GLOBAL MIGRATION OF ENVIRONMENTAL CONTAMINANTS AND HUMAN DISEASE

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The Grasshopper Effect

- Many chemicals migrate from temperate to polar regions. This is called the grasshopper effect.
- These chemicals may be carried by ocean current or air.
- A major route of migration from metals and water-soluble chemicals is ocean currents.
- Mercury can volatilize and be transported for long distances. Mercury and other metals can also be bound to particulates which are carried in air to remote regions.
- For volatile and semi-volatile organic compounds the major route in air currents.
- In the cold polar regions these volatile compounds precipitate and can then bioaccumulate in food.

The Grasshopper Effect

http://www.eoearth.org/view/article/153019

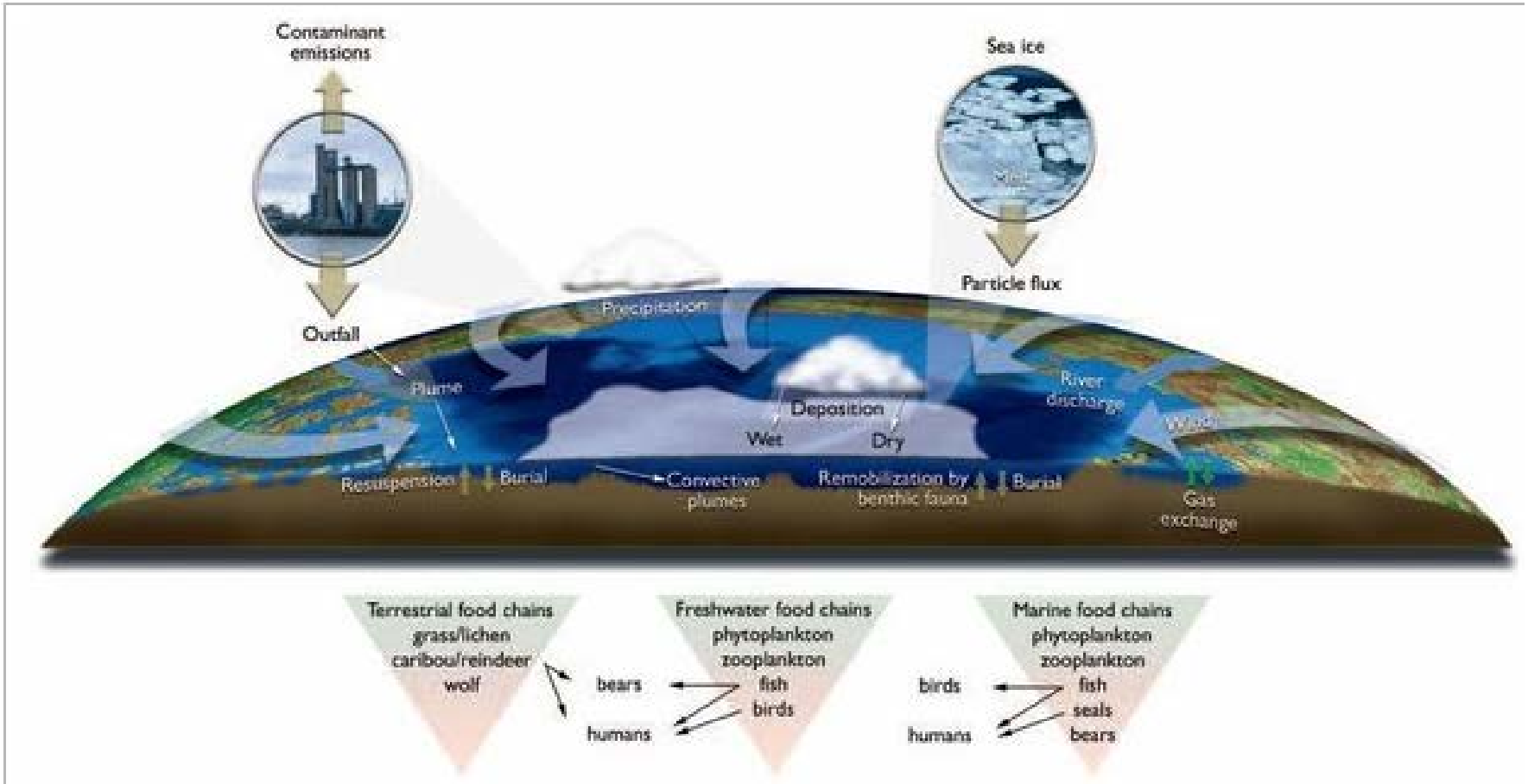


Fig. 8.21. Contaminant pathways, transfers, and exchanges in freshwater systems: land–atmosphere–water interactions[1].

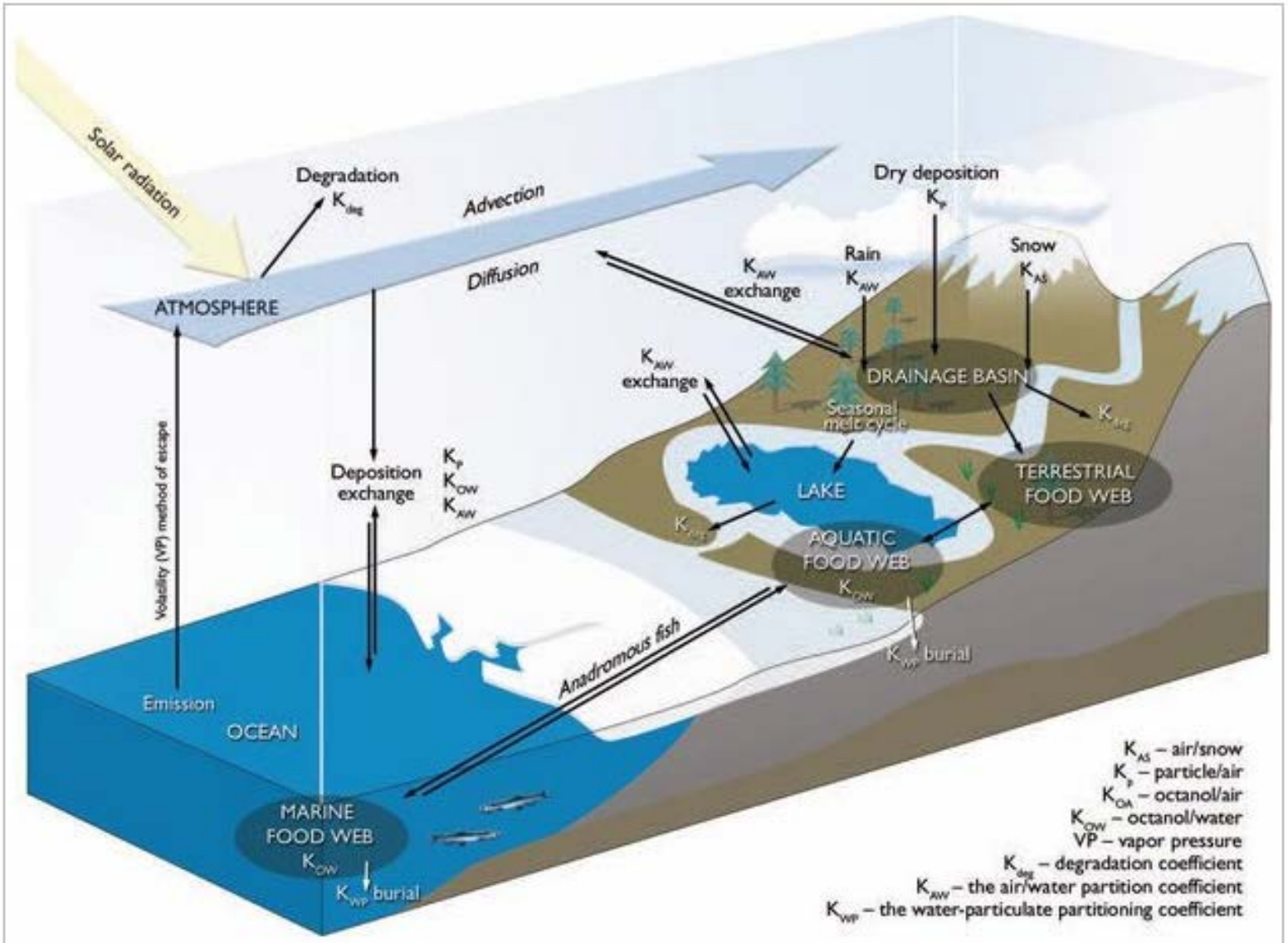


Fig. 8.22. Processes involved in transporting POPs to the Arctic and depositing them into terrestrial ecosystems. Transport, deposition, and exchange can occur anywhere along the transport pathway. Contaminants can also be transported within aquatic and terrestrial food chains. Climate change can alter the physical couplings between the systems (e.g., by changing rain or snowfall patterns), or alter the biological couplings by changing trophic structure or migratory pathways.

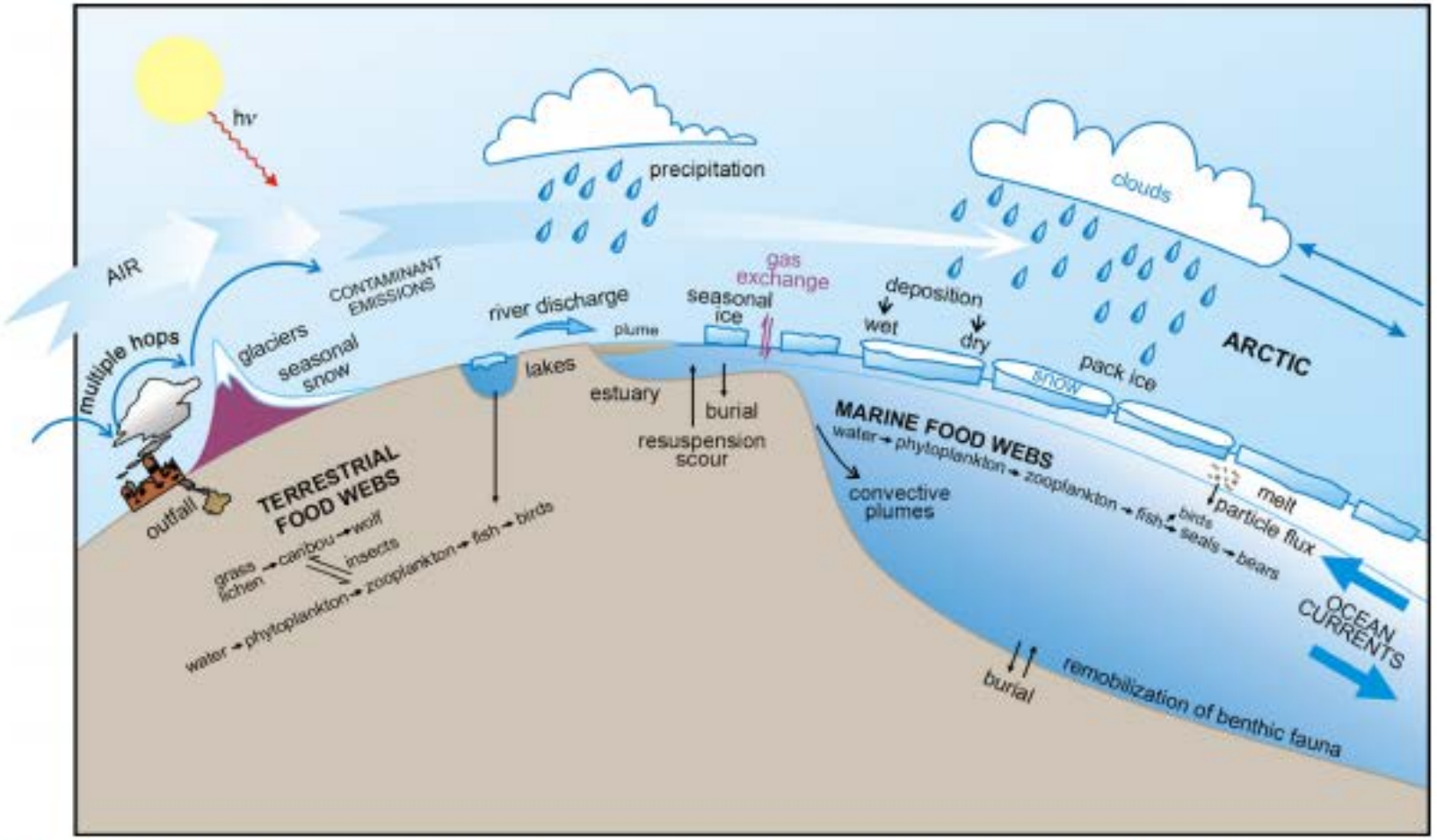


Fig. 2. A simplified schematic diagram showing how physical pathways deliver contaminants emitted from northern industrial regions to the Arctic where they may be concentrated in biota or removed through degradation and burial.

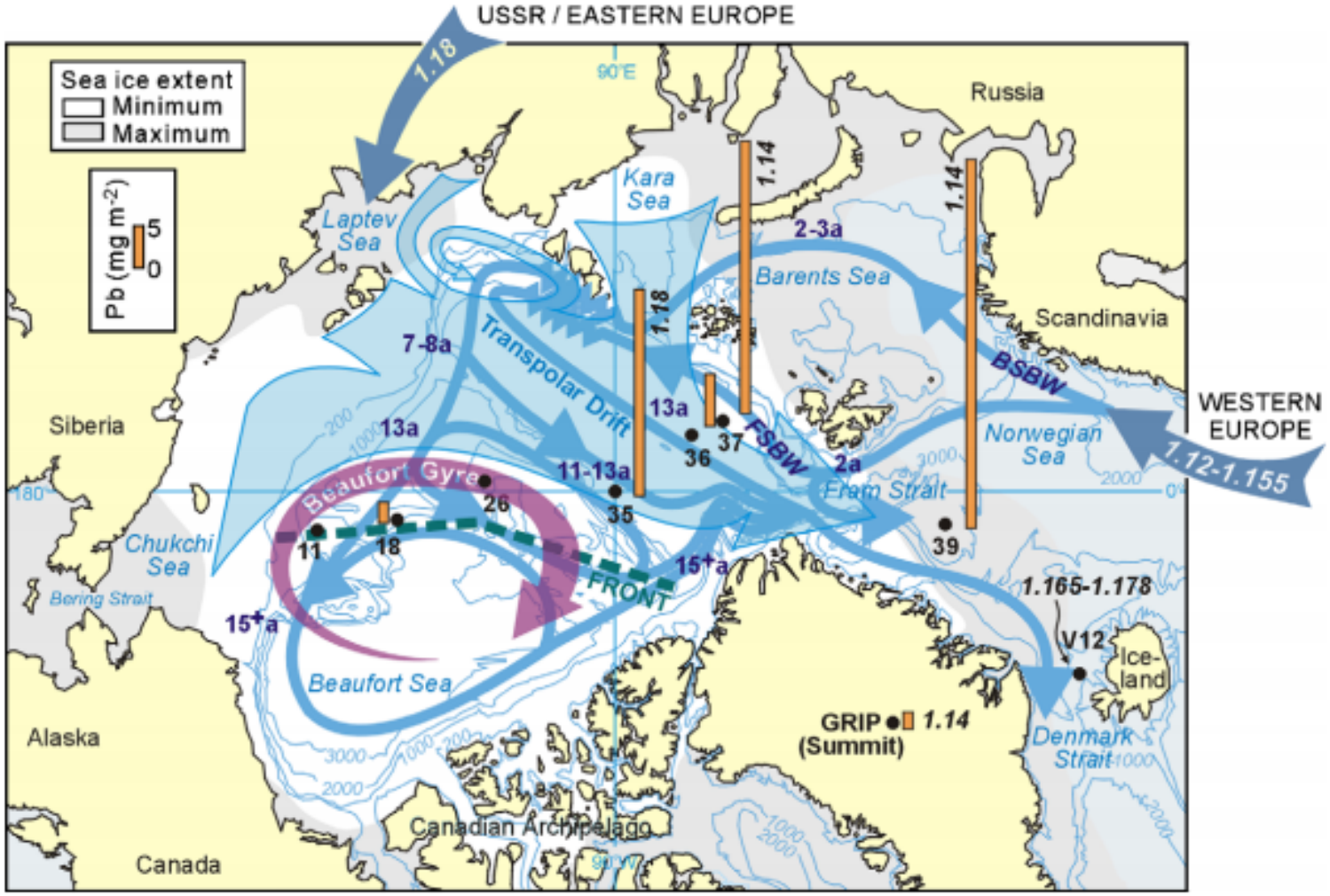


Fig. 24. The transport of lead into the Arctic Ocean following boundary currents shown by the contaminant lead inventory in sediment cores. Source of the lead (western Europe or Eurasia) is shown by the stable lead isotope composition (figure adapted from Gobeil et al., 2001a).

Mercury Species

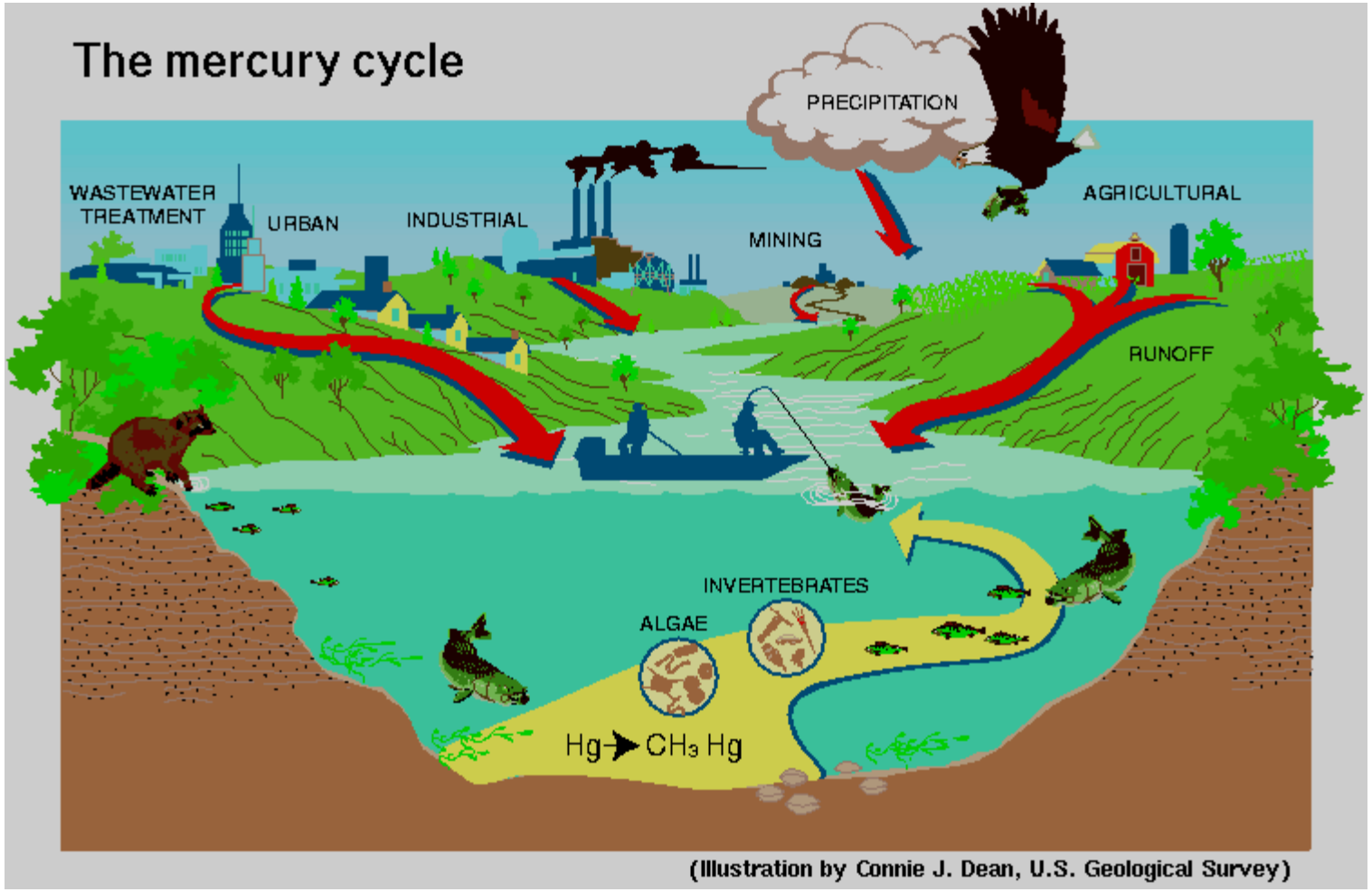
- **Elemental mercury (Hg^0) is not very toxic, but has some neurotoxicity.**
- **Inorganic Hg (Hg^{2+}) is Mercury Species toxic: iHg.**
- **Microorganisms convert Hg^{2+} into organomercury species that are highly toxic: e.g. methylmercury (CH_3Hg^+-), dimethylmercury ($(CH_3)_2Hg$-).**

Mercury Toxicity

- **Hg^{2+} binds strongly to sulphydryl (-SH) groups of proteins causing a loss of biological activity. Since iHg accumulates in the kidney, it is particularly nephrotoxic.**

- **Organomercury species such as methylmercury (MeHg), CH_3Hg^+, and dimethylmercury (MeHg), $(CH_3)_2Hg$ are highly lipophilic and bind proteins in lipid-rich tissues such as neurons. MeHg is neurotoxic.**

How does MeHg get into fish?



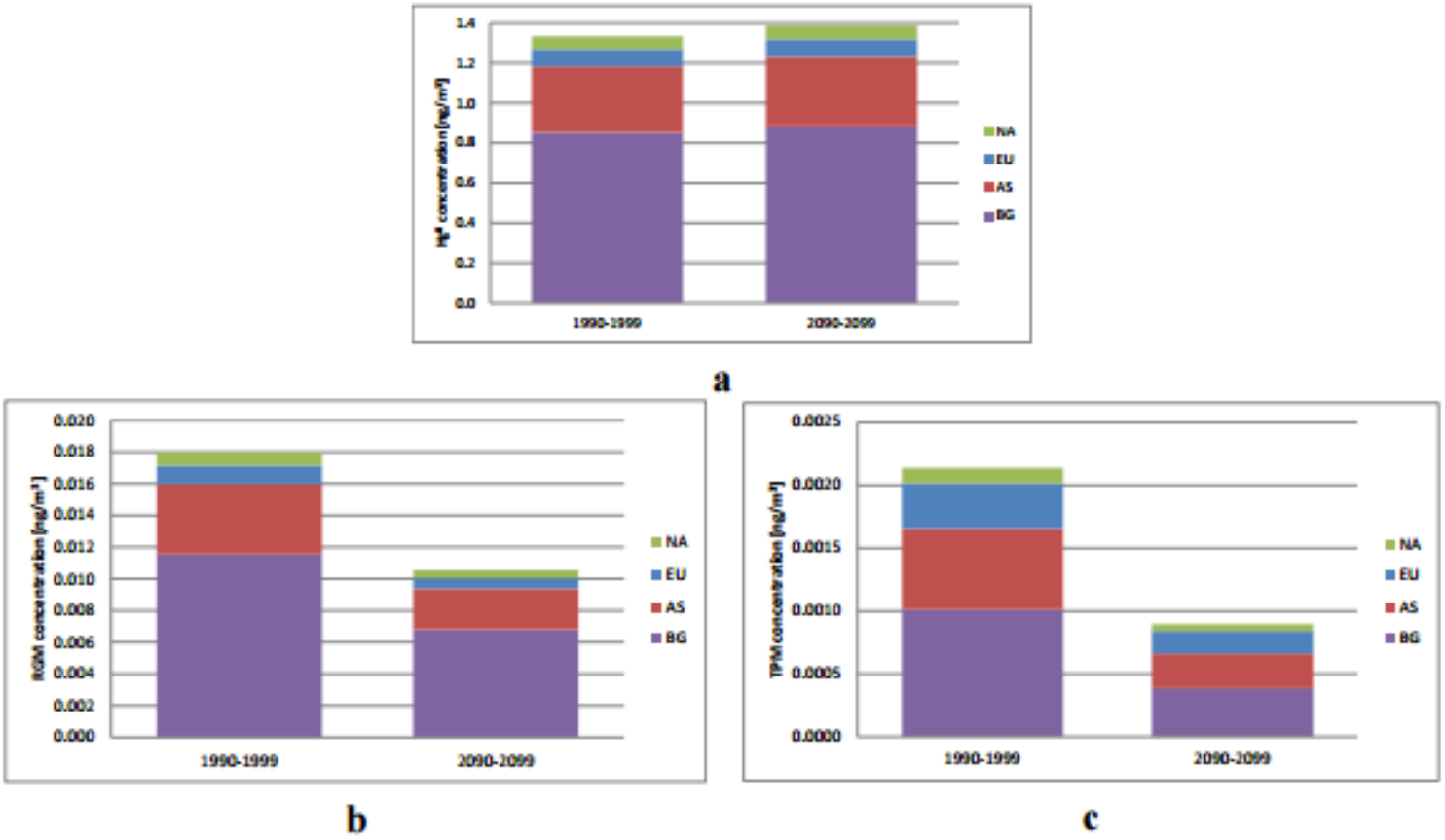


Figure 2. The average Artic air concentrations of Hg^0 (**a**), Reactive Gaseous Mercury (RGM = HgO + $HgCl_2$) (**b**) and Total Particular Mercury (TPM = primary + oxidized particulate Hg) (**c**) for the 1990s and 2090s divided into the contribution from North America (NA), Europe (EU), Asia (AS), and background concentration (BG).

Table 2
Potential input of selected organochlorines from glacial melt

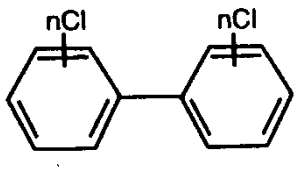
Compound	Concentration (pg/L)	Total glacial input (kg)	Glacial input for 1993 (kg/year)	Flux through the Archipelago[a] (kg/year)
α–HCH[b]	256	205	39	195,000
γ-HCH[b]	115	92	18	27,900
ΣDDT[b]	480	384	74	161
CHLOR[b]	35	28	5	96
HCB[b]	65	52	10	810
PCB[c]	3.5	2.8	0.5	2700

[a] Flux through Archipelago was estimated assuming a mean flow of 54,000 km^3/year (Macdonald et al., 2000a) and using concentration data collected in the Archipelago during 1993 (HCH, HCB, CHLOR, Hargrave et al., 1997) or for the Canada Basin in 1997–1998 (PCB, DDT, Macdonald et al., 2001).

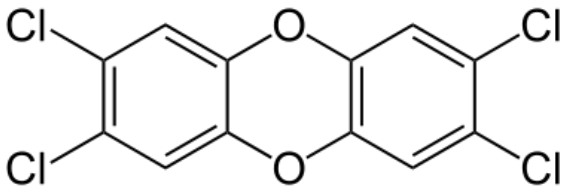
[b] Concentration data from Franz et al. (1997). Samples collected for 1987, 1990 and 1992 in snow layers after first year loss.

[c] Concentration data from Gregor et al. (1995); average concentration over 30-year period from 1964/1965 to 1992/1993 (n=34).

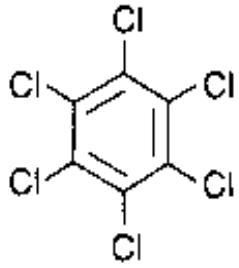
Structures of Some POPs



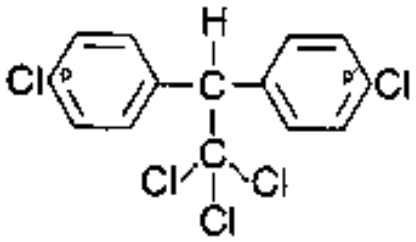
PCBs



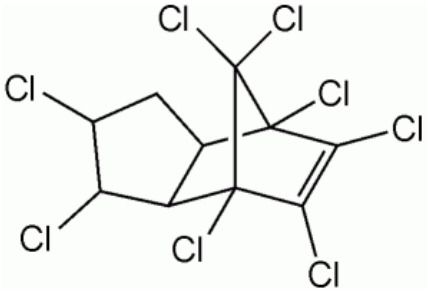
TCDD



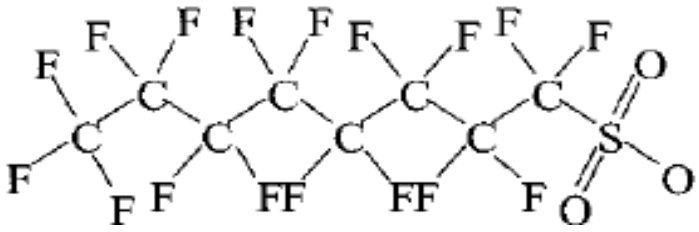
Hexachlorobenzene



p,p' – DDT



Chlordane



PFOS

Polychlorinated Biphenols (PCBs)

- PCBs were widely used in the US between 1929-1977 as hydraulic fluids, electrical insulators in capacitors and transformers, in paint, caulking and many other uses.
- PCBs are lipophilic and persistent, with the half-life in the human body being about 10 years. They persist even longer in the environment and bioaccumulate in the food supply.
- PCBs are semi-volatile compounds. The polar regions of the world are highly contaminated due to atmospheric transport to the cold regions, where they come out of the vapor phase and bioaccumulate in animal fat.

Air Transport of PCBs

- The polar regions of the earth have high concentrations of PCBs even though there are few local sources. This is because of air currents that transport to cold regions, where the PCBs come out of the vapor phase and get into fish and animals.
- Recent studies show PCBs in the air near contaminated sites, and resultant exposure to local residents.
- PCBs in indoor environments are even more serious routes of exposure by breathing the air.

Table 1. Physical characteristics of PCBs by homologue groups at 25º

PCB Homologue group	Vapor pressure (Pa)	Water solubility (g/m^3)	Log Octanol/ Water Coefficient	Evaporation Rate ($g/m^3/hr$)
Monochloro	1.1	4.0	4.7	0.25
Dichloro	0.24	1.6	5.1	0.065
Tetrachloro	0.012	0.26	5.9	4.2×10^{-3}
Hexachloro	5.8×10^{-4}	0.038	6.7	2.5×10^{-4}
Octachloro	2.8×10^{-5}	5.5×10^{-4}	7.5	1.5×10^{-5}
Decachloro	1.4×10^{-6}	7.6×10^{-4}	8.3	8.5×10^{-7}

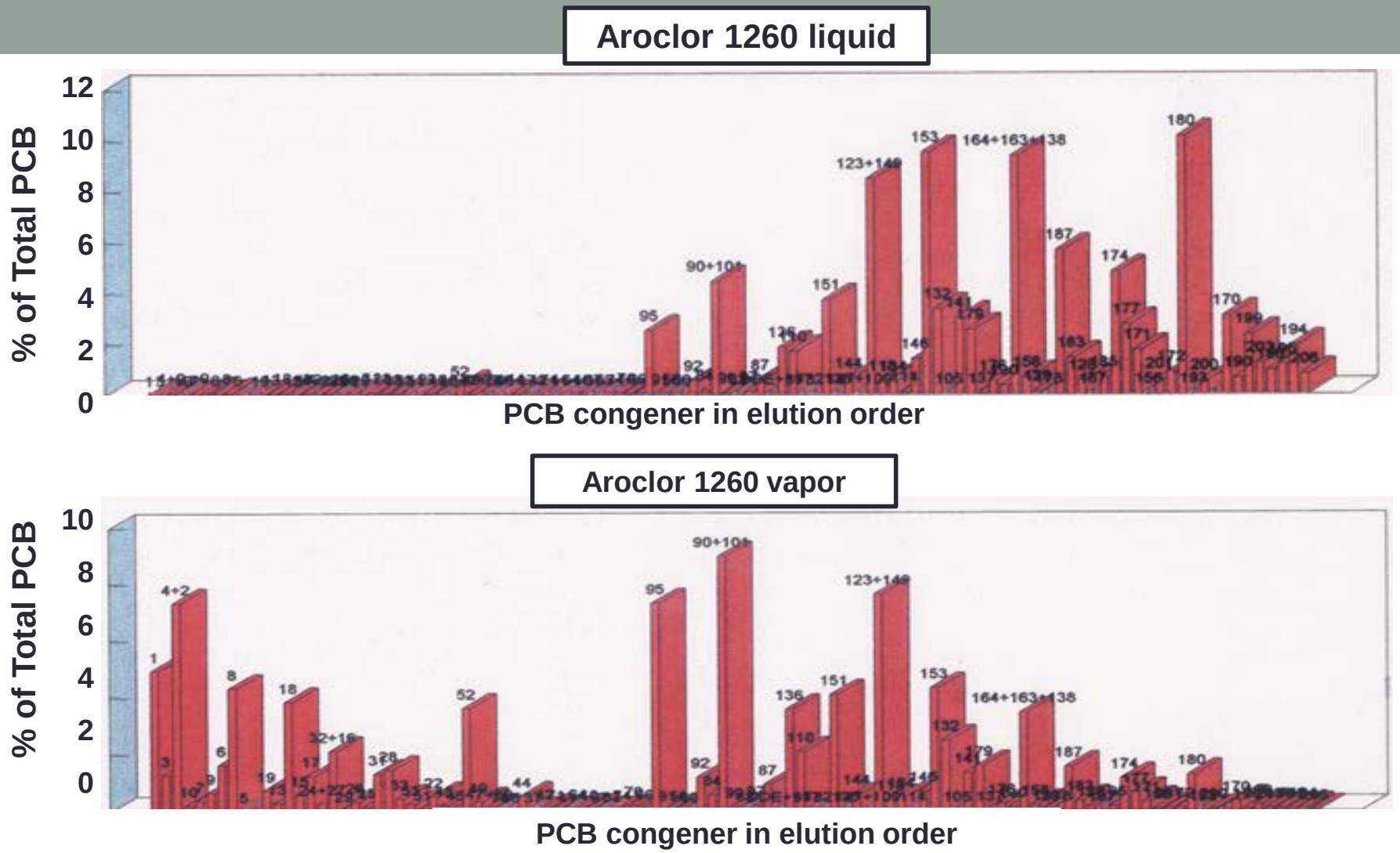


Figure 2. The congener patterns in Aroclor 1260 liquid (top) and the congener pattern seen when passing air over the liquid and collecting and analyzing the vapor-phase PCBs

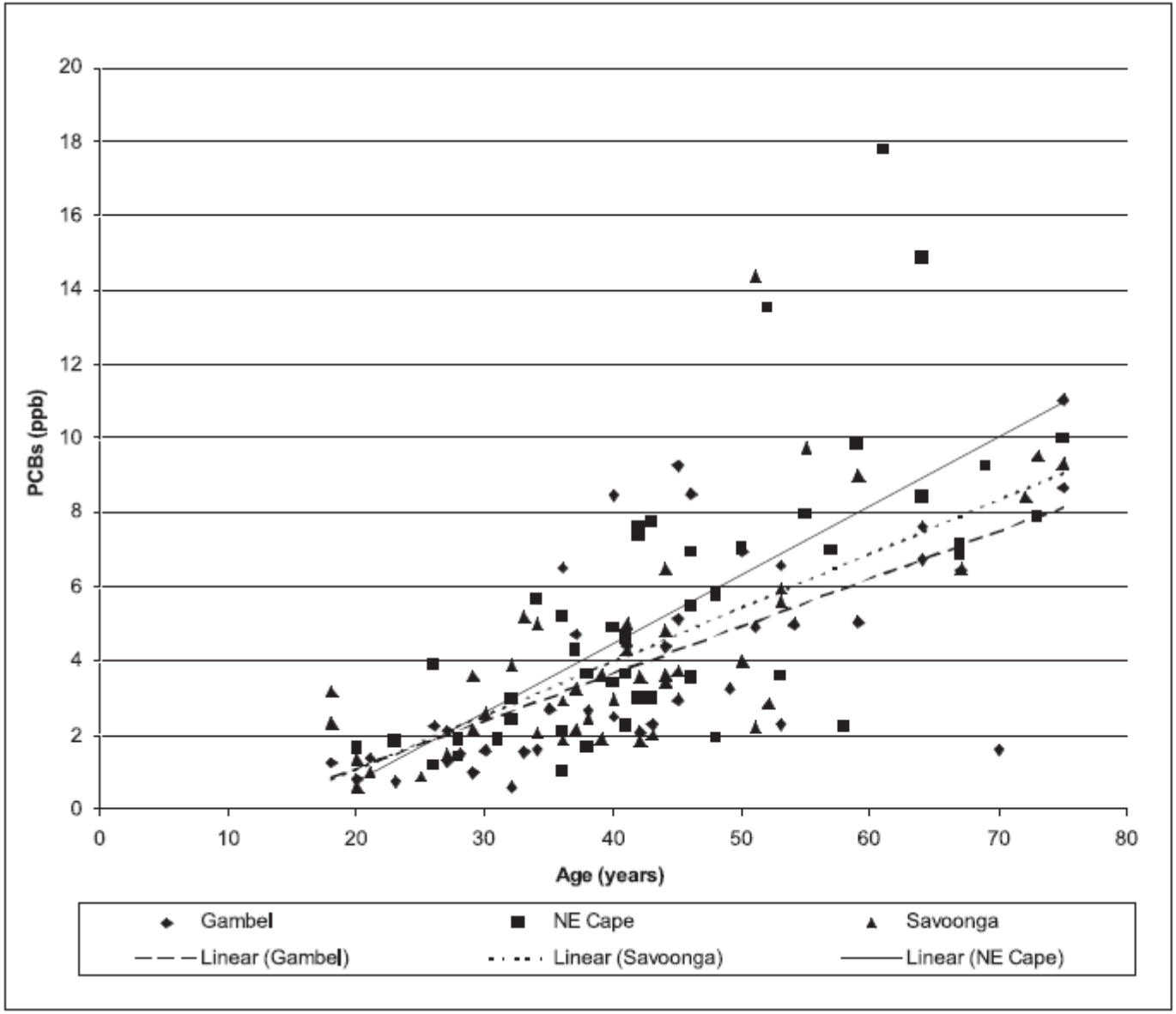


Figure 2. Serum PCB (wet weight) as a function of age for residents of Gambell, Savoonga and those with family camps at the NEC. The data from each individual in the study is plotted, as well as the linear regression best fit for each of the three populations. For Gambell the R^2 = 0.4696, for NEC R^2 = 0.4713 and for Savoonga R^2 = 0.5134.

Pesticides in Yupiks and NHANES

Byrne et al., J Toxicol Environ Health A 78: 976: 2015

TABLE 4. Comparison of Current Study Sample to Nationally Representative Sample of National Health and Nutrition Examination Study (NHANES) Data from 2001–2002, Stratified by Sex (μg/kg lw)

		Current median	Current 95th percentile	NHANES median	NHANES 95th percentile
Men	Lindane	nd	8.7	nd	nd
	Oxychlordane	75.3	279.1	11.1	48.1
	trans-Nonachlor	54.3	124.7	18.3	77.2
	HCB	94.3	160.5	nd	nd
	o,p′-DDT	nd	4.0	nd	nd
	p,p′-DDE/PCB85	358.5	706.4	245	1900
	Mirex	28.7	75.8	nd	50.8
Women	Lindane	nd	34.2	nd	nd
	Oxychlordane	72.6	215.9	11.0	52.5
	trans-Nonachlor	40.2	104.3	17.5	76.8
	HCB	54.2	202.3	nd	nd
	o,p′-DDT	nd	6.5	nd	nd
	p,p′-DDE/PCB85	264.9	1159.5	256	2630
	Mirex	11.6	33.3	nd	63.0

Note. nd, Nondetectable.

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PCBs in Ringed Seal Tissues

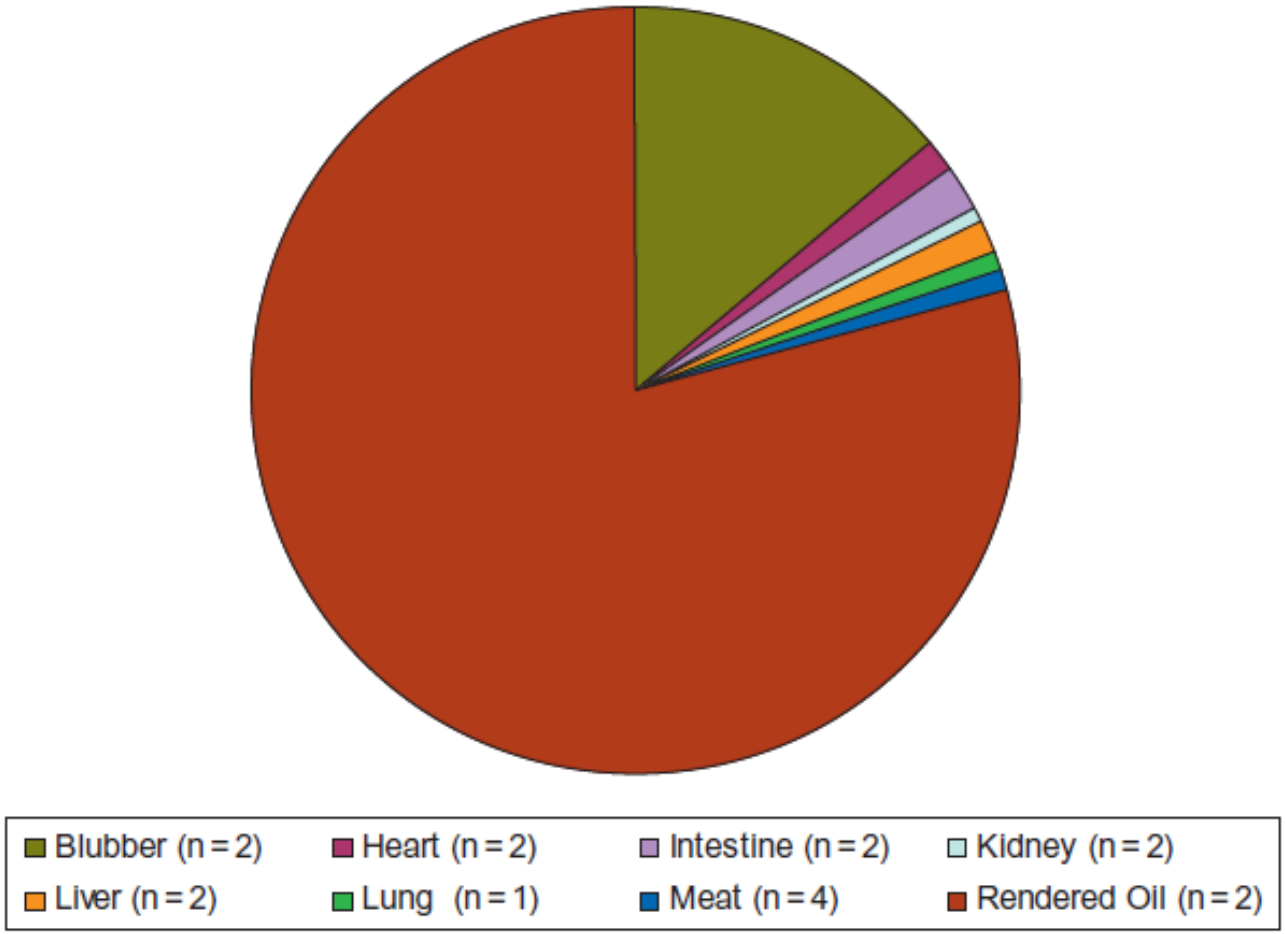

FIGURE 1. Distribution of percentage of total PCB in different types of ringed seal samples (color figure available online).

Impacts of Climate Change

- Climate change is only going to increase exposures in the Arctic.
- Elevated temperatures will increase the evaporation volatile and semi-volatile chemicals from everywhere.
- There are many contaminants locked in permafrost, and these will be released as the permafrost thaws.
- All of these factors will increase exposure of Arctic populations.
- These are populations that are already excessively exposed.
- Climate change will have many others adverse effects on quality of life in the Arctic.

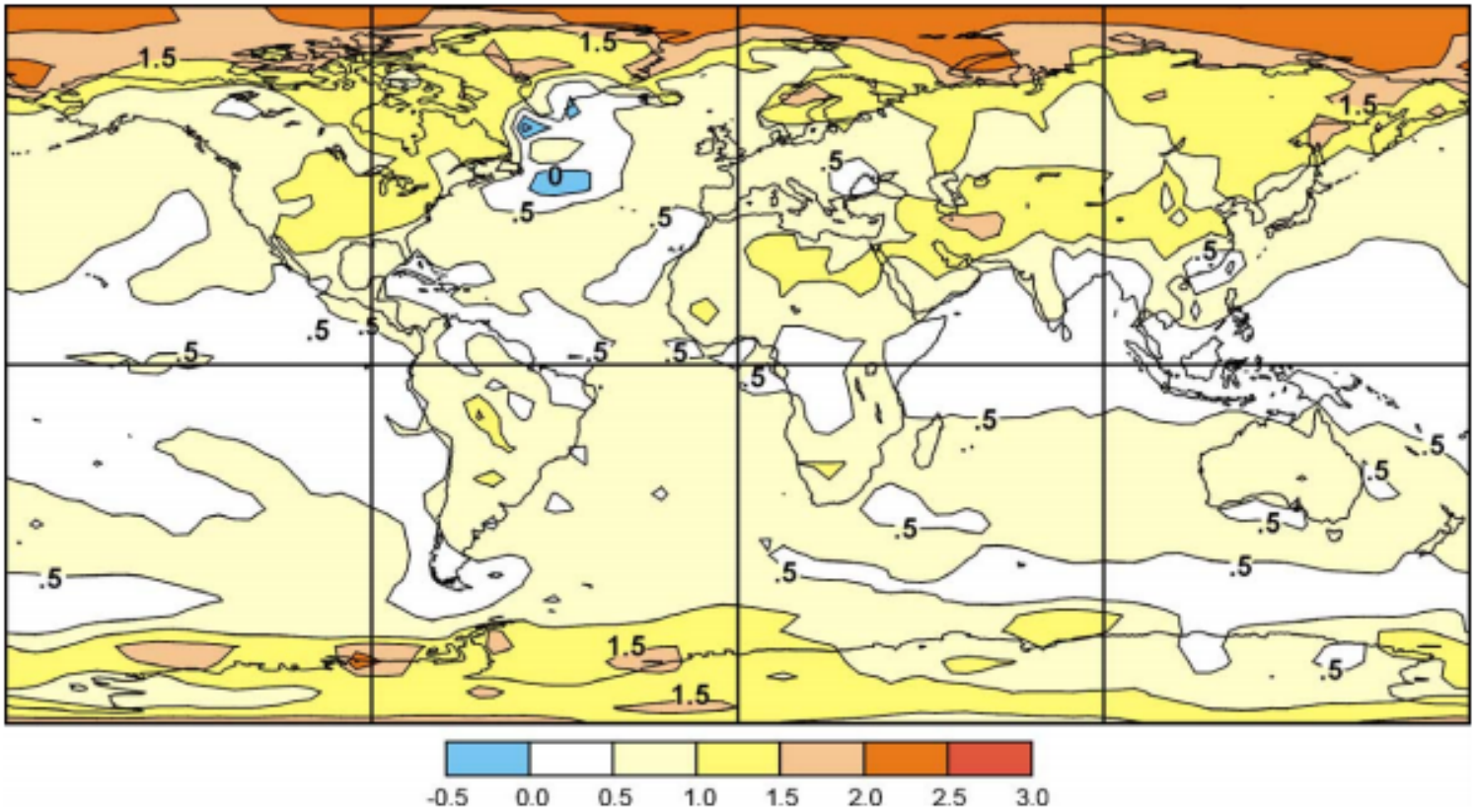

Fig. 4. Change in surface air temperature for 2020–2030 relative to 1990–2000 as projected by the Canadian Centre for Climate Modeling and Analysis CGCM2. Global warming is expected to have an uneven geographic distribution with the Arctic experiencing the highest projected warming (courtesy of CCCma and see Zwiers, 2002).

Conclusions

- Many dangerous environmental contaminants migrate toward polar regions, where they adversely affect the health of both humans and wildlife.
- Because most traditional cultures in the Arctic must rely upon traditional food stuffs, these people are especially vulnerable to development of diseases that are associated with environmental exposures.
- Climate change is only going to make this already bad situation worse.
- We must take steps to reduce exposures and protect people from the diseases that result from them.