Title

Investigation of Hydrologic and Biogeochemical Controls on Arsenic Mobilization Using Distributed Sensing at a Field Site in Munshiganj, Bangladesh

Journal

Center for Embedded Network Sensing, 87(52)

Authors

Ramanathan, Nithya
Rothenberg, Sarah
Estrin, D
et al.

Publication Date

2006

Center for Embedded Networked Sensing

Investigation of hydrologic and biogeochemical controls on arsenic mobilization using distributed sensing at a field site in Munshiganj, Bangladesh

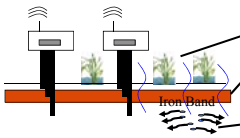
Nithya Ramanathan[2], Sarah Rothenberg[6], Deborah Estrin[2], Thomas Harmon[4], Charlie Harvey[5], Jenny Jay[1], Eddie Kohler[2]

[1]UCLA Civil & Environmental Engineering, [2]UCLA Computer Science, [3]UCLA Electrical Engineering, [4]UC Merced School of Engineering, [5]MIT, [6]UCLA Environmental Science and Engineering Program

Overview: Understanding the Impact of Irrigation on Arsenic Mobilization

Arsenic in Groundwater has Lead to Massive Poisoning

- Tens of millions of people drink dangerously high levels of naturally occurring arsenic in groundwater, resulting in adverse health effects.
- A current working **HYPOTHESIS**



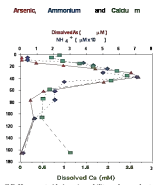
(1) *During irrigation, rice-paddy return flow is the main water infiltrating through the Fe band*

(2) *Anoxic irrigation water causes changes in the redox environment of the Fe band and below*

(3) *Arsenic is mobilized as the recharge flows through the Fe band*

GOALS

- Use dense temporal/spatial sensing of a sensor network to validate hypothesis
- Develop proxy geochemical measurements to indicate elevated arsenic concentrations, as arsenic sensors are not available. Previous work showed that ammonium and calcium correlated with arsenic at our site
- Develop a reactive transport model for arsenic mobilization. This will inform well placement decisions and deep well construction.



C.F. Harvey, et. Al. Arsenic mobility and groundwater extraction in bangladesh. *Science*, (298).1602–1606, 2002.

Results: Diurnal Cycles Validate Dense Temporal and Spatial Sampling of a Wireless Sensing System

Diurnal Cycles

- Pylon 1 data
- Ammonium sensors in Pylon 3 (graphs on the right hand side)

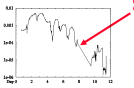
Cycles terminate upon field irrigation

Pylon 1

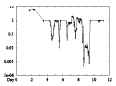
2 Feet

Ammonium

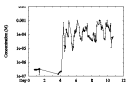
Irrigation Starts



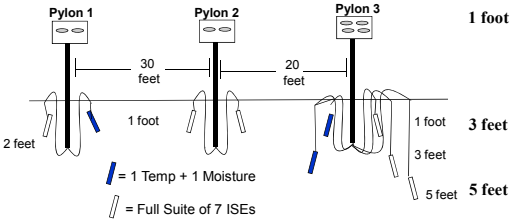
Chloride



Carbonate

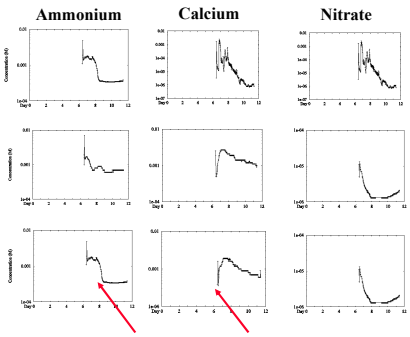


Deployed 48 sensors over 12 Days
Collected 25,000 measurements



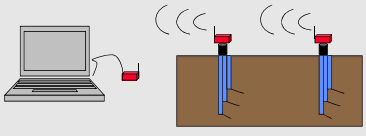
Full Suite of 7 Ion Selective Electrodes (ISEs)
Ammonium, Calcium, Carbonate, Chloride, Nitrate, Oxidation-reduction potential, pH

Pylon 3

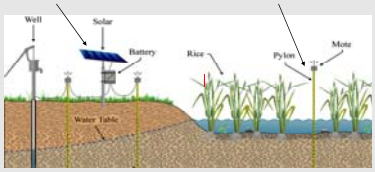


Technical Background: Wireless Sensing Systems

Base-station collects data over wireless radio from sensors



Base-station Pylon



Pylon in the field

Mica2 Mote handles wireless communication

MDA300 sensor board translates analog signal from sensors

Base-station in the field

Why Wireless

	Datalogger	Wireless Dataloggers	WSS
Sensor sampling	X	X	X
Store data locally	X	X	X
Realtime data transmission		X	X
Local Processing			X

Why Local Processing

- **Individual nodes can make decisions based on data** e.g. signal an alert when water quality is bad
- **Form multi-hop networks** to extend transmission distances and enable communication between all nodes
- **Extend network lifetime e.g.** by only sending data when necessary to minimize power-hungry transmission, or coordinating sleep wake schedules so nodes can spend most of their time in *sleep mode*

Sample Wireless Sensing Systems

- **Sonoma County:** temperature, PAR, and humidity sensors instrument a Redwood tree for 44 days
- **James Reserve, CA:** CO_2, moisture, and temperature sensors embedded underground, and image sensors above ground; a robotic node strung across two trees with imagers, and microclimate sensors provides high spatial resolution measurements above ground; a robotic boat with water chemistry sensors provides high spatial resolution measurements in a nearby lake
- **Ecuador and Mexico:** acoustic and vibration sensors monitor volcano eruptions and earthquakes, respectively

Methods: Addressing Challenges in Deploying a Wireless Sensing Systems

RAPID DEPLOYMENTS (i.e. a short or temporary deployments) are useful; for water quality applications that use sensors which cannot remain in the field for extended periods of time.

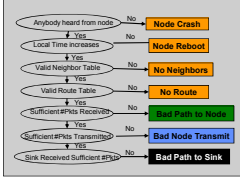
- However, *even small disruptions or problems in collected data must be addressed quickly*, as overall quantity of gathered data is small relative to long-term deployments

We present several approaches successfully used in the field to improve the **QUANTITY** and **QUALITY** of collected data

Improving Quantity of Data

- Wireless channels are unreliable so packets are dropped
- Nodes fail so not all data is delivered
- Base-station fails, so not all data is received

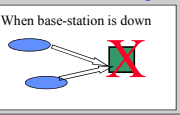
Sympathy addresses faults impacting the QUANTITY of data



- Monitors network in real-time
- Uses *decision tree* to diagnose faults
- Based on diagnosis, Sympathy suggests actions a user can take to remediate faults
- Software runs on the base-station

Delay Tolerant Network provides reliable delivery to improve the QUANTITY of data

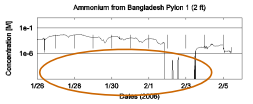
When base-station is down



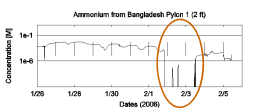
Nodes store data locally

Improving Quality of Data

- Hardware faults impact the quality of data collected

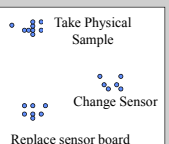


Broken calcium sensor never reports data within expected range (horizontal lines)



Faulty sensor-board results in sudden drops in data value

Confidence addresses faults impacting the QUALITY of data

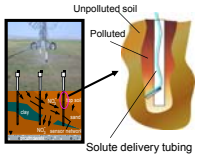


- Monitors data quality in real-time
- Uses *machine learning* to learn what actions have successfully fixed similar looking data points in the past
- Software runs on the base-station

Improving Sensor Calibration

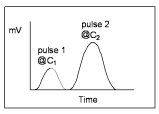
- Sensors go out of calibration, impacting the interpretation of data
- Removing the sensors for calibration is labor-intensive and destroys soil environments

In-Situ Calibration

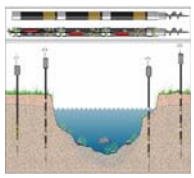


- Solute delivered to sensor through tube deployed with sensor
- Changes in pulse characteristics indicative that sensor should be removed and re-calibrated

Slide Courtesy of Tom Harmon



Javelin Pylon



- Platform that contains sensors and wireless nodes
- Supports *in-situ calibration*
- End designed as a point, so sensors can be deployed by pushing the platform down instead of digging holes; making it easy to deploy
- Designed for moisture saturated soils