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Heavy metal concentrations in terrestrial compartments and runoff across European IM sites

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Heavy metal music meets complexity and sustainability science

David G. Angeler*

Abstract

This paper builds a bridge between heavy metal music, complexity theory and sustainability science to show the potential of the (auditory) arts to inform different aspects of complex systems of people and nature. The links are described along different dimensions. This first dimension focuses on the scientific aspect of heavy metal. It uses complex adaptive systems theory to show that the rapid diversification and evolution of heavy metal into multiple subgenres leads to a self-organizing and resilient socio-musicological system. The second dimension builds on the recent use of heavy metal as a critical thinking model and educational tool, emphasizing the artistic component of heavy metal and its potential to increase people's awareness of environmental sustainability challenges. The relationships between metal, complexity theory and sustainability are first discussed independently to specifically show mechanistic links and the reciprocal potential to inform one domain (science) by the other (metal) within these dimensions. The paper concludes by highlighting that these dimensions entrain each other within a broader social-cultural-environmental system that cannot be explained simply by the sum of independent, individual dimensions. Such a unified view embraces the inherent complexity with which systems of people and nature interact. These lines of exploration suggest that the arts and the sciences form a logical partnership. Such a partnership might help in endeavors to envision, understand and cope with the broad ramifications of sustainability challenges in times of rapid social, cultural, and environmental change.

Keywords: Auditory arts, Complexity science, Complex adaptive systems, Heavy metal music, Social-ecological systems, Sustainability, Transdisciplinary science, Environmental education, Global change

Angeler, D.G., 2016. Heavy metal music meets complexity and sustainability science. SpringerPlus 5, 20.

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Heavy metal concentrations in terrestrial compartments and runoff across European IM sites

Outline

- Background
- European and global heavy metal emissions
- Heavy metal fluxes in catchments
- Inventory of ICP IM heavy metal data
  - Cadmium
  - Lead
  - Mercury
  - Copper
  - Zink
- Conclusions
- *POPs (if possible…)*

Heavy metal concentrations in terrestrial compartments and runoff across European IM sites

Objective

- Evaluate spatial variation in HM levels in forest compartments (bulk deposition (BD), throughfall (TF), littefall (LF), runoff water (RW), soil chemistry (SC)) and across member states

Background
Heavy metals in the CLRTAP

- Lead (Pb), cadmium (Cd) and mercury (Hg) are atmospheric long-range pollutants that are readily transported across national borders and identified as being particularly harmful in the ***1998 Aarhus Protocol on Heavy Metal***; one international agreements on pollution control under the ***UN ECE Convention on Long-range Transboundary Air Pollution (CLRTAP)***

- Hg also of special interest for the Minamata Convention on Mercury

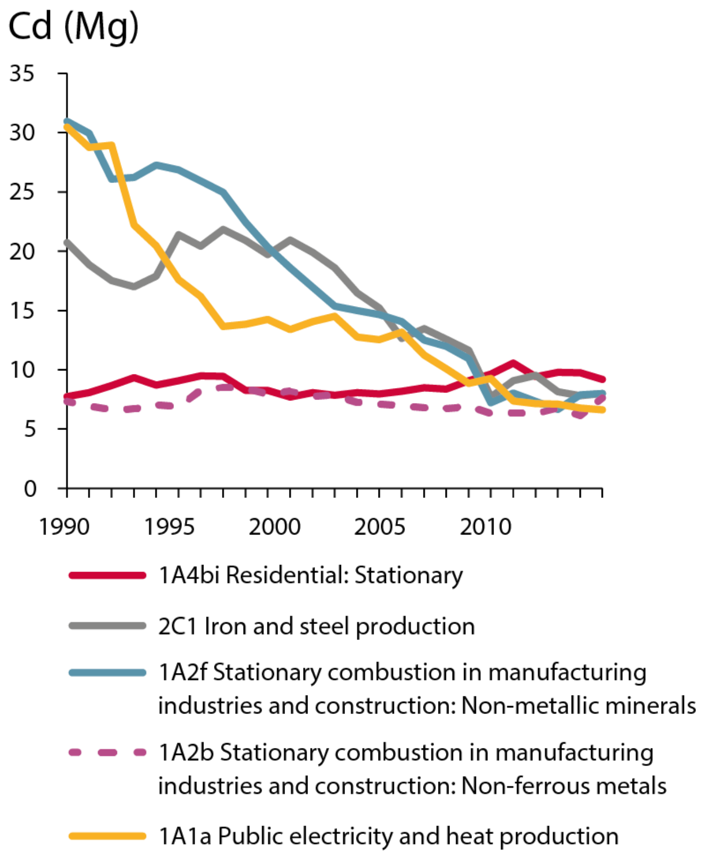
- Copper (Cu) and zinc (Zn) are not identified as being particularly harmful in CLRTAP but have the potential for disturbing ecological functions at high levels

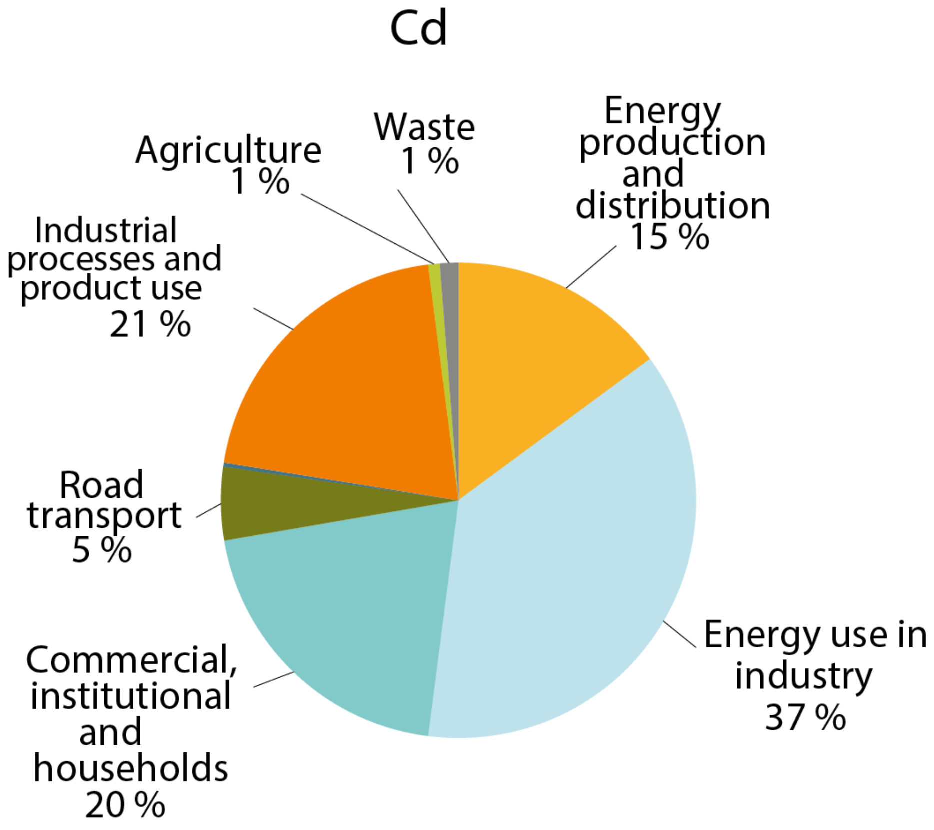
Background
Critical indicators of heavy metal pollution in forest and aquatic environments

- Terrestrial
  - Ecosystem functioning: Pb, Cd, and Hg have effects on soil micro-organisms, plants and invertebrates
- Aquatic
  - Human health effects: Hg in freshwater fish
  - Ecosystem functioning: effects on algae, crustacea, worms, fish and top predators

Cd emissions in the EU

From the *European Union emission inventory report 1990–2014 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) (2016)*





Pb emissions in the EU

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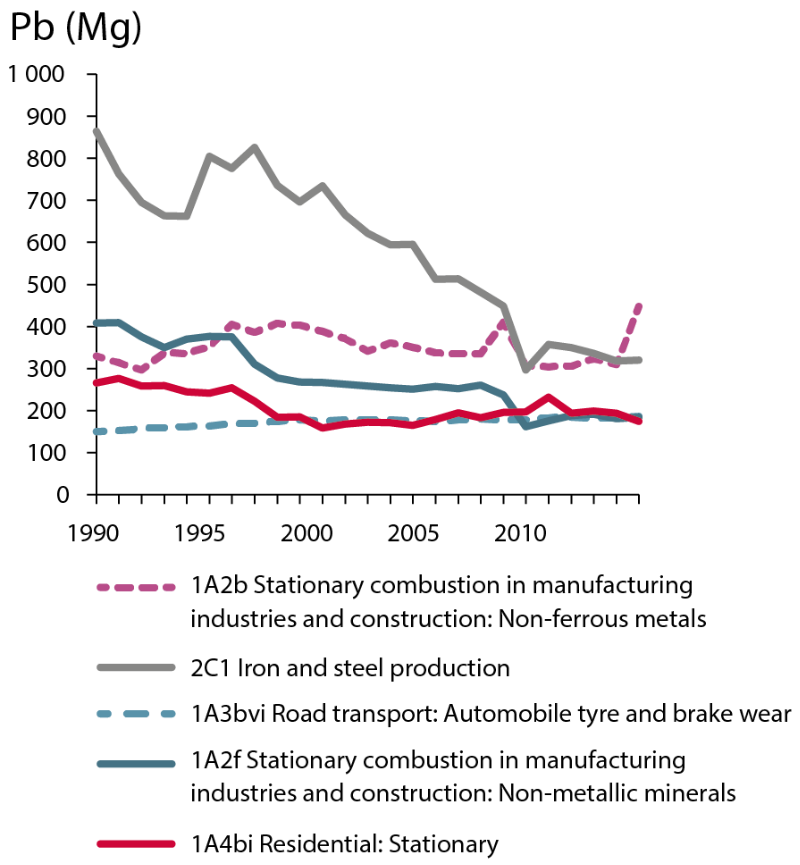
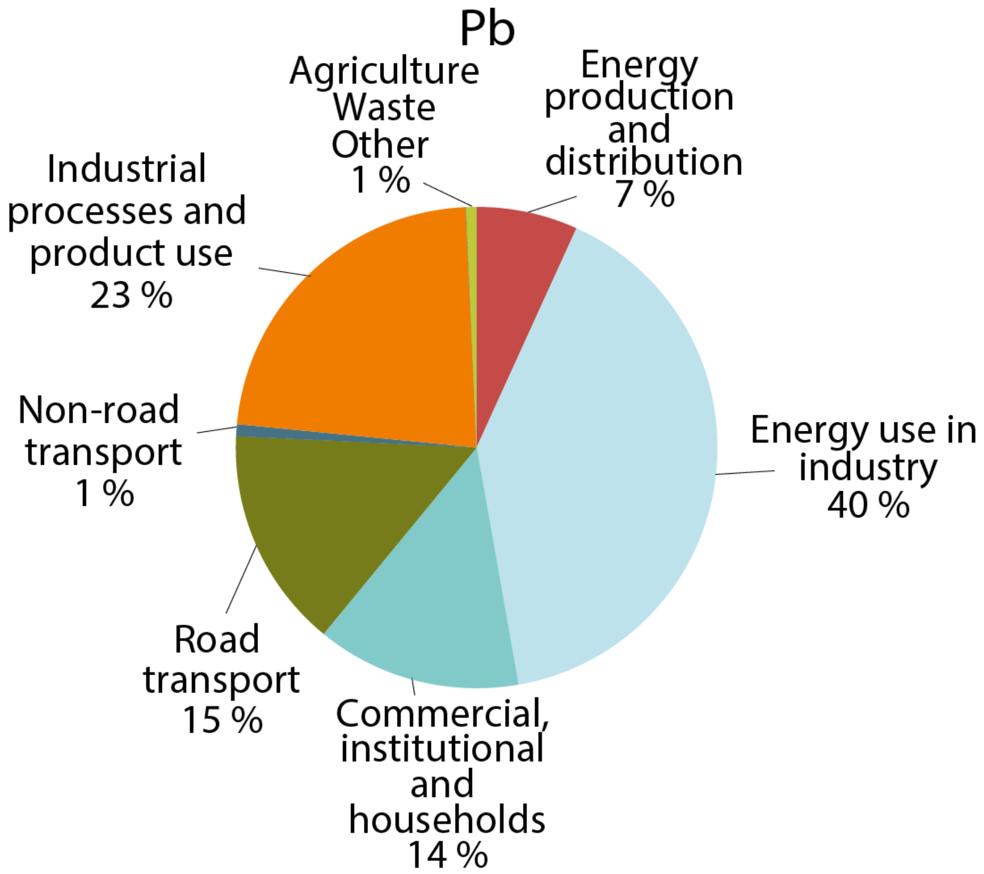
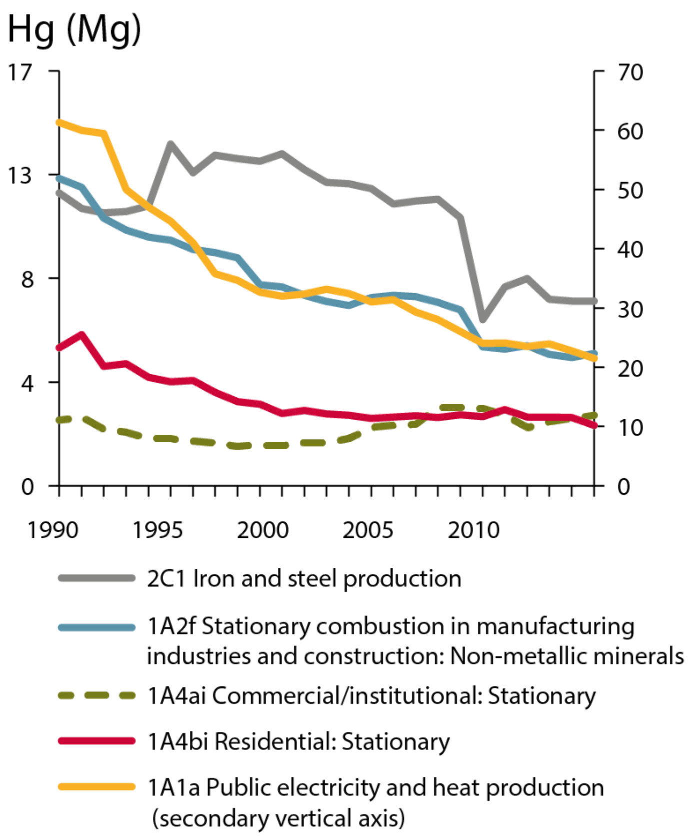
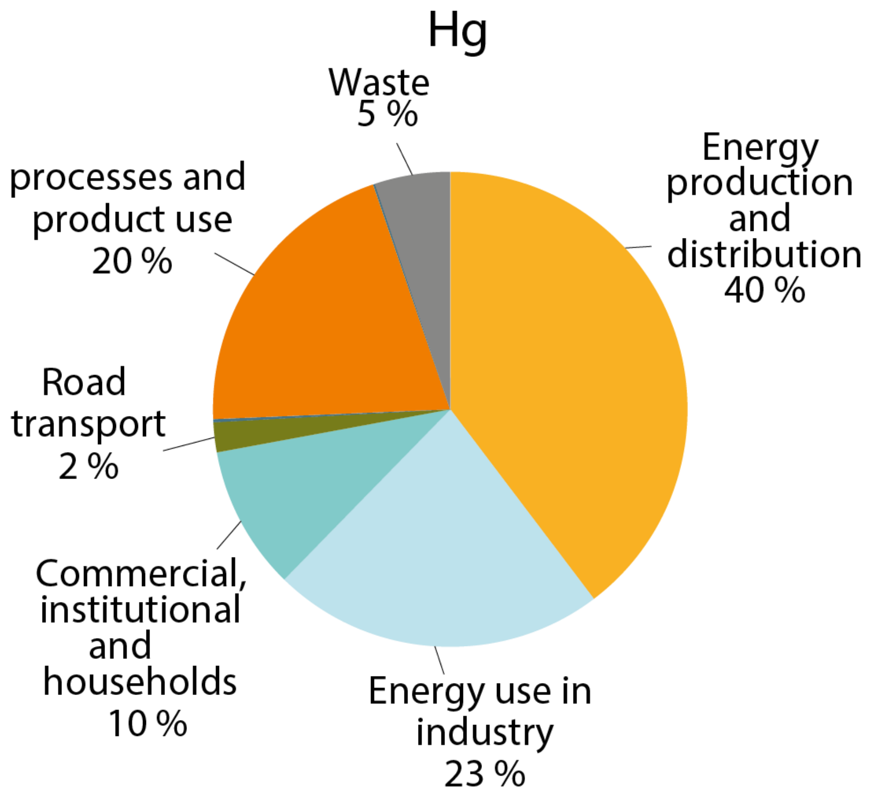




Hg emissions in the EU

From the *European Union emission inventory report 1990–2014 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) (2016)*





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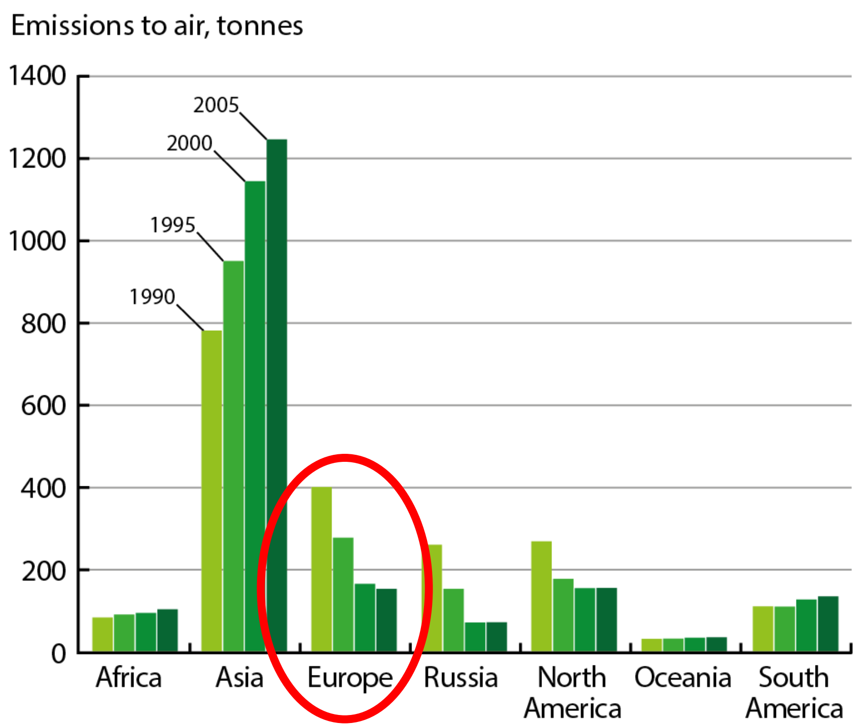
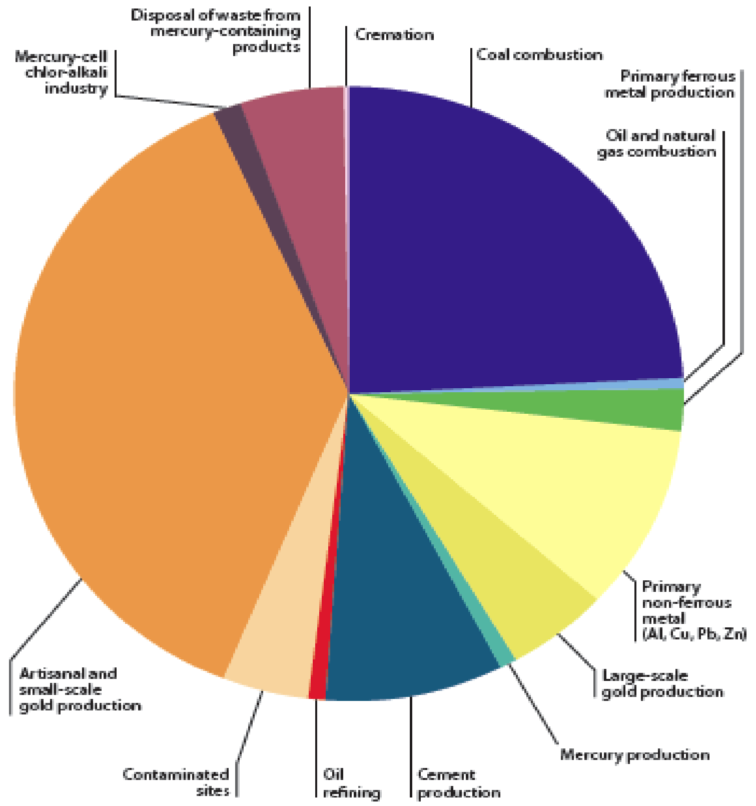
Global Hg emissions

From *UNEP, 2013. Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport.*

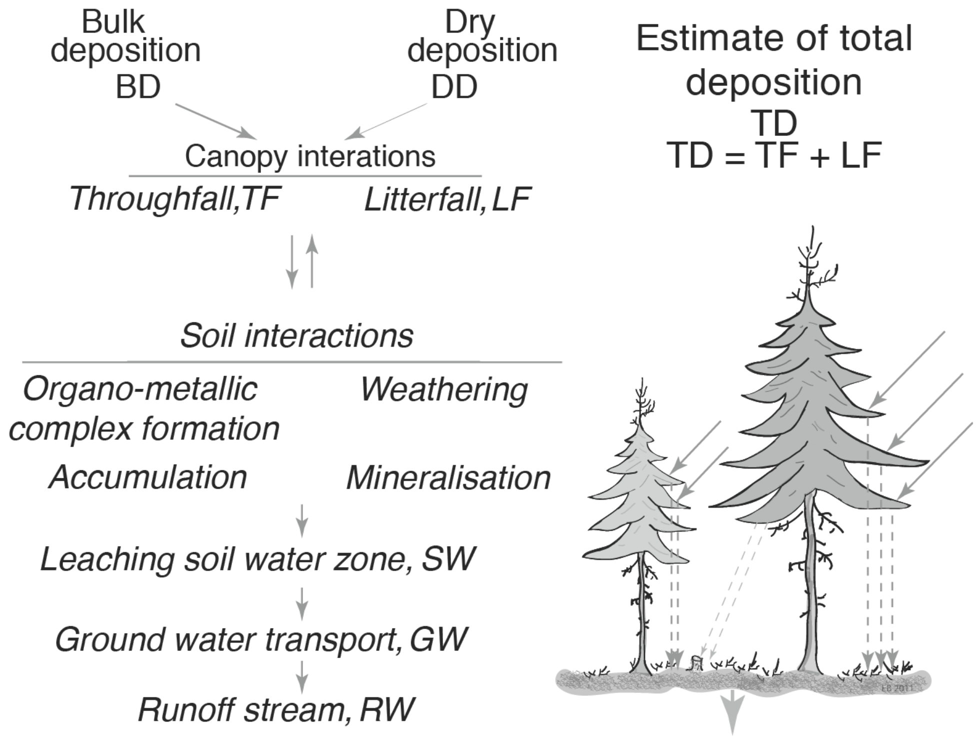


Estimates of annual anthropogenic mercury emissions from different continents/regions, 1990-2005.



Relative contributions to estimated emissions to air from anthropogenic sources in 2010.

Processes involving metals in forest catchment mass balance

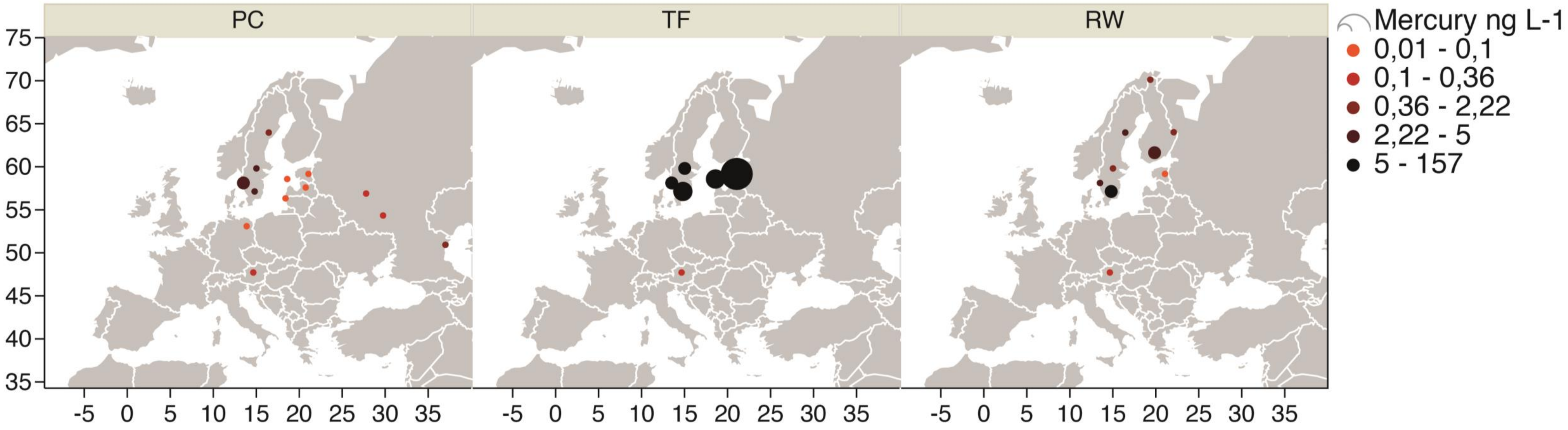


Retention = 1 - RW / Input
Input = TF (+ LF for Hg and Pb)

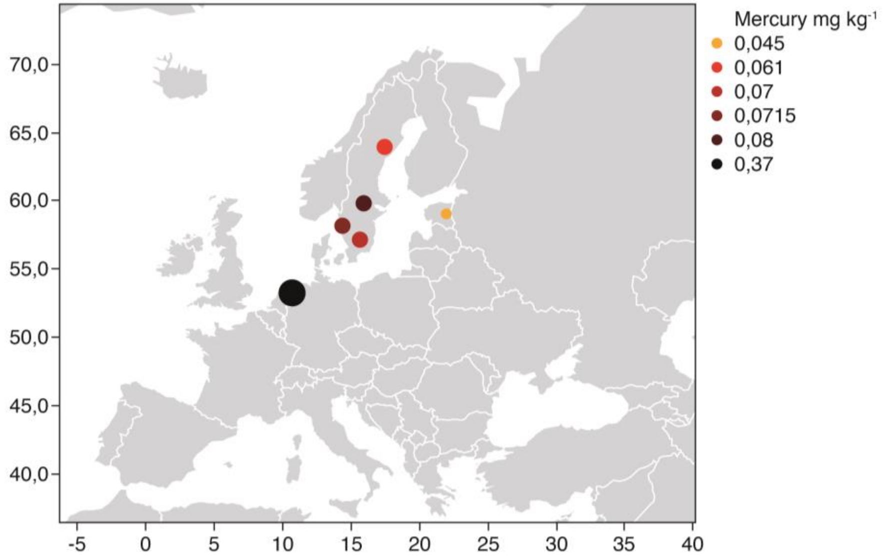
Retention of heavy metals in catchments:
Cd: (0) – 91%
Pb: 74 – 94 %
Hg: 86 – 99 %
Cu: 80 – 97 %
Zn: 38 – 96 %

From *Bringmark, L. et al. 2013. Trace metal budgets for forested catchments in Europe-Pb, Cd, Hg, Cu and Zn. Water Air Soil Pollut. 224, 1501-1515.*

Mercury

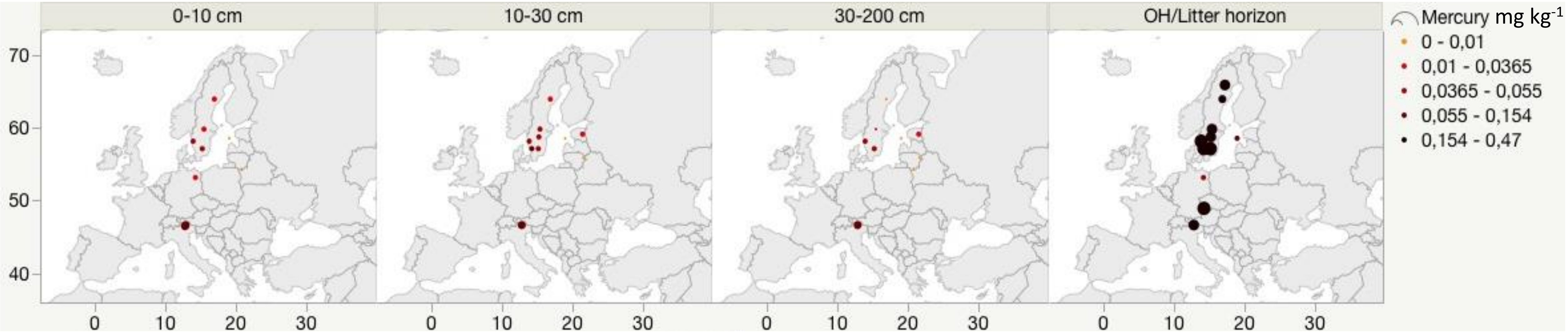


Litterfall



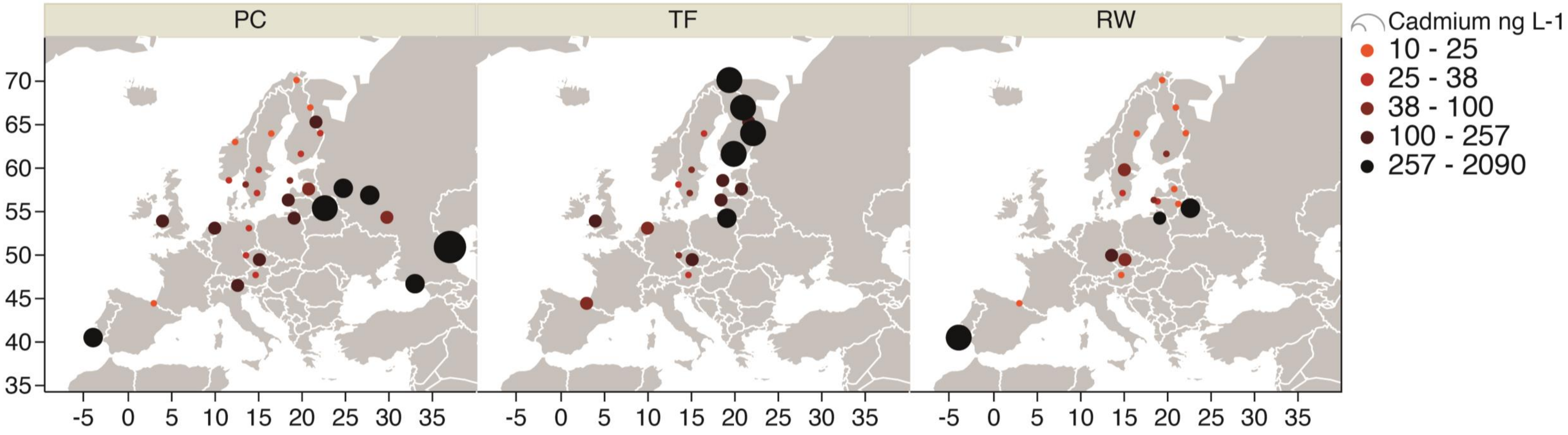
Hg Enrichment	mean	SD	n sites
RW/TF	0.40	0.40	4
TF/PC	160	349	5

Mercury
Soil chemistry

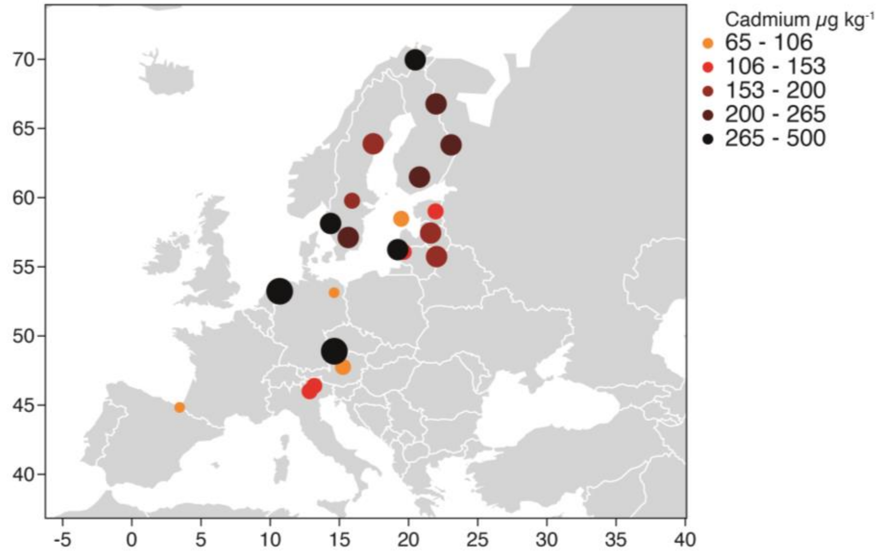


Mercury	Depth (cm)	Mean	median	min	max	n sites
BD ng L^{-1}		1.23	0.25	0.01	4.6	13
TF ng L^{-1}		85.3	33.5	18.8	250	6
LF mg kg^{-1}		0.12	0.07	0.05	0.37	6
RW ng L^{-1}		2.90	2.21	0.1	7.4	9
SC mg kg^{-1}	0 – 10	0.05	0.04	0.005	0.15	8
	10 – 30	0.05	0.04	0.005	0.15	11
	30 – 200	0.03	0.01	0.005	0.12	10
	OH/litter	0.23	0.23	0.06	0.47	12

Cadmium

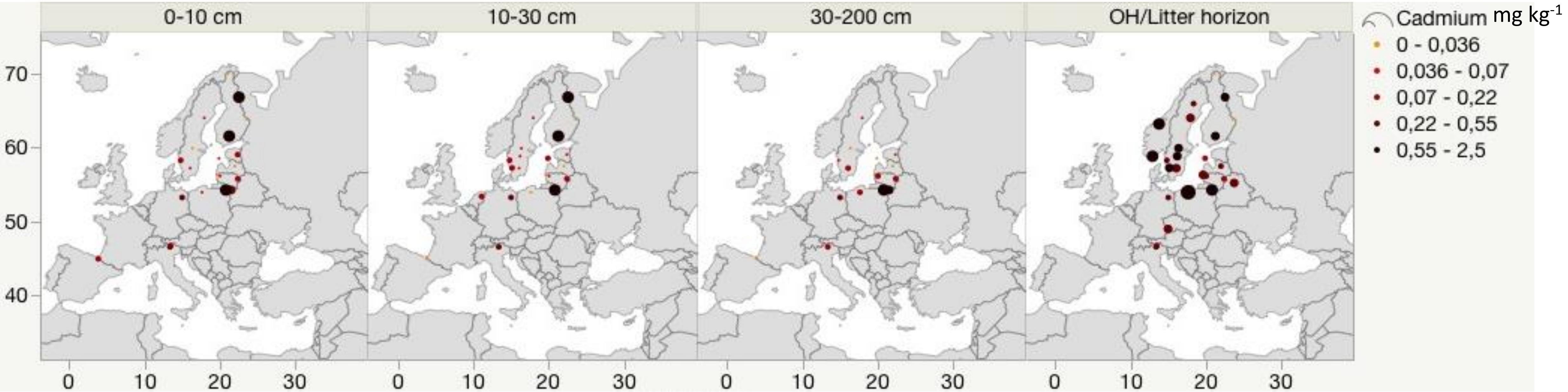


Litterfall



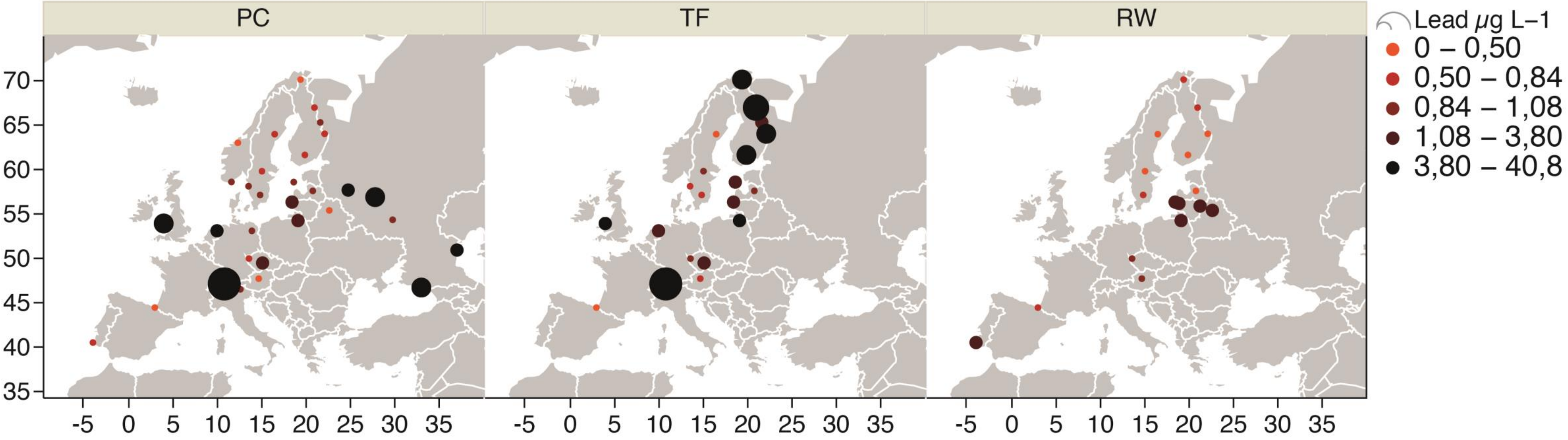
Cd Enrichment	mean	SD	n sites
RW/TF	0.64	1.13	14
TF/PC	9.9	17.4	19

Cadmium
Soil chemistry

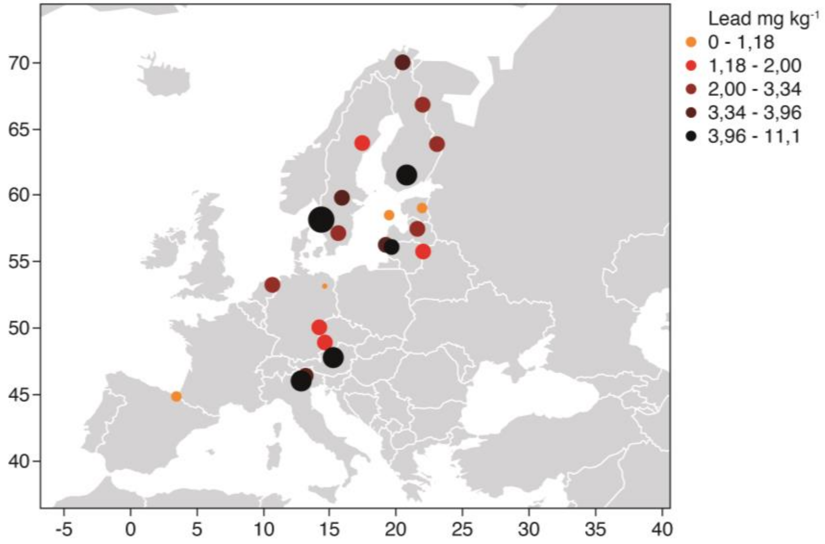


Cadmium	Depth (cm)	Mean	median	min	max	n sites
BD ng L^{-1}		0.24	0.06	0.01	2.09	30
TF ng L^{-1}		0.32	0.15	0.03	1.10	19
LF mg kg^{-1}		0.21	0.20	0.07	0.5	21
RW ng L^{-1}		0.12	0.03	0.01	0.85	19
SC mg kg^{-1}	0 – 10	0.30	0.082	0.01	1.54	19
	10 – 30	0.25	0.07	0.01	1.55	21
	30 – 200	0.19	0,07	0.015	1.44	17
	OH/litter	0.63	0.44	0.11	2.5	23

Lead

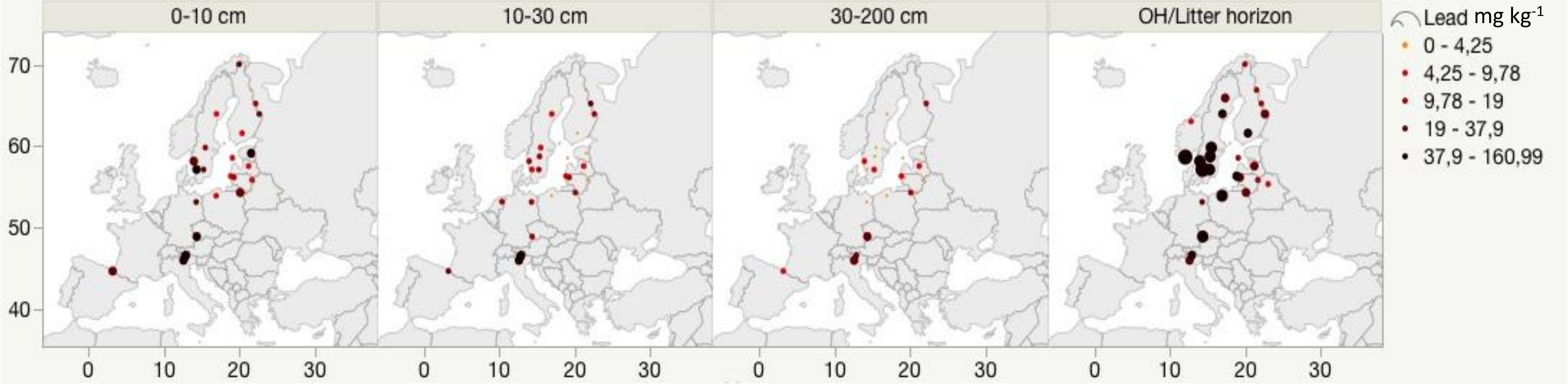


Litterfall



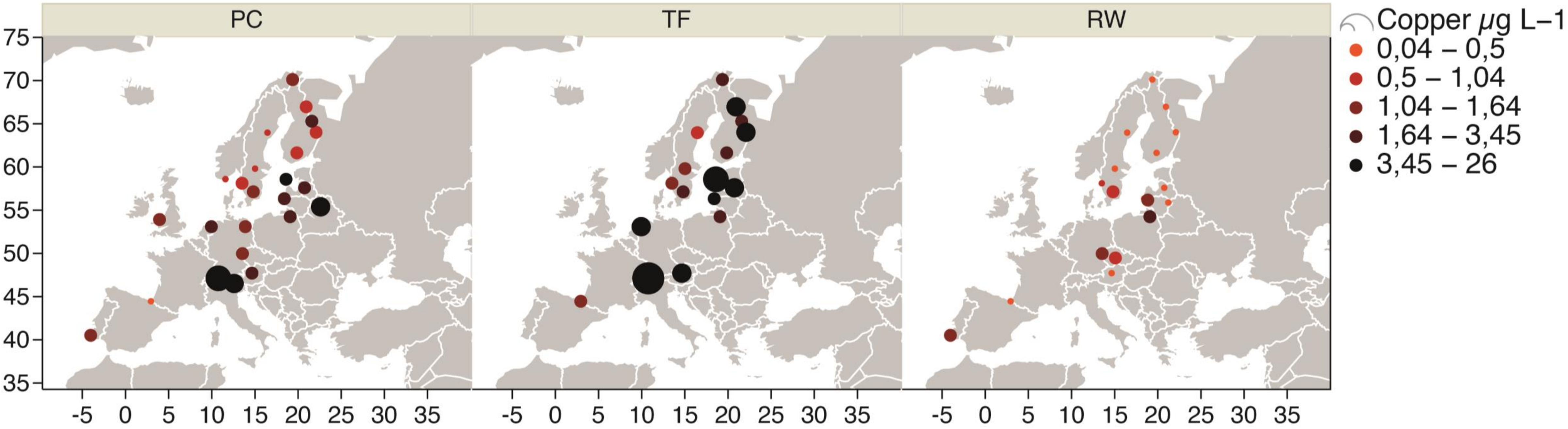
Pb Enrichment	mean	SD	n sites
RW/TF	0.57	0.67	13
TF/PC	5.7	9.9	20

Lead
Soil chemistry

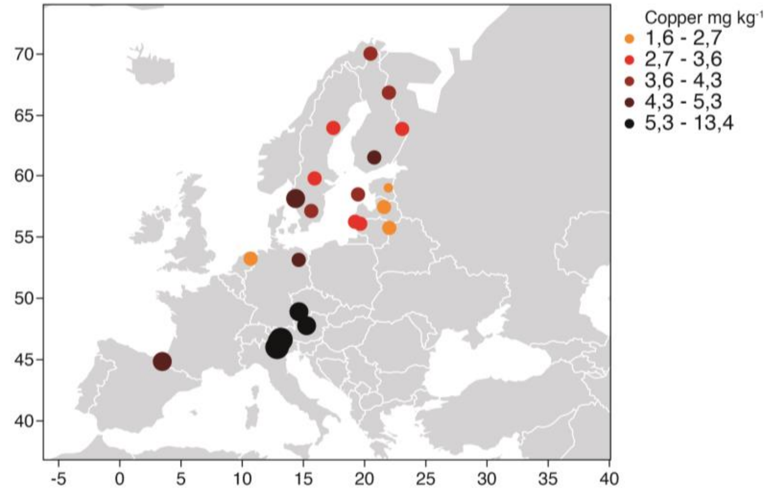


Lead	Depth (cm)	Mean	median	min	max	n sites
BD ng L^{-1}		3.42	1	0.01	40	31
TF ng L^{-1}		6.12	1.86	0.25	40.8	20
LF mg kg^{-1}		3.38	3.31	0.83	11.1	21
RW ng L^{-1}		0.68	0.49	0.04	3	18
SC mg kg^{-1}	0 – 10	21.0	17.6	0.5	59	26
	10 – 30	13.7	11.2	1.0	46	25
	30 – 200	9.3	4.8	1.0	34	23
	OH/litter	45.7	33.6	5.6	161	28

Copper

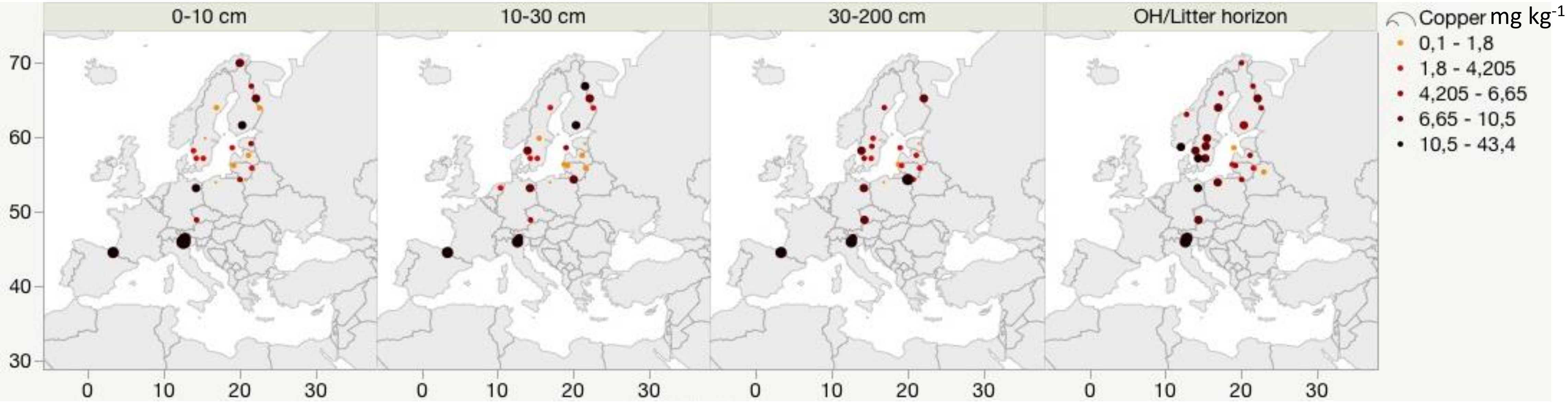


Litterfall



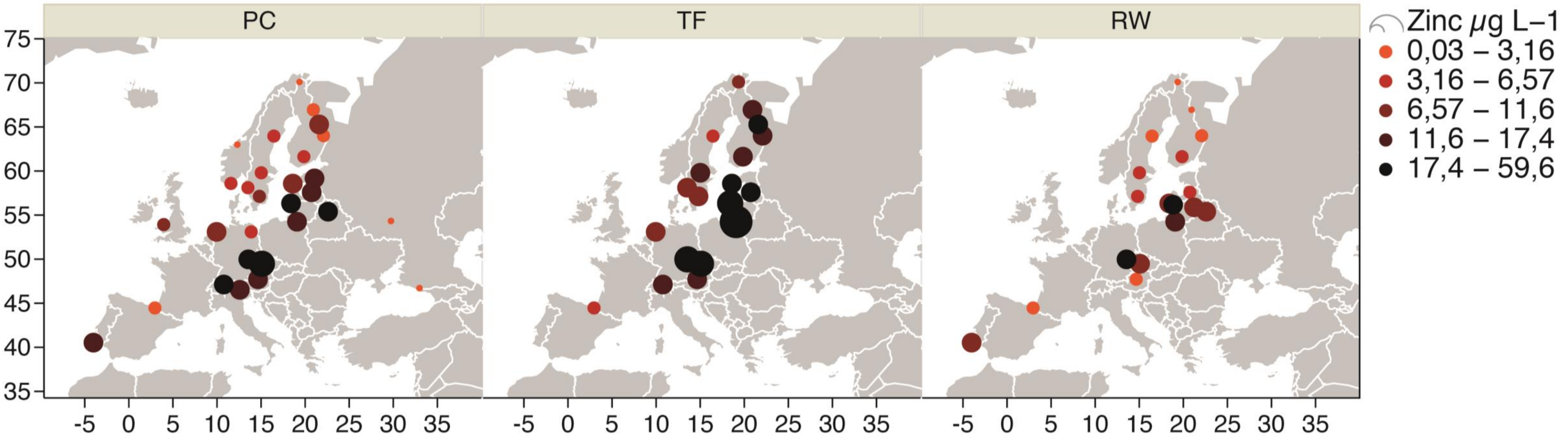
Cu Enrichment	mean	SD	n sites
RW/TF	0.24	0.15	13
TF/PC	2.7	1.7	17

Copper
Soil chemistry

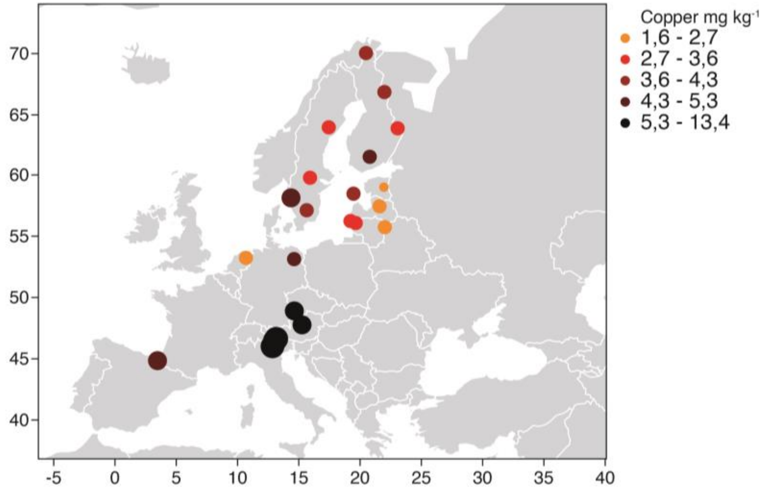


Copper	Depth (cm)	Mean	median	min	max	n sites
BD ng L^{-1}		2.10	1.34	0.40	11.7	24
TF ng L^{-1}		5.14	3.45	0.95	26.0	17
LF mg kg^{-1}		5.02	4.27	1.6	13.4	23
RW ng L^{-1}		1.13	0.66	0.1	3.5	19
SC mg kg^{-1}	0 – 10	7.1	4.5	0.4	43.4	26
	10 – 30	6.9	4.5	0.1	19.4	25
	30 – 200	6.6	4.4	0.2	33.7	23
	OH/litter	8.2	7.0	1.5	23	28

Zinc

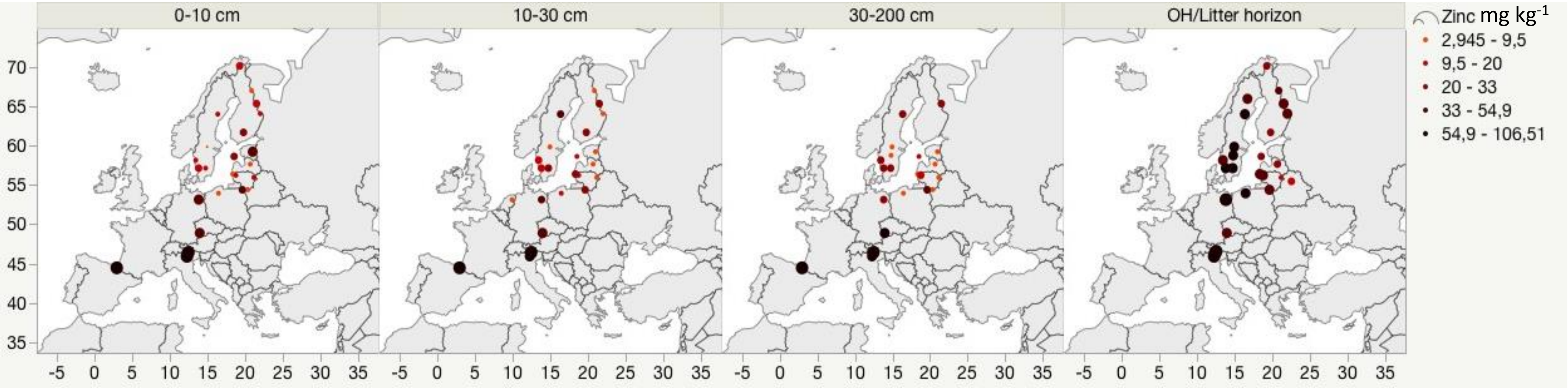


Litterfall



Zn Enrichment	mean	SD	n sites
RW/TF	0.29	0.21	14
TF/PC	2.67	1.92	19

Zinc
Soil chemistry



Zinc	Depth (cm)	Mean	median	min	max	n sites
BD ng L^{-1}		9.52	7.25	0.03	29.5	29
TF ng L^{-1}		19.2	16.3	5.6	60	19
LF mg kg^{-1}		56.0	53.2	21.6	132	24
RW ng L^{-1}		7.2	5.4	0.62	21	19
SC mg kg^{-1}	0 – 10	27.8	15.8	2.9	102	26
	10 – 30	26.8	20.5	4.0	93	25
	30 – 200	30.0	25	3.0	106	23
	OH/litter	48.9	46	13.2	101	26

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Heavy metal concentrations in terrestrial compartments and runoff across European IM sites

Conclusions

- HM data from ICP IM sites important for evaluating responses from emissions and atmospheric transport of HM
- Uncertainty in data comparison between sites and regions
- Better resolution in spatial coverage of HM data; complement of data from compartments
- Others HM: Ni, Cr, Mo, V… (Sweden)
- More to come in ICP IM progress report autumn 2017…

Heavy metal concentrations in terrestrial compartments and runoff across European IM sites

What about POPs?

What about POPs?

Variation and accumulation patterns of poly- and perfluoroalkyl substances (PFAS) in European perch *(Perca fluviatilis*) across a gradient of pristine Swedish lakes

Åkerblom S. et al. Accepted for publication in *Science of the Total Environment*

(Not ICP IM or ICP Waters, but related….)

- 7 PFASs detected: 6:2 FTSA, PFOS, PFDA, PFUnDA, PFDoDA, PFTriDA, and PFTeDA

Increaing length of carbon chain →

- ΣPFAS : mean ± SD: 0.99 ± 0.63 ng g^{-1} ww (min / max : 0.31 / 3.4 ng g^{-1} ww)
- Comparable background **Σ**PFAS levels from high mountain lakes in France
  ranging from 20.7 to 36.1 ng g^{-1} ww (Ahrens et al. 2010)
- PFOS in Sweden: 0.01 / 0.93 ng g^{-1} ww'
- PFOS in Resolute Bay (Nunavut, Canada): <0.001 – 2.0 ng g^{-1} ww (Lescord et al. 2015)