Arsenic in Groundwater: Impact on Agro-ecosystem and Low-cost Removal Option in the Perspective of Bangladesh

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Agendas

- ❖ Background (Arsenic Contamination and Impact on Agro-ecosystem)
  - Arsenic Contamination in Groundwater
  - Impact of Arsenic on Agro-ecosystem
  - Arsenic Contamination in Bangladesh
  - Impact of Arsenic on Agro-ecosystem in Bangladesh
  - Studies on Arsenic Removal from Irrigation Water
- ❖ Study on Low-cost Arsenic Removal
  - Experimental Objectives
  - Methodology
  - Experimental Design
  - Results & Findings
  - Field Implementation Concept
  - Follow-up Researches
  - Conclusion
  - Suggestions for Future Works

Background: Arsenic Contamination in Groundwater

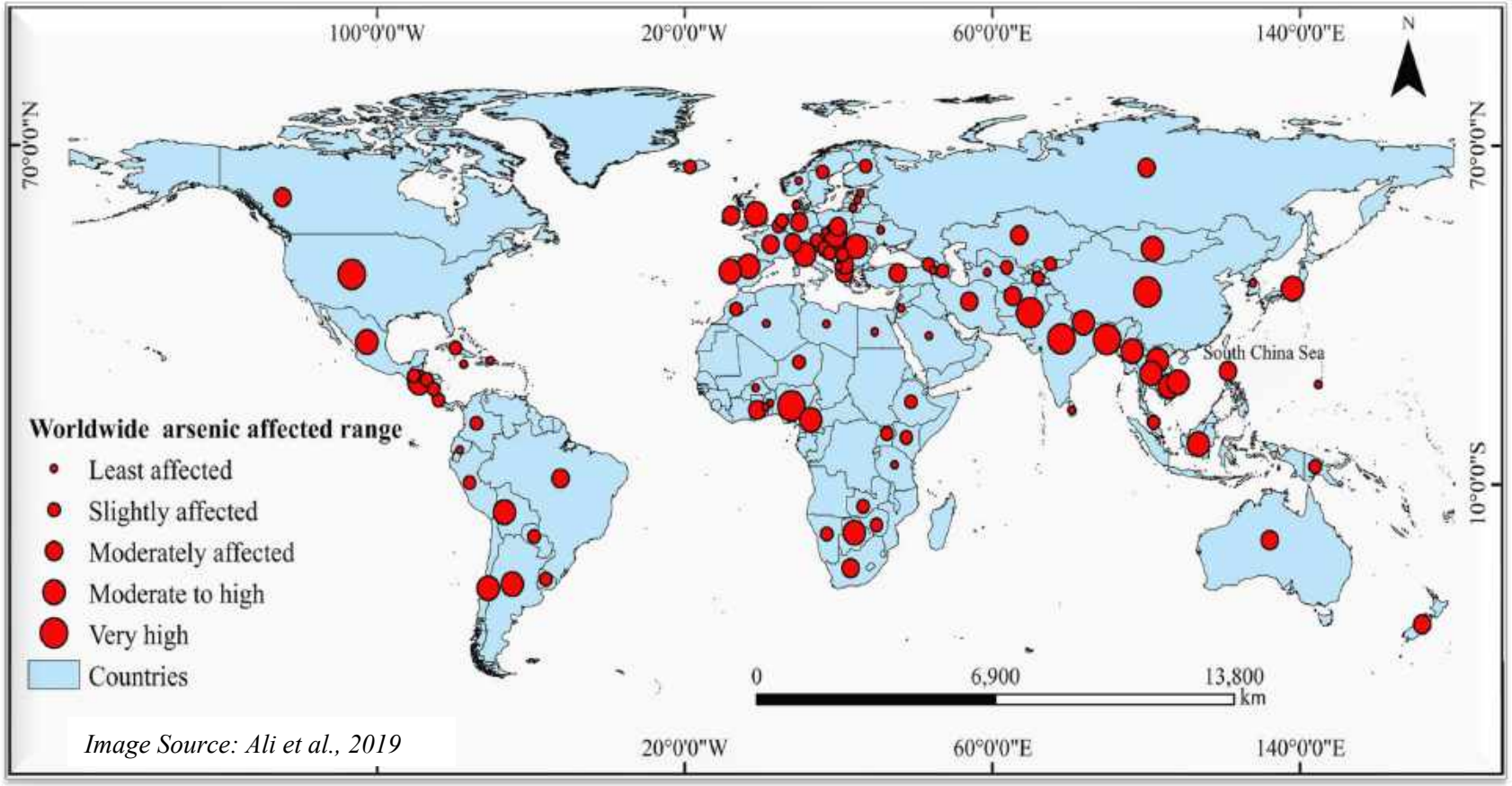


Image Source: Ali et al., 2019

Continent-wise arsenic source characterization

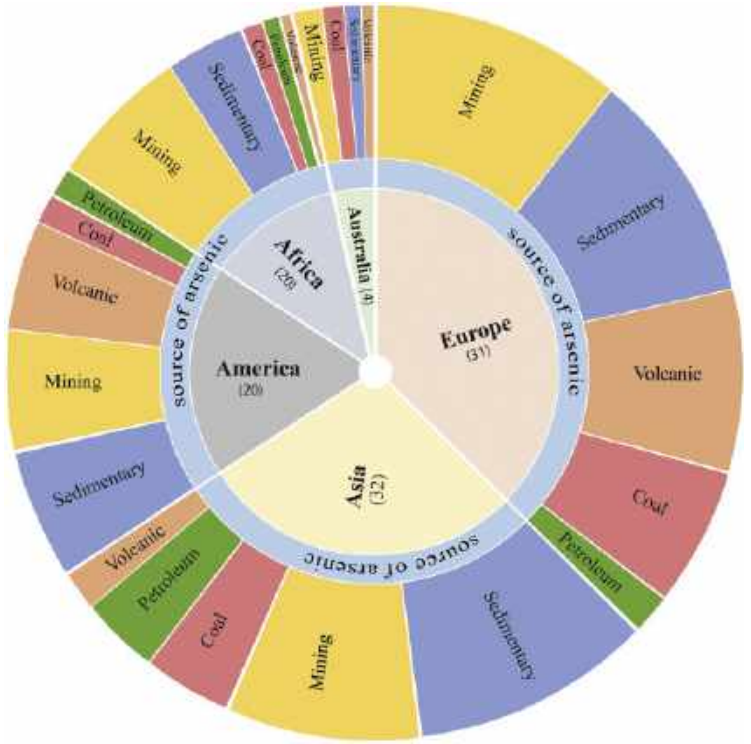


Image Source: Shaji et al., 2021

- **108** countries affected by arsenic contamination in groundwater[1]
- More than 90% of arsenic pollution is **geogenic**[1]
- Ranks **number one in the 2001 priority list of hazardous substances** and disease registry defined by WHO
- Maximum permissible limit: **10 ppb (10µg/L)** (recommended by WHO)

Background: Arsenic Contamination in Groundwater

Exposure Pathways of Arsenic in Groundwater

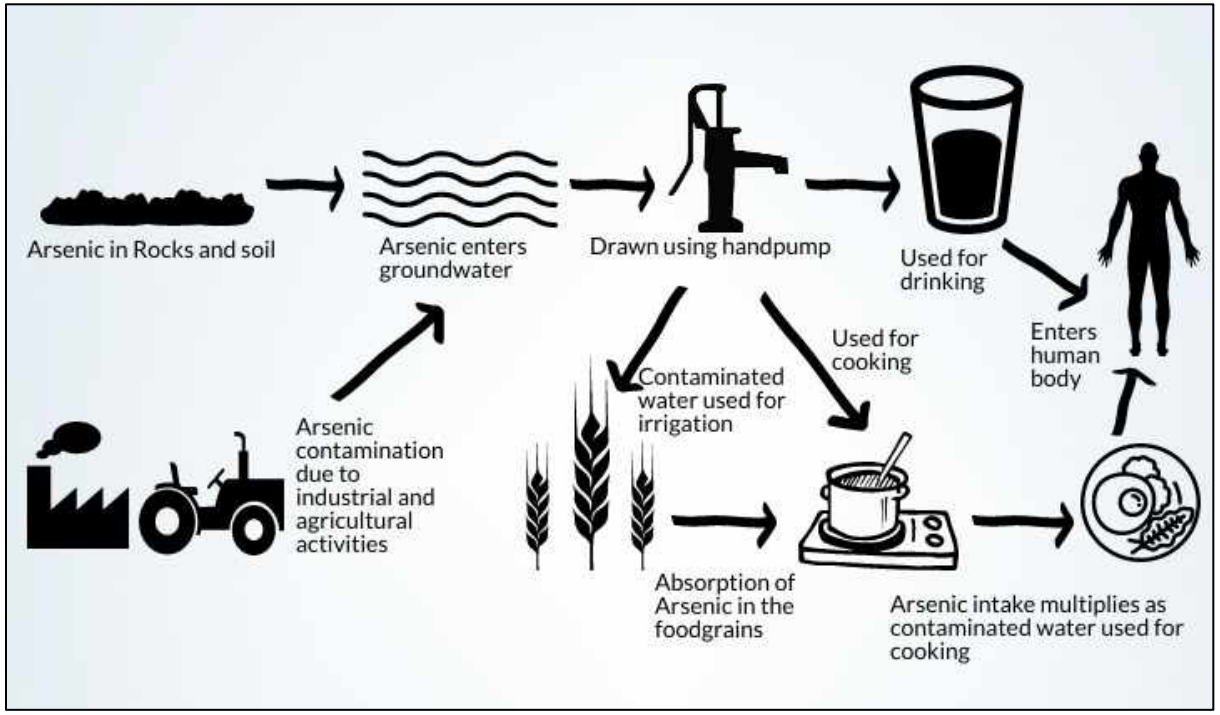
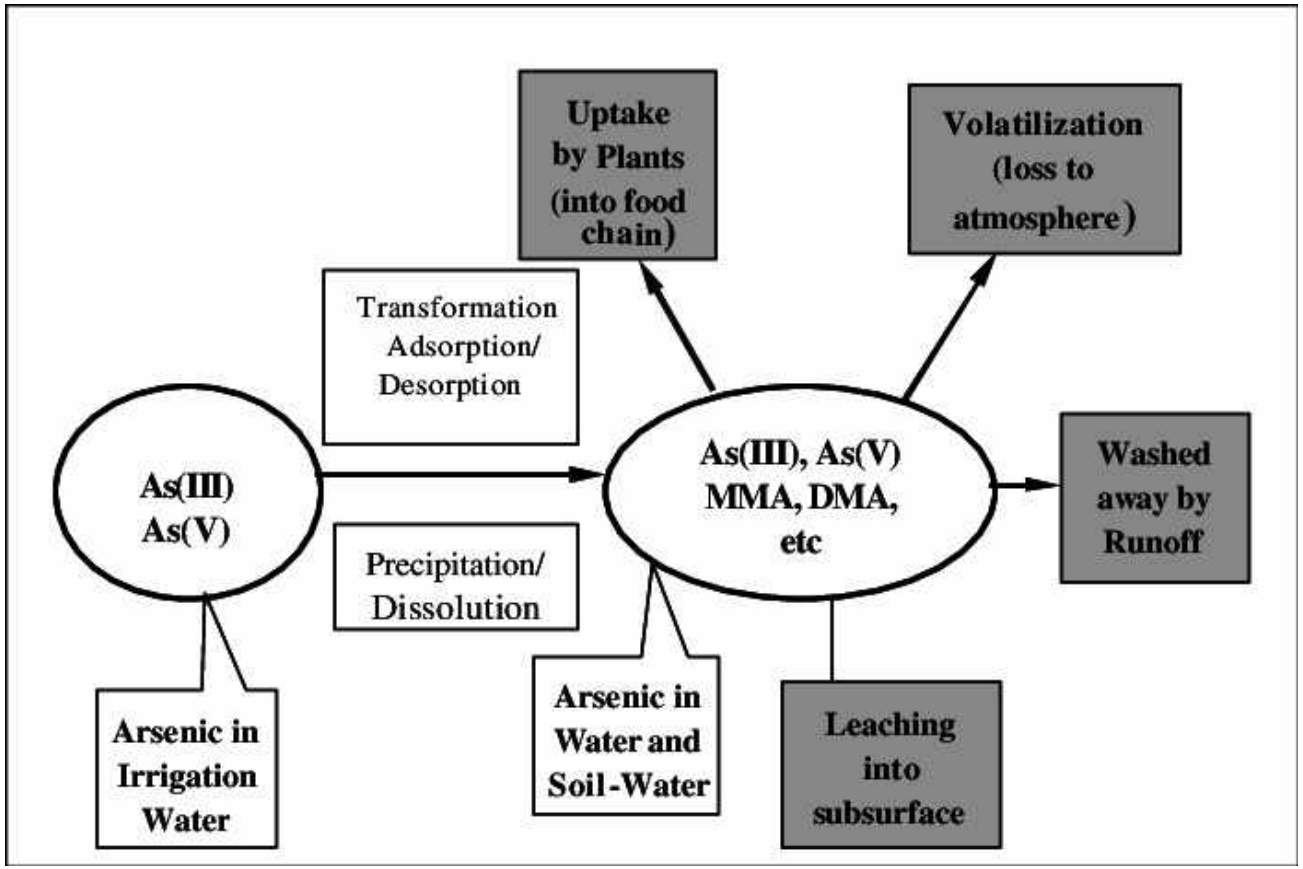


Image Source: Jiang et al., 2013

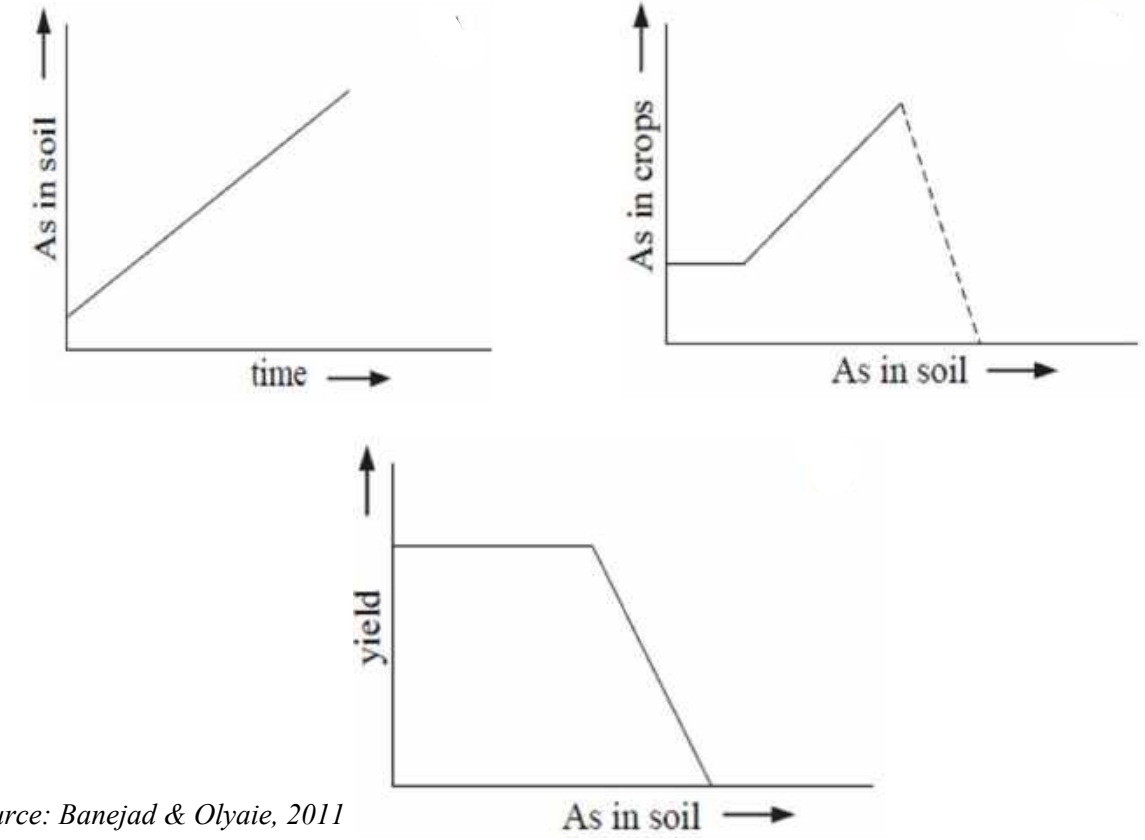
Fate of Arsenic in Soil-Water Environment



Source: Ali et al., 2003

Background: Impact of Arsenic on Agro-ecosystem

Potential effect of arsenic contaminated irrigation water on agricultural soils



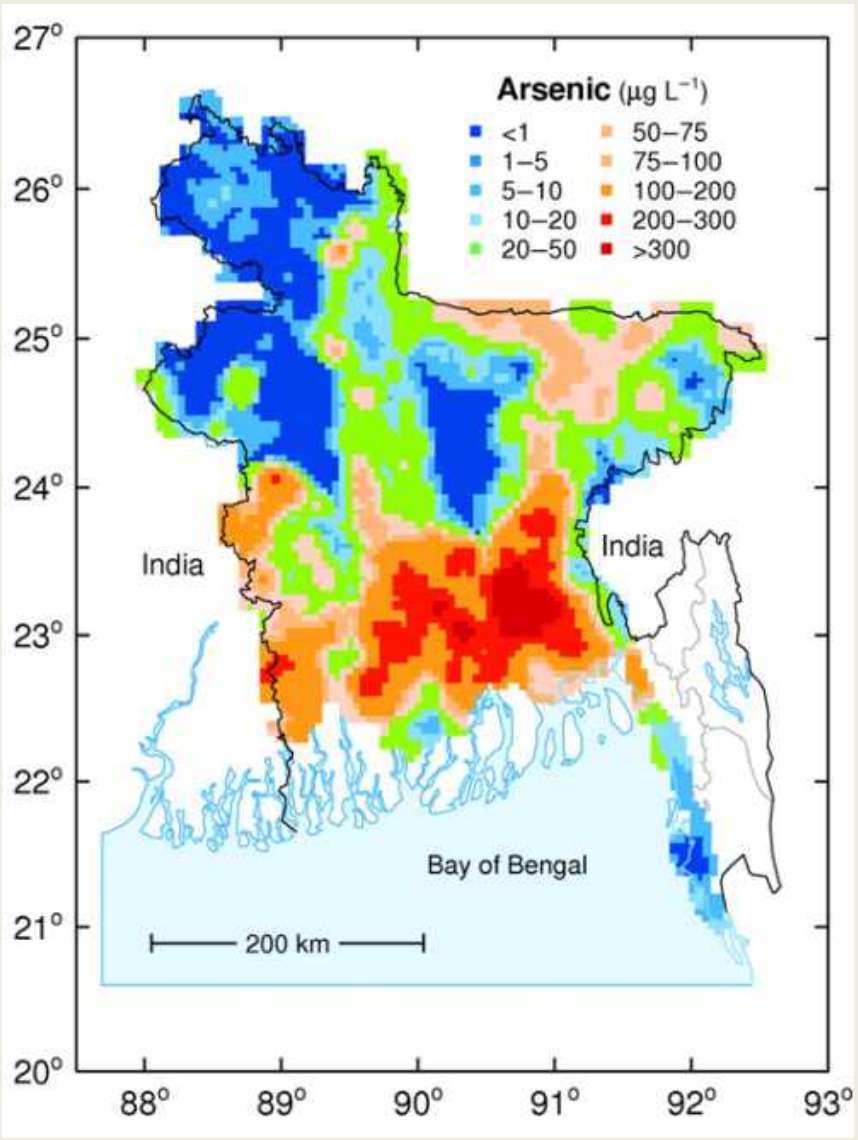
Source: Banejad & Olyaie, 2011

Years of irrigation	Arsenic in irrigation water (ppb)				
	50	100	250	500	1000
	Arsenic added to soil (µg/g)				
1	0.28	0.56	1.4	2.8	5.6
5	1.4	2.8	7	14	28
10	2.4	5.6	14	28	56
20	5.6	11	28	56	110
30	8.4	17	42	84	170
50	14	28	70	140	280

Source: Brammer & Ravenscroft, 2009

Daily consumption of rice with a total As level of 0.08 µg/g ≡ drinking water As level of 10 µg/L [2]

Background: Arsenic contamination in Bangladesh



As contamination range in groundwater of Bangladesh: < 0.5 to > 4600 µg/L

Image source: BGS and DHPE, 2001

Background: Impact of Arsenic on Agro-ecosystem in Bangladesh

Image source: Daily Sun, 2020

- Agriculture sector contributes 14.74% to the country's GDP[3] and employs 39% of total labor force[4]
- 75.01% of total arable land used for growing rice[5]
- Dry season boro rice accounts for about 55.3% of the total rice production in Bangladesh[6]
- Probable accumulation of Arsenic in rice fields and subsequent plant-uptake, due to use of Arsenic contaminated groundwater for irrigation purpose[3]
- Average rice consumption: ~455 gm/person/day. [3]
- Apparent exposure, adverse health impacts & decreased rice yield due to increased Arsenic exposure through food chain[7, 8]
- Lack of practical & economic method for large scale Arsenic removal from irrigation water

Background: Studies on Arsenic Removal from Irrigation Water

❑ **Norton et al. (2017)**

- Employed AWD (alternative wetting and drying)
- Decreased As concentration in grains but undesirable change in other compounds

❑ **Polizzotto et al. (2014)**

- Hypothesized utilization of in-channel physical structure for As removal from flowing irrigation water
- Suggested amending distribution channel with locally available jute mesh could reduce As loading to rice fields

❑ Iron-oxide coated jute fabric could improve Arsenic removal

Image source: Polizzotto et al. (2014)

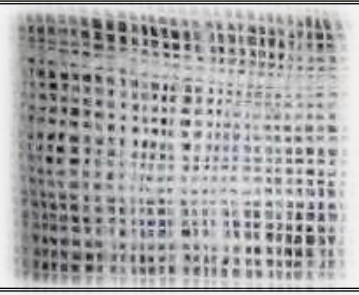
Study on Low-cost Arsenic Removal: Experimental Objectives

1. Developing methods for providing iron-oxide coating to jute fabrics
2. Evaluating effectiveness of different coating methods to find optimum condition
3. Assessing Arsenite and Arsenate removal efficiency of iron oxide coated jute fabrics through laboratory batch experiments

(Ramim et al., 2017)

Methodology

Materials (Jute Fabrics)

Properties of Jute Fabrics		
Color	White	Brown
Mass Per Unit Area (g/m^2)	269.5	146.5
Nominal Thickness (mm)	1.28	0.923
Apparent Opening Size	Relatively large	Relatively small
Price ($CAD/m^{2)}$	1.0	0.35

Materials (Chemicals)

(As_2O_3) for preparing As(iii) stock solution

($Na_2HAsO_4.7H_2O$) for preparing As(v) stock solution

Ferric Nitrate [$Fe(NO_3)_3$] for providing iron coating

Sodium Hydroxide [NaOH] for providing iron coating

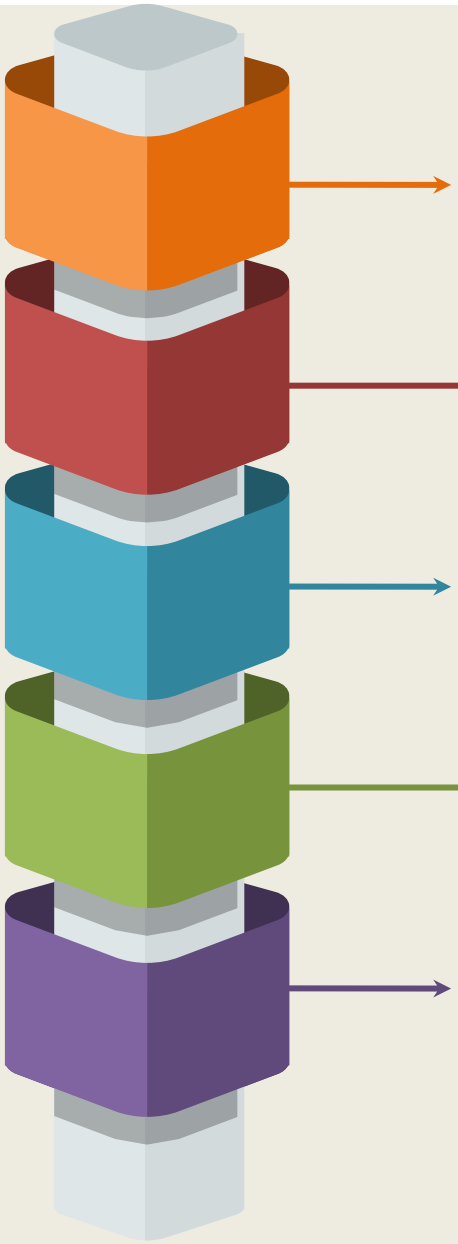
Experimental Design

Preparation of
Iron Coated Jute Fabrics

Batch Experiments for
Arsenic Removal

(Ramim et al., 2017)

Experimental Design: Preparation of Iron Coated Jute Fabrics



Coating Method A

- 0.25 M ferric nitrate [$Fe(NO_3)_3$] solution was adjusted to pH 10.0 with 10.0 M NaOH solution
- Then jute fabric was soaked in the solution

Coating Method B

- Jute fabric was first soaked in 0.25 M ferric nitrate [$Fe(NO_3)_3$] solution
- Iron was precipitated by addition of 10.0 M NaOH solution, adjusting to pH 10.0

Drying Procedure 1

- heating at 110°C in an oven for 14 hours

Drying Procedure 2

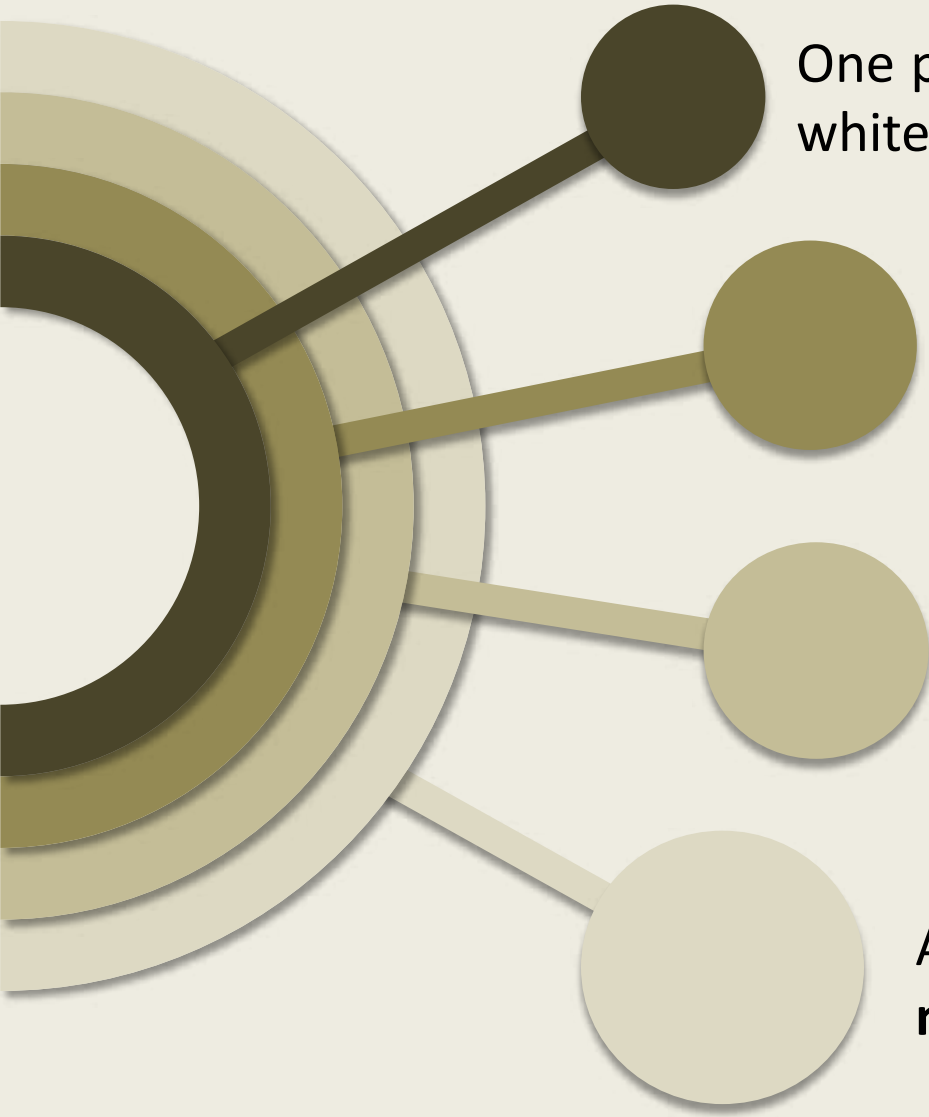
- heating at 45°C in an oven for 24 hour

Drying Procedure 3

- drying at room temperature for one week

(Ramim et al., 2017)

Experimental Design: Batch Experiments for Arsenic Removal



One piece (2.5” x 5”) of jute fabric (iron-coated and uncoated white and brown jute fabrics) was added to each beaker

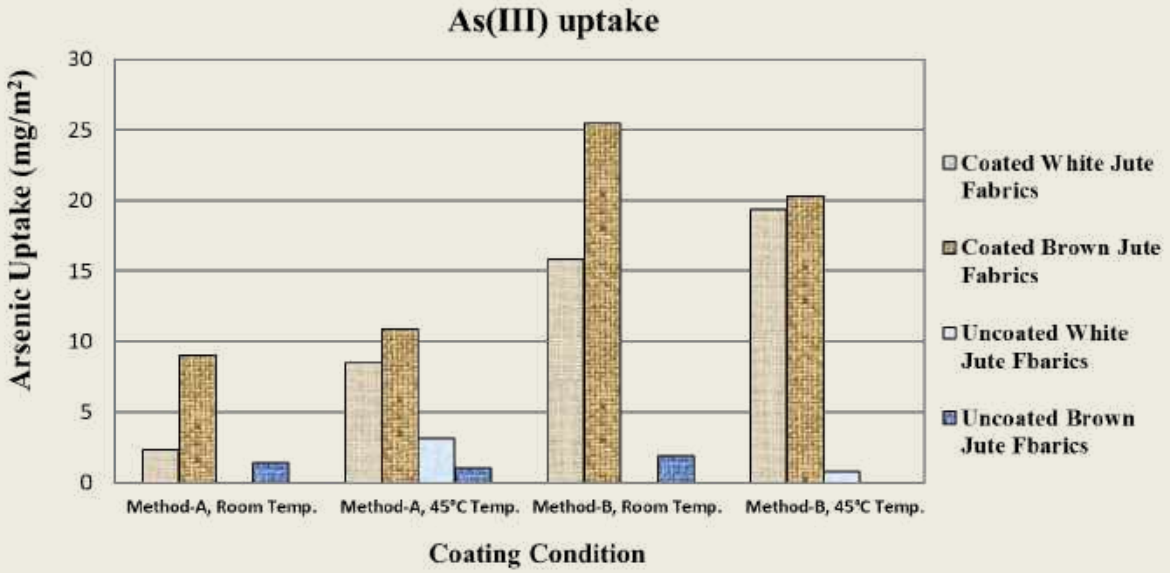
Contents of beakers were stirred with a glass rod for 15 minutes and then kept at rest for 30 minutes

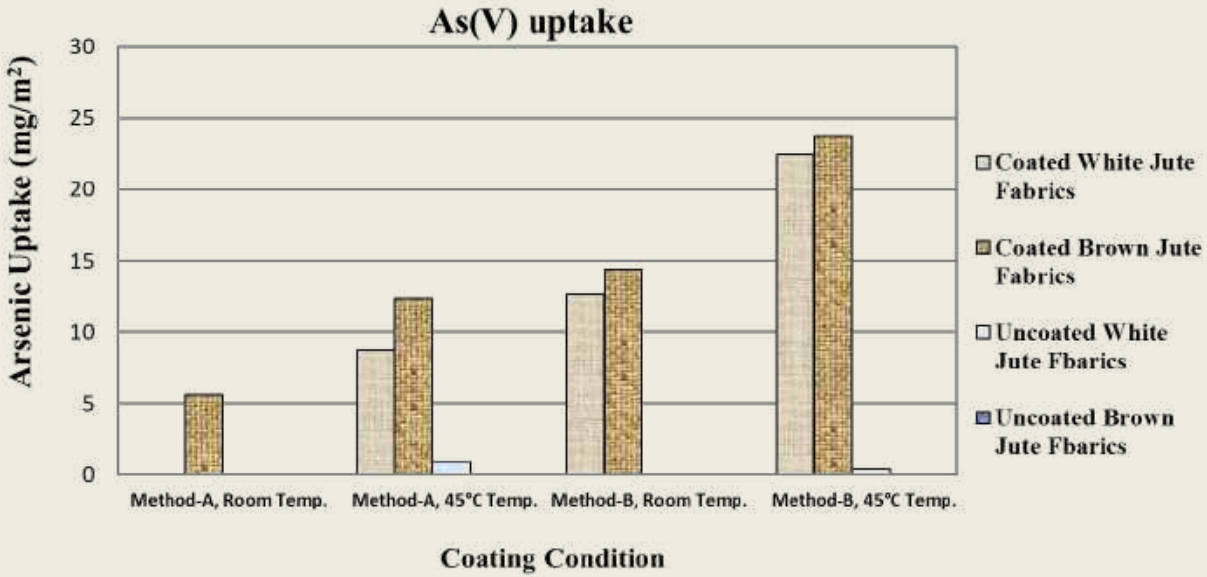
Samples were taken from the beakers for analysis of As using Atomic Absorption Spectrophotometer (Shimadzu, AA 6800)

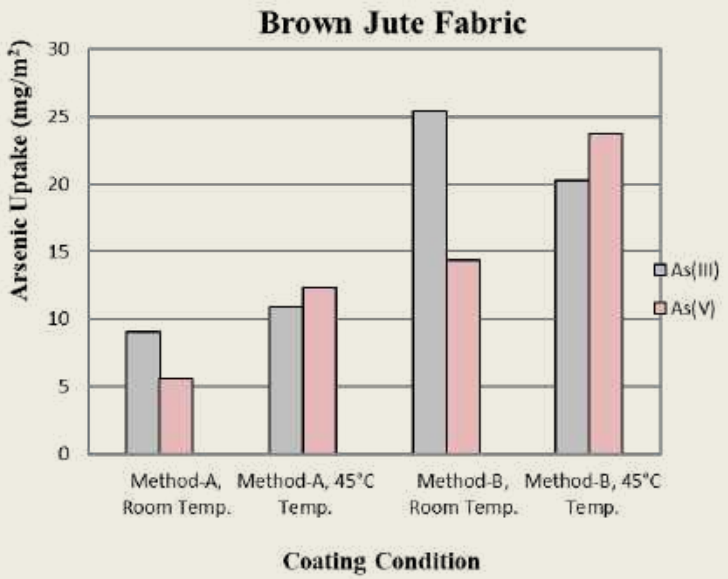
Arsenic uptake/removal by jute fabrics was expressed as **mg As/m^2 of jute fabric**

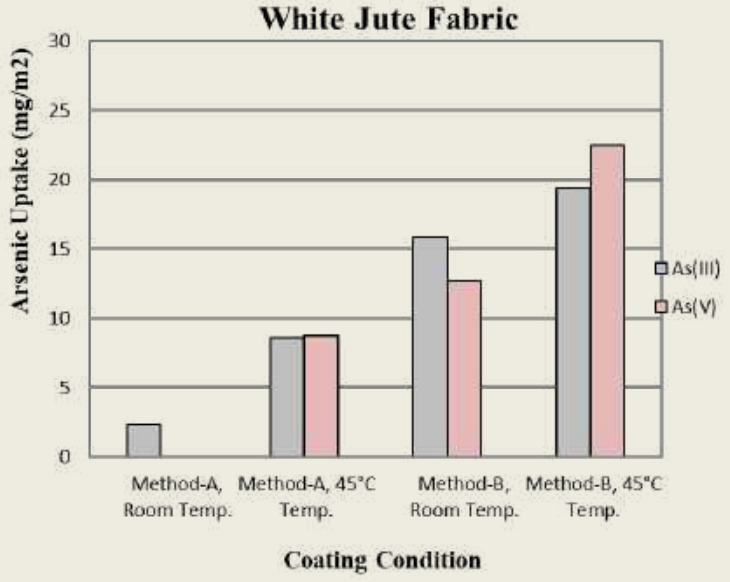
(Ramim et al., 2017)

Results and Findings







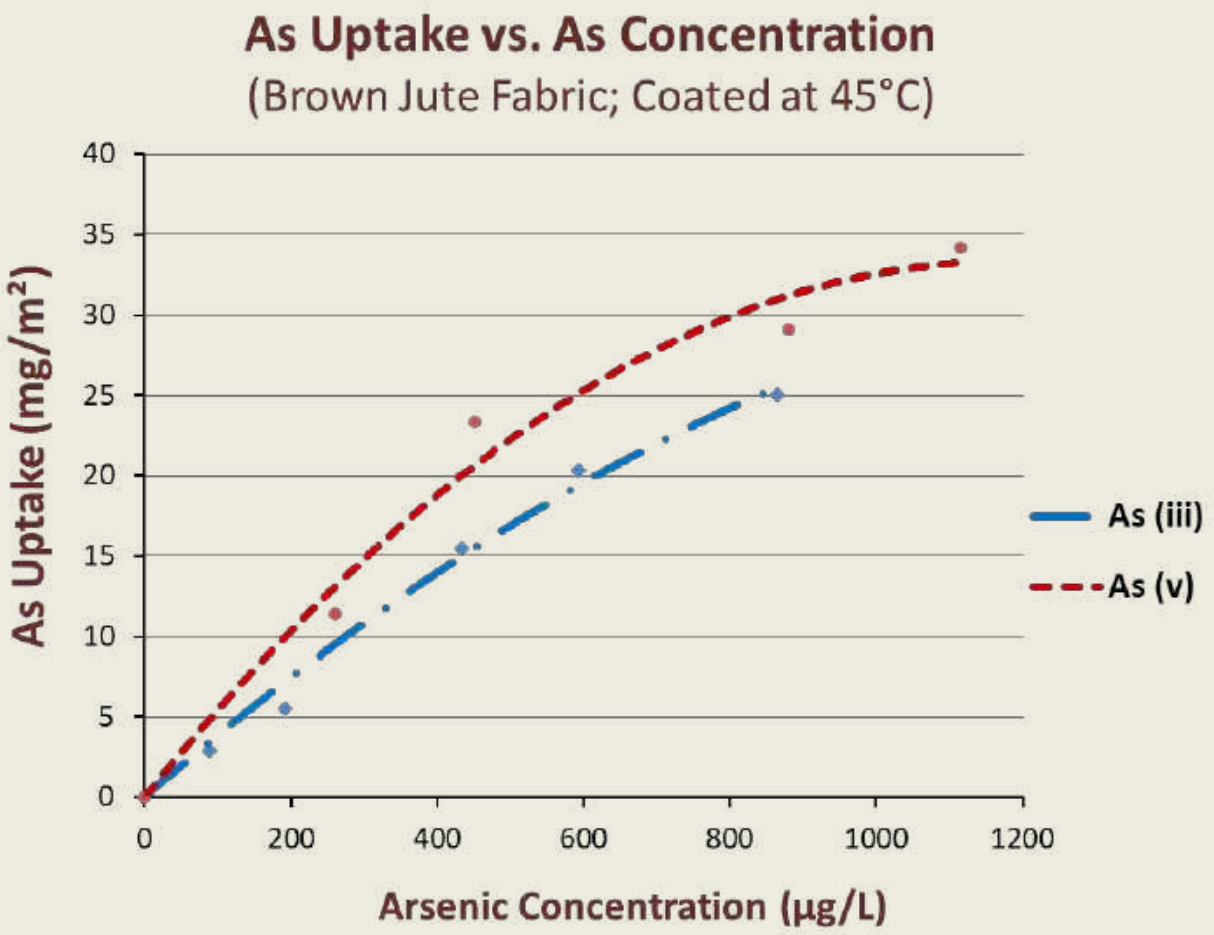


(Ramim et al., 2017)

Results and Findings

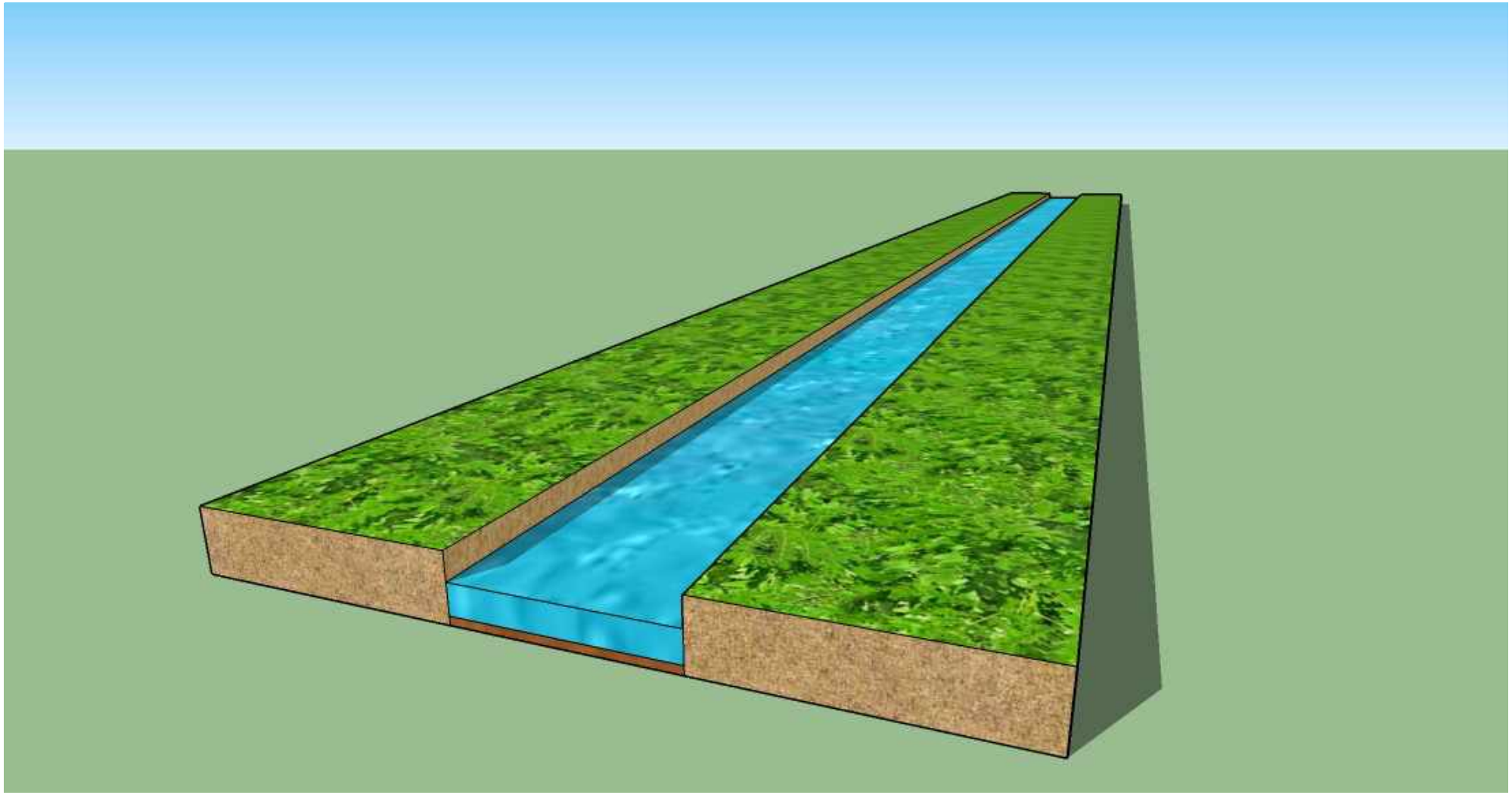
Optimum Conditions

Arsenic removal	As(III) removal	As (V) removal
Jute Fabric	Brown > White	Brown > White
Iron oxide coating method	Method B	Method B
Drying Method	Room temperature	Heating at 45°C
Highest As Uptake	25.5 mg/m²	23.7 mg/m²
Maximum % Removal	88.5%	67.5%



(Ramim et al., 2017)

Field Implementation Concept



A Proposed Model: Irrigation Channel
with Iron oxide Coated Jute Lining

Follow up Researches

❑ Akter et al. (2018)

- Use of iron oxide coated jute fabrics for Arsenic removal from groundwater **under flowing conditions** in a **lab-scale experimental channel** fabricated using PVC pipe
- Findings
  - *Initial As concentration: ~230 µg/l*
  - *As removal: 40%*
  - *Impact of water flow rate: lower flow rate (and higher contact time) promotes higher removal*
- Challenges
  - *Capacity of the coated fabrics decreases with time*

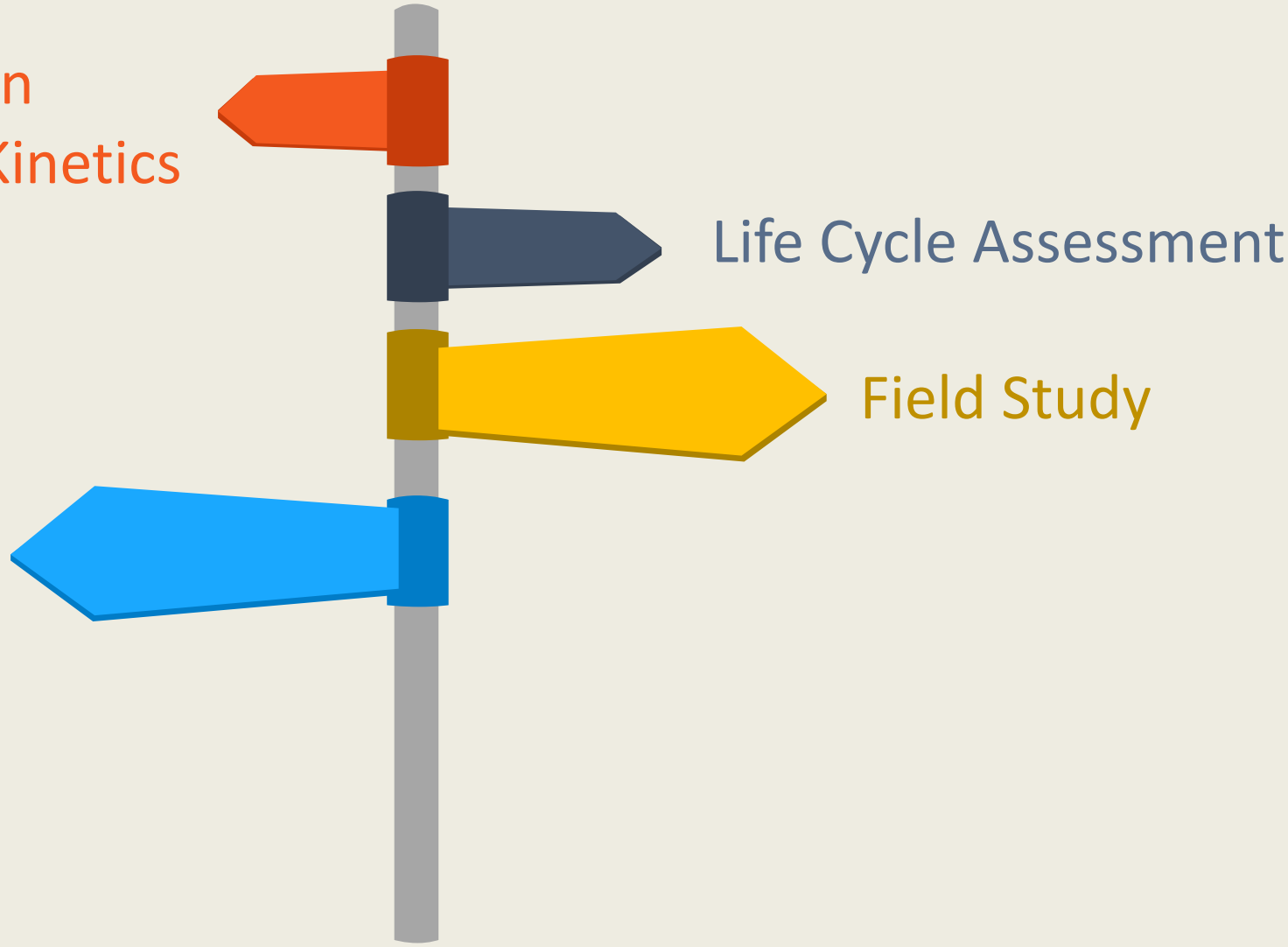
Conclusion

Promising application of iron oxide coated jute fabric as lining material in irrigation channels for reducing arsenic loadings (both As(III) & As(V)) to agricultural soil

(Image Source: Adobe Stock, by Jimbophotoart

Suggestions for Future Work

Study on
Adsorption Kinetics



Life Cycle Assessment

Field Study

Safe disposal of
used-up jute fabrics

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Members of the Project:

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- Tanjinur Akter


Thank
You


Question?

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