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➤ Spatial variations of organic contaminants in French soils

A case study of PAH

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Nicolas P.A. Saby, Claudy Jolivet, Antonio Bispo



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Spatial variations of organic contaminants in French soils
22nd World Congress of Soil Science / Glasgow 2022 / Froger

➤ Context

- Polycyclic Aromatic Hydrocarbons (PAH)
 - More than 2000 molecules from 2 to 8 rings
 - 16 identified as persistent organic pollutants
 - Origin : incomplete combustion of organic material
 - *Natural : volcanic eruption, wild fires...*
 - *Anthropogenic : coal and wood combustion, fossil fuel combustion and crude oil*
- Well documented in atmosphere and water
 - ➔ Scarce knowledge of soil contamination

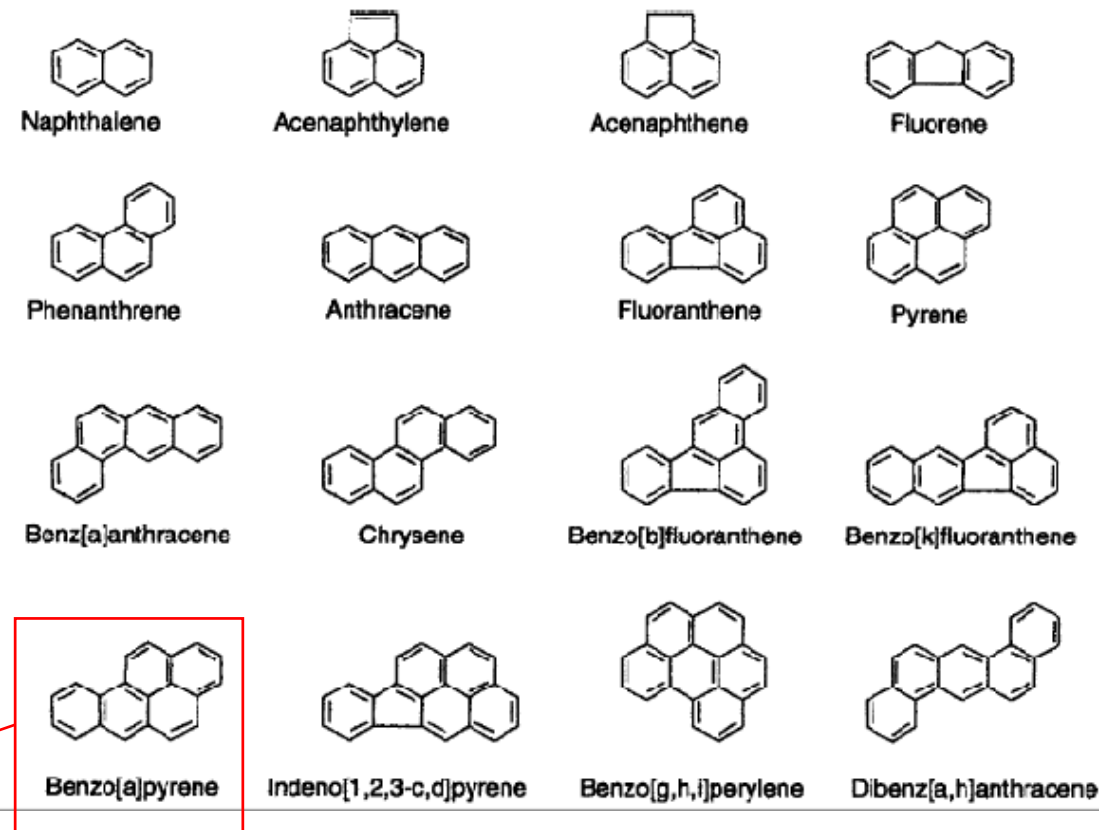
Main source

Carcinogenic



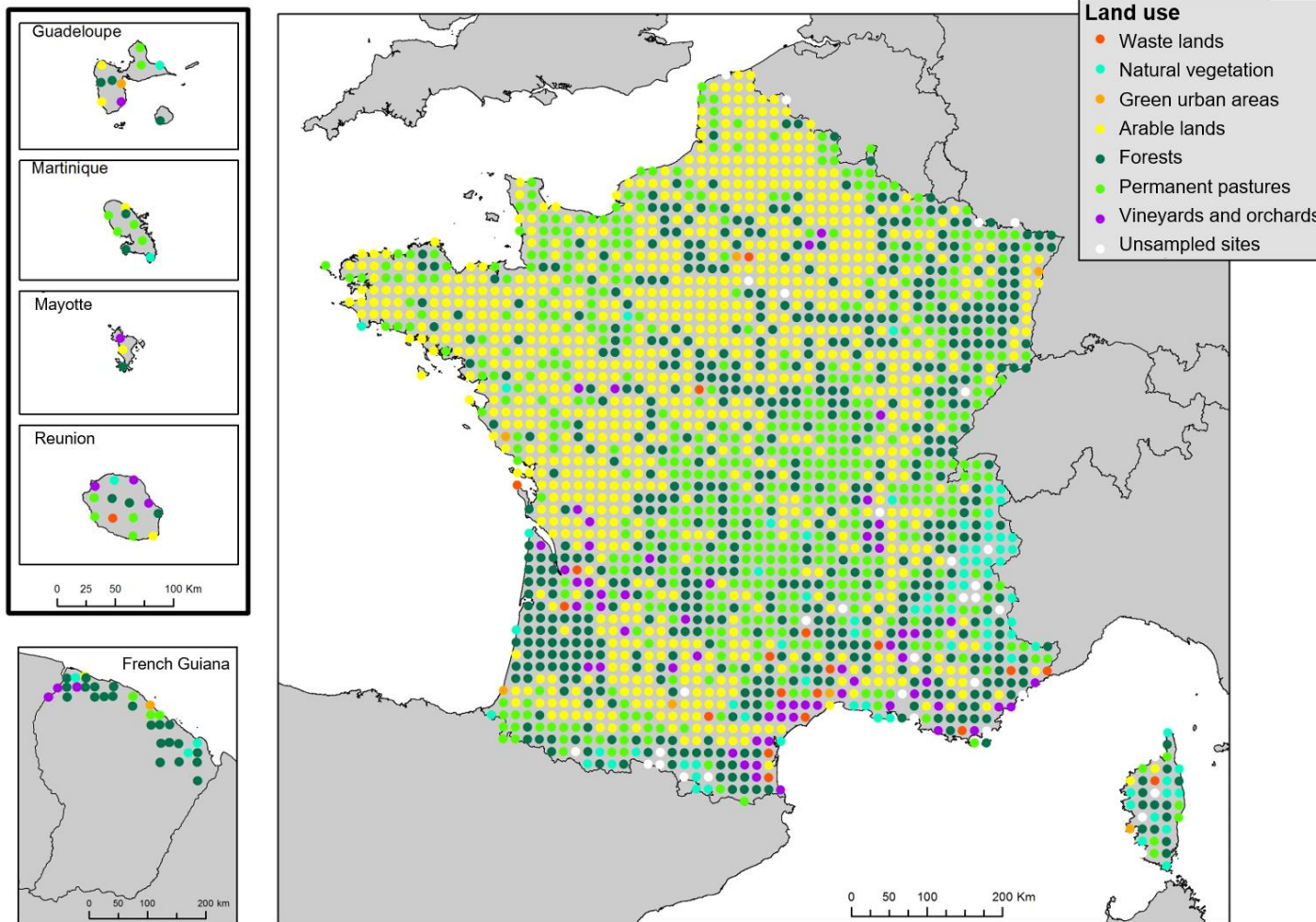
Persistent Organic Pollutants (*forever chemicals*) :

- Persistents
- Bioaccumulative
- Toxic
- Mobiles in the environment (long range transport)



➤ Objectives

Levels of soil contamination by PAH in France, spatial distribution and sources



• National Soil Quality Monitoring Network

- Based on a systematic grid (16 km x 16 km)
- Around 2200 sampling sites
- First campaign: 2000 – 2008
- Analysis of 15PAH from 2008 to 2012 on surface soil samples

➤ Levels of PAH contamination

	N > LOQ (%)	Q50	Max	Mean
Σ15PAHs (μg/kg)	70	32.6	31193	161.0
2–3-ring PAHs (%)		10.3	100	18.5
4-ring PAHs (%)		36.3	100	28.9
5–6-ring PAHs (%)		22.8	100	22.7

- Mostly 4 to 6 rings (heavy PAH)
- Same order of magnitude found in soil in Europe

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Spatial variations, origins, and risk assessments of polycyclic aromatic hydrocarbons in French soils

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Soil classification	PAH ranges (μg·kg ⁻¹)	Proportion of French soils (in %)
Non-contaminated	< 200	83
Weakly contaminated	200–600	12
Contaminated	600–1000	2.1
Heavily contaminated	> 1000	2.9

Based on Maliszewka-Kordybach (1996)



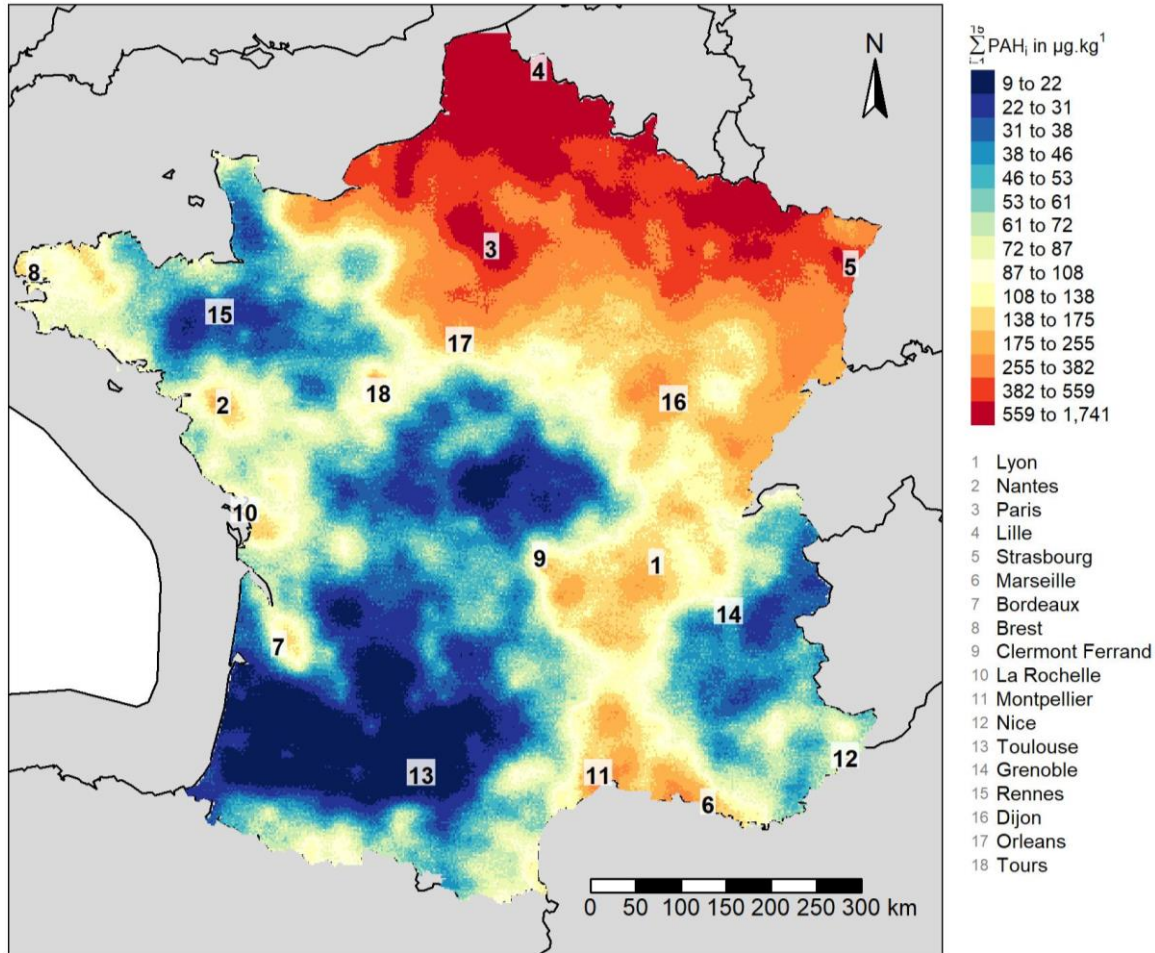
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Maliszewka-Kordybach, B.: Polycyclic aromatic hydrocarbons in agricultural soils in Poland: preliminary proposals for criteria to evaluate the level of soil contamination, Appl. Geochemistry, 11(1–2), 121–127, doi:10.1016/0883-2927(95)00076-3, 1996.

➤ Spatial distribution of PAH in French soils

Sum of 15 PAH



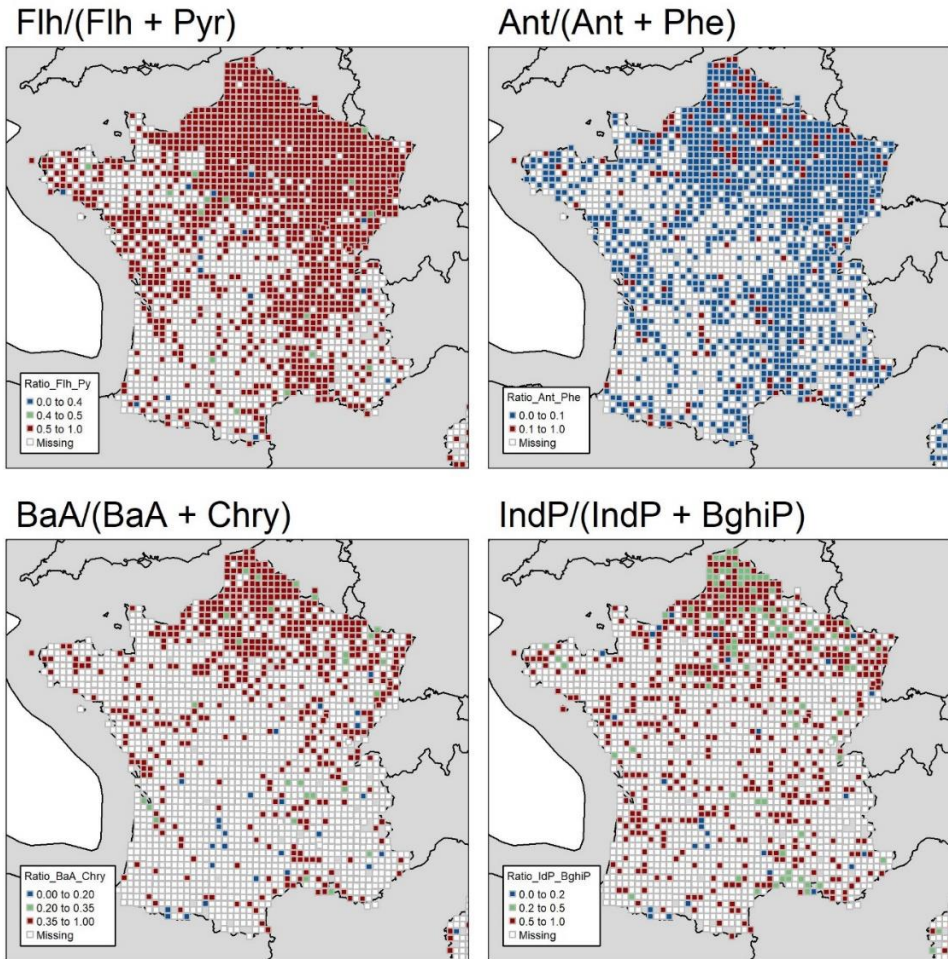
- Disparities between regions

- North-East and rhodanian corridor (S-E):
 - industrial regions (coal, metallurgy)
- Around the main cities

- Threshold value of $100 \mu\text{g.kg}^{-1}$ in the literature
 - North-East with a high probability of exceeding this value (> 50%)

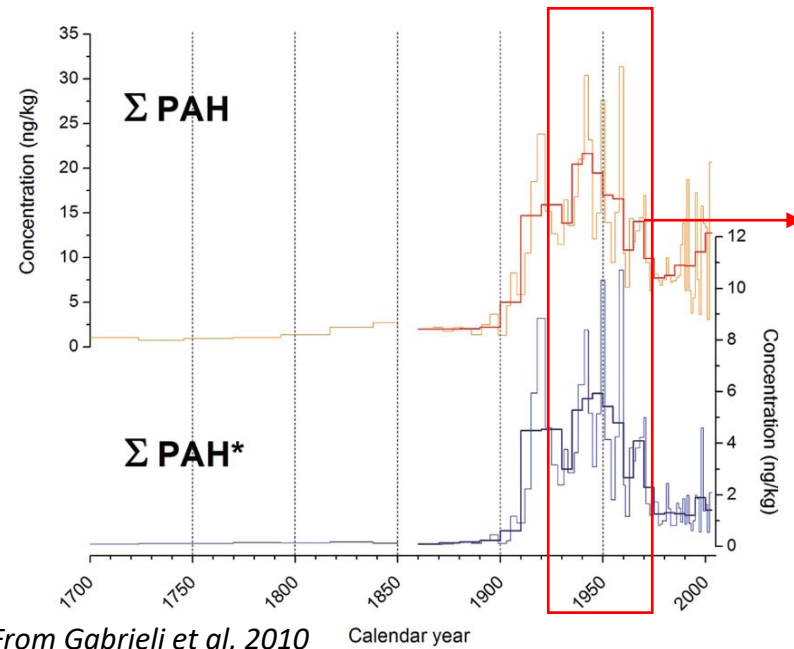
➤ Origin of PAH in French soils

Comparison of molecular ratios of PAH and literature values



• Signature information

- Pyrogenic origin : coal/wood combustion
- Large pattern with same signature : suggesting atmospheric deposition



Peak of emissions in Europe in 1960's :

- ➔ Main producers: Germany, UK and France
- ➔ Emissions 10 to 100 times current depositions

From Gabrieli et al, 2010



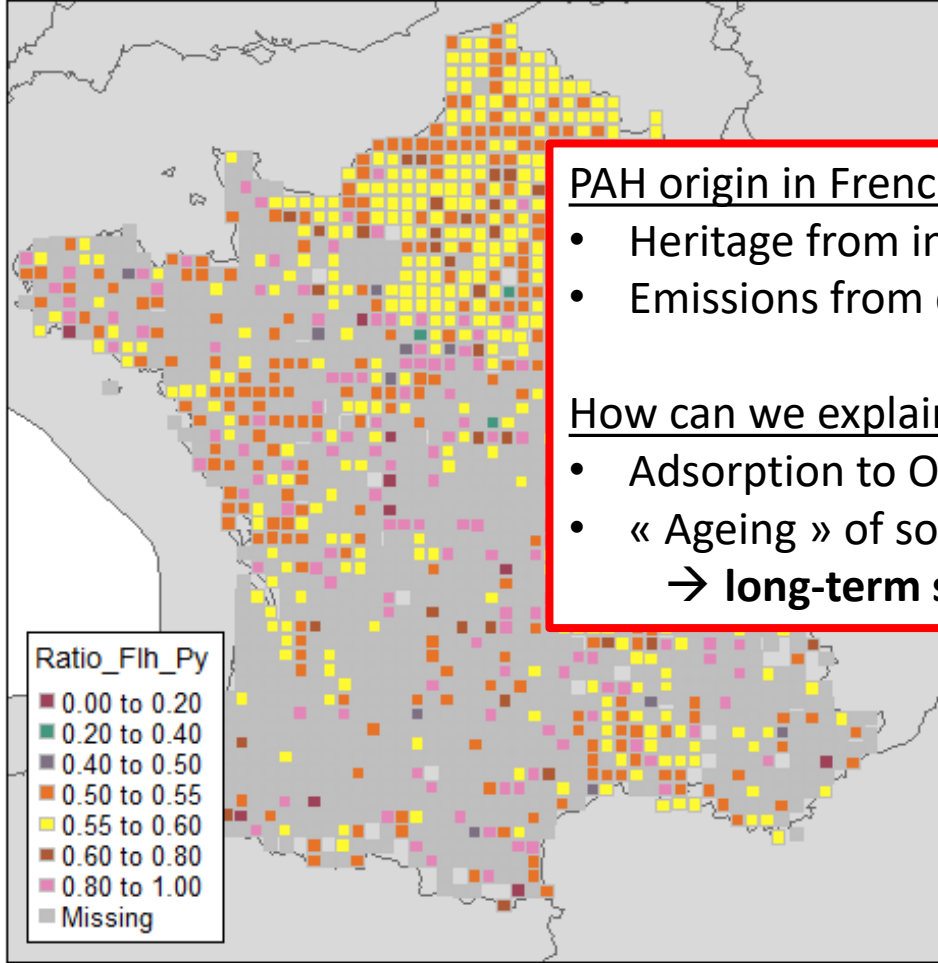
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Gabrieli, J., Vallelonga, P., Cozzi, G., Gabrielli, P., Gambaro, A., Sigl, M., Decet, F., Schwikowski, M., Gäggeler, H., Boutron, C., Cescon, P. and Barbante, C.: Post 17th-century changes of european pah emissions recorded in high-altitude alpine snow and ice, Environ. Sci. Technol., 44(9), 3260–3266, doi:10.1021/es903365s, 2010.

➤ Origin of PAH in French soils

Flh/(Flh + Pyr)



PAH and literature values

- Signature information

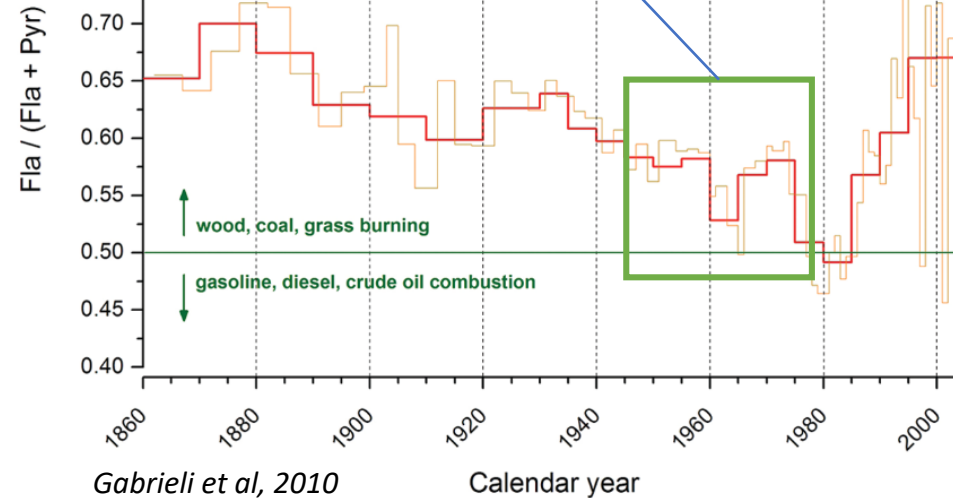
- Signature of Flh/Pyr → matching the signature of

PAH origin in French soils:

- Heritage from industrial era (European + local emissions)
- Emissions from cities (heating + industry)

How can we explain this persistence ?

- Adsorption to OM
- « Ageing » of soils (increasing PAH interactions in soils)
→ **long-term sequestration in soils**



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➤ Risk assessment

Chronic risk : Total Lifetime Cancer Risk for residents

• Risk for PAH in soil

- Calculated for residents

- *Pathways : ingestion, inhalation, dermal*

• *Low risk directly induced by soil contamination but :*

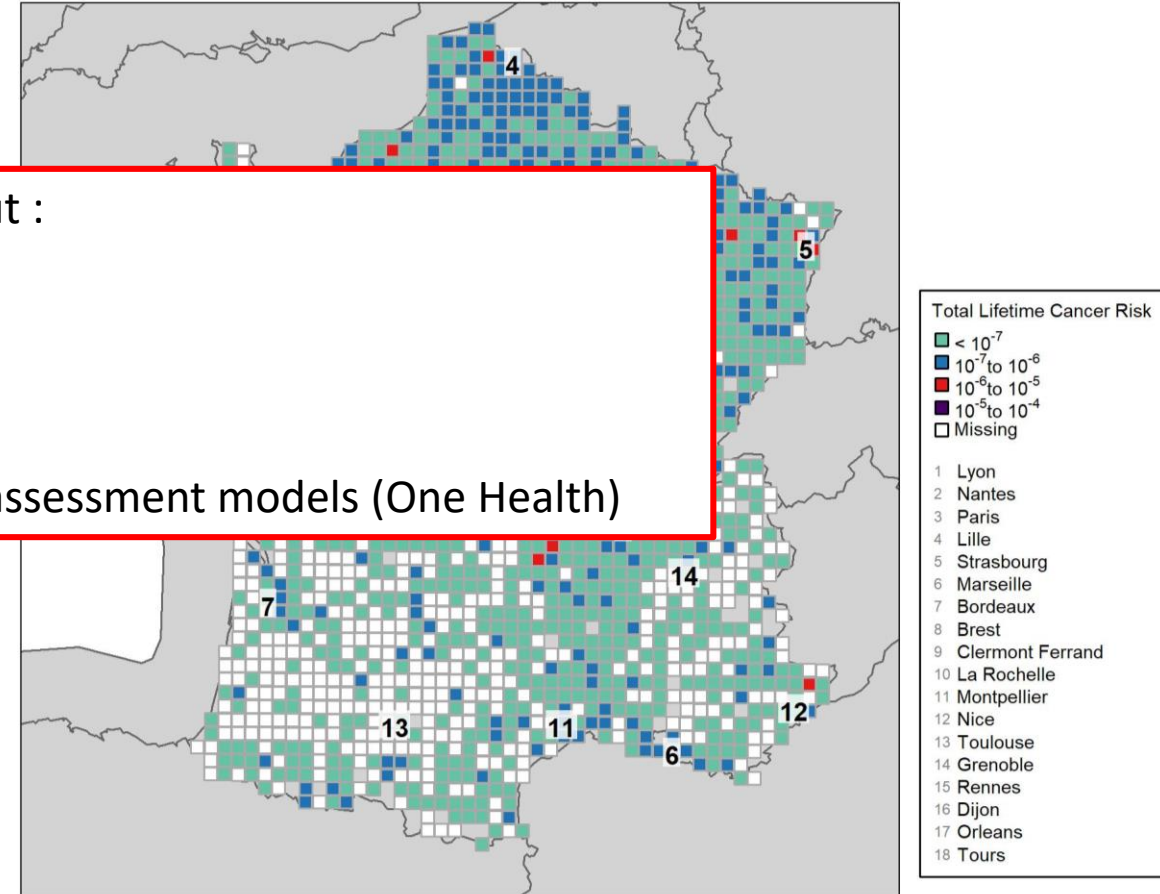
- *Lifetime*
 - Non-negligible risk → need to be assessed
- *pl*
 - What about their transfer to plants/food?
- *th*
 - Cocktail effect of multi-contamination ?

→ Need to integrate soil contamination into risk assessment models (One Health)

- *Risk threshold of 10^{-7} : 1 over 1 million*

- *Most of the sites $< 10^{-7}$*
- *Highest risk in northern France*

Risk for residents



➤ Conclusion and perspectives

• Widespread contamination

- PAH detected in most of French soil
- Spatial pattern : North-East and main cities contaminated

• Origins :

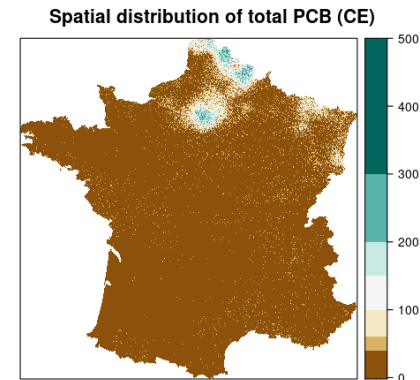
- Historical heritage for PAH (1960's)
 - European emissions
 - Local industries and cities

• Risk assessment :

- non-negligible, North of France with highest risk
- Need to be considered in risk assessments

• Perspectives

- Ongoing... Similar work on PCB
 - Spatial variation & origin
 - Risk assessment



- Indicator of multi-contamination (organic and TE)
- Emerging pollutants :
 - Pesticides
 - Drugs
 - Microplastics...

- Integration of soil contamination in the risk assessment models and exposome

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➤ Thanks!

Questions?