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Miljøgifter I terrestrisk og bynært miljø
Environmental pollutants in the terrestrial and urban environment, part II

Summary - sammendrag

On an assignment from the Norwegian Environmental Agency, the Norwegian Institute for Air Research (NILU) in collaboration with the Norwegian Institute for Nature Research (NINA) collected and analysed biological samples from terrestrial and urban regions for various inorganic and organic contaminants. The purpose of this report is to provide an updated assessment of pollution present within an urban environment in Norway, compared with that of more rural sites. The selected species were sparrowhawk and fieldfare (eggs), red fox (liver) and earthworms. Of all the organisms and tissues measured in the study, sparrowhawk eggs had the highest average concentration of the sum of all organic pollutants measured, followed by fieldfare, earthworm and red fox on a wet weight basis. Higher concentrations in the urban site, Oslo, compared to the rural site were observed for sparrowhawk and earthworms.

4 emneord	4 subject words
POPs, PFAS, tungmetaller, spurvehauk, gråtrost, rødrev, meitemark, terrestrisk miljø	POPs, PFAS, heavy metals, sparrowhawk, fieldfare, red fox, earthworms, terrestrial environment

Front page photo

Jan Ove Gjershaug, NINA

Summary

On behalf of the Norwegian Environment Agency, the Norwegian Institute for Air Research (NILU) in collaboration with Norwegian Institute for Nature Research (NINA) analysed biological samples from the terrestrial and urban environment 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 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 order to evaluate potential environmental hazard, and to provide information to 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 a 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

Representative species of different trophic levels of the terrestrial foodweb were investigated. Earthworm, eggs of the terrestrial bird species fieldfare and sparrowhawk as well as liver from red fox were investigated in this study. For all species, except fieldfare, samples from both urban and rural sites were analysed. The investigated compound classes were PCBs (polychlorinated biphenyls), PBDEs (polybrominated biphenylethers), PFAS (perfluorianted alkylated substances), cyclic siloxanes, short- and medium chain chloroparaffins and metals.

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

- Earthworms: Heavy metals >> sumPFAS > sumPCB > sumPBDE
- Fieldfare: Mercury ~ sumPCB > sumPFAS > sumPBDE
- Sparrowhawk: sumPCB > Mercury > sumPBDE > sumPFAS
- Red fox: Mercury >> sumPCB > sumPFAS > sumPBDE

Of all the organisms and tissues measured in the study, sparrowhawk eggs had the highest average concentration of the sum of all organic pollutants measured, followed by fieldfare, earthworm and red fox on a wet weight basis. For the average sum of the toxic metals Hg, Cd and Pb, earthworm revealed the highest load followed by red fox, sparrowhawk and fieldfare. Higher concentrations in the urban site, Oslo, compared to the rural site were observed for sparrowhawk and earthworms.

In order to estimate the biomagnification potential, trophic magnification factors (TMF) were calculated from the consumer relationship earthworm, fieldfare and sparrowhawk. The TMF calculations indicated trophic biomagnification for sumPCBs, sumPBDEs and sum PFAS, in descending order, in the observed terrestrial foodweb.

The combined risk for predators with earthworm and fieldfare as substantial part of their diet was evaluated with a first tier conservative concentration addition (CA) approach. Measured environmental concentrations were compared to predicted no effect

concentration for predators (PNECpred). Only metals, PBDEs and PFOS with available PNECpred values were included in the combined risk assessment The earthworms from the reference site and Oslo area showed a Sum(MEC/PNECpred) of 17 and 49 respectively, indicating reason for concern for predators with earthworm as an important food item. Cadmium contributed most to the estimated risk, followed by lead and PFOS. Fieldfare could only be assessed at the reference site. Several compound groups were not detected and sum of ratios was below 0.5 for this species, indicating no reason for concern for predators. A preliminary estimation of risk of effects from exposure in eggs of fieldfare and sparrowhawk was performed for some compound groups based on previous published effect data from exposure to contaminants in egg from non-raptor species. The sum values were higher than 1 for both areas for sparrowhawks and below 1 for fieldfare, indicating a risk for effects on sparrowhawk chicks, but not fieldfare.

Sammendrag

På oppdrag fra Miljødirektoratet analyserte Norsk institutt for luftforskning (NILU) og Norsk institutt for naturforskning (NINA) en lang rekke uorganiske og organiske miljøgifter i dyrearter fra bynært og terrestrisk miljø. Institutt for energiteknikk (IFE) analyserte stabile isotoper av nitrogen og karbon ($\delta^{15}N$ og $\delta^{13}C$). NINA og andre var ansvarlig for innsamling av prøvene. Formålet med studien var å gi vurdering av forurensningssituasjonen i det terrestriske miljøet i bynære områder samt å se på samlet effekt av miljøgifter. Resultatene vil også kunne brukes i forbindelse med nasjonale og internasjonale reguleringer av stoffene.

Prosjektet hadde følgende delmål :
- Rapportere konsentrasjoner av de utvalgte miljøgifter på flere nivå av en terrestrisk næringskjede
- Vurdere bioakkumuleringspotensialet av forurensninger i en terrestrisk næringskjede
- Vurdere kombinert eksponering og risikovurdering av miljøgiftblandinger
- Vurdere hvordan terrestriske arter er utsatt for en rekke miljøgifter

Dyr fra ulike trofiske nivå i et terrestrisk næringsnett ble undersøkt. Det ble samlet inn egg fra spurvehauk og gråtrost, samt meitemark og lever fra rødrev. Som referanse ble det samlet inn samme arter fra mer avsidesliggende områder. Gråtrostegg ble samlet inn bare fra et referanseområde. Prøvene ble analysert for metaller, PCB (polyklorerte bifenyler), PBDE (polybromerte bifenylether) og PFAS (perfluorerte alkyl stoffer), sykliske siloksaner og kort- og mellomkjedete klorparafiner.

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

- Meitemark: Tungmetaller >> sumPFAS > sumPCB > sumPBDE
- Gråtrost: Kvikksølv~ sumPCB > sumPFAS > sumPBDE
- Spurvehauk: sumPCB > Kvikksølv > sumPBDE > sumPFAS
- Rødrev: Kvikksølv >> sumPCB > sumPFAS > sumPBDE

På våtvektbasis hadde spurvehaukegg de høyeste middelkonsentrasjonene av sum organiske miljøgifter etterfulgt av gråtrost, meitemark og rødrev. For gjennomsnittlig sum av de giftige metallene Hg, Cd og Pb, hadde meitemark mye høyere konsentrasjoner enn de andre artene med avtagende konsentrasjon i denne rekkefølgen rødrev, spurvehauk og gråtrost. Det var høyere konsentrasjoner i spurvehaukegg og i meitemark i prøvene fra Oslo sammenlignet med referanseområdene.

For å vurdere biomagnifiseringspotensialet ble trofiske magnifiseringsfaktorer beregnet for næringskjeden meitemark - gråtrost - spurvehauk. TMF-beregningene indikerte trofisk magnifisering for organiske miljøgifter sumPCBs, sumPBDE, sum PFAS i avtagende rekkefølge.

Kombinert risiko for predatorer med meitemark og gråtrost som en vesentlig del av dietten ble evaluert med konsentrasjonaddisjons tilnærming. Målte miljøkonsentrasjoner ble sammenlignet med predikert ingen effekt konsentrasjon for rovdyr (PNECpred). Bare noen metaller, PBDEer og PFOS med tilgjengelige PNECpred verdier, ble inkludert i den samlede risikovurderingen. Meitemark fra referanseområdet og Oslo-området viste en

sum ($MEC/PNEC_{pred}$) på 17 og 49, noe som indikerer fare for predatorer med meitemark som viktig føde. Kadmium bidro mest til den beregnede risikoen, etterfulgt av bly og PFOS. Gråtrostegg kun fra referanseområdet viste sum (MEC / PNECpred) under 0.5 og viste ingen grunn til bekymring for predatorer, men kun få miljøgiftgrupper var detektert. En estimering av risiko for effekter i eggene av gråtrost og spurvehauk ble gjennomført for noen kjemiske stoffer. Sum verdiene var høyere enn 1 for spurvehauk og lavere enn 1 for gråtrost noe som indikerer risiko for toksiske effekter på spurvehauk kyllinger, men ikke gråtrost.

Abbreviations

BFR	brominated flame retardants
CA	concentration addition
CI	confidence interval
EI	electron impact ionization
ESI	electrospray ionization
EAC	ecotoxicological assessment criteria
EQS	environmental quality standard
fw	fresh weight
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
lw	lipid weight
MEC	measured environmental concentration
M-W U	Mann–Whitney *U* test
MSCP	medium-chain chlorinated paraffins
NCI	negative chemical ionization
NOEC	no observed effect concentration
NP-detector	nitrogen-phosphorous detector
PBDE	polybrominated diphenylethers
PCA	principal component analysis
PCB	polychlorinated biphenyls
PCI	positive chemical ionization
PEC	predicted environmental concentration
PFAS	perfluorinated alkylated substances
PNEC	predicted no effect concentration
$PNEC_{pred}$	predicted no effect concentration for predator
PSA	primary/secondary amine phase
SCCP	short-chain chlorinated paraffins
SSD	species sensitivity distribution
SIR	selective ion reaction
SPE	solid phase extraction
STU	sum toxic unit
TL	Trophic level
TMF	Trophic magnification factor
UHPLC	ultra high pressure liquid chromatography
ww	wet weight

Content

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 urban sites were chosen in or in the near vicinity of Oslo, while reference samples were collected in Åmotsdalen, Oppdal in Sør-Trøndelag county (fieldfare and red fox) and from Aust-Agder and Telemark counties (sparrowhawk and earthworms). 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 belonging to different trophic levels were selected.

1.2 Investigated species

Sparrowhawk (*Accipiter nisus*)
The sparrowhawk is a small bird of prey with a widespread distribution in Norway. It feeds mainly on birds of small to medium size, and thrushes (*Turdidae*) are preferred prey (Hagen 1952, Haftorn 1971). It commonly occurs close to human habitations, where it can breed in different types of forest patches. Most of the population migrates to south-western Europe during winter, but some individuals stay, and often feed on small garden birds during winter (Haftorn 1971). The sparrowhawk is on top of a terrestrial food-chain (invertebrates-small birds-sparrowhawk), and is therefore subjected to bioaccumulation of persistent organic pollutants (POPs). The sparrowhawk is a protected species in Norway, so the collection of eggs for analysis was carried out under a special license issued by the Norwegian Environment Agency. The species nests in stick-nests in forests or forest patches, and lays 4-6 eggs. It has been documented that the sparrowhawk is one of the species most affected by environmental pollutants in Europe after World War II (Ratcliffe 1960, Bennington 1971, Bennington 1974, Newton & Bogan 1978, Cooke 1979, Burgers et al. 1986, Newton et al. 1986), and also in Norway (Holt & Sakshaug 1968, Bühler & Norheim 1981, Frøslie et al. 1986, Nygård et al. 2006, Nygård & Polder 2012). Estimated trophic level 4.

Fieldfare (*Turdus pilaris*)
The fieldfare is a member of the thrush family, and is a common breeding bird in Eurasia. It is a migratory species; birds that breed in the northern regions migrate to the south and south-west in the winter. The majority of the birds that breed in Norway spend the winter months in south-west Europe (Bakken et al. 2006). It is omnivorous, with its diet mainly consisting of invertebrates during spring and summer, especially earthworms. The

diet changes more to berries, grain and seeds during autumn and winter (Haftorn 1971). Estimated trophic level 3.

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 coelomic fluid that moves within the fluid-filled coelom 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, snails, slugs). They are found almost anywhere in soil that contains some moisture (Macdonald 1983). *Lumbricus terrestris* was the most common species. Estimated trophic level 2 (Hui et al. 2012).

Red fox (*Vulpes vulpes)*
The red fox is the most abundant carnivore in Europe, and is widespread. It is found over most of the world. It inhabits most of Norway, from the mountains, through the forests and the agricultural landscape and is also found in the cities. It primarily feeds on rodents, but it is a generalist predator feeding on everything from small ungulate calves, hares, game-birds and other birds, reptiles and invertebrates, to human offal. Estimated trophic level 3-4.

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 $\delta^{13}C$. In fox liver, three siloxanes (D4, D5 and D6) and the chlorinated paraffins were measured too. An overview over the analysed compounds is given in Table 1.

Table 1: Overview over analysed compounds

Parameters	Abbreviation	CAS number
Metals		
Chromium	Cr	7440-47-3
Nickel	Ni	7440-02-0
Copper	Cu	7440-50-8
Zinc	Zn	7440-66-6
Arsenic	As	7440-38-2
Silver	Ag	7440-22-4
Cadmium	Cd	7440-43-9
Lead	Pb	7439-92-1
Methyl Mercury	Me-Hg	22967-92-6
Total-Mercury	Hg	7440-02-0
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
Cyclic Siloxanes	D4	556-67-2
	D5	541-02-6
	D6	540-97-6
Chloroparaffins	SCCP (C10-C13)	85535-84-8
	MCCP (C14-C17)	85535-85-9

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 environmentally hazardous compounds (Latif et al. 2013). Recently, there has been an increased use of silver as nanoparticles. Nanotechnology makes it possible to combine silver (Ag) with other materials, 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 Ag may have long residence time in the organism (Rungby 1990). Arsenic is also known as a toxic metalloid (Klaassen 2008). Among the different metals determined in the present work, Pb and Cd have a potential to bioaccumulate (Connell 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 insulation 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 poorly water soluble, but dissolve efficiently in lipid-rich parts of organisms (hydrophobic and lipophilic). They can affect the reproduction success, impair immune response and may cause defects in 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 result, 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 electrical and electronic products entered into force in the EU. A restriction on the manufacture, use and placing on the market of decaBDE is also under discussion in the EU. In North-America voluntary agreements with the industry have led to reduced use of decaBDE. Globally, commercial deca-BDE is still widely used and remains a high production volume chemical. However, decaBDE is currently being considered for inclusion in the Stockholm Convention as a persistent organic pollutant.

The tetra- and pentaBDE congeners BDE 47 and 99, which were the main components of commercial pentaBDE mixtures, are among the most studied PBDEs. 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 better waste handling, have resulted in a decrease of 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 to hexaBDEs biomagnify in arctic food webs while results for the fully brominated PBDE congener, BDE 209 or decaBDE, are more ambiguous. Several lines of evidence show that also BDE-209 bioaccumulates, at least in some species. The equivocation in the available bioaccumulation data largely reflects species and tissue differences in uptake, metabolism and elimination, as well as differences in exposure and also analytical challenges in measuring BDE-209. Moreover, in the environment and biota, BDE 209 can debrominate to lower PBDE congeners that are more persistent,

bioaccumulative and toxic. PBDE concentrations are often lower in terrestrial organisms compared to 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 due to their widespread use, PFASs have been detected worldwide in the environment, wildlife, and humans. Scientific studies focus on how these substances are transported in the environment, and to what extent and how humans and wildlife are exposed and their 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; de Wit 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 humans 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. Polyfluorinated acids are structurally similar to natural long-chain fatty acids and may displace them in biochemical processes and at receptors, such as PPARα and the liver-fatty acid binding protein (L-FABP). Perfluoroalkanoates, particularly PFOA, PFNA and PFDA but not PFHxA, are highly potent peroxisome proliferators in rodent livers and affect mitochondrial, microsomal, and cytosolic enzymes and proteins involved in lipid metabolism. Beach, Newsted et al. (2006) reported an increased mortality for birds (mallards *Anas platyrhynchos* and northern bobwhite quail *Colinus virginianus*) and a reduced reproduction success have been observed. PFOA and other PFAS are suspected to be endocrine disruptors and exposure during pregnancy has induced both early and later life adverse health outcomes in rodents. Associations between PFOA exposures and human health effects have been reported. PFOS, its salts and PFOSF are listed in the Stockholm Convention and are recognized as persistent organic pollutants. However globally, the production and use of PFOS, its salts and PFOSF is still allowed for certain applications. In Norway, PFOS and PFOA are banned, and the C9-C14 PFCAs are on the Norway's Priority List of Hazardous substances.

1.3.5 Cyclic siloxanes, (cVMS)

There have been raised concern about the properties and environmental fate of the three most common cyclic siloxanes D4, D5, and D6. These compounds are used in large volumes in personal care products and technical applications, and are released to the environment either through volatilization to air or through wastewater effluents. Once emitted to water, they can sorb to particles and sediments or be taken up by aquatic biota. They are persistent in the environment, can undergo long-range atmospheric transport, and can have high concentrations in aquatic biota but often lower in the terrestrial environment. There is still limited knowledge on their toxicity, but D4 has been shown to display endrocrine disrupting effects.D4 and D5 are listed on Norway's priority list with the aim to stop emissions of these substances within 2020, and in 2015 there is expected to be

submitted a current restriction intention to REACH for the use of D4 and D5 in wash-off personal care products in EU (ECHA).

1.3.6 Chlorinated paraffins (CPs)

CPs have been produced since the 1930s and the world production of chloroparaffins was 300,000 tonnes in 2009. Chloroparaffins are used in coolants and lubricants in metal manufacturing industry and as plasticizers and flame retardant additives in plastic, sealants, rubber and leather (KEMI, 2013, WHO 1996). The non-flammability of CPs, particularly at high chlorine contents, relies on their ability to release hydrochloric acid at elevated temperatures, thereby inhibiting the radical reactions in flames (WHO, 1996).

CPs have been studied in the environment but data from Scandinavia and the Arctic is limited (Bayen et al. 2006). In air collected at Bear Island (Norway), concentrations were 1.8 to 10.6 ng/m^3 (Borgen et al. 2003) while SCCPs have been detected in river water in a range of 15.7 to 59.6 ng/L in the St. Lawrence River, Canada (Moore et al., 2004) and < 0.1 to 1.7 µg/L in England and Wales (Nicholls et al., 2001). SCCP have been detected in surface sediments in Arctic lakes in Canada 1.6 to 257 ng/g (Tomy et al., 1997), and SCCPs and MCCPs have been found in sediments from landfills in Norway at levels of up to 19,400 and 11,400 ng/g ww with peak levels associated with waste deposition from mechanical and shipping industries (Borgen et al., 2003). CPs have been detected in biota samples collected in Norway, SCCPs ranged from 14 to 130 ng/g wet weight (ww) in mussels and were also detected in moss samples (3–100 ng/g ww), revealing the potential transportation of SCCPs in the atmosphere (Borgen et al., 2003). Levels of MCCPs ranged from 276 to 563 ng/g ww in carp and 0.257 to 4.39 µg/g ww in trout from Lake Ontario. In Beluga whales collected between 1987 and 1991, SCCPs ranged from 1.78 to 80.0 µg/g ww in blubber and 0.545 to 20.9 µg/g ww in liver samples (Bennie et al. 2000). In fish livers collected from samples in the North and Baltic Seas, SCCPs and MCCPs ranged from 19 to 286 and <10 to 260 ng/g ww (Geiss et al. 2010; Reth et al. 2005).

1.3.7 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, is used to define the relative position in a food chain of an organism. Subsequently, 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 selected terrestrial urban environments in Norway, especially the Oslo area, and to evaluate the

combined risk of these pollutants and assess their bioaccumulation. The different species included in the study were selected to represent different trophic concentrations, from primary consumers (earthworm) via secondary consumers (fieldfare) to a top predator (sparrowhawk). In addition, an omnivore generalist representing a truly urban environment, the red fox, was chosen. Sparrowhawk eggs were used in this study to give insights in how a terrestrial top predator within both urban and rural habitats is affected by pollution levels. An overview over the analysed samples is given in Table 2. All samples were sampled and handled according the guidelines given in OSPAR/ JAMP, 2009.

Table 2: Location and selection of samples

Sample type	***No. of Samples***	***Location***	***Date***	***Sampling strategy***
Sparrowhawk (*Accipiter nisus***)**	10	Oslo	2014	Fresh eggs
	10	Aust-Agder and Telemark (Reference)		
Fieldfare (*Turdus pilaris***)**	10	Oppdal (Reference)	2014	Fresh eggs
Earthworms (*Lumbricidae***)**	8	Oslo	2014	Pool of 5 individuals
	9	Aust-Agder and Telemark (Reference)		
Red fox (*Vulpes vulpes)*	7	Oslo	2013 /14	Individual liver samples
	15	Oppdal (Reference)		

Sparrowhawk (*Accipiter nisus*)
Sparrowhawk eggs were collected at different locations in the Oslo area (N=10), Aust-Agder and Telemark (N=10). The specified location of the nests is known to the authors and the contractor, but will not be published here in order to protect the nesting sites. Nests were located early in the breeding season, and sampled in April-May just after eggs had been laid. The laying order of the eggs was not taken into account when collecting the eggs due to practical considerations as not to disturb the nest more than necessary. Only one egg from each nest was taken, under permission from the Norwegian Environment Agency. The eggs were kept individually in polyethylene bags in a refrigerator (+4°C), before being shipped by express mail to NINA for measurements and emptying. When emptying, the whole content of the eggs were removed from the shell and transferred to clean glass vials for storage at − 21 °C.

Fieldfare (*Turdus pilaris*)
Ten fieldfare eggs were collected from ten nests in Åmotsdalen in the Dovre Mountains in June 2014, under permission from the Norwegian Environment Agency. The eggs were handled by the same method as the sparrowhawk eggs at NINA.

Earthworms (*Lumbricidae)*
Earthworms were collected at three locations in Oslo (Voksenkollen, Brekke and Østmarksetra), and at three reference sites, two in Telemark (Hegna and Kåsmyra), and one in Aust Agder (Gjerstad) (Figure 1). All pooled samples consisted of up to 10 individuals. Three parallel pools per location were prepared, resulting in total of 17 samples. To purge their guts, earthworms were kept in plastic containers lined with moist paper sheets for three days before being frozen at -21°C.

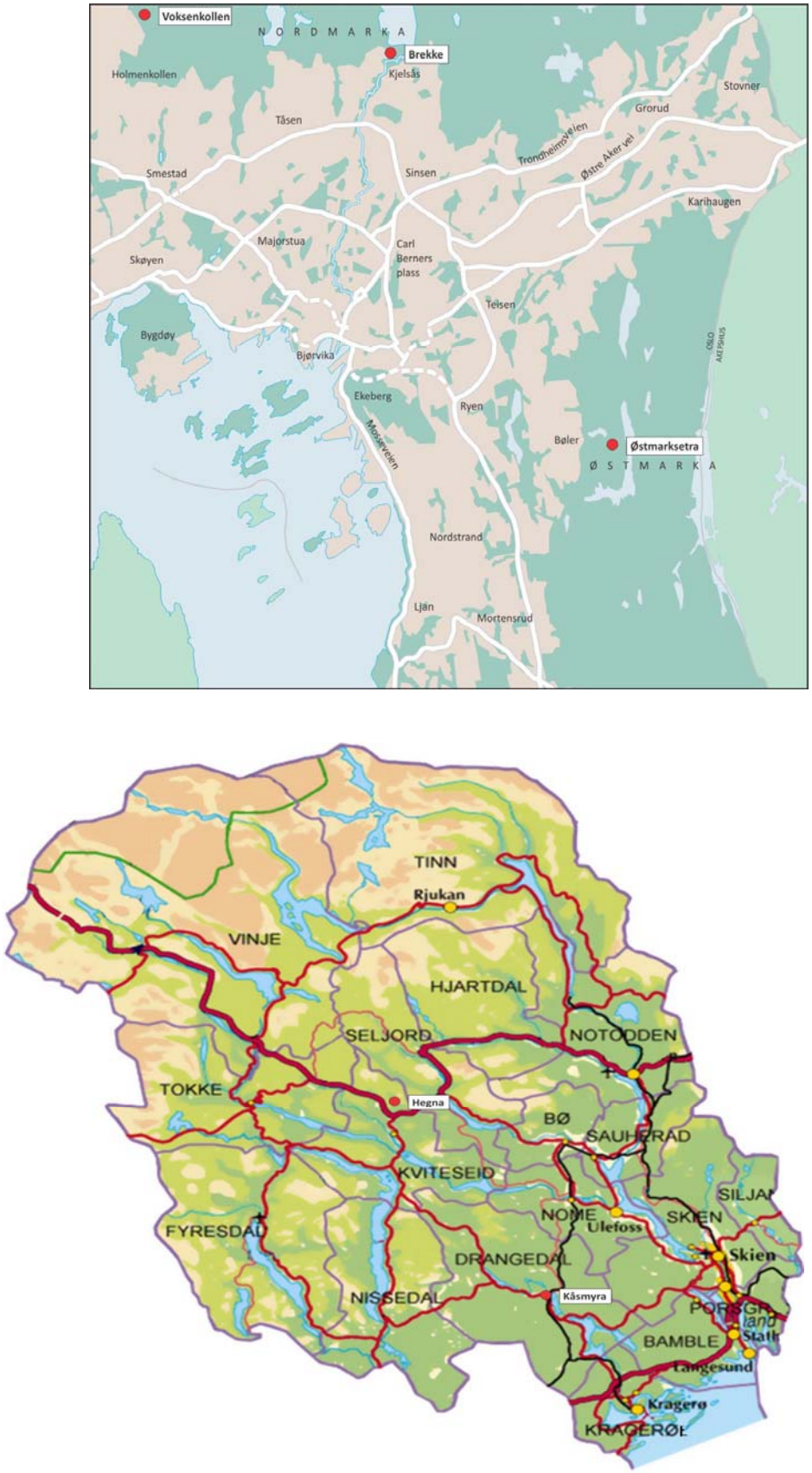


Figure 1: Reference location for earthworms sampled in Oslo (above) and Telemark, reference (below).

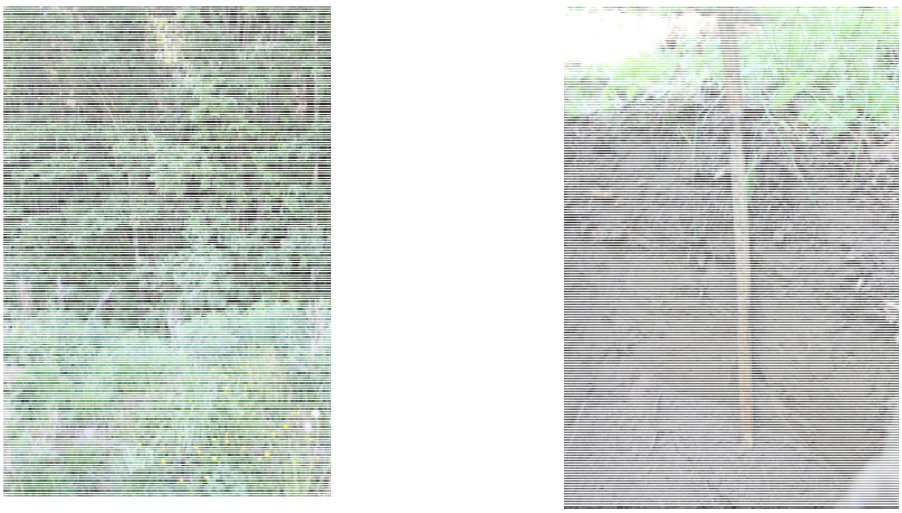


Figure 2: Habitat (left) and soil profile (right) of the sampling-site at Hegna in Telemark

Red fox (*Vulpes vulpes)*
Red foxes were collected in Sørkedalen and Movann in Oslo (n= 7) and at several sites in Oppdal (n= 15). The foxes were shot by local hunters on assignment from NINA. Dissection of their livers was carried out at the laboratories of NINA, applying the siloxane relevant precautions. The samples were wrapped in aluminum foil and thereafter put into sealed polyethylene bags before being frozen at – 21°C. Among the sampled foxes, we collected 7 males and 15 females. Their bodyweight varied between 3984 and 8742 g. Their sex was determined by inspection of the gonads, while the age was determined by examining the incremental layer-structure in their teeth (Morris, 1972).

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 (JAMP; OSPAR). 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, siloxanes and BFRs during sampling, handling and storage, were followed. Sampling materials as bags, containers, knives, scalpels, gloves etc. were 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. For the same compound group, samples were dissected and prepared in the same laboratory which minimized sample handling, shipment, repeated freezing and thawing, etc. This was done to ensure minimum variation in sample quality in all steps and at the same time improve comparability of results.

2.3 Sample preparation and analysis

Preparation of bird eggs
Length and breadth 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. Eggs were taken fresh from the nests under permission from the Norwegian Environment Agency. As the eggs were brooded by the parent bird for a different length of time, 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:

$V = 0.51 * \text{length} * (\text{breadth})^2$

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. Extracts were measured using GC/MS/MS.

PFAS. Samples were extracted with acetonitrile and treated with emulsive clean-up prior to analyses with UPLC/MS/MS in ESI(-) mode.

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 220°C as maximum temperature. After digestion, the samples were split in two aliquots, where concentrated HCl were added to the aliquot used for Hg determination. Metals were analysed applying an ICP-MS.

Siloxanes.
Established methods based on liquid/liquid extraction (Warner et al. 2010; Warner et al. 2013) were used to extract and quantify siloxanes, in addition to headspace extraction techniques (Sparham et al. 2008) for analysing siloxanes in water and sediment samples. Analysis of siloxanes (D4, D5 and D6) was performed using gas chromatography with mass spectrometric detection (GC-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. In general, only analytes with concentrations above the detection limit are presented in tables and figures. For siloxanes the greatest risk in the analysis is background contamination, as these chemicals (D4, D5 and D6) are applied in e.g. skin care products. Using a state-of-the-art cleanroom, NILU may perform trace analysis of these compounds in matrices from pristine environments, such as the Arctic (Krogseth et al. 2013; Warner et al. 2013). Samples were analysed in groups with at least one additive standard sample and a blank control. The data from these were used to calculate the uncertainty for each sample group. To ensure repeatability, a random sample from each matrix was selected for duplicate analysis. Field blanks were prepared for the sampling of samples for siloxane analyses by packing 2 or 3 grams of XAD resin in filter bags of polypropylene/cellulose, which were thereafter cleaned by ultrasonic treatment in hexane for 30 min. Subsequently, used hexane was removed and substituted with clean hexane and the field blanks were sonicated once more for 30 min. After ultrasonic treatment, the field blanks were dried in a clean cabinet equipped with HEPA- and charcoal filter to prevent contamination from indoor air. After drying, the field blanks were put in sealed polypropylene containers and sent for sampling purposes. Several field-blanks were stored at NILU's laboratories and analysed to determine reference concentrations before sampling. The field blanks sent for sampling purposes were exposed and handled in the field during sampling and during preparation of samples.

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.

2.4 Biomagnification

In contrast to the monitoring performed in 2013, a more complete food chain was available to the project, thereby allowing a better assessment of the biomagnification of the different chemicals investigated. Similar to the urban terrestrial study from 2013, (Herzke et al., 2014), a TMF on the basis of trophic levels was estimated. The trophic level (TL) was calculated for each species per individual relative to the species representing the lowest position, assuming a 3.8 ‰ increase of δ^{15} per full trophic level (Hallanger et al., 2011). Earthworm was used as a base level and defined as inhabiting TL 2.

Based on their known food-choice and their position in their food chain, their trophic levels (TL) would be as follows *a priori*: Earthworms = 2, red fox = 3, fieldfare = 3, sparrowhawk = 4.

For earthworms we modified the TL value by multiplying it with the ratio between the sample $\delta^{15}N_{\text{sample}}$ and the average $\delta^{15}N$ value for earthworms.

For birds the trophic enrichment of δ^{15} changes with an isotopic enrichment factor of 2.4‰ causing a modification of the equation for TL calculations as follows (Hallanger et al., 2011) :

$$TL_{\text{fieldfare}} = 3 + (\delta^{15}N_{\text{fieldfare}} - (\delta^{15}N_{\text{earthworm}} + 2.4))/3.8$$

$TL_{sparrowhawk} = 4 + (\delta^{15}N_{sparrowhawk} - (\delta^{15}N_{earthworm} + 2.4))/3.8$

For further data assessment of the biomagnification, all sumPCB and sumPBDE data were lipid normalized. PFAS are not lipophilic compounds (Kelly, 2009), however we performed calculations for SumPFAS both on lipid weight basis and wet weight basis for comparisons. Trophic magnification factors (TMFs) were calculated as the power of 10 of the slope (b) of the linear regression between log concentration and the samples TL.

Log [compound] = a + *b*TL

$TMF = 10^b$

In addition a comparison of $\delta^{15}N$ levels in each species was done.

2.5 Statistical methods

Numbers in tables refer to the numbers that had concentration levels >LOD. Statistics were performed using SPSS statistics, ver. 21 (® IBM). We tested differences between groups by using the non-parametric Mann-Whitney test. This test is conservative, as it does not require any assumptions of the distribution of the values (Zar, 1984).

2.6 Mixture risk assessment

The method of summing up PEC/PNEC or MEC/PNEC ratios, has been recommended as a justifiable mixture risk approximation in order to estimate in a first tier approach whether there is a potential risk for an exposed ecosystem (Backhaus and Karlsson, 2014; Petersen et al, 2013; Backhaus and Faust 2012). The sum of MEC/PNECs was calculated where MEC was the median measured concentration of contaminants in earthworm, fieldfare egg and the predicted no-effect concentration (PNEC) for predators in terrestrial environment feeding on these organisms. PNEC values were adopted from previously assessed and reported values (Andersen et al., 2012). The single MEC/PNEC was calculated and summed up to assess if the sum exceeded 1 or not. A sum value of MEC/PNEC below 1 indicates no unacceptable risk (Altenburger et al., 2014). If the sum was below 1 for median concentration, same calculations with 90 % percentile value were performed to assess worst case of the sum of MEC/PNEC. The methodology was applied with the presumption that the available PNEC values (Andersen et al., 2012) were protective and assessed for the most sensitive predator species, in accordance to the guidelines for deriving PNEC values (ECHA, 2008).

An evaluation of the risk of effects for fieldfare and sparrowhawk eggs was performed by comparing measured concentrations in eggs to literature effect data; i.e. effect concentration from exposure in eggs (Andersen et al., 2014 with references therein). Effect from exposure in eggs was related to mortality, reduced number of eggs, effect on gender development for various endpoints (LOEC, EC(D)10, EC(D)50, LC(D)50) from studies on various bird species (chicken, hen, common quail, zebra finch etc.). The single (MEC/Effect concentration) ratios were calculated and summed up to evaluate the risk of combined effects.

3. Results

Of the 47 compounds that were analysed in all samples, 40 could be detected. In the chapters below, we mainly discuss the sum for each group of contaminants investigated. Single compounds/ congeners are only discussed in special cases. Detected concentrations are summarized in the tables below and individual data can be found in the Appendix. In the tables below, means as well as maximum and minimum values are reported. The number of cases (N) in all tables denotes the number of samples with detectable levels.

In general, the highest concentrations of halogenated organic pollutants were found in sparrowhawk eggs. PCBs and PBDEs were highest in sparrowhawk, while PFAS levels were high in sparrowhawk and earthworms. Mercury was found in highest concentrations in sparrowhawk and earthworms, followed by red fox and fieldfare. Lead was highest in earthworms, followed by red fox and sparrowhawk. Siloxanes and SCCP were only measured in red fox livers.

3.1 PCBs

3.1.1 Sparrowhawk

Twenty eggs were available for analysis, ten from the Oslo area, and ten from the reference areas in Aust-Agder and Telemark. The detailed results are shown in Table 3.

In Figure 3, the average PCB concentrations by sampling location and congeners are shown. Elevated PCB concentrations were found in a number of eggs, with a maximum concentration of sumPCB of 2952 ng/g fw (fresh weight) in one sample from Oslo. The average sumPCB concentration for Oslo was 750 ng/g fw, which was higher than that of the reference locations (181 ng/g fw), but not significantly different ($P = 0.089$, $Z = -1.74$, M-W U). PCB 138 and 153 were the dominating PCB congeners. All PCB congeners were higher in the Oslo area compared to the reference sites, and significant differences were obtained for PCBs 28, 52, 101 and 118 ($P < 0.05$, M-W U).

Table 3: Concentrations of PCB congeners in sparrowhawk eggs in ng/g ww.

Area		PCB 28	PCB 52	PCB 101	PCB 118	PCB 138	PCB 153	PCB 180	Sum PCB
Oslo area	N	10	10	10	10	10	10	10	
	Mean	1.38	1.74	18.59	29.52	264	379	55.74	750
	Median	0.15	0.56	5.65	14.38	81.76	103	51.23	256
	Minimum	0.06	0.14	1.34	3.77	15.74	20.79	12.70	54.70
	Maximum	7.39	6.09	79.3	99.1	1125	1576	132	2952
Reference	N	9	8	10	10	10	10	10	10
	Mean	0.07	0.22	2.45	6.87	53.41	78.07	40.38	181
	Median	0.05	0.18	1.51	4.73	38.49	64.24	35.91	146
	Minimum	<LOD	0.06	1.03	3.71	26.90	41.16	20.73	98.36
	Maximum	0.16	0.47	7.45	18.63	130	173	66.39	396

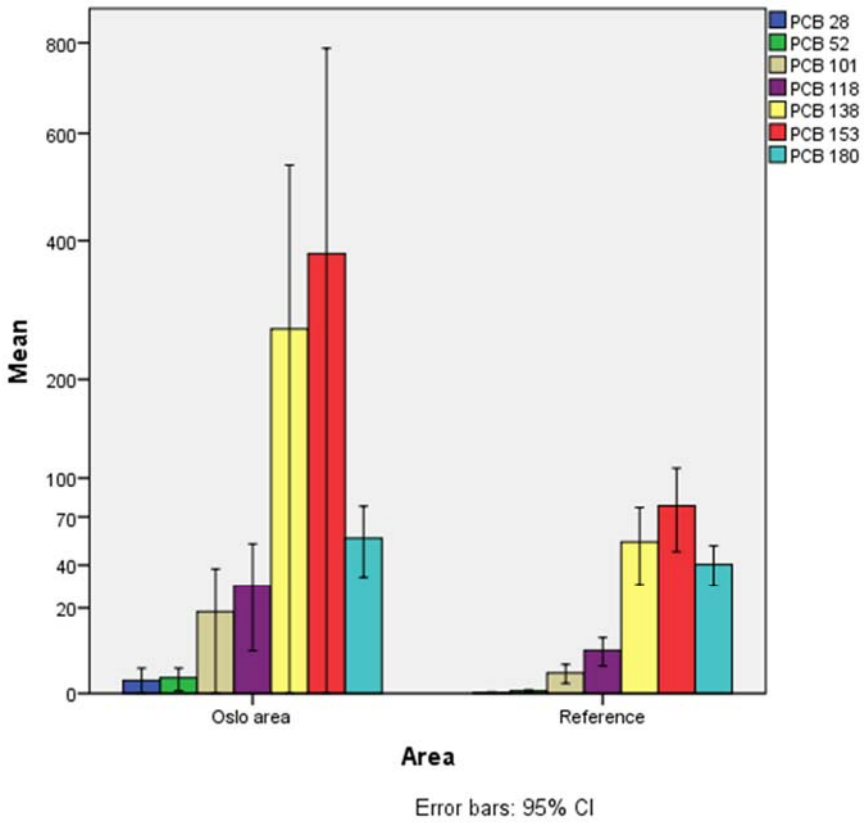


Figure 3: Main PCB congener distribution by location of sampling in eggs of sparrowhawk (ng/g fw). Errorbars show the 95% confidence limits.

The lower chlorinated PCBs as PCB101 and 118 contribute more in the urban location than at the reference site, indicating fresh sources. The levels of PCB 180 were almost equally high in the reference sites compared to the Oslo samples.

3.1.2 Fieldfare

For fieldfare, only samples from the reference site were available for analysis. Five PCBs could be detected in the fieldfare eggs. SumPCB concentrations varied between 2 and 30.5 ng/g ww, with an average of 11.1 ng/g ww sumPCB. A summary of values are given in Table 4. PCB 138, 153 and 180 dominate the PCB pattern (Figure 4).

Table 4: PCB congener concentrations at different sampling sites in pied fieldfare eggs from 2014 in ng/g ww.

Area		PCB 101	PCB 118	PCB 138	PCB 153	PCB 180	Sum PCB
Reference	N	9	7	9	9	9	9
	Mean	0.32	0.25	4.71	3.81	2.07	11.10
	Median	0.31	0.26	4.13	2.67	1.55	9.79
	Minimum	0.07	0.09	0.74	0.70	0.28	2.00
	Maximum	0.68	0.43	13.24	11.23	5.22	30.53

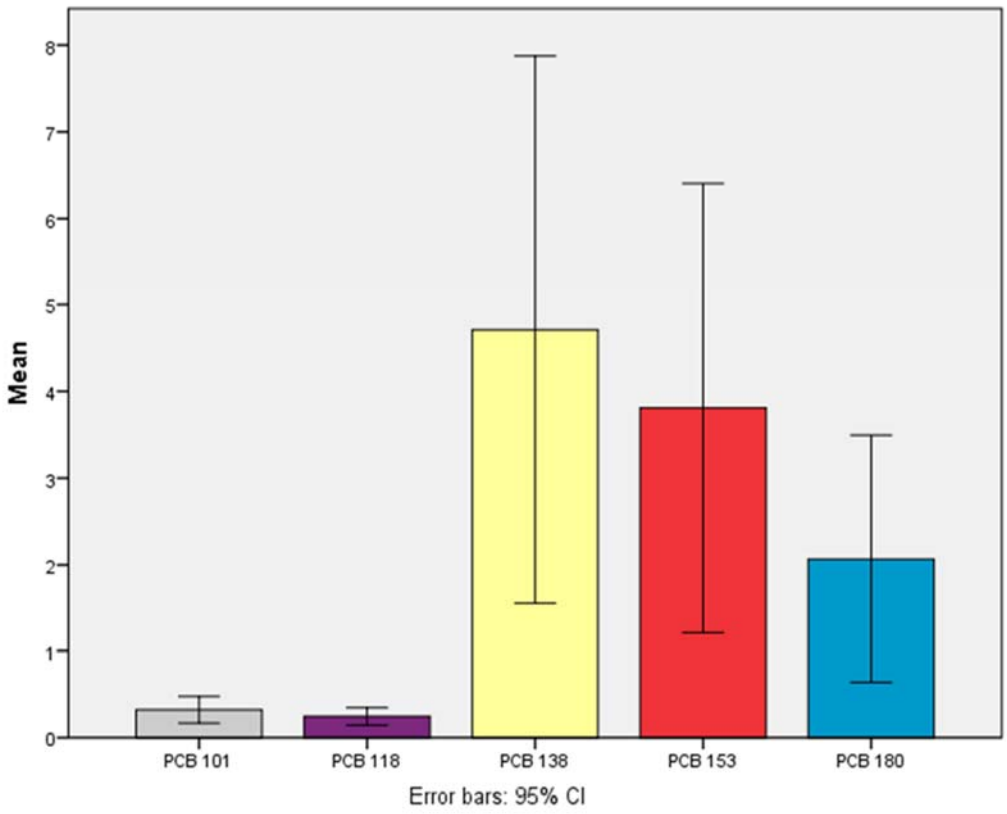


Figure 4: Average concentrations of PCBs in fieldfare eggs (ng/g ww).

3.1.3 Red fox

In total, 22 livers of foxes were analysed for PCBs. Fifteen individuals were sampled at the reference site and seven in Oslo. Seven of them were classified as males, and fifteen of them as females.

Even though there was a tendency for foxes from Oslo to have higher concentrations of PCB than those from reference sites, none of the differences were significant. No difference between females and males was observed, as well as no effects of age. PCB 153 and 180 were the dominant congeners (Figure 5). The observed sumPCB concentration ranged between 0.87 and 24.3 ng/g ww, with an average of 5.3 at the reference site and 6.5 ng/g ww in Oslo. A summary of values are given in (Table 5).

Table 5: PCB concentrations in red fox liver in (ng/g ww)

Area		PCB 118	PCB 138	PCB 153	PCB 180	Sum PCB
Oslo area	N	1	7	7	7	7
	Mean	0.12	0.81	1.66	4.03	6.52
	Median	0.12	0.36	0.59	2.30	3.02
	Minimum		0.19	0.38	1.43	2.02
	Maximum		2.44	4.93	10.62	17.99
Reference	N	3	15	15	15	15
	Mean	0.16	0.71	1.31	3.25	5.29
	Median	0.15	0.44	0.80	1.74	3.49
	Minimum	0.11	0.14	0.21	0.41	0.87

Maximum	0.21	1.97	5.19	17.17	24.30

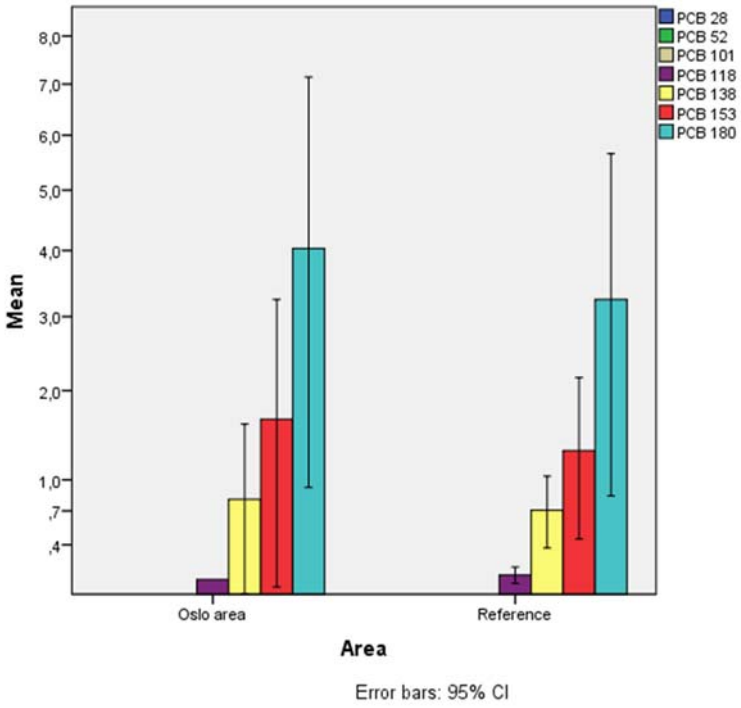


Figure 5: Average PCB congener concentrations between Oslo (n=7) and the reference site (n=15) in fox livers in ng/g ww.

3.1.4 Earthworms

SumPCB concentrations in Earthworms ranged from 0.02 ng/g ww (from Kåsmyra, Telemark (reference site)) to 3.8 ng/g ww (from Østmarksetra, Oslo). The average sumPCB concentration was 0.09 ng/g ww at the reference sites and clearly higher with 1.11 ng/g ww in Oslo. The detailed results are shown in Table 6. PCB 138 and 153 were the dominating PCBs measured. Very low concentrations of low-chlorinated PCBs were found at the reference sites. There were significant differences between Oslo and the reference samples for sumPCBs (P = 0.004, Z = -2.7, M-W U) and for PCB 153 (P = 0.007, Z = -2.6, M-W U). Low-chlorinated PCBs were almost only found in Oslo (Figure 6).

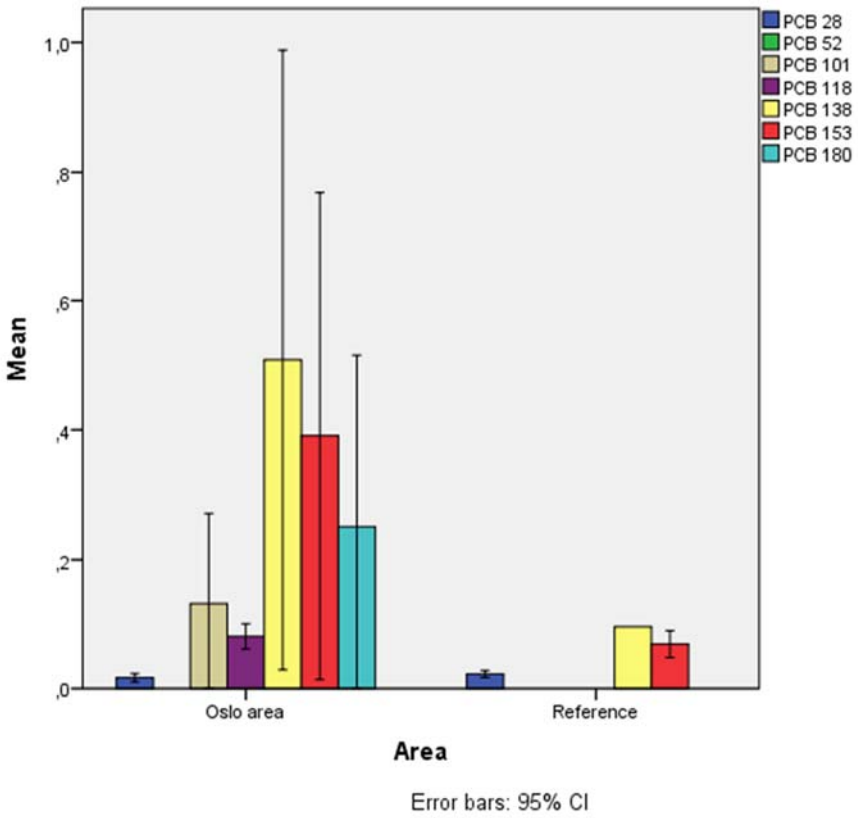


Figure 6: Average PCB concentrations in earthworm in ng/g ww

Table 6: PCB concentrations in earthworms in ng/g ww (nd: not detected)

Area		PCB 28	PCB 101	PCB 118	PCB 138	PCB 153	PCB 180	Sum PCB
Oslo area	N	4	6	5	6	7	3	7
	Mean	0.02	0.13	0.08	0.51	0.39	0.25	1.11
	Median	0.02	0.08	0.08	0.37	0.29	0.15	0.79
	Minimum	0.01	0.05	0.06	0.13	0.07	0.13	0.08
	Maximum	0.02	0.43	0.10	1.50	1.32	0.47	3.83
Reference	N	8			1	7		8
	Mean	0.02	nd	nd	0.10	0.07	nd	0.09
	Median	0.02			0.10	0.07		0.08
	Minimum	0.02				0.04		0.02
	Maximum	0.03				0.10		0.21

3.2 PBDEs

3.2.1 Sparrowhawk

The dominating PBDE congener was PBDE 99, followed by PBDE 153 and PBDE 47. Of the analysed PBDEs, PBDE 126, 190, 202, 206 and 207 were only detected at very few occasions or not at all. SumPBDE concentrations ranged from 13 to 171 ng/g ww in Oslo,

and from 13 to 141 ng/g ww in eggs collected at reference sites (average sumPBDE 56 ng/g fw in Oslo and 37 ng/g reference samples from Aust-Agder and Telemark). The difference between the sites was not significant (P = 0.086, Z = -1.72, M-W U). The highest PBDE concentrations were detected in one egg with sumPBDE concentrations of 171 ng/g ww from Oslo. PBDE 183 was significantly higher in egg from Oslo (P = 0.028, Z = -2.24, M-W U), as was PBDE 196 (P = 0.006, Z = -2.8, M-W U). Both compounds can be formed during aerobic biotransformation of PBDE 209 as well as are part of the technical Octa-PBDE mixture. Concentrations of the congeners PBDE 47, 99, 153 and were apparently more abundant in eggs collected in Oslo compared to the eggs from the reference site, but not significantly so (Figure 7). The detailed results are shown in Table 7. Figure 7 shows the average PBDE concentration of the measured congeners.

Table 7: PBDE congener values in sparrowhawk eggs in ng/g ww.

Area		PBDE 47	PBDE 99	PBDE 100	PBDE 126	PBDE 153	PBDE 154	PBDE 183	PBDE 196	PBDE 207	PBDE 209	Sum PBDE
Oslo area	N	10	10	10	10	10	10	10	10	7	9	10
	Mean	8.94	18.34	6.36	0.20	11.99	2.69	5.04	2.36	0.08	0.40	56.33
	Median	5.66	14.01	4.92	0.18	7.72	2.04	2.69	1.59	0.07	0.38	42.59
	Minimum	2.47	4.45	2.07	0.01	1.44	0.76	1.01	0.45	0.02	0.24	13.15
	Maximum	23.41	50.11	13.14	0.49	46.17	6.05	22.80	9.10	0.17	0.86	171
Reference	N	9	9	9	9	9	9	9	9	2	6	9
	Mean	6.19	13.18	6.15	0.23	7.20	2.19	1.46	0.58	0.03	0.23	37.33
	Median	4.27	7.33	3.35	0.14	4.34	1.69	1.23	0.46	0.03	0.17	22.92
	Minimum	2.72	5.72	2.44	0.06	3.51	1.07	0.64	0.17	0.03	0.11	17.49
	Maximum	20.90	55.21	26.51	0.59	26.01	6.94	2.75	1.60	0.03	0.61	141

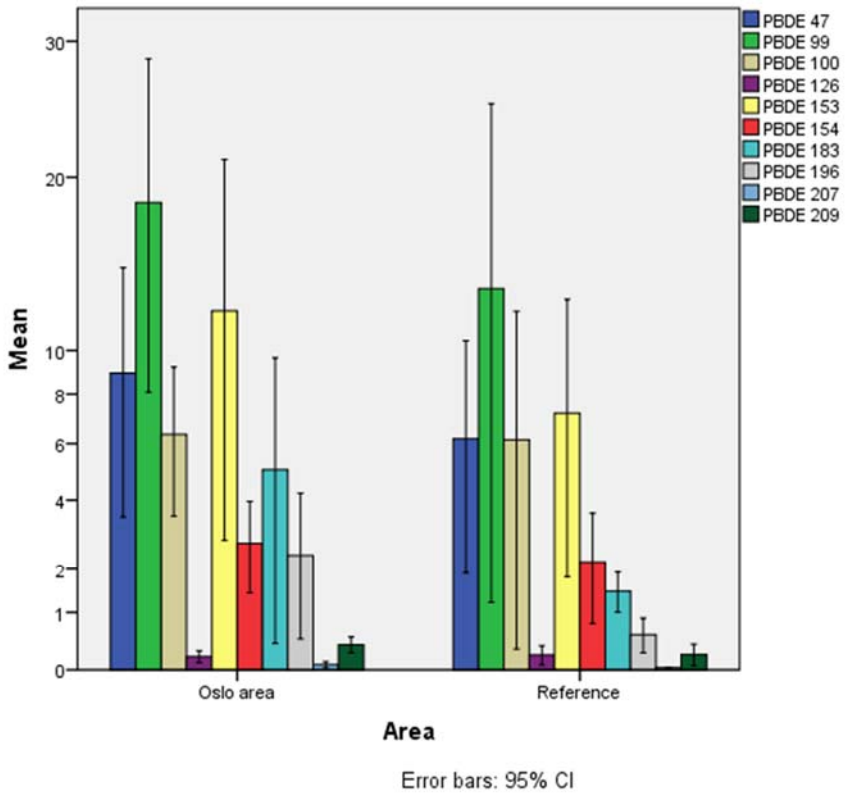


Figure 7: Average concentrations of different PBDEs in eggs of sparrowhawk (ng/g ww).

3.2.2 Fieldfare

Only samples from the reference site were available for analysis. The concentrations of the PBDEs detected at the reference site were in general low (mean 3.71 ng/g ww, range 0.83 to 13.24), with PBDE 99 being the dominating one (100% detection rate) followed by PBDE 47 and 100 (Table 8, Figure 8). On average, sumPBDE concentrations in fieldfare eggs were almost 10 times lower than the sumPBDE concentrations found in sparrowhawk eggs (37.3 ng/g ww at the reference site).

Table 8: Values of individual congeners of PBDE and sum PBDEs in fieldfare eggs at the reference site (Åmotsdalen, Oppdal) (ng/g ww).

	PBDE 47	PBDE 99	PBDE 100	PBDE 126	PBDE 153	PBDE 154	PBDE 183	PBDE 196	PBDE 209	Sum PBDE
N	9	9	8	9	4	4	9	9	6	9
Mean	0.67	1.23	0.55	0.10	0.69	0.17	0.25	0.41	0.26	3.71
Median	0.45	0.79	0.30	0.10	0.77	0.19	0.13	0.38	0.19	2.13
Minimum	0.17	0.19	0.02	0.03	0.11	0.08	0.02	0.04	0.05	0.83
Maximum	2.71	5.47	2.46	0.19	1.08	0.23	1.19	1.01	0.49	13.24

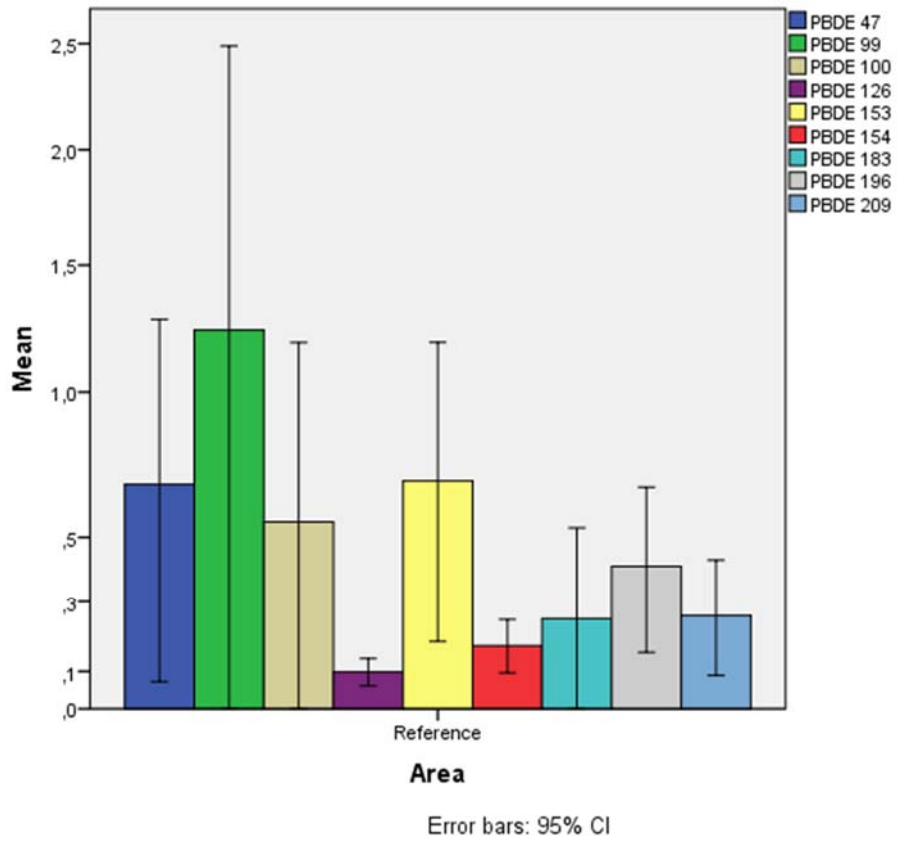


Figure 8: Average PBDE concentrations in eggs of fieldfare from the reference area in ng/g ww.

3.2.3 Red fox

In fox, sumPBDE ranged from 0.14 to 1.04 ng/g ww in Oslo (mean 0.47) and 0.03 to 1.03 ng/g ww (mean 0.34) at the reference site in Oppdal. PBDE 209 was the dominating PBDE in fox liver samples from both the reference site and Oslo with an average concentration of 0.25 ng/g ww followed by PBDE 153, 196 and 100 in the samples from Oslo. No PBDE 153 was found in the samples from the reference site (Table 9, Figure 9).

Table 9. Values of individual congeners of PBDE and sum PBDEs in red fox livers at the different sites (ng/g ww).

Area		PBDE 47	PBDE 99	PBDE 100	PBDE 153	PBDE 154	PBDE 196	PBDE 209	Sum PBDE
Oslo area	N	7	1	6	1		4	5	7
	Mean	0.03	0.03	0.06	0.53	nd	0.11	0.34	0.47
	Median	0.03	0.03	0.06	0.53		0.11	0.26	0.34
	Minimum	0.02		0.03			0.07	0.18	0.14
	Maximum	0.05		0.09			0.13	0.78	1.04
Reference	N	14		11		1	5	9	15
	Mean	0.03	nd	0.05	nd	0.02	0.13	0.39	0.34
	Median	0.02		0.04		0.02	0.08	0.37	0.36
	Minimum	0.01		0.02			0.06	0.13	0.03
	Maximum	0.14		0.11			0.28	1.00	1.03

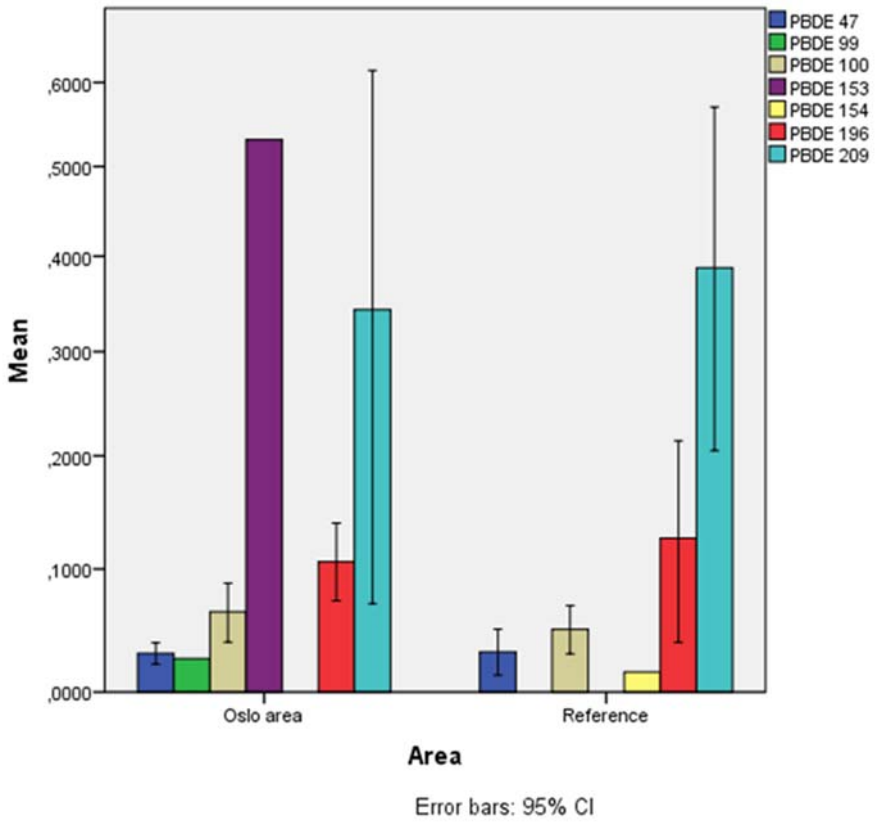


Figure 9: Average concentrations of individual congeners of PBDE in red fox livers in Oslo and at the reference site (Oppdal) (ng/g ww).

The PBDE pattern in fox liver differs from the PBDE pattern found in fieldfare eggs and sparrowhawk eggs by being dominated by the decabrominated PBDE 209 (Figure 9). No significant differences in the congener pattern or sumPBDE between Oslo and the reference site was detected.

3.2.4 Earthworms

Due to improvements in the analytical methods used, PBDEs could be detected in earthworms sampled in 2014, when comparing with the 2013 campaign. In the Oslo area the sumPBDE concentration levels ranged from 0.20 to 0.97 ng/ g ww (mean 0.55). Concentrations in reference samples from Aust-Agder and Telemark ranged from 0.14-0.78 ng/g ww (mean 0.49). PBDE 196 and 209 were the dominating congeners in the earthworm samples collected, followed by PBDE 100. (Table 10). Overall very similar concentrations of PBDE were found in worms collected at the reference sites and in Oslo (Figure 10), with no significant differences detected.

Table 10. Values of detected individual congeners of PBDE and sum PBDEs in earthworms at the different sites (ng/g ww).

Area		PBDE 47	PBDE 99	PBDE 100	PBDE 154	PBDE 196	PBDE 209	Sum PBDE
Oslo area	N	7	4	6	2	7	1	7
	Mean	0.04	0.06	0.18	0.02	0.22	0.62	0.55
	Median	0.04	0.05	0.09	0.02	0.19	0.62	0.35
	Minimum	0.02	0.03	0.04	0.01	0.06		0.20
	Maximum	0.07	0.12	0.64	0.02	0.64		0.97
Reference	N	8	3	8	2	8	3	8
	Mean	0.04	0.06	0.06	0.01	0.29	0.21	0.49
	Median	0.03	0.05	0.06	0.01	0.33	0.23	0.48
	Minimum	0.02	0.04	0.02	0.01	0.08	0.15	0.14
	Maximum	0.08	0.10	0.15	0.01	0.56	0.26	0.78

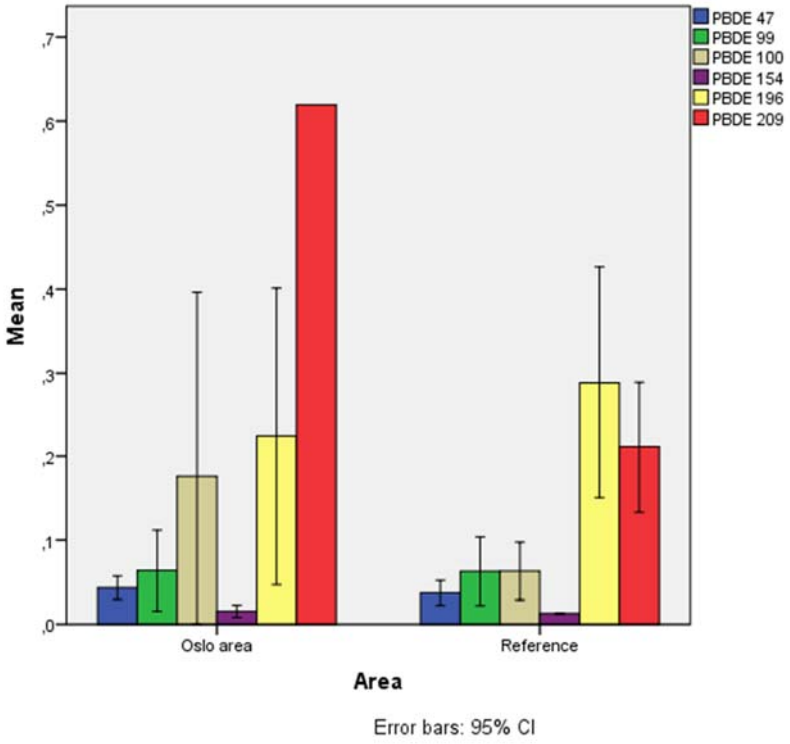


Figure 10: Average concentrations of individual congeners of PBDE in earthworms in Oslo and at the reference site (Oppdal) (ng/g ww).

3.3 Per-and polyfluoroalkyl substances (PFASs)

3.3.1 Sparrowhawk

PFAS binds to proteins and do not, like most other bioaccumating chemicals, accumulate in lipid rich tissues (proteinophilic). It is therefore only appropriate to report concentrations per fresh weight (fw) tissue. The highest sumPFAS concentration of 40 ng/g fw was found in eggs from the reference site. Average sumPFAS concentrations at the reference site were 15.6 ng/g fw and 19.2 ng/g fw in eggs collected in Oslo, ranging

from 8.5 ng/g fw to 40.0 ng/g fw at the reference site and 2.98 to 23.9 ng/g fw in Oslo.. The detailed results of detected PFAS are shown in Table 11.

Table 11: Detected PFAS congener concentrations in sparrowhawk eggs in ng/g fw.

Area		PFOSA	PFHxS	PFHpS	PFOS	PFNS	PFDcS	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum PFAS
Oslo area	N	8	10	10	10	7	7	10	10	10	10	10	10	10
	Mean	0.04	0.06	0.12	11.84	0.01	0.03	0.45	0.38	1.18	1.27	2.26	1.93	13.90
	Median	0.03	0.05	0.09	7.73	0.01	0.02	0.49	0.40	1.19	1.29	2.33	1.69	13.98
	Minimum	<LOD	0.02	0.03	3.78	<LOD	<LOD	0.16	0.12	0.40	0.32	0.61	0.42	2.98
	Maximum	0.09	0.15	0.28	31.20	0.02	0.06	0.71	0.61	2.19	2.13	3.73	5.46	23.93
Reference	N	9	10	10	10	4	10	10	10	10	10	10	10	10
	Mean	0.02	0.08	0.12	6.65	0.01	0.39	0.53	0.68	1.24	1.91	1.84	2.13	21.74
	Median	0.01	0.07	0.09	6.36	0.01	0.19	0.42	0.49	0.75	1.34	1.50	1.81	18.05
	Minimum	0.01	0.02	0.02	2.09	<LOD	0.004	0.19	0.23	0.55	0.65	1.02	0.82	8.49
	Maximum	0.06	0.17	0.45	13.56	0.03	1.82	1.32	1.57	2.99	4.51	3.86	5.22	40.02

As Figure 11 shows, PFAS concentrations in eggs collected at the reference site are comparable with levels found in eggs collected in Oslo, with the exception of PFOS. PFOS average concentration of 6.65 ng/g fw can be found at the reference site compared to 11.8 found in eggs from Oslo, but the difference was not significant ($P = 0.23$, $Z = -1.2$, M-W U).

PFOS is the dominating compound in the majority of the egg samples, however there is also a considerable contribution of the long chain carboxylic acids (PFNA to PFTeDA), with longer chained PFCAs dominating the PFCA pattern. 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). On average, PFOS contributed with more than 40% to the sumPFAS load compared to 55 % sumPFCA contribution at the reference site and 38% sumPFCA contribution in Oslo. PFOA, was not detected in any of the samples.

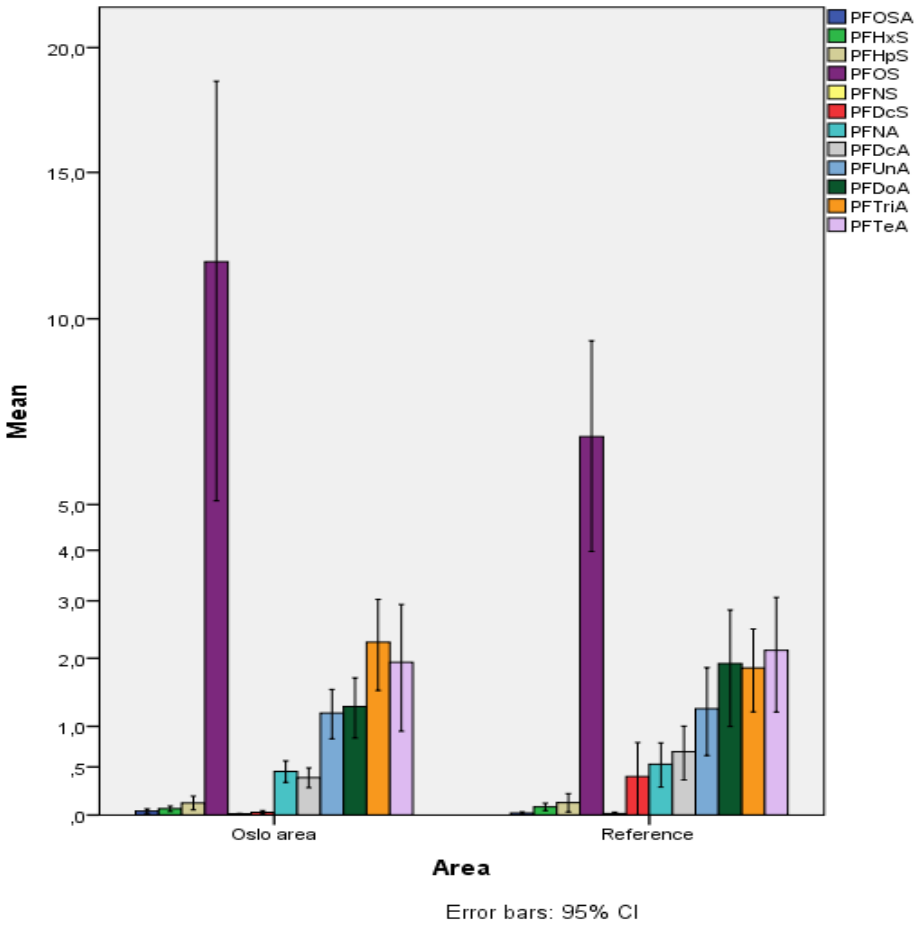


Figure 11: Average PFAS concentrations (ng/g fw) in eggs of sparrowhawk.

3.3.2 Fieldfare

Since only samples from the reference site were available for fieldfare, only the background PFAS concentration could be assessed. PFAS was detected in all eggs collected at the reference site in Oppdal, with PFTrA dominating the PFAS pattern, followed by PFOS and PFUnA and PFDoA. Higher PFCA concentrations than PFOS is an uncommon pattern, which has been observed only a few times before (Hlouskova, 2013). SumPFAS concentrations in reference samples ranged from 4.41 to 17.25 ng/g ww (mean 8.97) (Table 12, Figure 12).

Table 12. PFAS compounds with detectable concentrations in fieldfare eggs from the reference site (Åmotsdalen)(ng/g ww).

Area		PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum PFAS
Reference	N	10	10	9	10	9	10	10	10	10
	Mean	1.87	0.19	0.42	0.34	1.59	1.36	2.51	0.90	8.97
	Median	1.33	0.17	0.32	0.26	1.25	1.01	2.01	0.89	7.30
	Minimum	0.72	0.07	0.16	0.10	0.63	0.73	0.98	0.31	4.41
	Maximum	5.67	0.42	0.81	0.96	3.34	3.25	5.05	1.43	17.25

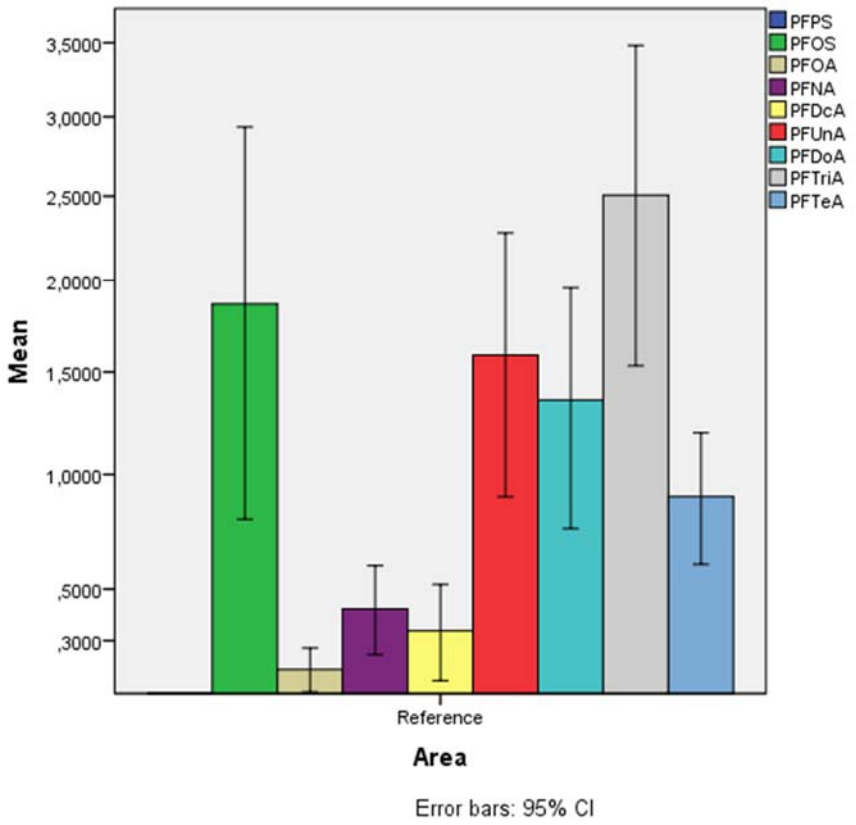


Figure 12: Average concentrations of detectable PFAS compounds in fieldfare eggs from the reference site (Åmotsdalen).

3.3.3 Red fox

PFAS could be detected in all fox liver samples (Table 13, Figure 13). SumPFAS concentrations ranged from 0.8 to 5.9 ng/g ww. Linear PFOS was the dominating PFAS in all samples, followed by PFNA (Figure 13). SumPFAS concentrations at the reference site showed an average of 1.1 ng/g ww (range 0.26 - 3.2) compared to 3.8 ng/g ww (range 2.45 – 5.95) in samples from Oslo. The difference was mainly caused by PFOS with average concentration of 0.57 ng/g ww in the reference site and 2.11 ng/g ww in Oslo samples. The differences between Oslo and the reference site was significant for sumPFAS, PFOS, PFHxA, PFNA, PFDCA, PFUNA, PFTriA and PFTeA (all < 0.01, M-W U).

Table 13. Concentrations of detected PFAS compounds in red fox livers (ng/g, ww).

Area		PFOSA	PFHxS	PFHpS	PFOS	PFDcS	PFHpA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum PFAS
Oslo area	N	5	6	5	7	1	4	7	7	7	7	7	7	7
	Mean	0.043	0.045	0.008	2.107	0.011	0.002	0.494	0.409	0.361	0.110	0.139	0.070	3.76
	Median	0.027	0.045	0.008	1.774	0.011	0.002	0.404	0.431	0.314	0.087	0.092	0.050	3.15
	Minimum	0.005	0.027	0.003	1.359		<LOD	0.295	0.201	0.153	0.070	0.079	0.034	2.45
	Maximum	0.141	0.064	0.014	3.488		0.003	1.081	0.639	0.746	0.239	0.375	0.149	5.95
Reference	N	6	15	1	14		1	15	15	15	15	15	15	15
	Mean	0.027	0.013	0.009	0.570	nd	0.001	0.193	0.106	0.142	0.028	0.049	0.011	1.08
	Median	0.013	0.012	0.009	0.420		0.001	0.185	0.114	0.104	0.021	0.038	0.009	0.86
	Minimum	0.003	0.002		0.083			0.067	0.033	0.053	0.008	0.012	0.005	0.26
	Maximum	0.074	0.038		2.189			0.441	0.232	0.367	0.058	0.128	0.020	3.20

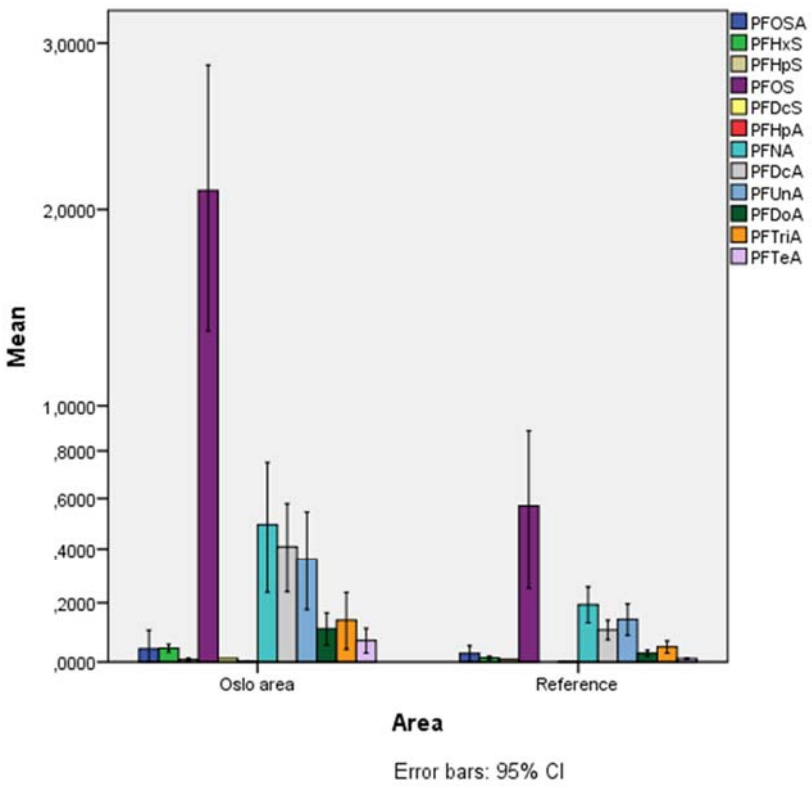


Figure 13: Average concentrations of detected PFAS compounds in the analysed fox livers, in the Oslo area and the reference site (ng/g, ww).

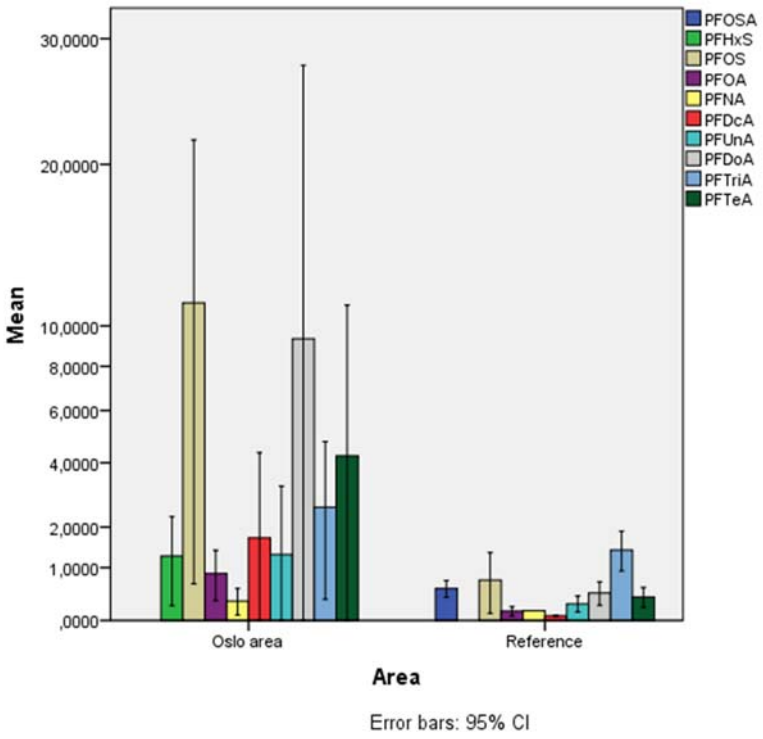
3.3.4 Earthworms

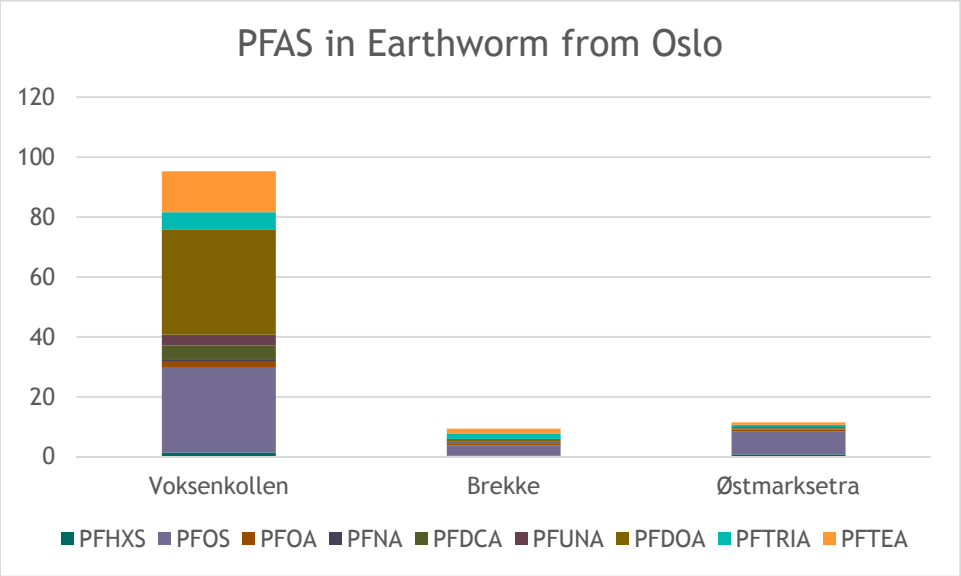
As shown in Table 14, PFASs were present in every sample. The sumPFAS concentrations at the Oslo sites ranged from 6.9 to 151 ng/g ww (maximum value in in one sample from Voksenkollen, Oslo), the mean value was 34.9 ng/g ww. The average sumPFAS concentration in the reference site was with 4.4 ng/g ww, eight times lower than in Oslo. PFOS was dominating the sumPFAS, both at the reference site and in Oslo, closely followed by PFDoA. PFHxS was only detected in Oslo, a potential indication for emissions as a PFOS substitute. 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 14. Concentrations of detected PFAS compounds in earthworms (ng/g, ww).

Area		PFOSA	PFHxS	PFOS	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	Sum PFAS
Oslo area	N		5	7	7	6	6	6	7	7	7	7
	Mean		1,27	12,36	0,97	0,36	1,71	1,39	10,48	2,47	4,70	34,85
	Median		0,98	5,41	0,80	0,28	0,19	0,37	0,77	1,74	1,28	10,46
	Minimum		0,45	3,24	0,37	0,11	0,06	0,18	0,33	0,66	0,56	6,90
	Maximum		2,94	39,63	2,24	0,84	6,86	6,10	63,51	8,66	24,47	151,30
Reference	N	4		9	8	2	2	9	9	9	9	9
	Mean	0,56		1,02	0,15	0,13	0,07	0,33	0,58	1,61	0,48	4,44
	Median	0,60		0,56	0,16	0,13	0,07	0,21	0,55	1,52	0,44	3,73
	Minimum	0,37		0,10	0,02	0,11	0,07	0,12	0,16	0,61	0,19	1,36
	Maximum	0,68		3,31	0,27	0,16	0,08	0,75	1,39	3,21	1,08	10,04

There is a major contribution of PFOS, PFDoA and PFTeA in samples from Oslo, while PFTriA, followed by PFOS dominate in the samples from the reference site, as was already observed in earthworms in the 2013 report (M-354|2015) as well as in the fieldfare eggs. The differences were significant for sumPFAS (P = 0.001) PFOS (P = 0.007) and PFTeA (P = 0.004) only (M-W U). Discussion of differences at the urban sites can be found below in the chapter discussing combined exposure. However, we can point out that when comparing the different sampling locations for earthworms in the urban site, Oslo, PFAS is dominating in all sites, but most abundant in Voksenkollen. This site is heavily used for ski competitions and cross-country exercises in the winter time and we might see the impact of application of fluorinated skiwax in these earthworms. To further elucidate possible sources, follow up sampling is recommended (Figure 14).





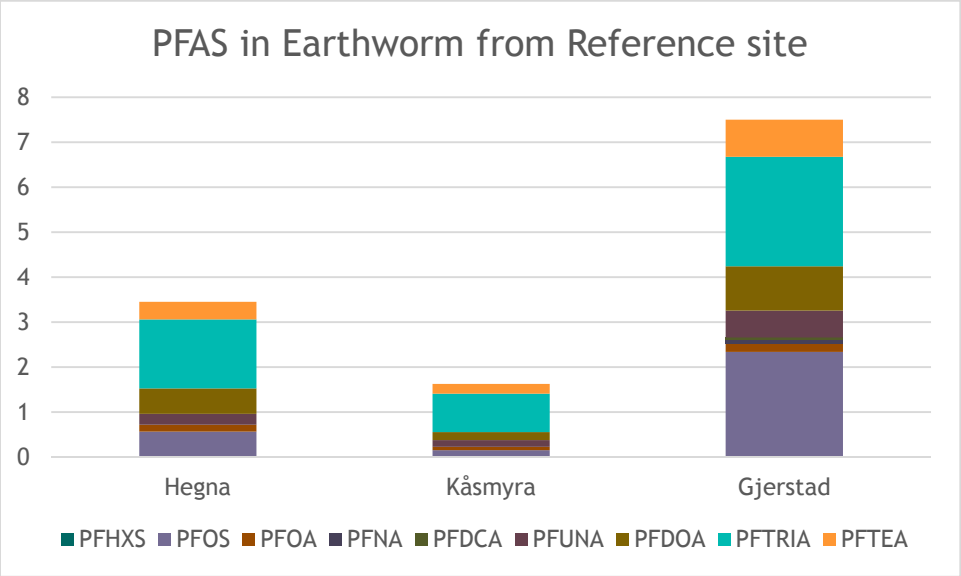


Figure 14: Average PFAS concentrations of detected PFAS in earthworms from Oslo and the reference site (above) and per location (below) (ng/g ww).

3.4 Metals

3.4.1 Sparrowhawk

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 (Table 15, Figure 15). The sum of metals determined varied between 2454 and 12357 ng/g. Cu, Zn, total-Hg and MeHg were found in all samples. The concentration of MeHg determined was for most samples close to the concentration of total-mercury, indicating that mercury is mostly present as MeHg in sparrowhawk eggs. This is in line with results published by Ackerman et al (2013).

Zn was the most dominant metal and accounted for about 90% of the sum of metals determined. The concentration of Zn found in sparrowhawk eggs where in the range of what was found in Audouins's gull *Larus audouinii* (Morera 1997), and Cory's shearwater *Calonectris diomedea* (Renzoni et al.1986). Cu concentrations found where in agreement with results obtained for *Larus audouinii* (Morera 1997). Since Cu and Zn are physiologically regulated in birds (Richards and Steele 1987), mostly Hg, Pb, Cd and As can prove toxic at concentrations that can be found in the environment (Depledge et al. 1998). Ag, was not detected in any of the analysed egg samples, and Cd and As were only found in some samples at low concentrations.

Table 15. The concentrations of the detected metals in the sparrowhawk eggs (ng/g fw).

Area		Hg	MeHg	Ag	Cd	Pb	Cu	Zn	Cr	Ni	As
Oslo area	N	10	10		7	9	10	10	10	10	
	Mean	122.0	105.2	nd	0.64	17.66	402	4798	4.24	3.83	nd
	Median	129.1	107.7		0.58	11.25	355	3546	3.27	2.53	
	Minimum	62.9	54.9		0.27	6.67	289	1942	2.79	1.05	
	Maximum	163.3	136.6		1.22	36.92	668	11612	9.88	14.13	
Reference	N	9.0	10.0	1	1	1	10	10	10	9	1
	Mean	186.5	164.1	0.0003	0.54	8.52	460	7302	5.34	2.76	4.18
	Median	189.1	160.5	0.0003	0.54	8.52	463	7576	4.69	1.97	4.18
	Minimum	115.0	96.4		0.54		290	3682	2.66	1.43	
	Maximum	301.0	248.0		0.54		688	11474	9.62	6.38	

The following significant correlations were detected: MeHg-Hg, Cd-Zn, Cu-Zn, Cu-CR and Zn-Cr ($p < 0.05$, Spearman corr).

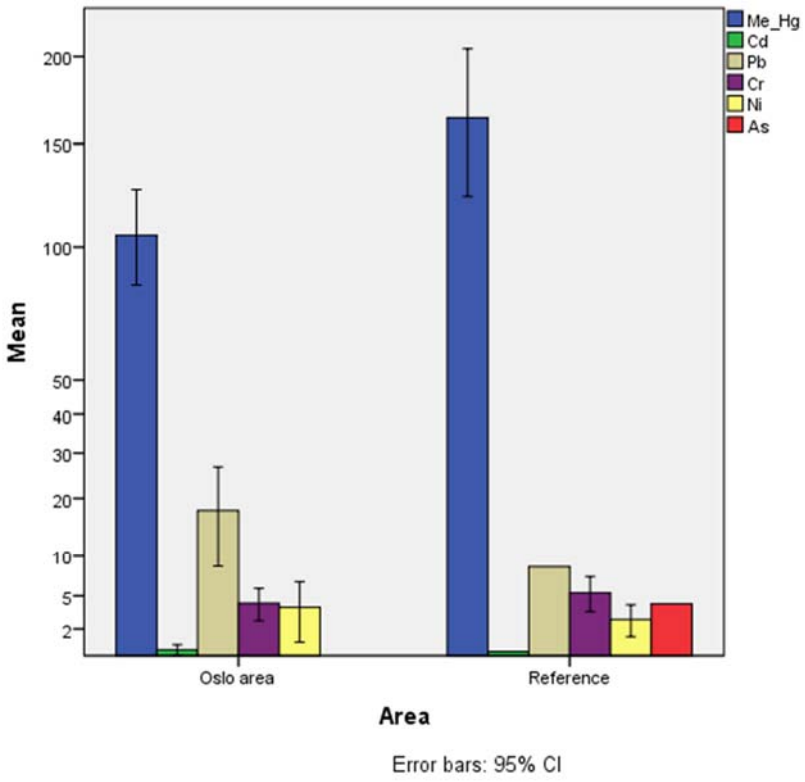


Figure 15: The average concentration of different metals in the sparrowhawk eggs (ng/g fw).

The concentrations of MeHg were significantly higher in the eggs from the reference site than those from Oslo (P = 0.028, Z = - 2.2, M-W U). No other significant differences between reference and urban location could be found.

3.4.2 Fieldfare

Zn and Cu are the predominant metals in fieldfare eggs similar to the sparrowhawk. When looking at the other metals Hg, Cr and Ni can be found in decreasing order in the eggs too (Table 16, Figure 16). No data from the urban sites were available for comparison. SumMetal concentrations ranged between 6305 and 8184 ng/g ww.

Table 16. Concentration of detected metals in eggs of fieldfare from Åmotsdalen (reference), in ng/g ww.

Area		Hg	Me_Hg	Ag	Pb	Cu	Zn	Cr	Ni	As
Reference	N	5	5	5	1	5	5	5	5	5
	Mean	11.17	8.49	1.21	7.31	456	6678	8.35	6.31	4.51
	Median	11.17	8.60	1.43	7.31	435	6996	7.13	6.28	3.54
	Minimum	7.12	4.47	0.40		400	5713	3.79	3.07	2.27
	Maximum	15.79	13.80	2.24		553	7650	13.53	10.58	7.19

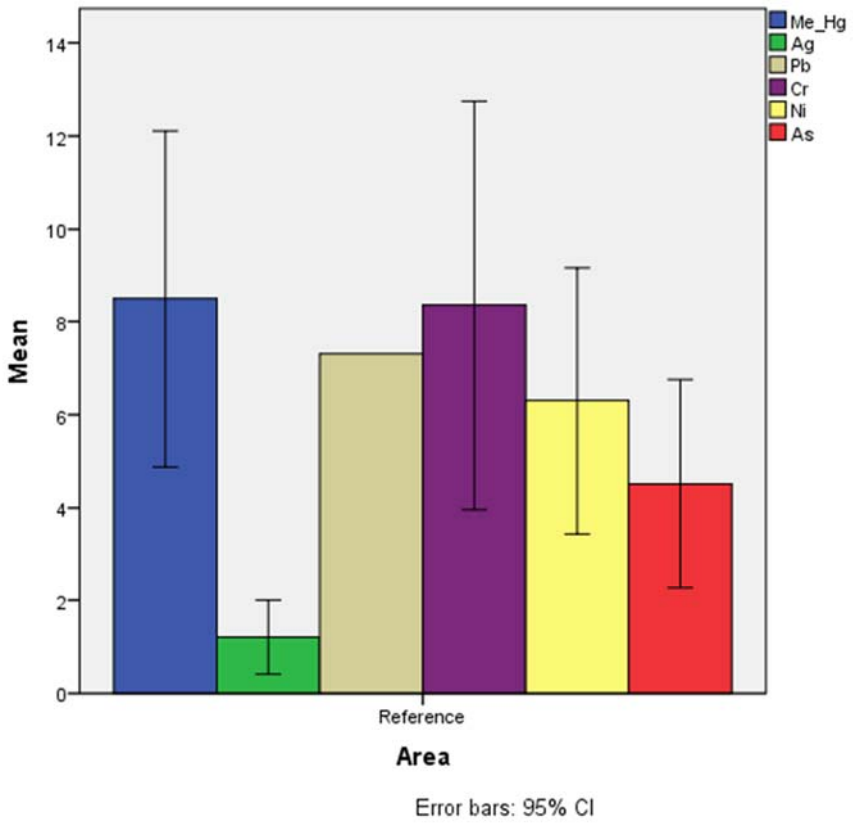


Figure 16: Average concentration of detected metals in fieldfare eggs from Åmotsdalen (ng/g). Cu and Zn not shown due to large concentration differences.

3.4.3 Red fox

Zn was the dominating metal detected in fox liver with concentrations varying from 24 000 ng/g to 55 000 ng/g, followed by Cu with concentrations ranging from 7 200 to 29 000 ng/g ww. Of the other elements determined, only Cd and Pb were found in concentrations above 100 ng/g ww. Concentrations of MeHg in fox livers were found to be low and representing less than 50% of the total Hg in most cases (Table 17, Figure 17).

Table 17. Concentrations of metals in livers of red fox from Oslo and the reference site (Oppdal) in ng/g ww.

Area		Hg	Me_Hg	Ag	Cd	Pb	Cu	Zn	Cr	Ni	As
Oslo area	N	7	7	7	7	7	7	7	7	7	7
	Mean	45.3	13.6	4.6	350	202	18753	43154	35.4	9.1	10.6
	Median	35.6	10.6	4.8	256	92	17593	41652	7.8	6.6	7.2
	Minimum	25.3	6.2	2.0	82	51	9174	32197	4.7	4.4	5.1
	Maximum	87.7	36.3	7.0	775	727	27760	54985	106.5	19.0	28.3
Reference	N	15	15	14	15	13	15	15	15	14	10
	Mean	32.4	13.5	1.9	50	949	15329	46338	8.2	9.6	8.7
	Median	21.9	6.5	1.6	45	45	13688	40118	7.2	8.3	7.3
	Minimum	7.8	2.4	0.3	8	10	6210	24184	2.4	2.0	2.9
	Maximum	120.7	47.1	4.8	146	10724	28982	163145	24.2	21.4	21.3

SumMetal concentrations were comparable with an average of 64 537 and 62 578 ng/g ww at the reference site and in Oslo respectively. Ag, Cd and Cr were considerably higher in Oslo compared to the reference site. Hg was higher in Oslo compared to the reference site ($P = 0.053$, $Z = -1.94$, M-W U), as was the case for Cd ($P < 0.001$, $Z = -3.5$, M-W U), and Ag ($P = 0.002$, $Z = -2.98$, M-W U). Other differences were not significant.In contrast, Pb levels were clearly higher in fox livers from the rural location where it was detected at an average concentration of 949 ng/g ww compared to 202 ng/g ww in Oslo. One rural sample with 10 724 ng/g ww exceeded the 1000 ng/g threshold for clinical lead poisoning by a factor of 10. When removing that individual from the statistics, the difference between Oslo and the rural site is minimal. It is unclear if the high levels found in this individual is attributed to the use of lead ammunition. However, one possible explanation is that lead ammunition used to kill the animal has contaminated the liver sample, another explanation is that the animal ingested lead ammunition along with prey, prior hurt by lead ammunition.

Dip et al. (2001) report, that liver of suburban and rural foxes contained the highest Cd concentrations, whereas urban foxes contained the highest Pb levels within the municipality of Zurich (Switzerland). In the liver of suburban foxes Cd levels of 94 ng/g were found (Dip et al., 2001).

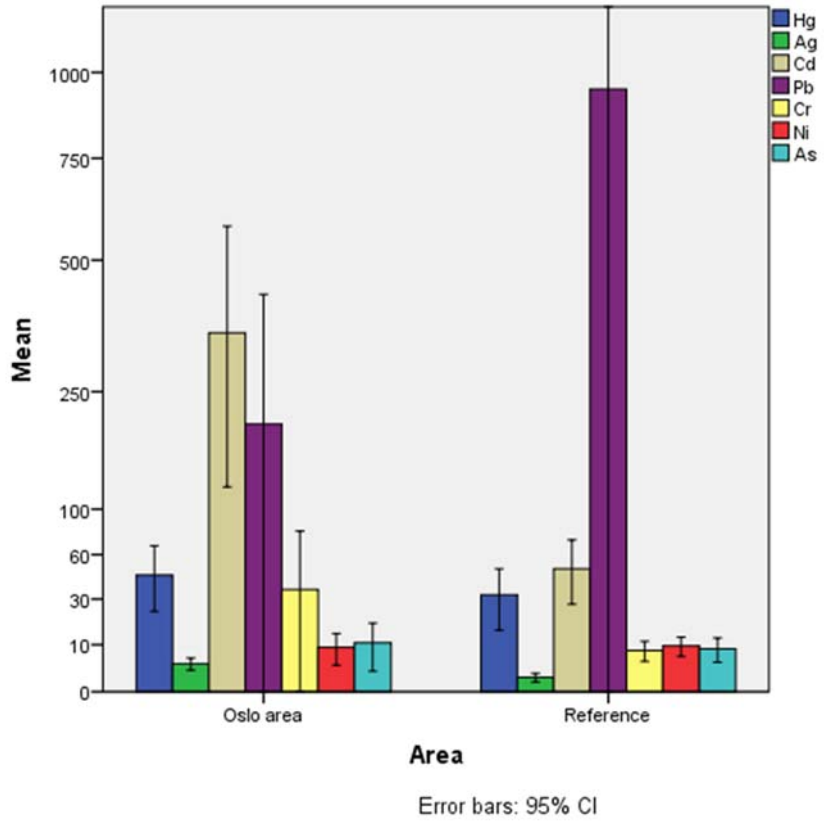


Figure 17: Average concentrations of detected metals in livers of red fox from Oslo and Oppdal (reference) in ng/g ww.

3.4.4 Earthworms

All 9 measured metals were detected in all samples. The sum of the metals determined varied between 70 000-749 000 ng/g ww. As seen in the other tissues, Zn was by far the most dominating element, with a content varying between 60-90% of the sum of the determined metals, with concentration ranging between 52 000 ng/g and 291 000 ng/g ww. However, as Zn has important physiological functions in all organisms, the concentrations cannot be interpreted as toxic. The most prominent difference was found for Pb, where the concentrations in earthworms from Oslo were much higher than from the reference sites in Telemark and Aust-Agder (126434 *vs* 9758 ng/g) ($P < 0.015$, $Z = -2.4$, M-W U). Hg and Cd were also significantly higher in Oslo than in reference sites (Table 18, Figure 18).

Table 18: Metals in earthworms from Oslo and the reference sites, in ng/g ww.

Area		Hg	Ag	Cd	Pb	Cu	Cr	Ni	As
Oslo area	N	7	7	7	7	7	7	7	7
	Mean	231.5	19.9	4066	143438	2072	218	217	549
	Median	201.4	20.0	4938	64219	1947	200	237	619
	Minimum	101.5	11.1	2420	13625	1781	69.5	138	355
	Maximum	359.4	32.2	5808	454535	2746	443	301	683
Reference	N	9	9	9	9	9	9	9	9
	Mean	103.3	26.8	2523	9497	1629	415	297	373
	Median	126.1	24.1	2256	8452	1593	300	270	414
	Minimum	23.4	15.8	607	1354	1343	36.5	87.5	109
	Maximum	144.9	50.3	4888	20688	1975	836	529	587

When comparing the different urban and reference locations where earthworm were collected, Cd varies the most between the three urban and the three reference sites, with highest concentrations found in Voksenkollen and Brekke. As, Ni and Cr are also higher in these location but not as distinct.

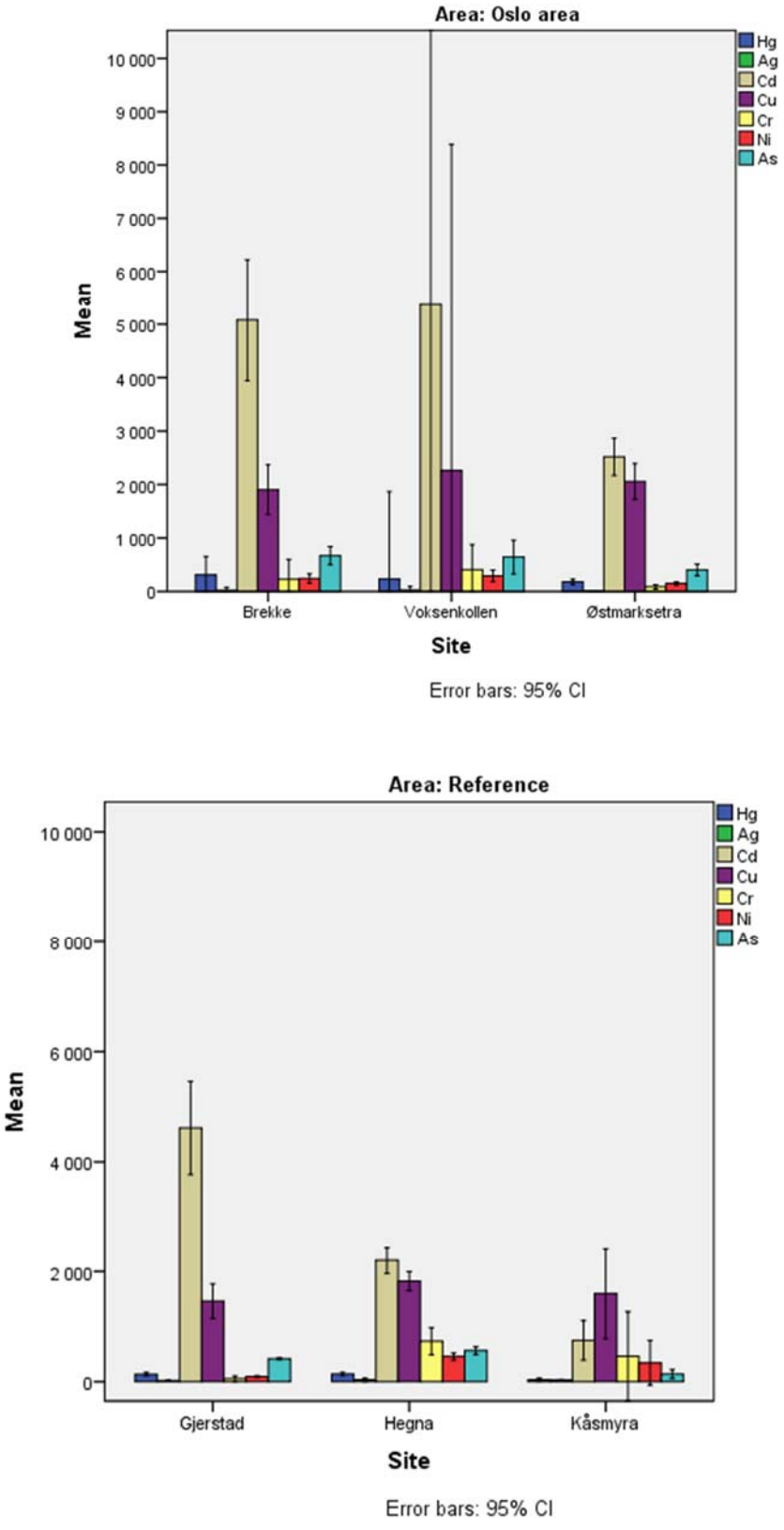


Figure 18: Average concentrations of metals in earthworms from Oslo and the reference sites (Zn not shown)(ng/g ww).

Among the reference sites, Gjerstad has the highest Cd concentrations but Cr and Ni are higher in Hegna and Kåsmyra.

In contrast to the other investigated species, Cu was not following Zn as second in concentration order. Pb on the other hand, was found in highest concentrations in Oslo (range between 13625 and 454535 ng/g ww). Hg had low concentrations at all sites, but highest in Voksenkollen and Brekke in Oslo. Opposite to other species, the methyl mercury concentrations were only a small proportion of the total Hg concentrations found. This shows that mercury in earthworms mainly is present as inorganic forms. 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).

As the second most abundant metal, the concentration of Pb varied considerably both within and between sampling sites, but a clear difference between urban and reference sites could be observed. A minimum value of 1 300 ng/g was found at Kåsmyra and a maximum value of 454 000 ng/g was found in a sample from Voksenkollen. Variation within and between sampling sites were also observed for Cr.

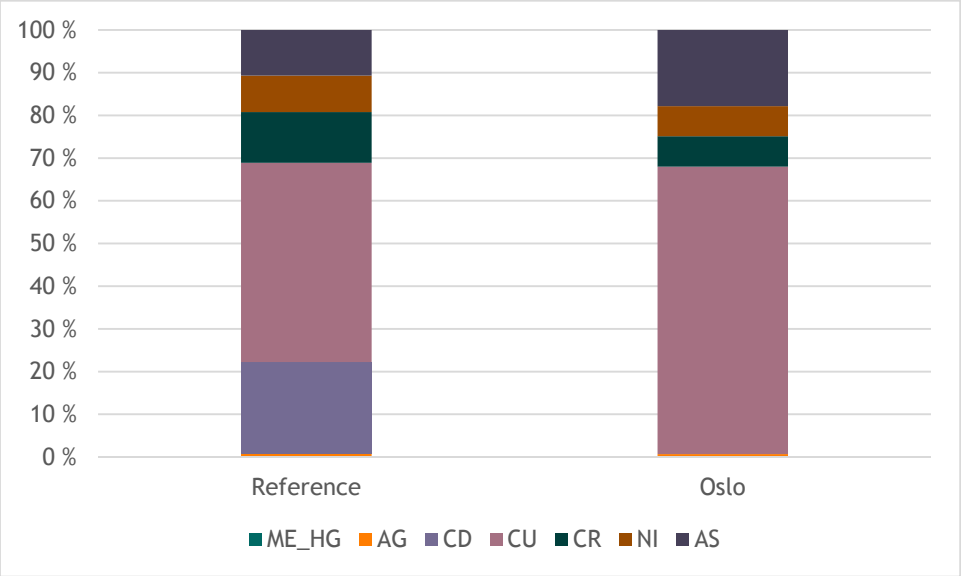


Figure 19: Relative distribution of metals (Zn and Pb excluded) in Lumbricidae. *Z*n and Pb, which were the predominant metals (in sum > 90% of total), are excluded to make the differences between the other elements more visible.

Figure 19 shows the relative metal pattern at the reference site *vs.* Oslo. The pattern at the reference site is more diverse, but there were no major concentration differences between urban and rural sites.

3.5 Siloxanes and chlorinated paraffins

Within the frame of the project, in four fox livers from the urban site, also chlorinated paraffin's and volatile cyclic siloxanes (cVMS) were measured.

Of the cVMS analyzed, D4 and D6 were not found above the limits of detection (0.9 and 1.8 ng/g ww, respectively). D5 was detected in several samples above detection limits (0.3 ng/g ww) but were below limits of quantification (1.0 ng/g ww). As variation caused by the sample matrix can have a significant impact on the analytical signal measured (Warner et al., 2013), concentrations found below limits of quantification should be treated with caution. More data is needed to interpret the findings in a scientific context. Among the chlorinated paraffins analyzed, only SCCP was detected in one sample from Oslo, indicating a limited impact of these pollutants on urban terrestrial mammals (Table 19).

Table 19: Concentrations of siloxanes (D4, D5 and D6) and chlorinated paraffins (SCCP and MCCP) in red fox liver. nd: non-detectable concentrations

ng/g ww	Siloxane D4	Siloxane D5	Siloxane D6	SCCP	MCCP
Fox liver 1	nd	0.43	nd	nd	nd
Fox liver 2	nd	0.43	nd	nd	nd
Fox liver 3	nd	nd	nd	nd	nd
Fox liver 4	nd	0.53	nd	8.1	nd

3.6 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. Mostly sum parameters of the investigated pollutants will be discussed, information for single compounds can be found in the chapters above. 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. The risk for toxic/biological effects will then be considered in chapter 3.7.

3.6.1 Sparrowhawk

The sum of all analysed major pollutant groups in sparrowhawk eggs is shown in Figure 20 (in ng/g fw). PCBs were the most important group, followed by Hg and PBDEs, in both locations. The overall pollutant load in sparrowhawk eggs was higher in Oslo compared to the reference location, mainly caused by higher sumPCB and sumPBDE concentrations in eggs.

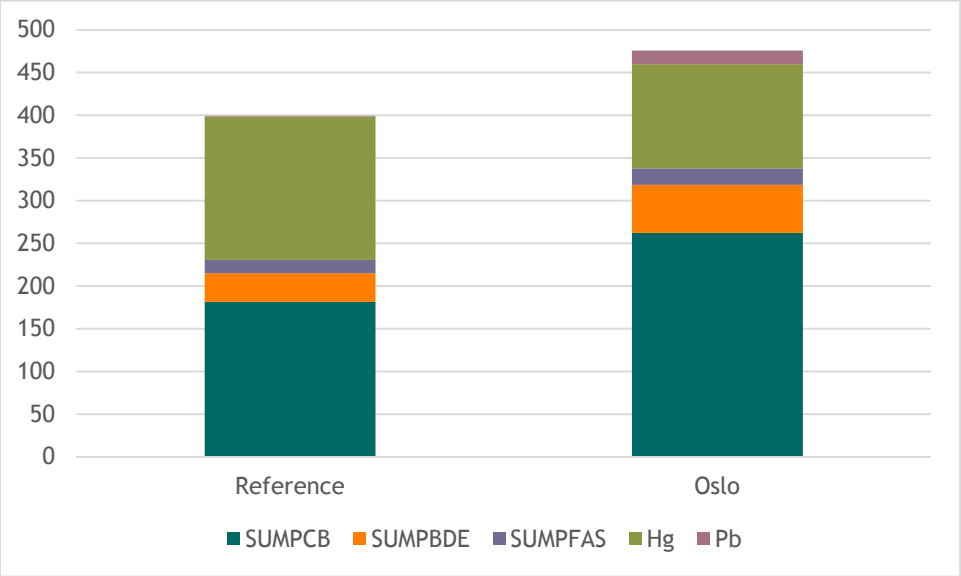


Figure 20: Combined pollutant load in eggs of sparrowhawk in ng/g fw.

3.6.2 Fieldfare

For fieldfare, only data from the reference location are available. In fieldfare eggs like in sparrowhawk eggs, PCB and Hg are the predominant pollutants. Concentrations of the organic pollutants measured i.e. PBDEs and PCBs are considerably lower in fieldfare eggs compared to sparrowhawk eggs, for sumPCB by a factor of 10 – 20, sumPBDE by a factor of 10 (Figure 21).

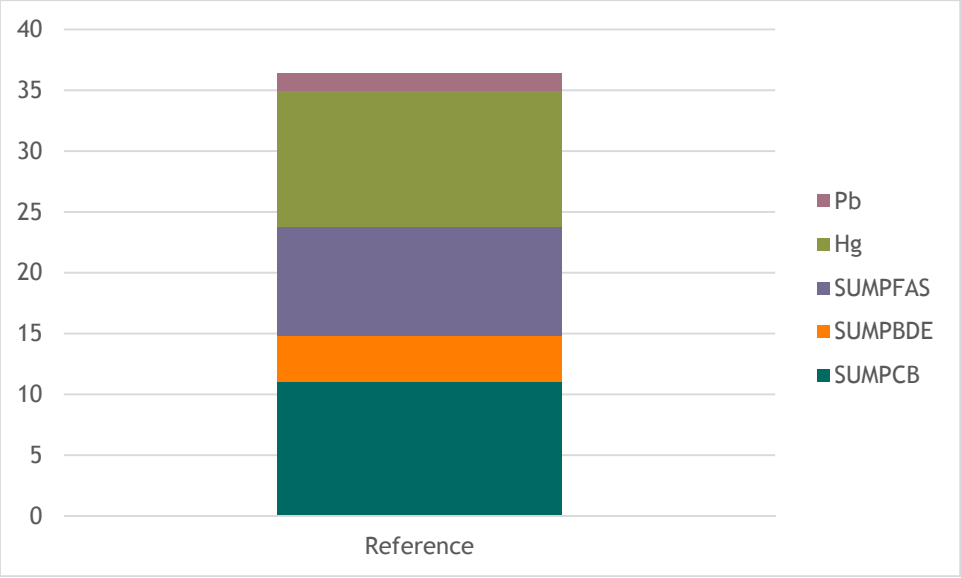


Figure 21: Average concentration of all measured pollutants in eggs of fieldfare (ng/g ww) and their contribution to the total pollutant load in fieldfare eggs

3.6.3 Red fox

Red fox liver samples were mostly contaminated with heavy metals, mainly Pb and Hg (more than 95 % of the overall load). Of the organic pollutants, PCBs were the most important contributors with 40 – 90% of the overall organic pollutants load. However, concentrations varied considerably between individuals (Figure 22).

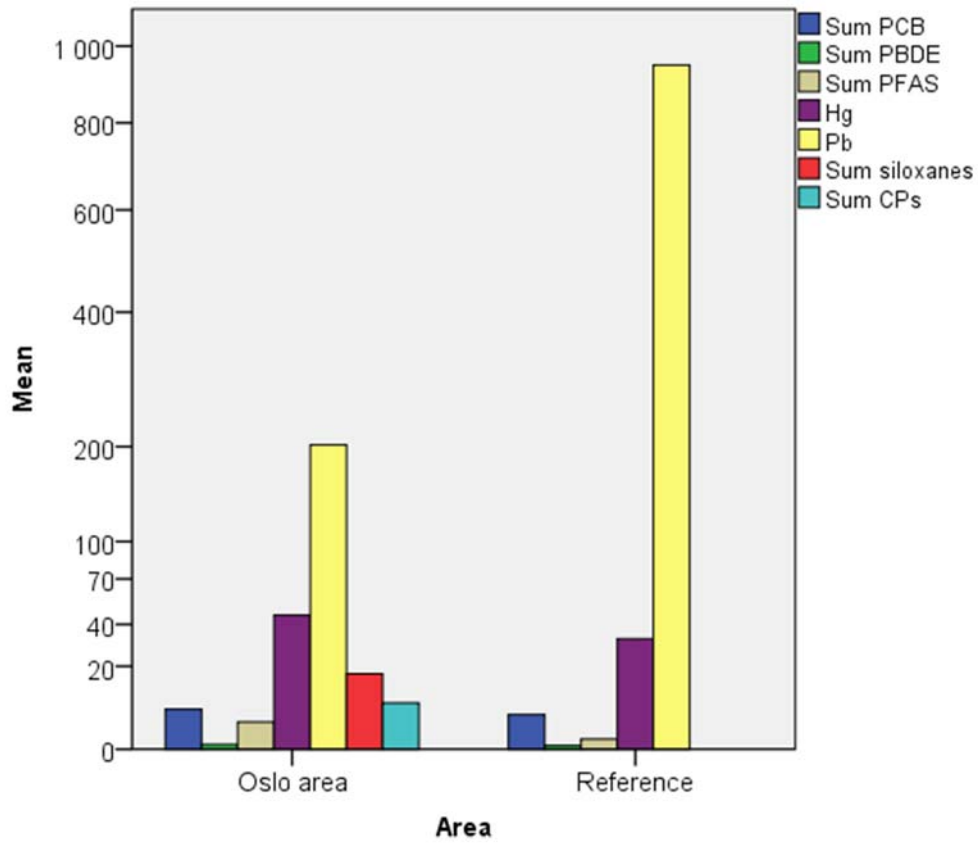


Figure 22: Concentrations of major organic pollutant groups and metals measured in red fox liver in ng/g ww. For the organic pollutants the concentrations are reported as sum of all pollutant congeners within a group of pollutants (CPs: chlorinated paraffins)

Pb dominates the contribution of toxic compounds in red fox livers, as seen in Figure 22. In Oslo, when the data from the 4 individuals analysed for siloxanes and CPs also are included, the order becomes Pb > Hg > siloxanes > sumCP > sumPCB > sumPFAS > > sumPBDE. All measured pollutant groups were elevated in the urban site, except for lead.

3.6.4 Earthworms

Metals are the dominating contributor to the pollutant load in earthworms. The relative contribution of the toxic metals is much higher in earthworms than in the other species (Figure 23). In Oslo, sumPFAS were on average 35 ng/g, and sumPCBs were 1.3 ng/g ww, while Pb was 143438 ng/g ww for comparison. At the reference site, sumPFAS and sumPCB concentrations were lower with 4.2 and 0.09 ng/g ww respectively, as was the case also for Pb, with 9497 ng/g ww. Organic pollutants seem to play a minor role in the contamination pattern of earthworms, with PFAS dominating the organic contamination load followed by PCB (Figure 23). Due to their ionic nature, most PFAS are more water-soluble than PCBs, explaining partly the domination of PFAS in the earthworms (very low lipid content of < 2%).

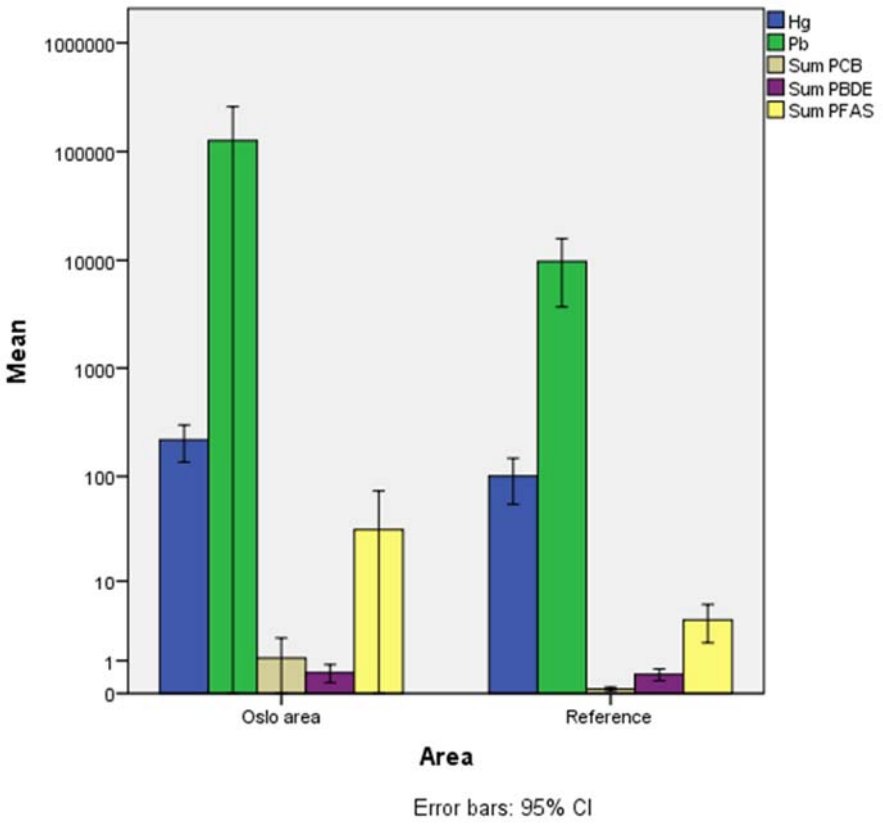


Figure 23: Comparison of pollutant load in earthworms in Oslo and the reference site (ng/g ww).

Leaving out Pb, the role of the other measured pollutants becomes apparent with Hg > sumPFAS (Figure 23). When comparing the different sampling locations for earthworms in the urban site, Oslo, PFAS is dominating in all sites, but is most abundant at Voksenkollen (Figure 24). This site is heavily used for ski competitions and cross-country exercises in the winter time and we might see the impact of application of fluorinated skiwax in these earthworms. To further elucidate possible sources, follow up sampling is recommended.

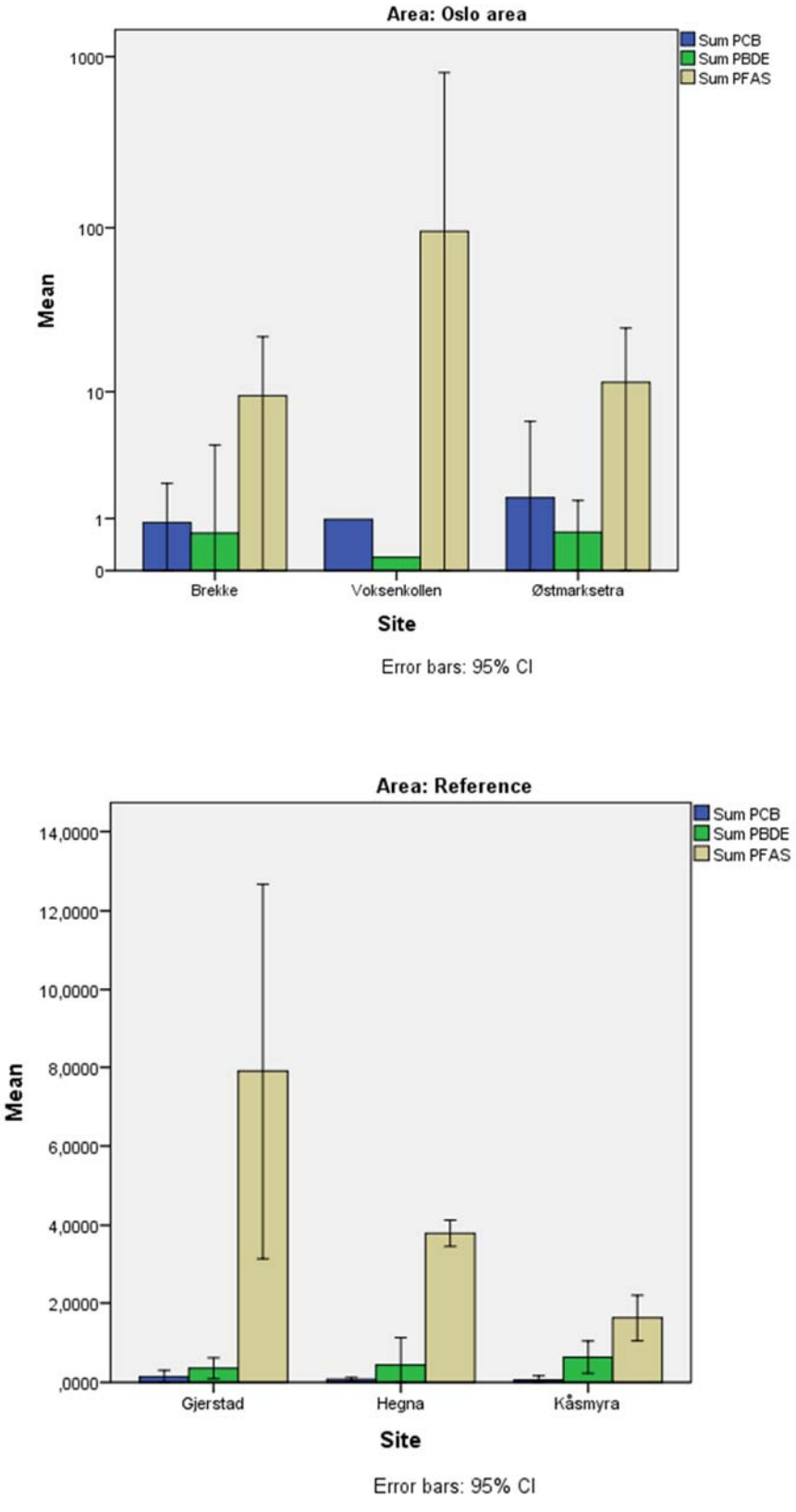
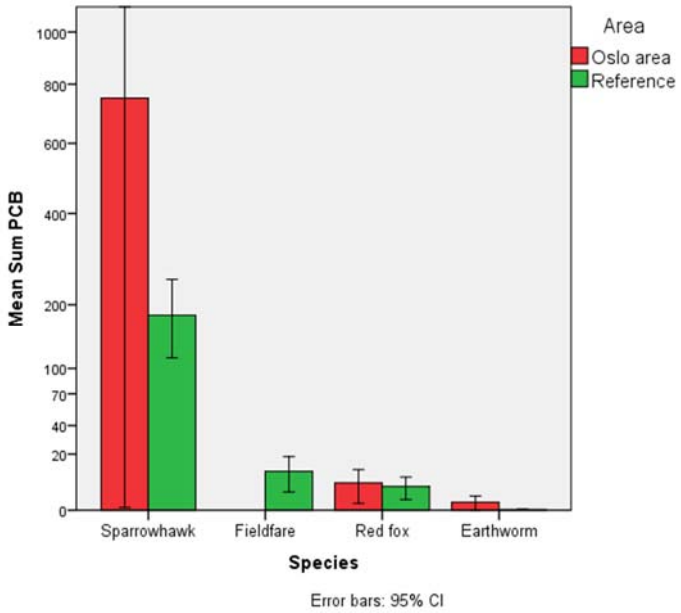


Figure 24: Combined exposure of organic pollutants in earthworm per urban site (above) and reference site (below) (ng/g ww)

3.6.5 Interspecies comparison

When comparing the average sum concentrations of the analysed pollutants in the four observed species, interesting species related differences can be observed. The comparisons were made on a wet weight basis to include non-lipophilic compounds as PFAS and metals as well. The lipid content in the observed tissues ranged from 1% in earthworms, to 2.6% in fieldfare eggs, 4.3% in sparrowhawk eggs to 4.5% in red fox livers. Biomagnification is discussed in the next chapter.



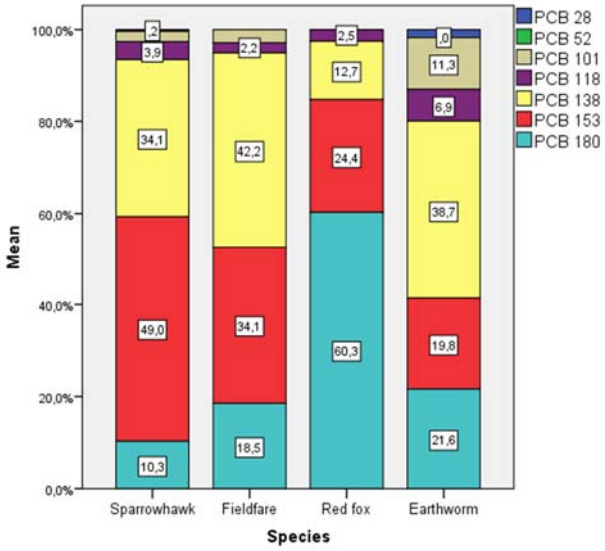


Figure 25: Comparison of mean sum of PCBs in ng/g ww in all species included in this study, Upper panel: sumPCB (red: Oslo, green: reference site); Lower panel: relative concentrations of PCB congeners

For PCBs, sparrowhawk eggs had the highest concentrations, followed by fieldfare eggs and fox liver. The individual PCB congeners were differently distributed in the different species observed (Figure 25). PCB 180 contributed majorly to the sumPCB load in fox liver, in contrast to sparrowhawk and fieldfare eggs, where PCB 153 and 138 were the dominating congeners. In earthworms, the lower chlorinated PCBs were more abundant. On a lipid weight basis the following sumPCB order can be found: Sparrowhawk > fieldfare

> fox liver > earthworms. No difference in congener contribution between urban and rural sites was observed.

For PBDEs, a similar trend as for the PCBs can be found (Figure 26). The contribution of the different PBDE congeners to the sumPBDE load varies between species. SumPBDE is dominated by the lower brominated PBDE 99 in sparrowhawk- and fieldfare eggs, while it is dominated by higher brominated congeners PBDE 153, and 209 in fox liver, and by 196 and 209 in earthworms (Figure 26). On a lipid weight basis the following sumPBDE order can be found: Sparrowhawk > fieldfare > earthworms > fox liver.

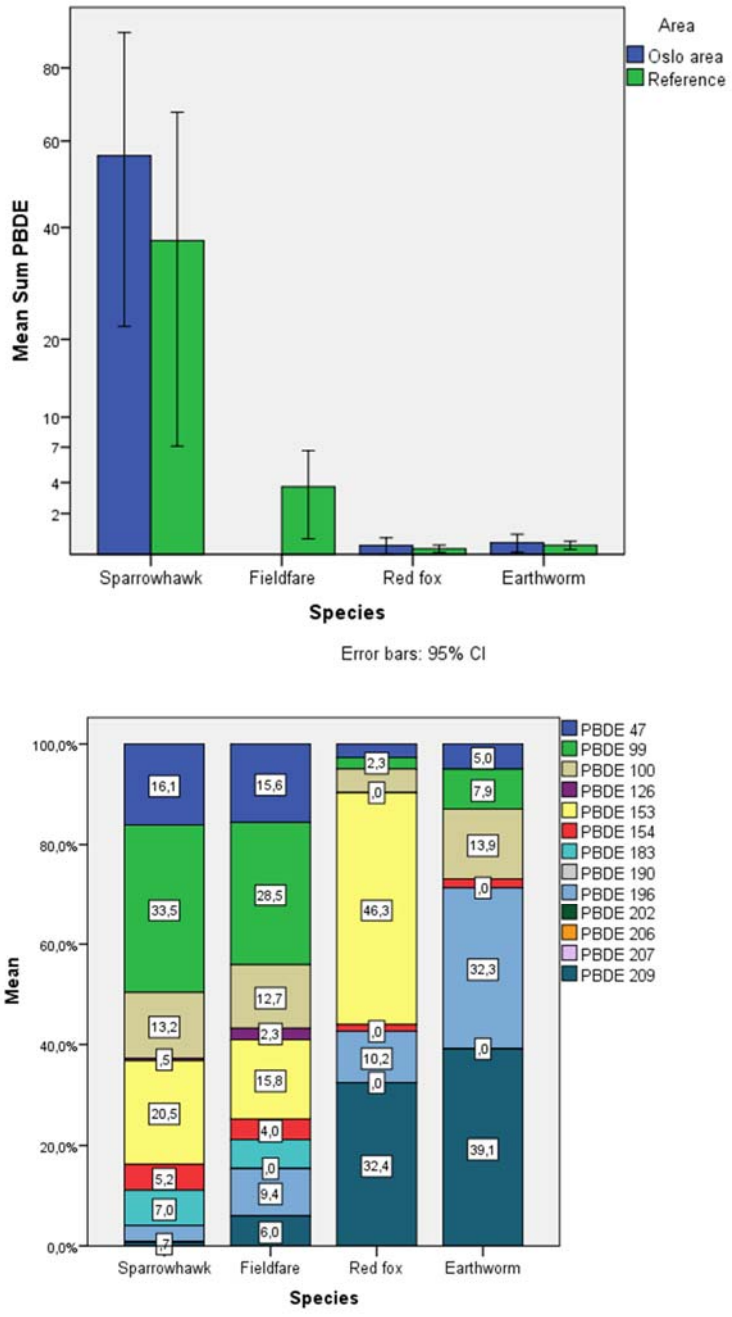


Figure 26: Comparison of mean sum of PBDEs in ng/g ww in all species included in this study. Upper panel: sumPBDE; Lower panel: relative concentrations of PBDE congeners

For PFAS a different picture was found, with less distinct interspecies differences (Figure 27). In Oslo, the following concentration order was measured: earthworms > sparrowhawk > red fox. In the reference site we found: sparrowhawk > fieldfare > earthworm > red fox. PFOS was the main PFAS in all species, except in fieldfare eggs which had higher concentrations of PFTriA (27.2%), than PFOS (20.2%).

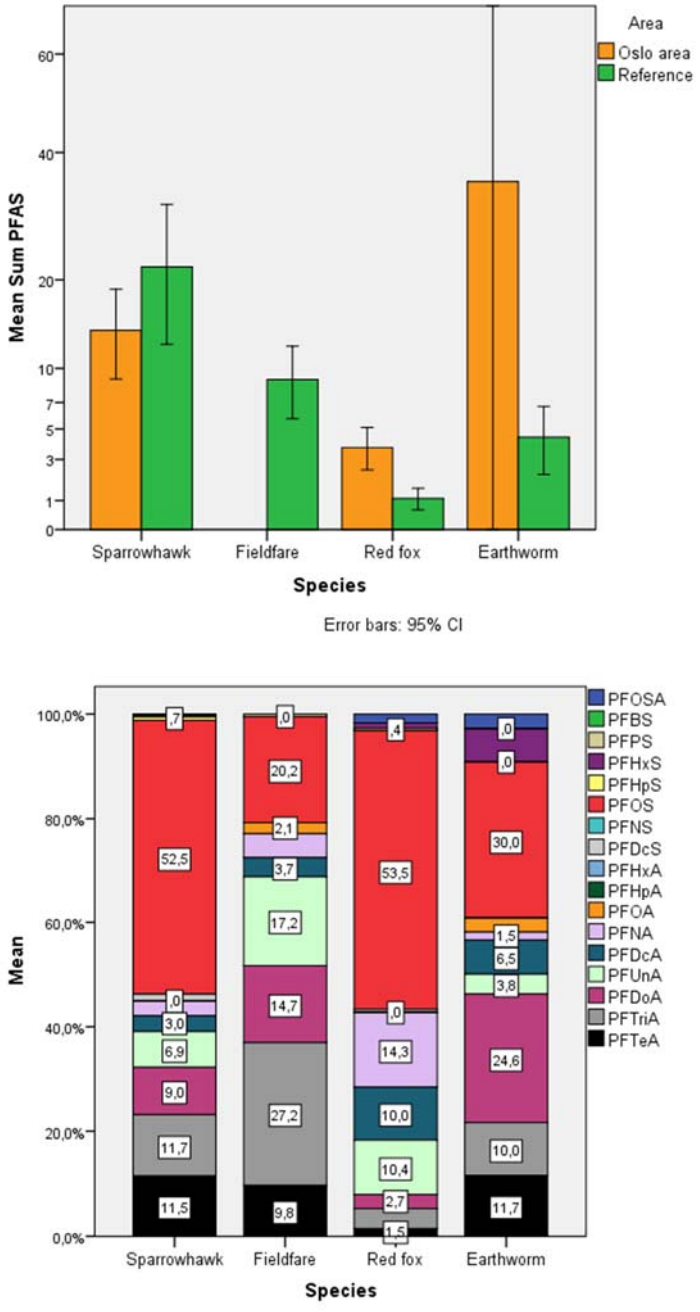


Figure 27: Comparison of mean sumPFASs in ng/g ww in all species included in this study, Upper panel: sumPFAS; Lower panel: relative concentrations of PFAS congeners

When comparing the relative contribution of the measured organic pollutants on a wet weight basis, different pollutant groups are contributing differently in the observed species. Earthworm is dominated by PFAS ca. 90%, while in PCBs are the dominating

compounds in red fox (60 - 80%), fieldfare (ca. 45 – 60 %) and sparrowhawk (80 – 90) (Figure 28).

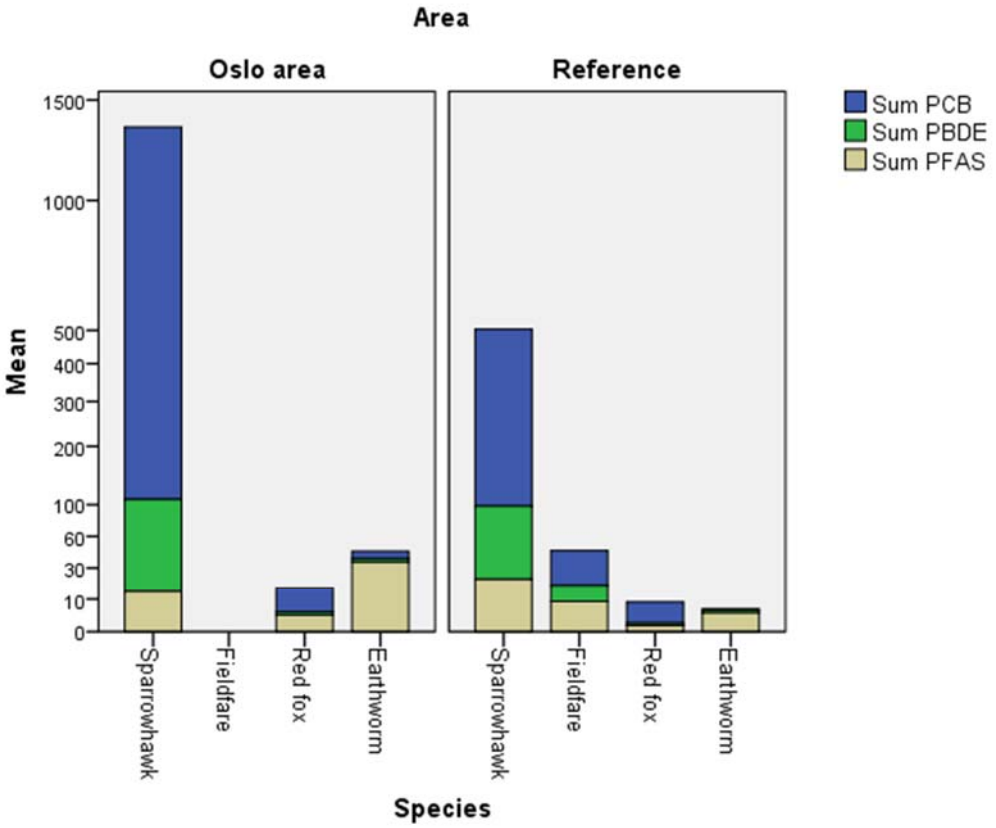


Figure 28: Comparison of the contribution of the major organic pollutant groups in ng/g ww

For the metals (Figure 29), we can make following observations, when not considering Zn and Pb due to their dominating abundancy: Earthworm has the highest Cd, Cr, Ni and As concentrations of all observed species. Hg and MeHg are more abundant in the sparrowhawk. MeHg contributes majorly to the overall Hg load in all species, with the exception of earthworm, where only minor amounts of MeHg can be found.

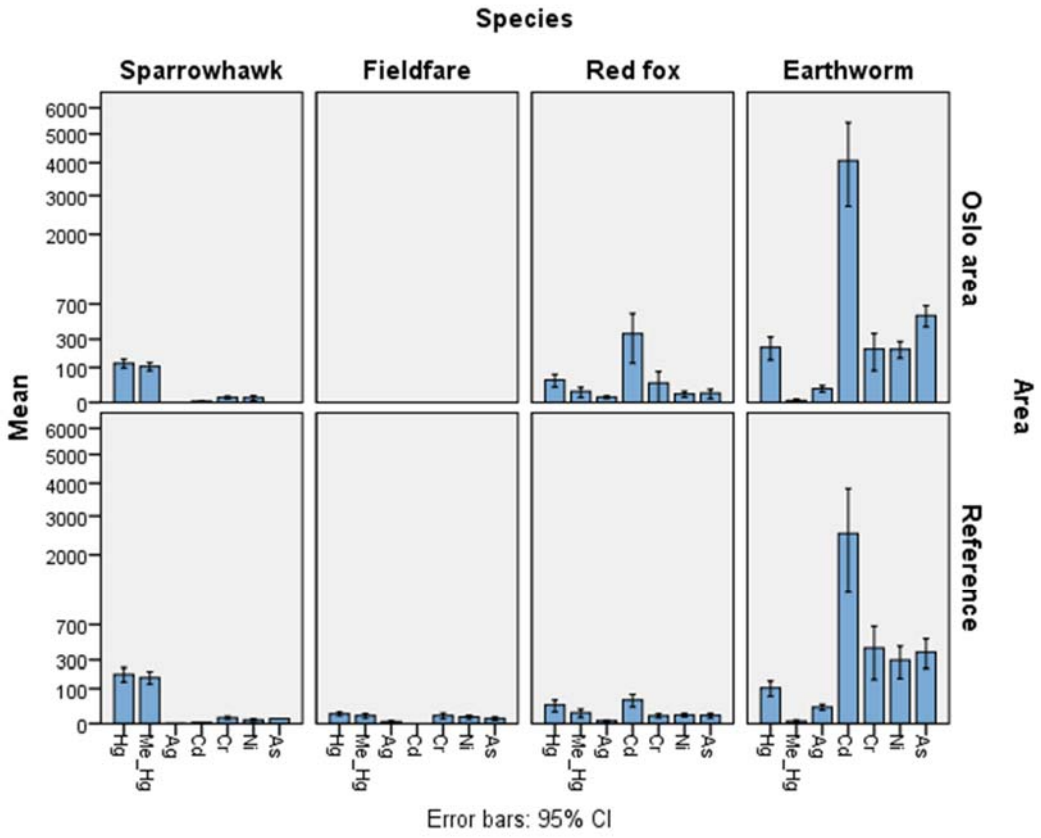


Figure 29: Interspecies comparison of metal concentrations, without Zn and Pb, in ng/g ww.

3.7 Bioaccumulation and biomagnification

No complete food chain, but rather representatives of a food web were sampled within the frame of the project. In addition the measuring the concentrations of different pollutants, stable isotopes were determined as supporting parameters on all biological samples within this study. Using this information trophic magnification factors (TMFs) were calculated to determine the bioaccumulation potential of a chemical within the food web. TMFs are increasingly used to quantify biomagnification and represent the average diet-to-consumer transfer of a chemical through food webs. They have been suggested as a more reliable tool for bioaccumulation assessment of chemicals that have been in commerce long enough to be quantitatively measured in environmental samples. TMFs differ from biomagnification factors, which apply to individual species and can be highly variable between predator-prey combinations. The TMF is calculated from the slope of a regression between the chemical concentration and trophic level of organisms in the food web. The trophic level can be determined from stable nitrogen (N) isotope ratios (δ(15) N) (Borgå et al. 2012). The general scientific consensus is that chemicals are considered bioaccumulative if they exhibit a TMF > 1.

3.7.1 Results from stable nitrogen and carbon isotope analyses

$\delta^{15}N$ data can be used to estimate the relative trophic positions of an organism. Terrestrial food chains are in general very short. Biomagnification is generally assumed to be positively linked to food chain length such that the longer the food chain is, the higher the pollutant concentrations will be at the top of the food chain. Thus, despite bioaccumulation capabilities of some pollutants, top predators in the terrestrial food webs may be at lower risk for experiencing secondary poisoning than top predators in marine food webs, which are typically long. The strength of the relationship between tissue concentrations and trophic position is however also influenced by the properties of the chemicals, the types of tissue analysed, sampling period and location. In general, more lipophilic chemicals show stronger relationships between measured tissue concentrations and trophic position.

Table 20. $\delta^{15}N$ in the different sample types.

Species		N	Mean	Median	Minimum	Maximum
Sparrow-hawk	Oslo area	10	7.84	7.49	6.47	11.76
	Reference	10	6.17	6.42	4.66	7.42
Fieldfare	Reference	9	8.24	8.61	5.44	10.27
Red fox	Oslo area	7	7.56	7.98	6.18	8.34
	Reference	15	10.1	10.1	7.44	11.7
Earth-worm	Oslo area	6	4.82	4.93	3.97	5.53
	Reference	9	3.29	3.29	2.24	5.23

According to the measured $\delta^{15}N$ data, the organisms included in this monitoring covers/ spans different trophic levels. Within the rural samples, earthworms showed the lowest $\delta^{15}N$ which indicates that it holds the lowest tropic position among the different

organisms/species in this study, followed sparrowhawk, fieldfare and red fox. A similar order in $\delta^{15}N$ concentrations was found in Oslo.

Figure 30 shows the $\delta^{15}N$ signature of the four investigated species. The higher $\delta^{15}N$ data in urban sparrowhawk eggs and earthworms compared to their rural counterparts indicate that these organisms feed on prey at higher trophic levels than organisms from reference sites in rural regions. Elevated biomagnification concentrations of for example PCBs, in urban locations, could be explained by that.

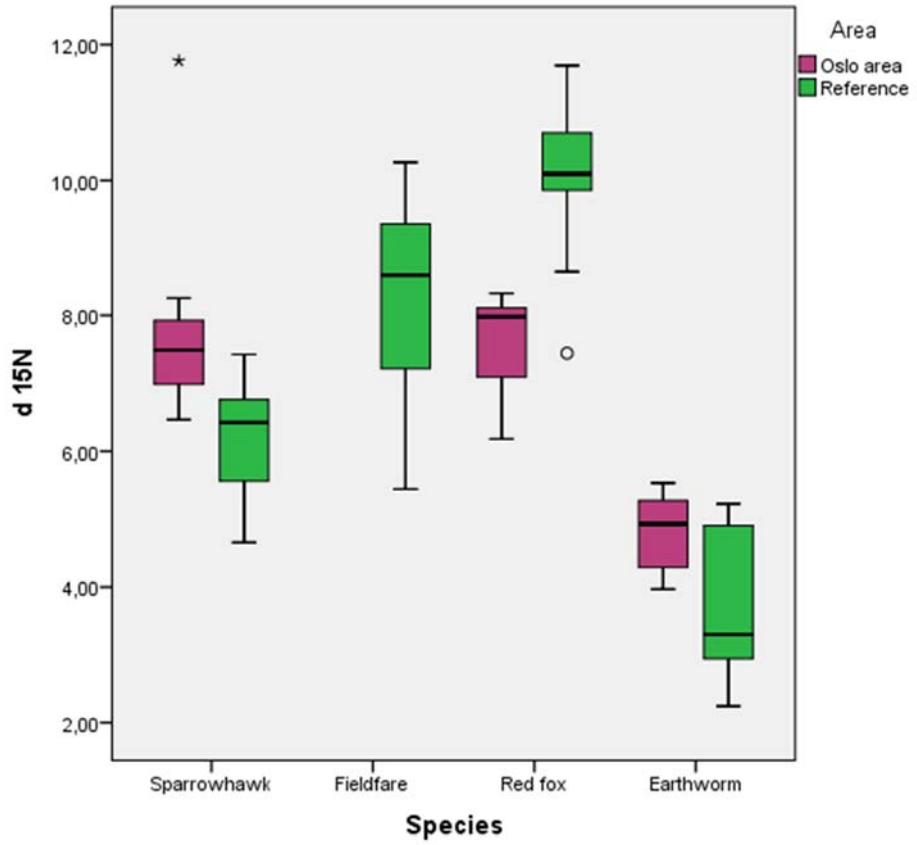


Figure 30: $\delta^{15}N$ concentrations in all species analysed (‰)

The difference in $\delta^{15}N$ between the consumer and its prey is known as $\Delta^{15}N$. Nitrogen in the protein of consumers is generally enriched in $\delta^{15}N$ by 3–5‰ relative to prey nitrogen (i.e. $\delta^{15}N$ = 3–5‰). This nitrogen heavy isotope enrichment appears to be caused by isotopic fractionation occurring with transamination during protein catabolism (Doucett et al., 1999). This increase allows determination of an animal's trophic level (TL) in a food web (DeNiro and Epstein, 1981; Post, 2002). As described above, red fox is characterized by the highest $\delta^{15}N$ concentrations (average 10.1 in reference site and 7.6 in Oslo) followed by fieldfare (8.2), sparrowhawk (6.2 in Oslo and 7.8 in Oslo) and earthworms. Thus, the rural red fox seems to be residing on the highest trophic level, apparently caused by the opportunistic feeding on a broad range of food items often consisting of rodents and human food waste. In literature, even higher $\delta^{15}N$ were reported for polar fox, varying between 10 and 12 ‰ (Andersen et al., 2015). The finding that the sparrowhawk had relatively low levels of $\delta^{15}N$ was quite surprising, and may indicate that the fractionation rate in this species or its prey species is different than expected. The fieldfare is considered to be a secondary consumer, feeding on insects and earthworms.

Since some insect species can be carnivorous, they might reside on a higher TL than the prey of sparrowhawk and those causing higher $\delta^{15}N$ concentration in fieldfare compared to sparrowhawks. Tillberg et al., found for example a difference in $\delta^{15}N$ of 6.0 ‰ among some ant colonies suggesting that estimates of trophic position in a single species can span up to two trophic levels (Tillberg et al., 2006).

As the distribution of $\delta^{15}N$ concentrations in sparrowhawk eggs found in this study illustrates, the $\delta^{15}N$ varies only little, indicating that the sparrowhawk has a narrow food source, consisting of a limited variety of species. Small, but significant differences between the reference sites and Oslo were found for sparrowhawk, with 6.2 and 7.8 respectively (P = 0.001, Z = -3.2, M-W U), indicating that the sparrowhawk relies on different food sources in those locations. The difference between the reference site and Oslo regarding red fox levels (10.1 *vs* 7.6) was also significant (P = 0.001, Z = -3.4, M-W U). For earthworms, the average $\delta^{15}N$ concentrations varied less (average of 4.5 in urban and 3.8 in reference location), and they were not significantly different (P = 0.165, Z = -1.4, M-W U).

$\delta^{13}C$ values provide information regarding the source of dietary carbon, e.g. whether and to what extent an organism feeds on marine or freshwater organisms or aquatic or terrestrial organisms. Eggs from marine locations are expected to show a less negative $\delta^{13}C$ value than eggs from terrestrial locations. However, direct comparison of the data presented in this report/ monitoring study should be done with care, since different tissues were analysed for the different species in the study (eggs, liver, whole individuals). Different tissues may have different $\delta^{13}C$ turnover rates and may reflect the dietary exposure differently and in an optimal study design only data from the same tissue type should be compared (optimally muscle tissue due to slow turn-over rates). The differences in $\delta^{13}C$ concentrations found in sparrowhawk eggs ranged between -24 and -27 (Table 21, Figure 31) but with an average of -25.7 in the reference site and -25.4 in Oslo. For comparison with the marine food chain, a range of $\delta^{13}C$ concentrations between different gull species of -17 to -25 has been reported previously (Gebbink and Letcher 2012; Gebbink et al. 2011), indicating that little food of marine origin is present in the food of the sparrowhawk. Red fox and fieldfare as well as earthworms showed similar concentrations, averaging at -26.8, -27 and 26.5 ‰ (Figure 31), indicating that all selected species are part of a similar food chain, feeding on terrestrial food items. We could not detect any significant differences between Oslo and the reference sites for any of the species. Between-species differences were found for sparrowhawk *vs.* all other species, and fieldfare *vs.* earthworms. No other inter-specific differences were found (Mann-Whitney U tests).

Table 21. $\delta^{13}C$ levels in the different sample types.

Species		N	Mean	Median	Minimum	Maximum
Sparrowhawk	Oslo area	10	-25,36	-25,44	-26,92	-24,60
	Reference	10	-25,72	-25,79	-26,55	-24,41
Fieldfare	Reference	9	-27,09	-27,19	-27,43	-26,57
Red fox	Oslo area	7	-26,68	-27,01	-27,37	-25,57
	Reference	15	-26,80	-27,21	-27,72	-25,11
Earthworm	Oslo area	6	-25,75	-25,49	-26,95	-24,59
	Reference	9	-26,95	-26,64	-28,23	-26,09

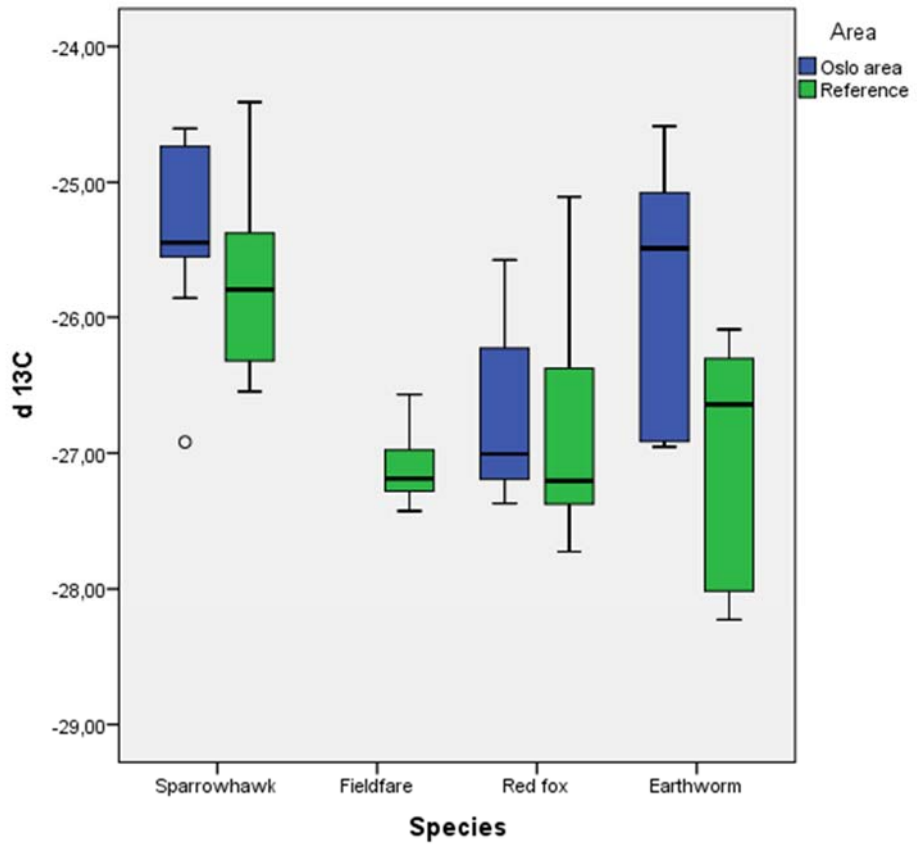


Figure 31: Boxplot of δ^{13}C concentrations in the different species analysed.

When relating all samples against δ^{13}C and δ^{15}N, the following graph is achieved, showing differences between foxes, sparrowhawks and earthworms with some overlap, spanning more than one trophic level but without any distinct clustering of the species, indicating a more complex food web rather than a food chain (Figure 32). In general, little stable isotope data exist from terrestrial food chains similar to the one sampled here. The variation in δ^{13}C values in earthworm is difficult to explain, as we know little about the diet of earthworms, except that they feed on organic matter in the soil where they live. The difference may depend on the local origin and parent organisms of this organic matter, and also on different species of earthworms involved, but this is only open to speculations. The range of values was least for the fieldfare, which may be caused by the fact that the eggs of this species was sampled from one single site. Foxes showed a large spread of values, probably caused by the fact that it is a true omnivore, feeding on a wide range of species and food items. The sparrowhawk eggs were rather well grouped, and the variation is probably due to the different prey species taken by the different breeding pairs.

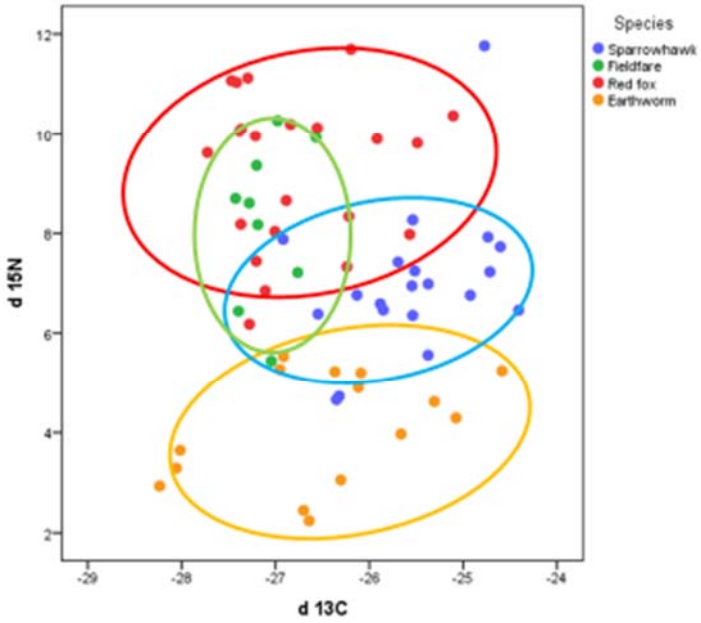


Figure 32: Relationship between the dietary descriptors $\delta^{15}N$ and $\delta^{13}C$ in biota from urban and terrestrial environments

3.7.2 Estimation of biomagnification by calculation of TMF values

The selected species in this study represent species from the 2nd trophic concentration (earthworms), 2nd to 3rd (fieldfare) and the 3rd and 4th trophic concentration (red fox and sparrowhawk). To assess the biomagnification of each chemical we correlated the log sum concentrations of the different pollutants in the different species of the food web with $\delta^{15}N$, i.e information on the relative tropic position of the organisms (Figure 33). At the reference site, sparrowhawk, fieldfare and red fox were clearly distinct from the earthworm, but not aligned according to their *a priori* TL definition for the lipophilic compounds as PCBs, not clustering along a straight line as expected. For PFAS, data points overlapped independently of species, also not following a linear relationship as expected for biomagnifying compounds.

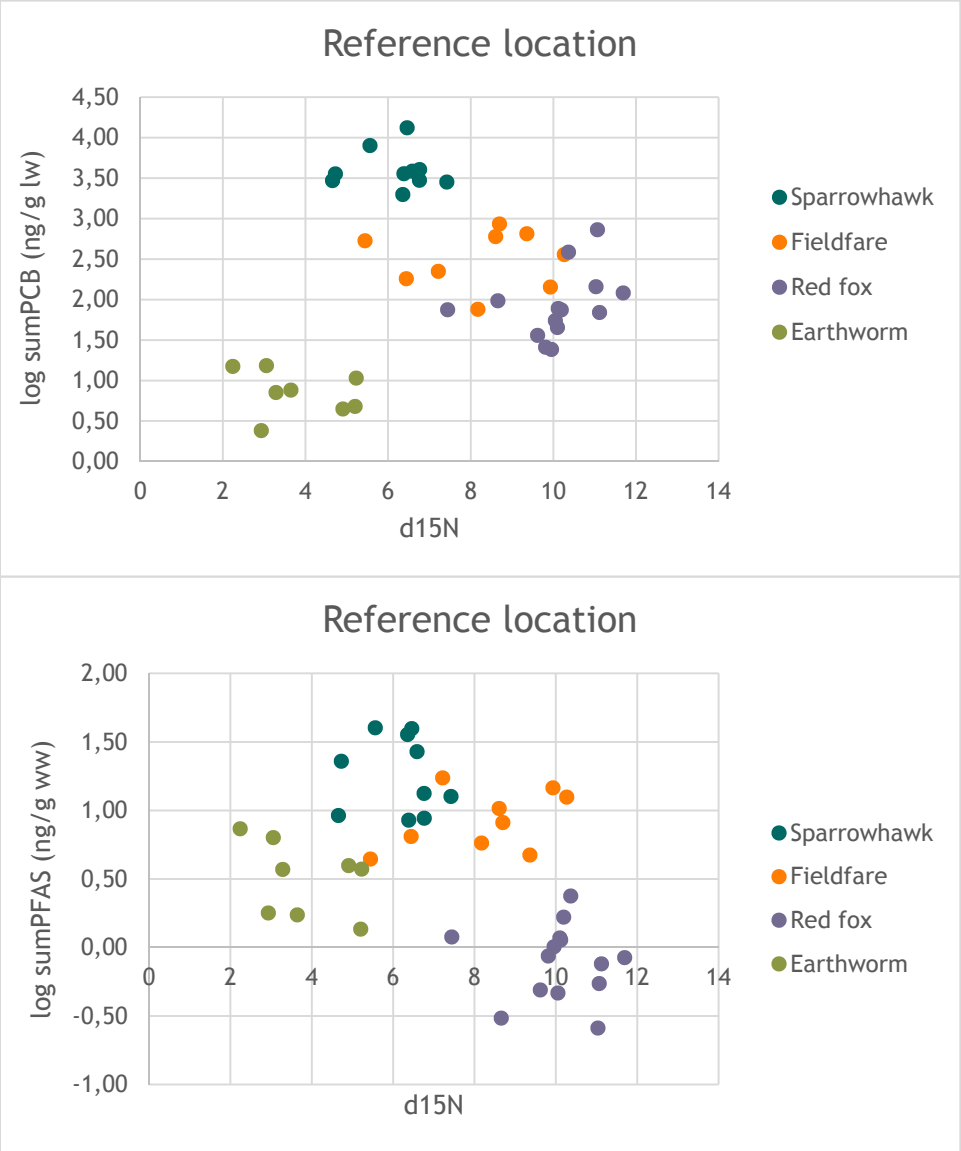


Figure 33: Relationship between $\delta^{15}N$ and log sumPCB and sumPFAS concentrations at the reference site

In Oslo, the higher PCB levels combined with lower $\delta^{15}N$ data for the red fox caused the data points to align in a more linear fashion, indicating biomagnification of PCBs. For PFAS, no such change can be observed.

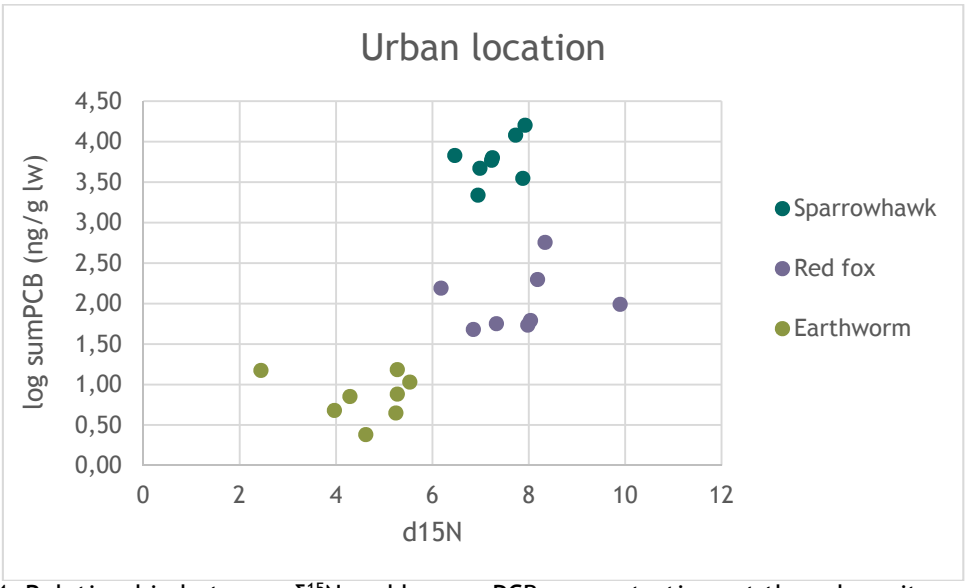


Figure 34: Relationship between $\delta^{15}N$ and log sumPCB concentrations at the urban site

The red fox was omitted from further calculations, as it does not belong to the studied food-chain, due to their omnivore diet. Using the formulae above, we obtained the following TMFs at the reference location, based on lipid concentrations and on a wet weight basis for sumPFAS, using the equation Log [compound] = a + *b*TL, and TMF = 10^b :

SumPCBs: 10.2, SumPBDEs: 6.0, and for sumPFAS 1.4

resulting in TMFs >1 for all organic compound groups investigated indicating biomagnification of these compounds in the terrestrial foodchain. TMF for PCB 153 alone was calculated to 8.8, representing one of the main PCBs but only one chlorination degree and substitution pattern.

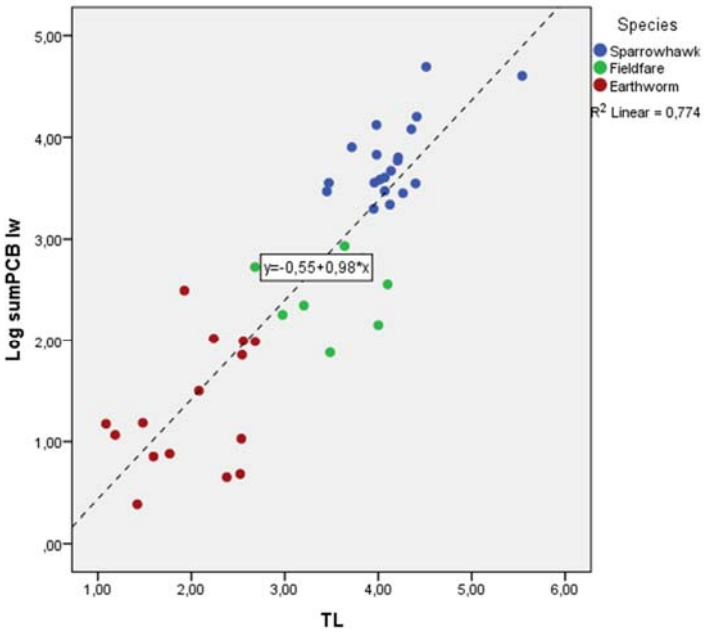


Figure 35: The relation between log SumPCBs (lw) and trophic level.

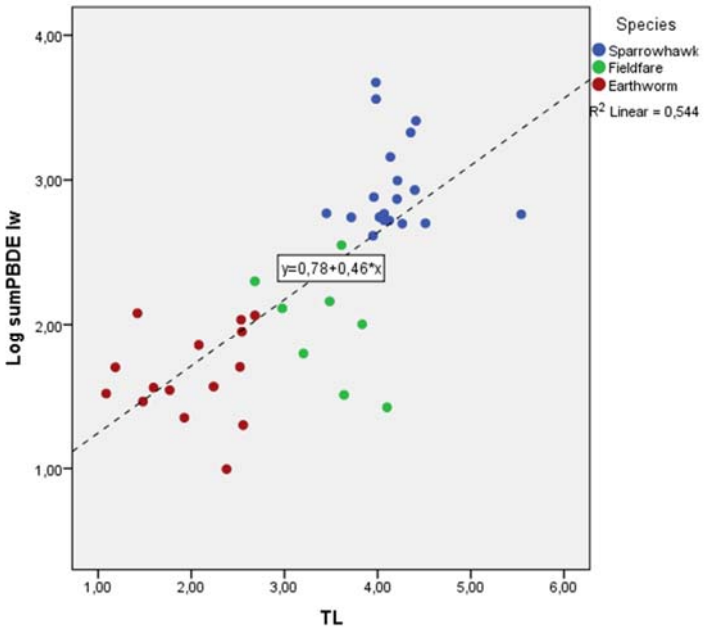


Figure 36: The relation between log SumPBDEs (lw) and trophic level.

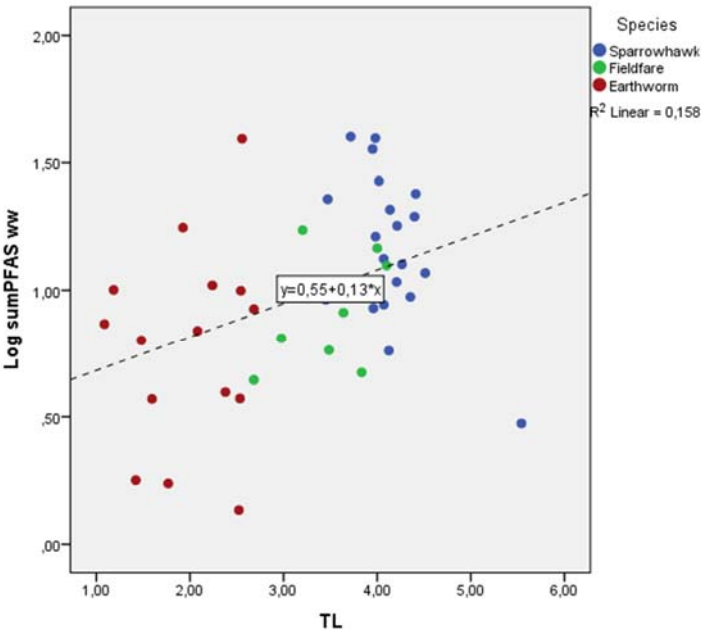


Figure 37: The relation between log SumPFAS (ww) and trophic level.

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. Component-based approaches are suitable methods for evaluating risk of mixtures when exposure data (i.e. concentrations) in addition to toxicity endpoints or similar toxicity reference values exist for the individual chemical components. (Altenburger et al., 2014). Two methods were investigated in the present study, one based on the recommended REACH method to evaluate risk for predators from food intake, and another method looking at mixture risk for specific species based on available toxicity data.

4.1 Risk evaluation of predators from food exposure

Within the European regulation of chemicals i.e., Registration, Evaluation, Authorisation and Restriction of Chemicals [REACH]) enacted in 2007, guidance exists on how to quantitatively assess the effects of a substance on the environment by determining the concentration of the substance below which adverse effects are not expected to occur in the environment. This concentration is known as Predicted No-Effect Concentrations (PNECs) (ECHA, 2008). 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. In order to derive risk of contaminants for soil living organisms, such as plants, microorganisms and earthworm, $PNEC_{soil}$ should be determined (Andersen et al 2012). The evaluation of risk for soil living organisms (for instance earthworm) is performed by comparing predicted or measured concentrations in soil with the derived $PNEC_{soil}$. To avoid risk for terrestrial soil ecosystem the MEC should not exceed the PNEC levels.

Risk of contaminants for wildlife as higher member of the food chain has to consider and include bioaccumulative properties of contaminants, which is a highly relevant property of several persistent organic pollutants. Biomagnification is defined as accumulation and transfer of chemicals via the food chain, resulting in an increase of the internal concentration in organisms at higher levels in the trophic chain. Secondary poisoning is concerned with toxic effects in the higher members of the food chain of the terrestrial environment, which result from ingestion of organisms from lower trophic levels that contain accumulated substances. In order to estimate risk for wildlife and predators due to oral intake from lower trophic levels of bioaccumulative contaminants, $PNEC_{oral}$ (or $PNEC_{predator}$) should be determined (Mayfield et al., 2014). $PNEC_{oral}$ values represent dietary predicted no effect concentrations, below which food concentrations are not expected to pose a risk to birds or mammals (ECHA 2008). Secondary poisoning effects on bird and mammal populations rarely become manifest in short-term laboratory studies. Therefore, results from long-term laboratory studies are strongly preferred, such as NOECs for mortality, reproduction or growth. If a chronic NOEC for both birds and mammals is available, the lower of the resulting PNECs may be used as the secondary poisoning assessment to represent all predatory organisms (ECHA, 2008). To avoid risk for wildlife, the PEC or MEC in feed should not exceed the $PNEC_{oral}$ levels for the specific chemical or chemical group; i.e. the MEC/PNEC ratio should not exceed 1.

The component-based method of summing up PEC/PNEC or MEC/PNEC ratios has been recommended as a justifiable mixture risk approximation (Backhaus and Faust 2012; Kortenkamp et al., 2014) in order to estimate in a first tier whether there is a potential risk for an exposed ecosystem; i.e. if the sum of MEC/PNEC exceed 1. This approach has been used in the present study in order to evaluate the risk for combined effects in predators where earthworm and fieldfare eggs could be substantial part of the diet.

$PNEC_{pred}$ (=$PNEC_{oral}$) values were adopted from a previous Norwegian study (Andersen et al. 2012, Table 22).

As a realistic approach, median concentrations were used as Measured Environmental Concentration (MEC_{med}) and the $MEC_{med}/PNEC_{pred}$ was 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. If the sum based on median concentrations was below 1, the sum was calculated with 90 % percentile concentrations in order to assess worst case. It should be emphasized that the risk evaluation is only done for predators where earthworm and/or bird eggs from fieldfare are important food items.

According to Nost et al., median values were only calculated for compounds where minimum 60 % of the samples have concentrations above limit of detection (LOD) for each site (Nost, et al., 2013). As a result, the impact on the median was minimised and as a pragmatic approach, LOD values could be treated as zero in the median calculations in these cases, according to EFSA, 2010. Substituted values as for example ½ LOD depend on the conditions which determined the detection limit, such as the laboratory precision or the sample matrix interferences. These factors do not necessarily bear a relation to the true concentration and change over time as well.

Table 22: $PNEC_{pred}$ values (mg/kg in food) for secondary poisoning with references (adopted from Andersen et al 2012; 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	Newsted et al 2005	30	Quail reproduction study
Cd	0.16	EU RAR	10	Based on 4 studies with birds and 5 studies with mammals
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 or ortho-chlorinated PCB congeners

As Table 22 illustrates, PFOS, cadmium and mercury pose the highest risk for predators with low PNEC values ($PNEC_{pred}$ < 1 mg/kg).

4.2 Earthworm and fieldfare eggs as food for consumers

4.2.1 Earthworm as prey

The summation of all MEC/PNECpred values for the median concentrations of PFOS, PBDEs and some metals revealed ∑MEC/PNECpred >1 in the Oslo area and reference areas.

Table 23: 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.

	Oslo	Reference		Oslo	Reference
Components	**MEC_{med}**	**MEC_{med}**	**$PNEC_{pred}$**	**$MEC_{med}/PNEC_{pred}$**	**$MEC_{med}/PNEC_{pred}$**
PFOS	5.405	0.555	13.0	0.42	0.04
PentaBDE (BDE47, 99, 100)	0.160	0.096	1000	0.16E-03	0.096E-03
OctaBDE (BDE153,154, 175/183, 196, 206, 207)	0.099	0.316	6.7E+03	1E-05	4.7E-05
Hg	201	126	400	0.50	0.32
Cd	4938	2256	160	30.9	14.1
Ni	237	270	8500	0.03	0.03
Pb	64218	8451	3600	17.8	2.34

Worm	Oslo	Reference areas
Σ $MEC_{med}/PNEC_{pred}$	49.7	16.8

As seen from the table above, Cd had the highest MEC/PNEC ratio and was the main contributor to the sum with high MEC/PNEC value followed by Pb, Hg and PFOS. BDE 209 was only found in one (0.61 ng /g ww) and three samples (0.15-0.26 ng/g ww) from Oslo and reference sites, respectively, and therefore not included. However the ratio MEC/PNEC of BDE 209 would not contribute noticeably to the sum. Both Cd and Pb revealed MEC/PNEC values well above 1 and the high Sum ($MEC_{med}/PNEC_{pred}$) indicate reason for concern for predators where earthworm is a substantial part of the diet for both the Oslo area and the reference areas. In the sampling campaign from 2013, the $\sum MEC_{med}/PNEC_{pred}$ for earthworm ranged between 5.9 and 12.6 in the sampled sites in Oslo, which is between 10 and 5 times lower than in this study. The difference found is mostly caused by much higher Cd and Pb concentrations found in this study compared to 2013, most probable due to the selection of potentially more polluted sites compared to urban parks in 2013.

4.2.2 Fieldfare eggs as food

The summation of all MEC/PNEC values for both the median and 90 % percentile concentrations of PFOS, PBDEs and some metals revealed ∑MEC/PNECpred < 1.

Table 24: Median (MEC_{med}) and 90 % percentile ($MEC_{90\%}$) environmental concentration and $PNEC_{pred}$ of PBDE isomer groups, PFOS and metals in **fieldfare,** and calculated MEC /PNEC values. MEC and PNEC values for organic contaminants and metals are given as ng/g ww.

	MEC_{med}	**$MEC_{90\%}$** percentile	**$PNEC_{pred}$**	**$MEC_{med}/PNEC_{pred}$**	**$MEC_{90\%}/PNEC_{pred}$**
PentaBDE (BDE47, 99, 100)	1.3	3.5	1000	0.001	0.004
OctaBDE (BDE183, BDE196)	0.5	1.2	6.7E+03	7.4E-05	1.8E-04
DecaBDE (BDE209)	0.1	0.47	833E+03	1.2E-07	6E-07
PFOS	1.3	3.1	13	0.1	0.24
Hg	3.6	12.7	400	0.009	0.032
Ni	1.5	7.3	8500	1.8E-4	0.001

Fieldfare	Reference (Åmotsdalen)
Σ $MEC_{med}/PNEC_{pred}$	0.11
Σ $MEC_{90\%}/PNEC_{pred}$	0.27

Fieldfare eggs were only sampled in Åmotsdalen. Cd was not detected in the samples and Pb was only detected in one sample, and therefore not included in the calculations. Median values of Hg and Ni were included although only 50 % detection for both of the metals was observed. The $\sum MEC/PNEC_{pred}$ for both median and 90% percentile concentrations were well below 1 and does not indicate an unacceptable risk for the few compounds with known $PNEC_{pred}$ values for species feeding on fieldfare eggs.

When doing the same calculations with maximum values the sum MEC/PNEC show a value 0.5. In the 2013 study, egg from pied flycatcher was characterized by a $\sum MEC_{med}/PNEC_{pred}$ of 0.008, which indicate lower risk for predatory organism compared to the fieldfare.

4.3 Risk of effects for fieldfare and sparrowhawk from exposure in eggs

The component-based calculations above used PNEC predator reference values which commonly are used in risk assessment of new chemicals under the EU REACH regulation. These reference values are used in order to evaluate the risk of predators due to consuming organisms from lower trophic levels. However, in order to evaluate the risk for the respective species based on the measured concentrations, relevant toxicity data for the same species or similar species are required.

A recent study from Miljødirektoratet (Andersen et al., 2014 with references therein) evaluated the combined risk of effects in seabird eggs by comparing measured concentrations in eggs to literature effect data; i.e. effect concentration from exposure in eggs. Effect from exposure in eggs was related to mortality, reduced number of eggs, effect on gender development for various endpoints (LOEC, EC(D)10, EC(D)50, LC(D)50) and from various bird species (chicken, hen, common quail, zebra finch etc.). These effect concentrations were adopted in this study in order to do a first tier evaluation of combined risk for fieldfare and sparrowhawk eggs.

The results for the present first tier mixture risk for fieldfare and sparrowhawk should be interpreted with caution due to the fact that no specific and single biological effect endpoint and toxicology test were common for all chemicals, but rather various biological effect endpoints, and for different bird species. The results are more scientifically appropriate in order to evaluate and interpret the risk of effects for the single compound groups (i.e. the single MEC/Effect ratios) which refer to a specific biological effect endpoint.

4.3.1 Fieldfare

First-tier mixture risk assessment identified no risk for combined effects in fieldfare eggs.

The Sum of ratios MEC/Effects for median and 90 % percentile concentrations were 0.31 and 0.84 respectively. The metal Cu and BDE99 had the highest contribution to the sum. Although PNECpred concentrations of earthworm as feed indicated reason for concern for predators and likely fieldfare, the risk of effect calculations for fieldfare eggs do not reveal the same.

Although metals only were detected in 50 % of the samples, median and 90 % percentile values were calculated and included.

Table 25: Median (MEC_{med}) and 90 % percentile ($MEC_{90\%}$) concentrations in fieldfare and Effect concentrations of PFOS, SumPCB, PBDE isomer groups and metals (Andersen et al 2014), and calculated MEC/Effect values. All concentrations are given as ng/g ww.

			M177 report (Andersen et al 2014)		
	MEC_{med}	**$MEC_{90\ \%}$**	**Effect ng/g egg**	**MEC_{med}/Effect**	**$MEC_{90\%}$/Effect**
PFOS	1.33	3.11	100	0.01	0.03
SumPCB	9.8	24	400	0.03	0.06
BDE99	0.6	2.0	10	0.06	0.2
BDE100	0.2	0.81	10	0.02	0.08
BDE126	0.09	0.16	10	0.009	0.016
Hg	3.6	12.7	400	0.009	0.03
Ni	1.5	7.3	1000	0.002	0.007
Cu	200	483	1160	0.17	0.42
Sum				**0.31**	**0.84**

4.3.2 Sparrowhawk

First-tier mixture risk assessment identified risk for combined effects in sparrowhawk eggs from both Oslo and reference areas.

The sum of MEC/Effect ratios was 3.1 and 2.3 for Oslo and reference sites, respectively. Only summing up the ratios for SumPCB, PFOS, BDE47, BDE99, BDE100 reveal ratio values of 2.5 and 1.5 for Oslo and reference sites, respectively. SumPCB and the three PBDE congeners, in addition to Hg and Cu, contribute most to the sum value. Since most of the effect data in the Andersen et al 2014 study are determined in studies on other bird species than sparrowhawk, these effect data most probably cannot be used directly to evaluate the risk for effects in sparrowhawks. It is recommended to find data for same or similar species and preferentially the same effect endpoint (acute or chronic) for the various compound classes.

Table 26: Median (MEC_{med}) and 90 % percentile ($MEC_{90\%}$) concentration in sparrowhawk and Effect concentration of PFOS, SumPCB, PBDE isomer groups and metals (Andersen et al 2014) and calculated MEC/Effect values. All concentrations are given as ng/g ww.

	Oslo	**Reference**	M177 report (Andersen et al 2014)	**Oslo MEC/Effect**	**Reference MEC/Effect**
	MEC_{med}	**MEC_{med}**	**Effect ng/g egg**		
PFOS	7.73	6.36	100	0.077	0.064
SumPCB	189	146	400	0.47	0.37
BDE99	14.01	7.17	10	1.4	0.72
BDE100	4.92	3.11	10	0.49	0.31
BDE126	0.18	0.11	10	0.02	0.01
Cd	0.33	-	100	0.003	-
Hg	129	169	400	0.32	0.42
Ni	2.53	1.9	1000	0.003	0.002
Cu	354	463	1160	0.31	0.39
Sum				**3.1**	**2.3**

4.3.3 Toxicity data from literature

Very few studies have been found where toxicity data or PNEC values for wildlife are available for the relevant species in present study.

Hazard quotients (HQs) defined as MEC/PNEC of PBDEs and p,p'-DDE for osprey and peregrine falcon eggs were calculated and applied as a preliminary risk evaluation in a study of Chen et al. (2010) using median concentrations as MEC values. The PNECs values of DDE of 870 and 1500 ng/g ww in osprey and peregrines were calculated by dividing reported levels associated with 20% eggshell thinning in respective species by an uncertainty factor of 10. A reported LOEL level of PBDEs associated with pipping and hatching success in American kestrel of 1800 ng/g ww was used for deriving PNEC for peregrine falcon, and a threshold level for reduction of reproduction performance in osprey of 1000 ng/g ww was used. A PNEC of 180 ng/g ww and 100 ng/g ww for peregrine falcon and osprey, respectively, were estimated.

The same PNECs for PBDEs in the Chen study was recently applied in a study of eggshells of two bird species where maximum measured concentrations were used in the risk assessment (Daso et al., 2015). One study on risk estimation based on toxicity reference values of PCBs in wild bird eggs from South Africa (Quinn et al., 2013) used a NOEL of SumPCB of 4000 ng/g ww. These same toxicity reference values for PCBs and PBDEs have been used in a risk assessments for raptors in a study from China (Yu et al 2013). Hazard quotients (HQs) were determined by dividing median MEC of the various contaminants with toxicity reference values such as NOEL or LOEL. In addition to a NOEL of 4000 ng/g ww for SumPCB and 1800 ng/g ww for PBDEs, a LOEL value of 12000 and 3000 ng/g ww for *p,p'*-DDE was used, from a study on owls and from reproduction study of peregrine falcon, respectively.

For an estimated risk assessment of sparrowhawk in the present study due to the presence of PCBs and PBDEs, we have used the above suggested PNEC for SumPBDEs of 100 ng/g ww (for osprey) and a provisional PNEC for SumPCB of 400 ng/g (NOEL divided by 10). As seen from the table, this preliminary risk evaluation for sparrowhawk indicate no reason for concern for combined effects based on median concentration for both the Oslo and reference areas. The 90 percentile concentration however reveal a reason for concern with Sum MEC/PNEC >1 for both the Oslo and reference areas. The PNEC values should be used with caution until more comprehensive evaluation of toxicity reference values and PNEC values have been accomplished from available literature and databases; for instance if the NOEL value of 4000 ng/g for SumPCB is appropriate to apply for the effect of non-dioxin like PCBs.

Table 27: Preliminary risk for sparrowhawk due to the presence of two component groups PCBs and PBDEs. All concentrations are given as ng/g wet weight. The provisional PNEC for PBDEs and PCBs are based on data from Chen et al., 2010 and Quinn et al 2013.

	MEC_{med} Oslo	MEC_{med} Reference	Provisional PNEC	MEC/PNEC Oslo	MEC/PNEC Reference
SumPBDE	42.6	22.3	100	0.43	0.22
SumPCB	189	146	400	0.47	0.37

	$MEC_{90\ percentile}$ Oslo	$MEC_{90\ percentile}$ Reference	Provisional PNEC	$MEC_{90\%}$/PNEC Oslo	$MEC_{90\%}$/PNEC Reference
SumPBDE	114	44	100	1.14	0.44
SumPCB	355	268	400	0.89	0.67

No mixture risk assessment was performed for red fox. Red fox liver concentrations was not relevant for assessing oral toxicity for predators with the use of PNECpred. To the best of our knowledge, little or no toxicity reference data (NOAEL, LOEL, PNEC etc.) exist for this species or other relevant species. Risk assessment for contaminant groups or for mixture of contaminants was therefore not done.

5. Discussion

Very little data on concentrations of environmental pollutants in earthworms for comparative purposes are available in the literature. Good reference-data are available on concentrations of legacy POPs for predatory birds, but to a lesser degree for passerines and foxes (Corsolini *et al.*, 2000, Custer *et al.*, 2010, Mateo *et al.*, 2012).

Sparrowhawk

The highest sumPCB contamination found in Norway in any bird of prey, was in peregrine falcon eggs from 1976 in Rogaland, with 110 000 ng/g ww (Nygård, 1983). During the 1970's, average PCB values of more than 23 000 ng/g ww and DDE values of more than 38 000 ng/g ww were measured in sparrowhawks from Norway, making it one of the most contaminated species by environmental pollutants at that time, and with eggshells that were between 20 and 30 % thinner than normal (Nygård & Polder 2012). However, pollutant concentrations have decreased considerably in Norwegian sparrowhawks since then. One sparrowhawk egg from the period 2005-2010 had an average value of 229 ng/g PCBs and 509 ng/g DDE (Nygård and Polder 2012). In the present material, an average of 181 ng/g ww PCBs was found at the reference site compared to 410 ng/g ww in Oslo. Its food choice, feeding other birds (Hagen et al. 1952), makes it vulnerable to trophic magnification of pollutants, but one must expect large variations in pollutant levels, due to variations in local prey species.

There is limited information with respect to PFAS concentrations in eggs from sparrowhawk. For comparison, in a study from 2012, common kestrel eggs were analysed with respect to PFASs (Nygård and Polder 2012). They were collected in the time period 2005-2010 with reported sum concentrations on the average of 4.5 ng/g fw., but the common kestrel mainly preys on rodents, placing it lower in the food chain than sparrowhawks. The mean concentration of sum PFASs in this study was 15 and 19 ng/g fw, from the reference sites and Oslo respectively. 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 Cu 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). When comparing with earlier data, sparrowhawk eggs collected in a period between 2005 and 2010 showed a similar concentration of 175 ng/g ww as found in our study with 164 ng/g ww in Oslo, but the sample size precludes any comparison over time(Nygård & Polder 2012). The concentration of Zn found in sparrowhawk eggs where in the range of values found in Audouins's gull *Larus audouinii* (Morera 1997), and Cory's shearwater *Calonectris diomedea* (Renzoni et al. 1986). Cu concentrations found where in agreement with results obtained for *Larus audouinii* (Morera 1997). Since Cu and Zn are physiologically regulated in birds (Richards and Steele 1987), of the here measured metals mostly Hg, Pb, Cd and As can prove toxic at concentrations that can be found in the environment (Depledge et al. 1998).

Fieldfare

No data for organic pollutants and metals could be found for fieldfare eggs or other matrices in the literature. For improved interspecies 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 427 ng/g lw sumPCB were detected in the fieldfare eggs, about a tenth fold less than 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 143 ng/g lw was found, comparable with 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. The PCBs concentrations of 1000 ng/g lw were twice as high as found in the here presented study, 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 (*Sturnus vulgaris*), 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), similar and three times lower than observed in the fieldfare eggs.

Red fox

The foxes collected in Oslo were contaminated with on average 3.8 ng/g ww sumPFAS. PFOS contributed about 50% to that load (2.1 ng/g ww). At the reference site, 0.53 ng/g ww PFOS was found, constituting a similar percentage of the sumPFAS. Rat liver, collected in Oslo in 2013 were contaminated with on average 5.2 ng/g ww sumPFAS, which is comparable with what was found in red foxes from Oslo in this study. At the reference site, sumPFAS was four times lower than in the urban location, indicating a strong urban contribution to the PFAS exposure. In polar fox liver, PFOS concentrations ranging between 10 and 220 ng/g ww were found, up to 100 times higher caused by the partly marine diet of polar foxes (Aas et al., 2014).

In respect to the PCBs and PBDEs found in red fox, Voorspoels et al. (2007) reported means of sumPBDE 9.2 ng/g lw and sumPCBs of 300 ng/g lw in rodents from Belgium, which can be compared with 10 ng/g lw sumPBDE and 145 ng/g lw sumPCB in the red fox liver samples from our study. In a second study by Mateo et al., 2012, sumPCB concentrations of 1262 ng/g ww are reported in fox liver samples from a Natural reserve in south west Andalusia in Southern Spain, more than 250 times more than what we found in samples from the urban site in Oslo.

Earthworms

The average sumPFAS concentration in *Lumbricidae*/earthworm varied between the different sites, but were the dominating organic pollutant group in all cases when compared to PCBs and PBDEs. The lowest concentration was reported for Østmarkssetra, but all urban sites were higher than the reference sites (except one site in Gjerstad). The highest concentration of PFAS was found in Voksenkollen, which is a popular skiing area (potential impact of ski wax depositions). The majority of the samples had a PFAS profile dominated by PFOS followed by PFTrA. 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 earthworm's reproductive ability (SFT, 2006). High PFOS concentrations in soil can 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

within the range of reported toxic effect concentrations. However, this study shows that PFASs are ubiquitously present in the urban environment, reaching elevated concentrations in some locations. 151 ng/g ww was found in Voksenkollen, which is even more than what was observed in 2013, where the highest sumPFAS level found was about five times lower (31 ng/g ww in Grorud). However, metals were by far the dominating pollutant group investigated (average of 360 µg/g ww). Latif *et al.*, 2013 found Pb and Cd concentrations in three different earthworm species varying between 200 – 600 ng/g for lead and 200 and 350 ng/g Cd, which is much lower than found in the samples in Oslo with 143 µg/g and 4.1 µg/g for Pb and Cd respectively. Possible harmful effects caused by the 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 physiologically 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; Kennette et al. 2002).
When comparing the organic pollutants measured in the urban *vs.* remote locations, sumPCBs were 1.3 and 0.09 ng/g ww, sumPBDEs 0.58 and 0.48 while PFAS were 34.8 compared to 4.2 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 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 sparrowhawk) 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 from Oslo show the highest average values, ca. three times higher than the red fox, and almost double of the sparrowhawk.

Biomagnification
In summary, the terrestrial food chain is very short (consisting of 3 – 4 trophic levels: 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 (3rd trophic level) and predators that feed on secondary consumers (4th trophic level). In addition, many species fall into intermediate categories because they have mixed diets. The selected species in this study represent species from the 2nd trophic concentration (earthworms), 2nd to 3rd (fieldfare) and the 3rd and 4th trophic concentration (red fox and sparrowhawk). The sparrowhawk feeds on a variety of primary and secondary consumers, so some individuals may belong to the 3rd level, others to the 4th, and many in between. Different habitats, migration and feeding habits will have an impact on pollutants concentrations found in eggs too. The urban red fox is difficult to assign to a trophic level, since it feeds opportunistically, including human food waste. A linear relationship between d15N and concentrations of investigated pollutant could not be achieved at the rural location, and only slightly better in Oslo. The trophic magnification could be estimated for the rural location only, resulting in TMFs >1 for all organic compound groups investigated (SumPCBs: 10.2, SumPBDEs: 6.0, and for sumPFAS 1.4), indicating biomagnification of these compounds in the terrestrial foodchain.

6. Conclusions and Recommendations

Pesticides such as DDTs, HCH, HCB and chlordanes were not included in this study. They may however contribute substantially to the overall pollutant load and toxicological effect. DDE, a metabolite of the pesticide DDT, is the only environmental pollutant that has been proven to be firmly linked to eggshell thinning, but as DDE was not included in the analytical programme, we are unable to conclude of possible effects in our material. This should be included in future studies.

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

- Sparrowhawk: sumPCB > Mercury > sumPBDE > sumPFAS
- Fieldfare: Mercury ~ sumPCB > sumPFAS > sumPBDE
- Red fox: Mercury >> sumPCB > sumPFAS > sumPBDE
- Earthworms: Toxic metals>> sumPFAS > sumPCB > sumPBDE

Of all the organisms and tissues measured in the study, sparrowhawk eggs had the highest average concentration of the sum of all organic pollutants measured, followed by fieldfare, earthworm and red fox on a wet weight basis. For the average sum of the toxic the metals Hg, Cd and Pb, earthworm revealed the highest load followed by red fox, sparrowhawk and fieldfare.

Only an estimation of the trophic magnification was possible because no complete food chain was available but rather representatives of a food web. In order to assess the bioaccumulation potential, trophic magnification factors (TMF) were calculated from the consumer relationship earthworm, fieldfare and sparrowhawk at the reference location. The TMF calculations indicated trophic biomagnification for sumPCBs, sumPBDEs and sumPFAS, in decreasing order.

The combined risk of the measured pollutants was evaluated with a first tier conservative concentration addition (CA) approach using predicted no effect concentration for predators ($PNEC_{pred}$) as reference values. Only some metals, PBDEs, cyclic siloxanes and PFOS with available $PNEC_{pred}$ values were included in the combined risk assessment. The earthworm from the reference site and Oslo area showed a $Sum(MEC/PNEC_{pred}) > 1$ of 17 and 49 respectively, indicating a risk for predators with earthworm as an important food item. Cd contributed most to the estimated risk, followed by Pb and PFOS. Fieldfare eggs could only be assessed at the reference site, resulting in a very low $Sum(MEC/PNEC_{pred})$ of 0.3 for predators when using the 90 % percentile concentration.

A preliminary estimation of risk of effects from exposure in eggs of fieldfare and sparrowhawk was performed for some compound groups based using previous published effect data from exposure to contaminants in egg from non-raptor species. The sum values was higher than 1 for both areas for sparrowhawks and below 1 for fieldfare.

The earthworms feed on detritus, the fieldfare on insects and worms, the fox is an omnivore, while the sparrowhawk is mainly a predator on small and medium sized birds. 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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9. Appendix

Table A1: PBDE in sparrowhawk eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	3856	Sparrowhawk	2014	Harekjær	2.72	5.93	2.64	0.14	4.33	1.20	1.81	<LOD	0.78	<LOD	<LOD	<LOD	0.11
2	3857	Sparrowhawk	2014	Napane	3.36	5.72	2.44	0.06	3.79	1.07	0.64	<LOD	0.17	<LOD	<LOD	<LOD	0.23
3	3858	Sparrowhawk	2014	Katerås	3.72	6.78	2.87	0.06	3.51	1.09	1.04	<LOD	0.38	<LOD	<LOD	<LOD	0.14
4	3859	Sparrowhawk	2014	Årmot	4.48	9.82	5.16	0.36	6.84	2.19	1.57	<LOD	0.46	<LOD	<LOD	<LOD	<LOD
5	3860	Sparrowhawk	2014	Gviteflåg	3.15	7.33	2.57	0.06	6.34	1.75	1.16	<LOD	0.36	<LOD	<LOD	<LOD	0.19
6	3861	Sparrowhawk	2014	Hegna	6.72	9.93	4.54	0.20	4.34	1.69	1.23	<LOD	0.50	<LOD	<LOD	<LOD	0.12
7	3862	Sparrowhawk	2014	Deiltjørn	6.31	10.88	5.26	0.08	5.82	2.54	1.75	<LOD	0.62	<LOD	<LOD	<LOD	<LOD
8	3863	Sparrowhawk	2014	Kurdølsheia	4.27	7.01	3.35	0.48	3.80	1.23	1.21	<LOD	0.34	<LOD	<LOD	0.03	<LOD
9	3864	Sparrowhawk	2014	Værheim	20.90	55.21	26.51	0.59	26.01	6.94	2.75	<LOD	1.60	<LOD	<LOD	0.03	0.61
10	3865	Sparrowhawk	2014	Berli	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
11	3866	Sparrowhawk	2014	Oslo	4.24	14.12	4.79	0.18	12.12	1.66	7.36	<LOD	4.49	<LOD	<LOD	0.17	0.38
12	3867	Sparrowhawk	2014	Oslo	2.47	4.45	2.07	0.11	1.44	0.76	1.01	<LOD	0.45	<LOD	<LOD	<LOD	0.39
13	3868	Sparrowhawk	2014	Oslo	3.84	7.86	2.51	0.32	4.52	1.66	2.00	<LOD	1.27	<LOD	<LOD	0.13	0.86
14	3869	Sparrowhawk	2014	Oslo	5.36	8.20	2.96	0.01	5.74	1.77	1.25	<LOD	0.77	<LOD	<LOD	0.02	0.26
15	3870	Sparrowhawk	2014	Oslo	9.73	20.37	8.86	0.20	8.30	2.44	2.13	<LOD	0.91	<LOD	<LOD	0.02	0.39
16	3871	Sparrowhawk	2014	Oslo	5.95	13.90	6.61	0.13	8.10	2.60	3.25	<LOD	2.13	<LOD	<LOD	<LOD	<LOD
17	3872	Sparrowhawk	2014	Oslo	5.25	11.14	5.05	0.11	5.66	1.78	1.41	<LOD	0.63	<LOD	<LOD	<LOD	0.34
18	3873	Sparrowhawk	2014	Oslo	23.41	50.11	13.14	0.28	46.17	6.05	22.80	<LOD	9.10	<LOD	<LOD	0.09	0.43
19	3942	Sparrowhawk	2014	Oslo	23.03	38.04	13.00	0.49	20.48	5.87	4.71	<LOD	1.91	<LOD	<LOD	0.03	0.24
21	3944	Sparrowhawk	2014	Oslo	6.04	15.26	4.59	0.19	7.34	2.31	4.44	<LOD	1.97	<LOD	<LOD	0.07	0.29

Table A2: PCB and stable isotopes in sparrowhawk eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PCBs							Stabile isotoper	
					28	50	101	118	138	153	180	d13Cvpdb	d15Nair
1	3856	Sparrowhawk	2014	Harekjær	0.05	0.16	1.43	3.71	<LOD	45.13	30.99	-25.69	7.42
2	3857	Sparrowhawk	2014	Napane	0.06	0.16	1.51	3.83	72.64	116.78	58.68	-25.37	5.56
3	3858	Sparrowhawk	2014	Katerås	0.05	0.14	1.50	4.42	30.36	41.16	20.73	-26.35	4.66
4	3859	Sparrowhawk	2014	Årmot	0.05	0.20	2.82	8.71	65.12	104.04	56.52	-26.13	6.77
5	3860	Sparrowhawk	2014	Gviteflåg	0.05	0.06	1.03	4.27	26.90	47.57	36.78	-24.92	6.76
6	3861	Sparrowhawk	2014	Hegna	0.12	0.34	4.35	8.84	73.04	82.16	35.03	-25.88	6.59
7	3862	Sparrowhawk	2014	Deiltjørn	<LOD	<LOD	1.87	6.87	42.20	72.00	33.99	-26.55	6.39
8	3863	Sparrowhawk	2014	Kurdølsheia	0.12	0.24	1.44	5.04	29.13	42.08	26.47	-25.54	6.36
9	3864	Sparrowhawk	2014	Værheim	0.16	0.47	7.45	18.63	129.91	173.30	66.39	-24.41	6.46
10	3865	Sparrowhawk	2014	Berli	<LOD	<LOD	1.11	4.38	34.78	56.48	38.24	-26.32	4.73
11	3866	Sparrowhawk	2014	Oslo	0.16	0.31	2.77	7.69	51.37	63.26	35.69	-25.37	6.99
12	3867	Sparrowhawk	2014	Oslo	0.07	0.29	1.34	3.77	15.74	20.79	12.70	-25.55	6.95
13	3868	Sparrowhawk	2014	Oslo	5.16	4.83	59.32	67.97	825.69	<LOD	132.61	-25.54	8.27
14	3869	Sparrowhawk	2014	Oslo	0.13	0.43	4.01	9.62	64.67	82.74	48.75	-24.72	7.23
15	3870	Sparrowhawk	2014	Oslo	0.13	0.68	7.29	22.15	98.85	118.89	53.71	-24.60	7.73
16	3871	Sparrowhawk	2014	Oslo	0.11	0.34	2.78	8.57	48.79	71.72	44.51	-26.92	7.88
17	3872	Sparrowhawk	2014	Oslo	0.06	0.14	2.16	6.92	62.99	87.68	41.21	-25.52	7.25
18	3873	Sparrowhawk	2014	Oslo	0.25	2.86	8.52	19.14	110.53	119.78	59.21	-25.85	6.47
19	3942	Sparrowhawk	2014	Oslo	0.29	1.41	18.36	50.24	241.65	289.42	70.24	-24.74	7.93
21	3944	Sparrowhawk	2014	Oslo	7.39	6.09	79.35	99.10	1125.25	1576.16	58.73	-24.77	11.76

Table A3: P**FAS** in sparrowhawk eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHXS	PFHPS	PFOS	PFNS	PFDCS	PFHXA	PFHPA	PFOA	PFNA	PFDCA	PFUNA	PFDOA	PFTRIA	PFTEA
1	3856	Sparrowhawk	2014	Harekjær	0.01	<LOD	<LOD	0.06	0.11	10.45	<LOD	0.22	<LOD	<LOD	<LOD	0.19	0.29	0.57	0.91	1.02	1.10
2	3857	Sparrowhawk	2014	Napane	<LOD	<LOD	<LOD	0.04	0.02	2.09	0.02	1.82	<LOD	<LOD	<LOD	0.45	0.54	0.78	1.38	1.62	1.82
3	3858	Sparrowhawk	2014	Katerås	0.01	<LOD	<LOD	0.07	0.11	6.23	0.03	0.07	<LOD	<LOD	<LOD	0.39	0.44	0.67	1.03	1.37	1.33
4	3859	Sparrowhawk	2014	Årmot	0.01	<LOD	<LOD	0.04	0.05	3.85	0.01	0.09	<LOD	<LOD	<LOD	0.21	0.29	0.55	0.97	1.09	1.12
5	3860	Sparrowhawk	2014	Gviteflåg	0.01	<LOD	<LOD	0.05	0.04	4.05	<LOD	0.11	<LOD	<LOD	<LOD	0.29	0.44	0.71	1.29	1.39	1.80
6	3861	Sparrowhawk	2014	Hegna	0.06	<LOD	<LOD	0.17	0.17	9.36	<LOD	0.19	<LOD	<LOD	<LOD	0.68	0.76	1.48	2.10	2.39	2.34
7	3862	Sparrowhawk	2014	Deiltjørn	0.01	<LOD	<LOD	0.10	0.14	8.13	<LOD	<LOD	<LOD	<LOD	<LOD	0.28	0.23	0.61	0.65	1.09	0.82
8	3863	Sparrowhawk	2014	Kurdølsheia	0.02	<LOD	<LOD	0.08	0.08	6.48	<LOD	0.20	<LOD	<LOD	<LOD	0.64	1.05	1.99	3.11	2.72	2.97
9	3864	Sparrowhawk	2014	Værheim	0.03	<LOD	<LOD	0.16	0.45	13.56	<LOD	0.36	<LOD	<LOD	<LOD	1.32	1.57	2.99	4.51	3.86	5.22
10	3865	Sparrowhawk	2014	Berli	0.01	<LOD	<LOD	0.02	0.03	2.33	<LOD	0.86	<LOD	<LOD	<LOD	0.86	1.19	2.07	3.20	1.89	2.78
11	3866	Sparrowhawk	2014	Oslo	0.02	<LOD	<LOD	0.04	0.07	8.24	0.01	0.03	<LOD	<LOD	<LOD	0.61	0.61	2.19	2.08	2.47	2.10
12	3867	Sparrowhawk	2014	Oslo	0.03	<LOD	<LOD	0.08	0.28	31.20	<LOD	<LOD	<LOD	<LOD	<LOD	0.26	0.18	0.73	0.60	1.01	0.82
13	3868	Sparrowhawk	2014	Oslo	<LOD	<LOD	<LOD	0.04	0.03	3.78	<LOD	0.01	<LOD	<LOD	<LOD	0.29	0.31	1.02	1.00	1.37	1.28
14	3869	Sparrowhawk	2014	Oslo	0.02	<LOD	<LOD	0.02	0.03	4.44	0.01	0.01	<LOD	<LOD	<LOD	0.51	0.35	1.12	1.15	2.19	1.44
15	3870	Sparrowhawk	2014	Oslo	0.02	<LOD	<LOD	0.06	0.10	7.21	0.02	0.04	<LOD	<LOD	<LOD	0.42	0.34	0.93	0.84	1.59	1.05
16	3871	Sparrowhawk	2014	Oslo	0.04	<LOD	<LOD	0.09	0.21	16.59	0.02	0.02	<LOD	<LOD	<LOD	0.47	0.45	1.29	1.66	3.17	2.65
17	3872	Sparrowhawk	2014	Oslo	<LOD	<LOD	<LOD	0.03	0.04	4.73	0.02	0.06	<LOD	<LOD	<LOD	0.71	0.55	1.48	1.49	3.31	1.94
18	3873	Sparrowhawk	2014	Oslo	0.09	<LOD	<LOD	0.06	0.10	24.38	<LOD	0.01	<LOD	<LOD	<LOD	0.51	0.45	1.38	1.42	3.19	2.19
19	3942	Sparrowhawk	2014	Oslo	0.06	<LOD	<LOD	0.15	0.26	13.88	<LOD	<LOD	<LOD	<LOD	<LOD	0.55	0.44	1.26	2.13	3.73	5.46
21	3944	Sparrowhawk	2014	Oslo	<LOD	<LOD	<LOD	0.04	0.04	3.93	<LOD	<LOD	<LOD	<LOD	<LOD	0.16	0.12	0.40	0.32	0.61	0.42

Table A 4: Metals in sparrowhawk eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	Compound name:									
					Mercury	Methyl-mercury	Silver	Cadmium	Lead	Cupper	Zink	Chrome	Nickel	Arsenic
					HG	ME_HG	AG	CD	PB	CU	ZN	CR	NI	AS
1	3856	Sparrowhawk	2014	Harekjær	189.31	160.44	<LOD	<LOD	<LOD	302.80	3681.70	3.01	1.47	<LOD
2	3857	Sparrowhawk	2014	Napane	149.86	131.14	<LOD	<LOD	8.50	585.10	9943.00	5.62	2.27	<LOD
3	3858	Sparrowhawk	2014	Katerås	127.02	108.21	<LOD	<LOD	<LOD	290.30	4524.50	3.06	1.84	<LOD
4	3859	Sparrowhawk	2014	Årmot	236.22	215.93	<LOD	<LOD	<LOD	498.40	7779.10	5.08	1.97	<LOD
5	3860	Sparrowhawk	2014	Gviteflåg	115.03	96.40	<LOD	<LOD	<LOD	574.10	8911.30	9.62	3.12	<LOD
6	3861	Sparrowhawk	2014	Hegna	252.02	240.78	<LOD	<LOD	<LOD	356.10	6236.40	4.30	1.43	<LOD
7	3862	Sparrowhawk	2014	Deiltjørn	189.07	160.57	<LOD	<LOD	<LOD	427.60	7903.50	2.66	1.49	<LOD
8	3863	Sparrowhawk	2014	Kurdølsheia	<LOD	182.24	<LOD	<LOD	<LOD	688.50	11474.40	7.05	4.86	<LOD
9	3864	Sparrowhawk	2014	Værheim	119.28	97.33	<LOD	0.54	<LOD	503.70	7373.70	9.59	6.38	4.18
10	3865	Sparrowhawk	2014	Berli	301.00	247.95	<LOD	<LOD	<LOD	371.40	5194.50	3.36	<LOD	<LOD
11	3866	Sparrowhawk	2014	Oslo	62.92	55.89	<LOD	1.22	36.90	315.90	3258.60	2.79	2.83	<LOD
12	3867	Sparrowhawk	2014	Oslo	152.53	133.34	<LOD	0.93	26.60	409.80	2695.30	3.03	14.13	<LOD
13	3868	Sparrowhawk	2014	Oslo	109.99	96.67	<LOD	0.58	15.10	489.40	3973.40	4.58	2.05	<LOD
14	3869	Sparrowhawk	2014	Oslo	92.05	104.11	<LOD	0.81	10.80	297.30	1941.50	3.47	4.22	<LOD
15	3870	Sparrowhawk	2014	Oslo	149.79	136.62	<LOD	<LOD	7.10	319.00	2623.30	3.09	5.97	<LOD
16	3871	Sparrowhawk	2014	Oslo	163.32	133.33	<LOD	<LOD	6.70	299.10	3832.90	3.15	1.05	<LOD
17	3872	Sparrowhawk	2014	Oslo	148.20	130.51	<LOD	<LOD	<LOD	289.10	2433.60	3.39	1.67	<LOD
18	3873	Sparrowhawk	2014	Oslo	100.16	95.52	<LOD	0.29	11.30	390.10	6218.60	2.82	1.18	<LOD
19	3942	Sparrowhawk	2014	Oslo	161.01	111.34	<LOD	0.37	35.90	668.00	9394.80	9.88	2.24	<LOD
21	3944	Sparrowhawk	2014	Oslo	80.40	54.88	<LOD	0.27	8.70	546.60	11612.40	6.18	2.99	<LOD

Table A5: **PBDE** in fieldfare eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
2	3961	Fieldfare	2014	Åmotsdalen	0.70	0.97	0.40	0.15	1.08	0.22	1.19	<LOD	0.26	<LOD	<LOD	<LOD	0.22
3	3963	Fieldfare	2014	Åmotsdalen	0.45	1.63	0.63	0.03	0.56	0.23	0.10	<LOD	0.04	<LOD	<LOD	<LOD	0.15
4	3960	Fieldfare	2014	Åmotsdalen	0.22	0.41	0.21	0.05	<LOD	<LOD	0.13	<LOD	0.08	<LOD	<LOD	<LOD	0.05
5	3959	Fieldfare	2014	Åmotsdalen	2.71	5.47	2.46	0.12	0.99	0.15	0.41	<LOD	0.76	<LOD	<LOD	<LOD	0.17
6	3958	Fieldfare	2014	Åmotsdalen	0.66	0.79	0.20	0.06	<LOD	<LOD	0.03	<LOD	0.38	<LOD	<LOD	<LOD	<LOD
7	3957	Fieldfare	2014	Åmotsdalen	0.23	0.29	0.02	0.08	<LOD	<LOD	0.02	<LOD	0.59	<LOD	<LOD	<LOD	0.48
8	3956	Fieldfare	2014	Åmotsdalen	0.18	0.22	0.05	0.10	<LOD	<LOD	0.08	<LOD	0.51	<LOD	<LOD	<LOD	0.49
9	3955	Fieldfare	2014	Åmotsdalen	0.74	1.14	0.44	0.19	<LOD	<LOD	0.16	<LOD	1.01	<LOD	<LOD	<LOD	<LOD
10	3962	Fieldfare	2014	Åmotsdalen	0.17	0.19	<LOD	0.10	0.11	0.08	0.13	<LOD	0.05	<LOD	<LOD	<LOD	<LOD

Table A6: **PCB** and stable isotopes in fieldfare eggs in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PCBs							Stabile isotoper	
					28	50	101	118	138	153	180	d13Cvpdb	d15Nair
2	3961	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.08	0.09	1.23	1.11	0.46	-26.57	9.93
3	3963	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.12	0.16	0.74	0.70	0.28	-27.19	8.17
4	3960	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.50	0.34	13.24	11.23	5.22	-27.43	8.70
5	3959	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.68	0.43	9.53	7.20	4.51	-27.28	8.61
6	3958	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.42	0.26	3.23	2.67	1.06	-26.76	7.22
7	3957	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.41	0.29	4.13	2.61	3.64	-27.20	9.36
8	3956	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.07	<LOD	0.92	0.95	0.32	-27.39	6.44
9	3955	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.31	<LOD	4.51	3.40	1.58	-27.04	5.44
10	3962	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.31	0.16	4.86	4.41	1.55	-26.98	10.27

Table A7: **PFAS and metals** in fieldfare eggs in ng/g www

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHXS	PFHPS	PFOS	PFNS	PFDCS	PFHXA	PFHPA	PFOA	PFNA	PFDCA	PFUNA	PFDOA	PFTRIA	PFTEA
1	3964	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	0.97	<LOD	<LOD	<LOD	<LOD	0.16	0.30	0.22	1.07	0.80	1.52	0.41
2	3961	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	0.05	<LOD	<LOD	1.21	<LOD	<LOD	<LOD	<LOD	0.42	0.73	0.48	2.92	2.42	5.05	1.37
3	3963	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	0.83	<LOD	<LOD	<LOD	<LOD	0.18	0.32	0.30	1.12	0.98	1.53	0.53
4	3960	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	1.45	<LOD	<LOD	<LOD	<LOD	0.11	0.36	0.38	1.55	1.05	2.55	0.71
5	3959	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	2.25	<LOD	<LOD	<LOD	<LOD	0.25	0.81	0.21	1.33	1.34	3.15	1.00
6	3958	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	2.82	<LOD	<LOD	<LOD	<LOD	0.26	0.60	0.96	3.34	3.25	4.60	1.42
7	3957	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	0.72	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	0.10	0.63	0.73	1.68	0.79
8	3956	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	1.68	<LOD	<LOD	<LOD	<LOD	0.07	0.24	0.20	1.07	0.78	0.98	1.43
9	3955	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	1.05	<LOD	<LOD	<LOD	<LOD	0.14	0.16	0.10	<LOD	0.76	1.89	0.31
10	3962	Fieldfare	2014	Åmotsdalen	<LOD	<LOD	<LOD	<LOD	<LOD	5.67	<LOD	<LOD	<LOD	<LOD	0.28	0.28	0.43	1.25	1.46	2.13	1.02

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	Compound name:									
					Mercury	Methyl-mercury	Silver	Cadmium	Lead	Cupper	Zink	Chrome	Nickel	Arsenic
					HG	ME_HG	AG	CD	PB	CU	ZN	CR	NI	AS
1	3964	Fieldfare	2014	Åmotsdalen	7.12	4.47	1.53	<LOD	<LOD	419.20	7163.90	5.04	3.07	3.54
2	3961	Fieldfare	2014	Åmotsdalen	na	na	na	na	na	na	na	na	na	na
3	3963	Fieldfare	2014	Åmotsdalen	na	na	na	na	na	na	na	na	na	na
4	3960	Fieldfare	2014	Åmotsdalen	na	na	na	na	na	na	na	na	na	na
5	3959	Fieldfare	2014	Åmotsdalen	na	na	na	na	na	na	na	na	na	na
6	3958	Fieldfare	2014	Åmotsdalen	na	na	na	na	na	na	na	na	na	na
7	3957	Fieldfare	2014	Åmotsdalen	15.79	13.80	2.24	<LOD	<LOD	553.50	5712.60	3.79	6.28	2.27
8	3956	Fieldfare	2014	Åmotsdalen	11.17	8.60	0.40	<LOD	<LOD	399.70	5867.90	7.13	6.98	2.99
9	3955	Fieldfare	2014	Åmotsdalen	12.31	9.50	0.44	<LOD	7.30	474.90	7649.90	12.27	10.58	6.57
10	3962	Fieldfare	2014	Åmotsdalen	9.48	6.10	1.43	<LOD	<LOD	434.60	6996.30	13.53	4.61	7.19

Table A8: **PBDE** in red fox liver in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	20049	Fox	2014	Oslo	0.03	<LOD	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	<LOD	<LOD	0.21
2	20056	Fox	2014	Oslo	0.03	<LOD	0.09	<LOD	0.53	<LOD	<LOD	<LOD	0.10	<LOD	<LOD	<LOD	0.29
3	20058	Fox	2014	Oslo	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.13	<LOD	<LOD	<LOD	0.18
4	20183	Fox	2014	Oslo	0.05	<LOD	0.09	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
5	20187	Fox	2014	Oslo	0.02	<LOD	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.26
6	20197	Fox	2014	Oslo	0.02	<LOD	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	0.12	<LOD	<LOD	<LOD	<LOD
7	20938	Fox	2014	Oslo	0.03	0.03	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.78
8	20933	Fox	2014	Reference	0.02	<LOD	0.07	<LOD	<LOD	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
9	20934	Fox	2014	Reference	0.04	<LOD	0.05	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.37
10	20935	Fox	2014	Reference	0.02	<LOD	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	<LOD	<LOD	0.40
11	20936	Fox	2014	Reference	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.00
12	20937	Fox	2014	Reference	0.02	<LOD	0.11	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
13	21083	Fox	2014	Reference	0.14	<LOD	0.10	<LOD	<LOD	<LOD	<LOD	<LOD	0.28	<LOD	<LOD	<LOD	<LOD
14	21084	Fox	2014	Reference	0.02	<LOD	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	<LOD	<LOD	0.24
15	21091	Fox	2014	Reference	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.13	<LOD	<LOD	<LOD	<LOD
16	21092	Fox	2014	Reference	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.38
17	21093	Fox	2014	Reference	<LOD	<LOD	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
18	21107	Fox	2014	Reference	0.02	<LOD	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	0.06	<LOD	<LOD	<LOD	0.25
19	21110	Fox	2014	Reference	0.02	<LOD	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.22
20	21111	Fox	2014	Reference	0.01	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.49
21	21112	Fox	2014	Reference	0.04	<LOD	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.13
22	21118	Fox	2014	Reference	0.03	<LOD	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

Table A9: **PCB** and stable isotopes in red fox liver in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PCBs							Stabile isotoper	
					28	50	101	118	138	153	180	d13Cvpdb	d15Nair
1	20049	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	0.68	1.96	5.69	-27.28	6.18
2	20056	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	2.44	4.93	10.62	-26.22	8.34
3	20058	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	0.21	0.38	1.43	-25.57	7.98
4	20183	Fox	2014	Oslo	<LOD	<LOD	<LOD	0.12	1.52	2.82	4.84	-27.37	8.18
5	20187	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	0.19	0.48	1.91	-27.11	6.85
6	20197	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	0.26	0.46	2.30	-26.24	7.33
7	20938	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	0.36	0.59	1.45	-27.01	8.04
8	20933	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.50	0.80	2.70	-25.92	9.90
9	20934	Fox	2014	Reference	<LOD	<LOD	<LOD	0.15	0.84	1.91	2.48	-27.72	9.62
10	20935	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.23	0.24	0.71	-27.37	10.10
11	20936	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.28	0.42	4.62	-27.41	11.03
12	20937	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.30	0.48	1.00	-27.38	10.05
13	21083	Fox	2014	Reference	<LOD	<LOD	<LOD	0.11	1.35	0.94	1.16	-26.56	10.12
14	21084	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	1.93	5.19	17.17	-27.47	11.07
15	21091	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.14	0.21	0.52	-27.21	9.96
16	21092	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.33	0.76	1.59	-27.30	11.12
17	21093	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.24	0.67	1.88	-26.88	8.66
18	21107	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.71	1.03	1.74	-26.84	10.19
19	21110	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.93	0.81	1.32	-27.21	7.44
20	21111	Fox	2014	Reference	<LOD	<LOD	<LOD	0.21	0.44	1.00	3.11	-26.20	11.69
21	21112	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	1.97	4.75	8.33	-25.11	10.37
22	21118	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	0.40	0.36	0.41	-25.49	9.81

Table A10: **PFAS** in red fox liver in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHXS	PFHPS	PFOS	PFNS	PFDCS	PFHXA	PFHPA	PFOA	PFNA	PFDCA	PFUNA	PFDOA	PFTRIA	PFTEA
1	20049	Fox	2014	Oslo	<LOD	<LOD	<LOD	0.04	<LOD	1.36	<LOD	<LOD	<LOD	<LOD	<LOD	0.35	0.27	0.22	0.07	0.09	0.03
2	20056	Fox	2014	Oslo	<LOD	<LOD	<LOD	<LOD	<LOD	1.46	<LOD	<LOD	<LOD	<LOD	<LOD	0.30	0.43	0.31	0.11	0.09	0.05
3	20058	Fox	2014	Oslo	0.04	<LOD	<LOD	0.06	0.01	2.00	<LOD	0.01	<LOD	<LOD	<LOD	0.29	0.23	0.15	0.11	0.13	0.11
4	20183	Fox	2014	Oslo	0.14	<LOD	<LOD	0.05	<LOD	2.99	<LOD	<LOD	<LOD	<LOD	<LOD	0.40	0.63	0.75	0.24	0.37	0.15
5	20187	Fox	2014	Oslo	0.01	<LOD	<LOD	0.04	0.01	3.49	<LOD	<LOD	<LOD	<LOD	<LOD	1.08	0.64	0.49	0.08	0.08	0.04
6	20197	Fox	2014	Oslo	<LOD	<LOD	<LOD	0.05	0.01	1.68	<LOD	<LOD	<LOD	<LOD	<LOD	0.58	0.47	0.33	0.07	0.08	0.05
7	20938	Fox	2014	Oslo	0.03	<LOD	<LOD	0.03	<LOD	1.77	<LOD	<LOD	<LOD	<LOD	<LOD	0.44	0.20	0.27	0.09	0.13	0.06
8	20933	Fox	2014	Reference	0.01	<LOD	<LOD	0.03	0.01	2.19	<LOD	<LOD	<LOD	<LOD	<LOD	0.42	0.19	0.22	0.03	0.07	0.02
9	20934	Fox	2014	Reference	<LOD	<LOD	<LOD	0.01	<LOD	0.23	<LOD	<LOD	<LOD	<LOD	<LOD	0.12	0.04	0.06	0.01	0.02	<LOD
10	20935	Fox	2014	Reference	0.05	<LOD	<LOD	0.01	<LOD	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	0.22	0.12	0.14	0.03	0.04	0.01
11	20936	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	0.05	0.07	0.02	0.02	<LOD
12	20937	Fox	2014	Reference	<LOD	<LOD	<LOD	0.02	<LOD	0.17	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	0.04	0.05	0.02	0.04	0.02
13	21083	Fox	2014	Reference	0.01	<LOD	<LOD	<LOD	<LOD	0.30	<LOD	<LOD	<LOD	<LOD	<LOD	0.27	0.16	0.25	0.05	0.07	0.01
14	21084	Fox	2014	Reference	<LOD	<LOD	<LOD	<LOD	<LOD	0.24	<LOD	<LOD	<LOD	<LOD	<LOD	0.13	0.09	0.06	0.01	0.01	0.01
15	21091	Fox	2014	Reference	<LOD	<LOD	<LOD	0.01	<LOD	0.44	<LOD	<LOD	<LOD	<LOD	<LOD	0.23	0.13	0.13	0.02	0.05	0.01
16	21092	Fox	2014	Reference	<LOD	<LOD	<LOD	0.01	<LOD	0.35	<LOD	<LOD	<LOD	<LOD	<LOD	0.12	0.11	0.10	0.03	0.03	0.01
17	21093	Fox	2014	Reference	<LOD	<LOD	<LOD	0.02	<LOD	0.08	<LOD	<LOD	<LOD	<LOD	<LOD	0.07	0.03	0.06	0.02	0.02	0.01
18	21107	Fox	2014	Reference	<LOD	<LOD	<LOD	0.02	<LOD	0.51	<LOD	<LOD	<LOD	<LOD	<LOD	0.44	0.23	0.27	0.06	0.11	0.02
19	21110	Fox	2014	Reference	<LOD	<LOD	<LOD	0.01	<LOD	0.56	<LOD	<LOD	<LOD	<LOD	<LOD	0.19	0.10	0.18	0.05	0.08	0.01
20	21111	Fox	2014	Reference	<LOD	<LOD	<LOD	0.01	<LOD	0.62	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	0.03	0.05	0.01	0.02	0.01
21	21112	Fox	2014	Reference	0.07	<LOD	<LOD	0.04	<LOD	1.33	<LOD	<LOD	<LOD	<LOD	<LOD	0.23	0.14	0.37	0.06	0.13	0.01
22	21118	Fox	2014	Reference	0.01	<LOD	<LOD	<LOD	<LOD	0.40	<LOD	<LOD	<LOD	<LOD	<LOD	0.19	0.13	0.10	0.01	0.02	0.01

Table A 11: Metals in red fox liver in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	Compound name:									
					Mercury	Methyl-mercury	Silver	Cadmium	Lead	Cupper	Zink	Chrome	Nickel	Arsenic
					HG	ME_HG	AG	CD	PB	CU	ZN	CR	NI	AS
1	20049	Fox	2014	Oslo	27.94	6.69	4.99	255.59	229.40	15815.80	40372.80	6.82	12.53	5.14
2	20056	Fox	2014	Oslo	37.99	9.78	3.68	217.95	65.40	9173.60	47506.70	4.75	10.14	7.17
3	20058	Fox	2014	Oslo	34.25	13.81	6.96	152.32	727.40	27759.70	32196.70	103.31	18.98	12.91
4	20183	Fox	2014	Oslo	87.69	36.31	5.35	775.12	62.20	17592.90	46397.60	5.62	5.28	28.32
5	20187	Fox	2014	Oslo	25.34	6.20	2.03	424.46	51.10	22394.60	54985.30	13.10	4.37	5.64
6	20197	Fox	2014	Oslo	68.05	10.59	4.76	544.94	92.10	16649.20	41651.80	106.46	6.13	8.18
7	20938	Fox	2014	Oslo	35.57	11.85	4.76	81.50	186.60	21888.10	38966.70	7.76	6.60	7.11
8	20933	Fox	2014	Reference	80.14	47.11	<LOD	57.51	<LOD	6210.20	29237.40	2.38	<LOD	<LOD
9	20934	Fox	2014	Reference	32.18	13.86	2.19	85.90	21.00	21059.80	35127.60	7.23	5.23	8.88
10	20935	Fox	2014	Reference	7.77	3.72	0.80	26.30	9.70	11953.90	24184.50	7.97	6.36	<LOD
11	20936	Fox	2014	Reference	12.56	2.42	1.06	54.40	9.60	12044.00	34651.70	4.47	2.03	6.94
12	20937	Fox	2014	Reference	14.31	6.50	2.49	11.09	16.60	13600.50	36023.30	7.92	6.42	7.52
13	21083	Fox	2014	Reference	22.01	9.81	3.41	12.87	108.10	15613.60	46898.40	5.68	17.98	2.89
14	21084	Fox	2014	Reference	15.32	4.91	1.40	27.10	76.70	14945.70	41343.50	14.69	8.34	<LOD
15	21091	Fox	2014	Reference	8.64	4.16	0.72	21.45	361.90	11666.70	42694.10	10.38	7.78	21.25
16	21092	Fox	2014	Reference	21.87	3.75	0.85	109.71	36.00	13689.80	42317.10	6.32	13.03	6.99
17	21093	Fox	2014	Reference	15.66	3.82	0.33	75.55	61.40	7214.10	30684.80	8.89	8.31	3.43
18	21107	Fox	2014	Reference	34.95	15.74	1.73	50.64	21.40	18513.10	39434.00	6.07	9.47	<LOD
19	21110	Fox	2014	Reference	51.38	30.91	2.16	145.59	<LOD	13688.10	45580.30	7.98	12.37	<LOD
20	21111	Fox	2014	Reference	32.77	7.89	3.39	44.62	10724.10	28982.10	163145.10	24.23	21.44	8.16
21	21112	Fox	2014	Reference	120.73	41.52	4.77	12.68	842.00	28376.60	43634.00	4.93	11.75	14.14
22	21118	Fox	2014	Reference	15.34	5.82	1.53	8.18	45.20	12381.70	40117.50	3.36	3.65	6.54

Table A12: **PBDE** in earthworm in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PBDEs												
					47	99	100	126	153	154	175_183	190	196	202	206	207	209
1	22284	Earthworms	2014	Voksenkollen	0.07	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	<LOD	<LOD	<LOD	<LOD
3	22287	Earthworms	2014	Brekke	0.04	<LOD	0.64	<LOD	<LOD	<LOD	<LOD	<LOD	0.26	<LOD	<LOD	<LOD	<LOD
4	22288	Earthworms	2014	Brekke	0.04	0.06	0.06	<LOD	<LOD	<LOD	<LOD	<LOD	0.19	<LOD	<LOD	<LOD	<LOD
5	22290	Earthworms	2014	Østmarksetra	0.05	0.04	0.09	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	<LOD	<LOD	<LOD	<LOD
6	22291	Earthworms	2014	Østmarksetra	0.03	<LOD	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	0.06	<LOD	<LOD	<LOD	0.62
7	22292	Earthworms	2014	Østmarksetra	0.06	0.12	0.13	<LOD	<LOD	0.02	<LOD	<LOD	0.64	<LOD	<LOD	<LOD	<LOD
8	22296	Earthworms	2014	Hegna	0.02	0.04	0.03	<LOD	<LOD	<LOD	<LOD	<LOD	0.34	<LOD	<LOD	<LOD	0.26
9	22297	Earthworms	2014	Hegna	0.02	<LOD	0.04	<LOD	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	<LOD	<LOD	<LOD
10	22298	Earthworms	2014	Hegna	0.03	<LOD	0.04	<LOD	<LOD	0.01	<LOD	<LOD	0.41	<LOD	<LOD	<LOD	<LOD
11	22299	Earthworms	2014	Kåsmyra	0.03	<LOD	0.07	<LOD	<LOD	0.01	<LOD	<LOD	0.34	<LOD	<LOD	<LOD	0.23
12	22300	Earthworms	2014	Kåsmyra	0.08	<LOD	0.15	<LOD	<LOD	<LOD	<LOD	<LOD	0.56	<LOD	<LOD	<LOD	<LOD
13	22301	Earthworms	2014	Kåsmyra	0.04	<LOD	0.09	<LOD	<LOD	<LOD	<LOD	<LOD	0.32	<LOD	<LOD	<LOD	<LOD
14	22293	Earthworms	2014	Gjerstad	0.02	<LOD	0.10	<LOD	<LOD	0.01	<LOD	<LOD	0.22	<LOD	<LOD	<LOD	<LOD
15	22294	Earthworms	2014	Gjerstad	0.04	0.10	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	0.09	<LOD	<LOD	<LOD	<LOD
16	22295	Earthworms	2014	Gjerstad	0.03	0.05	0.07	<LOD	<LOD	<LOD	<LOD	<LOD	0.17	<LOD	<LOD	<LOD	0.15

Table A13: **PCB** and stable isotopes in earthworm in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PCBs							Stabile isotoper	
					28	50	101	118	138	153	180	d13Cvpdb	d15Nair
1	22284	Earthworms	2014	Voksenkollen	<LOD	<LOD	0.08	0.06	0.36	0.34	0.13	-26.95	5.27
3	22287	Earthworms	2014	Brekke	<LOD	<LOD	0.06	0.06	0.38	0.29	<LOD	-26.91	5.53
4	22288	Earthworms	2014	Brekke	0.02	<LOD	0.09	0.09	0.37	0.29	0.15	-25.31	4.62
5	22290	Earthworms	2014	Østmarksetra	<LOD	<LOD	0.43	0.11	1.50	1.32	0.47	-25.66	3.97
6	22291	Earthworms	2014	Østmarksetra	0.01	<LOD	0.05	<LOD	0.13	0.14	<LOD	-25.08	4.29
7	22292	Earthworms	2014	Østmarksetra	0.02	<LOD	0.08	0.09	0.31	0.28	<LOD	-24.59	5.25
8	22296	Earthworms	2014	Hegna	0.02	<LOD	<LOD	<LOD	<LOD	0.05	<LOD	-26.37	5.23
9	22297	Earthworms	2014	Hegna	0.02	<LOD	<LOD	<LOD	<LOD	0.04	<LOD	-26.12	4.91
10	22298	Earthworms	2014	Hegna	0.03	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	-28.06	3.29
11	22299	Earthworms	2014	Kåsmyra	0.02	<LOD	<LOD	<LOD	<LOD	0.05	<LOD	-26.09	5.20
12	22300	Earthworms	2014	Kåsmyra	0.02	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	-28.23	2.93
13	22301	Earthworms	2014	Kåsmyra	0.02	<LOD	<LOD	<LOD	<LOD	0.08	<LOD	-28.02	3.65
14	22293	Earthworms	2014	Gjerstad	0.01	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	-26.70	2.44
15	22294	Earthworms	2014	Gjerstad	0.03	<LOD	<LOD	<LOD	<LOD	0.10	<LOD	-26.30	3.05
16	22295	Earthworms	2014	Gjerstad	0.03	<LOD	<LOD	<LOD	0.10	0.08	<LOD	-26.64	2.24

Table A14: **PFAS** in earthworm in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	PFOSA	PFBS	PFPS	PFHXS	PFHPS	PFOS	PFNS	PFDCS	PFHXA	PFHPA	PFOA	PFNA	PFDCA	PFUNA	PFDOA	PFTRIA	PFTEA
1	22284	Earthworms	2014	Voksenkollen	<LOD	<LOD	<LOD	2.94	<LOD	17.38	<LOD	<LOD	<LOD	<LOD	2.24	0.36	2.86	1.11	6.75	2.75	2.87
2	22285	Earthworms	2014	Voksenkollen	<LOD	<LOD	<LOD	<LOD	<LOD	39.63	<LOD	<LOD	<LOD	<LOD	1.23	0.84	6.86	6.10	63.51	8.66	24.47
3	22287	Earthworms	2014	Brekke	<LOD	<LOD	<LOD	<LOD	<LOD	3.24	<LOD	<LOD	<LOD	<LOD	0.80	0.48	0.12	<LOD	0.77	1.74	1.28
4	22288	Earthworms	2014	Brekke	<LOD	<LOD	<LOD	0.91	<LOD	3.53	<LOD	<LOD	<LOD	<LOD	0.57	0.20	0.17	0.39	0.83	1.90	1.96
5	22290	Earthworms	2014	Østmarksetra	<LOD	<LOD	<LOD	0.98	<LOD	13.21	<LOD	<LOD	<LOD	<LOD	0.87	<LOD	0.21	0.35	0.66	0.67	0.70
6	22291	Earthworms	2014	Østmarksetra	<LOD	<LOD	<LOD	0.45	<LOD	4.10	<LOD	<LOD	<LOD	<LOD	0.37	0.19	0.06	0.18	0.33	0.66	0.56
7	22292	Earthworms	2014	Østmarksetra	<LOD	<LOD	<LOD	1.05	<LOD	5.41	<LOD	<LOD	<LOD	<LOD	0.69	0.11	<LOD	0.24	0.49	0.92	1.06
8	22296	Earthworms	2014	Hegna	0.37	<LOD	<LOD	<LOD	<LOD	0.56	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.17	0.60	1.52	0.51
9	22297	Earthworms	2014	Hegna	<LOD	<LOD	<LOD	<LOD	<LOD	0.76	<LOD	<LOD	<LOD	<LOD	0.27	<LOD	<LOD	0.35	0.54	1.59	0.44
10	22298	Earthworms	2014	Hegna	0.68	<LOD	<LOD	<LOD	<LOD	0.38	<LOD	<LOD	<LOD	<LOD	0.18	<LOD	<LOD	0.21	0.55	1.50	0.22
11	22299	Earthworms	2014	Kåsmyra	<LOD	<LOD	<LOD	<LOD	<LOD	0.14	<LOD	<LOD	<LOD	<LOD	0.13	<LOD	<LOD	0.12	0.16	0.61	0.20
12	22300	Earthworms	2014	Kåsmyra	<LOD	<LOD	<LOD	<LOD	<LOD	0.10	<LOD	<LOD	<LOD	<LOD	0.07	<LOD	<LOD	0.17	0.21	0.97	0.26
13	22301	Earthworms	2014	Kåsmyra	<LOD	<LOD	<LOD	<LOD	<LOD	0.21	<LOD	<LOD	<LOD	<LOD	0.02	<LOD	<LOD	0.16	0.17	0.98	0.19
14	22293	Earthworms	2014	Gjerstad	<LOD	<LOD	<LOD	<LOD	<LOD	3.31	<LOD	<LOD	<LOD	<LOD	0.18	0.11	<LOD	0.75	1.39	3.21	1.08
15	22294	Earthworms	2014	Gjerstad	0.56	<LOD	<LOD	<LOD	<LOD	2.06	<LOD	<LOD	<LOD	<LOD	0.14	<LOD	0.07	0.47	0.67	1.58	0.78
16	22295	Earthworms	2014	Gjerstad	0.65	<LOD	<LOD	<LOD	<LOD	1.64	<LOD	<LOD	<LOD	<LOD	0.23	0.16	0.08	0.57	0.90	2.51	0.61

Table A15: Metals in earthworm in ng/g ww

Nr. of samples	Customers samples ID:	Individual:	Sampling year	Location	Compound name:									
					Mercury	Methyl-mercury	Silver	Cadmium	Lead	Cupper	Zink	Chrome	Nickel	Arsenic
					HG	ME_HG	AG	CD	PB	CU	ZN	CR	NI	AS
1	22284	Earthworms	2014	Voksenkollen	101.50	0.93	21.47	5807.50	21368.50	2745.70	180344.50	442.77	283.44	619.27
2	22285	Earthworms	2014	Voksenkollen	359.42	<LOD	32.22	4937.77	454535.00	1781.30	291537.10	368.57	300.62	669.07
3	22287	Earthworms	2014	Brekke	338.17	0.73	28.50	5171.08	224132.00	1866.30	281781.00	200.05	250.88	682.59
4	22288	Earthworms	2014	Brekke	284.20	<LOD	19.97	4991.54	204623.00	1939.50	223538.90	258.27	237.25	655.66
5	22290	Earthworms	2014	Østmarksetra	201.42	<LOD	14.40	2678.24	64218.50	2207.10	189737.10	89.29	163.74	441.20
6	22291	Earthworms	2014	Østmarksetra	174.51	0.57	11.10	2419.92	13625.10	2018.40	167816.50	69.52	138.34	355.30
7	22292	Earthworms	2014	Østmarksetra	161.36	2.75	11.36	2456.03	21564.00	1947.40	159285.60	100.89	143.96	417.61
8	22296	Earthworms	2014	Hegna	144.83	<LOD	27.30	2255.72	20688.20	1869.90	66481.40	619.45	427.58	586.63
9	22297	Earthworms	2014	Hegna	126.13	3.23	26.31	2092.86	14579.20	1743.40	52658.20	791.15	467.55	532.39
10	22298	Earthworms	2014	Hegna	144.91	<LOD	50.28	2265.17	14224.00	1859.00	57515.30	790.23	477.22	575.09
11	22299	Earthworms	2014	Kåsmyra	48.01	<LOD	33.42	895.06	1870.90	1975.00	148678.80	835.54	529.21	173.77
12	22300	Earthworms	2014	Kåsmyra	34.12	<LOD	23.75	743.69	2430.90	1483.80	105715.80	300.46	225.57	131.80
13	22301	Earthworms	2014	Kåsmyra	23.39	0.71	24.09	606.79	1353.70	1346.30	80599.90	244.67	270.41	109.44
14	22293	Earthworms	2014	Gjerstad	122.34	0.89	15.80	4234.38	7408.00	1342.60	121056.80	75.79	99.61	414.07
15	22294	Earthworms	2014	Gjerstad	142.87	<LOD	18.32	4726.49	8451.60	1448.80	169047.90	36.49	91.17	423.80
16	22295	Earthworms	2014	Gjerstad	143.15	1.38	21.50	4887.66	14468.90	1592.70	171286.50	44.35	87.49	408.24

Table A 16: GPS locations for sampling locations

Location	UTM-zone	East Coordinates	North Coordinates
Earthworm			
Voksenkollen	32V	0593098	6650289
Brekke	32V	0598627	6649266
Østmarksetra	32V	0604207	6640584
Hegna	32V	0498471	6585374
Kåsmyra	32V	0501488	6556419
Gjerstad	32V	0500943	6527390
Red fox			
14/2322	32V	601393	1035915
14/2323	32V	588966	6655077
14/2324	32V	601286	6657445
14/2325	32V	588964	6655082
14/2326	32V	588971	6655082
14/2327	32V	588969	6655072
14/2328	32V	601281	6657648
14/2355	33V	223865	6951267
14/2356	33V	223865	6951267
14/2357	33V	225081	6944720
14/2358	33V	222225	6954155
14/2359	33V	237003	6959762
14/2360	32V	531800	6939950
14/2361	32V	46700	6948600
14/2362	32V	532400	6934150
14/2363	32V	531800	6939950
14/2364	32V	27696	6942134
14/2365	32V	532400	6933250
14/2366	32V	531800	6939950
14/2367	32V	538600	6942300
14/2368	32V	546900	6950500
14/2369	32V	543000	6946800
Brown rat			
All same location	32V	598100	6643200
Fieldfare			
Region Åmotsdalen	32V	519000	6923200
Sparrowhawk	Confidential for species protection	Confidential for species protection	Confidential for species protection

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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.