[Korea-Taiwan Cooperation Conference]

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

-Laws, Policies & Remedial Technologies-

2019. 12. 18.

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1. Backgrounds & Purpose

01. Heavy metal contamination

- Mercury

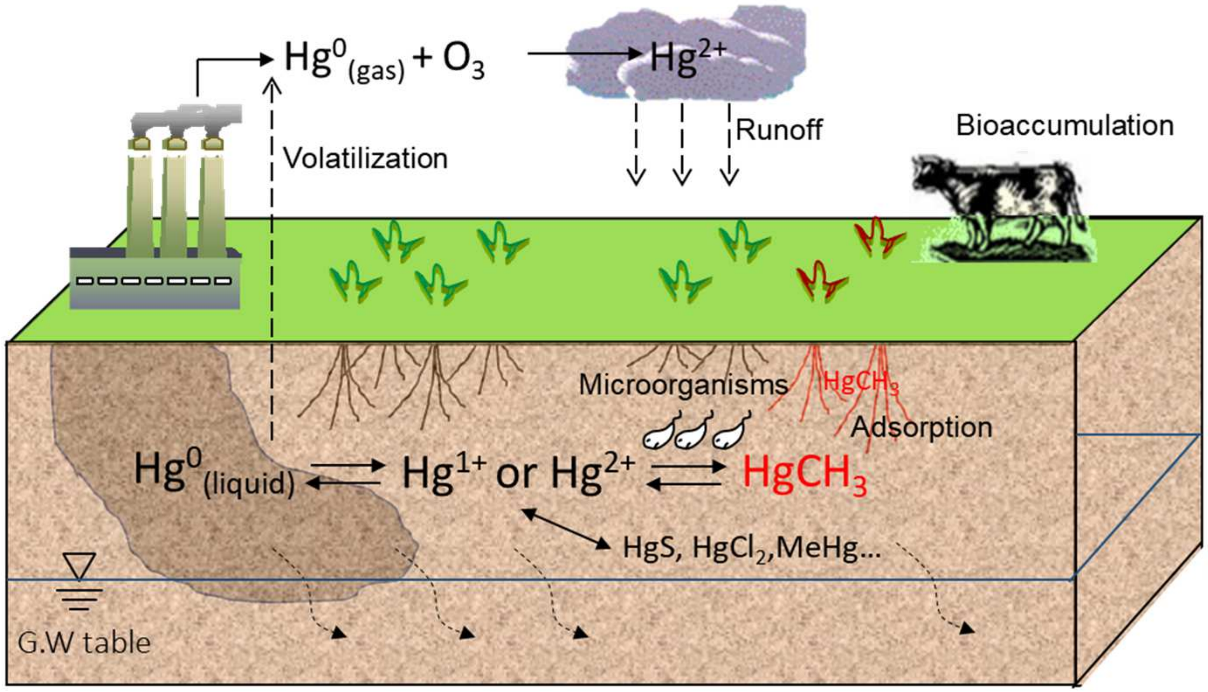
- Arsenic

1. Backgrounds & Purpose

02. Behavior of Mercury & Arsenic in soil and groundwater

Behavior of Mercury in soil and groundwater

- **Long-distance transport** is possible
- **Bioaccumulated** in forms of methyl mercury with high toxicities
- Mercury compounds : HgS, HgCl, Hg(OH), $HgCH_3^+$(methylmercury), CH_3HgCl (methylmercury chloride), CH_3HgOH (methylmercury hydroxide), organic mercury, etc. → **Need sophisticated detection technique**

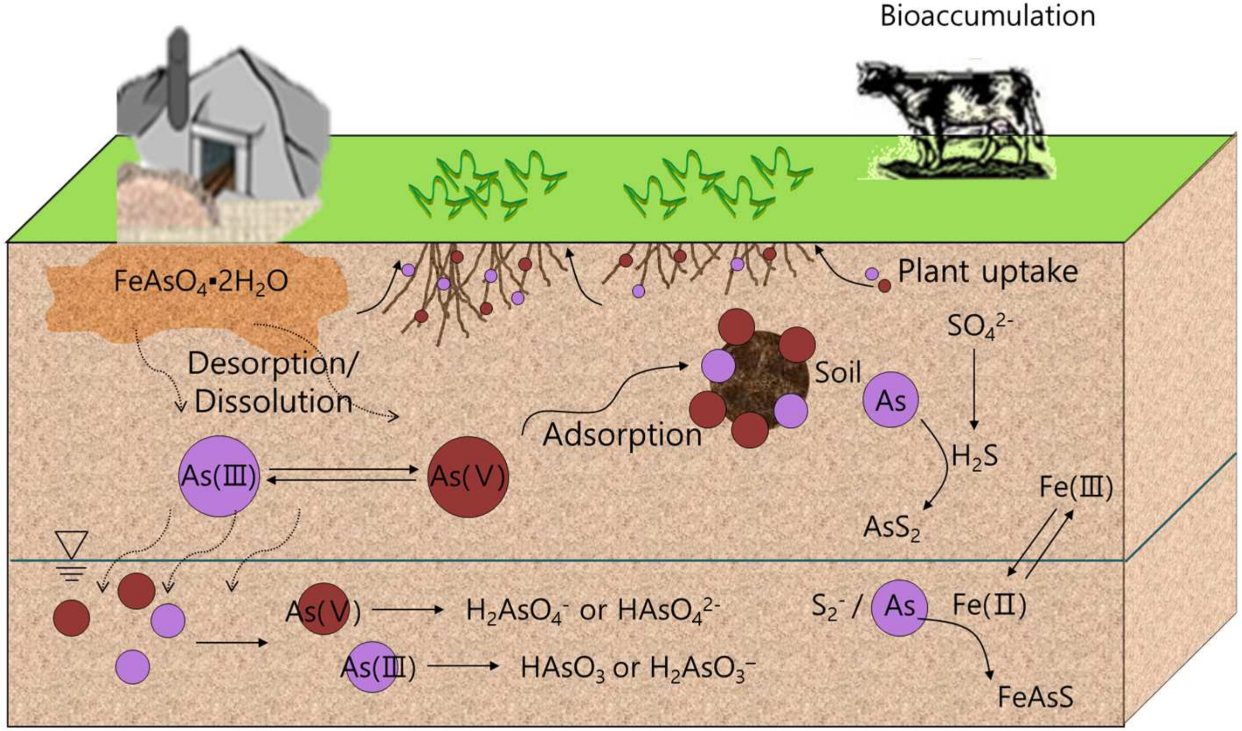


1. Backgrounds & Purpose

02. Behavior of Mercury & Arsenic in soil and groundwater

- Behavior of Mercury in soil and groundwater
  - **As(III) and As(VI)** as major species frequently biding with iron in soil and groundwater
  - Changes in chemical species depending on pH and E^h

    → **Identification of contaminated sites and species study** are important

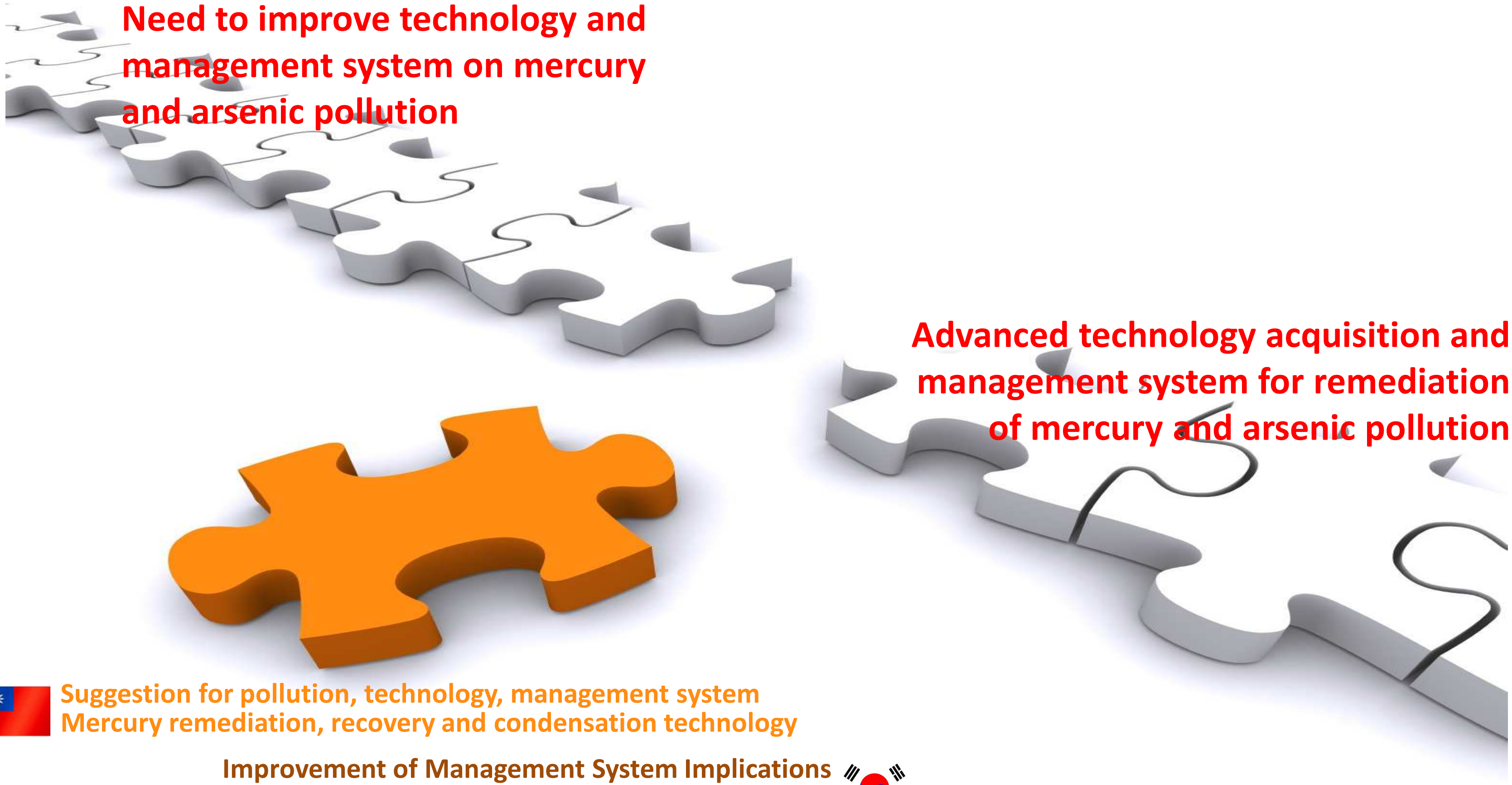


1. Backgrounds & Purpose

02. Purpose

▶ Goals

Need to improve technology and management system on mercury and arsenic pollution



Advanced technology acquisition and management system for remediation of mercury and arsenic pollution

Suggestion for pollution, technology, management system
Mercury remediation, recovery and condensation technology

Improvement of Management System Implications
Obtain optimal technology

2. Mercury and Arsenic Pollution in Korea

01. Soil and Groundwater Monitoring in Korea

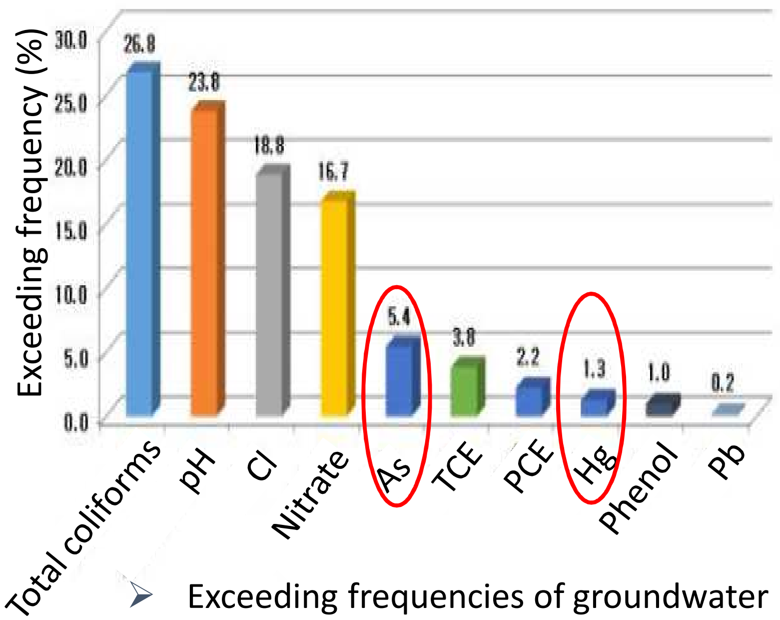
- Soil Groundwater Information System (SGIS, http://sgis.nier.go.kr)
- Mercury and arsenic monitoring is available

< Available information>

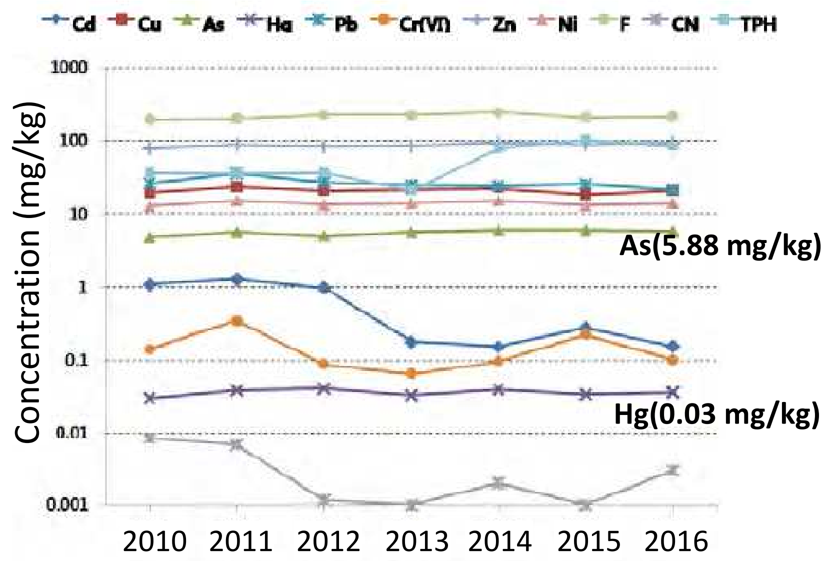
- Operation of monitoring network
- Search groundwater monitoring data
- Search soil monitoring data
- Search current status of soil contamination
- Search remediation status data
- Search information on contamination source
- Search monitoring network location
- Information on designated sites monitoring result

2. Mercury and Arsenic Pollution in Korea

< Groundwater monitoring network, 2016 >



< Soil monitoring network, 2016 >



- Exceeding frequencies of groundwater regulatory levels: As 5.4%, Hg 1.3%
- Below the soil regulatory levels generally
  - As : 5.88 mg/kg << 25 mg/kg (regulatory level)
  - Hg : 0.03 mg/kg << 4 mg/kg (regulatory level)

Groundwater regulatory levels
- As : <0.01 mg/L
- Hg : <0.001mg/L

3. Laws, Institution and Policies

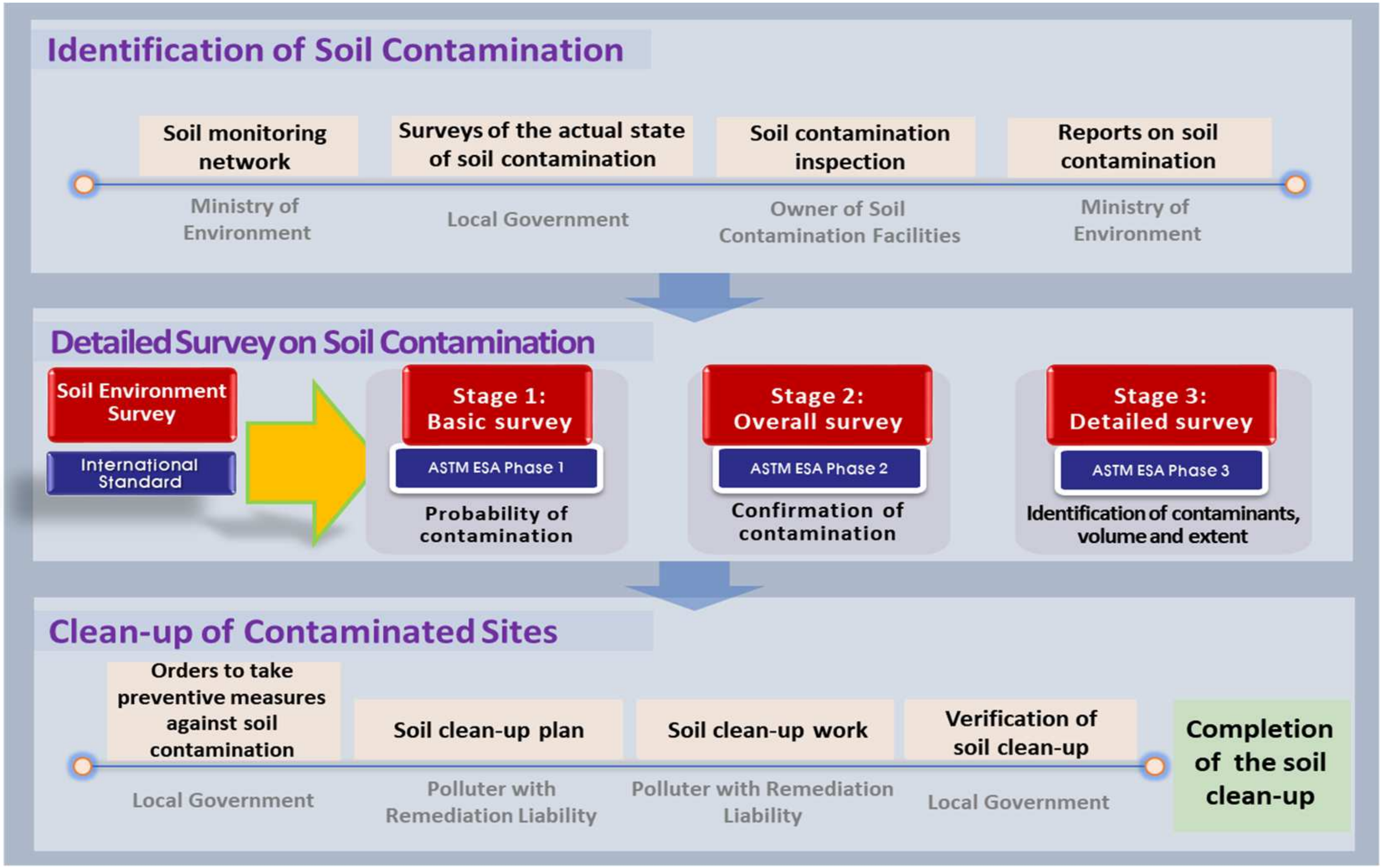
01. Basic Plan for Soil Conservation in KOREA(2010-2019)

Key tasks for promoting soil conservation

Expansion of the Role of the State in Executing Soil remediation	Promotion of Integrated Management of Soil and Groundwater
Development of Soil and Groundwater Technology and Industry	Expansion of Risk Assessment for Soil Contamination

02. Structure of Soil Environment Conservation Act (SECA)

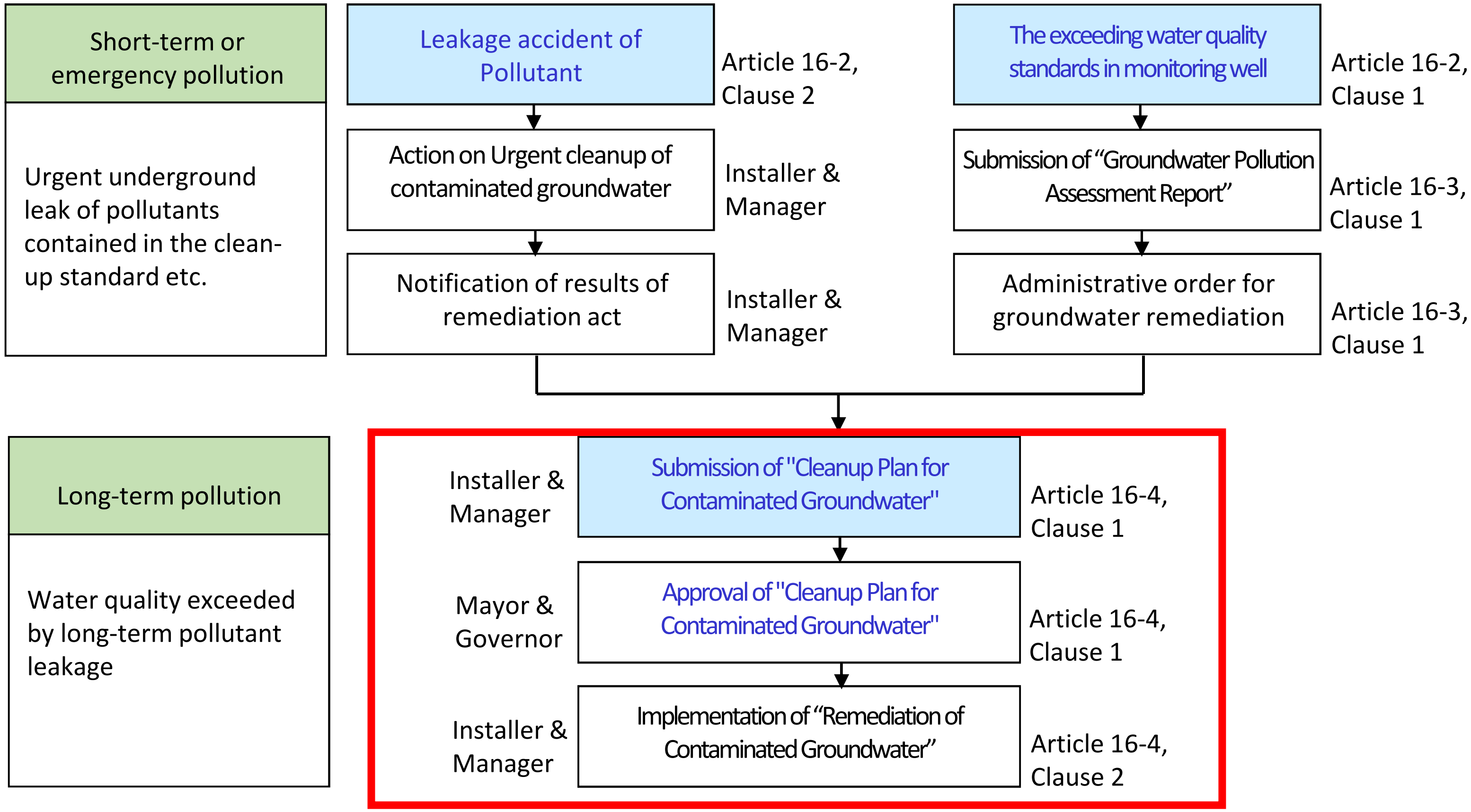
Process of clean-up of contaminated sites



3. Laws, Institution and Policies

03. Structure of Groundwater Act

Process of clean-up of contaminated sites



3. Laws, Institution and Policies

04. Soil Standard (22 contaminants)

Contaminants (mg/kg)	Worrisome level			Countermeasure standard		
	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Cadmium	4	10	60	12	30	180
Copper	150	500	2,000	450	1,500	6,000
Arsenic	25	50	200	75	150	600
Mercury	4	10	20	12	30	60
Lead	200	400	700	600	1,200	2,100
Hexavalent chromium	5	15	40	15	45	120
Zinc	300	600	2,000	900	1,800	5,000
Nickel	100	200	500	300	600	1,500
Fluorine	400	400	800	800	800	2,000
Organic phosphorus compound	10	10	30	-	-	-
Polychlorinated biphenyl	1	4	12	3	12	36
Cyanide	2	2	120	5	5	300
Phenol	4	4	20	10	10	50
Benzene	1	1	3	3	3	9
Toluene	20	20	60	60	60	180
Ethylbenzene	50	50	340	150	150	1,020
Xylene	15	15	45	45	45	135
TPH	500	800	2,000	2,000	2,400	6,000
TCE	8	8	40	24	24	120
PCE	4	4	25	12	12	75
Benzo (a) pyrene	0.7	2	7	2	6	21
1.2-Dichloroethane	5	7	70	15	20	210

05. Groundwater Standard (20 contaminants)

Category	Contaminanants	Standards		
		Household water	Agricultural water	Industrial water
General contaminants (4)	pH	5.8-8.5	6.0-8.5	5.0-9.0
	Total coliforms (MPN/100 ml)	5,000 ≥	-	-
	Nitrate (mg/L)	20 ≥	20 ≥	40 ≥
	Chloride (mg/L)	250 ≥	250 ≥	500 ≥
Specific hazardous contaminants (16)	Cadmium (mg/L)	0.01 ≥	0.01 ≥	0.02 ≥
	Arsenic (mg/L)	0.05 ≥	0.05 ≥	0.1 ≥
	Cyanide (mg/L)	0.01 ≥	0.01 ≥	0.2 ≥
	Mercury (mg/L)	0.001 ≥	0.001 ≥	0.001 ≥
	Diazinon (mg/L)	0.02 ≥	0.02 ≥	0.02 ≥
	Parathion (mg/L)	0.06 ≥	0.06 ≥	0.06 ≥
	Phenol (mg/L)	0.005 ≥	0.005 ≥	0.01 ≥
	Lead (mg/L)	0.1 ≥	0.1 ≥	0.2 ≥
	Chromium (mg/L)	0.05 ≥	0.05 ≥	0.1 ≥
	Trichloroethylene (mg/L)	0.03 ≥	0.03 ≥	0.06 ≥
	Tetrachloroethylene (mg/L)	0.01 ≥	0.01 ≥	0.02 ≥
	1.1.1-Thrichloroethane (mg/L)	0.15 ≥	0.3 ≥	0.5 ≥
	Benzene (mg/L)	0.015 ≥	-	-
	Toluene (mg/L)	1 ≥	-	-
	Ethylbenzene (mg/L)	0.45 ≥	-	-
	Xylene(mg/L)	0.75 ≥	-	-

4. Remedial Technology

01. Remedial technologies for heavy metal

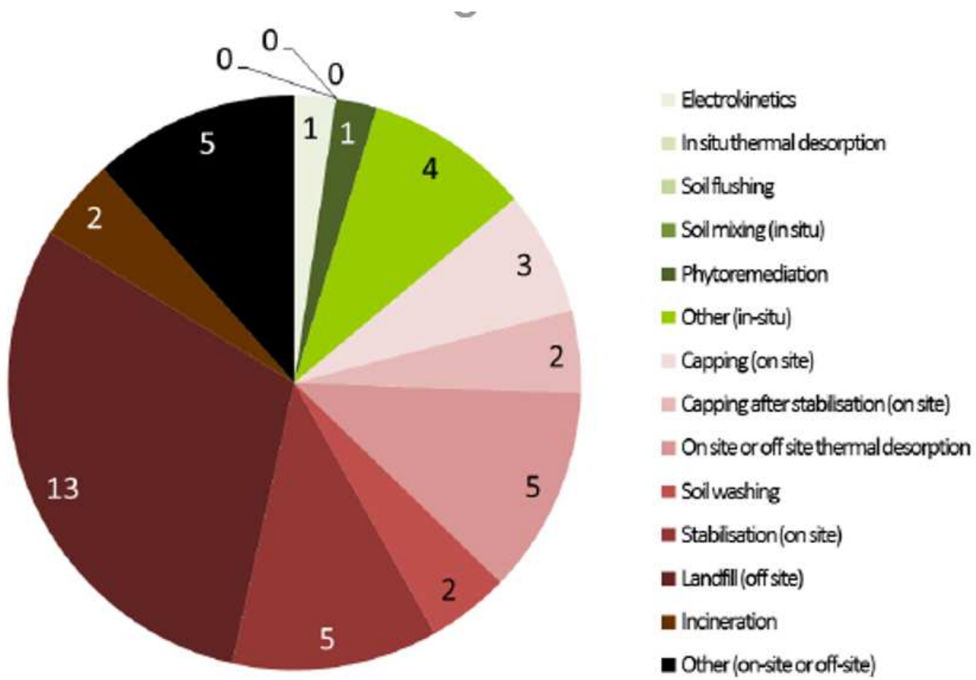
Methods	Targeted metal(loid)s	Efficiency (%)	References
Physical remediation			
Thermal remediation	Hg	99% of Hg could be removed from soil	Hseu et al. (2014)
Soil washing (column test)	Cd, Zn, Cr, Pb	70, 30, 25, and 10% of Cd, Zn, Cr, Pb at neutral pH were extracted, respectively	Abumaizar and Smith (1999)
Soil washing (pilot test)	As	63–75% of As was leached out	Ko et al. (2006)
Chemical remediation			
Chemical leaching			
Using 0.1 M sodium metabisulfite + 0.01M EDTA	Cd, Zn, Pb, Cr	100, 70, 60, and 16% of Cd, Zn, Pb, Cr were extracted, respectively	Abumaizar and Smith (1999)
Using $CaCl_2$	Cd	83% of Cd was decreased after treatment	Makino et al. (2007)
Using 0.1 M hydrochloric acid	Co, As, Hg	80–90% of metals depending on temperature and time were leached out	Alghanmi et al. (2015)

4. Remedial Technology

01. Remedial technologies for heavy metal

Methods	Targeted metal(loid)s	Efficiency (%)	References
Immobilization			
Using amendments			
$CaCO_3$	Zn, Cd, Pb	Flow-weighted mean concentration of Zn, Cd, and Pb were decreased by 98.5, 88.3, and 57%, respectively	Houben et al. (2012)
Iron grit	Pb	Flow-weighted mean concentration of Pb was decreased by 83%	Houben et al. (2012)
Conocarpus biochar	Mn, Cu, Cd, Zn	Reduced shoot heavy metal concentration in plants by 61–28%, respectively	Al-Wabel et al. (2014)
Phosphate rock	Cd, Pb, Cu, Zn	Reduced uptake in plant shoots by 74–14%, respectively	Zhao et al. (2014)
Vitrification	Mn, Cu, As, Fe, Ni, Zn, Hg, Pb, Cd, Cr, Se	Concentration of heavy metals after treatment ($T > 1300$ °C) reduced in leachate by almost 91–100%	Navarro et al. (2013)
Electrokinetic remediation	Cu, Pb	After treatment, 41 and 31% removal of Cu and Pb were observed (using 4–26 V as current)	Ottosen et al. (2012)
Phytoremediation			
Phytoextraction	Pb, Zn, As, Cd, Cu, Ni	Removal capacity by Alnus firma was evaluated 77–10%, respectively	Babu et al. (2013)
Phytoextraction	Pb	Efficiency process 30–80% with maximum value in *Alternanthera phyloxeroides*	Cho-Ruk et al. (2006)
Phytoextraction	Cd, Zn	Populus accumulated both Cd and Zn up to 82%	Hassinen et al. (2009)
Biological remediation			
Bioleaching	Cu, Cd, Pb, Zn	Maximum removals of 98–15% for metals were achieved. (Using a fungus Aspergillus niger)	Ren et al. (2009)
Taken up metals by	Cd, Hg, Ag, Zn, Cu, Ni	170, 58, 54, 14, 15, 13% dry wt of metals were taken up	Rajendran et al.

02. Remedial technologies for Mercury



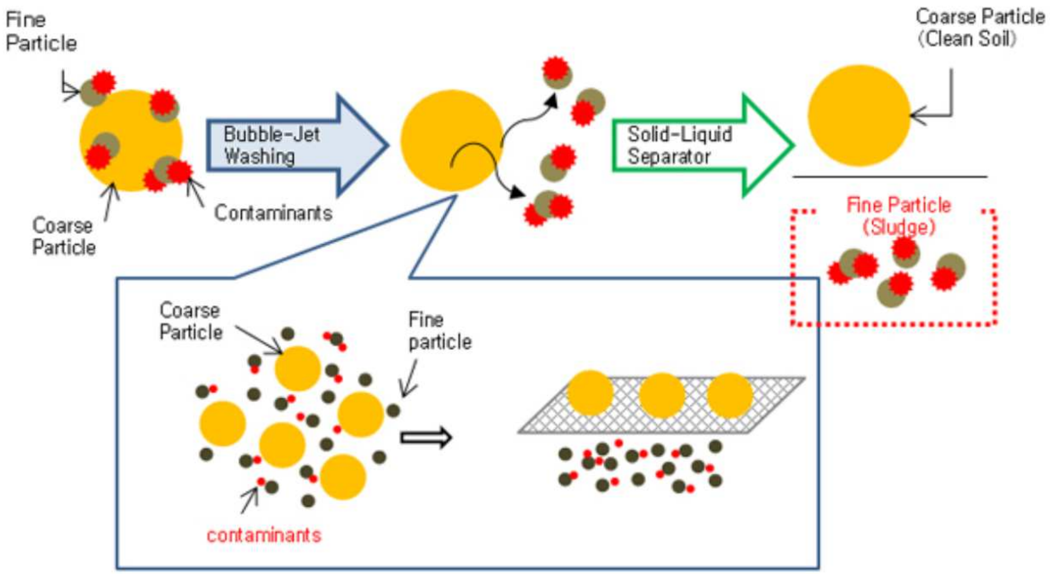
Current practices for mercury contaminated soil remediation in-situ technologies in green; ex-situ (on-site or off-site) technologies in brown – the numbers on the chart pie correspond to the number of times de remediation technologies have been cited by the participants.

4. Remedial Technology

03. Soil Washing (Recently Developed)

High pressure bubble jet washing technology

Bubble jet washing system is a technology to remediate the contaminated soil particle by separating fine particles where many toxic contaminant species exists.
Particularly, even in the case of pollution of harmful substances (heavy metals) having low solubility, since the fine particles containing contaminants are separated and purified, theoretically, it is a technology applicable to the majority of pollution due to low dependence on the contaminant species or concentration.

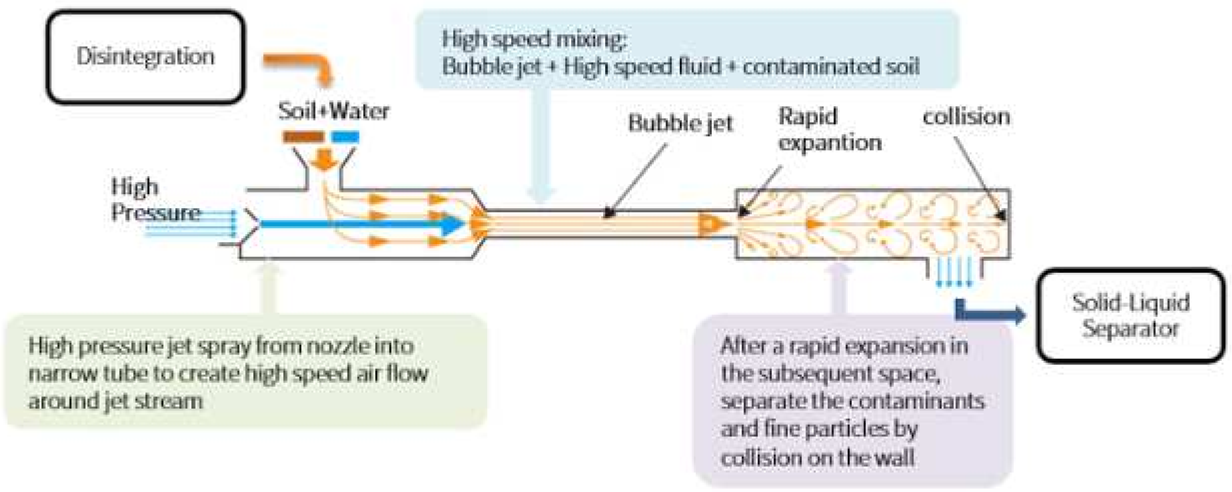


4. Remedial Technology

03. Soil Washing (Recently Developed)

High pressure bubble jet washing technology

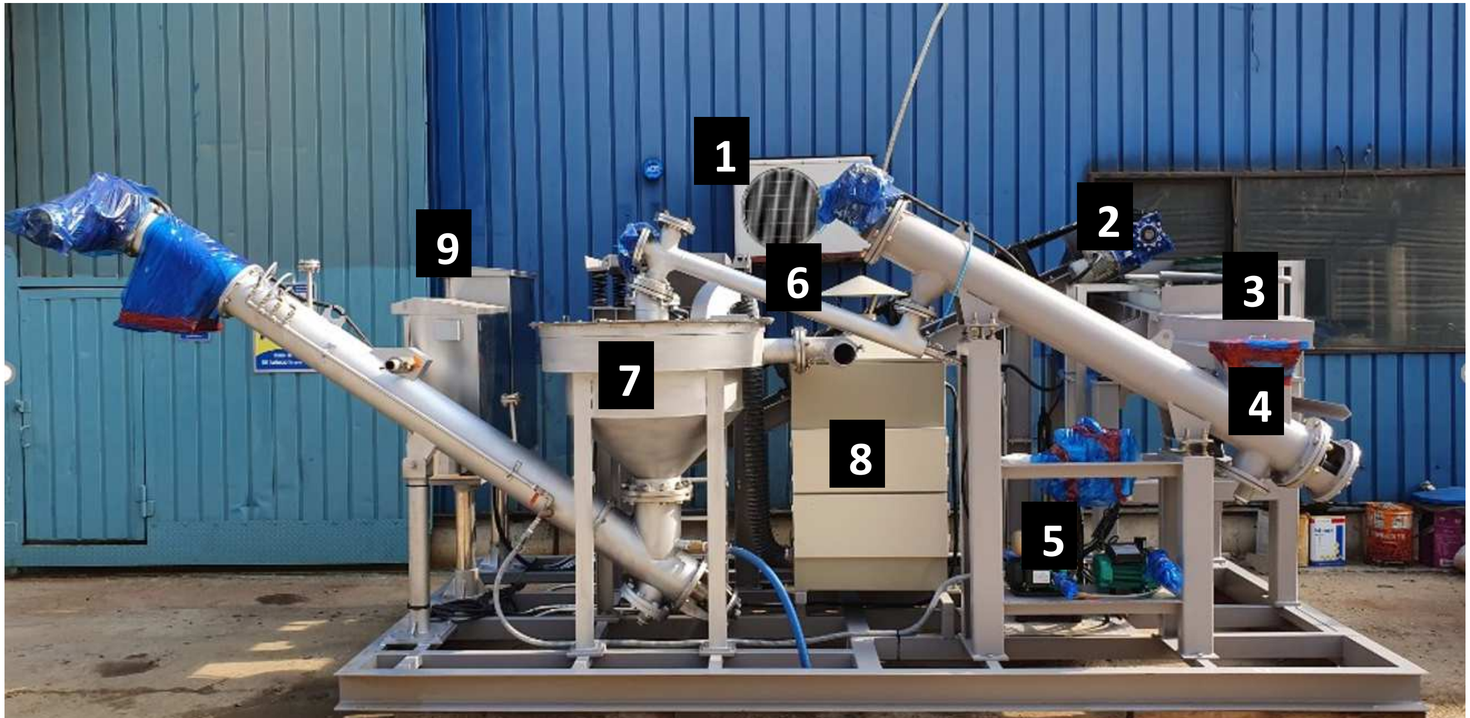
The high-pressure jet water is sprayed from the nozzle into narrow tube, creating a high-speed air flow around the jet stream. When contaminated soil and water are injected into it, jet streams and fast air are pulled into the integrated narrow tube and instantly mixed.
Contaminants(and file particles) are separated from coarse soil particles through rapid expansions and collision on the wall



4. Remedial Technology

03. Soil Washing (Recently Developed)

▶ High pressure bubble jet washing technology(Capacity 5t/h)



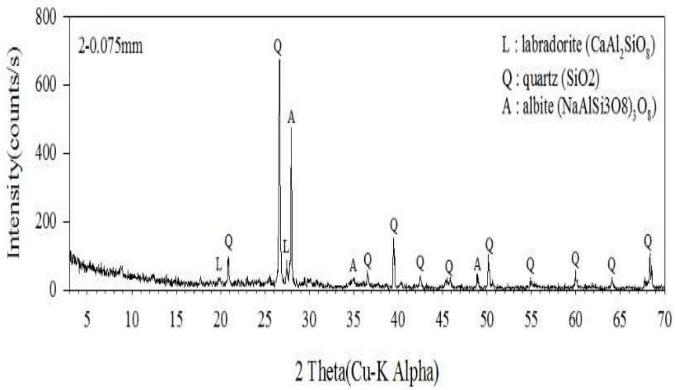
1 Vibrating Hopper	2 Belt Conveyor	3 Vibrating Screen
4 Screw Feeder	5 High Pressure Pump	6 Cavitation Jet Flow
7 Soil-Water Separator	8 Gas Treatment System	9 Control Unit

4. Remedial Technology

03. Soil Washing (Recently Developed)

Experimental Results

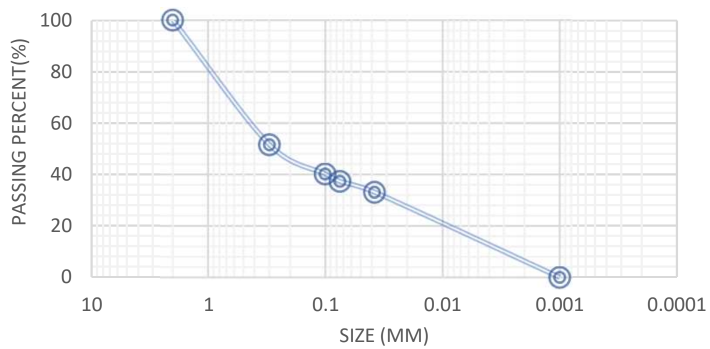
XRD



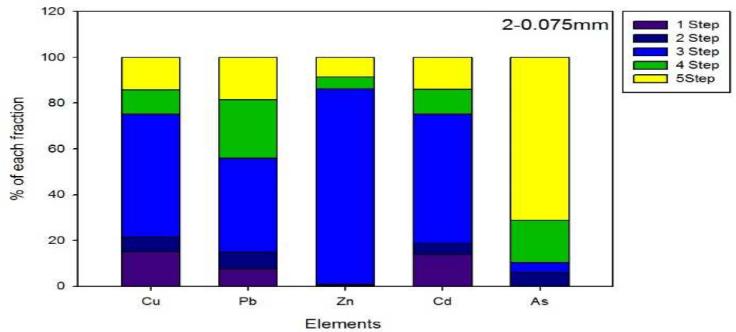
XRF

No	Compound Name	Conc.(%)	No	Compound Name	Conc.(%)
1	Na_2O	0.679	13	Co_3O_4	0.018
2	MgO	1.73	14	CuO	0.111
3	Al_2O_3	18.25	15	ZnO	0.393
4	SiO_2	56.01	16	Rb_2O	0.023
5	P_2O_5	0.113	17	SrO	0.014
6	SO_3	0.563	18	ZrO_2	0.029
7	K_2O	4.171	19	Nb_2O_5	0.03
8	CaO	1.953	20	CdO	0.037
9	TiO_2	0.716	21	BaO	0.055
10	Cr_2O_3	0.026	22	CeO_2	0.00
11	MnO	0.195	23	PbO	0.091
12	Fe_2O_3	5.724			

Particle size curve



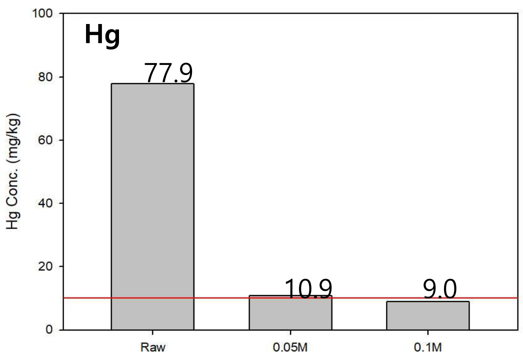
Sequential Extraction

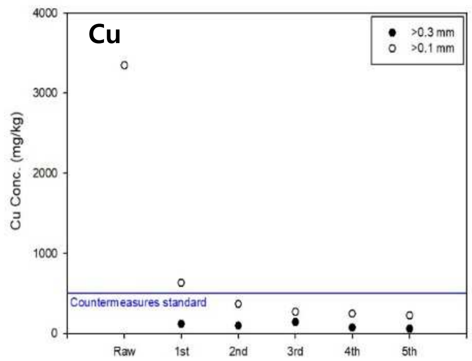


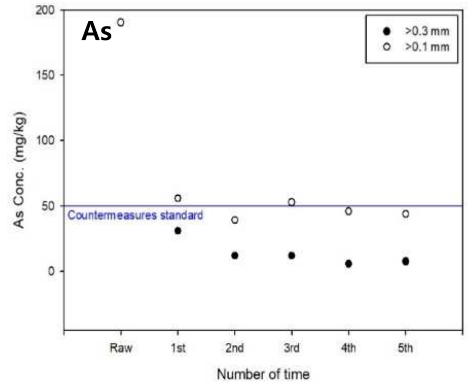
4. Remedial Technology

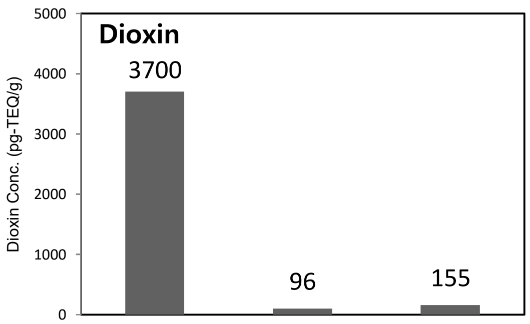
03. Soil Washing (Recently Developed)

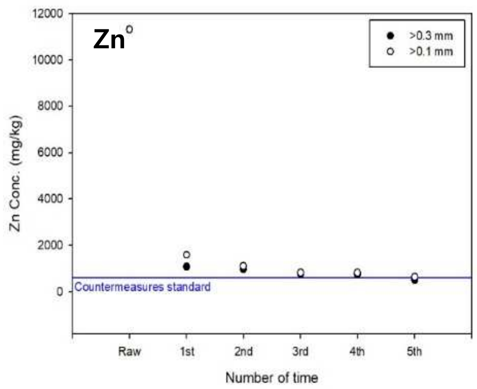
Experimental Results

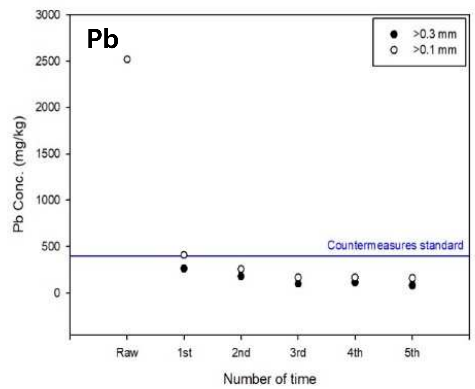












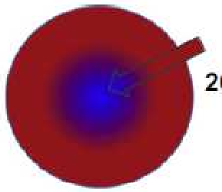
4. Remedial Technology

04. Thermal Desorption (Recently Developed)

▶ Microwave and condensation technology for thermal desorption technology

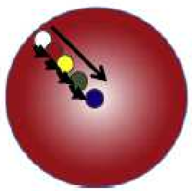
CONVENTIONAL HEATING

350°C at the outer edge



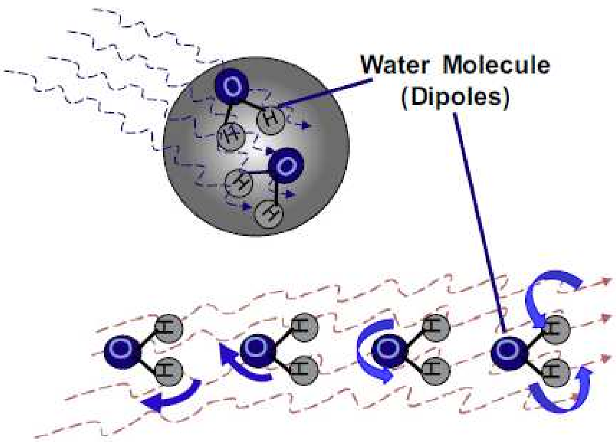
200°C at the centre

Heat is transferred molecule by molecule from outside

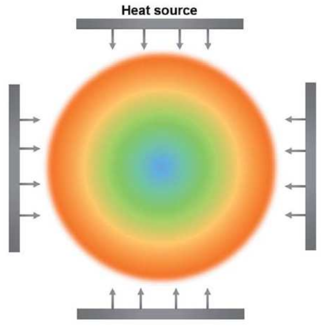


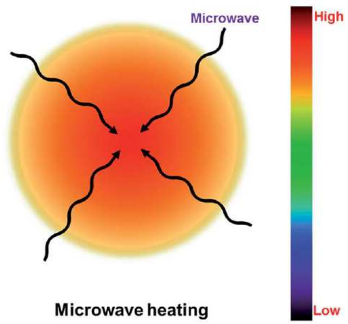
Overheating can occur on the outside

MICROWAVE HEATING



- MW penetrate the material and create the rapidly changing field
- Dipole (water molecule) continuously react attempting to align in the field, which generates heat
- Heat is uniformly distributed throughout the material

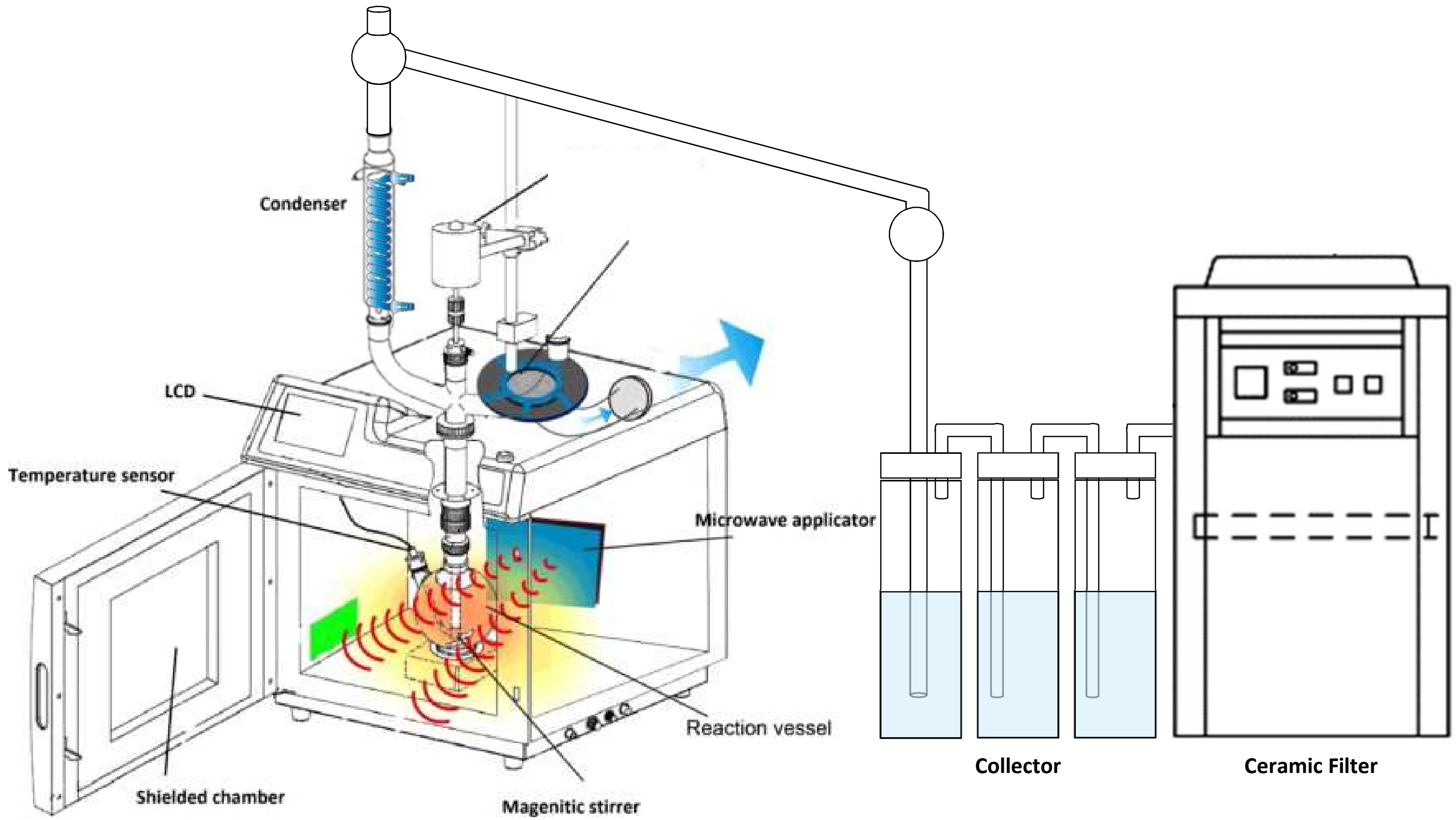




4. Remedial Technology

04. Thermal Desorption (Recently Developed)

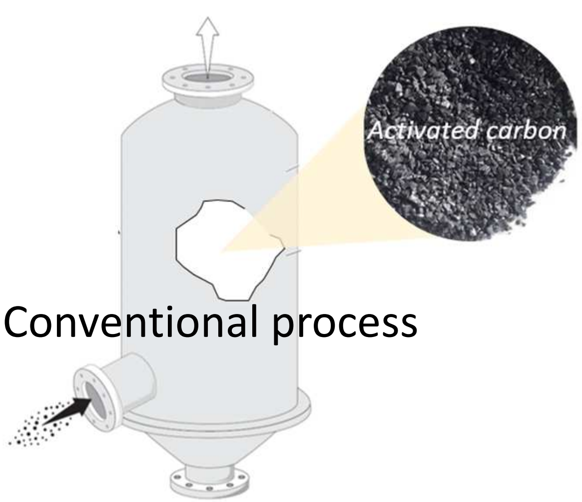
- Microwave and condensation technology for thermal desorption technology

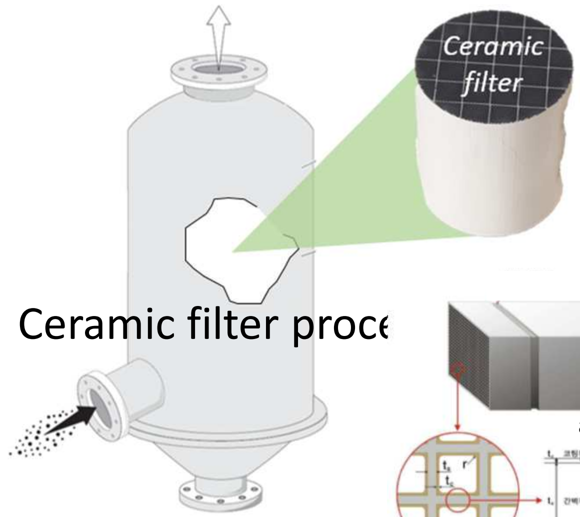


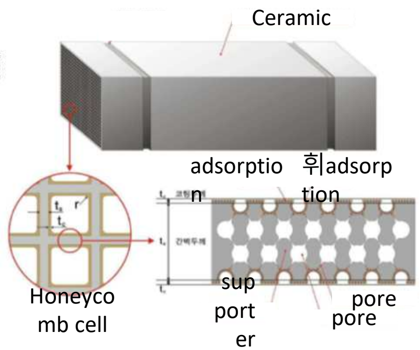
4. Remedial Technology

04. Thermal Desorption (Recently Developed)

▶ Microwave and condensation technology for thermal desorption technology





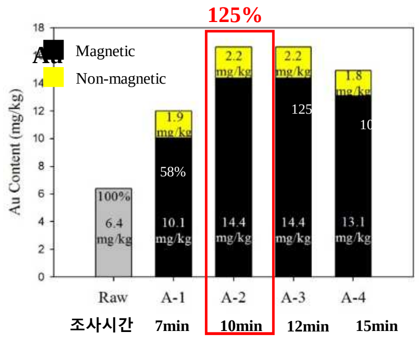


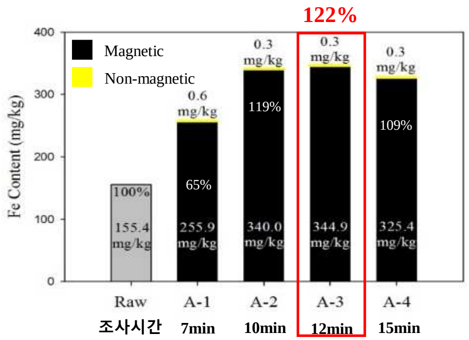
- Ceramic filter has a high melting point, which makes it very durable.
- The key to the filter is the honeycomb design and ceramic materials.
- As air passes through the structure, particulate matter sticks to the walls, leaving clean air to be expelled.
- The honeycomb structure is geared to obtain a very large filtration area over a very small space.

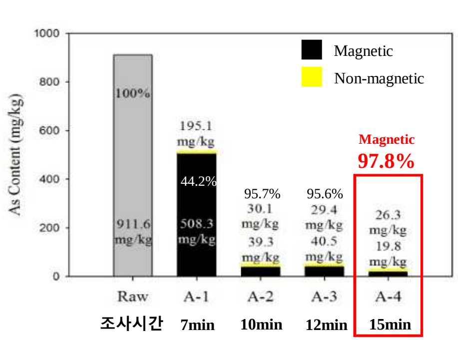
4. Remedial Technology

04. Thermal Desorption (Recently Developed)

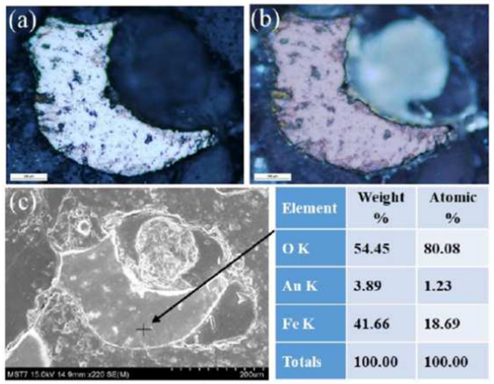
Experimental Results







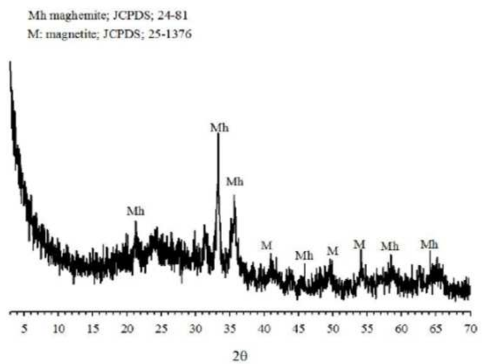
Open nicols→



← Cross nicols

Element	Weight %	Atomic %
O K	54.45	80.08
Au K	3.89	1.23
Fe K	41.66	18.69
Totals	100.00	100.00

SEM & EDS



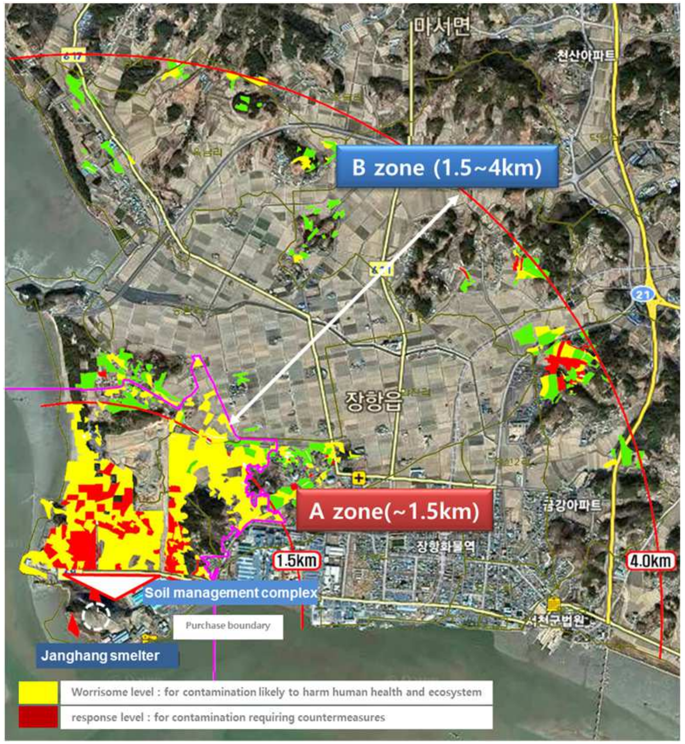
XRD Patterns of Reduction Material

Mh; Maghemite(Fe_2O_3)
M; Magnetite(Fe_3O_4)

4. Case Studies

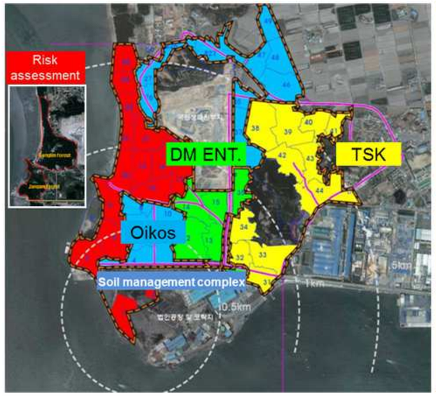
01. Chemical Washing & Electrokinetic Process

▶ Overview / State of contaminations



Janghang smelter in Chungcheongnam-do
(Due to air pollutants and soil contamination which caused serious problem to corps and human health)

A zone
(1.5km from Janghang smlter)



Oikos 158,209㎡	· Intensive screening · Acidic soil washing (abstergent : Sulfuric acid) · Flotation
Dong myung 155,011㎡	· Intensive screening · Acidic soil washing (abstergent : Sulfuric acid) · Flotation
TSK Water 129,433㎡	· Intensive screening · Acidic soil washing (abstergent : oxalic acid)
Risk Assessment 128,263㎡	· Soil capping · Fe oxide Stabilization · Phytoremediation · Acidic soil washing(partially)

B zone
(1.5~4km from Janghang smelter)

GS 74,700㎡	· Intensive screening · Acidic soil washing (abstergent : Sulfuric acid) · Electrokinetic separation
Hyundai 72,700㎡	· Intensive screening · Acidic soil washing (abstergent : Sulfuric acid, phosphoric acid) · Electrokinetic separation
Hanwha 67,000㎡	· Intensive screening · Reduction leaching soil washing (abstergent : sodium hydroxide) · Phytoremediation

4. Case Studies

01. Chemical Washing & Electrokinetic Process

▶ Remediation process

A zone
(1.5km from Janghang smlter)

Remediation process

Contaminated sites

- General lands(Ex–situ) →
  - Intensive screening,
  - Acidic soil washing ect.
- Vegetation areas(In–situ) →
  - Soil capping,
  - Fe oxide stabilization ect.

B zone
(1.5~4km from Janghang smelter)

Remediation process

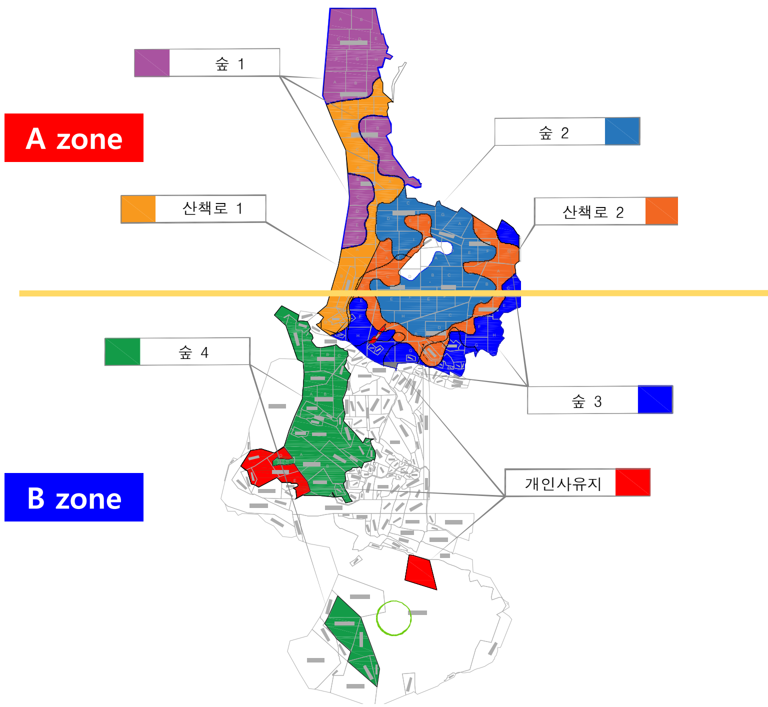
Contaminated soil

- Lowly–contaminated soil →
  - Intensive screening
  - Soil washing
  - Phytoremediation
- Highly–contaminated soil →
  - Electrokinetic separation

4. Case Studies

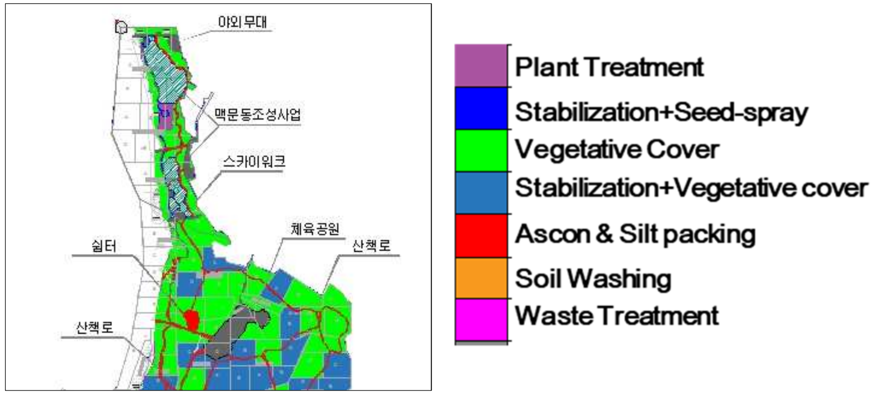
03. Stabilization

▶ Overview / State of contaminations

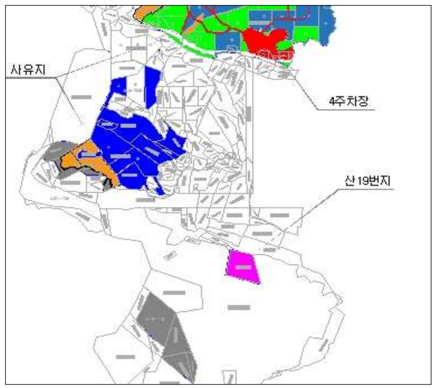


Song-rim Forest in Chungcheongnam-do
(Due to air pollutants and soil contamination which caused serious problem to corps and human health)

A zone
(Song-rim Forest)



B zone
(Jang-am Forest)



Stabilization

: High concentration of As ≥ 150mg/kg

: Considering ecosystem impact in the forest bath field

: Consider scattering dust generation packing and seedspray

4. Case Studies

04. Stabilization

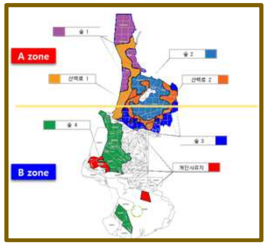
▶ Remediation process

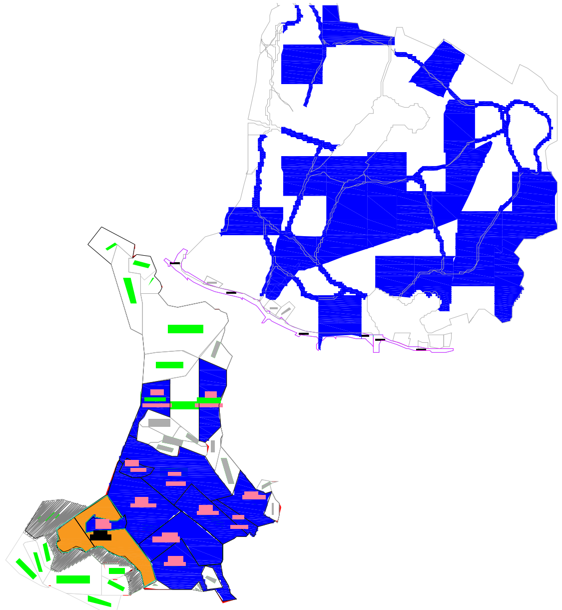
Purpose

- Reducing the bioavailability of arsenic in contaminated soil
- Prevention of leaching of pollutants by rainfall

Area

ZONE	TARGET AREA (㎡)	Additional Action
A zone	75,732	Vegetative Cover
B zone	34,262	Seedspray





- Stabilizer : Metafix (EHC5)
- Input ratio (Target soil weight ratio) : 1%

THANKS

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