Minamata Online Season

Mercury Flow in the Wastes Stream of China

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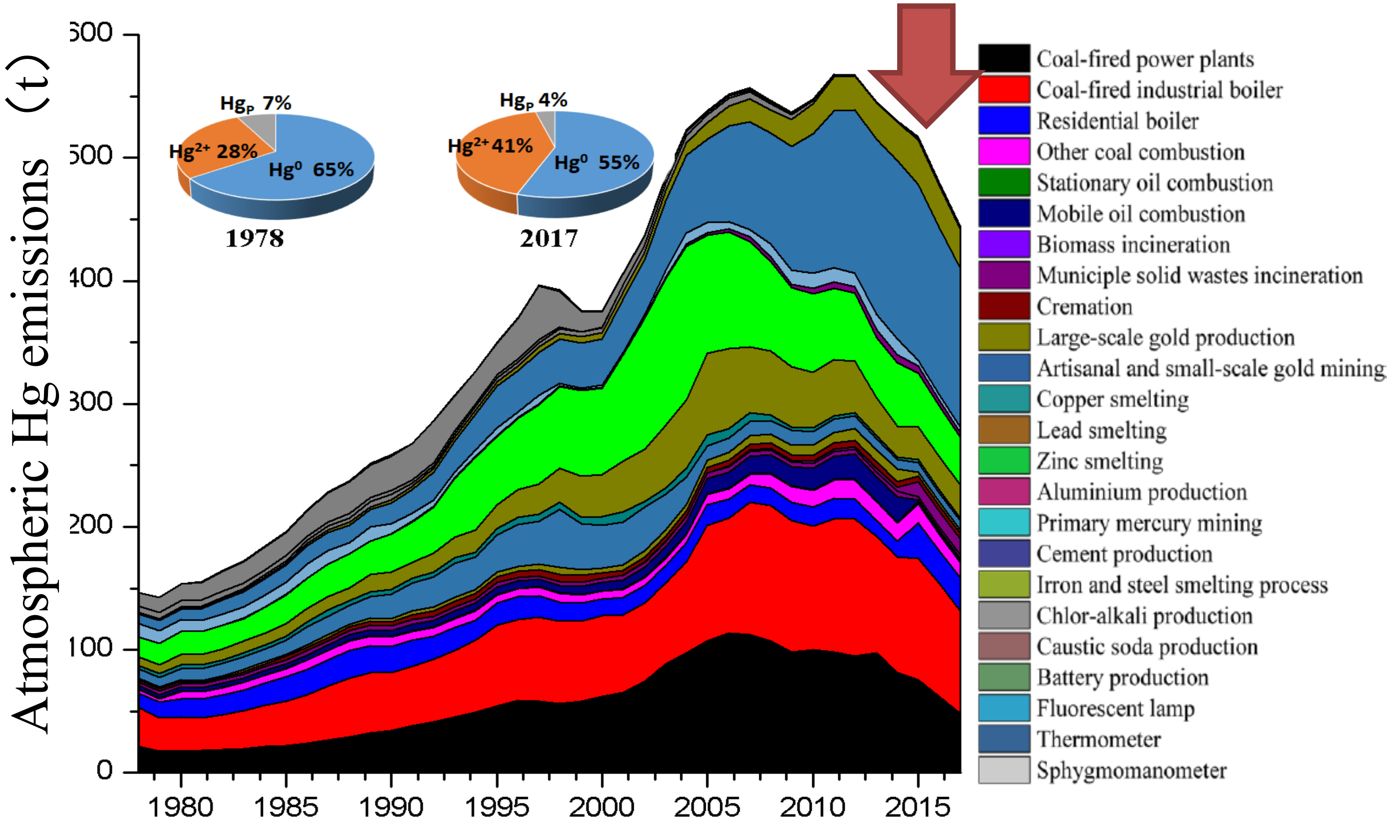
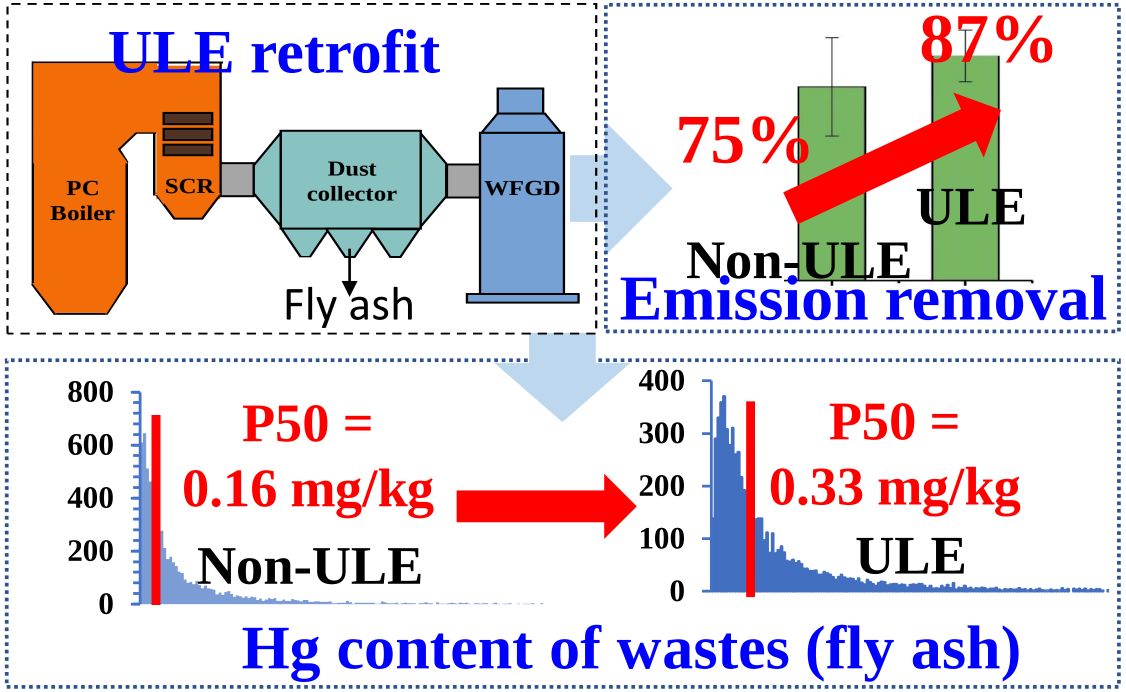
Oct 15, 2020

Air Hg emission trend and cross-media effect





ULE: Ultra-low emission

Atmospheric Hg emissions have shown a downward trend in China.

Improved air Hg emission control led to the increase of Hg burden in the waste.

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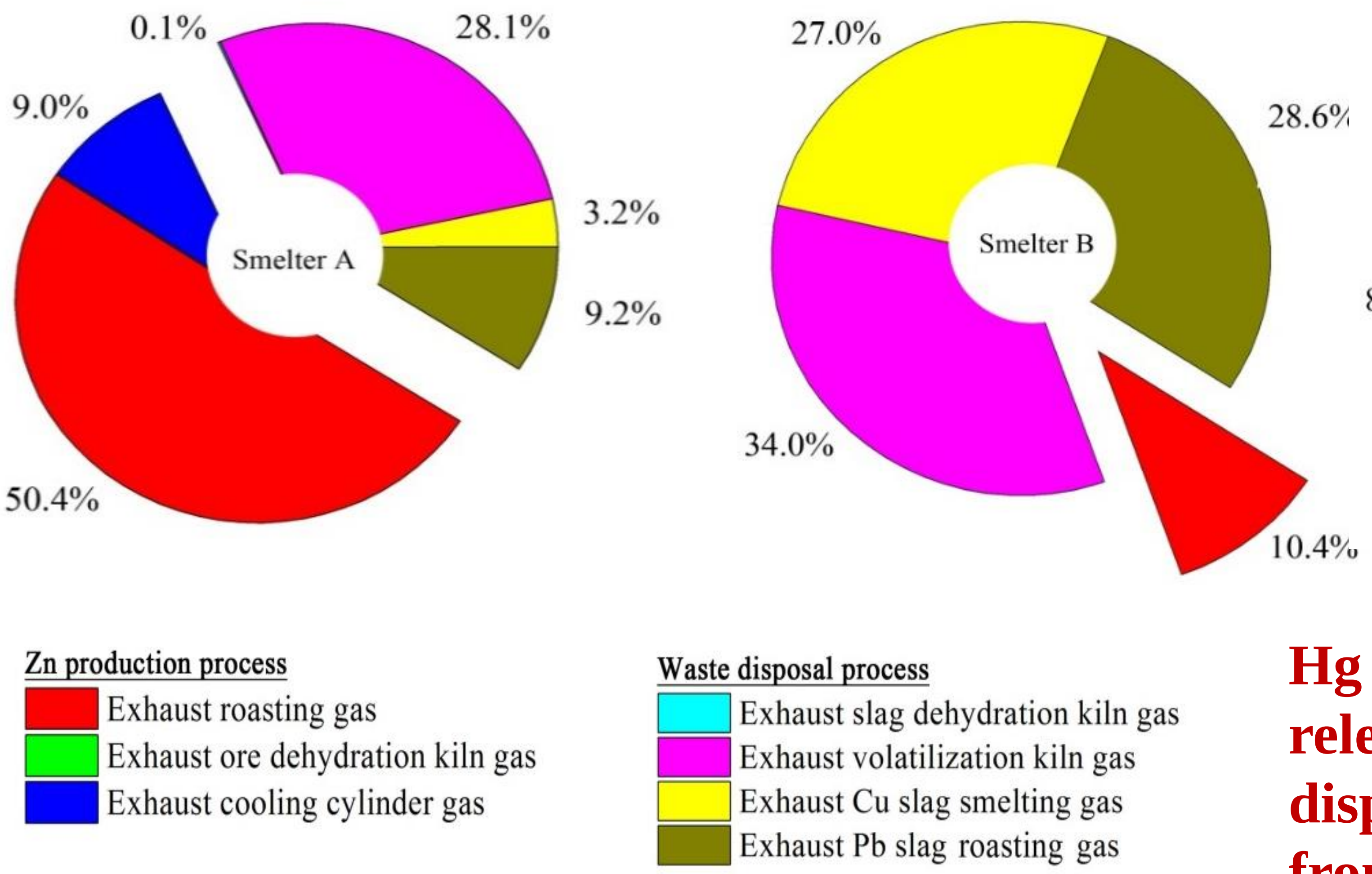
Wu et al., ES&T, 2016; Liu et al., ES&T, 2019 Wen et al., JHM, 2020

How much of Hg in solid wastes is re-emitted?



Hg would be reemitted to air or released to water/soil during the disposal of those waste/byproduct from air pollution control devices.

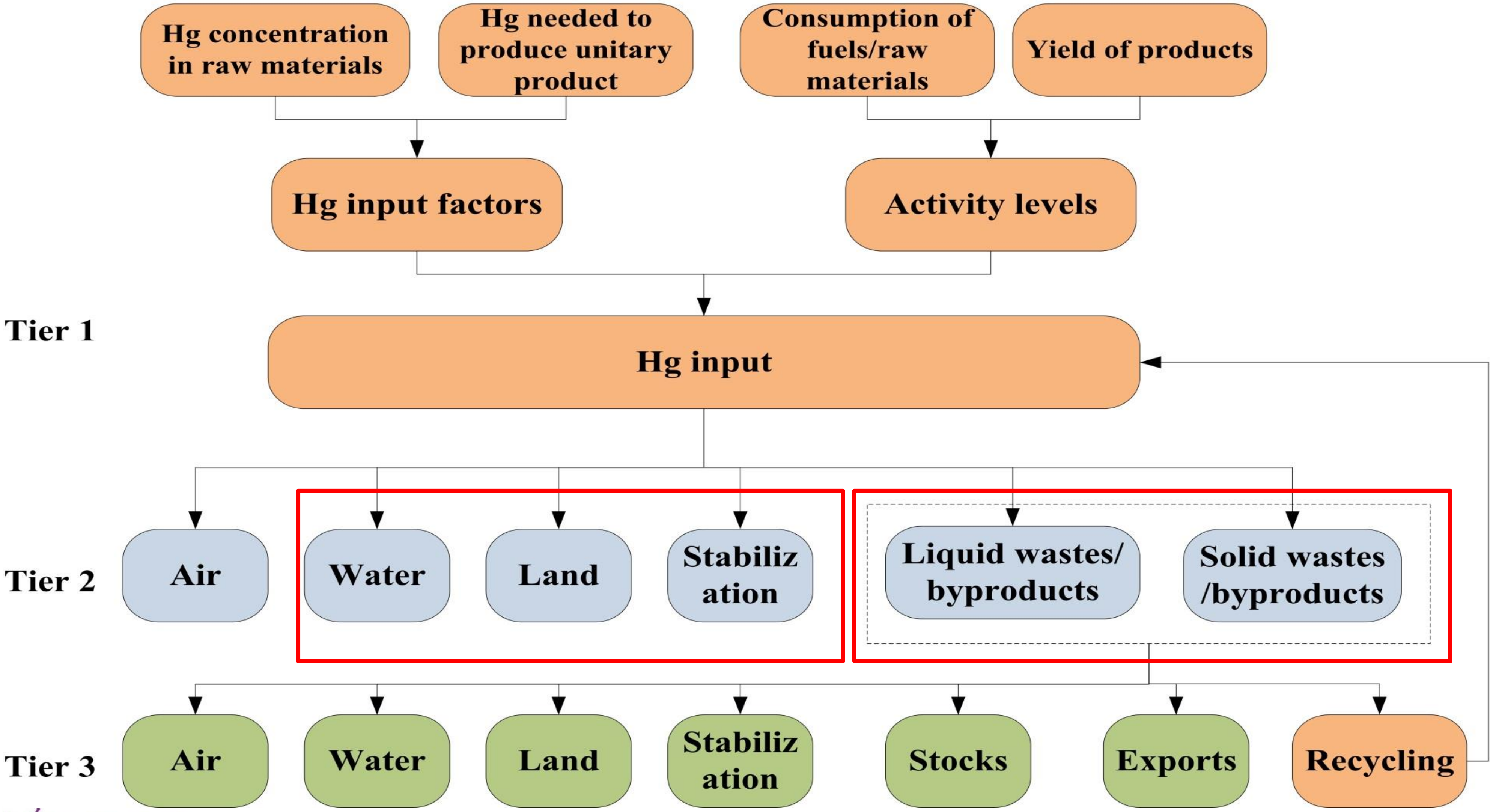
Wu et al., ES&T,2015

Research scope of this study

- To examine the Hg sources and fate in China
- To examine the flow of mercury within and among 8 sectors (31 subsectors)

Fuel consumption	Coal-fired power plants	Incineration and interment	Municipal solid wastes incineration
	Coal-fired industrial boilers		
	Residential coal combustion		Biomass combustion
	Other coal combustion		Interment
	Natural gas combustion	Production activities using Hg	Mercuric chloride catalyst production
	Oil refining		Vinyl chloride monomer (VCM) production
	Oil combustion		
Building materials production	Iron and steel smelting		Thermometer production
			Sphygmomanometer production
	Cement production		Fluorescent lamp production
Nonferrous metal smelting	Copper smelting		Battery production
	Lead smelting		Dental amalgam production
	Zinc smelting	Use of Hg-added products	Use of thermometer
	Industrial gold smelting		Use of sphygmomanometer
	Artisanal and small-scale gold mining		Use of fluorescent lamp
	Aluminum smelting		Use of battery
Hg recovery	Hg production from recyclable resources	Primary Hg ore mining	Primary Hg ore mining

Conceptual framework of mercury flow analysis



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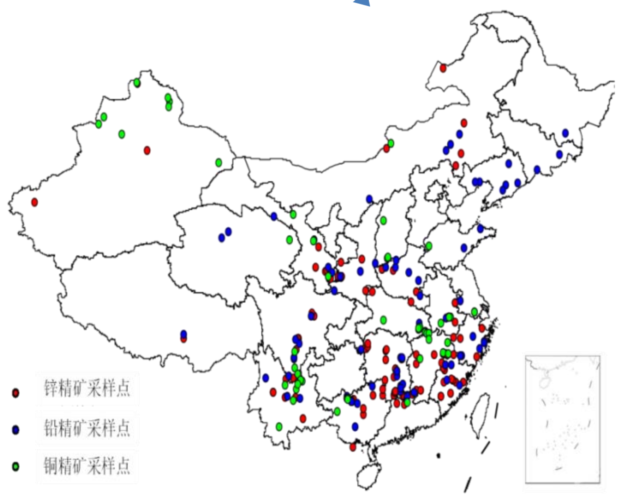
Hui et al., ES&T, 2017

Hg input (Tier 1) and distribution (Tier 2)

Mercury is inputted embedded in raw materials or as pure Hg.

Hg input = Activity level × Hg input factor

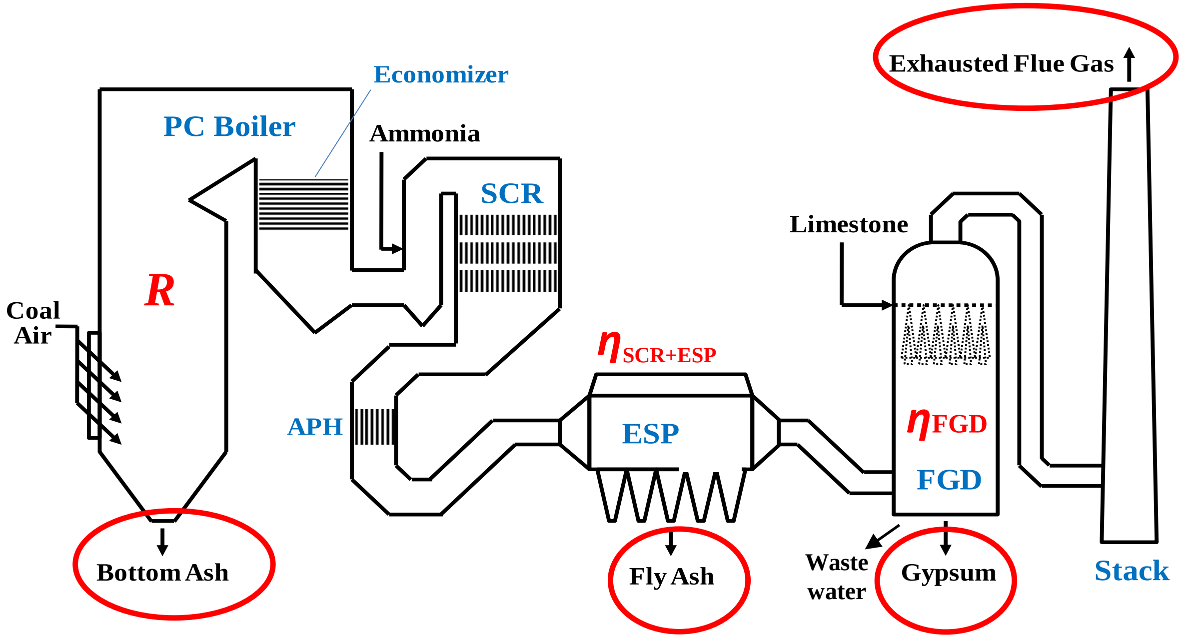


National concentrates sampling sites

Raw material	Sample number
Raw coal	494
Zinc concentrate	381
Lead concentrate	198
Copper concentrate	207
Gold concentrate	26
Limestone	167
Iron concentrate	73

Number of samples

Hg distribution factor are determined by the Hg removal efficiency of air pollution control devices, which are obtained from field measurements.



$df_{bottom\ ash} = 1 - R \quad df_{fly\ ash} = R \times (1 - \eta_{SCR+ESP})$

$df_{waste\ water} = R \times (1 - \eta_{SCR+ESP}) \times \eta_{FGD} \times a$

$df_{gypsum} = R \times (1 - \eta_{SCR+ESP}) \times \eta_{FGD} \times (1 - a)$

$df_{flue\ gas} = R \times (1 - \eta_{SCR+ESP}) \times (1 - \eta_{FGD})$

***R* released rate of PC boiler; $\eta_{SCR+ESP}$ mercury removal efficiency of SCR and ESP; η_{FGD} mercury removal efficiency of FGD; *a* the proportion of mercury to waster waste water**

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Tier 3: Wastes & byproducts

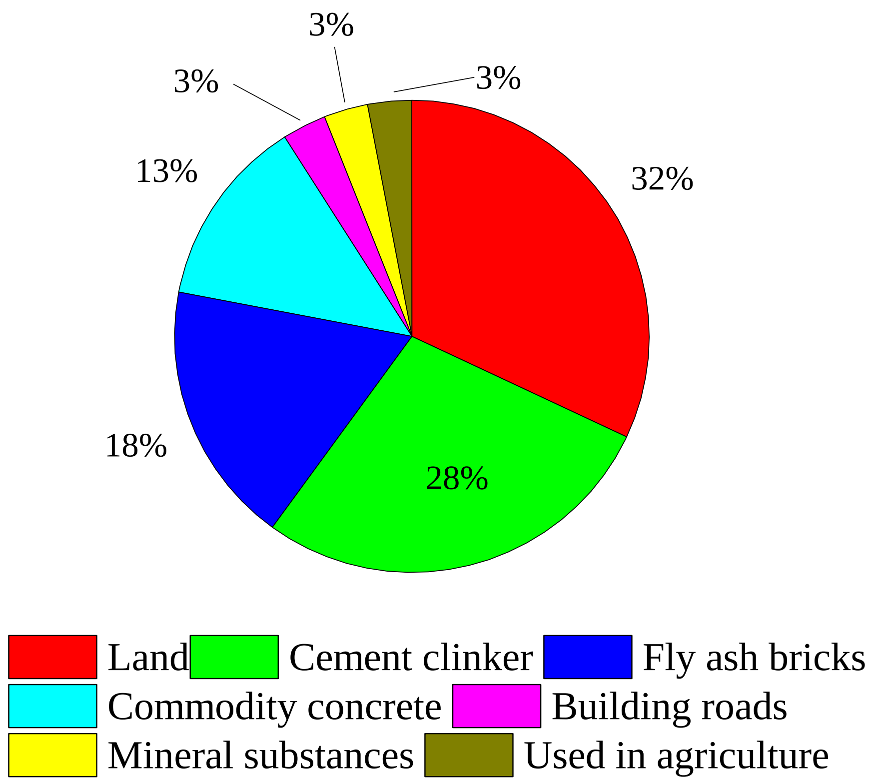
- **How wastes were disposed?**
- **How was Hg re-distributed during different types of waste disposal processes?**

Wastes disposal

- **Wastes**
  - **Industrial wastes**
    - **Metallurgical industry**
    - **Energy industry**
    - **Petrochemical industry**
    - **Mining industry**
    - **Light industry**
    - **Other industry**
  - **Hazardous wastes** — ***National List of Hazardous Wastes***
  - **Municipal wastes**

Disposal of industry wastes

Over half industrial wastes are re-used or land-filled



Wastes disposal

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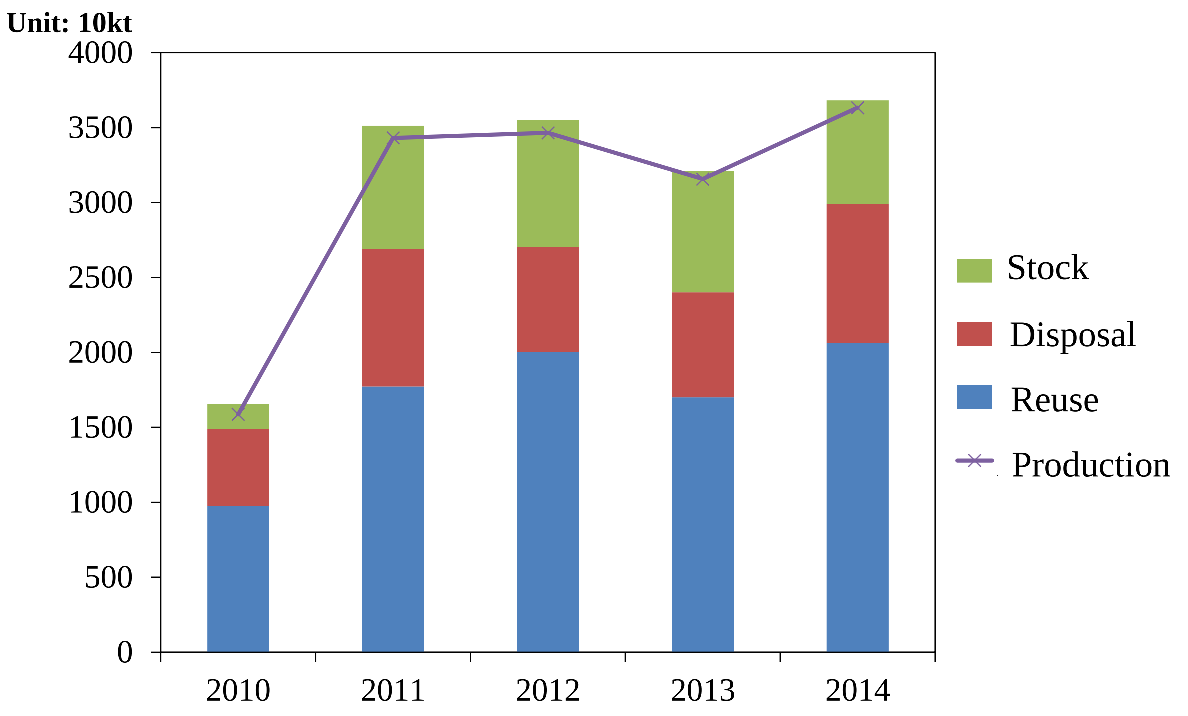
Disposal of hazardous wastes



Wastes disposal

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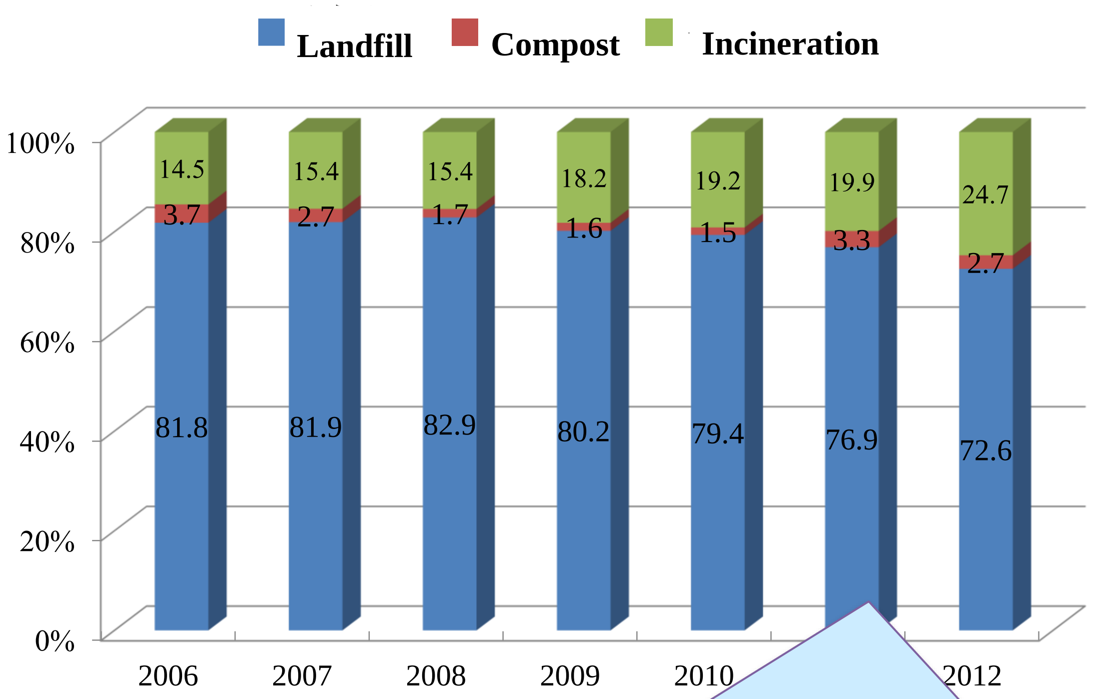

1) **Poor landfill site: Significant environmental pollution**
2) **Controlled landfill site: Problems on seepage, leachate treatment, daily cover**
3) **Advanced landfill site: Standard landfill site, accounting for more than 20%.**

Hg re-distribution during waste disposal (Tier 3)

Final fates of Hg consist of six categories:

- **Hg emissions to air, releases to water, and releases to land**

  Hg emissions/releases in this study do not consider Hg transportation across different environmental media through biogeochemical cycling.

- **Hg exports**

  The term "export" indicates Hg exported abroad by embedding in Hg-containing products

- **Hg stabilization**

  The term "stabilization" means that Hg is properly treated in an environmental sound manner.

- **Hg stocks**

  The term "stock" implies that Hg is stored in wastes and byproducts due to the delay of sales or disposal (more than 1 year). Wastes and products containing Hg are generally sealed-stored. Thus, they are regarded to have few environmental impacts during the storage period. However, once these wastes and products are reused, the embedded Hg will re-enter production activities and cause potential environmental impacts.

Hg re-distribution factors are calculated by identifying the utilization/disposal method of wastes/byproducts and Hg distribution during different utilization/disposal process.

$$r-RE_{l,q}=\sum_{h} RM_{l}\times\alpha_{l}\times\beta_{h}\times\theta_{q\times1,l,h}$$

- The notation $r\text{-}RE_{l,q}$ indicates Hg re-distribution from waste/byproduct l to fate q;
- RM_l stands for Hg embedded in byproduct l;
- α is the utilization rate of waste/byproduct l;
- β_h is the application proportion of treatment process h;
- $\theta_{q\times1,l,h}$ is a column vector, whose element $\theta q_{1,l,h}$ represents the distribution factor from waste/byproduct l to fate q during the treatment process h.

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Re-distribution of Hg in fly ash disposal processes for example

Hg re-distribution during utilization of fly ash

1)Producing cement clinker   5% stabilized; 95% emitted to air

2)Producing fly ash bricks   7%-40% emitted to air; the rest stabilized

3)Producing commodity concrete   100% stabilized

4)Building roads   100% stabilized

5)Producing mineral substances   5% released to water;

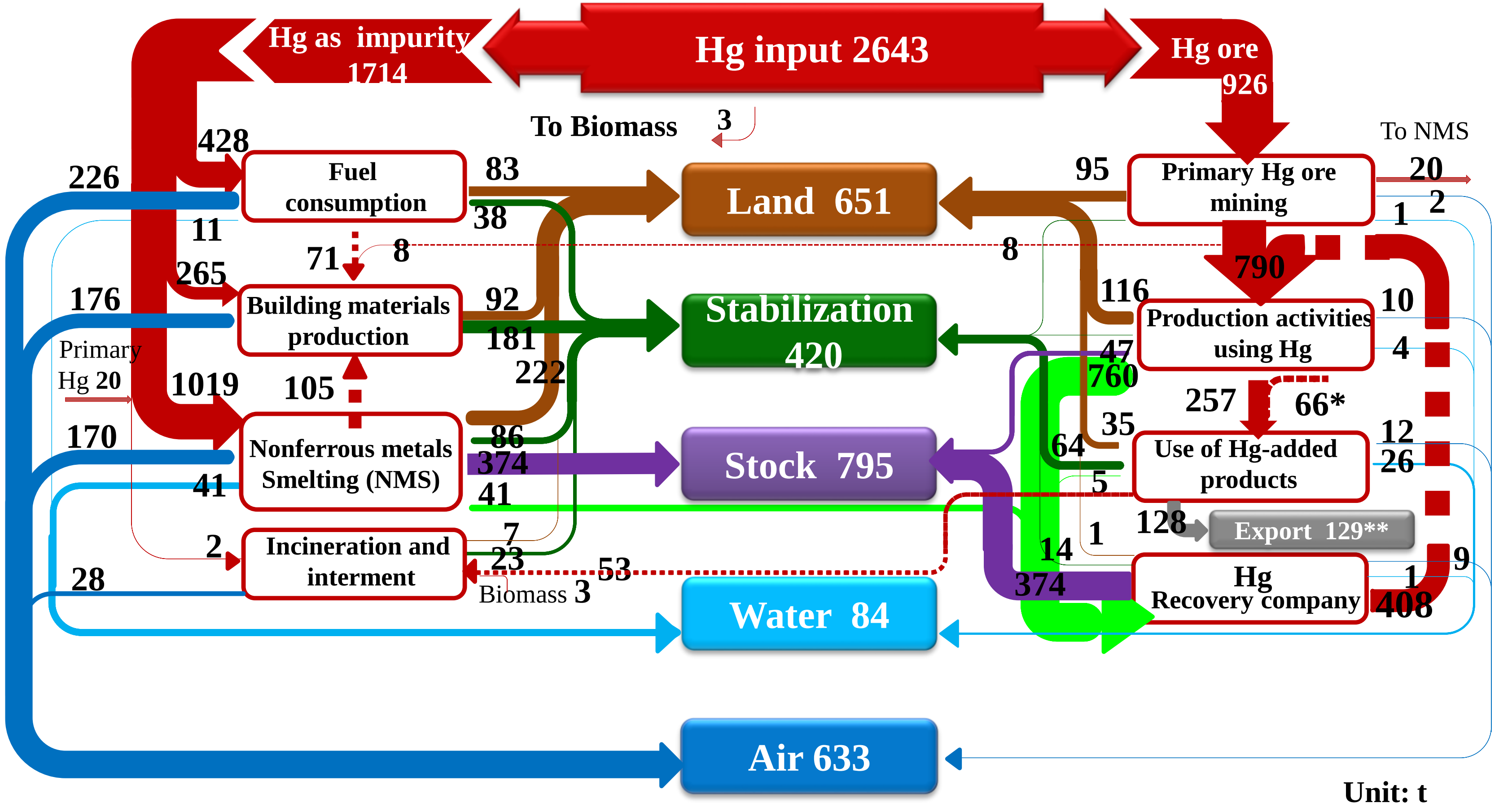
the rest released to land as wastewater treatment residues

6) Used in agriculture   100% released to land

Hg re-distribution factors for fly ash utilization/disposal

Fate	Air	Water	Land	Stabilization
Hg re-distribution factor, %	30.0	0.1	38.0	31.9

Hg flows in China



Hg input: overall situation of motive Hg in China's anthropogenic activities.

clean energy or scrap metals substitution; use of recycled Hg; reducing the production and use of Hg-added products.

Emission and Release: Direct environmental impact:,51.8%

end-of-pipe Hg control;
increasing controlled landfills and strengthening solid waste recycling

Safely disposed: 15.8%

Stock: Potential environmental impact, depending on the disposal/utilization methods

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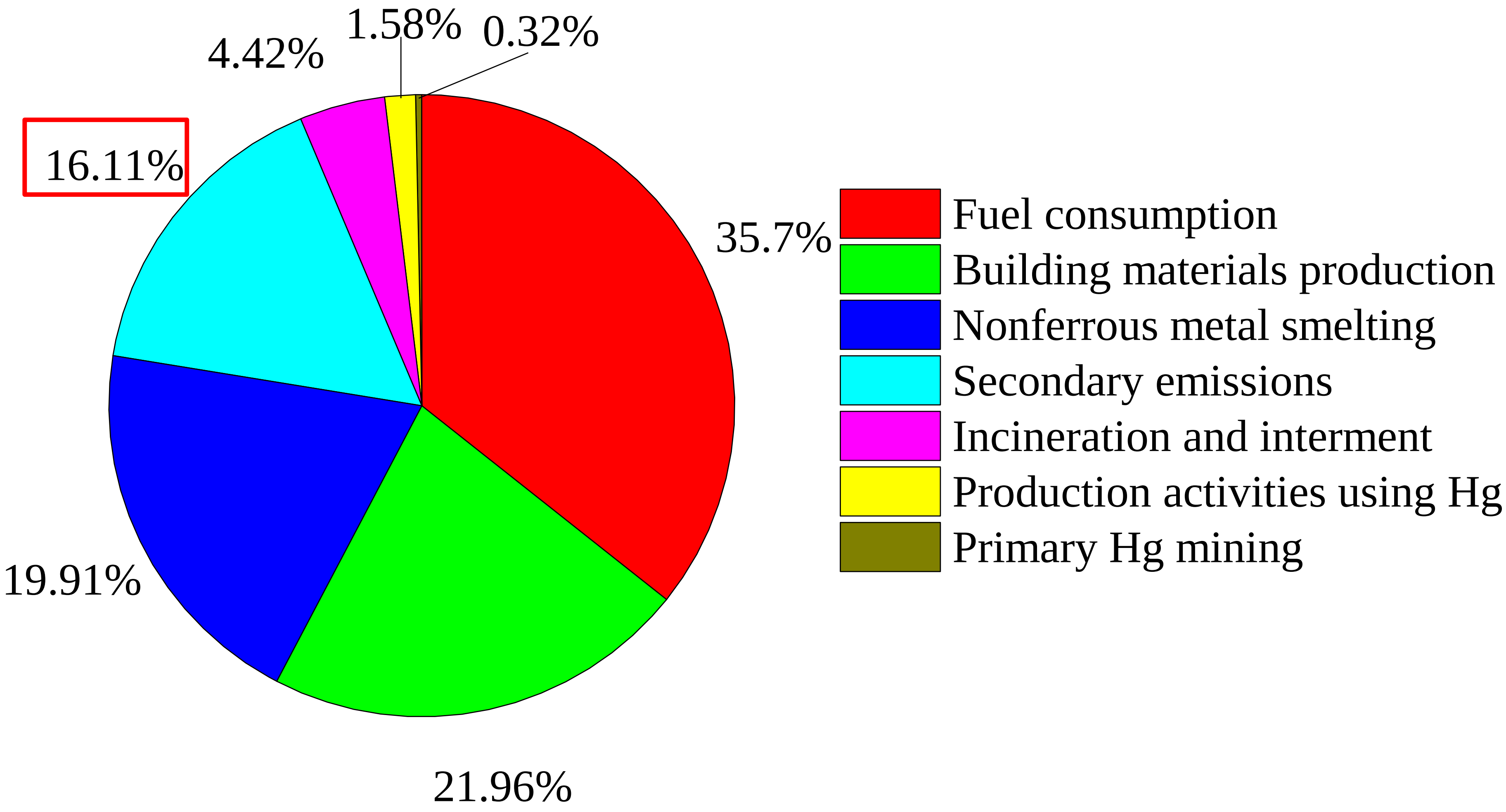
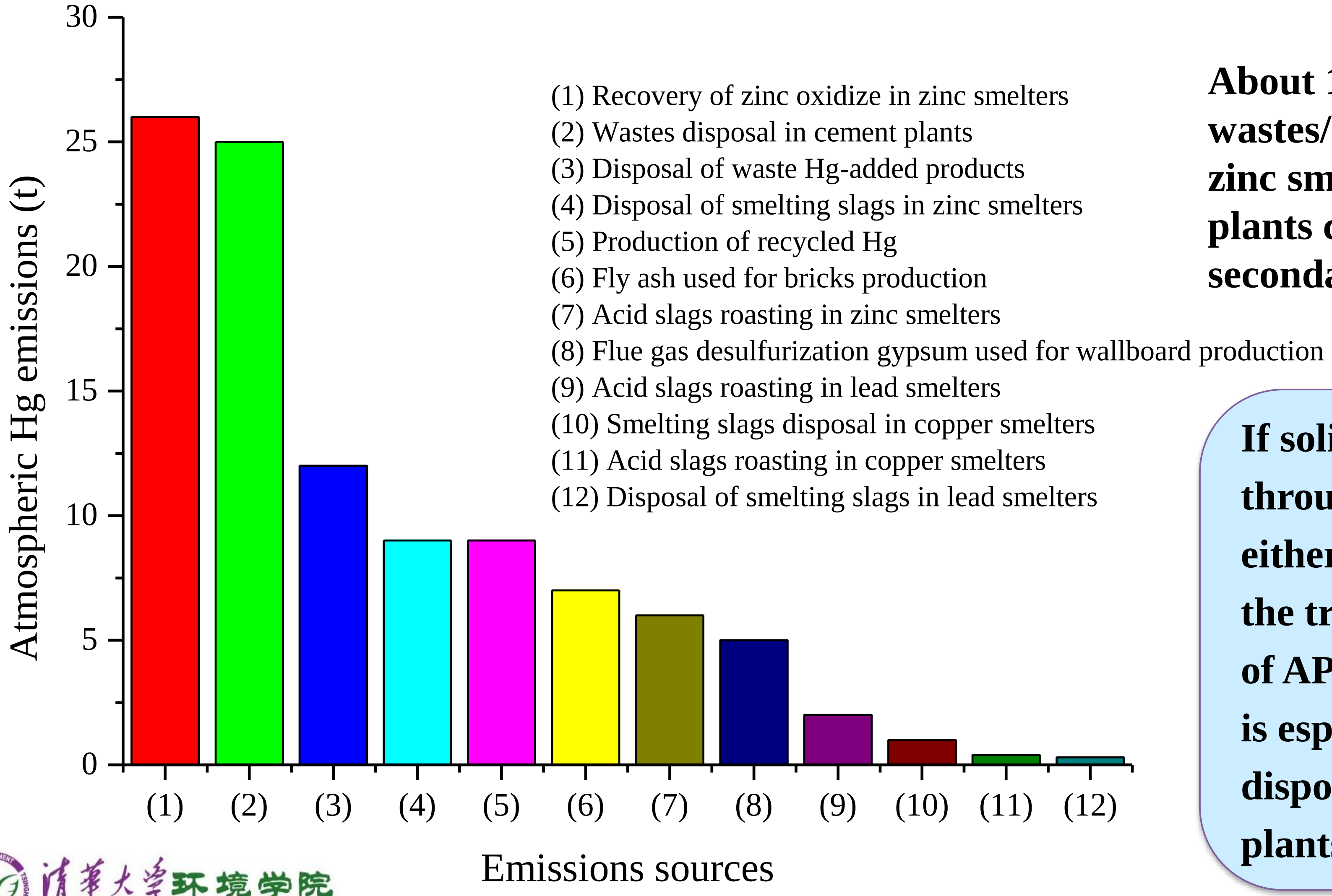
Atmospheric Hg emissions



Hg re-emissions from waste reuse



About 102 t of Hg is emitted due to the use of wastes/byproducts. Recovery of zinc oxide in zinc smelters and wastes disposal in cement plants contribute to 26% and 25% of total secondary atmospheric Hg emissions.

If solid wastes containing Hg are treated through high temperature, we should either remove Hg from solid wastes before the treatment or strengthen Hg reduction of APCDs for treatment procedures. This is especially important for solid wastes disposal in zinc smelting and cement plants.

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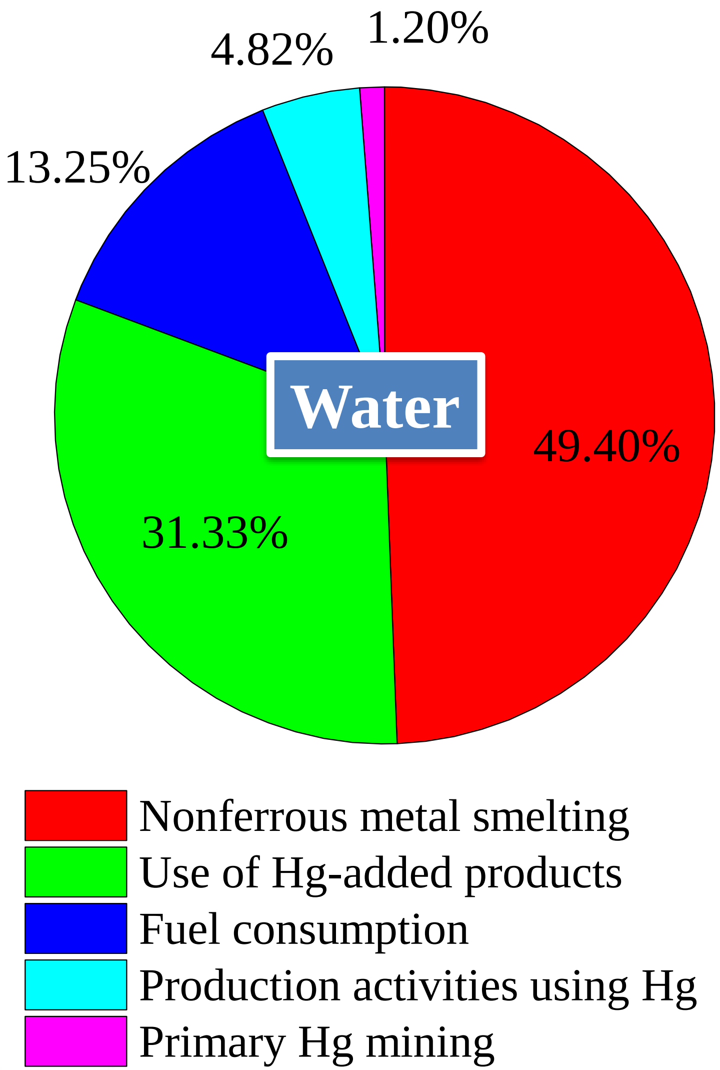
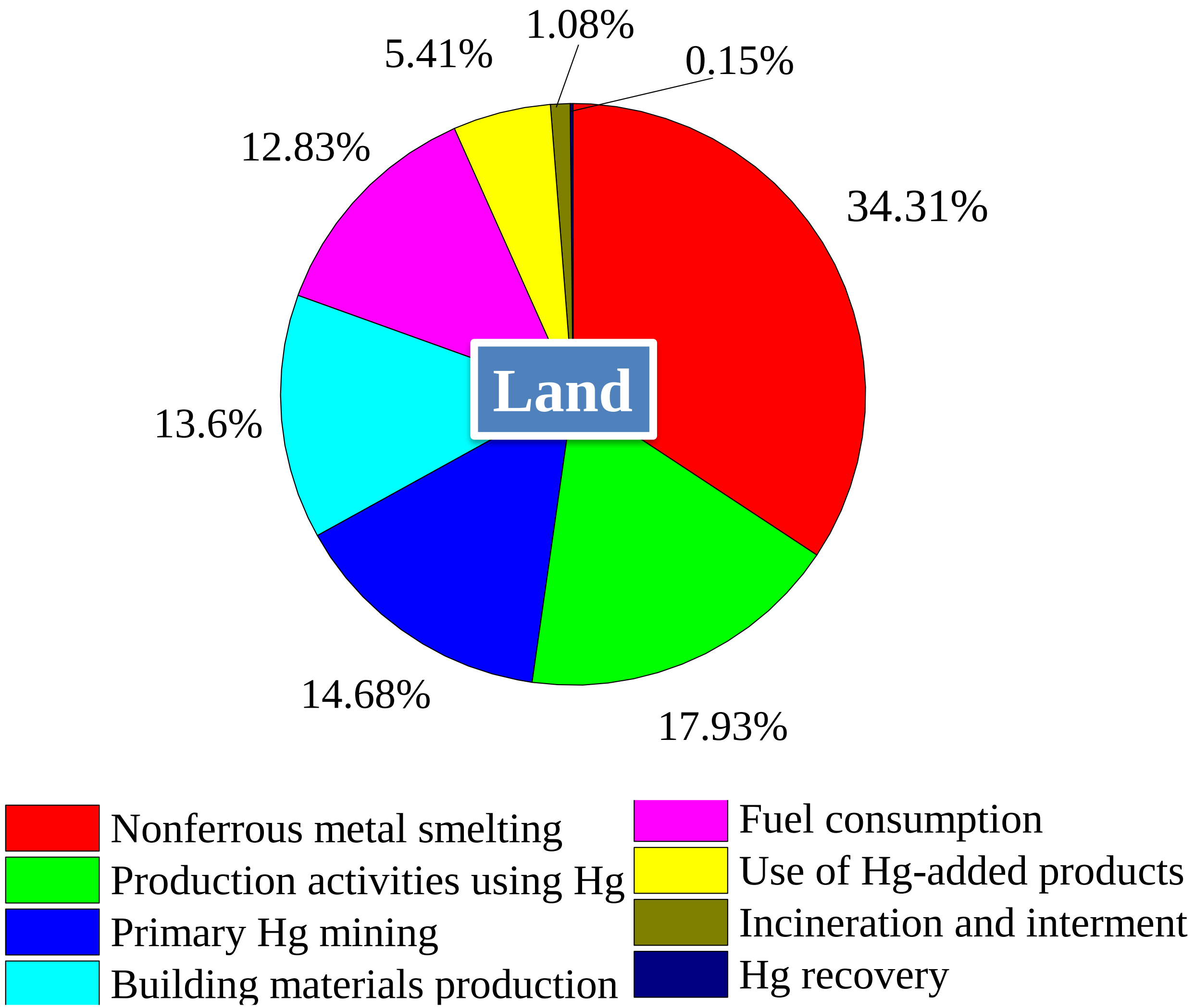
Hg release to water and land





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Hg stocks in wastes/products

Subsectors	Hg stocks (t)	Waste/product types
Hg recovery	374	Hg-containing catalysts, waste activated carbon
Zinc smelting	310	Waste acid sludge, waste water treatment sludge, calomel
Lead smelting	40	Waste acid sludge, waste water treatment sludge
Fluorescent lamp production	40	Fluorescent lamp
Copper smelting	18	Waste acid sludge, arsenic slag, waste water treatment sludge
Dental amalgam production	7	Dental amalgam
LGSP	7	Waste acid sludge, waste water treatment sludge, arsenic slag

- Wastes stored in the Hg recovery companies and zinc smelters can be used as Hg recovery materials.
- Utilization/disposal of these wastes in a environmental sound manner will reduce potential emissions/releases

Challenges for Hg waste management

Around 651 t Hg released to land, which proposes environmental risks. Around 795 t Hg stored in the wastes, which proposes big challenge for waste treatment/disposal.

- **Information gaps: No information system on the production, transfer, recycle, and disposal of Hg-containing waste.**
- **The system of waste sorting, collection and recycling is still in its infancy.**
- **Current comprehensive utilization of solid wastes can reduce Hg releases to land, but lead to Hg re-emissions to air.**
- **Limit values for mercury containing waste are not set. Technical guidelines on mercury waste management in environmentally sound manners not set.**

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Thank you for your attention!

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