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First Ever Heavy Metal Stabilization Project in Korea

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TSK water

JM ENVIRO PARTNERS

Korea Environment Corporation
Department of Soil & Groundwater

Acknowledgements

Korea Environment Corporation
Department of Soil & Groundwater

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Outline

1. Korean regulatory framework for heavy metal contaminated sites
2. Background of Janghang smelter site remediation project
3. Summary of lab treatability study
4. Summary of field pilot study
5. Launch of full scale field work

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1. KOREAN REGULATIONS FOR HEAVY METAL CONTAMINATED SITES

Regulatory Background in Korea

- **Soil Environment Conservation Act (SECA)**
  - ✓ SECA/Enforcement Decree/Enforcement Rule was enacted in 1996 and subsequently amended
  - ✓ Total of twenty-one (21) contaminants regulated

Petroleum Hydrocarbons	Heavy Metals	Others
TPH, Benzene, Toluene, Ethylbenzene and Xylene	Cd, Cu, As, Hg, Pb, Cr(VI), Zn and Ni	Fluoride, Organic Phosphorus, PCBs, Cyanide, Phenols, TCE, PCE and Benzo(a)pyrene

Regulatory Background in Korea

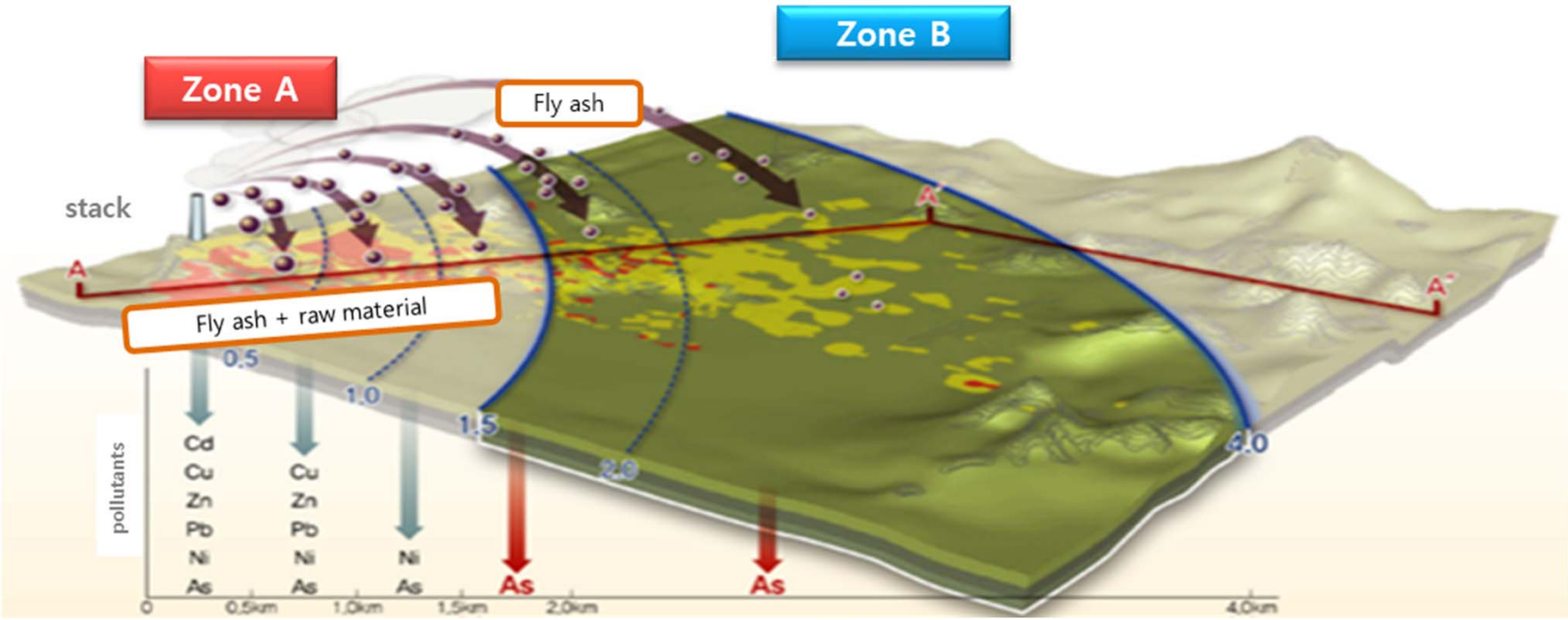
- **Korean Standards for Heavy Metals in Soil**
  - ✓ Before 2009, the criteria were based on the acid extractable or total contents of heavy metals
  - ✓ Since 2010, designated analytical method for total mass: Aqua-regia digestion
  - ✓ SECA only allows mass removal technologies, unless the remediation project is funded and supervised by the government
  - ✓ Soil Washing and Electro Kinetics have been the primary remedies employed in Korea to address heavy metals in soil
- **Risk Based Remediation in Korea**
  - ✓ Risk Based Remediation is allowed only for government remediation projects
  - ✓ The government may develop site specific remedial goals based on a risk assessment
  - ✓ Numerous leaching tests have been utilized as part of the risk assessment process
  - ✓ SECA is expected to allow Risk Based Remedy for private sites in the future

2. JANGHANG SMELTER

SITE REMEDIATION PROJECT

Janghang Smelter Site Background

- The Janghang smelter in operation since 1936!
- The area surrounding Janghang smelter was contaminated by fly ash and resulted in soil contamination by various heavy metals including As and Pb



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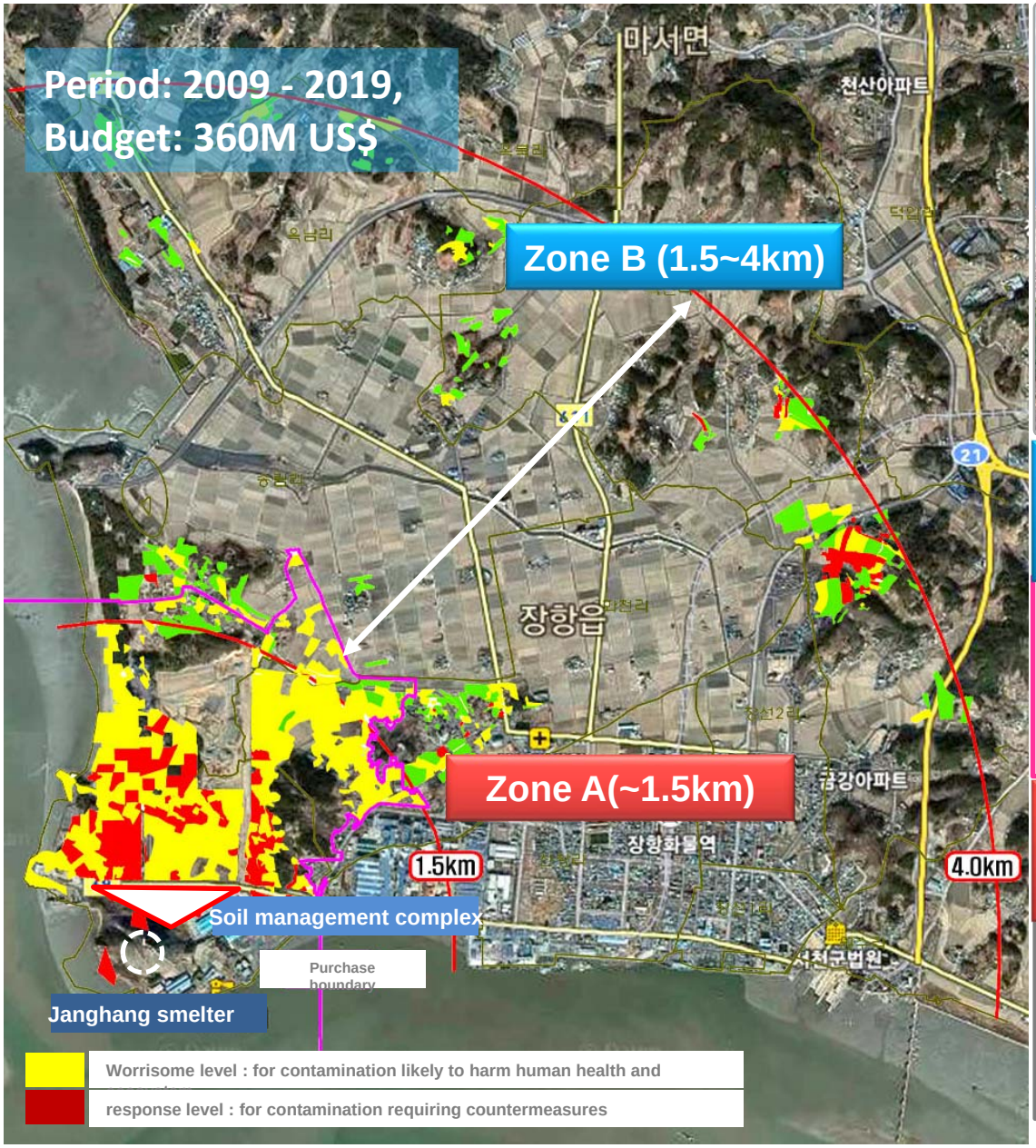

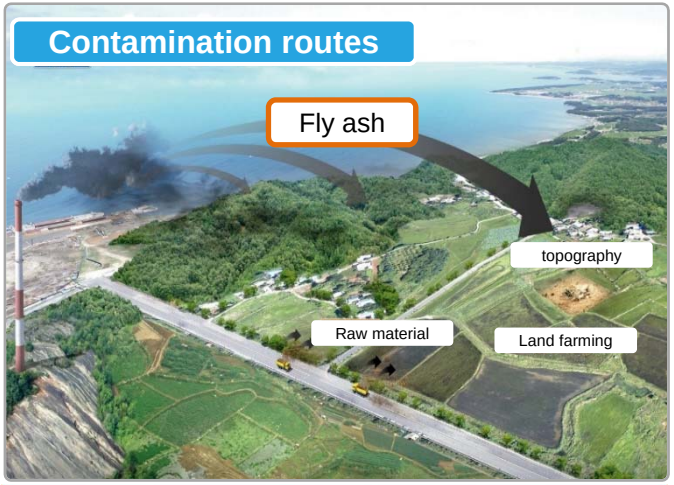

Zone B
(1.5~4km from the stack of Janghang smelter)

- Contamination is lower than zone A
- Required to do remediation earlier than zone A because of residents are living and farming

Zone A
(within 1.5km from the stack of Janghang smlter)

- Heavily contaminated and has more contaminants than zone B
- Remediation to be conducted after relocation of residents

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Zone A (~1.5km) Remediation

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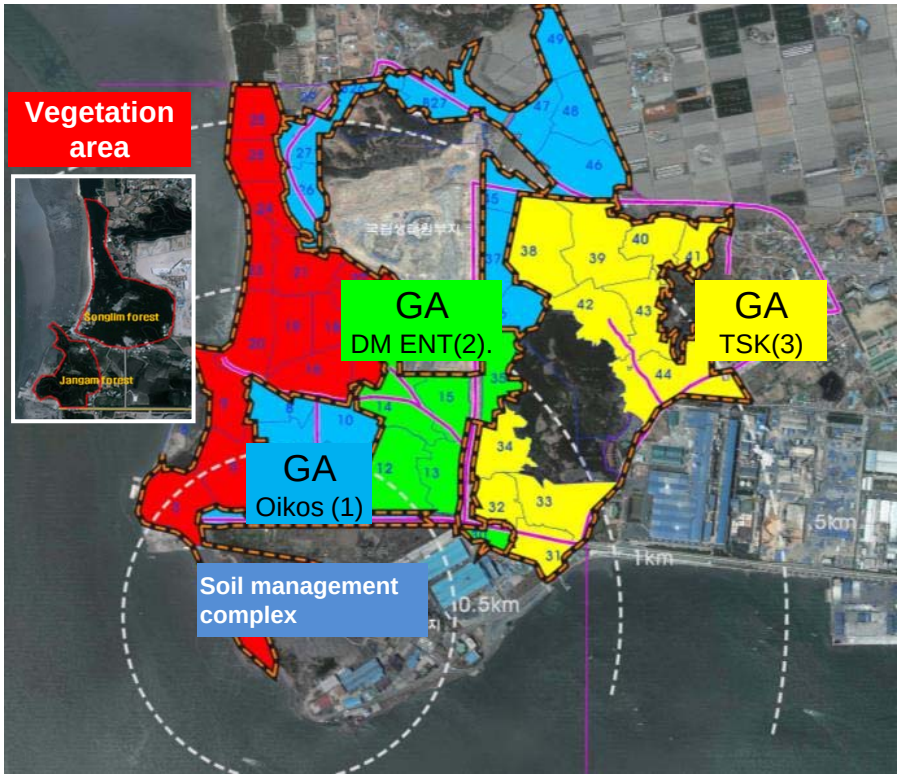

- Korean government purchased contaminated properties in general area
- Ministry of Environment decided to apply risk reduction based remedy in the forested area

Remediation process

General area (aggressive) → · Screening, · Soil washing

Vegetation area (risk based) → · Soil capping and stabilization

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Vegetation Area - Risk Reduction

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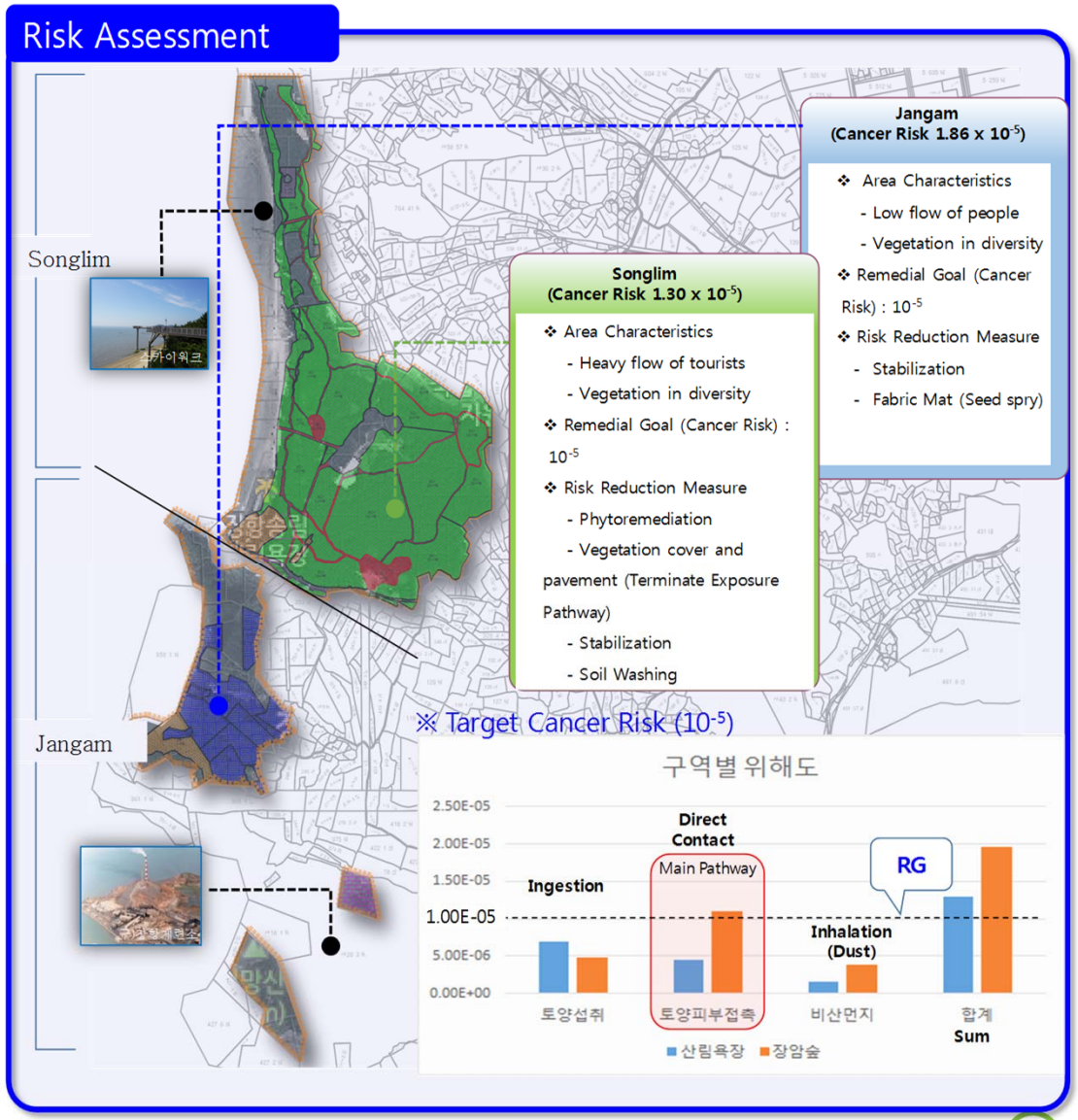
- **A risk based remedial goal was established in compliance with SECA**
  - ✓ To conserve vegetation area around Janghang Smelter
  - ✓ 10^{-5} of cancer risk, 25mg/kg of As
- **Funded by MOE; Managed by KECO; Contractor – TSK Water**
- **Project Period : 9/2016 - 7/2019**



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3. SUMMARY OF LAB STUDY (JAN. – MARCH 2017)

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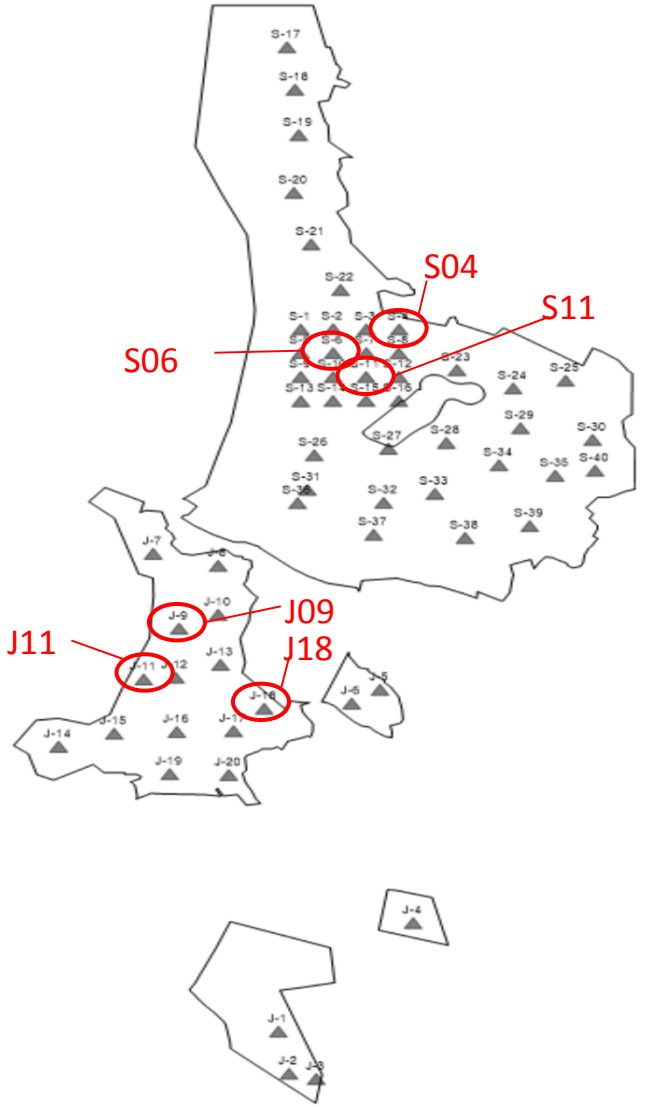
Treatability Test Methods

Multiple Evaluation Methods

- ✓ **SPLP**, apply Korean groundwater standards as RG
  - Cd (0.01 mg/L)
  - **As (0.05 mg/L)**
  - Cu (1.00 mg/L)
  - Ni (0.10 mg/L)
  - Pb (0.10 mg/L)
  - Zn (1.00 mg/L)
- ✓ **Sequential Extraction Procedure*** for As fractionation
  1) non-specifically sorbed
  2) specifically-sorbed
  3) amorphous and poorly-crystalline hydrous oxides of Fe and Al
  4) well-crystallized hydrous oxides of Fe and Al
  5) residual phases



*Wenzel (2001) Analytica Chimica Acta 436 309–323

Treatability Test Methods

- **Solubility/Bioavailability Research Consortium (SBRC)**

  Protocol for comprehensive evaluation of bioaccessible fraction of As in soil through *in vitro* test under simulated gastric conditions

- **Bioaccessibility value =**

$$\frac{As\ conc.\ in\ in\ vitro\ extract\ (mg/L)*0.1L}{As\ conc.in\ soil\ (mg/kg)*0.001kg}\times 100$$

- **Protocol**

  250 μm soil , 0.4M glycine, pH 1.5, 37°C,

  soil:extracting solution=1:100

Selection of Stabilization Reagents

- Criteria
  - ✓ Prefer reagents with demonstrated long term stabilization effect and iron minerals/oxides based
  - ✓ No detectable hazardous components tested by SPLP
- Approved alternatives
  - ✓ MetaFix® from PeroxyChem
  - ✓ AC5 from Amron: artificial zeolite with iron oxides, sulfate, MgO
  - ✓ KSP: mostly Fly ash and limestone, and proprietary components

MetaFix® Stabilization Technology

- ✓ MetaFix reagents are customized blends of reducing agents, reactive minerals, mineral activators, catalysts, pH modifiers, and adsorbents
- ✓ The appropriate MetaFix blend is selected based on site specific conditions
- ✓ MetaFix treatment mechanisms are based on the **formation of iron, iron sulfide, and other iron-bearing mineral precipitates** with heavy metals that have low solubility and are highly stabile
- ✓ MetaFix reagents do not depend on microbial activity and can function in acutely toxic soils with various physicochemical properties

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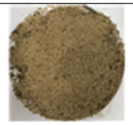
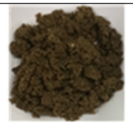
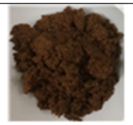
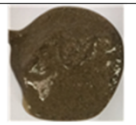
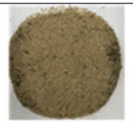
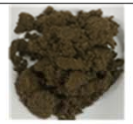
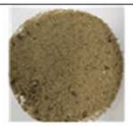
Lab test – 4 Reagents Tested

ID	Dried sample	MetaFix H-1E	MetaFix I-6A		AC5	KSP
		Dosage 1%	Dosage 1%	Dosage 2%	Dosage 0.5%	Dosage 5%
S4				NA		
S6				NA		
S11				NA		
J9		NA				
J11		NA				
J18		NA				

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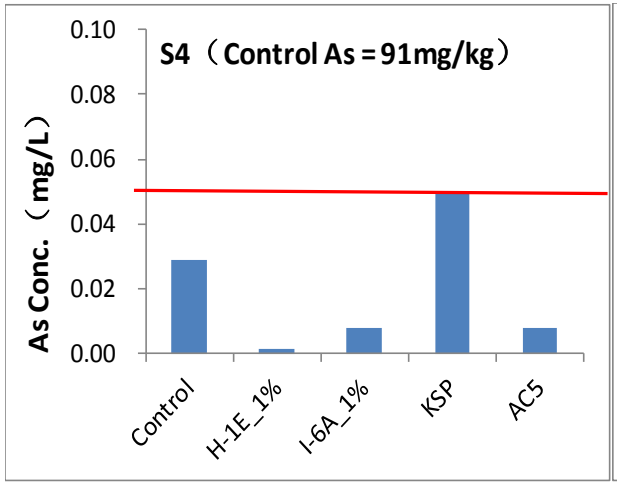
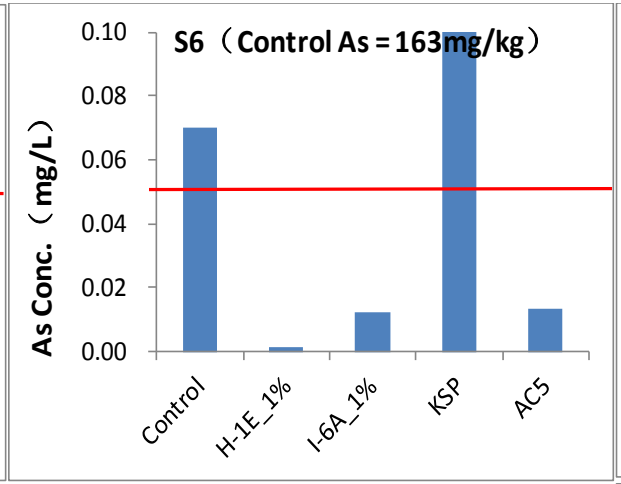
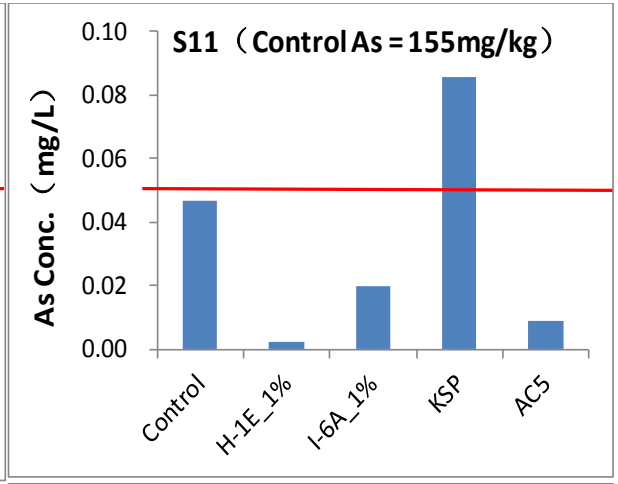
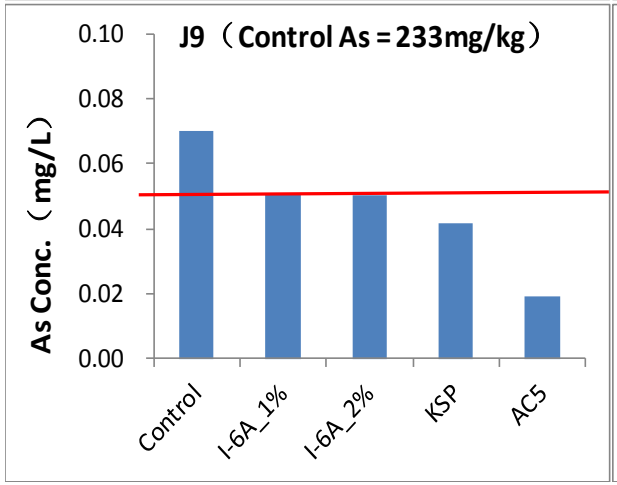
SPLP Results

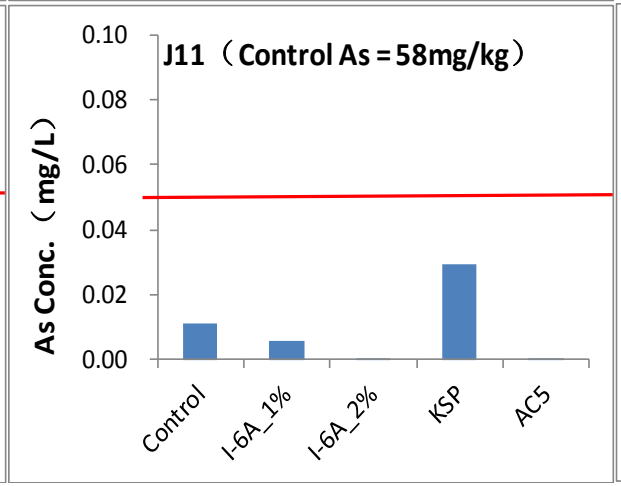
- MetaFix and AC5 met RG (0.05 mg/L As)
- KSP failed due to alkaline pH, hence, eliminated

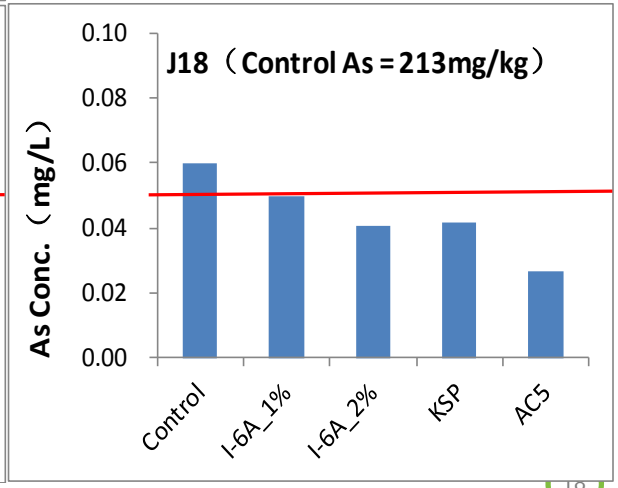












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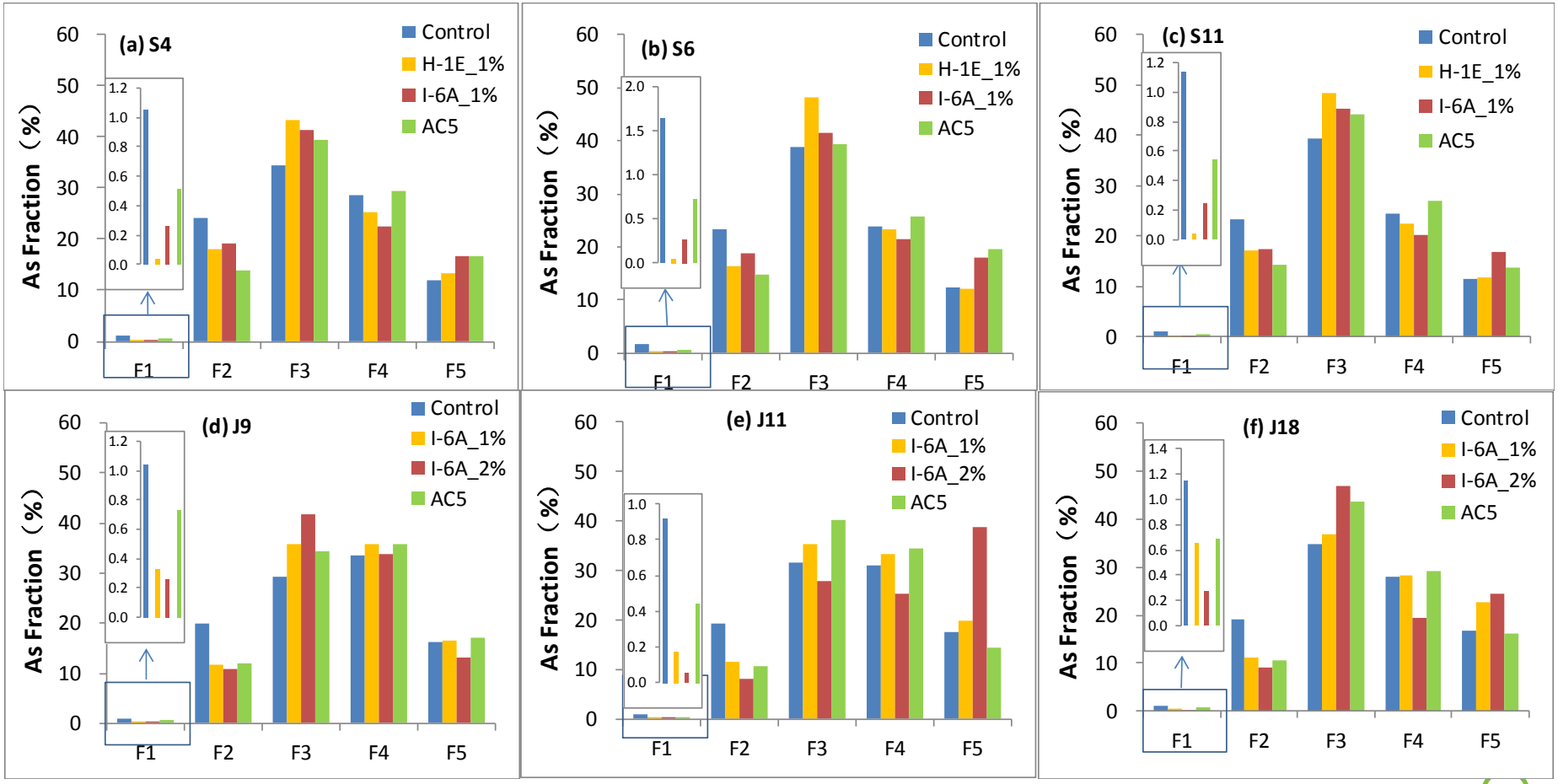
SEP results

MetaFix® showed clearer trend of converting more labile and bioavailable fractions, F1 and F2, to more stabilized fractions than AC5



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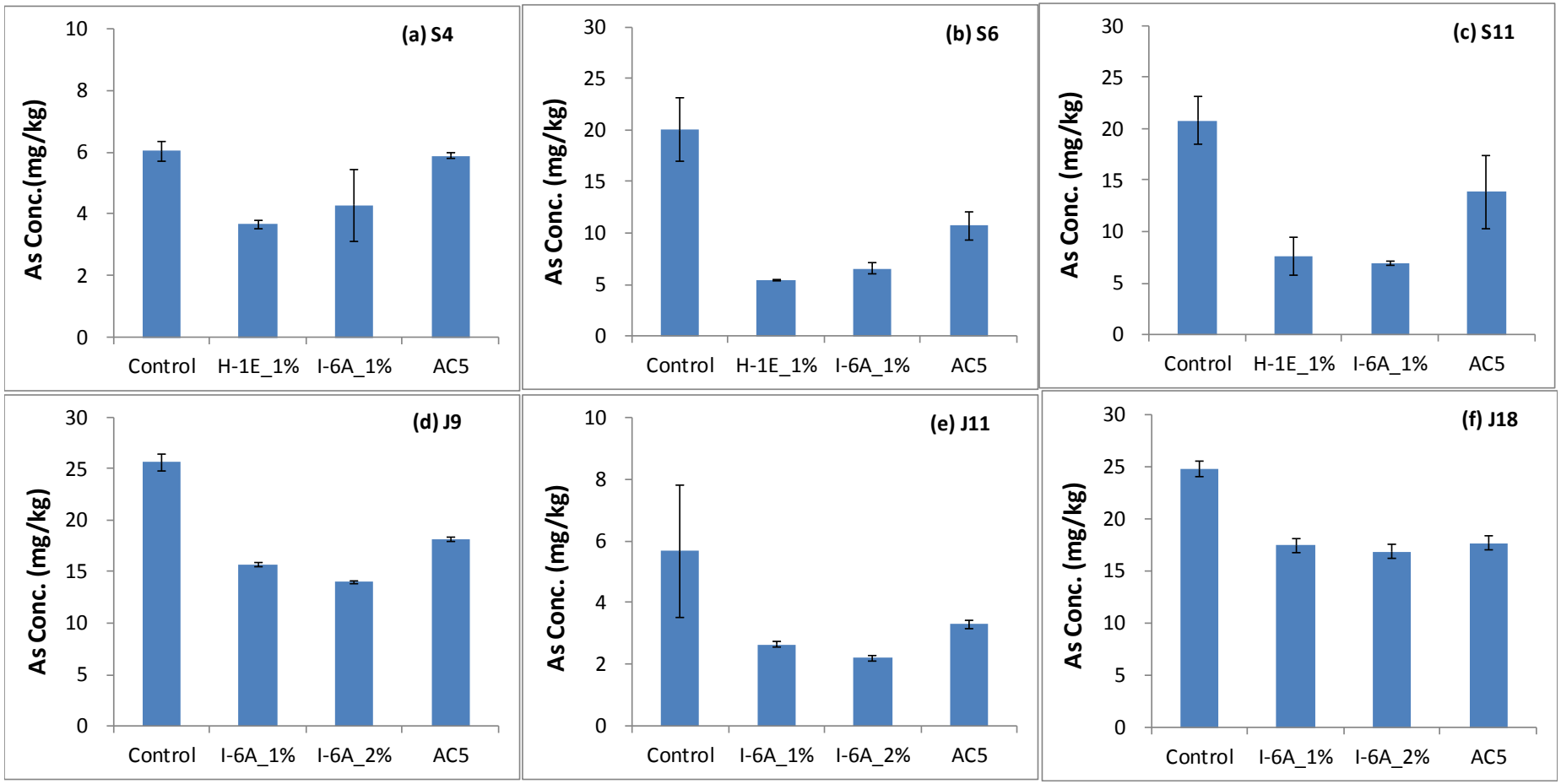
SBRC Results

MetaFix® reduced bioaccessibility much more significantly than AC5



4. SUMMARY OF FIELD PILOT (APRIL-MAY 2017)


Site preparation


Dosage is 1% for both MetaFix and AC5
MetaFix stabilization


Site preparation


Moisture adjustment

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Sampling

1	2	3	Section A
4	5	6	Section B
7	8	9	Section C

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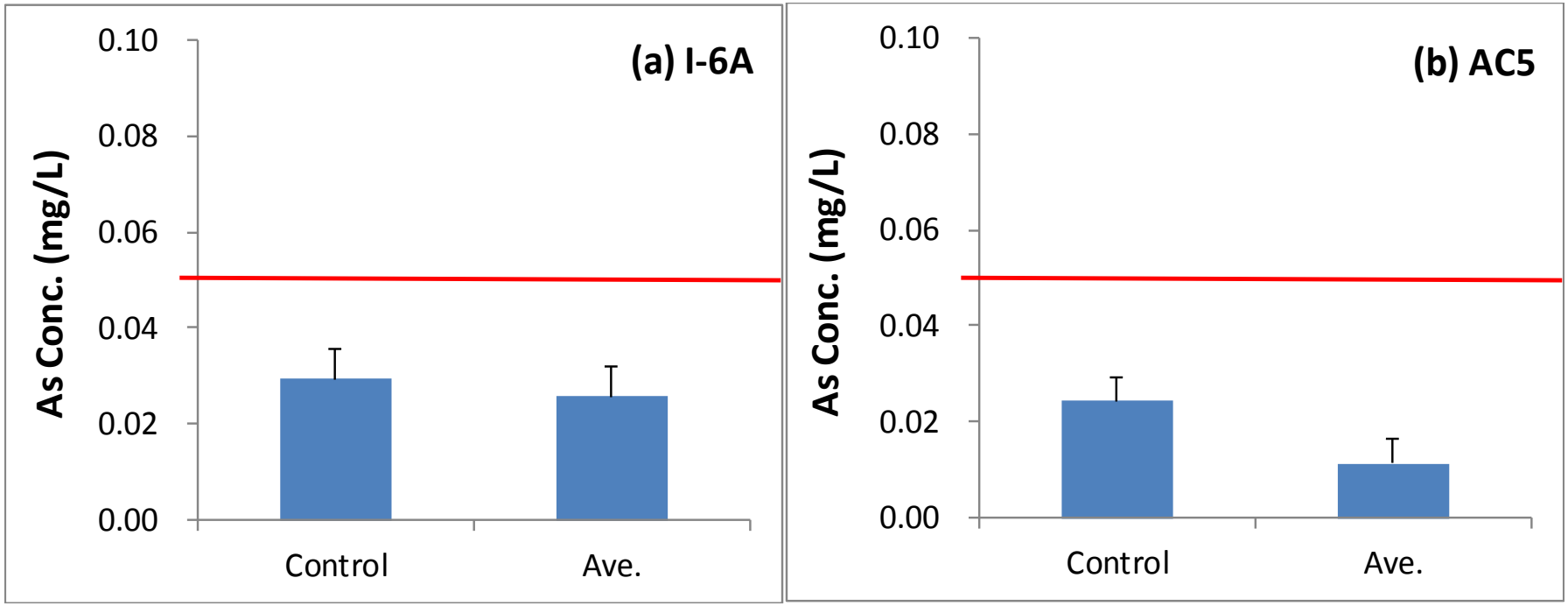
Pilot Results

Pilot SPLP Results



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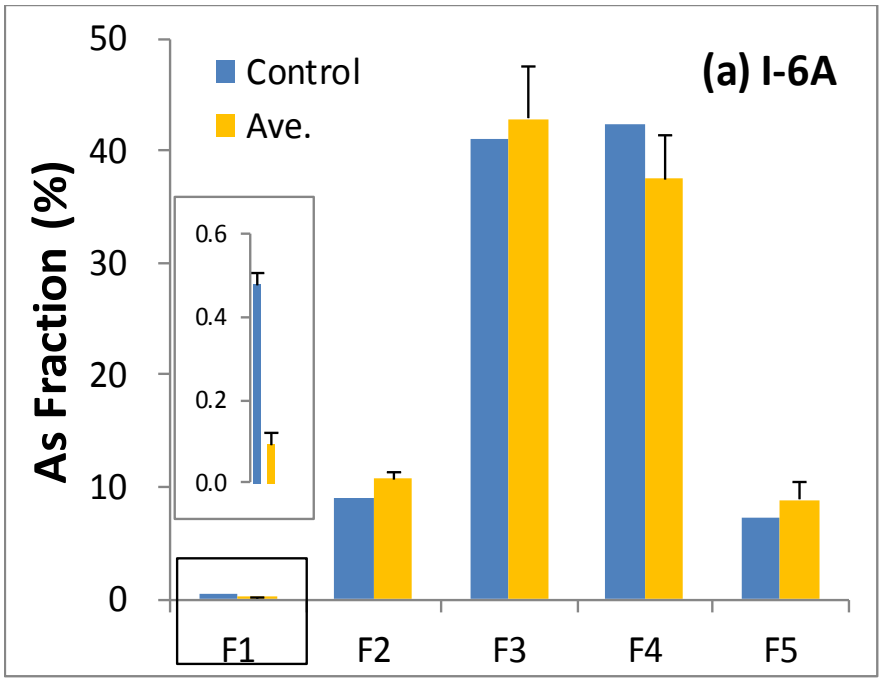
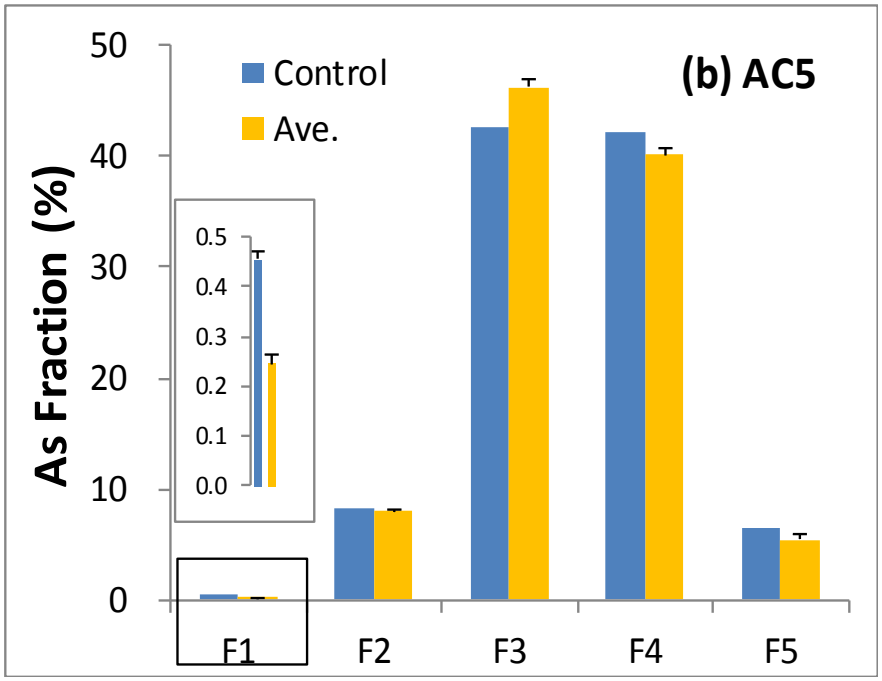
Pilot Results

Pilot SEP Results





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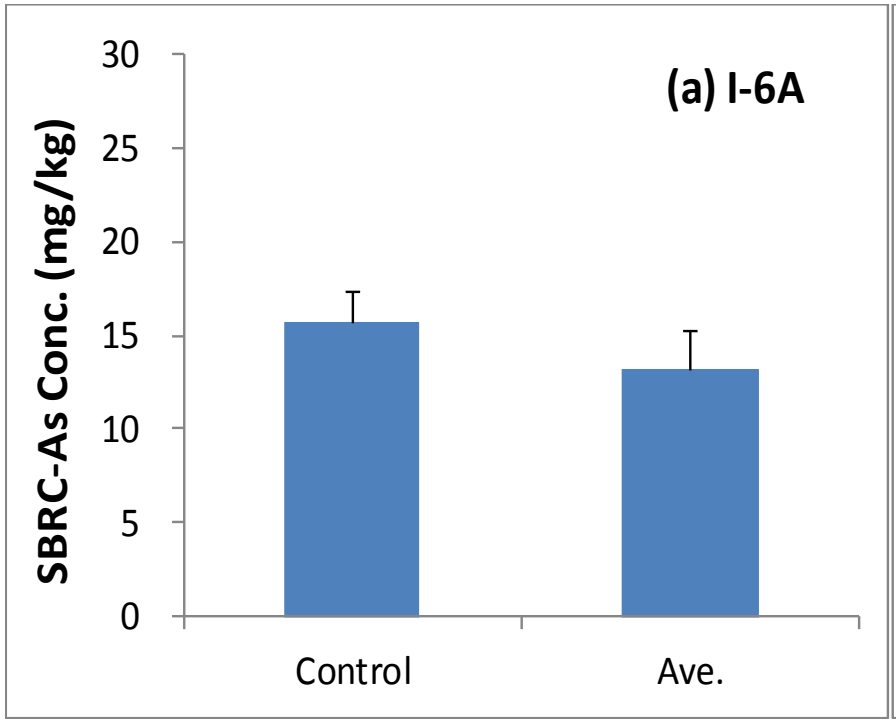
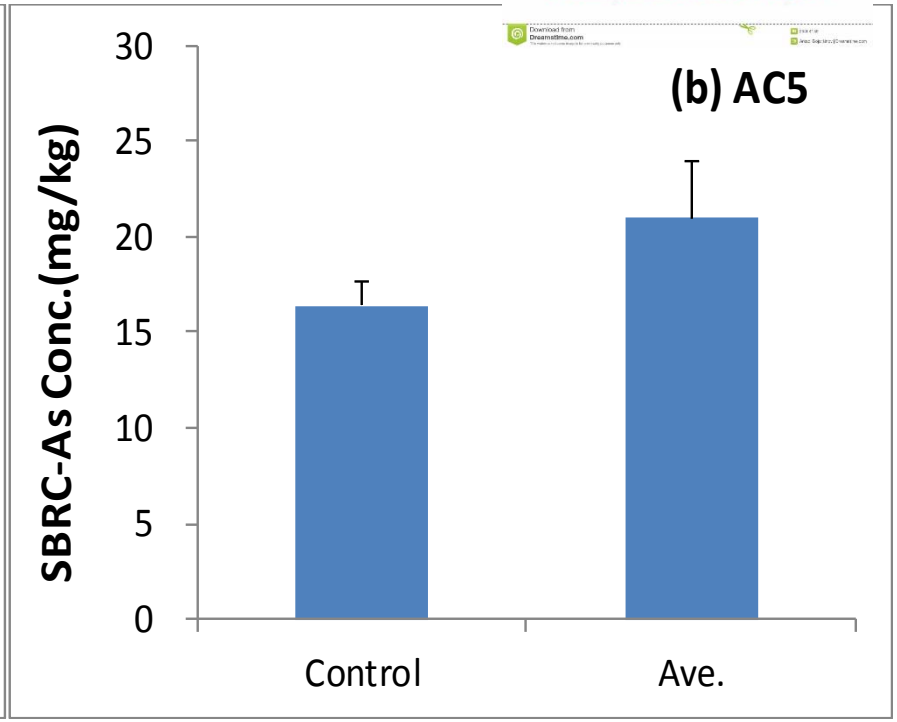
Pilot Results

Pilot SRBC Results





Field Treatability Study Conclusion

- MetaFix was selected over alternative reagent AC5
  - ✓ SBRC risk reduced by (41.1%) while AC5 increased SBRC risk by +37.2%
  - ✓ MetaFix showed a superior As stabilization effect in SEP evaluation

Reagent	pH change	SPLP	Wenzel SEP	SBRC	Economy	Implementability	Ave. Score
MetaFix	●	●	●	◐	◐	◐	
	5	5	5	3	3	3	4.0
AC5	●	●	◐	○	◐	●	
	5	5	3	1	3	5	3.67

5. LAUNCH OF FULL SCALE FIELD WORK (FEB. 2018)

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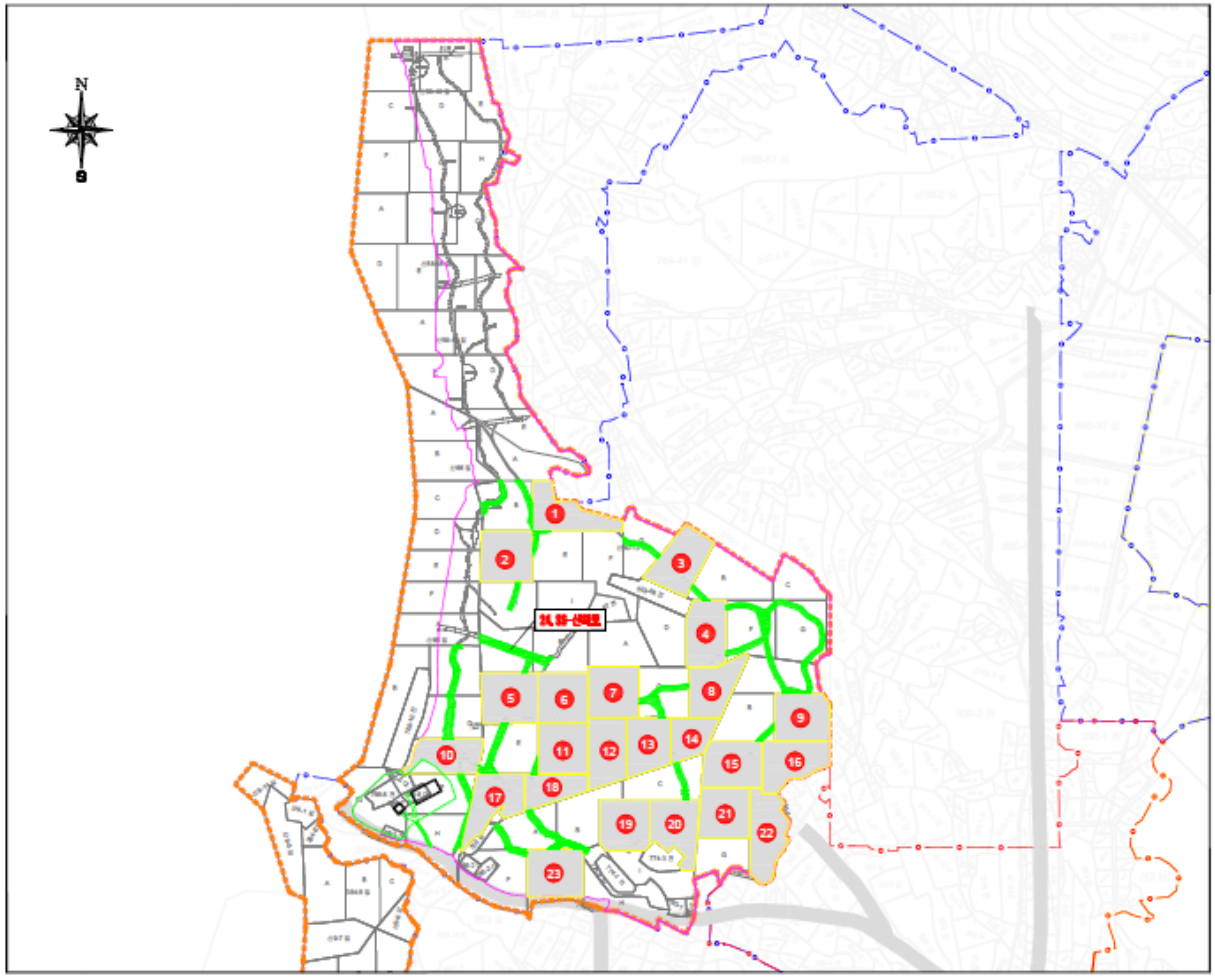
Full scale Treatment

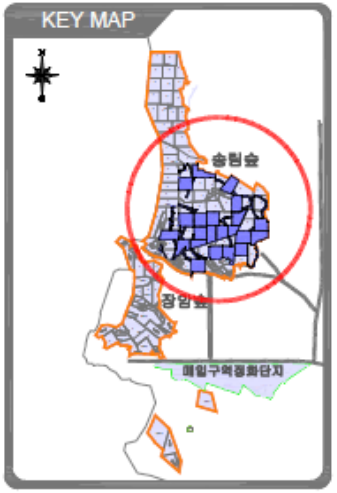
- Songlim forest 75,451 m^2
  - ✓ Sandy soil
  - ✓ pH 6-7, no need pH adjustment
- Jangam forest 34,262 m^2
  - ✓ Clayey soil
  - ✓ pH 5-6, only few locations below 5, suggest pH adjustment to ~5.5 with <0.1% w/w lime
- TTZ: Top 15 cm
- MetaFix dosage: **1% w/w**

Songlim Forest

[Stabilization] Layout (Songlim)

(S=1/5,000)





Zone Area

1	SS-1	2,944 M2
2	SS-2	3,057 M2
3	SS-3	3,082 M2
4	SS-4	3,019 M2
5	SS-5	3,338 M2
6	SS-6	2,992 M2
7	SS-7	2,992 M2
8	SS-8	2,801 M2
9	SS-9	3,051 M2
10	SS-10	2,849 M2
11	SS-11	2,990 M2
12	SS-12	3,031 M2
13	SS-13	2,785 M2
14	SS-14	1,946 M2
15	SS-15	3,180 M2
16	SS-16	3,068 M2
17	SS-17	3,143 M2
18	SS-18	2,043 M2
19	SS-19	2,974 M2
20	SS-20	3,068 M2
21	SS-21	3,019 M2
22	SS-22	3,283 M2
23	SS-23	3,128 M2
	SS-산책로	7,670 M2
	합 계	75,451 M2

0 50 100 200(m)

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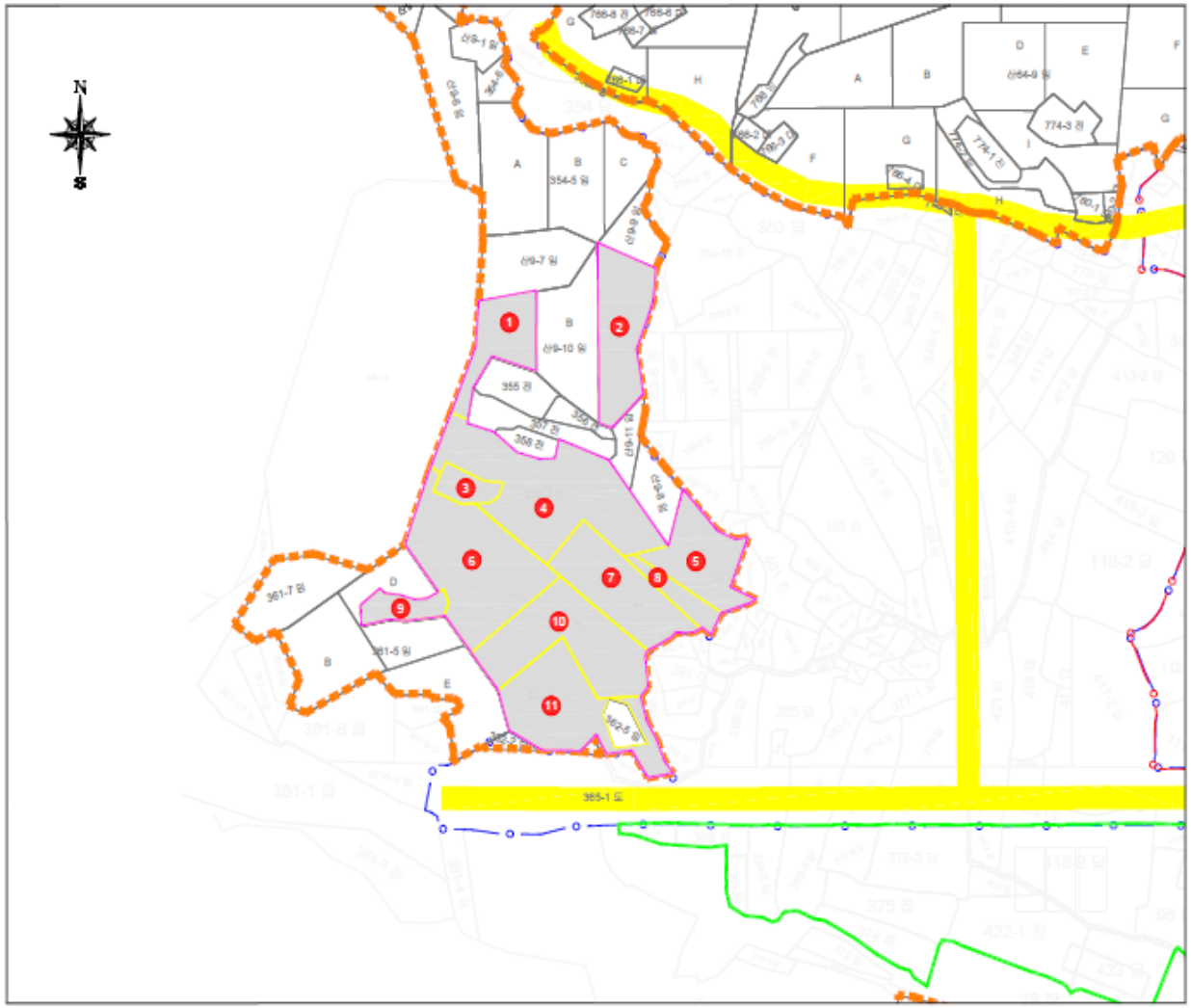
Jangam Forest

[Stabilization] Layout (Jangam)

(S=1/3,000)

평 면 도



Zone Area

1	JS-1	2,037 M2
2	JS-2	3,195 M2
3	JS-3	720 M2
4	JS-4	6,677 M2
5	JS-5	2,615 M2
6	JS-6	5,508 M2
7	JS-7	3,323 M2
8	JS-8	804 M2
9	JS-9	879 M2
10	JS-10	4,466 M2
11	JS-11	4,039 M2
	합 계	34,262 M2

0 50 100 200(m)

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Baseline Investigation

- ✓ Comparable extent of contamination at both Songlim and Jangam forests
- ✓ **COC – As**, significantly exceeding standards
- ✓ Implementation challenges
  - Narrow space for operation
  - Limited water source nearby
  - First ever stabilization project

Songlim	Total Mass	SBRC	SPLP	Bioaccessibility
	(mg/kg)	(mg/kg)	(mg/L)	(%)
Max.	176.6	48.2	1.81	27.3
Min.	93.9	15.2	0.47	13.7
Ave.	123.4	24.3	0.90	19.0

Jangam	Total Mass	SBRC	SPLP	Bioaccessibility
	(mg/kg)	(mg/kg)	(mg/L)	(%)
Max.	170.4	29.4	1.18	17.3
Min.	87.1	7.8	0.31	7.8
Ave.	123.8	15.4	0.81	11.33

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Field Implementation

- First field demo launched at Songlim forest 2/28/2018
  - ✓ Site preparation
  - ✓ Lay 1 bg MetaFix (25kg)/10 m^2
  - ✓ Manually spread MetaFix
  - ✓ Till in
  - ✓ Water
  - ✓ Cover with fiber mat
  - ✓ Maintain **7 days** before inspection sampling

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Field Implementation

Future Land Use

- **Environmental industry & R&D complex**
- **Residential tourism**
  - ✓ Ecological park, Theme park, Recreation space, cultural creative space etc.
- **New renewable energy production**

Conclusions

- Comprehensive treatability study and evaluation methodology helped screening the best choice of reagent
- International collaboration led to acceptance and application of this new heavy metal stabilization technology in Korea

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Thank You!

Huifeng Shan, PhD, PE
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