ARSENIC POLLUTION
PART B: GEOCHEMICAL CONTROLS ON DISTRIBUTION AND MOBILISATION MECHANISMS

The material presented here has been prepared by George Wilson in April 2021, with input from Dr. Laura Richards and Prof. David Polya of the Department of Earth & Environmental Sciences, The University of Manchester, and other sources as acknowledged. The associated video recordings have been made by George Wilson.

The Transformation by Innovation in Distance Education (TIDE) project is enhancing distance learning in Myanmar by building the capacity of Higher Education staff and students, enhancing programmes of study, and strengthening systems that support Higher Educational Institutions in Myanmar. TIDE is part of the UK-Aid-funded Strategic Partnerships for Higher Education Innovation and Reform (SPHEIR) programme (www.spheir.org.uk). SPHEIR is managed on behalf of FCDO by a consortium led by the British Council that includes PwC and Universities UK International. The TIDE project will close in May 2021.

Geochemistry of arsenic

- Outline
  - Introduction
  - Objectives
  - Geochemistry of As-contaminated groundwater
  - Adsorption and desorption of arsenic on mineral phases
  - Organic matter and arsenic
  - Learning exercise
  - References & Further Information
- Summary

Introduction

- Arsenic geochemical controls are dependent on hydrogeochemical setting and can be highly localized
- Important to understand what causes naturally-occurring arsenic to be mobilized and accumulate in groundwater at potentially dangerous concentrations
- Bioavailable organic matter recently (past ~ 20 years) postulated to facilitate the microbially-mediated mobilization of geogenic arsenic, although details of mechanistic understanding remain unclear

Objectives

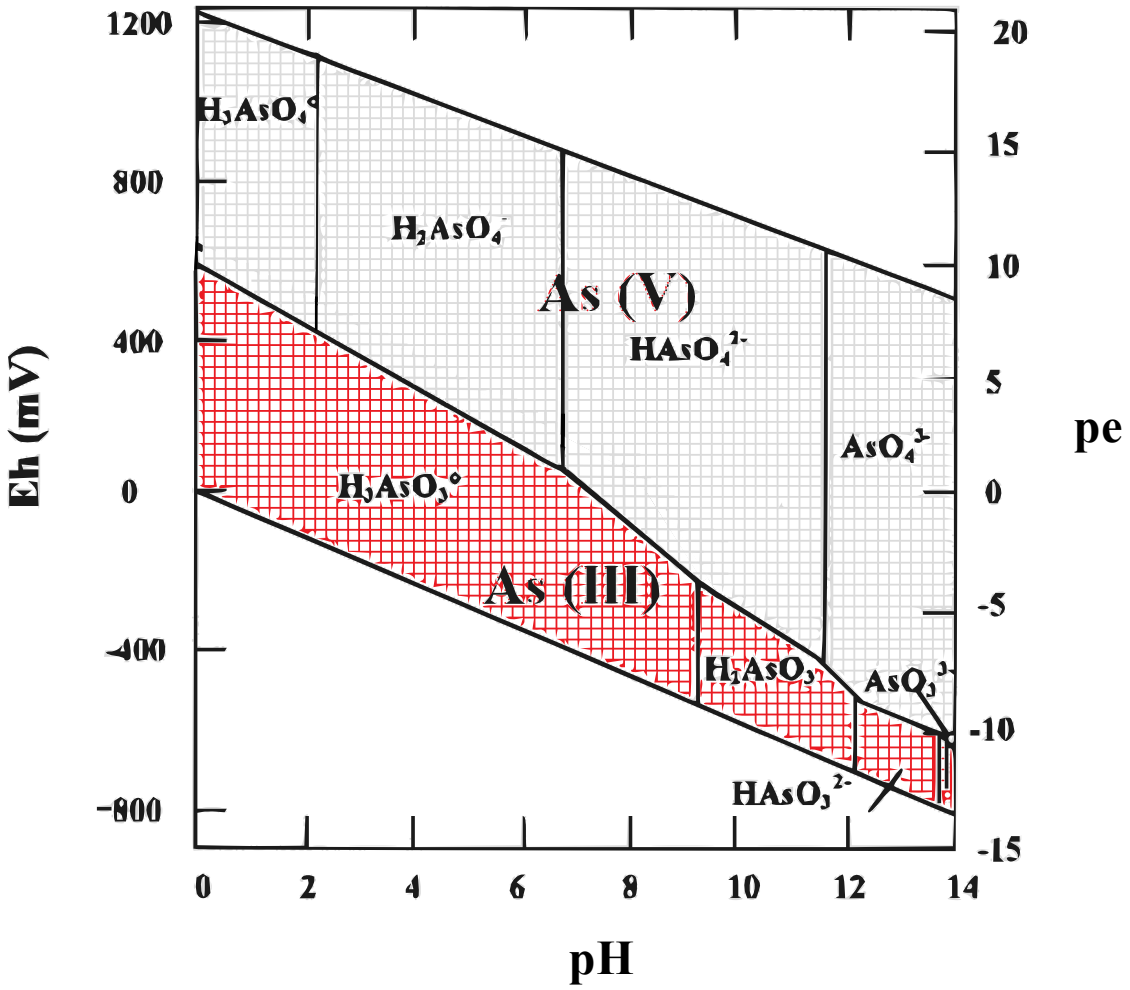
- Explain the predominant geochemical controls on arsenic mobilisation
- Recognize how we can categorize organic matter into different fractions and how this might relate to arsenic mobilization
- Recognize the potential role of organic matter in mobilising arsenic from iron (oxyhyr)oxides

GEOCHEMISTRY OF ARSENIC-CONTAMINATED GROUNDWATER

As speciation

Arsenic exists as two predominant species – As (V) or As (III) depending on Eh/pH

(USGS, 2003)



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Geochemical controls on As

- From last time:

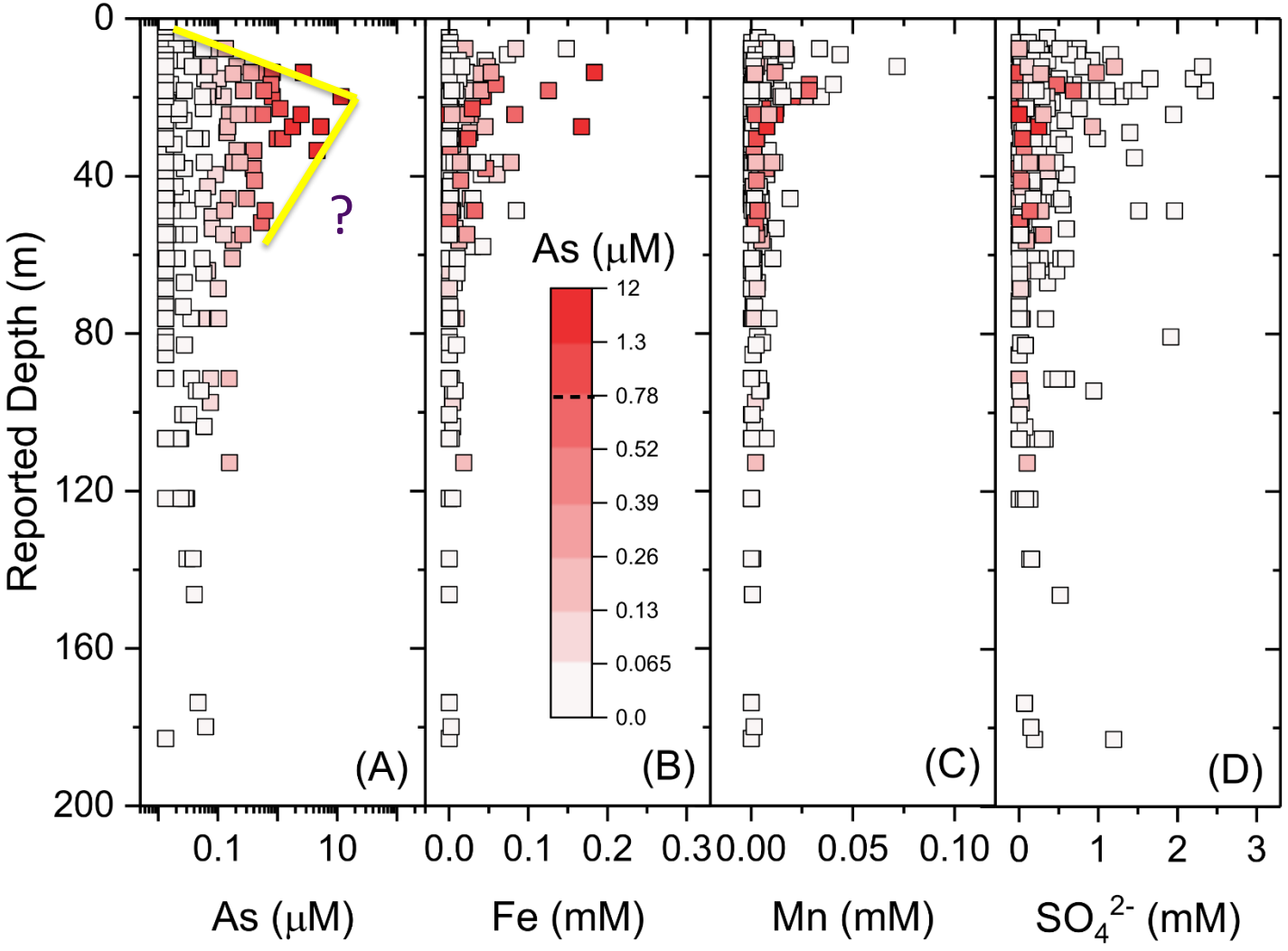
  - Reductive dissolution and alkali-desorption (RD) controls the majority of high-As systems worldwide

  - RD of iron (oxyhydr)oxides the most important mechanism in South/South East Asia
  - Reduction of iron oxides redox controlled

  ➡ Do we get higher or lower As with depth?

(Ravenscroft, 2007) (OA)

As mobilisation and depth



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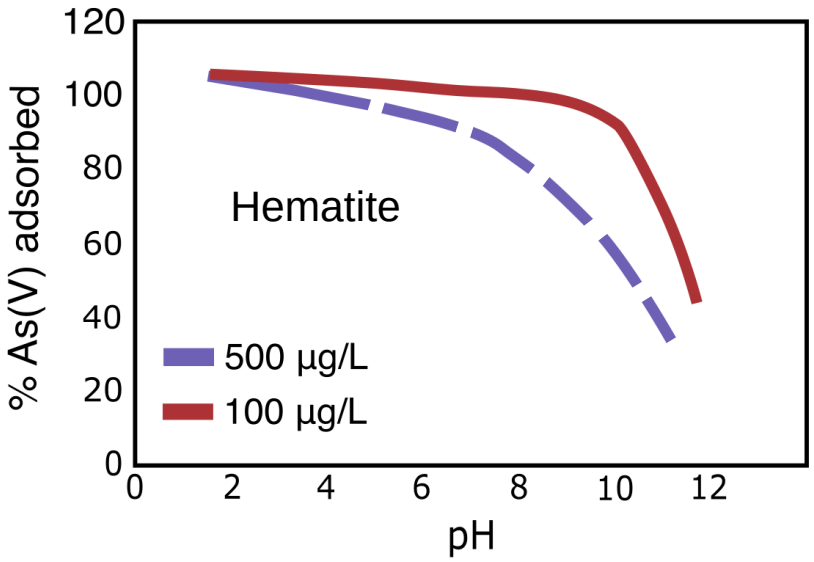
ADSORPTION AND DESORPTION OF ARSENIC ON MINERAL PHASES

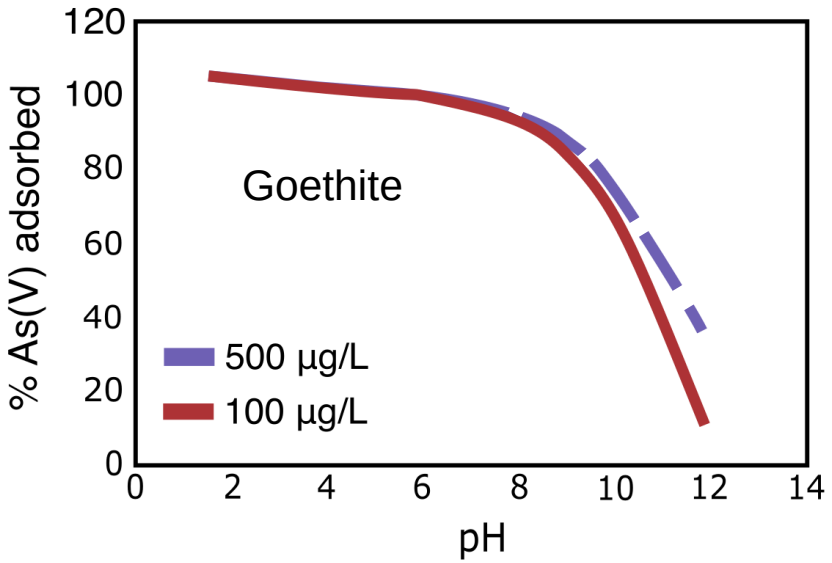
As adsorption/desorption on minerals

- Main sorbents are iron oxyhyr(oxides) for arsenic in aquifers and soils
  - Ferrihydrite $Fe^{3+}10O{\cdot}14[OH]_2$
  - Goethite α-FeO[OH]
- Clay minerals follow similar patterns to above, less adsorbed per unit mass
  - Kaolinite $Al_2Si_2O_5(OH)_4$
  - Illite $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,(H_2O)]$
  - Montmorillonite $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2{\cdot}nH_2O$
- Phosphate sorption?

(Feng *et al.*, 2013) (OA)

As adsorption/desorption on minerals





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- Adsorption of arsenate onto most oxides and clays decreases significantly at pH ≥ 8.5 - 'Alkali-desorption'

ORGANIC MATTER AND ARSENIC

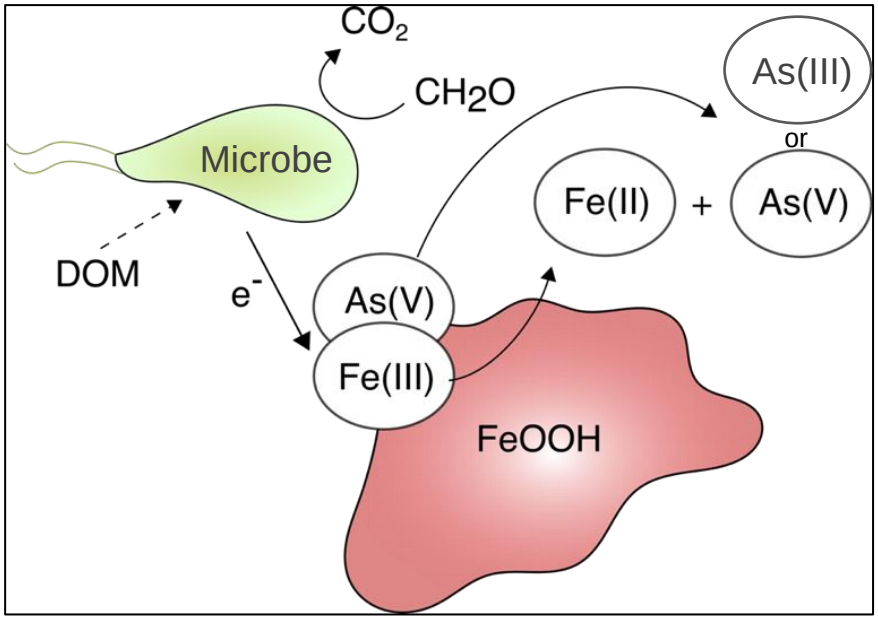
Categorization of organic matter

- Types of organic matter (OM):
  - Sediment-bound OM
  - Sources of petroleum
  - Surface-derived OM (ingress through ponds/wetlands/groundwater pumping)
  - Plant-derived OM
- Organic matter contribution to As mobilisation?

(Lawson *et al.,* 2013) (OA)

Organic matter mediated mobilisation

- Reductive dissolution mediated by organic matter
  - OM acts as an electron donor to reduce oxides
  - OM and As in competition for sorption sites on Fe-oxides



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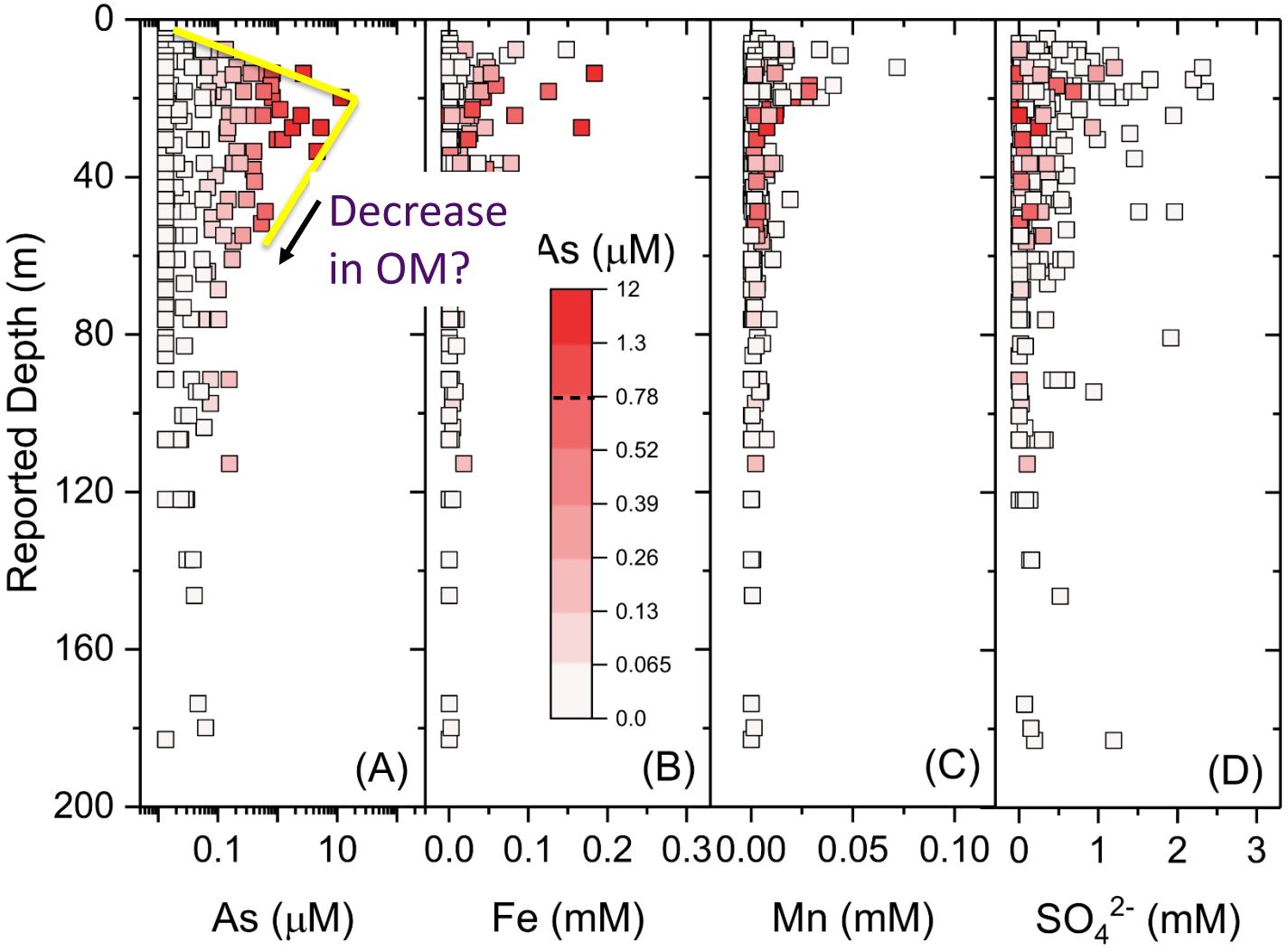
As mobilisation and depth



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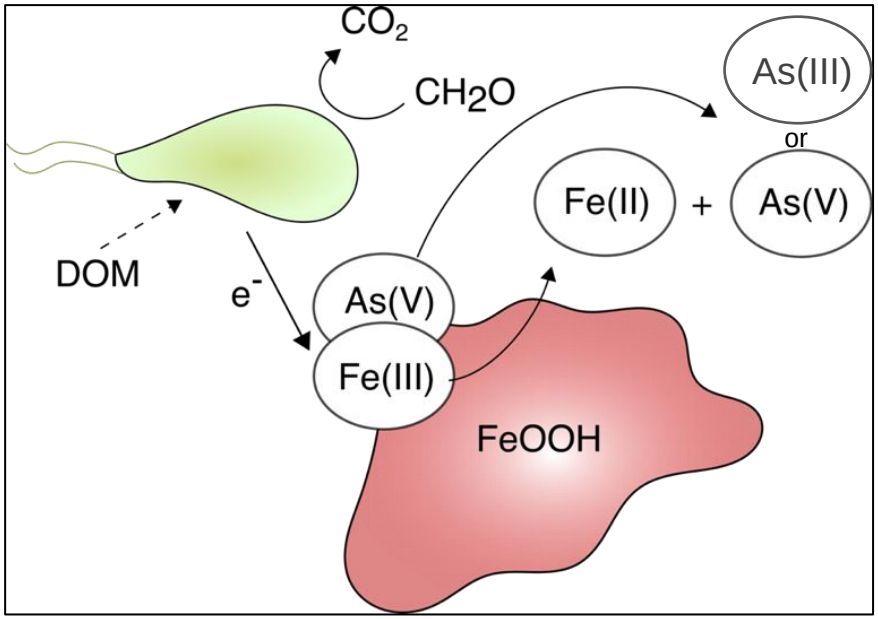

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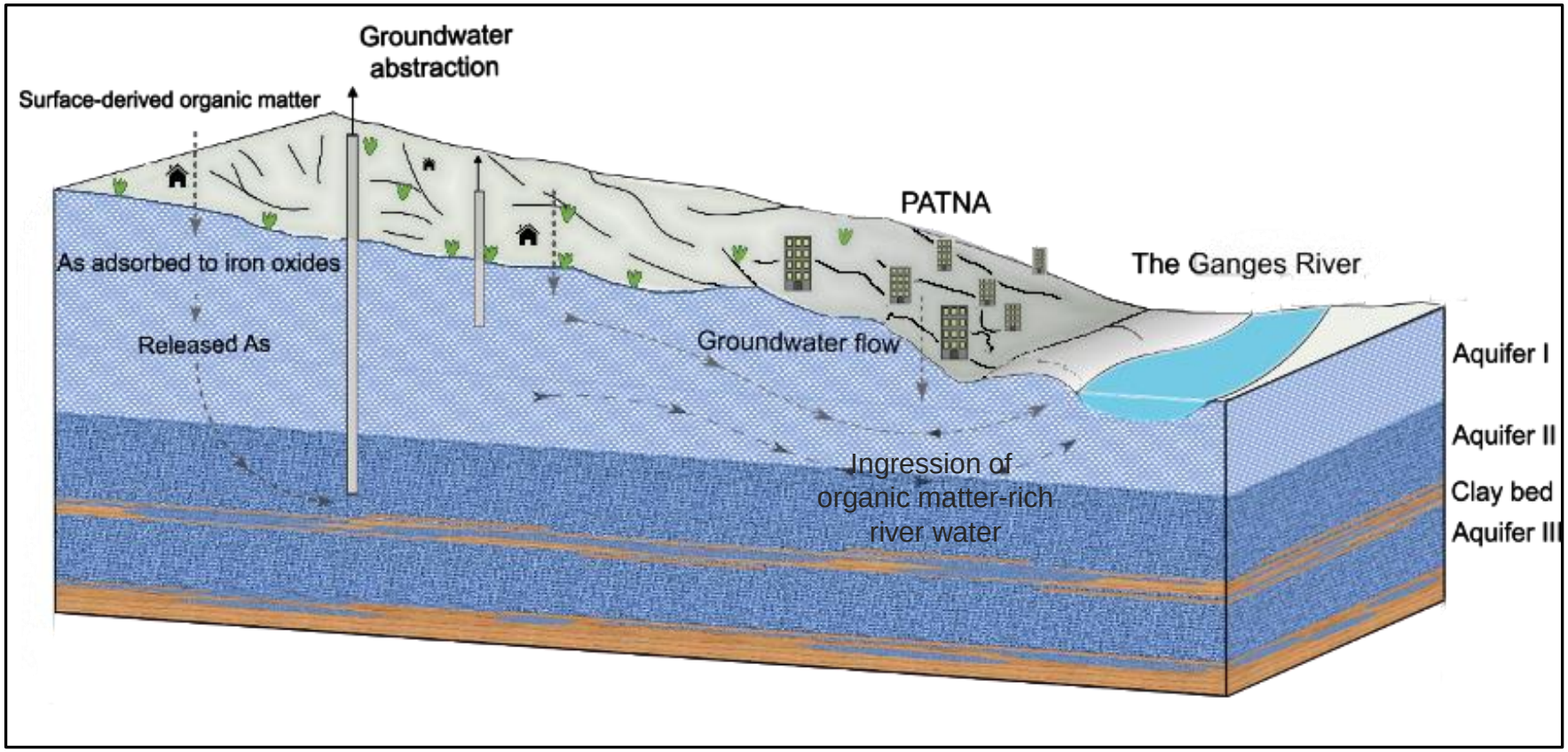
Surface-derived organic matter hypothesis



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SUMMARY

Summary

- Arsenic speciation is important to consider - arsenite/As(III) is typically more mobile and difficult to remove than arsenate/As(V)
- Iron (oxyhydr)oxides regulate the release of arsenic in most of As-affected groundwaters
- Organic matter, particularly its type, is thought to play a significant role in the mobilisation of groundwater arsenic

LEARNING EXERCISE

Learning exercise

1. List and describe two expected geochemical controls on arsenic mobilization for a setting along the Ganges

2a. Explain how organic matter could potentially increase arsenic concentration in groundwater

2b. How might the type of organic matter affect this?

REFERENCES & FURTHER RESOURCES

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Further Resources

Arsenic pollution guide

Bhattacharya, P., Polya, D. and Jovanovic, D. eds., 2017. *Best practice guide on the control of arsenic in drinking water*. IWA Publishing. https://doi.org/10.2166/9781780404929 (OA chapters)

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