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University of Chinese Academy of Sciences

Temporal and Spatial Analysis of Atmospheric Mercury and CO_2 Emissions from Municipal Solid Waste Incineration (MSWI) in China

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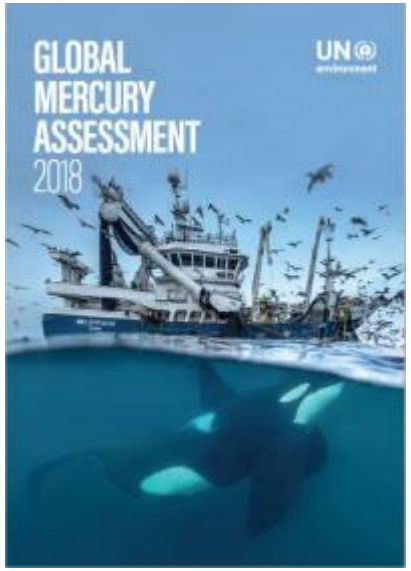
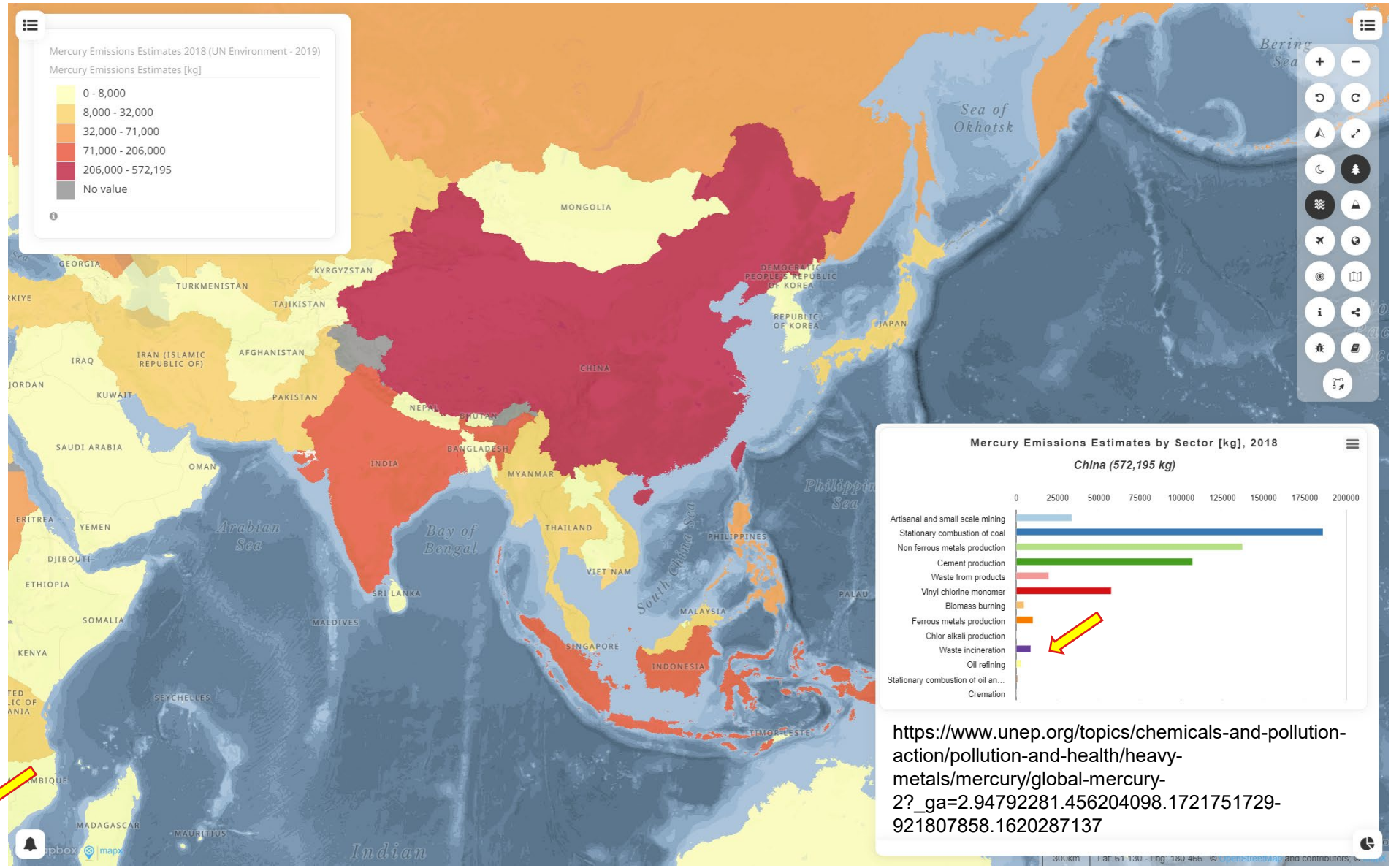
Mercury Emission from Waste Incineration



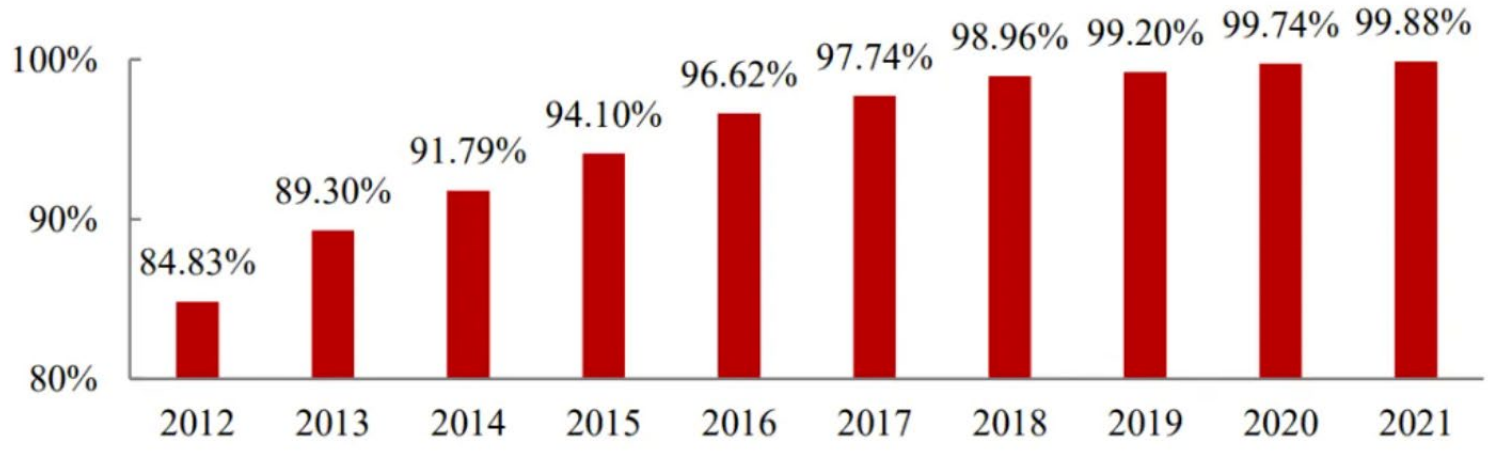
▼ Quantities of mercury emitted to air from anthropogenic sources in 2015, by different sectors.

Sector	Mercury emission (range), tonnes	Sector % of total
Artisanal and small-scale gold mining (ASGM)	838 (675-1000)	37.7
Biomass burning (domestic, industrial and power plant) *	51.9 (44.3-62.1)	2.33
Cement production (raw materials and fuel, excluding coal)	233 (117-782)	10.5
Cremation emissions	3.77 (3.51-4.02)	0.17
Chlor-alkali production (mercury process)	15.1 (12.2-18.3)	0.68
Non-ferrous metal production (primary Al, Cu, Pb, Zn)	228 (154-338)	10.3
Large-scale gold production	84.5 (72.3-97.4)	3.8
Mercury production	13.8 (7.9-19.7)	0.62
Oil refining	14.4 (11.5-17.2)	0.65
Pig iron and steel production (primary)	29.8 (19.1-76.0)	1.34
Stationary combustion of coal (domestic/residential, transportation)	55.8 (36.7-69.4)	2.51
Stationary combustion of gas (domestic/residential, transportation)	0.165 (0.13-0.22)	0.01
Stationary combustion of oil (domestic/residential, transportation)	2.70 (2.33-3.21)	0.12
Stationary combustion of coal (industrial)	126 (106-146)	5.67
Stationary combustion of gas (industrial)	0.123 (0.10-0.15)	0.01
Stationary combustion of oil (industrial)	1.40 (1.18-1.69)	0.06
Stationary combustion of coal (power plants)	292 (255-346)	13.1
Stationary combustion of gas (power plants)	0.349 (0.285-0.435)	0.02
Stationary combustion of oil (power plants)	2.45 (2.17-2.84)	0.11
Secondary steel production *	10.1 (7.65-18.1)	0.46
Vinyl-chloride monomer (mercury catalyst) *	58.2 (28.0-88.8)	2.6
Waste (other waste)	147 (120-223)	6.6
Waste incineration (controlled burning)	15.0 (8.9-32.3)	0.67
Total	*2220 (2000-2820)*	*100*

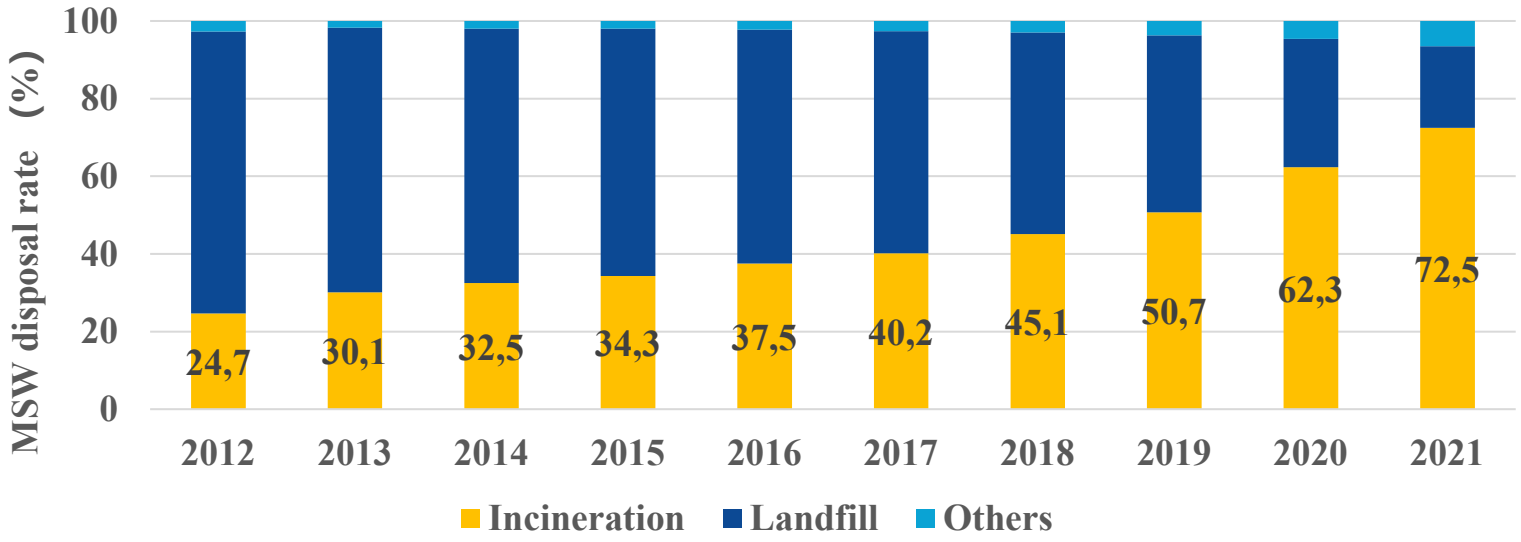


https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/heavy-metals/mercury/global-mercury-2?_ga=2.94792281.456204098.1721751729-921807858.1620287137

Municipal Solid Waste Incineration in China



MSW centralized disposal rate (2012-2021)

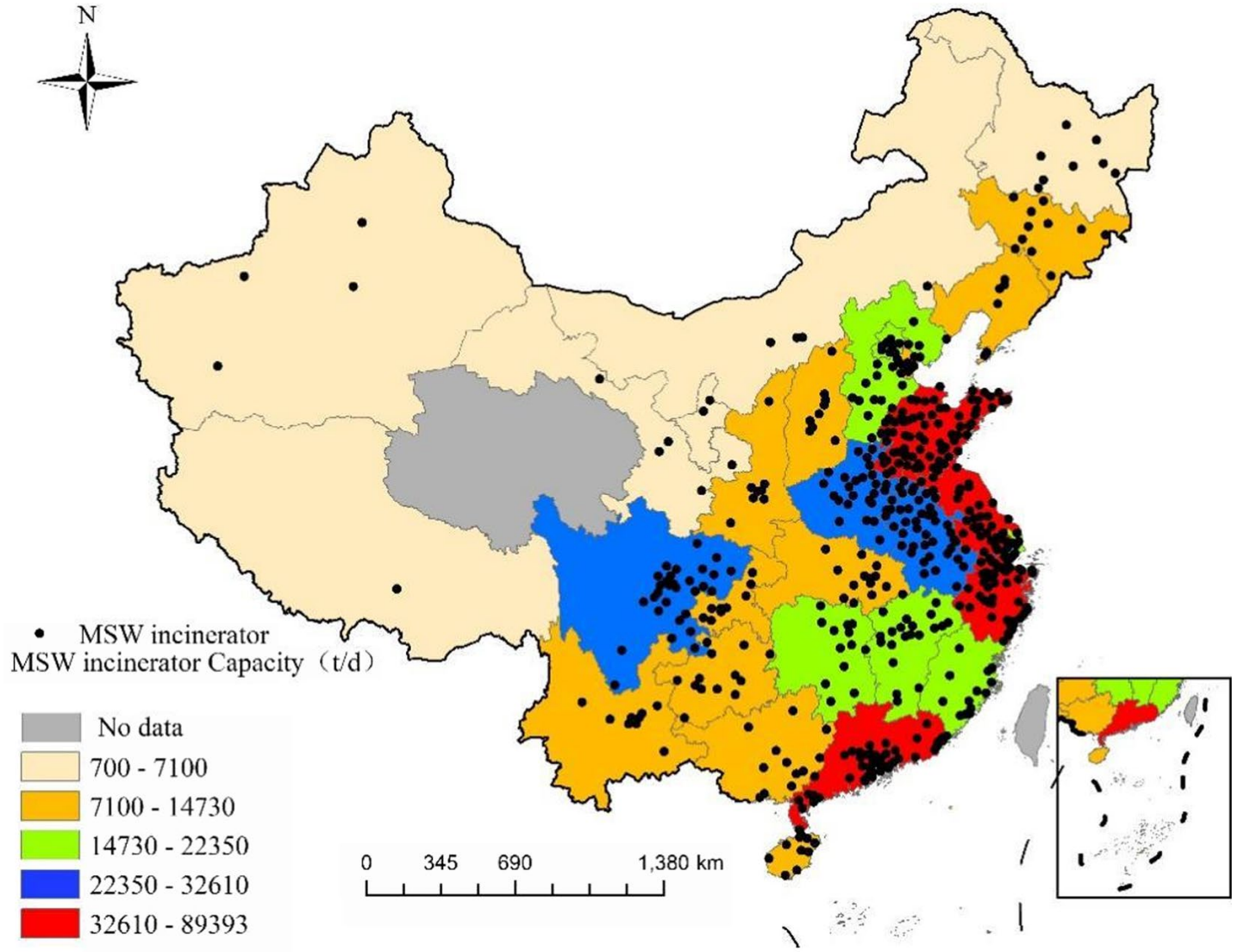


Proportion of MSW disposal methods (2012-2021)

- *Standard for pollution control on the municipal solid waste incineration* (GB 18485-2014)
- China *"14th Five-Year Plan" of the municipal solid waste classification and treatment facilities,* 2021.
- Municipal Solid Waste Incineration (MSWI) has become the dominant method for MSW disposal .

Data source: National Bureau of Statistics of China

Municipal Solid Waste Incineration in China



Spatial distribution of MSWI plants across China in 2020

- 548 MSWI plants and 1308 MSW incinerators in 2020
- More than 1000 MSWI plants in 2024

Where does the mercury in MSW come from?

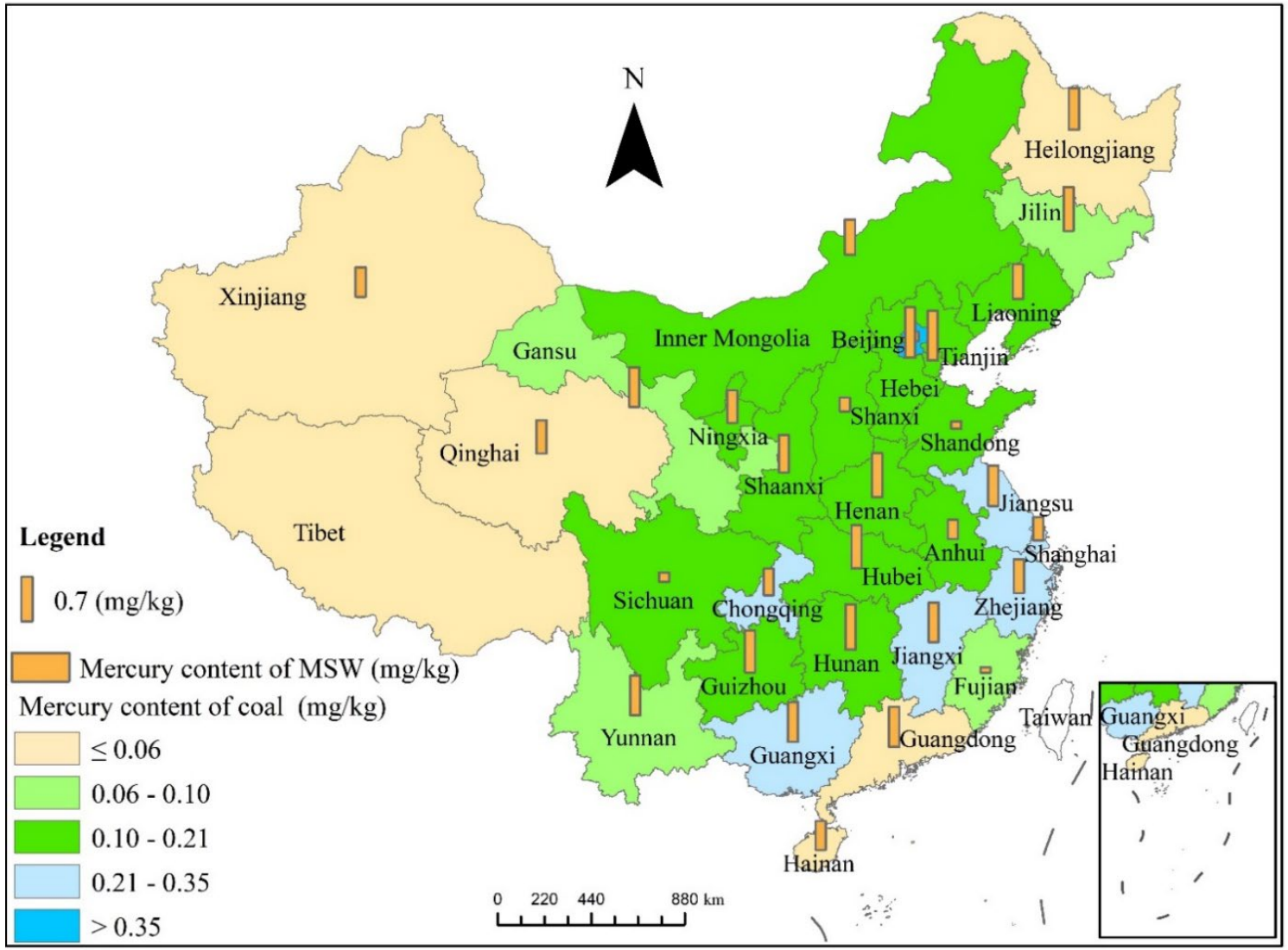
Most of the Hg in municipal solid waste comes from batteries, electronic components, household appliances (fluorescent lamps, etc.), mercury containing thermometers, skin lightening products, and so on.

Mercury content and category proportion of MSW in China

Category	Organic matter	Inorganic matter		Recyclable substance						
	Food waste	Lime	Brick	Metal (including batteries)	Glass	Paper	Rubber and Plastic	Weave	Wood, Bamboo	Total
Average Hg content in each category (mg/kg)	0.0008-0.535	0.038	/	0.876	0.0012	0.007-0.378	0.039-0.418	0.061-0.445	0.005-0.529	/
Average proportion in MSW (%)	51.00	16.43	8.02	1.33	2.79	6.65	8.40	2.07	3.21	99.9
Average Hg content in MSW (mg/kg)	0-0.273	0.006	/	0.0120-0.025	0.000	0-0.025	0.003-0.035	0.001-0.009	0-0.017	0.024-0.377

Li, C. Y.,et al. Jia, Y.,et al. Zhang, H., et al. Zhao, X., etal. Duan, Z. Y., et al.

Mercury content of MSW and coal in China

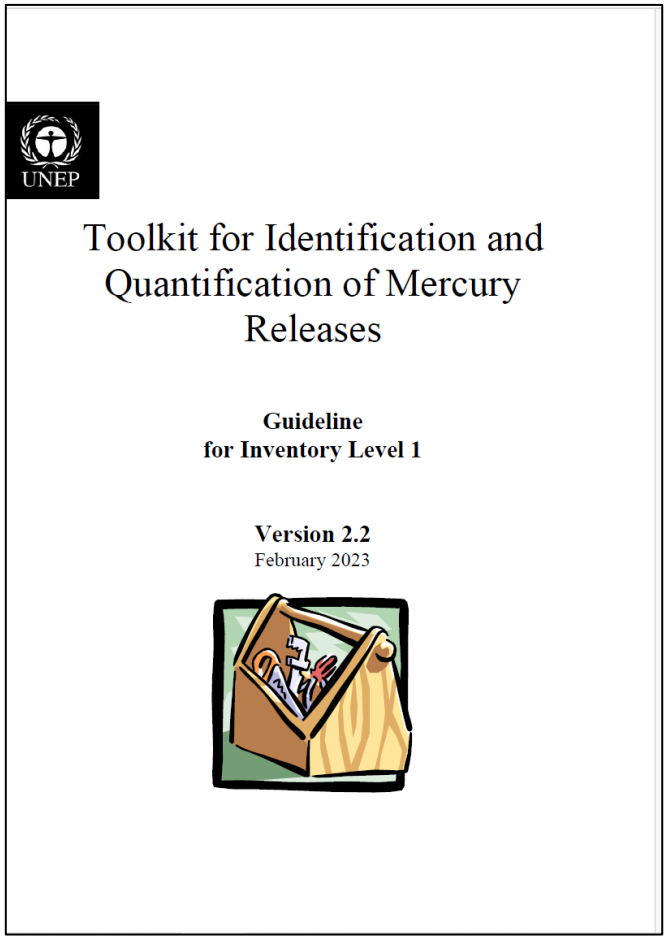


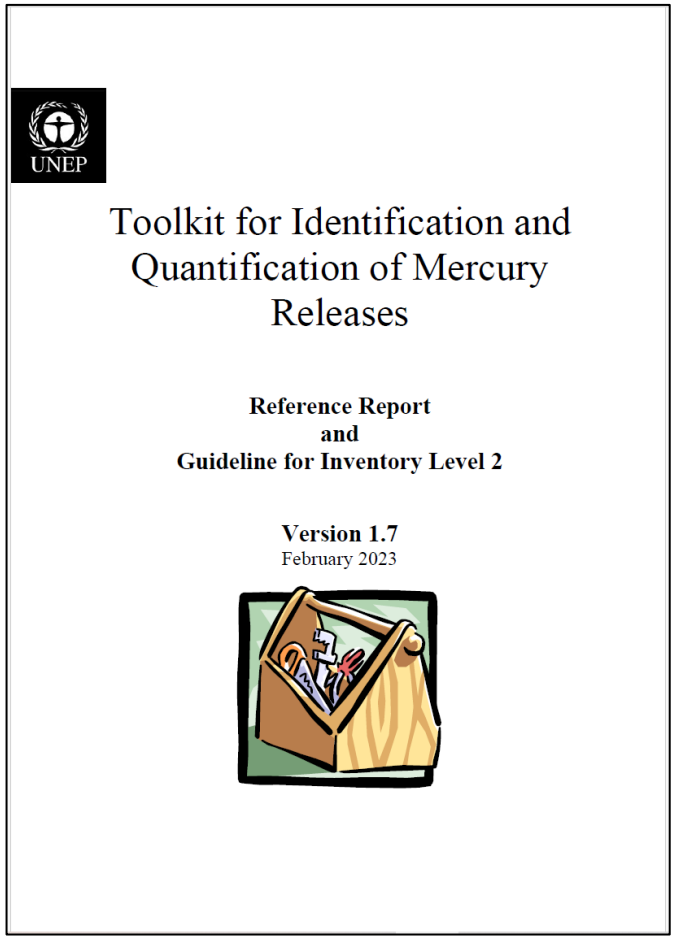
Mercury content of MSW and coal in China (literate data)

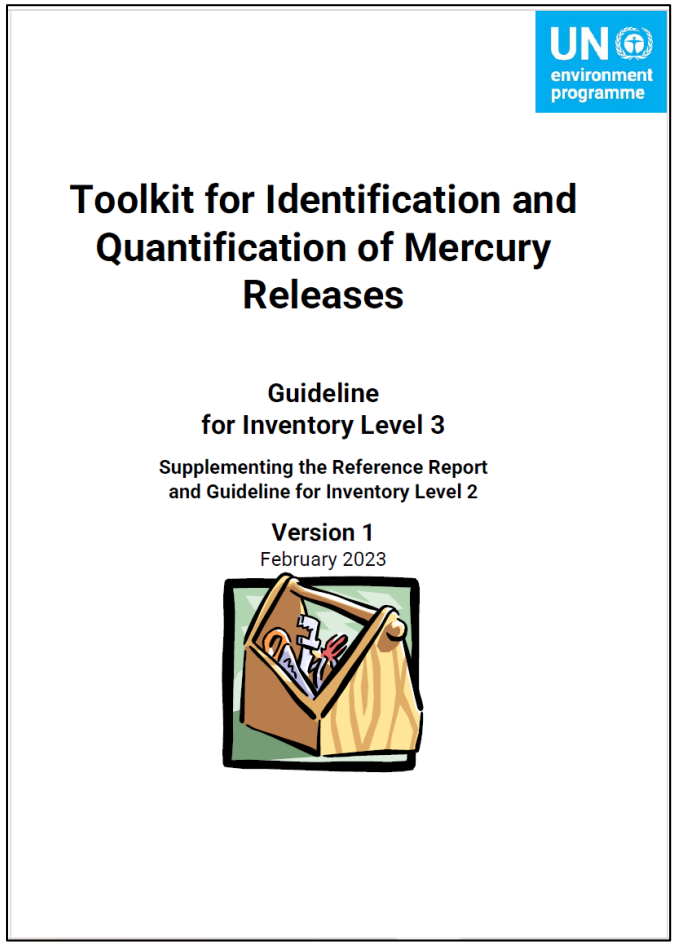
- The average mercury content of MSW in China is 0.08 ~ 0.91 mg/kg.
- The average mercury content of coal in China is 0.03 ~ 0.55 mg/kg.

Atmospheric mercury emission inventory methods

According to the UNEP's *Toolkit for identification and quantification of mercury releases*







https://www.unep.org/topics/chemicals-and-pollution-action/pollution-and-health/heavy-metals/mercury/mercury-inventory

Atmospheric mercury emission inventory methods

$$E_{Hg} = \left(\sum_i \sum_j C_{m,i} M_{i,j} + \sum_i C_{c,i} A_i\right)(1 - \eta_{i,j})$$

$$A_i = M_{i,j} R$$

E_{Hg} the annual anthropogenic mercury emissions from the MSWI sector (kg);

i, j the MSW incinerator and the type;

$C_{m,i}$ the mercury concentration in MSW($mg \cdot kg^{-1}$);

$C_{c,i}$ the mercury concentration in coal;

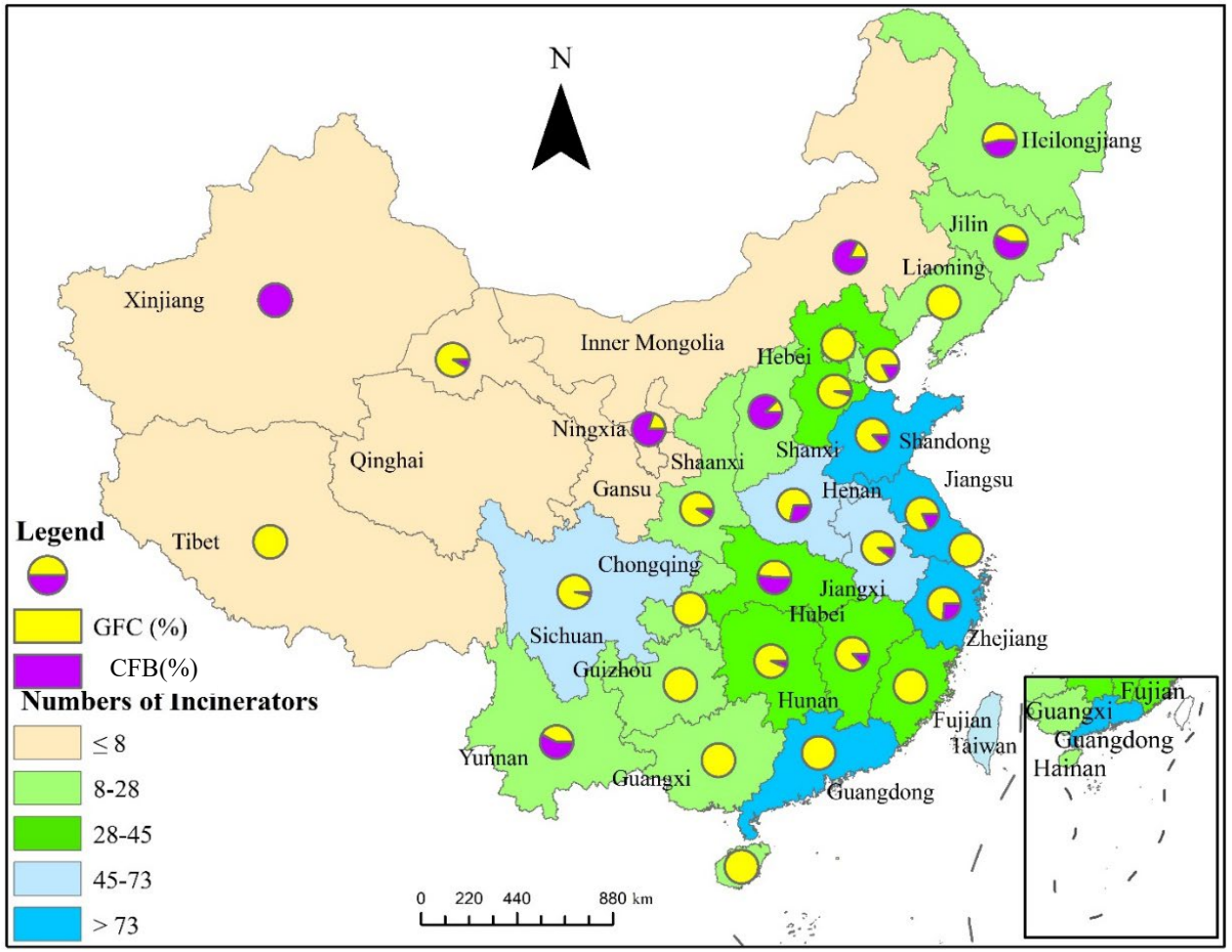
$M_{i,j}$ the amount of MSW (t);

A the coal consumption (t);

R the ratio of coal consumption and the amount of MSWI;

η the mercury removal efficiency

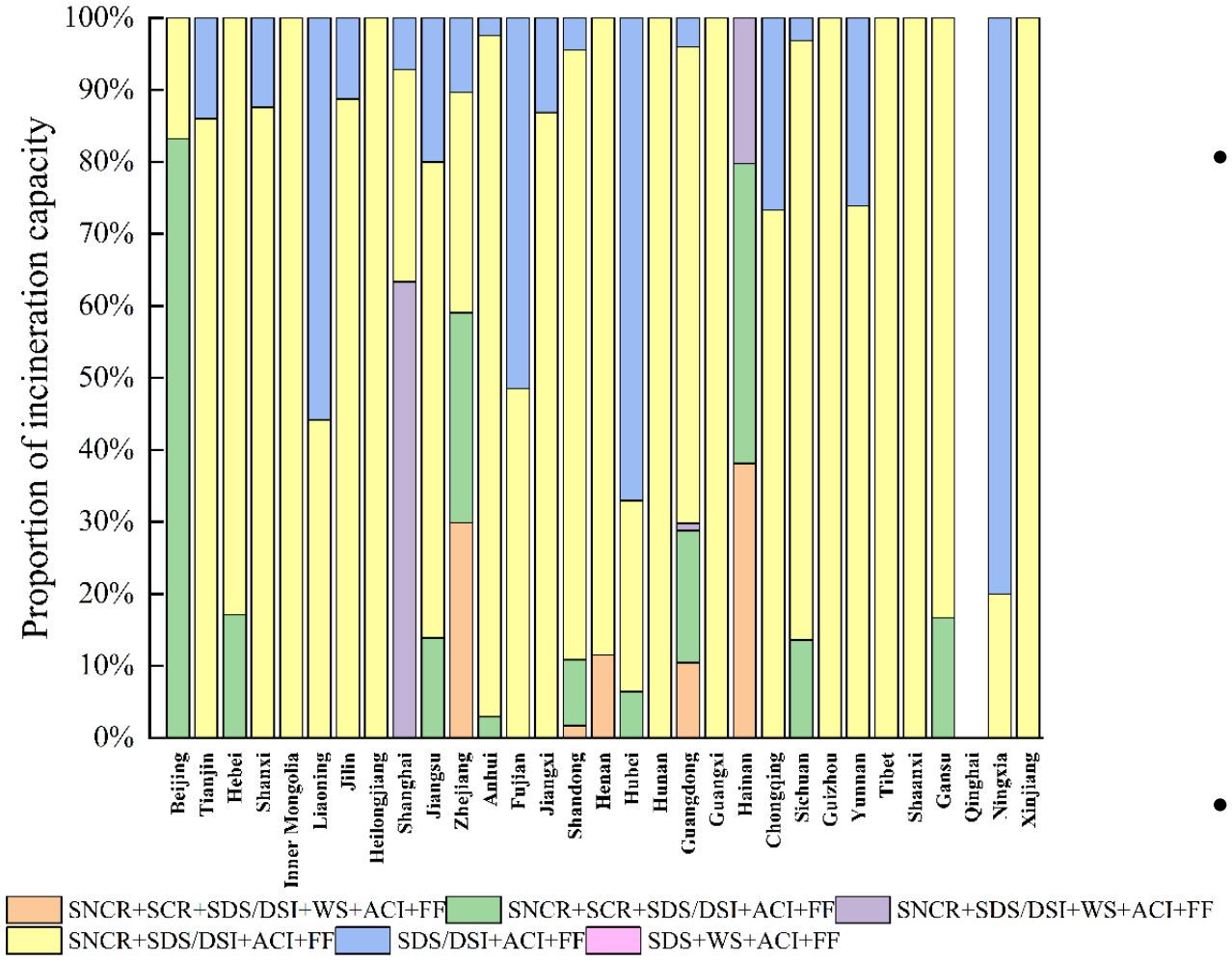
Incinerator type of MSWI plants in China



Geographical distribution of the incineration scale of MSW incinerators and incineration type (2020)

- **Grate furnace combustor (GFC)** and **Circulating Fluidized Bed (CFB)** are the major incinerator types in China.
- **GFCs** are the major incinerator with the 88.76% incineration capacity in China
- **CFBs** are mainly distributed in the central and western China, as the coal resources are mainly located in those area.

APCD types of MSWI plants in China

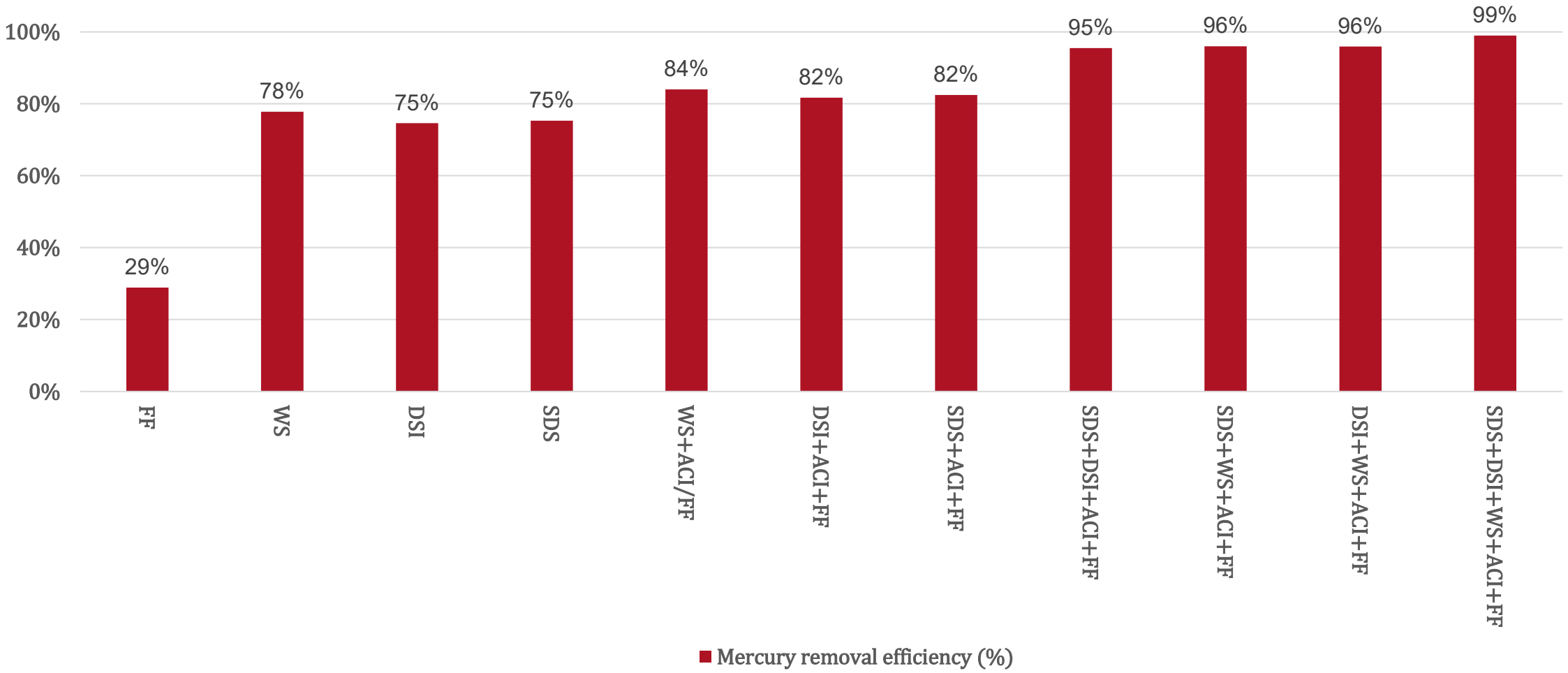


APCD types by MSWI amount in China (2020)

- APCDs including: Selective non-catalytic reduction (SNCR), Selective Catalytic Reduction (SCR),semidry scrubber (SDS), dry sorbent injection (DSI), wet scrubber (WS), activated carbon injection (ACI), fabric filter (FF).

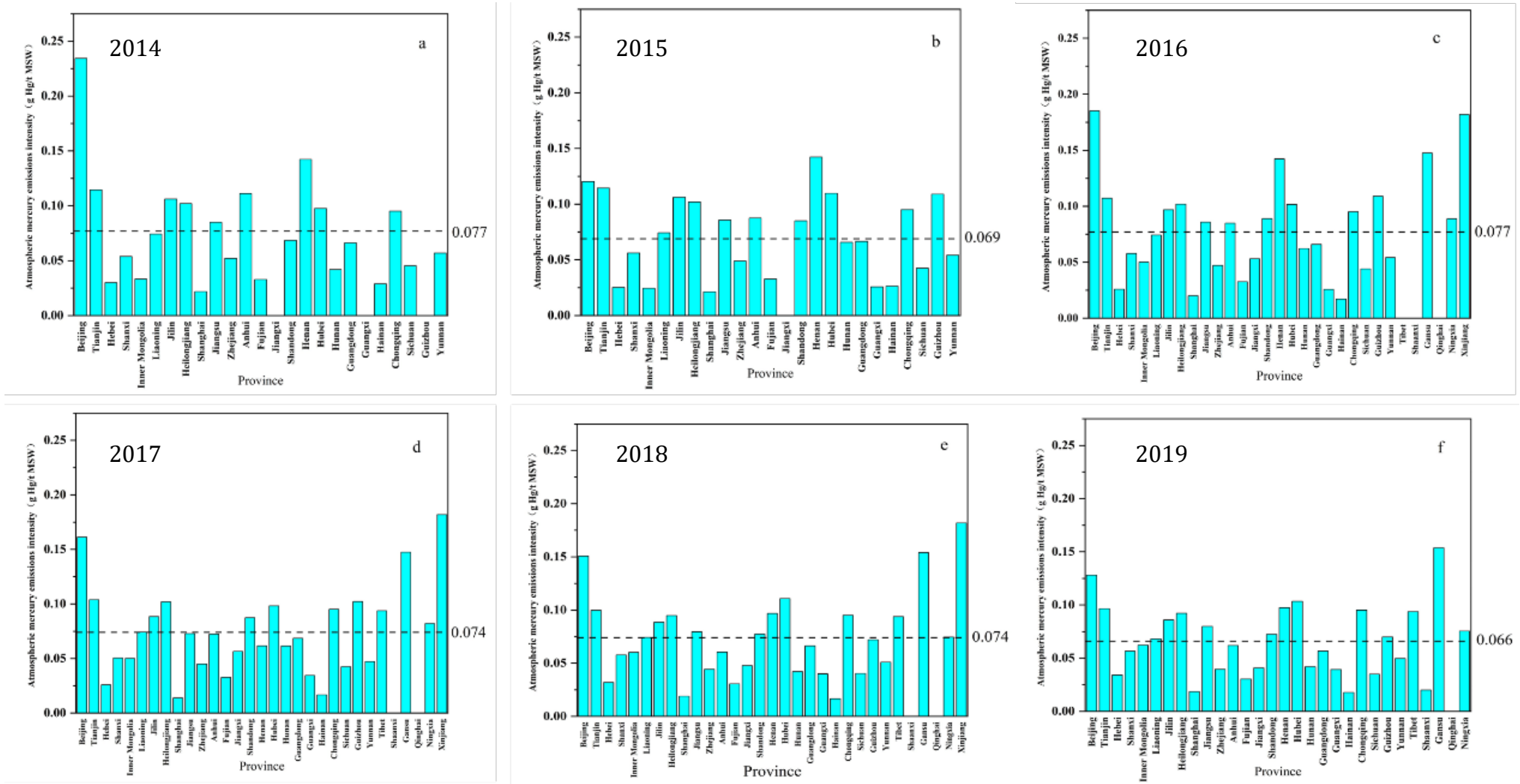
- APCD types of MSWI plants in China are dominated by SNCR+ SDS/DSI+ACI+FF, accounting for 68.94% in 2020.

Mercury removal efficiency (MRE) of APCDs



Takahashi, F. et al. Su , H. T.,et al. Hu, Y., et al. Cheng, H.,et al. Hu, D.,et al.

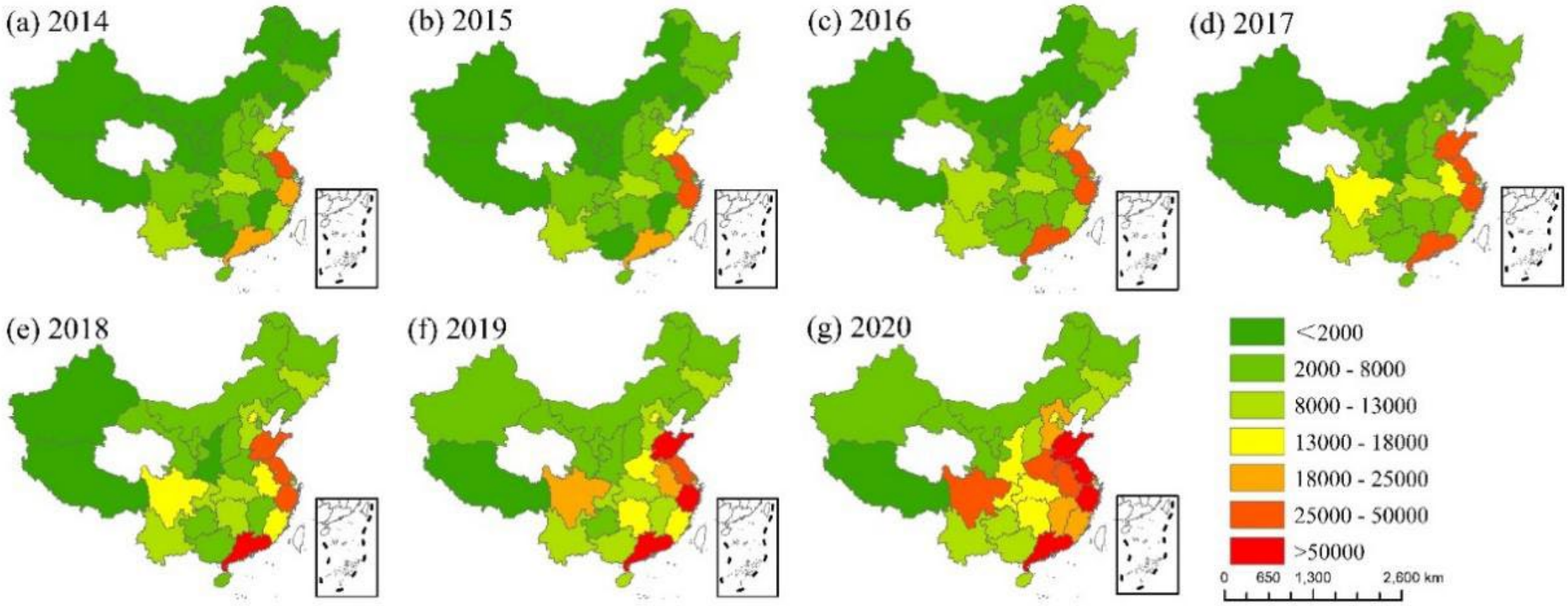
Mercury emission intensity of MSWI process in China



Intensity of mercury emissions from MSWI process in China

The average Hg emission intensity decreased from 0.077 mg·kg^{-1} in 2014 to 0.060 mg·kg^{-1} in 2020

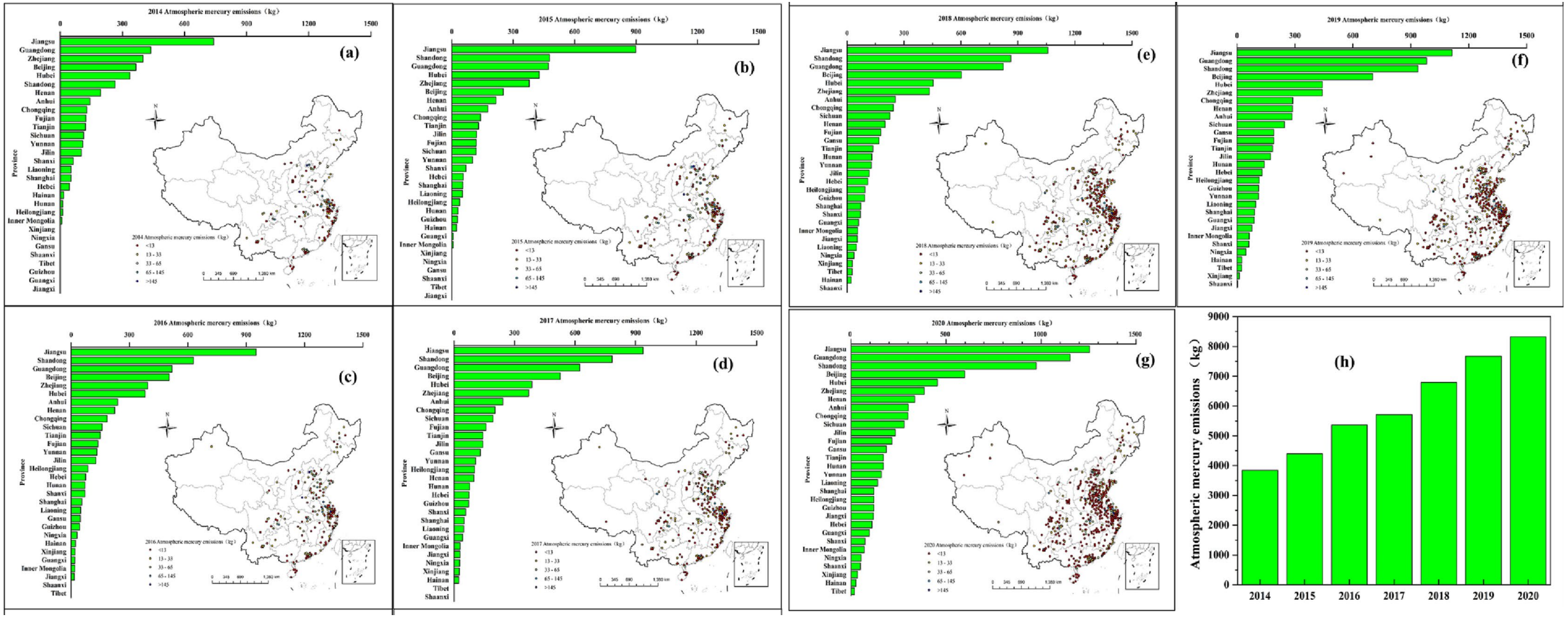
MSWI incineration capacity in China (2014-2020)



Geographical distribution of MSWI incineration capacity in China (t/d)

With the rapid increase in China, the total MSWI capacity increased from 53.29 Mt in 2014 to 146.07 Mt in 2020

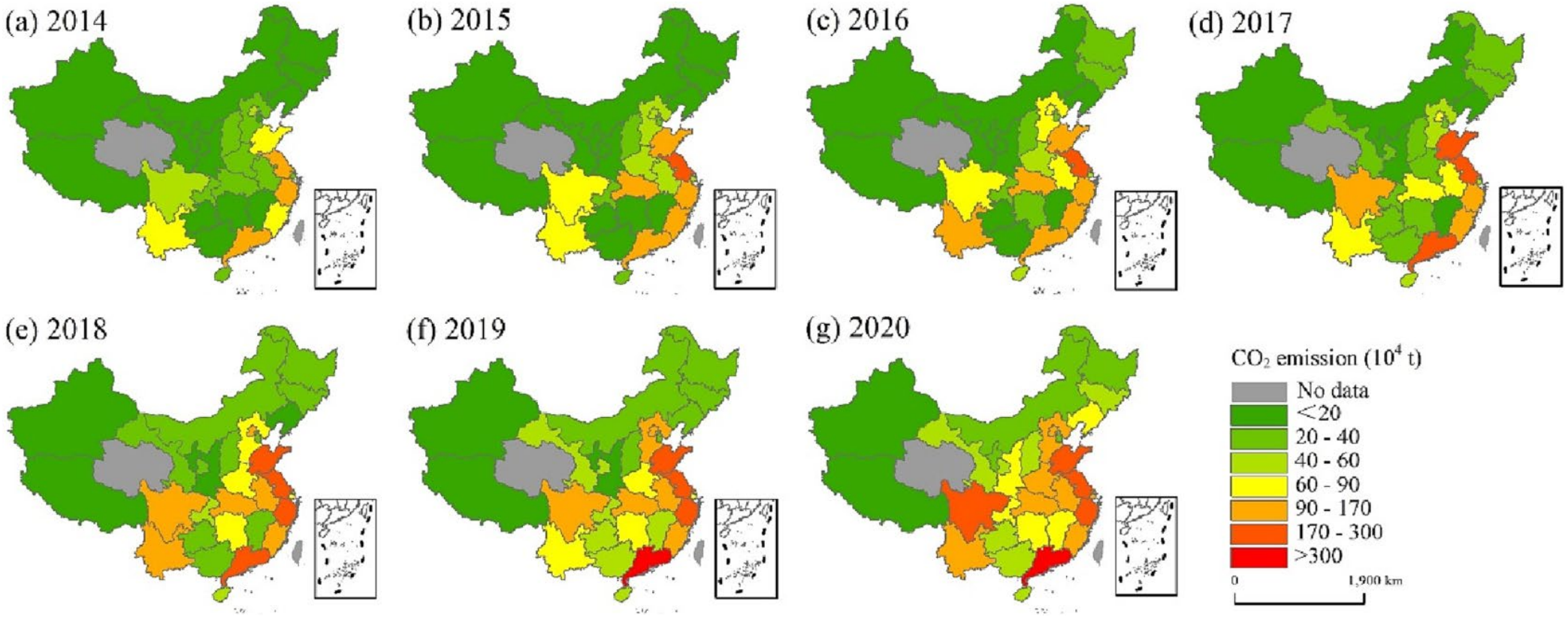
Atmospheric Hg emission amount of MSWI in China



Mercury emissions in the MSWI process in China from 2014 to 2020

The atmospheric Hg emission had been increased from 3.77 t in 2014 to 8.13 t in 2020!

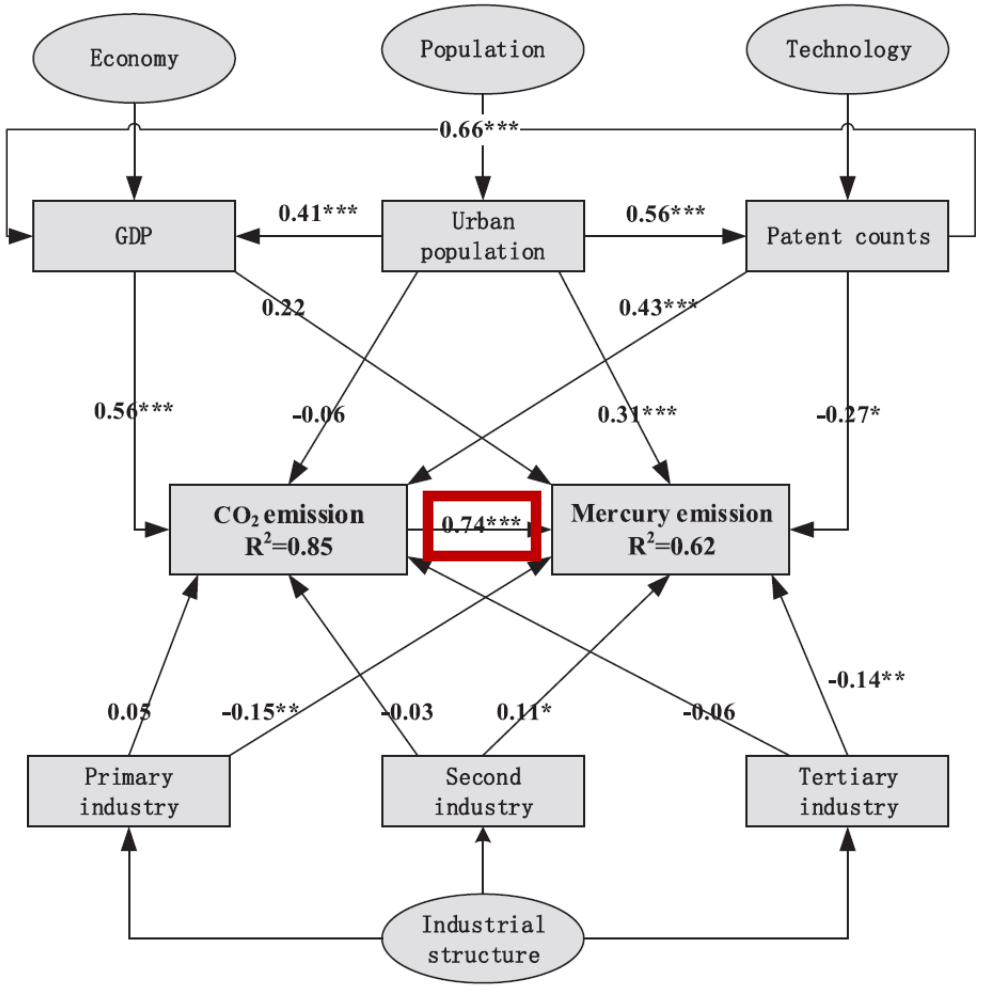
CO_2 emission amount of MSWI process in China



Geographical distribution of CO_2 emissions from MSWI process in China (2014–2020)

According to the method in IPCC Guidelines for National Greenhouse Gas Inventories, the CO_2 emissions from MSWI process was calculated, which had been increased from 21.69 Mt in 2014 to 64.48 Mt in 2020!

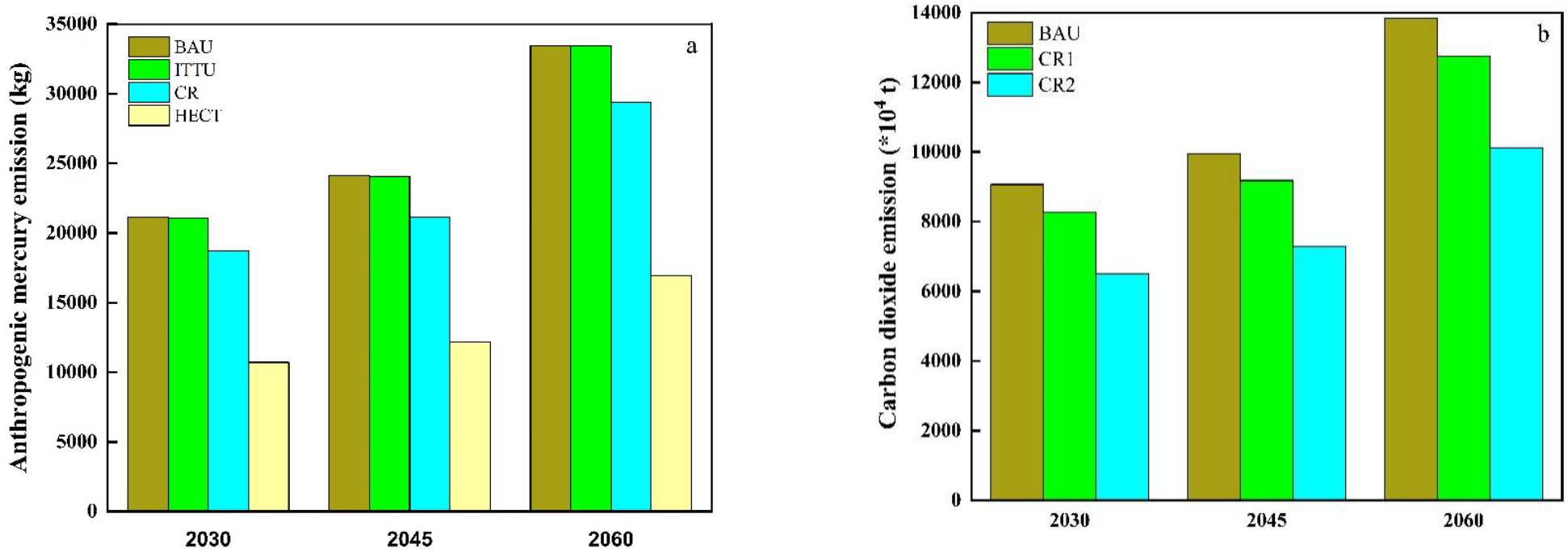
Structural equation modeling (SEM) analysis



SEM results of the mercury and CO_2 emission

- SEM is a statistical research method that analyses the relationship between different variables by constructing a covariance matrix.
- The CO_2 emission was the key factor influencing mercury emission amount from the MSWI process, while GDP was the most important factor influencing CO_2 emission.
- Urban population was the main driver of Hg emission increase, while the patent accounts and the increase of primary and tertiary sectors were the strongest prevention to mercury emission.

Scenarios analysis



Atmospheric mercury emission (a) and CO_2 emissions (b) reduction under different scenarios from 2030 to 2060

- The results indicate that the combining carbon neutrality scenarios with current air pollution control policies is the most cost-effective collaborative approach to Hg and CO_2 emissions reduction.

Implications

- ✓ Promote mercury free products alternatives and reducing the MSW amount to reduce the mercury input in MSWI process.
- ✓ APCDs update and prevent secondary pollution on the solid waste generated from the MSWI process (such as fly ash and slag).
- ✓ To develop carbon mercury collaborative mitigation pathways to explore more cost-effective carbon dioxide and mercury pollution reduction policies and measures.

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Thanks!

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