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Miljøgifter i terrestrisk og bynært miljø 2018
Environmental pollutants in the terrestrial and urban environment 2018

Summary - sammendrag

Samples from the urban terrestrial environment in the Oslo area were analysed for various inorganic and organic environmental pollutants. The selected species were earthworm, fieldfare, sparrowhawk, brown rat, red fox and badger. Air and soil samples were also included in the study to further the understanding on sources and uptake of pollutants. A foodchain approach was used to investigate trophic magnification of the different compounds.

Prøver fra det urbane terrestriske miljøet i Oslo-området ble analysert for flere uorganiske og organiske miljøgifter. De utvalgte artene var meitemark, gråtrost, spurvehauk, brunrotte, rødrev og grevling. Luft og jordprøver ble også analysert for å øke forståelsen av kilder og opptak av miljøgifter. En næringskjedetilnærming ble valgt for å undersøke trofisk magnifisering av de forskjellige stoffene.

4 emneord

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Knut Riise

Summary

On behalf of the Norwegian Environment Agency, the Norwegian Institute for Air Research (NILU) in collaboration with Norwegian Institute for Nature Research (NINA) and Norwegian Institute for Water Research (NIVA) analysed air, soil and biological samples from the terrestrial and urban environment for various inorganic and organic environmental pollutants.

The monitoring programme has the following key goals:

- Report concentrations of selected environmental pollutants in several trophic levels of a terrestrial food web;
- Compare the concentration of the selected pollutants across samples and species;
- Evaluate potential trophic magnification of the different pollutants using a foodchain approach

This report presents the findings from the sixth year of the urban terrestrial programme. Samples for this monitoring period was sampled in 2018.

A broad cocktail of environmental pollutants, consisting both of persistent organic pollutants, organic phenolic pollutants, biocides, pesticides, UV compounds, emerging and legacy PFAS, siloxanes, chlorinated paraffins, organic phosphorous flame retardants and metals were measured in air, soil and biota samples. The concentrations of the selected pollutants were compared across species and to data from previous years. In addition, the levels of the various pollutant groups were evaluated for each species. Potential biomagnification was also investigated.

Below follows a short summary for each compound class investigated. Where a comparison of concentrations was performed for hydrophobic pollutants (PCBs, PBDEs, CPs, Cyclic siloxanes, Biocides, UV compounds) between species and organs, this was done on a lipid weight basis.

Metals: As also shown in previous years, toxic metal (Hg, Pb, Cd, As) concentrations were highest in soil. Of the biological matrices analysed, earthworms, brown rats, badger and foxes contained the highest amounts of metals. The pooled sample of two fieldfare eggs from the site Kjelsås showed a Pb concentration of 136 ng/g ww (fieldfare egg from same site had 206 ng/g ww in 2017 and 494 ng/g ww in 2016). This concentration is more than 10-20 times higher than the levels detected in fieldfare eggs from the other sites. A general threshold for adverse physiological effects of Pb is set at 400 ng/g ww in bird blood, however direct comparison between concentrations in bird eggs and bird blood are not recommended. Hg concentrations were highest in earthworm and red fox with median values of 143 and 110 ng/g ww. One rat liver sample had a Hg concentration of 1093 ng/g ww. Cd was highest in badger liver samples, where concentrations in three samples exceeded 2000 ng/g ww.

PCBs: Data across all species revealed that sparrowhawk had the highest median concentrations of sumPCB of 6974 ng/g lipid weight (lw) followed by fieldfare and red fox with 784 ng/g lw and 550 ng/g lw respectively. One sparrowhawk sample had a high sumPCB value of 1874 ng/g ww. Although this concentration is lower than a general reported NOEL value for wild birds of 4000 ng/g for PCB, potential effects cannot be excluded due to different sensitivity among bird species. PCB-153 dominated in almost all matrices, with the

exception of foxes where PCB-180 dominated, and air where PCB-52 and -101 dominated. The air concentrations of PCBs at the urban sites, especially the sites in Slottsparken (0.91 ng/day) and at Alnabru (0.12 ng/day), were much higher than those measured at background air monitoring stations in Norway, suggesting the urban area to be a source to PCBs.

PBDEs: As shown also in previous years, the levels of PBDEs were lower in all environmental matrices compared to PCB and PFAS. Sparrowhawk eggs had the highest median concentration of sumPBDEs (465 ng/g lw) followed by brown rat liver (224 ng/g lw) and fieldfare eggs (181 ng/g lw). For the egg samples, PBDE-99 had in general higher concentrations than 100, 153 and 47, while BDE-207 and 209 dominated in brown rat liver. As in 2017, one sparrowhawk egg had much higher sumPBDE than the other eggs of 147 ng/g ww. The same egg had also highest sumPCB value. This measured sumPBDE concentration is seven times lower than a threshold level of 1000 ng/g ww for reduction of reproductive performance in osprey. The passive air sampler could detect several PBDE congeners in urban air. The highest concentrations of sumPBDEs in air were observed at Alnabru (0.48 ng/day) and Slottsparken (0.23 ng/day), and as with PCBs, these levels indicate that the urban area is a source of PBDEs detected in air.

New BFRs: The various compounds in this pollutant class was first and foremost detected in air, soil, earthworm and brown rat. The concentrations of new BFRs were lower than the concentrations of PBDEs in air and sparrowhawk eggs, but higher in the other matrices, primarily due to relatively high concentrations of DBDPE, and partially BTBPE and PBBZ. In air, Alnabru and Slottsparken had highest sum concentrations (0.18 and 0.13 ng/day). The highest median sum concentration of new BFRs was found in fieldfare which had a median concentration of 490 ng/g lw. DBDPE had highest concentrations among the newBFR compounds, but was detected in fewer samples than BTBPE and PBBZ. One extreme concentration of DBDPE was detected in brown rat liver of 940 ng/g ww. We have not been able to relate these levels to any known toxic effect of DBDPE. NOAEL for DBDPE in rat has been determined to be 1000 mg/kg bw/day.

PFAS: The dominating PFAS compound was PFOS in all environmental matrices, except for air where only PFBS and PFHxS were detected. The levels of PFOS in earthworm from Alnabru (69 ng/g ww) in 2018 was much lower than in 2017 (531 ng/g ww). This year, the median concentration of sumPFAS was high in sparrowhawk (143 ng/g ww) and fieldfare (99 ng/g ww) eggs. The highest PFOS (sum of linear and branched PFOS) concentration was detected in a sparrowhawk egg sample which contained 417 ng/g ww PFOS. This PFOS concentration is lower than a recommended threshold value for hatching success of PFOS of 1900 ng/g ww in bird egg. In agreement with what was found in 2016 and 2017 for fieldfare eggs, the 2018 sample from Grønmo had the highest PFOS concentration of 250 ng/g ww, ten times higher than the mean concentrations of the other fieldfare samples. Fieldfare egg from Holmenkollen had even higher sumPFAS concentration than the egg from Grønmo due to high concentration of the long-chain perfluorinated carboxylates, where the PFTeA concentration was 137 ng/g ww. Of the new PFAS (6:2 FTS, 8:2 FTS, 10:2 FTS, Cl-PFOS, Cl-PFOA and PFECHS) included in the monitoring in 2018, the compound PFECHS was found in all nine sparrowhawk eggs and in one liver sample from rat. The highest concentration was 2.4 ng/g ww in sparrowhawk egg. The compounds 8:2 FTS and 10:2 FTS were detected in all fieldfare and sparrowhawk eggs. 10:2 FTS was also detected in badger and rat liver. 6:2 FTS and 8:2 FTS were also detected in some samples of rat liver. The highest concentration was 11.8 ng/g ww for 10:2 FTS in fieldfare egg. Cl-PFOS was only detected in one rat liver sample, 1.2 ng/g ww.

SCCPs/MCCPs: Chlorinated paraffins (CPs) were found in most matrices. The lowest detection rate of SCCPs and MCCPs was found in fieldfare. The detection frequency of SCCPs and MCCPs in fieldfare was 50% and 80%, respectively. One sparrowhawk sample and one fieldfare sample had extremely high values of SCCPs and MCCPs. The highest concentration of sumCPs in sparrowhawk eggs was 9722 ng/g ww where MCCPs dominated the sum concentration with 6697 ng/g ww. The fieldfare sample with highest CP concentration was from Bøler and had a sumCP concentration of 6580 ng/g ww where SCCPs dominated the sum concentration with 4730 ng/g ww. A fieldfare sample from the same location had the highest sumCPs in 2017. It is not known if these extremely high concentrations may pose a risk to fieldfare and sparrowhawk. Estimated air concentrations at Slottsparken and VEAS sites were approximately ten times higher than annual mean concentrations measured at background stations in Norway.

Cyclic siloxanes (cVMS): Air samples had high levels of D4, D5 and D6. The highest sumSiloxane concentration of 51 ng/day was found in Slottsparken. The estimated air concentrations in Slottsparken based on uptake rates of D5 and D6 were 100-1000 times higher than the measured concentrations at background stations in Norway. This reflects that there are many emission sources for siloxanes in urban areas. The other matrices revealed very few detectable concentrations. Based on PNEC for predators, the levels of D4, D5 and D6 in earthworms and fieldfare eggs as prey are not high enough to pose any risk for predators.

OPFRs: As with siloxanes, air samples had high loads of OPFR with sumOPFR ranging from 1.04 to 6.82 ng/day. As in 2017, TCPP was the dominating compound, and as with siloxanes, the highest concentration of TCPP and sumOPFR were observed in Slottsparken and at Alnabru. For biological samples, OPFRs were mainly detected in the single pooled sample of soil (sumOPFR of 10.6 ng/g dw) and the pooled earthworm sample (14.4 ng/g ww), as well as the three pooled samples of brown rat (1.8-112 ng/g ww). EHDP (95.6 ng/g ww) had highest contribution to the maximum sumOPFR concentration of 112 ng/g ww in rats.

Dechloranes; were analysed in earthworm, fieldfare, sparrowhawk and red fox. Dechloranes were sparsely detected in earthworms, but Dec-602, Dec-603 and anti-DP were detected in many of the other samples, but at relatively low levels compared to the other pollutants measured in this study. Dec-603 dominated in fieldfare (<LOD-2.23 ng/g ww) and sparrowhawk eggs (0.37-4.62 ng/g ww) with 90 % and 100 % detection rate, respectively. In fox liver, anti-DP had highest concentrations, but was only detected in 50% of the samples. The highest median sum concentration of dechloranes was detected in sparrowhawk eggs followed by fieldfare eggs and was 72 ng/g lw (2.9 ng/g ww) and 33 ng/g lw (1.6 ng/g ww), respectively. We have not been able to relate these levels to any effect of dechloranes.

Pesticides; were only analysed in sparrowhawk eggs and the median concentration of SumDDT measured in 2018 was 1222 ng/g ww (mean 1358 ng/g ww). *P,p'*-DDE was clearly dominating the sumDDT with a median concentration of 1210 ng/g ww. This concentration is higher than a reported PNEC of 870 ng/g ww associated with 20% eggshell thinning in osprey. Seven of nine eggs from Oslo area exceeded 1000 ng/g ww in 2018, indicating a potential risk for reproductive effects of DDT in birds in this urban environment today.

UV compounds; were detected in some of the pooled samples. UV-327, UV-328 and OC were detected in the three sparrowhawk samples. UV-328 was the dominating compound in liver samples (red fox, badger and brown rat), while OC had highest concentration in one pooled sample of soil, and was the only compound detected in the one sample of earthworm. The highest sum concentration was found in the one pooled earthworm sample and in brown rat liver. Effect levels for these compounds were not found for terrestrial ecosystems.

Biocides (rodenticides); were measured in fox, badger and rat livers. The compounds were mainly detected in red fox liver where bromadiolone and brodifacoum dominated. Only bromadiolone was detected in rat liver at lower concentrations than in fox liver. Bromadiolone and brodifacoum were generally detected at lower concentrations in 2018 than in 2017 with mean concentrations of 543 ng/g ww and 132 ng/g ww in red fox liver in 2017 and 2018, respectively. The highest concentration of bromadiolone detected in 2018 was 3473 ng/g ww, and was found in red fox liver.

Phenols; were detected in the earthworm samples, and only sporadically detected in the other samples. Bisphenol-A dominated in the few samples of earthworm (64-76 ng/g ww), red fox (41-55 ng/g ww) and brown rat liver (124 ng/g ww) where phenols were detected.

Dominant pollutant groups in each matrix
The median of sum concentrations of the dominant pollutant group for each matrix in the investigated species in 2018 is given below. Note that pesticides were only measured in sparrowhawk eggs. SumToxicMetals is the sum of Hg, Cd, Pb and As.

- Air	:	SumSiloxanes >> SumCPs > SumOPFRs >sumPCBs
- Soil	:	SumToxicMetals >> SumCPs >> SumOPFR> SumUVcomp.
- Earthworm	:	SumToxicMetals >> SumPhenols~ SumCPs > SumPFAS
- Fieldfare egg	:	SumPFAS > SumCPs >SumPCBs~ SumToxicMetals
- Sparrowhawk egg	:	SumDDT >> SumCPs ~ SumPCBs > SumPFAS
- Red fox liver	:	SumToxicMetals ~ SumBiocides > SumCPs > SumPFAS
- Brown rat liver	:	SumToxicMetals >> SumBiocides > SumCPs ~ SumPFAS
- Badger liver	:	SumToxicMetals > SumBiocides > SumCPs > SumPFAS

Trophic magnification factors (TMFs): The typical hydrophobic and well known POPs such as PCBs and PBDEs were found to have TMF values well above 1, indicating a high potential for biomagnification in the food chain earthworm-fieldfare-sparrowhawk. The perfluorinated substance, PFTriA, had a TMF of 2.6, and the TMF for PFOS was 1.8 was slightly higher than in previous years.

Sammendrag

På oppdrag fra Miljødirektoratet analyserte NILU (Norsk institutt for luftforskning), i samarbeid med Norsk institutt for naturforskning (NINA) og Norsk institutt for vannforskning (NIVA) en lang rekke uorganiske og organiske miljøgifter i luft, jord og dyrearter fra bynært og terrestrisk miljø.

Prosjektet hadde følgende delmål:

- Rapportere konsentrasjoner av utvalgte miljøgifter på flere trofiske nivå av et terrestrisk næringsnett.
- Sammenstille og vurdere fordeling av miljøgiftklassene på tvers av prøver og arter
- Vurdere biomagnifiseringspotensialet av miljøgifter ved bruk av næringskjedetilnærming

Denne rapporten presenterer funnene fra det sjette året av det urbane terrestriske programmet. Prøver fra denne overvåkingsperioden ble samlet inn i 2018.

Et stort spekter av kjemiske stoffer ble analysert; persistente organiske miljøgifter, bisfenoler, biocider, pesticider, UV forbindelser, regulerte og nye PFAS stoffer, siloksaner, klorerte paraffiner, organiske fosforflammehemmere og metaller i de ulike prøvene. For hver stoffgruppe ble forurensingsnivåene sammenlignet på tvers av arter og prøver. I tillegg er det vurdert hvilke stoffgrupper som dominerte i de ulike prøvene og artene. Potensialet for biomagnifisering ble også undersøkt.

Under følger en kort oppsummering for hver komponentgruppe som ble analysert i prøvene. Der sammenligning er gjort mellom artene og ulike organer så er konsentrasjoner av hydrofobe miljøgifter normalisert til fettvekt (fv).

Metaller: I samsvar med tidligere års resultater i overvåkingsprogrammet så var metallkonsentrasjonene høyest i jord. Av de biologiske prøvene inneholdt meitemark, brunrotte og grevling de høyeste konsentrasjonene av tungmetallene Hg, Cd, Pb og As. Som i 2016 og 2017, hadde samleprøven bestående av to gråtrostegg fra et reir ved Kjelsås høyere Pb-konsentrasjon (136 ng/g vv) enn egg fra andre lokaliteter, mer enn 10-20 ganger høyere. En generell terskelverdi for fysiologisk skadevirkning er satt til ca. 400 ng/g vv i fugleblod. Konsentrasjon i fugleblod er ikke direkte sammenlignbar med fugleegg, men ingen gråtrostegg hadde konsentrasjon opp mot denne terskelverdien i 2018. Median Hg konsentrasjonen var høyest i meitemark og rødrev på 143 og 110 ng/g vv. En rotteleverprøve hadde en konsentrasjon av Hg på 1093 ng/g vv. Konsentrasjonen av Cd var høyest i leverprøver av grevling, hvor tre prøver var høyere enn 2000 ng/g vv.

PCB: 2018 data bekreftet tidligere års data at egg fra spurvehauk hadde høyeste median konsentrasjonen av sumPCB med 6974 ng/g fv etterfulgt av gråtrost og rødrev med 784 ng/g fv og 550 ng/g fv. En spurvehaukprøve hadde en sumPCB-verdi på 1874 ng/g vv. Selv om denne konsentrasjonen er lavere enn en generell NOEL verdi for fugl på 4000 ng/g, så kan en ikke neglisjere potensielle effekter siden følsomheten kan variere mellom fuglearter. PCB-153 dominerte i nesten alle prøvetyper, med unntak av lever fra rødrev hvor PCB-180 dominerte, og luft hvor de mer flyktige PCB 52 og 101 dominerte. Luftkonsentrasjonene fra passive luftprøvetakere av PCB i Slottsparken (0.91 ng/dag) og Alnabru (0.12 ng/dag), var mye høyere

enn de som ble målt på overvåkningsstasjoner i Norge, noe som tyder på at byområdet er en kilde for PCB i luft.

PBDE: Nivåene av PBDEer var lavere i alle miljøprøver sammenlignet med PCB og PFAS, noe som er i overensstemmelse med tidligere års resultater. Spurvehauk hadde høyeste median konsentrasjonen av sumPBDEs (465 ng/g fv) etterfulgt av lever fra brunrotte (224 ng/g fv) og gråtrost (181 ng/g fv). BDE-99, -47, -153 og -100 var de viktigste og hadde størst bidrag til sumPBDE i eggene, men BDE-207 og -209 dominerte i lever fra brunrotte. Den høyeste sum konsentrasjonen i ett spurvehaukegg var 147 ng/g vv (2101 ng/g fv). Denne sumkonsentrasjonen hos spurvehauk er ti ganger lavere enn terskelverdien for reproduksjonseffekter hos fiskeørn på 1000 ng/g vv. Det samme egget med høyest sumPBDE hadde også høyest sumPCB verdi. Fra passive luftprøvetakere kunne det detekteres flere PBDE-kongenere i byluft. Høyeste konsentrasjoner av sumPBDE i luft ble observert på Alnabru (0.48 ng/dag) og i Slottsparken (0.23 ng/dag), og som for PCB indikerer dette at byen Oslo er en kilde til PBDE i luft.

Nye BFR: De forskjellige stoffene i denne gruppen ble først og fremst detektert i luft, jord, meitemark og brunrotte. Konsentrasjonene av nye BFR var lavere enn konsentrasjonene av PBDE i luft og spurvehauk, men høyere i de andre prøvene, først og fremst på grunn av relativt høye konsentrasjoner av DBDPE, og delvis BTBPE og PBBZ. Passive luftprøvetakere viste høyeste konsentrasjoner for Alnabru og Slottsparken (0.18 og 0.13 ng/dag).
Høyeste median sumBFR konsentrasjon ble målt i gråtrostegg med 490 ng/g lw. DBDPE hadde høyeste konsentrasjon blant new BFR komponenter, men ble detektert i færre prøver enn BTBPE og PBBZ. En ekstrem konsentrasjon av DBDPE ble påvist i lever fra brunrotte på 940 ng/g vv. Vi har ikke kunnet relatere denne konsentrasjonen til en toksisk effekt av DBDPE. NOAEL for DBDPE i rotte har blitt bestemt til å være 1 000 mg/kg kroppsvekt/dag.

PFAS: Den dominerende PFAS-forbindelsen var PFOS i alle prøvene, bortsett fra luft der kun PFBS og PFHxS ble påvist. Nivåene av PFOS i meitemark fra Alnabru (69 ng/g vv) i 2018 var mye lavere enn i 2017 (531 ng/g vv). Høye median sum konsentrasjoner av sumPFAS ble påvist i spurvehauk (143 ng/g vv) og gråtrost (99 ng/g vv) egg. Høyeste PFOS konsentrasjon (sum av lineær og forgrenet PFOS) ble påvist i spurvehaukegg med 417 ng/g vv. Denne PFOS-konsentrasjonen er lavere enn en anbefalt terskelverdi for hekkesuksess for PFOS på 1900 ng/g vv i fugleegg. Som observert i 2016 og 2017 for gråtrostegg, hadde prøven fra Grønmo den høyeste PFOS konsentrasjonen på 250 ng/g vv, ti ganger høyere enn gjennomsnitts-konsentrasjonene av de resterende ni prøvene. Gråtrostegg fra Holmenkollen hadde enda høyere sumPFAS-konsentrasjon enn egget fra Grønmo på grunn av høy konsentrasjon av langkjedete perfluorerte karboksylater hvor PFTeA-konsentrasjonen var 137 ng/g vv. Blant nye PFAS forbindelser (6:2 FTS, 8:2 FTS, 10:2 FTS, Cl-PFOS, Cl-PFOA and PFECHS), ble PFECHS funnet i alle ni spurvehaukeggene og en leverprøve fra rotte med relativt lave konsentrasjoner. Høyeste konsentrasjon av PFECHS i spurvehaukegg var 2.4 ng/g vv. Forbindelsene 8:2 FTS og 10:2 FTS ble detektert i alle eggene fra gråtrost og spurvehauk. 10:2 FTS ble også detektert i grevling og rottelever. 6:2 FTS og 8:2 FTS ble påvist i noen prøver av rottelever. Høyeste detekterte konsentrasjon av de nye PFAS var 11.8 ng/g vv for 10:2 FTS i gråtrostegg. Cl-PFOS ble kun detektert i en leverprøve fra rotte, 1.2 ng/g vv.

SCCPs/ MCCPs: Klorerte paraffiner (CPs) ble funnet i de fleste prøvene. Gråtrostegg hadde laveste deteksjon der SCCPs og MCCPs ble detektert i henholdsvis 50 og 80 % av prøvene. En prøve av spurvehauk og en prøve fra gråtrost hadde ekstremt høye konsentrasjoner av SCCPs og MCCPs. Gråtrostegg fra Bøler hadde høyeste konsentrasjon med sumCPs verdi på 6850 ng/g vv. Gråstrostegg fra samme lokalitet hadde også høyeste sumkonsentrasjon i 2017. SCCPs dominerte summen for begge årene. Den ekstreme konsentrasjonen av sumCPs i spurvehaukegg var 9722 ng/g vv hvor MCCPs dominerte summen med 6697 ng/g vv. Det er ikke kjent om disse konsentrasjonene kan utgjøre en risiko for spurvehauk og gråtrost. De estimerte konsentrasjonene av klorparafiner i luft målt i Slottsparken og VEAS var omtrent ti ganger høyere enn de som ble observert på bakgrunnsstasjoner i Norge.

Sykliske siloksaner (cVMS): Luftprøvene hadde høye nivåer av forbindelsene D4, D5 og D6. Høyeste sum konsentrasjon på 51 ng/dag ble funnet i Slottsparken. Konsentrasjonene av D5 og D6 i Slottsparken basert på opptaksrate i passive prøvetakere var 100-1000 ganger høyere enn data fra bakgrunnsstasjoner i Norge, og reflekterer utslippskilder av siloksaner i byområdet. I jord og biotaprøvene var siloksanene sporadisk detektert. Basert på PNEC så var ikke nivåene av D4, D5 og D6 i meitemark og gråtrostegg som byttedyr høye nok til å utgjøre noen risiko for rovdyr.

OPFRs: Som med siloksaner hadde luftprøver store mengder OPFR med sumOPFR som varierte fra 1.04 til 6.82 ng/dag. Som i 2017 så var TCPP den dominerende forbindelsen, og i likhet med siloksaner ble den høyeste konsentrasjonen av TCPP og sumOPFR målt i Slottsparken og Alnabru. For biologiske prøver ble OPFRs først og fremst detektert i en samleprøve av jord (sumOPFR på 10.6 ng/g dw) og meitemark (14.4 ng/g vv) og tre samleprøver av brunrotte (1.8-112 ng/g vv). EHDP (95.6 ng/g vv) hadde største bidrag til maksimum sumOPFR i rotter på 112 ng/g vv.

Dekloraner; ble analysert i meitemark, gråtrost, spurvehauk og rødrev. Dekloraner ble kun påvist i noen prøver av meitemark, men Dec-602, Dec-603 og anti-DP ble detektert i mange av de andre organismene, men i relativt lave nivåer sammenlignet med de andre komponent-gruppene i dette programmet. Dec-603 dominerte i gråstrostegg (<LOD-2.23 ng/g vv) og spurvehaukegg (0.37-4.62 ng/g vv), og ble funnet i hhv. 90 % og 100 % av prøvene. I lever fra rødrev hadde anti-DP høyeste konsentrasjon, men ble kun detektert i 50 % av prøvene. Den høyeste median sumkonsentrasjonen av dekloraner ble funnet i spurvehaukegg etterfulgt av gråtrostegg og var på hhv 72 ng/g fv (2.9 ng/g vv) og 33 ng/g fv (1.6 ng/g vv). Vi har ikke kunnet relatere disse nivåene til noen effekter av dekloraner.

Plantevernmidler; ble bare analysert i spurvehaukegg og median konsentrasjon av SumDDT målt i 2018 var 1222 ng/g vv. *P,p'*-DDE dominerte sumDDT med en mediankonsentrasjon på 1210 ng/g vv. Denne konsentrasjonen er høyere enn en rapportert PNEC på 870 ng/g vv assosiert med 20% eggeskallfortynning i fiskeørn. Syv av ni egg fra Oslo-området var høyere enn 1000 ng/g vv i 2018, som indikerer en risiko for reproduksjonseffekter av DDT for fugl som lever i dette urbane området.

UV-forbindelser; ble detektert i noen av de samleprøvene. UV-327, UV-328 og OC ble detektert i de tre samleprøvene av spurvehauk. UV-328 var den dominerende forbindelsen i leverprøvene (rev, rotte og grevling), mens OC hadde den høyeste konsentrasjonen i en samleprøve av jord, og var den eneste forbindelsen detektert i samleprøven av meitemark. Høyeste sumkonsentrasjon ble funnet i den ene samleprøven av meitemark og i lever av brunrotte. Effektnivåer for UV-forbindelser er ikke funnet for terrestriske økosystemer.

Biocider (rodenticider); ble målt i rev-, grevling- og rottelever. Forbindelsene ble først og fremst påvist i rødrevlever hvor bromadiolon og brodifacoum dominerte. Bare bromadiolon ble påvist i rottelever ved lavere konsentrasjoner sammenlignet med rødrev. Bromadiolon og brodifacoum var generelt i lavere konsentrasjoner i år sammenlignet med 2017, gjennomsnittlig verdi på 543 ng/g vv og 132 ng/g vv i rødrevlever. Maksimum konsentrasjon av bromadiolon var 3473 ng/g vv, og ble funnet i lever fra rødrev.

Fenoler; ble detektert i tre analyserte meitemarkprøver, og ble bare sporadisk detektert i de andre artene. Bisfenol-A dominerte i prøvene av meitemark (64-76 ng/g vv), rødrev (41-55 ng/g vv) og brunrotte (124 ng/g vv) hvor fenoler ble detektert.

Dominerende stoffgrupper i de ulike miljøprøvene

Median av sumkonsentrasjoner av de mest dominerende miljøgiftgruppene i de ulike miljøprøvene i 2018 er vist nedenfor. Pesticider ble bare analysert i spurvehauk og SumToxicMetals er summen av konsentrasjonene av Hg, Cd, Pb og As.

- Luft	:	SumSiloxanes >> SumCPs > SumOPFRs >SumPCBs
- Jord	:	SumToxicMetals >> SumCPs >> SumOPFR> SumUVcomp.
- Meitemark	:	SumToxicMetals >> SumPhenols~ SumCPs> SumPFAS
- Gråtrost egg	:	SumPFAS > SumCPs >SumPCBs~ SumToxicMetals
- Spurvehauk egg	:	SumDDT >> SumCPs ~ SumPCBs > SumPFAS
- Rødrev lever	:	SumToxicMetals ~ SumBiocides > SumCPs> SumPFAS
- Brunrotte lever	:	SumToxicMetals >> SumBiocides > SumCPs > SumPFAS
- Grevling lever	:	SumToxicMetals >> SumBiocides > SumCPs~ SumPFAS

TMF: De typiske hydrofobe og velkjente POPene som PCB og PBDE hadde TMF godt over 1, som indikerte høyt potensial for magnifisering i næringskjeden meitemark-gråtrost-spurvehauk. Den perfluorerte substansen PFTRiA hadde en TMF på 2.6 og PFOS var noe høyere enn tidligere år med 1.8.

Abbreviations

BAF	Bioaccumulation factor
BFR	brominated flame retardants
CI	confidence interval
dw	dry weight
EI	electron impact ionization
ESI	electrospray ionization
ww	wet weight
vv	våtvekt
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
fv	fettvekt
LOEL	lowest observed effect level
MEC	measured environmental concentration
M-W U	Mann–Whitney *U* test
MCCP	medium-chain chlorinated paraffins
N	detected/measured samples
n.a.	not analysed
NCI	negative chemical ionization
NOEC	no observed effect concentration
NOAEL	no observed adverse level
NOEL	no observed effect level
n-PFAS	neutral polyfluorinated compounds
newPFAS	new polyfluorinated compounds
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
PSA	primary/secondary amine phase
SCCPs	short-chain chlorinated paraffins
SSD	species sensitivity distribution
SIR	selective ion reaction
SPE	solid phase extraction
TL	Trophic level
TMF	Trophic magnification factor
UHPLC	ultra high pressure liquid chromatography

Content

Attachments:

Appendix 1: Concentrations of pollutants in individual samples 2018
Appendix 2: GPS coordinates for sampling locations 2018
Appendix 3: Eggshell data in sparrowhawks from the Oslo area 2018
Appendix 4: Pathology studies of red foxes and brown rats 2018

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 potential and possible adverse effects in species living in a terrestrial and urban ecosystem. The urban sites in or in the near vicinity of Oslo were identified for sampling. The results from this study will feed into the evaluation of potential environmental hazards 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 trophic levels of the terrestrial food chain
- Evaluate the bioaccumulation potential of pollutants in the terrestrial food chain
- Evaluate the total exposure in terrestrial animals
- Evaluate how land-living species are exposed to a variety of pollutants
- Evaluate trends in various pollutants over time

1.2 Investigated samples

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 (Haftorn 1971, Hagen 1952). 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 (Bennington 1971, Bennington 1974, Burgers et al. 1986, Cooke 1979, Newton & Bogan 1978, Newton et al. 1986, Ratcliffe 1960), and also in Norway (Bühler & Norheim 1981, Frøslie et al. 1986, Holt & Sakshaug 1968, 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, badgers, foxes, hedgehogs), and invertebrates (e.g. ground beetles, snails). They are found almost anywhere in soil that contains some moisture (Macdonald 1983). Lumbricus terrestrisk was the most common species in the samples. Estimated trophic level 2 (Hui et al. 2012). Sampling sites for earthworm were Alnabru, Slottsparken, Fornebu, VEAS, and Frognerseteren.

European Badger (*Meles meles*)
The European badger is a predator and is the second largest member of the family Mustelidae, next to the wolverine. It can be up to 80 cm in length and up to 16 kg during the autumn when it has plenty of food. The most important food item is earthworm, but it is an opportunistic feeder. The badger can be found in Østlandet and Sørlandet and up to Trøndelag in Norway, and also detected in southern part of Nordland county. It is not an uncommon inhabitor in more populated areas and cities. Estimated trophic level: 3

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.

Brown rat (*Rattus norvegicus*)
The brown rat is one of the most common rats in Europe. This rodent can become up to 25 cm long. The brown rat can be found wherever humans are living, particularly in urban areas. It is a true omnivore, feeding on everything from bird eggs to earthworms and human waste. The brown rat breeds throughout the whole year, producing up to 5 litters a year. Estimated trophic level: 3-4.

Bumblebees (Bombus)
For the first time in the monitoring program, bumblebee samples were available for PFAS analysis in 2018. The sampling of bumblebees were from three locations, two locations Frognerseteren and Sognsvann in Oslo area, and Hvasser, Vestfold as a reference area. Bumblebees is common in Norway and may be seen as a link from soil/plant system to some of the bird species. Several species are common in Norway.

Soil
Soil samples were taken from the surface layer (0-20 cm), combining three subsamples to one combined sample per location. The locations for soil samples were the same locations as for the earthworm samplings to make direct comparisons possible.

Air

For the third time in the urban terrestrial program, air samples were collected using passive air samplers (PAS) at the five locations chosen for soil- and earthworm sampling (Alnabru, Slottsparken, Grønmo, VEAS, and Frognerseteren). Two types of PAS adsorbents were used at all sites: i) polyurethane foam (PUF), and ii) polystyrene-divinylbenzene copolymeric resin (XAD). The PAS were deployed over a period of three months (late June/early July to October 2018) giving time-weighted mean concentration over that time period.

1.3 Investigated pollutants

In this study a total of 138 compounds were investigated. These included nine metals, seven PCBs, 40 PFAS, 13 PBDEs, new BFRs, three siloxanes (D4, D5 and D6), chlorinated paraffins (SCCPs and MCCPs), organic phosphorous compounds (OPFRs), UV compounds, biocides and phenolic compounds, together with the stable isotopes $\delta^{15}N$, $\delta^{13}C$ and $\delta^{34}S$. Some pesticides (DDT and its breakdown products, HCB and HCH isomers) were analysed in sparrowhawk eggs. OPFR and UV compounds were measured in a selection of pooled samples, representing the species covered within the project. 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
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 alkyl substances (PFAS)		
PFCA (perfluorinated carboxylate acids)		
Perfluorinated butanoic acid	PFBA	307-24-4
Perfluorinated hexanoic acid	PFHxA	375-85-9
Perfluorinated heptanoic acid	PFHpA	335-67-1
Perfluorinated octanoic acid	PFOA	375-95-1
Perfluorinated nonanoic acid	PFNA	335-76-2
Perfluorinated decanoic acid	PFDcA	2058-94-8
Perfluorinated undecanoic acid	PFUnA	307-55-1
Perfluorinated dodecanoic acid	PFDoA	72629-94-8
Perfluorinated tridecanoic acid	PFTriA	376-06-7
Perfluorinated tetradecanoic acid	PFTeA	67905-19-5
Perfluorinated hexadecanoic acid	PFHxDA	16517-11-6

Perfluorinated octadecanoic acid	PFOcDA	375-73-5
PFSA (Perfluorinated sulfonates)		
Perfluorinated butane sulfonate	PFBS	
Perfluorinated pentane sulfonate	PFPS	2706-91-4
Perfluorinated hexane sulfonate	PFHxS	355-46-4
Perfluorinated heptane sulfonate	PFHpS	375-92-8
Perfluorinated octane sulfonate	PFOS	2795-39-3
Perfluorinated octane sulfonate (branched)	brPFOS	
Perfluorinated nonane sulfonate	PFNS	17202-41-4
Perfluorinated decane sulfonate	PFDcS	67906-42-7
Perfluoroundecane sulfonate	PFUnS	
Perfluorododecane sulfonate	PFDoS	
Perfluorotridecane sulfonate	PFTrS	
Perfluorotetradecane sulfonate	PFTS	
nPFAS (polyfluorinated neutral compounds)		
Perfluorooctane sulfonamide	PFOSA	754-91-6
N-Methyl perfluorooctane sulphonamide	meFOSA	31506-32-8
N-Ethyl perfluorooctane sulfonamide	etFOSA	4151-50-2
N-Methyl perfluorooctane sulfonamidoethanol	meFOSE	24448-09-7
N-Ethyl perfluorooctane sulfonamidoethanol	etFOSE	1691-99-2
6:2-Fluorotelomer alcohol	6:2 FTOH	647-42-7
8:2-Fluorotelomer alcohol	8:2 FTOH	678-39-7
10:2-Fluorotelomer alcohol	10:2 FTOH	865-86-1
12:2-Fluorotelomer alcohol	12:2 FTOH	39239-77-5
New PFAS		
6:2 Fluortelomersulphonate	6:2 FTS	27619-97-2
8:2 Fluortelomersulphonate	8:2 FTS	481071-78-7
10:2 Fluortelomersulphonate	10:2 FTS	
dodecafluorohexyloxy)- 1,1,2,2-tetrafluoroethane sulfonate		
Monochlorinated PFOS	Cl-PFOS	777011-38-8
Monochlorinated PFOA	Cl-PFOA	335-63-7
Cyclohexanesulfonic acid	PFECHS	67584-42-3
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	446255-22-7
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	67797-09-5
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	437701-79-6
Decabromodiphenylether 209	BDE-209	1163-19-5
New BFR		
Decabromodiphenyl ethane	DBDPE	84852-53-9
2,4,6-tribromophenyl ether)	ATE (TBP-AE)	3278-89-5
α-1,2-Dibromo-4-(1,2-di-bromo-ethyl)cyclohexane	α-TBECH	3322-93-8
β-1,2-Dibromo-4-(1,2-di-bromo-ethyl)cyclohexane	β-TBECH	
γ/δ- 1,2-Dibromo-4-(1,2-di-bromo-ethyl)cyclohexane	γ/δ-TBECH	
2-bromoallyl 2,4,6-tribromophenyl ether	BATE	99717-56-3
1,2,3,4,5 Pentabromobenzene	PBBZ	608-90-2
Pentabromotoluene	PBT	87-83-2
Pentabromoethylbenzene	PBEB	85-22-3
Hexabromobenzene	HBB	87-82-1
2,3-dibromopropyl 2,4,6-tribromophenyl ether	DPTE	35109-60-5
2-Ethylhexyl 2,3,4,5-tetrabromobenzoate	EHTBB	183658-27-7
1,2-Bis(2,4,6-tribromophenoxy)ethane	BTBPE	37853-59-1

2,3,4,5-tetrabromophthalate	TBPH (BEH /TBP)	26040-51-7
Dechloranes		
Dechlorane plus	DP	13560-89-9
Dechlorane plus syn	syn-DP	135821-03-3
Dechlorane plus anti	anti-DP	135821-74-8
Dechlorane 601	Dec-601	3560-90-2
Dechlorane 602	Dec-602	31107-44-5
Dechlorane 603	Dec-603	13560-92-4
Dechlorane 604	Dec-604	34571-16-9
Dibromo-aldrin	DBA	20389-65-5
Cyclic volatile methyl siloxanes	D4	556-67-2
	D5	541-02-6
	D6	540-97-6
Chlorinated paraffins		
Short-chain chlorinated paraffins (C10-C13)	SCCPs	85535-84-8
Medium-chain chlorinated paraffins (C14-C17)	MCCPs	85535-85-9
Organic phosphorous flame retardants (OPFR)		
Tri(2-chloroethyl)phosphate	TCEP	115-96-8
Tris(2-chloroisopropyl) phosphate	TCPP/TCIPP	13674-84-5
Tris(1,3-dichloro-2-propyl)phosphate	TDCPP/TDCIPP	13674-87-8
Tris(2-butoxyethyl) phosphate	TBEP/TBOEP	78-51-3
2-etylhexyldiphenyl phosphate	EHDP/EHDPP	1241-94-7
Tricresyl phosphate	TCP	1330-78-5
Tri-n-butylphosphate	TBP/ TnBP	126-73-8
Tri-iso-butylphosphate	TBP/TiBP	126-71-6
Triethyl phosphate	TEP	78-40-0
Tripropyl phosphate	TPrP/TPP	513-08-6
Triisobutyl phosphate	TiBP	126-71-6
Butyl diphenyl phosphate	BdPhP	2752-95-6
Triphenyl phosphate	TPP/TPhP	115-86-6
Dibutylphenyl phosphate	DBPhP	2528-36-1
Trixylylphosphate	TXP	25155-23-1
Tris(4-isopropylphenyl)phosphate	TIPPP/T4IPP	26967-76-0
Tris(4-Tert-butylphenyl)phosphate	TTBPP	78-33-1
Tris(2-ethylhexyl)phosphate	TEHP	78-42-2
UV compounds		
Octocrylen	OC	6197-30-4
Benzophenone-3	BP3	131-57-7
Ethylhexylmethoxycinnamate	EHMC	5466-77-3
UV-327	UV-327	3864-99-1
UV-328	UV-328	25973-55-1
UV-329	UV-329	3147-75-9
Biocides (Rodenticides)		
Bromadiolon		28772-56-7
Brodifacoum		56073-10-0
Flocumafen		90035-08-8
Difenacoum		56073-07-5
Phenols		
Bisphenol A	Bis-A	80-05-7
Bisphenol S	Bis-S	80-09-1
Bisphenol F	Bis-F	620-92-8
4-n-Nonylphenol	4n-nonyl	104-40-5
4-n-Octylphenol	4n-octyl	1806-26-4
4-t-Octylphenol	4t-octyl	140-66-9
Tetrabromobisphenol A	TBBPA	79-94-7
Pesticides		
Hexachlorobenzene	HCB	118-74-1
α-hexachlorohexane	α-HCH	319-84-6
β-hexachlorohexane	β-HCH	319-85-7
γ-hexachlorohexane	γ-HCH	58-89-9
1,1,1-Trichloro-2-(o-chlorophenyl)-2-(p-chlorophenyl)ethane	*o,p'*-DDT	789-02-6
1-chloro-4-[2,2,2-trichloro-1-(4-chlorophenyl)ethyl]benzene	*p,p'*-DDT	50-29-3
2,2-(2-Chlorophenyl-4'-chlorophenyl)-1,1-dichloroethene	*o,p'*-DDE	3424-82-6
1-chloro-4-[2,2-dichloro-1-(4-chlorophenyl)ethenyl]benzene	*p,p'*-DDE	72-55-9

1.3.1 Metals including Hg

Because of their high degree of toxicity, even at low concentrations, mercury (Hg), lead (Pb) cadmium (Cd) and arsenic (As) are considered priority metals that are of environmental and public health concern (Tchounwou et al. 2012; AMAP, 2009). This group is therefore of main focus in this report and defined as the group 'toxic metals'. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. Best studied is the uptake of metals from soil to invertebrates (Heikens et al. 2001). The impact these metals have on humans and animals is well known, and all four 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, Hg, 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 (PCB)

Polychlorinated biphenyls (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 result, PCBs are recognized as persistent organic pollutants (POPs) and are regulated under the Stockholm Convention and the convention on long-range transboundary air pollution (CLRTAP). 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. This study includes the group of PCBs found to be dominating in most environmental matrices, the non-dioxin like PCBs, the so-called PCB7 group.

1.3.3 Polybrominated diphenylethers (PBDEs)

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 deca-BDE. These are all technical mixtures containing different PBDE congeners. Tetra-, penta-, hexa- and heptaBDE congeners were listed in the Stockholm Convention and CLRTAP 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 in EU enter into force in 2019. 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, an agreement for including decaBDE in the Stockholm Convention as a POP was settled in May, 2017.

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 deca-BDE, 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 hexa-BDEs biomagnify in arctic food webs while results for the fully brominated PBDE congener, BDE 209 or deca-BDE, are more ambiguous. Several lines of evidence show that also BDE-209 bioaccumulates, at least in some species. 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 correctly. 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).

New brominated flame retardants (New BFR)
As a result of the regulation of the penta- and octa-BDEs and more recently also deca-BDE, new non-PBDE BFRs have been introduced into the market as replacement FRs. For example, firemaster 550 (containing BEHTBP) is a replacement product for penta-BDE (Venier and Hites, 2008) that was introduced to the market in 2003 (Stapleton et al., 2008). Saytex 8010 (Albemarle) and Firemaster 2100 (Chemtura), which are common trade names for decabromodiphenyl ethane (DBDPE), are replacement products for deca-BDE that were introduced into the market in the mid-1980s (Umweltbundesamt, 2001).

1.3.4 Per- and polyfluorinated alkyl substances (PFAS)

Per- and polyfluorinated alkyl substances (PFASs) have been widely used in many industrial and commercial applications. The chemical and thermal stability of a perfluoroalkyl moiety, caused by a 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 (Buck et al 2011). 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). Studies have revealed the potential for atmospheric long-range transport of PFAS (Ahrens et al, 2011; AMAP Assessment 2015). 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 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 recognized as POPs, and are listed in the Stockholm Convention and CLRTAP. 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 and PFHxS[1] are on the Norway's Priority List of Hazardous substances as well as being included in the candidate list of substances of very high concern for Authorization in ECHA.

New PFASs

In addition to the well known PFAS, more than 5000 PFASs are on the global market for intentional uses, and the chemical identities of many are yet unknown (Wang et al., 2017). Emissions and leakage to the environment are unavoidable, and sooner or later, environmental concentrations will be reported. For example, in a recent study (MacInnis et al 2017) perfluoro-4-ethylcyclohexane-sulfonate (PFECHS) was detected for the first time in an atmospherically derived sample, and a potential source was attributed to aircraft hydraulic system leakage. Also, Pan reported the occurrence and bioaccumulation of hexafluoropropylene oxide trimer acid in surface water and fish (Pan et al., 2017). Gebbink et al. 2017, published findings of the PFOA replacement chemical GenX at all downstream river sampling sites with the highest concentration (812 ng/L) at the first sampling location downstream from a production plant in the Netherlands, proving the necessity of measuring for a broad range of emerging PFAS.

1.3.5 Cyclic volatile methyl siloxanes, (cVMS)

There are concerns about the properties and environmental fate of the three most common cVMS; D4, D5, and D6 (Wang et al., 2013). 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. The European Commission has published its Regulation to restrict the use of octamethylcyclotetrasiloxane (D4) and decamethylcyclopentasiloxane (D5) in wash-off cosmetic products in a concentration equal to or greater than 0.1% by weight.

1.3.6 Chlorinated paraffins (CPs)

CPs have been produced since the 1930s and the world production of CPs was 300,000 tonnes in 2009. CPs 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).

[1] https://echa.europa.eu/documents/10162/40a82ea7-dcd2-5e6f-9bff-6504c7a226c5

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).

There exist some data on SCCPs and MCCPs detected in Norwegian environment and other parts of the world, including Arctic. Air monitoring at Zeppelin observatory, Svalbard, reports air concentrations of sum S/MCCPs around 300 pg/m3. In air collected at Bear Island (Norway), concentrations were 1.8 to 10.6 ng/m^3 (Borgen et al. 2003). In a screening study (Harju et al., 2013), SCCPs and MCCPs were detected in Norwegian Arctic biota. Levels of SCCPs were found to dominate compared to MCCPs in polar bear and seal plasma, kittiwake eggs, cod liver and polar cod. However, the opposite trend was observed for glaucous gull plasma and eider duck eggs where MCCPs were found at higher concentrations. The data indicated that SCCPs and MCCPs biomagnified in Arctic food webs with TMF > 1. A recent subtropical marine food web study also indicated that SCCPs and MCCPs biomagnified with trophic magnification factors for ∑SCCPs and ∑MCCPs were 4.29 and 4.79 (Zeng et al 2017). In a Canadian freshwater study in Lake Ontaio and Lake Michigan , SCCPs and MCCPs were found to biomagnify between prey and predators from both lakes with highest values observed for Diporeia-sculpin (Lake Ontario, C15Cl9 = 43; Lake Michigan, C10Cl5 = 26). Trophic magnification factors for the invertebrates−forage fish−lake trout food webs from the same study ranged from 0.41 to 2.4 for SCCPs and from 0.06 to 0.36 for MCCPs (Houde et al., 2008). 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). 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. 2006). In a recent study (Yuan & de Wit, 2018), SCCPs and MCCPs were measured in Swedish terrestrial birds and animals; SCCPs and MCCPs concentrations in starling were 360 and 310 ng/g lw, respectively; in peregrine falcon SCCPs and MCCPs were 580 and 410 ng/g lw. Bank vole had 420 and 30 ng/g and lynx had 820 and 750 ng/g lw for SCCPs and MCCPs, respectively. SCCPs was included in the POPs Regulation (EC) 850/2004 by the amendment (EU) 2015/2030 in 2015. So far MCCPs are not globally regulated, however, SCCPs has recently been included in the Stockholm Convention, and a global regulation will be effectuated within November 2019.

1.3.7 Organophosphorous flame retardants (OPFR)

The global use of phosphorous containing flame retardants in 2001 was 186 000 tonnes (Marklund et al., 2005). Arylphosphate is used as a flame retardant, but also as a softener in PVC and ABS. They are also used as flame retardants in hydraulic oils and lubricants. Some PFRs are known to be very toxic. PFRs can be either inorganic or organic, and the organic PFRs can be divided into non-halogen PFRs and halogenated PFRs. In the halogenated PFRs chlorine is the most common halogen (Hallanger et al., 2015). In this study both halogenated and non-halogen organic PFRs are included. The chlorinated OPFR compounds are thought to be sufficiently stable for short- and medium-range atmospheric transportation (Regnery and Püttmann, 2009), and observations of PFRs in the marine environment (Bollmann et al., 2012) and in remote areas (Aston et al., 1996; Regnery and Püttmann, 2009, 2010), such as glacier-ice in the Arctic and particulate organic matter in Antarctic (Ciccioli et al., 1994; Hermanson et al., 2005) suggests that some PFRs are subject to long-range transport (Möller et al., 2012).

1.3.8 Dechloranes

Under the common term dechloranes we find different dechlorane structures and the closely related dibromoaldrine (DBALD). All of them are used as flame retardants or are impurities of DP and are polycyclic and highly chlorinated (or partly brominated) compounds. As the production of these compounds start with hexachlorocyclopentadiene (HCCP) they are chemically closely related to Mirex and a lot of other pesticides.

There is a growing international interest in dechlorane related compounds with an increasing number of scientific papers and reports on this compound group. A review study in 2011 on Dechlorane Plus (DP) summarized the available information as following: Dechlorane Plus (DP) is a high production volume and very persistent compound. DP is a global pollutant and has recently been detected along a pole-to-pole transect of the Atlantic Ocean. There seems to be one production site in North America and at least one in China. Beside DP there are other closely related compounds in the environment. These DP analogues have also been detected globally. Modelling data are in agreement with available environmental data, proposing DP and analogues to be persistent, bioaccumulative, and long-range transported (Sverko et al., 2011). A recent Norwegian screening study from the Oslo area reported detectable concentrations of syn- and anti-DP in rat liver samples, in influent, effluent and sludge from Vestfjorden Wastewater Treatment Plant (Veas) and in indoor house dust samples (Schlabach et al., 2017a).

In a screening study of Arctic biota samples Dec-602 was found in detectable concentrations in glaucous gull, kittiwake and polar bear. Syn- and anti-DP were only detected in ringed seal and polar bear samples (Schlabach et al., 2017b).

1.3.9 Alkylphenols and bisphenols

Nonyl- and octylphenols are used in manufacturing antioxidants, lubricating oil additives, laundry and dish detergents, emulsifiers, and solubilizers. Nonylphenol has attracted attention due to its prevalence in the environment and due to its ability to act with estrogen-like activity. Nonyl- and octylphenols are also precursors of the degradation products alkylphenol ethoxylates.

Waste water treatment plants are recipients from relevant sources such as roads, industries etc. of nonyl- and octylphenols besides degradation in the environment (Loyo-Rosales et al., 2007). Nonylphenol is rated harmful and corrosive, as well as harmful for the aquatic ecosystem (Preuss et al., 2006).

Bisphenol A (Bis-A) is an industrial chemical with high production volumes used in the production of polycarbonate plastics and epoxy resins. Due to its versatile use, Bis-A is a pollutant found in all ecosystems worldwide (Fromme et al. 2002). Especially the endocrine disrupting capability is of concern. Following opinions of scientists, public and regulators, manufacturers have begun to remove bisphenol A from their products with a gradual shift to using bisphenol analogues in their products. In these days two of the analogues – bisphenol S (Bis-S) and bisphenol F (Bis-F) have been mostly used as bisphenol A replacements. Bis-S is used in a variety of applications, for example as a developer in a thermal paper, even in the products marketed as “BPA-free paper”(Liao et al., 2012). Bis-S is also used as a wash fastening agent in cleaning products, an electroplating solvent and constituent of phenolic resins (Clark, 2000). Bis-F is used to make epoxy resins and coatings such as tanks and pipe linings, industrial floors, adhesives, coatings and electrical varnishes (Fiege et al., 2000). The brominated version, tetrabromobisphenol A, is used as one of the major brominated flame-retardants.

The restrictions for the use of Bisphenol A by the polymer industry triggered its replacement with bisphenol S (Bis-S) in thermal paper and other products. Bisphenol F (Bis-F) and bisphenol B (Bis-B) can replace Bis-A in the production of epoxy resin and polycarbonate. They have been detected in canned foods and soft drinks. In addition to these analogues, bisphenol AF (Bis-AF) has broad application in the manufacture of phenolic resins or fluoroelastomers. Annual production is assumed to be in the range of 5 to 300 tons in the USA (Yang et al. 2014). Unfortunately, those new bisphenol compounds could have similar deleterious effects as Bis-A. Recent studies have indeed demonstrated possible estrogenic activity similar to that of Bis-A (Rosenmai et al. 2014).

1.3.10 UV compounds

Concern over our contribution to the loads of environmental pollutants originating from our use of personal care products is continuously growing. Due to their continuous release via wastewater effluent, personal care products have been termed pseudo-persistent (Barceló & Petrovic, 2007) irrespective of their PBT characteristics. The increase in public awareness over the dangers of over-exposure to sunlight has lead to an increase in products available to protect us. The first reported environmental occurrence of an organic UV filter was over 30 years ago when benzophenone was determined in the Baltic Sea (Ehrhardt et al., 1982), although personal care products were not identified as the source. UV filters and UV stabilizers all absorb UV light and in general can be loosely divided into 2 categories; UV filters used in personal care products to protect hair and cutaneous membranes from sun damage, and UV stabilizers used in technical products such as plastics and paints to protect polymers and pigments against photodegradation, and to prevent discolouring. Many of the compounds are used for both purposes and frequently used in combination to extend the UV range protection provided. It is widely reported that UV filters and stabilizers used in personal care products enter the aquatic environment indirectly via sewage effluent discharges and directly from water sports activities causing them to wash directly from skin surfaces into receiving waters (Langford et al., 2015). UV filter occurrence can be season- and weather dependent, higher concentrations were detected in wastewater influents in summer than in winter (Tsui et al., 2014) and receiving waters have demonstrated the same patterns of distribution with higher concentrations in hot weather than in cold (Langford and Thomas, 2008).

Benzotriazoles

Orthohydroxy benzotriazole UV stabilizers are heterocyclic compounds with a hydroxyphenyl group attached to the benzotriazole structure. This class of UV stabilizers has a broad range of physico-chemical properties enabling them to absorb or scatter UV light as well as reflect it, making them very useful for UV protection. The ozone layer is efficient at removing UV radiation below 280 nm so benzotriazoles have been developed to absorb the full spectrum of UV light from 280 nm to 400 nm.

Bioaccumulation has been observed in the marine environment in Japan for this group of UV stabilizers (Nakata et al., 2009). UV-320 (2-(3,5-di-t-butyl-2-hydroxyphenylbenzotriazole) for example is considered to be a PBT compound and has been banned from manufacture or use in Japan. Filter-feeding and sediment-dwelling organisms contained some of the high concentrations indicating sorption to particulates is a likely sink for some benzotraizole UV stabilizers. UV 328 was found in breastmilk of women in Korea by Lee et al. 2015, emphasising human exposure of these chemicals.

BP3 (Benzophenone-3)
Benzophenones have a high stability in UV light and absorb UV light in the UVA and UVB range. Benzophenones interact with the estrogen and androgen receptor and induce vitellogenin in male fathead minnow (*Pimephales promelas*), although *in vitro* BP-3 was up to 100,000 times less potent than estradiol. BP-3 demonstrated some limited agonistic activity at the androgen receptor, but significant anti-estrogenic activity in vitro. Androgen receptor antagonist activity using yeast cells possessing the androgen receptor was equally as potent as flutamide. It is possible that the estrogenic activity may have resulted from demethylation of BP-3 to the 4-hydroxy metabolite, which is a more potent estrogen receptor agonist than the BP-3 (Kunz and Fent, 2006).

ODPABA (2-ethylhexyl-4-dimethylaminobenzoate)
ODPABA absorbs UV light only in the UVB range. ODPABA has a half-life of 39 hours in seawater and the presence of organic matter may inhibit photolysis (Sakkas et al., 2003).

EHMC (Ethylhexylmethoxycinnamate)
EHMC is the most commonly used UV filter in sun lotions and is used in over 90% of those available in Europe. It has demonstrated multiple hormone activities in fish with gene expression profiling showing antiestrogenic activity compared to estrogenic/antiandrogenic activity using VTG induction (Christen et al., 2011; Fent et al., 2008). EHMC is lipophilic and accumulates in biota showing a tendency to bioaccumulate through different trophic levels (Fent et al., 2010).

OC (Octocrylene)
OC absorbs light in the UVB range and short wavelength UVA light also, and is frequently used to protect other UV filters from photodegradation in the UVB range. OC was one of the main UV filters detected during the Screening 2013, found in treated wastewater, sludge, sediments and cod liver, indicating bioavailability, but no biomagnification (Thomas, 2014).

1.3.11 Biocides
Rodenticides are classed as biocides, and in Europe they are regulated by the EU Biocidal Products Regulation (EU) no 528/2012. The first-generation rodenticides were introduced for pest control in the 1940s, but after some rodents developed resistance to these compounds, second-generation anticoagulant rodenticides (SGARs) were developed and introduced in the 1970s. The SGAR group includes brodifacoum, bromadiolone, difenacoum, difethialone, and flocoumafen. They act as vitamin K antagonists and interfere with the synthesis of blood clotting agents in vertebrates making them vulnerable to haemorrhage (Stone *et al*. 2003; Vandenbroucke 2008).

Compared to the first generation of rodenticides such as warfarin, SGARs are more likely to have effects on non-target species due to their extremely slow elimination rate from the target species and their higher vertebrate liver toxicity. They are likely to accumulate in non-target species which consume either bait or poisoned prey. Exposed rodents for example, can survive for several days after consumption of SGARs and continue to consume bait which in turn increases their body burden allowing an even greater exposure potential to non-target predators. SGARs are considered high potency anticoagulants and the substances are retained in the liver for 6-12 months after exposure, compared to up to one month for warfarin, a first-generation rodenticide (Eason *et al*. 2002).

Exposure can occur indirectly as a result of avian and mammalian predators consuming exposed target or non-target rodent species (secondary poisoning), or directly through consumption of the baits (primary poisoning). The use of SGARs has been extensive in Norway and Europe. As a result of the risk assessment of the SGARs under the Biocidal Products Regulation (EU 528/2012), several risk mitigation measures have been implemented in Norway and other European countries. Limited data are available on the occurrence of SGAR residues in non-target species in Norway (Langford et al., 2013). However, monitoring data show that SGARs are found in non-target animals throughout Europe (Laakso et al. 2010; Elmeros et al. 2015). The environmental occurrence of brodifacoum was investigated in New Zealand (Ogilvie 1997). Aerial application of brodifacoum was used on a small island to eradicate rats. After an aerial application of cereal-based bait, no residues were detected in water or soil, or in the beetles found on the bait although it is possible that the sampling campaign was not extensive enough. However, residues were detected in one anthropod (*Gymnoplectron* spp), and in the livers of one owl (*Ninox novaeseelandiae*) and one parakeet (*Cyanoramphus novaezelandiae*). Clearly, it is difficult to draw conclusions from such a small study, but it does highlight the potential of exposure. The occurrence of residues in the anthropods raise concerns about insectivore exposure whereas other studies have all focused on carnivorous species such as raptors and vultures.

In a previous study of Norwegian raptors (Langford et al, 2013), brodifacoum, bromadiolone, difenacoum and flocoumafen were detected in golden eagle (*Aquila chrysaetos*) and eagle owl (*Bubo bubo*) livers at a total SGAR concentration of between 11 and 255 ng/g in approximately 70% of the golden eagles and 50% of the eagle owls examined. In the absence of specific golden eagle and eagle owl toxicity thresholds for SGARs, a level of >100 ng/g was used as a potential lethal range, accepting that poisoning may occur below this level. Thirty percent of the golden eagle and eagle owl livers contained total SGAR residue levels above this threshold.

A recent publication (Fourel et al., 2018) stated that liver samples of red fox from France had higher concentrations of trans compared to the cis isomer of bromadiolone. The cis-isomer were rarely found in the red fox samples and the authors concluded that the cis-isomer would not persist in the food chain. Further, they recommended that monitoring of rodenticides should differentiate diastereoisomers in non-target species.

1.3.12 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 presence of the targeted pollutants in a terrestrial urban environment in Norway, and to assess the bioaccumulation potential of the pollutants. Same locations for the various matrices were aimed at when possible. This was most relevant for sampling of air, soil, earthworms and, when possible, fieldfare eggs. In additions, locations were selected to reflect the different area uses in an urban setting: Alnabru, an industrialised site; Slottsparken, an urban park surrounded by traffic; Frognerseteren, a popular skiing area, also used for international competitions; Grønmo, an area with a former landfill, and VEAS, Vestfjorden Wastewater Treatment Plant, Norway's largest sewage treatment plant.

Fieldfare from Grønmo (a former landfill) has revealed high loads of PFAS during previous years' monitoring. We therefore wanted to investigate if the same pollutants and loads was reflected in air, soil and earthworm at this site in 2018. Grønmo replaced Fornebu site for soil and earthworm sampling in 2018. In addition, the industrialised area of Alnabru has revealed high concentrations of PFASs in soil and earthworm, but we lacked data for fieldfare eggs from the same area. In 2018 we sampled three sites at Alnabru (Alna I, II and III) for fieldfare eggs.

The different biota species included in the study were selected to represent different trophic levels, from primary consumers (earthworm) via secondary consumers (fieldfare and badger) to a top predator (sparrowhawk). In addition, two omnivore generalists representing a truly urban environment, the red fox and the brown rat, were chosen. Sparrowhawk were used in this study to give insights to how terrestrial top predators within both urban and rural habitats are affected by pollution levels and their biomagnification potentials. An overview over the analysed species and 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 (Coordinates can be found in the Appendix 2).

Sample type	No. of samples	Location	Date	Sampling strategy
Air	5	Oslo	2018	Passive air samples
Soil	5	Oslo	2018	Pool of individual samples
Earthworms (*Lumbricidae*)	5	Oslo	2018	Pool of individual samples
Fieldfare (*Turdus pilaris*)	10	Oslo	2018	Pool of 2 eggs from same nest
Sparrowhawk (*Accipiter nisus*)	9	Oslo	2018	Fresh eggs
Brown rat (*Rattus norvegicus*)	9	Oslo	2018	Pool of 2 individual samples for samples
Red fox (*Vulpes vulpes*)	10	Oslo	2018	Individual liver samples
Badger (Melis melis)	8	Oslo	2018	Individual liver samples
Bumblebees	30	Oslo & Hvasser	2018	Individual samples (only PFAS analyses)

Air

Air concentrations were measured using two types of passive air samplers (PAS) at five locations; Grønmo, VEAS, Alnabru, Slottsparken, and Frognerseteren, the same sites as for soil and earthworms. The PAS were prepared, deployed and retrieved by NILU personnel. Each PAS type was exposed for three months (Table 3) according to standard routines in the guidance document for the Global Monitoring Plan, GMP (UNEP, 2015). Field blanks for air samples were continuously included. These were transported and stored together with the exposed samples to provide information about any contamination during sampling or storage.

VEAS is the largest wastewater treatment plant in Norway. For the site at VEAS, the air samplers were installed at the pipe outlet, see Figure 1 (left photo), in order to capture potential polluted air from the plant.

The two types of PAS were chosen to collect a wide spectrum of volatile and semi-volatile pollutants; i) PUF disks were used to collect semi-volatile non-polar pollutants (i.e. PCBs, PBDEs, nBFRs, CPs, and OPFRs), and ii) XAD was used to collect more volatile and more polar pollutants (i.e. siloxanes and PFAS). While XAD is considered a pure gas-phase sampler, the PUF-PAS can also sample particle-associated compounds to some extent although with lower accuracy. Some particle-associated compounds (e.g. BDE-209) are collected by the PUF-PAS, but the results should be considered as less certain due to the uncertainties of the uptake in the sampler (which is not designed to sample particles, but gases) (Bohlin et al., 2014; Melymuk et al., 2016). The PUF disk and the XAD are placed in metal containers specially designed for each sampler type to control the uptake of chemicals. The use of PAS for volatile-semivolatile organic pollutants is considered as a good sampling strategy for screening at several sites simultaneously (Melymuk et al., 2016). It is important to highlight that the PAS are designed as complementary tools to active air samplers and that the PAS provide semi-quantitative levels which should be treated with caution in further analyses. The data from PAS can be compared between sampling sites when normalized to ng/day or further converted to estimated concentrations in air (pg/m3). Conversion to estimated concentrations is done using class-specific uptake rates obtained from calibration studies (Bohlin et al. 2014; Melymuk et al., 2016). The estimated concentrations in air can then be compared with data from active air samplers in previous studies. However, a direct comparison to data from active samplers used at monitoring stations (for example Zeppelin and Birkenes stations) should be done with caution as the accumulation in PAS and the applied uptake rates introduce factors of uncertainty.

For the targeted pollutants in this study there are published uptake rates from calibration studies for PCBs, PBDEs, cVMS and CPs, but not for PFAS, OPFRs and dechloranes (Bohlin et al., 2014; Krogseth et al., 2013; Li et al., 2012). For PCBs and CPs, an uptake rate of 4 m3/day is used in this study (Harner et al., 2006; Bohlin et al., 2014; Li et al., 2012). For PBDEs an uptake rate of 2 m3/day is used (Bohlin et al., 2014) and for siloxanes an uptake rate of 0.5 m^3/day was used (Krogseth et al 2013a). Data from the PAS in this study are presented as ng/day for all targeted pollutants and as estimated air concentrations (pg/m3 or ng/m3) for the pollutants with uptake rates as mentioned above, without including physical-chemical properties for the specific compounds and ambient temperature for the specific site in the sampling period. Due to the uncertainty of uptake rates, it is first recommended to make a relative comparison of levels (ng/day) across sites for the various pollutant groups in this present study.

Table 3: Locations and number of exposure days for passive air samples

Air samples	Deployed 2018	Retrieved 2018	Number of exposure days
Slottsparken (Dronningparken)	June 26	October 4	100
Frognerseteren (Holmenkollen)	June 26	October 4	100
Grønmo	June 26	October 4	100
Alnabru	June 26	October 4	100
VEAS	July 4	October 3	91

*Figure 1. **Air samples (PUF and XAD) at two sampling sites, VEAS site to the left and Slottsparken to the right.***

Soil

Soil samples were collected at the same five locations as air samples, Table 4. The upper layer of 0-20 cm of soil was sampled. The different locations varied between forest soil (Holmenkollen), and urban soil characterized by little plant debris and artificial fertilisation (Slottsparken), and potential industrially affected soil (Alnabru, Grønmo, VEAS). Soil site for Alnabru is shown in Figure 2.

Earthworms (*Lumbricidae*)

Earthworms were collected at the same five locations in Oslo as the soil samples to allow a direct comparison. All pooled samples consisted of up to 10 individuals. To purge their guts, earthworms were kept in plastic containers lined with moist paper sheets for three days before being frozen at -21°C.

Table 4: Locations for soil and earthworm sampling.

Location for soil and earthworms	Soil depth	Site description
Slottsparken	10-15 cm	Castle park, tourism
Frognerseteren	15-20 cm	Recreation, tracks
Grønmo	15-18 cm	Landfill, golf, road
Alna	15-20 cm	Industry, railway
VEAS	15-20 cm	Road, schools, VEAS STP

Figure 2: Soil and earthworm sampling site at Alna together with field blank (egg).

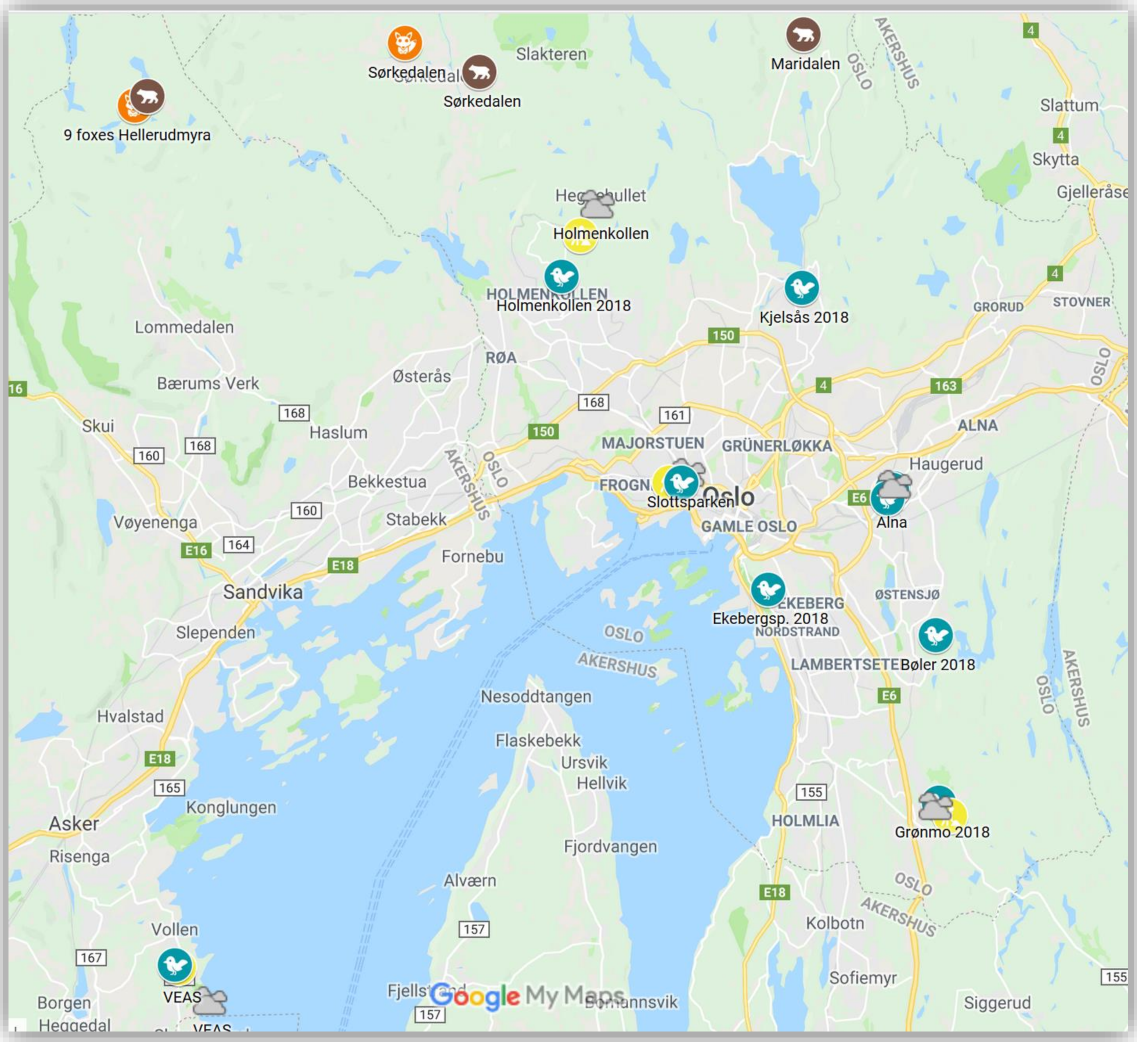

Figure 3: Locations for soil & earthworms (yellow icon), air samples (grey icon), fieldfare egg (blue-green icon), badger liver (brown icon) and red fox liver (orange icon). Brown rats not shown due to no coordinates, but samples are from central Oslo. Coordinates for the various sites and sample types are given in Appendix 2.Locations for sparrowhawk eggs are not shown in the figure due to the protection of the species.

Fieldfare *(Turdus pilaris)*

Two fieldfare eggs were collected from each out of ten nests in the Oslo area, Table 5 and Figure 3, under permission from the Norwegian Environment Agency. 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. 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 was removed from the shell and transferred to clean glass vials for storage at – 21 °C. The dried eggshells were measured (length, breadth and weight of shell) in order to calculate the eggshell index, which is a measure of eggshell quality (Ratcliffe, 1970). In addition, the shell thickness was measured using a special calliper (Starrett model 1010).

Table 5: Locations and collection date for fieldfare egg sampling (Coordinates for the sites are given in Appendix 2)

Location for fieldfare egg sampling	Collection date
Grønmo	07.05.2018
Ekebergparken	07.05.2018
Bøler	07.05.2018
Alna I	07.05.2018
Alna II	07.05.2018
Alna III	07.05.2018
Kjelsås	07.05.2018
Holmenkollen	07.05.2018
Arnestad (near VEAS)	07.05.2018
Slottsparken	08.05.2018

Sparrowhawk *(Accipiter nisus)*
Sparrowhawk eggs were collected at different locations in the Oslo area (N=9). The exact location of the nests is known to the authors and the contractor, but will not be published here to protect the nesting sites. Nests were located early in the breeding season and sampled in May just after eggs had been laid. The eggs were handled by the same method as the fieldfare eggs at NINA.

Brown rat *(Rattus norvegicus)*
Brown rats were caught using clap-traps (no rat poison involved).

Red fox *(Vulpes vulpes)*
Nine out of ten red foxes were shot by local hunter in the area around Hellerudmyra. One animal came from Sørkedalen. The weight of the animals varied from 4.5 to 7.4 kg. Among the sampled foxes, there were seven males and three females. 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).

Badger *(Melis melis)*
Eight liver samples of badger was available for the project. All but one of the badgers were obtained as shot. One was hit by a car. Four animals came from the area Kryssbydalen, three from Maridalen and one form Sørkedalen. The weight of the animals varied from 3.7 to 13.6 kg.

Dissection of liver samples from red fox, rat and badger was carried out at the laboratories of NINA, applying the siloxane relevant precautions, while the livers from the Veterinary institute were sampled in their laboratory. The samples were wrapped in aluminium foil and thereafter put into sealed polyethylene bags before being frozen at – 21°C

Bumblebees
The sampling of bumblebees were from three locations, two locations at Frognerseteren and Sognsvann in the Oslo area, and Hvasser as a reference area.

One sample consisted of one bumblebee, 10 from each locations, 30 in total. The 30 samples were only analysed for PFAS compounds.

Quality assurance
NINA, NIVA and NILU are certified to both ISO 9001 and 14001. The laboratories of NILU and NIVA are furthermore accredited according to ISO 17025. 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 to avoid materials which may contain PFAS, siloxanes and BFRs during sampling, handling and storage, were followed. Sampling materials such 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. Fieldblanks for air samples were continuously included. These are transported and stored together with the exposed samples and give information about any contamination during sampling or storage.

2.2 Sample preparation and analysis

Preparation of bird eggs and measurement of eggshell thickness
Length (L) and breadth (B) of eggs were measured with a vernier calliper to the nearest 0.1 mm. The eggs were weighed before emptying (W_b). A hole was drilled at the equator, and the contents were transferred to a glass container and sealed with sheets of aluminium foil. The egg volume was calculated by using the formula (Hoyt, 1979):

$$V = 0.51 * L * B^2$$

The dried eggshells were measured (length (mm), breadth (mm) and weight (W_s) (in mg)) in order to calculate the eggshell index, which is a measure of eggshell quality (Ratcliffe, 1970). In addition, the shell thickness was measured using a special calliper (Starrett model 1010). The data for shell thickness can be found in the Appendix.

The shell index was calculated according to following equation:

$$SI = W_s \text{ (mg)}/L \times B.$$

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

<u>PBDEs, CPs, DDTs, pesticides and PCBs.</u> 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 sulphuric acid to remove the lipids. Extracts were measured using GC/HRMS. Air and soil: Soxhlet extraction in acetone/hexane (1:1, v:v) were used for all samples prior to GC/MS analysis. Soil: Solvent acetone: hexane, Cu-treatment in order to remove sulphur. The extract was evaporated and treated 2-4 times with 3-4 mL of concentrated sulphuric acid. Following by adsorption chromatography (silica). Air: The extract was evaporated and treated 2-4 times with 3-4 mL of concentrated sulphuric acid. Following by adsorption chromatography (silica).

PFAS. Ionic and new PFAS: Air and soil samples were extracted with methanol whilst biological tissues were extracted with acetonitrile (ACN), subsequently evaporated to 1 ml and treated with emulsive clean-up prior to analyses with UPLC/MS/MS in ESI(-) mode. Neutral PFAS: Samples were homogenized and 2 g aliquots taken. Internal standards were added and the samples were shaken and sonicated for 1 hour with ACN (5 mL) and then centrifuged. The solvent was decanted off and the procedure was repeated and the two extracts were combined. Water was "salted out" with the addition of 1 g of NaCl and the ACN extract was finally centrifuged with a 0.2 um nylon Spin-X filter (Costar).UPLC-HighRes MS analysis: Neutral PFAS analytes were separated on a Acquity BEH C8 column (100 x 2 mm x 1.7 µm) with water and MeOH (both containing 0,2 % NH4OH) using a gradient elution program over a period of 10 minutes with a flow rate of 0.5 ml/min. Analytes were ionized with ESI in negative mode and ions measured with a TOF mass spectrometer.

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

Siloxanes. All operations were performed inside a clean cabinet to avoid contamination by siloxanes from the lab air. In addition, operators retained from using cosmetics or personal care products on the day of sample processing. Soil extraction: One gram of soil was extracted overnight using a biphasic mixture of acetonitrile and hexane (1:1) using a slightly modified method previously published by Sparham et al. (2008; 2011). Hexane fraction was collected and analyzed by Concurrent solvent recondensation large volume injection gas chromatography mass spectrometry (CSR-LVI-GC/MS) using a modified method previously published by Companioni-Damas et al., 2012. Biota extraction: One gram of homogenized egg, liver, or whole body worm was extracted using a biphasic mixture of acetonitrile and hexane (3:1). Extraction mixture was sonicated for 15 minutes followed by vigorous mixing on a horizontal mixer for one hour. Resulting hexane phase was collected and analysed using CSR-LVI-GC/MS. Air samples: Air samples were spiked with ISTD (C13 labeled siloxanes), extracted with hexane and, after addition of RSTD, the extracts were injected to GC-MS without further work-up or concentration.

Dechloranes. Prior to extraction, the samples were added a mixture of isotope labelled PCB and dechloranes for quantification purposes. The soil and biota-samples were extracted with organic solvents and concentrated under nitrogen flow, followed by a clean-up procedure using concentrated sulphuric acid and a silica column to remove lipids and other interferences prior to analysis. Prior to analysis, all samples were concentrated to ~150 µL sample volume. The extracts were injected into an Agilent 7890N GC system coupled to an Agilent 7200 QToF mass spectrometer operated in electron capture negative ionization mode (GC-ECNI-HRMS) and PCB-153 and the dechlorane compounds were quantified based on the use of internal standards.

OPFR. Samples of 1-2g was homogenized and internal standards were added to samples (d12-TCEP, d18-TCPP, d15-TDCPP, d15-TPP, d27-TnBP and d51-TEHP). Samples were extracted by ultrasonication and evaporated to near dryness. Cleanup of the samples was done using solid phase extraction. The sample was eluted using acetonitrile, and the eluate was evaporated to 100-200uL and recovery standard (2,4-TXP-d27) and 50uL of 0.2% formic acid in cleaned deionized water were added. Analysis was carried out on a UPLC/MSMS (TSQ Vantage, Thermo Scientific inc). Multiple reaction monitoring (MRM) of the M+H+ was used using Argon as collisions gas for the monitoring of two product ions for each analyte. Air and soil: The PUF-PAS used for air sampling were spiked with internal standard and extracted using Soxhlet with a solvent mix of Acetone/n-Hexane (1:1, v:v). Extract was concentrated and cleanup was performed using solid phase extraction as for biota and soil samples. Soil samples was added internal standard and extracted by ultra-sonication using acetonitrile. The extract was concentrated and diluted with purified water and cleanup was performed using solid phase extraction using acetonitrile as eluent. Cleaned extract was concentrated, transferred to analytical glass and added recovery standard and 50uL 0.2% formic acid in cleaned deionized water.

Biocides. Coumachlor was used as an internal standard for all samples.
Zinc chloride (200 µl) was added to rat livers (0.3-0.4 g), fox livers (0.6-0.8 g), worms (1 g) or soil (1 g). These were then extracted with 2.5 ml acetonitrile by vortex. Samples were centrifuged before extracts were analysed by LC-HRMS (liquid chromatography high-resolution mass spectrometry). Rodenticides were separated on a C8 column with a gradient elution of 0.01% formic acid in 75:25 methanol:acetonitrile and 0.01% formic acid in water. CIS-, and TRANS-, isomers were identified by retention time as per Fourel et al (2018). [Sci. Tot. Env. (622-623) pp 924-929]

UV compounds. Chrysene-d_{12} and benzophenone-d_{10} was used as internal standards.
Liver, worms (1.7 g) and soil (0.6-1.6 g) were extracted with iso-hexane/isopropanol (50/50) by ultrasonication for 1 hour. Samples were centrifuged and the solvent decanted. This extraction was repeated, and the extracts combined. The iso-hexane fraction was isolated by the addition of 0.5% NaCl and evaporated to approximately 1 ml before solvent exchange to cyclohexane. Different clean up methods were used for each matrix in response to differing interferences.

Phenolic compounds. Soil samples were extracted with accelerated solvent extraction and further cleaned with SPE. Egg samples were extracted using ultrasonic assisted liquid extraction, cleaned on a Florisil column and with dSPE (C18). Remaining interferences were removed with SPE. Biological samples were extracted with acetonitrile and water. Separation of the organic fraction including analytes was induced by the addition of salts. Fat was removed by liquid-liquid extraction with hexane and remaining interferences were removed with SPE. All samples were analyzed with the use the Agilent 1290 UHPLC coupled to Agilent 6550 HR-QTOF equipped with Agilent Dual Jet Stream electrospray source operating in a negative mode.

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 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. 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. Therefore, all sample preparation was performed within a clean cabinet (equipped with HEPA- and activated carbon filter) to avoid contamination from sources within the indoor environment and to allow trace analysis of these compounds in matrices from pristine environment (Krogseth et al. 2013b; Warner et al. 2013). Samples were analysed in groups with 3 procedural blanks with every extraction batch to account for background response and analytical variation. The data were used to calculate limits of quantification (average blank response + 3 times standard deviation of response). To ensure accuracy of measured results, a random sample from each matrix was selected for duplicate analysis. Field blanks were prepared 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 followed by additional treatment with dichloromethane. After ultrasonic treatment, the field blanks were dried in a clean cabinet to avoid contamination. After drying, the field blanks were placed within solvent washed polypropylene /cellulose filter bags and put into 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.

2.3 Biomagnification

Like in the urban terrestrial study from 2017 (Heimstad et al., 2018) and previous years, 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, badger = 3, tawny owl = 3, fieldfare = 3, and sparrowhawk = 4.

For earthworms we modified the TL value by multiplying it with the ratio between the sample $\delta^{15}N_{sample}$ and the mean $\delta^{15}N$ 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):

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

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

For further data assessment of the biomagnification, all hydrophobic pollutants such as PCB and PBDE data were lipid normalized. PFAS are not lipophilic compounds (Kelly, 2009), and we calculations were performed on wet weight basis. 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.

The here estimated TMFs must be treated with caution since the recommended tissue type (muscle) could not be used. Instead liver and egg samples were available which are characterized by a much shorter turnover rate and thus reflect the short term exposure rather than the long term one.

2.4 Statistical methods

Statistics were performed using SPSS statistics, ver. 25 (® 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).

In many of the sample groups, the values of measurement were below the detection limit (LOD). However, if some, but not all samples of a certain species and type were below LOD, the following calculation (Voorspoels et al., 2002) was made to substitute LOD with an expected concentration value (C_{exp}), using the total number of analysed samples of same type (N_{tot}), and the number of samples with concentration levels above LOD (N_{above}):

$$C_{exp} = LOD^* N_{above}/N_{tot}.$$

In such cases, <LOD has been substituted with C_{exp} in the calculation of mean values, and the number of detected (n) over measured samples (N) are given in Table 6.

3. Results

In total, 138 single compounds were analysed in this study. Some of the compounds such as pesticides were only measured in sparrowhawk. Metals were not measured in air samples and biocides only in liver samples of fox, rat and badger. Some compounds such as OPFR and UV substances were only analysed in one or three pooled samples prepared from the various environmental samples.

In the chapters below, we mainly discuss the sum for each group of pollutants investigated. Single compounds/congeners are only discussed in special cases, for instance when high concentrations were detected. Box and whiskers plots (SPSS program) are given for each component class. Concentrations (mean, maximum and minimum) are summarized in the tables for each pollutant class and individual data can be found in the Appendix 1.

Table 6 below shows the ratio of detected to analysed chemicals in the samples (n/N) in the different sample types. As can be seen, metals were detected in almost all samples which is also the case with PCBs, many of the perfluorinated sulfonates (PFSA) and carboxylates (PFCA).

Components	Air	Soil	Earthworm	Fieldfare egg	Sparrowhawk egg	Red fox liver	Rat liver	Badger liver
Cr	n.a.	1.0	1.0	0.9	1.0	1.0	1.0	1.0
Ni	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cu	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Zn	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
As	n.a.	1.0	1.0	1.0	0.9	1.0	1.0	1.0
Ag	n.a.	1.0	1.0	0.9	0.1	1.0	0.2	1.0
Cd	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Pb	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Hg	n.a.	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PCB28	1.0	1.0		0.4	1.0		0.6	
PCB52	1.0	1.0	0.8	1.0	1.0	0.1	0.1	
PCB101	1.0	0.4	0.4	1.0	1.0	0.3	0.4	0.1
PCB118	1.0	0.4	0.6	1.0	1.0	0.3	0.8	0.1
PCB138	1.0	0.4	0.4	1.0	1.0	0.9	0.9	0.1
PCB153	1.0	0.4	0.4	1.0	1.0	1.0	0.9	0.1
PCB180	1.0	0.6	0.4	1.0	1.0	1.0	1.0	0.9
BDE47	1.0	0.4	0.4	1.0	1.0	0.8	0.8	0.6
BDE99	1.0	0.6	0.4	1.0	1.0	0.1	0.7	
BDE100	1.0	0.8	0.6	1.0	1.0	0.7	1.0	
BDE126		0.4		0.9	0.6		0.1	
BDE153	1.0	0.4		1.0	1.0	0.9	0.9	
BDE154	1.0	0.4		1.0	1.0		0.4	
BDE175/BDE180	1.0	0.4	0.2	1.0	1.0	0.4	0.8	0.1
BDE190		0.2			0.3		0.2	
BDE196	0.2	0.2		1.0	0.7	0.3	0.6	
BDE202	0.2	0.4		1.0	0.8	0.3	0.4	
BDE206	0.6	0.6		1.0	0.1	0.7	0.7	
BDE207	0.6	0.6	0.2	1.0	0.7	0.9	1.0	0.3
BDE209	0.6	0.8	0.6	1.0	0.2	0.8	1.0	
PFBS	1.0	0.2	0.6			0.2		0.9
PFPS			0.1					
PFHxS	0.8	0.2	1.0	0.8	0.9	0.7		0.9
PFHpS			0.6	0.9	1.0	0.9		1.0
brPFOS		0.8	0.8	1.0	1.0	0.2		0.8
PFOS		1.0	1.0	1.0	1.0	1.0		1.0
PFNS			0.2	0.2	1.0	0.1		0.1
PFDcS			0.4	0.9	1.0	0.3		1.0
PFUnDS								
PFDoDS								
PFTrDS								
PFTeDS								
PFBA								
PFPA			0.2					0.1
PFHxA		0.6	0.4	0.2		0.2		
PFHpA		0.8	1.0	0.4	0.7	0.6		0.8
PFOA		1.0	1.0	1.0	1.0	0.9		1.0
PFNA		0.8	1.0	1.0	1.0	1.0		1.0
PFDcA		0.8	1.0	1.0	1.0	1.0		1.0
PFUnA		0.4	1.0	1.0	1.0	1.0		1.0
PFDoA		0.4	1.0	1.0	1.0	1.0		1.0
PFTriA		0.6	1.0	1.0	1.0	1.0		1.0
PFTeA		0.2	1.0	1.0	1.0	1.0		0.9
PFHxDA			0.8	1.0	1.0	0.1		1.0
PFOSA			0.4	0.6	0.7	0.4		1.0
meFOSA								
etFOSA								
meFOSEA								
meFOSE								
etFOSE								
6:2 FTOH								
8:2 FTOH								
10:2 FTOH								
12:2 FTOH								
6:2FTS			0.2	0.1				
8:2 FTS			0.4	1.0	1.0	0.1		1.0
10:2 FTS				1.0	1.0			0.3
PFECHS					1.0			
Cl-PFOS								
Cl-PFOA								

Table 6: The detection rate (n/N) for each chemical in the various matrices, no colour is zero detection. The intensity of the colour reflects the detection rate, with dark green indicating the highest detection rate.

Components	Air	Soil	Earthworm	Fieldfare egg	Sparrowhawk egg	Red fox liver	Rat liver	Badger liver
SCCP	1.0	1.0	1.0	0.5	1.0	1.0	1.0	1.0
MCCP	1.0	1.0	0.8	0.8	1.0	1.0	1.0	1.0
D4	1.0	0.2				0.2	0.2	
D5	1.0				0.1	0.6	0.4	
D6	1.0		1.0	0.9		0.4	0.3	0.1
TEP	n.a.			n.a.				
TCEP	1.0	1.0	1.0	n.a.				
TPrP				n.a.				
TCPP	1.0	1.0	1.0	n.a.		0.3		
TiBP	1.0		1.0	n.a.				
BdPhP				n.a.				
TPP	1.0	1.0	1.0	n.a.				0.3
DBPhP	1.0			n.a.				
TnBP	1.0	1.0	1.0	n.a.				
TDCPP	1.0		1.0	n.a.				
TBEP	1.0	1.0	1.0	n.a.				
TCP	0.8	1.0	1.0	n.a.				
EHDP	1.0	1.0		n.a.				
TXP	0.4			n.a.				
TEHP	0.2	1.0		n.a.				
ATE (TBP-AE)		1.0			0.1		0.4	
a-TBECH	1.0	0.2			0.1		0.2	
b-TBECH	1.0	1.0			0.1		0.1	
g/d-TBECH	0.2				0.8		0.0	
BATE		1.0	0.4	0.1			0.9	
PBT	0.8						0.1	
PBEB							0.1	
PBBZ	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0
HBB	0.4	1.0	0.2	0.1	0.7		0.6	
DPTE	0.6				0.1		0.4	
EHTBB	0.2						0.1	
BTBPE	1.0	1.0	1.0	1.0	0.9	1.0	0.3	0.3
TBPH (BEH /TBP)	0.8	0.4	0.2		0.1	0.2	0.2	0.0
DBDPE	0.4	0.4	0.2	0.6	0.3	0.3	0.4	0.3
DBA	n.a.	n.a.			0.1		n.a.	n.a.
Dec-602	n.a.	n.a.	0.2	1.0	1.0	1.0	n.a.	n.a.
Dec-603	n.a.	n.a.		0.9	1.0	0.3	n.a.	n.a.
Dec-604	n.a.	n.a.			0.1		n.a.	n.a.
Dec-601	n.a.	n.a.			0.1		n.a.	n.a.
syn-DP	n.a.	n.a.	0.2	0.2	0.9	0.1	n.a.	n.a.
anti-DP	n.a.	n.a.	0.2	0.9	1.0	0.5	n.a.	n.a.
a-HCH	n.a.	n.a.	n.a.	n.a.	0.2	n.a.	n.a.	n.a.
b-HCH	n.a.	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.
g-HCH	n.a.	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.
o.p'-DDE	n.a.	n.a.	n.a.	n.a.		n.a.	n.a.	n.a.
p,p'-DDE	n.a.	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.
o,p'-DDD	n.a.	n.a.	n.a.	n.a.	0.2	n.a.	n.a.	n.a.
p,p'-DDD	n.a.	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.
o,p'-DDT	n.a.	n.a.	n.a.	n.a.	0.1	n.a.	n.a.	n.a.
p,p'-DDT	n.a.	n.a.	n.a.	n.a.	1.0	n.a.	n.a.	n.a.
BP3	n.a.	1.0		n.a.				
EHMC-Z	n.a.	1.0		n.a.				
EHMC-E	n.a.	1.0		n.a.				
UV-329	n.a.			n.a.				
UV-328	n.a.	1.0		n.a.	0.7	1.0	1.0	
UV-327	n.a.	1.0		n.a.	0.7	0.3	1.0	
OC	n.a.	1.0	1.0	n.a.	0.3	0.0	0.3	
Bromodiolone	n.a.	n.a.	n.a.	n.a.	n.a.	0.8	0.8	
Brodifacoum	n.a.	n.a.	n.a.	n.a.	n.a.	0.8		0.1
Flocumafen	n.a.	n.a.	n.a.	n.a.	n.a.			
Difenacoum	n.a.	n.a.	n.a.	n.a.	n.a.	0.3		
4,4-bis A	n.a.		1.0			0.3	0.3	
4,4-bis- S	n.a.						0.3	
4,4-bis-F	n.a.		0.3					
TBBPA	n.a.							
4-tert-octylphenol	n.a.							
4-octylphenol	n.a.							
4-nonylphenol	n.a.							

3.1 PCBs

3.1.1 Air

As in 2017, all seven PCBs (PCB_7) were detected at all the five sampling sites and PCB 28, 52, 101 were the dominant congeners. The highest concentrations of PCB_7 were observed at Slottsparken with sumPCB (=$SumPCB_7$) of 913 pg/day, followed by Alnabru, Frognerseteren, VEAS and Grønmo with 119, 35, 29 and 25 pg/day, respectively. The 2018 sum concentrations at Slottsparken and Alnabru were higher than sum concentrations detected in 2017 with 500 and 80 pg/day. The concentrations at the other sites were comparable to those measured in 2017.

The calculated estimated air concentrations for sum PCB_7, using an uptake rate of 4 m^3/day, were 230 pg/m^3 at Slottsparken, 30 pg/m^3 at Alnabru and 9, 7 and 6 pg/m^3 at Frognerseteren, VEAS and Grønmo, respectively.

For comparison, the concentrations of $sumPCB_7$ in air from the background air monitoring station at Birkenes in southern Norway (2.5-2.7 pg/m^3 in 2015-2017) are 10-100 times lower than those measured at Slottsparken and Alnabru in this study, but comparable to those at Frognerseteren, VEAS and Grønmo (Bohlin-Nizzetto et al, 2015; Bohlin-Nizzetto et al, 2016; Bohlin-Nizzetto et al, 2017). The dominating congeners of PCB_7 were 28, 52 and 101 at Birkenes, in accordance with the results from the PAS measurements in Oslo in 2018. A direct comparison to data from active samplers used at monitoring stations (for example Zeppelin and Birkenes stations) should be done with caution as the accumulation in PAS and the applied uptake rates introduce factors of uncertainty.

The higher concentrations observed at Slottsparken and Alnabru in this study indicates that some specific sites in the urban area of Oslo act as significant source to PCB concentrations in air. For information, the deployment of PAS in Slottsparken had to be done using a protection felt below the samplers during all the sampling period (in order to protect the trees). Chemical analysis of these protection felts showed presence of PCBs in the felts ($sumPCB_7$: 16 ng/100 cm^2). It cannot be excluded that the samplers in Slottsparken can have been affected by the PCBs in these felts, especially if the felts have been extensively used to protect many other trees in the park. This will be evaluated by NILU in 2019. However, the findings of PCBs in both soil and earthworms from Slottsparken, do indicate a local PCB source in this city environment, and most probably also from other sources than only the felt.

3.1.2 Soil

The highest sumPCB concentration was observed at the site Grønmo with 5.0 ng/g dw followed by Slottsparken, 3.9 ng/g dw. All congeners could be detected at these two sites. The other sites revealed lower sum concentration (0.2-0.4 ng/g dw) where PCB28 and 52 were dominating. According to the Norwegian guidelines on classification of environmental quality of soil (normverdi), 10 ng/g dw $sumPCB_7$ corresponds to a good environmental status[2]. None of the samples analysed in this study exceeded this threshold value.

3.1.3 Earthworms

SumPCB concentrations in earthworms ranged from <LOD to 4.8 ng/g ww and is comparable with the 2017 data. PCB28 was below LOD at all sites. Grønmo and Slottsparken had the highest

[2] https://lovdata.no/dokument/SF/forskrift/2004-06-01-931/KAPITTEL_1-2#KAPITTEL_1-2

sumPCB reflecting a similar spatial trend as found in soil. The median sumPCB concentration of 2.3 ng/g ww was in accordance with previous year's data of 1.15 and 2.27 for 2017 and 2016, respectively.

3.1.4 Fieldfare

SumPCB concentrations across the 10 fieldfare eggs varied between 17 to 218 ng/g ww compared to 2017 data with a range from 13.3 to 60.9 ng/g ww. The higher chlorinated PCB-138, 153 and 180 congeners dominated, but PCB101 had slightly higher concentrations than PCB-118. The highest sum value was found in eggs collected at Arnestad near VEAS with 218 ng/g ww, followed by Ekebergparken and Alna 2 of 75.7 and 50.4 ng/g ww respectively. The median sum value of 31.0 was comparable with a median of 38.5 in 2017, which was higher than the median concentration 17.9 and 18.7 ng/g ww reported for the 2016 and 2015 data (Herzke et al., 2016; 2017).

For improved interspecies comparison lipid adjusted concentrations (lw) were used to compare with other published data. In our study, SumPCB varied between 495 to 11480 ng/g lw in the fieldfare eggs, with a mean value of 2146 ng/g lw. The mean value in our study is approximately half of that found in eggs of great tits in Belgium (mean $sumPCB_{21}$ concentrations of 4110 ng/g lw) (Voorspoels et al., 2007). 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, a suburban site close to Oslo. The PCB concentration of 22 congeners of nearly 1000 ng/g lw in the Norwegian location was half of the mean value of $SumPCB_7$ (2146 ng/g lw) in our present study. A more recent study on starling eggs (*Sturnus vulgaris*), sampled worldwide, showed less than 500 ng/g lw sumPCBs at one Norwegian rural location in Northern Trøndelag (Eens et al. 2013), which is lower than most sites in the present study.

3.1.5 Sparrowhawk

Nine eggs were available for analysis, all from the Oslo area. In general, higher PCB concentrations were detected than in fieldfare eggs. The maximum concentration of sumPCB in sparrowhawk eggs was 1873 ng/g ww in 2018 compared to a maximum value of 1299 and 1700 ng/g ww for 2017 and 2016, respectively. PCB-138, 153 and 180 were the dominating PCB congeners. During the 1970's, mean PCB values of more than 23 000 ng/g ww were measured in sparrowhawks from Norway, making it one of the most contaminated species by environmental pollutants at that time. Eggshells from these birds were between 20 and 30 % thinner than normal (Nygård and Polder, 2012). However, pollutant concentrations have decreased considerably in Norwegian sparrowhawks since then. Findings from the period 2005-2010 showed a mean value of 229 ng/g PCBs in sparrowhawk eggs in Norway (Nygård and Polder 2012). From the 2018 data, a mean value of sumPCBs of 524 ng/g ww was comparable to 2017, 2016 and 2015 data[3] when measured values were 460, 660 and 750 ng/g ww, respectively (Herzke et al., 2016, 2017; Heimstad et al., 2018).

Giesy et al. (1995) and Quinn et al. (2013) suggested 4000 ng PCB/g egg as a reasonable estimate of the concentration required to cause adverse effects in bird eggs. This is higher than what is observed in sparrowhawk eggs from Oslo.

[3] http://www.miljodirektoratet.no/no/Tema/Miljoovervakning/Naturovervaking/Giftfritt-miljo/Miljogifter-i-terrestrisk-og-bynart-miljo/Rapporter-fra-programmet-Miljogifter-i-terrestrisk-og-bynart-miljo/

Sparrowhawk feeds on other birds. Its food choice (Hagen et al. 1952), makes it vulnerable to pollutants that biomagnify via the food chain, but due to variations in local prey species, one might expect large variations in pollutant levels. The presence and still high concentrations of regulated POPs like PCB in sparrowhawks emphasize the need of continuous monitoring and for the identification of potential local urban sources. The total accumulated body burden of pollutants in mother birds are likely to be most important during egg laying. The total accumulated body burden in migratory birds like sparrowhawks would include previous accumulated PCBs from exposure in wintering grounds, during migration and the amount of pollution accumulated after reaching the breeding-grounds in the spring. The migration from lower to higher latitudes during spring time is energy demanding, and it is uncertain how much of the pollutant load is still left in the fat resources of the bird upon arrival to their breeding grounds at higher latitudes. It is a disadvantage for migrating species to carry the extra burden of developing eggs on migration. It is therefore common that eggs are formed on a daily basis at the breeding-site (Perrins 1996). A study from Svalbard of snow buntings indicated that concentration of POPs in egg were influenced by local pollution (Warner et al, 2019; Kristoffersen, 2012). Significant higher concentrations (ng/g wet weight) of $SumPCB_7$ were found in the eggs from the Russian settlements (Barentsburg and Pyramiden) than in the eggs from the Norwegian (Longyearbyen and Ny-Ålesund) settlements, Warner et al, 2019; Kristoffersen, 2012).

3.1.6 Brown Rats

PCBs were analysed in nine available rat liver samples. SumPCB varied between 0.1 to 74.7 ng/g. Maximum sumPCB was lower than data for 2017 and comparable with sumPCB data from 2016 from <LOD and 50.2 ng/g ww. As in 2016 and 2017, PCB-138, PCB-153 together with 180 dominated the PCB pattern. The median of sumPCB of 3.6 ng/g ww were lower than 2017 data with a median of 15 ng/g ww and comparable with 2016 median value of 2.8 ng/g ww (Herzke et al., 2017).

3.1.7 Red fox

In total, 10 livers of foxes, all from the Oslo area, were analysed for PCBs. PCB-153 and 180 were the dominant congeners. The sumPCB concentration ranged between 7 and 310 ng/g ww and comparable with 2017 data from 2.4 and 261 ng/g ww. This years' median sumPCB was 14.7 ng/g ww compared to 9.2 ng/g ww in 2017 and 14.2 ng/g ww in 2016. One fox liver sample had significantly higher PCB-153, PCB-138 and PCB-180 concentration than the other nine samples. For comparison, in a study by Mateo et al., 2012, sumPCB concentrations of 1262 ng/g ww were reported in fox liver samples from a natural reserve in south west Andalucia in Southern Spain, i.e. levels approximately 5 times higher than the maximum sumPCB concentration in our present study.

Andersen et al. reported in Arctic fox liver from Svalbard, Norway, a median sumPCB of 342 ng/g ww, more than thirty times higher than median sumPCB of the urban foxes in this study. The higher concentration in Arctic fox are explained by their marine diet (Andersen et al., 2015).

3.1.8 Badger

Only one sample out of the eight liver samples had concentrations levels above LOD for other congeners than PCB-180. The sumPCB values varied between <LOD and 2.4 ng/g ww and were significantly lower than rat and red fox liver, also when normalised to lipid weight. In a study from south west Andalucia in Southern Spain, Mateo et al. (2012) analysed one badger liver

sample and the concentrations of the dominating congeners PCB-138, PCB-153 and PCB-180 were 23.5, 12.3 and 25.1 ng/g ww, considerable higher levels than in our 2018 liver samples of badgers.

3.1.9 Summary of PCB results

PCB data across all species and media revealed that sparrowhawk had the highest concentrations with mean sumPCB of 524 ng/g ww followed by eggs from fieldfare and red fox liver. PCB 153 dominated in most sample types, Table 7 and Figure 4. PCB-52 and PCB-101 dominated in air as expected due to lower chlorinated PCBs and higher volatility.

Table 7: Mean concentrations in bold with min-max interval in grey below for the various PCB congeners in Air (pg/day), Soil (ng/dw), Earthworm (EW), Fieldfare (FF), Sparrowhawk (SH), Red fox (RF), Badger (B) and Brown rat (BR). All concentrations in biological samples are given in ng/g ww.

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare egg	Sparrowhawk	Red fox	Badger	Brown rat
PCB-28	36.2 4.95-122	0.12 0.10-0.20	<LOD	0.05 <LOD-0.20	1.66 0.12-7.11	<LOD	<LOD	0.18 <LOD-1.01
PCB-52	57.5 6.87-233	0.17 0.07-0.51	0.16 LOD-0.5	0.60 0.12-1.30	1.02 0.26-3.32	<LOD	<LOD	0.1 <LOD-0.70
PCB-101	59.0 5.49-255	0.36 LOD-0.98	0.48 LOD-1.13	4.36 1.44-13.9	13.5 2.87-54.0	0.13 LOD-0.9	<LOD LOD-0.25	0.38 LOD-2.90
PCB-118	13.8 1.43-56.0	0.35 LOD-0.79	0.24 LOD-0.56	1.71 0.88-4.46	31.4 9.49-104	1.18 LOD-9.2	<LOD LOD-0.39	1.29 LOD-8.76
PCB-138	19.8 2.02-83.6	0.54 LOD-1.07	0.69 LOD-1.16	14.5 3.78-55.8	109 23.4-408	8.66 LOD-73.7	<LOD LOD-0.50	4.90 LOD-28.9
PCB-153	30.5 3.15-131	0.63 LOD-1.12	0.79 LOD-1.32	22.4 5.79-99.4	244 46.4-871	23 0.54-172	<LOD LOD-0.92	4.67 LOD-25.3
PCB-180	7.38 0.54-31.9	0.25 LOD-0.43	0.18 LOD-0.32	9.87 2.49-43.8	123 30.3-428	14.2 1.42-54.2	0.19 0.10-0.40	1.98 0.07-7.13

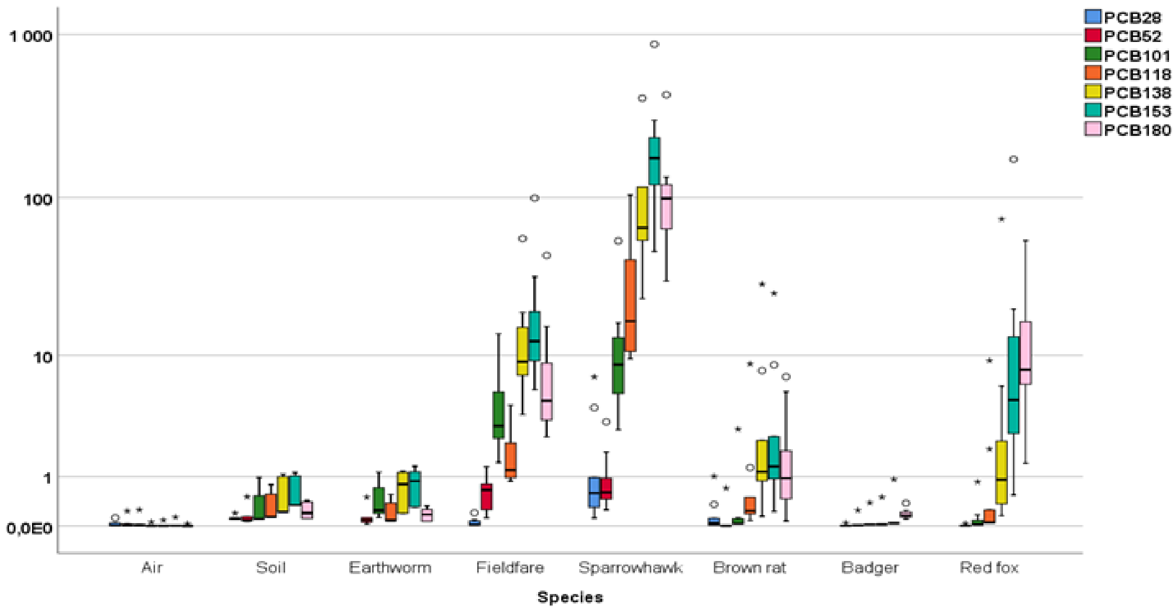

Figure 4. Box plot of PCB congeners in the various samples. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points. Concentrations given in (ng/g ww) for all, except soil given in ng/g dw and air given in ng/day.

3.2 PBDEs and new BFR

3.2.1 Air

Of the targeted PBDE congeners, the congeners BDE-47, -99, -100, -153, -154 and -175/-183 could be detected at all the sites, although at low concentrations compared to PCBs. As in 2017, the highest concentrations of sumPBDE were observed at Alnabru (sumPBDE: 483 pg/day) and Slottsparken (227 pg/day) followed by Grønmo (29 pg/day). BDE-209 dominated the sum PBDE at these three sites and were not detected at Frognerseteren and VEAS. Detection of BDE-209 by the PUF-PAS should be interpreted with caution as it has been shown not to be accumulated in a reliable way by the PUF-PAS. The sumPBDE excluding BDE-209 were 42 pg/day for Alnabru, and 19 and 4 pg/day for Slottsparken and Grønmo, respectively. The sum concentrations for BDE-47, -99 and -100 were 14 pg/day for Alnabru, followed by Slottsparken with 6 pg/day, Frognerseteren and Grønmo with 2 pg/day and VEAS with 1.7 pg/day.

The estimated air concentrations for the sum of BDE-47, -99 and -100, using an uptake rate of 2 m^3/day, were 7 and 3 pg/m^3 for Alnabru and Slottsparken, respectively. The concentrations at the other sites were 1 pg/m^3. The concentrations at Alnabru and Slottsparken are approximately 10-100 times higher than annual mean concentrations of sum of BDE-47, -99 and -100 in background air at Birkenes in 2017 (0.09 pg/m^3). This indicates urban sources for PBDEs.

Of the targeted new BFRs, DBDPE was detected in highest concentrations, but it was only detected at Alnabru and Slottsparken. The concentrations measured at these locations were 170 pg/day and 69 pg/day, respectively. The compound BTBPE, the isomers α- and ß-TBECH were detected at all sites and γ-TBECH only in Slottsparken. More compounds were detectable in Slottsparken, but sumNewBFR was highest at Alna due to the higher concentration of DBDPE.

3.2.2 Soil

Like air samples, soil samples from Alna and Slottsparken had the highest sum concentrations of 3.2 and 1.5 ng /g dw. The sum was dominated by BDE-209 of 1.2 ng/g dw at both sites. For the Alna site, all congeners except BDE-47 were detected, and the higher brominated congeners BDE-196, -202, -206, -207 were detected with concentrations from 0.2 to 0.5 ng/g dw.

The sum of new brominated compounds in soil was higher than the sum of PBDE congeners. Alna and VEAS had highest sumNewBFR with 35.2 and 25 ng/g dw. DBDPE contributed with 34 and 24 ng/g dw to this sum, respectively. TBPE, PBBZ, BATE, ATE and ß-TBECH were detected at all sites. DBDPE was only detected at Alna and VEAS.

3.2.3 Earthworms

Very few BDE congeners were detected in the earthworm samples. Alna dominated with sum of 0.8 ng/g ww followed by Frognerseteren. BDE-209 gave highest contribution to the sum. For the new brominated compounds, BTBPE, PBBZ were detected at all sites, where BTBPE had highest concentrations (0.2-0.3 ng/g ww).

3.2.4 Fieldfare

Almost all BDE congeners were detected in the fieldfare eggs. The sumBDE varied between 2.9 and 50.8 ng/g ww. The highest sum was detected in an egg at Arnestad near VEAS waste water treatment plant. BDE-47 (25 ng/g ww) was the dominant congener followed by BDE-100, -99, -153 and 154. Median sumPBDE was 7.0 ng/g ww and higher than previous years with 2.40, 3.2 and 2.3 ng/g ww in 2017, 2016 and 2015, respectively. BDE-209 was detected in all fieldfare eggs from 0.5 to 4.3 ng/g ww, where the latter was detected at the Alnabru 1 site. On average, sumPBDE concentrations in fieldfare eggs were almost four times lower than the sumPBDE concentrations found in sparrowhawk eggs.

Data for great tits (*Parus major*) were available from a Belgian study (Voorspoels et al. 2007). The authors reported that PBDEs were found in eggs of great tits with levels averaging 220 ng/g lw. In our study, a mean sumPBDE of 449 ng/g lw was found which is almost 3 times higher than 2017 mean data of 162 ng/g lw. The high mean sum value from this year was caused by the high concentration at VEAS; without this sample, the mean value was 202 ng/g lw.

Of new BFRs, DBDPE was detected in six fieldfare bird eggs from 25 to 64 ng/g ww. For the other compounds, only PBBZ was detected in all samples at similar concentrations (0.05 ng/g ww).

3.2.5 Sparrowhawk

As previous years' data 2014-2017 also showed, the dominating PBDE congener was BDE-99, followed by BDE-47, and -100. The mean value for BDE-99 and -47 was 14.6 and 7.1, respectively. As observed in 2017, one egg sample had significantly higher BDE-99, -47, -153 and 100 concentrations (55.3, 26.7, 22.9 and 19.7 ng/g ww, respectively) than the other samples. SumPBDE concentrations ranged from 8 to 147 with a median of 21 ng/g ww, and was comparable to 2017 data. BDE-209 was only detected in two egg samples. In the absence of data from a comparable raptor species nesting in urban sites, we compared our data to data from terrestrial passerine bird eggs from the Pearl River Delta, South China, a highly industrialised area (Sun et al., 2014). In the Chinese study sumPBDE concentrations ranged between 6-14 ng/g ww, and are comparable with this year’s median sumPBDE value for sparrowhawk eggs in Oslo. However, the passerine birds that were included in the Chinese study most probably belong to a different trophic level than sparrowhawk.

A threshold level for reduction of reproduction performance in osprey of 1000 ng/g ww has been proposed by Chen et al., 2010. The levels in sparrowhawk eggs from Oslo in the present study were well below this threshold.

Few new BFR compounds were detected in sparrowhawk eggs. PBBZ and BTBPE were detected in eight of the nine samples. HBB was detected in six samples, but DBDPE in only three samples with 14, 16 and 36.4 ng/g ww, where LOD was quite high of 11 ng/g ww. The concentration of DBDPE was the highest concentration of all new BFR. In the 2015 study, DBDPE was found in nine out of ten sparrowhawk eggs, three out of ten samples in 2016, and in 2017 it was detected in five out of ten samples.

In a study from south China, a median concentration of DBDPE of 12 ng/g lw was measured in muscle samples of common kingfishers near an electronic waste-recycling site (Mo et al, 2012). The sparrowhawk eggs in the Oslo area revealed a median value of 61 ng/g lw, but comparison to levels in muscle are not optimal, the same organs are preferable. In a recent study from Great lakes in Canada measuring DBDPE in plasma of nestling peregrine falcons from rural and urban regions, the median DBDPE concentrations was 4.41 ng/g ww and 2.46 ng/g ww, respectively (Fernie et al., 2017). The lipid content in the plasma was not reported.

3.2.6 Brown rat

SumPBDE concentrations in brown rat livers varied between 2 to 54.8 ng/g ww and was higher than the sumPBDE levels from 2017 (0.5 - 3.6 ng/g ww) and 2016 (0.4 ng/g - 4.5 ng/g ww). In 2018, BDE-209 was detected in all samples compared to only 50 % of the samples in 2017. As in 2017, BDE-207 was in 2018 detected in all samples and at higher concentrations than the lower brominated congeners. The median sumPBDE concentration was 8.9 ng/g ww and higher than last year's median of 2 ng/g ww.

Among the new BFRs, many compounds were not detected in the rat samples, however the compounds PBBZ and BATE were detected in 100 and 90 % of the samples, respectively. DBDPE was detected in four of the nine rat liver samples, and one sample had an extremely high concentration of 940 ng/g ww DBDPE, the next highest was 8.5 ng/g ww.

3.2.7 Red fox

In red fox, the sumPBDE in liver ranged from 0.32 to 5.59 compared to 0.52 to 9.63 ng/g ww in 2017 and 0.31 to 3.5 ng/g ww in 2016.

BDE-47, -100 and the higher chlorinated congeners BDE-153, -206, -207 and -209 were detected in at least seven of ten samples, and BDE-209 was found with highest concentrations from 0.2 to 4.8 ng/g ww. As in 2017, BDE-99, -126 and -190 had no detectable levels. Median sumPBDe was 0.75 ng/g ww compared to of 1.41, 0.31 and 0.53 ng/g ww for 2017, 2016 and 2015, respectively. Andersen et al. reported PBDEs in Arctic fox liver from Svalbard, Norway, with comparable median BDE-47 and -153 concentrations of 0.16 and 0.08 ng/g ww respectively (Andersen et al., 2015).

The new BFRs PBBZ and BTBPE were detected in all ten samples, at a low concentration with maximum concentration of 0.07 ng/g ww. DBDPE was only detected in three samples at concentrations up to 32 ng/g ww. TBPH was detected in two samples with 0.09 and 0.10 ng/g ww. All other newBFR compounds were below LOD.

3.2.8 Badger

In agreement with the 2017 data, the PBDE concentrations in badger liver were in general low or non-detectable. BDE-47 was detected in five out of eight samples. BDE-175/-183 was detected in one sample and BDE-207 in two samples. Of the new BFR compounds, PBBZ was detected in all samples up to 0.02 ng/g ww and BTBPE in six of eight samples up to 0.07 ng/g ww. DBDPE was detected in only two samples with the concentrations 9.09 and 11.4 ng/g ww.

3.2.9 Summary PBDEs and new BFR

In accordance with 2017 data and similar to the observations made for PCBs, sparrowhawk eggs had the highest levels of PBDE (mean SumPBDE 40.1 ng/g ww). The second highest PBDE levels were found in brown rat liver (13 ng/g ww) followed by fieldfare eggs (11.7 ng/g ww). As also seen last year and (see Table 8 and Figure 5), BDE-209 dominated in red fox and brown rat livers, while BDE-99 dominated in the bird eggs, and BDE-47 dominated in the other biological samples,. Of the new BFR compounds, DBDPE was found in highest frequencies and at the highest concentrations (Table 9, Figure 6 and *Figure 7*). For fieldfare eggs, due to relatively high concentrations of DBDPE, the mean sum value of new BFRs (21.1 ng/g ww) was higher than mean sumPBDE. An extremely high concentration of DBDPE (940 ng/g ww) was detected in brown rat liver.

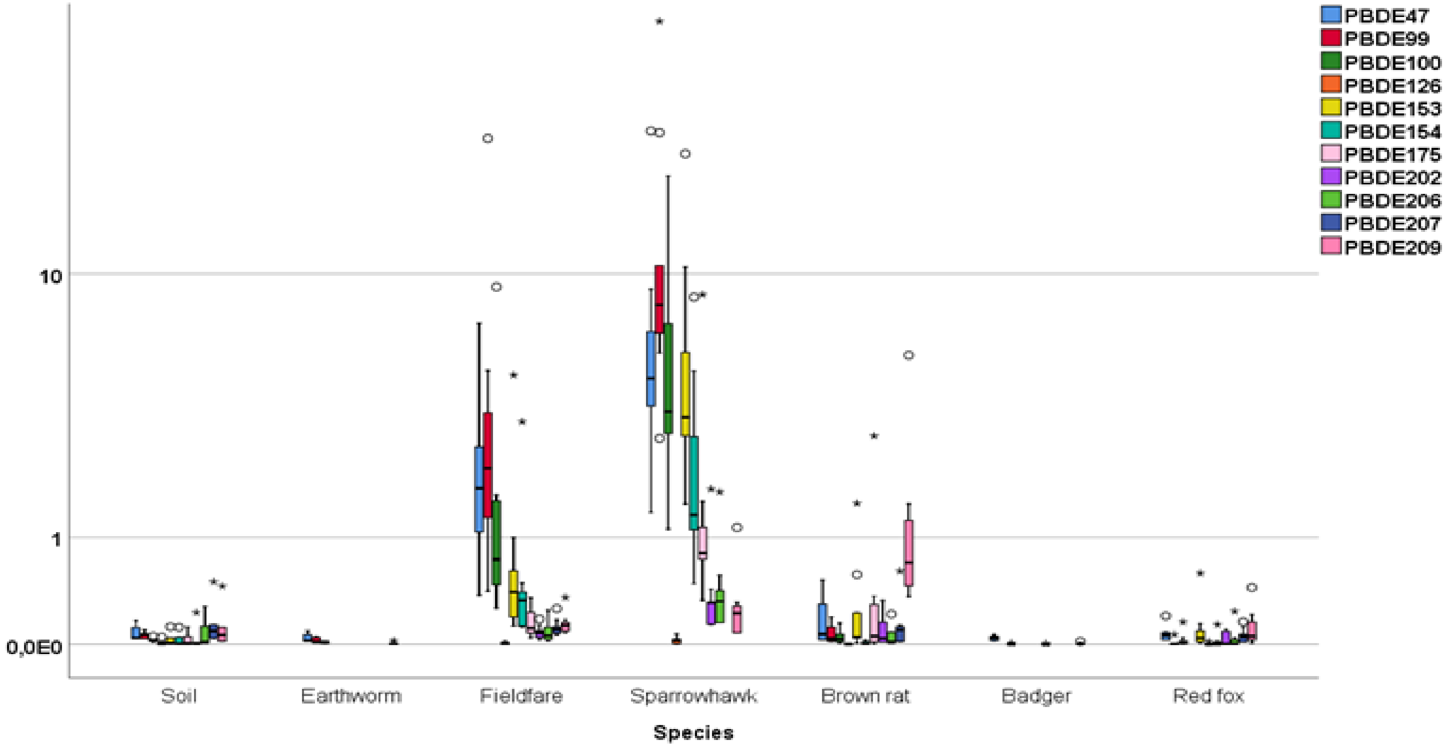

Figure 5: Box plot of PBDE congeners in the various samples. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points. Concentrations given in (ng/g ww) for all, except soil given in ng/g dw.

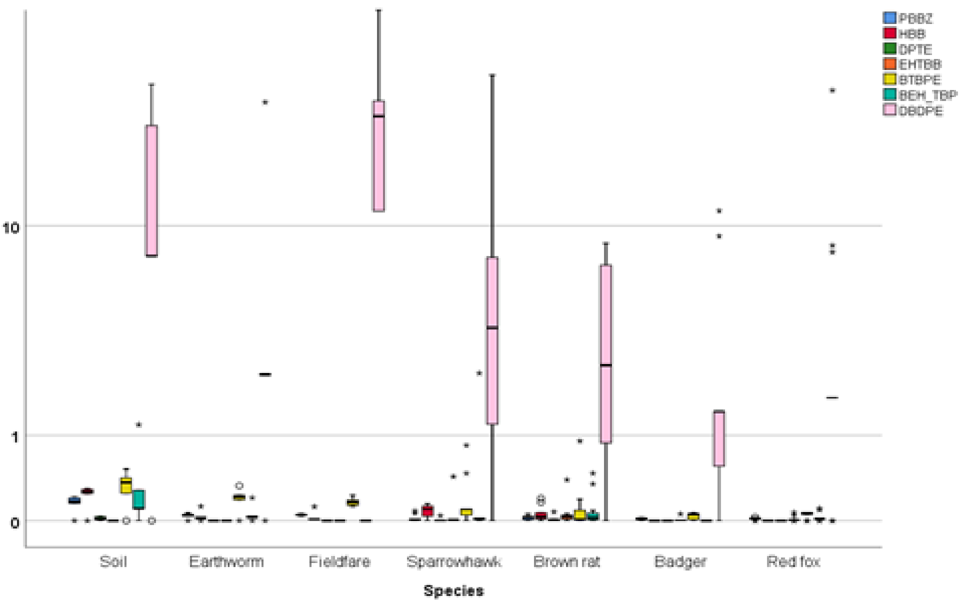

Figure 6: Box plot of NewBFR compounds in the various samples. Box plot of PCB congeners in the various samples. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points. Concentrations given in (ng/g ww) for all, except soil given in ng/g dw.

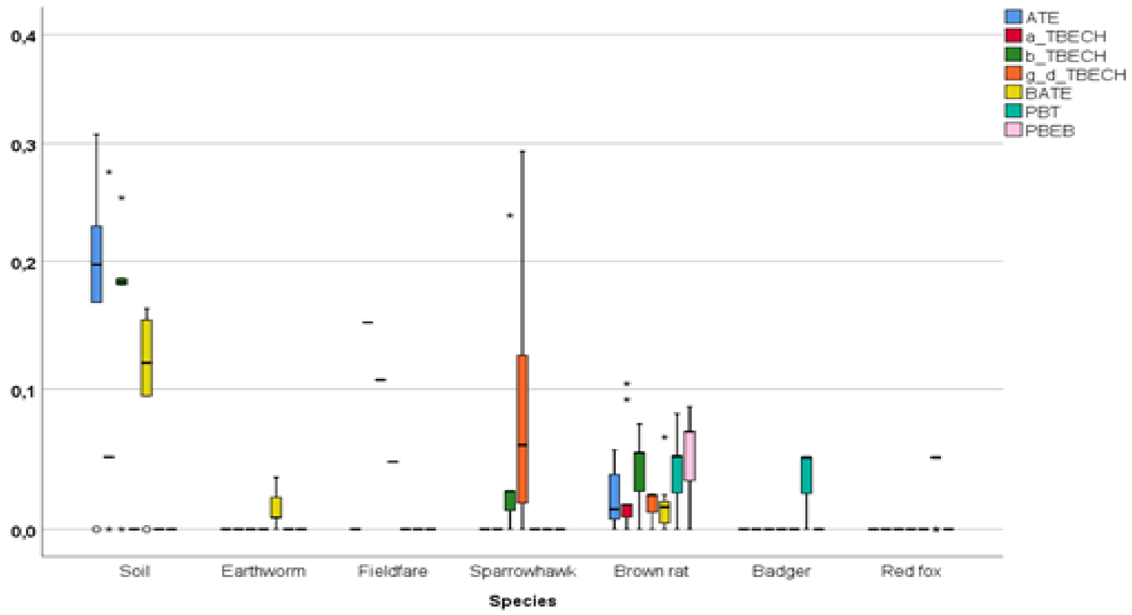

Figure 7: Box plot of NewBFR compounds in the various samples. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points. Concentrations given in (ng/g ww) for all, except soil given in ng/g dw.

Table 8: Mean concentrations with min-max interval below in grey colour of the various PBDE congeners in Air (pg/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk), Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww.

Comp.	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
BDE47	3.21 1.23-7.94	0.10 LOD-0.17	LOD LOD-0.09	2.18 0.37-6.99	7.08 1.35-26.7	0.07 LOD-0.20	LOD LOD-0.07	0.18 LOD-0.52
BDE99	1.54 0.29-5.19	0.06 LOD-0.10	LOD LOD-0.05	4.55 0.41-25.4	14.6 2.79-55.3	LOD LOD-0.07	<LOD	0.08 LOD-0.19
BDE100	0.41 0.10-1.10	0.03 LOD-0.05	LOD LOD-0.02	1.70 0.26-9.10	6.70 1.11-19.7	0.03 LOD-0.16	<LOD	0.05 0.01-0.15
BDE126	<LOD	0.01 LOD-0.05	<LOD	0.01 LOD-0.02	0.02 LOD-0.1	<LOD	<LOD	LOD LOD-0.004
BDE153	0.26 0.06-0.89	0.04 LOD-0.12	<LOD	0.85 0.13-4.71	6.19 1.48-22.9	0.10 LOD-0.58	<LOD	0.29 LOD-1.49
BDE154	0.13 0.04-0.45	0.04 LOD-0.12	<LOD	0.58 0.12-3.22	2.51 0.48-8.5	<LOD	<LOD	0.01 LOD-0.026
BDE 175/183	0.54 0.09-1.88	0.04 LOD-0.12	<LOD	0.15 0.04-0.35	1.69 0.33-8.6	0.02 LOD-0.14	LOD LOD-0.01	0.41 LOD-2.85
BDE191	<LOD	0.01 LOD-0.04	<LOD	LOD	0.04 LOD-0.12	<LOD	<LOD	LOD 0.04-0.01
BDE196	LOD LOD-0.87	0.05 LOD-0.23	<LOD	0.08 0.03-0.18	0.41 LOD-1.73	0.03 LOD-0.10	<LOD	0.10 LOD-0.33
BDE202	LOD LOD-0.26	0.09 LOD-0.28	<LOD	0.08 0.02-0.25	0.45 0.14-1.68	0.03 LOD-0.24	<LOD	0.06 LOD-0.22
BDE206	4.46 LOD-13.8	0.16 LOD-0.50	<LOD	0.12 0.06-0.26	<LOD	0.06 LOD-0.16	<LOD	0.13 LOD-0.61
BDE207	3.34 LOD-9.96	0.14 LOD-0.46	<LOD	0.15 0.08-0.35	0.27 LOD-1.13	0.11 LOD-0.44	LOD LOD-0.02	1.28 0.36-5.49
BDE209	136 LOD-441	0.80 LOD-1.12	0.34 LOD-0.72	1.27 0.53-4.25	0.21 0.10-0.68	1.20 LOD-4.77	<LOD	10.4 1.10-46.5

Table 9: Mean concentrations in with min-max interval below in grey colour of the various new BFR compounds in Air (pg/day), Soil (ng/dw), Earthworm (EW), Fieldfare (FF), Sparrowhawk (SH), Red fox (RF), Badger (B) and Brown rat (BR). All concentrations in biological samples are given in ng/g ww.

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare egg	Sparrowhawk	Red fox	Badger	Brown rat
ATE (TBP-AE)	<LOD	0.22 0.17-0.31	<LOD	<LOD	LOD LOD-0.17	<LOD	<LOD	LOD LOD-0.06
α-TBECH	8.30 1.18-31.3	LOD LOD-0.28	<LOD	<LOD	LOD LOD-0.32	<LOD	<LOD	LOD LOD-0.10
β-TBECH	4.69 0.70-17.6	0.20 0.18-0.25	<LOD	<LOD	LOD LOD-0.24	<LOD	<LOD	LOD LOD-0.07
γ/δ-TBECH	LOD LOD-0.65	<LOD	<LOD	<LOD	0.10 LOD-0.29	<LOD	<LOD	<LOD
BATE	<LOD	0.13 0.10-0.16	LOD LOD-0.04	<LOD	<LOD	<LOD	<LOD	0.02 LOD-0.06
PBT	3.29 LOD-11.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	LOD LOD-0.08
PBEB	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	LOD LOD-0.09
PBBZ	LOD LOD-2.83	0.18 0.15-0.21	0.05 0.04-0.07	0.05 0.04-0.06	0.04 0.03-0.08	0.02 0.02-0.03	0.02 0.015-0.024	0.03 0.02-0.06
HBB	LOD LOD-0.99	0.27 0.25-0.30	LOD LOD-0.12	LOD LOD-0.12	LOD LOD-0.15	<LOD	<LOD	0.07 LOD-0.20
DPTE	0.19 LOD-0.47	<LOD	<LOD	<LOD	LOD LOD-0.04	<LOD	<LOD	0.01 LOD-0.07
EHTBB	LOD LOD-0.46	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.08 LOD-0.40
BTBPE	1.74 0.79-3.84	0.38 0.25-0.52	0.23 0.18-0.33	0.16 0.12-0.23	0.36 0.22-0.84	0.06 0.05-0.07	0.05 LOD-0.07	0.15 LOD-0.91
TBPH (BEH /TBP)	2.16 LOD-4.80	0.35 LOD-1.18	LOD LOD-0.20	<LOD	0.27 LOD-2.32	LOD LOD-0.10	<LOD	0.12 LOD-0.47
DBDPE	62.0 LOD-170	16.0 LOD-33.6	LOD LOD-29.0	25.0 LOD-68.4	LOD LOD-36.4	6.02 LOD-32.1	LOD LOD-11.4	108 LOD-940

3.3 Per- and polyfluoroalkyl substances (PFASs)

The PFAS group consists of many per- and polyfluorinated compunds. We have chosen to separate this big class of compounds into four relevant subgroups (see also Table 1) dependent on functional groups and properties: the perfluorinated sulfonates (PFSA), the perfluorinated carboxylates (PFCA), the neutral polyfluorinated compounds (nPFAS) with the compounds PFOSA, meFOSA, etFOSA, meFOSE, etFOSE, 6:2 FTOH, 8:2 FTOH, 10:2 FTOH and 12:2 FTOH; and emerging polyfluorinated compounds (newPFAS) with the compounds 6:2 FTS, 8:2 FTS, 10:2 FTS, PFECHS, Cl-PFOA and Cl-PFOS. In this chapter and in Summary, SumPFAS is the sum of all sub-groups.

3.3.1 Air

In 2018, only PFBS and PFHxS were detectable in the XAD-PAS samplers that were used to collect air samples. In contrast, PFBS, PFBA and PFHxA were detected in 2017. PFBS (18.6-28.1 pg/day) were detected at all sites with low spatial variability. The same was also seen for PFHxS which was detected at three of the four sites from <LOD to 40 pg/day. The low detection of PFAS and general low levels of the detected PFAS suggests that either the urban area is not an important source for PFAS in air, or our passive samplers with XAD were not optimal for PFAS measurements.

None of the neutral PFAS class or newPFAS were detected in the air samples in this study. The reason for this is not known. In contrast, Ahrens et al. reported passive air data for ionic and neutral (volatile) PFAS in a suburban site in Toronto in 2011 (Ahrens et al., 2013). The passive air samplers used in the study of Ahrens, consisted of polyurethane foam (PUF) and sorbent-impregnated PUF (SIP) disks. The most abundant PFAS class for the total air concentration detected on these samplers in Toronto (Ahrens et al., 2013) were the neutral FTOHs representing on average ~80% of the SumPFAS. The presence of a few ionic PFAS, but none of the volatile PFAS, in the XAD-PAS samplers used in our study may possibly be caused by fine dust settling in the sampler, acting as a carrier for these compounds, and/or due to degradation of volatile precursor PFAS.

Karásková et al. 2018 concluded that XAD-PAS as passive air samplers appears to be a useful tool in the measurement of PFAS, but there is still variability between those compounds detected by active air and passive samplers. Concerning PUF-PAS samplers, the authors stated that the qualitative determination of PFAS profiles is not appropriate with PUF-PAS samplers due to different sorptive capacities for different classes of PFASs. Karásková et al. 2018 further concluded that given the importance of establishing reliable long-term monitoring for PFASs, passive sampling techniques for these compounds should continue to be investigated and optimized.

The data for the PFAS cannot be converted to estimated air concentrations due to lack of uptake rates for this compound class in the samplers. This hampers the comparison to active air sampling data from Birkenes. However, air measurements at Birkenes station in year 2017 revealed that the perfluorinated carboxylates dominated the pattern of detected PFAS compounds with PFOA>PFHxA>PFNA>PFHpA for the annual mean concentrations. In contrast to the findings from our study with passive samplers in 2018, PFBS and PFHxS were below LOD at Birkenes in 2017. The different profiles at the background station at Birkenes in Southern Norway and the urban sites in the Oslo area might suggest different sources, but it may also be a reflection of the different sampling methodologies and that the passive XAD samplers were not optimal for measuring PFAS.

3.3.2 Soil

PFOS was the dominating compound at all five sites. Alnabru (6 ng/g dw) and Slottsparken (4.3 ng/g dw) had approximately twice the concentration of the other sites. Alnabru had much lower concentration of PFOS this year compared to 2017 and 2016 with 101 and 162 ng/g dw, respectively. The possible reason for much lower soil concentration of PFOS in 2018 at Alna is not obvious, but could be explained if the location for sampling in 2018 was slightly different from the years before. Other sulfonates such as PFHxS and PFBS were only detected in 10% of the samples.

Several perfluorinated carboxylates (PFCA) were also detected in the soil samples. The highest concentration was found for PFOA, but the sum PFOA levels were lower than the PFOS concentration. Neutral PFAS (nPFAS) compounds were not detected in the soil samples.

3.3.3 Earthworms

PFSA and PFCA were present in many samples of earthworm. As with soil, PFOS dominated and Alna had the highest sumPFSA concentration of 89 ng/g ww followed by Grønmo with 55 ng/g ww. Frognerseteren had the highest sumPFCA concentration (23 ng/g ww) followed by Alna with 13 ng/g ww. PFHpA, PFOA, PFTriA, PFTeA dominated at Frognerseteren and PFDoA, PFTriA, PFTeA dominated at Alna. The nPFAS and newPFAS compounds were hardly detected in any samples. At Alna 6:2 and 8:2FTS were detected at 0.43 and 0.87 ng/g ww.

The sumPFAS (i.e. sum of all four sub groups) ranged from 13 to 103 ng/g ww, where Alna had the highest sum concentration followed by Grønmo (59 ng/g ww) and Frognerseteren (50.4 ng/g ww). This years' concentrations, especially at Alna and Frognerseteren, were much lower than the data from 2017 where sumPFAS for these two sites exceeded 500 ng/g ww.

3.3.4 Fieldfare

PFOS dominated in all fieldfare eggs, except the sample from Holmenkollen which was dominated by PFTeA. The maximum PFOS concentration was 250 ng/g ww and detected in egg from Grønmo. This is lower than reported reference value for PFOS of 1900 ng/g ww in bird egg (ECCC, 2017) for hatching success. The maximum sumPFAS was detected in eggs from Holmenkollen and Grønmo with reported concentrations of 339 and 297 ng/g ww, respectively, followed by Alna sites and Bøler. The maximum sumPFAS this year is lower than last year 2017 maximum sumPFAS of 1015 ng/g ww at Grønmo.

PFOSA was the only compound detected as part of the neutral group, nPFAS. Highest concentration was found at Grønmo with 0.2 ng/g ww. Of the newPFAS group, 8:2 and 10:2 FTS were detected in all egg samples. The highest concentrations were detected in eggs collected at the Alnabru 2 site with reported concentrations of 5.7 and 11.8 ng/g ww for 8:2 and 10:2 FTS, respectively. These concentrations were approximately 10 times higher than the mean of the remaining sites.

3.3.5 Sparrowhawk

The highest sumPFAS concentration found in 2018 was 534 ng/g ww compared to 246 ng/g in 2017 and 383 ng/g ww in 2016. SumPFOS (linear and branched PFOS) was the dominating compound ranging from 36 to 417 ng/g ww with a mean value of 108 ng/g ww; compared to a mean value of 74 ng/g ww in 2017 and 108 ng/g ww in 2016.

As last year, additional important PFAS compounds were PFTrA, PFDoA, PFTeA, PFUnA with concentration up to 37 ng/g ww for PFTeA. Several other ionic PFAS compounds were detected in all nine egg samples but at lower concentrations; PFHxS, PFHpS, PFDcS, PFOA, PFDcA.

In the nPFAS group only PFOSA was detected in six of the nine samples. In the newPFAS group 8:2 FTS, 10:2 FTS and PFECHS were detected in all samples, but at rather low concentrations compared to other PFAS compounds. The highest concentration of these three compounds was found for 10:2 FTS (2.4 ng/g ww), the same egg with highest sumPFAS and PFOS concentration.

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 mean value of 4.5 ng/g ww, but the common kestrel mainly preys on rodents, placing it lower in the food chain than sparrowhawks. A more comparable species is the Merlin, which preys on small birds, and which had 67 ng/g sumPFAS during the same period.

3.3.6 Brown rat

SumPFAS varied from 31 to 129 ng/g ww compared 16 to 168 ng/g ww from 2017, and as in previous years PFOS was the dominating PFAS in all samples. The highest PFOS concentration measured in this year's monitoring was 62.4 ng/g ww compared to 116 ng/g ww in 2017 and 188 ng/g in 2016. PFCA compounds, PFOA to PFTriA, were detected in all nine samples, and at lower concentration than PFOS. The new PFAS compounds 10:2 FTS was detected in all samples, while 8:2 FTS was detected in five, and 6:2 FTS in two out of nine samples. PFECHS and Cl-PFOS was detected in one sample. The dominating food items for brown rat are not known, but since rats are opportunistic feeder many potential sources and food items are possible within an urban settlement.

3.3.7 Red fox

As for all other samples, except air and bumblebees samples, PFOS was the dominating PFSA compound also in red fox liver with maximum concentration of 22 ng/g ww. The PFCA compounds were detectable in all samples, but at lower concentrations, maximum of 2.56 ng/g ww.

The sumPFAS concentrations ranged from 7 to 31 ng/g ww, and were much lower in 2018 than in 2017 (6.6 to 201 ng/g ww; Heimstad et al; 2018) and more comparable to the 2016 data (4.6 to 37.1 ng/g ww).

For comparison, in polar fox from Svalbard, PFOS concentrations in liver ranged between 10 and 220 ng/g ww. The high levels in this fox species is most probably explained by the partly marine diet of polar foxes (Aas et al., 2014).

3.3.8 Badger

The eight badger liver samples revealed higher sumPFAS values (46-144 ng/g ww) than red fox liver samples and slightly higher than rat liver samples. PFOS was the dominating compound and many PFCA compounds were detected in most samples. PFOS concentrations were comparable with the rat liver concentrations. Badgers are omnivores and earthworms are expected to be an important food item (Brøseth et al 1997; Piza-Roca et al 2015), however the diet can be very variable with a variety of animal and plant food sources, such as earthworms and other invertebrates, birds' eggs and young rodents, fruits, oats and wheat (Piza-Roca et al 2015).

3.3.9 Bumblebees

Many PFAS compounds were not detected in the 30 bumblebees. PFOA had highest detection rate and was present in 43 % of the bumblebee samples in the range of 0.013-0.13 ng/g ww. PFOA in bumblebees from Frognerseteren was detected in 70 % of the samples. In bumblebees from Sognsvann PFOA was found in 50 % of the samples and only 10 % in samples from Hvasser, Vestfold. Next after PFOA, PFHpS was detected in four samples (13 % detection), PFTriA and PFHxDA were detected in three samples and PFHpA was found in two samples. Highest concentration was found for PFTriA with 0.54 ng/g ww. The results or bumblebees are not shown in tables or figures, data can be found in Appendix 1.

3.3.10 Summary PFAS

PFAS compounds could be detected in all the investigated matrices. PFOS was the dominating compound in all matrices, except for air and bumblebees (

Table 10 and *Figure 8*). PFOS concentrations in earthworm and soil were lower this year than in 2017, especially at Alna and Grønmo. This year's data revealed that sparrowhawk egg had highest mean sumPFAS concentration of 175 ng/g ww, followed by fieldfare egg 132 ng/g ww and rat and badger liver with 77 and 60 ng/g ww, respectively.

The higher prevalence of long-chained perfluorinated carboxylates (PFCA compounds) in earthworm and fieldfare from Holmenkollen, relative to the other sites, may be attributed to direct sources as emissions from use of skiwax as well as indirect sources from degradation of fluorinated precursor compounds used in these applications. PFECHS, part of the newPFAS group was only detected in several samples of sparrowhawk eggs. 8:2 FTS and 10:2 FTS were detected in several of the samples and detected in all fieldfare and sparrowhawk eggs. 6:2 FTS was only detected in one sample of fieldfare and two samples of rat liver. The lowest detection rate of the FTS compounds were observed in red fox liver, earthworm and soil. The highest concentrations of 8:2 FTS (5.65 ng/g ww) and 10:2 FTS (11.8 ng/g ww) were detected in fieldfare eggs collected from Alnabru 2, (see *Table 12*).

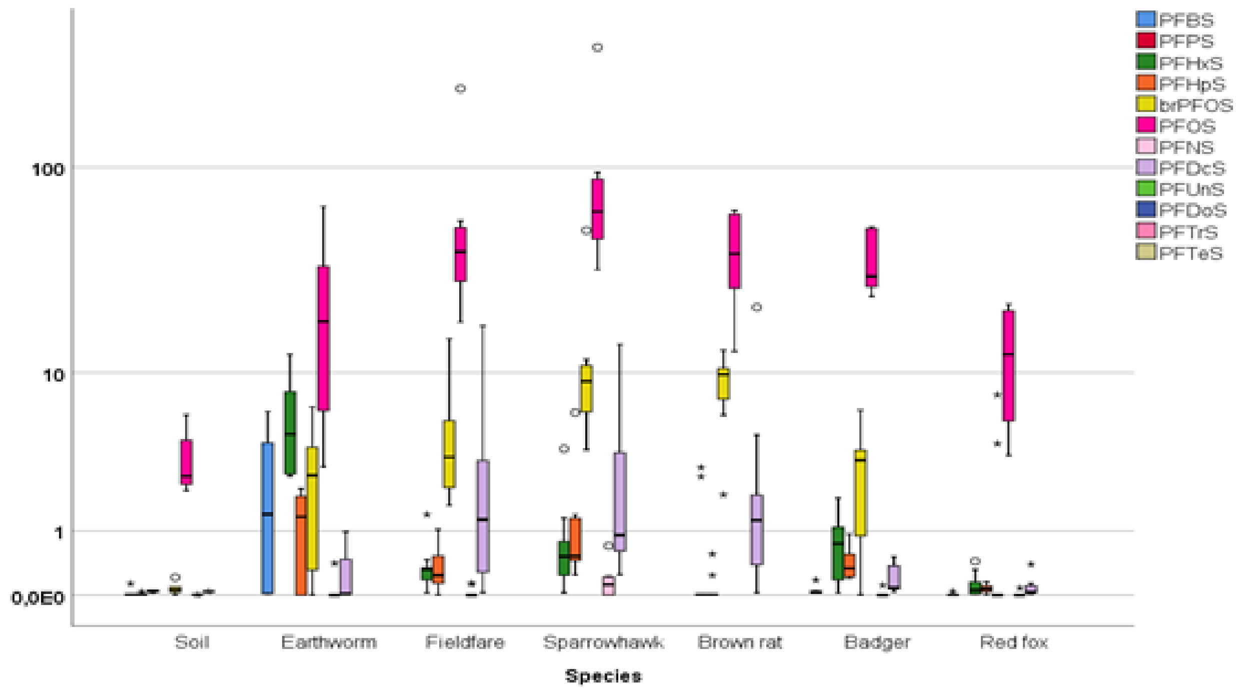

Figure 8: Box plot of PFSA compounds in the different sample types. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points. Concentrations in ng/g ww for biota samples, ng/g dw for soil.

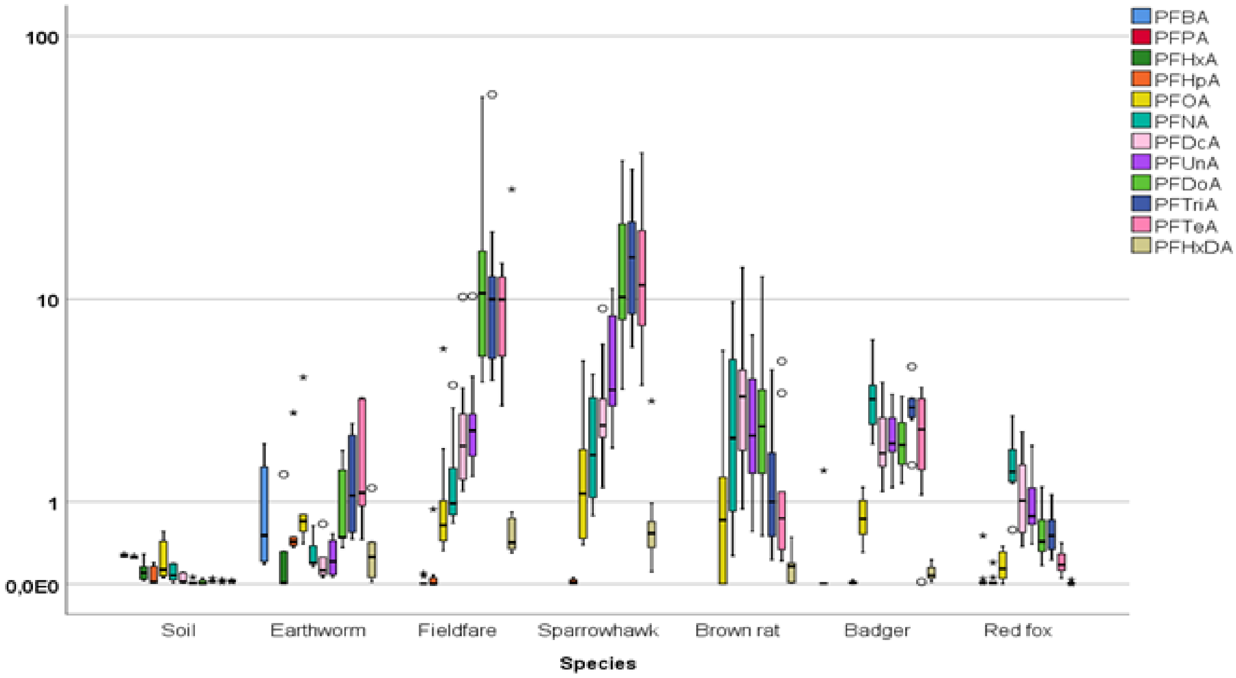

Figure 9: Box plot of PFCA compounds (ng/g ww) in the different sample types. Soil concentrations in ng/dw. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points

Table 10: Mean concentrations in with min-max interval below in grey colour of the various perfluorinated sulfonates (PFSA compounds) in Air (pg/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww. Compounds not detected in any samples are omitted.

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
PFBS	23.1 18.6-28.1	0.04 LOD-0.13	2.37 LOD-6.25	<LOD	<LOD	LOD LOD-0.04	0.05 LOD-0.18	<LOD
PFPS	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
PFHxS	1.42 LOD-2.95	LOD LOD-0.05	6.06 2.61-12.4	0.37 LOD-1.38	0.89 LOD-3.85	0.13 0.01-0.44	0.74 LOD-1.84	0.62 LOD-2.96
PFHpS	<LOD	LOD	1.08 LOD-2.16	0.34 LOD-1.03	1.35 0.24-6.16	0.08 LOD-0.15	0.42 0.20-0.93	0.09 LOD-0.56
brPFOS	<LOD	0.08 LOD-0.21	2.69 LOD-6.59	4.64 1.64-14.8	12.7 3.8-50.1	1.31 LOD-7.67	2.88 LOD-6.34	8.85 1.95-13.01
PFOS	<LOD	**3.46** 2.09-5.99	**25.2** 3.0-65.1	**56.4** 18-235	**95** 32.4-367	**12.2** 3.52-22.0	**36.5** 24.1-52.1	40.5 12.9-62.4
PFNS	<LOD	<LOD	0.08 LOD-0.41	0.03 LOD-0.14	0.18 LOD-0.70	0.01 LOD-0.08	0.02 LOD-0.12	<LOD
PFDcS	<LOD	<LOD	0.30 LOD-0.98	3.10 LOD-17.2	3.07 0.25-14.0	0.08 LOD-0.39	0.20 0.04-0.51	3.62 LOD-21.3

Table 11: Mean concentrations in with min-max interval below in grey colour of the various perfluorinated carboxylates (PFCA compounds) in Air (ng/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww.

Compounds	Air ng/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
PFBA	LOD	LOD	LOD	LOD	LOD	LOD	LOD	LOD
PFPA	LOD	LOD	0.97 LOD-2.26	LOD	LOD	LOD	LOD LOD-1.6	LOD
PFHxA	LOD	0.12 LOD-0.29	0.38 LOD-1.51	LOD LOD-0.09	LOD	0.07 LOD-0.50	LOD	LOD
PFHpA	LOD	0.08 LOD-0.20	0.98 0.36-3.22	0.10 LOD-0.87	0.02 LOD-0.06	0.03 LOD-0.20	0.01 LOD-0.04	LOD
PFOA	LOD	0.25 LOD-0.56	1.43 0.41-4.70	1.30 0.32-6.25	1.64 LOD-5.54	0.19 LOD-0.37	0.77 0.31-1.26	1.26 LOD-6.13
PFNA	LOD	0.10 LOD-0.19	0.31 0.16-0.63	1.55 0.67-4.34	2.39 LOD-4.85	1.77 0.58-3.12	3.87 2.24-6.82	3.84 0.27-9.74
PFDcA	LOD	0.05 LOD-0.10	0.23 0.06-0.66	3.07 1.19-10.2	3.72 LOD-9.18	1.14 0.37-2.60	2.40 1.18-4.47	5.27 0.88-13.4
PFUnA	LOD	0.02 LOD-0.06	0.26 0.06-0.52	3.42 1.47-10.3	5.73 LOD-11.0	1.04 0.40-2.20	2.49 1.26-3.94	3.22 0.56-7.13
PFDoA	LOD	0.02 LOD-0.05	1.00 0.36-2.07	15.1 4.48-59.3	14.8 LOD-34.3	0.52 0.17-1.27	2.37 1.34-3.85	4.27 0.50-12.3
PFTriA	<LOD	0.03 LOD-0.05	1.49 0.46-2.86	14.6 4.56-60.7	15.8 LOD-31.8	0.57 0.22-1.12	3.44 1.72-5.23	1.73 0.23-5.08
PFTeA	<LOD	LOD LOD-0.04	2.02 0.45-3.80	21.3 3.49-137	14.8 LOD-36.7	0.20 0.05-0.41	2.56 LOD-4.24	1.51 0.21-5.53
PFHxDA	<LOD	<LOD	0.40 LOD-1.24	3.10 LOD-26.7	0.86 0.11-3.66	LOD LOD-0.04	0.10 0.02-0.23	0.14 LOD-0.48

Table 12: Mean concentrations in with min-max interval below in grey colour of the nPFAS and newPFAS compounds in Air (ng/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww. Compounds not detected in any samples are not included in the table. One value is given for those with only one detected concentration.

Compounds	Air ng/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
PFOSA	<LOD	<LOD	0.03 LOD-0.08	0.04 LOD-0.21	0.07 LOD-0.17	0.35 LOD-1.86	0.56 0.28-0.84	0.14 LOD-0.48
6:2 FTS	<LOD	<LOD	0.43	0.10	<LOD	<LOD	<LOD	0.18 LOD-0.97
8:2 FTS	<LOD	<LOD	0.19 LOD-0.87	1.00 0.05-5.65	0.40 0.01-1.51	0.14	0.20 0.03-0.41	0.33 LOD-0.63
10:2 FTS	<LOD	<LOD	<LOD	2.22 0.37-11.8	0.90 0.37-2.35	<LOD	0.22 LOD-1.32	1.85 0.31-6.67
PFECHS	<LOD	<LOD	<LOD	<LOD	0.18 0.07-0.84	<LOD	<LOD	0.39
Cl-PFOS								1.16

3.4 Metals

3.4.1 Soil

Zn and Cr were the dominating metals in all soils, except for soil from Frognerseteren, were the Pb concentration was highest. The same was observed in previous years' findings. (Herzke et al., 2017, Heimstad et al., 2018). The sum concentrations of the subgroup toxic metals (Cd, Pb, Hg, As) ranged from 24950 ng/g dw at VEAS to 73000 ng/g dw in soil from Slottsparken. The following order of sum toxic metal concentrations was found in decreasing order: Slottsparken ~Frognerseteren > Grønmo> Alnabru ~ VEAS. As observed in 2017, the expected more polluted site Alnabru was not the one with highest sum of the metals Cd, Pb, Hg and As.

According to the Norwegian guidelines on classification of environmental quality of soil (normative values), 8000 ng/g dw of As, 60 000 ng/g dw of Pb, 1500 ng/g dw of Cd, 1000 ng/g dw of Hg, 100 000 ng/g Cu, 200 000 ng/g Zn, 50 000 ng/g dw of Cr (III) and 60 000 ng/g dw of Ni represent the threshold for clean soil (Lovdata, kap.2, vedlegg 1[4]).

Threshold values were exceeded for Pb, Cr and Ni at five locations:

- Pb, Slottsparken and Frognersteren
- Cr, Alnabru and VEAS
- Ni, VEAS exceeded

For As, Zn, Cd, Cu and Hg, no locations exceeded the thresholds.
For comparison, Luo et al, reported a median of 25 000 ng/g dw for Pb and 13 000 ng/g dw for Cr in urban park surface soils of Xiamen City, China (Luo, et al., 2012), which is lower than what was found in Oslo this year with a median of 39 000 ng/g dw for Pb and 49000 ng/g dw for Cr.

In Torino, Italy, soil concentrations of 288 000 ng/g dw for Cr and 1 405 000 ng/g dw for Pb were reported, all considerably higher than in Oslo soils (Madrid, 2008). In soil in parks from Bristol, UK, these mean concentrations were observed; 22 000 ng/g for As, 180 000 ng/g dw for Pb, 500 ng/g dw of Cd, 40 000 ng/g dw for Cu, 250 000 ng/g for Zn, 20 000 ng/g dw for Cr and 25 000 ng/g dw for Ni was found (Giusti, 2011). When comparing these Bristol concentrations with our data from Oslo, only mean value of Ni from Oslo was comparable with Ni from Bristol, Cr from Oslo was higher, and the rest of metals from Oslo had lower mean concentrations than Bristol. With 450 000 inhabitants, Bristol is of comparable size as Oslo, also both are coastal cities.

3.4.2 Earthworm

As previous years, Zn was the dominating metal with a mean value of 161 000 ng/g ww. As in 2017, very high Pb concentration (55 281 ng/g ww) was detected in earthworm from Frognerseteren, approximately 15 times higher than the next highest concentration found in earthworm from Grønmo.

When comparing the different urban locations where earthworm was collected, the highest sum toxic metal (sum of Cd, Pb, Hg and As) concentration was found in Frognerseteren (59 016 ng/g ww) followed by Grønmo (6212 ng/g ww), Alnabru (4498 ng/g ww), Slottsparken (3087 ng/g ww) and VEAS (2674 ng/g ww).

As in 2017, Pb was the major contributor to the sum of toxic metals, and was highest in Frognerseteren and lowest at VEAS (581 ng/g ww).

[4] https://lovdata.no/dokument/SF/forskrift/2004-06-01-931/KAPITTEL_1-2#KAPITTEL_1-2

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 from the Oslo area. 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 100 000-200 000 ng/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 2004; Kennette et al. 2002).

Song et al 2002, investigated acute and sub-acute lethal effects of single and combined Cu, Zn, Pb and Cd on earthworm in meadow brown soil. In this study concentrations leading to death in individual earthworms was estimated to be 300 mg.kg-1 for Cu, 1300 mg.kg-1 for Zn, 1700 mg.kg-1 for Pb, 300 mg.kg-1 for Cd. LC50 in was 400-450 mg.kg-1 for Cu, 1500-1900 mg.kg-1 for Zn, 2350-2400 mg.kg-1 for Pb and 900 mg.kg-1 for Cd (Song et al 2002). They concluded that combined effects of single Cu, Zn, Pb and Cd, to conduce more than 10% of the death rate of earthworm, could result in 100% of the death rate of earthworm, revealing strong synergistic joint effect of the heavy metals (Song et al, 2002). Our study from Oslo in 2018 revealed lower concentrations than these thresholds for Cu, Zn, Pb and Cd; however we cannot exclude combined and synergistic effects of these same metals that may affect the earthworms.

3.4.3 Fieldfare

As in 2017, Zn and Cu dominated in fieldfare eggs. However, Zn and Cu are physiologically regulated and supposed to have little toxicological effect (Lukkari et al. 2004). Of the toxic metals investigated, Pb, Hg and As were the most abundant ones. The mean level of Pb (28 ng/g ww) was equal to 2017 mean level and lower than 2016 data with 58.5 ng/g ww. Hg and As concentrations were slightly higher than previous year data with 13.7 and 4.6 ng/g ww, respectively.

Tsipoura et al., reported on metal concentrations in three species of passerine birds breeding in New Jersey, US (Tsipoura et al., 2008). Concentrations in eggs of 38, 120 and 48 ng/g respectively were reported for Pb, Cr and Hg besides 6 ng/g for arsenic and 0.3 ng/g for Cd in the red-winged blackbird (*Agelaius phoeniceus*) a passerine bird, feeding on seeds, insects and worms. These concentrations are comparable to the average levels of these metals in this years' study. Further, lead levels as low as 0.4 ppm (400 ng/g) in blood can result in adverse physiological effects, while 4 ppm in feathers is associated with negative effects on behaviour, thermoregulation, locomotion, and depth perception resulting in lowered nestling survival (Tsipoura et al, 2008). As last year, one egg from Kjelsås had the maximum Pb concentration of 136 ng/g ww compared to 206 ng/g ww in 2017. The same location Kjelsås had highest Pb concentration of 494 ng/g ww in 2016, an exceptionally elevated level, crossing the effect-level mentioned above.

3.4.4 Sparrowhawk

As previous years, Zn, Cu and Hg dominated in the sparrowhawk eggs. The concentration of Zn (2196-9263 ng/g ww) found in sparrowhawk eggs were 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 (395-1359 ng/g ww) were slightly lower than in 2017 which was comparable with results obtained for *Larus audouinii* (Morera 1997). Since Cu and Zn are physiologically regulated in birds (Richards and Steele 1987), first and foremost Hg, Pb, Cd and As can prove toxic at concentrations that can be found in the environment (Depledge et al. 1998). Ag was only detected in one of the analysed egg samples. Cr, Pb, Ni, Cd and As were only found at low concentrations of <19 ng/g ww. Ni concentrations up to 81 ng/g ww were higher in 2017 than in this years' data with maximum of 16 ng/g ww. Hg was found with a mean value of 76 ng/g ww, 5 times higher than in the fieldfare.

Pb and Hg are neurotoxins that cause cognitive and behaviour deficits as well as decreased survival, growth, learning, and metabolism (Carvalho et al., 2008, Khadeim, 2015). As mentioned also above, in birds, Pb levels as low as 400 ng/g can cause negative effects on behaviour, thermoregulation, and locomotion. The highest level of 17 ng/g ww in the present study for sparrowhawk eggs were more than 20 times lower than this levels.

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 Cd and Pb (Furness, 1996 and Spahn and Sherry, 1999).

As, Hg, and Pb belong to the non-essential metals while Cu and Zn belong to the essential metals. Cu, Zn and Cd have been shown to significantly bioconcentrate from soils to invertebrates, but to biodilute from invertebrates to birds (Hargreaves et al., 2011). Cu, Zn and Fe are essential macro elements with many important biological functions, and body concentrations are usually well-regulated. Sparrowhawk eggs collected in a period between 2005 and 2010 have been reported to have a Hg concentration of 175 ng/g ww (Nygård and Polder, 2012). This is higher than this years' maximum level, but comparable to the maximum concentration of Hg in 2017 of 162 ng/g ww in our study. An often used reproductive effect threshold level for mercury in bird eggs is 800 ng/g (Heinz 1979, Henny et al. 2002), while other investigators and ecological risk assessors may use 500 ng Hg/g as an ecological effect screening benchmark value of (RAIS 2004). A recent publication (Fuchsman et al. 2017) reported Hg effect thresholds of approximately 600- 2700 ng/g ww in bird egg.

3.4.5 Brown rat

As in 2017, metals in rat liver from 2018 were mostly represented by high levels of Zn (mean value of of 30 785 ng/g ww compared to 38 826 ng/g ww in 2017) followed by Cu and As (mean value of 5396 and 1561 ng/g respectively). As previous years, 2018 data also revealed that rats contained, with a mean of 1561 ng/g ww, the highest levels of As of all analysed species with a maximum of 6020 ng/g ww, and four samples were above 1000 ng/g ww. The levels of As in brown rat were in general lower this year compared to 2017.

3.4.6 Red fox

Zn was also the dominating metal detected in fox liver, with mean concentrations of 33 693 ng/g ww (comparable to 37 943 ng/g ww in 2016) followed by Cu with 10 800 ng/g ww (comparable to 10 351 ng/g ww in 2016). These were followed by Cd, Hg and Cr with mean concentrations between 106 and 163 ng/g ww. Pb concentrations ranged from 18-119 ng/g ww and were well below levels related to Pb toxicosis in mammals of 10 000–25 000 ng/g (Bilandžić et al, 2010). Bilandžić et al, 2010 reported Pb levels in liver from suburban red foxes (n=12) from Croatia in the range 0.024 - 0.584 mg/kg ww (24 – 584 ng/g ww) which is slightly higher than the Pb levels in red fox from Oslo area in 2018. Cd concentrations in red fox livers in the study from Croatia ranged from 0.2 - 553 ng/g ww and were comparable to the concentrations in red fox from Oslo in 2018 with 67.9- 492 ng/g ww. In the same Croatian red fox liver samples, the Hg levels varied from 0.3 to 80 ng/g ww, As levels from 5-36 ng/g ww and Cu levels varied from 5800 to 86800 ng/g ww (Bilandžić et al, 2010). Notable the Hg concentrations from Oslo in 2018 (31.1-690 ng/g ww) were much higher than the levels detected in the Croatian red fox liver samples.

Dip et al. (2001) reported 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 urban foxes, mean Cd levels of 520 ng/g were found (Dip et al., 2001), which is slightly higher than our mean value of 273 ng/g. Mean value of Pb in liver in the municipality of Zurich was 1200 ng/g which is much higher than our mean value of 69 ng/g. Threshold for potential liver disfuncton in terrestrial mammals and birds for cadmium was set to 40 000 ng/g ww in the AMAP Arctic Pollution report of 2002 (AMAP, 2002).

3.4.7 Badger

The same pattern as in red fox liver was found with highest concentration of Zn followed by Cu. As in 2017, very high concentrations of Cd were detected in three of eight samples. The three samples ranged from 2129 to 3511 ng/g ww. The sample with highest Cd concentration also had the highest Pb (630 ng/g ww) concentration.

In a study of metals in badgers from Croatia (Ozimec et al., 2015) the mean Cd concentration in liver was 395 ng/g ww (0.395 mg/kg ww). In our 2018 data from Oslo, the mean concentration of Cd in the eight badger livers is higher with 1190 ng/g. The maximum concentration in the Croatian badger livers was 1628 ng/g ww, half of the max value in our 2018 dataset. Further in the Croatian study, the mean Pb concentration was highest in the liver (197 ng/g), which is lower than our 2018 mean value of 243 ng/g. The maximum value of Pb in badger livers from Croatia was 2253 ng/g which was considerable higher than our data.

In another study from the Czech Republic, metals have been analysed in tissues of European badger affected by ovarian tumour (Bukovjan et al., 2014). The concentration of Hg, Pb, Cd and As in liver tissues were 490, 2980, 1090 and 70 ng/g ww. Our eight liver samples from the Oslo area revealed comparable concentration of Cd with mean value of 1190 ng/g ww. The other metals revealed lower mean values in Oslo area.

3.4.8 Summary metals

The heavy metal (Hg, Pb, Cd, As) concentrations were high in soil, see Table 13, *Figure 10*. Of the biological matrices analysed, earthworms, brown rats, badger and foxes contained the highest amounts. The levels in earthworms were most certainly caused by the feeding technique of the worms, eating their way through the soil. Similar to last year, fieldfare egg from one sampling site (Kjelsås) showed high Pb concentration of 136 ng/g ww (fieldfare egg from same site had 206 ng/g ww in 2017 and 494 ng/g ww in 2016), more than 10-20 times higher than at the other sites. Hg concentration was highest in earthworm and red fox followed by sparrowhawk eggs. One rat liver sample had Hg of 1093 ng/g ww. Cd was high in badger liver samples, where three samples exceeded 2000 ng/g ww.

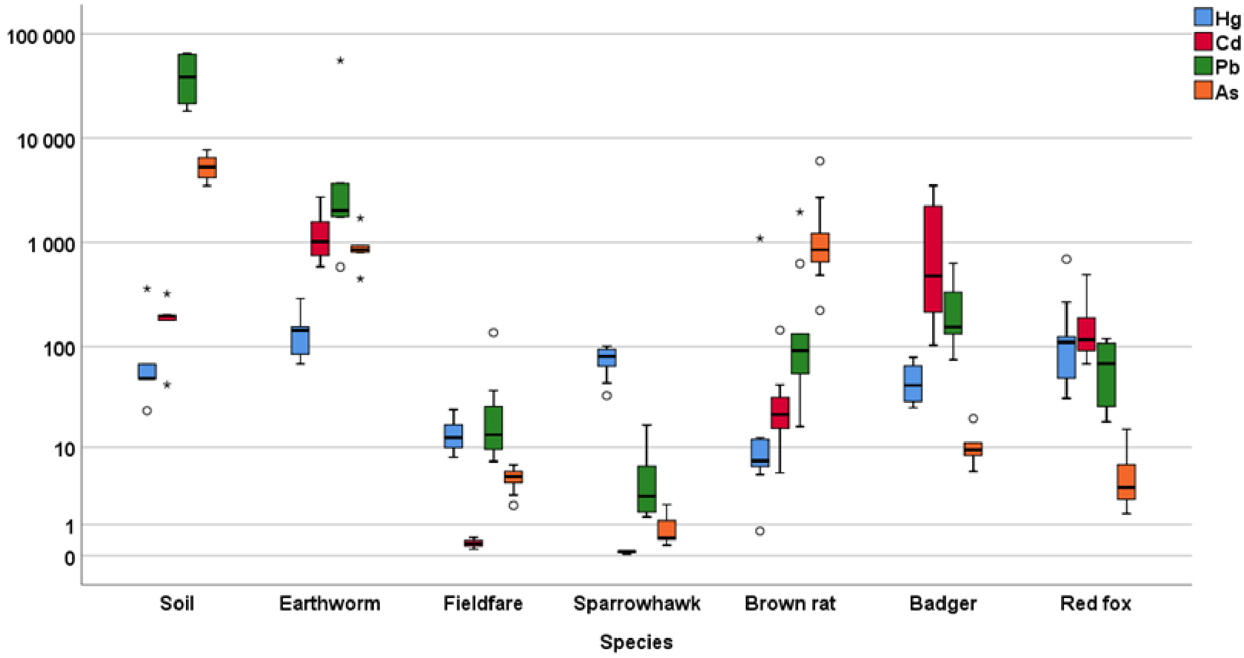

Figure 10: Box plot of selected toxic metals in all samples. Concentrations are given in ng/g ww, except soil with ng/g dw. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

Table 13: Mean concentrations with min-max interval below in grey colour of the various metals in Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww.

Compounds	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
Cr	46220 7818-88775	3601 617-6110	43.4 LOD-147	9.57 2.52-19.3	106 39.9-173	217 97.1-570	573 16.3-2090
Ni	27408 1934-61684	1716 430-3035	28.9 2.72-117	7.09 2.44-15.9	54.8 28.3-91	101 46.2-284	267 27.2-958
Cu	25335 8077-32523	4817 1870-9391	471 314-743	784 395-1359	10800 6709-16653	10678 4947-27119	5395 2557-17213
Zn	90561 42622-140309	161366 107201-225320	8603 3284-15227	5383 2196-9263	33693 25042-57981	31627 20477-59277	30785 23232-41792
As	5437 3492-7734	951 448-1707	4.57 2.04-6.43	0.81 0.27-2.11	5.73 1.53-15.3	10.3 5.4-19.6	1561 223-6020
Ag	164 98-247	46.2 19.9-80.5	0.35 LOD-1.06	LOD LOD-0.4	2.36 0.61-7.43	24.0 5.2-57.8	31.7 LOD-256
Cd	190 53-322	1330 587-2723	0.32 0.16-0.50	0.09 0.03-0.13	163 67.9-492	1190 103-3511	35.5 5.2-144
Pb	41259 18211- 64589	12669 581-55281	27.9 7.01-136	4.91 1.35-17.0	69.3 18.2-119	243 74.2-630	345 16.3-1959
Hg	110 24-361	148 67.9-289	13.7 7.77-24.1	76.2 33.15-101	158 31.1-690	47.1 25.3-78	128 0.7-1093

3.5 Chlorinated paraffins (CPs)

3.5.1 Air

CPs were detected in the PUF-PAS at all five air sampling stations; SCCPs in the range of 1.9-23.6 ng/day and MCCPs in the range of 1.2-4.2 ng/day. The SCCPs concentration were in general higher or similar to MCCPs. The levels were in general higher in 2018 than in 2017 with mean values of 7.9 and 2.6 ng/day for SCCPs and MCCPs, respectively. SCCPs ranged from 1.9 to 23.6 ng/day with highest concentration at Slottsparken, six times higher than the mean value of the remaining four sites. The levels of MCCPs ranged from 1.2-4.2 ng/day with the highest levels at VEAS and Slottsparken. The high levels of SCCPs at Slottsparken may indicate a source in this area.

The estimated air concentrations, using an uptake rate of 4 m^3/day according to Li et al. (2012), were 0.5-5.9 ng/m^3 for SCCPs and 0.3-1.1 ng/m^3 for MCCPs. Annual mean concentrations of SCCPs and MCCPs at Birkenes were 0.38 ng/m^3 and 0.12 ng/m^3, in 2017 (Nizzetto et al., 2018). These are similar to the lowest estimated concentrations of SCCPs and MCCPs in this study at Grønmo site, but 10 times lower than the highest estimated concentrations at Slottsparken and VEAS.

3.5.2 Soil

SCCPs and MCCPs were also detected in all soil samples. SCCPs concentrations ranged from 364 to 546 ng/dw compared to 308 to 763 ng/dw in 2017. MCCPs concentration were higher than SCCPs concentration at all stations. MCCPs varied between 520 and 1129 ng/g dw which was much higher than 57 to 282 ng/g dw in 2017, and <LOD to 3.6 ng/g dw in 2016. Highest sum concentration of SCCPs and MCCPs (1577 ng/g dw) was detected at Slottsparken due to the high MCCPs concentration of 1129 ng/g ww.

For comparison, Wang et al found mean SCCPs and MCCPs concentrations of 18.3 and 59.3 ng/g for soil samples in the Pearl River Delta in South China, (Wang et al., 2013). The authors also pointed out the large spatial variation found for CPs in soils. In a recent publication (Zhao et al, 2019) higher concentrations of SCCPs and MCCPS were detected in soil from intertidal zone of Shandong peninsula, China, with range of mean values from 61 to 164 ng/g dw for coastal soil.

3.5.3 Earthworms

SCCPs and MCCPs were detected in almost all earthworms from Oslo; MCCPs at Slottsparken was below LOD. For SCCPs, concentrations varied between 33.8-64.9 ng/g ww compared to 64-187 ng/g ww in 2017 and 28- 33 ng/g ww in 2016. MCCPs varied between <LOD and 134 ng/g ww compared to 25 - 46 ng/g ww in 2017 and 1.2 -12.6 ng/g ww in 2016. Concentrations in worms from Slottsparken did not reflect the elevated SCCPs levels found in air and soil, indicating a low biomagnification potential in earthworms. As in 2017, Frognerseteren had highest sum concentration of chlorinated paraffins with 184 ng/g ww.

Nicholls et al. (2001) investigated the presence of SCCPs and MCCPs in farm soils in the UK and found that they were below detection limits (< 100 ng/g ww); however, CPs were present in earthworms living in the associated soils (<100–1700 ng/g ww), the levels were higher than what was found in Oslo. Thomson (2001) investigated the effects of MCCPs on the survival, growth and reproduction of the earthworm. The most sensitive toxicity value for reproduction for earthworms in soil is the chronic (28-day) lowest observed effect concentration (LOEC) of

383 000 ng/g dw, which was clearly above the highest soil samples reported here. This indicates that the present level of CPs in soil in Oslo most likely poses no significant risk for earthworms.

3.5.4 Fieldfare

SCCPs were detected in five out of ten samples and MCCPs in eight out of ten samples. The pooled sample of two fieldfare eggs from Bøler in 2017 had an extreme high concentration of SCCPs of 1280 ng/g ww. This year an even higher concentration of SCCPs of 4730 ng/g ww was detected at the same location. This pooled egg sample also contained an extremely high concentration of MCCPs of 1850 ng/g ww. The SCCPs concentrations of the other four eggs varied from 16 to 45 ng/g ww.

In a recent study of SCCPs and MCCPs in marine and terrestrial animals from Scandinavia, the levels of SCCPs and MCCPs in four eggs of tawny owl and three eggs of common kestrel ranged from 85–88 and 85–87 ng/g lipid, respectively (Yuan et al., 2019). Our fieldfare egg data of SCCPs from the Oslo area are much higher with concentrations on a lipid weight basis in the range 284-118250 ng/g lipid. Similar, MCCPs in fieldfare eggs from Oslo on a lipid weight basis were between 245-46250 ng/g lipid. Yuan et al. 2019 also investigated SCCPs and MCCPs in muscles of starlings which were 350 and 310 ng/g lipid, respectively.

SCCPs in muscle of terrestrial bird species (n=38) inhabiting an e-waste recycling site in South China varied from 620 to 17000 ng/g lipid (Luo et al., 2015), and resident birds accumulated significantly higher SCCPs concentrations than migratory birds.

3.5.5 Sparrowhawk

SCCPs and MCCPs were found in all of the nine sparrowhawk eggs. MCCPs had higher concentrations than SCCPs in all samples. This year’s data ranged from 42 to 3026 for SCCPs compared to <LOD to 38 ng/g ww in 2017 and <LOD and 318 ng/g ww in 2016. Like the fieldfare eggs, one sparrowhawk egg had extreme SCCPs concentration of 3026 ng/g ww. The mean value for SCCPs without this extreme concentration was 111 ng/g ww. The same egg had even higher concentration of MCCPs (6697 ng/g ww). MCCPs ranged from 57 to 6697 ng/g ww compared to <LOD to 74 ng/g ww in 2017 and <LOD and 0.5 ng/g ww in 2016. The mean value for MCCPs without the extreme maximum concentration was 247 ng/g ww.

Although muscle and egg samples are not directly comparable, a recent study on muscle samples from peregrine falcons in southern-middle of Sweden reported 540 and 410 ng/g lipid weight for SCCPs and MCCPs, respectively (Yuan et al., 2019). The same study (Yuan et al., 2019) reported 550 and 360 ng/g lw of golden eagle (n=10, muscle) for SCCPs and MCCPs, respectively. The highest concentrations of terrestrial birds were detected in muscle of eagle owl (n=10) from 2013-2017 of 730 and 720 ng/g lw (Yuan et al., 2019). Our 2018 data without the extreme maximum concentrations of SCCPs and MCPPs revealed a much higher mean of 2018 ng/g lw and 4675 ng/g lw for SCCPs and MCCPs, respectively. SCCPs and MCCPs were investigated in muscle peregrine falcon in the area of Yangtze River Delta, China; the mean value of SCCPs and MCCPs were 1300 ng/g lw and 2100 ng/g lw, respectively (Du et al., 2018)

3.5.6 Brown Rats

SCCPs and MCCPs were detected in all of the nine analysed rat liver samples and ranged from 3.4 to 145 ng/g ww for SCCPs and 8.1 to 821 ng/g ww for MCCPs. Last year 2017 revealed 59 to 143 ng/g ww for SCCPs and 81 to 327 ng/g ww for MCCPs. In the 2016 data SCCPs were only detected in 4/10 samples with maximum concentration of 160 ng/g ww. MCCPs was detected in 9/10 samples in 2016 with maximum concentration of 70 ng/g ww. As with sparrowhawk, MCCPs had the highest concentrations with a mean value of 217 ng/g ww (median 83 ng/g ww) compared to SCCPs with a mean of 28 ng/g ww (median 7.4 ng/g ww). Yuan et al 2019 investigated SCCPs and MCCPs in ten muscle samples of bank vole collected in 2014, and the concentrations were 400 and 370 ng/g lipid for SCCPs and MCCPs, respectively. Our data from 2018 revealed higher mean value of 705 and 6025 ng/g lw for SCCPs and MCCPs, respectively. Our median values of SCCPs and MCCPs were 175 and 1128 ng/g lw.

3.5.7 Red fox

In fox liver, SCCPs were detected in all ten samples and MCCPs were found in nine samples. MCCPs concentrations were higher than SCCPs. SCCPs ranged from 12 to 34 ng/g ww and MCCPs from <LOD to 377 ng/g ww. Our 2017 data for SCCPs were slightly higher with a range from 27 to 65 ng/g ww, and MCCPs from 2017 ranged from 23 to 130 ng/g ww. Ten muscle samples of lynx sampled 2012-2016 in Scandinavia revealed 800 and 750 ng/g lipid for SCCPs and MCCPs, respectively (Yuan et al., 2019). For comparison, the red fox liver samples from Oslo this year were in the range of 408-1212 ng/g lw and 402-13460 ng/g lw for SCCPs and MCCPs, respectively. In the study of Du et al., 2018 of CPs in wildlife in the Yangtze river delta (YRD), yellow weasel contained the highest level of SCCPs (43 000 ng/g lw) followed by a reptile short-tailed mamushi (22 000 ng/g lw) and peregrine falcon (14 000 ng/g lw).

3.5.8 Badger

SCCPs and MCCPs were detected in all eight badger liver samples. The concentration were lower than in rat- and red fox liver, and concentrations of SCCPs and MCCPs were quite similar for many samples. SCCPs ranged from 22.5-31.8 ng/g ww and MCCPs ranged from 46.1- 144 ng/g ww. One sample had low lipid content 0.34 % and revealed maximum concentrations of 7225 and 11000 ng/g lw. Median concentrations in badger liver were 1712 and 2236 ng/g lw for SCCPs and MCCPs, respectively; and were higher than the median value in red fox liver of 794 and 737 ng/g lw and in brown rat liver with 175 and 1128 ng/g lw for SCCPs and MCCPs, repectively.

3.5.9 Summary S/MCCPs

SCCPs and MCCPs were present in all air, soil, earthworm, fieldfare eggs, sparrowhawk eggs, fox, rat and badger samples, indicating a ubiquitous distribution in Oslo, *Figure 11*, Table 14. MCCPs were higher than SCCPs in many of the samples, except air, earthworm and fieldfare. Extreme high concentration of SCCPs and MCCPs were detected in fieldfare eggs from Bøler in Oslo with over 4730 ng/g and 1850 ng/g ww. One sample of sparrowhawk eggs also showed extreme concentration of 3026 and 6697 ng/g ww for SCCPs and MCCPs, respectively.

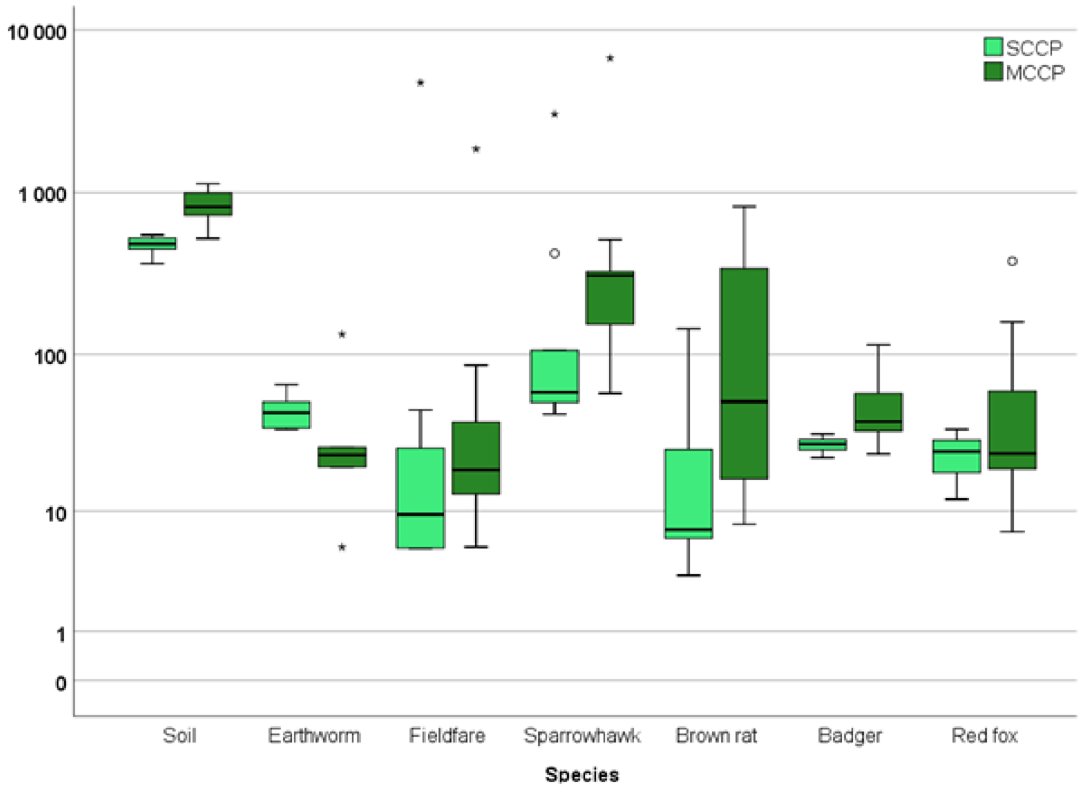

Figure 11: Box plot of SCCPs and MCCPs in the various samples. Concentration of soil in ng/dw, the other sample in ng/g ww. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

Table 14: Mean concentrations in with min-max interval below in grey colour of chlorinated paraffins SCCPs and MCCPs in Air (pg/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww. Compounds not detected in any samples are not included in the table

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
SCCPs	7857 1927-23601	473 364-546	45.4 33.8-64.9	486 LOD-4730	435 42.4-3026	23.7 12.2-33.9	27.2 22.5-31.8	27.6 3.42-145
MCCPs	2552 1200-4197	836 520-1129	41.9 LOD-134	208 LOD-1850	964 57.1-6697	75.5 LOD-377	50.1 23.7-114.8	217 8.11-821

3.6 Cyclic Siloxanes

The three cyclic volatile methylsiloxanes, D4, D5 and D6, have been found to accumulate in biota (Warner et al. 2010; Kierkegaard et al. 2011; Kierkegaard et al. 2013). They do however bioaccumulate to varying degrees depending on the chemical and organism studied. The Member State Committee (MSC) has identified D4, D5 and D6 as substances of very high concern (SVHC), because they are very persistent and very bioaccumulative (vPvB).

All sample concentrations reported for D4-D6 have been blank corrected. Variation observed within the procedural blanks has been used to determine the limit of detection (3 x blank std.

dev.) and LOQ (10 x blank std. dev). Co-extracted matrix can have a substantial effect on background variance introduced (Warner et al. 2013), and thus, is ideal to account for variation introduced for the sample matrix investigated to avoid reporting false positive concentrations (Warner et al 2013.). However, due to the numerous sample matrix types investigated within this study, accounting for the variation introduced by each sample matrix was beyond the scope of this study. Thus, the LOQ was used as a conservative detection limit to insure concentrations reported were well over blank levels and were not influenced by variation introduced by the co-extracted sample matrix.

3.6.1 Air

All three siloxanes were detected at all five sites in Oslo. D4 dominated with twice the concentrations of D5 at most sites, except Slottsparken and VEAS where D5 dominated. The highest sum concentrations were measured at Slottsparken (51.0 ng/day) and Alnabru (45.6 ng/day), followed by VEAS (31.6 ng/day), Frognerseteren (22.7 ng/day) and Grønmo (20.6 ng/day). D4 ranged between 9.8 to 26.6 ng/day with maximum at Alnabru, D5 from 6.7 to 34.6 ng/day with maximum at Slottsparken and D6 from 0.7 to 3.1 ng/day with maximum at Slottsparken. D5 and D6 data were comparable to 2017, while D4 concentrations were in general higher in 2018.

The estimated air concentrations, using an uptake rate of 0.5 m^3/day (Krogseth et al., 2013a), were 19.5-53.2 ng/m^3 for D4, 13.4-69.2 ng/m^3 for D5 and 1.5 to 6.2 ng/m^3 for D6. The mean values were 30.8, 34.4 and 3.4 ng/m^3 for D4, D5 and D6, respectively.

The estimated concentrations of D5 and D6 in this study are 100-1000 times higher than the concentrations measured at background stations in summer 2017: Zeppelin; 0.08 and 0.03 ng/m^3, and Birkenes; 0.5 and 0.04 ng/m^3 of D5 and D6, respectively (Bohlin-Nizzetto et al 2018). This considerable concentration difference reflects the emission sources in urban areas. Genualdi et al., reported in 2011 in a global review, D5 concentrations ranging between 0.3 (Barrow, Alaska) and 280 ng/m^3 in Paris (Genualdi et al., 2011). The authors suggest that D5 and D6 have elevated concentrations in urban areas, which is most likely due to personal care product use. D4 cannot be compared to background air as the adsorbent used in active air samplers at the background site do not give trustworthy results for D4.

A high D5/D4 ratio has been associated with vicinity to emission source areas. This was only observed at two sites in this study; Slottsparken and VEAS, suggesting source areas at these two sites. High ratio at VEAS is expected since VEAS is a waste water treatment plant and a potential source for emissions of siloxanes.

3.6.2 Soil and earthworm

Only D4 was above LOQ in soil at Grønmo with 3.1 ng/g dw. Due to lack of sample material, only three earthworm samples were analysed. D6 was detected in all three samples 1.1-1.4 ng/g ww, but not D4 or D5.

3.6.3 Fieldfare

Regarding siloxanes in fieldfare, D4 and D5 were below LOQ for all samples. D6 was detected in nine out of ten samples and ranged between <LOQ and 2.8 ng/g ww.

3.6.4 Sparrowhawk

In sparrowhawk eggs, only D5 with concentration of 76.3 ng/g ww was detected in one sample This was the same sample that had highest sumPCB, sumPBDE, sumPFSA, PFOSA, sumDechloranes and sumDDT. This concentration was higher than the maximum concentration from previous years.

The concentration in sparrowhawk were lower than for herring gull eggs from Oslo 2018 (Urban fjord monitoring project), were the highest concentration of D5 was more than 721 ng/g ww. Glaucous gull eggs from Svalbard showed D4 and D5 concentrations varying between <LOQ and 5.8 for D4 and 3.1 and 40 ng/g ww for D5 in 2016 (Lucia et al., 2016).

3.6.5 Brown Rat

All three siloxanes were detected in less than half the samples. D4 (mean 1.48 ng/g ww) was detected in two out of nine samples, D5 (mean 5.99 ng/g ww) in four and D6 (mean 2.04 ng/g ww) in three samples. The maximum concentration was detected for D5 of 27.4 ng/g ww. Lower concentrations for D4, D5 and D6 were detected in 2018 than previous years 2015-2017.

3.6.6 Red fox

D4 was only detected in 20 %, D5 in 50 % and D6 in 40 % of the samples. The mean levels were 2.45, 2.9 and 2.6 ng/g ww for D4, D5 and D6, respectively. Maximum concentrations for all three compounds in 2018 were detected in the same sample. In 2017, the mean levels were 0.60 and 0.99 ng/g ww for D4 and D6, respectively (D5 was not detected).

3.6.7 Badger

Only D6 was detected in one sample with concentration 1.5 ng/g ww.

3.6.8 Summary cyclic siloxanes

D4, D5 and D6 were present in air samples and ranged across all three siloxanes from 0.73 to 34.6 ng/day. Slottsparken in the middle of the city centre had highest concentrations for all three siloxanes. D4, D5, D6 were only sparsely detected in the other samples. Red fox liver had the highest detection rate of the compounds and higher concentrations than most other samples on wet weight. Highest detected concentration was in one sparrowhawk egg of D5 (76.3 ng/g ww), see Figure 12 and Table 15.

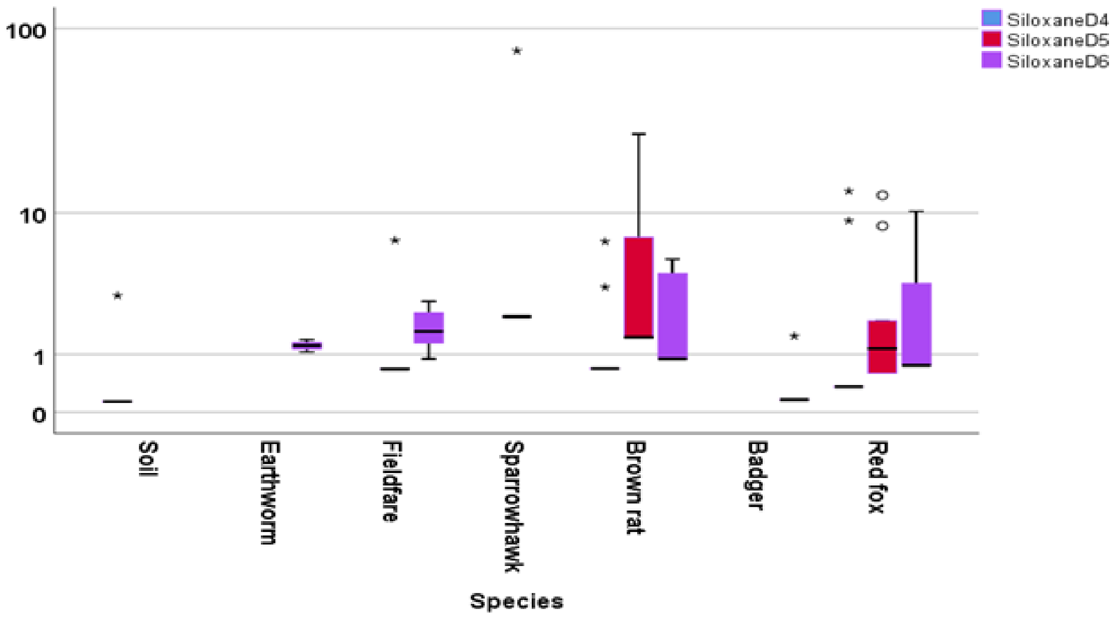

Figure 12: Box plot of D4, D5 and D6 in the various samples. Concentration of soil in ng/dw, the other samples in ng/g ww. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

Table 15 Mean concentrations with min-max interval below in grey colour of cyclic siloxanes in Air (pg/day), Soil (ng/dw), Earthworm, Fieldfare, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww. For samples with only detection in one sample, the concentration is given as one value.

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
D4	15400 9760-26579	<LOD LOD-3.07	<LOD	<LOD	<LOD	2.45 LOD-13.3	<LOD	1.48 LOD-6.80
D5	17221 6703-34619	<LOD	<LOD	<LOD	76.3	2.89 LOD-12.6	<LOD	5.99 LOD-27.4
D6	1693 733-3082	<LOD	1.23 1.07-1.40	1.74 LOD-2.81	<LOD	2.65 LOD-10.2	1.5	2.04 LOD-5.30

3.7 Organic phosphorous flame retardants (OPFR)

3.7.1 Air

Many of the target OPFR compounds were detected by PUF-PAS at all sites. SumOPFR varied from 1.04 to 6.82 ng/day compared to 0.6 to 3.5 ng/day in 2017. As in 2017, Slottsparken had the highest concentration of sumOPFR. Next highest concentration of sumOPFR was detected at Alnabru followed by VEAS, Grønmo and Frognerseteren in decreasing order. As in 2017, TCPP was the dominating compound at all sites. TCPP was also the dominant OPFR compound at Zeppelin in 2017. Next after TCPP followed TiBP(TBP) and TCEP, detected at all sites in Oslo. These latter two compounds had also highest concentrations at Slottsparken and VEAS.

Generally, few air data of OPFR exists in outdoor air. Measurements at Zeppelin station in summer and winter 2017 showed mean concentrations of 170 and 310 pg/m^3, in summer and winter respectively. Conversion to estimated air concentrations is not done for the OPFRs in our study from Oslo due to lack of assured uptake rates.

A recent study from the highly industrialized city Bursa in Turkey, measured OPFRs in air over 43-75 days using PUF-PAS (Kurt-Karakus et al., 2018). Uptake rates for PUF-PAS were estimated using depuration rates of PCB congeners (3.33-11.15 m^3/day with a mean of 6.21 ± 1.69 m^3/day). Estimated concentrations of sum OPFRs in air, using the uptake rates from PCB depuration compounds, (excluding non-detects) ranged from 529 to 19139 pg/m^3 (Kurt-Karakus et al., 2018). The detection frequency was TCPP and TPHP (100%) > TBOEP (88%) > TCEP (85%) > TEHP (78%) > T2iPPP (20%), and concentrations were in the order TBOEP ≫ TCPP > TPHP > TEHP > TCEP. Further, Kurt-Karakas et al found that the relative contribution to total OPFRs decreased for alkylated OPEs and increased for halogenated OPFRs in samples going from background to suburban to urban and industrial sites.

Cao et al., found TCIPP, TCEP and TPHP in road dust of one composite road dust sample sampled from main roads of Beijing, China in 2012 (Cao et al., 2014). So far, mostly OPFR in indoor air of buildings and cars have been reported, both are a potential source for outdoor air. TCEP is regulated in the EU and in Norway. In the EU further information is collected in support of a possible restriction proposal to regulate TCEP, TCPP and TDCP, in flexible polyuretane foam, in child products and furniture and other products.[5]

3.7.2 Soil

For OPFR analyses a single pooled sample was prepared to represent all five locations from Oslo. The sumOPFR concentration for this sample was 10.6 ng/g dw compared to 7.9 ng/g ww in 2017 and 8.6 ng/g dw in 2016.

TCEP had highest concentration with 4.2 ng/g dw followed by TCPP of 2.26 ng/g dw (similar to 2017), and slightly lower than the 2016 concentration of TCPP of 4.2 ng/g dw. In the study from the highly industrialized city Bursa in Turkey (Kurt-Karakus et al., 2018), total OPFR in soil ranged from 38 to 468 ng/g dw, and was from one to several order of magnitude higher than in the Oslo area.

3.7.3 Earthworms

The SumOPFR was 14.4 ng/g ww, comparable to 11.3 ng/g ww from 2017 and lower than in 2016 with 25.4 ng/g ww. The dominating OPFR in 2018 was TiBP of 7.24 ng/g ww followed by TnBP 3.46 ng/g ww and TCPP of 1.25 ng/g ww. In 2017, TCP had the highest concentration of 3.7 ng/g ww followed by TnBP and TCPP, 2.68 and 1.57 ng/g ww respectively.

In the 2015 study, TPP, TCP, EHDP and TEHP were found in most earthworms, but at low concentrations less than 1.5 ng/g ww (Herzke et al., 2016). The dominating OPFR in earthworms in 2015 was TBP with concentrations ranging between <LOD and 3.2 ng/g ww.

[5] https://echa.europa.eu/view-article/-/journal_content/title/echa-weekly-3-april-2019

A recent study (Yang et al., 2018) evaluated the toxicity of ris (2-chloroethyl) phosphate (TCEP) and tricresyl phosphate (TCP) on earthworm (*Eisenia fetida*). Histopathological examination, oxidative stress, DNA damage and gene expression analysis (RT-qPCR) was used to identify the effects and potential mechanism of their toxicity. Both TCEP and TCP significantly increased the DNA damage when the concentrations exceeded 1 mg/kg and a dose-response relationship was observed. In addition, TCEP and TCP also changed the acetylcholinesterase (AChE) activity and expression of genes associated with neurotoxic effects in earthworms under exposure to low concentration (0.1 mg/kg). The concentrations of TCEP and TCP in earthworm from Oslo in 2018 of 0.87 ng/g ww (0.00087 mg/kg ww) and 0.22 ng/g ww (0.00022 mg/kg ww) were well below the observed neurotoxic effect of 0.1 mg/kg.

3.7.4 Fieldfare

No OPFR analyses were carried out.

3.7.5 Sparrowhawk

For OPFR analyses, three pooled samples, each consisting of three eggs, were prepared. None of the OPFR compounds were detected above LOD in 2018. In 2017, the compounds detected in more than two samples and with highest concentrations were TiBP, TnBP, TCPP, TEHP. SumOPFR for the three samples were 1,8, 1.8 and 2.3 ng/g ww, and were comparable to the levels found in 2016.

3.7.6 Brown Rat

In rat liver, three pools consisting of three individuals were prepared prior to analyses. The compounds detected in all three samples were TBEP (0.36-11.4 ng/g ww) and TCPP (0.97-6.06 ng/g ww). The highest concentration was detected in one sample of EHDP with the concentration 95.6 ng/g ww.

In 2017, TCPP (1.1-1.3 ng/ww) was detected in two samples, TBEP (0.3-4.4 ng/g ww) in three samples, the rest of the compounds were below LOD. TCPP and TBEP were also the dominating compounds in 2016.

3.7.7 Red fox

Only TCPP was detected in one sample of 0.65 ng/g ww. In 2017, none of the OPFR compounds were detected in the three pooled fox liver samples. In 2016, only TCPP was detected (0.23 - 3.92 ng/g).

3.7.8 Badger

Only one badger sample revealed concentration above LOD; TPP of 0.14 ng/g ww. In 2017, TDCPP (0.78 ng/g ww) and TBEP (5.49 ng/g ww) was detected in one out of the three badger liver samples.

3.7.9 Summary OPFRs

OPFRs were detected in all air samples at the five sites in the Oslo area. OPFRs were either not detectable or found in very low levels at the higher trophic levels in biota, except for rat liver samples. The highest sumOPFR was detected in rat liver where a concentration of 112 ng/g ww was detected, mainly due to a high concentration of EHDP (95.6 ng/g ww). Next after rat liver samples, the one pooled sample of earthworm revealed sumOPFR of 14.4 ng/g ww followed by soil with 10.6 ng/g dw, Table 16. Based on our findings, the trophic magnification potential of these compounds seems to be low.

Table 16: Mean concentrations with min-max interval below in grey colour of organophosphorus compounds (OPFR) in Air (pg/day), Soil (ng/dw), Earthworm, Sparrowhawk, Red fox, Badger and Brown rat. All concentrations in biological samples are given in ng/g ww. Compounds not detected in any samples are not included in the table. OPFRs were only analysed in one pooled sample of soil and earthworm, and three pooled samples of the rest of biological samples. Fieldfare eggs were not included. For compounds with only one detection above LOD, this concentration is given in the table.

Compounds	Air pg/day	Soil ng/g dw	Earthworm	Sparrowhawk	Red fox	Badger	Brown rat
TEP	n.a.	<LOD	<LOD	<LOD	<LOD	<LOD	0.70 LOD-1.73
TCEP	214 36-521	4.17	0.87	<LOD	<LOD	<LOD	<LOD
TPrP	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
TCPP	1599 431-4057	2.26	1.25	<LOD	0.65	<LOD	3.79 0.97-6.06
TiBP	439 296-588	<LOD	7.24	<LOD	<LOD	<LOD	0.27 LOD-0.67
BdPhP	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
TPP	154 52.9-208	0.20	**0.37**	<LOD	<LOD	0.14	0.16 LOD-0.40
DBPhP	9.28 6.26-14.6	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
TnBP	75.3 15.8-162	0.16	3.46	<LOD	<LOD	<LOD	0.16 LOD-0.25
TDCPP	64.9 13.9-197	<LOD	0.72	<LOD	<LOD	<LOD	<LOD
TBEP	36.1 LOD-83.0	0.71	0.25	<LOD	<LOD	<LOD	5.19 0.36-11.4
TCP	162 15.1-668	1.05	0.22	<LOD	<LOD	<LOD	<LOD
EHDP	377 LOD-959	1.37	<LOD	<LOD	<LOD	<LOD	32.0 LOD-95.6
TXP	3.73 LOD-17.8	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
TEHP	55.9 21.3-111	0.71	<LOD	<LOD	<LOD	<LOD	0.21 LOD-0.47

3.8 Dechloranes and dibromoaldrin

The chlorinated flame retardant group dechloranes (Dec-602 to Dec-604, syn- and anti-DP) were analysed in earthworm, fieldfare eggs, sparrowhawk egg and red fox liver together with dibromoaldrin. Dibromoaldrin, Dec-601 and Des-604 were only detected in one sample from sparrowhawk (site Hellerasten). Dec-602, Dec-603 and anti-DP were detected in 90-100 % of the samples of fieldfare, sparrowhawk and red fox.

3.8.1 Earthworm

Very few compounds were detected above LOD in earthworms, only Dec-602 (0.02 ng/g ww) in one sample from Alna, and syn-DP (0.18 ng/g ww) and anti-DP (0.55 ng/g ww) in one sample from Frognerseteren.

3.8.2 Fieldfare

Several dechloranes were detectable in fieldfare eggs. Dec-602 was detected in all ten samples, and dec-603 and anti-DP in nine of the ten samples. The highest concentration of 2.23 ng/g ww in fieldfare eggs was detected for Dec-603 from the site Alnabru 3. Sum values for all dechloranes varied from 0.08 to 2.72 ng/g ww.

3.8.3 Sparrowhawk

In sparrowhawk eggs, Dec-602, Dec-603 and anti-DP were detected in all samples and syn-DP in nine of ten samples. Dec-603 was detected in highest concentrations followed by Dec-602 and anti-DP. Sum values varied between 1.51 and 8.50 ng/g ww and were higher than in fieldfare. Maximum concentration in Dec-603 was 4.62 ng/g ww.

A study from China (Chen et al., 2013) studied the levels of syn- and anti-DP in various terrestrial birds. Syn- and anti-DP in muscle of eleven Eurasian sparrowhawk ranged from 6 to 230 ng/g lw (median 21) and 20-1090 ng/g lw (median 80) in muscle, respectively. Chen et al. 2013 also suggested that the dechlorane plus (DP) burdens in terrestrial raptors could be driven by the accumulation of the anti-DP isomer, and that factors other than lipid solubility such as hepatic binding protein could be important in determining tissue deposition. In another study, Li et al. (2019) concluded that selective enrichment of anti-DP was observed in hens and their eggs. In addition, stereo-selective excretion of syn-DP was dominant in bioaccumulation of DP in chicken.

A recent North American study (Liu et al., 2019) of peregrine falcon eggs (n=15) reported these concentrations of Dec-602 (23.3-247 ng/g lw), Dec-603 (21.9-145 ng/g lw), anti-DP (3.4-170 ng/g lw) and syn-DP (1.2- 52.6 ng/g lw).

Lipid normalised concentrations of the sparrowhawk eggs from Oslo in 2018 were lower than the North American study and were in the range of 3.0-15.1 ng/g lw (median 4.5) for syn-DP and 7.1-32.6 ng/g lw (median 14.0) for anti-DP. In 2017 we detected 1.3 to 36.2 (median 2.3) and from 3.7 to 35.8 ng/g lw (median 5.6) for syn- and anti-DP, respectively.

A study of peregrine falcon eggs collected from Canada and Spain showed a distinct difference in the dechlorane levels (Dechlorane Plus (DP), Dec 602, Dec 603, and Dec 604) in the two countries, with a mean of 1.78 ng/g lw in Spanish samples compared to 36.4 ng/g lw in Canadian samples, suggesting greater use of the chemical in North America (Guerra et al., 2011).

3.8.4 Red fox

Fewer samples of red fox liver had detectable levels compared to fieldfare and sparrowhawk samples. Dec-602 was detected in all ten samples, Dec-603 detected in only three samples, syn-DP detected in one sample and anti-DP in five samples, the rest were below LOD. The sum values of dechloranes in the samples were also lower than in fieldfare and sparrowhawk and ranged from 0.02 to 0.8 ng/g ww.

Boyles et al. (2017) reported sum dechloranes (including anti- and syn-DP, Dec-602, 603, and 604) in 44 bobcat livers in the range of 1.8 to 120 ng/g lw (median 28.7 ng/g lw). In this study, from midwestern US, bobcat samples were predominated by Dec-603 (34.1% in average), followed by Dec-604 (25.8%) anti-DP (15.7%).

In another study (Boyles et al., 2017b), dechlorane analogues were detected in 38% of raccoon samples and ranged from 0.15 to 50.5 ng/g lw (median = 2.32). In these raccoon samples Dec-603 dominated, followed by Dec-602, as in the study with bobcats. In the present study of red fox livers from Oslo 2018, the sum value ranged from 3.1 to 28.6 ng/g lw (median 3.1 ng/g lw). 2017 sum data in red fox liver from Oslo was 4.9 to 158 ng/g lw (median of 7.5 ng/g lw).

3.8.5 Summary dechloranes

Dechloranes were detected in the foodchain of earthworm-fieldfare- sparrowhawk, and in red fox, but at relatively low levels compared to other pollutant classes (see Figure 13 and Table 17). Anti-DP had 100% detection rate in sparrowhawk. Sparrowhawk eggs had higher detection rate of the various dechloranes and sum concentrations than the other species. Mean and median sum concentration on a lipid weight basis was highest in sparrowhawk, followed by fieldfare, earthworm and red fox liver. Although no studies to date are known known to show effects on dechloranes on birds, a recent study where mice were orally exposed to environmentally relevant doses of Dec 602 (1 and 10 µg/kg body weight per day) for 7 consecutive days, revealed effects on immune function in mice (Feng et. al, 2016). Another study of DP revealed no effects on pipping success up to 500 ng/g egg (Crump et al., 2011).

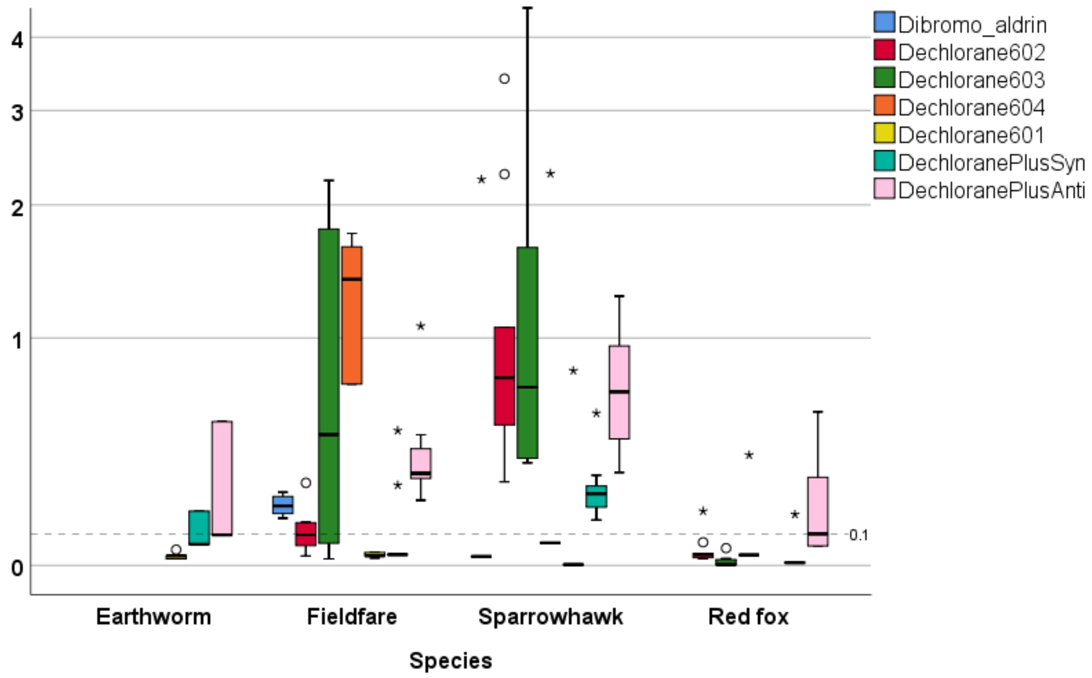

Figure 13: Box plot for dechloranes, concentrations in ng/g ww. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

Table 17: Mean concentrations with min-max interval below in grey colour of dechlorane compounds Earthworm Fieldfare eggs, Sparrowhawk eggs and Red fox liver. All concentrations are given in ng/g ww. For compounds with only one detected concentration in the samples, no average is calculated, only the detected concentration is given.

Compounds	Earthworm	Fieldfare	Sparrowhawk	Red fox
DBA	<LOD	<LOD	2.24	<LOD
Dec-602	0.019	0.11 0.03-0.29	1.15 0.29-3.41	0.05 0.02-0.2
Dec-603	<LOD	0.85 LOD-2.23	1.35 0.37-4.62	0.01 LOD-0.1
Dec-604	<LOD	<LOD	2.30	<LOD
Dec-601	<LOD	<LOD	0.82	<LOD
Syn-DP	0.18	0.11 LOD-0.51	0.27 LOD-0.59	0.17
Anti-DP	0.55	0.41 0.22-1.07	0.74 0.33-1.27	0.19 LOD-0.6

3.9 Phenolic compounds and alkyl ethoxilates

Phenolic compound (bis-A, bis-S, bis-F, TBBPA, octyl- and nonylphenols) were not analysed in air samples, and these compounds were only sporadically detected in the other samples where earthworm had highest detection rate.

None of the phenolic compounds were detected in the soil samples, fieldfare- and sparrowhawk egg and badger samples.

3.9.1 Earthworms

Only three samples of earthworm were analysed due to lack of material. Bis-A was detected in all three samples varying from 64.5-76.1 ng/g ww. Bis-F was detected in one sample at 6.3 ng/g ww and the rest of the compounds were below LOD.

3.9.2 Red fox

Only bis-A detected in three out of ten samples from 41.0 to 55.4 ng/g ww.

3.9.3 Brown rats

Three samples of brown rat liver were analysed. Bis-A and Bis-F was detected in one sample each, 123.6 and 13.6 ng/g, respectively.

3.9.4 Summary phenols

Phenols were only detected in earthworms and livers from red fox and brown rat this year (see Table 18). Highest concentration (124 ng/g ww) was detected in rat liver and next highest in earthworms. A NOAEL value has been reported from rat studies of 5 mg/kg-bw/day for bis-A (US EPA, 2010). Based on this NOAEL value one would expect that effects in rats from Oslo area is negligible.

Table 18: Mean concentrations with min-max interval below in grey colour of phenolic compounds in Soil, Earthworm, Fieldfare eggs, Sparrowhawk eggs, Red fox liver and Brown rat liver. All concentrations are given in ng/g ww. Mean concentrations for compounds with only one detected concentration are also reported in the table.

Compounds	Soil	Earthworm	Fieldfare	Sparrowhawk	Red fox	Badger	Brown rat
Bis-A	<LOD	69.3 64.5-76.1	<LOD	<LOD	21.5 LOD-55.4		57.9 LOD-123.6
Bis-S	<LOD	<LOD	<LOD	<LOD	<LOD		6.7 LOD-13.6
Bis-F	<LOD	4.31 LOD-6.27	<LOD	<LOD	<LOD		<LOD
TBBPA	<LOD	<LOD	<LOD	<LOD	<LOD		<LOD
4-t-Octylphenol	<LOD	<LOD	<LOD	<LOD	<LOD		<LOD
4-octylphenol	<LOD	<LOD	<LOD	<LOD	<LOD		<LOD
Nonylphenol	<LOD	<LOD	<LOD	<LOD	<LOD		<LOD

3.10 UV compounds

Pooled samples were used for analyses, one sample for soil, one sample for earthworm and three samples for the other species. Fieldfare samples were not analysed due to lack of material.

Highest detection rate was found in the one pooled sample of soil and rat liver had highest sum value of UV compounds. The compound OC had highest concentration in all samples, except in rat liver where UV-328 dominated (see Table 19).

Table 19: Mean concentrations with min-max interval below in grey colour of UV compounds in pooled samples of Soil (one sample), Earthworm (one sample), Sparrowhawk egg (three samples), Red fox liver (three samples), Badger liver (three samples) and Brown rat liver (three samples). All biota concentrations are given in ng/g ww and soil in ng/g dw. Only one value is given for those samples with one detection.

Compounds	Soil	Earthworm	Sparrowhawk	Red fox	Badger	Brown rat
BP3	0.54	<LOD	<LOD	<LOD	<LOD	<LOD
EHMC-Z	0.17	<LOD	<LOD	<LOD		
EHMC-E	1.3	<LOD	<LOD	<LOD	<LOD	<LOD
UV-329	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
UV-328	0.72	<LOD	0.52 LOD-0.84	0.51 0.05-1.32	<LOD	6.5 3.2-10.4
UV-327	0.06	<LOD	0.28 LOD-0.32	0.04 LOD-0.08	<LOD	0.6 0.4-1.0
OC	4.9	8.3	3.4 LOD-7.6	<LOD	<LOD	1.6 LOD-3.2

3.11 Biocides

Biocides (rodenticides) were only analysed for in red fox, rat and badger liver samples i.e. species that were more likely to be exposed to these substances through their diet. Four biocides were selected for analyses in these samples (Bromadiolone, Brodifacoum, Flocumafen and Difenacoum).

3.11.1 Red fox

As in 2017, bromadiolone and brodifacoum were the dominating compounds. Bromadiolone were detected in eight of ten red fox liver samples and ranged from LOD to 3473 ng/g ww. The 2018 data revealed only one sample above 2000 ng/g ww of 3473 ng/g ww (see Table 20), with mean value of 543 ng/g ww (median 114 ng/g ww), and much lower compared to the mean value of 1800 ng/g ww (median of 996 ng/g ww) in 2017.

Brodifacoum is a highly lethal 4-hydroxycoumarin vitamin K antagonist anticoagulant poison. In recent years, it has become one of the world's most widely used biocide. It is typically used as a rodenticide but is also toxic to all mammals. Brodifacoum was detected in eight out of ten samples and ranged from 3.6 to 818 ng/ww with a median of 55 ng/g ww and a mean value of 132 ng/g ww. The concentrations were also lower than 2017 results with a mean value 299 ng/g ww. In 2018, flocumafen was not detected and difenacoum was detected in three samples, in agreement with last years' results.

Bromadiolone persists very long in the liver, up to 270 days (Giraudoux et al., 2006). In a study from Sweden (Nordström et al., 2012), bromadiolone was found in the range <LOQ to 1100 ng/g ww in red fox livers (n=10), and a Finnish study (Koivisto et al., 2016), revelealed mean and maximum concentration of bromadiolone in fox livers (n=11) of 209 and 911 ng/g ww, respectively. In our 2018 study, the two highest concentrations were 969 and 3473 ng/g ww. The rest of the samples were below 390 ng/g ww. The sample with highest concentration of bromadiolone had also highest concentration of Brodifacoum of 818 ng/g ww.

A study from Spain (Sánchez-Barbudo et al., 2012) reported a bromadiolone mean concentration of 150 ng/g ww with maximum concentration of 12300 ng/g ww in red fox livers. Berny et al. (1997) described liver concentrations ranging from 800 to 6900 ng/g ww (median of 1500 ng/g) in confirmed bromadiolone-poisoned foxes.

A hepatic toxicity threshold of 200 ng/g ww for anticoagulant rodenticides (AC) has formerly been considered to represent a lethal hazard for birds and mammals (Fourel et al., 2018). Four samples of bromadiolone and one sample containing brodifacoum were above this threshold. Berny et al 1997 suggested a threshold of 2000 ng/g ww in animal liver for AC poisoning. Routine analysis by Berny et al. of hundreds of animals over a 10 years period could not find clinical evidence of AC poisoning for AC liver concentration below 2000 ng/g (< 0.2 mg/kg). One red fox liver sample from Oslo area in 2018 was above this threshold with 3473 ng/g ww.

3.11.2 Brown rats

In rats, only bromadiolone was found in seven out of nine samples. The concentration in rats <LOD-205 ng/g ww (mean 154 ng/g ww) were lower than in red fox, and lower than 2017 and 2016 data.

3.11.3 Badger

Brodifacoum was the only rodenticide detected, and in only one (90.7 ng/g ww) out of eight samples. In 2017, more samples were detected and with higher concentrations.

3.11.4 Summary biocides

The concentrations of biocides this year (2018) were lower than in 2017 and 2016. Still, the levels of rat poisons were much higher in the red fox than in the target species; the rats, Figure 14, Table 20. A possible explanation for this may be the fact that in our study all the rats sampled were taken by clap-traps, not in traps baited with poison. So maybe poisoned rats are an easy prey for the fox, as sick animals are a much easier prey than healthy ones. Badger might also feed on poisoned rats, or from contaminated soil species, but this is not known for the authors.

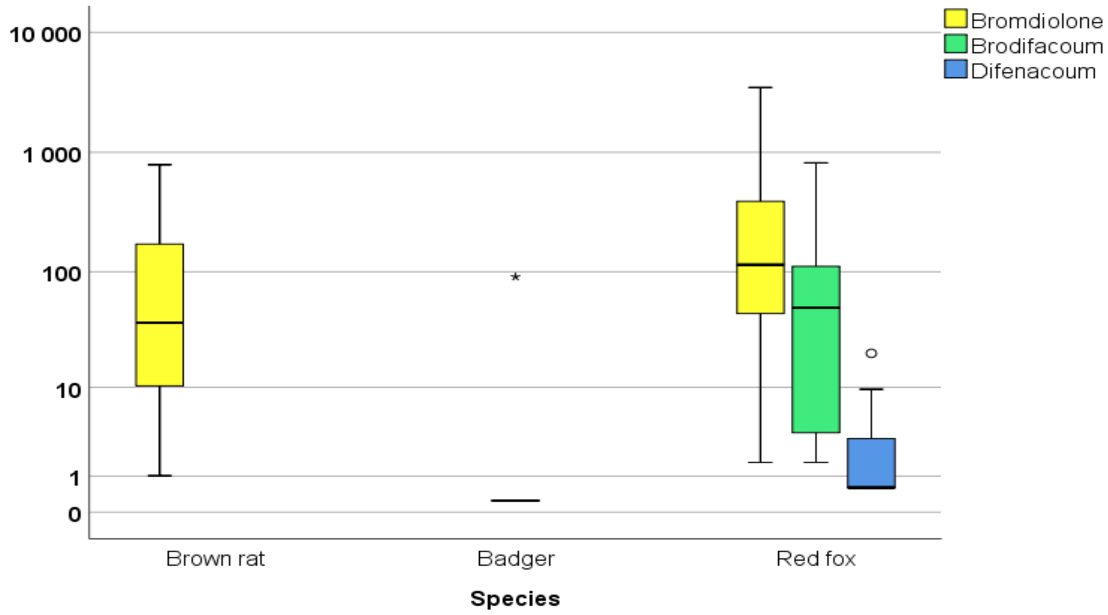

Figure 14: Box plot of rodenticides in liver samples of brown rat, badger and red fox. Concentrations in ng/g ww. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

Table 20: Mean concentrations with min-max interval below in grey colour of biocides in Red fox liver, Badger liver and Brown rat liver). All concentrations are given in ng/g ww. Only one value is given for Badger liver with one detection.

Compounds	Red fox	Badger	Brown rat
Bromadiolone	543 LOD-3473	<LOD	154 LOD-789
Brodifacoum	132 LOD-818	90.7	<LOD
Flocumafen	<LOD	<LOD	<LOD
Difenacoum	3.7 LOD-20.1	<LOD	<LOD
Sum Biocides	847 79.5-4291	90.7	154 LOD-789

3.12 Pesticides

Pesticides were only analysed in sparrowhawk eggs.

Pesticides, especially *p,p'*-DDE are still a dominating pollutants in sparrowhawk egg, despite the fact that DDT has been banned for general use in Norway since 1972. One suspects long-range transport to be the main factor behind this, either via air, precipitation or ocean currents, but due to the long half-life of DDTs, especially in cold environments, one cannot exclude that some of the DTTs may be of local origin. Equally important may be the fact that this species also feeds on migrating prey, i.e. small birds, especially passerines, which may have spent their winter in Europe or Africa (Haftorn, 1971), thus being able to carry pollutants in their bodies from areas more polluted than ours. However, its eggs are probably primarily formed in its body after the return to Norway from its winter quarters in south-western Europe, since it is energetically costly to migrate with a body burden of eggs that may weigh up to half of its own mass (Haftorn, 1971).

Relatively low concentrations of HCB, were found relative to *p,p'*-DDE, Table 21. The concentration range for HCB was 3.7 to 58 ng/g ww in 2018 and in agreement with 3.4 to 36.6 ng/g ww in 2017, and with 5.4 to 28.9 ng/g ww in 2016. The concentration range for *p,p'*-DDE (186-2740 ng/g ww) was higher than data in 2017 with 113-1600 ng/g ww (mean 874 ng/g ww) and comparable with 2016 data (range of 615-2400 ng/g ww). 78 % of the samples from 2018 exceeded the reported PNEC for *p,p'*-DDE of 870 ng/g ww in osprey. This PNEC value was based on a LOEL of 8700 ng/g ww for *p,p'*-DDE associated with 20% eggshell thinning in osprey (Chen et al., 2010).

Table 21: Mean concentrations of pesticides with min-max levels below in sparrowhawk eggs, concentrations in ng/g ww.

Compounds	Sparrowhawk
HCB	23.3 3.7-58.0
α-HCH	<LOD LOD-0.1
β-HCH	2.06 0.34-5.93
γ-HCH	0.11 0.06-0.29
o,p'-DDE	<LOD
p,p'-DDE	**1337** **186-2740**
o,p'-DDD	<LOD LOD-0.06
p,p'-DDD	9.11 2.03-14.6
o,p'-DDT	<LOD LOD-0.14
p,p'-DDT	11.8 2.91-30.7
SumDDT	1358 191-2764

The effect on eggs was determined by measuring the eggshell thickness and by computing the eggshell index (see Methods chapter). These parameters were compared to same parameters of eggs that were collected before DDT was introduced on the market (before 1947). Compared to the eggshell index levels of eggs prior to 1947 (the year normally chosen as dividing the pre- and post-DDT era), the eggshell index was significantly lowered in the 2015-2018 eggs compared to the pre-DDT period, Figure 15. The reference index before 1947 is 1.45, while the mean index for 2015-18 is 1.27 (- 12.5 %). The difference is significant (Mann-Whitney U-test, Z = -4,47, P < 0.001). The sparrowhawk has been one of the species most affected by shell thinning on a European level (Ratcliffe, 1970, Newton and Bogan, 1978), and also in Norway (Nygård and Polder, 2012).

The results also show that eggshells from our data 2015-2018 are on median 2.6 % thinner than the pre-1947 average. The difference is not significant (Mann-Whitney U-test, Z = -0.794, P = 0.43). The mean SumDDT level during 2015-2018 was 1147 ng/g ww, which is lower than the critical level of 3000 ng/g of DDE proposed for population decline by Newton & Bogan (1986). The time-trend of the eggshell index is shown in Figure 15. There was a significant correlation between eggshell index and logSumDDT levels (Pearson corr., R = - 0,481, N = 51, P < 0,001), (see Figure 16) and between logSumDDT and eggshell thickness (R = -0.445, N = 37, P = 0.006).

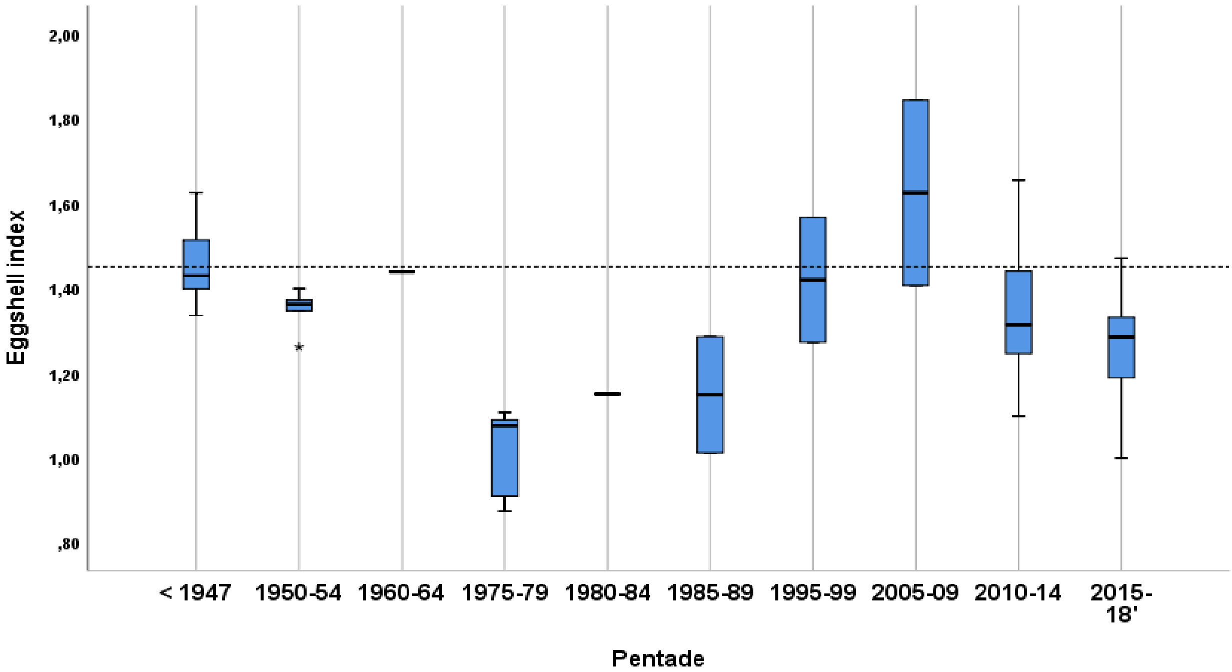

Figure 15 : Eggshell index of sparrowhawk eggs from Norway by pentade. The eggs from the monitoring scheme reported here are represented in the box to the right (2015-18). The dashed line shows the pre-1947 mean.

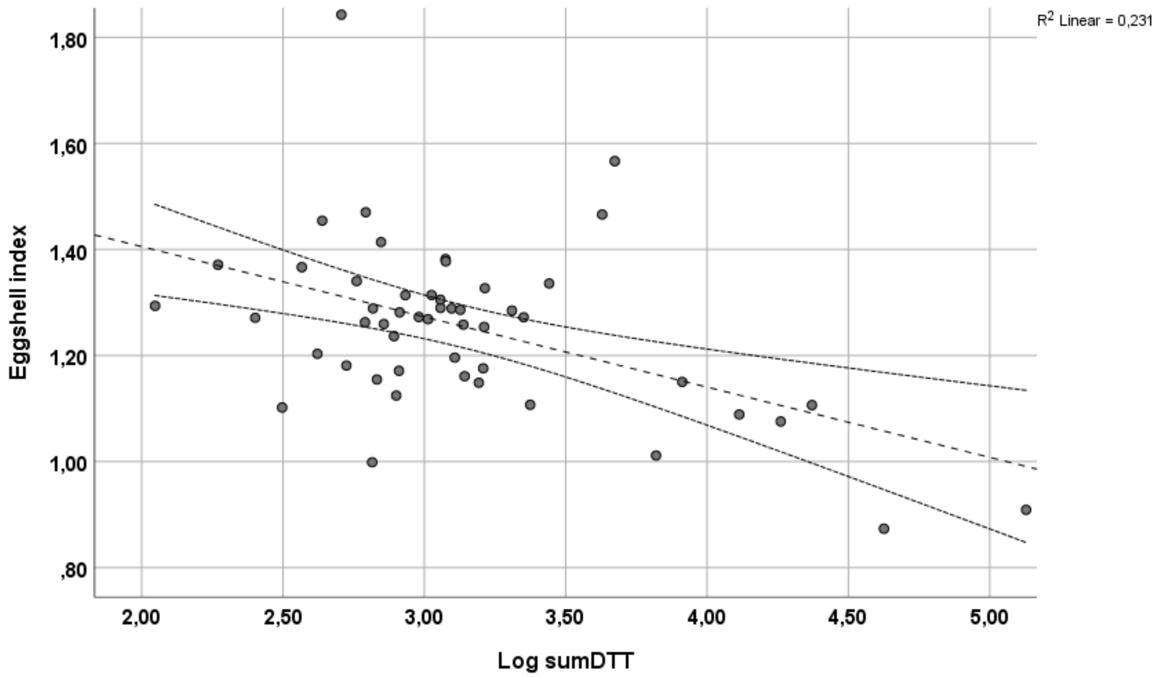

Figure 16: The relation between log SumDDT in eggs and eggshell index in sparrowhawk eggs. The graph contains all relevant egg data of sparrowhawks from Norway.

P,p'-DDE still dominates among the pesticides, despite the fact that it is more than 40 years since it was banned for most uses in Norway. A study in Vietnam showed that the half-life in soil of SumDDT was 6.7 years, but it may be much longer in temperate and cold climates, since the breakdown rate is very temperature-dependent (Toan et al., 2009). The levels are generally decreasing over time in birds of prey in Norway, but the decrease rate is slow (Nygård & Polder 2012). The DDT compounds are still affecting the sparrowhawk eggs, by reducing their shell quality. The levels of HCB and HCH were very low compared to *p,p'*-DDE, and they are not expected to have any notable negative effects on the sparrowhawk.

3.12.1 Summary pesticides

P,p'-DDE still dominates among the pesticides, despite the fact that it is more than 40 years since it was banned for most uses in Norway. A study in Vietnam showed that the half-life in soil of SumDDT was 6.7 years, but it may be much longer in temperate and cold climates, since the breakdown rate is very temperature-dependent. The DDT compounds are still affecting the sparrowhawk eggs, by reducing their shell quality.

3.13 Compound classes across air, soil and species

In the following chapter we will only give a short summary of similarities and the dissimilarities in the load of the major compound classes across matrices. Each compound class has been discussed in the previous chapters across species, including box and whiskers plot. In this chapter we will summarize the dominating compound classes across environmental matrices using sum values and mean sum concentrations. For air, soil and earthworm, we have chosen to report sum values per site since at least soil and earthworm samples are closely site related, and possibly air too. Birds and mammals move and migrate over larger distances in the Oslo area and mean sum values are more relevant for these species. The overview will first and foremost be given in form of graphical information in figures. Individual data can be found in the Annex 1.

Air

Air concentrations from passive sampler given in ng/day (or pg/day) cannot be compared directly to concentrations in other environmental matrices, but comparison of pattern with soil and earthworms can be done. More importantly, comparison across sites for the air data has revealed that there are areas in Oslo that have higher concentrations than other sites for some of the pollutant groups.

When comparing concentrations in air, the emerging pollutants cyclic siloxanes, chlorinated paraffins and OPFRs were dominating. Siloxanes were measured at highest concentrations (ng/day), followed by SCCPs and OPFRs. The very volatile siloxanes constitute more than 70% of the sum concentrations of all measured pollutants. Of per- and polyfluorinated compounds, only the sulfonate groups with PFBS and PFHxS were detected, the rest of compounds were below LOD.

Weather data have revealed that the most important/prevailing wind direction is from south-west for the Oslo area. For intercontinental air transport this means that Denmark, Great Britain and Northern Europe are potential source regions (Heimstad et al., 2018). In 2017, on a local scale, a clear south-west to north-east orientation could be seen, which was also reflected in the prevailing wind direction. The total load of pollutants in air from the Oslo sites can therefore be a combination of local and more distant sources. However, a dominance of urban sources are most likely since the levels from the PAS in Oslo, compared to data from background stations such as Zeppelin (Svalbard) and Birkenes, indicate the existence of a number of point sources/emissions caused by human activities in Oslo, especially for cyclic siloxanes, PCBs and PBDEs.

As in 2017, Slottsparken is the site with highest concentrations in 2018, and significantly higher concentrations of some compound groups in comparison to the other sites, see Figure 17 and Table 22. Alnabru showed comparable sum concentrations with Slottsparken for OPFR and cyclic siloxanes (cVMS). Slottsparken is in the middle of the city centre of Oslo while Alnabru is an area with industry activities. Measurements of the emissions from the pipe at VEAS had comparable concentrations of CPs with Alnabru, and had higher sum of cyclic siloxanes than Frognerseteren and Grønmo.

Slottsparken and Alna, together with Grønmo (near old landfill area), also revealed the highest sum concentrations in the soil samples for the same pollutant groups.

The results from this year and previous years revealed that central city and industry areas in Oslo contributed with emissions to the total load in air of several pollutants.

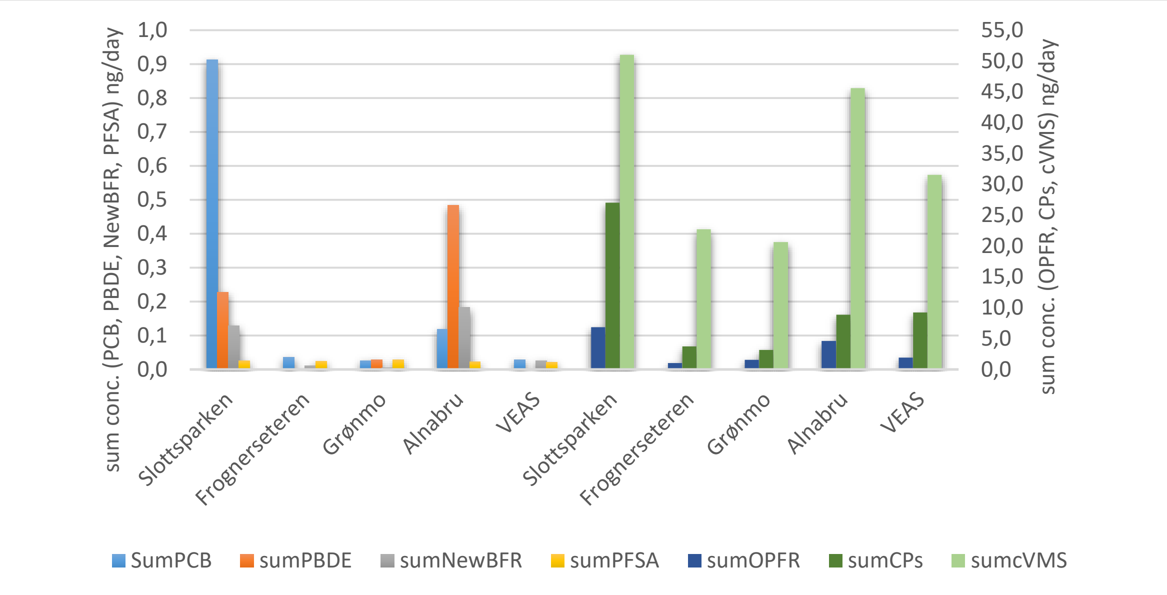

Figure 17: Sum concentrations (ng/day) of the various pollutant groups in air at the five sites in the Oslo area. The y-axis to the right gives the scale for the highest concentrations; i.e. the groups OPFR, CPs and cVMS, while the y-axis to left is the scale for the lowest concentrations given by PCBs, PBDEs, NewBFR and PFAS.

Table 22: Sum concentrations (ng/day) of the various pollutant groups in air at the five sites in the Oslo area.

Site	sumPCB	sumPBDE	sumnewBFR	sumPFSA	sumOPFR	sumCPs	sumcVMS
Slottsparken	0.91	0.228	0.129	0.026	6.82	27.0	51.0
Frognerseteren	0.04	0.002	0.010	0.024	1.04	3.75	22.7
Grønmo	0.03	0.029	0.004	0.029	1.56	3.19	20.6
Alna	0.12	0.483	0.183	0.023	4.63	8.88	45.6
VEAS	0.03	0.002	0.025	0.020	1.91	9.21	31.6

Soil

In soil, as last years, the main contributors to the overall pollution were besides metals (where Pb was the major toxic metal), chlorinated paraffins (CPs), new BFR and OPFR. Slottsparken and Frognerseteren revealed highest Pb and SumToxicMetal concentrations. PCBs and PBDEs played only a small role of the overall contamination. The levels of PFAS in soil in 2018 were much lower than in 2017. SumPFAS of 106 ng/g dw at Alna was detected in 2017 compared to 6 ng/g dw (highest sum conc. in soil) at Alna in 2018.

The sum concentrations of the various organic pollutant groups in soil samples measured at the different locations are shown in Figure 18. As revealed in the figure, the sum of chlorinated paraffins (green bars, y-axis to the right) were significantly higher than the other organic pollutants and were highest at Slottsparken and Grønmo. After CPs, new brominated flame retardants (sum newBFR, grey bars, y-axis to the right) were highest at Alnabru and VEAS due to the high level of DBDPE with 34 and 24 ng/ dw, respectively.

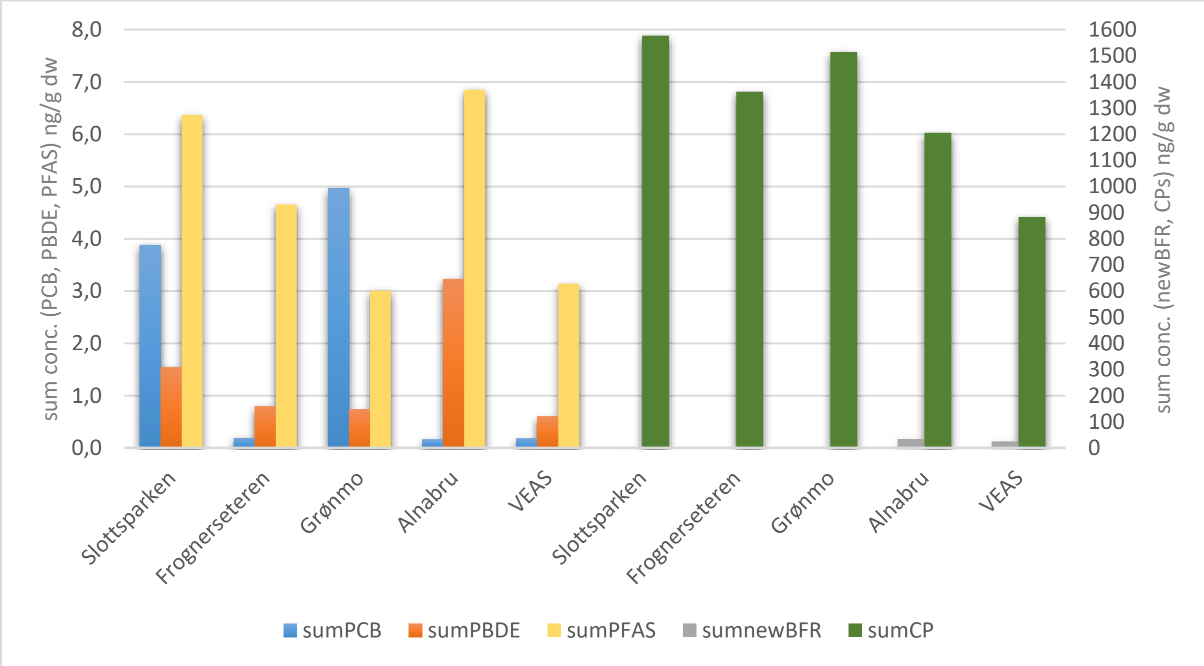

Figure 18: Sum concentrations of organic pollutants in soil samples at the five Oslo locations. Concentrations of OPFR and UV compounds are omitted due to analysed in one pooled sample. The y-axis to the right represents the scale for sumnewBFR and sumCP.

When comparing air and soil data, Slottsparken and Alnabru dominated the air concentrations, while for soil, the site Grønmo also revealed high concentrations of both CPs and PCBs.

Earthworms

Sum concentrations for earthworms (Figure 19) revealed some similarities to sum concentrations of soil samples. For PCBs, Slottsparken and Grønmo dominated and for the PFAS and PBDE, Alnabru had highest concentrations. However, for CPs, Frognerseteren had highest sum concentration in earthworms, while Slottsparken and Grønmo had highest sum CPs for soil data. The sumCPs in earthworm from Frognerseteren was dominated by MCCPs (134 ng/g ww).

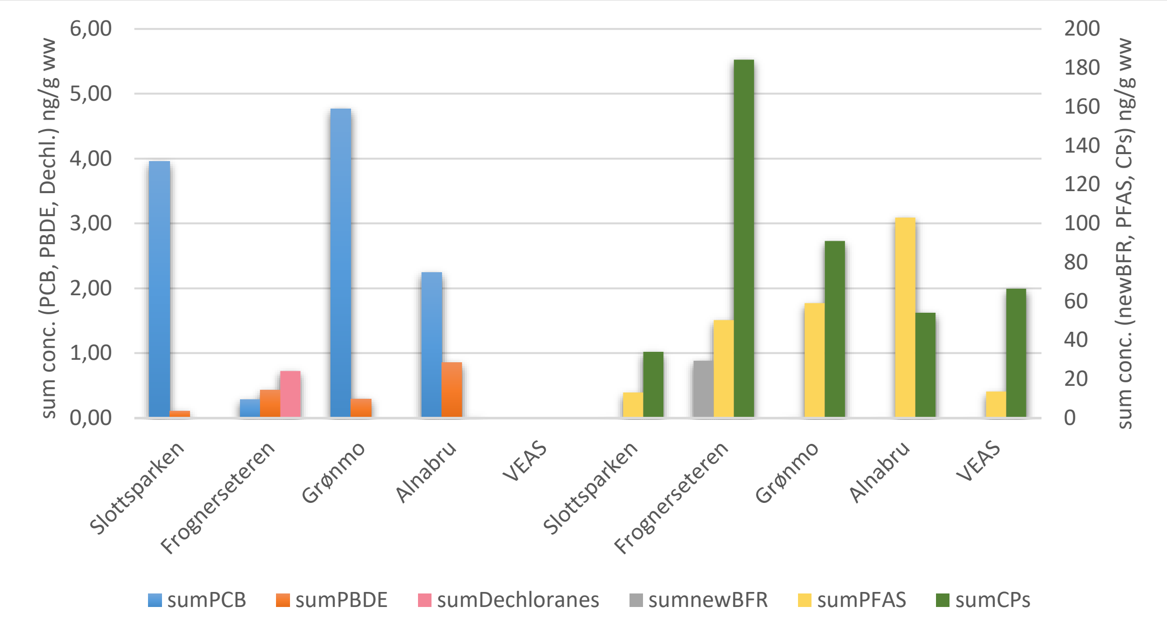

Figure 19: Sum concentrations of organic pollutants in earthworm samples at the five Oslo locations. Compounds not analysed at all five locations are omitted. The y-axis to the right represents the scale for sumnewBFR, sumPFAS and sumCP.

Pollutant loads across species and inter-species comparisons

In general, direct comparison of the pollutant concentrations detected in the investigated species is difficult, since different tissue types were sampled (whole earthworm, eggs and liver samples). 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 predators (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, behaves differently in biota compared to the “classic” organic pollutants such as PCBs, however some PFAS have been shown to bioaccumulate like PCBs.

Figure 20 shows the mean sum concentrations of the toxic metals in soil and biological samples the concentration of Pb is dominating and highest in soil and earthworm across sample types, Cd concentration is highest in earthworm and badger liver, As in soil and brown rat liver, and Hg in red fox liver and earthworm.

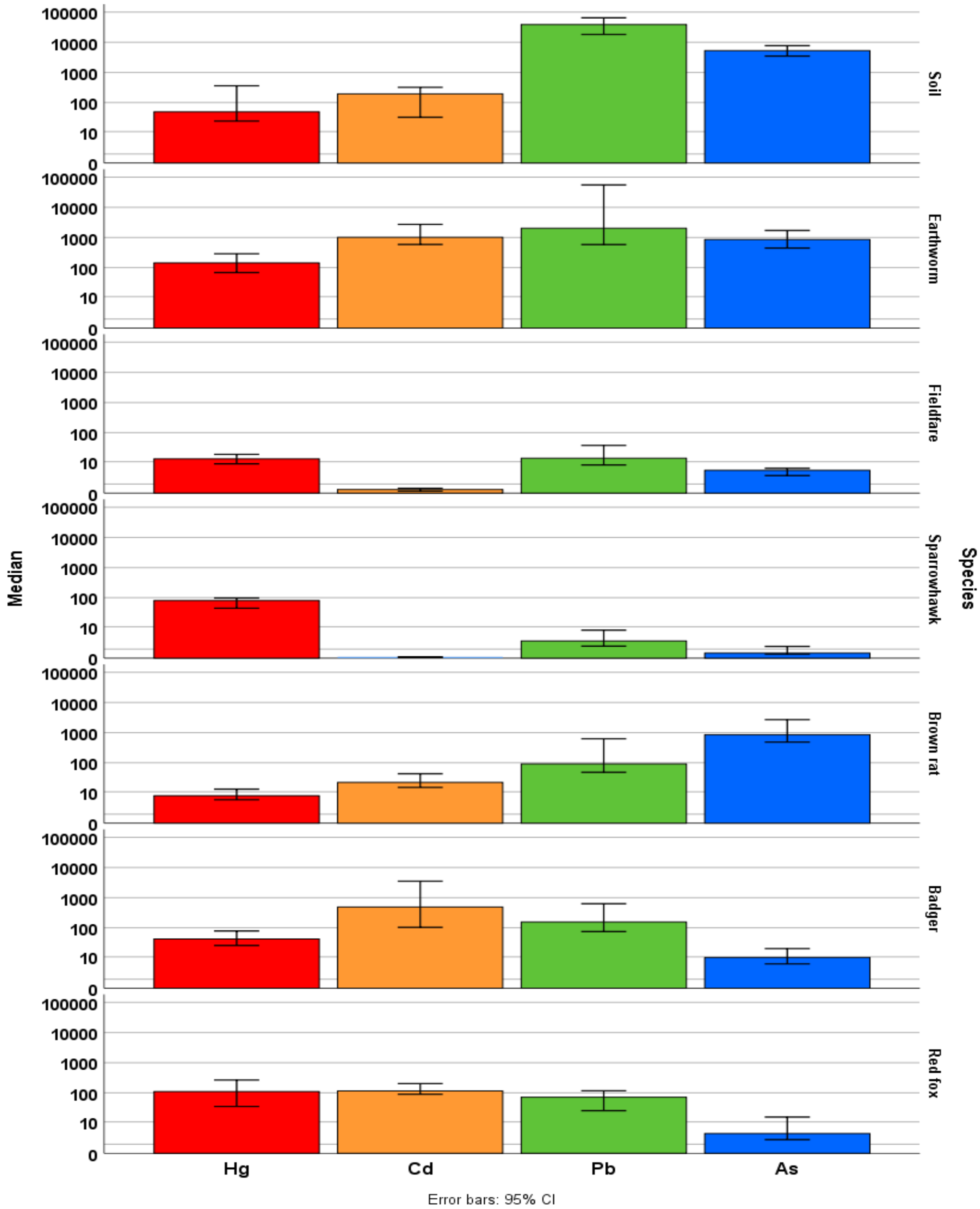

Figure 20: Comparison across species for most important metals given as Mean values with 95 % confidence interval.

Figure 21 shows median Sum concentrations for all pollutant groups. The toxic metals were the dominating group in soil, earthworm, brown rat and badger. Of the organic pollutants, CPs had high contribution in all samples. In bird eggs PFAS, CPs and PCBs (and DDT group for sparrowhawk) were important groups, and in red fox, brown rat and badger livers biocides had high contribution to the sum of organic pollutants. Air samples were dominated by the volatile siloxanes.

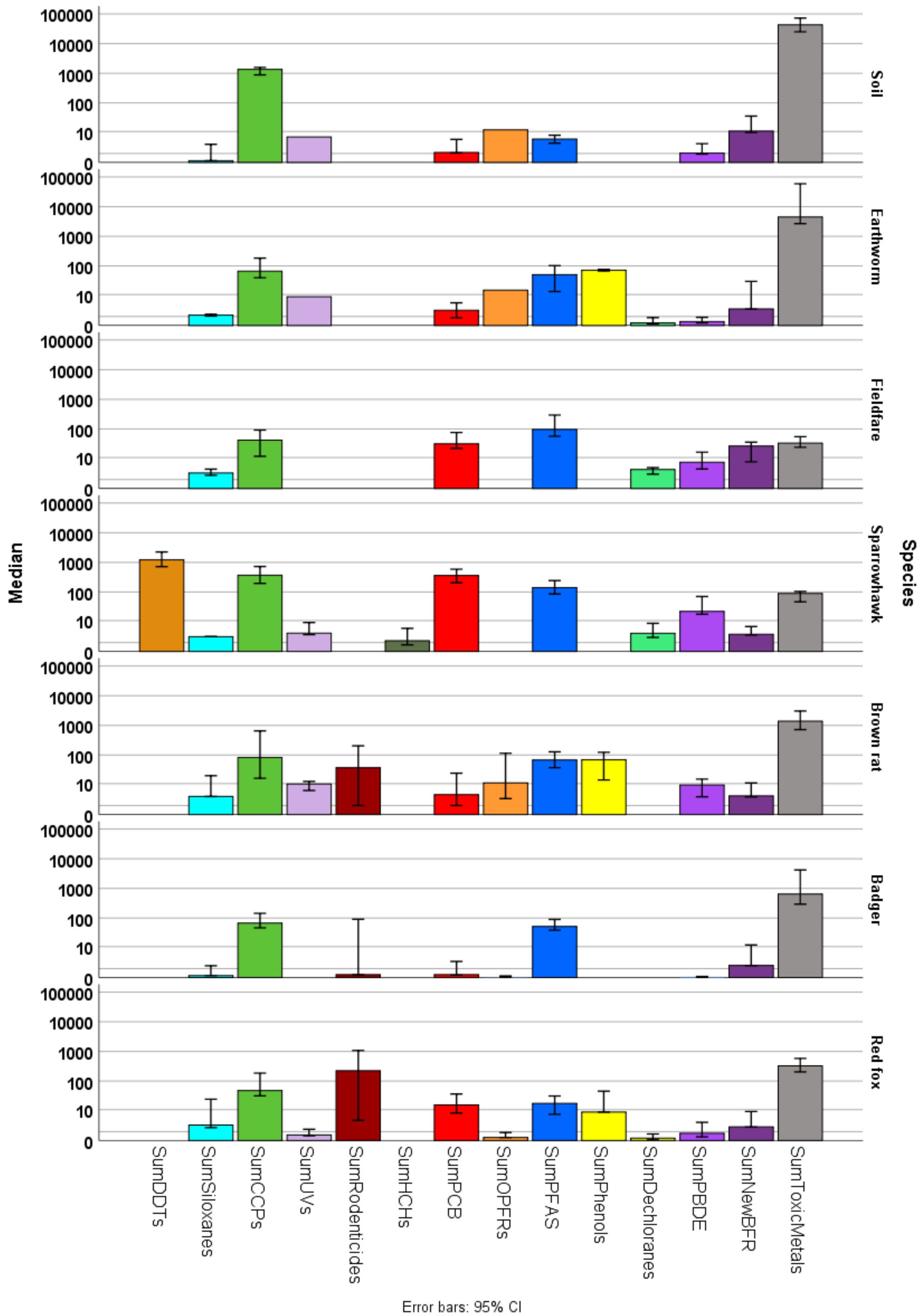

Figure 21: Comparison across environmental matrices and species of pollutant groups given by Median Sum concentrations in air (ng/100 days) the soil (ng/g dw) and biota (ng/g ww) samples.

Figure 22 shows box and whiskers plot of the sum concentrations of each organic compound groups for the biological samples.

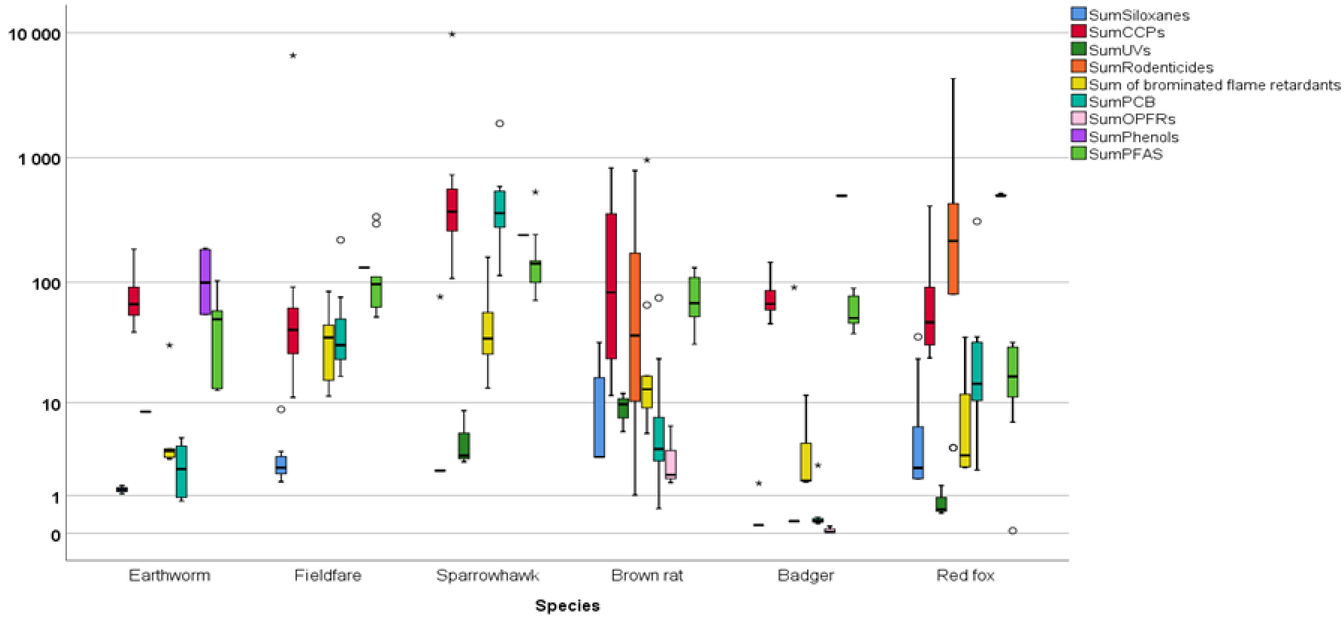

Figure 22: Box plot of the sum concentrations of the most dominating organic pollutant groups in the various biological samples. Concentrations are given in ng/g ww. The upper and lower boundaries of the box are representing the 25th and 75th percentile, the horizontal line in the box marks the median; plotted with error bars and outlying points.

For many species and soil, in 2018, chlorinated paraffins (CPs) contributed with high load to the total sum concentration of organic pollutants analysed in the samples. In 2017, the red fox liver samples had highest total sum concentrations of organic pollutants due to very high mean sum concentrations of biocides. In 2018, sparrowhawk egg revealed highest total mean and median sum concentrations across species, both on wet weight on lipid weight scale, also without the DDT group, Figure 23. In 2017, the PFAS group had a higher impact to the total load, especially in earthworm and fieldfare eggs.

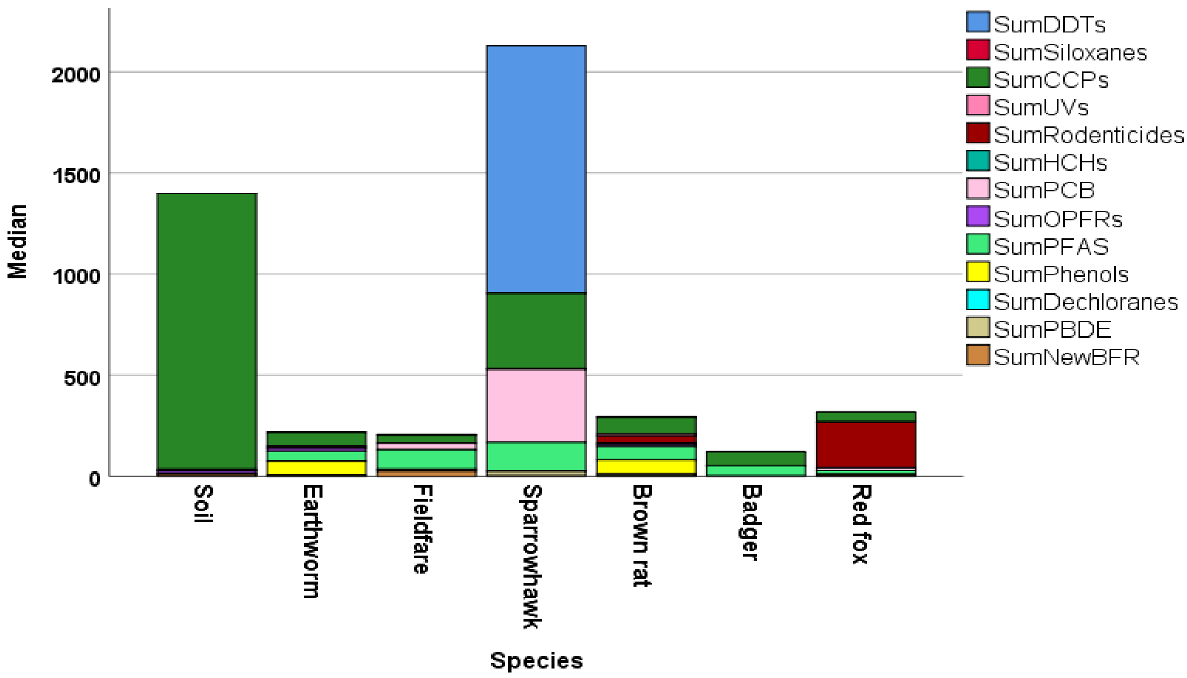

Figure 23: Median sum concentrations of organic pollutant groups in the various samples. Air samples are omitted. Soil concentrations in ng/g dw, ng/g ww in the species.

3.14 Bioaccumulation and biomagnification

As part of the sampling campaign, the following species representing a terrestrial food chain were sampled: Soil, earthworms, fieldfare eggs and sparrowhawk eggs. In our case, we use fieldfare eggs as representatives of fieldfare chicks, which are potential prey items of sparrowhawks, along with adult fieldfares. In addition, stable isotopes were determined as supporting parameters on all biological samples within this study. Using this information, trophic magnification factors (TMFs) were estimated 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 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 ($\delta 15N$) (Borgå et al. 2012). The general scientific consensus is that chemicals are considered bioaccumulative if they exhibit a TMF > 1.

3.14.1 Results from stable nitrogen and carbon isotope analyses

δ^{15}N values can be used to estimate the relative trophic positions of an organism. Terrestrial food chains are in general very short, and 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, and feeding habits of the species. In general, more lipophilic chemicals show stronger relationships between measured tissue concentrations and trophic position.

Table 23: $\delta^{15}N$ in the different sample types from the Oslo area.

Species	N	Mean	Median	Minimum	Maximum
Soil	5	2.57	2.64	0.18	5.01
Earthworm	5	4.46	4.65	3.37	5.51
Fieldfare	10	7.55	7.35	5.92	10.05
Sparrowhawk	9	7.91	7.96	6.50	9.13
Brown rat	9	7.96	7.79	6.97	9.96
Red fox	10	8.48	8.74	6.71	9.87
Badger	8	7.92	7.75	6.74	8.98

According to the measured δ^{15}N data, the organisms included in this monitoring cover different trophic levels. Earthworms showed the lowest δ^{15}N which is consistent with the fact that it holds the lowest tropic position among the different organisms/species in this study, while red foxes had highest mean value. Many of the other species had quite similar values.

Figure 24 shows the $\delta^{15}N$ signature of the investigated species. Differences between soil and earthworms to the other species are quite considerable, with moderate $\delta^{15}N$ enrichment further up the food web.

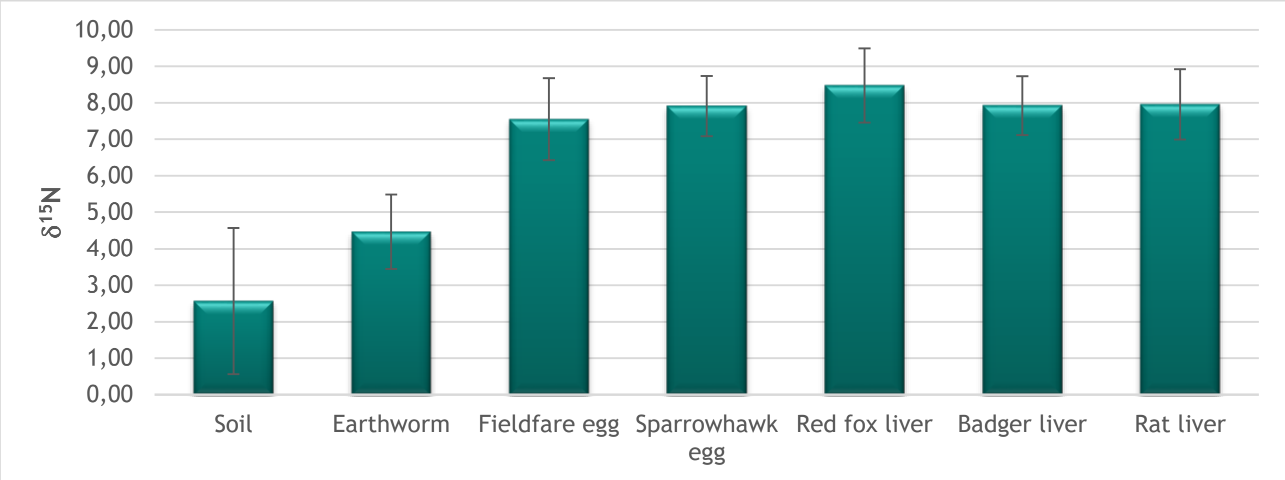

Figure 24: Mean $\delta^{15}N$ concentrations in all species analysed (‰) with standard deviations.

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, 1978; Post, 2002). In this study, the brown rat and the red fox were characterized by the highest $\delta^{15}N$ concentrations (mean of 8.48 and 7.96 respectively), followed by sparrowhawk and badger (7.92-7.93), fieldfare (7.55) and earthworms (4.46). Soil showed an average $\delta^{15}N$ of 2.6 which is lower than 2017 mean value of 4.8, and comparable to mean value of 2.1 from 2016.

Similar to the 2015 and 2016 data, the finding in this year's report 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. However, it might more likely be caused by the fact that the prey of the sparrowhawk is almost dominated by terrestrial prey. The fieldfare is considered to be a secondary consumer, feeding on insects, earthworms, berries and seeds. Since some insect species can be carnivorous also, they might reside on an equally high TL as the prey of sparrowhawk and thus causing elevated $\delta^{15}N$ concentrations. 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).

$\delta^{13}C$ 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. For example, samples from marine locations are expected to show a less negative $\delta^{13}C$ value than samples from terrestrial locations. However, direct comparison of the data presented in this report should be taken with care, since different tissues were analyzed 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 turnover rates).

The $\delta^{13}C$ concentrations found in sparrowhawk eggs ranged between -27.6 to -24.9 with a mean of -25.9. In 2017, $\delta^{13}C$ ranged from-26.2 to -24.5 with a mean value of -25.5. 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). Of the organisms, fieldfare eggs revealed lowest δ^{13}C concentrations (mean and min values), which was in accordance with last year when excluding tawny owl.

Table 24: δ^{13}C levels in the different sample types.

Species	N	Mean	Median	Minimum	Maximum
Soil	5	-27.8	-28.1	-28.6	-26.9
Earthworm	5	-26.7	-27.0	-27.7	-25.6
Fieldfare	10	-27.0	-27.0	-28.1	-25.4
Sparrowhawk	9	-25.9	-25.9	-26.7	-25.3
Brown rat	9	-25.5	-25.5	-26.1	-25.3
Red fox	10	-26.0	-25.8	-27.6	-24.9
Badger	8	-26.4	-26.4	-27.2	-25.5

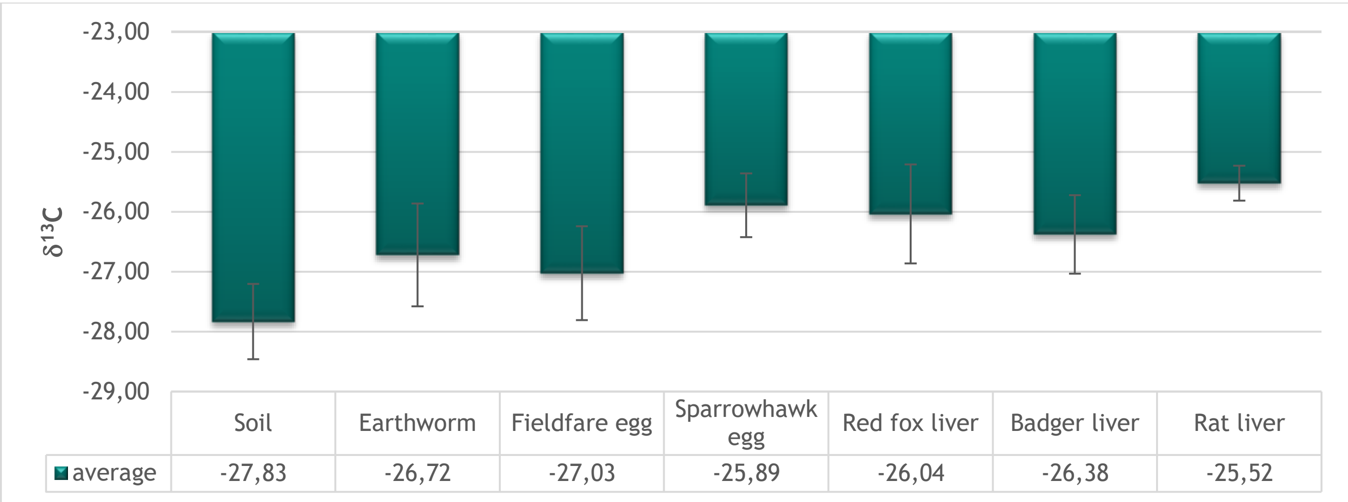

Figure 25: Mean δ^{13} C concentrations with standard deviation in the different species analysed.

δ ^{34}S values provide information regarding the foraging ecology of certain species. Marine sulfate generally has higher δ ^{34}S values than terrestrial materials or waters (Michener and Schell 1994) and sulfur isotope analyses have been used extensively in wetlands and fisheries studies to determine the amount of marine derived nutrients in estuarine systems (Hesslein et al. 1991; Kwak and Zedler 1997; MacAvoy et al. 2000). Using this method, Lott et al., managed to develop four foraging groups of raptors: Coastal bird-eaters (CB), coastal generalists (CG), inland bird-eaters (IB), and inland generalists (IG) (Lott et al., 2003).

Figure 26 illustrates the four foraging groups from Lott et al., 2003. Sparrowhawk would belong to the bird eater category, tawny owls belong to the generalist's category and fieldfare to the inland generalists. The investigated mammals are in the same range as the sparrowhawk.

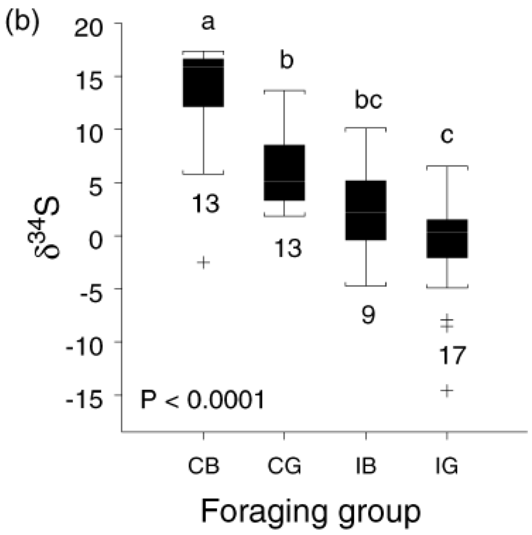

Fig. 2 Box plot showing the central 50% (*boxes*) and range (*lines*) of **a** $\delta D_{f\text{-}p}$ and **b** $\delta^{34}S$ for four foraging groups of raptors: coastal bird-eaters (*CB*), coastal generalists (*CG*), inland bird-eaters (*IB*), and inland generalists (*IG*). Letters above boxes indicate group membership and numbers below boxes indicate sample size. + An outlier value

Figure 26: Boxplot illustrating $\delta^{34}S$ relationships in respect to foraging strategies in raptors, taken from (Lott et al., 2003).

Table 25: $\delta^{34}S$ levels in the different sample types.

Species	N	Mean	Median	Minimum	Maximum
Soil	5	-0.97	2.10	-18.7	6.63
Earthworm	5	-0.39	-0.11	-8.49	4.96
Fieldfare	10	1.04	1.38	-4.59	4.30
Sparrowhawk	9	5.65	5.30	4.83	6.58
Brown rat	9	4.07	3.86	1.11	6.15
Red fox	10	5.08	5.23	4.20	6.33
Badger	8	4.94	4.95	4.49	5.63

Earthworm and fieldfare eggs at VEAS had both the lowest $\delta^{34}S$ values.

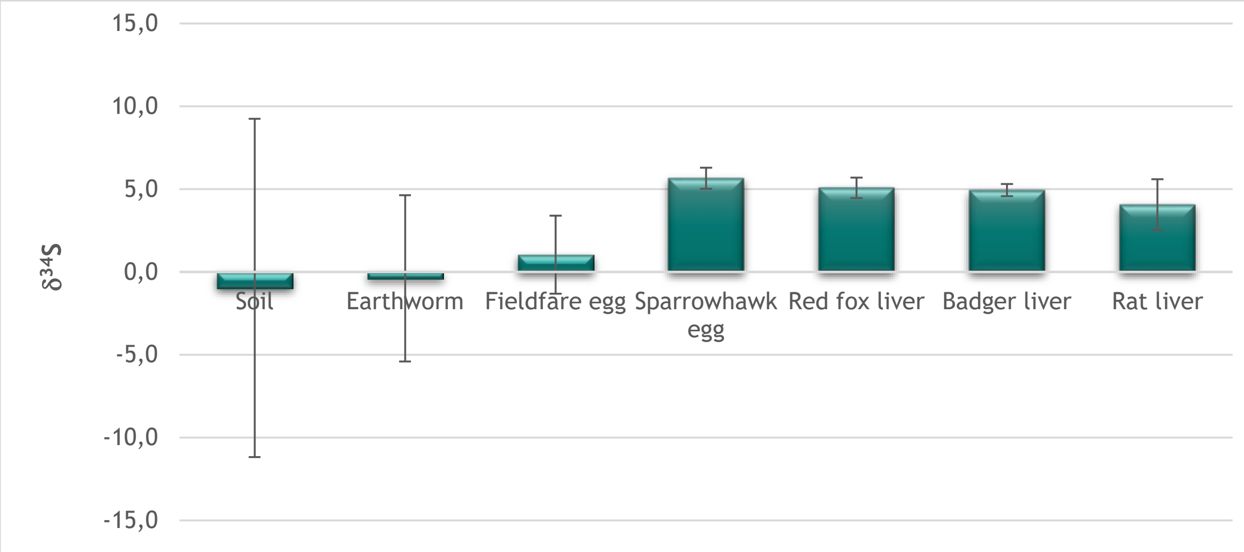

Figure 27: δ^{34} S mean data with standard deviation in the urban terrestrial environment in the Oslo area.

Fieldfare as a terrestrial omnivore (seeds, berries, earthworms and insects), shows a distinction to the sparrowhawk and other species, overlapping earthworm data. δ^{34} S levels are not enriched in the foodchain and stay stable within the same location, allowing comparison of foraging habits.

When relating all samples against $\delta^{13}C$ and $\delta^{15}N$, the following graph is achieved, with soil samples in the lowest left corner followed by earthworm and fieldfare and sparrowhawk. There are some overlap, but rather distinct clustering. One fieldfare sampled revealed very high $\delta^{13}C$ and $\delta^{15}N$ values and treated as an outlier. Sparrowhawk data show a quite narrow spread of data, especially when comparing to badger and red fox.

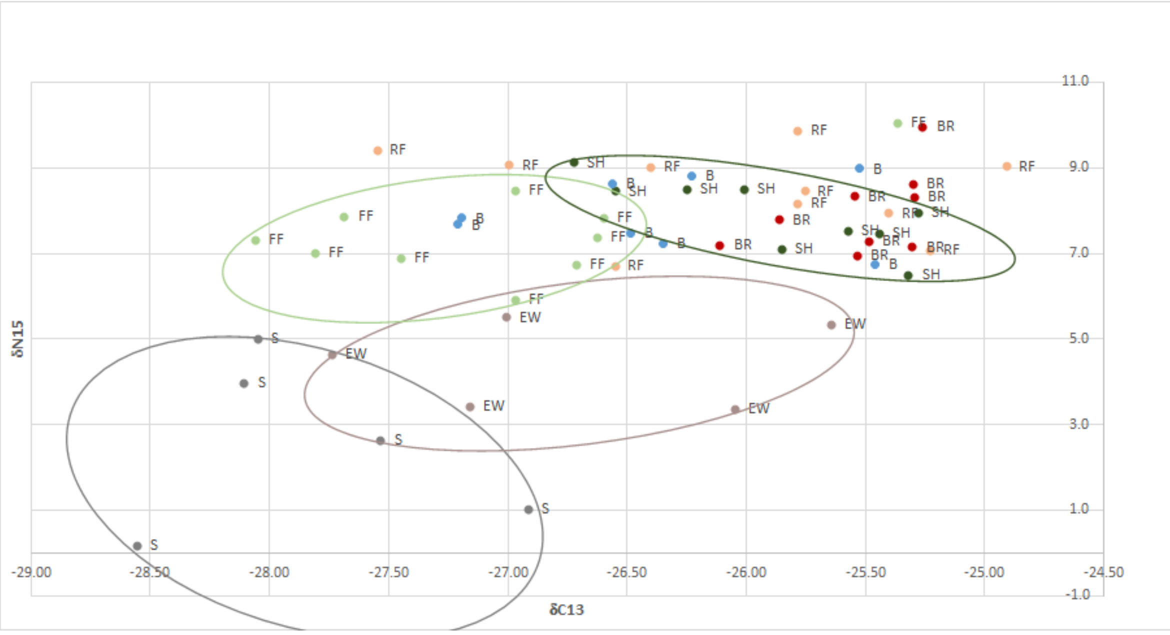

Figure 28: Relationship between the dietary descriptors δ¹⁵N and δ¹³C in soil and biota samples from urban terrestrial environment in Oslo, 2018. Colour codes: Grey: soil (S), brown: earthworm (EW), light green: fieldfare (FF), dark green: sparrowhawk (SH), orange: red fox (RF), red: brown rat (BR), blue: badger (B). Circles are drawn for the soil, earthworm, fieldfare and sparrowhawk eggs.

3.14.2 Estimation of biomagnification by calculation of TMF values

The selected species in this study represent species from the 2^{nd} trophic level (earthworms), 2^{nd} to 3^{rd} (fieldfare) and the 3^{rd} and 4^{th} trophic level (brown rat, red fox and sparrowhawk). To assess the biomagnification of each chemical we correlated the lipid-corrected (except for the case of PFAS compounds, which are wet weight) log concentrations of the different pollutants in the different species of the food web with $\delta^{15}N$, i.e. information on the relative trophic position of the organisms. Within the frame of this study, we applied a foodchain approach earthworm – fieldfare– sparrowhawk to estimate the TMF.

$$TL_{earthworm} = 2 * (\delta^{15}N_{earthworm} / \delta^{15}N_{mean})$$

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

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

All hydrophobic pollutants such as PCB and PBDE data were lipid normalized. PFAS are not lipophilic and wet weight basis were applied. 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.

$$\text{Log [compound]} = a + b\text{TL}$$

$$\text{TMF} = 10^{b}$$

The here estimated TMFs must be treated with caution since the recommended tissue type (muscle) could not be used which is the basis for the TL equation for birds. Instead egg samples were available which are characterized by a much shorter turnover rate and thus reflect the short term exposure rather than the long term one.

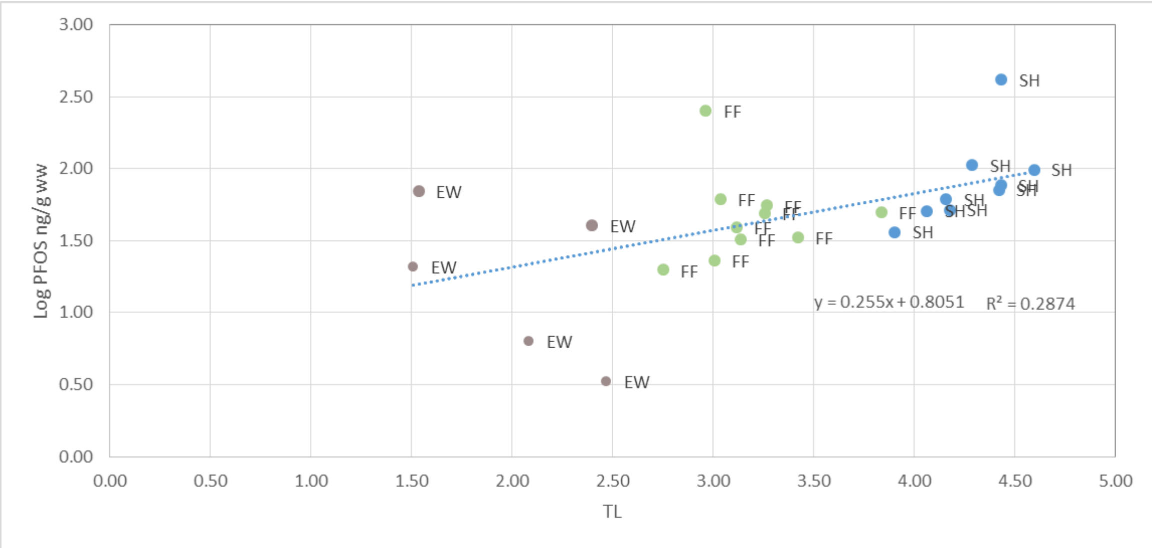

Figure 29: Relationship between trophic level (TL) and Log PFOS for the 2018 dataset, concentrations in ng/g ww. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks.

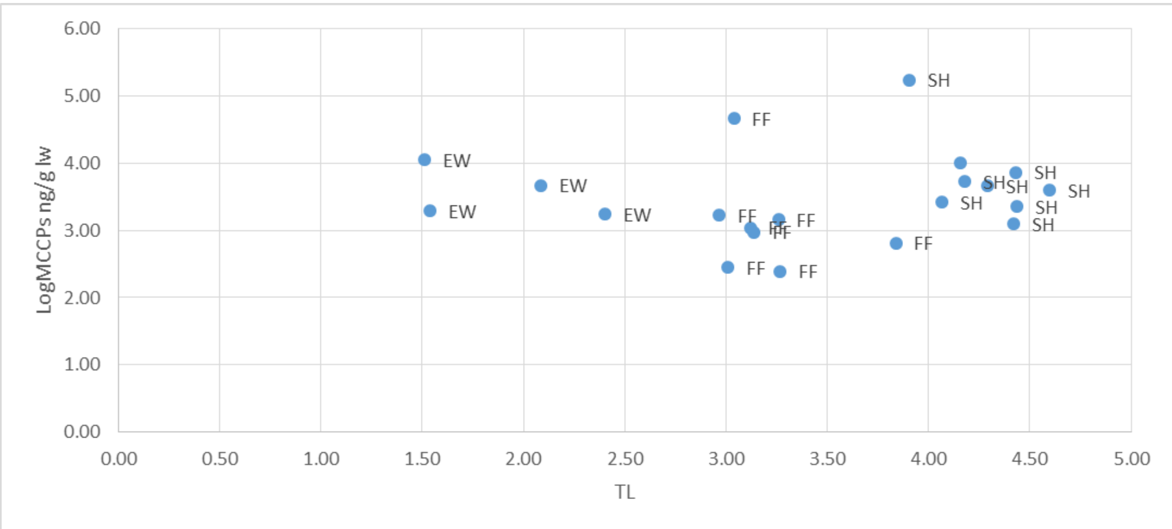

Figure 30: Relationship between trophic level (TL) and Log MCCP for the 2018 dataset, concentrations in ng/g lw. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks. Concentrations below LOD are excluded.

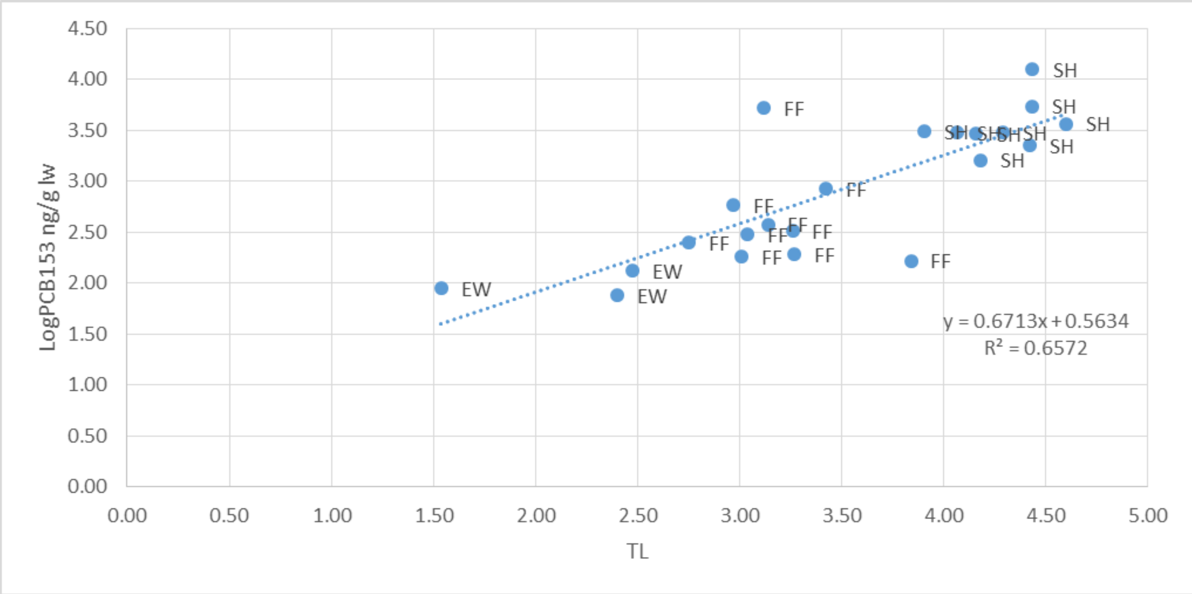

Figure 31: Relationship between trophic level (TL) and Log PCB153 for the 2018 dataset, concentrations in ng/g lw. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks. Concentrations below LOD for earthworms are excluded.

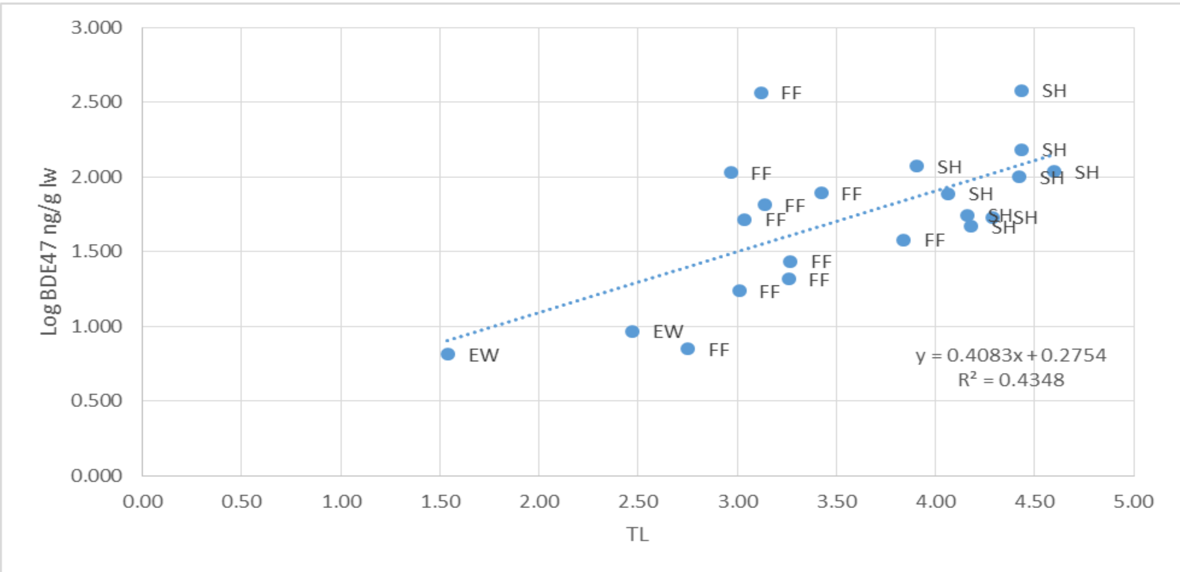

Figure 32: Relationship between trophic level (TL) and Log BDE47 for the 2018 dataset, concentrations in ng/g lw. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks. Concentrations below LOD for earthworms are excluded.

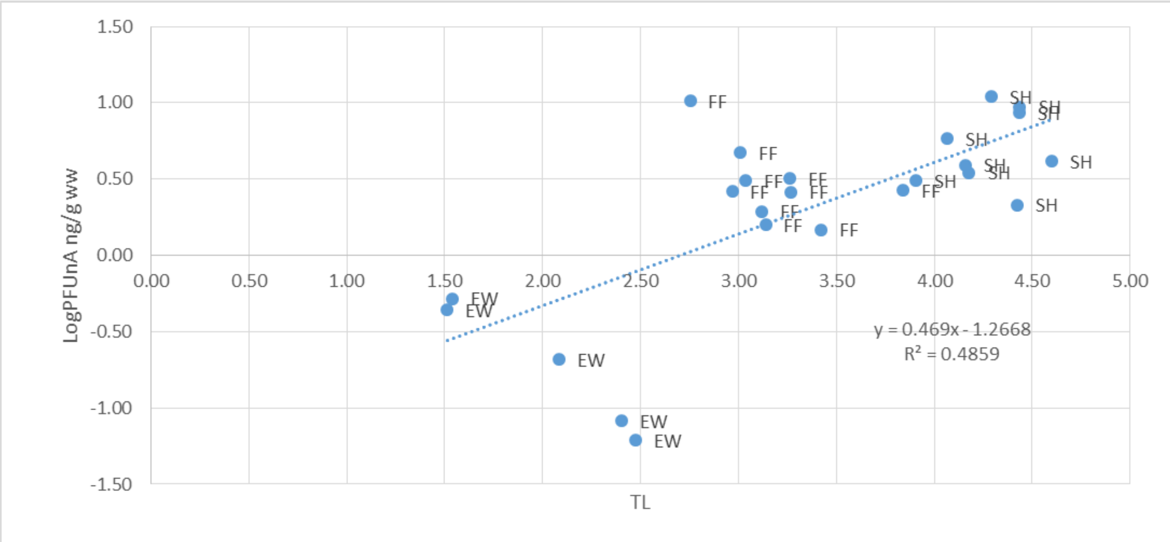

Figure 33: Relationship between trophic level (TL) and Log PFUnA for the 2018 dataset, concentrations in ng/g ww. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks.

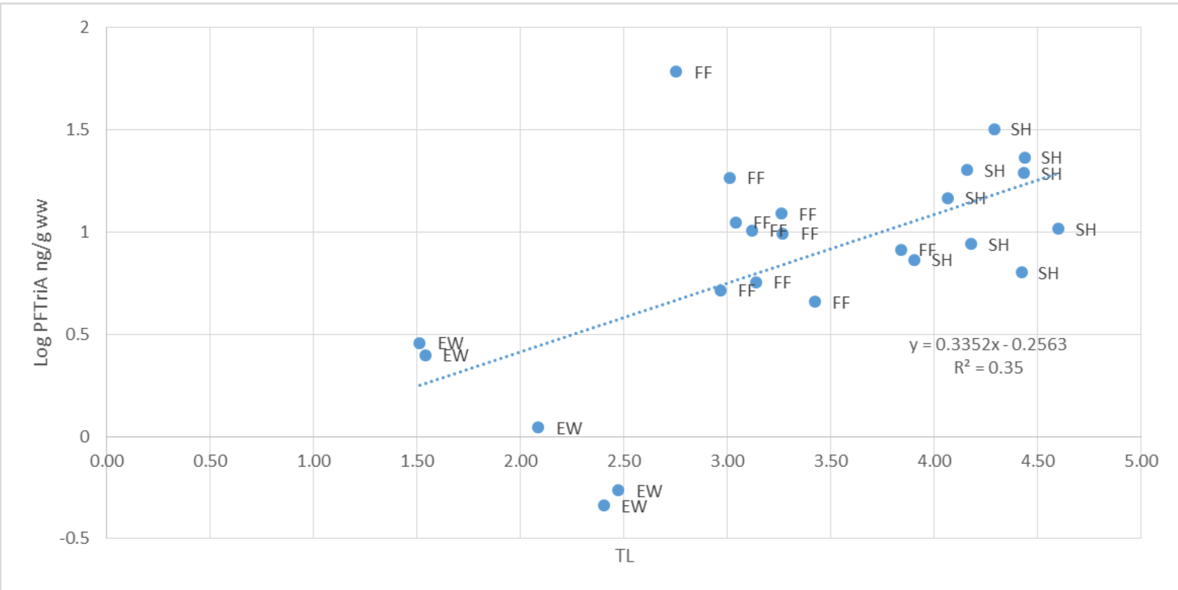

Figure 34: Relationship between trophic level (TL) and Log PFTriA for the 2018 dataset, concentrations in ng/g ww. Data points are labelled with EW for earthworms, FF for fieldfare and SH for sparrowhawks.

The red fox, brown rat and badger were omitted from the calculations, as they do not belong to the studied food-chain, due to their omnivore diet. We obtained the following TMFs for Oslo, based on lipid concentrations and on a wet weight basis for PFAS compounds, for the year 2018 using the equation Log [compound] = a + *b*TL, and TMF = 10^b, (see Table 26).

Table 26: Calculated TMF values of selected organic pollutants based on the 2018 data set for earthworm, fieldfare and sparrowhawk.

	PCB-153	BDE-47	PFHxS	PFOS	PFUnA	PFTriA
TMF(2018)	4.7	2.6	0.5	1.8	2.9 (ww)	2.6 (ww)

TMFs >1 indicate biomagnification of these compounds in the terrestrial foodchain. In respect to these criteria, PCB153, BDE47, PFOS, PFUnA and PFTriA bioaccumulate in the observed food-chain for the year 2018. Based on the 2018 data, PFOA, PFHxS, SCCPs, MCCPs and anti-DP do not biomagnify in this food chain, either no clear trend or decrease with trophic levels. Loi et al 2011 reported TMF values of 1.3 and 1.74 for PFOS and PFUnA, respectively, in a subtropical food web in Hong Kong. However, a study of a terrestrial food chain lichen-caribou-wolf (Müller et al 2011) revealed higher TMF values for PFOS (2.3-2.6) and PFUnA (2.2-2.9), and further concluded that the biomagnification process was mainly dependent on the fluorinated chain and not on the functional group of PFCAs and PFSAs.

The same plots (not shown here) were generated for the sum values of PCBs, PBDEs and PFAS for comparison with previous years' data. 2018 data revealed lower TMF values for PCBs and PBDEs than previous years, but still indicating biomagnification from earthworm via fieldfare to sparrowhawk. sumPFAS revealed slightly higher TMF in 2018 than previous years on a wet weight scale.

Following TMFs were found from previous years; a reference location in 2014 (Herzke et al., 2015) and in Oslo in 2015 and 2016 (Herzke et 2016; 2017), Heimstad et al. 2018, for 2014-2017 data, showing approximately the same levels of biomagnification.

Table 27: Calculated TMFs from the various sampling years and the period 2014-2017 of sumPCBs, sumPBDEs and sumPFAS

	2014	2015	2015	2014-2017	2018
SumPCBs	10.2	11.5	9.8	7.9	4.9
SumPBDEs	6.0	6.3	5.2	4.4	2.8
SumPFAS	1.4	1.3 (PFOS)	1.1	1.4 (PFOS)	1.6

3.15 Changes over time of pollution loads

Data acquired for organic compound classes over the past five years of this project (2014/5 - 2018) for birds and mammals were used to assess potential changes in levels over time. No statistical trend analysis was performed due to insufficient data material.

Data from air, soil and earthworm were omitted in this comparison over time since sampling were performed at specific locations in Oslo that have been changed during the years. Calculation of mean or median values were therefore less relevant for air, soil and eathworm than for birds and mammals that are moving over lager areas.

We have graphically displayed the median sum concentrations of the most dominating organic pollutant groups for birds and mammals over the years (see Figure 35). Median sum was chosen due to some extreme concentrations in single samples from year to year which have high influence on the mean values. Note that tawny owl eggs were only available in years 2016 and 2017, and badgers were only sampled in 2017 and 2018.

The general overview is that the PFAS and CPs groups dominate the organic pollutant loads in the in mammalian liver samples. For sparrowhawk and tawny owl (only 2016 and 2017 data) eggs the DDT- and PCB groups dominate over the years. In fieldfare, PFAS and PCB dominate from 2015 to 2018. For sparrowhawk, the group of PCBs, DDTs followed by PFAS had highest concentrations over the years, where CPs revealed high concentration in 2018. For red fox liver, PFAS, CPs show more or less the same increasing or constant levels during the last three years, and slightly higher concentrations than PCB.

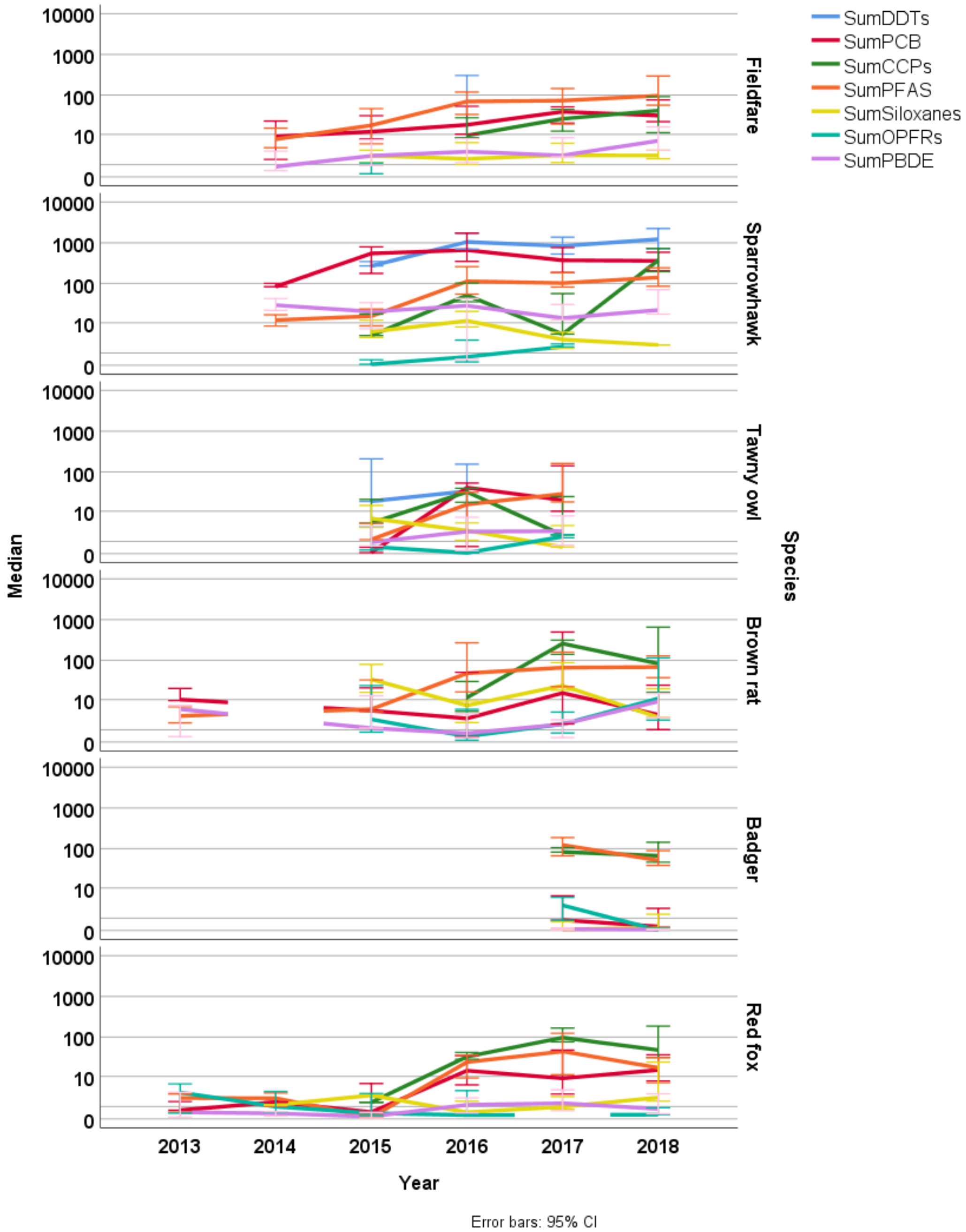

Figure 35: Changes over years of groups of organic pollutants in different biological sample types with Median value of sum concentrations including 95 % confidence interval. Concentrations are given in ng/g ww.

4. Conclusion and Recommendations

This report presents the findings from the sixth year of the urban terrestrial programme.

The median of sum concentrations of the various pollutant group in the investigated species in 2018 was as follows[1,2]:

- Air (ng/day)	:	SumSiloxanes >> SumCPs > SumOPFRs >>SumPCBs
- Soil (ng/g dw)	:	SumToxicMetals >> SumCPs >> SumOPFR> SumUVcomp.
- Earthworm	:	SumToxicMetals >> SumPhenols~ SumCPs > SumPFAS
- Fieldfare	:	SumPFAS > SumCPs >SumPCBs~ SumToxicMetals
- Sparrowhawk	:	SumDDT >> SumCPs ~ SumPCBs > SumPFAS
- Red fox	:	SumToxicMetals ~ SumBiocides > SumCPs > SumPFAS
- Brown rat	:	SumToxicMetals >> SumBiocides > SumCPs ~ SumPFAS
- Badger	:	SumToxicMetals > SumBiocides > SumCPs > SumPFAS

[1]Note that the pesticide DDT was only measured in sparrowhawk eggs.

[2]SumToxicMetals is the sum of Hg, Cd, Pb and As.

An estimation of the trophic magnification was carried out for the foodchain:
earthworm - fieldfare – sparrowhawk

In order to assess the bioaccumulation potential, trophic magnification factors (TMF) were calculated. The TMF calculations revealed that the typical hydrophobic and well known POPs such as PCBs and PBDEs had TMF well above 1, and a high potential for magnification in the food chain earthworm-fieldfare-sparrowhawk investigated in this study. These findings are in agreement with published literature on freshwater- and marine food webs (Ruus et al., 2017; Munoz et al., 2017; Zhou et al., 2016; Walters et al, 2011). TMF for PFOS, PFUnA and PFTRiA was also above 1, but the data were more scattered and had a less clear linear relationship.

A successful campaign for collecting sparrowhawk egg was conducted in the period 2014-2018. The eggs were found to have high levels of certain pollutants, especially PCBs and p,p'-DDE. Based on a comparison of eggs from this study and eggs collected prior to any known use of DDT in Norway, there is also evidence for eggshell thinning in sparrowhawks from this study as a result of DDT exposure.

Experience from this monitoring program with sampling of the same species from same locations over several years indicate that eggs from fieldfare may reflect and act as marker for local pollution. We also recommend to continue using sparrowhawk as a true trophic level 4 representative for long-term studies.

The following findings and recommendations should be followed up in future campaigns:

- Fieldfare eggs may act as an important sampling matrix to detect pollution hotspots on local/regional scale (as the Oslo city region) due to their fast adaption to their habitat:
    - Although lower PFOS levels were detected in 2018 than in 2017, fieldfare from the locality Grønmo (former landfill) had the highest concentrations of PFOS.

  - o Fieldfare from the suburban area at Bøler had very high concentration of SCCPs and MCCPs, and potential sources should be investigated
  - o Fieldfare from Kjelsås (near an artificial turf arena) revealed for the third year high concentration of Pb, and potential sources should be further explored.
- Biocide concentrations were lower in 2018 than in 2017, but are still higher in red fox liver than in rat livers.
- We suggest to include measurements of biocides in raptor samples due to an increased risk of secondary poisoning of these top predators.
- The emerging brominated compound DBDPE had higher concentrations than SumPBDE in some of the fieldfare egg samples. An extremely high concentrations of DBDPE was detected in one brown rat liver of 940 ng/g ww.
- cVMS, SCCPs/MCCPs, OPFR and PCBs play an important role as air pollutants in Oslo, with highest concentrations at the Slottsparken site. Campaigns to better clarify spatial variations of air pollutants in the city centre is needed, and continuous monitoring similar to that at Birkenes and Zeppelin is recommended.
- SCCPs/MCCPs were detected in many samples and at high concentrations. Extremely high concentrations were detected in one sparrowhawk egg and one pooled egg sample from fieldfare (Bøler). For future studies we recommend to analyse SCCPs and MCCPs in soil and earthworm from Bøler to provide further insights that may be used to identify the source of this pollution.
- We also recommend investigating PFOS levels in runoff or at the former landfill at Grønmo, and Pb levels near the artificial turf arena at Kjelsås.
- Sampling should be improved in the future with use of traps for red fox and badger to be able to catch animals closer to the city and over a larger area.
- We propose to investigate pollutant load in relevant scavenger insects and/or insects living of organic material in soil.

By keeping and building on this monitoring scheme, we can expect to follow pollutant levels over time in the Oslo region and establish temporal and spatial trends, and in addition identify hotspots where mitigation and management measures can be implemented.

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Appendix 1

Concentrations of pollutants in individual samples

All biological samples are given in ng/g ww, air samples in pg/day and soil in ng/g dw.

Lipid, dry material percentages and isotopes

NILU-Sample number:	Sample type:	% lipids	% dry material	d13CVPDB	d15NAIR	W% C	W% N	C/N	d34SVCDT	W% S
18/2902	Soil		86	-28,05	5.01	8.71	0.54	16.04	2.10	0.06
18/2903	Soil		80	-27.54	2.64	8.69	0.46	18.94	6.63	0.03
18/2904	Soil		85	-26.92	1.03	3.71	0.19	19.69	0.18	0.13
18/2905	Soil		84	-28.56	0.18	2.12	0.19	11.26	4.93	0.01
18/2906	Soil		85	-28.11	3.98	4.65	0.43	10.82	-18.70	0.05
18/2908	Earthworm	1		-27.01	5.51	49.19	10.15	4.85	2.11	0.77
18/2909	Earthworm	1.2		-26.05	3.37	43.74	8.75	5.00	4.96	0.53
18/2910	Earthworm	1.5		-25.64	5.35	35.86	8.11	4.42	-0.40	0.67
18/2911	Earthworm	1		-27.16	3.43	42.74	9.89	4.32	-0.11	0.64
18/2912	Earthworm	0.5		-27.74	4.65	47.61	10.85	4.39	-8.49	0.89
18/2914	Fieldfare egg	1.0		-26.71	6.74	53.10	10.15	5.23	0.68	0.87
18/2915	Fieldfare egg	3.9		-26.97	8.47	59.47	8.96	6.63	1.77	0.62
18/2916	Fieldfare egg	4.0		-27.81	7.01	56.47	8.71	6.49	2.81	0.62
18/2917	Fieldfare egg	4.0		-26.63	7.38	55.46	9.37	5.92	0.10	0.69
18/2918	Fieldfare egg	6.0		-26.60	7.85	53.93	8.09	6.67	0.99	0.58
18/2919	Fieldfare egg	5.3		-27.69	7.88	61.80	8.18	7.56	0.20	0.58
18/2920	Fieldfare egg	4.8		-27.45	6.90	55.94	8.60	6.51	4.30	0.66
18/2921	Fieldfare egg	5.3		-26.97	5.92	60.72	8.63	7.04	2.30	0.59
18/2922	Fieldfare egg	1.9		-28.06	7.31	55.14	8.20	6.73	-4.59	0.59

NILU-Sample number:	Sample type:	% lipids	% dry material	d13CVPDB	d15NAIR	W% C	W% N	C/N	d34SVCDT	W% S
18/2923	Fieldfare egg	5.6		-25.37	10.05	52.70	9.15	5.76	1.81	0.70
18/2924	Sparrowhawk egg	3.9		-25.32	6.50	55.13	9.24	5.97	5.23	0.71
18/2925	Sparrowhawk egg	2.9		-25.58	7.54	55.80	9.25	6.03	6.20	0.75
18/2926	Sparrowhawk egg	4.6		-26.55	8.46	56.58	8.86	6.38	6.39	0.66
18/2927	Sparrowhawk egg	7.0		-26.25	8.51	61.46	7.55	8.15	5.30	0.52
18/2928	Sparrowhawk egg	6.8		-25.28	7.96	57.89	8.54	6.78	5.15	0.64
18/2929	Sparrowhawk egg	5.9		-25.,85	7.10	57.74	8.15	7.08	5.21	0.59
18/2930	Sparrowhawk egg	4.3		-26.01	8.50	58.35	8.44	6.91	4.83	0.57
18/2931	Sparrowhawk egg	8.2		-26.72	9.13	57.62	8.44	6.83	5.97	0.63
18/2932	Sparrowhawk egg	5.0		-25.45	7.47	53.94	9.76	5.53	6.58	0.76
18/3509	Red fox liver	3.3		-25.,41	7.95	52.64	11.25	4.68	4.20	0.80
18/3510	Red fox liver	2.2		-25.,76	8.46	52.51	11.61	4.52	5.41	0.77
18/3511	Red fox liver	1.8		-25.,23	7.07	47.88	10.31	4.64	5.22	0.73
18/3512	Red fox liver	3.0		-25.79	8.16	48.11	11.42	4.21	5.41	0.75
18/3513	Red fox liver	4.3		-27.55	9.42	51.71	11.57	4.47	4.37	0.78
18/3514	Red fox liver	3.3		-24.91	9.04	46.71	11.03	4.23	6.33	0.86
18/3515	Red fox liver	2.5		-26.40	9.02	45.15	10.90	4.14	4.58	0.77
18/3516	Red fox liver	2.8		-27.00	9.07	48.04	11.06	4.34	4.75	0.76
18/3517	Red fox liver	3.9		-26.55	6.71	49.88	10.73	4.65	5.23	0.83
18/3518	Red fox liver	3.8		-25.79	9.87	53.97	10.72	5.03	5.27	0.68
18/3519	Badger liver	2.9		-25.52	8.98	49.58	12.64	3.92	4.74	0.88
18/3520	Badger liver	1.7		-27.21	7.67	48.19	10.10	4.77	4.89	0.58

NILU-Sample number:	Sample type:	% Lipids	% dry material	d13CVPDB	d15NAIR	W% C	W% N	C/N	d34SVCDT	W% S
18/3521	Badger liver	1.3		-27.19	7.83	47.77	11.35	4.21	5.02	0.69
18/3522	Badger liver	0.3		-26.49	7.49	48.01	11.20	4.29	4.49	0.83
18/3523	Badger liver	1.9		-26.35	7.23	45.62	8.76	5.21	5.11	0.56
18/3524	Badger liver	3.2		-26.56	8.62	51.72	10.38	4.98	4.54	0.67
18/3525	Badger liver	3.9		-26.23	8.82	48.08	10.86	4.43	5.07	0.85
18/3526	Badger liver	0.9		-25.46	6.74	47.70	9.12	5.23	5.63	0.56
18/4053	Rat liver	6.5		-26.11	7.20	50.99	10.19	5.01	1.11	0.85
18/4054	Rat liver	2.3		-25.30	8.32	54.00	10.72	5.04	4.04	0.70
18/4055	Rat liver	9.5		-25.49	7.28	53.47	10.28	5.20	3.43	0.65
18/4056	Rat liver	1.9		-25.87	7.79	51.46	11.75	4.38	3.86	0.79
18/4057	Rat liver	4.6		-25.54	6.97	50.75	11.25	4.51	3.35	0.71
18/4058	Rat liver	4.3		-25.55	8.34	53.96	10.93	4.94	4.94	0.73
18/4059	Rat liver	3.6		-25.26	9.96	51.50	11.93	4.32	3.70	0.82
18/4060	Rat liver	2.4		-25.30	8.62	51.25	12.08	4.24	6.05	0.80
18/4061	Rat liver	4.5		-25.31	7.15	51.05	11.69	4.37	6.15	0.77

Metals

NILU-Sample number:	Sample type:	Cr	Ni	Cu	Zn	As	Ag	Cd	Pb	Hg
18/2902	Soil (ng/g dw)	49154	28298	32523	135749	7734	226	196	64589	361
18/2903	Soil (ng/g dw)	7818	1934	8077	42622	3492	153	322	63655	48.7
18/2904	Soil (ng/g dw)	32095	14038	29858	52532	4195	247	<66	38504	67.3
18/2905	Soil (ng/g dw)	53260	31084	25426	140309	5274	98.0	179	21334	23.5
18/2906	Soil (ng/g dw)	88775	61684	30790	81591	6493	98.1	201	18211	48.6
18/2908	Earthworm	617	430	1870	147647	448	41.9	587	1764	289
18/2909	Earthworm	3641	667	3782	142405	857	80.5	2723	55281	156
18/2910	Earthworm	6110	2967	9391	107201	1707	63.6	750	3687	67.9
18/2911	Earthworm	5673	3035	6003	225320	808	25.3	1573	2033	84.3
18/2912	Earthworm	1961	1480	3039	184258	934	19.9	1015	581	143
18/2914	Fieldfare egg	57.0	117	512	3284	4.46	0.22	0.16	7.01	8.38
18/2915	Fieldfare egg	71.9	24.6	364	6220	6.43	0.22	0.45	13.9	15.7
18/2916	Fieldfare egg	85.9	36.2	552	12067	5.00	1.06	0.36	18.8	9.85
18/2917	Fieldfare egg	16.5	21.8	407	10696	2.04	0.15	0.50	12.9	14.2
18/2918	Fieldfare egg	10.2	9.22	356	5470	5.46	0.09	0.26	7.58	18.2
18/2919	Fieldfare egg	<2.6	2.72	314	7027	4.39	<0.1	0.27	9.47	11.1
18/2920	Fieldfare egg	6.51	4.10	347	5992	2.81	0.43	0.17	136	17.0
18/2921	Fieldfare egg	7.40	5.51	391	7918	5.65	0.76	0.36	37.2	10.2
18/2922	Fieldfare egg	29.3	18.0	728	12124	5.41	0.22	0.24	9.92	7.77
18/2923	Fieldfare egg	147	50.0	743	15227	4.04	0.28	0.41	26.0	24.1

NILU-Sample number:	Sample type:	Cr	Ni	Cu	Zn	As	Ag	Cd	Pb	Hg
18/2924	Sparrowhawk egg	11.1	7.61	502	4280	0.47	0.37	0.05	1.50	44.1
18/2925	Sparrowhawk egg	2.52	2.69	395	2196	0.43	<0.1	0.07	1.35	33.1
18/2926	Sparrowhawk egg	10.5	15.9	582	4513	<0.3	<0.1	0.11	2.42	101
18/2927	Sparrowhawk egg	8.71	2.44	596	5366	0.58	<0.1	0.10	1.62	94.2
18/2928	Sparrowhawk egg	6.81	5.79	493	4201	1.45	<0.1	0.13	6.21	64.7
18/2929	Sparrowhawk egg	6.04	4.12	1066	4225	0.36	<0.05	0.03	3.92	91.3
18/2930	Sparrowhawk egg	11.5	6.81	1359	9263	2.11	<0.1	0.10	16.97	97.5
18/2931	Sparrowhawk egg	19.3	11.2	989	6682	0.49	<0.1	0.10	2.71	79.9
18/2932	Sparrowhawk egg	9.73	7.18	1071	7720	1.17	<0.1	0.08	7.52	80.2
18/3509	Red fox liver	154	48.0	10290	27878	4.72	0.61	492	51.8	34.7
18/3510	Red fox liver	39.9	28.3	15742	25155	3.23	3.29	91.1	26.0	111
18/3511	Red fox liver	72.6	47.2	8573	27874	1.84	0.83	118	117	49.7
18/3512	Red fox liver	126	67.0	11639	36707	6.46	2.72	203	107	124
18/3513	Red fox liver	173	91.0	6709	25042	2.45	2.29	67.9	25.0	31.1
18/3514	Red fox liver	108	55.1	16653	43149	15.3	7.43	89.5	119	109
18/3515	Red fox liver	141	73.6	8803	33157	3.00	1.27	114	37.5	49.1
18/3516	Red fox liver	71.7	50.2	10288	28389	3.85	0.81	175	90.1	267
18/3517	Red fox liver	94.1	49.5	8743	57981	1.53	0.61	189	18.2	690
18/3518	Red fox liver	75.8	37.6	10560	31595	14.9	3.71	90.9	101	112
18/3519	Badger liver	570	284	12123	38521	9.46	22.9	299	145	32.0
18/3520	Badger liver	227	113	5377	20480	7.82	20.1	154	154	25.3
18/3521	Badger liver	148	68.5	8170	20477	8.44	19.9	103	156	26.3

NILU-Sample number:	Sample type:	Cr	Ni	Cu	Zn	As	Ag	Cd	Pb	Hg
18/3522	Badger liver	138	63.8	4947	22280	5.43	6.31	612	119	60.5
18/3523	Badger liver	164	63.0	5902	23064	9.27	5.24	371	74.2	42.9
18/3524	Badger liver	147	64.2	15555	38293	11.0	26.3	2352	351	78.5
18/3525	Badger liver	97.1	46.2	27119	59277	11.1	57.8	2119	317	70.0
18/3526	Badger liver	241	107	6234	30626	19.6	33.1	3511	630	41.1
18/4053	Rat liver	425	209	17213	30076	223	256	15.6	627	1093
18/4054	Rat liver	641	348	2557	23233	648	<5.4	5.22	62.2	7.12
18/4055	Rat liver	1442	604	4140	27171	486	22.3	42.5	117	6.88
18/4056	Rat liver	104	45.6	5904	36978	1067	<4.4	31.9	1959	0.73
18/4057	Rat liver	2090	958	3941	27514	853	<5.2	14.4	91.3	5.00
18/4058	Rat liver	16.3	27.2	2788	24444	833	<5.2	21.5	16.3	7.15
18/4059	Rat liver	257	141	4371	41792	2696	<5.0	144	47.6	12.5
18/4060	Rat liver	92.2	37.5	4118	39738	1222	<5.4	24.6	132	6.18
18/4061	Rat liver	92.4	36.0	3526	26120	6020	<5.0	19.4	54.5	12.0

PCBs

NILU-Sample number:	Sample type:	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180
18/3356	Air (**pg/day**)	122	233	255	56.0	83.6	131	31.9
18/3357	Air (**pg/day**)	6.16	10.10	8.62	2.62	2.94	4.20	0.84
18/3358	Air (**pg/day**)	4.95	6.87	5.49	1.43	2.23	3.35	0.75
18/3359	Air (**pg/day**)	41.6	28.5	19.8	6.87	8.36	10.6	2.88
18/3360	Air (**pg/day**)	6.25	9.16	6.26	1.81	2.02	3.15	0.54
18/2902	Soil (ng/g dw)	0.11	0.14	0.53	0.56	1.00	1.12	0.43
18/2903	Soil (ng/g dw)	0.12	0.08	< 0.260	< 0.336	< 0.546	< 0.850	< 0.186
18/2904	Soil (ng/g dw)	0.20	0.51	0.98	0.79	1.07	1.02	0.40
18/2905	Soil (ng/g dw)	0.10	0.07	< 0.260	< 0.336	< 0.546	< 0.850	0.20
18/2906	Soil (ng/g dw)	0.10	0.08	< 0.260	< 0.336	< 0.546	< 0.850	< 0.186
18/2908	Earthworm	< 0.041	0.12	0.71	0.38	1.16	1.32	0.26
18/2909	Earthworm	< 0.041	0.09	0.19	< 0.202	< 0.327	< 0.510	< 0.112
18/2910	Earthworm	< 0.041	0.50	1.13	0.56	1.12	1.14	0.32
18/2911	Earthworm	< 0.041	0.06	0.25	< 0.202	0.80	0.88	0.18
18/2912	Earthworm	< 0.041	< 0.036	< 0.156	< 0.202	< 0.327	< 0.510	< 0.112
18/2914	Fieldfare egg	< 0.041	0.70	2.81	1.35	3.78	5.79	2.49
18/2915	Fieldfare egg	0,20	0.80	5.70	2.21	19.1	32.2	15.5
18/2916	Fieldfare egg	< 0.041	0.28	2.43	0.98	8.28	11.9	5.22
18/2917	Fieldfare egg	0.09	0.62	2.53	1.05	10.9	14.9	8.01
18/2918	Fieldfare egg	0.07	0.96	4.33	1.55	15.3	19.3	8.86

NILU-Sample number:	Sample type:	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180
18/2919	Fieldfare egg	0.05	1.30	5.56	2.66	9.14	10.1	3.90
18/2920	Fieldfare egg	< 0.041	0.26	3.36	1.03	7.31	8.52	3.00
18/2921	Fieldfare egg	< 0.041	0.12	1.44	0.89	8.96	13.0	4.44
18/2922	Fieldfare egg	< 0.041	0.75	13.9	4.46	55.8	99.4	43.8
18/2923	Fieldfare egg	< 0.041	0.22	1.51	0.88	6.28	9.19	3.44
18/2924	Sparrowhawk egg	0.56	0.90	8.64	16.8	63.5	120	71.0
18/2925	Sparrowhawk egg	0.18	0.30	2.87	9.74	23.4	46.4	30.3
18/2926	Sparrowhawk egg	0.59	0.54	5.78	9.49	42.7	103	44.4
18/2927	Sparrowhawk egg	4.28	3.32	54.0	104	408	871	428
18/2928	Sparrowhawk egg	0.98	1.83	16.4	41.1	89.9	204	120
18/2929	Sparrowhawk egg	0.30	0.46	5.44	15.7	65.1	175	99.0
18/2930	Sparrowhawk egg	7.11	0.60	13.1	48.4	116	234	120
18/2931	Sparrowhawk egg	0.82	0.96	11.8	26.4	116	299	134
18/2932	Sparrowhawk egg	0.12	0.26	3.65	10.6	54.5	145	64.2
18/3509	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	0.54	1.42
18/3510	Red fox liver	< 0.023	< 0.035	0.17	1.95	6.16	20.1	7.73
18/3511	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	0.65	5.72	25.0
18/3512	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	0.51	2.67	7.17
18/3513	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	0.36	1.65	5.39
18/3514	Red fox liver	< 0.023	< 0.035	0.08	0.25	2.30	13.3	16.6
18/3515	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	1.22	5.46	9.87
18/3516	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	1.30	4.36	6.32

NILU-Sample number:	Sample type:	PCB28	PCB52	PCB101	PCB118	PCB138	PCB153	PCB180
18/3517	Red fox liver	< 0.023	< 0.035	< 0.075	< 0.163	0.27	4.32	8.26
18/3518	Red fox liver	< 0.023	0.04	0.86	9.23	73.7	172	54.2
18/3519	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.15
18/3520	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.17
18/3521	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.13
18/3522	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.13
18/3523	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.25
18/3524	Badger liver	< 0.023	0.045	0.248	0.385	0.497	0.924	0.38
18/3525	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	0.18
18/3526	Badger liver	< 0.023	< 0.035	< 0.075	< 0.163	< 0.172	< 0.319	< 0.118
18/4053	Rat liver	1.01	0.704	2.9	8.76	28.9	25.3	7.13
18/4054	Rat liver	<0.02	<0.018	<0.078	<0.101	0.316	0.357	0.214
18/4055	Rat liver	0.04	<0.018	<0.078	0.197	1.09	1.31	1.01
18/4056	Rat liver	0.085	<0.023	0.092	0.495	2.33	2.51	1.87
18/4057	Rat liver	0.113	<0.018	0.122	0.239	0.886	0.945	0.463
18/4058	Rat liver	<0.02	<0.018	0.078	0.187	1.14	1.18	0.494
18/4059	Rat liver	<0.023	<0.023	0.106	0.309	1.42	1.6	0.957
18/4060	Rat liver	0.354	<0.02	<0.078	1.27	7.87	8.61	5.61
18/4061	Rat liver	<0.024	<0.019	<0.078	<0.101	<0.164	<0.255	0.071

PBDEs

NILU-Sample number:	Sample type:	BDE47	BDE99	BDE100	BDE126	BDE153	BDE154	BDE 175/183	BDE190	BDE196	BDE202	BDE206	BDE207	BDE209
18/3356	Air (pg/day)	4.16	1.20	0.58	<0.02	0.14	0.07	0.27	<0.05	<0.10	<0.13	6.48	5.57	209
18/3357	Air (pg/day)	1.47	0.44	0.13	<0.01	0.06	0.04	0.29	<0.05	<0.10	<0.13	<0.50	<0.20	<1.67
18/3358	Air (pg/day)	1.23	0.60	0.15	<0.02	0.12	0.06	0.18	<0.05	<0.10	<0.13	0.98	0.73	24.7
18/3359	Air (pg/day)	7.94	5.19	1.10	<0.02	0.89	0.45	1.88	<0.05	0.87	0.26	13.80	9.96	441
18/3360	Air (pg/day)	1.27	0.29	0.10	<0.01	0.08	0.04	0.09	<0.05	<0.11	<0.14	<0.55	<0.22	<1.83
18/2902	Soil (ng/g dw)	0.166	0.072	0.03	<0.005	<0.019	<0.011	<0.015	<0.018	<0.03	<0.034	0.091	<0.035	1.18
18/2903	Soil (ng/g dw)	0.114	0.066	0.022	<0.005	<0.019	<0.011	<0.015	<0.018	<0.03	<0.034	<0.068	<0.035	0.59
18/2904	Soil (ng/g dw)	<0.105	<0.064	<0.017	<0.005	<0.019	<0.011	<0.015	<0.018	<0.03	<0.034	<0.068	0.064	0.669
18/2905	Soil (ng/g dw)	<0.105	0.100	0.054	0.049	0.121	0.117	0.118	<0.018	0.229	0.278	0.499	0.458	1.21
18/2906	Soil (ng/g dw)	<0.105	<0.064	0.028	0.015	0.042	0.047	0.051	0.044	<0.03	0.124	0.135	0.115	<0.446
18/2908	Earthworm	0.093	<0.038	0.016	<0.003	<0.012	<0.007	<0.009	<0.01	<0.018	<0.02	<0.04	<0.02	<0.268
18/2909	Earthworm	<0.063	0.046	0.015	<0.003	<0.012	<0.007	<0.009	<0.01	<0.018	<0.02	<0.04	<0.02	0.37
18/2910	Earthworm	<0.063	<0.038	<0.01	<0.003	<0.012	<0.007	<0.009	<0.01	<0.018	<0.02	<0.04	<0.02	0.294
18/2911	Earthworm	0.065	0.049	0.020	<0.003	<0.012	<0.007	0.009	<0.01	<0.018	<0.02	<0.04	0.024	0.718
18/2912	Earthworm	<0.063	<0.038	<0.01	<0.003	<0.012	<0.007	<0.009	<0.01	<0.018	<0.02	<0.04	<0.02	<0.268
18/2914	Fieldfare egg	1.070	1.270	0.472	0.017	0.193	0.127	0.049	<0.01	0.033	0.022	0.085	0.078	0.975
18/2915	Fieldfare egg	3.030	3.470	1.530	0.005	0.387	0.401	0.084	<0.01	0.082	0.115	0.114	0.17	1.03
18/2916	Fieldfare egg	2.080	3.460	1.430	0.004	0.610	0.387	0.165	<0.01	0.079	0.122	0.075	0.15	0.73
18/2917	Fieldfare egg	2.590	4.880	1.630	0.007	0.997	0.488	0.23	<0.01	0.134	0.114	0.261	0.354	4.25

NILU-Sample number:	Sample type:	BDE47	BDE99	BDE100	BDE126	BDE153	BDE154	BDE 175/183	BDE190	BDE196	BDE202	BDE206	BDE207	BDE209
18/2918	Fieldfare egg	1.240	2.040	0.717	0.004	0.392	0.337	0.244	<0.01	0.077	0.048	0.12	0.139	1.39
18/2919	Fieldfare egg	1.440	1.650	0.672	0.005	0.414	0.259	0.093	<0.01	0.065	0.061	0.098	0.123	0.775
18/2920	Fieldfare egg	0.823	0.691	0.404	<0.003	0.130	0.123	0.043	<0.01	0.041	0.033	0.064	0.09	0.532
18/2921	Fieldfare egg	0.373	0.409	0.264	0.005	0.126	0.12	0.078	<0.01	0.047	0.055	0.172	0.139	1.83
18/2922	Fieldfare egg	6.990	25.400	9.100	0.012	4.710	3.22	0.353	<0.01	0.178	0.028	0.073	0.089	0.613
18/2923	Fieldfare egg	2.120	2.210	0.751	0.018	0.506	0.324	0.129	<0.01	0.092	0.247	0.107	0.12	0.605
18/2924	Sparrowhawk egg	4.590	9.250	3.710	0.015	3.340	1.22	0.806	<0.016	0.315	0.32	<0.044	0.224	0.481
18/2925	Sparrowhawk egg	1.350	2.790	1.110	<0.006	1.480	0.481	0.514	<0.028	0.299	0.181	<0.044	0.241	<0.465
18/2926	Sparrowhawk egg	4.600	7.980	3.060	<0.006	3.000	0.987	0.806	0.025	0.31	0.342	<0.044	0.282	<0.465
18/2927	Sparrowhawk egg	26.700	55.300	19.700	0.071	22.900	8.46	8.61	0.124	1.73	1.68	<0.044	1.13	0.681
18/2928	Sparrowhawk egg	3.670	6.490	2.910	<0.049	2.470	1.31	1.13	<0.178	<0.209	<0.272	<0.13	<0.118	<0.465
18/2929	Sparrowhawk egg	4.560	7.220	3.500	0.038	3.530	1.37	0.788	<0.054	<0.041	0.24	<0.044	<0.023	<0.465
18/2930	Sparrowhawk egg	6.560	10.600	6.960	0.030	5.610	2.83	0.33	<0.131	<0.136	<0.175	<0.044	<0.025	<0.465
18/2931	Sparrowhawk egg	8.940	26.400	16.500	0.033	10.500	4.86	1.52	0.042	0.427	0.564	<0.044	0.314	<0.465
18/2932	Sparrowhawk egg	2.780	5.590	2.810	<0.006	2.850	1.1	0.736	<0.016	0.317	0.415	0.06	0.142	<0.465
18/3509	Red fox liver	<0.042	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	0.053	0.04	0.49
18/3510	Red fox liver	0.055	<0.029	0.022	<0.003	0.091	<0.007	0.014	<0.006	<0.011	0.042	0.052	0.06	0.473
18/3511	Red fox liver	0.062	<0.029	0.008	<0.003	0.050	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	0.03	0.235
18/3512	Red fox liver	0.042	<0.029	<0.008	<0.003	0.017	<0.007	0.008	<0.006	<0.011	<0.013	0.051	0.214	1.43
18/3513	Red fox liver	0.059	<0.029	0.010	<0.005	0.020	<0.007	<0.004	<0.006	0.102	<0.013	0.157	0.444	4.77
18/3514	Red fox liver	0.082	<0.029	0.044	<0.004	0.144	<0.007	0.022	<0.006	0.091	0.03	0.118	0.155	2.35

NILU-Sample number:	Sample type:	BDE47	BDE99	BDE100	BDE126	BDE153	BDE154	BDE 175/183	BDE190	BDE196	BDE202	BDE206	BDE207	BDE209
18/3515	Red fox liver	0.075	<0.029	0.010	<0.006	0.014	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	0.02	<0.232
18/3516	Red fox liver	0.080	<0.029	0.015	<0.004	0.044	<0.007	<0.004	<0.006	<0.011	<0.013	0.039	0.05	0.456
18/3517	Red fox liver	<0.042	<0.029	<0.008	<0.003	0.041	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3518	Red fox liver	0.202	0.067	0.155	<0.006	0.584	<0.019	0.137	<0.008	0.088	0.239	0.068	0.1	1.46
18/3519	Badger liver	<0.042	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3520	Badger liver	0.066	<0.029	0.009	<0.003	<0.011	<0.007	0.006	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3521	Badger liver	0.044	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3522	Badger liver	<0.042	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	0.013	<0.232
18/3523	Badger liver	0.045	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3524	Badger liver	0.047	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/3525	Badger liver	<0.042	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	0.019	<0.232
18/3526	Badger liver	0.058	<0.029	<0.008	<0.003	<0.011	<0.007	<0.004	<0.006	<0.011	<0.013	<0.022	<0.011	<0.232
18/4053	Rat liver	0.297	0.0823	0.0673	<0.0031	1.49	0.017	2.85	0.0157	0.207	0.0827	0.12	1.48	7.87
18/4054	Rat liver	0.0696	0.193	0.0203	<0.00433	0.049	<0.008	0.055	0.04	<0.021	0.082	<0.024	0.362	1.08
18/4055	Rat liver	0.065	0.032	0.034	<0.003	0.117	<0.008	0.095	<0.012	<0.016	<0.02	0.069	0.462	3.12
18/4056	Rat liver	0,438	0.117	0.147	<0.00363	0.57	0.026	0.366	<0.016	0.328	0.216	0.606	5.49	46.5
18/4057	Rat liver	0.10	0.037	0.037	<0.003	0.044	<0.008	<0.007	<0.01	<0.026	<0.032	0.132	0.84	9.05
18/4058	Rat liver	<0.047	<0.03	0.013	<0.003	0.035	<0.008	0.045	<0.011	0.148	<0.03	<0.029	0.698	1.94
18/4059	Rat liver	0.043	<0.03	0.017	<0.003	0.041	<0.008	0.016	<0.009	<0.019	<0.024	0.097	0.62	8.03
18/4060	Rat liver	0.516	0.167	0.11	<0.003	0.226	0.021	0.293	<0.011	0.154	0.079	0.105	1.23	10.4
18/4061	Rat liver	<0.043	<0.03	0.01	0.004	<0.011	0.013	<0.005	<0.007	0.04	<0.028	<0.022	0.374	5.55

PFSAs

NILU-Sample number:	Sample type:	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFUnDS	PFDoDS	PFTrDS	PFTeDS
18/3356	Air (pg/day)	24.53	<0.50	1.28	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3357	Air (pg/day)	21.47	<0.50	2.95	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3358	Air (pg/day)	28.05	<0.50	0.56	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3359	Air (pg/day)	22.66	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3360	Air (pg/day)	18.60	<0.55	1.89	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55
18/2902	Soil (ng/g dw)	0.133	<0.034	<0.204	<0.002	0.21	4.31	<0.00	<0.04	<0.15	<0.15	<0.15	<0.15
18/2903	Soil (ng/g dw)	<0.036	<0.036	<0.144	<0.003	0.03	2.61	<0.01	<0.04	<0.15	<0.15	<0.15	<0.15
18/2904	Soil (ng/g dw)	<0.034	<0.034	<0.196	<0.002	0.06	2.09	<0.00	<0.04	<0.15	<0.15	<0.15	<0.15
18/2905	Soil (ng/g dw)	<0.035	<0.035	0.123	<0.002	0.09	5.99	<0.00	<0.04	<0.15	<0.15	<0.15	<0.15
18/2906	Soil (ng/g dw)	<0.034	<0.034	<0.191	<0.002	<0.00	2.31	<0.00	<0.04	<0.15	<0.15	<0.15	<0.15
18/2908	Earthworm	1.39	<0.029	2.70	1.33	0.31	3.00	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/2909	Earthworm	<0.029	<0.029	4.68	1.90	2.64	18.1	0.41	<0.033	<0.15	<0.15	<0.15	<0.15
18/2910	Earthworm	4.17	<0.029	7.94	2.16	6.59	33.7	<0.004	0.47	<0.15	<0.15	<0.15	<0.15
18/2911	Earthworm	6.25	<0.029	12.4	<0.002	3.93	65.1	<0.004	0.98	<0.15	<0.15	<0.15	<0.15
18/2912	Earthworm	<0.029	<0.029	2.61	<0.002	<0.004	6.31	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/2914	Fieldfare egg	<0.029	<0.029	0.46	1.03	14.8	235	<0.004	17.19	<0.15	<0.15	<0.15	<0.15
18/2915	Fieldfare egg	<0.029	<0.029	0.33	0.19	3.72	29.4	<0.004	0.28	<0.15	<0.15	<0.15	<0.15
18/2916	Fieldfare egg	<0.029	<0.029	0.34	0.53	5.57	55.7	<0.004	0.93	<0.15	<0.15	<0.15	<0.15
18/2917	Fieldfare egg	<0.029	<0.029	<0.029	0.25	3.37	28.5	<0.004	1.23	<0.15	<0.15	<0.15	<0.15
18/2918	Fieldfare egg	<0.029	<0.029	0.26	0.43	2.74	45.8	0.13	4.23	<0.15	<0.15	<0.15	<0.15

NILU-Sample number:	Sample type:	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFUnDS	PFDoDS	PFTrDS	PFTeDS
18/2919	Fieldfare egg	<0.029	<0.029	1.38	0.14	3.50	51.5	0.14	2.36	<0.15	<0.15	<0.15	<0.15
18/2920	Fieldfare egg	<0.029	<0.029	0.18	<0.002	2.01	20.9	<0.004	1.28	<0.15	<0.15	<0.15	<0.15
18/2921	Fieldfare egg	<0.029	<0.029	0.32	0.11	1.64	18.0	<0.004	0.17	<0.15	<0.15	<0.15	<0.15
18/2922	Fieldfare egg	<0.029	<0.029	0.34	0.22	2.19	36.9	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/2923	Fieldfare egg	<0.029	<0.029	<0.029	0.54	6.78	42.5	<0.004	3.27	<0.15	<0.15	<0.15	<0.15
18/2924	Sparrowhawk egg	<0.029	<0.029	0.239	0.522	3.8	32.4	<0.004	3.6	<0.15	<0.15	<0.15	<0.15
18/2925	Sparrowhawk egg	<0.029	<0.029	0.174	0.243	6.2	45.6	0.2	0.6	<0.15	<0.15	<0.15	<0.15
18/2926	Sparrowhawk egg	<0.029	<0.029	0.672	1.222	9.7	61.5	0.2	5.7	<0.15	<0.15	<0.15	<0.15
18/2927	Sparrowhawk egg	<0.029	<0.029	3.849	6.157	50.1	367	0.7	14.0	<0.15	<0.15	<0.15	<0.15
18/2928	Sparrowhawk egg	<0.029	<0.029	0.500	0.453	11.7	94.3	<0.004	1.6	<0.15	<0.15	<0.15	<0.15
18/2929	Sparrowhawk egg	<0.029	<0.029	0.517	0.405	6.9	44.1	0.1	0.7	<0.15	<0.15	<0.15	<0.15
18/2930	Sparrowhawk egg	<0.029	<0.029	1.293	1.389	9.0	67.5	0.2	0.2	<0.15	<0.15	<0.15	<0.15
18/2931	Sparrowhawk egg	<0.029	<0.029	0.784	1.286	10.9	87.9	0.1	0.3	<0.15	<0.15	<0.15	<0.15
18/2932	Sparrowhawk egg	<0.029	<0.029	<0.029	0.461	6.0	55.3	<0.004	0.9	<0.15	<0.15	<0.15	<0.15
18/3509	Red fox liver	0.043	<0.029	0.116	<0.002	7.67	5.08	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/3510	Red fox liver	<0.029	<0.029	0.151	0.104	<0.004	3.52	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/3512	Red fox liver	<0.029	<0.029	<0.029	0.109	4.13	6.33	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/3513	Red fox liver	<0.029	<0.029	<0.029	0.082	<0.004	12.41	0.081	<0.033	<0.15	<0.15	<0.15	<0.15
18/3514	Red fox liver	<0.029	<0.029	0.008	0.056	<0.004	21.65	<0.004	0.394	<0.15	<0.15	<0.15	<0.15
18/3515	Red fox liver	<0.029	<0.029	0.319	0.037	<0.004	12.48	<0.004	0.106	<0.15	<0.15	<0.15	<0.15
18/3516	Red fox liver	<0.029	<0.029	0.106	0.044	<0.004	5.56	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/3517	Red fox liver	<0.029	<0.029	<0.029	0.095	<0.004	20.47	<0.004	0.136	<0.15	<0.15	<0.15	<0.15

NILU-Sample number:	Sample type:	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFUnDS	PFDoDS	PFTrDS	PFTeDS
18/3518	Red fox liver	0.022	<0.029	0.44	0.154	<0.004	22.04	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/3519	Badger liver	0.18	<0.029	0.81	0.72	<0.004	**52.1**	<0.004	0.51	<0.15	<0.15	<0.15	<0.15
18/3520	Badger liver	0.03	<0.029	<0.029	0.21	3.28	24.1	<0.004	0.10	<0.15	<0.15	<0.15	<0.15
18/3521	Badger liver	<0.029	<0.029	0.68	0.28	2.58	26.7	<0.004	0.30	<0.15	<0.15	<0.15	<0.15
18/3522	Badger liver	0.03	<0.029	1.16	0.40	<0.004	51.0	0.12	0.08	<0.15	<0.15	<0.15	<0.15
18/3523	Badger liver	0.04	<0.029	1.00	0.39	3.29	29.3	<0.004	0.04	<0.15	<0.15	<0.15	<0.15
18/3524	Badger liver	0.05	<0.029	0.02	0.23	3.94	31.0	<0.004	0.07	<0.15	<0.15	<0.15	<0.15
18/3525	Badger liver	0.04	<0.029	0.36	0.20	3.60	27.0	<0.004	0.07	<0.15	<0.15	<0.15	<0.15
18/3526	Badger liver	0.01	<0.029	1.84	0.93	6.34	51.1	<0.004	0.44	<0.15	<0.15	<0.15	<0.15
18/4053	Rat liver	<0.029	<0.029	<0.029	<0.029	13.01	62.4	<0.004	21.3	<0.15	<0.15	<0.15	<0.15
18/4054	Rat liver	<0.029	<0.029	<0.029	<0.029	5.97	20.3	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/4055	Rat liver	<0.029	<0.029	2.59	0.24	10.51	38.7	<0.004	<0.033	<0.15	<0.15	<0.15	<0.15
18/4056	Rat liver	<0.029	<0.029	2.96	<0.029	9.83	47.7	<0.004	4.62	<0.15	<0.15	<0.15	<0.15
18/4057	Rat liver	<0.029	<0.029	<0.029	<0.029	7.28	26.4	<0.004	1.81	<0.15	<0.15	<0.15	<0.15
18/4058	Rat liver	<0.029	<0.029	<0.029	0.56	8.33	59.7	<0.004	1.17	<0.15	<0.15	<0.15	<0.15
18/4059	Rat liver	<0.029	<0.029	<0.029	<0.029	12.95	62.4	<0.004	1.24	<0.15	<0.15	<0.15	<0.15
18/4060	Rat liver	<0.029	<0.029	<0.029	<0.029	9.85	34.5	<0.004	0.39	<0.15	<0.15	<0.15	<0.15
18/4061	Rat liver	<0.029	<0.029	<0.029	<0.029	1.95	12.9	<0.004	1.94	<0.15	<0.15	<0.15	<0.15

NILU-Sample number:	Sample type:	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFUnDS	PFDoDS	PFTrDS	PFTeDS
A: Sognsvann	Humle A1	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A2	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A3	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A4	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A5	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A6	0.252	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A7	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A8	<0.029	<0.029	0.048	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A9	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A10	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B1	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B2	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B3	<0.029	<0.029	<0.029	0.284	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B4	<0.029	<0.029	<0.029	0.084	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B5	<0.029	<0.029	<0.029	0.082	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B6	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B7	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B8	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.

NILU-Sample number:	Sample type:	PFBS	PFPS	PFHxS	PFHpS	brPFOS	PFOS	PFNS	PFDcS	PFUnDS	PFDoDS	PFTrDS	PFTeDS
B: Frognerseteren	Humle B9	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B10	<0.029	<0.029	<0.029	0,055	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C1	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C2	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C3	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C4	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C5	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C6	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C7	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C8	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C9	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C10	<0.029	<0.029	<0.029	<0.002	<0.004	<0.004	<0.004	<0.033	n.a.	n.a.	n.a.	n.a.

PFCAs

NILU-Sample number:	Sample type:	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	PFHxDA
18/3356	Air (pg/day)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3357	Air (pg/day)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3358	Air (pg/day)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3359	Air (pg/day)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
18/3360	Air (pg/day)	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55	<0.55
18/2902	Soil (ng/g dw)	<0.24	<0.26	0.16	0.16	0.43	0.19	0.10	0.057	0.047	<0,020	<0.021	<0.03
18/2903	Soil (ng/g dw)	<0.26	<0.28	0.29	0.20	0.56	0.19	0.10	<0.011	0.029	0.047	0.036	<0.03
18/2904	Soil (ng/g dw)	<025	<0.27	0.10	<0.00	0.07	0.08	0.02	<0.011	<0.009	0.023	<0.021	<0.03
18/2905	Soil (ng/g dw)	<0,.25	<0.27	<0.07	0.02	0.06	<0.01	0.02	0.014	<0.010	<0.020	<0.021	<0.03
18/2906	Soil (ng/g dw)	<0.25	<0.27	<0.07	0.04	0.13	0.03	<0.01	<0.011	<0.009	0.014	<0.021	<0.03
18/2908	Earthworm	<0.210	<0.226	<0.056	0.39	0.79	0.38	0.08	0.06	0.47	0.55	1.15	<0.022
18/2909	Earthworm	<0.210	1.68	1.51	3.22	4.70	0.63	0.66	0.44	1.60	2.86	3.80	1.24
18/2910	Earthworm	<0.210	0.21	<0.056	0.43	0.70	0.16	0.06	0.08	0.36	0.46	0.93	0.26
18/2911	Earthworm	<0.210	2.26	<0.056	0.48	0.41	0.18	0.25	0.52	2.07	2.50	3.75	0.42
18/2912	Earthworm	<0.210	0.51	0.31	0.36	0.56	0.20	0.12	0.21	0.48	1.11	0.45	0.06
18/2914	Fieldfare egg	<0.210	<0.226	<0.056	<0.004	0.44	0.79	2.72	2.62	9.33	5.18	5.81	0.31
18/2915	Fieldfare egg	<0.210	<0.226	<0.056	0.02	0.51	0.90	1.34	1.47	5.00	4.56	4.03	0.30
18/2916	Fieldfare egg	<0.210	<0.226	<0.056	0.08	0.65	1.04	1.73	3.10	13.25	11.14	10.47	0.74
18/2917	Fieldfare egg	<0.210	<0.226	<0.056	<0.004	0.41	0.74	1.19	1.59	5.81	5.68	5.91	0.42
18/2918	Fieldfare egg	<0.210	<0.226	<0.056	<0.004	0.64	0.79	2.94	3.18	16.93	12.31	13.88	0.50

NILU-Sample number:	Sample type:	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	PFHxDA
18/2919	Fieldfare egg	<0.210	<0.226	<0.056	0.05	0.32	1.13	1.75	2.61	11.81	9.83	10.31	0.42
18/2920	Fieldfare egg	<0.210	<0.226	<0.056	<0.004	1.02	1.65	3.19	4.73	15.50	18.39	12.26	0.37
18/2921	Fieldfare egg	<0.210	0.05	0.09	0.87	6.25	4.34	10.2	10.3	59.3	60.7	137	26.7
18/2922	Fieldfare egg	<0.210	<0.226	<0.056	<0.004	0.64	0.67	1.41	1.94	4.48	10.17	3.49	0.34
18/2923	Fieldfare egg	<0.210	<0.226	0.07	<0.004	2.12	3.41	4.20	2.66	9.47	8.21	9.63	0.83
18/2924	Sparrowhawk egg	<0.210	<0.226	<0.056	0.013	0.41	0.78	2.94	3.10	7.43	7.30	6.53	0.53
18/2925	Sparrowhawk egg	<0.210	<0.226	<0.056	0.013	0.47	1.07	2.04	3.49	8.26	8.72	7.82	0.36
18/2926	Sparrowhawk egg	<0.210	<0.226	<0.056	<0.004	1.14	0.99	1.25	2.14	4.16	6.34	4.34	0.11
18/2927	Sparrowhawk egg	<0.210	<0.226	<0.056	0.027	5.54	3.80	6.52	9.38	19.7	23.2	18.6	0.97
18/2928	Sparrowhawk egg	<0.210	<0.226	<0.056	0.037	2.10	4.85	9.18	11.0	34.3	31.8	36.7	3.66
18/2929	Sparrowhawk egg	<0.210	<0.226	<0.056	0.056	1.04	2.28	2.80	5.80	10.2	14.7	10.5	0.52
18/2930	Sparrowhawk egg	<0.210	<0.226	<0.056	0.052	2.26	4.63	3.75	8.56	12.9	19.3	15.5	0.69
18/2931	Sparrowhawk egg	<0.210	<0.226	<0.056	<0.004	1.41	1.96	2.57	4.12	8.63	10.3	11.4	0.35
18/2932	Sparrowhawk egg	<0.210	<0.226	<0.056	<0.004	0.39	1.14	2.44	3.92	27.6	20.1	21.8	0.56
18/3509	Red fox liver	<0.210	<0.226	0.197	0.004	<0.002	1.333	0.433	0.403	0.315	0.338	0.136	<0.022
18/3510	Red fox liver	<0.210	<0.226	<0.056	0.007	0.071	0.577	0.370	0.761	0.242	0.547	0.286	<0.022
18/3512	Red fox liver	<0.210	<0.226	<0.056	<0.004	0.056	1.531	0.540	0.403	0.168	0.221	0.051	<0.022
18/3513	Red fox liver	<0.210	<0.226	<0.056	0.198	0.275	1.939	1.018	0.995	0.431	0.322	0.067	<0.022
18/3514	Red fox liver	<0.210	<0.226	<0.056	<0.004	0.372	1.570	1.727	1.885	1.266	1.119	0.414	<0.022
18/3515	Red fox liver	<0.210	<0.226	<0.056	0.014	0.206	1.372	1.085	0.772	0.712	0.712	0.355	0.035
18/3516	Red fox liver	<0.210	<0.226	0.50	<0.004	0.308	2.096	0.720	0.654	0.339	0.408	0.122	<0.022
18/3517	Red fox liver	<0.210	<0.226	<0.056	0.055	0.048	3.116	2.601	2.202	0.736	0.977	0.175	<0.022

NILU-Sample number:	Sample type:	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	PFHxDA
18/3518	Red fox liver	<0.210	<0.226	<0.056	<0.004	0.342	2.410	1.764	1.242	0.504	0.503	0.207	<0.022
18/3519	Badger liver	<0.210	1.60	<0.056	0.04	1.26	4.36	3.16	3.18	3.36	5.23	4.19	0.20
18/3520	Badger liver	<0.210	<0.226	<0.056	0.01	0.52	2.29	1.18	1.26	1.34	1.72	1.12	0.02
18/3521	Badger liver	<0.210	<0.226	<0.056	0.01	0.85	2.24	1.66	2.16	2.06	3.78	2.23	0.06
18/3522	Badger liver	<0.210	<0.226	<0.056	0.01	0.52	4.31	2.94	2.92	2.40	3.56	2.68	0.07
18/3523	Badger liver	<0.210	<0.226	<0.056	<0.004	0.31	3.47	1.73	2.15	1.88	2.99	<0.018	0.05
18/3524	Badger liver	<0.210	<0.226	<0.056	<0.004	0.67	3.65	1.75	1.94	1.60	3.29	2.67	0.10
18/3525	Badger liver	<0.210	<0.226	<0.056	0.01	0.80	3.84	2.29	2.38	2.47	3.76	3.38	0.08
18/3526	Badger liver	<0.210	<0.226	<0.056	0.02	1.21	6.82	4.47	3.94	3.85	3.17	4.24	0.23
18/4053	Rat liver	<0.210	<0.226	<0.056	<0.004	<0.002	0.27	3.85	1.54	2.78	0.63	0.85	0.19
18/4054	Rat liver	<0.210	<0.226	<0.056	<0.004	1.46	0.85	0.88	0.56	0.50	0.23	0.21	<0.022
18/4055	Rat liver	<0.210	<0.226	<0.056	<0.004	1.19	2.42	4.18	1.74	4.13	1.00	1.17	<0.022
18/4056	Rat liver	<0.210	<0.226	<0.056	<0.004	<0.002	0.83	5.05	3.43	3.51	1.48	0.74	0.19
18/4057	Rat liver	<0.210	<0.226	<0.056	<0.004	<0.002	4.92	2.95	2.49	1.46	0.50	0.22	<0.022
18/4058	Rat liver	<0.210	<0.226	<0.056	<0.004	6.13	8.53	13.35	4.62	12.3	5.08	5.53	0.48
18/4059	Rat liver	<0.210	<0.226	<0.056	<0.004	0.71	9.74	13.17	7.13	10.3	4.34	3.99	0.19
18/4060	Rat liver	<0.210	<0.226	<0.056	<0.004	1.81	1.36	2.08	0.90	1.54	0.32	0.34	0.16
18/4061	Rat liver	<0.210	<0.226	<0.056	<0.004	<0.002	5.63	1.89	6.55	1.92	2.01	0.51	<0.022

NILU-Sample number:	Sample type:	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	PFHxDA
A: Sognsvann	Humle A1	<0.226	<0.056	<0.004	0.098	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A2	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A3	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A4	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A5	<0.226	0.084	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A6	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	0.540	<0.018	<0.022	<0.226
A: Sognsvann	Humle A7	0.575	<0.056	<0.004	0.055	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	0.138	0.575
A: Sognsvann	Humle A8	<0.226	<0.056	<0.004	0.013	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A9	<0.226	<0.056	<0.004	0.042	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
A: Sognsvann	Humle A10	<0.226	<0.056	<0.004	0.019	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B1	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	0.171	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B2	<0.226	<0.056	<0.004	0.058	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B3	<0.226	<0.056	<0.004	0.126	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B4	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B5	<0.226	<0.056	0.073	0.019	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B6	<0.226	<0.056	<0.004	0.036	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B7	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B8	<0.226	<0.056	<0.004	0.027	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226

NILU-Sample number:	Sample type:	PFBA	PFPA	PFHxA	PFHpA	PFOA	PFNA	PFDcA	PFUnA	PFDoA	PFTriA	PFTeA	PFHxDA
B: Frognerseteren	Humle B9	<0.226	<0.056	0.03	0.017	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
B: Frognerseteren	Humle B10	<0.226	<0.056	<0.004	0.027	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C1	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	0.086	0.033	<0.018	<0.022	<0.226
C: Hvasser	Humle C2	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	0.124	<0.226
C: Hvasser	Humle C3	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C4	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C5	<0.226	<0.056	<0.004	0.075	<0.007	0.039	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C6	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	0.165	<0.008	<0.017	<0.018	0.325	<0.226
C: Hvasser	Humle C7	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C8	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C9	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226
C: Hvasser	Humle C10	<0.226	<0.056	<0.004	<0.002	<0.007	<0.006	<0.009	<0.008	<0.017	<0.018	<0.022	<0.226

nPFAS

NILU-Sample number:	Sample type:	PFOSA	meFOSA	etFOSA	meFOSEA	meFOSE	etFOSE	6:2 FTOH	8:2 FTOH	10:2 FTOH
18/3356	Air (pg/day)	<1.00	<3.00	<3.00	<50.0	<50.0	<50.0	<20.0	<20.0	<20.0
18/3357	Air (pg/day)	<1.00	<3.00	<3.00	<50.0	<50.0	<50.0	<20.0	<20.0	<20.0
18/3358	Air (pg/day)	<1.00	<3.00	<3.00	<50.0	<50.0	<50.0	<20.0	<20.0	<20.0
18/3359	Air (pg/day)	<1.00	<3.00	<3.00	<50.0	<50.0	<50.0	<20.0	<20.0	<20.0
18/3360	Air (pg/day)	<1.00	<3.30	<3.30	<54.9	<54.9	<54.9	<20.0	<20.0	<20.0
18/2902	Soil (ng/g dw)	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2903	Soil (ng/g dw)	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2904	Soil (ng/g dw)	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2905	Soil (ng/g dw)	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2906	Soil (ng/g dw)	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2908	Earthworm	<0.001	<0,3	<0,3	<5	<5	<5	<2	<2	<2
18/2909	Earthworm	<0.001	<0,3	<0,3	<5	<5	<5	<2	<2	<2
18/2910	Earthworm	0.06	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
18/2911	Earthworm	<0.001	<0,3	<0,3	<5	<5	<5	<2	<2	<2
18/2912	Earthworm	0.08	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
18/2914	Fieldfare egg	0.212	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2915	Fieldfare egg	0.103	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2916	Fieldfare egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2917	Fieldfare egg	0.005	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2918	Fieldfare egg	0.007	<0.3	<0.3	<5	<5	<5	<2	<2	<2

NILU-Sample number:	Sample type:	PFOSA	meFOSA	etFOSA	meFOSEA	meFOSE	etFOSE	6:2 FTOH	8:2 FTOH	10:2 FTOH
18/2919	Fieldfare egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2920	Fieldfare egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2921	Fieldfare egg	0.113	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2922	Fieldfare egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2923	Fieldfare egg	0.007	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2924	Sparrowhawk egg	0.080	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2925	Sparrowhawk egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2926	Sparrowhawk egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2927	Sparrowhawk egg	0.169	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2928	Sparrowhawk egg	0.070	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2929	Sparrowhawk egg	0.122	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2930	Sparrowhawk egg	0.132	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2931	Sparrowhawk egg	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/2932	Sparrowhawk egg	0.082	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3509	Red fox liver	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3510	Red fox liver	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3511	Red fox liver	n.a	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3512	Red fox liver	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3513	Red fox liver	0.04	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3514	Red fox liver	1.86	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3515	Red fox liver	0.98	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3516	Red fox liver	0.26	<0.3	<0.3	<5	<5	<5	<2	<2	<2

NILU-Sample number:	Sample type:	PFOSA	meFOSA	etFOSA	meFOSEA	meFOSE	etFOSE	6:2 FTOH	8:2 FTOH	10:2 FTOH
18/3517	Red fox liver	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3518	Red fox liver	<0.001	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3519	Badger liver	0.39	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3520	Badger liver	0.71	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3521	Badger liver	0.28	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3522	Badger liver	0.72	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3523	Badger liver	0.39	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3524	Badger liver	0.55	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3525	Badger liver	0.57	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/3526	Badger liver	0.84	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4053	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4054	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4055	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4056	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4057	Rat liver	0.34	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4058	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4059	Rat liver	0.48	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4060	Rat liver	<0.1	<0.3	<0.3	<5	<5	<5	<2	<2	<2
18/4061	Rat liver	0.22	<0.3	<0.3	<5	<5	<5	<2	<2	<2

NILU-Sample number:	Sample type:	PFOSA	meFOSA	etFOSA	meFOSEA	meFOSE	etFOSE	6:2 FTOH	8:2 FTOH	10:2 FTOH	PFOSA	meFOSA	etFOSA
A: Sognsvann	Humle A1	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A2	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A3	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A4	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A5	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A6	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A7	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A8	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A9	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
A: Sognsvann	Humle A10	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B1	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B2	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B3	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B4	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B5	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B6	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B7	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B8	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

NILU-Sample number:	Sample type:	PFOSA	meFOSA	etFOSA	meFOSEA	meFOSE	etFOSE	6:2 FTOH	8:2 FTOH	10:2 FTOH	PFOSA	meFOSA	etFOSA
B: Frognerseteren	Humle B9	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
B: Frognerseteren	Humle B10	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C1	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C2	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C3	0.676	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C4	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C5	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C6	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C7	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C8	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C9	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
C: Hvasser	Humle C10	<0.001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

NewPFAS

NILU-Sample number:	Sample type:	6:2FTS	8:2 FTS	10:2 FTS	PFECHS	Cl-PFOS	Cl-PFOA
18/3356	Air (pg/day)	<3.00	<3.00	<3.00	n.a	n.a	n.a
18/3357	Air (pg/day)	<3.00	<3.00	<3.00	n.a	n.a	n.a
18/3358	Air (pg/day)	<3.00	<3.00	<3.00	n.a	n.a	n.a
18/3359	Air (pg/day)	<3.00	<3.00	<3.00	n.a	n.a	n.a
18/3360	Air (pg/day)	<3.00	<3.00	<3.00	n.a	n.a	n.a
18/2902	Soil (ng/g dw)	<0.01	<0.020	n.a	<0.069	<0.116	<0.116
18/2903	Soil (ng/g dw)	<0.01	<0.022	n.a	<0.075	<0.125	<0.125
18/2904	Soil (ng/g dw)	<0.01	<0.021	n.a	<0.070	<0.117	<0.117
18/2905	Soil (ng/g dw)	<0.01	<0.021	n.a	<0.071	<0.119	<0.119
18/2906	Soil (ng/g dw)	<0.01	<0.021	n.a	<0.070	<0.117	<0.117
18/2908	Earthworm	<0.011	<0.018	n.a	<0.06	<0.10	<0.10
18/2909	Earthworm	<0.011	0.05	n.a	<0.06	<0.10	<0.10
18/2910	Earthworm	<0.011	<0.018	n.a	<0.06	<0.10	<0.10
18/2911	Earthworm	0.43	0.87	n.a	<0.06	<0.10	<0.10
18/2912	Earthworm	<0.011	<0.018	n.a	<0.06	<0.10	<0.10
18/2914	Fieldfare egg	<0.011	0.11	0.88	<0.06	<0.10	<0.10
18/2915	Fieldfare egg	<0.011	0.11	0.37	<0.06	<0.10	<0.10
18/2916	Fieldfare egg	<0.011	0.05	0.67	<0.06	<0.10	<0.10
18/2917	Fieldfare egg	<0.011	1.08	1.92	<0.06	<0.10	<0.10
18/2918	Fieldfare egg	0.10	5.65	11.8	<0.06	<0.10	<0.10

NILU-Sample number:	Sample type:	6:2FTS	8:2 FTS	10:2 FTS	PFECHS	Cl-PFOS	Cl-PFOA
18/2919	Fieldfare egg	<0.011	1.61	2.17	<0.06	<0.10	<0.10
18/2920	Fieldfare egg	<0.011	0.13	0.37	<0.06	<0.10	<0.10
18/2921	Fieldfare egg	<0.011	0.61	0.86	<0.06	<0.10	<0.10
18/2922	Fieldfare egg	<0.011	0.05	1.81	<0.06	<0.10	<0.10
18/2923	Fieldfare egg	<0.011	0.56	1.38	<0.06	<0.10	<0.10
18/2924	Sparrowhawk egg	<0.011	1.51	0.86	0.076	<0.10	<0.10
18/2925	Sparrowhawk egg	<0.011	0.22	0.61	0.085	<0.10	<0.10
18/2926	Sparrowhawk egg	<0.011	0.03	0.48	0.088	<0.10	<0.10
18/2927	Sparrowhawk egg	<0.011	0.73	2.35	0.836	<0.10	<0.10
18/2928	Sparrowhawk egg	<0.011	0.16	0.94	0.068	<0.10	<0.10
18/2929	Sparrowhawk egg	<0.011	0.08	0.37	0.110	<0.10	<0.10
18/2930	Sparrowhawk egg	<0.011	0.65	0.48	0.128	<0.10	<0.10
18/2931	Sparrowhawk egg	<0.011	0.17	0.82	0.155	<0.10	<0.10
18/2932	Sparrowhawk egg	<0.011	0.01	1.18	0.072	<0.10	<0.10
18/3509	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3510	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3511	Red fox liver	n.a	n.a	n.a	n.a	n.a	n.a
18/3512	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3513	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3514	Red fox liver	<0.011	0.143	<0,3	<0.06	<0.10	<0.10
18/3515	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3516	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10

NILU-Sample number:	Sample type:	6:2FTS	8:2 FTS	10:2 FTS	PFECHS	Cl-PFOS	Cl-PFOA
18/3517	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3518	Red fox liver	<0.011	<0.018	<0,3	<0.06	<0.10	<0.10
18/3519	Badger liver	<0.011	0.21	<0.08	<0.06	<0.10	<0.10
18/3520	Badger liver	<0.011	0.41	1.32	<0.06	<0.10	<0.10
18/3521	Badger liver	<0.011	0.40	0.36	<0.06	<0.10	<0.10
18/3522	Badger liver	<0.011	0.29	<0.08	<0.06	<0.10	<0.10
18/3523	Badger liver	<0.011	0.13	<0.08	<0.06	<0.10	<0.10
18/3524	Badger liver	<0.011	0.07	<0.08	<0.06	<0.10	<0.10
18/3525	Badger liver	<0.011	0.03	<0.08	<0.06	<0.10	<0.10
18/3526	Badger liver	<0.011	0.09	<0.08	<0.06	<0.10	<0.10
18/4053	Rat liver	<0.1	<0.2	2.1	<0.06	<0.10	<0.10
18/4054	Rat liver	<0.1	<0.2	0.3	<0.06	<0.10	<0.10
18/4055	Rat liver	0.3	0.5	1.2	0.39	<0.10	<0.10
18/4056	Rat liver	<0.11	0.3	6.7	<0.06	<0.10	<0.10
18/4057	Rat liver	<0.1	0.5	0.8	<0.06	<0.10	<0.10
18/4058	Rat liver	1.0	0.6	2.3	<0.06	1.16	<0.10
18/4059	Rat liver	<0.1	0.4	1.1	<0.06	<0.10	<0.10
18/4060	Rat liver	<0.1	<0.2	1.0	<0.06	<0.10	<0.10
18/4061	Rat liver	<0.1	<0.2	1.2	<0.06	<0.10	<0.10

NILU-Sample number:	Sample type:	6:2FTS	8:2 FTS	10:2 FTS	PFECHS	Cl-PFOS	Cl-PFOA
A: Sognsvann	Humle A1	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A2	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A3	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A4	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A5	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A6	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A7	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A8	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A9	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
A: Sognsvann	Humle A10	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B1	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B2	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B3	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B4	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B5	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B6	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B7	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B8	0.057	<0.018	n.a.	<0.06	<0.10	<0.10

NILU-Sample number:	Sample type:	6:2FTS	8:2 FTS	10:2 FTS	PFECHS	Cl-PFOS	Cl-PFOA
B: Frognerseteren	Humle B9	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
B: Frognerseteren	Humle B10	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C1	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C2	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C3	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C4	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C5	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C6	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C7	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C8	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C9	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10
C: Hvasser	Humle C10	<0.011	<0.018	n.a.	<0.06	<0.10	<0.10

Chlorinated paraffins (CPs)

NILU-Sample number:	Sample type:	SCCPs	MCCPs
18/3356	Air (pg/day)	23601	3413
18/3357	Air (pg/day)	2550	1200
18/3358	Air (pg/day)	1927	1259
18/3359	Air (pg/day)	6194	2691
18/3360	Air (pg/day)	5012	4197
18/2902	Soil (ng/g dw)	449	1129
18/2903	Soil (ng/g dw)	546	816
18/2904	Soil (ng/g dw)	521	993
18/2905	Soil (ng/g dw)	482	724
18/2906	Soil (ng/g dw)	364	520
18/2908	Earthworm	33.8	<7
18/2909	Earthworm	50.5	134
18/2910	Earthworm	64.9	26.1
18/2911	Earthworm	34.6	19.5
18/2912	Earthworm	43.2	23.3
18/2914	Fieldfare egg	44.9	16.8
18/2915	Fieldfare egg	<10	<7
18/2916	Fieldfare egg	4730	1850
18/2917	Fieldfare egg	<8	37.7
18/2918	Fieldfare egg	<11	85.7

NILU-Sample number:	Sample type:	SCCPs	MCCPs
18/2919	Fieldfare egg	24.9	13.0
18/2920	Fieldfare egg	25.9	13.4
18/2921	Fieldfare egg	<7	<3
18/2922	Fieldfare egg	<10	20.8
18/2923	Fieldfare egg	15.9	36.5
18/2924	Sparrowhawk egg	3026	6697
18/2925	Sparrowhawk egg	106	154
18/2926	Sparrowhawk egg	50.2	57.1
18/2927	Sparrowhawk egg	103	157
18/2928	Sparrowhawk egg	421	308
18/2929	Sparrowhawk egg	42.4	153
18/2930	Sparrowhawk egg	58.0	313
18/2931	Sparrowhawk egg	57.0	324
18/2932	Sparrowhawk egg	48.2	513
18/3509	Red fox liver	25.4	19.2
18/3510	Red fox liver	18.0	12.6
18/3511	Red fox liver	16.8	<8
18/3512	Red fox liver	12.1	19.1
18/3513	Red fox liver	18.4	21.3
18/3514	Red fox liver	24.0	27.5
18/3515	Red fox liver	27.4	159
18/3516	Red fox liver	33.9	377

NILU-Sample number:	Sample type:	SCCPs	MCCPs
18/3517	Red fox liver	32.3	59.4
18/3518	Red fox liver	29.2	52.8
18/3519	Badger liver	22.5	23.7
18/3520	Badger liver	31.8	35.4
18/3521	Badger liver	26.6	31.1
18/3522	Badger liver	24.6	37.4
18/3523	Badger liver	29.6	115
18/3524	Badger liver	28.2	38.4
18/3525	Badger liver	29.0	41.5
18/3526	Badger liver	25.7	78.5
18/4053	Rat liver	6.47	821
18/4054	Rat liver	3.42	8.11
18/4055	Rat liver	16.6	340
18/4056	Rat liver	25.2	628
18/4057	Rat liver	32.0	50.7
18/4058	Rat liver	7.44	16.4
18/4059	Rat liver	5.55	10.0
18/4060	Rat liver	7.18	26.6
18/4061	Rat liver	144	55.8

Cyclic siloxanes (cVMS)

NILU-Sample number:	Sample type:	D4	D5	D6
18/3356	Air (pg/day)	13307	34619	3082
18/3357	Air (pg/day)	14154	7750	836
18/3358	Air (pg/day)	13206	6703	733
18/3359	Air (pg/day)	26579	17094	1946
18/3360	Air (pg/day)	9758	19940	1867
18/2902	Soil (ng/g dw)	<0.8	<6.5	<1.7
18/2903	Soil (ng/g dw)	<0.9	<7.0	<1.9
18/2904	Soil (ng/g dw)	3.1	<6.6	<1.8
18/2905	Soil (ng/g dw)	<0.8	<6.7	<0.8
18/2906	Soil (ng/g dw)	<0.8	<6.6	<1.3
18/2908	Earthworm	< 4.6	<6.8	1.23
18/2909	Earthworm	< 4.6	<6.8	1.40
18/2910	Earthworm	not suff. sample	not suff. sample	not suff. sample
18/2911	Earthworm	< 4.6	<6.8	1.07
18/2912	Earthworm	not suff. sample	not suff. sample	not suff. sample
18/2914	Fieldfare egg	<4.6	<6.8	1.61
18/2915	Fieldfare egg	<4.6	<6.8	2.81
18/2916	Fieldfare egg	<4.6	<2.8	1.73
18/2917	Fieldfare egg	<4.6	<6.8	2.29
18/2918	Fieldfare egg	<4.6	6.90	1.77

NILU-Sample number:	**Sample type:**	**D4**	**D5**	**D6**
18/2919	Fieldfare egg	<4.6	<6.8	< 1.0
18/2920	Fieldfare egg	<4.6	<2.8	1.13
18/2921	Fieldfare egg	<4.6	<2.8	1.55
18/2922	Fieldfare egg	<4.6	<6.8	1.26
18/2923	Fieldfare egg	<4.6	<6.8	2.37
18/2924	Sparrowhawk egg	<4.7	<7.1	<3.1
18/2925	Sparrowhawk egg	<4.7	<7.1	<1.4
18/2926	Sparrowhawk egg	<4.7	<7.1	<1.4
18/2927	Sparrowhawk egg	<4.7	76.3	<3.1
18/2928	Sparrowhawk egg	<4.7	<7.1	<1.4
18/2929	Sparrowhawk egg	<4.7	<7.1	<1.4
18/2930	Sparrowhawk egg	<4.7	<19.4	<3.1
18/2931	Sparrowhawk egg	<4.7	<19.4	<3.1
18/2932	Sparrowhawk egg	<4.7	<7.1	<1.4
18/3509	Red fox liver	9.0	8.4	6.3
18/3510	Red fox liver	<1.8	2.0	3.7
18/3511	Red fox liver	<1.8	1.2	<1.9
18/3512	Red fox liver	<1.8	1.2	<1.9
18/3513	Red fox liver	<1.8	<1.0	<1.9
18/3514	Red fox liver	<1.8	1.1	2.5
18/3515	Red fox liver	<0.7	<1.0	<1.9
18/3516	Red fox liver	<0.7	<1.0	<0.8

NILU-Sample number:	Sample type:	D4	D5	D6
18/3517	Red fox liver	<0.7	<0.6	<0.8
18/3518	Red fox liver	13.3	12.6	10.2
18/3519	Badger liver	<1.3	<1.0	<0.6
18/3520	Badger liver	<1.3	<2.2	<1.3
18/3521	Badger liver	<1.3	<1.0	<1.3
18/3522	Badger liver	<3.4	<2.2	<1.3
18/3523	Badger liver	<1.3	<1.0	<0.6
18/3524	Badger liver	<1.3	<1.0	<0.6
18/3525	Badger liver	<1.3	<1.0	1.50
18/3526	Badger liver	<1.3	<1.0	<0.6
18/4053	Rat liver	<3.1	4.3	4.9
18/4054	Rat liver	<3.1	27.4	4.3
18/4055	Rat liver	<1.1	<1.3	<1.2
18/4056	Rat liver	<1.1	<3.3	<2.7
18/4057	Rat liver	3.5	12.1	<2.7
18/4058	Rat liver	<3.1	<1.3	<1.2
18/4059	Rat liver	<1.1	<1.3	<1.2
18/4060	Rat liver	6.8	7.2	5.3
18/4061	Rat liver	<1.1	<1.3	<2.7

OPFR

NILU-Sample number:	Sample type:	TEP	TCEP	TPrP	TCPP	TiBP	BdPhP	TPP	DBPhP	TnBP	TDCPP	TBEP	TCP	EHDP	TXP	TEHP
18/3356	Air (pg/day)	n.a.	521	<0.40	4057	588	<0.50	208	8.61	162	68.4	83.0	56	959	<0.20	111
18/3357	Air (pg/day)	n.a.	36.4	<0.40	431	296	<0.50	52.9	6.26	15.8	13.9	11.4	26	<128	<0.20	21.3
18/3358	Air (pg/day)	n.a.	47.6	<0.40	667	347	<0.50	177	10.6	24.6	27.7	37.4	43	<128	<0.20	44.2
18/3359	Air (pg/day)	n.a.	186	<0.40	2116	472	<0.50	193	14.6	156	197	43.5	668	528	17.8	33.1
18/3360	Air (pg/day)	n.a.	279	<0.44	724	493	<0.55	142	6.31	18.0	17.7	<5.27	15	<141	<0.22	69.3
18/2907	Soil pool (ng/g dw)	<0.36	4.17	<0.01	2.26	<0.36	<0.01	0.20	<0.01	0.16	<0.24	0.71	1.05	1.37	<0.12	0.71
18/2913	Earthworm pool	<0.30	0.87	< 0.01	1,25	7.24	<0.01	0.37	<0.01	3.46	0.72	0.25	0.22	< 0.35	< 0.10	< 0.20
18/2934	Sparrowhawk egg pool	<0.30	<0.10	< 0.01	<0.30	< 0.30	<0.01	< 0.03	<0.01	<0.10	< 0.20	< 0.15	< 0.05	< 0.35	< 0.10	< 0.20
18/2935	Sparrowhawk egg pool	<0.30	<0.10	< 0.01	<0.30	< 0.30	<0.01	< 0.03	<0.01	<0.10	< 0.20	< 0.15	< 0.05	< 0.35	< 0.10	< 0.20
18/2936	Sparrowhawk egg pool	n.a	<0.10	< 0.01	<0.30	< 0.30	<0.01	< 0.03	<0.01	<0.10	< 0.20	< 0.15	< 0.05	< 0.35	< 0.10	< 0.20
18/3570	Red fox liver pool	< 1.0	<0.05	< 0.01	0.65	< 0.15	<0.02	< 0.07	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/3571	Red fox liver pool	< 1.0	<0.05	< 0.01	<0.14	< 0.15	<0.02	< 0.07	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/3572	Red fox liver pool	< 1.0	<0.05	< 0.01	<0.14	< 0.15	<0.02	< 0.07	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/3573	Badger liver pool	< 1.0	<0.05	< 0.01	<0.14	< 0.15	<0.02	< 0.07	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/3574	Badger liver pool	< 1.0	<0.05	< 0.01	<0.14	< 0.15	<0.02	0.14	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/3575	Badger liver pool	< 1.0	<0.05	< 0.01	<0.14	< 0.15	<0.02	< 0.07	<0.02	<0.06	< 0.10	< 0.20	< 0.02	< 1.0	< 0.04	< 0.22
18/4063	Rat liver pool	1.73	< 0.23	< 0.01	4.35	0.67	< 0.02	0.40	<0.03	0.25	< 0.08	11.44	< 0.02	1.73	< 0.23	< 0.01
18/4064	Rat liver pool	< 0.54	< 0.23	< 0.01	0.97	< 0.22	< 0.02	< 0.1	<0.03	<0.1	< 0.08	0.36	< 0.02	< 0.54	< 0.23	< 0.01
18/4065	Rat liver pool	< 0.54	< 0.23	< 0.01	6.06	< 0.22	< 0.02	< 0.1	<0.03	0.16	< 0.08	3.77	< 0.02	< 0.54	< 0.23	< 0.01

NewBrom

NILU-Sample number:	Sample type:	ATE (TBP-AE)	a-TBECH	b-TBECH	g/d-TBECH	BATE	PBT	PBEB	PBBZ	HBB	DPTE	EHTBB	BTBPE	TBPH (BEH /TBP)	DBDPE
18/3356	Air (pg/day)	<0.31	<31.3	<17.6	0.65	<0.1	2.48	<0.69	2.83	<1.00	0.23	<0.06	0.4	2.45	69.2
18/3357	Air (pg/day)	<0.31	<3.77	<2.14	<0.05	<0.235	0.63	<0.69	<0.55	<0.23	0.12	<0.06	1.10	1.85	<22.8
18/3358	Air (pg/day)	<0.31	<1.18	<0.698	<0.05	<0.235	<0.41	<0.69	<0.55	<0.23	<0.06	<0.06	2.01	<0.62	<22.8
18/3359	Air (pg/day)	<0.31	<3.57	<2.07	<0.05	<0.1	1.16	<0.69	<1.23	<0.23	<0.06	<0.06	3.84	1.06	170
18/3360	Air (pg/day)	<0.34	<1.70	<0.93	<0.05	<0.11	11.8	<0.75	<2.33	<1.73	<0.47	0.46	0.79	4.80	<25.1
18/2902	Soil (ng/g dw)	0.308	<0.252	0.184	<0.078	0.162	<0.17	<0.229	0.182	0.298	<0.031	<0.091	0.386	1.18	<19
18/2903	Soil (ng/g dw)	0.229	<0.252	0.186	<0.078	0.095	<0.17	<0.229	0.156	0.245	<0.031	<0.091	0.417	0.278	<19
18/2904	Soil (ng/g dw)	0.212	0.275	0.253	<0.078	0.153	<0.17	<0.229	0.202	0.286	0.033	<0.091	0.342	<0.257	<19
18/2905	Soil (ng/g dw)	0.183	<0.252	0.181	<0.078	0.131	<0.17	<0.229	0.21	0.283	0.032	<0.091	0.521	<0.257	33.6
18/2906	Soil (ng/g dw)	0.167	<0.252	0.182	<0.078	0.109	<0.17	<0.229	0.15	0.245	<0.031	<0.091	0.248	<0.257	23.8
18/2908	Earthworm	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.044	<0.115	<0.018	<0.055	0.183	<0.15	<11.4
18/2909	Earthworm	<0.061	<0.151	<0.107	<0.047	0.036	<0.101	<0.136	0.065	0.123	<0.018	<0.055	0.219	<0.15	29
18/2910	Earthworm	<0.061	<0.151	<0.107	<0.047	0.022	<0.101	<0.136	0.053	<0.115	<0.018	<0.055	0.328	0.203	<11.4
18/2911	Earthworm	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.04	<0.115	<0.018	<0.055	0.227	<0.15	<11.4
18/2912	Earthworm	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.043	<0.115	<0.018	<0.055	0.209	<0.15	<11.4
18/2914	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.06	<0.115	<0.018	<0.055	0.18	<0.15	<11.4
18/2915	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.043	<0.115	<0.018	<0.055	0.124	<0.15	26.5
18/2916	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.045	<0.115	<0.018	<0.055	0.132	<0.15	<19
18/2917	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.036	<0.115	<0.018	<0.055	0.143	<0.15	64.4
18/2918	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.037	<0.115	<0.018	<0.055	0.127	<0.15	25.1

NILU-Sample number:	Sample type:	ATE (TBP-AE)	a-TBECH	b-TBECH	g/d-TBECH	BATE	PBT	PBEB	PBBZ	HBB	DPTE	EHTBB	BTBPE	TBPH (BEH /TBP)	DBDPE
18/2919	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	0.024	<0.101	<0.136	0.055	0.12	<0.018	<0.055	0.228	<0.154	35.1
18/2920	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.053	<0.115	<0.018	<0.055	0.176	<0.154	<19
18/2921	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.048	<0.115	<0.018	<0.055	0.155	<0.154	29.3
18/2922	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.05	<0.115	<0.018	<0.055	0.168	<0.154	28.2
18/2923	Fieldfare egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.051	<0.115	<0.018	<0.055	0.207	<0.154	<19
18/2924	Sparrowhawk egg	<0.061	<0.151	<0.107	0.137	<0.02	<0.101	<0.136	0.039	0.125	<0.018	<0.055	0.223	<0.154	14.0
18/2925	Sparrowhawk egg	<0.061	<0.151	<0.107	0.06	<0.02	<0.101	<0.136	0.04	<0.115	<0.018	<0.055	0.223	<0.154	<11.4
18/2926	Sparrowhawk egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.038	0.123	<0.018	<0.055	0.217	<0.154	<11.4
18/2927	Sparrowhawk egg	<0.061	<0.151	<0.107	0.058	<0.02	<0.101	<0.136	0.032	<0.115	<0.018	<0.055	0.842	<0.154	<11.4
18/2928	Sparrowhawk egg	<0.061	0.321	0.238	0.114	<0.02	<0.101	<0.136	0.031	0.117	<0.018	<0.055	0.47	<0.154	16.3
18/2929	Sparrowhawk egg	<0.061	<0.151	<0.107	0.144	<0.02	<0.101	<0.136	0.036	0.122	<0.018	<0.055	0.309	<0.154	<11.4
18/2930	Sparrowhawk egg	0.165	<0.312	<0.236	0.293	<0.039	<0.101	<0.136	<0.04	<0.115	0,042	<0.43	<0.437	2.32	<11.4
18/2931	Sparrowhawk egg	<0.061	<0.151	<0.107	0.065	<0.02	<0.101	<0.136	0.083	0.148	<0.018	<0.055	0.333	<0.154	<11.4
18/2932	Sparrowhawk egg	<0.061	<0.151	<0.107	<0.047	<0.02	<0.101	<0.136	0.062	0.132	<0.018	<0.055	0.275	<0.154	36.4
18/3509	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.016	<0.057	<0.009	<0.027	0.051	0.092	<5.71
18/3510	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.029	<0.057	<0.009	<0.027	0.052	<0.078	<5.71
18/3511	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.027	<0.057	<0.009	<0.027	0.066	<0.078	<5.71
18/3512	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.017	<0.057	<0.009	<0.027	0.065	<0.078	<5.71
18/3513	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.019	<0.057	<0.009	<0.027	0.067	<0.078	8.36
18/3514	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.019	<0.057	<0.009	<0.045	0.066	<0.078	32.0
18/3515	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.017	<0.057	<0.009	<0.027	0.061	<0.078	<5.71
18/3516	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.016	<0.057	<0.009	<0.068	0.069	0.104	<5.71

NILU-Sample number:	Sample type:	ATE (TBP-AE)	a-TBECH	b-TBECH	g/d-TBECH	BATE	PBT	PBEB	PBBZ	HBB	DPTE	EHTBB	BTBPE	TBPH (BEH /TBP)	DBDPE
18/3517	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.023	<0.057	<0.009	<0.027	0.062	<0.078	<5.71
18/3518	Red fox liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.021	<0.057	<0.009	<0.027	0.061	<0.078	7.87
18/3519	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.021	<0.057	<0.009	<0.027	<0.027	<0.078	<5.71
18/3520	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.016	<0.057	<0.009	<0.027	0.053	<0.078	<5.71
18/3521	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.02	<0.057	<0.009	<0.027	0.06	<0.078	11.4
18/3522	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.015	<0.057	<0.009	<0.027	<0.027	<0.078	9.09
18/3523	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.016	<0.057	<0.009	<0.027	0.056	<0.078	<5.71
18/3524	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.019	<0.057	<0.009	<0.027	0.069	<0.078	<5.71
18/3525	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.018	<0.057	<0.009	<0.055	0.061	<0.078	<5.71
18/3526	Badger liver	<0.03	<0.075	<0.053	<0.023	<0.009	<0.05	<0.068	0.024	<0.057	<0.009	<0.027	0.058	<0.078	<5.71
18/4053	Rat liver	0.0517	<0.08	<0.0534	<0.0235	0.0237	<0.0539	<0.0686	0.0559	0.197	0.0119	<0.0599	<0.0445	<0.112	940
18/4054	Rat liver	0.0361	0.0923	<0.0534	<0.0239	0.0194	<0.0509	<0.0686	0.026	0.066	0.0118	<0.0446	0.189	<0.141	<5.71
18/4055	Rat liver	0.0555	<0.08	<0.0534	<0.0243	0.0186	<0.0509	<0.0686	0.0343	0.064	0.0143	<0.0483	0.165	<0.18	8.51
18/4056	Rat liver	<0.031	0.104	0.0741	<0.0247	0.0646	0.082	0.0869	0.0538	0.159	0.074	0.395	0.909	0.348	8.21
18/4057	Rat liver	0.0399	<0.08	<0.0534	<0.0251	0.0161	<0.0539	<0.0686	0.0324	<0.0573	<0.0095	<0.0415	<0.0362	0.471	5.91
18/4058	Rat liver	<0.031	<0.08	<0.0534	<0.0255	0.0103	<0.0509	<0.0686	0.0187	0.059	<0.0095	<0.0275	<0.0274	<0.0821	<5.71
18/4059	Rat liver	<0.031	<0.09	<0.0534	<0.0259	<0.01	<0.0509	<0.0686	0.0277	<0.0573	<0.0095	<0.0285	<0.0274	<0.0863	<5.71
18/4060	Rat liver	<0.031	<0.10	<0.0534	<0.0263	0.016	<0.0509	<0.0686	0.0266	<0.0573	<0.0095	<0.037	<0.0435	<0.108	<5.71
18/4061	Rat liver	<0.031	<0.11	<0.0534	<0.0267	0.014	<0.0509	<0.0686	0.0232	<0.0573	<0.0095	<0.0275	<0.0295	<0.0794	<5.71

Dechloranes and dibromoaldrin

NILU-Sample number:	Sample type:	DBA	Dec-602	Dec-603	Dec-604	Dec-601	syn-DP	anti-DP
18/2908	Earthworm	<0.190	<0.014	<0.015	<0.863	<0.025	<0.167	<0.244
18/2909	Earthworm	<0.321	<0.029	<0.033	<2.25	<0.049	0.18	0.55
18/2910	Earthworm	<0.190	<0.014	<0.015	<0.740	<0.025	<0.167	<0.244
18/2911	Earthworm	<0.190	0.019	<0.015	<0.801	<0.025	<0.167	<0.244
18/2912	Earthworm	<0.190	<0.014	<0.015	<1.03	<0.025	<0.167	<0.244
18/2914	Fieldfare egg	<0.190	0.029	<0.018	<1.23	<0.027	<0.167	0.305
18/2915	Fieldfare egg	<0.190	0.093	0.827	<1.31	<0.029	<0.167	0.306
18/2916	Fieldfare egg	<0.190	0.063	1.786	<1.13	<0.025	<0.167	0.308
18/2917	Fieldfare egg	<0.190	0.14	1.87	<0.871	<0.025	<0.167	0.428
18/2918	Fieldfare egg	<0.190	0.14	1.35	<1.23	<0.027	<0.167	0.489
18/2919	Fieldfare egg	<0.190	0.124	2.23	<0.912	<0.025	<0.167	0.368
18/2920	Fieldfare egg	<0.190	0.037	0.042	<0.817	<0.025	<0.167	<0.244
18/2921	Fieldfare egg	<0.190	0.103	0.216	< 1.13	<0.025	0.278	0.342
18/2922	Fieldfare egg	<0.190	0.286	0.071	<0.901	<0.025	0.508	1.07
18/2923	Fieldfare egg	<0.190	0.094	0.096	<0.959	<0.025	<0.167	0.253
18/2924	Sparrowhawk egg	2.242	0.290	0.367	2.30	0.82	0.590	1.271
18/2925	Sparrowhawk egg	<0.190	1.065	0.386	<0.644	<0.025	0.194	0.440
18/2926	Sparrowhawk egg	<0.190	0.459	0.722	<0.644	<0.025	<0.167	0.327
18/2927	Sparrowhawk egg	<0.190	2.294	4.623	<0.644	<0.025	0.316	1.265
18/2928	Sparrowhawk egg	<0.190	0.534	0.496	<0.644	<0.025	0.275	0.952

NILU-Sample number:	Sample type:	DBA	Dec-602	Dec-603	Dec-604	Dec-601	syn-DP	anti-DP
18/2929	Sparrowhawk egg	<0.190	0.736	0.373	<0.644	<0.025	0.175	0.470
18/2930	Sparrowhawk egg	<0.190	0.776	1.635	<0.644	<0.025	0.244	0.698
18/2931	Sparrowhawk egg	<0.190	3.407	2.257	<0.644	<0.025	0.264	0.698
18/2932	Sparrowhawk egg	<0.190	0.773	1.300	<0.644	<0.025	0.224	0.580
18/3509	Red fox liver	<0.095	0.020	<0.008	<0.322	<0.012	<0.083	<0.122
18/3510	Red fox liver	<0.095	0.037	<0.008	<0.322	<0.012	<0.083	<0.122
18/3511	Red fox liver	<0.095	0.028	<0.008	<0.322	<0.012	<0.083	<0.122
18/3512	Red fox liver	<0.095	0.024	<0.008	<0.322	<0.012	<0.083	<0.122
18/3513	Red fox liver	<0.095	0.021	0.018	<0.322	<0.012	<0.083	0.169
18/3514	Red fox liver	<0.095	0.073	0.054	<0.322	<0.012	<0.083	0.308
18/3515	Red fox liver	<0.095	0.033	<0.008	<0.322	<0.012	<0.083	<0.122
18/3516	Red fox liver	<0.095	0.036	<0.008	<0.322	<0.012	0.167	0.597
18/3517	Red fox liver	<0.095	0.035	<0.008	<0.322	<0.012	<0.083	0.141
18/3518	Red fox liver	<0.140	0.180	0.021	<0.322	<0.012	<0.083	0.389

Pesticides

NILU-Sample number:	Sample type:	HCB	□-HCH	□-HCH	□-HCH	o.p'-DDE	p.p'-DDE	o.p'-DDD	p.p'-DDD	o.p'-DDT	p.p'-DDT
18/2924	Sparrowhawk egg	13.7	<0.041	0.62	0.064	<0.045	697	<0.037	11.0	<0.112	10.7
18/2925	Sparrowhawk egg	3.67	<0.041	0.34	0.069	<0.048	186	<0.037	2.03	<0.112	2.91
18/2926	Sparrowhawk egg	15.3	<0.041	1.26	0.056	<0.108	1600	<0.037	5.71	<0.112	9.14
18/2927	Sparrowhawk egg	51.5	0.099	4.74	0.288	<0.106	2200	<0.037	14.6	<0.112	30.7
18/2928	Sparrowhawk egg	14.2	<0.045	1.23	0.081	<0.093	1260	<0.043	10.4	<0.112	10.3
18/2929	Sparrowhawk egg	17.5	<0.041	1.26	0.090	<0.047	1120	0.061	9.15	0.139	9.83
18/2930	Sparrowhawk egg	58.0	<0.042	0.93	0.090	<0.057	1020	0.056	9.88	<0.112	15.7
18/2931	Sparrowhawk egg	28.3	0.055	5.93	0.125	<0.085	2740	<0.037	13.6	<0.112	10.5
18/2932	Sparrowhawk egg	7.40	<0.041	2.24	0.164	<0.066	1210	<0.037	5.61	<0.112	6.07

UV compounds

NILU-Sample number:	Sample type:	BP3	EHMC-Z	EHMC-E	UV-329	UV-328	UV-327	OC
18/2907	Soil pool (ng/g dw)	0.54	0.174	1.3	<5	0.72	0.06	4.9
18/2913	Earthworm pool	<5	<0.5	<4	<1.8	<0.13	<0.12	8.3
18/2934	Sparrowhawk egg pool	<5	<1	<4	7.6	0.58	<0.3	7.6
18/2935	Sparrowhawk egg pool	<5	<1	<4	<4	0.84	0.32	<4
18/2936	Sparrowhawk egg pool	<5	<1	<4	<4	<0.4	0.30	<4
18/3570	Red fox liver pool	<1.7	<0.2	<1.4	<0.7	1.32	0.084	<1.1
18/3571	Red fox liver pool	<1.7	<0.2	<1.4	<0.7	0.15	<0.04	<1.1
18/3572	Red fox liver pool	<1.7	<0.2	<1.4	<0.7	0.05	<0.04	<1.1
18/3573	Badger liver pool	<1.7	<0.2	<1.4	<0.7	<0.05	<0.04	<1.1
18/3574	Badger liver pool	<1.7	<0.2	<1.4	<0.7	<0.05	<0.04	<1.1
18/3575	Badger liver pool	<1.7	<0.2	<1.4	<0.7	<0.05	<0.04	<1.1
18/4063	Rat liver pool	<4	<0.3	<3	<1.4	5.95	0.56	3.2
18/4064	Rat liver pool	<4	<0.3	<3	<1.4	3.23	1.00	<2.5
18/4065	Rat liver pool	<4	<0.3	<3	<1.4	10.4	0.36	<2.5

Biocides (Rodenticides)

NILU-Sample number:	**Sample type:**	Bromadiolone	Brodifacoum	Flocumafen	Difenacoum
18/3509	Red fox liver	116	175	<2	3.10
18/3510	Red fox liver	113	3.60	<2	<2
18/3511	Red fox liver	<2	<2	<2	<2
18/3512	Red fox liver	<2	<2	<2	<2
18/3513	Red fox liver	969	89.1	<2	20.1
18/3514	Red fox liver	3473	818	<2	<2
18/3515	Red fox liver	74.6	4.90	<2	<2
18/3516	Red fox liver	389	31.1	<2	9.6
18/3517	Red fox liver	247	79.2	<2	<2
18/3518	Red fox liver	44.4	111	<2	<2
18/3519	Badger liver	<2	<2	<2	<2
18/3520	Badger liver	<2	<2	<2	<2
18/3521	Badger liver	<2	<2	<2	<2
18/3522	Badger liver	<2	<2	<2	<2
18/3523	Badger liver	<2	<2	<2	<2
18/3524	Badger liver	<2	<2	<2	<2
18/3525	Badger liver	<2	90.7	<2	<2
18/3526	Badger liver	<2	<2	<2	<2
18/4053	Rat liver	<1.3	<1.3	<1.3	<1.3
18/4054	Rat liver	<1.3	<1.3	<1.3	<1.3

NILU-Sample number:	**Sample type:**	Bromadiolone	Brodifacoum	Flocumafen	Difenacoum
18/4055	Rat liver	152	<1.3	<1.3	<1.3
18/4056	Rat liver	10.3	<1.3	<1.3	<1.3
18/4057	Rat liver	789	<1.3	<1.3	<1.3
18/4058	Rat liver	37.0	<1.3	<1.3	<1.3
18/4059	Rat liver	171	<1.3	<1.3	<1.3
18/4060	Rat liver	21.9	<1.3	<1.3	<1.3
18/4061	Rat liver	205	<1.3	<1.3	<1.3

Phenols

NILU-Sample number:	Sample type:	4,4-bis A	4,4-bis-S	4,4-bis-F	TBBPA(1)	4-tert-octylphenol	4-octylphenol	4-nonylphenol
18/2902	Soil (ng/g dw)	< 15.0	< 5.0	< 7.0	< 150.0	< 40.0	< 35.0	< 70.0
18/2903	Soil (ng/g dw)	< 15.0	< 5.0	< 7.0	< 150.0	< 40.0	< 35.0	< 70.0
18/2904	Soil (ng/g dw)	< 15.0	< 5.0	< 7.0	< 150.0	< 40.0	< 35.0	< 70.0
18/2905	Soil (ng/g dw)	< 15.0	< 5.0	< 7.0	< 150.0	< 40.0	< 35.0	< 70.0
18/2906	Soil (ng/g dw)	< 15.0	< 5.0	< 7.0	< 150.0	< 40.0	< 35.0	< 70.0
18/2908	Earthworm	67.2	< 5.0	< 5.0	< 20.0	< 30.0	< 25.0	< 50.0
18/2909	Earthworm	64.5	< 5.0	6.3	< 20.0	< 30.0	< 25.0	< 50.0
18/2911	Earthworm	76.1	< 5.0	< 5.0	< 20.0	< 30.0	< 25.0	< 50.0
18/2914	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2915	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2916	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2917	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2918	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2919	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2920	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2921	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2922	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20.0	< 25.0	< 25.0	< 50.0
18/2923	Fieldfare egg	< 25.0	< 5.0	< 5.0	< 20,0	< 25.0	< 25.0	< 50.0
18/2924	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0

NILU-Sample number:	Sample type:	4,4-bis A	4,4-bis-S	4,4-bis-F	TBBPA(1)	4-tert-octylphenol	4-octylphenol	4-nonylphenol
18/2925	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2926	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2927	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2928	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2929	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2930	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2931	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/2932	Sparrowhawk egg	< 50.0	< 5.0	< 10.0	< 60.0	< 50.0	< 40.0	< 60.0
18/3509	Red fox liver	55.4	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3510	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3511	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3512	Red fox liver	41.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3513	Red fox liver	< 54.6	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3514	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3515	Red fox liver	45.2	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3516	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3517	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3518	Red fox liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3519	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3520	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0

NILU-Sample number:	Sample type:	4,4-bis A	4,4-bis-S	4,4-bis-F	TBBPA(1)	4-tert-octylphenol	4-octylphenol	4-nonylphenol
18/3521	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3522	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3523	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3524	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3525	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/3526	Badger liver	< 35.0	< 5.0	< 30.0	< 60.0	< 170.0	< 150.0	< 190.0
18/4063	Rat liver pool	123.6	< 10.0	< 45.0	< 200.0	< 480.0	< 450.0	< 530.0
18/4064	Rat liver pool	< 75.0	< 10.0	< 45.0	< 200.0	< 480.0	< 450.0	< 530.0
18/4065	Rat liver pool	< 75.0	13.6	< 45.0	< 200.0	< 480.0	< 450.0	< 530.0

Appendix 2

GPS coordinates for sampling locations

GPS coordinates for sampling locations

ID	Location	UTM-zone	Latitude	Longitude
Air				
18/3356	Slottsparken/Dronningparken	32V	59.9166	10.7263
18/3357	Frognerseteren	32V	59.983611	10.69083
18/3358	Grønmo	32V	59.8397	10.8523
18/3359	Alnabru	32V	59.9169	10.8327
18/3360	VEAS	32V	59.7915	10.5021
Soil				
18/2902	Slottsparken	32V	59.917025	10.724283
18/2903	Frognerseteren	32V	59.976947	10.680538
18/2904	Grønmo	32V	59.840782	10.8551
18/2905	Alna	32V	59.914611	10.829474
18/2906	VEAS	32V	59.799631	10.487164
Earthworm				
18/2908	Slottsparken	32V	59.917025	10.724283
18/2909	Frognerseteren	32V	59.976947	10.680538
18/2910	Grønmo	32V	59.840782	10.8551
18/2911	Alna	32V	59.914611	10.829474
18/2912	VEAS	32V	59.799631	10.487164
Red fox				
18/3509	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3510	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3511	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3512	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3513	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3514	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3515	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3516	Hellerudmyra, Oslo	32V	60.008337	10.465587
18/3517	Sørkedalen, Oslo	32V	60.023276	10.596235
19/3518	Hellerudmyra, Oslo	32V	60.008337	10.465587
Badger				
18/3519	Kryssbydalen	32V	60.008337	10.465587
18/3520	Kryssbydalen	32V	60.008337	10.465587
18/3521	Kryssbydalen	32V	60.008337	10.465587
18/3522	Kryssbydalen	32V	60.008337	10.465587
18/3523	Maridalen, Granum	32V	60.025313	10.788517
18/2324	Maridalen, Granum	32V	60.025313	10.788517
18/3525	Maridalen, Granum	32V	60.025313	10.788517
18/3526	Sørkedalen	32V	60.016621	10.632281

Fieldfare				
18/2914	Grønmo	32V	59.840754	10.855152
18/2915	Ekebergparken	32V	59.891285	10.771673
18/2916	Bøler	32V	59.880294	10.851834
18/2917	Alna 1	32V	59.915837	10.831723
18/2918	Alna 2	32V	59.915556	10.831261
18/2919	Alna 3	32V	59.91335	10.829029
18/2920	Kjelsås	32V	59.964299	10.787358
18/2921	Holmenkollen	32V	59.967091	10.671672
18/2922	Arnestad (VEAS)	32V	59.800229	10.485123
18/2923	Slottsparken	32V	59.917219	10.729355
Sparrow hawk	Confidential for species protection	Confidential for species protection	Confidential for species protection	Confidential for species protection

Appendix 3

Eggshell data in sparrowhawks from the Oslo area 2017.

Eggshell data in sparrowhawks from the Oslo area 2018.

NILU ID	NINA ID	Eggshell index	Eggshell thinning (%)
18/2924	6727	1,26	-12,27
18/2925	6728	1,37	-4,49
18/2926	6729	1,18	-18,09
18/2927	6730	1,27	-11,38
18/2928	6731	1,2	-16,69
18/2929	6732	1,31	-9,08
18/2930	6733	1,27	-11,64
18/2931	6734	1,34	-6,95
18/2932	6735	1,38	-4,05

Appendix 4

Pathology studies 2018 of red foxes and brown rats.

A necropsy was performed on thirteen rats (internal reference no. 8023 – 8032) and ten foxes (internal reference no. RR 1591 to 1600) at the laboratory at NINA in Trondheim by a trained veterinary pathologist and certified wildlife population health specialist (Dr. Bjørnar Ytrehus.) The necropsy was performed according to standard routines at NINA and included gross examination of all organ systems. In the foxes we also performed a routine histological examination of tissue samples from myocard, lung, liver, spleen, kidney and any lesions found. One rat was excluded, as the body cavities were opened and internal organs (incl. liver) were missing.
All animal carcasses had been stored at -20°C and were thawed before necropsy. Consequently, the postmortal changes were prominent. All the red foxes had lesions consistent with shot wounds. Six of the ten foxes had stomach content indicating that they had fed or were fed food from anthropogenic sources, i.e. bread, dog food etc. They were all in average or over average condition. Most of them were young adults. Macroscopical and histological examination of the fox carcasses did not reveal any specific diseases that either could affect the level of environmental toxicants or be an effect of exposure to such toxicants. The moderate to low numbers of parasites has most probably not had an impact on the foxes. The good condition of these animals and the gastric content found in many of them raises suspicion that they have had access to anthropogenic food. Consequently, it can be discussed if they are representative for red foxes reliant on food from environmental sources.
The rats had variable gastric content which origin was hard to determine with the naked eye. Several of the animals were adults in their prime reproductive stage, judged on size and activity of reproductive organs. Macroscopical and histological examination of the rat carcasses did not reveal any specific diseases that either could affect the level of environmental toxicants or be an effect of exposure to such toxicants.

Table: Overview of findings in necropsied red foxes:

Red fox no.	Marked (info on package)	Age group/ gender	Condition/ weight	Findings
1591	Morten Olsen Oslo 13th Jan 18	Adult female	Over average, 5,6	Considerable wear of teeth, mild multifocal enteritis, left kidney small, right kidney enlarged. Five dark bands in uterus (interpreted as remnants of five placentas)
1592	Morten Olsen, Oslo 11th Oct 18	Young female	Average 4,5	Multiple roundworms (presumably *Toxocara*/Toxascaris sp.) in oral jejunum. Juvenile uterus.
1593	Morten Olsen, Oslo 20th Jan 18	Young male	Over average 4,7	Multiple lungworms (pres. *Capillaria* sp.) in bronchi.
1594	7th Jan 18	Young male	Average 5,3	Some cestodes in intestines, some lungworms
1595	Oslo. Received 14th Nov 17	Young male	Over average 7,4	Left canince tooth upper jaw broken. Serosa in abdomen hyperemic indicating mild peritonitis
1596	Oslo 21st Dec 18	Young male	Average 6,2	
1597	Oslo	Adult male	7,0	Some cestodes in intestines.

	30th Nov 17			
1598	Oslo 7th Dec 17	Young male	Average 7,0	Multiple roundworms (presumably *Toxocara*/Toxascaris sp.) in oral jejunum. Some lungworms.
1599	Oslo	Adult male	Average 6,2	Some roundworms (presumably *Toxocara*/Toxascaris sp.) in oral jejunum.
1600	Oslo	Young female	Above 5,57	

Table: Overview of findings in necropsied brown rats:

Rat no.	Marked (info on package)	Age group/ gender	Condition/ weight	Findings
8020	Anticimex, Bislett, Oslo, 11th Nov 18	Adult female	Below average 224 g	Air gun projectiles in bullet wound. Eight dark bands indicating remnants of placentas in uterus. Follicles in the ovaries.
8021	Anticimex, CHB, Oslo 18	Adult male	Average 329 g	Free non-coagulated blood in abdomen. Haemorrhages from the nose, the jaws and in the face and in intercostal muscles of caudal part of thorax. Blood on cut survace of lungs. Old, healed wounds on the margin of its ears.
8022	Anticimex, CHB, Tøyen, Oslo 18	Adult male	Average 341 g	Head and thorax crushed, stomach ruptured and liver contaminated by gastric content. One testis large with normal texture, while the other was small and firm.
8023	Anticimex, Erik L, Østre Aker vei, Oslo Oct. 18	Young male	Below average 100 g	Lost right digit III. Ipsilateral prescapular lymph node lenlarged.
8024	Anticimex, Oslo, 7th Nov 18	Adult female	Below average 293	Old lesion with healed wound on lateral skin of left foreleg. Impressions in skin over thorax and abdomen, subcutaneous haemorrhages , rupture of thoraci/abdominal wall musculature, rupture of diaphragm and diplacement of liver into thoracic cavity. Lesions consistent with major trauma (bite?). 3 – 4 mm thick uterus without dark bands.
8025	Anticimex, Kolstads gate	Young female.	Average 150 g	Uterus 3 mm thick without dark bands.

	18, Oslo, 24th Oct 18			
8026	Anticimex, Erik Linge, Collosseum Majorstuen, Oslo, 16th Nov 18	Adult male	Average 225 g	Major trauma to head, mouth and snout and to right side of thorax. Non-coagulated blood in thoracic cavity. Mottled and moist lungs.
8027	Anticimex, Kalbakken, Oslo Oct 18	Young male	Average 151 g	Dark and moist lungs with blood on cut surface. Dilated heart.
8028	Anticimex, CHB, Oslo, 18	Adult male	Below average 297 g	Haemorrhages from mouth and snout, non-coagulated blood in thoracic cavity, mottled lungs with dark and moist cut surface
8029	Anticimex, Carl Berners plass 18, Oslo	Female	Below average 249 g	Fracured scapula and haemorrhages in musculature of right side, moderate amount of non-coagulated blood in thoracic cavity, alopecia over mammary glands (probably lactating). Uterus dark with numerous coalescing dark bands.
8030	Anticimex, Carl Berners plass, Oslo	Female	Missing organs in thoracic cavity. 91 g	Skull crushed. Body cavities opened. All organs missing in thoracic cavity. Liver missing in abdominal cavity. Excluded.
8031	Anticimex, Oslo, Carl Berners plass, 18	Young female	Below average. 107 g	Skull crushed. Large haemorrhages over thoracic cavity and neck. Uterus very thin. Some small follicles in ovaries. Thymus present (10 x 8 x 3 mm)
8032	Anticimex, Carl Berners plass, 18	Young female	Average 110 g	Haemorrhages from nose. Uterus 2 mm thick and without bands.

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The Norwegian Environment Agency is working for a clean and diverse environment. Our primary tasks are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

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

We implement and give advice on the development of climate and environmental policy. We are professionally independent. This means that we act independently in the individual cases that we decide and when we communicate knowledge and information or give advice.

Our principal functions include collating and communicating environmental information, exercising regulatory authority, supervising and guiding regional and local government level, giving professional and technical advice, and participating in international environmental activities.