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Changes in mercury volatilization flux induced by water vapor generation in subsurface soils under dynamic temperature

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Minamata Convention & Hg cycling

Minamata Convention

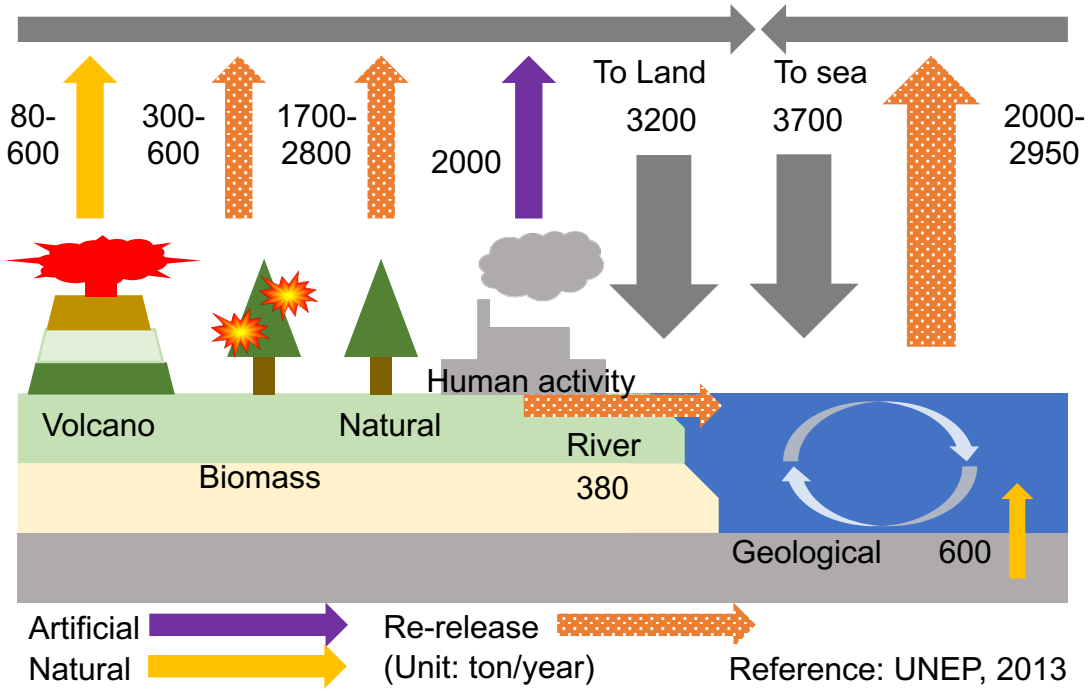
From Minamata disease in Japan (1956)

- Launched in 2017
- To manage & reduce the **risks** of Hg to human health from its mining & in Hg cycling loops
- Provides for regular implementation of '**Effectiveness assessments**' of convention

Hg global model

by UNEP (2013)

- Hg emissions from soil account for **1/3** of total Hg emissions from all environment



Volatile Hg concentration from contaminated soil

Ministry of the Environment, JAPAN (2016)

- In underground space of fresh fish market in Tokyo
- Even though the concentrations in the groundwater were below the standard
- Still unexplained

Few studies can clearly explain Hg emission from soil.

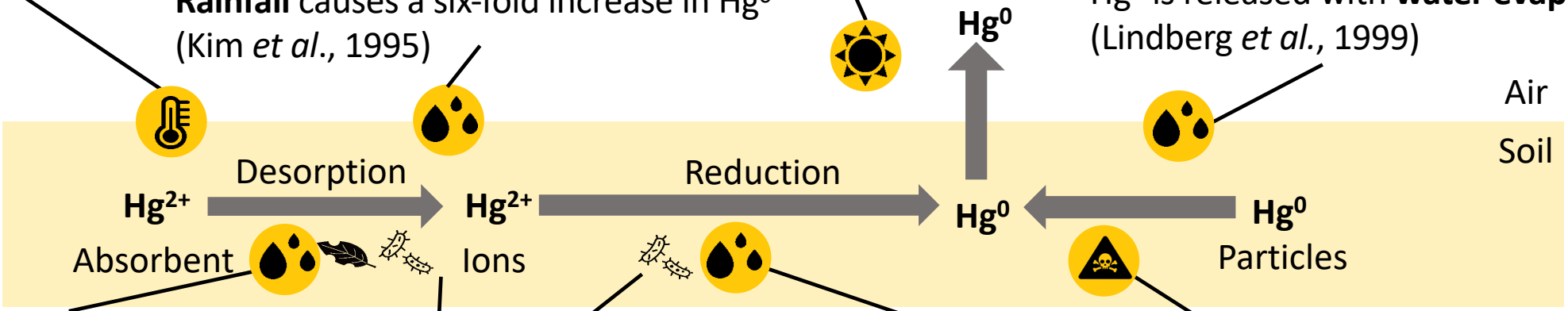
Influence of factors studied in previous studies

The higher **temperature**, the more volatile Hg^0 (Marumoto *et al.*,2005)

Sunlight promotes reduction to Hg^0 (Sizmur *et al.*,2017)

Rainfall causes a six-fold increase in Hg^0 (Kim *et al.*, 1995)

Hg^0 is released with **water evaporates** (Lindberg *et al.*, 1999)



Dissolved **organic matter** facilitates the desorption of Hg^0 (Yang, *et al.*, 2008)

merB：Break C-Hg bond
merA：Promotes Hg^{2+}→Hg^0 reduction
(Silver *et al.*,1996)

Water saturation inhibits oxygen exchange, creates **reducing atmosphere** (Gustin *et al.*,2005)

Hg^0 fluxes from contaminated sites are 10 times higher (Pannu *et al.*, 2014)

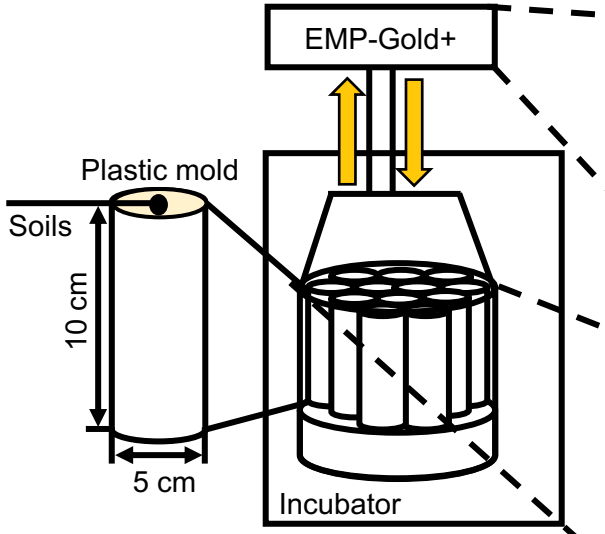
- Some environmental factors are known to affect mercury release, but this all applies to **static** conditions only.
- These findings do not apply to dynamic temperature changes or water vapor generation and deposition.

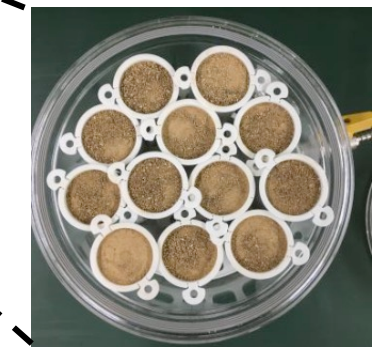
→ **Most of the actual environmental factors are dynamically changing.**

Objectives & Methodology

Objectives: **Understand how Hg volatilization fluxes are induced by temperature change and water vapor generation by comparing flux behavior under static and dynamic temperature conditions.**

	Particle Size Distribution [%]			Particle density	Loss on	Total Hg[mg/kg]
	Sand (0.05-2.00 mm)	Silt (0.002-0.05 mm)	Clay (<0.002 mm)	[g/cm^3]	Ignition [%]	
Loam	53	39	8	2.52	37.29	21.717
Silt	1	93	6	2.23	9.79	41.835

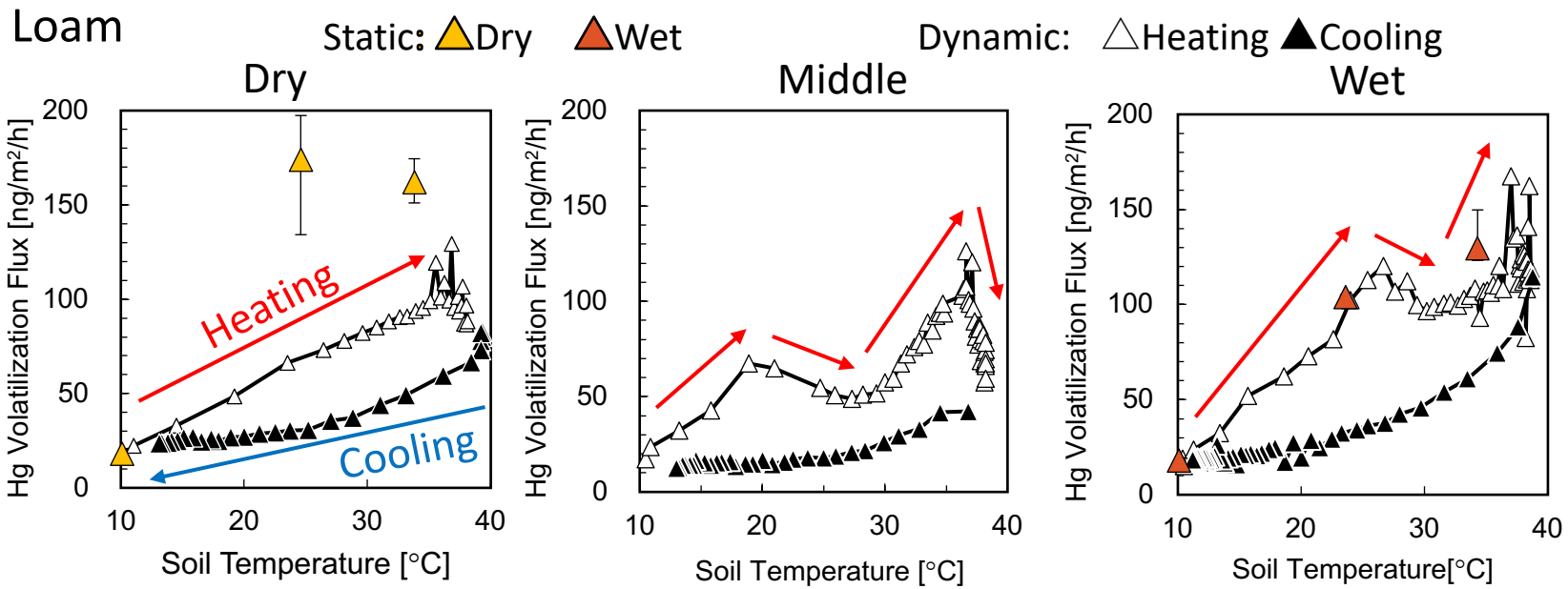


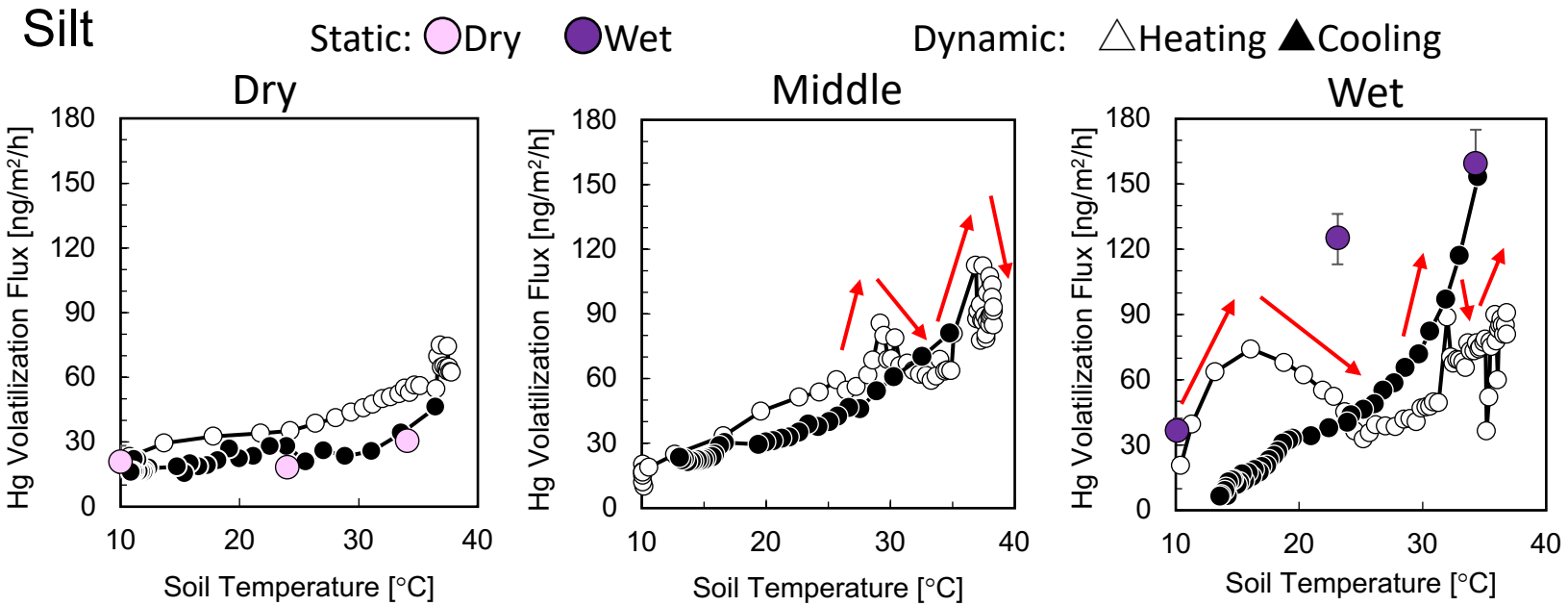


	Soil water content [wt%]		
	Dry	Middle	Wet
Loam	6.3	11.7	16.6
Silt	7.2	28.8	53.0

- Used old mine-area in Hokkaido Prefecture, which originally contains high levels of Hg.
- Packed soil were set in temp-controlled incubator.
- **Static conditions;** Conducted after soil temperature remained constant, set to 10, 25, 35 °C for around 12 hours.
- **Dynamic conditions;** Conducted while temperature changing from 10 °C to 40 °C (heating process) & from 40 °C to 10 °C (cooling process).
- Consecutive measurements are taken in every 10 minutes, flow rate was 0.3 L/min.

Hg flux trends under dynamic temperature





- Hg^0 flux values measured under static conditions were different from those measured under dynamic conditions.
- Heating and cooling processes took different paths and had different flux values, even though they were at the same temperature.
- In heating process, increase in initial phase was followed by a rapid decrease and further increase in Hg^0 flux. This is more pronounced the higher the soil water content, Wet > Middle > Dry.
- **Generation of water vapor derived from soil water content, which occurs during dynamic temperature increases, has a significant effect on Hg^0 flux.**

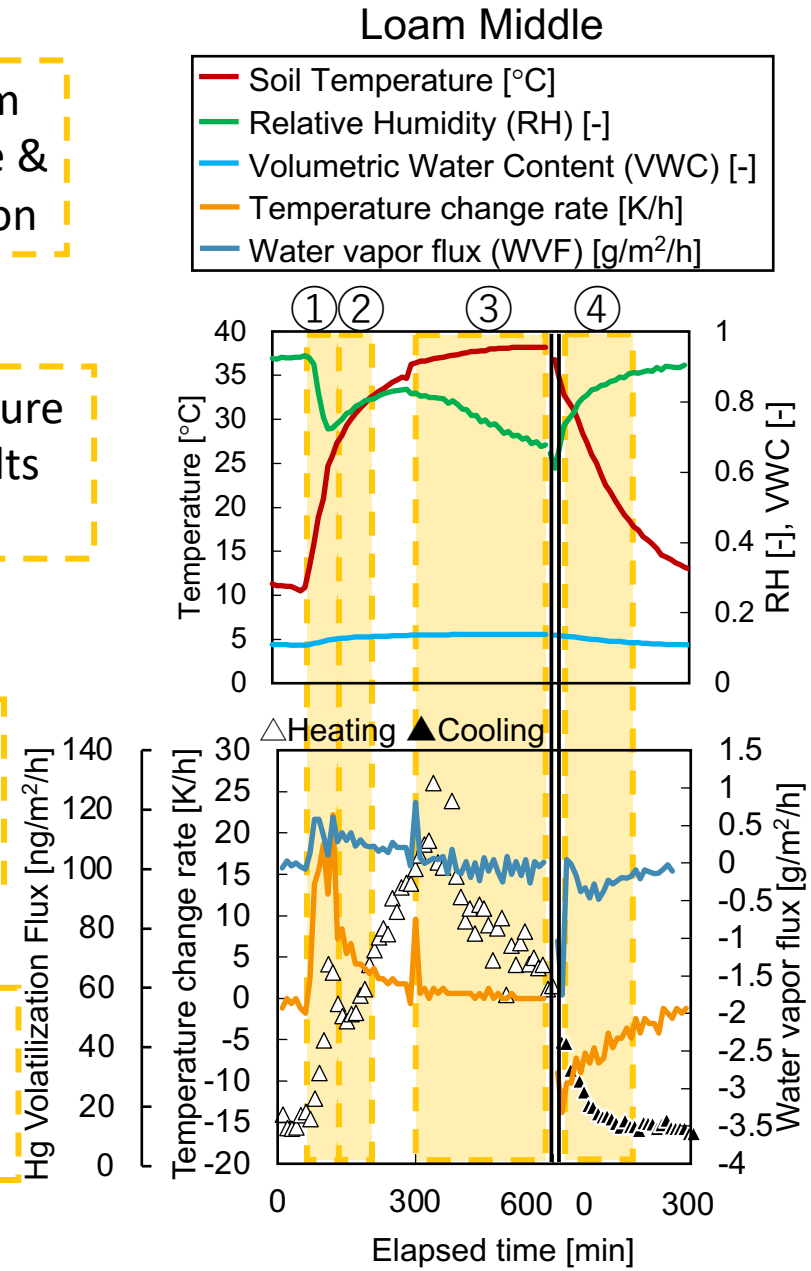
Temperature change and water vapor movement

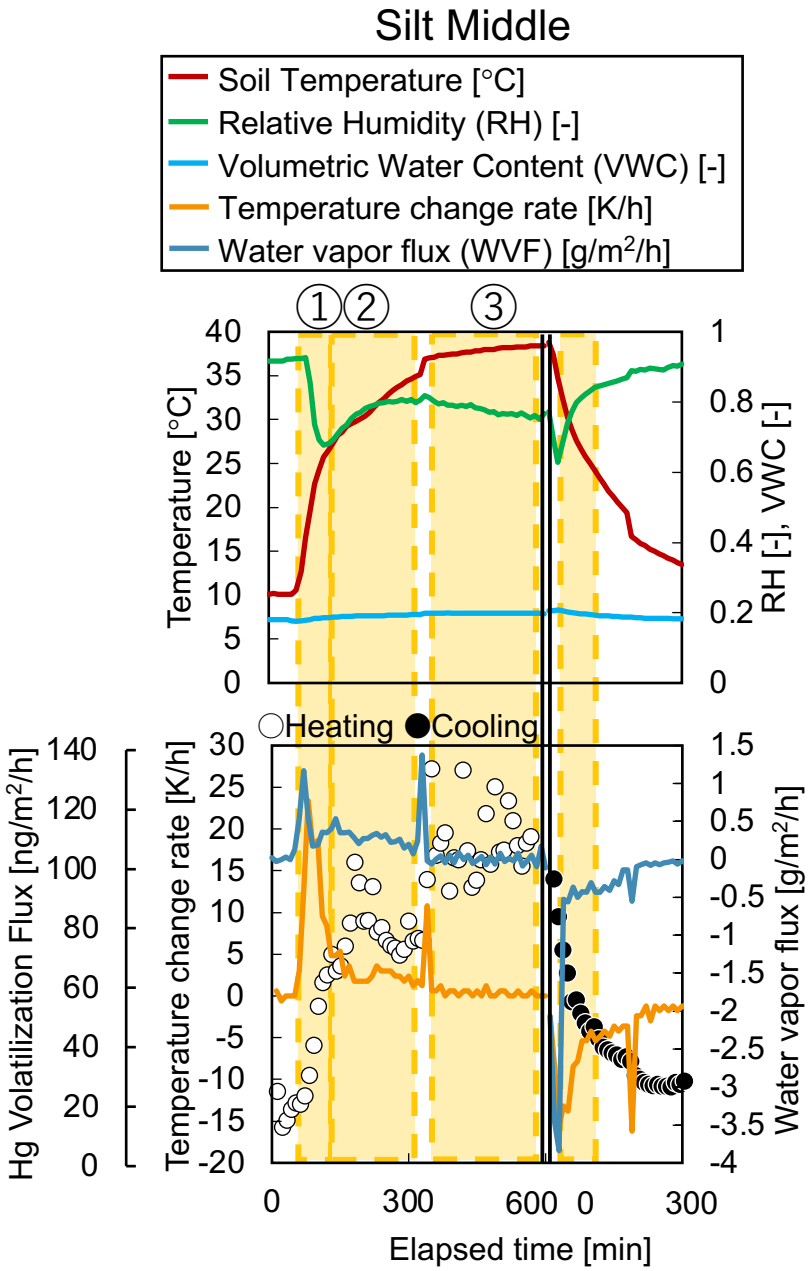
①Flux derived from Temperature rise & water vaporization

②Slower temperature change rate results in smaller flux

③Released water vapor returns to soil

④Water vapor suddenly returns to the soil





①Flux derived from Temperature rise & water vaporization

②Flux increase and decrease occurrence were slower than Loam

③Released water vapor doesn't return to soil

④Water vapor suddenly returns to the soil

Conclusions

- Lack of scientific evidence to assess the effectiveness of the Minamata Convention.
- The partial effects of each environmental factor, such as temperature and rainfall, are known, but their dynamic effect for Hg^0 emission is unclear.
- We clarified changes in Hg^0 volatilization flux induced by water vapor generation in subsurface soils under dynamic temperature.
- Even with similar temperature changes, the Hg^0 release differed between soil types, partly induced with water vapor and partly not.
- It will be possible to accurately predict Hg^0 release from soil by capturing dynamic parameter change.

Thank you for listening