Groundwater arsenic distribution reconnaissance survey in Myanmar

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ABSTRACT: Dangerous arsenic concentrations in shallow groundwaters threaten the health and livelihoods of millions of people, particularly in South/Southeast Asia. However, the scope and magnitude of groundwater arsenic hazard is relatively poorly understood in Myanmar as compared to neighboring countries. We undertook a groundwater quality survey across five (hydro)geologically distinct regions of Myanmar, and initial field results indicate elevated arsenic in a number of samples including in areas where previously modeled probability of arsenic concentrations exceeding the provisional WHO guideline was low. Data validation and interpretation of possible geochemical and/or hydrological controls are the subject of ongoing investigation.

1 INTRODUCTION

Millions of people in South/Southeast Asia are chronically exposed to dangerous concentrations of geogenic arsenic in groundwater (e.g. Charlet & Polya, 2006; Smedley & Kinniburgh, 2002 and refs within). Although the scope and magnitude of this problem is reasonably well defined in some areas particularly in countries such as Bangladesh, India, Cambodia, Vietnam and China, widespread international understanding of the distribution of arsenic in Myanmar is much more limited and in some cases is restricted to predictive models based on surface geological parameters (Amini *et al.*, 2008; Winkel *et al.*, 2008), despite elevated levels of arsenic being confirmed in the Ayeyarwady Basin (van Geen *et al.*, 2014). We aim to improve the understanding of arsenic distribution in a cross-country groundwater quality survey incorporating five geologically distinct regions within Myanmar.

2 METHODS/EXPERIMENTAL

2.1 Field area

Field sites ($n=85$) were located across Myanmar and were broadly based around Maubin ($n=13$), Thongwa ($n=11$), Loikaw ($n=18$), Kalay ($n=23$) and Mandalay ($n=20$) (Fig. 1). General sampling regions were selected on the basis of (i) encompassing different predicted arsenic hazard categories (Winkel *et al.*, 2008); (ii) encompassing areas of different (hydro)-geological characteristics; (iii) collaboration with local partners. Specific sampling locations within each region were selected with the input of local partners. In brief, the geology is dominated by recent alluvial deposits in the Ayeyarwady basin, Permian limestones in the Shan Plateau, and Cretaceous flysch

sedimentary sequences in the Indo-Burman Ranges (Bender, 1983).

2.2 Sample collection and analysis

Groundwater samples ($n=85$) were collected from existing tube wells and dug wells in December 2017 during which *in-situ* analysis of parameters such as pH, *Eh*, temperature, electrical conductivity, alkalinity, sulfide, ammonium, nitrate, nitrite and fluoride were conducted using methods adapted from previous studies in Cambodia (cf. Richards *et al.*, 2017). Initial field measurements of arsenic were made visually using the ITS Econo-Quick arsenic kit (van Geen *et al.*, 2014).

3 RESULTS AND DISCUSSION

Groundwater arsenic, as measured visually with field kits, ranged from 0–500 $\mu\text{g L}^{-1}$ (Fig. 2), with the highest concentrations observed in the Ayeyarwady Basin as previously predicted by arsenic hazard models (Winkel *et al.*, 2008) and confirmed by field measurements (van Geen *et al.*, 2014) undertaken within the same region but in different specific areas. Elevated arsenic was also observed in other areas, including the area surrounding Loikaw, an area which was not predicted to be likely to have elevated arsenic by previous predictive models (Winkel *et al.*, 2008). Overall 42% of samples collected (36 of 85) estimated arsenic $\geq 10 \mu\text{g L}^{-1}$, including in areas not encompassed by previous arsenic hazard maps, which suggests that it is possible that higher populations and/or additional geographical areas may be at risk from elevated arsenic than previously predicted. Confirming field measurements and linking results with other groundwater geochemical parameters (e.g. Fe, HCO_3^- , *Eh*, pH, *etc.*)

Figure 1. Map showing sampling sites ($n = 85$) from general field areas based around Maubin ($n = 13$), Thongwa ($n = 11$), Loikaw ($n = 18$), Kalay ($n = 23$), and Mandalay ($n = 20$); map adapted from Google Earth with attribution as shown. Samples with arsenic $\geq 50 \mu\text{g L}^{-1}$ ($n = 9$) were located in the Maubin ($n = 4$), Thongwa ($n = 3$) and Loikaw ($n = 2$) sampling areas.

Figure 2. Arsenic (ITS Econo Quick Visual test kit) versus reported depth for each sampling region. Note test kit reports a semi-quantitative range of values assessed visually.

as well as potential (hydro)-geological controls is the subject of ongoing work.

4 CONCLUSIONS

A cross-country groundwater quality survey indicates that elevated levels of arsenic are likely to occur in several distinct, previously under-studied regions of Myanmar. Results will be validated by further, laboratory-based analysis including analysis of major and trace elements and arsenic speciation.

ACKNOWLEDGEMENTS

This research was supported by the Leverhulme Trust (ECF2015-657 to LR), with additional support

from an Engineering and Physical Sciences Research Council Improving Diversity Award (to LR, Tun, Gibson and DP). We are very grateful to substantial support especially from Yin Min Tun (eTekkatho Digital Library), project partners and field assistants from Dagon University, Maubin University, Loikaw University, Kalay University and Mandalay University, Helen Downie (University of Manchester) and local authorities and landowners.

REFERENCES

- Amini, M., Abbaspour, K.M., Berg, M., Winkel, L., Hug, S.F., Hoehn, E., Yang, H. & Johnson, A. 2008. Statistical modeling of global geogenic arsenic contamination in groundwater. *Environ. Sci. Technol.* 42: 3669–3675.
- Bender, F. 1983. *Geology of Burma*: Gebrüder Borntraeger.
- Charlet, L. & Polya, D.A. 2006. Arsenic in shallow, reducing groundwaters in southern Asia: An environmental health disaster. *Elements* 2: 91–96.
- Richards, L.A., Magnone, D., Sovann, C., Kong, C., Uhlemann, S., Kuras, O., van Dongen, B.E., Ballentine, C.J. & Polya, D.A. 2017. High resolution profile of inorganic aqueous geochemistry and key redox zones in an arsenic bearing aquifer in Cambodia. *Sci. Total Environ.* 590–591: 540–553.
- Smedley, P.L. & Kinniburgh, D.G. 2002. A review of the source, behaviour and distribution of arsenic in natural waters. *Appl. Geochem.* 17(5): 517–568.
- van Geen, A., Win, K.H., Zaw, T., Naing, W., Mey, J.I., & Mallioux, B. 2014. Confirmation of elevated arsenic levels in groundwater of Myanmar. *Sci. Total Environ.* 478: 21–24.
- Winkel, L., Berg, M., Amini, M., Hug, S.J. & Johnson, C.A. 2008. Predicting groundwaters arsenic contamination in Southeast Asia from surface parameters. *Nat. Geosci.* 1: 536–542.