Monitoring Water Quality after Natural Disasters: Rapid Adaptive Needs Assessment (RANA) Kit

Joseph Angello, Anna Corrigan, Ramit Garg, Samuel Hewitt, Kathleen Hudgins, Erica Lester, Caroline Sorensen, Madeline Wilson

Professors Bethany Brinkman and Garrick Louis

Problem Description

Drinking water is often compromised during natural disasters. The U.S. Military currently ships bottled water into disaster zones to supply first responders for the first 72 hours before more permanent solutions are established. This consumes both time and money.

The U.S. Department of Defense (DoD) has established a Prepositioned Expeditionary Assistance Kit (PEAK) program to provide power, filtered water, communications, and situational awareness for the first 72 hours after a natural disaster. To meet the need for clean water, the DoD must know which water source is the most efficient to purify.

The RANA kit is a multi-year project which aims to determine which water source should be used. The project is coming to the end of its second year and will hopefully continue for another year to refine and improve the kit.

Goals and Objectives

Increase access to safe drinking water for relief personnel during disaster aid missions

- Remotely monitor water quality quickly and accurately
  - Maximize accuracy, portability, durability, and versatility
  - Minimize deployment time & num. of personnel
- Quickly and accurately communicate data to command center
  - Maximize transmission adaptability and reliability
  - Minimize transmission time
- Determine optimal water source based on fouling rate of the filter
  - Maximize decision accuracy and interface simplicity
  - Minimize computation time

Supplemental PEAK System

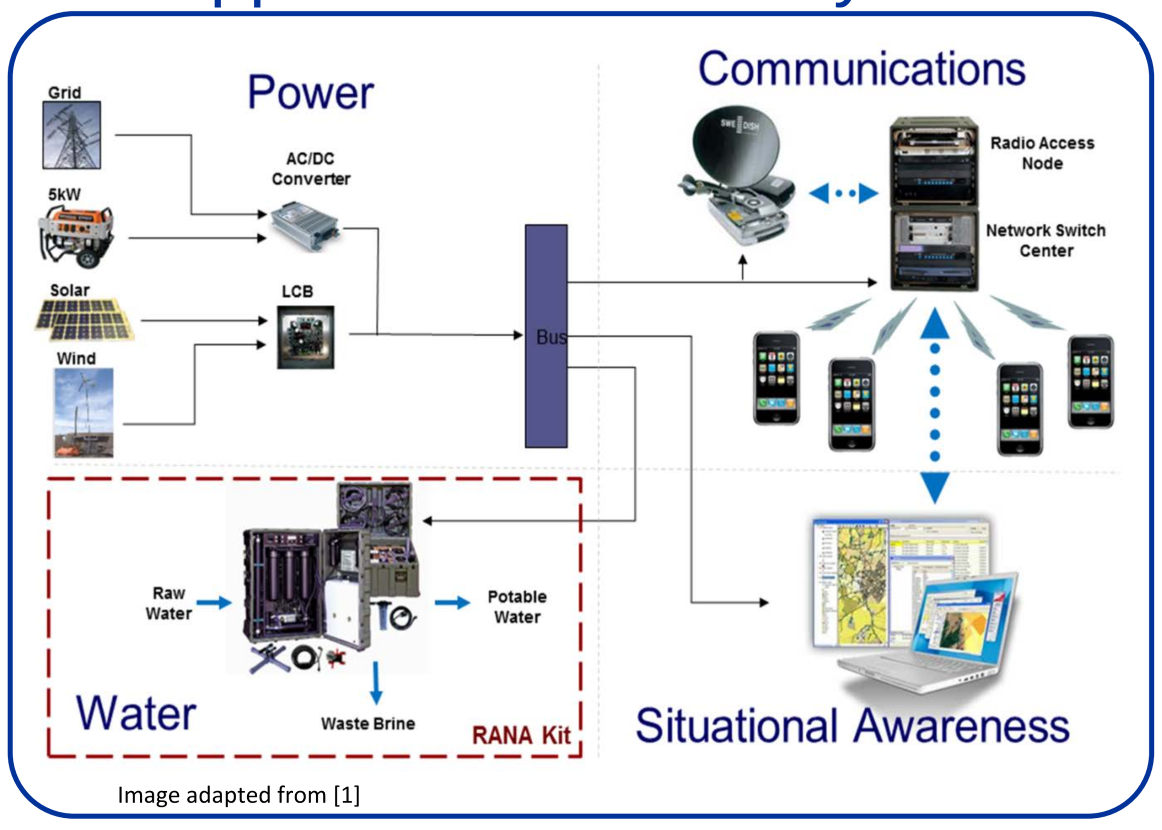
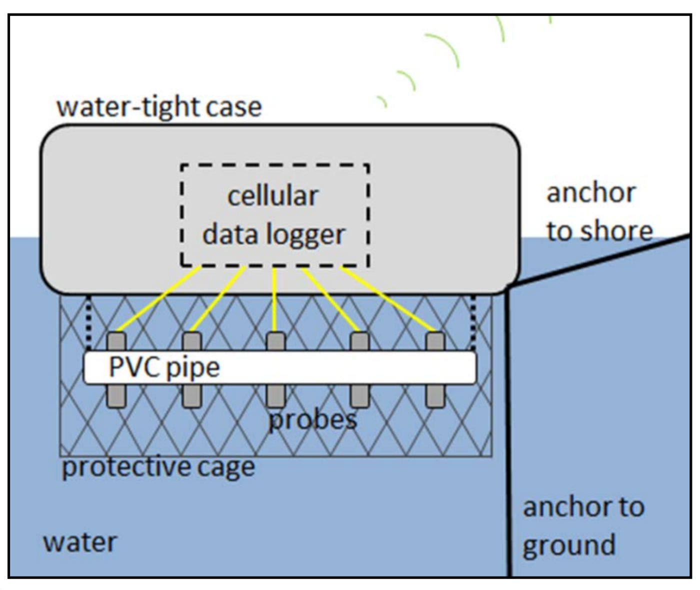


Image adapted from [1]

Phase 1 (Previous Work)

- Environmental research
- Functional kit design
- Equipment diagnostics

RANA Kit Design



What do the Probes Measure?

- Conductivity – A measure of the soluble inorganic contaminants of the water
- Temperature – An indication of the potential for microorganisms including harmful bacteria
- Dissolved oxygen – A measure of oxygen in the water, essential for organism survival
- Turbidity - The amount of particulate matter present in the water source
- pH – A measure of the alkaline or acidic nature of the water source

Information Flow of RANA Kit

Probes take readings (turbidity, pH, conductivity, dissolved oxygen, temperature, humidity, GPS) → Cellular data-logger captures readings and sends them via GSM to command center database → Data used as input in decision algorithm to determine optimal water source → Decision displayed to user using text and maps on computer and cellular interfaces

Phase 2 (Enhancement)

- Anchoring system
- Probe protection
- Humidity sensor
- Communication system

Anchoring System

Requirements:

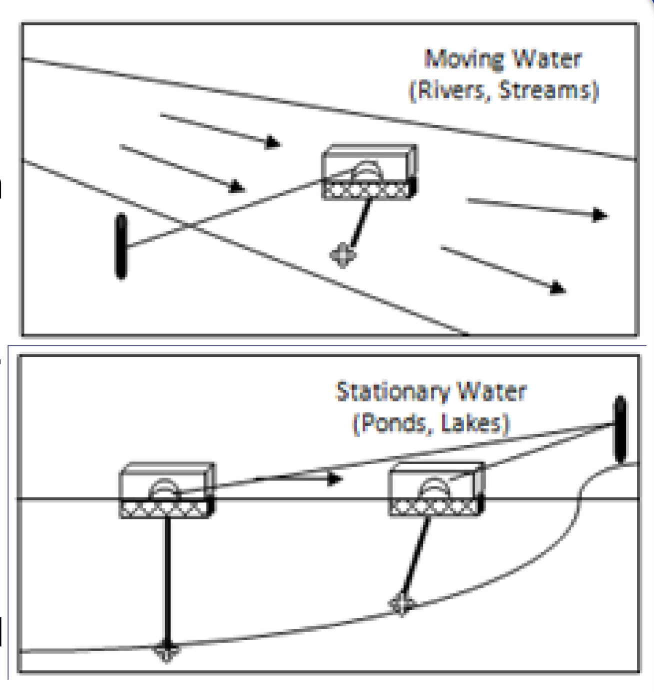
- Probes shall be submerged and kit afloat
- Kit shall be deployed and retrievable from land

Anchor Design:

- Nylon rope attached from kit to the 7 lb. Guardian anchor
- Stake on shore connected via pulley system

Expectations:

- Anchor sufficiently holds kit in place
- Rope is strong enough to support and retrieve kit and anchor



Probe Protection

- Cage protects water quality probes from damage
- Strong but lightweight garolite frame
- Aluminum mesh allows water to reach probes

Communication System

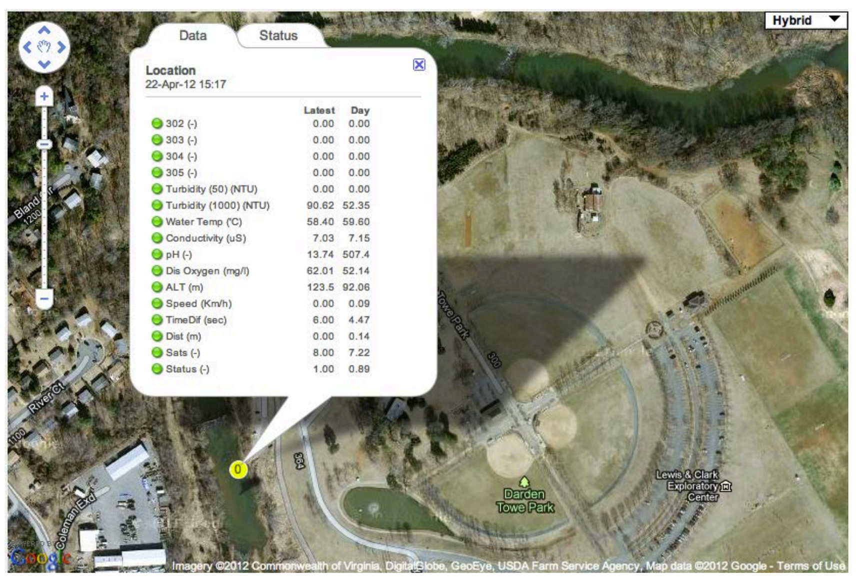
Design

- Uses Ibexis MSP: GSM data logger
- Transfers data at user specified intervals
- Transmits data over PEAK GSM cellular network
- Stores data in online database

Database and Software

- Provides access to Ibexis data software
- Displays data graphically
- Displays information on a map using GPS input
- Allows export in multiple file formats, providing easy input into many decision algorithm formats
- Provides access to decider from any computer with an internet connection

Ibexis Software GPS and Data Display Examples



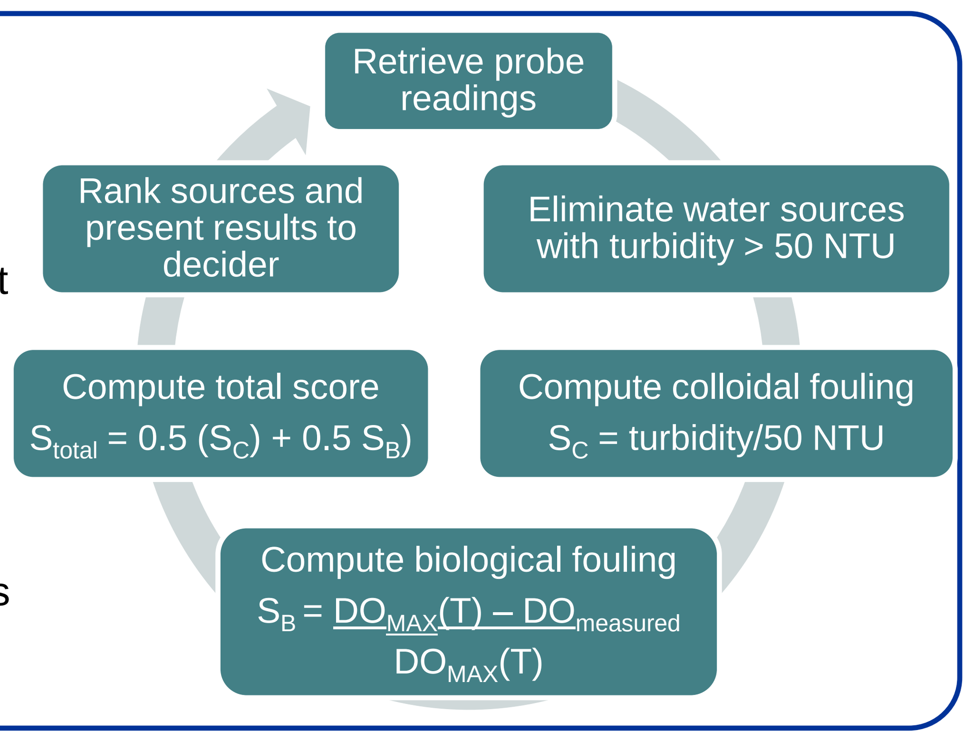
Retrieved from [2]

Phase 3 (Data Decision)

- GPS integration
- Decision algorithm and software
- User interface

Decision Algorithm

- DoD uses ASPEN 2000DM reverse osmosis filter to purify water
- Best source provides lowest fouling rate of the filter
- Filter fouling occurs via colloidal and biological fouling, which are scored separately
- Combined score determines overall rankings



Phase 4 (Integration)

- Full System integration
- Field testing and refinement

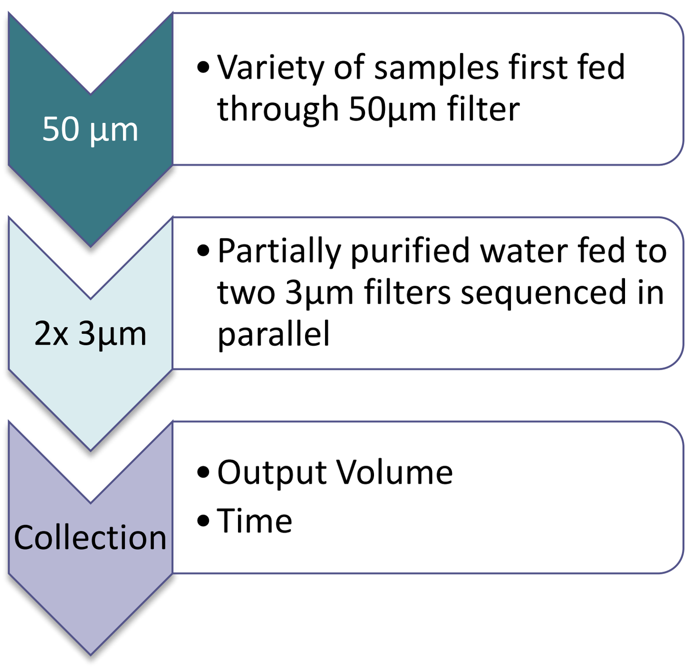
Testing

The team has tested the new anchoring system in moving and still water. The anchoring system holds the kit in place and the pulley works to deploy and retrieve the kit. The kit is buoyant and waterproof and the probe protection cage has proved to be functional, protecting the probes from rocks under the surface of the water.

Deployment of RANA Kit

Recommended Further Testing

Throughput for the ASPEN 2000DM is determined by the fouling rate of the pre-filtration system. To improve the accuracy of the decision algorithm, the team designed a testing plan using a replication of this pre-filtration system. Volume/time (measured in gal/min) will be regressed on the 5 water quality measurements to provide a predictive formula for determining the optimal water source.



Cost & Significance

Cost of Materials in RANA Kit

Item	Price ($)
Pelican Case (Large)	123
Iron Rod Stake	3
Engineer's Hammer	15
Anchoring System	54
Ibexis Data Logger	1,490
Humidity Sensor	300
Probe Protection Cage	200
5 Probes	3,203
Total:	**$5,388**

- Target cost per kit: <$10,000
  - Mass-production may reduce cost per kit
- Using RO unit on local water vs. importing bottled water saves cost/gallon[4]
  - Break-even point: 2,840 gallons

Global Public Use

884 million people globally do not have access to safe drinking water[3]. RANA kits could be used to help locate safer, cleaner local water sources when they are available.

Future Work

The project is currently between phases 3 and 4. The current team outlined the basic logic of the decision algorithm. However, the decision algorithm may need to be modified based on the results of the testing plan recommended above. Testing will confirm whether other water quality parameters significantly affect the fouling rate of the filters. Next, the decision algorithm needs to be implemented and supported with a user interface with graphical displays.

The RANA kit could be made considerably smaller since the current team reduced the size of the equipment inside the kit. The kit size can be reduced by using a smaller outer Pelican case and replacing the five individual probes with a multi-parameter sonode.

Acknowledgments

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References

[1] Department of Defense (DOD) Pre-positioned Expeditionary Assistance Kits (PEAK) Joint Capability Technology Demonstration (JCTD). (2010, August 23). *Pre-positioned Expeditionary Assistance Kits* [PowerPoint slides].
[2] [Untitled graphics of Ibexis software outputs]. Retreived April 14, 2012 from http://www.ibexis.net.
[3] UNICEF and World Health Organization. (2008). *Progress on drinking water and sanitation: Special focus on sanitation.*
[4] Moore, J.S., LTC(P). (2011). *The U.S. Military's Reliance on Bottled Water during Military Operations*. p. 18. Retrieved April 22, 2012 from http://www.dtic.mil/dtic/tr/fulltext/u2/a545433.pdf.