A Study on the Improvement of Mercury and Arsenic Pollution Treatment Technologies of Soil and Groundwater in Korea and Taiwan

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Outlines

1. Introduction and Background
2. Current Status of Hg and As Contamination Challenges in Taiwan
3. Remediation Technologies for Hg and As
4. Case Study
5. Conclusions and Recommendations

1 Introduction and Background

The objectives of this study

- ☑ Seeking for ways to advance the management system for Hg and As contamination in soil and groundwater;
- ☑ Proposing an advanced Hg and As management system for discharge, exposure reduction, and monitoring in Taiwan (and Korea);
- ☑ Seeking for ways to improve law, system, and policies to advance the mercury contamination management

2 Current Status of Hg and As Contamination Challenges in Taiwan

Taiwan's regulatory standards and principles

Arsenic

- Soil Pollution Monitoring Standard:**30** mg/kg
- Soil Pollution Control Standard:**60** mg/kg
- The first type of Groundwater Pollution Control Standard is **0.05** mg/L, and the second type is **0.5** mg/L, while the first type of Groundwater Pollution Monitoring Standard is **0.025** mg/L, and the second type is **0.25** mg/L

Mercury

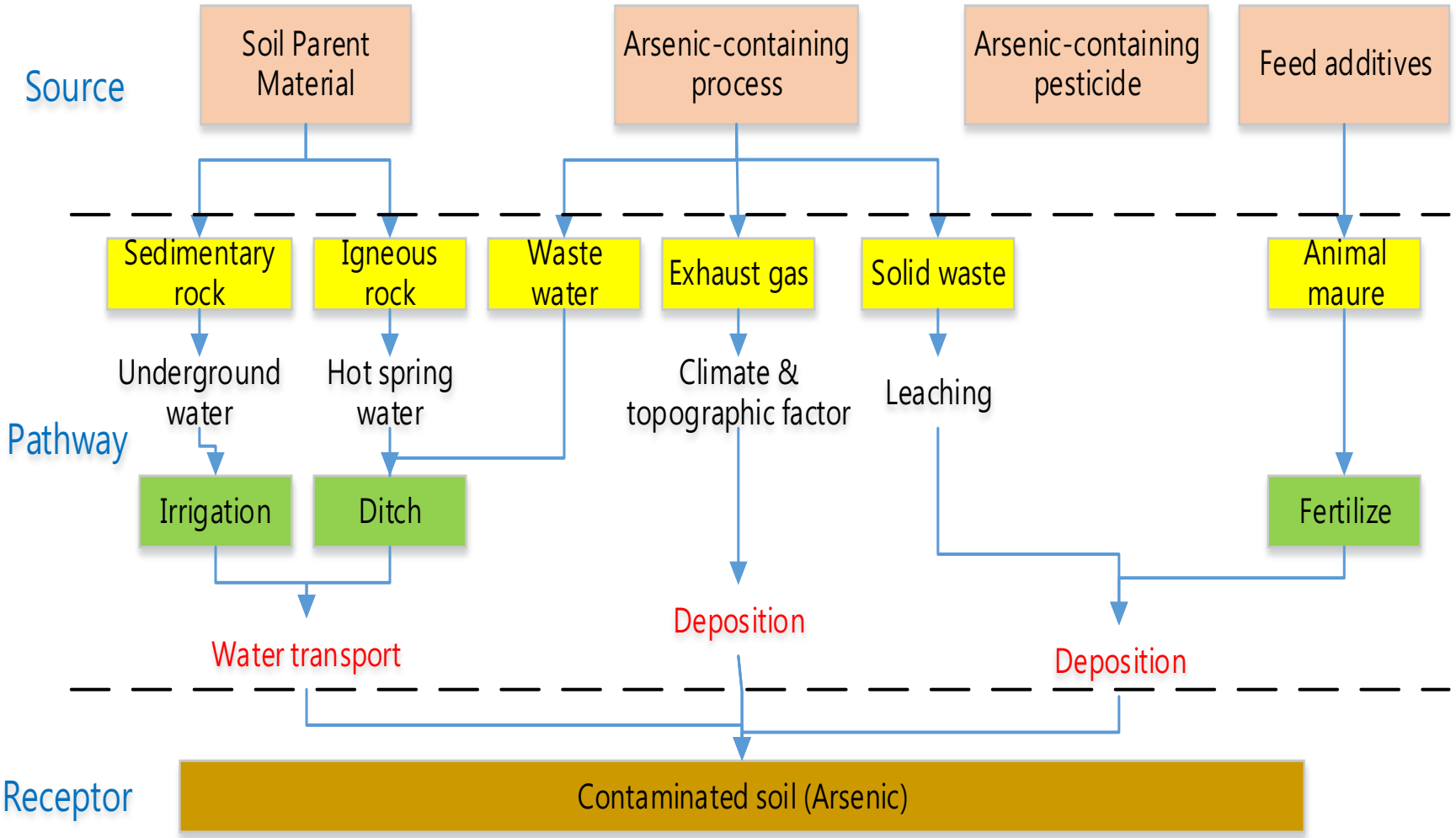
- Soil Pollution Monitoring Standard:**10** mg/kg
- Soil Pollution Control Standard:**20** mg/kg
- The first type of Groundwater Pollution Control Standard is **0.001** mg/L, and the second type is **0.01** mg/L, while the first type of Groundwater Pollution Monitoring Standard is **0.002** mg/L, and the second type is **0.02** mg/L

Mercury Contamination

- Mainly from industrial operation such as alkali chloride industry, fluorescent tube manufacturing
- Some are agricultural land and illegal dumping sites
- There are two listed sites from industrial operation. One site has been delisted and under post delisting monitoring

序	縣市別	場址名稱	統合案件	場址類別	場址面積(平方公尺)	土壤污染物 / 地下水污染物	列管狀態 / 列管日期	改善整治進度
1	新北市	原台灣金屬鑄業股份有限公司及其所屬三條廢煙道地區(部分) [F10055]	污染行為人自行辦理之污染控制場址 [IC00031]	工廠	297,668.00	鎘;砷;銅;鉛;鋅;汞;總石油碳氫化合物;多氯聯苯	公告為整治場址	10%
						砷	107.08.15	第2階段-(123-2-01)通知行為人/關係人提出調查及評估計畫
2	苗栗縣	國泰塑膠工業股份有限公司竹南廠 [K10020]	污染行為人自行辦理之污染控制場址 [IC00031]	工廠	12,581.00	汞	公告解除控制場址	100%
						汞	105.07.01	第5階段-(999-0-01)結束程序
3	新北市	順正泰化工股份有限公司(部分場址) [F00018]	無	工廠	1,729.49	汞	公告為控制場址	10%
						汞	99.05.27	第1階段-(A16)行為人/潛在責任人/關係人是否願意提出控制計畫

2 Current Status of Hg and As Contamination Challenges in Taiwan



The sources of As contamination are more various compared to Hg. Thus, it needs to consider the nature cause in addition to human activities.

Arsenic concentration in soil affected by human activities

- Extract arsenic-containing groundwater as irrigation water
- Surface arsenic-containing hot spring water as irrigation water
- Conversion and accumulation of arsenic species caused by the use of fertilizers and pesticides
- Emissions pollution from industries containing arsenic

Arsenic concentration in groundwater is mostly caused by nature environment

- Mainly, the geological setting and mineralogy
- The environmental conditions may influence the release of As into groundwater, such as
  - pH value
  - Redox environment
  - Organic matter
- For natural cause of contamination, risk based assessment, remedy, and management are allowed

2 Current Status of Hg and As Contamination Challenges in Taiwan

Risk Management Framework for Nature Cause

Risk assessment

- Nature cause confirmation
- Human health risk assessment (usually Tier 3 due to the involvement of food chain)
- Related authority and agency assemble the committee

Risk management

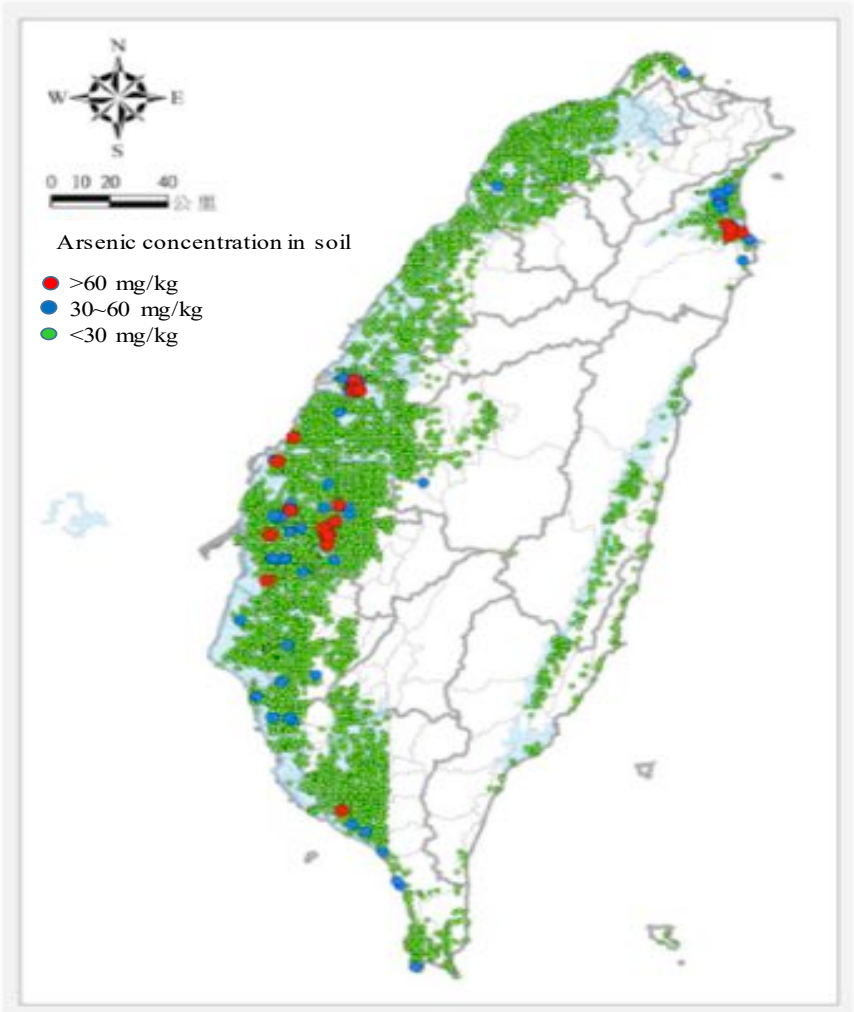
- Potential remedy choices
- Find alternative sources of water (for irrigation)
- Change the behavior of receptors (e.g., farmer)
- Continuous and long term monitoring

Risk communication

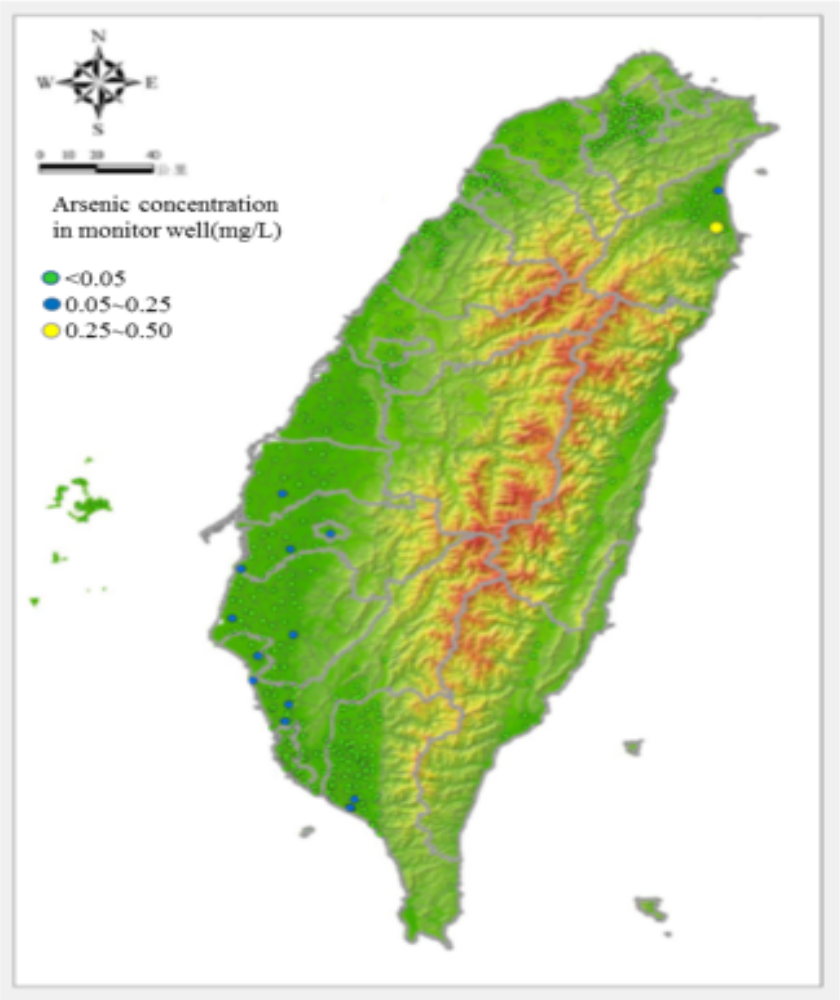
- Release of information and notices to stakeholders
- Meeting and advice to stakeholders with respect to daily behavior (*e.g*, production, diet, and used of groundwater)
- Risk-based remediation goal reveal

2 Current Status of Hg and As Contamination Challenges in Taiwan

Investigation of the arsenic in soil

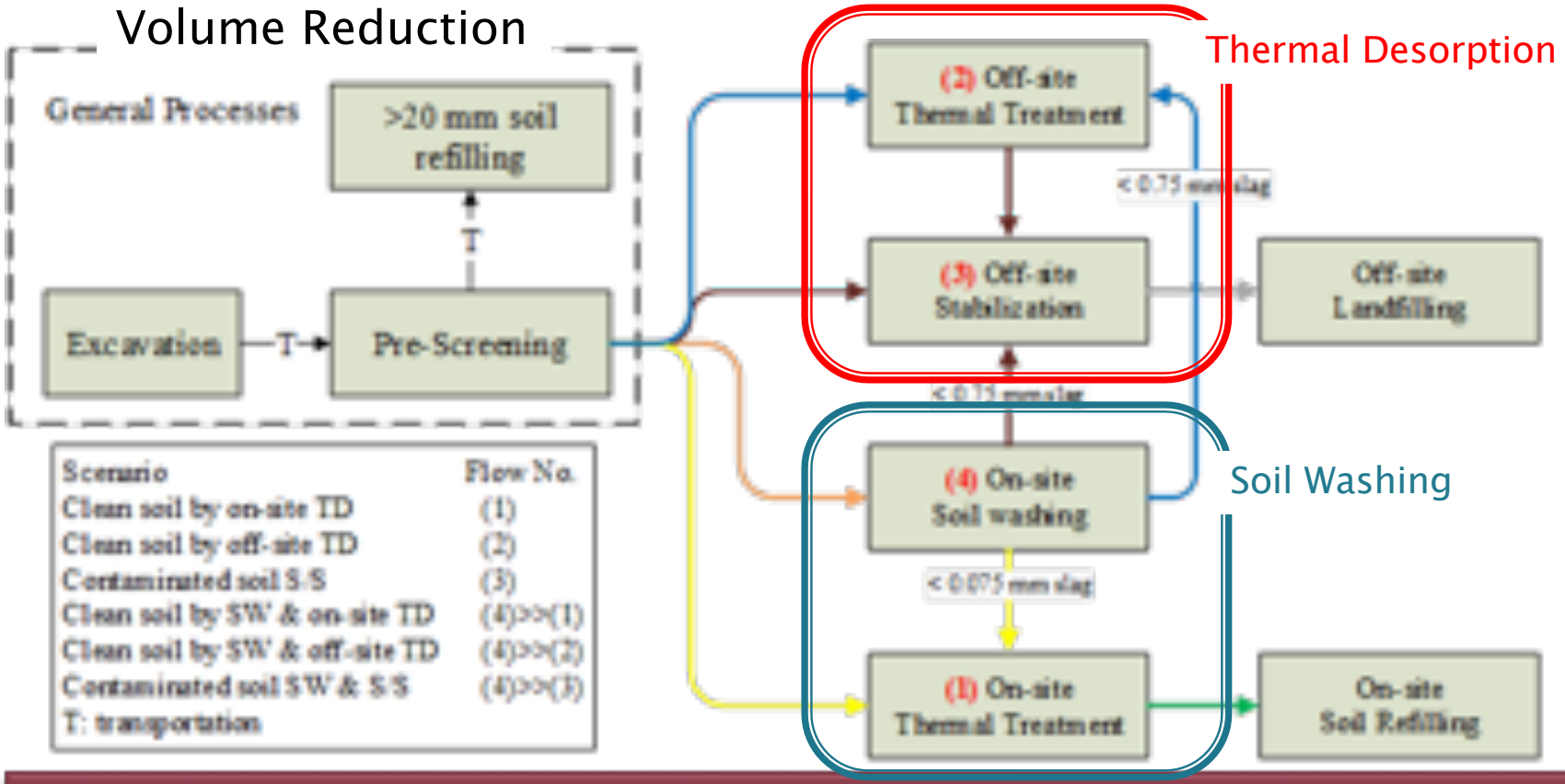


Investigation of the arsenic in groundwater



3 Remediation Technologies for Hg and As

Remediation Technologies for Mercury



Most frequently used of technologies for Hg contaminated soil are thermal desorption and soil washing(screening) or combination of both.

3 Remediation Technologies for Hg and As

The advantages and disadvantages of remediating arsenic in soil

Process	Type	Advantages	Disadvantages
Soil disposal	*Ex-situ*	■ Operation easily ■ Shorter remediation period	■ A lot of waste soil ■ Noise and dust problems ■ Not sustainable
Vertical soil mixing	*In-situ*	■ Operation easily ■ Easily to control remediation period and cost ■ Multipoint operation	■ Contaminant is not removed ■ Making deeper soil polluted ■ Not suitable for high water table and concentration ■ Hard to stir well
Solidification	*In-situ* *Ex-situ*	■ Lower cost ■ Shorter remediation period	■ Possible leaching ■ Need monitoring for a long time
Leaching extraction	*In-situ* *Ex-situ*	■ Suitable for sandy soil ■ Lower energy cost ■ Good efficiency in medium/heavy pollution	■ Waste water ■ Reduce fertility ■ Different Eluent for each site

3 Remediation Technologies for Hg and As

The advantages and disadvantages of remediating arsenic in soil

Process	Type	Advantages	Disadvantages
Vitrification	*In-situ* *Ex-situ*	■ Stabilize	■ Unable to cultivate
Smelting recovery	*Ex-situ*	■ Economic benefit in recovery	■ Spend a lot of energy
Bio-remediation	*In-situ*	■ Lower cost ■ Less effect for original soil and underground water	■ Water table need lower than the distance that plant root can reach ■ The efficiency depends on the growth of plant ■ Waste plant ■ Unable fo high concentration ■ Longer remediation period
Electrode	*In-situ* *Ex-situ*	■ Operation easily ■ Good efficiency	■ Need power supply ■ Suitable for low permeability ■ Smaller efficient range

3 Remediation Technologies for Hg and As

The advantages and disadvantages of remediating arsenic in water

Process	Type	Advantages	Disadvantages
Pump and treat	*Ex-situ*	■ Lower cost ■ Can combine with other process	■ Dead zone ■ Cost a lot of energy ■ Risk of secondary contamination
Irrigation channel treatment	*In-situ*	■ Lower cost and operation easily ■ Can observe directly ■ Recycling	■ Only for channel ■ Longer retention time ■ Bad efficiency
In-situ bio-remediation	*In-situ*	■ Reduce the toxicity of contaminant ■ Contaminant degradation ■ No waste ■ Good social perception	■ Not suitable for low permeability soil ■ It might rise the concentration of trivalent arsenic

3 Remediation Technologies for Hg and As

The advantages and disadvantages of emediating arsenic in water

Process	Type	Advantages	Disadvantages
Electrode	*In-situ*	■ Less effect on landscape ■ Suitable for saturated/vadose zone	■ Cost a lot of energy ■ Change the underground environment ■ Precipitation problems of electrode
In-situ aeration	*In-situ*	■ Less effect on landscape ■ Lower cost ■ No waste water	■ High setup cost ■ Dead zone
Chemical coagulation	*Ex-situ*	■ High efficiency ■ Less effect on landscape	■ Produce waste
Precipitation and filtration	*Ex-situ*	■ Lower cost and operation easily ■ Can observe directly	■ Produce waste
Alumina adsorption	*Ex-situ*	■ High efficiency ■ Lower cost and operation easily	■ Produce waste

3 Remediation Technologies for Hg and As

Arsenic Contamination Soil

- According to the remediation methods of the three remediation sites in the domestic implementation control plan, it can be found that except for risk control, the off-site treatment method is adopted.

Arsenic Contamination Groundwater

- After evaluating of area, time course, cost and ease of operation, etc., chemical coagulation and aeration Precipitation filtration for arsenic removal in water is the recommended preferred solution.

4 Case Study – Hg (1)

Site History

- EPA conducted an investigation in 2008 and found soil is contaminated with mercury (Hg) concentration up to 27,900 mg/kg and Up to 0.578 mg/L of Hg in groundwater
- The Site was listed as the Control Site in 31 August 2009 for a contaminated area approximated 12,581 m
- Remedy Implemented (2010)
  - Soil:

    On-site thermal desorption
  - Groundwater: Pump & Treat

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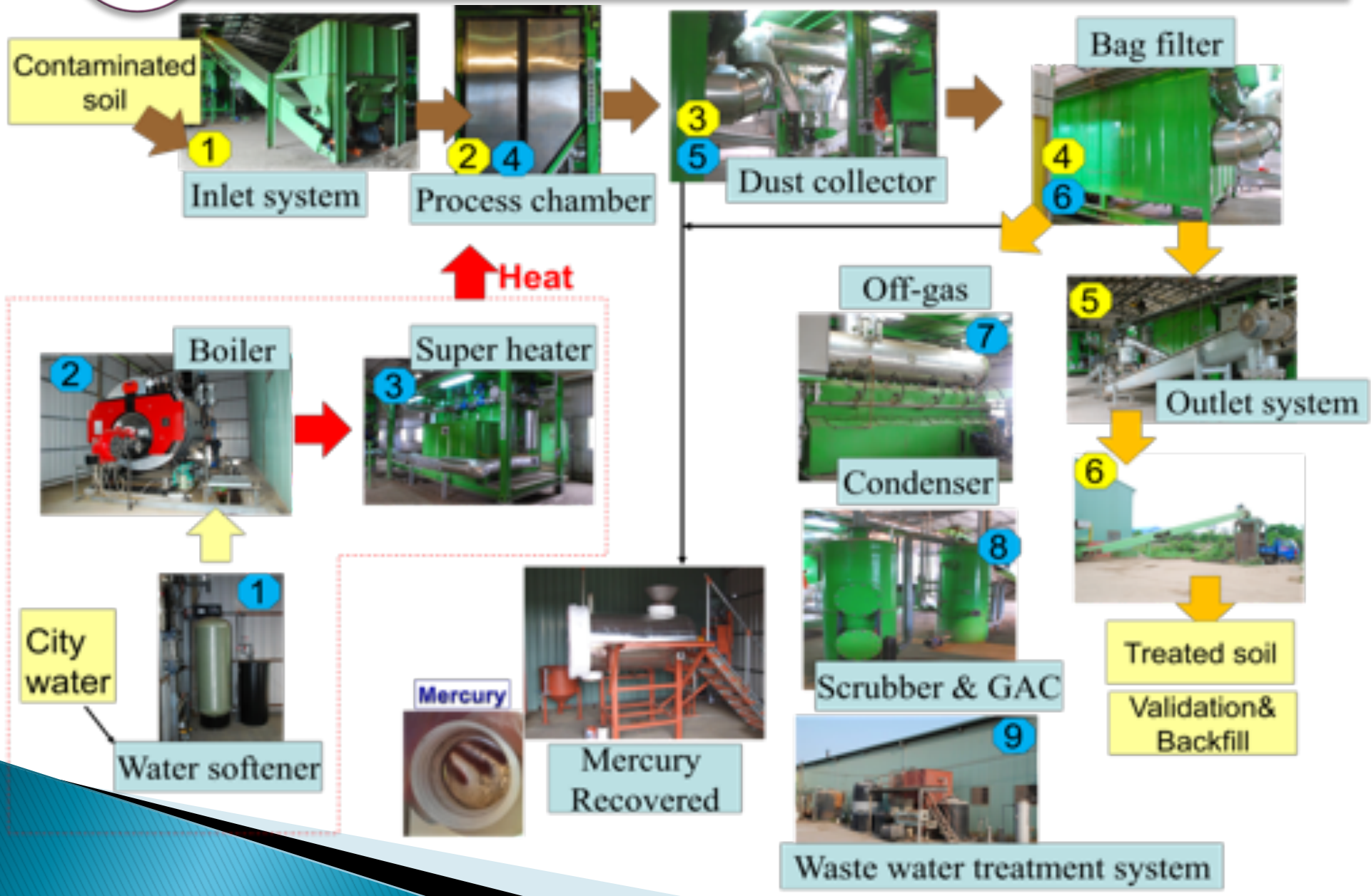
4 Case Study – Hg (1)



4 Case Study – Hg (1)

Mercury Recovery & Treatment

Indirect-heating to recover Hg

Hg (purity≒89.45%)

The recovered mercury were reused for the fluorescent light manufacturing process.

4 Case Study – Hg (1)

- The contaminated soil was treated using thermal desorption technology and the contaminated groundwater was treated with P&T technology
- A total of 770 kg Hg with an average purity of 89.5% were recovered from thermal desorption system and reused by EPA-certified waste treatment facility
- The site was officially delisted on July 2016

4 Case Study – Hg (2)

Site History

- Highest concentrations detected
  - Soil:

    9,550 mg/kg (vs. 20mg/kg standard)
  - Sediment:

    1410 mg/kg (vs. 1 mg/kg standard)
- Total Hg mass estimated to be over 40 tons
  - Some hot spots in soil have been removed and contained in temporary storage areas
  - The storage place zone contains highly contaminated soil
- Mercury derivative
  - React with CL_2/NaOH/S to form $HgCl_2$ /$Hg(OH)_2$ /amalgam/HgS

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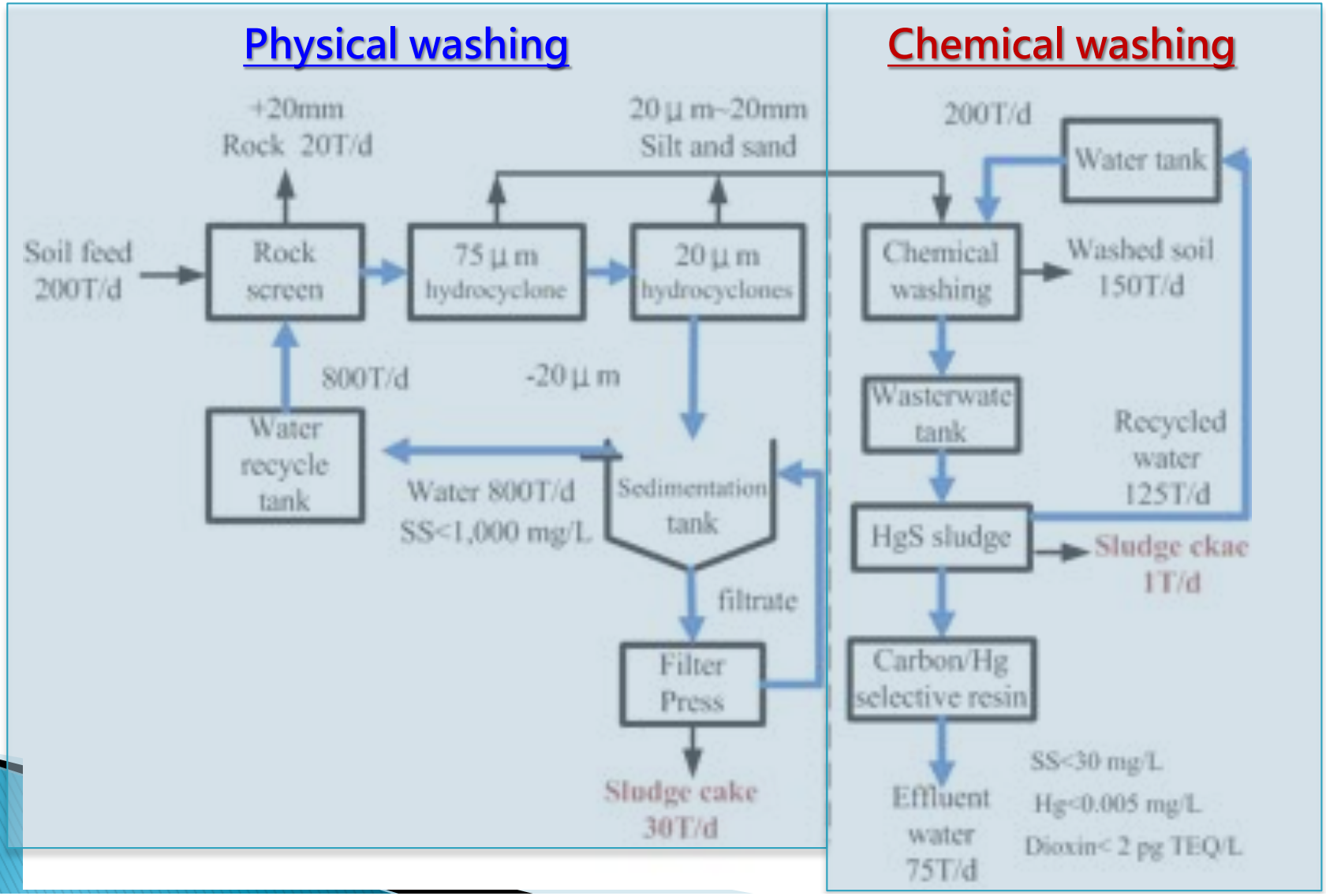
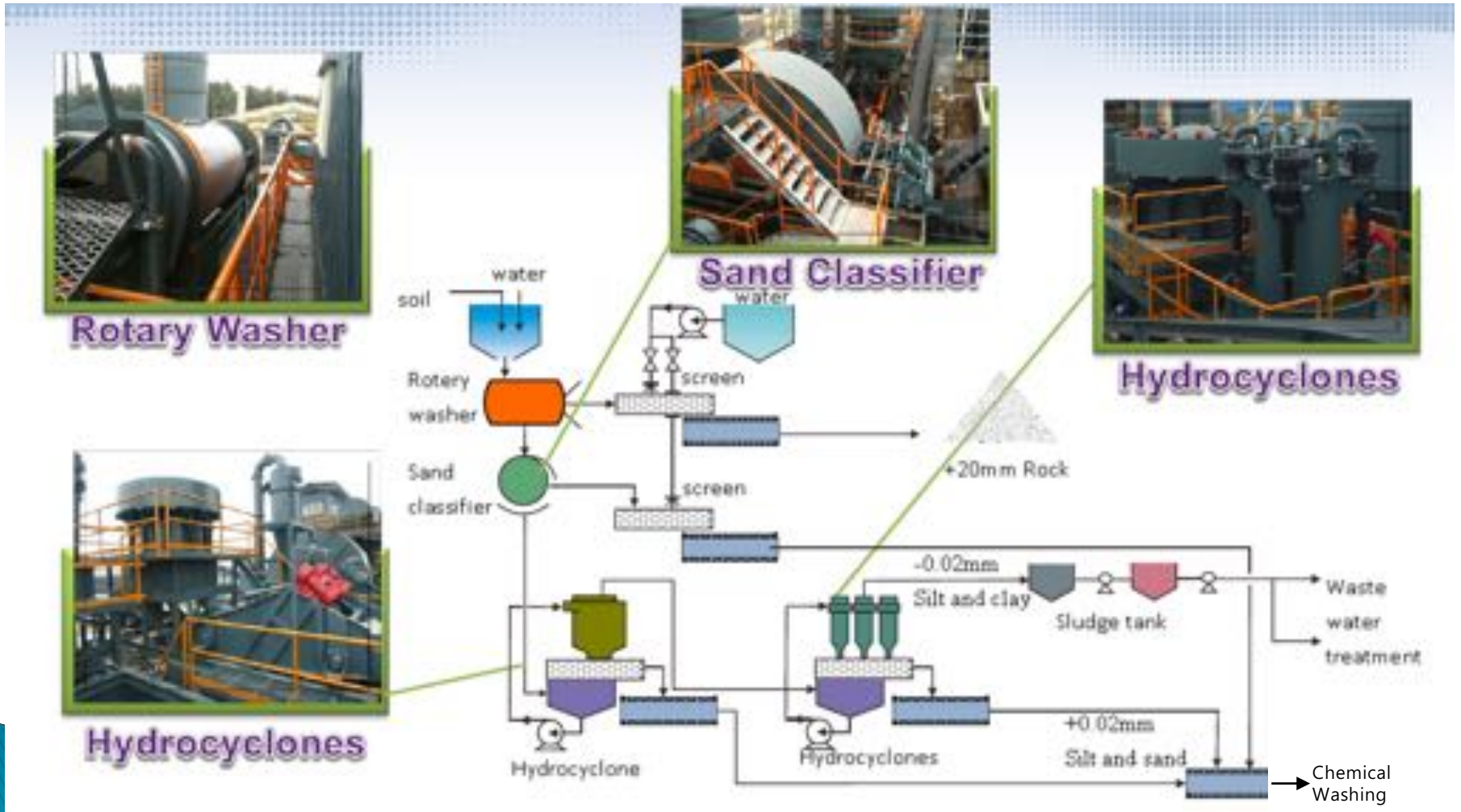
4 Case Study – Hg (2)

Soil Washing Treatment Process



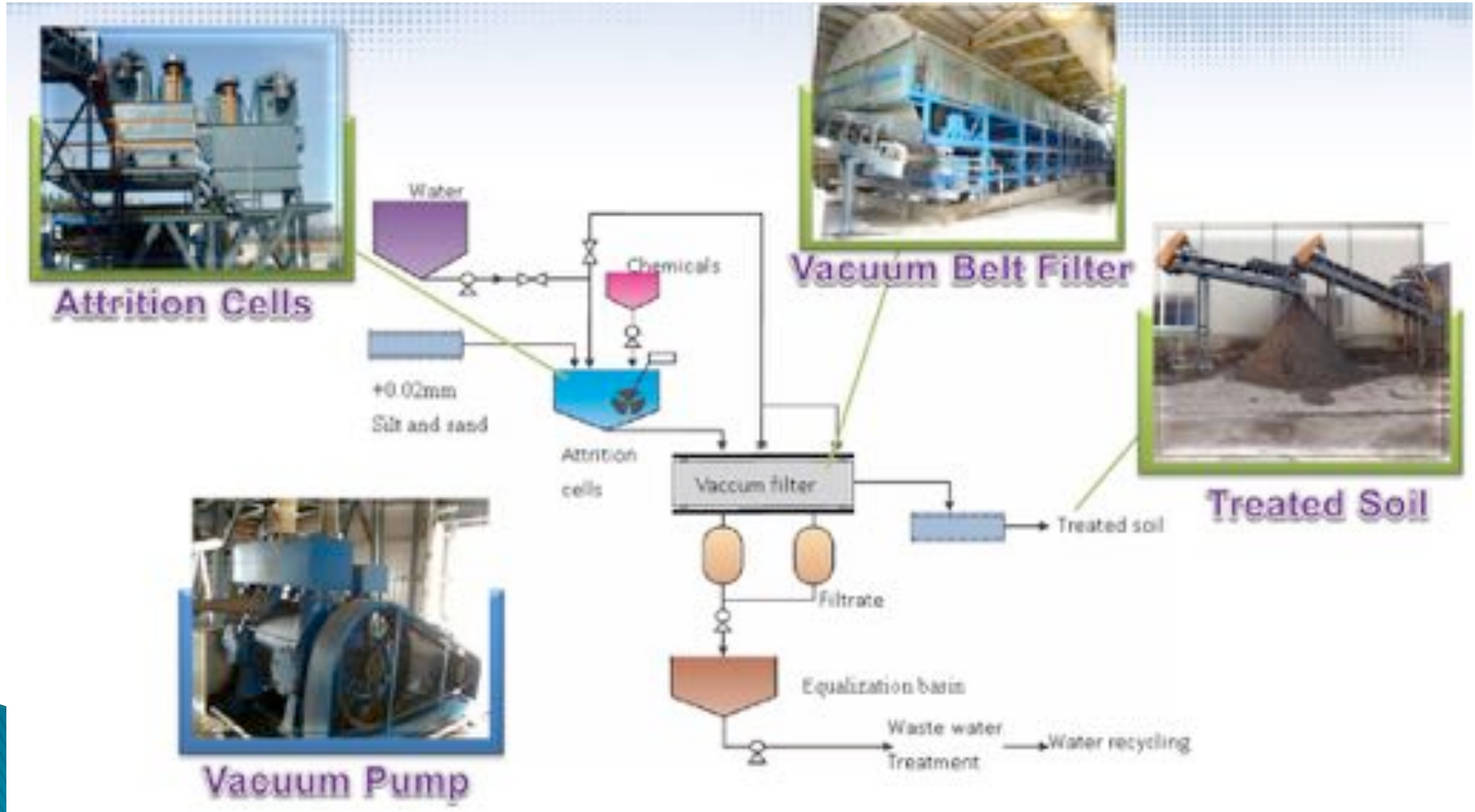
4 Case Study – Hg (2)

Physical Washing



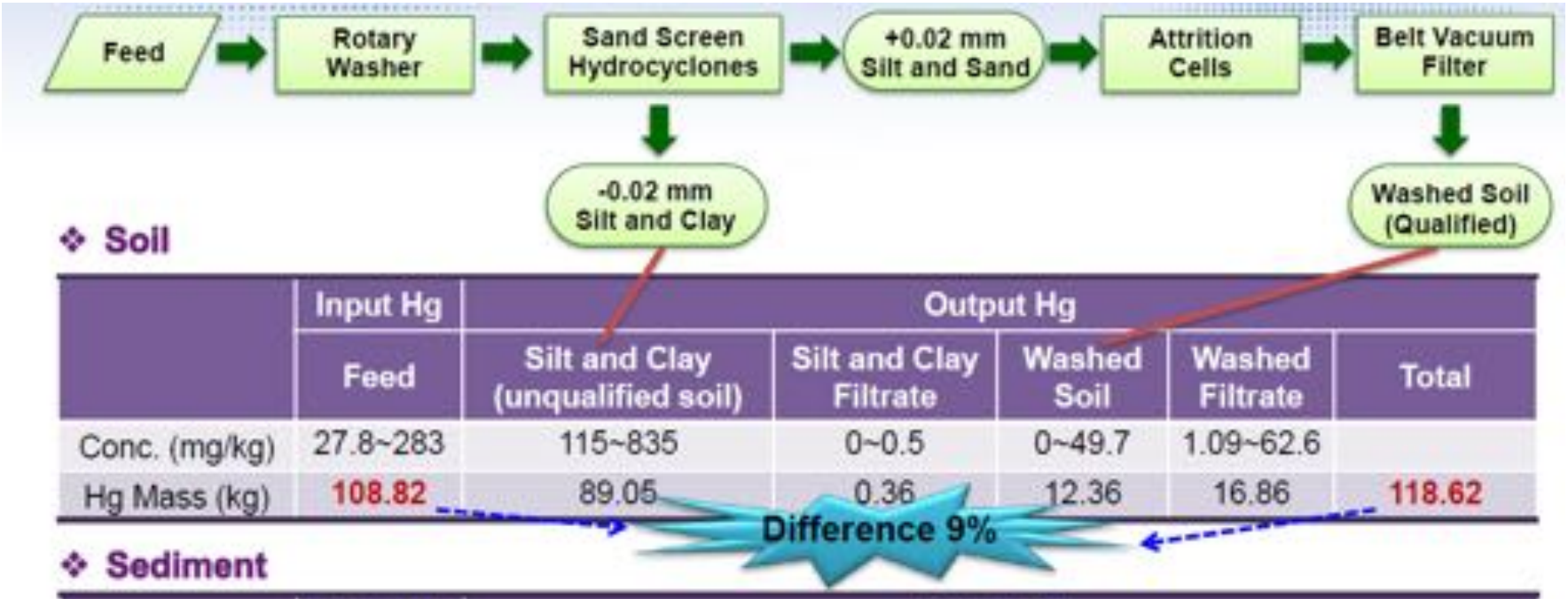
4 Case Study – Hg (2)

Chemical Washing



4 Case Study – Hg (2)

Mercury Mass Balance During Commissioning



❖ **Soil**

	Input Hg	Output Hg				
	Feed	Silt and Clay (unqualified soil)	Silt and Clay Filtrate	Washed Soil	Washed Filtrate	Total
Conc. (mg/kg)	27.8~283	115~835	0~0.5	0~49.7	1.09~62.6	
Hg Mass (kg)	108.82	89.05	0.36	12.36	16.86	118.62

Difference 9%

❖ **Sediment**

	Input Hg	Output Hg				
	Feed	Silt and Clay (unqualified soil)	Silt and Clay Filtrate	Washed Soil	Washed Filtrate	Total
Hg Mass (kg)	203.15	179.02	-	6.21	2.02	187.25

Difference 8%

4 Case Study – Hg (2)

- While thermal treatment is a common practice, soil washing treatment could be another practice that can be used effectively in mercury remediation.
- Furthermore, if the two treatments can be combined in the remediation process, the results is not only effective, but economical.
- The soil washing plant in An-Shun site is currently in process. Other than mercury treatment, the plant is also proved valid for treating dioxins at lower concentration.

4 Case Study - As

Site History

- Former Taiwan Metal Mining Co., Ltd. (hereafter referred to as Taijin Company)

- After the Company shutdown, it was found that the waste was not properly disposed, which resulting in the pollution of heavy metal from the Xiaotong copper smelting plant and its three waste flue pipes.

4 Case Study - As

- The pollutants have been scattered with soil erosion and surface runoff, and the concentration of arsenic in the surrounding soil is up to 104,000 mg/kg, the maximum concentration of arsenic in groundwater is 0.657 mg/L.

- Although there is no large-scale agricultural farming behavior around this site, it still affects the human body and threats the health care.

- It has been 30 years and still need the environmental monitoring.

5 Conclusions and Recommendations

Conclusions

- Mercury contamination is mainly from industrial operation such as alkali chloride industry, fluorescent tube manufacturing. Some are agricultural land and illegal dumping sites

- Arsenic concentration in soil is affected by human activities. Arsenic concentration in groundwater is mostly caused by environmental background.

5 Conclusions and Recommendations

- Risk assessment, risk management and risk communication are three major aspects of Taiwan's current risk management work

Recommendations

- Strive for collaboration between two parties to extend the partnership to work at third country in need
- Further discussion on the synergy of collaboration works and topics

Thank you

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