ARSENIC POLLUTION
PART C: MYANMAR CASE STUDY

*The material presented here has been prepared by **Dr. Laura Richards** of the Department of Earth & Environmental Sciences, The University of Manchester, as based on recent research outputs (in particular Pincetti Zuniga et al, 2020, Applied Geochemistry, https://doi.org/10.1016/j.apgeochem.2020.104535) – full acknowledgements including to the original funding source are provided in journal article.*

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SPHEIR Strategic Partnerships for Higher Education Innovation and Reform

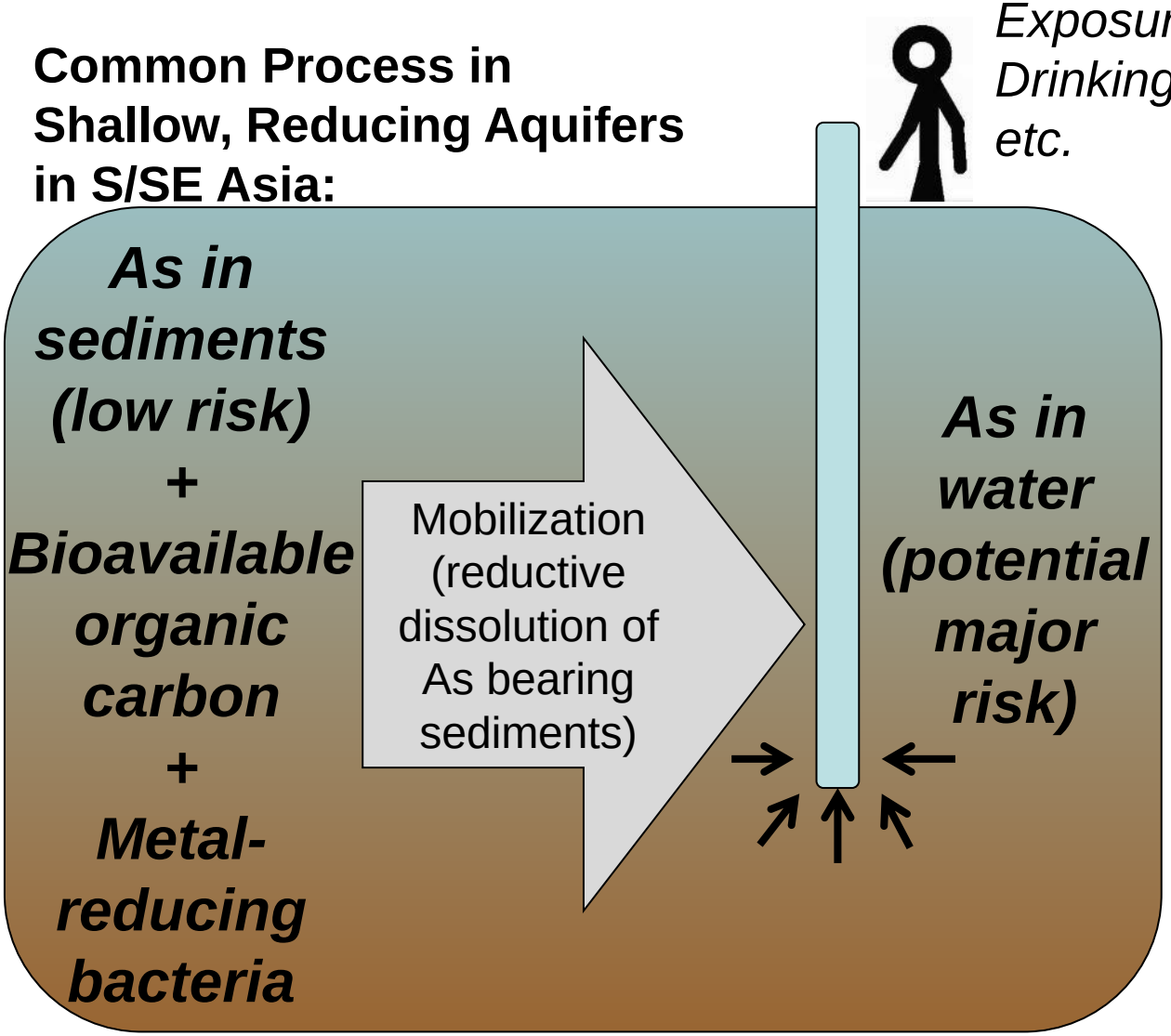
Arsenic pollution

- Outline
  - Introduction/Recap
  - Myanmar Case Study Example
  - References & Further Information
- Summary

BACKGROUND

Arsenic Mobilization Schematic

Common Process in Shallow, Reducing Aquifers in S/SE Asia:

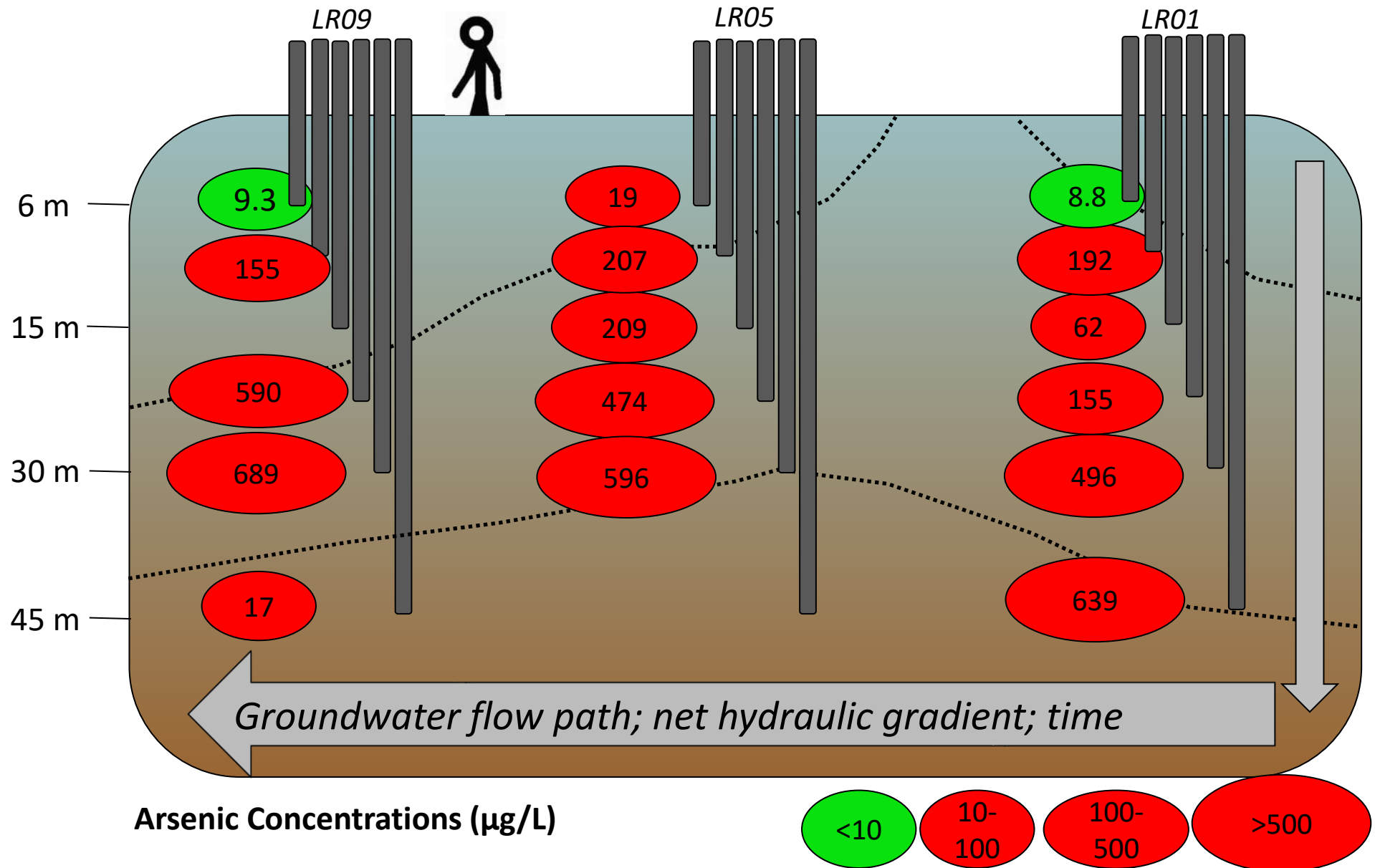


Exposure via: Drinking, Cooking, etc.

Chronic exposure exceeding World Health Guideline of 10 µg/L may lead to skin lesions, skin and internal cancers (bladder, kidney, lung), neurological effects, and more…

Islam et al., 2004; Smith et al., 2000; World Health Organization 2011

Secular Changes (Arsenic)



As vulnerability prediction / GAP Maps

GAP, Groundwater Assessment Platform (2015).
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OUR RESEARCH

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Major and trace (including arsenic) groundwater chemistry in central and southern Myanmar

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- **Open access**

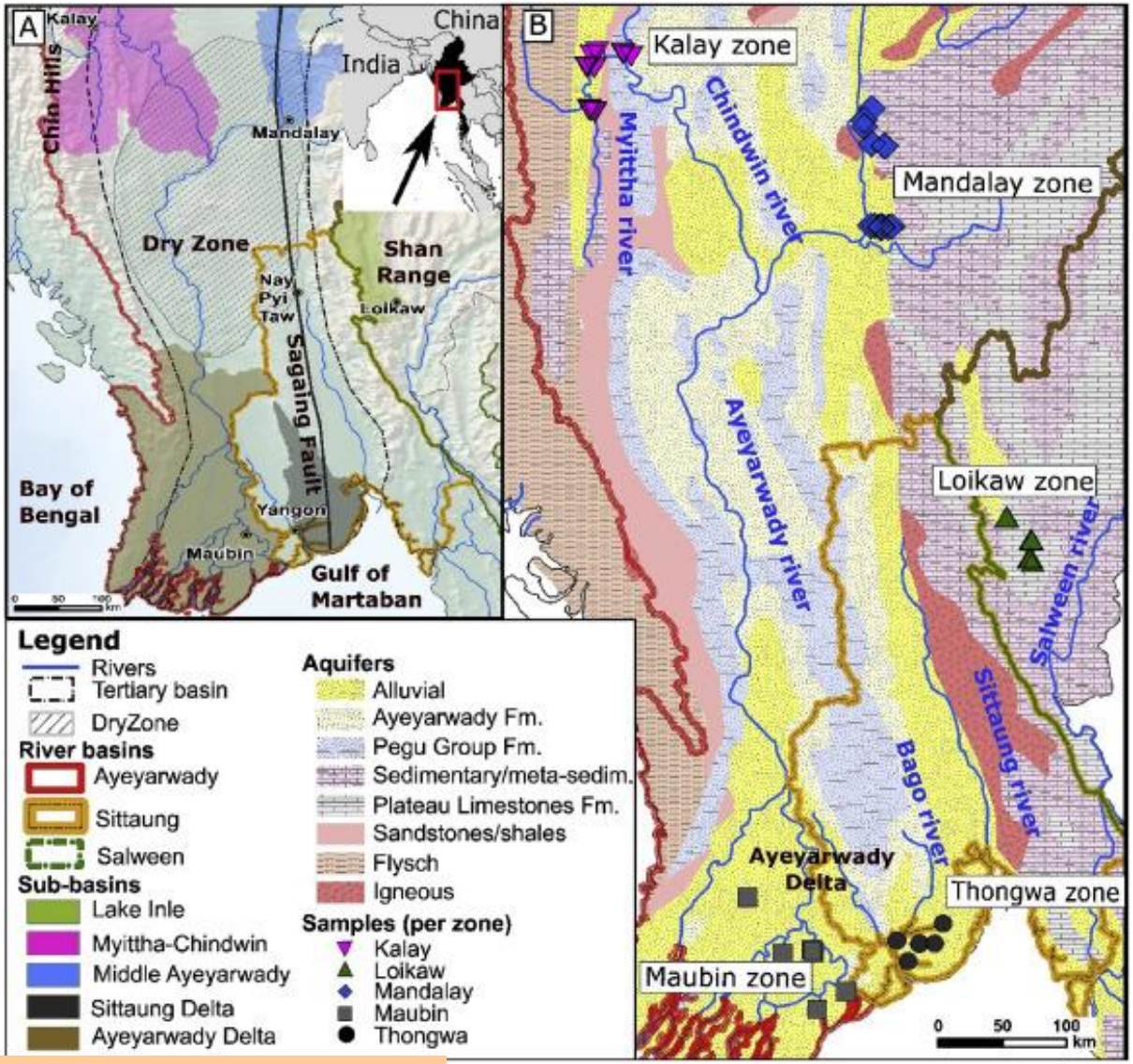
Aims and Objectives

The aim is to better understand the (inorganic) chemical groundwater quality and the spatial distribution of trace contaminants, including arsenic, in contrasting zones in Central and Southern Myanmar

- Objectives
  - assess the occurrence, spatial variations, speciation, and possible release mechanisms of As in groundwater, including in comparison to previous work
  - assess the overall drinking water quality based on other inorganic parameters (*e.g.* F, Pb, NO_3, Fe, Al, Mn)
  - identify the dominant geochemical controls and processes impacting the major and trace groundwater geochemistry in the selected regions of Central and Southern Myanmar.

Pincetti-Zúniga et al, 2020

Field Area



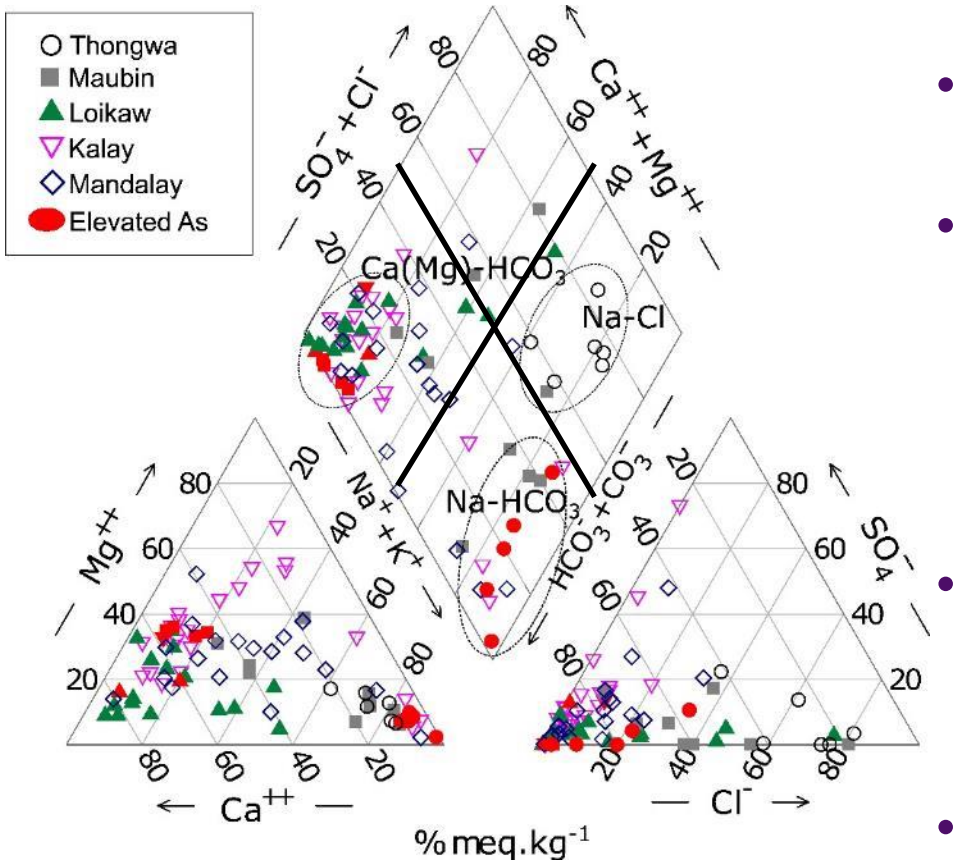
- Field sites (n = 85) were located in “zones” around Maubin (n = 13), Thongwa (n = 11), Loikaw (n = 18), Kalay (n = 23) and Mandalay (n = 20)
- Site selection based on contrasting predicted arsenic hazard, contrasting (hydro)-geological characteristics and collaboration with local partners

Pincetti-Zúniga et al, 2020

Sampling & Analysis

Sampling methods & analyses similar to Richards et al., 2017 (STOTEN)

Dominant Water Type



- Piper diagram used to visualize relative abundance of major ions
- Water type associated with sampling zone
- Loikaw, Kalay, Mandalay zones
  - Ca(Mg)-HCO_3 (~ 65 %) groundwaters
  - Typical of shallow, fresh GW
  - Consistent with high As GW in Cambodia
- Thongwa zone
  - NaCl type (~ 10 %)
  - Saline, typical of marine influence and/or deep/old groundwater
- Found in all zones
  - Na-HCO_3 type (~ 20 %)
  - Suggests groundwater influenced by ion exchange

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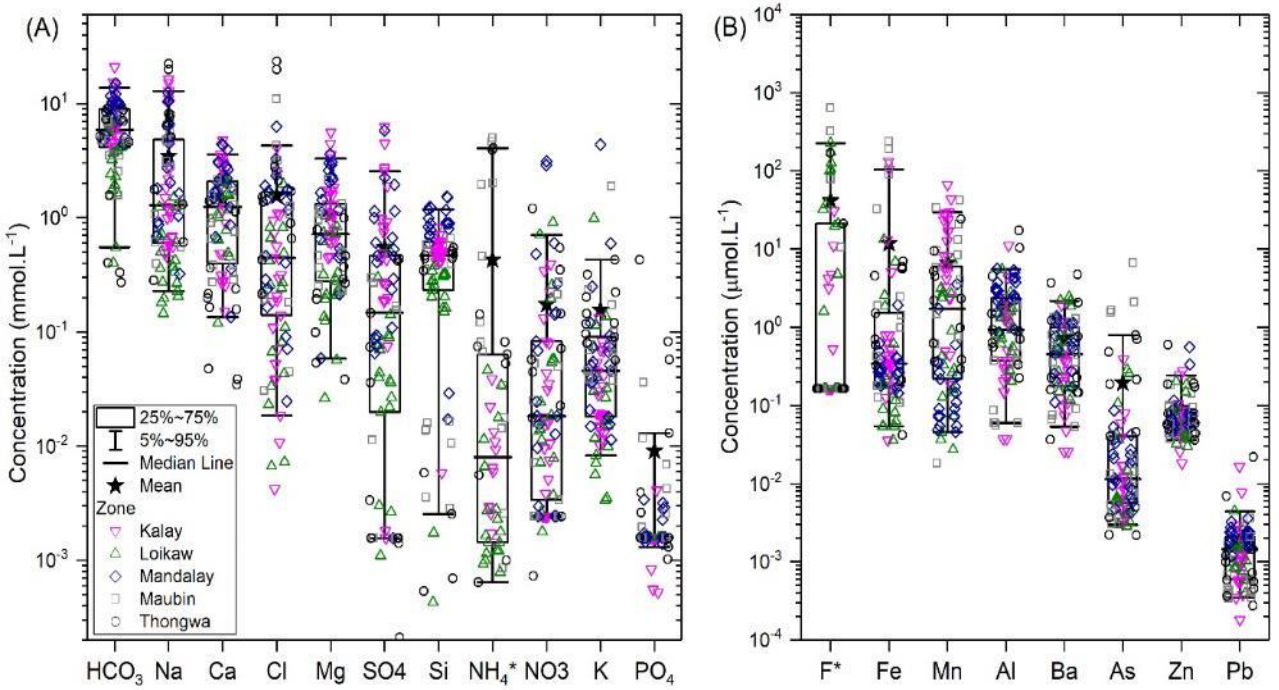
Chemical Composition



- Box plots used to visualize concentration distribution of chemicals
- Most abundant constituents: HCO_3^-, Na, Ca, Cl and Mg
- Lower concentrations and more variability: SO_4, Si, NO_3, NH_4, K
- Trace elements: wide variability and regional differences
  - *e.g.* Mandalay = high Al, low Mn
  - Kalay = high Mn, low Al
- Arsenic: variable, discussed separately

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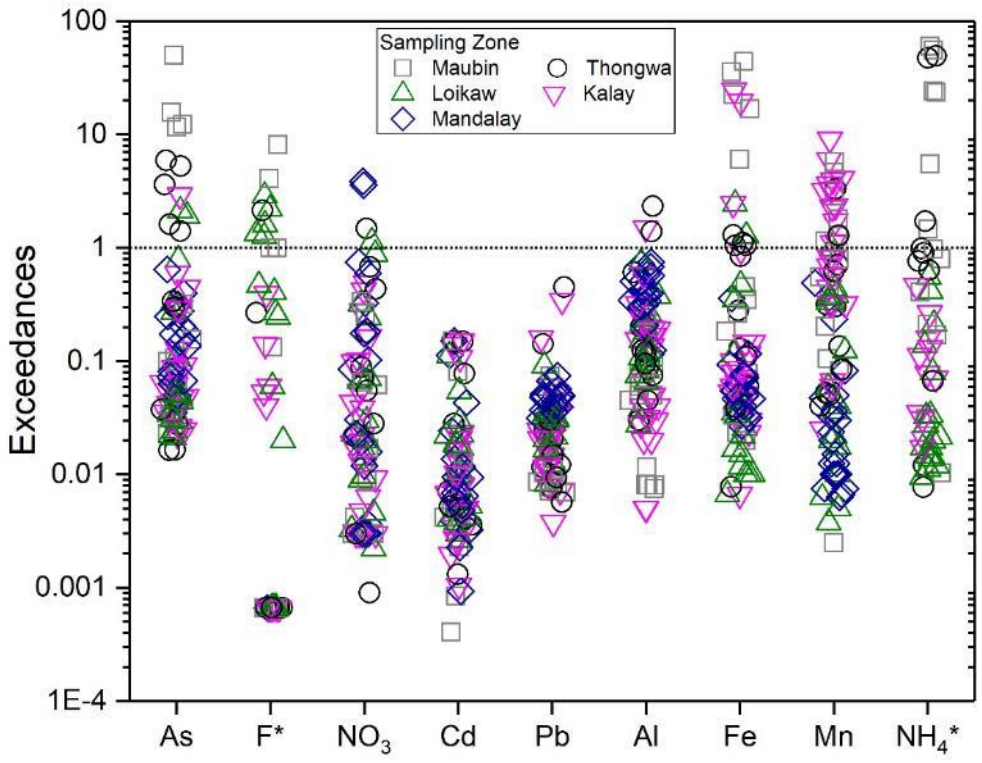
Comparison to WHO Guidelines



- Water quality assessment as compared to World Health Organization (WHO) guidelines
- Exceedance > 1 means that WHO guideline for that chemical is exceeded
- Many samples exceeded guidelines for As (10 µg/L), F^- (1.5 mg/L), NO_3^- (50 mg/L), Al, Fe, Mn (note old guideline) and NH_4^+
- Spatial trends (*e.g.* high F in Loikaw; high Mn in Kalay) – shown in more detail in paper
- Selected parameters only – not a comprehensive quality assessment

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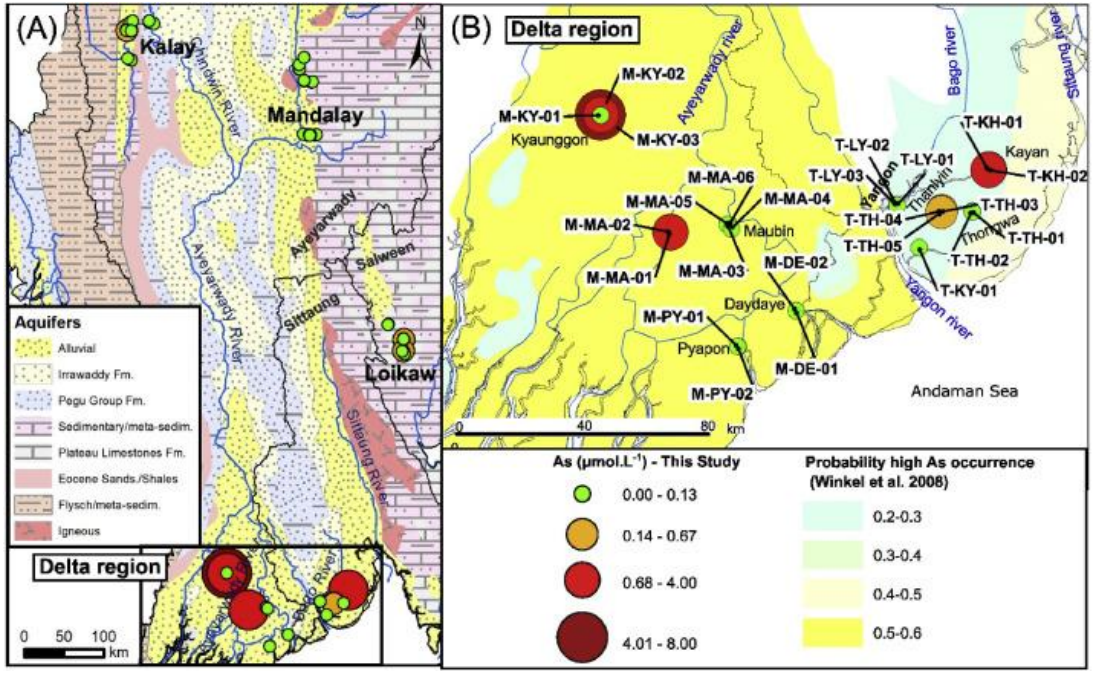
Spatial Arsenic Distribution



- As ranged from 0 to > 500 µg.L^{-1} , with maximums in Ayeyarwady Basin → consistent with hazard predictive models in areas of recent alluvial and deltaic deposits (Winkel *et al.* 2008) & previous field studies (van Geen *et al.*, 2014)
- Elevated As in some other areas (Loikaw, Kalay) → low probability predicted from hazard maps
- Overall ~ 14 % of samples (n = 85) with As ≥ 10 µg.L^{-1}
- *Are greater populations or additional geographical areas at risk?*

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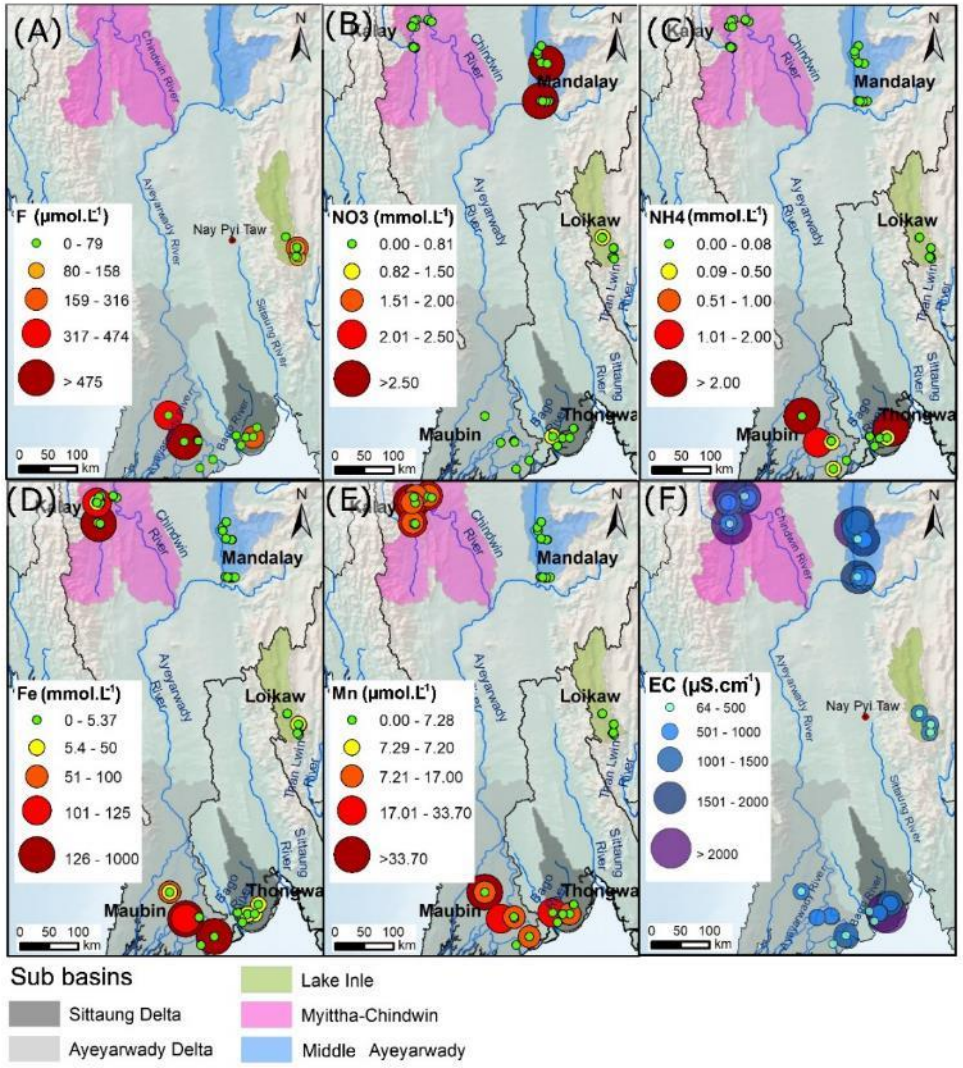
Spatial Distribution of Inorganics



- F: mostly elevated in delta region; some elevated in Loikaw
- NO_3: mostly elevated in Mandalay area
- NH_4: mostly elevated in Maubin (13% out of 54 samples) and Thongwa (7% of 54 samples
- Fe: > 5.4 µmol.L^{-1} (0.3 mg.L^{-1}) in 17% of all samples (n= 85): Maubin (6%), Thongwa (5%), Kalay (4%), and Loikaw (2%)
- Mn: Mn >7.3 µmol.L^{-1} (400 µg.L^{-1}) in 19% of all samples, mostly from Kalay (12%) and Maubin (7%) zones
- EC: elevated EC >1500 µS.cm^{-1} in 14% of all samples, particularly in Thongwa (2%), Mandalay (6%), and Kalay (6%) zones

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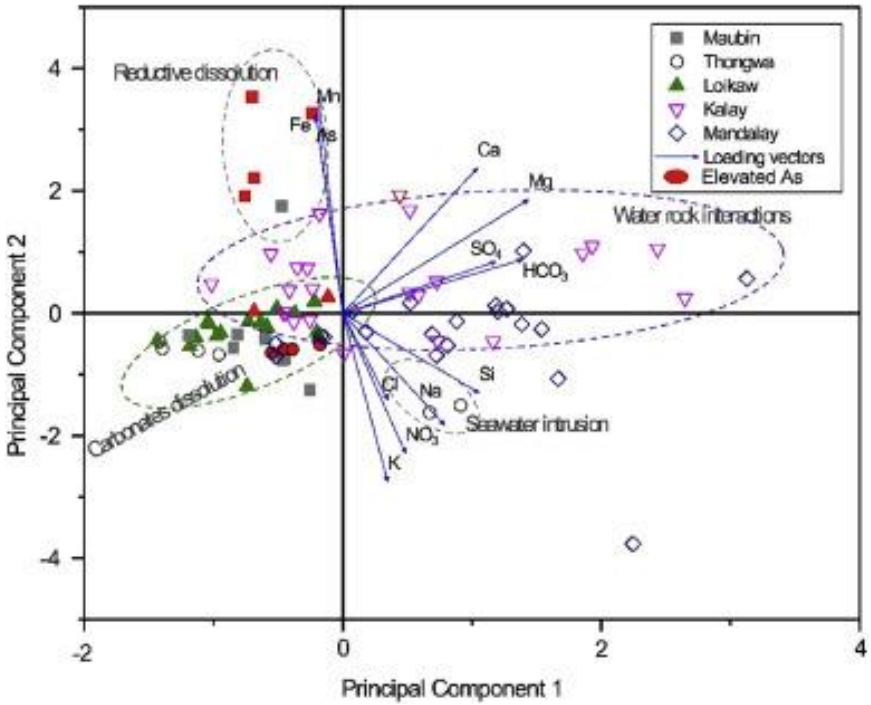
Principal Component Analysis



PCs to reflect the main expected geochemical processes:

(i) PC-1: water-rock interactions, including carbonate dissolution and silicate weathering (Mg, SO_4, HCO_3, Ca, and Si);

(ii) PC-2: Reductive dissolution of Fe(Mn)-(hydr)oxides (Fe, Mn, As)

(iii) PC-3: Saline water mixing & agricultural (Na, Cl, NO_3, K)

Main processes:

(i) reductive dissolution of Fe(Mn)-(hydr)oxides, notably in Maubin zone;

(ii) saline mixing or seawater intrusion in samples from the deltaic region, notably from Thongwa zone;

(iii) carbonate dissolution in the Loikaw zone;

(iv) other water-rock interactions in Kalay and Mandalay zones.

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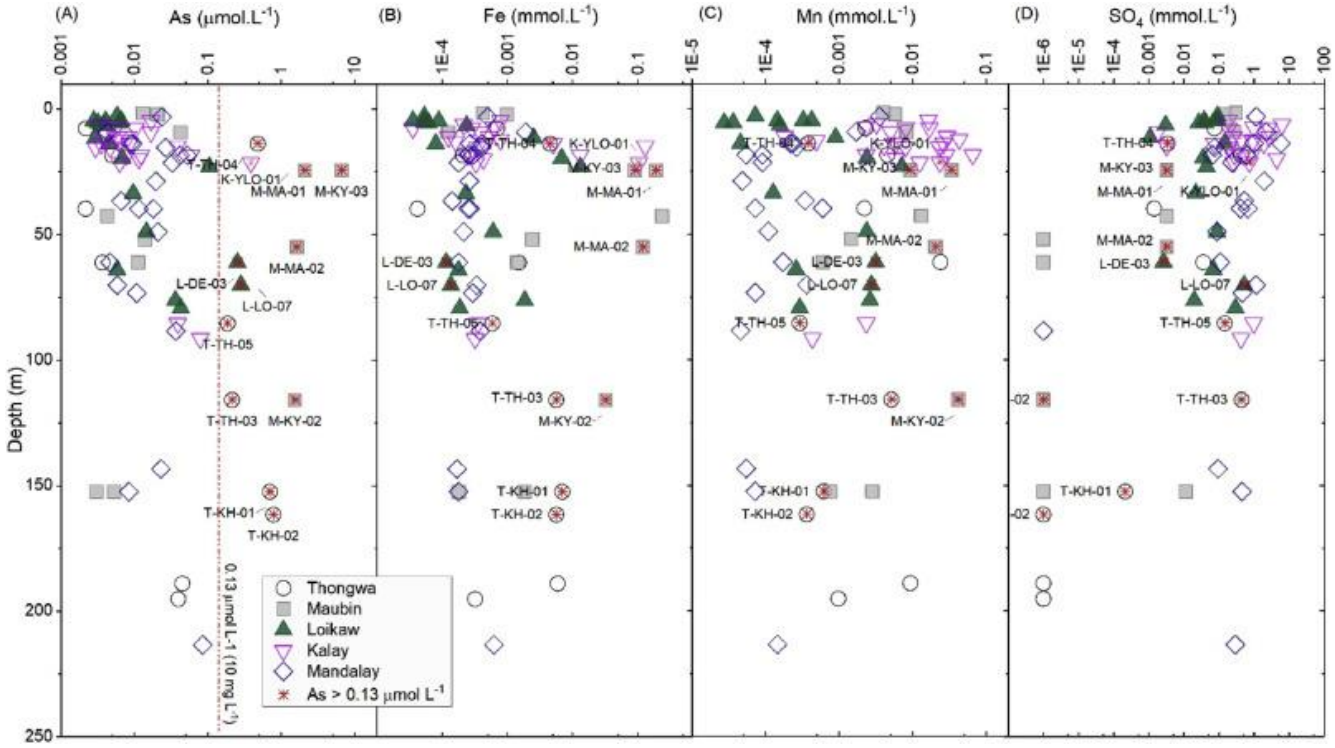
Spatial Arsenic Distribution



- No clear systematic relationship between As and depth
- As correlates with Fe ($t(83) = 4.3$, $p < 0.01$)
- As (broadly) inversely correlated with SO_4^{2-}
- Highest As groundwaters are consistent with reductive dissolution of Fe-hydroxides (characteristics of shallow, reducing aquifers in S/SE Asia)

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CONCLUSIONS

Conclusions

- A cross-country groundwater survey undertaken in several contrasting, and previously under-represented, regions of Myanmar
- Elevated concentrations of As, F, NO_3, Fe, Mn, NH_4 and salinity were identified in some cases
- Approximately 14 % of samples exceed the WHO provisional guideline value for arsenic, especially in Ayeyarwady Basin (but also some in Loikaw, Kalay)
- Main geochemical processes identified in each zone studied
- Information important for understanding and improving water quality in Myanmar
- Full paper provides much more detail

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