



USACEHR

## USACEHR Environmental Sentinel Biomonitor (ESB) Program

### Aquatic Biomonitoring for Rapid, Continuous Toxicity Assessment

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Environmental Health Research





USACEHR

## U.S. Army Center for Environmental Health Research (USACEHR)



USACEHR  
Fort Detrick, MD

- **Detachment of the U.S. Army Research Institute of Chemical Defense**
- **Part of the U.S. Army Medical Research and Materiel Command**
- **Mission: Conduct research, development, testing and evaluation in support of Force Health Protection**
  - **Medical/environmental surveillance**
  - **Environmental health**



# Army Requirements

- Need

Protect soldiers from water contaminated with toxic industrial materials

- Capabilities to be provided

- Drinking water protection
- Continuous monitoring with rapid response
- Responsive to a broad range of chemicals
- For use at fixed facilities



# Why Biomonitoring?

- **Chemical monitors alone are inadequate**
  - Comprehensive on-line monitoring?
  - Unsuspected chemicals?
  - Direct toxicity measurement?
- **Aquatic biomonitor advantages**
  - Toxic effects monitoring
  - Response to many chemicals
  - Continuous (24/7), real-time monitoring
  - Biologically-directed sampling



# Organisms Used in Biomonitoring



**Bacteria**



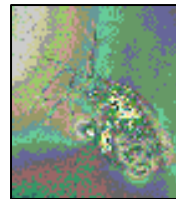
**Algae**



**Clams/mussels**



**Daphnids**

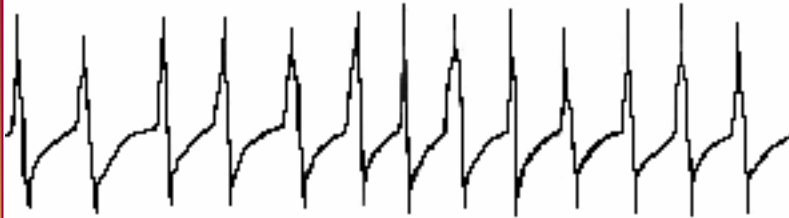


**Fish**

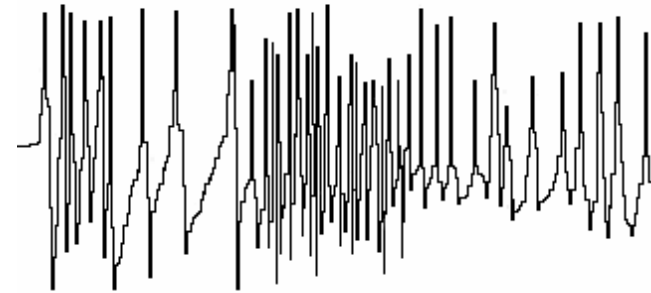




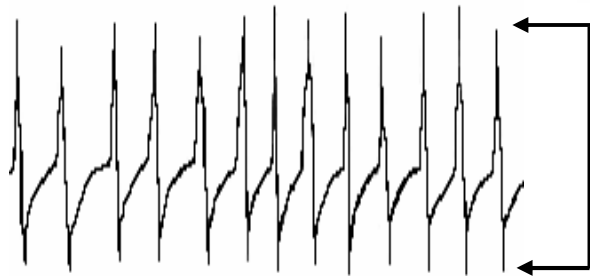
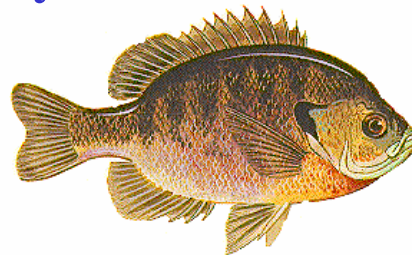
# Fish Ventilatory Signal Components



**Ventilatory Frequency**

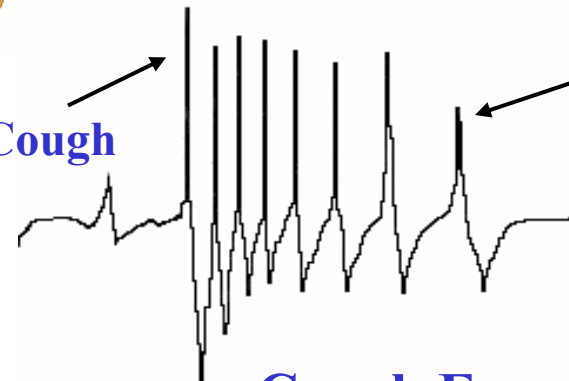


**Whole Body Movement**



**Ventilatory Depth**

**Spike Cough**



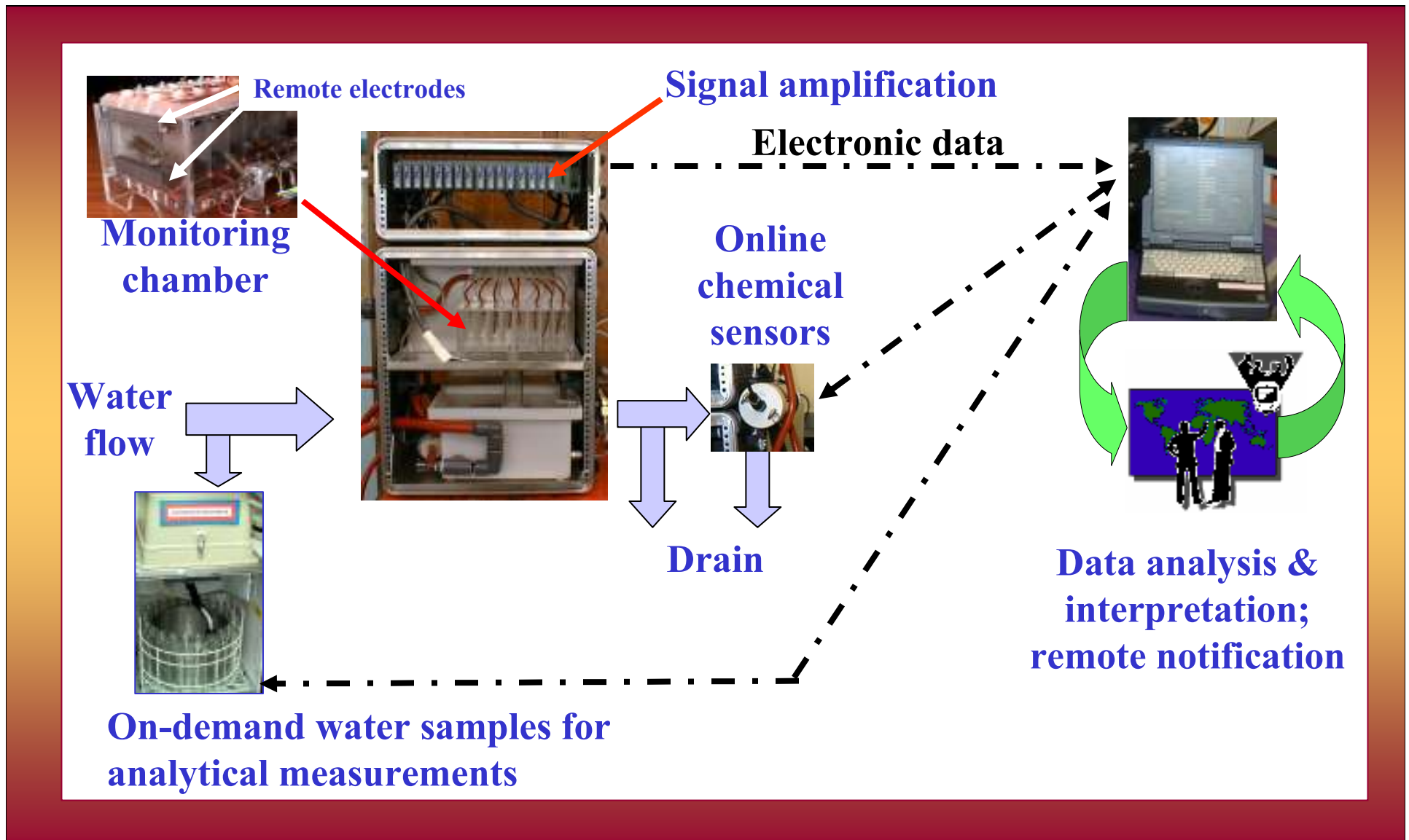
**High Frequency Cough**

**Cough Frequency**





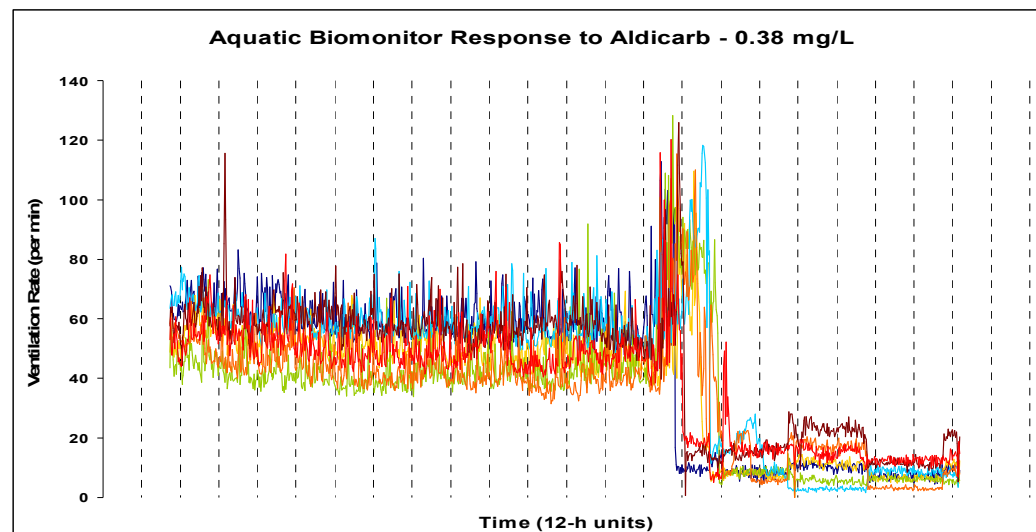
# USACEHR Biomonitor Operation





# Biomonitor Response to Toxicants

- Data for 27 chemicals having varying modes of toxic action, including potential threat agents
- Alarms within an hour to most chemicals at acutely toxic concentrations
- Best for:
  - Transient toxic events
  - Unknown or unsuspected chemicals
  - Biologically-directed sampling





<b>One Hour Response Level (mg/L)</b>	<b>Chemical (mode of acute toxic action)</b>	<b>MEG<sup>2</sup> (mg/L)</b>
<b>0.01 – 0.1</b>	Brevetoxin (neurotoxin)	NA <sup>3</sup>
	Cyanide (cellular respiration inhibitor)	6
<b>&gt;0.1 – 1.0</b>	Residual chlorine (direct gill effects)	NA
	Mercuric chloride <sup>1</sup> (direct gill effects)	NA
	Metham sodium, Phosdrin (acetylcholinesterase inhibitor)	NA
	Zinc (direct gill effects)	8
<b>&gt;1.0 – 10.0</b>	Aldicarb (acetylcholinesterase inhibitor)	0.01
	Carbaryl <sup>1</sup> (acetylcholinesterase inhibitor)	1.4
	p-Chlorophenol (polar narcosis)	0.8 (ortho-)
	Dichlorvos (acetylcholinesterase inhibitor)	NA
	Malathion (acetylcholinesterase inhibitor)	0.3
	Nicotine (CNS seizure agent)	0.4
	Pentachlorophenol (oxidative phosphorylation inhibitor)	1.4
	Strychnine (CNS seizure agent)	NA
	Tetrachloroethane (narcosis)	3
	Tetrachloroethylene <sup>1</sup> (narcosis)	2.8
<b>&gt;10.0 - 100</b>	Ammonia	3.4 (taste & odor)
	Arsenic (oxidative phosphorylation inhibitor, other)	0.3
	Chloroform <sup>1</sup> (narcosis)	6
	Phenol (polar narcosis)	8
	Tricaine methane sulfonate (polar narcosis)	NA
<b>&gt;100</b>	Acetone <sup>1</sup> , Meparfynol (narcosis)	NA
	2,4-Pentanedione <sup>1</sup> (electrophile)	NA
	Sodium fluoroacetate (interferes with metabolism)	NA
	Thallium sulfate	0.01

<sup>1</sup> From literature data    <sup>2</sup> Short-term Military Exposure Guideline level for water (5L/day, 14 days)    <sup>3</sup> NA - MEG not available



# Current Field Deployments

- Fort Detrick, MD
- New York City
- Cincinnati (US EPA)
- Cherry Point, NC
- Old O-Field (APG, MD)

## Source Water Protection



Fort Detrick



New York City

## Watershed Protection

### Effluent Monitoring



Old O-Field



Cherry Point, NC



US EPA (Cincinnati)



## Field Deployments: Lessons Learned

- **Biomonitor is highly reliable ( $\geq 94\%$  operational)**
- **Operates over a wide range of conditions**
  - Temperature: 5-30 deg. C
  - Salinity: up to 15 ppt
  - Turbidity: high tolerance
- **Minimal sample preparation**
  - Large particle filtration
- **Low maintenance**
  - About 4 h per week
- **Non-toxicant alarms**
  - Transition from general to site-specific expert system





# Case Study: NYC

- Reservoirs and lakes supply 1.3 billion gallons/day
- Biomonitor in use ~2 years
- One toxicity-related alarm event
  - Memorial Day weekend, 2003
  - Biomonitor notified appropriate personnel
  - Investigation discovered toxicant source
  - Corrective action taken
  - Reservoir was off-line at the time of the alarm
- NYC planning to purchase additional biomonitors



NYC: Kensico Reservoir



# Summary

- **Can monitor source water or product water**
  - Product water requires dechlorination
- **Will respond to a wide range of chemicals**
  - Investigational tool, not a human surrogate
- **Functions under a wide range of water quality conditions**
  - Expert system site-specific training to minimize alarms
- **Fits into decision-making process**
  - Need to have a plan in place
- **Basic system cost ~\$35K**







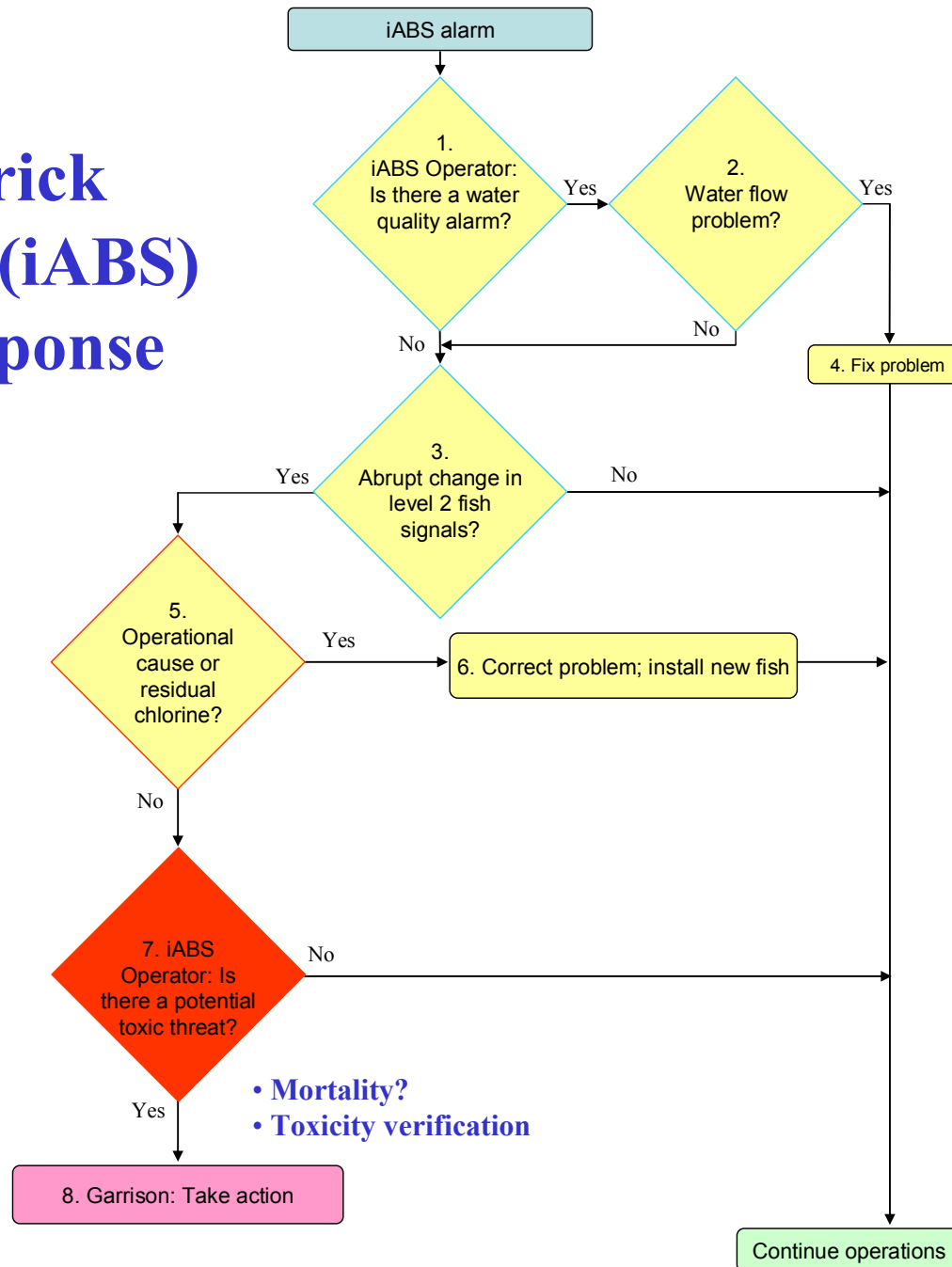
# Case Study: Fort Detrick

- **Uses about 1 million gallons/day from the Monocacy River**
- **Biomonitor in use since 10/01**
- **Toxicity-related alarm event**
  - **May 2004**
  - **Fish responded, died**
  - **Fort Detrick garrison and Maryland Department of the Environment notified**
  - **Possible cause of toxicity identified**
  - **No response by fish monitoring dechlorinated product water**



**Fort Detrick water  
treatment plant intake**

# Fort Detrick Biomonitor (iABS) Alarm Response





# Costs

- **Intelligent Automation Corporation: Dariusz Wroblewski (dariusz@iac-online.com)**
- **Base system (box, computer & software): \$35K.**  
**Additions:**
  - **Water quality multiprobe: \$4K (required)**
  - **Thermoelectric unit: \$4K**
  - **Automated water sampler: \$4K**
- **Operations (\$0-20K/yr)**
  - **Set-up (up to 1 week)**
  - **Continuing support (fish, consultations)**
  - **Maintenance (~4 h/week)**