A One Health View over Environment Contaminants in Wild Otter Populations

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Abstract. *In the 20th century, wild otter populations declined across the world. This decline was associated with several factors, such as habitat destruction and hunting. Other underlying causes were anthropogenic contaminant loads in their food and water sources. Aquatic mammals such as otters are very susceptible to chemical contamination and, as top predators, can be considered sentinel species for the health of the ecosystem. This brief review aims to show the presence of environmental contaminants in different otter species and how they may have contributed to the population decline of these species. Although many studies have been carried out on the presence of these compounds in otters, in the future, it is important to continue monitoring these populations to understand their impacts under the One Heath concept.*

Introduction

In the 20th century, American and Eurasian otter species declined. This decline was associated with several factors, such as habitat destruction and hunting. Other causes were the high environmental contaminant load in food and water, heavy metals and persistent organic pollutants in particular (Nelson et al., 2015; Roos et al., 2001). Pollutants such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCB) are examples of lipophilic persistent organic pollutants (POPs). Although they have been banned in many countries for several decades, they are still found in high concentrations in biota (Agostini et al., 2020; Islam and Malik, 2018). These compounds can bioamplify within the food chain, which means that residues not only affect species at the base of the chain, but also spread further up the food chain, reaching maximum concentrations in top predators (Rivera et al., 2021) (Figure 1).

River and sea otters are exposed to pesticides through their diet. Yet, as top predators, they are also particularly prone to the accumulation of pesticide residues that biomagnify with trophic levels (Nelson et al., 2015). Deaths resulting from direct poisoning are rarely reported in these species. However, sublethal effects associated with some compounds have been reported, such as organ failure, diseases (e.g., tumors, cardiovascular diseases, chronic nephropathies, autoimmune diseases), behavioral and reproductive changes (Peterson and Schulte, 2016).

One Health is an approach that recognizes that the health of people is closely linked to the health of animals and the environment (CDC, 2022). It is a collaborative, multidisciplinary approach to understanding the ecology of emerging zoonotic diseases to perform risk assessment and develop response and control tactics otter populations (Mackenzie and Jeggo, 2019). Aquatic mammals such as otters are susceptible to chemical contamination (Murata et al., 2008). As top predators, they can be considered sentinel species for the health of the ecosystem, as they interact strongly with the biotic and abiotic components of their habitat (Peterson and Schulte, 2016). Studying the concentration of environmental contaminants in otters can provide researchers with information about temporal and

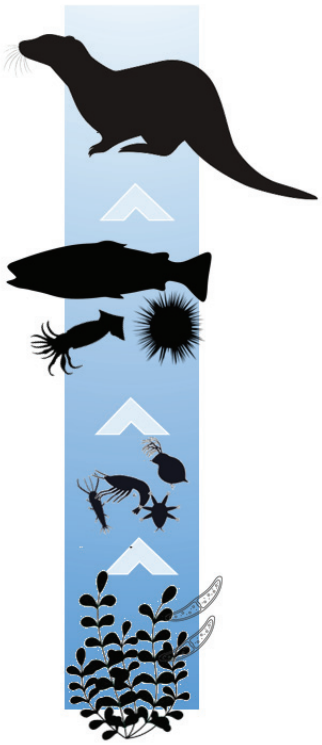

Fig. 1. Example of biomagnification of environmental contaminants moves further up in the food chain

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spatial changes in ecosystem contamination and contribute to the assessment of potential risks to human health due to dietary coincidences coupled with continuous exposure to different contaminated matrices (Rivera et al., 2021).

In this short review, we present just a few examples of some of the most significant works on environmental pesticides in some otter species, both aquatic and marine.

Otters and anthropogenic environmental contaminants

Otters are carnivorous mammals from the subfamily Lutrinae (Kruuk, 2006). Thirteen different species of otter can be found on every continent except Australia and Antarctica. These species are semiaquatic, aquatic or marine and their diets are based on fish and invertebrates (Kruuk, 2006). According to the IUCN Red List of Threatened Species, 11 out of 13 species are threatened (The IUCN Red List of Threatened Species, 2023).

Many substances have been studied in recent years in this species. In Table 1, we present some of the examples described in this review, the group and its impact on vertebrates (Harley et al., 2019; Hart et al., 2009; Kannan and Perrotta, 2008; Murata et al., 2008, 2008).

Environmental pollutants can be dispersed through the air, penetrate the soil, enter bodies of water, or be absorbed by plants and animals (Agostini et al., 2020; Baker et al., 2013; Chaturvedi et al., 2013). Their fate in the ecosystem depends on the physical and chemical properties of the compound, as well as environmental conditions. Their physical and chemical properties determine soil mobility, water solubility and volatility. Once released into the environment, these compounds can be broken down by exposure to sunlight (photolysis), exposure to other chemicals (oxidation and reduction), microbial activity (bacteria, fungi, and other microorganisms), plants or animals (metabolism), and exposure to water (hydrolysis) (Ames, 1992; Fry, 1995; Islam and Malik, 2018). Figure 2 shows the routes by which pesticides can enter the environment, their path through the food chain and how otters can be affected.

Sea otter

Table 2 presents some studies regarding environmental contaminants (pesticides and others) in sea otters (*Enhydra lutris kenyoni and Enhydra lutris nereis*). Table 3 shows some examples of heavy metals and metalloids in sea otters.

River otter

Table 4 presents some studies regarding environmental contaminants (pesticides and others) in otters (*Lutra lutra, L.canadensis, L. longicaudis*). Table 5 presents some examples of heavy metals and metalloids.

Implications about environment contaminants, otter population and One Health concept

Knowledge about the presence and concentration of environmental contaminants is essential in the One Health context. These studies acquire even more importance in species that do not share the same habitat as humans, but which, with greater or lesser proximity, suffer the effects of pollution irreparably. Otters, as semi-aquatic or marine animals, can be affected by contaminants in terrestrial and aquatic ecosystems, providing essential data on their health and sources of habitat contamination (Jessup et al., 2004).Therefore, they can be considered a good indicator of pollution, being a sentinel species (Harding, 1999; Jessup et al., 2004). However, several knowledge gaps remain in ecotoxicological studies on this species, as these animals are often ignored and neglected during epidemiological surveillance.

The presence of anthropogenic contaminants in the environment appears to be associated with the decline of some otter populations (Harding, 1999; Huang et al., 2018), particularly in areas where the use of components such as pesticides has been or continues to be very high (South America, India, North America) (Elliott et al., 2008; Halbrook et al., 1996). In this brief review, it is also possible to see that the otter with higher levels of contamination live in the areas that are more industrialized areas such as Europe or North America.

An example that illustrates the influence of environmental contaminants on the decline of otters is the case of PCB in Sweden. It was first suggested that PCBs were an important factor in the decline of the European otter in Sweden when a comparison was made between PCB content in the tissues of Swedish and Norwegian otters. Concentrations were highest in southern Sweden and lowest in northern Norway. These differences were correlated with differences in the status of the otter population (census taken 1975–1977). The census showed that Swedish otters in the north of the country were thriving, while otter populations in the south were declining. Sandegren et al. (1980) pointed out that the PCB concentration in these otters was greater than 50 mg/kg of lipids, a level that had already been associated with infertility in mink (Harley et al., 2019; Hart et al., 2009; Kannan and Perrotta, 2008; Murata et al., 2008, 2008; Roos et al., 2001).

Other factors such as habitat destruction, hunting for fur and climate change have also had a huge influence on the reduction of these populations. For example, Enhydra lutris populations in the Aleutian archipelago declined by 75% between 1965 and 2000 (Doroff et al., 2003), not only due pollution but also due to hunting.

Despite the confirmed presence of pesticides in otter tissues, some studies (Basu et al., 2007; Grove and Henny, 2008; Huang et al., 2018) show that these

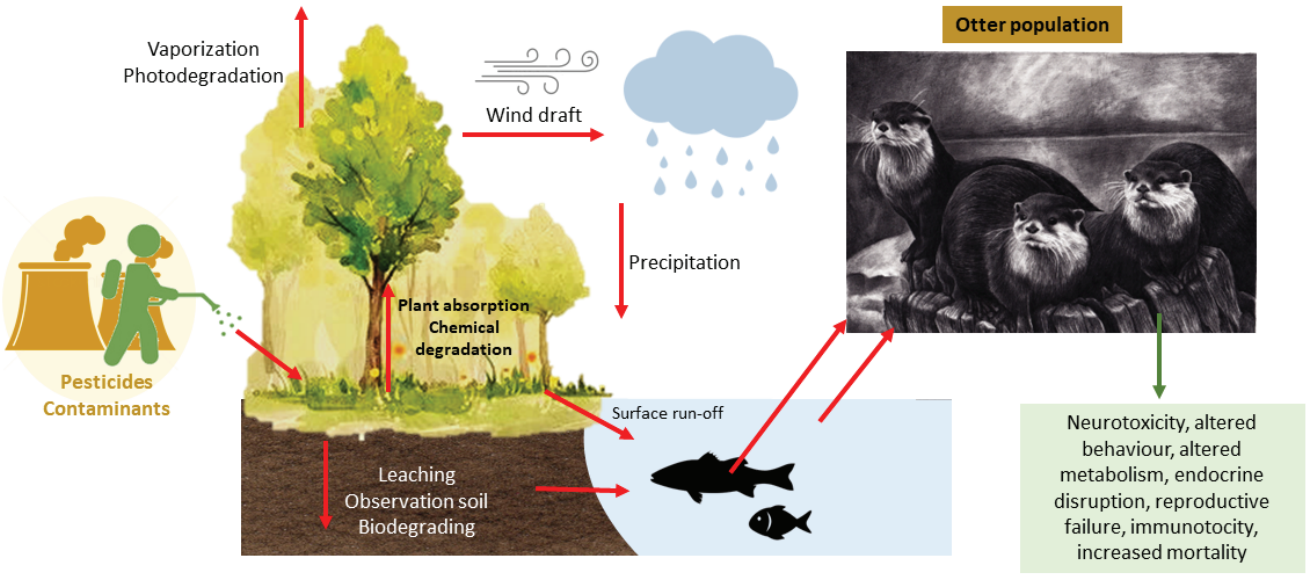

Fig. 2. Schematic representation of pesticide dispersion in the ecosystem and how they affect otter populations

Table 1. Examples of pollutant compounds and their impact in vertebrates

Compound	DL50	Characteristic	Effects in vertebrates	Ref.
Heavy metals and metalloids	Pb (50 µg/L), Cd (5 µg/L), Cr (50 µg/L), Zn (5000 µg/L), Cu (1500 µg/L), Co (10 µg/L), and Ni (100 µg/L)	Metallic chemical element with a relatively high density and toxic at low concentrations	Mutagenicity, teratogenicity, carcinogenicity; induced poor body conditions, reduced reproduction rate, immunosuppression	(Balali-Mood et al., 2021)
Perfluorooctanesulfonate (PFOS)	5.2 mg/L	Belongs to the synthetic chemicals perfluoroalkyl and polyfluoroalkyl with repellent properties	Infertility, cancer, preeclampsia, preterm labor, low birth weight gestational diabetes, thyroid and kidney disease, hypercholesterolemia	(Huang and Jaffé, 2019)
Dichlorodiphenyltrichloroethane (DDTs)	0.5 mg/m^3	It is an organochloride used as an insecticide.	Cancer, immunosuppression, teratogenic, toxic, seizures, liver disease	(Kabasenche and Skinner, 2014)
polybrominated diphenyl ethers (PBDEs)	0.5–5 g/kg	Synthetic chemicals used in plastics, textiles and electrical/electronic equipment to make them less flammable.	Cancer, teratogenic	(Palacio-Cortés et al., 2017)
Polycyclic aromatic hydrocarbons (PAHs)	0.2 mg/m^3	Class of organic compounds produced by incomplete combustion or high-pressure processes	Toxic, carcinogenic, pulmonary and gastrointestinal disease, infertility	(Boehm, 1964)
Organochlorine pesticides (OCs)	50 mg/kg	Synthetic chlorinated hydrocarbons used as insecticides	Toxic, effects in the nervous system, cancer, teratogenic, infertility, immunosuppression	(Mason and Macdonald, 1994)
Polychlorinated dibenzofurans (PCDFs)		Organic compounds with one or several of the hydrogens in the dibenzofuran structure replaced by chlorines used as pesticides	Severe skin lesions, altered liver function and lipid metabolism, weight loss, depression of the immune system, and endocrine alterations	(Muir et al., 1996)

Table 2. Papers that evaluated environmental contaminants in sea otters *(Enhydra lutris kenyoni* and *Enhydra lutris nereis)* regarding the number of animals, substance type, year, sample type analyzed, country, and compound concentration in the tissue. Results are in lipid weight (l.w.) or wet weight (w.w.).

Species	Substance*	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Enhydra lutris kenyoni	PFOS, PFOSA, PFNA, PFOA, PFUnDA, PFDA	Liver	Alaska	1992–2007	0.9 to 8 ng/g w.w.	(Hart et al., 2009)
	CHLs, PCBs, DDTs, PBDEs	Liver	Alaska	1992–2010	PCBs 262,000 ng/g l.w., DDTs 8,800 ng/g l.w., PBDEs 4,600 ng/g l.w.	(Harley et al., 2019)
Enhydra lutris nereis	PCBs, DDTs, HCHs, chlordane, HCB	Liver, kidney, brain	California	1992–1996	PCBs 58±8700 and DDTs 280±5900 ng/g w.w.	(Nakata et al., 1998)
	OTs- mono- to tributyltin, -phenyltins, and -octyltins	Liver	California, Washington, Alaska, Russia	1992–2002	34 to 4100 ng/g w.w.	(Murata et al., 2008)
	POPs	Liver	California	2000–2005	DDTs- 635 ng/g l.w., PCBs 177 ng/g l.w., PBDEs 48.1 ng/g l.w.,	(Miller et al., 2007)
	PBDEs, PCBs	Liver	California	1992–2002	PBDEs 10–26,800 ng/g and PCBs 81–210,000 ng/g l.w.	(Kannan et al., 2007)
	PAHs	Liver	California	1992–2002	588–17 400 ng/g l.w.	(Kannan and Perrotta, 2008)
	OCs, PCB, butyltins	Liver	California	1992–1996	PCB 8,700 ng/g w.w., DDT 5,900 ng/g w.w.	(Kannan et al., 2004)
	POPs, COECs	Blood	Alaska, California	1997–1998	PCBs 705 ng/g l.w., DDTs 145 ng/g l.w., HCHs 145 ng/g l.w., CHL 135 ng/g l.w.	(Jessup et al., 2010)
	OCs, PCBs, including non–ortho PCBs, PCDDs, PCDFs	Liver	Alaska, California, Aleutian	1998–1992	Dichlorodiphenyltrichloroethane concentrations in California otters 850 mg/kg w.w., Aleutian otters 40 mg/kg w.w. and Alaska 1 mg/kg w.w. PCBs in Aleutian otters 310 mg/kg w.w., California otters 190 mg/kg w.w., and Alaska otters 8 mg/kg w.w.	(Bacon et al., 1999)
	PFOS, PFOA	Liver	California	1992–2002	PFOS < 1, PFOA < 5–147 ng/g w.w.	(Kannan et al., 2006b)

*(Perfluorooctanesulfonate (PFOS), perfluorooctanesulfonamide (PFOSA), perfluorooctanoate (PFNA), perfluorooctanoate (PFOA), perfluoroundecanoate (PFUnDA), perfluorooctanoate (PFDA), chlordane (CHLs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDTs), polybrominated diphenyl ethers (PBDEs), hexachlorocyclohexanes (HCHs), Hexachlorobenzene (HCB), organotin compounds (OTs) - mono- to tributyltin, -phenyltins, and -octyltins, persistent organic pollutants (POPs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCs), and polychlorinated dibenzofurans (PCDFs).

Table 3. Papers that evaluated environmental contaminants in sea otters *(Enhydra lutris* and *Enhydra lutris nereis)* regarding the number of animals, substance type, year, sample type analyzed, country, and compound concentration in the tissue. Results are in dry weight (d.w.) or wet weight (w.w.).

Species	Substance*	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Enhydra lutris	As, Cd, Cu, Pb, THg, Se	Brain, kidney, gonad, liver, and stomach contents	Alaska	2021	As 0.05 to 3.01 mg/kg w.w., Cd 81.10 mg/kg .w., Cu 0.83 to 38.30 mg/kg w.w., Pb 0.01 to 6.47 mg/kg w.w., THg 0.01 to 2.26 mg/kg w.w., Se 0.70 to 7.83 mg/kg w.w.	(Brown et al., 2021)
	Hg	Fur	Russia	2003–2019	5.4 µg/g d.w.	(Ryazanov et al., 2023)
Enhydra lutris nereis	Cu, Zn, Cd, Hg, Pb	Liver	California	1992–2002	Zn 95.0–542 µg/g w.w., Cd and Hg > 15 µg/g w.w., Pb 0.019 to 1.06 µg/g w.w., Cu 5–50 µg/g w.w., Cd 0.5–25 µg/g w.w.	(Kannan et al., 2006a)
	Se, Al, Cu, Zn, Cd	Liver	California	1991 and 2002	Se > 3 ppm d.w., Al < 5.0 to 198 ppm d.w., Cu 15.3 to 191 ppm, d.w. Zn 00 to 258 ppm, d.w., Cd 6.03 –2.03 ppm w.w.	(Brancato et al., 2009)

*Arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), total mercury (THg), selenium (Se), mercury (Hg).

have been decreasing over time. This phenomenon can be associated with the fact that mitigation measures have been imposed to reduce these compounds in agriculture, veterinary and industry worldwide (OA US EPA, 2013; OP US EPA, 2013). Furthermore, as some species have an endangered conservation status (The Habitats Directive and Habitats Regulations, 2023), in some regions, otter populations have been recovering (Gutleb et al., 1998; Kruuk and Conroy, 1996). In 1998, the otter population in Netherlands became extinct. In 2002, a program for re-introducing otters was been implemented and the number increased to 360 otters in 2018 (Nature and Form, 2019)

The impact of these contaminants on the otter population is variable and depends on many factors, such as environmental conditions and concentrations of contaminants. Neurotoxicity, changes in behavior and metabolism, endocrine disruption, reproductive failure, immunotoxicity, neoplasia and mortality in extreme cases are some of the effects associated with these compounds (Köhler and Triebskorn, 2013). As some of these compounds will bioaccumulate in tissues in small quantities, the damage caused to animals can only be observed after a long period (years) (Ames, 1992; Köhler and Triebskorn, 2013). Some of these effects are subclinical, such as immunosuppression or decreased fertility, which are not easily detected without a prolonged study of the population. These effects have already been observed in humans and other animal populations with shorter lives (Brander et al., 2016; Chaturvedi et al., 2013; Damásio et al., 2010).

Conclusion

Environmental contaminants are a problem for wildlife and humans. These compounds are present in otter habitats and otters are susceptible to their presence. Years of overuse and abuse of these compounds are taking their toll on otters, directly and indirectly contributing to their decline.

In the future, it is important to develop One Health projects that include otters as sentinels of pollution, climate change and other anthropogenic threats. Within the scope of the One Health system, we can identify threat factors, understand their impact, establish measures to prevent or minimize their consequences and predict the emergence or re-emergence of diseases in different ecosystems, particularly aquatic ecosystems.

Table 4. Review of papers that evaluated environmental contaminates in river otters (*Lutra lutra, Lontra canadensis, Lontra longicaudis*) regarding the number of animals, substance type, year, sample type analyzed, country, and compound concentration in the tissue. Results are in lipid weight (l.w.) or wet weight (w.w.).

Species	Substance	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Lontra longicaudis	2,4-D, acetochlor, ametrine, atrazine, carbendazim, carbofuran, diazinon, dimethoate, emamectin, glyphosate, imazalil, λ-cyhalothrin, malathion, methomyl, metoxuron, molinate, parathion, picloram, pyraclostrobin, thiabendazole	Feaces	Mexico	2018–2019	Acetochlor 21.4, Ametrine 216.2, Diazinon 100.1, Emamectin 56.4, Glyphosate 373.2, Imazalil 3544.5, λ-cyhalothrin 75.4, Malathion 824.4, Methomyl 31.6, Molinate 64.1, Picloram 1280.7 μg kg^{-1} l.w.	(Rivera et al., 2021)
Lutra lutra	OCs	Muscle, liver, pericaudal fat	France	1987–1994	0 to 5.71 mg kg-1 l.w.	(Thome et al., 1995)
	PCB, DDE	Muscle	Sweden	1974–2004	DDE 1.4–970 mg s l.w., PBC 0.0–24 mg l.w.	(Roos et al., 2001)
	PCB	Muscle	Sweden	1970–2010	70 to 8 mg/ kg l.w.	(Roos et al., 2012)
	PCB, DDT	Muscle	Sweden	1968–1999	PCB 44±860 mg g^{-1} l.w., DDT 1.2 ± 27 mg g^{-1} l.w.	(Roos et al., 2001)
	PBDEs, PCBs, DDT	Liver	England and Wales	1995–2006	12–70 000 ng g^{-1} l.w.	(Pountney et al., 2015)
	OCs, PCBs	Tissue, faeces	Ireland	1991	p,p-DDE 1.61mg l.w., dieldrin 1.07mg l.w., PCBs 2.22nmg kg-1 l.w.	(O'Sullivan et al., 1993)
	Aldrin, chlordane, DDE, DDD, DDT, dieldrin, a-endosulfan, b-endosulfan, endrin, HCB, heptachlor, isodrin, methoxychlor, mirex, PCBs	Liver	Spain	2004–2006	PCB 3873–5426 ng g^{-1} l.w.	(Mateo et al., 2012)
	PCB, OCs	Faeces	England	1989–1991	Lindane 11.7 mg.kg^{-1}, 0.4 mg.kg^{-1} dieldrin, 22.3 mg.kg^{-1} p,p-D, 60.51 mg.kg^{-1} PBC	(Mason and Macdonald, 1994)
	PCB, OCs	Faeces	Scotland	1990–1991	9.4-19.5 mg kg^{-1} l.w.	(Mason et al., 1992)
	PCB, OCs	Liver	France	2004–2008	organochlorine pesticides 9.4 mg kg^{-1} l.w., PCBs 64.8 mg kg^{-1} l.w.	(Lemarchand et al., 2010)
	PCB, OCs	Faeces	France	2004–2005	2.72 mg kg^{-1} l.w. OC, 13.58 mg kg^{-1} l.w. PCBs	(Lemarchand et al., 2007)
	PCB, OCs	Liver	Scotland	1987–1992	PCB 14 ppm l.w.	(Kruuk, 2006)

Table 4 (cont.)

Species	Substance	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Lutra lutra	PCBs, OCPs	Liver	Italy	2014–2019	0.010 mg/kg to 4.99 mg/kg, OCPs and PCBs, IDs 1.59 mg/kg, 0.170 mg/kg, 1.09 mg/kg, and 2.64 mg/kg	(Esposito et al., 2020)
	OCs	Liver	France	2013–2014	1.96 mg/kg l.w.	(Alomar et al., 2016)
	PBDEs	Liver	England	1985–2005	BDE 47 ng/g w.w., BDE 153 ng/g w.w., BDE 100 ng/g w.w., PBDEs 3–718 ng/g w.w.	(Walker et al., 2013)
	PCB	Feaces, liver	Ireland	1984–1990	livers 0.18-1 23.2 mg kg^{-1} l.w., faeces 0.21–18.22 mg kg^{-1} l.w.	(Mason, 1989)
	Dieldrin, DDE, PCBs, lindane	Faeces	England	1981–1991	Lindane 0.39 ± 0.08 mg kg^{-1} l.w., DDE 1.61 4. 0.21 mg kg^{-1} l.w., PCBs 2,22 4. 0.54 mg kg^{-1} l.w., dieldrien 1,07 4. 0.16 mg kg -1 l.w.	(Mason and Macdonald, 1993a)**1993a**
	PCBs, DDE, DDT, lindane, Dieldrien	Liver, tissue	Denmark	1980–1990	Lindane 0.81 mg kg^{-1} lipid, Dieldrin 1.10 mg kg^{-1} l.w., DDE 2.88 mg kg^{-1} l.w., PCBs 16.76 mg kg^{-1} l.w.	(Mason and Maden, 1993)
	Perfluoroalkyl sulfonic acids (PFSAs),	Liver	Wales, England	2007–2008	PFAS 109 - 7652 µg/kg w.w.	(O'Rourke et al., 2022)
	DDE, PBCs	Liver	England, Wales	1992–2009	7660 µg kg^{-1} l.w., DDE 15.2 to 7868.6 µg kg^{-1} l.w.PCBs	(Kean et al., 2021)
	PCB	Muscle	Norfolk	1984	433 and 75 mg/kg l.w.	(Keymer et al. 1988)
	Lindane, dieldrin, DDE, PCBs	Faeces	Wales	1989–1992	Dieldren 1.19- 3.68 mg kg-I, DDE 2.12- 6.03 mg kg^{-1}, PCB 4.96- 7.99 mg kg-I l.w.	(Mason and Macdonald, 1993b)
	PCB	Faeces	England	1985– 1991	0.21 mg kg -1 l.w.	(Mason and Macdonald, 1993c)
	Dieldrin, DDE, PCBs, DDT	Muscle, Liver	Ireland	1984–90	Dieldrin 0.08-16.01 mg kg^{-1}, DDE 0.05–25.70 mg kg^{-1}, PCB 0.18–123.24 mg kg-I, DDT 0.07–44.47 mg kg^{-1} l.w.	(Mason and O'Sullivan, 1992)
	PCB	Faeces	Scotland	1992	19.5 mg kg^{-1} l.w.	(Mason et al., 1992)
	PCBs, HEOD, DDE	Liver	Scotland	1987–1992	DDE 0.12–2.81 ppm l.w., HEOD 0.08–0.28 ppm l.w.	(Kruuk and Conroy, 1996)
	Ocs, PCBs, PCDDs, PCDFs, PBDEs	Liver, testes	Oregon and Washington	2005–2007	PCB 540 ng/g w.w.,, PCDDs 172 to 2,783 pg/g w.w., PCDFs 1.50 to 2,719 pg/g w.w., PBDEs 0.82 to 436 ng/g w.w., DDT 0.71–2.20 ng/g w.w., Dieldrin 6.43–22.2 ng/g w.w., endrin 0.92–3.97 ng/g w.w, chlorpyrifos 0.62–1.50 ng/g w.w., aldrin 0.46-1.52 ng/g w.w.,	(Stansley et al., 2010)

Table 4 (cont.)

Species	Substance	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Lontra canadensis	PCB, HCB BHC, HE, Chlordane, Aldrin, Dieldrin, Endrin, DDT, DDE, DDD, Mirex, Pentachlorobenzene, Toxaphene, Methoxychlor	Liver, Fat tissue	Alberta	1980–81 to 1982–83	PCB 0.0130(0.014) ng/g w.w. chordane 0.001(0.001) ng/g w.w. DDE 0.002(0.001) ng/g w.w	(Somers et al., 1987)
	PBDEs	Feaces, blood	Vancouver Island	2009–2010	BDE-47 blood samples 0.37 lg/g l.w., BDE-206 0.18 lg/g v, BDE-47 0.16 lg/g l.w., scat samples, BDE-47 in blood 0.82 mg/kg l.w., scat 0.26 mg/kg l.w., BDEs blood 1.12 lg/g l.w., and scat 0.35 lg/g l.w.,	(Nelson et al., 2015)
	PCB, PBDEs, Ocs	Faeces, blood	Vancouver Island	2009–2010	PCB 0.713 (0.0903-11.1) mg/kg l.w., OCP 0.214 (0.0240–0.640) mg/kg l.w., PBDE 0.146 (0.0200–1.31) mg/kg l.w.	(Huang et al., 2018)
	Ocs, PBC	Liver	British Columbia	1995–1996	DDE 110 ng/g w.w., PCBs 120 ng/g w.w.,	(Harding et al. 1999)
	PHAH, OCPs, PBDEs	Feaces	British Columbia	2006–2009	PCB 6.0–38.2 mg/kg l.w., DDT 0.13[a] (0.04–0.93) mg/kg l.w., mirex 0.01[a] (0.002–0.26) l.w., PBDE 0.36A (0.04–2.7) mg/kg l.w.	(Guertin et al., 2010)
	Ocs, PCBs, PCDDs, PCDFs	Liver	Oregan, Washington	1994-1996	OCs 100 $\mu g kg^{-1}$ w.w., PCB < 1 $\mu g g^{-1}$ w.w.	(Grove and Henny, 2008)
	PCBs, Ocs, PCDDs, PCDFs, OCDD	Faeces	British Columbia	1991–1992	DDE 0.012.12 mg/kg l.w, HCB: 0.003–0.25 mg/kg l.w, OCDD 120–19,100 ng/kg l.w, PBC 49 – 12.3 mg/kg l.w, TCDD 1500 ng/kg l.w	(Elliott et al., 2008)
	PBDEs	Liver	Wisconsin	2009–2010	PBDE 0.5 to 72.9 ng/g l.w.	(Dornbos et al., 2015)
	OHCs, PCB, DDE	Liver	Illinois	2009–2011	dieldrin 14.4–534 ppb w.w., PCB: 30–3450 ppb w.w.	(Carpenter et al., 2014)
	PCB, OCP, PBDE	Cerebral cortex	Ontario and Nova Scotia	2002–2004	PCBs 70.9 12.1 ng/g l.w., OCPs 21.2 3.7 ng/g l.w., PBDEs were 3.2 0.6 ng/g l.w.	(Basu et al., 2007)
	Ocs, PCBs, PCDDs, PCDFs	Liver	Columbia	1994/95 and 1995/96	DDE 110–3056 ng/g l.w., PCBs 138 - 4615 l.w., 153 5769 ng/g l.w., and 180 7308 ng/g l.w., OCDD a – 1860 pg/g l.w.; b – 6923 pg/g l.w.	(Harding, 1999)
Lontra canadensis	DDT, PCBs, dieldrin, mirex	Muscle, hair, liver	Georgia	1979–80 and 1980 –81	0.08 to 91.90 ppm DDT, Mirex, dieldrin, and PCBs 0.16 to 75.40, 0.03 to 1.26, and 0.57 to 84.20 ppm.w.w.	(Clark et al., 1981)
	PCB, DDE,	Liver	New York	1982– 1984	PCB 114 µg/g l.w.,, DDE 5.14 µg/g, l.w.	(Foley et al., 1988)

Table 4 (cont.)

Species	Substance	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Aonyx capensis, Lutra maculicollis	DDE, dieldrin, PCBs	Faeces	South Africa	1990	Dieldrin 0.30–1.15 ng/g l.w., DDE 0.03-2.31 ng/g l.w., \PCBs 0.09–1.60 ng/g l.w.	(Mason and Rowe, 1992)

*(Organochlorinated pesticides (OCs), dibenzo-p-dioxins (PCDDs), Perfluorooctanesulfonate (PFOS), perfluorooctanesulfonamide (PFOSA), perfluorooctanoate (PFNA), perfluorooctanoate (PFOA), perfluoroundecanoate (PFUnDA), perfluorooctanoate (PFDA), chlordane (CHLs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDTs), polybrominated diphenyl ethers (PBDEs), hexachlorocyclohexanes (HCHs), Hexachlorobenzene (HCB), organotin compounds (OTs) - mono- to tributyltin, -phenyltins, and -octyltins, persistent organic pollutants (POPs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCs), and polychlorinated dibenzofurans (PCDFs).

Table 5. Papers that evaluated environmental contaminants in sea otters *(Lutra lutra, Lontra canadensis, Lontra longicaudis)* regarding the number of animals, substance type, year, sample type analyzed, country, and compound concentration in the tissue. Results are in dry weight (d.w.) or wet weight (w.w.).

Species	Substance*	Sample	Country/city	Year	Compound concentration in the tissue	Ref.
Lutra lutra	Pb, As, Cu, Cd, Hg	Liver	France	2004–2008	Pb 1.0, Cd 0.3 and As 0.1 mg kg^{-1} d.w., Hg 2.1 mg kg^{-1} w.w.,	(Lemarchand et al., 2010)
	Fe, Zn, Al, Mn, Cu, Pb, Cr , Cd	Faeces	South Korea	1994–1996	Cr 0.47–1.38 mg/Kg d.w., Zn 77.5–162.3 mg/Kg d.w, Cd 0.07–0.24 mg/Kg d.w, Cd 0.07–0.24 mg/Kg d.w, Pb 0.9–5.3 mg/Kg d.w, Cu 2.1–8.0 mg/Kg d.w, Fe 924–2451 mg/Kg d.w, Mn 39.5–98.1 mg/Kg d.w, Al 49.7–205.0 mg/Kg d.w	(Han et al., 2002)
	Hg, Cd, Pb, Ca, Zn	Liver	Ireland	1984–1990	Hg 5 mg kg^{-1} w.w, Cd10 mg kg^{-1} w.w., Ca 1 mg kg^{-1} w.w., Zn 100 mg kg-1 w.w.	(Mason and Sullivan, 1993)
	Cd, Pb	Liver	Austrian, Czech Republic, Hungary	1989–1994	Cd 4.6–5.4 μg g^{-1} d.w., Pb 3.5 μg g^{-1} d.w.,	(Gutleb et al., 1998)
	Hg, Cu, Zn, Pb, Cd	Liver	Hungary	2008	Hg 0–29.59 mg/Kg d.w., Cu 0–76.20 mg/Kg d.w., Zn 41.49–368.13 mg/Kg d.w., Pb 0–1.383 mg/Kg d.w.,, Cd 0-1.168 mg/Kg d.w.,	(Lanszki et al., 2009)
	Hg, Cu, Zn, Cd	Liver, kidney, fur	Finland	1986–2000	Hg 1.17–3.54 mg/Kg w.w., Cd 0.004–0.025 V, Cu o.44-7.76 mg/Kg w.w., Zn 19.50–19.91 mg/Kg w.w.,	(Hyvärinen et al., 2003)
	Cu, Zn, Cd, Pb, As	Faeces	Spain	1999–2003, 2006	Cu 21.1–133.0 ppm d.w., Cd 0.9–5.3 ppm d.w., Zn 113.4–672.5 ppm d.w., Pb 0.45-12-8 ppm d.w., As 0.83–84.5 ppm d.w.,	(Mateo et al. 2012)
Lontra longicaudis	Hg, Pb, Cd	Faces	Mexico	2008–2009	Hg0.02–0.17 mg kg^{-1} w.w., Pb 117.87 mg kg^{-1} w.w., Cd 9.14 mg kg^{-1} w.w.	(Ramos-Rosas et al., 2013)
Lontra canadensis	As, Cd, Cu, Co, Fe, Pb, Mg, Hg, Zn	Liver, kidney	California	2009 to 2016	As 0.14 μg/g w.w., Cd 0.2 μg/g w.w., Co 0.02 μg/g w.w., Cu 3.69 μg/g w.w., Fe 152.75 μg/g w.w., Pb 0.07 μg/g w.w., Mg 152.55 μg/g w.w., Hg 1.68 μg/g w.w., Zn 21.53 μg/g w.w	(Sanders et al., 2020)

*Arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), selenium (Se), mercury (Hg), cobalt (Co), zinc (Zn), iron (Fe), magnesium (Mg), calcium (Ca)

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