ARSENIC POLLUTION
PART A: THE BACKGROUND AND IMPORTANCE OF ARSENIC POLLUTION

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.

Arsenic pollution

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  - Objectives
  - Background
  - Health implications of drinking arsenic-contaminated groundwater
  - Global arsenic distribution and its controls
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Introduction

- Arsenic referred to as the ‘King of Poisons’
- Millions are exposed to arsenic contaminated groundwater - disproportionately high populations are impacted in South and Southeast Asia
- Generally considered a geogenic contaminant (see Contamination of Water series); human activity may impact arsenic release and/or transport (Harvey *et al*., 2002)

Objectives

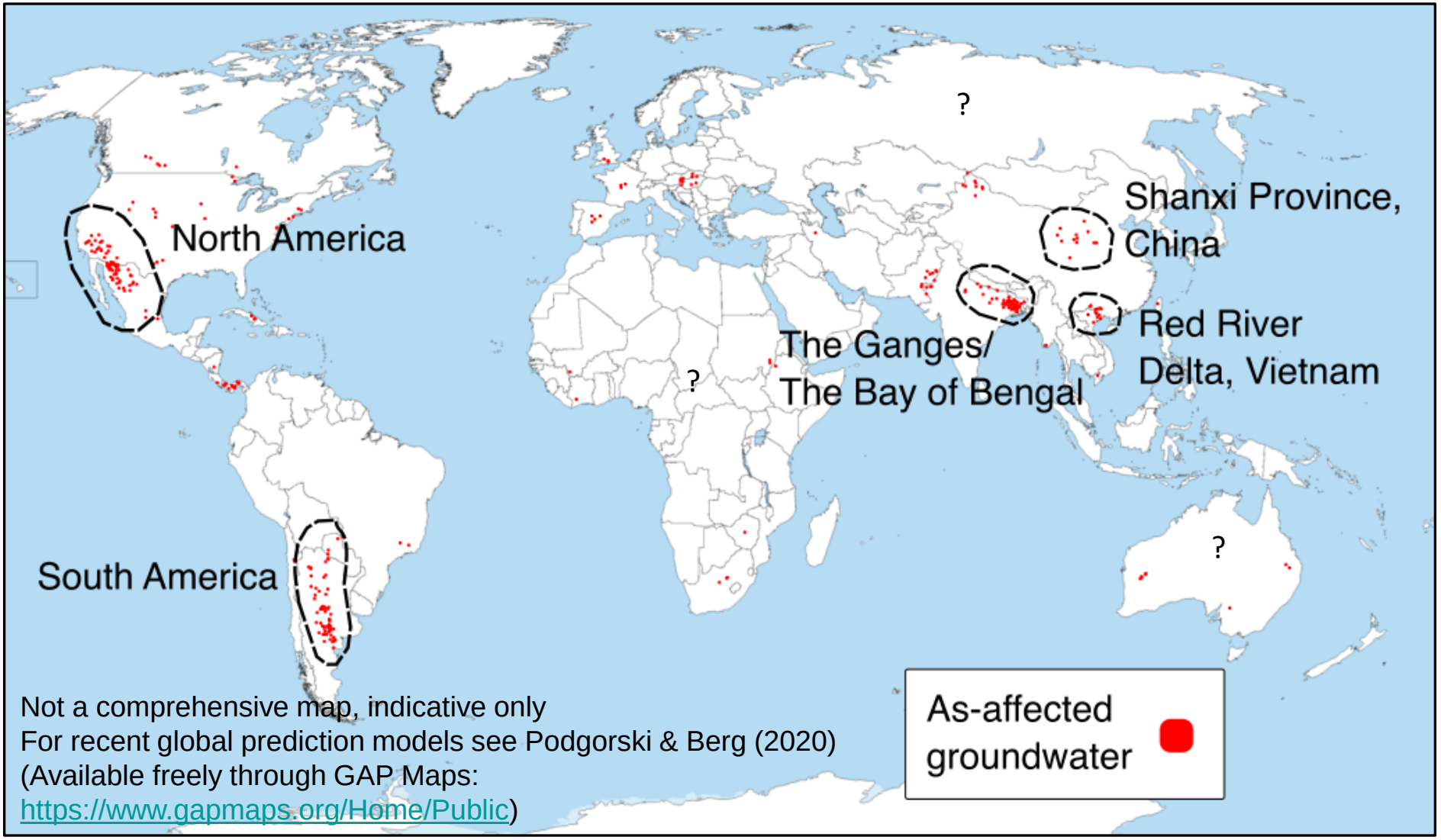
- Become aware of the scale and importance of arsenic pollution
- To explain the health implications of drinking arsenic-contaminated groundwater
- To know the major controls on the global distribution of arsenic

BACKGROUND

Background

- Geogenic arsenic contamination almost unknown 50 years ago (WHO, 2018) (OA)
- WHO guide value is 10 µg/L for drinking water; lower concentrations (<1 µg/L) are being targeted in some locations (Ahmad *et al*., 2020)

As-affected groundwater world map



Not a comprehensive map, indicative only
For recent global prediction models see Podgorski & Berg (2020)
(Available freely through GAP Maps:
https://www.gapmaps.org/Home/Public)

Produced by George Wilson, world map adapted from Wikipedia (2018) (CC0 1.0 license).
Locations from various authors based on a literature review.

Population exposure to arsenic

Largest three by number exposed

	Country	Population exposed to As-contaminated groundwater (>10µg/L)
1.	Bangladesh	50 million [1]
2.	India	18-30 million [3]
3.	China	15 million [2]
.	Nepal	13 million [2]
.	Mexico	2 million [2]
.	Argentina	2 million [2]

Total: 94-220 million [4]

[1]Ravenscroft *et al*. (2007) [2]Shaji *et al.* (2020) [3]Podgorski *et al*. (2020)
[4] Podgorski & Berg (2020)

HEALTH IMPLICATIONS OF DRINKING ARSENIC-CONTAMINATED GROUNDWATER

Exposure pathways

- Acute and chronic As exposure
- Chronic exposure though:
  - Contaminated drinking water (tube wells)
  - Crops irrigated/food prepared with high-As water, including rice (Xu *et al*., 2020) (OA)

Acute = high concentration over a short period
Chronic = low concentration over a long period

(India Water Portal, 2008) (CC BY 2.0 license)

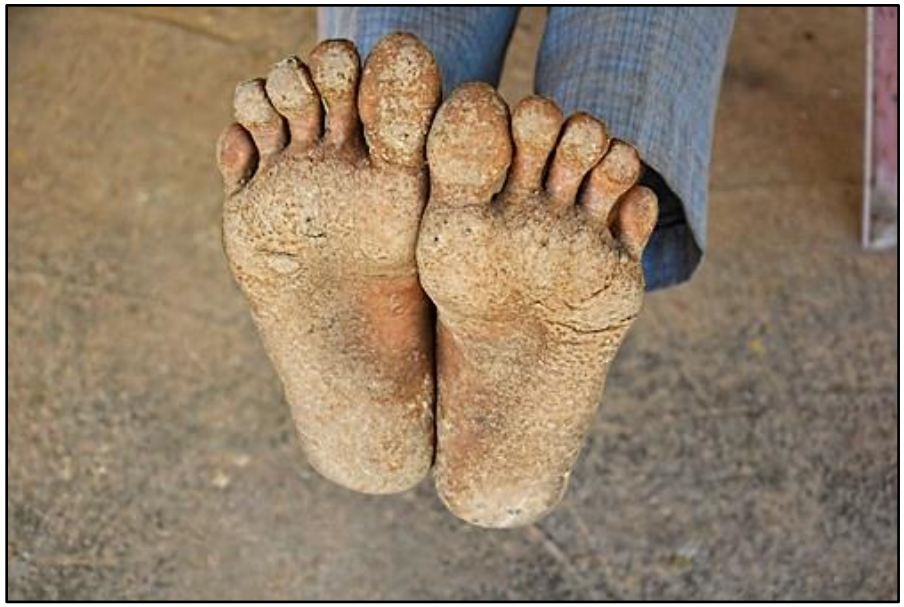
  - Industrial processes: alloying agent, textiles, preservatives

(WHO, 2018) (OA)

Chronic exposure to As

Chronic exposure implications (not a complete list):

- Respiratory
  - Lung disease
- Neurological
  - Neuropathy
- Dermatological
  - Skin cancer
  - Arsenical keratosis
- Cardiovascular
  - Heart disease; myocardial infarction
  - Gangrene



(India Water Portal, 2018) (CC BY 2.0 license)

(WHO, 2018) (OA)

GLOBAL ARSENIC DISTRIBUTION AND ITS CONTROLS

As occurence

- Principally in alluvial aquifers (59%)
- Arsenic-affected basins:
  - Weathering in upper catchment; high sediment load
  - Deep incision in delta
  - Humid lower catchment; abundant OM

(Ravenscroft, 2007) (OA)

As vulnerability prediction / GAP Maps

GAP, Groundwater Assessment Platform (2015).
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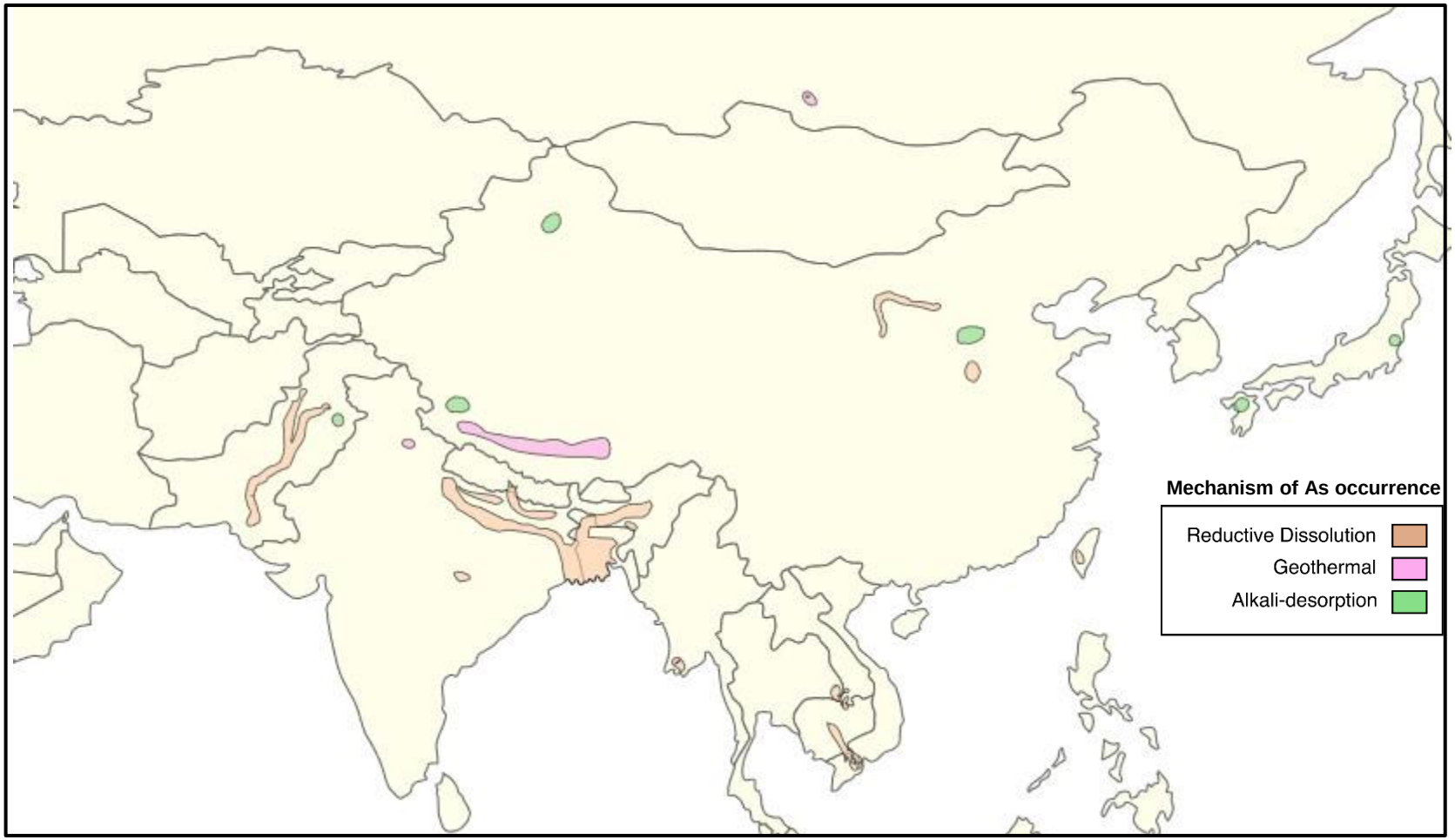
Water types

Four major explanations for As occurrence in groundwater:

- Reductive-dissolution (RD) mechanism
- Alkali-desorption (AD) mechanism
- Sulphide-oxidation mechanisms
- Geothermal waters

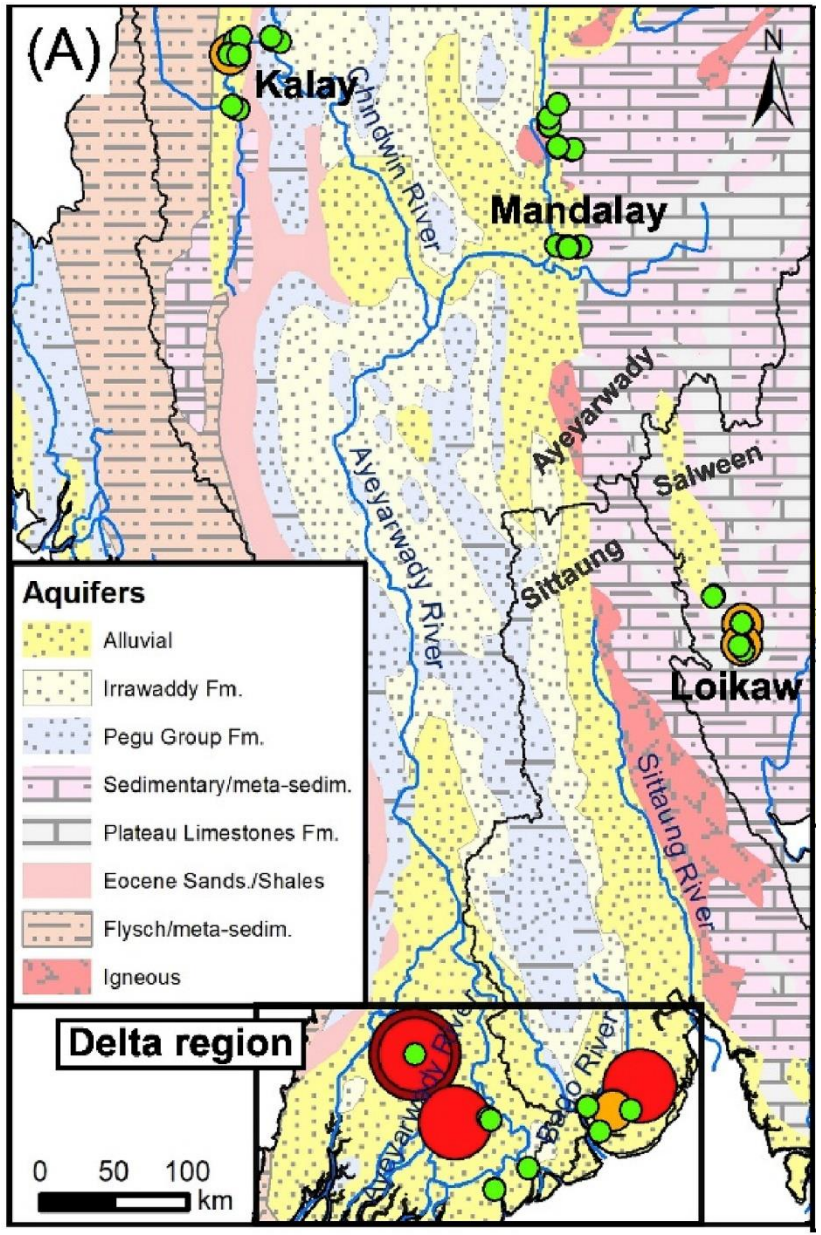
(Ravenscroft, 2007) (OA)

As mobilisation mechanisms in Asia

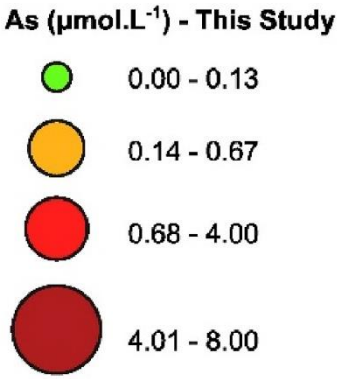


Produced by George Wilson from an adaptation of Ravenscroft (2007)

Arsenic distribution in Myanmar



- Elevated As (>10 µg/L) around Ayeyarwady Delta
- Predominantly As(III) from reductive dissolution



SUMMARY

Summary

- Arsenic a worldwide problem, disproportionally affecting populations in SE Asia
- Chronic exposure to As-contaminated groundwater can lead to respiratory, neurological, dermatological and cardiovascular issues
- Predictive models can be used to predict the occurrence of groundwater arsenic based on river basin types and surface characteristics (see for example Podgorski *et al*., 2020)
- The four methods for As-occurrence in groundwater include reductive dissolution, alkali-desorption, sulphide oxidation and geothermal water

LEARNING EXERCISE

Learning exercise

1. Summarize the health implications for chronic exposure to As-contaminated groundwater.

2. What is the predominant mechanism for arsenic mobilisation in Myanmar? Where else in the world does this mechanism occur?

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)

Red River Delta, Vietnam case study

Winkel, L.H., Trang, P.T.K., Lan, V.M., Stengel, C., Amini, M., Ha, N.T., Viet, P.H. and Berg, M., 2011. Arsenic pollution of groundwater in Vietnam exacerbated by deep aquifer exploitation for more than a century. *Proceedings of the National Academy of Sciences*, *108*(4), pp.1246-1251. https://doi.org/10.1073/pnas.1011915108 (OA)

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