ผลกระทบต่อสิ่งแวดล้อม
จากกระบวนการทิ้งและกำจัดขยะอิเล็กทรอนิกส์

โดย

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Environmental Impacts of E-Waste Disposal and Management

A Case Study from Khok Sa-ard Sub-district,
Khong Chai District, Kalasin Province, Thailand

By

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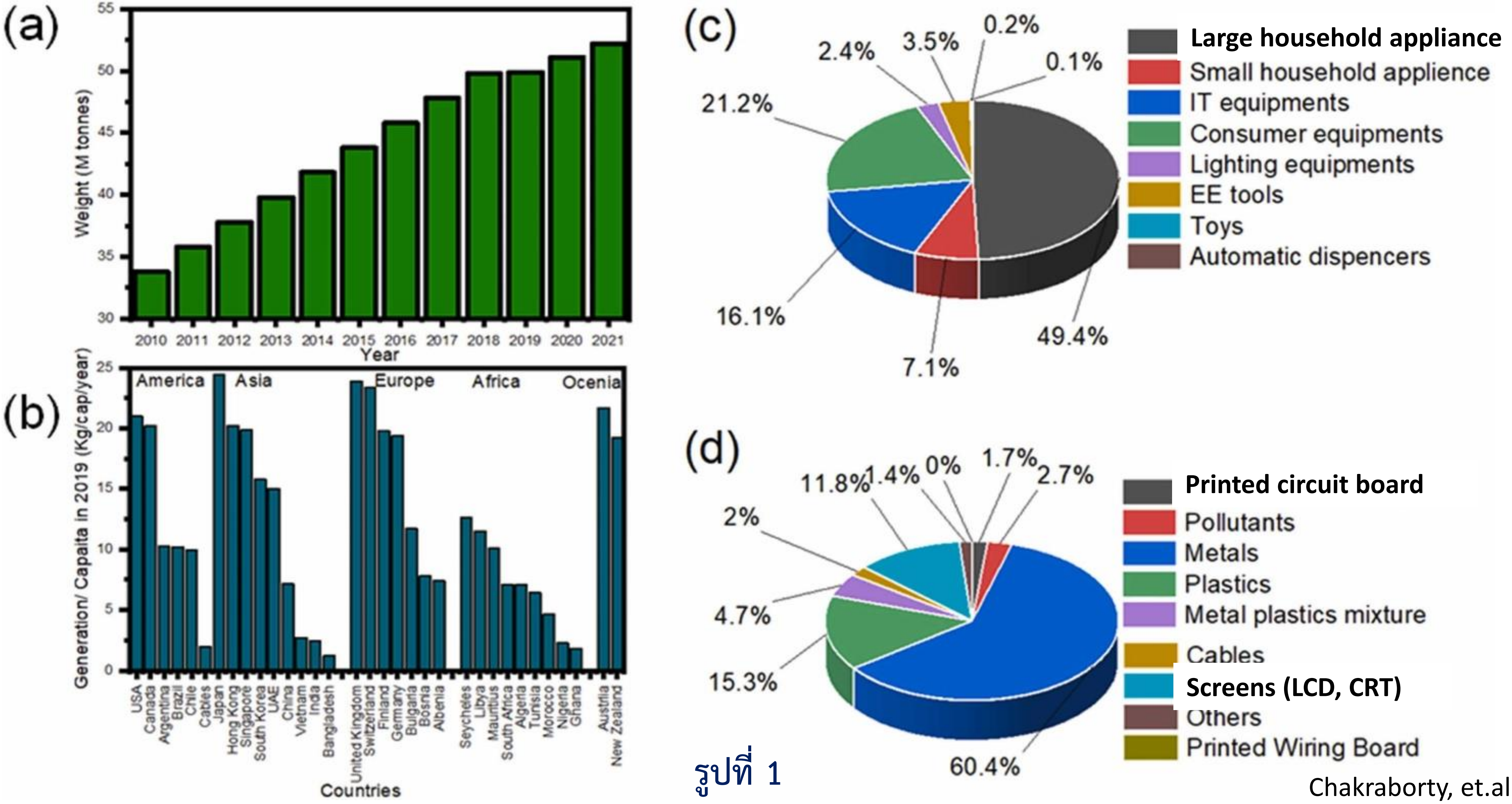
ขยะอิเล็กทรอนิกส์ (e-waste)

- ขยะอิเล็กทรอนิกส์ (e-waste) คือกลุ่มผลิตภัณฑ์เครื่องใช้ไฟฟ้า และอิเล็กทรอนิกส์ที่ไม่ได้ใช้งานแล้ว ซึ่งปัจจุบันจัดเป็นอีกหนึ่งปัญหาสิ่งแวดล้อมระดับโลก เนื่องจากชิ้นส่วนในอุปกรณ์อิเล็กทรอนิกส์ และเครื่องใช้ไฟฟ้ามีส่วนประกอบของสารก่อมลพิษ เช่น โลหะหนัก และสารเคมีอินทรีย์ ต่าง ๆ ซึ่งนอกจากส่งผลกระทบต่อสิ่งแวดล้อมแล้วยังส่งผลต่อสุขภาพของประชาชน และสิ่งมีชีวิตอื่น ๆ อีกด้วย
- ปริมาณขยะอิเล็กทรอนิกส์ในโลกระหว่างปี 2010-2021 มีจำนวนมากและเพิ่มขึ้นทุกปี (รูปที่ 1)

Global e-waste generation scenario over the period (2010-2021)



รูปที่ 1

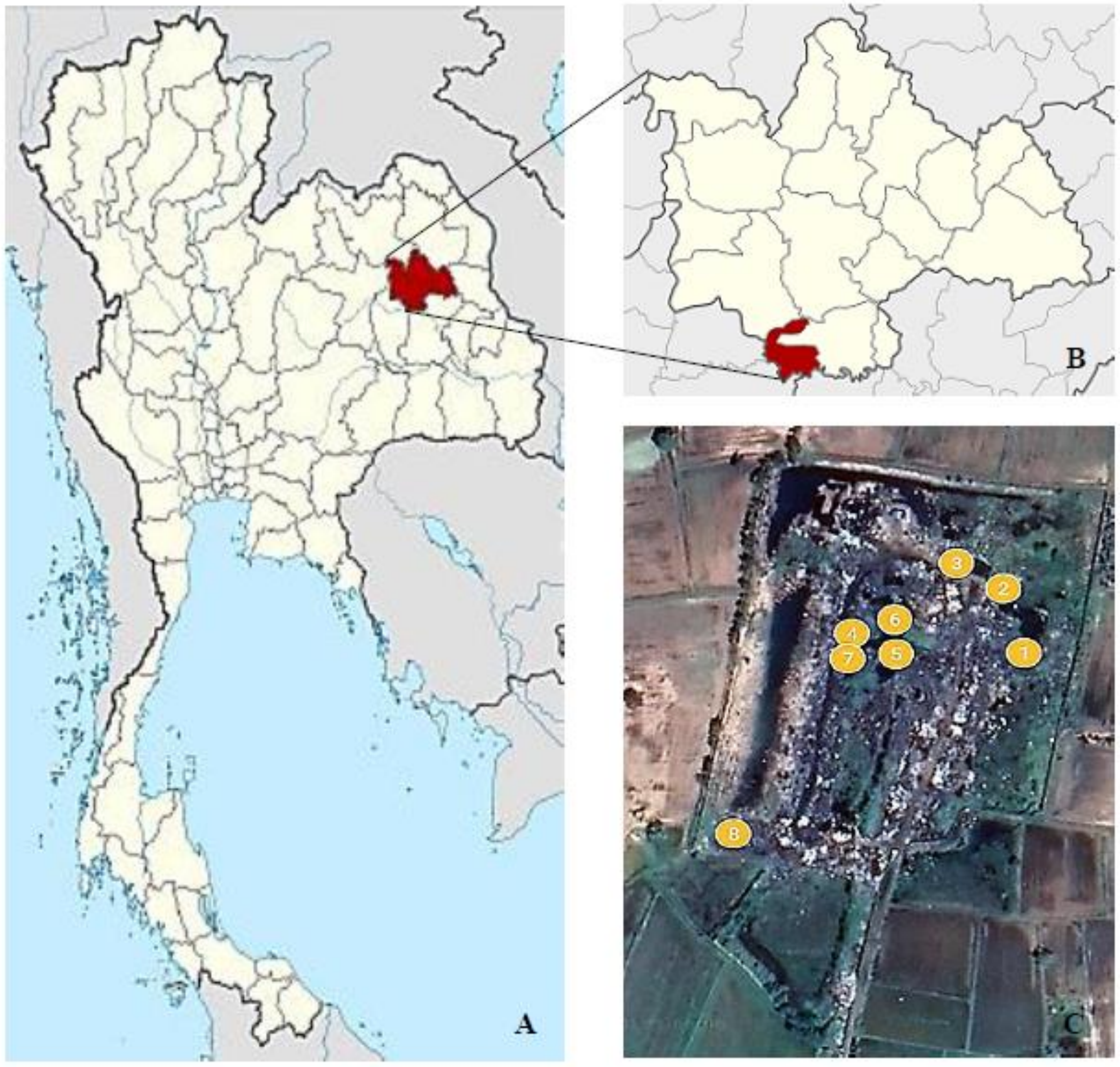
Chakraborty, et.al (2022)

- (a) Global quantity of e-waste generation (2020–2030 are estimated) (b) e-waste generation per capita in 2019 in different countries. (c) Composition and major sources of e-waste; average composition (d) and materials fractions of E-waste.

- โลหะที่สำคัญใน E-Waste ได้แก่ Pb, Ni, Al, Cu, Fe, Pd, Au, and Ag

CASE STUDIES

1. Introduction

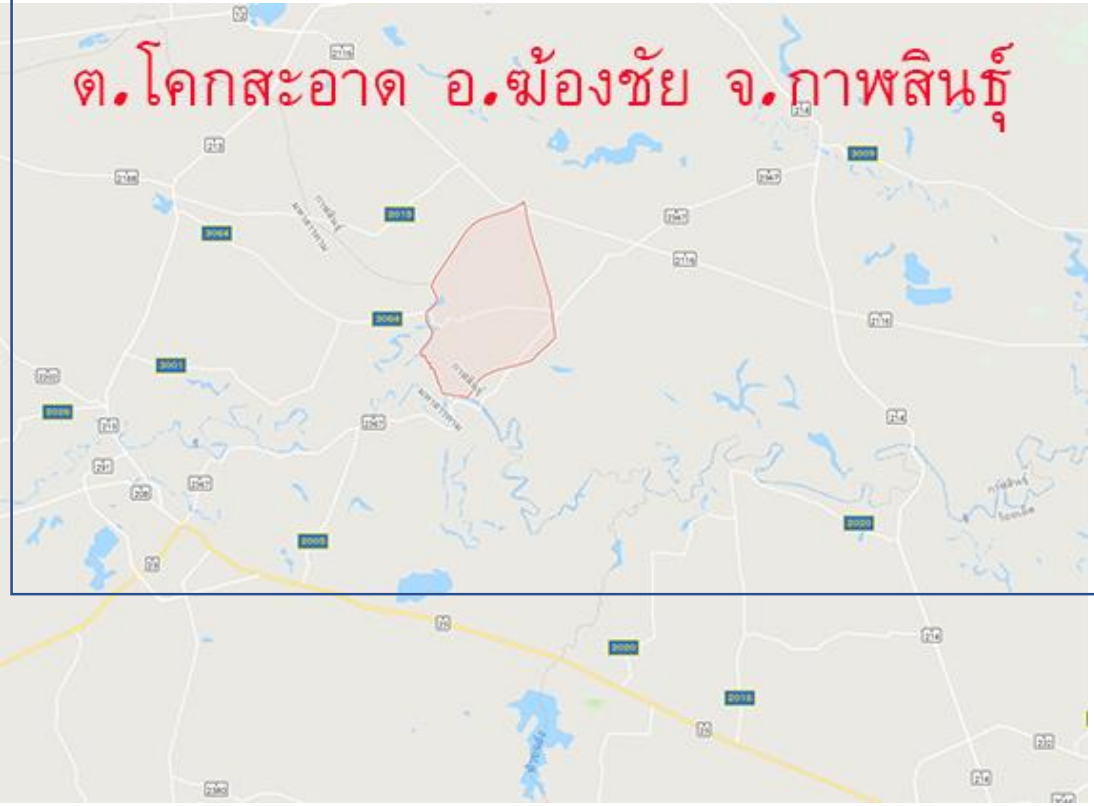


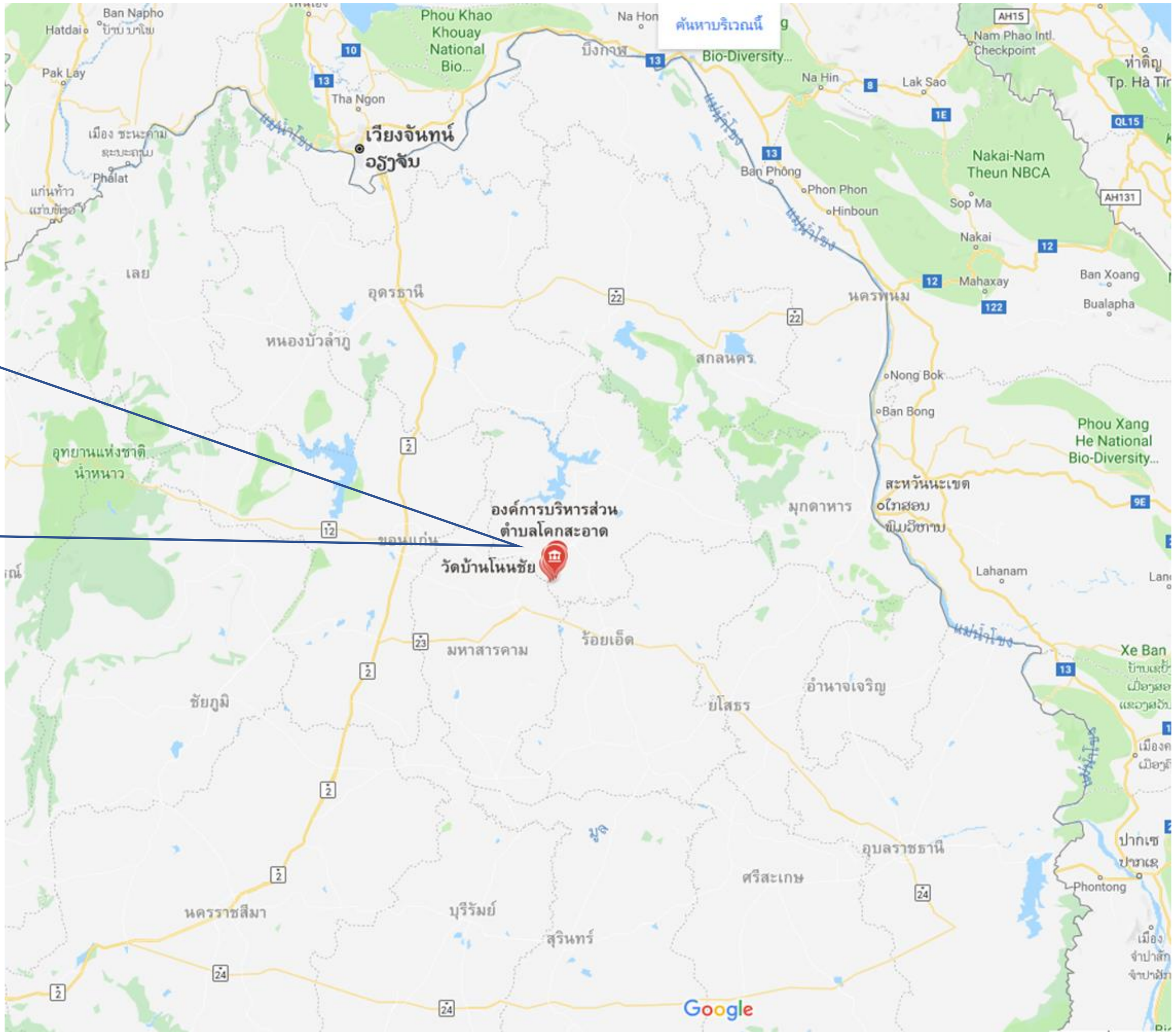
The Landfill site

Figure 1

- (A) The map of Thailand showing Kalasin province.
- (B) Khong Chai district where the landfill site containing mostly electronics waste (e-waste) is located.
- (C) 8 sampling sites within the landfill where soil and plant samples were collected.

Google contributor: https://www.google.com/maps


ต.โคกสะอาด อ.ฆ้องชัย จ.กาฬสินธุ์


ค้นหาบริเวณนี้
เวียงจันทน์
เลย
อุดรธานี
หนองบัวลำภู
สกลนคร
นครพนม
อุทยานแห่งชาติน้ำหนาว
องค์การบริหารส่วนตำบลโคกสะอาด
วัดบ้านโนนชัย
มุกดาหาร
สะหวันนะเขต
ขอนแก่น
มหาสารคาม
ร้อยเอ็ด
ชัยภูมิ
ยโสธร
อำนาจเจริญ
อุบลราชธานี
ศรีสะเกษ
นครราชสีมา
บุรีรัมย์
สุรินทร์
Phou Khao Khouay National Bio...
Nakai-Nam Theun NBCA
Phou Xang He National Bio-Diversity...
Google

And, The Story Begin…….

The Landfill site

- **Area: 32,900 m^2 (Approximately 5.14 Rai)**
- **Description:** This landfill site contains mostly **electronics waste (e-waste)** from dismantling electric appliances **such as CRT (cathode-ray tube) from old-model TV and computer monitor, refrigerator, watching machine and mosquito zapper.**
- The site are surrounded by **rice filed** and other **agricultural farms**.
- From the observation water source is supposing to be contaminated with heavy metals and any possible contaminants leaking from e-waste. It was concerned by public, media and government.


บ้านหนองบัว หมู่ที่ 3,11
ต. โคกสะอาด


TOYOTA
HILUX

ที่มา: https://theisaanrecord.co/2019/09/24/kalasin-e-waste-burning-th/






- Number of villagers involved is around 650
- E-waste loading =767 tons/month
- Once valuable metals were separated the left over is 20 tons/month
- The waste above is the unwanted waste after separation.
- There were scavengers who came and burn things for any left-over metals.

Research Studies

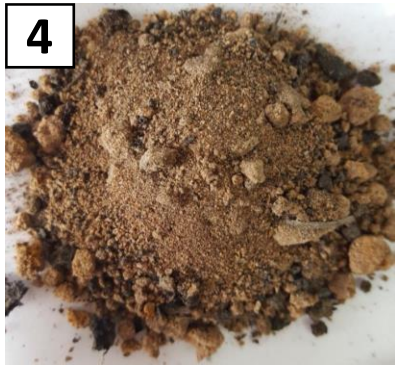
- Numbers on the picture indicate sampling sites
- Students and researchers collected plants and soil samples.

Landfill site

June 2019



Soil Collection

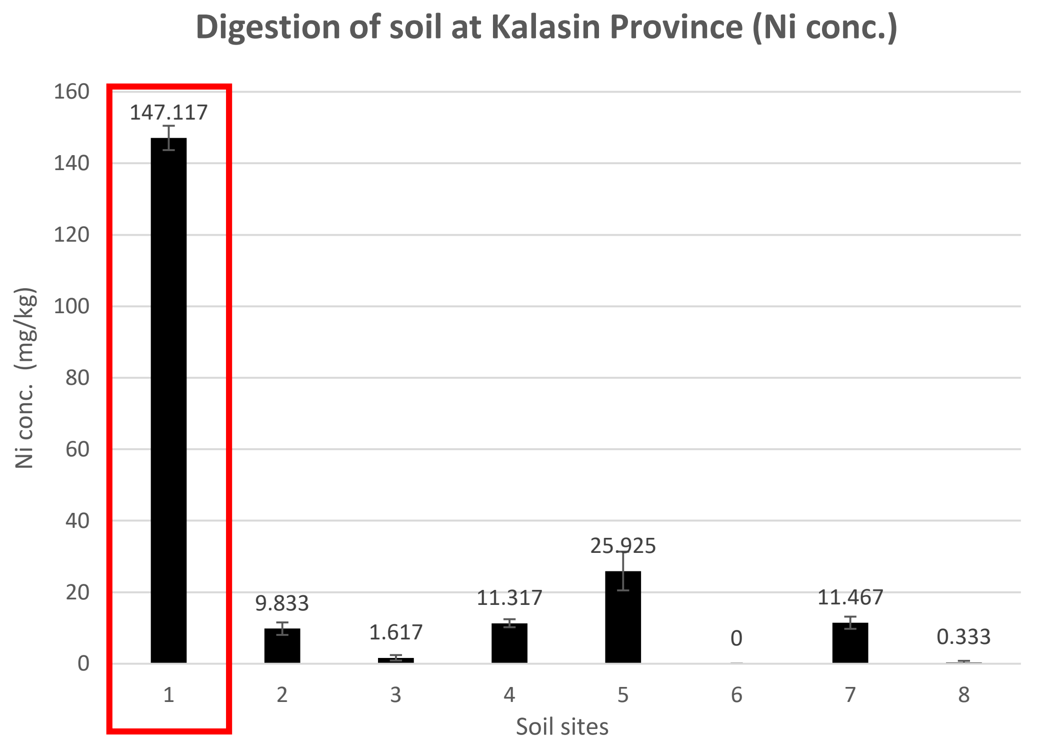


Kalasin Landfill site

- The pictures show soil samples from site 1 - 8
- Expected results
  - Heavy metals in soils (Ni, Zn, Cu, Pb, and Cd)
  - Available form of each metals

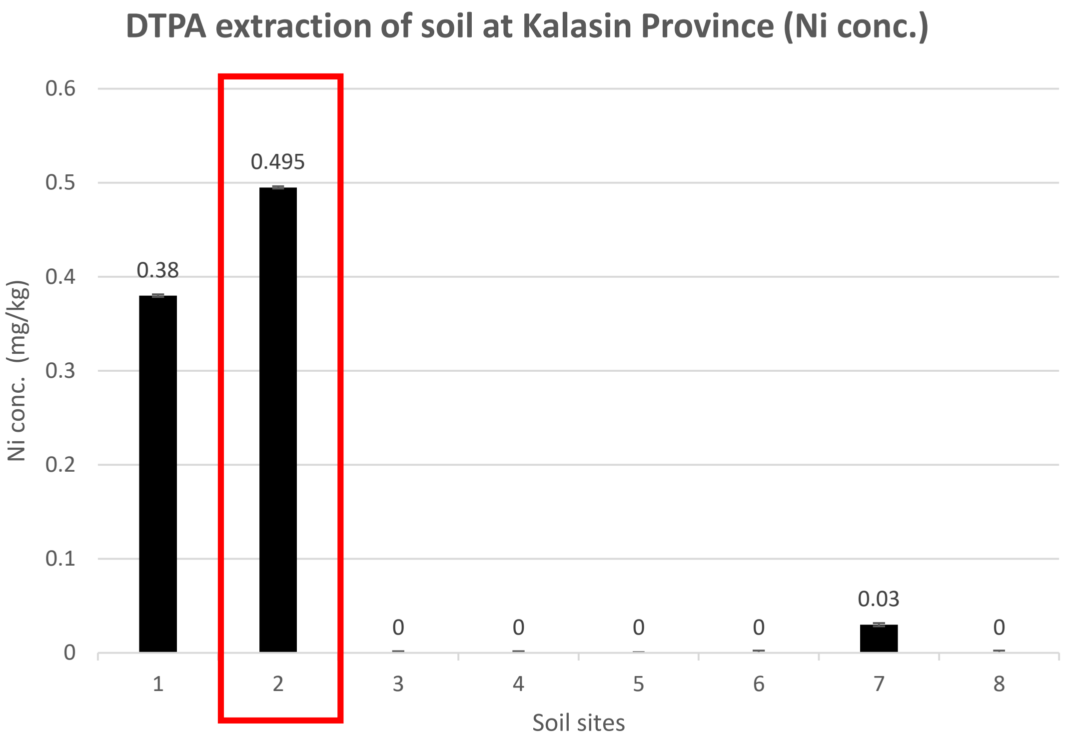
Results:

Total Ni concentration in soil samples

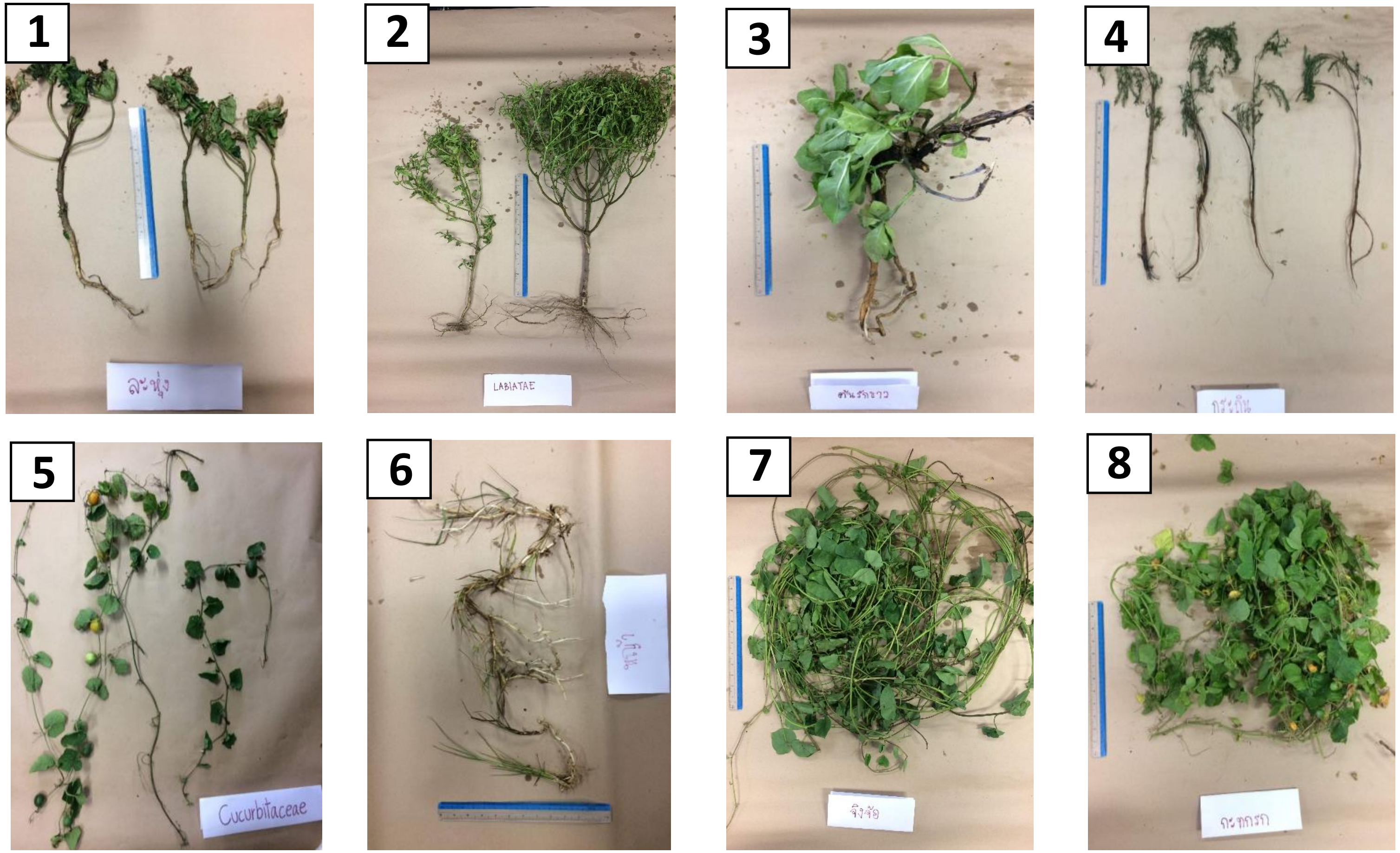


- The maximum value of Ni concentration is present in **soil site 1**, **147.117 mg/kg soil**.

DTPA-extractable Ni in soil samples



- The maximum value of available Ni is present in **soil site 2**, **0.495 mg/kg soil**.



Collected Plant Samples

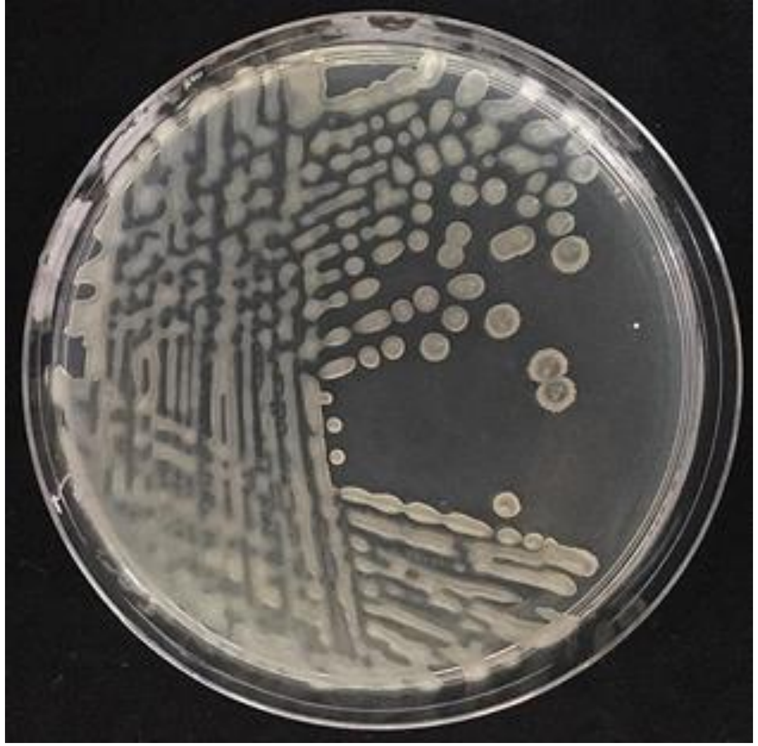
1. *Ricinus communis*
2. *Labiatae spp.*
3. *Semecarpus cochinchinensis*
4. *Leucaena leucocepphala*
5. *Cucurbitaceae spp.*
6. *Imperata spp.*
7. *Aniseia martinicensis*
8. *Passiflora foetida*

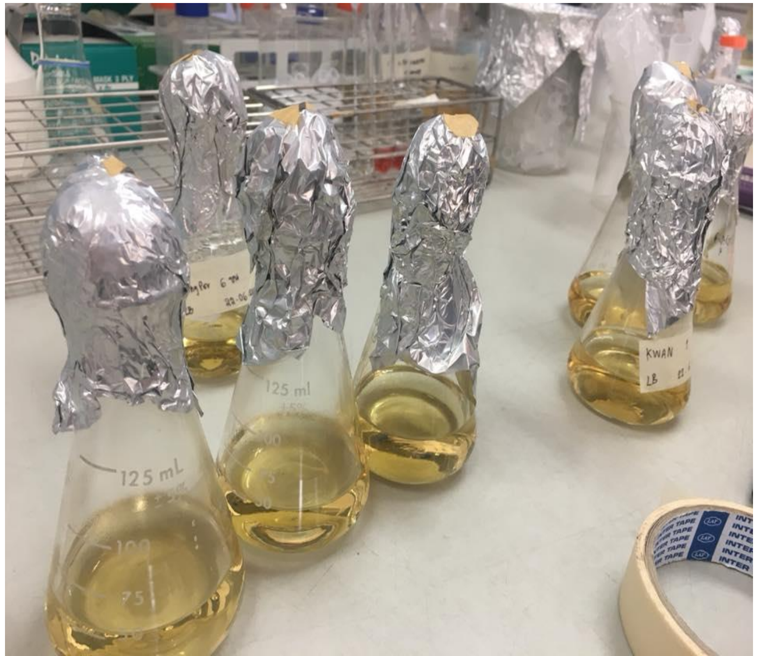
- Shoot and Root length / Plants dry weight
- Heavy metals concentrations in Plants (Ni)
- Bioaccumulation factor (BCF)
- Translocation factor (TF)
- Extraction coefficient (EC)

Results

- **Plants collected from the landfill site**

Number	Name	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)
1.	*Ricinus communis* (ละหุ่ง)	32.73±6.69	17.3±4.1	16.01	2.49
2.	*Labiatae* spp. (วงศ์ของ กะเพรา โหระพา แมงลัก)	56.4±4.8	26.55±1.77	10.75	6.74
3.	*Semecarpus cochinchinensis* (รักขาว)	42.1	39.0	21.83	18.41
4.	*Leucaena leucocephala* (กระถิน)	37.7±3.2	16.6±7.6	17.72	6.58
5.	*Cucurbitaceae spp.* (วงศ์แตง)	104.73±42.91	16.03±3.29	14.45	0.35
6.	*Imperata spp.* (หญ้าคา)	22.63±4.38	8.17±1.61	10.08	0.61
7.	*Aniseia martinicensis* (จิงจ้อ)	-	-	43.11	7.01
8.	*Passiflora foetida* (กะทกรก)	-	-	29.47	-





1) Isolation of bacteria
2) Ni tolerance test
3) Gram staining test
4) IAA production test
5) Siderophore test
6) ACC-deaminase test
7) Phosphate solubilization test

Isolated bacteria

from Kalasin's soil

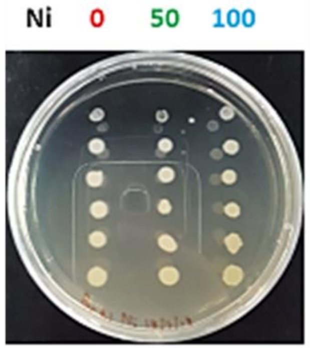
Soil	Number of bacteria in each soil site
Site 1	2
Site 2	2
Site 3	2
Site 4	1
Site 5	2
Site 6	2
Site 7	2
Site 8	2
Σ	**15**

Ni tolerance test

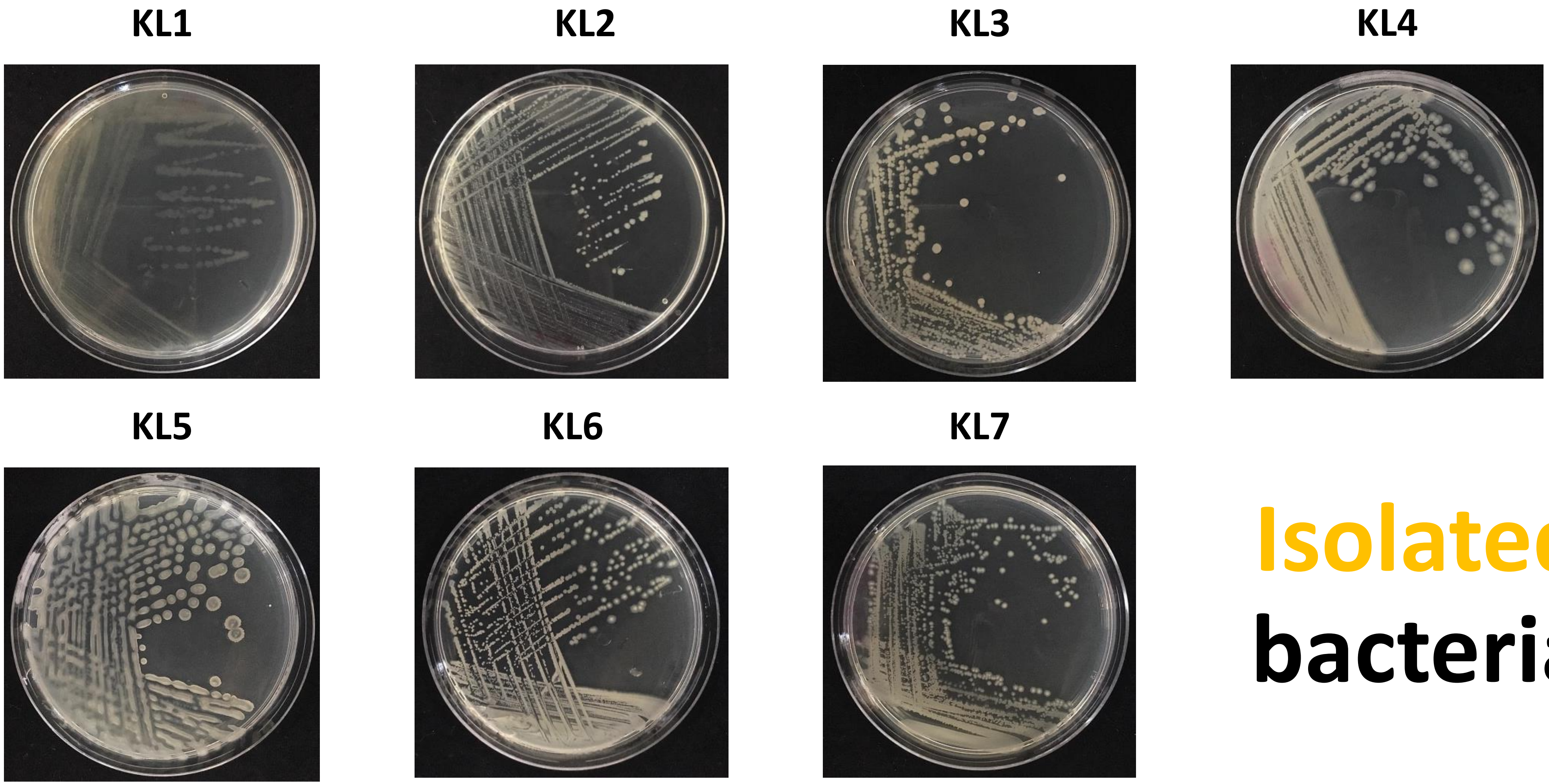
Soil	Number	Ni concentrations (ppm)			Select
		0	50	100	
Site 1	1	+++	+++	+	
	2	+++	+++	++	/
Site 2	1	+++	++	-	
	2	+++	+++	++	/
Site 3	1	+++	+++	-	
	2	+++	+++	+	
Site 4	1	+++	++	++	/
Site 5	1	+++	++	++	/
	2	+++	++	++	/
Site 6	1	+++	++	+	
	2	+++	++	-	
Site 7	1	+++	++	++	/
	2	+++	+	+	
Site 8	1	+++	+++	+++	/
	2	+++	+	+	

+ = Good
++ = Fair
+++ = Poor
- = No growth

7 bacterial species are selected.



LB agar plate

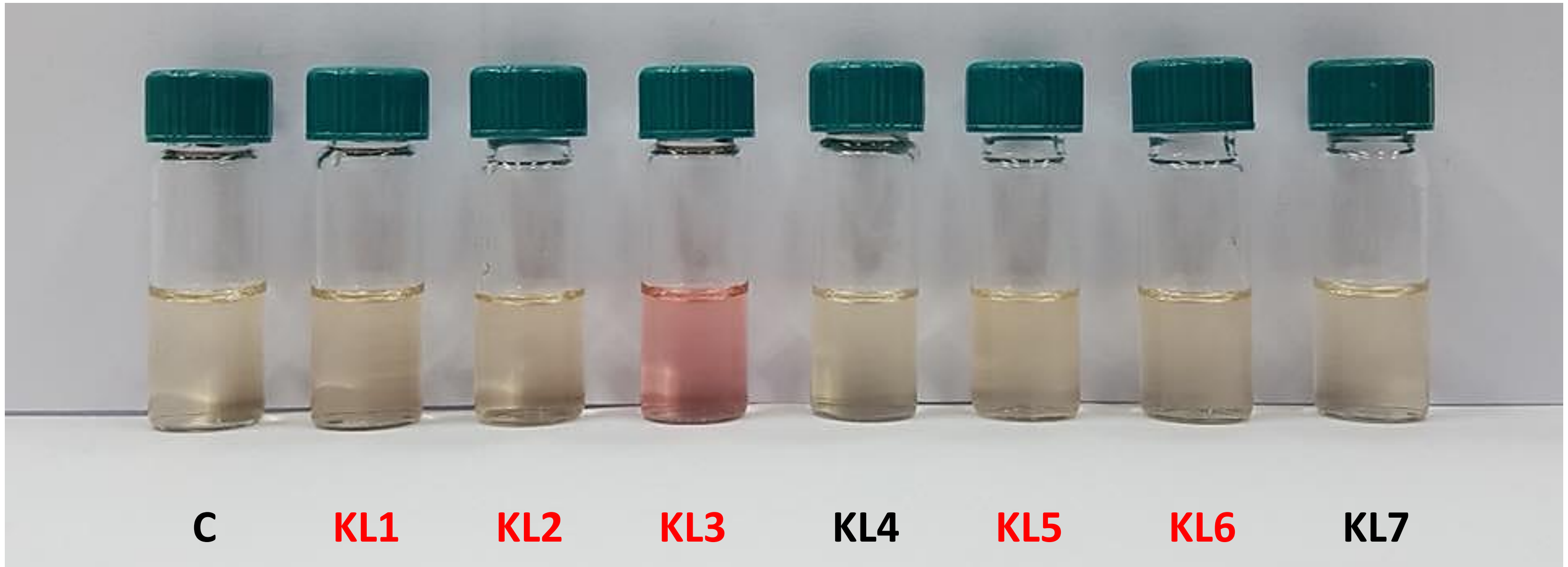


Isolated bacteria

Find the possible strains **beneficial** for improving phytoextraction

- IAA production
- Siderophore
- ACC-deaminase
- Phosphate solubilization

• IAA production (Colorimetric Determination)



Pink color

=

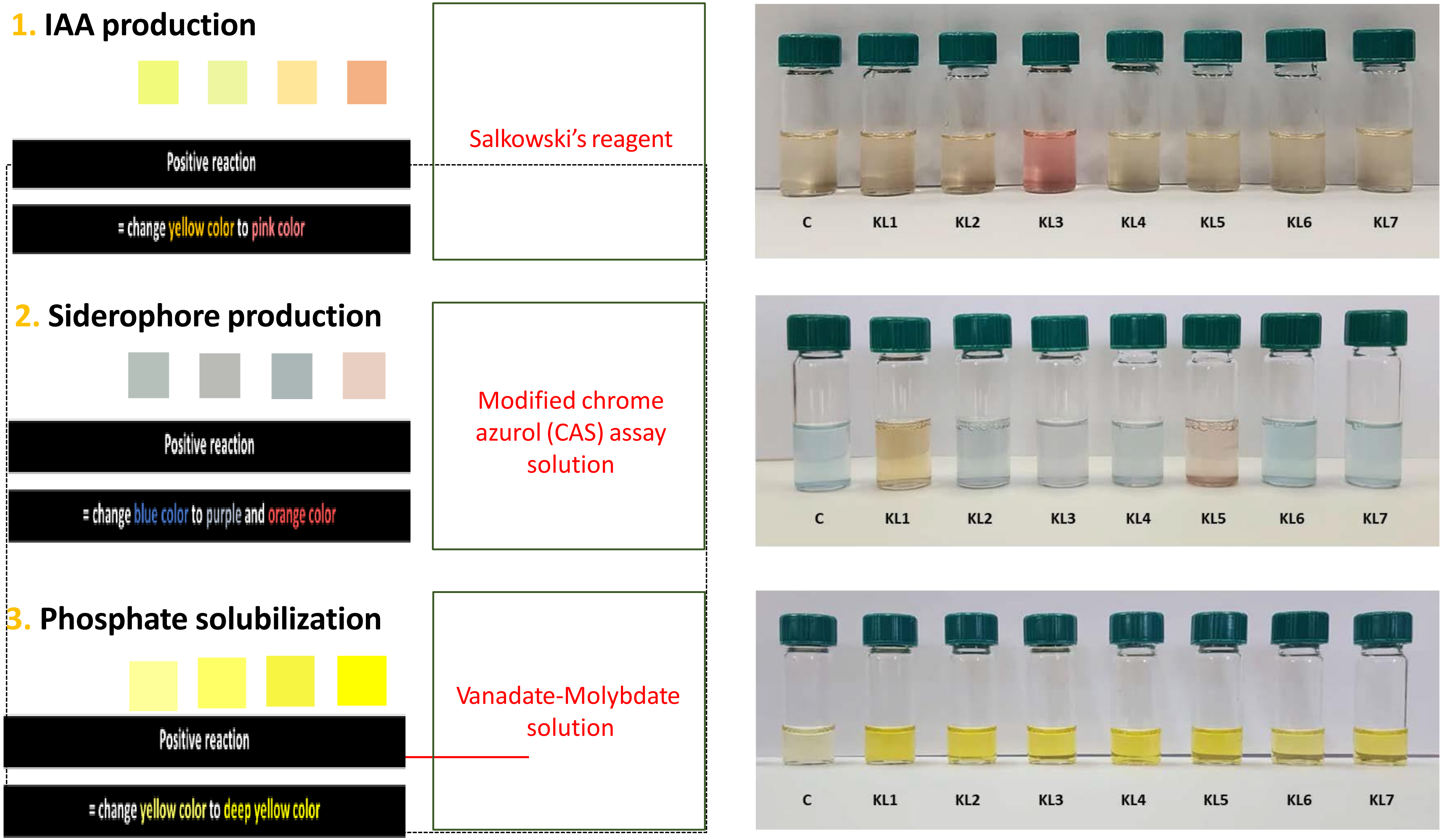
Sample contained IAA

The IAA intensity is related to change in color (from Yellow to Pink/Red)

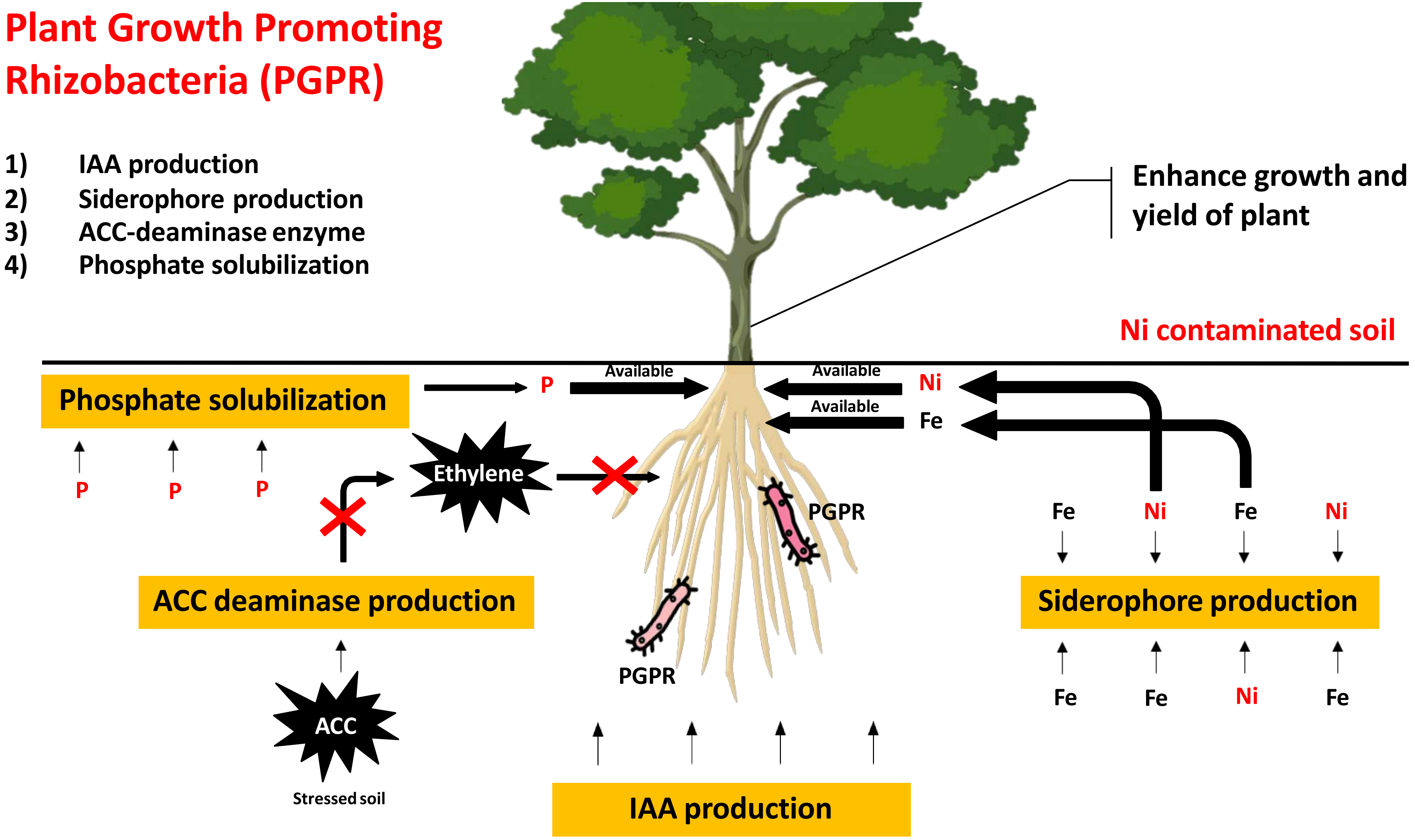
Measured OD value at **530 nm** by spectrophotometer

Control	**KL1**	**KL2**	**KL3**	**KL4**	**KL5**	**KL6**	**KL7**
0	0.021	0.026	0.128	0	0.008	0.016	0.001

Absorbance ↑ = IAA ↑



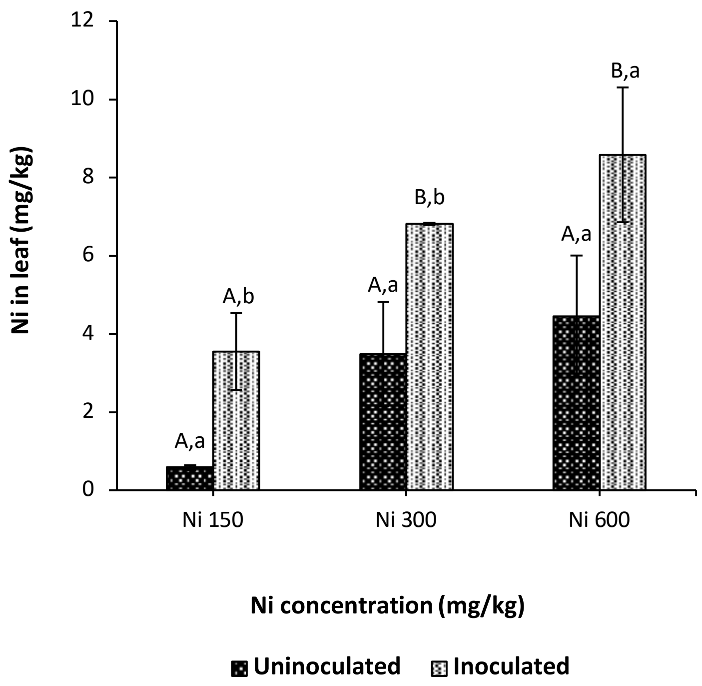
1. IAA production
Positive reaction
= change yellow color to pink color
Salkowski's reagent
C
KL1
KL2
KL3
KL4
KL5
KL6
KL7
2. Siderophore production
Positive reaction
= change blue color to purple and orange color
Modified chrome azurol (CAS) assay solution
C
KL1
KL2
KL3
KL4
KL5
KL6
KL7
3. Phosphate solubilization
Positive reaction
= change yellow color to deep yellow color
Vanadate-Molybdate solution
C
KL1
KL2
KL3
KL4
KL5
KL6
KL7


Plant Growth Promoting Rhizobacteria (PGPR)
1) IAA production
2) Siderophore production
3) ACC-deaminase enzyme
4) Phosphate solubilization
Enhance growth and yield of plant
Ni contaminated soil
Phosphate solubilization
P
Available
Available
Ni
Available
Fe
P
P
P
Ethylene
PGPR
Fe
Ni
Fe
Ni
ACC deaminase production
Siderophore production
Fe
Fe
Ni
Fe
PGPR
ACC
Stressed soil
IAA production

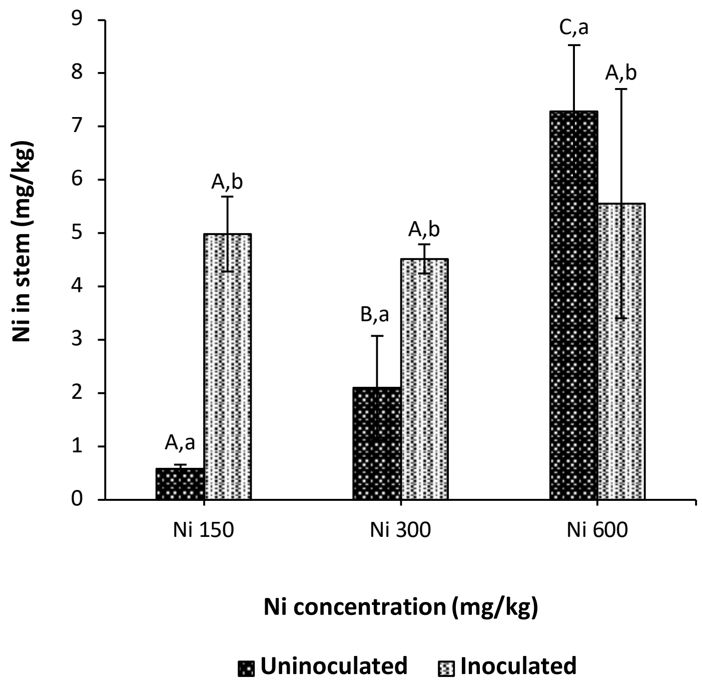
Results

Figure: Ni accumulation in leaf, stem, and root of *A. mangium* after 60 days in pot experiment (n=5).

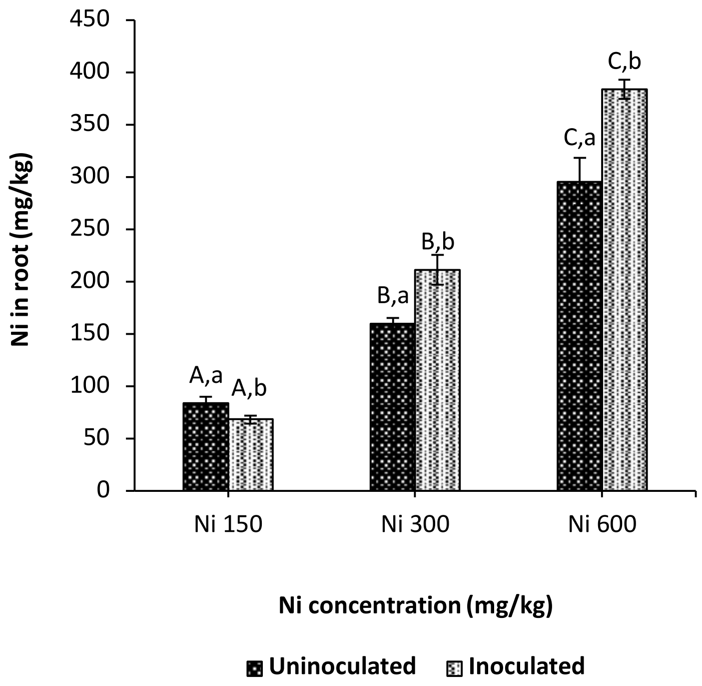
Ni accumulation in leaf



Ni accumulation in stem



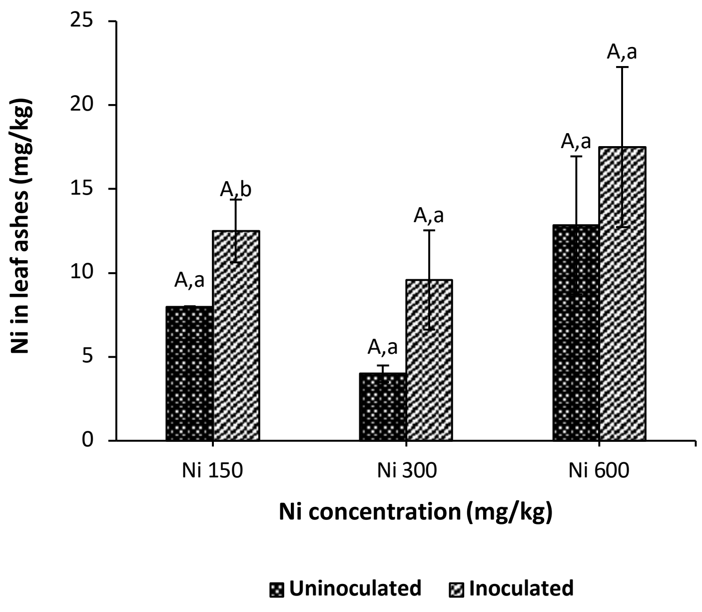
Ni accumulation in root



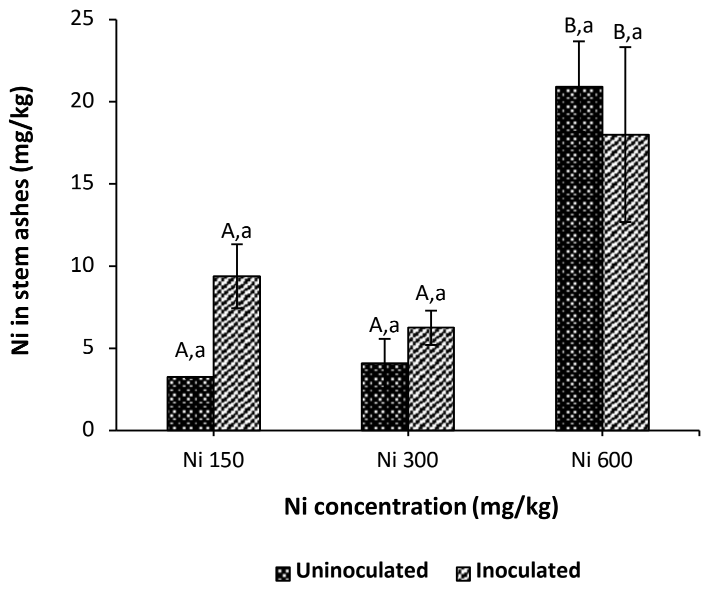
Results

Figure: Ni concentrations in leaf, stem, and root ashes of *A. mangium* after 60 days in pot experiment (n=5).

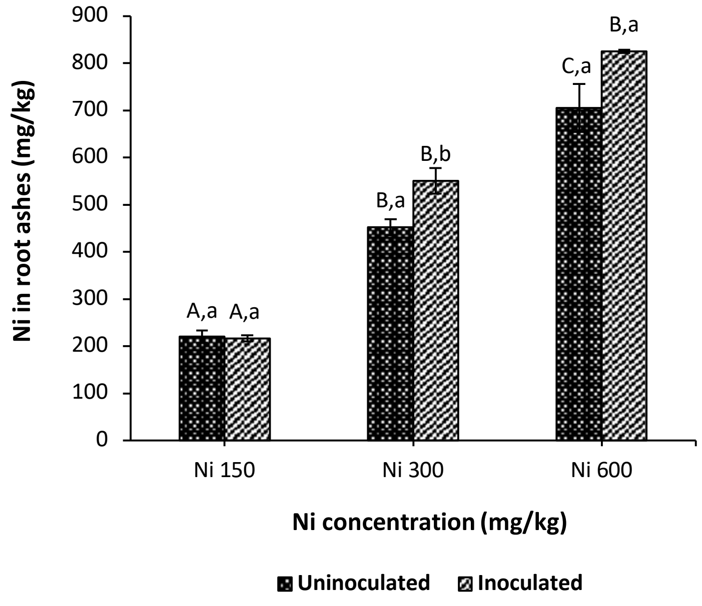
Ni concentrations in leaf ashes

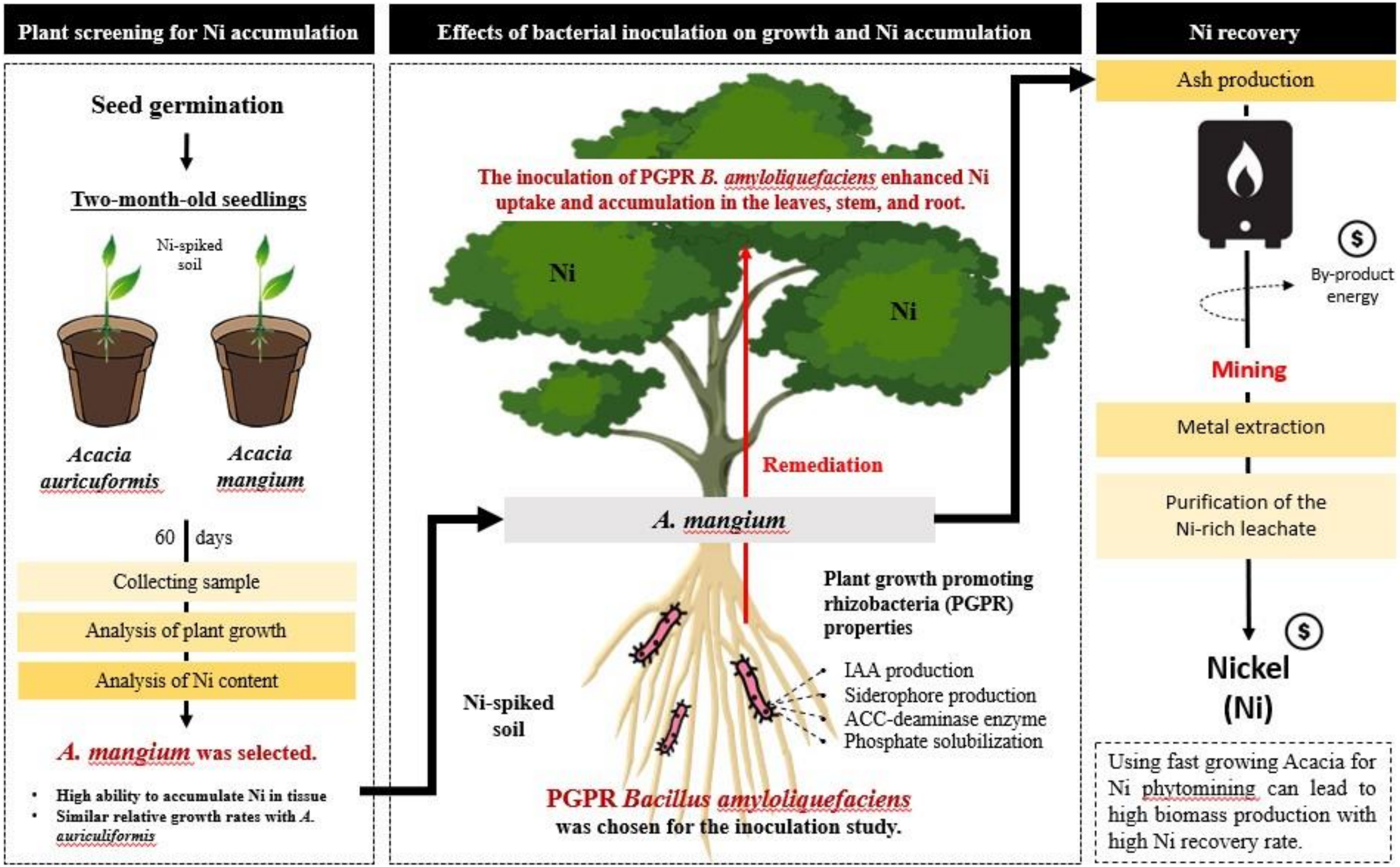


Ni concentrations in stem ashes



Ni concentrations in root ashes




Plant screening for Ni accumulation
Seed germination
Two-month-old seedlings
Ni-spiked soil
Acacia auricuformis
Acacia mangium
60 days
Collecting sample
Analysis of plant growth
Analysis of Ni content
A. mangium was selected.
High ability to accumulate Ni in tissue
Similar relative growth rates with A. auriculiformis
Effects of bacterial inoculation on growth and Ni accumulation
The inoculation of PGPR B. amyloliquefaciens enhanced Ni uptake and accumulation in the leaves, stem, and root.
Ni
Ni
Remediation
A. mangium
Plant growth promoting rhizobacteria (PGPR) properties
IAA production
Siderophore production
ACC-deaminase enzyme
Phosphate solubilization
Ni-spiked soil
PGPR Bacillus amyloliquefaciens was chosen for the inoculation study.
Ni recovery
Ash production
By-product energy
Mining
Metal extraction
Purification of the Ni-rich leachate
Nickel (Ni)
Using fast growing Acacia for Ni phytomining can lead to high biomass production with high Ni recovery rate.

Conclusion & Discussion

1) The recovery process was conducted by using only the **root ashes** of uninoculated and inoculated *A. mangium*. **The efficiency of Ni recovery percentage in the last treated leachate of inoculated plant ranged from 21.69 to 38.53%.**

2) The maximum Ni recovery percentage (**38.5% of Ni**) in this study was found in inoculated ***A. mangium*** grown in Ni concentration of 600 mg/kg.

3) These showed that Ni concentrations in the root ashes could be extracted and remain in the last solution after passing through the purification process.

These results may be applied to the economic scale for Ni recovery from plant biomass when growing inoculated *A. mangium* with *B. amyloliquefaciens* in the real field site.

References

1. S.C. Chakraborty, et.al (2022) Metals in e-waste: Occurrence, fate, impacts and remediation technologies, Process Safety and Environmental Protection, 162:230-252.
2. Barbaroux R, Plasari E, Mercier G, Simonnot MO, Morel JL, Blais JF. 2012. A new process for nickel ammonium disulfate production from ash of the hyperaccumulating plant Alyssum murale. *Sci Total Environ*. 423:111–119. doi: 10.1016/j.scitotenv.2012.01.063.

THANK YOU