TOPIC: GROUNDWATER ARSENIC POLLUTION

SUB-TOPIC:
PART A: THE BACKGROUND AND IMPORTANCE OF ARSENIC POLLUTION

Supporting Transcript

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This is a mini-lecture series on the significant and worldwide problem of arsenic pollution. In this lecture, I'll be going through an introduction to arsenic and its importance.

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I'll be talking through the health implications of being exposed to arsenic and trying to describe and explain the global distribution in groundwater.

SLIDE 3

Arsenic can be an extremely dangerous chemical and has been used for its deadly properties throughout history. Sometimes referred to as the King of Poisons, its presence in groundwater impacts the health and livelihoods of millions of people worldwide, particularly in South East Asia. Arsenic is a geogenic pollutant, but there is some evidence to suggest that human activity such as groundwater pumping may influence its release and transport.

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So the objectives are to become aware of the scale and importance of arsenic pollution, to explain the health implications of drinking arsenic-contaminated groundwater and to know the major controls on the global distribution of arsenic.

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Some background into the problem.

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Although the toxicity of arsenic compounds has been known for 1000s of years arsenic, the presence and implications of high arsenic in groundwater has only been increasingly realized in the past 50 years or so. And the WHO guide value is 10 µg/L for drinking water, but it's important to note that this is only a provisional value, some areas are targeting lower concentrations in drinking water to perhaps 1 µg/per litre, such as in the Netherlands.

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Now this map has compiled a number of studies and shows where arsenic is exceeding 10 µg/litre and as you can there's a number of reported cases in North and South America, the Ganges, The Bay of Bengal, the Shanxi province in China as well as the Red River Delta in Vietnam. And it's important to consider that this is only a compilation of actual reported concentrations, many areas of high arsenic have likely been missed from this map, as we'll discuss later.

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I've picked out some of the worst affected regions by population exposed to groundwater exceeding the WHO arsenic guideline. And this does not correlate necessarily to the distribution of arsenic - if the population is not actually exposed to the arsenic, then it is not a problem for them. For example, many supplies in North America are centrally treated, which could explain to some degree why it does not have a larger population exposed to the arsenic, yet their groundwater appears to be heavily affected by it on the previous map.

However, arsenic can still be a challenge in untreated or private water supplies.
The top three countries are Bangladesh, India and China in terms of purely number exposed to arsenic. Overall in the world, an estimated 94-220 million people worldwide are at risk from arsenic poisoning, and about 80% of these people are thought to be in Asia.

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We've talked about who is affected and where, but what about the exposure pathways and health implications.

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When we talk about exposure to a chemical we can refer to acute and chronic poisoning. Acute exposure means at very high concentrations over a short period, and for arsenic this can lead to muscle cramping and potentially death if the concentration is high enough. Fortunately there are extremely few cases of acute arsenic poisoning worldwide and to have this concentration naturally is fairly unlikely. What we do have to worry about more commonly is chronic exposure cases, which occur at lower concentrations. The biggest concern globally is arsenic-contaminated drinking water. This could expose a person to high arsenic through the drinking water itself, which is often taken from a tube well as shown in this photo. Rice often contains elevated levels of arsenic compared to other cereal crops, and the consumption of rice is considered a major arsenic exposure route for many people in the world that consume it. Perhaps less commonly but worth mentioning, since arsenic is used in many industrial processes, workers who work in these industries, like textile or preservative production, may be subject to chronic exposure.

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I've listed some illnesses and problems that are triggered by arsenic exposure here and have grouped them into respiratory, neurological, dermatological and cardiovascular issues. It can trigger a number of diseases and cancers through the body, but it is often difficult to attribute these to arsenic in particular. There is no method to distinguish cases of cancer caused by arsenic from cancers induced by other factors.

Perhaps most distinctively to arsenic, arsenical keratosis is a growth of keratin on the skin caused by arsenic, and I've shown a picture of that here. Arsenic exposure has also been linked to "Blackfoot disease", which is a severe disease of blood and can lead to a condition known as gangrene.

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We can look at the arsenic-affected areas of the world and try to understand what environments cause this natural enrichment from background levels. High arsenic aquifers are typically found in alluvial basins, and these basins can be characterised by high weathering in the upper catchments with the delta being cut into deeply. These areas are also humid and organic matter content is higher. We'll talk more about organic matter and its potential links with arsenic later. This describes the general occurrence of high arsenic in groundwater, but what about more detailed predictions?

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Perhaps a more recent take on things, our ability to predict arsenic has improved greatly There are a number of ways that we model groundwater arsenic concentration where it has not directly been measured. Generally, they include various climate and soil parameters, geology, and topography and that's exactly what has been used to generate this prediction map of South East Asia. The model calculates the probability of the groundwater exceeding the WHO limit of 10 micrograms per litre.

At this point I'd like to introduce you to this useful resource on groundwater assessment and where this image was visualized from - GAP Maps. GAP stands for Groundwater Assessment Platform and it compiles a number of studies on arsenic vulnerability at various scales. As well as arsenic, GAP Maps contains models on groundwater fluoride predictions and maps of surface properties, including soils and geology. You can use this site freely using this link and I recommend you have a look at what it has to offer.

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We've discussed the occurrence of groundwater and how it might be predicted, but what are the underlying processes on arsenic mobilisation? There are thought to be four dominant processes that can cause high arsenic to form in groundwater, and the majority of high arsenic cases can fall into one of these. They are reductive dissolution, alkali-desorption, sulphide-oxidation and geothermal. Out of the four, reductive dissolution occurs most commonly, particularly in shallow aquifers of South and Southeast Asia, and alkali-desorption also plays a significant role in some settings.

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And this is a map of South-East Asia according to which process is dominant. Here you can see the reductive dissolution setting closely maps the route of some of the largest alluvial basins in the world, including the Ganges, Brahmaputra, Indus and Yellow River. These regions correspond to the higher probability of occurrence of very high arsenic if we look at the literature. Alkali-desorption is arguably the next most important mechanism worldwide, perhaps more in South America, but you can see a few areas of that in that map, there also a few areas where geothermal activity causes higher groundwater arsenic. The sulphide-oxidation mechanism is much less common in this part of the world.

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And just to quickly summarize the distribution in Myanmar, groundwater arsenic levels are generally low across most parts of country except for the Ayeyarwady Delta, in particular, as well as other localized areas. A recent University of Manchester led survey in collaboration with Myanmar partners found ~ 14 % of groundwater samples from areas within Central and Southern Myanmar to exceed to WHO provisional guideline of 10 ug/L. The link here to this Open Access publication provides more information.

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To summarize, arsenic is a worldwide problem but is most significant to populations in South and South East Asia. Chronic exposure from arsenic contaminated groundwater can lead to a number of respiratory, neurological, dermatological and cardiovascular issues. We can roughly predict the occurrence of arsenic based on river basin types, and to greater detail from surface characteristics such as geology and soils. And all you need to know for now is that there are four methods for As-occurrence in groundwater include reductive dissolution, alkali-desorption, sulphide oxidation and geothermal water. We'll talk more about some of these next time, where we'll be talking about the geochemistry of arsenic.

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For the learning exercise, if you could please answer the following questions: For the first question, I'd like you to summarize the health implications for chronic exposure to As-contaminated groundwater. Secondly, what is the expected predominant mechanism for arsenic mobilisation in the lower Ayeyarwaddy Delta in Myanmar and can you say where else this mechanism occurs in the world.

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Here's a list of the references used for the slides.

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And further resources. Please refer to the best practice on arsenic in drinking water guide, which has some freely available chapters in it and has very useful information on arsenic.

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