SOURCES OF SALINITY and Arsenic IN SURFACE AND GROUND WATER IN A POLDER IN SW BANGLADESH

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Background

- 97% of people in Bangladesh obtain their drinking water from tubewells.
- 20% of population does not have access to safe drinking water due to salination, pathogens, and arsenic contamination.
- Salination may be caused by:
  - seawater intrusion.
  - use of brackish water from tubewells or tidal channels for irrigation.
  - Inundation following monsoon flooding.
  - brine shrimp aquaculture.

Field observation: groundwater from tubewells is not used for irrigation. Confirmed by chemical analysis.

Stratigraphy in polder 32 region

- Impermeable silt and clay cap from less than 10 m to 25 m thick known as the Madhupur Clay.
- Very fine to fine sand layers from depths of ~10 to 100 m (shallow aquifer).
- Clay and silt layers from depths of 100 to greater than 200 m – intermediate aquifer containing brackish water.

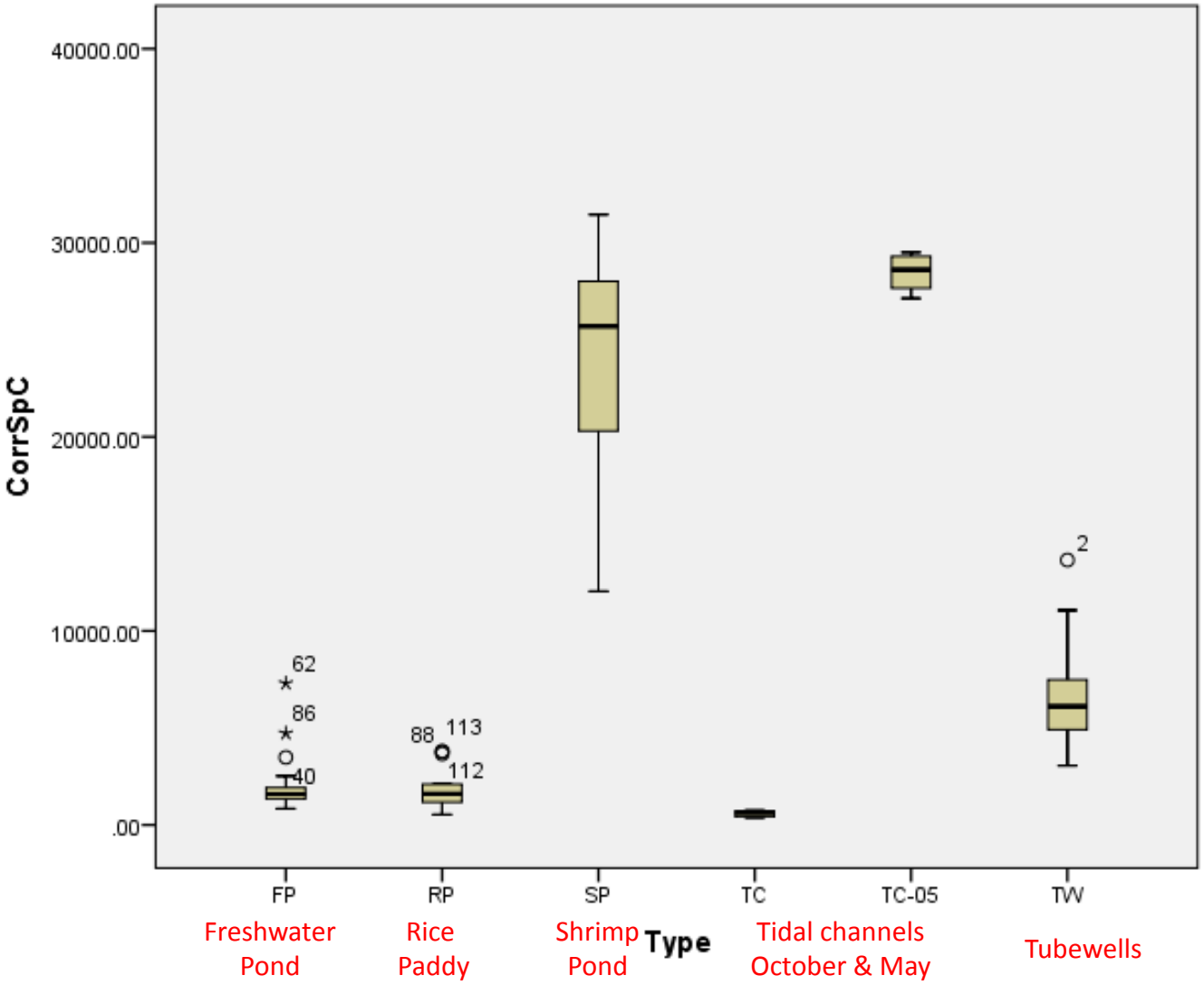
Approach

- Collect water samples from soil in agricultural fields and from all drinking water types and potential sources of salinity (freshwater ponds, tidal channels, tubewells, brine shrimp ponds).
- Measure in field: pH, temperature, Eh, conductivity, and turbidity.
- Analyze metals by ICP-OES and ICP-MS.
- Analyze anions by Ion Chromatography.
- Analyze organic and inorganic carbon using TOC.

General Observations

- Most surface water samples are Na-Cl type: $Cl^- > Na^+ > SO_4^{2-} > Mg^{2+} > K^+ > NO_3^-$.
- All groundwater samples are Na-Cl type with a lower proportion of SO_4^{2-} due to sulfate reduction: $Cl^- > Na^+ > Mg^{2+} > K^+ > SO_4^{2-} > NO_3^-$.
- Most water samples are saturated in goethite and calcite.
- For groundwater samples no systematic trends with depth were observed for salinity, temperature, Eh, or concentrations.
- No correlations were observed between measures of ORP, concentrations of reducing agents (DOC), and concentrations of metals with variable oxidation states (As, Fe, Mn, M, and S): redox disequilibrium.
- No coherent spatial trends in composition.

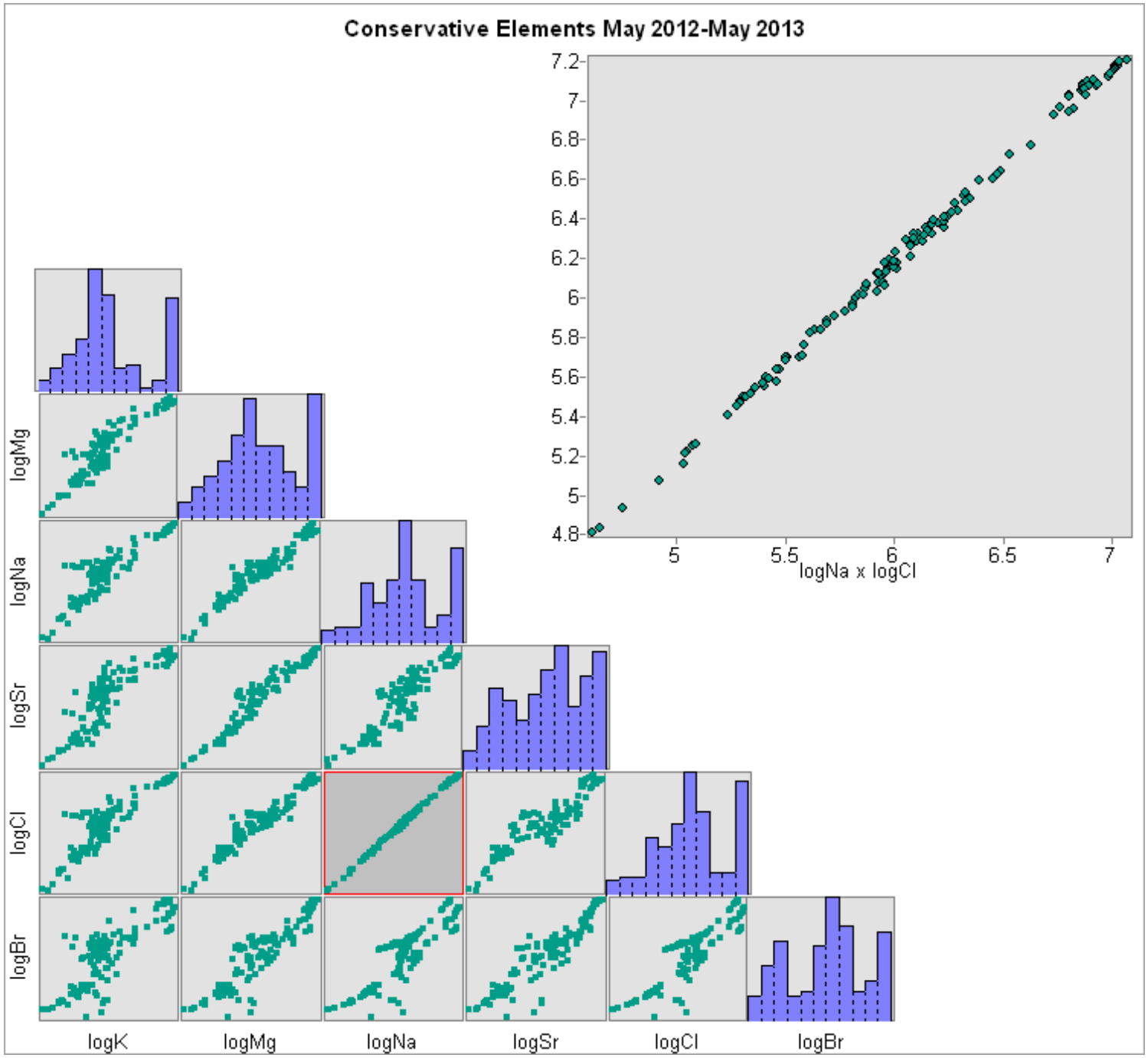
Conductivities



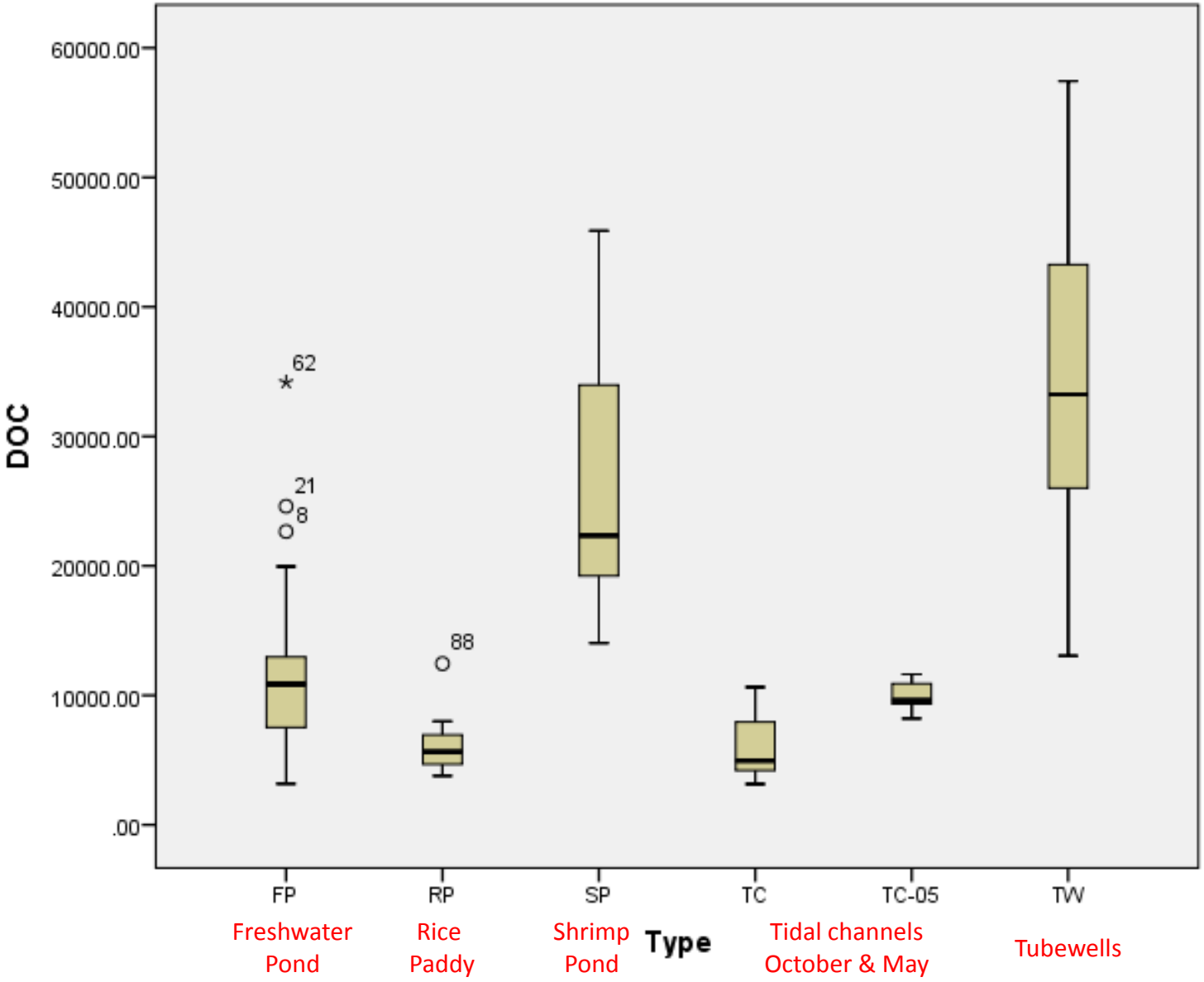
Salinity levels measured as conductivity (dS/m)

*1 dS/m is the Bangladesh safe drinking water limit.

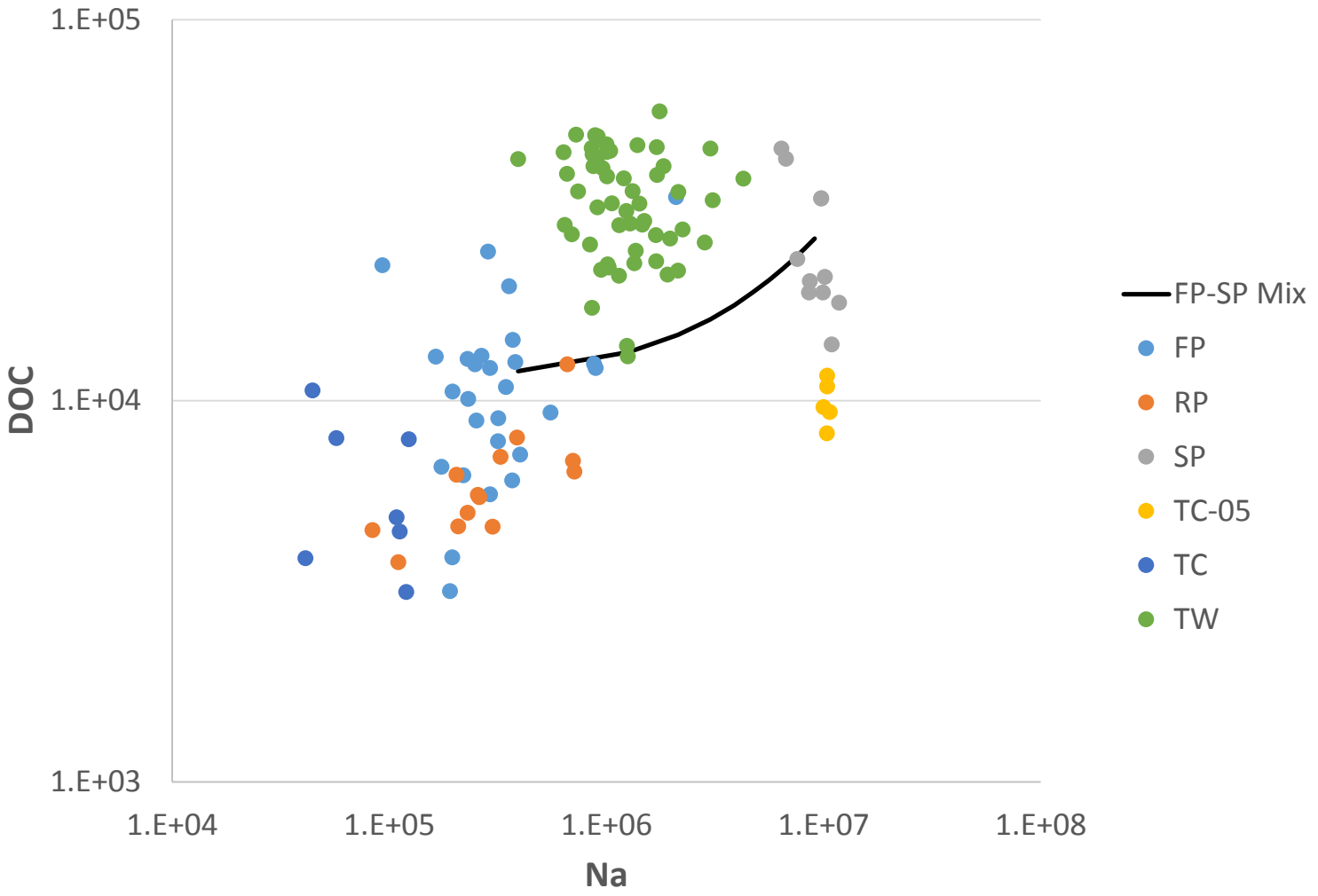
Water type	Fresh	Slightly saline	Moderately saline	Highly saline
Surface water ponds (n=27)	<1 (3.7%)	1-5 (93%)	5-10 (3.7%)	>10 (0%)
Ground water (n=54)	<1 (0%)	1-5 (28%)	5-10 (61%)	>10 (11%)
Irrigation water (rice paddies, n = 13)	< 1 (23%)	1-2 (vegetables only, 46%)	2-3 (8%)	> 3 (not recommended, 23%)


Conservative Elements May 2012-May 2013
7.2
7
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
5
5.5
6
6.5
7
logNa x logCl
logMg
logNa
logSr
logCl
logBr
logK
logMg
logNa
logSr
logCl
logBr

Dissolved Organic Carbon

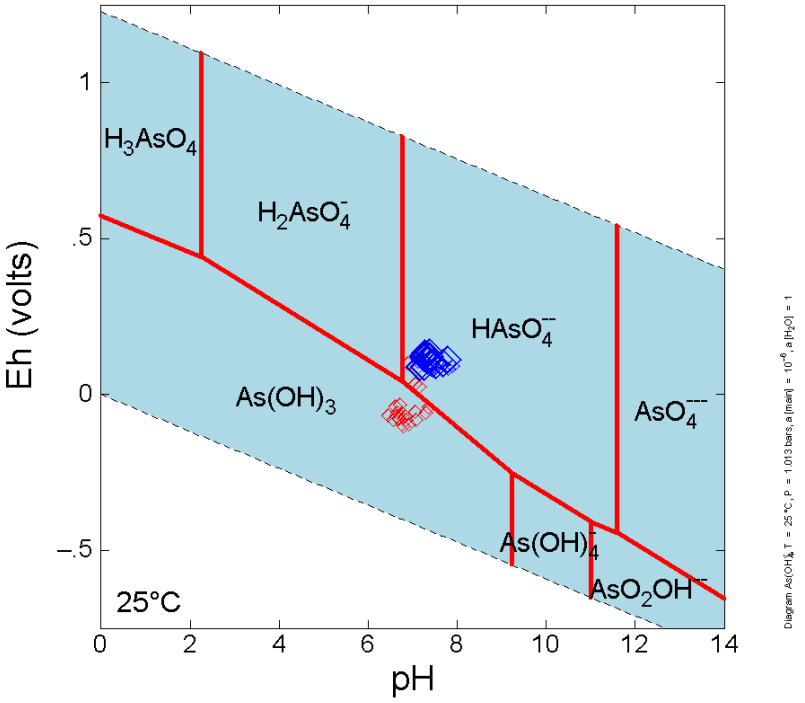


Shrimp Ponds Contaminating Shallow Aquifer?



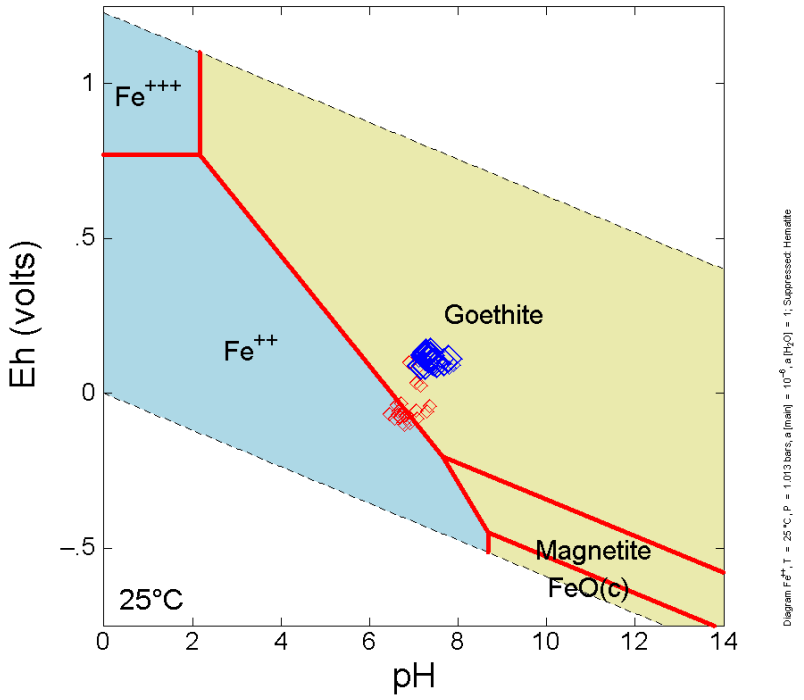
Arsenic speciation by season

- Blue is the wet season, and red is the dry season.
- Recharge of oxidizing water in the wet season? Or is organic waste not carried away by rivers in the dry season, but instead infiltrates into the subsurface?



Seasonal Fe speciation

- Seasonal change is inconsistent with our findings that the GW is old and therefore that recharge rates and flow velocities are low.



Key Findings

- Most drinking water sources exceed safe limits for salinity and Arsenic.
- 23% of irrigation water samples in wet season too salty for farmed crops.
- All sampled surface waters are mixtures of meteoric water and tidal channel water.
- Tidal channel water used for brine shrimp aquaculture in dry season.
- All sampled ground waters could have formed as mixtures of tidal channel water and meteoric water similar in composition to today.
- GW composition shows little or no seasonal variation, suggesting low recharge rates and slow flow. Recently measured ages indicate the water is connate.
- Groundwater from tubewells has high DOC, suggesting infiltration from shrimp ponds, latrines or uncased wells.
- Eh of groundwater decreases in dry season; this combined with high DOC may cause reduction of Fe oxyhydroxides, which would add As to groundwater and cause sulfide precipitation.