Deadly Relationships:
Arsenic Source Rocks, Arsenic Tolerant Microbes, & Arsenic Accumulating Plants

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In 1999, Nepal officially joined it's geographical neighbors in the Asian Arsenic Crisis. The most recent data reveals that 19% (2.4 million) of the Terai population are drinking arsenic contaminated water over the WHO guideline of . 10 ppb.

Analyses of rock samples from the Nepal Himalayas show that arsenic is ubiquitous throughout the mountains, rivers, and springs. The highest concentrations are found near the Central Mineral Belt located from Baglung to Palung and again in Illam District in the far eastern part of Nepal. Soil sample in these areas are over 4000 ppm. Part I of this research showed that 102 samples of 104 contained arsenic concentrations from 3 ppm to 85 ppm. The highest value is found in a Carboniferous marine shale, the Benighat Formation. Several rivers in the central and north-central sessions of Nepal were analyzed for arsenic. River arsenic concentrations varied from 0 to 40 ppb. Hot springs in the Annapurna area reached 76 ppb and cool springs were 40 ppb in the same area.

Soil and core samples were collected from two districts, Nawalparasi and Rautahat in the south central sections of the Terai. Even in the high arsenic Tubewell areas soil arsenic values did not exceed 48 ppm. Generally, the average values were 8 ppm, very close the global background of 5 ppm.

Indigenous jungle and wetland plants along with surrounding soil were analyzed for arsenic uptake. Whole plant samples were dried, ashed, and dissolved in acid before testing for arsenic. All jungle plants but three showed arsenic uptake and several wetland plants are hyper-bioaccumulators. Jungle soils showed the highest arsenic concentrations at the top of soil pits, decreasing downward as roots uptake arsenic from the soil.

Groundwater arsenic concentrations in Nawalparasi District reveal high monthly arsenic variations, particularly in the high arsenic wells. Monthly and seasonal arsenic values may exceed 100 to 400 ppb. Aquifer heterogeneity is high, most likely due to the original depositional environment of meandering streams with high clay overbank deposits. These clay bank deposits are barriers to lateral continuity of the aquifers. Recently, microbial cultures from the same high arsenic aquifers show a strong relationship between high arsenic groundwater and high counts of arsenic tolerant microbes. This suggests microbial redox reactions may drive the release of arsenic into the aquifers from sediments.

To better understand the ecological cycling of arsenic in Nepal, this research analyzed arsenic concentrations from 148 Himalayan sources, identified arsenic tolerant microbes in groundwater, measured the bioaccumulation of arsenic in jungle plants, collected Himalayan arsenic source rocks are found from the southern alluvial sediments to High Himalyan Crystoline rocks. copper mineral deposits, arsenopyrite coatings on ammonites, granites, schists, Carboniferous shales and slates, ssources host abundant sources of arsenic, from rock out crops, rivers, soils, groundwater, to jungle plants. throughout, Rautahat district in the Terai region of Nepal is examined through geological and ecological perspectives.

Rautahat lies south of the Siwalik Formation within the Quaternary alluvial deposits of the Indo-Gangetic Plain. Interestingly, the most arsenic affected aquifers in these districts are found at 18 to 23 meters, generally associated with moderate arsenic concentrations <38 ppm in the sediments. Although, aquifer sediments do not contain extremely high values, groundwater arsenic range from 0 to 300 ppb, exhibiting the common aquifer heterogeneity found in the Terai.

To understand this heterogeneity, water samples from three wells and a nearby river in Rautahat were collected to compare bacterial load and species diversity with arsenic concentrations. Surprisingly, the bacterial load is highest in the jungle well (8 ppb As), the bacterial load increases from 7400 CFU/ml in 0 ppm AsV to 16,200 CFU/ml in 80 ppm AsV, decreasing to 10,800 CFU/ml in 160 ppm AsV. The lowest bacterial load was cultured from an arsenic free river, 505 CFU/ml in 0 ppm AsV, decreasing to 182 CFU/ml in 160 ppm AsV. Although bacterial load is high in the jungle well, species diversity is low, only ten different species comprise the bacterial load found in 160 ppm AsV.

Indigenous plants and surrounding soils from the Toribari Jungle and Chandhi River Wetland are analyzed to determine plant arsenic uptake. Soils ranged from 3.54 ppm to 8.02 ppm, while plant arsenic concentrations are low, ranging from 0.0078 ppm to 0.73 ppm, results show that all plants tested uptake arsenic in the jungle. Sampled wetland silty-clay sediment contained 10.37 ppm arsenic. Four of thirteen wetland plants bioaccumulate arsenic: from 10.7 ppm to 50.62 ppm, while others uptake more arsenic than jungle plants (1.28 ppm to 10.15 ppm). Biomass---Soils from 30 inch deep pits from both jungle and non-jungle sites were analyzed for arsenic to determine if plant arsenic uptake by jungle plants altered soil arsenic. Jungle soils accumulated higher arsenic in the upper 0-5 inches than non-jungle soil pits, the middle horizon 10-15 inches was similar in both pits. The lower pit horizon (25-50 inches) shows the reverse trend from 0-5 inches, arsenic values decrease in the jungle pits as arsenic increases in the non-jungle pits.