

New measurements of mercury contamination in air, soil, sediments, and tailings at artisanal and small-scale gold mining sites across Côte d'Ivoire

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Background

Environmental health
(Chemistry, Health Sc.,
etc.)

Mining science

Mercury in ASGM :

38% of Global
emission

(UNEP, 2019)

Social sciences

Atmospheric Sciences

INTERDISCIPLINARY PROBLEM

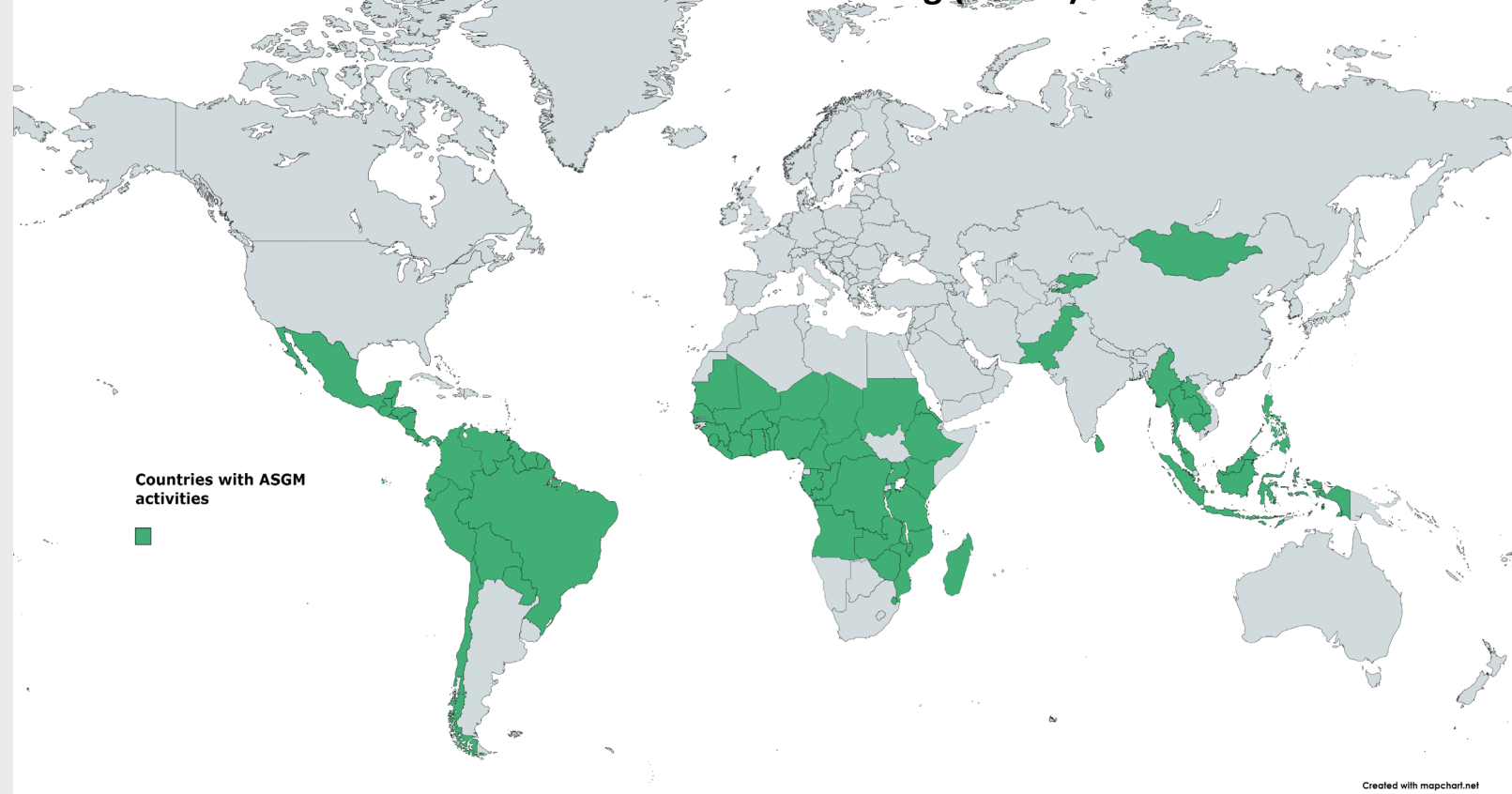


QUALITATIVE APPROACH



QUANTITATIVE APPROACH

Countries with Artisanal and Small-Scale Gold Mining (ASGM) within their territories



GOAL:

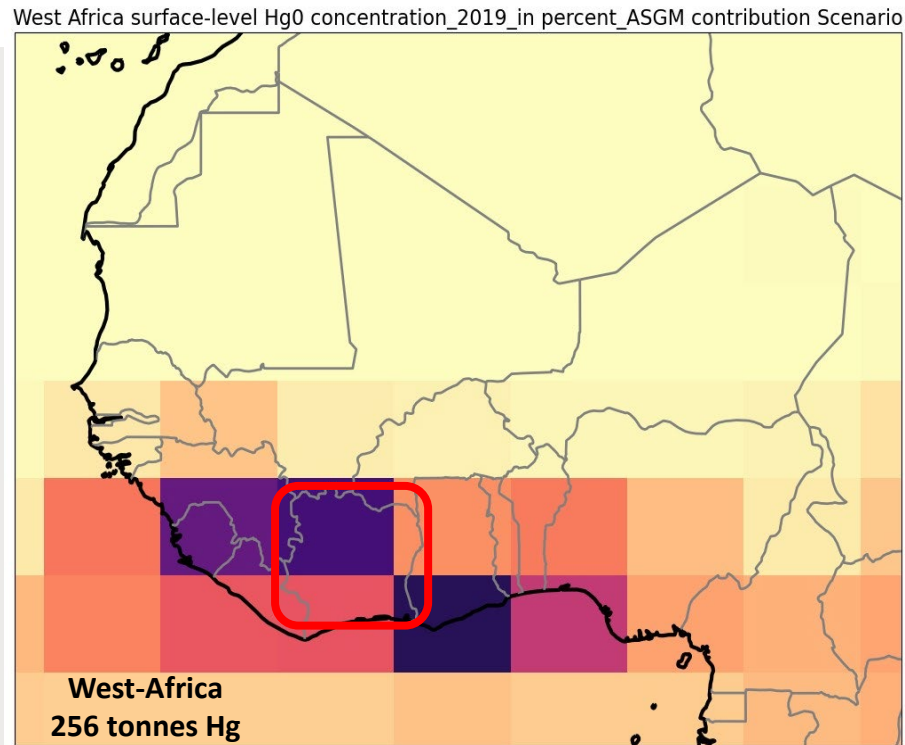
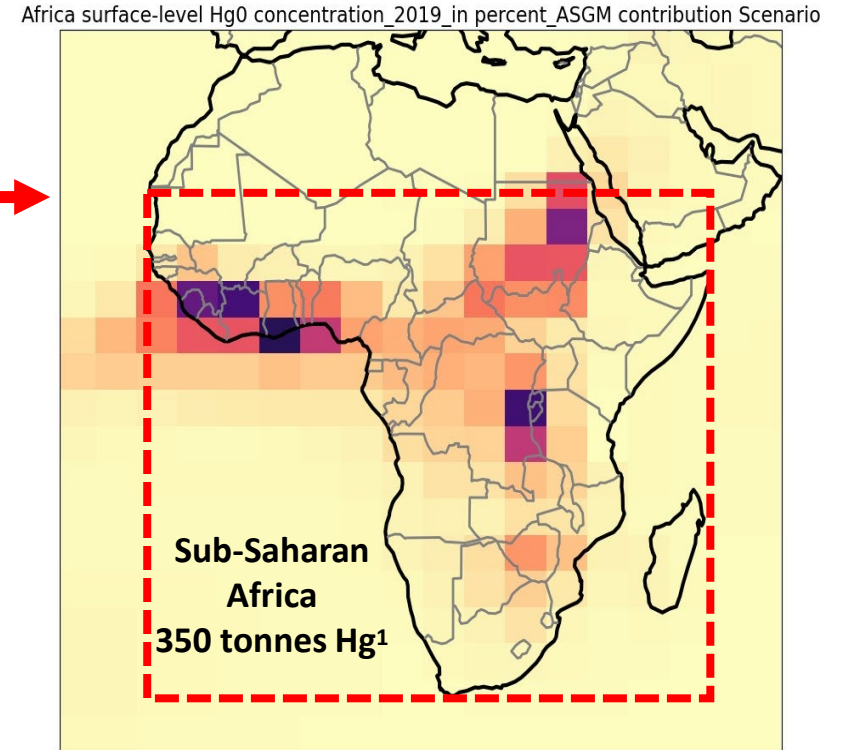
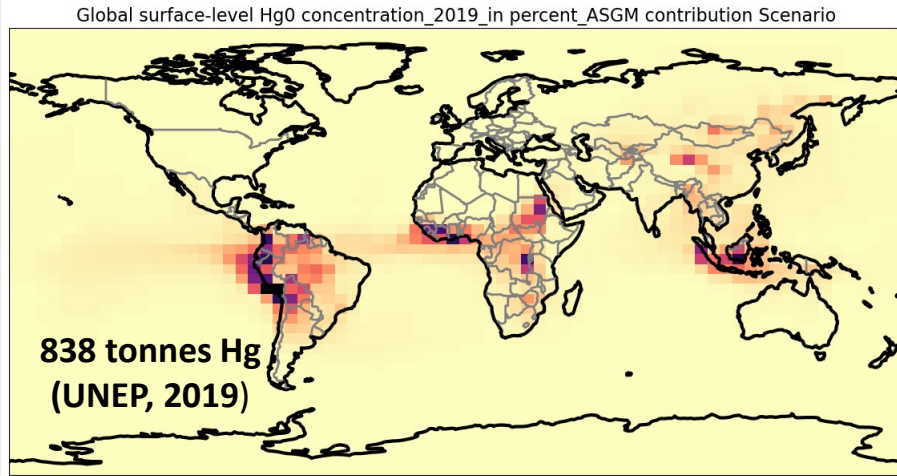
Identify the environmental
compartments affected by ASGM
mercury

Cote d'Ivoire - Case study



Background

Modelled contribution of ASGM to mercury in surface air (%)



Cote d'Ivoire

Mercury ASGM ≈

- 13 tonnes emitted to air in 2018²



1. Compilations from ASGM NAP reports submitted by African countries at the date of 30th June 2024.

2. Government of Cote d'Ivoire, Minamata Initial Assessment, National report, 2018. UNEP.

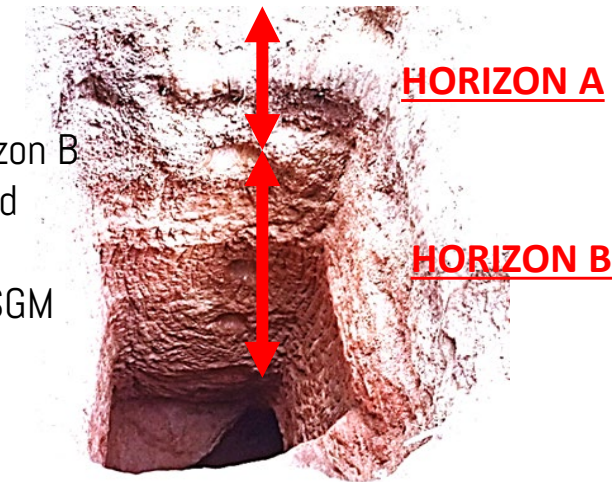
Methodology

Sampling sites

- Four sub-prefectures populated with more than 10,000 habitants with ASGM practiced at high intensity with or without mercury
- **Touba and Koutouba:** No current mercury use in ASGM
- **Djekanou & Diawala:** mercury use for ASGM

Sampling materials

- Surface soil referred as Horizon A
- Bottom soil (20 - 25 cm depth) referred as Horizon B
- Tailings from processing centres in Djekanou and Diawala
- Sediments in rivers near Touba and Koutouba ASGM sites
- Air through Passive Air Samplers (PAS) in towns removed after 1 month for a total period of 12 months



Results and discussions

Mercury concentrations in Air from ASGM towns

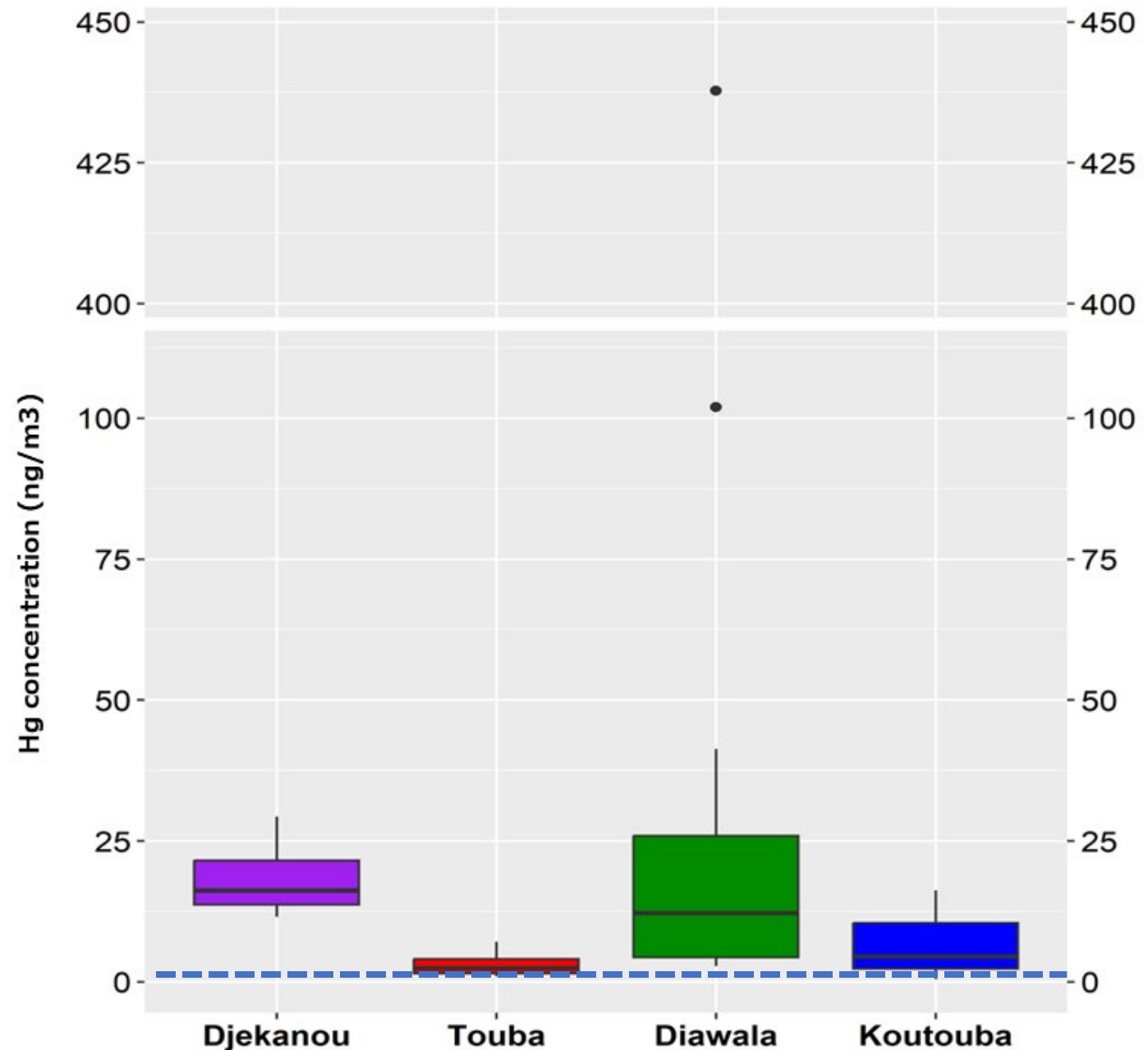
Hg air concentrations higher in ASGM towns using mercury

Consequence of Hg-Au amalgam open burning.

Air background levels in tropical zones: **1.23 ng m⁻³** (Sprovieri et al., 2016).

Highest Hg levels measured at:

- Djekanou (Centre): mean [Hg] = **18.1 ngHg.m⁻³** represents 13 times background values for air
- Diawala (North): mean [Hg] = **55.5 ngHg. m⁻³** represents 45 times background values for air

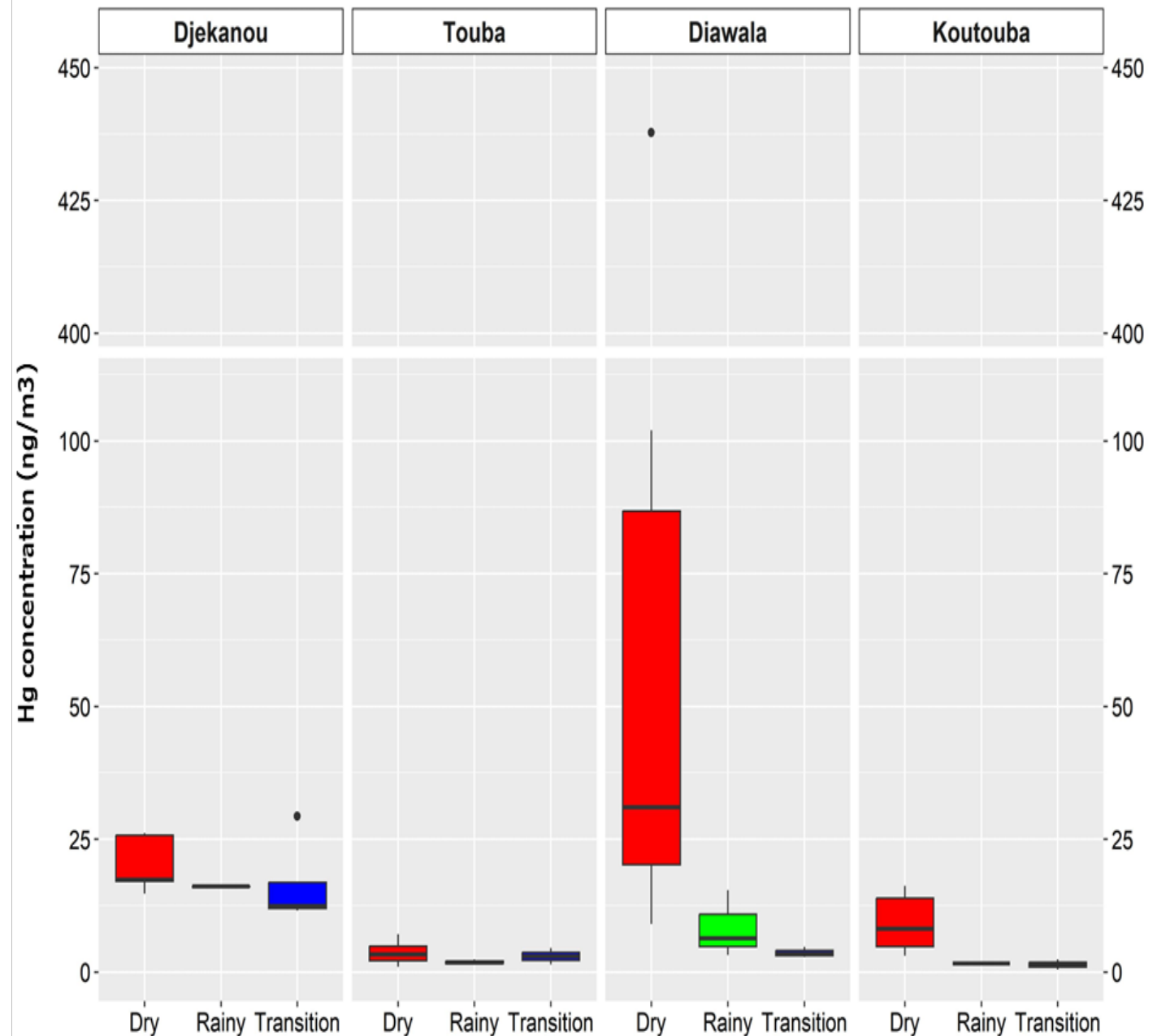


Results and discussions

Mercury concentrations in Air from ASGM towns

[Hg] Dry Season > [Hg] Wet Season > [Hg] Transition Season

- ASGM mainly occurs during dry seasons
- High concentrations observed in both transition and rainy seasons suggest the occurrence of ASGM all year long.



Results and discussions

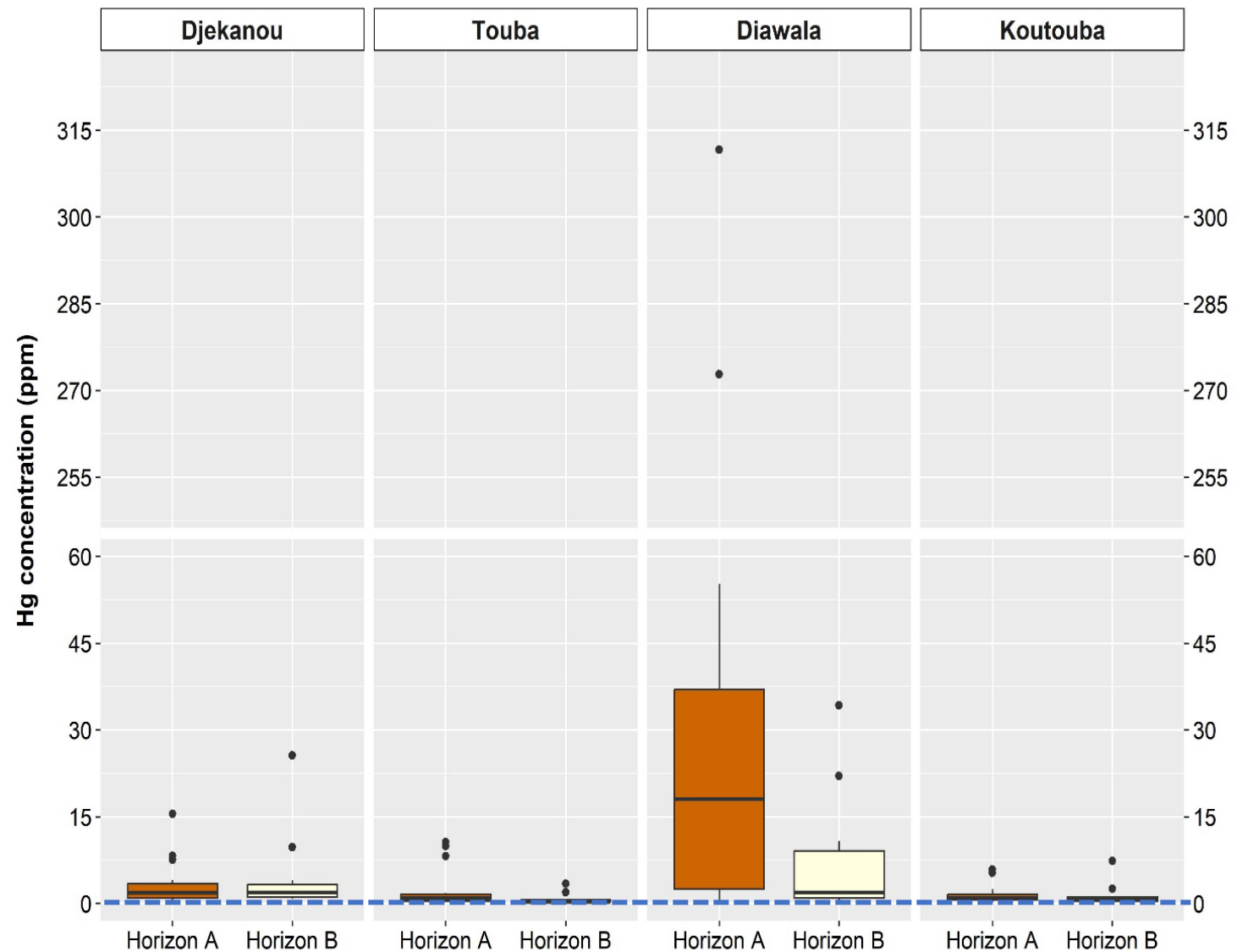
Mercury concentration in soil layers from ASGM sites in Cote d'Ivoire

High Hg found in soil layers

Background soils Africa

- Tanzania: 0.01 mg.kg⁻¹
- Uganda 0.05 mg.kg⁻¹

- Koutouba (No-Hg use in ASGM)(1.5 mg.kg⁻¹) : **30x** background
- Touba (2.5 mg kg⁻¹) : **50x** background
- Djekanou (3.4 mg kg⁻¹) : **68x** background
- Diawala (54 mg kg⁻¹) : **1,080x** background



- Non-parametric (Wilcoxon test) statistical test used to analyse the data revealed no statistical difference between horizons for each site: **Mercury contamination impacts both Horizon A and Horizon B of the soil profile.**



Results and discussions

Mercury concentrations in ASGM tailings

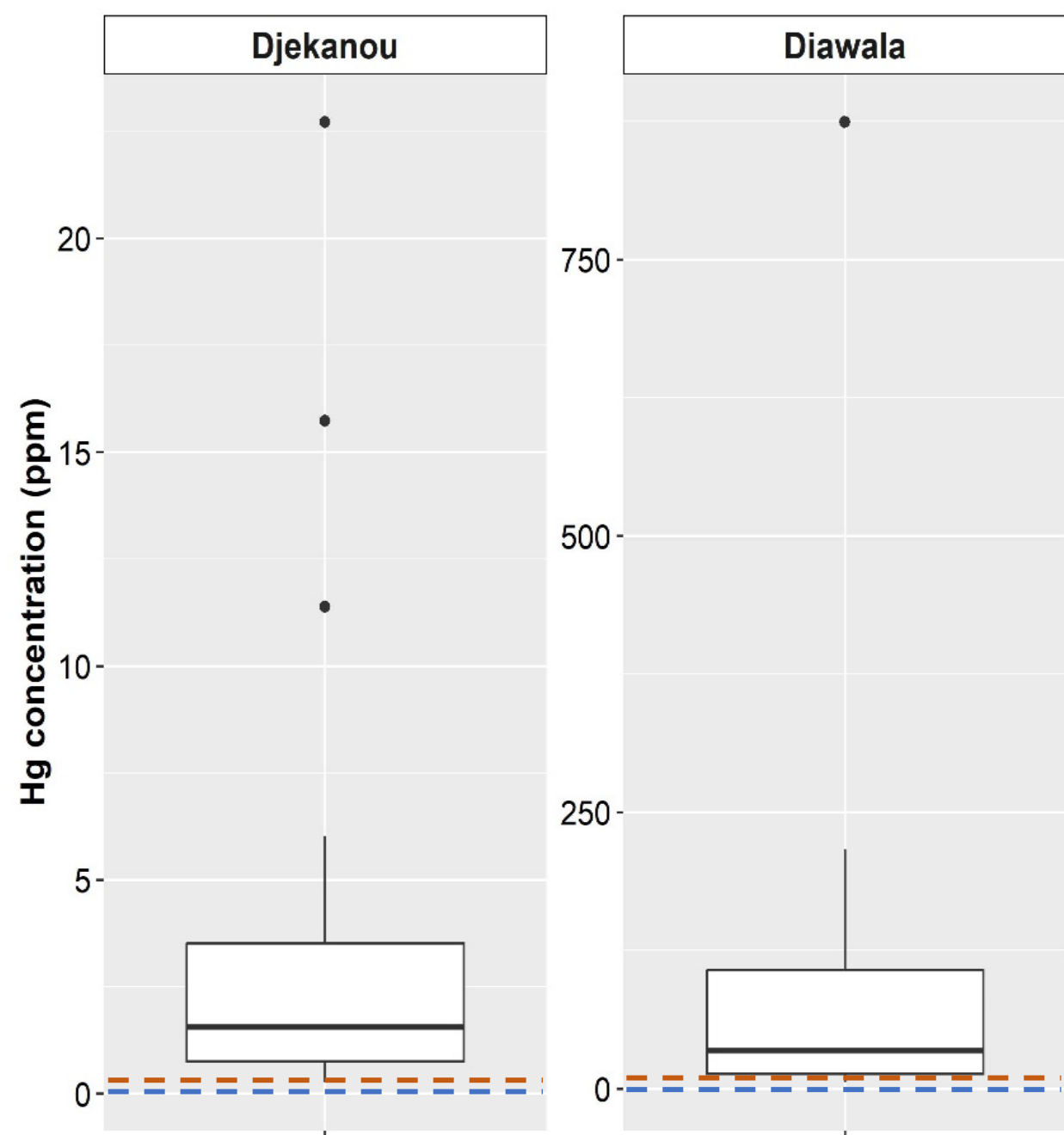
Elevated Hg concentrations in tailings

Previous studies in Africa

- **Ghana** : 0.86 mg.kg^{-1} (Addai-Arhin et al., 2022)
- **Zimbabwe** 0.28 mg.kg^{-1} (Greens, et al., 2019)

- Djekanou (4.1 mg kg^{-1}) :
 - **5x** Ghana
 - **15x** Zimbabwe

- Diawala (97.2 mg kg^{-1}):
 - **113x** Ghana
 - **347x** Zimbabwe

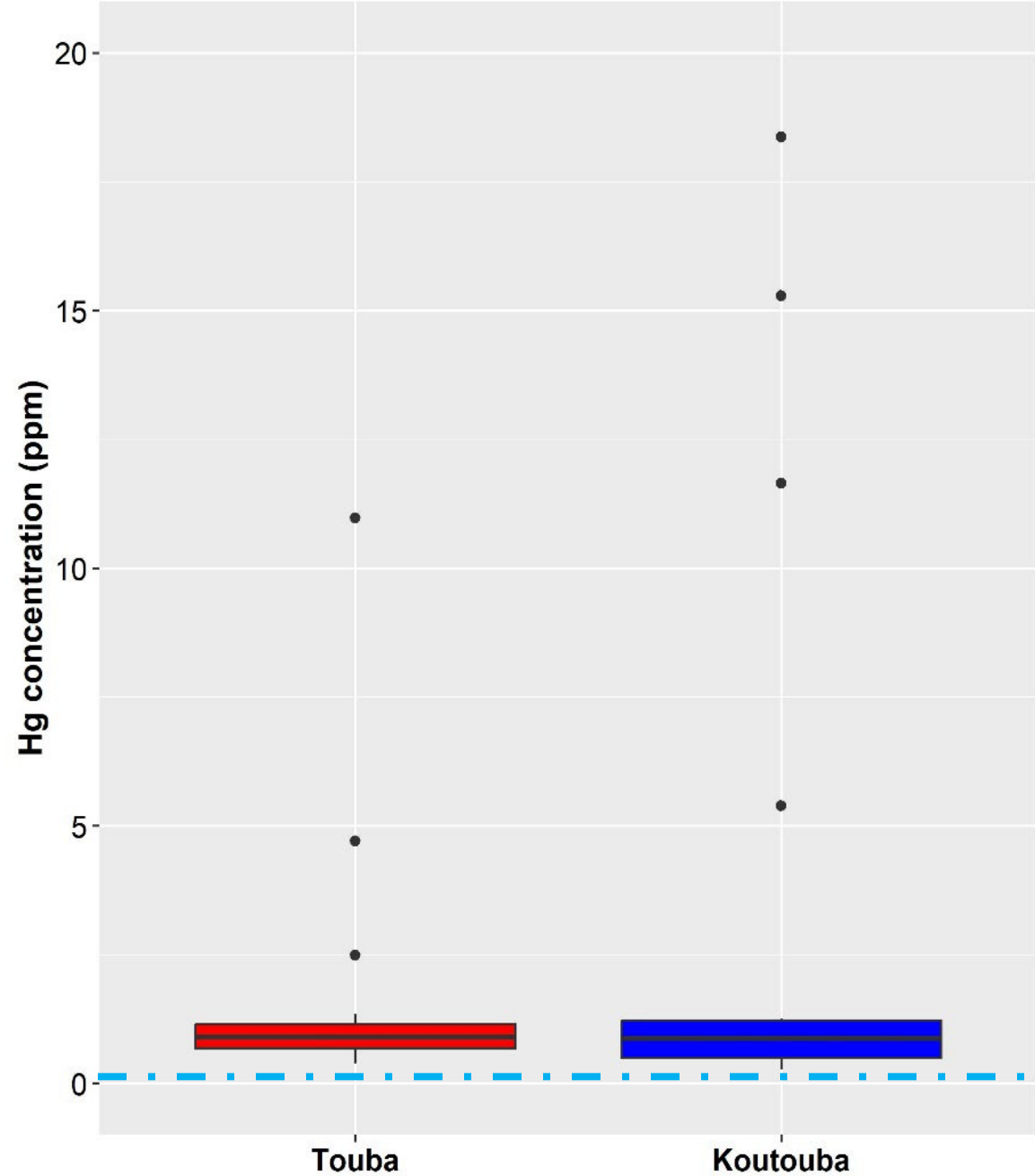


Results and discussions

Mercury concentrations in aquatic bodies connected to ASGM

High Hg concentration in sediments

- Reference value for sediment:
 - Canadian recommended value for sediment quality : **0.17 mg kg⁻¹** (CCEM, 1999)
- Touba (1.85 mg kg⁻¹): **11x** Canadian ref value
- Koutouba (No-Hg use in ASGM)(3.38 mg.kg-1): **20x** Canadian ref value
- High mercury concentration in sediments from Koutouba (No-Hg use in ASGM) suggests mercury transportation via runoff from distant ASGM sites during previous wet season.



Take home messages

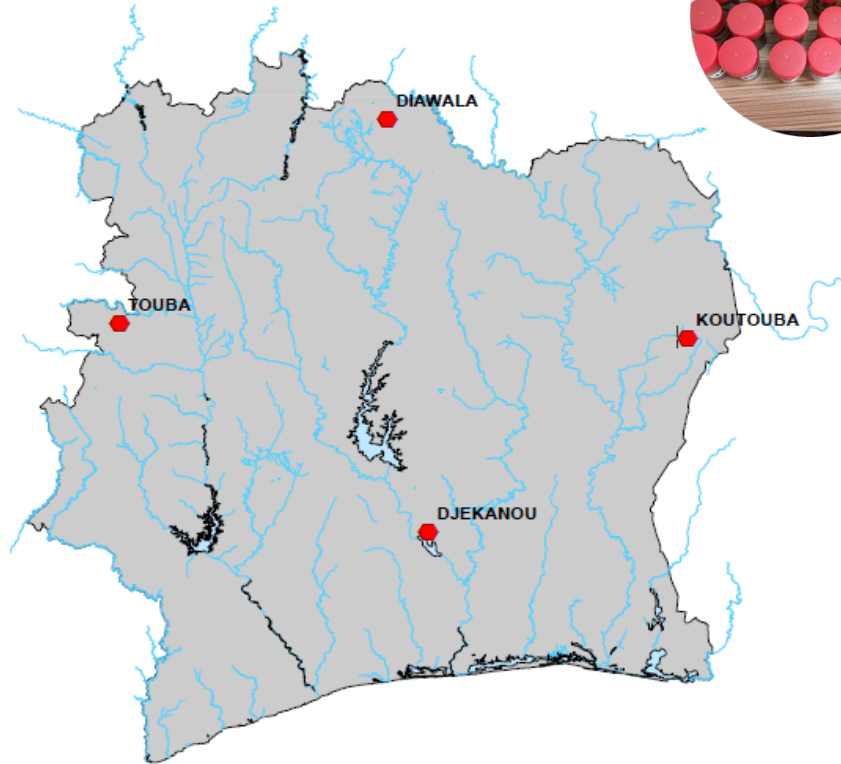


- **Mercury concentrations in air** follow patterns of its use in ASGM - but elevated air concentrations are seen where Hg is not currently used.
- ASGM is becoming a **year-long activity** instead of a seasonal one (practiced during the dry season).
- Hg concentrations **extremely high** in Cote d'Ivoire ASGM soils, sediments, and tailings from **informal mining sites using mercury**.
- Mercury **contamination impacts both** Horizon A and Horizon B of the soil profile posits some health and safety risks for farming activities and grown crops once informal ASGM sites are dismantled.
- There is a **need for remediation efforts** to encompass both surface soils and those at depth.
- Hg concentrations in sediment from eastern region sign of **long-distance transport** from ASGM sites by runoff from the previous rainy seasons.
- High Hg levels in sediments and tailings could pose **health risks** due to **probable contamination** of the food chain.



Extra materials

Methodology



Sampling sites

Mercury soil, sediment/tailings

- Collect a minimum of 30 soil samples from ASGM sites using Hg and controlled site
 - 15 samples of topsoil
 - 15 samples from the following strata
- Pack 150g per sample in a sterile container
- Keep cool in the dark and then freeze at -170 Celsius or freeze-dry if possible

Analyse via Direct Mercury Analyzer (DMA-80; Milestone Inc., Shelton, CT, USA) following the US EPA method 7473 based on thermal decomposition-atomic absorption spectrometry.

Mercury in air

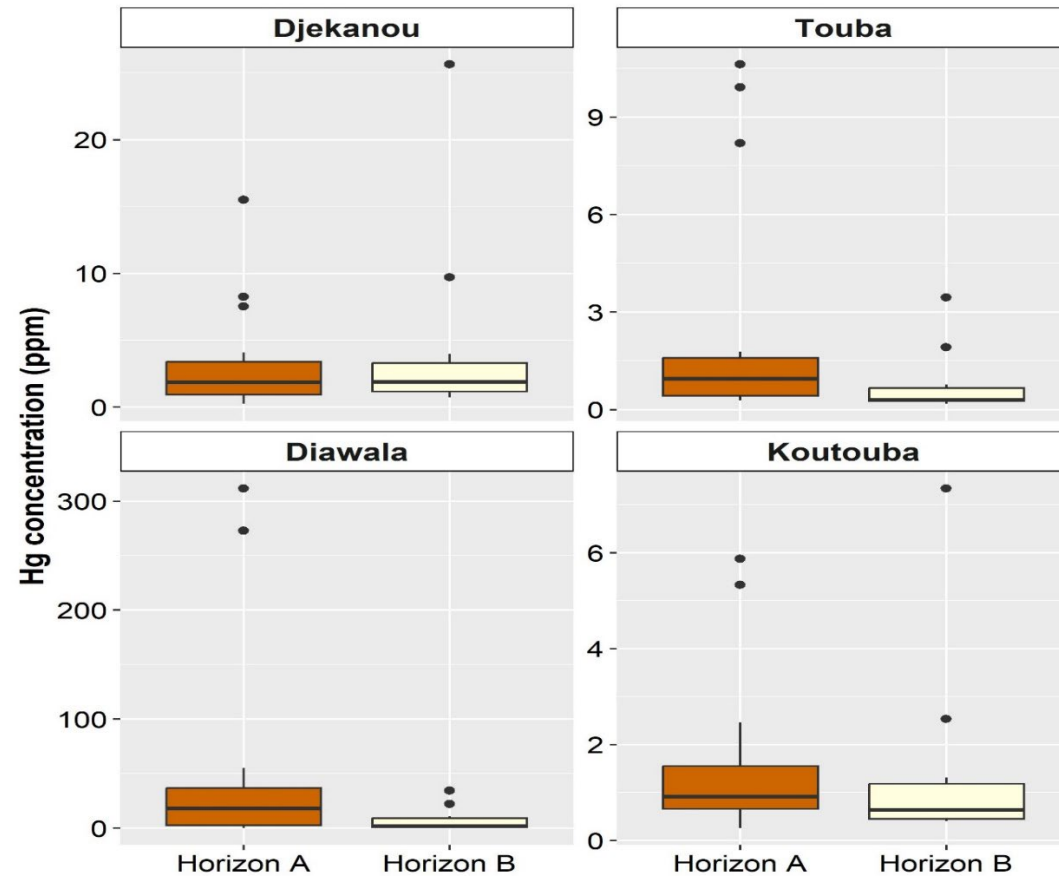
MerPAS installed in the nearest town from ASGM sites and removed after 1 month for a total period of 12 months

Air filters analysed at CNR laboratory in Italy according to the guidelines of US-EPA Method 7473.



Results and discussions

Mercury concentration soil layers from ASGM sites in Cote d'Ivoire



- Mercury concentration ranged from 0.12 to 311.61 mg kg⁻¹
- Average mercury concentrations from Horizon A soils higher to background soils documented in Africa (Tanzania: 0.01 & Uganda 0.05 mg.kg⁻¹).
 - 30 times for Koutouba.
 - 50 times for Touba.
 - 68 times for Djekanou.
 - 1,080 times for Diawala.

- Non-parametric (Wilcoxon test) statistical test served to compare mercury concentrations in Horizon A and B for each site.
- Mercury contamination impacts both Horizon A and Horizon B of the soil profile.

