Nanosensors & Decision Support Models Paired on a Mobile Device for Establishing a Participatory Program on Mercury Exposure in Rural Colombia

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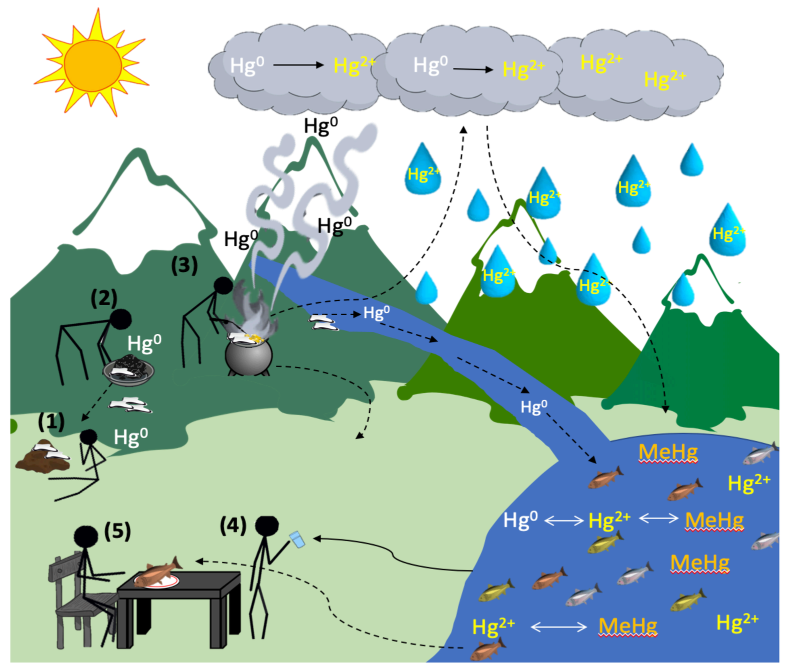
Background

- Artisanal Small-Scale Gold Mining (ASGM) often utilizes mercury (Hg) and is the leading source of global Hg emissions
- In Colombia, ASGM accounts for more than 60% of mining at the national level
- Members of the community in Cauca, Colombia sought out knowledge from local scientists to determine the amount of Hg in their drinking water after noticing mercury toxicity symptoms among their community
- A local agency, the Autonomous Region Corporation of Cauca (CRC), took nine grab water samples in Yolombo, Colombia in 2017
- We propose an innovative framework that combines risk analysis, sensors, and decision analysis to monitor and mitigate exposure of Hg



(A) Study region for the communities in Cauca, Colombia (I. Veleze-Torres, 2018). (B) ASGM process with pathways and forms of Hg shown

PROJECT GOAL: Design a water management framework to foster sustainable resources and resilient communities

1. Assess current risk and uncertainty of the grab samples to validate the need for participatory monitoring of Hg
2. Engineer low-cost, facile, and rapid sensors to monitor Hg in Yolombo's drinking water
3. Analyze potential alternatives based on socio-economic and environmental factors

Methods

(1) Risk Assessment

- Hazard Quotient (HQ) analysis is used to evaluate risk
- Global Sensitivity Uncertainty Analysis (GSUA) is used to evaluate uncertainty, variance, and significant inputs of Hg exposure
- Monte-Carlo Filtering (MCF) identifies low-risk intervention levels

(2) Nanosensing

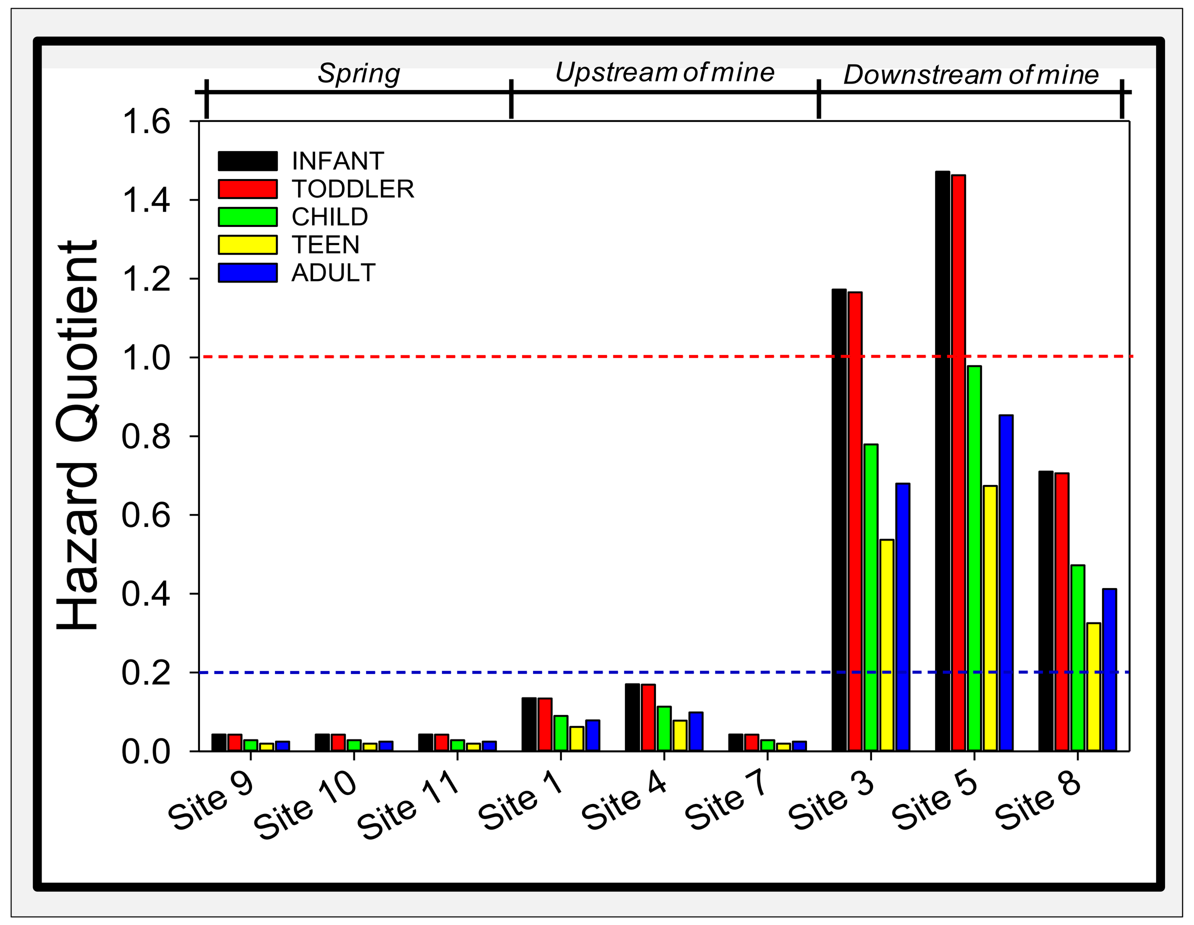
- Electrodes were fabricated via a low-cost UV laser and drop-casting of nanocopper particles
- Voltammetry techniques are used to quantify presence of Hg^{2+} peaks

(3) Decision Analysis

- Stochastic multicriteria acceptability analysis (SMAA) was simulated on JSMAA software
- Alternatives and criteria are based on stakeholder preferences

Results

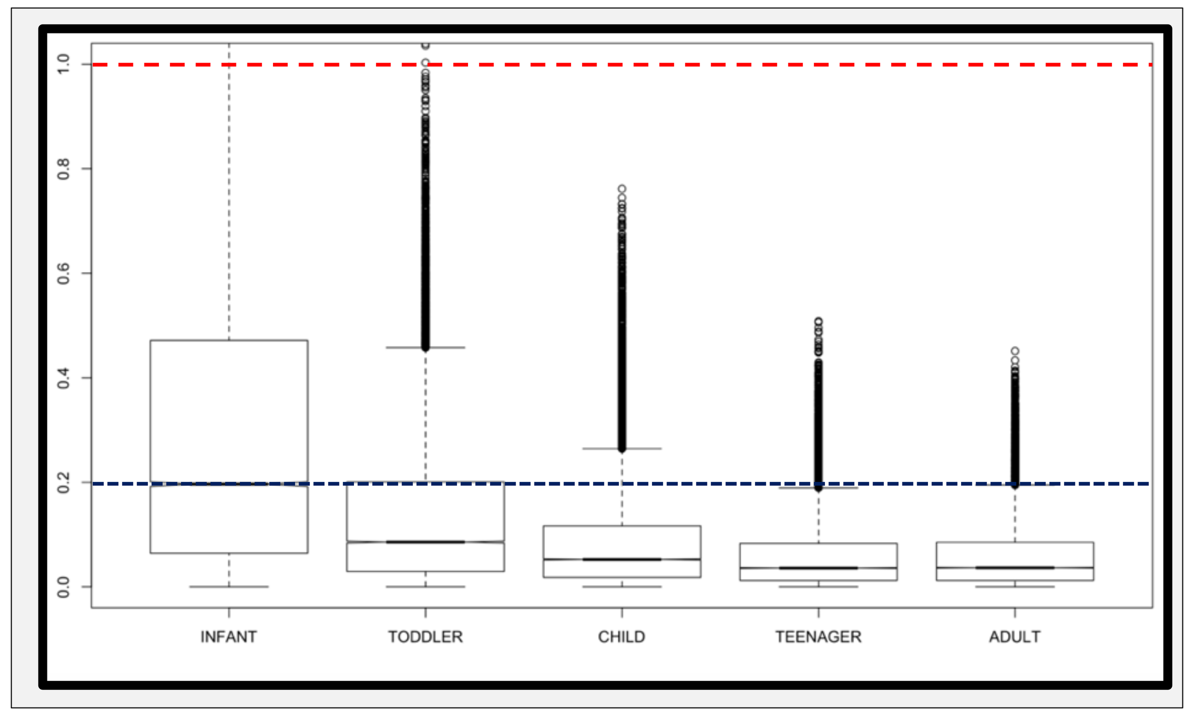
(1) Risk Assessment



HQ

- Using CRC's data and EPA Exposure averages for infant, toddler, child, and adult

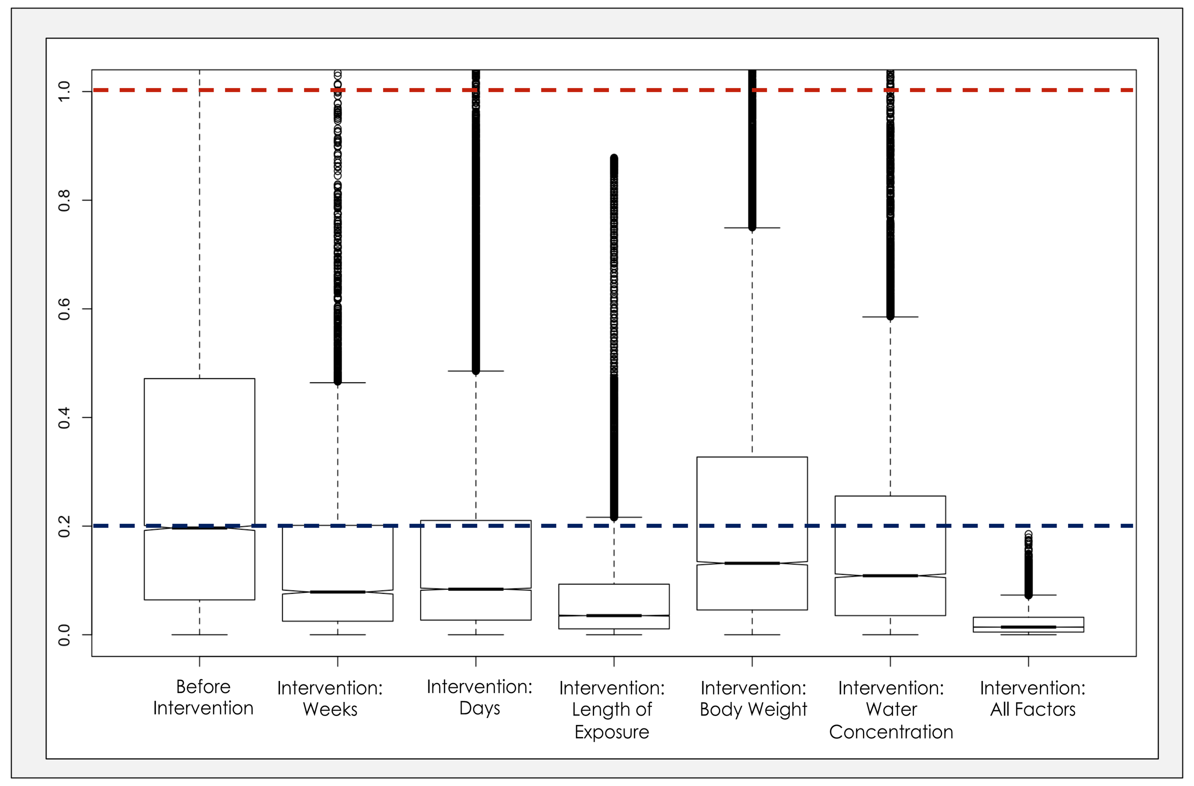
*Red line denotes EPA HQ threshold
*Blue line denotes Health Canada HQ threshold



HQ /GSUA All Age Groups: Pre-MCF

HQ Exceedance

- Infants: 50%
- Toddlers: 25%
- Child: 12%
- Teenager: 6%
- Adult: 6%



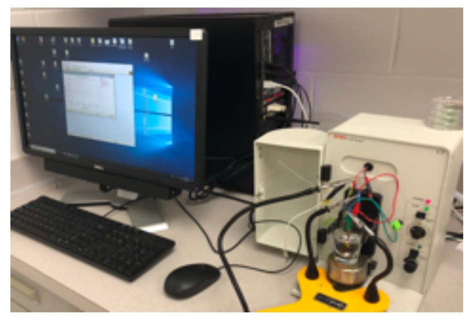
HQ /GSUA Infants: Post-MCF

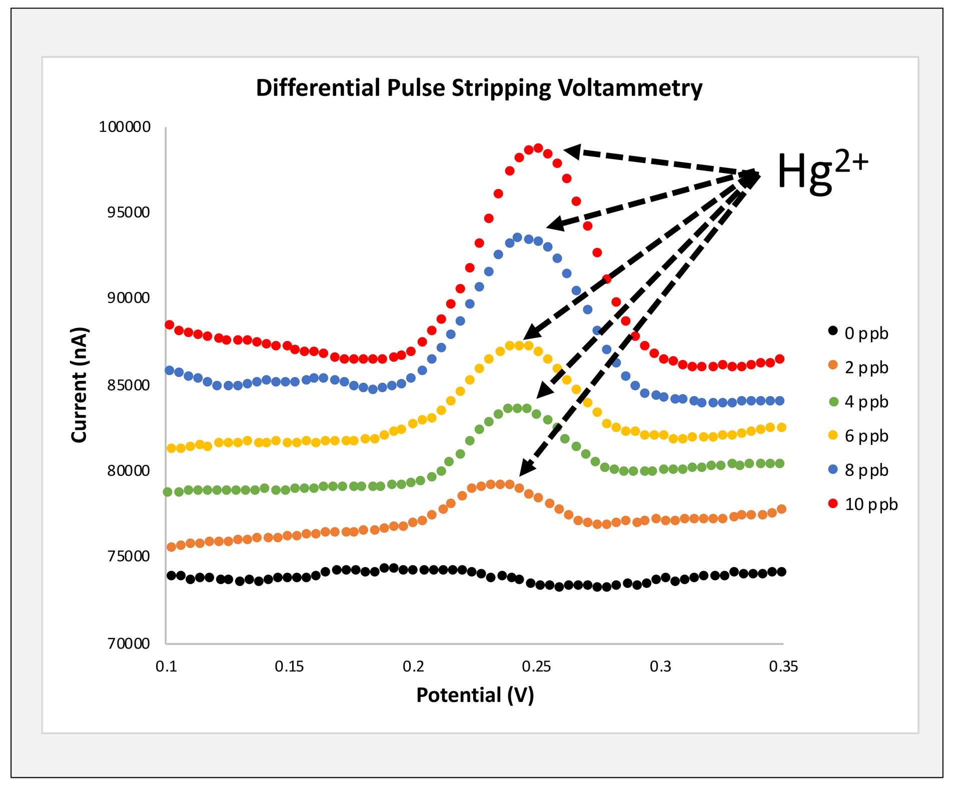
- Weeks: 22
- Days: 3
- Body Weight: 6 kg
- Concentration: 6 ppb

(2) Nanosensing

Method	Sample	Sensitivity	Response Time	Detection Limit	Range
LSSV	Tap Water	178 nA ppm^{-1}	< 2 min.	25 ppb	50 - 2500 ppb
DPSV	Tap Water	420 nA ppm^{-1}	< 3 min.	7 ppb	5 – 15 ppb
DPSV	Lake Alice Water	200 nA ppm^{-1}	< 3 min.	23 ppb	5 – 15 ppb

Voltammetry Results in Lab





*Spectral Peaks with moving average of n=10 of 2025 data points

Differential Pulse Voltammetry on a Portable Potentiostat

- Response Time: ~3 min.
- LOD: ~12 ppb

(3) Decision Analysis

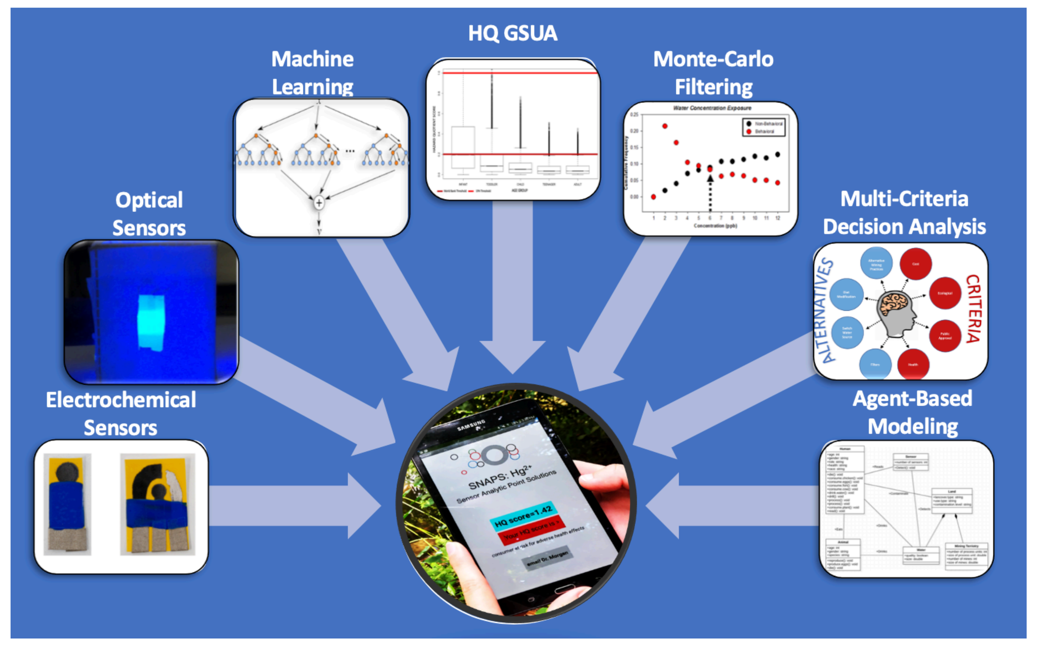
Alternatives	Description	Criteria
(1) Borax Method	No mercury is used	Total Cost
(2) Gravity Method	No mercury is used	Effectiveness
(3) Large-Scale Retort	Mercury is used but captured	Longevity
(4) Steel Retort	Mercury is used but captured	Pathway Reduction
(5) Water Pipe Retort	Mercury is used but captured	HQ Score
(6) DIY Retort	Mercury is used but captured	Ecological Impact
(BAU) No Change	Current operations remain	Smelter Risk
		Forms of Mercury

Alternative	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7
Alt(1)	0.64	0.22	0.07	0.03	0.02	0.01	0.00
Alt(2)	0.28	0.46	0.12	0.05	0.04	0.03	0.02
Alt(3)	0.03	0.15	0.44	0.18	0.14	0.05	0.00
Alt(4)	0.03	0.12	0.24	0.41	0.17	0.03	0.00
Alt(5)	0.01	0.05	0.10	0.24	0.46	0.14	0.00
Alt(6)	0.00	0.00	0.02	0.07	0.14	0.54	0.22
BAU	0.00	0.00	0.01	0.01	0.03	0.20	0.75

- Each alternative is given a probability score of each rank
- Alternative mining techniques with educational workshops ranked as the highest probability as the best mitigation strategy
- Current practices (BAU) ranked as the worst strategy

Future Work

Integration of sensors and modeling tools on smart devices to facilitate participatory decision support



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