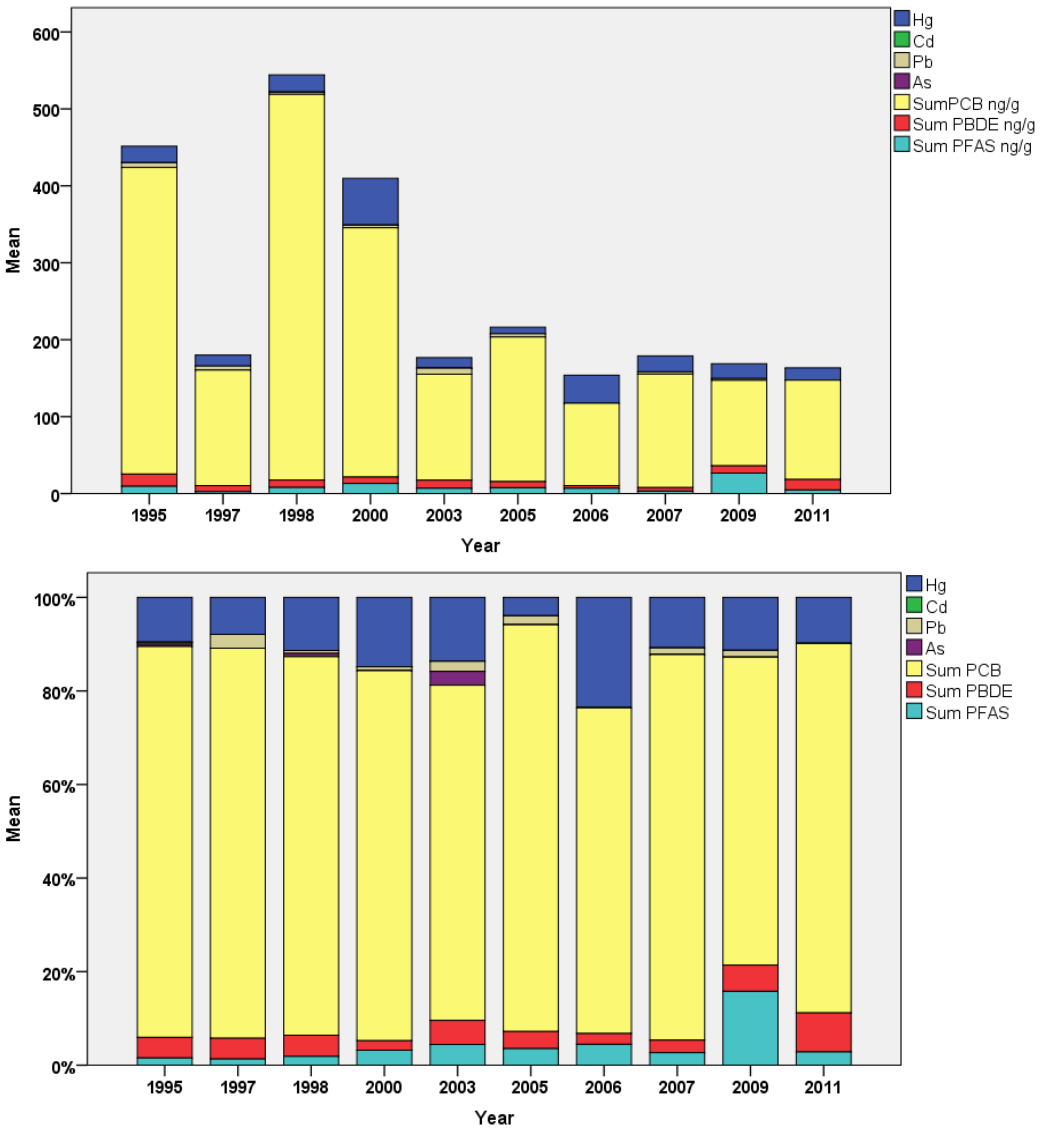


Figure 42: The actual (above) and relative distribution (below) between the different pollutants in golden eagle eggs over time.

3.5.2 Pied flycatcher

Samples of flycatcher eggs could only be analysed for PCBs and PBDE due to the limited sample amount. As shown above, sumPCB concentrations are on average 7 times higher than sumPBDE concentrations (38 and 4.9 ng/g ww respectively). Both PCBs and PBDEs, were on average considerably lower in the flycatcher eggs than in the golden eagle eggs, when compared on a wet weight basis, due to inhabiting different trophic concentrations in the trophic food chain and different lifespans. Only a week positive correlation of sumPBDE to sumPCB could be found in flycatcher egg, when analysed on a clutch average basis. This might be caused by different food choice at different sites and of different birds, but different migration habits can affect the exposure of the mother bird in the winter season too. (Figure 43). No information is available on the prey of the sampled flycatchers.

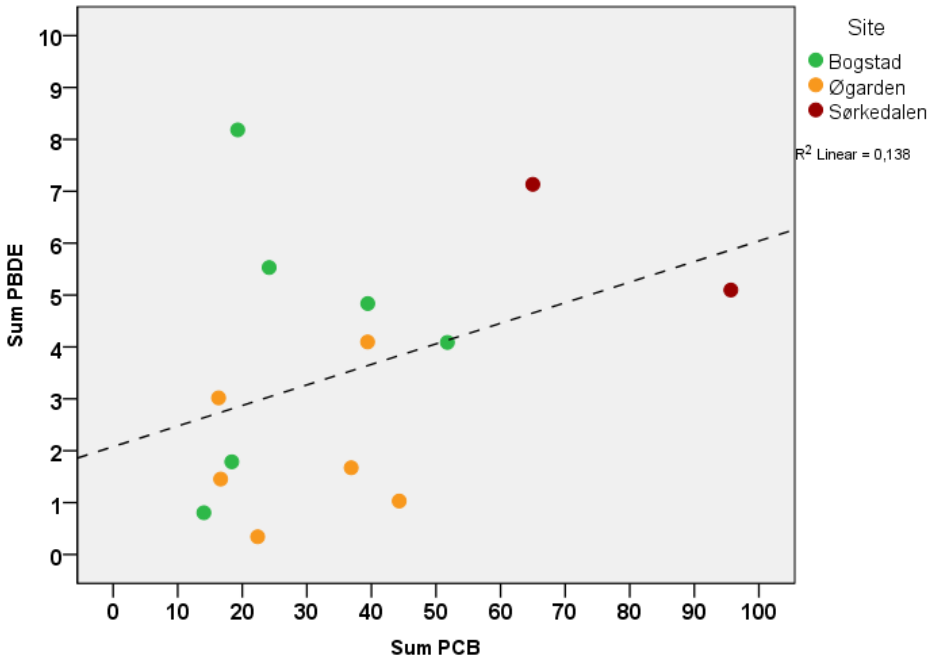


Figure 43: The correlation between sumPBDE (y-axis) and sumPCB (x-axis) for pied flycatcher eggs in ng/g ww).

3.5.3 Earthworms

Metals are the dominating contributor to the pollutant load in earthworms. The relative contribution of the toxic metals is much higher in worms than in the other species (Figure 44). PFAS were on average 12 ng/g, and PCBs were 3.4 ng/g ww in earthworms, while Pb was 2254 ng/g ww for comparison. Less than 1 % of the pollutants in earthworms were PCBs (PBDEs were not detected). At the reference site, sumPFAS concentrations reached 6.4 and sumPCB concentrations 1.4 ng/g ww. No metals were analysed in the reference sites due to limited sample amount. Organic pollutants seem to play a minor role in the contamination pattern of earthworms, with PFAS dominating the organic contamination load in earthworms followed by PCB. SumPFAS and sumPCB did not correlate with each other (r2 = 0.0016, excluding GRO 1). Due to their ionic nature are most PFAS more water-soluble than PCBs, explaining partly the domination of PFAS in the earthworms (very low lipid content of < 2%).

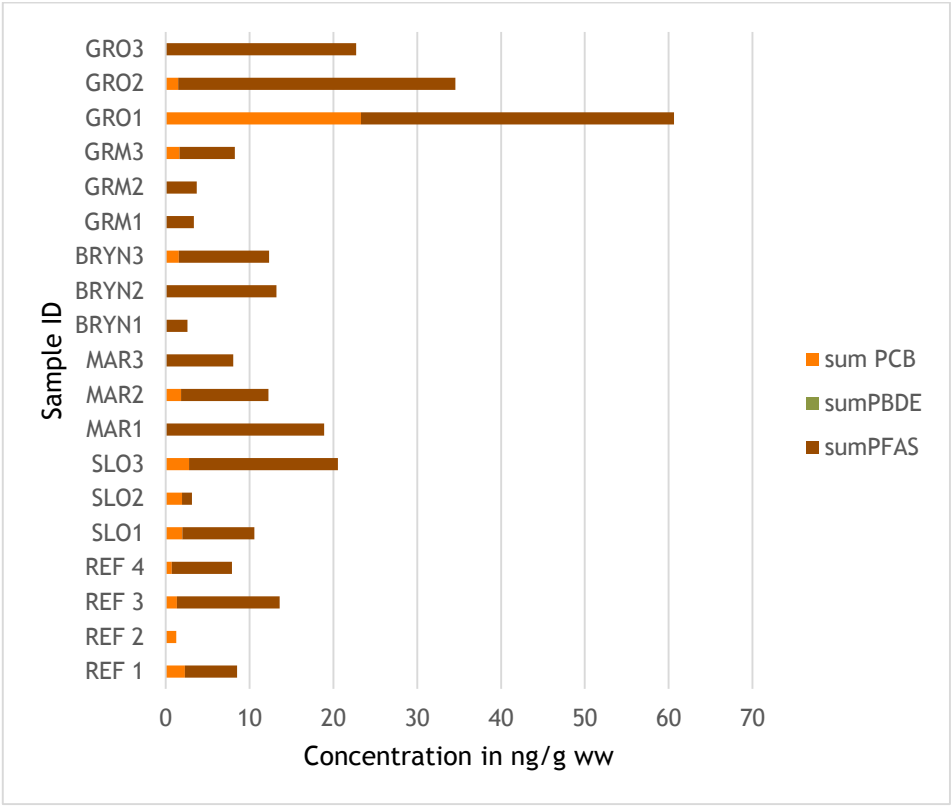


Figure 44: Overall pollution load in Earthworms in ng/g ww with organic pollutants

When considering the toxic metals measured too, the important contribution to the overall picture becomes apparent (Figure 45).

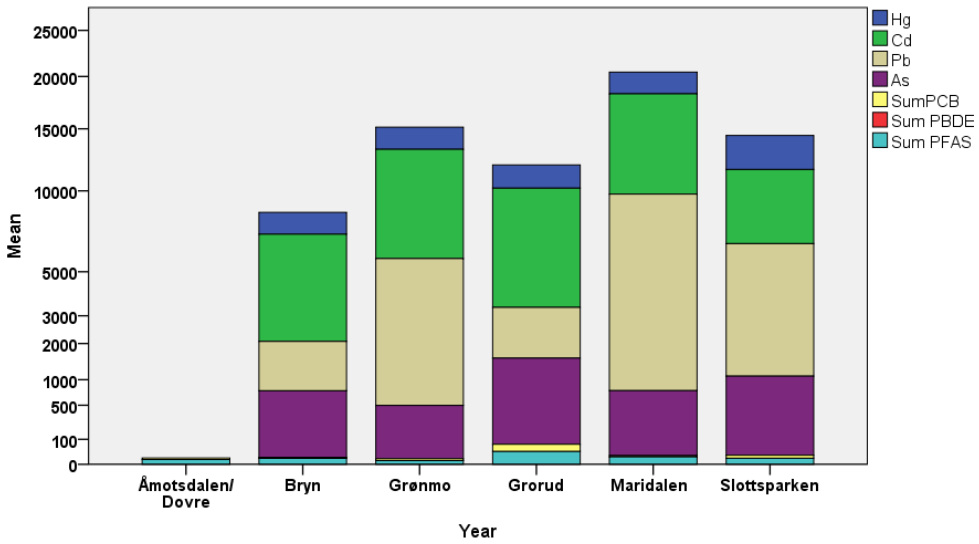


Figure 45: Overall pollution load of earthworms by site, ng/g ww. Metals were not analysed for at the reference site. Note logarithmic scale.

3.5.4 Brown rat liver

The brown rat liver samples was mostly contaminated with heavy metals (more than 95 % of the overall load). Of the organic pollutants PCBs represented the most important contributors with 40 – 90% of the overall organic pollutants load (as measured in this study). However, concentrations varied a lot between individuals (Figure 46). SumPBDE and sumPCBs were not correlated with each other. SumPCB and sumPFAS however showed a slight positive correlation of r2 = 0.35.

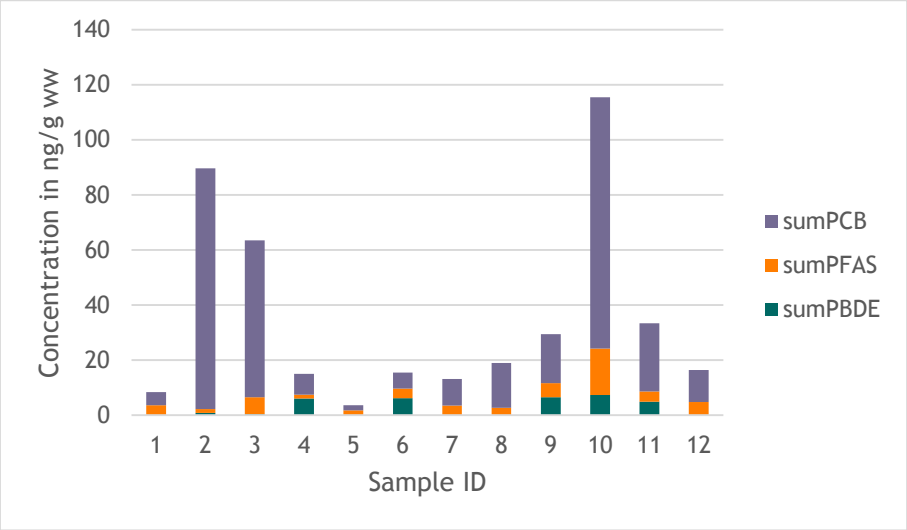


Figure 46: Combined concentrations of organic pollutants measured in brown rat liver in ng/g ww

3.5.5 Interspecies comparison; organic pollutants

When comparing the average sum concentrations of the analysed pollutants in the four observed species, interesting species related differences can be observed. We did the comparison on a wet weight basis, to be able to included non-lipophile compounds as PFAS and metals as well. Figure 47 shows the four species included in this study. Comparison is hindered by the limitation of available data caused by limited and varying sample material available. The results of this comparison should therefore be interpreted with care. In our case, no data for PFAS are available for flycatcher egg and no PBDE data for earthworms. Data for metals are left out in Figure 47, to improve the visualization of the comparison (ng/g ww).

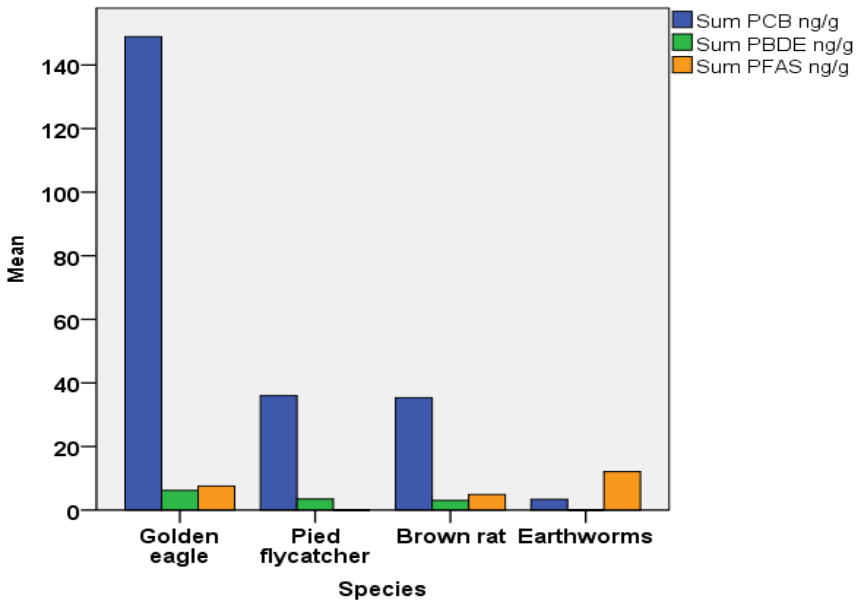


Figure 47: Comparison of average sum of different organic pollutant groups in ng/g ww. Only data from after year 2005 are used. No PFAS data available for pied flycatcher, PBDE <LOD for earthworms

On a wet weight basis, eggs of golden eagle have the highest load of total organic pollutant (average of 149 ng/g ww, after year 2005), followed by brown rats (43 ng/g ww) flycatcher eggs (39 ng/g ww), and the earthworms 15 ng/g ww).

The metal concentrations found in earthworms were much higher than compared to the other species, followed by rats (excluding Zn). The concentrations were low in golden eagle eggs, except for mercury, where concentrations were above those of rats. Metals were not analysed in pied flycatcher, due to lack of material. There were exceptionally high concentrations of cadmium in earthworms (mean of 1468 ng/g ww), much higher than in any of the other species investigated here. Latif *et al.*(2013) found lead and cadmium concentrations in three different earthworm species varying between 200 – 600 ng/g for lead and 200 and 350 ng/g cadmium . Furthermore, the lead and arsenic values were very high in both earthworms and rats. When comparing the relative contribution of the measured organic pollutants, different pollutant groups are contributing differently in the observed species. Earthworm is dominated by PFAS with more than 80%, whilst in brown rat and golden eagle PCBs are the dominating compounds. PFAS was not measured in Flycatcher eggs (Figure 48).

PCBs are the only compound group measured and detected in all target species. *Figure 48* shows that on a ww basis, very high loads in some eggs of golden eagle cause a major elevation of the average concentration.

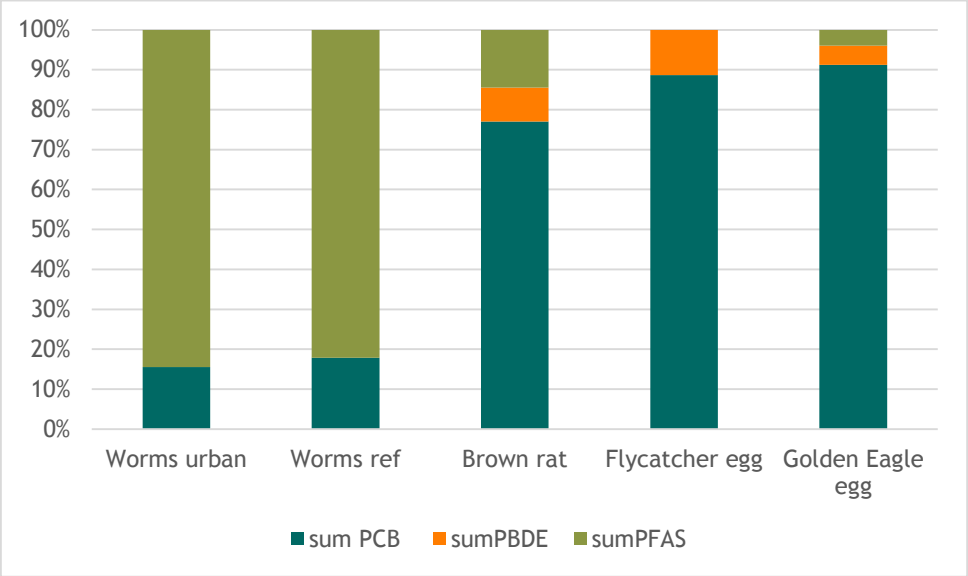


Figure 48: Comparison of relative contribution of organic pollutants in ng/g ww

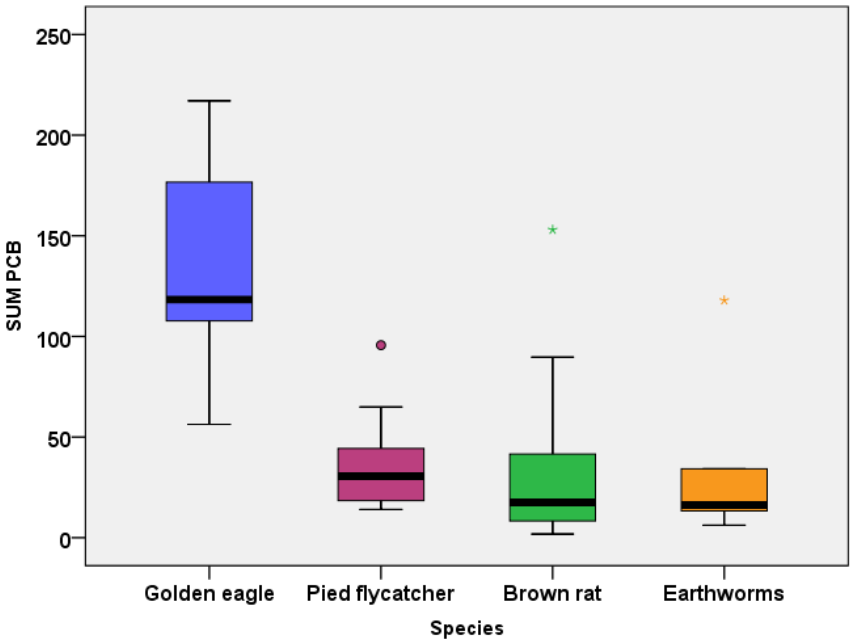


Figure 49: Comparison of sumPCB in the observed species (ng/g ww). For golden eagle eggs, only inland eggs from after 2005 were used for comparison.

3.6 Bioaccumulation

As a limiting factor, no complete food chain but rather representatives of a food web were sampled within the frame of the project. As a result, only an estimation of the biomagnification was possible. Stable isotopes were determined as supporting parameters on all biological samples within this study.

Table 15 shows an overview of log Kow values (Octanol/water coefficient) indicating the potential for bioaccumulation of lipophilic compounds. For PFAS and metals, the log Dow are given, due to their ionic nature (Rodea-Palomares et al. 2012; Li et al. 2003). PCBs and PBDEs are characterized by an increasing log Kow with increasing number of chlorine and bromine atoms in their molecules causing an increased bioaccumulation potential (log Kow > 5). The respective logDow for the ionic compounds is much lower, indicating a decreased potential for bioaccumulation. However, indications for bioaccumulations in the terrestrial food chain can be found in the literature. For comparison Müller et al. (2011), described BMF and TMFs from caribou - lichen for PFAS. Highest BMFs were found for PFDcA and PFUnA with 75 and 46 respectively. TMFs of the food chain wolf – caribou – lichen varied between 2.4 and 7.1 for all PFAS with PFDcA and PFOS showing the highest TMFs of 7.1 and 6.7 respectively. Additionally, Herzke et al, 2013, reported BMFs above 1 indicating trophic biomagnification for PFOS and all PFCAs from PFNA and longer chain length in the terrestrial ecosystems (TA-3025/2013).

Table 15: Log Kow and log Dow of selected compounds (Calculated using Advanced Chemistry Development (ACD/Labs) Software V11.02 (© 1994-2014 ACD/Labs) from SciFinder)

Compound	*Log K_{ow} or log D_{ow}*
PCB-28	5.716±0.274
PCB-52	5.831±0.362
PCB-101	6.437±0.372
PCB-105	6.712±0.371
PCB-118	6.773±0.371
PCB-138	6.983±0.381
PCB-153	7.043±0.381
PCB-170	7.445±0.390
PCB-180	7.506±0.390
PCB-183	7.250±0.390
PCB-194	7.968±0.398
PCB-206	8.170±0.406
PCB-209	8.372±0.414
PBDE-28	6.309±0.563
PBDE-47	6.680±0.588
PBDE-99	7.306±0.686
PBDE-100	7.103±0.685
PBDE-138	7.732±0.716
PBDE-153	7.933±0.715
PBDE-154	7.729±0.715
PBDE-183	8.185±0.788
PBDE-196	8.662±0.836
PBDE-206	9.169±0.855
PBDE-207	8.945±0.855
PBDE-209	9.453±0.871
PFOS	-4.76
PFOA	0.94
Hg2+	3.2
Cd2+	-0.07

δ^{15}N data can be used to estimate the relative trophic positions of an organism. The terrestrial food chain is in general very short, preventing major bioaccumulation of pollutants. In our case, four species, representing different positions in the food web, were sampled. Rural earthworms represents the lowest trophic position, followed by urban earthworms, brown rat, flycatcher and golden eagle. *Figure 54* shows the δ^{15}N signature of the four investigated species.

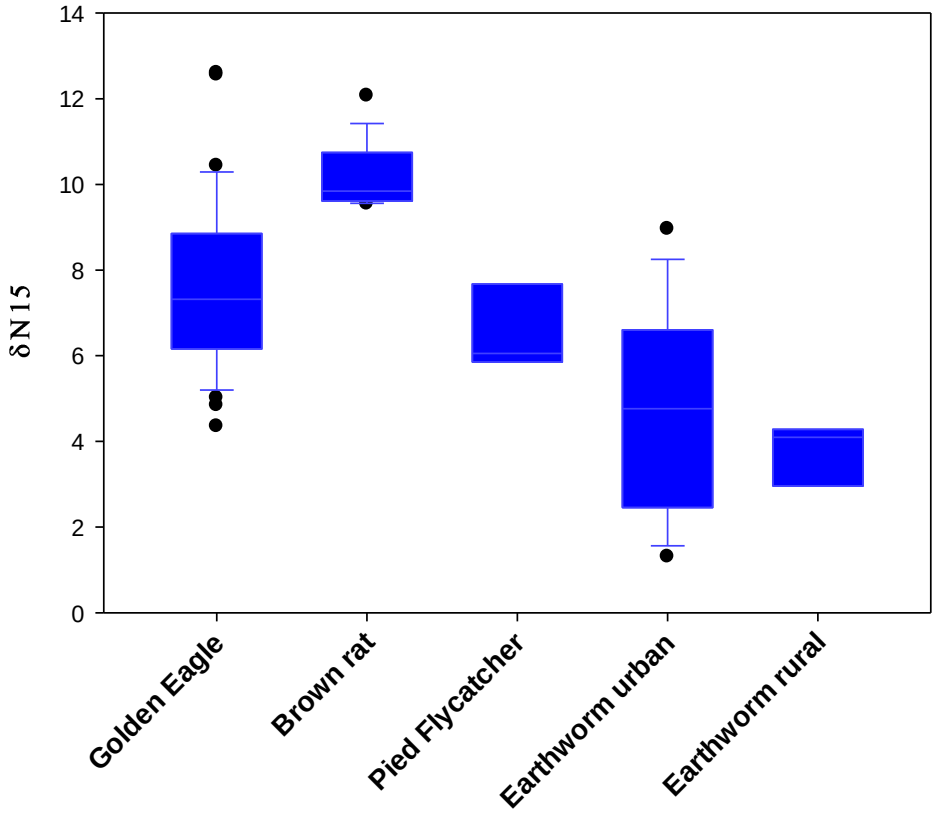


Figure 50: Boxplot of δ^{15}N concentrations in the different species analysed (golden eagle: includes all years).

The δ^{15}N concentrations indicate which trophic concentration is occupied by a species. δ^{13}C values provide information regarding the source of dietary carbon, e.g. marine or freshwater and aquatic or terrestrial. Eggs from marine locations are expected to show a less negative δ^{13}C value than eggs from terrestrial locations. However, direct comparison of the here presented data should be done with care, since different tissues were analyses (eggs, liver, whole individuals) reflecting a different turnover rate of the dietary exposure. Compared with a marine food chain, the terrestrial food chain is short and differences in δ^{15}N are not that distinguished. Concentrations of bioaccumulating pollutants (ex. PCBs, PBDEs, some PFAS) are therefor expected not to differ extensively between the here investigated species.

Brown rat is characterized by the highest δ^{15}N concentrations followed by golden eagle and pied flycatcher eggs. Both bird species are considered as tertiary consumers but feeding on different food items (insectivorous and carnivorous). As the distribution of δ^{15}N concentrations in golden eagle eggs illustrates, the δ^{15}N varies quite a lot (ranging between 4 and 13, average = 7.6, SD = 2.1), and the variation is probably caused by individual food choice. In general, eggs from sites classified as coastal exhibit higher δ^{15}N concentrations than eggs from inland sites, with the exception of one single egg, but even birds breeding fairly close to the coast can feed on a purely terrestrial diet (Figure 50) indicating that the respective species can reach higher

trophic concentrations than expected, probably caused by local feeding opportunities, where food of marine origin will play an important role (Figure 50). However, the data shown in Figure 50 indicate too, that eggs collected at various locations inland are characterized by a similar $\delta^{15}N$, evidencing the motherbirds are feeding on a similar trophic concentration, even if eggs are collected at different years and locations.

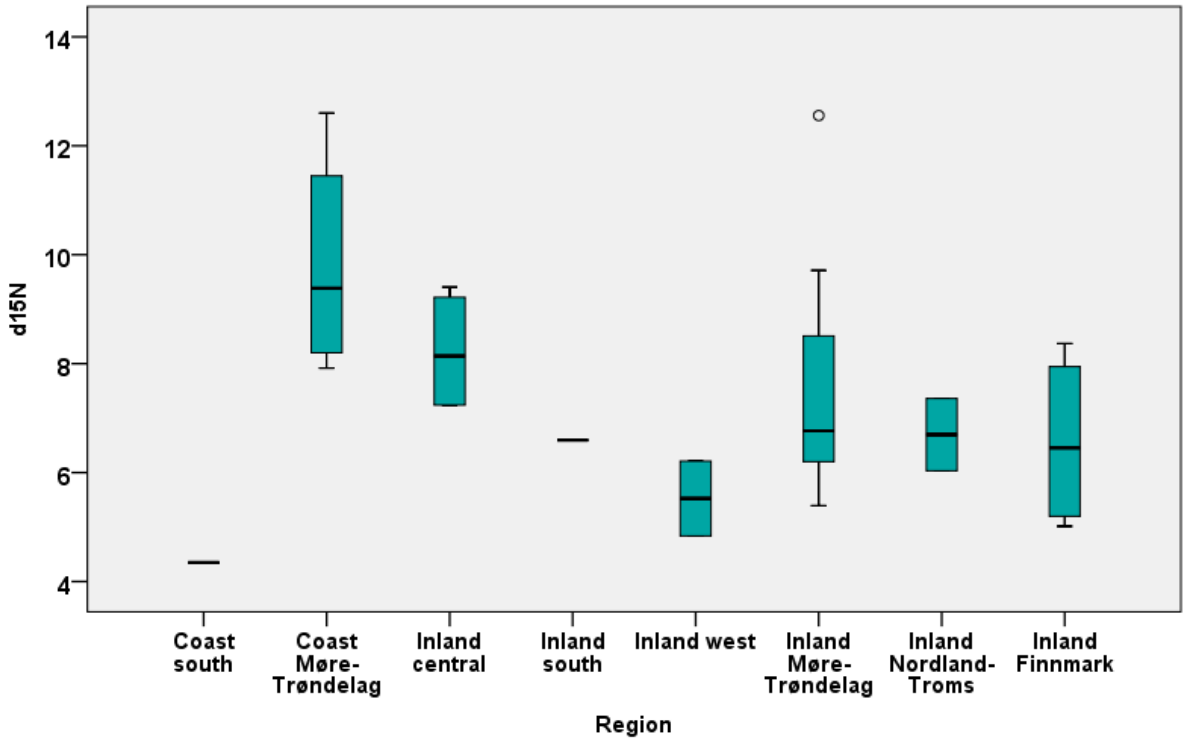


Figure 51: $\delta^{15}N$ concentrations in eggs of golden eagle from different regions in Norway (clutch averages)

The brown rat is residing on the highest trophic concentrations caused by the opportunistic feeding on a broad range of food items often consisting of human food waste. For earthworms, the average $\delta^{15}N$ concentrations vary considerably too (average of 4.7 in urban and 3.8 in reference location), maybe caused by the difference of measurements included in the measurements (n= 4 for the reference location and n= 15 at the urban site).

The differences in $\delta^{13}C$ concentrations found in golden eagle eggs ranged between -20 and -30 (Figure 52), but with an average of -26,6, SD = 1.7. For comparison with the marine food chain, a range of $\delta^{13}C$ concentrations between different gull species of -17 - -25 was found (Gebbink and Letcher 2012; Gebbink et al. 2011). Brown rat and pied flycatcher as well as earthworms were showing similar concentrations, averaging at -26 ‰ (*Figure 53*), indicating all selected species are part a similar food chain, feeding on the terrestrial food items.

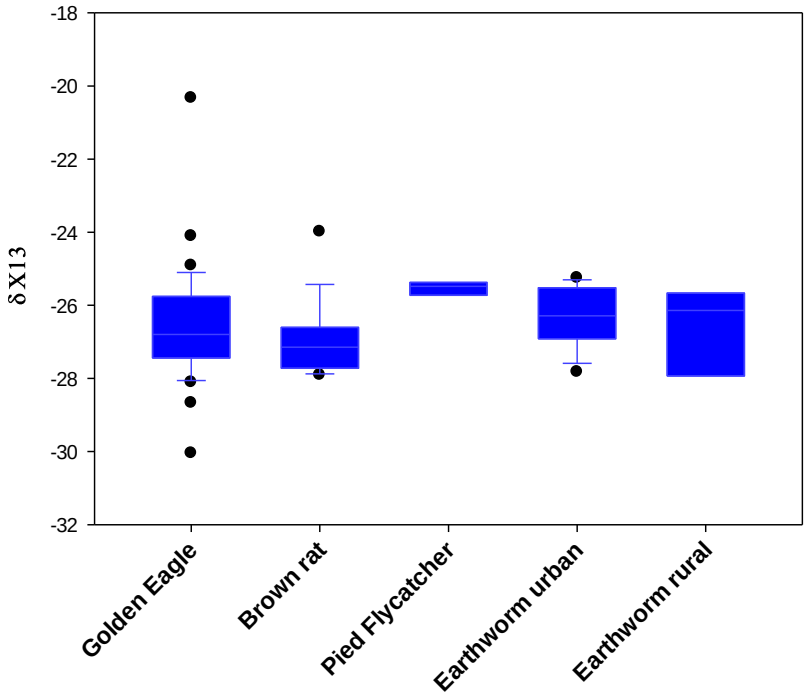


Figure 52: Boxplot of $\delta^{13}C$ concentrations in golden eagle eggs, pied flycatcher eggs, brown rat liver and earthworms; b: in eggs of golden eagle from different regions in Norway (clutch averages)

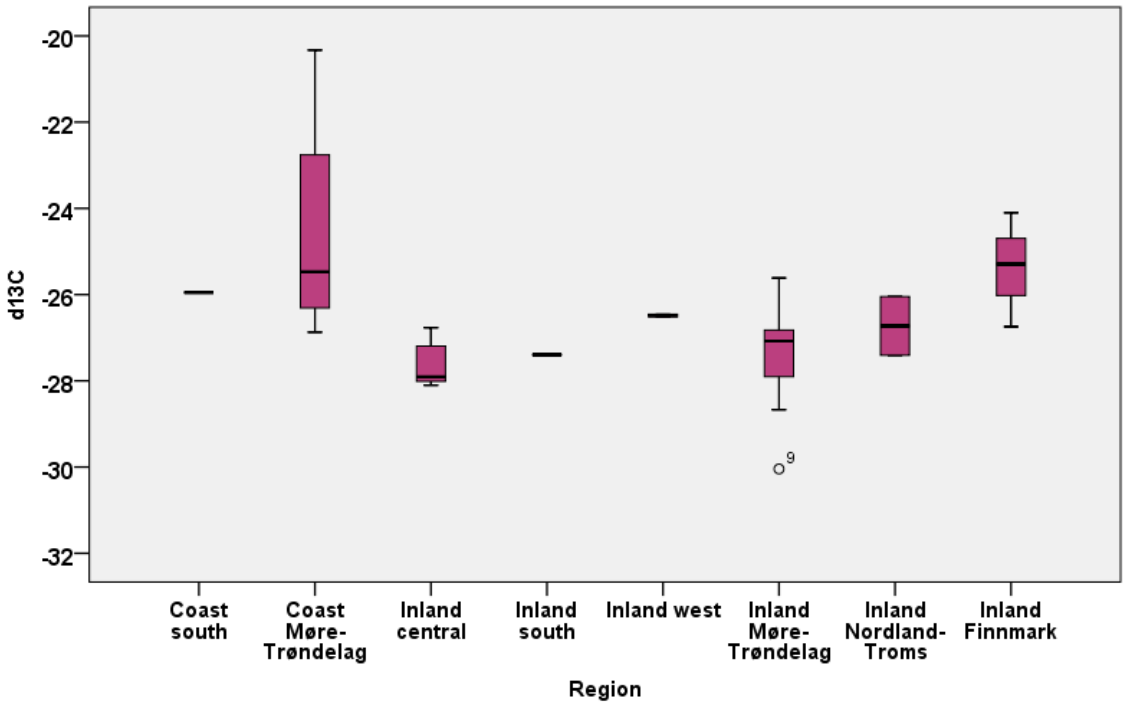


Figure 53*: Boxplot of $\delta^{13}C$ concentrations in golden eagle eggs from different regions in Norway (clutch averages)*

When relating all samples against $\delta^{13}C$ and $\delta^{15}N$, following graph is achieved, showing a clear distinction between feeding strategy of rats and earthworms and golden eagle and flycatcher with some overlap in between, spanning more than one trophic concentration (Figure 54). The spread in $\delta^{13}C$ suggest that there is considerable variation in the diet of golden eagle and much less for pied flycatchers.

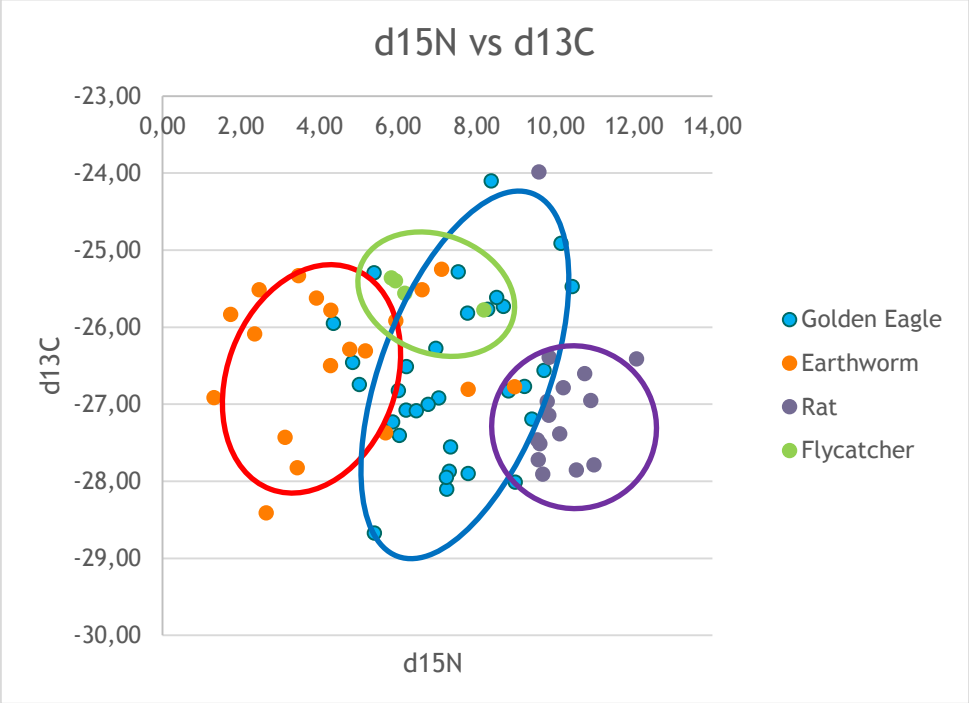
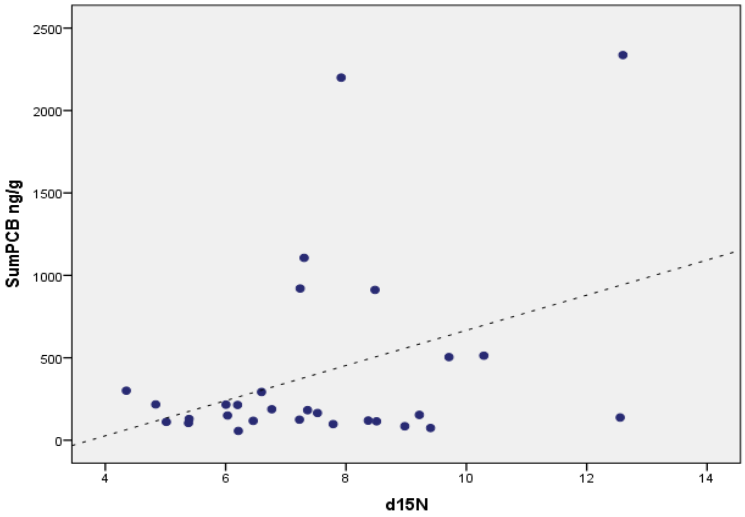
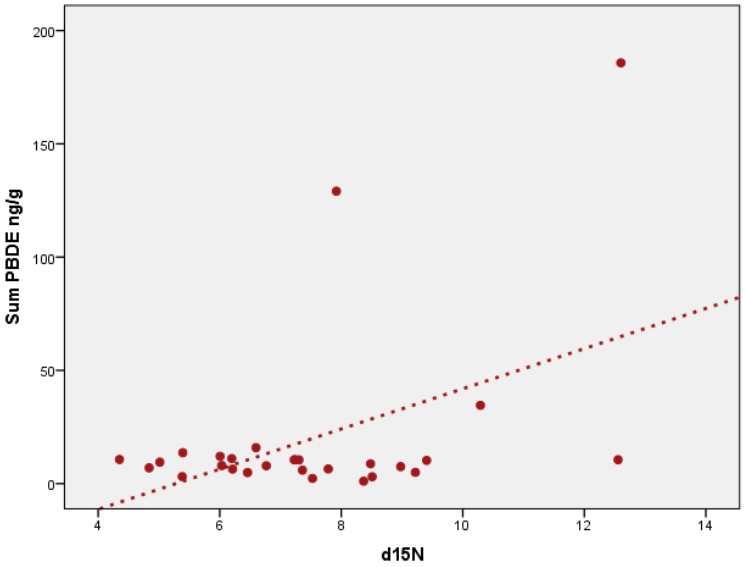
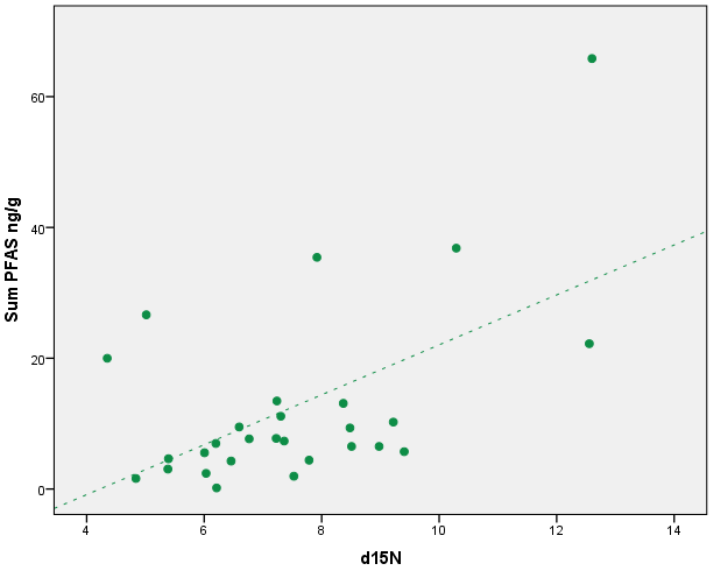


Figure 54: Relationship between the dietary descriptors $\delta^{15}N$ and $\delta^{13}C$ in biota from urban terrestrial environments

For the golden eagle eggs, $\delta^{15}N$ concentrations can be compared with the sum parameters of all investigated compounds groups and excluding coastal eggs (sumPCB, sumPBDE, sumPFAS and mercury).These correlations allow us to assess the impact the dietary exposure has on the respective pollutant load (feeding on food items high or low in the trophic chain). They are illustrated in *Figure 54*, where the x-axes represents the $\delta^{15}N$ concentrations and the y-axes the respective sum parameter. Only a week linear relationship was found, when relating sumPCB and sumPBDE to $\delta^{15}N$ concentrations. However, the main part of the samples show a broad range of $\delta^{15}N$ concentrations with relatively similar low sumPCB and sumPBDE concentrations, and with R^2 values < 0.25. This may be caused by the fact that a single or a few highly contaminated food items are able to raise the contamination concentrations in the eggs considerably, but the $\delta^{15}N$ concentrations will not be raised proportionally. Different transfer mechanisms and kinetics from mother to egg of the various organic pollutants might play a major role too. This is especially evident for both PCBs and PBDEs, also for PFAS and mercury, but to a lesser degree (Figure 55).


SumPCB ng/g
2500
2000
1500
1000
500
0
4
6
8
10
12
14
d15N


Sum PBDE ng/g
200
150
100
50
0
4
6
8
10
12
14
d15N


Sum PFAS ng/g
60
40
20
0
4
6
8
10
12
14
d15N

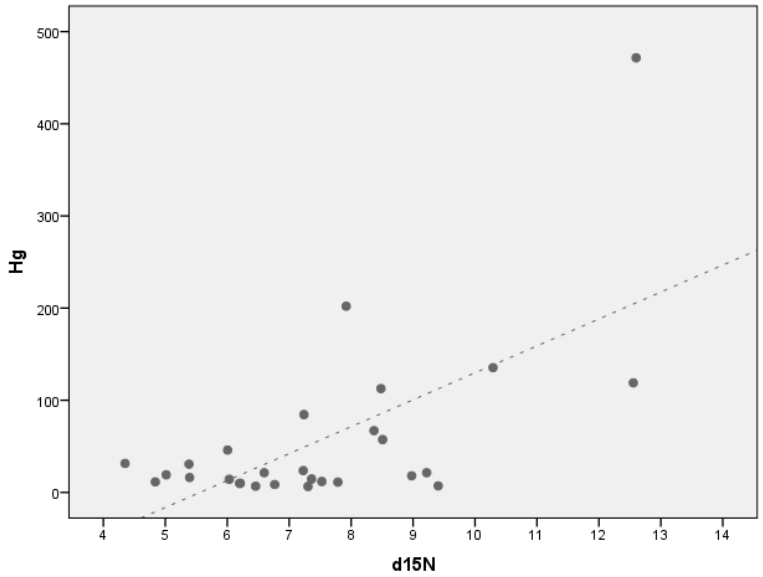
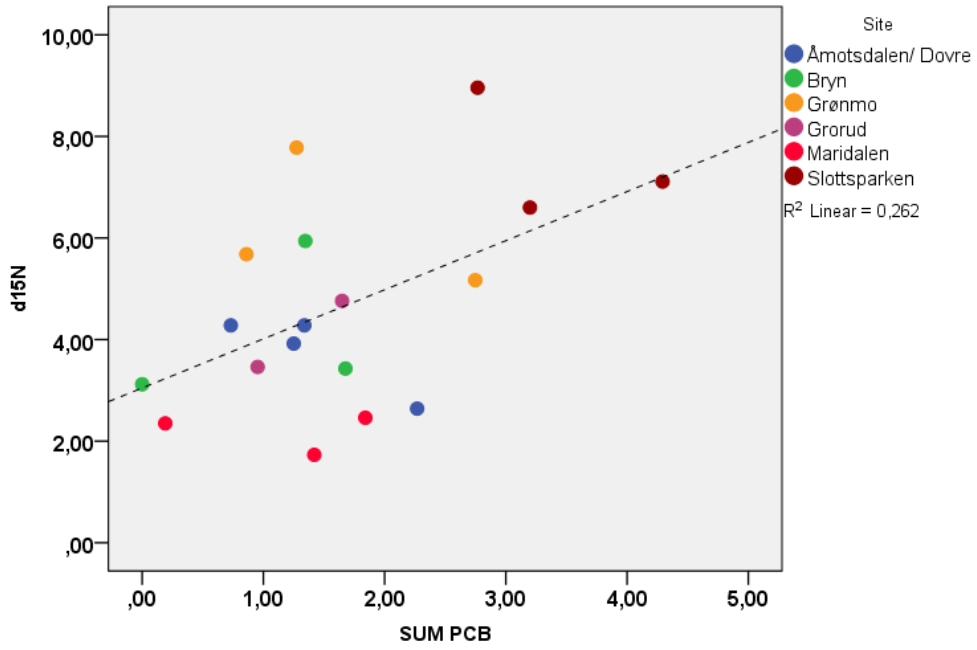
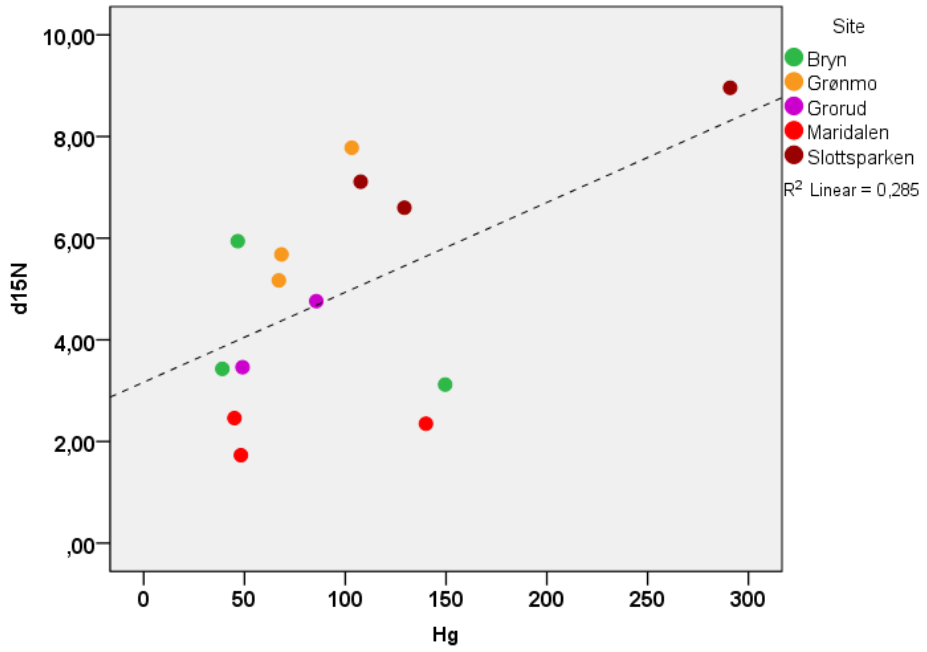


Figure 55: Linear relation of $\delta^{15}N$ and sum parameters data in golden eagle eggs in ng/g fw

For PFAS, a positive linear relationship between sumPFAS and $\delta^{15}N$ concentrations was found (R^2 = 0.31), indicating a stronger relationship between the diet of the mother bird prior egg laying and PFAS concentrations in the eggs caused by an efficient transfer of PFAS into the eggs. For mercury, a weaker positive relationship between and $\delta^{15}N$ concentrations was seen (R^2= 0.40). This indicates that PFAS and mercury (in organic form) are differently transferred to the eggs after dietary intake compared to PCBs and PBDEs during the egg-formation period. Subsequently do food items from higher trophic concentrations have a greater impact on the PFAS and mercury concentrations found in the eggs than on PCB and PBDE concentrations. Different mechanisms of re-mobilisation out of maternal lipid tissues versus direct transport from food items into the eggs might explain the differences found. The comparison of stable isotope concentrations with PCB and PBDE concentrations in golden eagle eggs might not be suitable for the assessment of bioaccumulation. The conversion of wet weight concentrations of PCBs and PBDE did not improve the correlation either. In general, the contaminate load in golden eagle eggs cannot be explained by the $\delta^{15}N$ concentrations for PCBs and PBDEs and in only a minor degree for PFAS and Hg.

In Figure 56 the relationship between $\delta^{15}N$ and contaminants in earthworms are shown in a similar manner as for the golden eagle eggs. For the relationship of $\delta^{15}N$ and sumPCB, one highly contaminated sample from Grorud was removed. A significant positive relationship was found (P = 0.03). A positive relationship between mercury and $\delta^{15}N$ values was also found (P = 0.04), but caution should be made due the limited number of samples and one outlier (*Figure 57*). No relationship between sumPFAS and $\delta^{15}N$ could be found. In general, $\delta^{15}N$ concentrations are contributing to the explanation of PCBs and mercury concentrations in earthworms to some degree, but not to PFAS.


Site
Åmotsdalen/ Dovre
Bryn
Grønmo
Grorud
Maridalen
Slottsparken
R² Linear = 0,262
d15N
SUM PCB
10,00
8,00
6,00
4,00
2,00
,00
,00
1,00
2,00
3,00
4,00
5,00


Site
Bryn
Grønmo
Grorud
Maridalen
Slottsparken
R² Linear = 0,285
d15N
Hg
10,00
8,00
6,00
4,00
2,00
,00
0
50
100
150
200
250
300

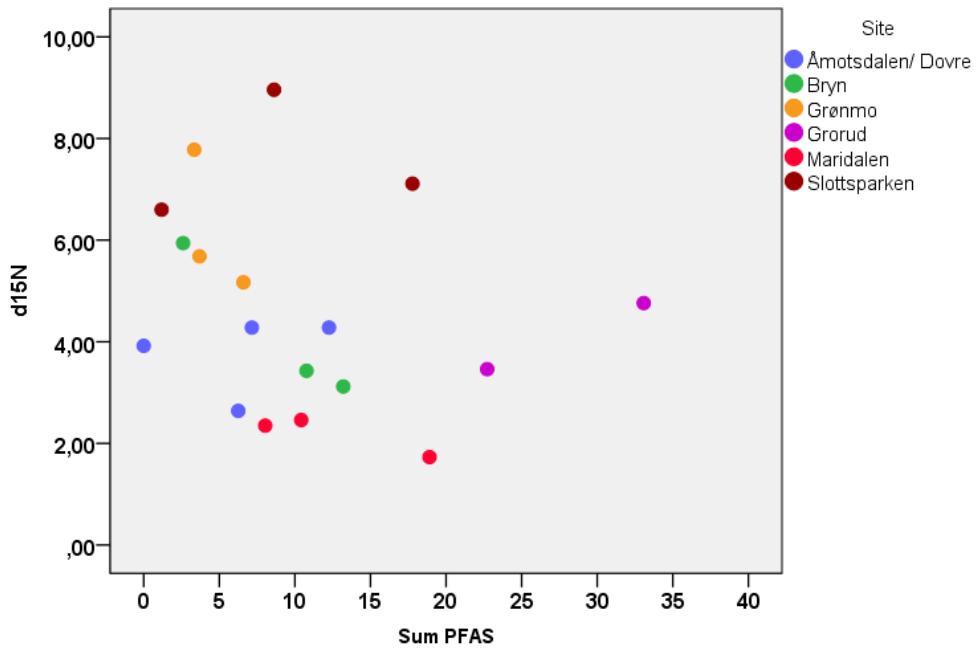


Figure 56: The relation between $\delta^{15}N$ and sumPCB, sumPFAS and mercury (wet weight values) in earthworms collected at different sites in Oslo.

Similar figures for pied flycatcher are unavailable since the stable isotopes were measured in liver from unhatched chicks whilst the pollutants were measured in eggs, caused by limited sample material available.

In summary, the terretsrial food chain is very short (consisting of 3 – 4 steps: plant as primary producer (1st trophic concentration), insects and smal mammals as primary consumer (2nd trophic concentration), small birds and mammals as secondary consumers (eats primary consumer, 3rd trophic concentration) and predators as tertiary consumer (4th trophic concentration). The in this study selected species represent species from the 2nd trophic concentration (earthworms), and from the 3rd and 4th trophic concentration (pied flycatcher and golden eagle), where the golden eagle feeds on a variety of primary and secondary consumers. Different migration habits and lifeexpectancies will have an impact on pollutants concentrations found in eggs too. The urban brown rat cannot be characterised by trophic concentrations, since it feeds opportunistically including human food waste. For future sampling campaigns the incorporation of a complete terrstrial food chain, consisting of non-migrational species sampled in the same region/ timeperiod and similar tissue types is recommended.

4. Mixture risk assessment

In the natural environment, living organisms are not only exposed to one single pollutant, but to a variety of different contaminants. The exposure to the mixture of chemicals is first and foremost through food (prey), but also from water and the environment they live in.

Current regulatory approaches to the assessment of chemicals are usually based on the evaluation of single substances, chemical by chemical. The assessments include safety margins to take account of uncertainties, such as how exposure to many different chemicals may affect the environment and humans. However, there are concerns that this does not provide sufficient security and that the combination effects of chemicals should be addressed in a more systematic way.

Several comprehensive studies and reviews have been conducted in the field of combined effects of contaminants from component based approach (Altenburger et al. 2013). The most known methodology able to predict combined effects in various studies is the method of concentration addition (CA) or dose addition. In a component based approach of CA the effects of mixture components as single chemicals must be known and their concentrations in the mixture (mixture ratio).

Mixture toxicities higher than predicted by CA are hardly ever found, and experts have suggested to apply CA as a precautious first tier, irrespective of the modes/mechanisms of action of the mixture components (Backhaus and Faust, 2012).

4.1 Pragmatic component-based approaches

Risk evaluation of combined effects of contaminants may be conducted when concentration and effect concentrations for the contaminants of interest are known. However, the effect data (i.e EC50) of all single chemicals are not always available for one particular species, especially not when one require the same mechanism and effect end points. However, various risk assessment methods according to the CA approach are in use, such as toxic equivalent factor approach, toxic unit summation, hazard index and the point of departure index (Kortenkamp et al. 2009; Altenburger et al. 2014). The CA approach gives a conservative estimate of risk. In most cases CA predicts higher mixture toxicity compared to other methods such as Independent Action (IA), which is why CA would seem a reasonable worst case model for a non interactive combined effect prediction (Altenburger et al. 2014).

The most appropriate method is to calculate the expectable toxicity of the mixture of concern on the basis of toxicity data for individual mixture components, by applying one or more methods from the so-called *component-based approach,* Table 16.

Table 16: Examples of pragmatic generalizations of CA for regulatory purposes (adapted from Altenburger et al. 2014, Table 4.1)

Approach	Assessment term	Notes
CA *Concentration (Dose) Addition*	$E_{mix} \leq x$ if $\sum_{i=1}^{n} \frac{c_i}{ECx_i} \leq 1$	$\frac{c_i}{ECx_i} = TU_i = ToxicUnit$
PODI *Point of Departure Index*	No significant effect if $\sum_{i=1}^{n} \frac{EL_i}{POD_i} \leq 1$	EL = Exposure Level POD = LOEL, NOAEL, NOEC
HI *Hazard Index*	No reason for concern if $\sum_{i=1}^{n} \frac{EL_i}{AL_i} \leq 1$	EL = Exposure Level AL = Acceptable Level = ADI, DNEL, …
PEC/PNEC Summation	No unacceptable risk if $\sum_{i=1}^{n} \frac{PEC_i}{PNEC_i} \leq 1$	PEC = Predicted Environmental Concentration PNEC = Predicted NEC

As seen form Table 15, the CA approach is the only method uses true effect concentration of the chemicals. i.e. EC_x. This is a scientifically more correct approach with the use of the same biological endpoint for all substances. In principle, the other CA-based approaches (PODI, HI and PEC/PNEC) have one thing in common; the replacement of actually effect concentrations (or doses) such as ECx of single substances by surrogate values (for instance POD, AL or PNEC), which are assumed to give an acceptable approximation. These CA approaches deviate from the original scientific definition of CA and basic requirements with some important parts briefly described (Altenburger et al. 2014) below:

(1)Not strictly identical toxicological endpoint
Pragmatic regulatory CA-based approaches may use single substance toxicity data although they do not refer to strictly identical toxicological endpoints under identical exposure situations. In principle, this kind of deviation from the original concept is therefore included in almost all suggested CA-based approaches, explicitly or implicitly. This is for instance relevant when applying PNEC approach.

(2) NOEC instead of ECx
Many suggested CA-based approaches use NOEC or NO(A)EL values instead of effect concentrations (ECx) as input variables, and correspondingly they generate estimates of NOEC or NO(A)EL values as output. NOEC and NO(A)EL from chronic effect test are applied when generating PNEC values, see also what is described in (3).

(3) Extrapolation factors included in single substance toxicity data
For the purpose of deriving regulatory *acceptable concentrations* (AL), experimental effect concentrations or NOEC or NO(A)EL values are usually multiplied with so-called *assessment factors*, *uncertainty factors*, or *extrapolation factors*. In general, they aim to take account of potential sensitivity differences between individuals and between species and to cover differing exposure conditions. Some CA-based approaches enter such *acceptable concentrations* of individual toxicants into the CA formula with the aim to derive a corresponding estimate for an acceptable concentration of a mixture. When generating PNEC values it is a common procedure to multiply NOEC or NO(A)EL with assessment factors dependent on type of ecosystem and trophic concentration.

CA based risk assessments have recently been performed to address topics such as cumulative health risks for hepatoxicity and reproductive toxicity of 17 perfluorinated and polyfluorinated substances (PFAS) in Swedish population (Borg et al. 2013) and combined risk of perfluorooctane sulfonate (PFOS), TBT, PBDEs, PCBs, PAHs, phenols, and organonitrogen pesticides from three Belgian coastal harbors (Ghekiere et al. 2013).

The reference value PNEC is the concentration of the substance below which adverse effects in the environment are not expected to occur in the most sensitive species of the respective ecosystem. This approach is known to be slightly more conservative than the summation of toxic units which would be the scientifically more correct approach with the use of same biological endpoint. A PNEC is obtained through the application of an assessment factor to ecotoxicological endpoints (EC50 or NOECs) using organisms with different sensitivities for any type of chemical. The size of the assessment factor depends on duration of the test (acute or chronic), the number of trophic concentrations tested and the general uncertainties in predicting ecosystem effects from laboratory data.

PEC/PNEC summation violates the principle that data entered into the CA formula should refer to the same biological endpoint in the same species. However, it has been proved slightly more conservative and, in some cases, more easily applicable. Therefore, for pragmatic reasons, it may be used as a first-tier conservative approach when applying concentration addition. Importantly, it must be assumed as a concentration protective for the highest hierarchical concentrations of the biological organization (population, community) and does not exclude effects on individuals (SCHER 2012). For ecological effects, the exposure to mixtures of dissimilarly acting substances at low but potentially relevant concentrations should be considered, even if all substances are below the individual PNECs. Only if PEC/PNEC indicates possible reasons for concern, the summation of toxic units (STU) approach, which may require the generation of further data, is recommended as a second step (Backhaus and Faust 2012; Altenburger et al. 2014).
In this present report the above mentioned approach recommended by Backhaus and Faust (2012) and Altenburger et al. (2014) was used. EQS or quality standards (QS) for terrestrial biota were scarce but PNEC values for soil ecosystem including PNEC for predator ($PNEC_{pred}$) for various contaminants, were available from a Norwegian study (Andersen et al. 2012). Secondary poisoning is related to toxic effects of the higher members of the food chain in the terrestrial environment, resulting from ingestion of organisms from lower trophic concentrations that contain accumulated substances. Only toxicity studies reporting on dietary and oral exposure are relevant as the pathway for secondary poisoning and is referring exclusively to the uptake through the food chain. Secondary poisoning effects on bird and mammal populations rarely become manifest in short-term studies. Therefore, results from long-term studies are strongly preferred, such as NOECs for mortality, reproduction or growth. If no adequate toxicity data for mammals or birds are available, an assessment of secondary poisoning cannot be made. If a chronic NOEC for both birds and mammals is available, the lower of the resulting PNECs is used in the secondary poisoning assessment to represent all predatory organisms (ECHA, 2008).

The $PNEC_{pred}$ values (Table 18) for the various contaminants investigated in present study were adopted and applied in order to do an initial mixture risk assessment. For the single contaminant or contaminant group the ratio MEC/PNEC was calculated, where MEC is Measured Concentration in the various organisms. The sum of the single MEC/PNEC was then calculated to assess if it exceeded 1 or not. The use of MEC for earthworm in relation to $PNEC_{pred}$ gave us an indication of the mixture risk for predators and higher trophic concentration where earthworm is an important prey. The $PNEC_{soil}$ values (Table 17) was only used in order to evaluate briefly the combined risk of contaminants to earthworm as an important species of soil system, data not shown in tables.

It must be emphasized that this is an initial mixture risk assessment of only some contaminants with available $PNEC_{pred}$ values. The presumption of our approach is that the available $PNEC_{pred}$ values are protective and assessed for the most sensitive species, in accordance to the guidelines for deriving PNEC values (ECHA, 2008).

Table 17: PNEC values for **soil ecosystem** with references (adopted from Andersen et al. (2012); SSD: species sensitivity distribution

Compound	$PNEC_{soil}$	Unit	Reference	Safety factor	Endpoint
PentaBDE	0.38	mg/kg dw	TA-2625	50	
OctaBDE	20.9	mg/kg ww	EU RAR 2003	50	Phytotoxicity
DecaBDE	98	mg/kg ww	EU RAR 2002	50	
HexBDE	1.2	mg/kg ww	EU RAR 2003	50	Phytotoxicity
TriBDE	20.9	mg/kg ww	Using Octa BDE value	50	Phytotoxicity
TetraBDE	20.9	mg/kg ww	Using Octa BDE value*	50	Phytotoxicity
HeptaBDE	20.9	mg/kg ww	Using Octa BDE value	50	Phytotoxicity
NonaBDE	20.9	mg/kg ww	Using Octa BDE value	50	Phytotoxicity
PFOA	0.16	mg/kg dw	TA-2444/2008	100	Worm reproductivity
PFOS	0.373	mg/kg dw	pfos.uk.risk.eval.report.2004	1000	Worm toxicity
$SumPCB_7$	0.01	mg/kg dw	Aquateam rapport nr 06-039	50	Calculated from aquatic data
Cd	1.15	mg/kg dw	European chemicals Bureau, 2007	2	SSD
Cr	62	mg/kg dw	European chemicals Bureau, 2005	3	Estimated from aquatic data
Cu	89.6	mg/kg dw	European chemicals Bureau, 2008	2	SSD
Hg	0.3	mg/kg dw	Euro-chlor, Voluntary risk assessment, Mercury, 2004	1000	Background value soil
Ni	50	mg/kg dw	VKM report 2009	2	SSD
Pb	166	mg/kg dw	EURAS, 2008	2	SSD
Zn	26	mg/kg dw	VROM, 2008	2	SSD

Table 18: $PNEC_{pred}$ values (mg/kg) for **secondary poisoning** with references (adopted from TA-3005/2012) [1]

Compound	$PNEC_{pred}$ mg/kg	Reference	Safety factor	Endpoint
PentaBDE	1	EU Risk assessment-Diphenyl Ether, Pentabromo derivative Final Report, August 2000	10	30 day oral rat study-liver effects
OctaBDE	6.7	EU Risk assessment-Diphenyl Ether, Octabromo derivative Final Report, August 2003	10	Rabbit phetotoxicity
DecaBDE	833	DecaBDE, EA-ENvRA-2009	30	Rat, two years carcinogenicity study
PFOS	0.013	Newstedt et al 2005	30	Quail reproduction study
Cd	0.16	EU RAR	10	Based on 4 studies with birds and 5 studies with mammals
Cr	1468*	EPA, Integrated Risk Information System		NOAEL rat experiments,
Cu	1.4*	NZ MFE Draft Toxicological Intake Values for Priority Contaminants in Soil		NOAEL from liver damage of humans. Uncertainty factor 10 removed.

Compound	$PNEC_{pred}$ mg/kg	Reference	Safety factor	Endpoint
Hg	0.4	2009, Munoz et al.	10	NOEC 4 mg/kg food for Coturnis c. Japonica.
Ni	8.5	EU RAR Ni 2008	10	Wild duck, tremor effects observed in chickens at day 28
Pb	3.6	Lead Water Framework Directive EQS dossier 2011	15	SSD

[1]$PNEC_{pred}$ not found for PCB7, * No PNEC value established for Cr and Cu

As Table 18 illustrate PFOS, cadmium and mercury pose the highest risk for predators with low PNEC values ($PNEC_{pred}$ < 1), and PentaBDE, PFOA, PFOS, sumPCB_7 and mercury for the soil ecosystems ($PNEC_{soil}$ <1), Table 17.

As a realistic approach, the median concentrations were used as Measured Environmental Concentration (MEC_{med}) and the $MEC_{med}/PNEC_{pred}$ is calculated for the single compounds and compound groups. The sum of the single $MEC_{med}/PNEC_{pred}$ was calculated in order to assess if there was possible reasons for concern with a $\sum MEC_{med}/PNEC_{pred}$ >1. It should be emphasized that the risk evaluation for birds is done for concentration measured in bird eggs. The authors stress that that the resulting calculations can only be used as an approximation of possible reason of concern for the discussed species, as a tier 0 or at best tier 1 of mixture risk assessment. Real toxicity data are lacking for the terrestrial species discussed in this report.

Only the compounds with $PNEC_{pred}$ values adopted from the study of Miljødirektoratet (Andersen et al. 2012) were used in an initial evaluation of combined risk for the organisms. These compound classes are PBDEs, PFOS and some of the metals. The element Nickel (Ni) was left out since it is relevant as an essential element and due to uncertainties related to the PNEC value of 8.5 mg/kg. Nickel is also known to biodilute in top predators (DeForest et al. 2011). However, the calculated the MEC/PNECpred ratio of Ni was very low in the various species and did not make a substantial contribution to the total sum.

4.2 Risk evaluation of earthworm as prey

PBDE data were all below limit of detection (<LOD). Median concentrations (MEC_{med}) are shown for all detected compounds. The summation of all MEC/PNEC values for the median concentrations of PFOS and some metals revealed that all earthworm populations at the various locations show ∑MEC/PNEC >1. The metal cadmium had the highest MEC/PNEC ratio and was the main contributor to the sum, followed by PFOS, mercury (Hg) and lead (Pb) in some locations.

Table 19: **Median** environmental concentrations (MEC_{med}) and $MEC_{med}/PNEC_{pred}$ in **earthworm**. MEC_{med} and $PNEC_{pred}$ values for organic contaminants and metals are given as ng/g ww.

MEC_{med}	BRY	SLO	MAR	GRO	GRM	Ref	$PNEC_{pred}$
PCB7	1.35	3.19	1.42	1.65	1.27	1.29	-
PFOS	6.58	6.17	6.51	9.11	2.42	0.39	13.0
PFOA	0.39	0.68	0.86	0.59	0.17	1.21	-
Cd	1520	750	1307	960	1950		160
Hg	50	130	50	90	70		400
Pb	460	1509	1860	330	250		3600

$MEC_{med}/PNEC_{pred}$	**BRY**	**SLO**	**MAR**	**GRO**	**GRM**	**Ref**	**$PNEC_{pred}$**
$PFOS_{med}/PNEC_{pred}$	0.51	0.47	0.50	0.70	0.19	0.03	13.0
$Cd_{med}/PNEC_{pred}$	**9.5**	**4.7**	**8.6**	**6.0**	**12.2**		160
$Hg_{med}/PNEC_{pred}$	0.13	0.33	0.13	0.23	0.18		400
$Pb_{med}/PNEC_{pred}$	0.13	0.44	0.52	0.09	0.07		3600
Σ $MEC_{med}/PNEC_{pred}$	**10.3**	**5.9**	**9.7**	**7.0**	**12.6**		

When applying the $PNEC_{soil}$ (on a wet weight basis based on Table 13) to evaluate the risk for earthworms as part of the soil ecosystem, the MEC/PNEC ratios decreased considerably by a factor of 10.

The use of $PNEC_{pred}$ was chosen in order to evaluate the risk for predators with earthworm as an important food item. The relatively high single $MEC_{med}/PNEC_{pred}$ ratio of Cadmium and the Sum($MEC_{med}/PNEC_{pred}$) might indicate reason for concern for predators where earthworm is a substantial part of diet. None of the birds or rat in this study have earthworm as an important food item in their diet.

4.3 Pied flycatcher

No metal data is available for flycatcher. We have chosen to include additional congeners in addition to the strict isomer group definition, that may be part of the technical mixtures of Penta- and OctaBDE (i.e. see Table 18 for PentaBDE).

In the following table median concentrations are derived across all data independent of specific locations.

Table 20: Median environmental concentration MEC_{med} (ng/g ww) and $PNEC_{pred}$ (ng/g ww) of PBDE isomer groups and PFOS in **pied flycatcher** and calculated MEC_{med} /$PNEC_{pred}$ values.

	MEC_{med}	**$PNEC_{pred}$**	**$MEC_{med}/PNEC_{pred}$**
PentaBDE (BDE47, 99, 100)	1.00	1000	0.001
OctaBDE (BDE153,154, 175/183, 206, 207)	0.574	6.7E+03	8.5E-05
DecaBDE (BDE209)	1.85	833E+03	2.2E-06
Σ $MEC_{med}/PNEC_{pred}$			**0.008**

For pied flycatcherΣ $MEC_{med}/PNEC_{pred}$ was well below 1 and does not indicate an unacceptable risk for the few compounds with known $PNEC_{pred}$ values. This was also the case for maximum concentrations. However, with the lack of substantial concentration data and for important contaminants, this mixture risk assessment is not very applicable and as such only relevant for risk assessment of the PBDE congener group.

4.4 Golden eagle

After excluding coastal eggs, no single $MEC_{med}/PNEC$ ratio > 1 is present for the median concentrations, nor for $\Sigma\ MEC_{med}/PNEC_{pred}$, indicating no possible reason for concern (Table 15). Including coastal eggs, PFOS and Hg concentrations caused single $MEC_{med}/PNECpred$ ratio higher than 1 for maximum values (4.95 and 1.2 for PFOS and Hg respectively), but below 1 for median values.

Table 21: **Median** environmental concentration (MEC_{med}) and $PNEC_{pred}$ values for contaminants in **golden eagle** across all locations and calculated $MEC_{med}/PNEC_{pred}$ ratios. Concentrations (MEC) and PNEC values are given as ng/g ww.

	MEC_{med}	**$PNEC_{pred}$**	**$MEC_{med}/PNEC_{pred}$**
PentaBDE (BDE47, 99, 100)	4.52	1000	0.005
OctaBDE (BDE153,154, 175/183, 206, 207)	7.18	6700	0.001
DecaBDE (BDE209)	0.10	833E+3	1.2e-7
PFOS	6.50	13.0	0.5
Cd	<LOD	160	-
Hg	24.1	400	0.06
Pb	4.8	3600	0.001
$\Sigma\ MEC_{med}/PNEC_{pred}$			**0.57**

4.5 Brown rat

The brown rat collected in Oslo city, feeding on human waste, not really belongs to the terrestrial food web. However, after calculating the $\Sigma MEC_{med}/PNEC_{pred}$ in a similar manner as above, no possible reason for concern was found.

Table 22: **Median** environmental concentration (MEC_{med}) and applied $PNEC_{pred}$ values of contaminants in **brown rat** and calculated $MEC_{med}/PNEC_{pred}$ values. Concentrations (MEC) and PNEC values are given as ng/g ww

	MEC_{med}	**$PNEC_{pred}$**	**$MEC_{med}/ PNEC_{pred}$**
PentaBDE (BDE47, 99, 100)	5.39	1000	0.005
OctaBDE (BDE153, 154, 175/183, 206, 207)	0.58	6700	8.7E-05
PFOS	2.2	13.0	0.17
Cd	15	160	0.094
Hg	7	400	0.018
Pb	827	3600	0.23
$\Sigma\ MEC_{med}/PNEC_{pred}$			**0.5**

Discussion of combined risk

In this study we have used available and previously reported PNECpredator data to assess and predict combined risks for earthworm, pied flycatcher, brown rat and golden eagle. A number of limitations have to be considered in the assessment:

1) This prediction should only be used as a simple assessment of combined risks followed up by later more comprehensive risk assessment, for instance by the use of sum toxic units (STU) referred to by Backhaus and Faust (2012). This includes also evaluation of the data with regard to their relevance for the various species, adequacy and completeness.

2) The use of predator PNEC data for risk assessment of concentrations in earthworm is first and foremost useful for predators of earthworm and PNEC predator data are not necessarily scientific correct for the risk assessment of bird populations using various contaminant concentrations in bird eggs.

3) No PNECpred for PCBs in terrestrial ecosystems were available to the authors, resulting in a considerable gap of the overall sum(MEC/PNEC) ratio and mixture risk assessment

4) Pesticides, especially DDTs, were not part of this study, resulting in a considerable gap to the overall sum(MEC/PNEC) ratio assessment

5) Other so far unknown pollutants, potentially more toxic, were not included in this combined risk estimation

As seen from the calculations it is not a surprise that the combined risk (i.e. ∑MEC/PNEC) is exceeding 1 when one or several single MEC/PNEC is exceeding 1. This is the case for the data of the metal cadmium for earthworm.

A recent report from Miljødirektoratet (2014), used effect values such as LOEC, EC(D)10, EC(D)50, LC(D)50, in order to evaluate the risk of effects. In this study data critical for bird populations based on exposure of contaminants in eggs was gathered. LD50 data was used for SumPCB (400 ng PCB mixture/g egg). In the original study (Carro et al. 2013), a PCB mixture of 58 congeners detected in egg from spotted sandpiper, was used to study embryonic survival with the use of domestic chicken eggs. If we apply this median lethal dose (LD50), without applying any safety factor, the maximum concentration of sumPCB_7 in golden eagle would not exceed the effect value and as such not indicate a risk for effect. If we apply a safety or assessment factor of 10 (which is a relatively low value compared to what is normally used to derive PNEC from acute toxicity tests) the situation is the opposite and all maximum, median and minimum concentrations of sumPCB_7 would exceed the pseudo derived PNEC value of 40 ng/g. For pied flycatcher and brown rat only the maximum concentration would exceed the PNEC of 40 ng/g. Using a higher safety factor will result in even higher risk for the sumPCB group for the two bird species and rat. The conclusion is that the choice of PNEC approach in this present study is not necessarily the best choice of method, since PNEC values of dominating contaminant group as PCBs for many species are missing, and certainly weakens the mixture risk assessment. Hopefully future studies can provide these lacking data.

Toxicological interactions of PFOA and PFOS with the metals such as $Cd^{2+,}$ Hg^{2+} have recently been investigated in binary, ternary and multicomponent mixtures (Rodea-Palomares et al. 2012). PFOA and PFOS showed an antagonistic interaction with each other and with metals at the whole range of effect concentrations in cyanobacteria, decreasing metal toxicity. However, for more complex mixtures including propylparaben, mitomycin c, 2,4-D and furazolidone, synergistic effects were also observed, especially at low and environmentally relevant concentrations (Rodea-Palomares et al. 2012). These results indicate that mixture effects are complex interactions and also dependent on the concentration concentrations.

5. Discussion

Very little data for comparative purposes are available in the literature for concentrations on environmental pollutants in urban rats and earthworms, while there are good reference-data available on concentrations of of lecacy POPs for predatory birds, but to a lesser degree for passerines.

Golden eagle

Among the Norwegian birds of prey, the golden eagle belongs to the less contaminated species (Gjershaug et al. 2008). The highest sumPCB contamination found in Norway, was in Peregrine Falcon eggs from 1976 in Rogaland, with 110000 ng/g ww (Nygård, 1983). PCB values have decreased considerably in Norwegian birds of prey since then. During the period 2005-2010, eggs of the eagle owl (*Bubo* bubo) showed the highest values (mean value sumPCB 4524 ng/g fw), followed by the white-tailed sea eagle (*Haliaetus albicilla*, 2840 ng/g fw), the peregrine falcon (*Falco peregrinus*, 2500 ng/g fw), merlin (*Falco columbarius*, 1053 ng/g and osprey (*Pandion haliaetus*), 678 ng/g). The golden eagle had an average value of 216 ng/g during the same period (Nygård and Polder 2012). In the present material, an average of 401 ng/g ww was found, which places it at the lower end of PCB contamination in Norwegian birds of prey. This is caused by its food-choice, which primarily consists of terrestrial herbivores such as hare, different grouse species and ungulates such as sheep and reindeer (Johnsen et al. 2007). Despite its low concentrations of pollutants, there is evidence that the golden eagle is particularly sensitive to organic pollutants such as DDE, as shell thinning effects has been found at concentrations one order of magnitude below that of many other bird of prey (Nygård and Gjershaug 2001). Besides the data on eggs of golden eagle, data for nestling body feathers of golden eagle from Northern Norway is available. Eulaers et al (2013), report here that golden eagle as the lowest contaminated species when comparing northern goshawk (*Accipiter gentilis)*, white tailed sea-eagle and golden eagle for PCB 153 and PBDE 47 (Eulaers *et al*. 2013). In the same study decreasing concentrations related to habitat were reported with coast > fjord > inland. A similar picture can be drawn for the golden eagle eggs analysed in this study, but sample numbers are too low for any statistical treatment of the data (*see Figure 56*).

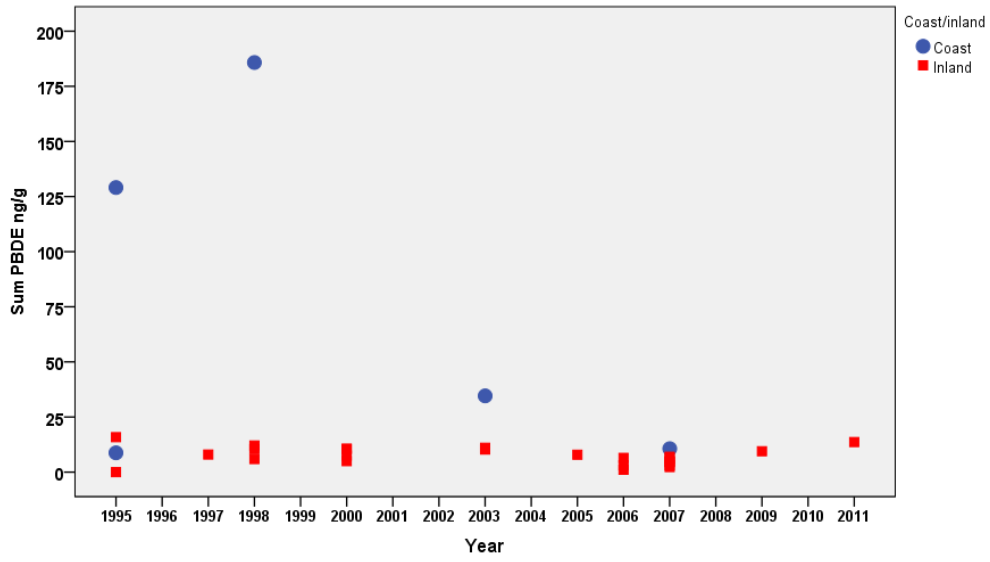


Figure 57: Change of average PBDE concentration over time and relation to geographical origin in golden eagle eggs (ng/g fw)

There is limited information with respect to PFAS concentrations in eggs from golden eagle. In a study from 2012, 14 eggs were analysed with respect to PFASs (Nygård and Polder 2012). They were collected in the time period 2005-2010 and the reported sum concentration were on the average 7.9 ng/g fw. The mean concentration of sum PFASs in this study was 12.2 ng/g fw. There is no clear temporal trend for PFASs in the period 1995-2011, partly caused by limited number of eggs available to this study and by the variability of sampling locations/ nesting sites sampled over the years (*Figure 27*). This is in contrast with a published study on PFASs in eggs from Swedish peregrine falcons (Holmstrom et al. 2010). In that study, there was a significant increase in PFAS concentrations for the majority of the reported PFASs throughout the studied time period (1974-2007), although there was a tendency of decrease in the latter part of that time-period. As in the present study, the overall PFAS profile in peregrine falcon eggs was dominated by PFOS. Metals in eggs reflect those in the maternal blood and organs during egg formation (Evers et al. 2005), with the exception of several toxic metals that are not effectively transferred to eggs, such as cadmium (Cd) and lead (Pb) (Furness, 1996 and Spahn and Sherry, 1999). As, Hg, and Pb belong to the non-essential metals whilst Co and Zn belong to the essential metals. Cu, Zn and Cd have been shown to significantly bioconcentrate from soils to invertebrates but biodilute from invertebrates to birds (Hargreaves *et al.*, 2011). Cu, Zn and Fe are essential macro elements with many important biological functions, and internal concentrations are usually well-regulated. Taxa-specific requirements might explain why these metals have been shown to biomagnify in some food chains but not others. Cadmium is a toxic element that also shows variable bioconcentration and biomagnification patterns depending on the organisms involved. Although Cd is prone to bioaccumulation it does not consistently biomagnify, and can even be negatively associated with trophic concentration (Hargreaves *et al*. 2011).

European pied flycatcher

No data for organic pollutants and metals could be found for pied flycatcher eggs or other matrices in the literature. For improved comparability, lipid related concentrations are used (lw). Data for great tits (*Parus major*) were available and will be used for comparison purposes. In our study 1601 ng/g lw were detected in the pied flycatcher egg, less than half of the concentrations found in eggs of great tits in Belgium (average sumPCB_{21} concentrations of 4110 ng/g lw) (Voorspoels *et al.*, 2007). PBDEs were found in eggs of great tits averaging with 220 ng/g lw). In our study 213 ng/g lw were found, very close to the Belgian data. In a second study, PBDEs and PCBs in eggs of great tits collected all over Europe were studied in 2009 (Van den Steen *et al*. 2009). This study included a Norwegian location as well, suburban close to Oslo, comparable to the location chosen for the flycatcher in this study. The PCBs concentrations of 1000 ng/g lw were comparable to our data, but the PBDEs concentrations of 25 ng/g lw were lower. Since samples were collected in 2006, changes over time in PBDE exposure as well as dietary differences can explain the observed differences. A more recent study on Starling eggs, sampled worldwide, with one Norwegian rural location in Nord Trøndelag, showed less than 500 ng/g lw sumPCBs and less than 50 ng/g lw sumPBDEs, (Eens *et al*. 2013), three and four times lower than observed in the flycatcher eggs.

Rats

The rats collected in Oslo were contaminated with on average 5.2 ng/g ww sumPFAS. PFOS contributed more than 50% to that load (2.8 ng/g ww). For comparison, data for wood mice collected in rural locations in Norway can be used, reported in the Miljødirektoratet Screening report M40-2013. In the wood mice liver collected in 2012, only 0.5 ng/g ww were found, 10-times lower compared to the urban rats in our present study. Voorspoels et al. (2007) reported means of sumPBDE 9.2 ng/g lw and sumPCBs of 300 ng/g lw in rodents from Belgium.

Earthworms

The average sumPFAS concentration in *Lumbricidae*/earthworm varied between the different sites, but in all cases representing the dominating organic pollutant group comparing to PCBs and PBDEs. The lowest concentration was reported for Grønmo, which was even lower than the reference site. This was surprising, as this is one of the main garbage dumps in the Oslo region. Even the other pollutants and metals on the list (with the exception of silver) did not show any elevated concentrations at this site. The highest concentration of PFAS was found in Grorud. The majority of the samples had a PFAS profile dominated by PFOS. There are a number of

studies where PFAS concentrations in earthworms have been reported, however often these studies have been investigating contamination from the use of fire-fighting foam and leakage to soil and do not represent background concentrations. Studies have shown that high concentrations of PFASs in soil can have a negative effect on the earthworms reproductive ability (TA-2212/2006). High PFOS concentrations in soil also cause DNA damage and induce oxidative stress (Xu et al. 2013). Even though earthworm accumulate long chain (C>9) PFAS, to a greater degree than short chain, the concentrations reported in the present study are not in range of toxic effect concentrations. However, this study shows that PFASs are ubiquitously present in the urban environment, reaching elevated concentrations in some locations (31 ng/g ww in Grorud). However, metals were by far the dominating pollutant group investigated (average of 184 µg/g ww). Latif *et al.*, 2013 found lead and cadmium concentrations in three different earthworm species varying between 200 – 600 ng/g for lead and 200 and 350 ng/g cadmium, which is in the same order of magnitude for lead and a factor 5 lower for cadmium than found in earthworms from Oslo. When comparing the organic pollutants measured in the *urban vs*. remote locations, sumPCBs were 2.4 and 1.4 ng/g ww, while PFAS were 13.2 compared to 6.4 ng/g ww, respectively.

Inter-species comparisons

In general, direct comparison of the pollutant concentrations found in the investigated species is difficult, since different tissue types as well as locations and time-periods were sampled. As a result, only general conclusions can be drawn. There are major differences between the concentrations and patterns of accumulation of organic pollutants and metals between the species involved in this study. Levels of organic pollutants, especially PCBs, are much higher in the top predator (eggs of golden eagle) than in the other species. On the other hand, metals were much higher in earthworms than in any other species. PFAS, which primarily binds to proteins, and thus behaves differently in biota compared to the "classic" organic pollutants such as PCBs, apparently show little to no apparent biomagnification among the studied species. In fact, earthworms show the highest average values, ca. three times higher than the rats, and almost double of the golden eagle (only eggs from 2005 and onwards compared). As we do not have a linear food-chain represented in our study, we are not able to present biomagnification factors between successive members of a food-chain. We encourage future studies, involving other species that are more directly connected to each other in the food-web.

Bioaccumulation

In summary, the terrestrial food chain is very short (consisting of 3 – 4 steps: plants as primary producers (1st trophic level), insects and herbivorous mammals and birds as primary consumers (2nd trophic level), insectivorous birds and predatory mammals and birds that feed on primary consumers as, 3rd trophic level) and predators that feed on secondary consumers are 4th trophic level). There will be many species that fall into intermediate categories because of mixed diets. The selected species in this study represent species from the 2nd trophic concentration (earthworms), 2nd to 3rd (rats) and the 3rd and 4th trophic concentration (pied flycatcher and golden eagle), The golden eagle feeds on a variety of primary and secondary consumers, so some individuals may belong to the 3rd level, others to the 4th, an many in between. Different habitats and feeding habits will have an impact on pollutants concentrations found in eggs too. The urban brown rat is difficult to assign to a trophic level, since it feeds opportunistically, including human food waste. For future sampling campaigns the incorporation of a coherent tererstrial food chain, consisting of non-migrational species sampled in the same region and timeperiod is recommended.

6. Conclusions and Recommendations

In comparison with available data from terrestrial studies carried out in Norway or Europe, concentrations of PCB, PBDE and PFAS have to be considered low. Samples from Oslo do not show significantly elevated concentrations of the pollutants measured in this study.

Pollutant concentrations analysed in golden eagle eggs show either a decreasing or a stable trend over time. However, pesticides such as DDTs and chlordanes were not in the frame of this study, potentially contributing substantially to the overall pollutant load and toxicological effect.

The load of the various contaminant group in the investigated species was as follows (on a wet weight basis):

- Golden eagle: sumPCB > toxic metals > sumPFAS > sumPBDE
- Pied flycatcher: sumPCB > sumPBDE
- Rats: Toxic metals >> sumPCB > sumPFAS > sumPBDE
- Earthworms: Toxic metals >> sumPFAS > sumPCB

Combined risk of the measured pollutants was evaluated with a first tier conservative concentration addition (CA) approach using predicted no effect concentration for predators (PNECpred) as reference values. Unfortunately, the PNECpred value for PCBs as well as for several PFAS including PFOA was unavailable, leading to a possible underestimation of the risk for combined effects. Only some metals, PBDEs and PFOS with available PNECpred values were included in the combined risk assessment. Based on the relatively few compounds with available reference values, the results gave no initial possible reason for concern for the species investigated. The earthworm from Oslo area showed a Sum(MEC/PNECpred) > 1 ranging between 5.9 and 12.6, indicating a risk for predators with earthworm as an important food item. Cadmium contributed most to the estimated risk, followed by PFOS and lead and mercury. Brown rat data gave a Sum(MEC/PNECpred) of 0.5 mainly affected by lead and PFOS. For pied flycatcher only the PBDE group could be considered and revealed a very low Sum(MEC/PNECpred) value of 0.008. The golden eagle data showed a Sum(MEC/PNECpred) of 0.57 mainly caused by PFOS. The present mixture risk assessment for all species should only be considered as an initial step in a mixture assessment and an evaluation of the applicability of PNEC values as reference values for these investigated compounds and species. There are large uncertainties in the assessment due to unavailable PNECpred values for PCBs and PFOA, other not investigated contaminants, and if PNECpred values are appropriate to use as reference values for bird egg concentrations.

The species investigated in the present report do not represent a coherent food-chain. The earthworms feed on detritus, the flycatcher on insects, the rat is an omnivore, while the golden eagle is mainly a predator on upland game species. For future sampling campaigns, a different array of species, that are connected through a food-chain is recommended. We propose to keep the earthworms due to their elevated risk indicator, and to exchange the fycatcher with the fieldfare (*Turdus pilaris*) which has earthworm as a food source. Especially in the spring, during the egg-laying season, earthworms and insects are important food for this species. It is abundant, both in urban and remote areas, and eggs of this species are readily available. As an urban top predator, perying to a large degre on thrushes, there are two potential candidates, the sparrowhawk (*Accipiter nisus*) and the goshawk (*Accipiter gentilis*). As a successful campaign for collecting sparrowhawk egg was conducted in 2014, with samples both from urban and rural aeas, we recommend to carry on using this species as a true trophic level four reperesentative for long-term studies. Other pollutants, such as organochlorine pesticides and emerging organic pollutants, should be included in the monitoring program. The establishment of time series is an extremly important and valuable tool for assessing the impact of legislation, climate change and other changing external pressures and impacts to the terrestrial environment. Sampling is recommended to occur in a short time period, at the same location and similar types of sample matrix should be collected of local, non-migrating species.

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8. Appendix

8.1 Analytical results

Sample type: Pied flycatcher eggs
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	273_1	273_1	2013	Sinober	0.80	<LOD	<LOD	<LOD	3.31	3.78	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.09
2	273_2	273_2	2013	Sinober	0.47	<LOD	<LOD	<LOD	6.09	6.19	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.30
3	273_3	273_3	2013	Sinober	<LOD	<LOD	<LOD	<LOD	4.32	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
4	273_4	273_4	2013	Sinober	0.23	<LOD	<LOD	<LOD	0.11	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
5	273_5	273_5	2013	Sinober	0.22	<LOD	<LOD	<LOD	0.15	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	10.41
6	273_6	273_6	2013	Sinober	0.10	<LOD	<LOD	<LOD	0.13	0.04	<LOD	<LOD	<LOD	<LOD	0.53	0.51	19.04
7	43_1	43_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	0.12	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
8	43_2	43_2	2013	Sinober	1.51	3.03	<LOD	<LOD	0.90	0.32	0.20	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	301_1	301_1	2013	Brenna	1.96	<LOD	<LOD	<LOD	1.37	0.46	0.44	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
10	301_2	301_2	2013	Brenna	1.00	<LOD	<LOD	<LOD	0.48	0.21	0.20	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
11	08_1	08_1	2013	Sinober	1.61	4.76	<LOD	<LOD	0.61	0.29	0.15	<LOD	<LOD	<LOD	<LOD	<LOD	4.95
12	23_1	23_1	2013	Sinober	<LOD	1.14	<LOD	<LOD	0.15	0.08	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.65
13	24_1	24_1	2013	Sinober	0.55	0.70	<LOD	<LOD	0.26	0.13	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14	51_1	51_1	2013	Sinober	0.46	<LOD	<LOD	<LOD	0.38	0.19	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	62_1	62_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	0.21	0.08	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
16	87_1	87_1	2013	Sinober	1.46	2.00	<LOD	<LOD	0.46	0.17	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
17	202_1	202_1	2013	Sinober	0.33	0.80	<LOD	<LOD	0.17	0.09	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18	214_1	214_1	2013	Sinober	0.21	0.41	<LOD	<LOD	0.15	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
19	242_1	242_1	2013	Sinober	2.12	2.18	0.54	<LOD	0.41	0.28	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
20	274_1	274_1	2013	Sinober	0.38	1.12	0.19	<LOD	0.42	0.09	0.08	<LOD	<LOD	<LOD	<LOD	<LOD	1.81
21	276_1	276_1	2013	Sinober	0.13	<LOD	0.08	<LOD	0.16	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.36

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Pied flycatcher eggs
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PCBs						
					28	50	101	118	138	153	180
1	273_1	273_1	2013	Sinober	<LOD	<LOD	<LOD	2.50	8.13	13.9	11.2
2	273_2	273_2	2013	Sinober	<LOD	<LOD	<LOD	<LOD	<LOD	6.79	5.52
3	273_3	273_3	2013	Sinober	<LOD	<LOD	<LOD	1.24	4.80	6.84	4.16
4	273_4	273_4	2013	Sinober	<LOD	<LOD	<LOD	1.46	5.18	7.79	4.66
5	273_5	273_5	2013	Sinober	<LOD	<LOD	<LOD	1.11	4.63	5.85	3.86
6	273_6	273_6	2013	Sinober	<LOD	<LOD	0.65	<LOD	4.30	6.52	4.64
7	43_1	43_1	2013	Sinober	<LOD	<LOD	<LOD	4.86	22.3	28.0	28.7
8	43_2	43_2	2013	Sinober	<LOD	<LOD	<LOD	7.05	24.4	35.9	39.7
9	301_1	301_1	2013	Brenna	<LOD	<LOD	<LOD	3.49	14.1	19.3	13.7
10	301_2	301_2	2013	Brenna	<LOD	<LOD	<LOD	5.57	20.9	30.0	19.9
11	08_1	08_1	2013	Sinober	<LOD	<LOD	2.99	<LOD	5.09	6.19	5.05
12	23_1	23_1	2013	Sinober	<LOD	<LOD	<LOD	3.08	10.20	12.7	9.29
13	24_1	24_1	2013	Sinober	<LOD	<LOD	1.60	2.66	15.50	16.2	9.95
14	51_1	51_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	8.73	7.60	6.05
15	62_1	62_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	11.40	15.2	12.8
16	87_1	87_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	5.44	6.55	4.66
17	202_1	202_1	2013	Sinober	<LOD	<LOD	<LOD	1.24	4.27	4.86	3.67
18	214_1	214_1	2013	Sinober	<LOD	<LOD	<LOD	<LOD	7.88	8.78	7.49
19	242_1	242_1	2013	Sinober	<LOD	<LOD	<LOD	2.84	14.7	17.3	15.7
20	274_1	274_1	2013	Sinober	<LOD	<LOD	1.21	1.19	4.45	6.64	6.10
21	276_1	276_1	2013	Sinober	<LOD	<LOD	<LOD	2.68	9.66	13.0	13.3

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Golden eagle egg
Concentration units: ng/g fw

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PBDE												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	1.1520 I	344	1995	Snillfjord	78.93	16.63	20.14	<LOD	13.03	4.22	<LOD	<LOD	<LOD	<LOD	0.09	<LOD	0.09
2	1.1520 II	345	1995	Snillfjord	81.93	13.08	15.63	<LOD	8.12	6.27	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
3	1.1523.1	349	1995	Nissedal	2.95	1.95	1.56	<LOD	0.32	3.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.09
4	1.1523.2	348	1995	Nissedal	11.16	4.73	4.03	<LOD	0.26	1.57	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.08
5	1.1546.1	382	1995	Agdenes	6.38	4.55	3.62	<LOD	<LOD	2.80	<LOD	<LOD	<LOD	<LOD	0.12	<LOD	0.05
6	1.1590.1	1835	1998	Røyrvik	1.61	4.24	2.79	<LOD	0.24	3.11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.09
7	1.1591.1	1836	1998	Os i Hedmark	2.87	1.80	4.43	<LOD	0.09	1.29	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
8	1.1603.1	1849	1998	Snillfjord	105	20.3	27.8	<LOD	21.4	10.70	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	1.1608.1	1854	1998	Vefsn	0.76	0.36	0.44	<LOD	3.14	3.53	3.57	<LOD	<LOD	<LOD	<LOD	<LOD	0.07
10	1.1609.1		1998	Vefsn	0.80	<LOD	<LOD	<LOD	3.31	3.78	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.09
11	1.1741.1	2346	2000	Tydal	1.39	0.45	0.81	<LOD	1.18	2.03	1.32	<LOD	<LOD	<LOD	3.30	<LOD	0.06
12	1.1746.1	2351	2000	Tolga	0.45	<LOD	0.62	<LOD	1.67	0.28	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
13	1.2347.2	1742	2000	Os i Hedmark	3.98	1.63	2.02	<LOD	0.17	0.76	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14	1.2348.1	1743	2000	Folldal	0.47	0.95	0.41	<LOD	1.89	0.27	1.09	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	1.1744.1	2349	2003	Hedmark	0.49	0.39	0.28	<LOD	2.88	0.13	2.73	<LOD	<LOD	<LOD	<LOD	<LOD	0.04
16	1.1745.1	2350	2003	Hedmark	1.58	0.91	0.62	<LOD	2.18	0.21	1.84	<LOD	<LOD	<LOD	0.10	<LOD	0.02
17	1.1748.1	2353	2003	Agdenes	22.13	5.15	6.39	<LOD	0.63	2.24	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18	1.1748.2	2354	2003	Agdenes	20.52	4.46	6.59	<LOD	0.65	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.12
19	1.2352.1	1747	2003	Oppdal	1.54	0.43	0.90	<LOD	2.54	0.43	1.09	<LOD	<LOD	<LOD	<LOD	<LOD	0.10
20	1.2462.1	1759	2005	Oppdal	1.14	1.10	0.83	<LOD	0.91	0.37	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.08
21	13.399.2	3114	2007	Aust-Agder	0.34	0.32	0.30	<LOD	2.36	3.99	2.34	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
22	1.3087.1	2019	2009	Porsanger	2.32	2.22	0.83	<LOD	0.33	3.35	0.42	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
23	1.3347.1	2147	2011	Meråker	3.04	0.75	0.77	<LOD	2.92	3.38	2.78	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Sample type: Golden eagle egg
Concentration units: ng/g fw

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PCBs							Stabile isotope	
					28	50	101	118	138	153	180	$d^{13}C_{VPDB}$	$d^{15}N_{AIR}$
1	1.1520 I	344	1995	Snillfjord	0.76	5.41	5.72	202.6	481.6	822.3	601.3	-26,92	7,03
2	1.1520 II	345	1995	Snillfjord	0.90	6.08	6.17	232.4	518.6	854.4	660.4	-26,83	8,81
3	1.1523.1	349	1995	Nissedal	0.18	0.90	2.86	19.3	83.8	138.3	93.8	-27,23	5,85
4	1.1523.2	348	1995	Nissedal	<LOD	<LOD	<LOD	10.2	35.7	82.1	118.1	-27,56	7,34
5	1.1546.1	382	1995	Agdenes	<LOD	<LOD	<LOD	20.2	64.0	148.6	267.3	-25,73	8,68
6	1.1590.1	1835	1998	Røyrvik	0.43	<LOD	<LOD	19.6	47.7	84.7	63.5	-26,82	6,01
7	1.1591.1	1836	1998	Os i Hedmark	<LOD	<LOD	1.88	72.6	283.2	437.4	311.0	-27,87	7,30
8	1.1603.1	1849	1998	Snillfjord	1.92	1.81	4.62	191.0	498.7	871.2	766.5	-20,33	12,60
9	1.1608.1	1854	1998	Vefsn	<LOD	<LOD	<LOD	11.8	37.1	64.2	30.4	-26,28	6,96
10	1.1609.1		1998	Vefsn	<LOD	<LOD	<LOD	10.1	32.8	68.3	38.9	-27,41	6,03
11	1.1741.1	2346	2000	Tydal	0.10	<LOD	0.79	6.6	27.6	53.1	49.5	-30,04	12,56
12	1.1746.1	2351	2000	Tolga	0.25	<LOD	0.47	6.0	20.1	51.8	75.5	-26,77	9,22
13	1.2347.2	1742	2000	Os i Hedmark	0.20	<LOD	1.83	93.1	195.0	350.0	280.2	-28,10	7,24
14	1.2348.1	1743	2000	Folldal	0.19	<LOD	0.20	2.8	11.1	30.6	39.9	-28,01	8,98
15	1.1744.1	2349	2003	Hedmark	54.90	<LOD	0.35	1.8	6.4	17.7	20.6	-27,19	9,40
16	1.1745.1	2350	2003	Hedmark	0.17	<LOD	0.53	4.9	15.8	49.8	54.0	-27,95	7,23
17	1.1748.1	2353	2003	Agdenes	1.05	1.06	3.61	47.4	127.7	245.3	168.6	-25,47	10,43
18	1.1748.2	2354	2003	Agdenes	0.44	0.76	1.94	36.1	103.5	169.4	119.5	-24,91	10,15
19	1.2352.1	1747	2003	Oppdal	0.13	<LOD	1.04	13.8	36.0	89.3	74.4	-27,08	6,20
20	1.2462.1	1759	2005	Oppdal	<LOD	0.29	0.43	4.3	21.0	66.3	95.7	-27,00	6,77
21	13.399.2	3114	2007	Aust-Agder	<LOD	<LOD	<LOD	2.2	7.5	17.0	23.1	-26,51	6,21

22	1.3087.1	2019	2009	Porsanger	0.29	1.99	4.17	7.4	21.1	39.3	36.9	-26,74	5,01
23	1.3347.1	2147	2011	Meråker	0.06	0.26	0.32	10.1	27.2	49.8	41.3	-28,67	5,39
24	2000	3064	2007	Oppdal								-25,61	8,51
25	397	3111	2007	Aust-Agder								-26,46	4,84
26	398	3112	2007	Froland								-25,95	4,35
27	2009	3074	2007	Finnmark								-25,28	7,53
28	2014	3081	2007	Oppdal								-27,09	6,46
29	1973	2957	2006	Karasjok								-25,30	5,38
30	1972	2956	2006	Karasjok								-24,10	8,37
31	1971	2955	2006	Oppdal								-27,90	7,79
32	1608	1855	1998	Vefsn								-25,82	7,76
33	1519	343	1995	Oppdal								-26,56	9,71
34	1546	383	1995	Agdenes								-25,77	8,28

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Golden eagle egg
Concentration units: ng/g fw

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTrA	PFTeA
1	344	1520	1995	Snillfjord	<LOD	<LOD	<LOD	<LOD	0.06	32.70	<LOD	<LOD	<LOD	<LOD	<LOD	0.11	0.38	1.64	0.61	2.42	0.39
2	382	1546	1995	Agdenes	<LOD	<LOD	<LOD	<LOD	0.07	28.69	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	0.28	1.28	0.55	1.54	<LOD
3	345	1520	1995	Snillfjord	<LOD	<LOD	<LOD	<LOD	<LOD	6.52	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	0.16	0.62	0.50	1.17	<LOD
4	349	1523	1995	Nissedal	<LOD	<LOD	<LOD	<LOD	<LOD	7.24	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	0.20	0.62	0.50	0.98	0.28
5	348	1523	1995	Nissedal	<LOD	<LOD	<LOD	<LOD	0.07	15.04	<LOD	<LOD	<LOD	<LOD	<LOD	0.35	0.44	1.14	0.48	1.17	<LOD
6	1835	1590	1998	Røyrvik	<LOD	<LOD	<LOD	<LOD	<LOD	3.50	<LOD	<LOD	<LOD	<LOD	<LOD	0.18	0.30	0.73	0.40	0.44	<LOD
7	1849	1603	1998	Snillfjord	<LOD	<LOD	<LOD	<LOD	<LOD	6.10	<LOD	<LOD	<LOD	<LOD	<LOD	0.24	0.57	1.34	0.53	1.86	0.49
8	1855	1608	1998	Vefsn	<LOD	0.09	<LOD	<LOD	<LOD	51.35	<LOD	0.70	<LOD	<LOD	0.12	0.31	0.81	3.67	1.39	6.26	1.12
9	1836	1591	1998	Os i Hedmark	<LOD	<LOD	<LOD	<LOD	<LOD	4.57	<LOD	<LOD	<LOD	<LOD	<LOD	0.18	0.31	0.61	0.32	0.31	<LOD
10	1854	1608	1998	Vefsn	<LOD	<LOD	<LOD	<LOD	<LOD	0.69	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	0.23	0.61	0.28	0.49	<LOD
11	30*	1609	1998	Vefsn	<LOD	<LOD	<LOD	<LOD	<LOD	6.79	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	0.29	1.41	1.08	10.20	2.36
12	2347	1742	2000	Os i Hedmark	<LOD	<LOD	<LOD	<LOD	<LOD	7.71	<LOD	0.23	<LOD	<LOD	<LOD	0.22	0.30	0.72	0.34	0.73	<LOD
13	2348	1743	2000	Folldal	<LOD	<LOD	<LOD	<LOD	<LOD	8.86	<LOD	<LOD	<LOD	<LOD	<LOD	0.20	0.41	0.91	0.58	1.95	0.55
14	2346	1741	2000	Tydal	<LOD	<LOD	<LOD	<LOD	<LOD	3.90	<LOD	<LOD	<LOD	<LOD	0.10	0.13	0.30	0.75	0.33	1.00	<LOD
15	2354	1748	2003	Agdenes	<LOD	<LOD	<LOD	<LOD	<LOD	2.48	<LOD	<LOD	<LOD	<LOD	<LOD	0.11	0.50	1.06	0.47	0.89	0.19
16	2350	1745	2003	Hedmark	<LOD	<LOD	<LOD	<LOD	<LOD	5.70	<LOD	<LOD	<LOD	<LOD	<LOD	0.16	0.25	0.64	0.34	0.65	<LOD
17	2349	1744	2003	Hedmark	<LOD	<LOD	<LOD	0.14	0.09	28.51	<LOD	0.11	<LOD	<LOD	<LOD	0.21	0.35	2.07	0.91	4.19	0.69
18	2353	1748	2003	Agdenes	<LOD	<LOD	<LOD	<LOD	0.08	29.01	<LOD	0.20	<LOD	<LOD	<LOD	0.14	0.45	2.43	0.96	3.12	<LOD
19	2351	1746	2003	Tolga	<LOD	<LOD	<LOD	<LOD	<LOD	2.96	<LOD	<LOD	<LOD	<LOD	<LOD	0.21	0.39	1.56	0.61	1.25	<LOD

Sample type: Golden eagle egg
Concentration units: ng/g fw

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTrA	PFTeA
20	2352	1747	2003	Oppdal	<LOD	<LOD	<LOD	<LOD	<LOD	4.00	<LOD	<LOD	<LOD	<LOD	0.09	0.21	0.53	1.27	0.49	1.08	<LOD
21	2462	1759	2005	Oppdal	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
22	3087	2019	2009	Porsanger	<LOD	<LOD	<LOD	<LOD	<LOD	6.19	<LOD	<LOD	<LOD	<LOD	0.08	2.84	4.25	8.93	1.72	2.64	<LOD
23	3347	2147	2011	Meråker	<LOD	<LOD	<LOD	<LOD	0.02	1.44	<LOD	<LOD	<LOD	<LOD	<LOD	0.26	0.40	1.60	0.92	<LOD	<LOD

Sample type: Golden Eagle egg
Concentration units: ng/g fw

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	Compound name:									
					Krom	Nickel	Kupper	Zink	Arsen	Sølv	Kadmium	Bly	Kvikksølv	Metyl-kvikksølv
					Cr	Ni	Cu	Zn	As	Ag	Cd	Pb	Hg	Me-Hg
1	1.1520 I	344	1995	Snillfjord	1.31	1.80	619	4650	As	<LOD	<LOD	4.07	175.54	<LOD
2	1.1520 II	345	1995	Snillfjord	<LOD	1.63	624	5035	0.69	<LOD	0.11	5.17	228.53	300.74
3	1.1523.1	349	1995	Nissedal	<LOD	1.38	682	8291	0.50	0.12	<LOD	7.03	20.69	24.36
4	1.1523.2	348	1995	Nissedal	<LOD	2.21	602	7487	<LOD	<LOD	0.09	5.60	22.02	25.80
5	1.1546.1	382	1995	Agdenes	2.95	12.99	368	5882	<LOD	0.12	0.12	3.89	112.68	125.74
6	1.1590.1	1835	1998	Røyrvik	1.31	1.48	365	4689	10.76	<LOD	0.10	2.33	45.96	54.59
7	1.1591.1	1836	1998	Os i Hedmark	146.48	12.12	693	8496	<LOD	0.21	0.12	2.39	6.48	13.93
8	1.1603.1	1849	1998	Snillfjord	64.90	26.91	2167	7135	<LOD	0.43	0.08	20.78	471.55	338.08
9	1.1608.1	1854	1998	Vefsn	2.74	1.62	556	5926	8.68	<LOD	<LOD	3.48	14.56	6.63
10	1.1609.1		1998	Vefsn	2.53	5.88	501	5431	<LOD	0.23	<LOD	5.37	14.22	<LOD
11	1.1741.1	2346	2000	Tydal	46.31	9.70	716	11334	<LOD	0.29	<LOD	2.21	118.86	128.47
12	1.1746.1	2351	2000	Tolga	4.11	6.02	558	7161	<LOD	0.14	<LOD	4.13	21.41	20.77
13	1.2347.2	1742	2000	Os i Hedmark	7.83	4.26	456	5905	<LOD	<LOD	0.14	5.17	84.42	<LOD
14	1.2348.1	1743	2000	Folldal	1.02	1.92	486	5787	<LOD	<LOD	<LOD	1.91	18.03	<LOD
15	1.1744.1	2349	2003	Hedmark	4.30	2.68	516	8653	<LOD	<LOD	0.13	13.10	7.10	<LOD
16	1.1745.1	2350	2003	Hedmark	4.59	3.83	726	3297	<LOD	0.09	<LOD	6.20	23.70	<LOD
17	1.1748.1	2353	2003	Agdenes	4.38	3.42	374	3856	<LOD	<LOD	<LOD	6.89	134.37	124.77
18	1.1748.2	2354	2003	Agdenes	<LOD	<LOD	242	4683	12.28	<LOD	<LOD	1.73	136.43	71.98

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	Compound name:									
					Krom	Nickel	Kupper	Zink	Arsen	Sølv	Kadmium	Bly	Kvikksølv	Metyl-kvikksølv
					Cr	Ni	Cu	Zn	As	Ag	Cd	Pb	Hg	Me-Hg
19	1.2352.1	1747	2003	Oppdal	1.55	1.39	314	5617	6.74	<LOD	<LOD	4.43	9.82	7.37
20	1.2462.1	1759	2005	Oppdal	2.93	6.11	456	4067	<LOD	<LOD	<LOD	4.12	8.55	2.99
21	13.399.2	3114	2007	Aust-Agder	<LOD	<LOD	312	7045	<LOD	<LOD	<LOD	2.92	9.33	4.07
22	1.3087.1	2019	2009	Porsanger	<LOD	<LOD	540	6428	<LOD	<LOD	<LOD	2.43	19.11	8.88
23	1.3347.1	2147	2011	Meråker	<LOD	<LOD	440	4959	<LOD	<LOD	<LOD	<LOD	16.12	9.99

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Earthworm
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PBDEs											
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	Bryn I	pool	2013	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
2	Bryn II	pool	2013	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
3	Bryn III	pool	2013	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
4	SLO I	pool	2013	Slottparken	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
5	SLO II	pool	2013	Slottparken	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
6	SLO III	pool	2013	Slottparken	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
7	MAR I	pool	2013	Maridalen	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
8	MAR II	pool	2013	Maridalen	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	MAR III	pool	2013	Maridalen	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
10	GRO I	pool	2013	Grorud	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
11	GRO II	pool	2013	Grorud	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
12	GRO III	pool	2013	Grorud	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
13	GRM I	pool	2013	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14	GRM II	pool	2013	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	GRM III	pool	2013	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
16	MAKK_01ref	pool	2013	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
17	MAKK_02ref	pool	2013	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18	MAKK_03ref	pool	2013	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
19	MAKK_04ref	pool	2013	Åmotsdalen/ Dovre	35,5	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

<LOD: Less than Limit of Detection
b: Less than Limit of Quantification

Sample type: Earthworm
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PCBs								Stabile isotope	
					28	50	101	118	138	153	180		$d^{13}C_{VPDB}$	$d^{15}N_{AIR}$
1	Bryn I	pool	2013	Bryn	<LOD	0.173	<LOD	0.149	0.458	0.369	0.197		-25,92	5,94
2	Bryn II	pool	2013	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD		-27,43	3,12
3	Bryn III	pool	2013	Bryn	<LOD	<LOD	0.111	<LOD	0.923	0.643	<LOD		-27,83	3,43
4	SLO I	pool	2013	Slottparken	<LOD	<LOD	0.800	<LOD	1.35	0.615	<LOD		-26,78	8,96
5	SLO II	pool	2013	Slottparken	<LOD	<LOD	0.490	0.379	0.955	0.991	0.384		-25,52	6,60
6	SLO III	pool	2013	Slottparken	<LOD	<LOD	<LOD	0.623	1.37	1.390	0.902		-25,25	7,11
7	MAR I	pool	2013	Maridalen	<LOD	<LOD	<LOD	0.304	0.632	0.484	<LOD		-25,84	1,73
8	MAR II	pool	2013	Maridalen	<LOD	<LOD	<LOD	<LOD	1.044	0.797	<LOD		-25,52	2,46
9	MAR III	pool	2013	Maridalen	<LOD	<LOD	0.190	<LOD	<LOD	<LOD	<LOD		-26,09	2,35
10	GRO I	pool	2013	Grorud	<LOD	0.695	<LOD	3.17	12.25	11.00	5.96		-26,92	1,31
11	GRO II	pool	2013	Grorud	<LOD	<LOD	0.163	<LOD	0761	0.725	<LOD		-26,29	4,76
12	GRO III	pool	2013	Grorud	<LOD	0.115	0.268	0.084	0265	0.221	<LOD		-25,33	3,46
13	GRM I	pool	2013	Grønmo	<LOD	0.271	0.146	0.146	0.394	0.238	0.079		-26,81	7,78
14	GRM II	pool	2013	Grønmo	<LOD	<LOD	0.287	0.110	0.260	0.203	<LOD		-27,37	5,68
15	GRM III	pool	2013	Grønmo	<LOD	0.389	0.463	0.265	0.977	0.653	<LOD		-26,31	5,17
16	MAKK_01ref	pool	2013	Åmotsdalen/ Dovre	<LOD	0.549	0.311	<LOD	0.518	0.586	0.305		-28,41	2,64
17	MAKK_02ref	pool	2013	Åmotsdalen/ Dovre	<LOD	0.358	0.185	0.140	0.287	0.280	<LOD		-25,62	3,92
18	MAKK_03ref	pool	2013	Åmotsdalen/ Dovre	<LOD	0.208	0.188	<LOD	0.431	0.511	<LOD		-26,50	4,28
19	MAKK_04ref	pool	2013	Åmotsdalen/ Dovre	<LOD	0.151	<LOD	<LOD	0.360	0.220	<LOD		-25,78	4,28

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Earthworm
Concentration units: ng/g ww
Sampling year: 2013

Nr. of samples	Customers sample ID:	Sample-type	Location	PFOSA	PFBS	PFPS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTrA	PFTeA
1	Bryn I	pool	Bryn	<LOD	<LOD	<LOD	<LOD	0.26	1.03	<LOD	<LOD	<LOD	0.18	0.12	0.03	<LOD	0.03	0.24	0.26	0.46
2	Bryn II	pool	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	7.04	<LOD	<LOD	<LOD	1.48	0.97	0.20	<LOD	0.30	0.62	0.98	1.61
3	Bryn III	pool	Bryn	<LOD	<LOD	<LOD	<LOD	<LOD	6.58	<LOD	<LOD	<LOD	0.50	0.40	0.23	0.23	0.38	0.84	0.66	0.93
4	SLO I	pool	Slottparken	<LOD	<LOD	<LOD	<LOD	<LOD	4.51	<LOD	<LOD	<LOD	0.54	<LOD	0.05	<LOD	0.15	0.57	0.98	1.83
5	SLO II	pool	Slottparken	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.02	<LOD	0.06	0.22	0.27	0.62
6	SLO III	pool	Slottparken	<LOD	<LOD	<LOD	0.27	1.37	7.83	<LOD	<LOD	<LOD	0.34	0.68	0.16	0.19	0.54	2.07	1.65	2.66
7	MAR I	pool	Maridalen	<LOD	<LOD	<LOD	<LOD	<LOD	10.13	<LOD	<LOD	<LOD	0.72	<LOD	1.74	0.72	1.57	1.37	1.71	0.94
8	MAR II	pool	Maridalen	<LOD	<LOD	<LOD	0.55	<LOD	6.51	<LOD	<LOD	<LOD	0.38	1.08	0.38	0.23	0.12	0.16	0.47	0.54
9	MAR III	pool	Maridalen	<LOD	<LOD	<LOD	<LOD	<LOD	4.57	<LOD	<LOD	<LOD	0.13	0.64	0.19	<LOD	0.25	0.60	1.65	<LOD
10	GRO I	pool	Grorud	<LOD	<LOD	<LOD	5.06	3.84	8.68	<LOD	4.21	<LOD	<LOD	0.59	0.55	0.58	1.25	2.88	3.34	6.36
11	GRO II	pool	Grorud	<LOD	<LOD	<LOD	3.23	2.43	9.11	<LOD	<LOD	<LOD	1.17	2.54	1.27	1.18	1.38	3.70	3.07	3.98
12	GRO III	pool	Grorud	<LOD	<LOD	<LOD	<LOD	<LOD	11.00	<LOD	<LOD	<LOD	0.83	0.33	0.28	0.49	1.09	2.26	2.42	4.01
13	GRM I	pool	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	2.42	<LOD	<LOD	<LOD	<LOD	0.17	<LOD	<LOD	<LOD	<LOD	0.42	0.32
14	GRM II	pool	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	1.77	<LOD	<LOD	<LOD	0.35	0.47	0.06	<LOD	0.11	0.13	0.57	0.24
15	GRM III	pool	Grønmo	<LOD	<LOD	<LOD	<LOD	<LOD	3.00	<LOD	<LOD	<LOD	0.22	0.07	0.05	<LOD	0.25	0.48	1.39	1.14
16	MAKK_01ref	pool	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	<LOD	0.36	<LOD	<LOD	<LOD	<LOD	0.68	0.20	0.26	0.58	0.70	2.66	0.82
17	MAKK_02ref	pool	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18	MAKK_03ref	pool	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	8.29	<LOD	<LOD	<LOD	<LOD	<LOD	1.40	0.34	0.17	0.27	0.20	1.06	0.52
19	MAKK_04ref	pool	Åmotsdalen/ Dovre	<LOD	<LOD	<LOD	<LOD	2.25	0.44	<LOD	<LOD	1.10	<LOD	1.21	0.25	0.12	0.26	0.26	0.92	0.35

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b: Less than Limit of Quantification

Nr. of samples	Customer:	Customers sample ID:	Individual:	Sampling year	Location	Sample type:	Concentration units:	Compound name:							
								Krom	Nickel	Kupper	Tinn	Arsen	Sølv	Bly	Kvikksølv
								Cr	Ni	Cu	Zn	As	Ag	Pb	Hg
1	Miljødirektorat	Bryn I	pool	2013	Bryn	Meitemakk	µg/g ww	0.04	0.12	3.56	335.42	0.53	0.04	0.10	0.05
2	Miljødirektorat	Bryn II	pool	2013	Bryn	Meitemakk	µg/g ww	0.32	0.37	3.01	172.24	0.70	0.03	0.46	0.15
3	Miljødirektorat	Bryn III	pool	2013	Bryn	Meitemakk	µg/g ww	0.67	0.56	3.71	156.38	0.65	0.03	0.50	0.04
4	Miljødirektorat	SLO I	pool	2013	Slottparken	Meitemakk	µg/g ww	1.47	0.98	3.76	129.88	0.82	0.05	1.59	0.29
5	Miljødirektorat	SLO II	pool	2013	Slottparken	Meitemakk	µg/g ww	1.11	0.83	2.39	193.94	0.83	0.03	1.30	0.13
6	Miljødirektorat	SLO III	pool	2013	Slottparken	Meitemakk	µg/g ww	2.22	1.48	5.46	119.75	0.99	0.07	4.30	0.11
7	Miljødirektorat	MAR I	pool	2013	Maridalen	Meitemakk	µg/g ww	0.73	0.89	2.96	178.63	0.56	0.03	1.86	0.05
8	Miljødirektorat	MAR II	pool	2013	Maridalen	Meitemakk	µg/g ww	0.07	0.12	1.92	145.61	0.50	0.01	12.00	0.05
9	Miljødirektorat	MAR III	pool	2013	Maridalen	Meitemakk	µg/g ww	0.13	0.13	1.54	85.19	0.74	0.02	1.76	0.14
10	Miljødirektorat	GRO I	pool	2013	Grorud	Meitemakk	µg/g ww	0.89	0.71	3.00	485.07	1.39	0.04	0.58	0.13
11	Miljødirektorat	GRO II	pool	2013	Grorud	Meitemakk	µg/g ww	0.37	0.38	2.39	128.55	1.06	0.02	0.22	0.09
12	Miljødirektorat	GRO III	pool	2013	Grorud	Meitemakk	µg/g ww	0.70	0.63	2.51	170.25	0.65	0.01	0.33	0.05
13	Miljødirektorat	GRM I	pool	2013	Grønmo	Meitemakk	µg/g ww	0.05	0.17	2.25	76.10	0.41	0.46	8.33	0.10
14	Miljødirektorat	GRM II	pool	2013	Grønmo	Meitemakk	µg/g ww	0.06	0.10	1.78	113.43	0.23	0.02	0.24	0.07
15	Miljødirektorat	GRM III	pool	2013	Grønmo	Meitemakk	µg/g ww	0.08	0.14	1.74	140.83	0.60	0.03	0.24	0.07

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Brown rat
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	Rotte_01	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
2	Rotte_02	liver	2013	Oslo	0.20	<LOD	6.71	<LOD	<LOD	<LOD	0.65	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
3	Rotte_03	liver	2013	Oslo	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	0.58	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
4	Rotte_04	liver	2013	Oslo	0.36	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
5	Rotte_05	liver	2013	Oslo	<LOD	<LOD	5.84	<LOD	<LOD	<LOD	0.27	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
6	Rotte_06	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
7	Rotte_07	liver	2013	Oslo	<LOD	<LOD	6.24	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
8	Rotte_08	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	Rotte_09	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
10	Rotte_10	liver	2013	Oslo	<LOD	<LOD	5.66	<LOD	<LOD	<LOD	0.94	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
11	Rotte_11	liver	2013	Oslo	1.23	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
12	Rotte_12	liver	2013	Oslo	0.40	<LOD	6.90	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
13	Rotte_13	liver	2013	Oslo	<LOD	<LOD	5.11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14	Rotte_14	liver	2013	Oslo	<LOD	<LOD	4.43	<LOD	<LOD	<LOD	0.46	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	Rotte_15	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Brown rat
Concentration units: ng/g ww

Nr. of samples	Customers sample ID:	Individual:	Sampling year	Location	PCBs								Stabile isotope	
					28	50	101	118	138	153	180		$d^{13}C_{VPDB}$	$d^{15}N_{AIR}$
1	Rotte_01	liver	2013	Oslo	<LOD	<LOD	0.31	0.52	1.06	2.09	0.79		-26.79	10.20
2	Rotte_02	liver	2013	Oslo	<LOD	<LOD	2.57	5.50	5.44	5.87	<LOD		-27.79	10.99
3	Rotte_03	liver	2013	Oslo	<LOD	0.52	0.93	12.31	21.07	20.41	5.72		-27.85	10.54
4	Rotte_04	liver	2013	Oslo	<LOD	0.32	0.75	7.45	16.36	10.62	5.24		-26.61	10.75
5	Rotte_05	liver	2013	Oslo	<LOD	<LOD	<LOD	0.92	1.95	2.52	<LOD		-27.91	9.68
6	Rotte_06	liver	2013	Oslo	<LOD	0.14	<LOD	<LOD	<LOD	1.21	0.45		-26.41	12.07
7	Rotte_07	liver	2013	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	0.24	4.56		-26.39	9.85
8	Rotte_08	liver	2013	Oslo	<LOD	0.13	0.20	0.83	1.93	1.89	1.95		-26.95	10.91
9	Rotte_09	liver	2013	Oslo	<LOD	0.23	<LOD	1.36	2.50	2.72	5.17		-27.46	9.54
10	Rotte_10	liver	2013	Oslo	<LOD	0.32	0.78	2.01	3.82	3.60	3.13		-27.72	9.57
11	Rotte_11	liver	2013	Oslo	<LOD	<LOD	<LOD	2.08	5.47	13.31	<LOD		-23.98	9.59
12	Rotte_12	liver	2013	Oslo	<LOD	0.61	<LOD	11.37	18.74	18.11	9.71		-27.51	9.61
13	Rotte_13	liver	2013	Oslo	<LOD	2.92	<LOD	34.50	22.66	61.99	<LOD		-27.38	10.11
14	Rotte_14	liver	2013	Oslo	<LOD	0.54	<LOD	3.20	4.22	4.41	4.04		-26.96	9.79
15	Rotte_15	liver	2013	Oslo	<LOD	0.16	0.36	1.50	1.79	1.86	1.40		-27.15	9.84

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Sample type: Brown rat
Concentration units: ng/g ww
Sampling year: 2013

Nr. of samples	Customers sample ID:	Individual	Location	PFOSA	PFBS	PFPS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTrA	PFTeA
1	Rotte_01	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	1.65	<LOD	<LOD	<LOD	<LOD	0.07	0.21	0.55	0.40	<LOD	0.42	0.32
2	Rotte_02	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	4.01	<LOD	<LOD	<LOD	<LOD	0.22	0.29	0.88	0.60	0.24	0.09	0.12
3	Rotte_03	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	0.82	<LOD	<LOD	<LOD	<LOD	0.16	0.11	0.26	0.14	<LOD	<LOD	<LOD
4	Rotte_04	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	3.27	<LOD	<LOD	<LOD	<LOD	0.08	0.32	0.80	0.47	0.47	0.18	<LOD
5	Rotte_05	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	1.08	<LOD	<LOD	<LOD	<LOD	0.06	<LOD	0.16	0.08	<LOD	<LOD	<LOD
6	Rotte_06	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	1.11	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	0.30	0.28	<LOD	<LOD	<LOD
7	Rotte_07	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	2.24	<LOD	<LOD	<LOD	<LOD	<LOD	0.23	0.59	0.30	0.07	<LOD	<LOD
8	Rotte_08	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	2.32	<LOD	<LOD	<LOD	<LOD	<LOD	0.17	0.61	0.33	0.11	<LOD	<LOD
9	Rotte_09	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	1.50	<LOD	<LOD	<LOD	<LOD	0.15	0.19	0.56	0.28	<LOD	<LOD	<LOD
10	Rotte_10	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	3.04	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	0.22	0.22	0.12	<LOD	<LOD
11	Rotte_11	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	3.93	<LOD	<LOD	<LOD	<LOD	<LOD	0.33	0.99	0.83	0.47	1.56	0.94
12	Rotte_12	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	7.28	<LOD	<LOD	<LOD	<LOD	0.21	0.92	2.10	1.26	0.64	<LOD	<LOD
13	Rotte_13	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	5.08	<LOD	<LOD	<LOD	<LOD	0.34	0.37	0.28	0.27	<LOD	<LOD	<LOD
14	Rotte_14	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	2.25	<LOD	<LOD	<LOD	<LOD	<LOD	0.26	0.70	0.28	0.10	<LOD	<LOD
15	Rotte_15	liver	2013	<LOD	<LOD	<LOD	<LOD	<LOD	1.97	<LOD	<LOD	<LOD	<LOD	0.16	0.23	0.53	0.20	0.12	0.20	<LOD

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b: Less than Limit of Quantification

Nr. of samples	Customer:	Customers sample ID:	Individual:	Sampling year	Location	Sample type:	Concentration units:	Compound name:								
								Krom	Nickel	Kupper	Tinn	Arsen	Sølv	Bly	Metyl-Kvikksølv	Kvikksølv
								Cr	Ni	Cu	Zn	As	Ag	Pb	Me-Hg	Hg
1	Rotte_01	liver	2013	1	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
2	Rotte_02	liver	2013	2	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
3	Rotte_03	liver	2013	3	Oslo	Lever	ng/g ww	15.19	20.19	4066	29243	541	5.42	1796	1.20	<LOD
4	Rotte_04	liver	2013	4	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
5	Rotte_05	liver	2013	5	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
6	Rotte_06	liver	2013	6	Oslo	Lever	ng/g ww	25.17	23.91	4268	41388	219	1.89	1113	1.00	7.60
7	Rotte_07	liver	2013	7	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
8	Rotte_08	liver	2013	8	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	Rotte_09	liver	2013	9	Oslo	Lever	ng/g ww	19.64	10.36	3645	21885	484	6.66	788	2.10	<LOD
10	Rotte_10	liver	2013	10	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
11	Rotte_11	liver	2013	11	Oslo	Lever	ng/g ww	4.79	9.39	3715	74574	1027	1.11	394	4.10	6.70
12	Rotte_12	liver	2013	12	Oslo	Lever	ng/g ww	15.20	19.01	3805	28392	672	3.13	827	<LOD	<LOD
13	Rotte_13	liver	2013	13	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
14	Rotte_14	liver	2013	14	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
15	Rotte_15	liver	2013	15	Oslo	Lever	ng/g ww	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

<LOD: Less than Limit of Detection

b: Less than Limit of Quantification

Norwegian Environment Agency
Telephone: +47 73 58 05 00 | Fax: +47 73 58 05 01
E-mail: post@miljodir.no
Web: www.environmentagency.no
Postal address: Postboks 5672 Sluppen, N-7485 Trondheim
Visiting address Trondheim: Brattørkaia 15, 7010 Trondheim
Visiting address Oslo: Strømsveien 96, 0602 Oslo

The Norwegian Environment Agency's primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

We are under the Ministry of Climate and Environment and have over 700 employees at our two offices in Trondheim and Oslo and at the Norwegian Nature Inspectorate's more than sixty local offices.

Our principal functions include monitoring the state of the environment, conveying environment-related information, exercising authority, overseeing and guiding regional and municipal authorities, cooperating with relevant industry authorities, acting as an expert advisor, and assisting in international environmental efforts.