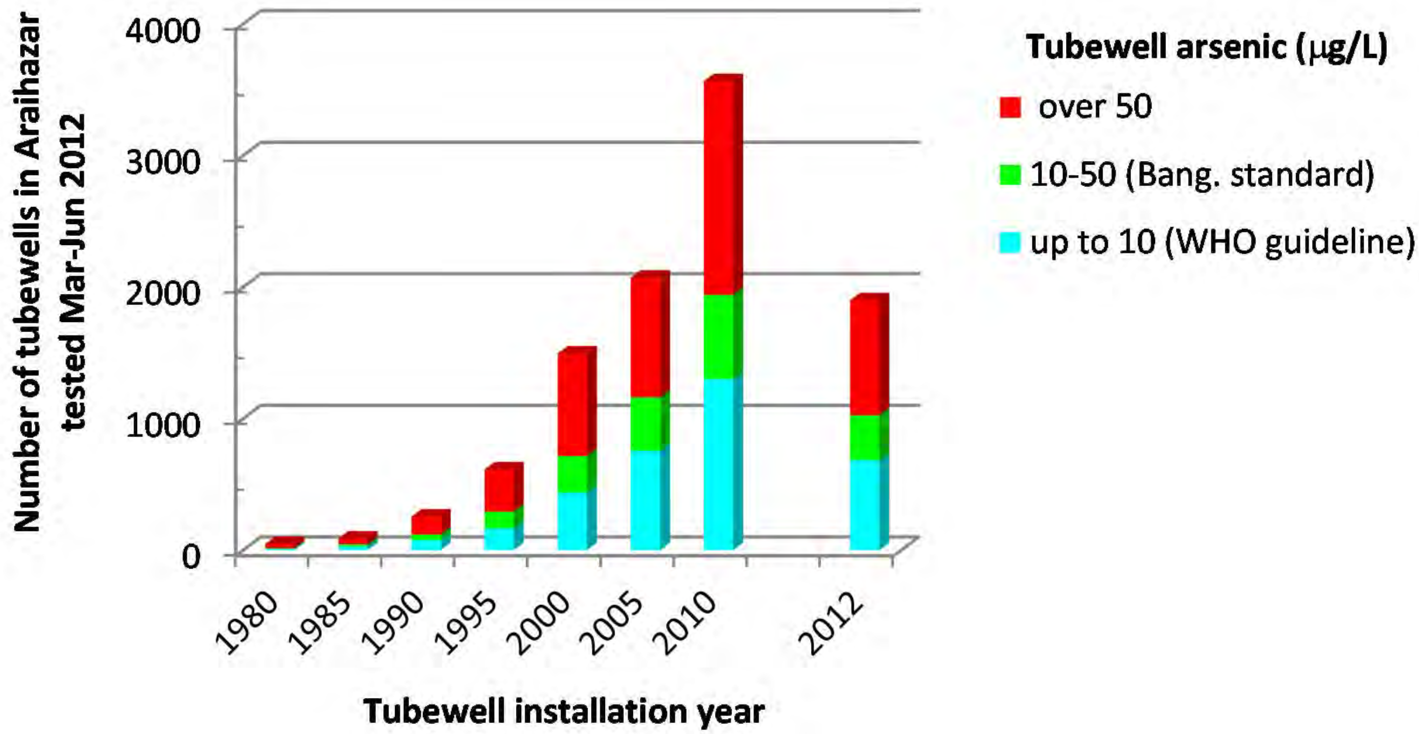


Recommendations

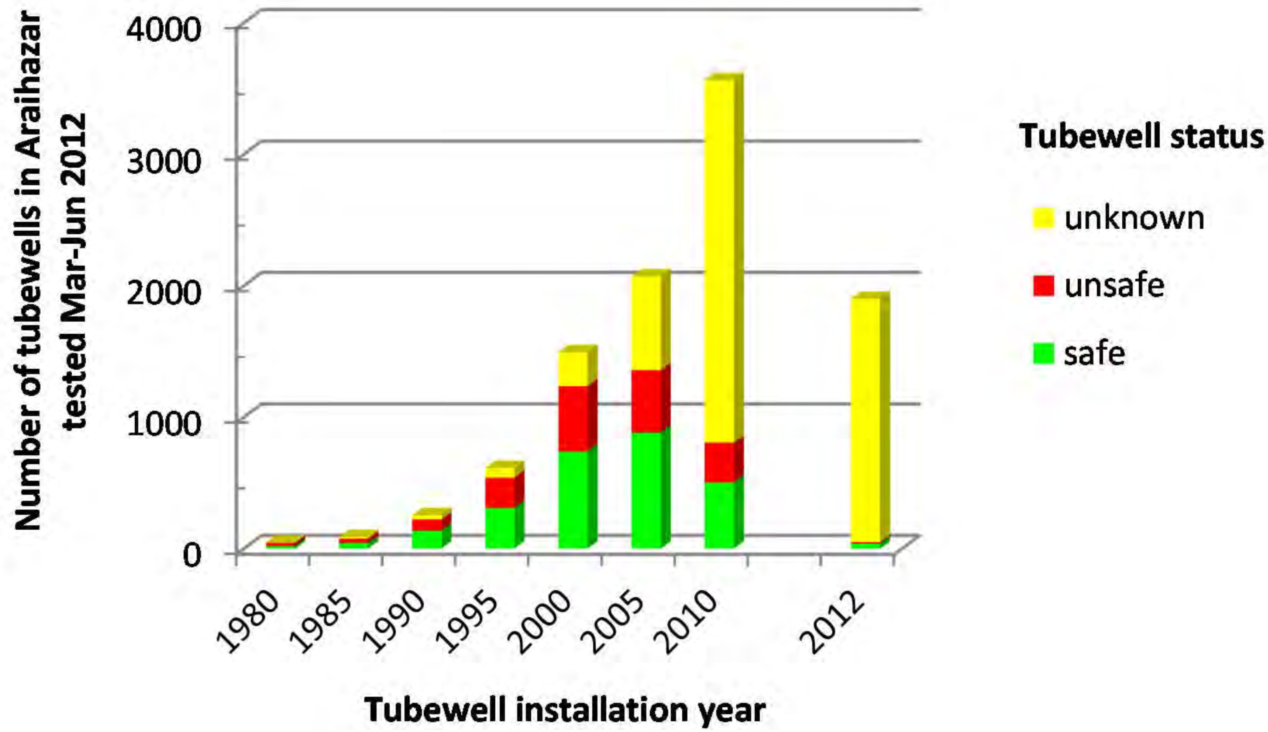
Promote and regulate commercial tubewell testing for arsenic

Launch national campaign to update households on risks of arsenic exposure

Encourage households to have their tubewell tested if status is in doubt

Disseminate arsenic-safe depth at the village level (past and new testing)

Encourage drillers and households to target low-arsenic aquifers



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Recommendations based on 12 years of arsenic mitigation in Araihazar, Bangladesh

Alexander van Geen (avangeen@ldeo.columbia.edu) and Kazi Matin Ahmed (kazimatin@yahoo.com)

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Columbia University | Earth Institute

Benjamin Bostick
Brian Mailloux
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Dhaka 1000
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Joseph Graziano
Habibul Ahsan
Mary Gamble
Yu Chen
Maria Argos

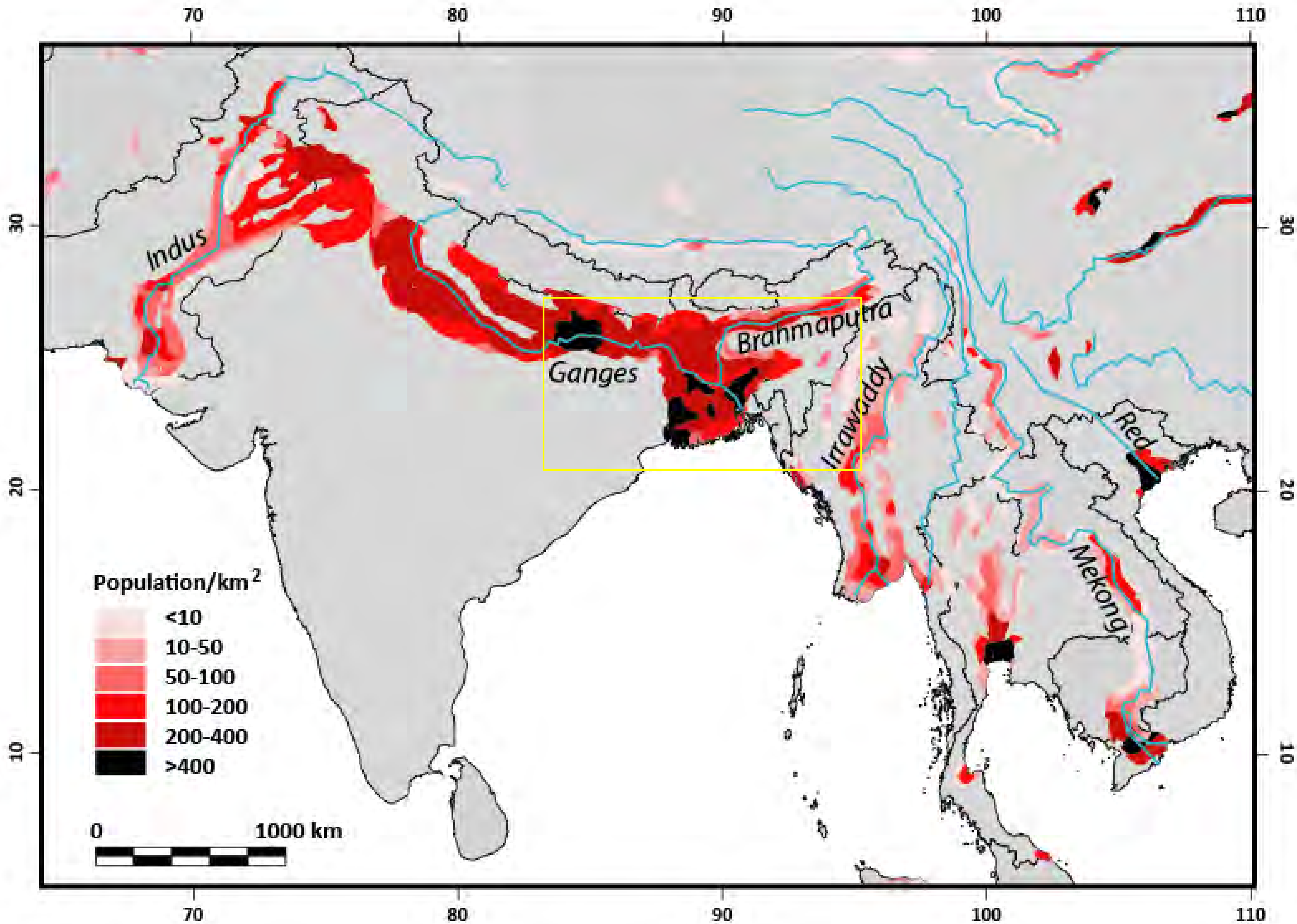
The University of Chicago

NIEHS National Institute of Environmental Health Sciences – National Institutes of Health

Superfund Research Program

National Science Foundation
Directorate for Geosciences (GEO)

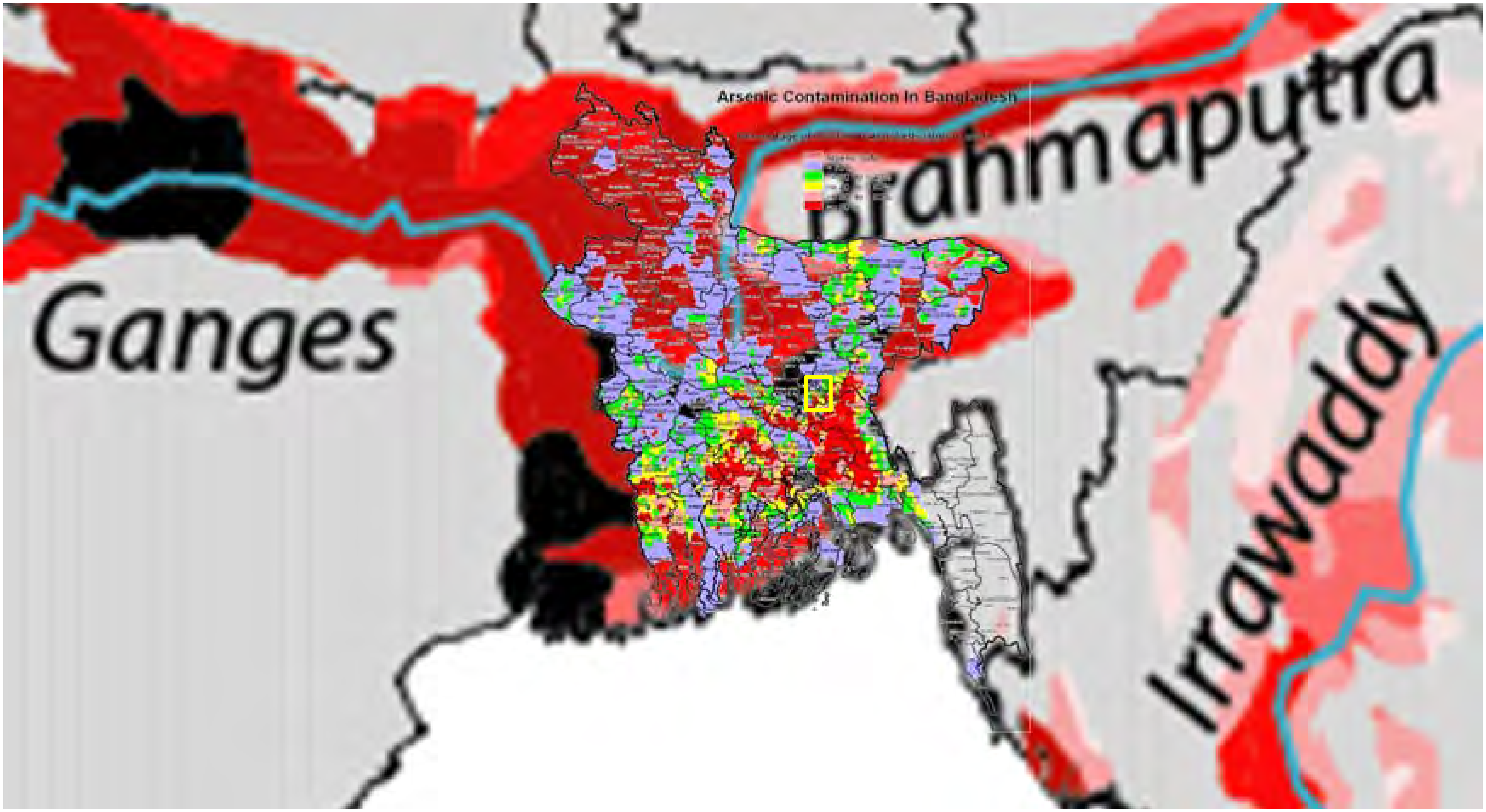
River floodplains with potentially elevated arsenic in groundwater



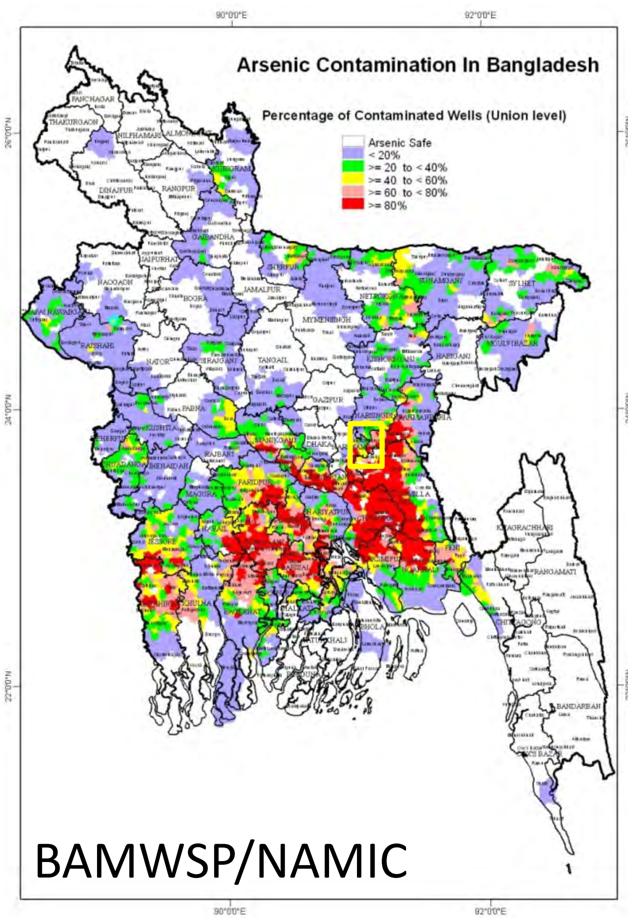
Ravenscroft for UNICEF, 2007

Over 100 million across South/East Asia drink water with >10 ug/L As (WHO guideline)

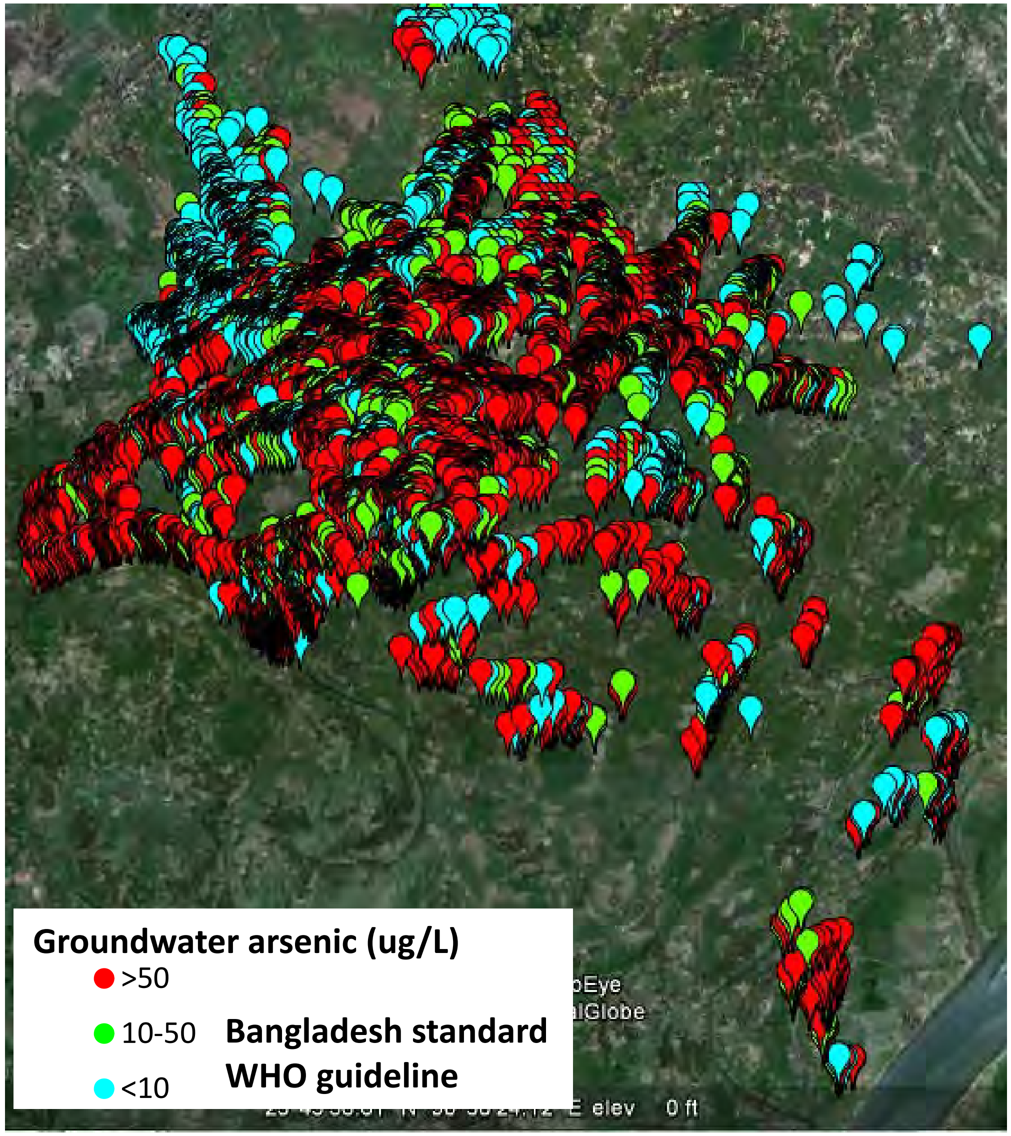
Bangladesh most affected



Regional variability within Bangladesh



Araihazar upazilla: Columbia/Dhaka University study area since 2000



Main public health results from cohort study in Araihazar

www.thelancet.com Published online June 19, 2010 DOI:10.1016/S0140-673(10)60481-3

Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study

Maria Argos, Tara Kalra, Paul J Rathouz, Yu Chen, Brandon Pierce, Faruque Parvez, Tariqul Islam, Alauddin Ahmed, Muhammad Rakibuz-Zaman, Rabiul Hasan, Golam Sarwar, Vesna Slavkovich, Alexander van Geen, Joseph Graziano, Habibul Ahsan

400 deaths within cohort of 12,000 over ~8 years
All-cause death almost twice as high when drinking >150 ug/L As compared to $\leq$10 ug/L (WHO guideline)

Also dose-response relationships for: skin lesions
mental development of children

Groundwater is the cause of poisoning but also the main solution

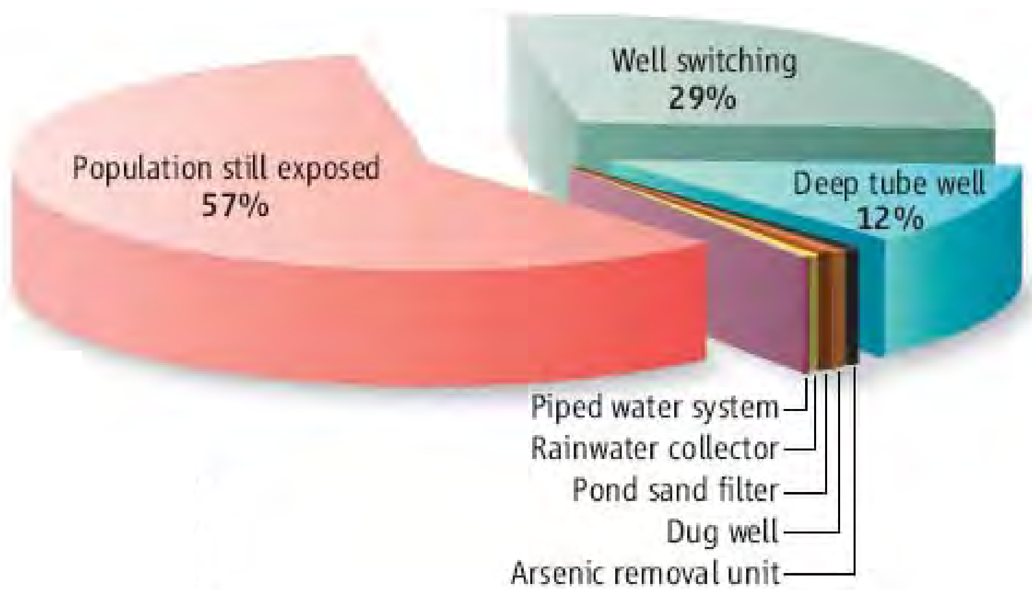
POLICYFORUM

EPIDEMIOLOGY

Ensuring Safe Drinking Water in Bangladesh

Excessive levels of arsenic in drinking water is a vast health problem in Southeast Asia. Several viable approaches to mitigation could drastically reduce arsenic exposure, but they all require periodic testing.

M. F. Ahmed,[1] S. Ahuja,[2] M. Alauddin,[3] S. J. Hug,[4] J. R. Lloyd,[5] A. Pfaff,[6] T. Pichler,[7] C. Saltikov,[8] M. Stute,[9,10] A. van Geen[10*]



Ahmed et al., *Science*, 2006

Results from testing of 10,027 wells by 10 village health workers in 4 months

10 village health workers and 2 supervisors

Md. Zakir Hossein   Ershad Bin Ahmed Shumon

Each VHW tests 12 wells between 8 AM and 3 PM

New kit first deployed in Bangladesh by Christine George/Yan Zheng, UNICEF (US$85/300 tests)

Data entry in the field directly on handheld Garmin GPS Map76Cx (US$164 ea.)

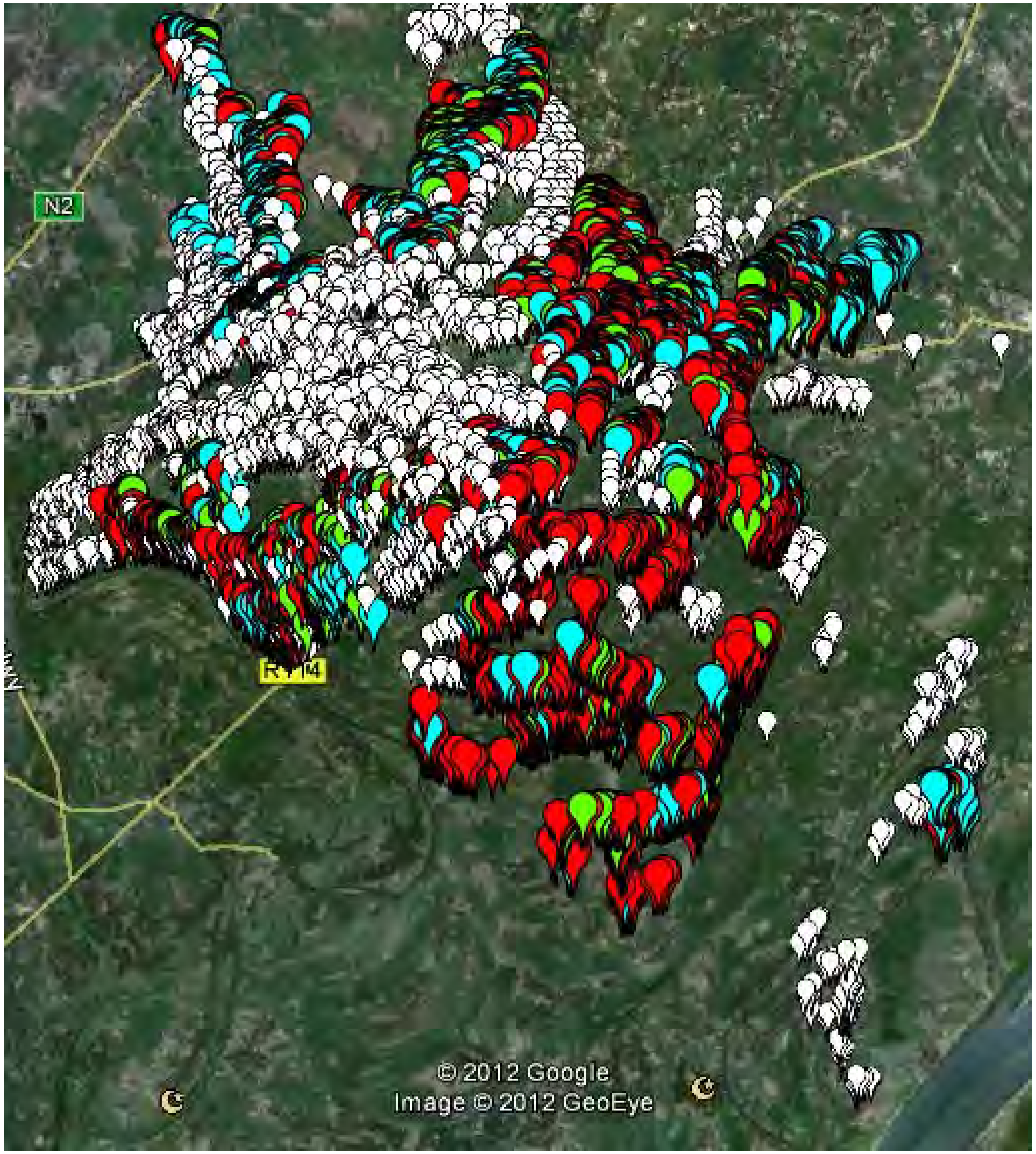
Google Earth for quality control

Durable placards with result attached to handpumps

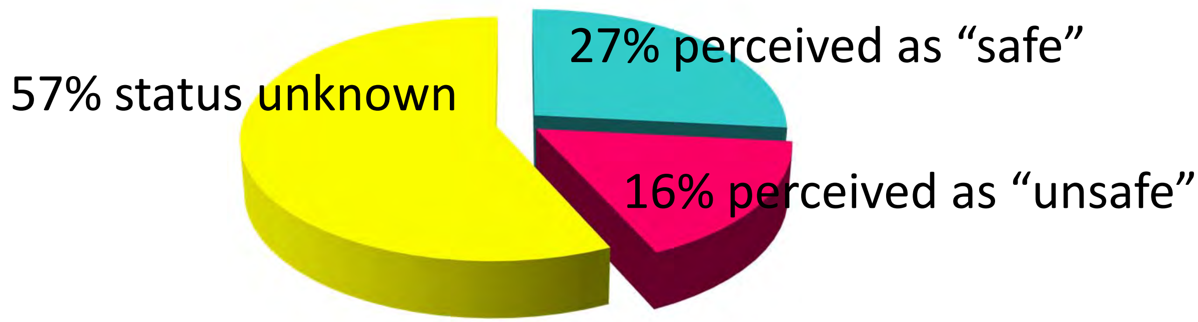
DPHE agreed to 3 colors/2 statements

10% near limits misclassified

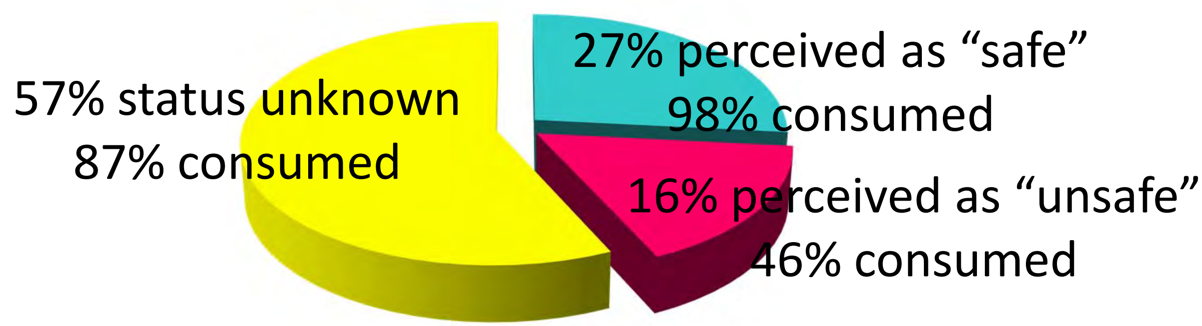
Results for 10,027 of ~30,000 tubewells in upazilla



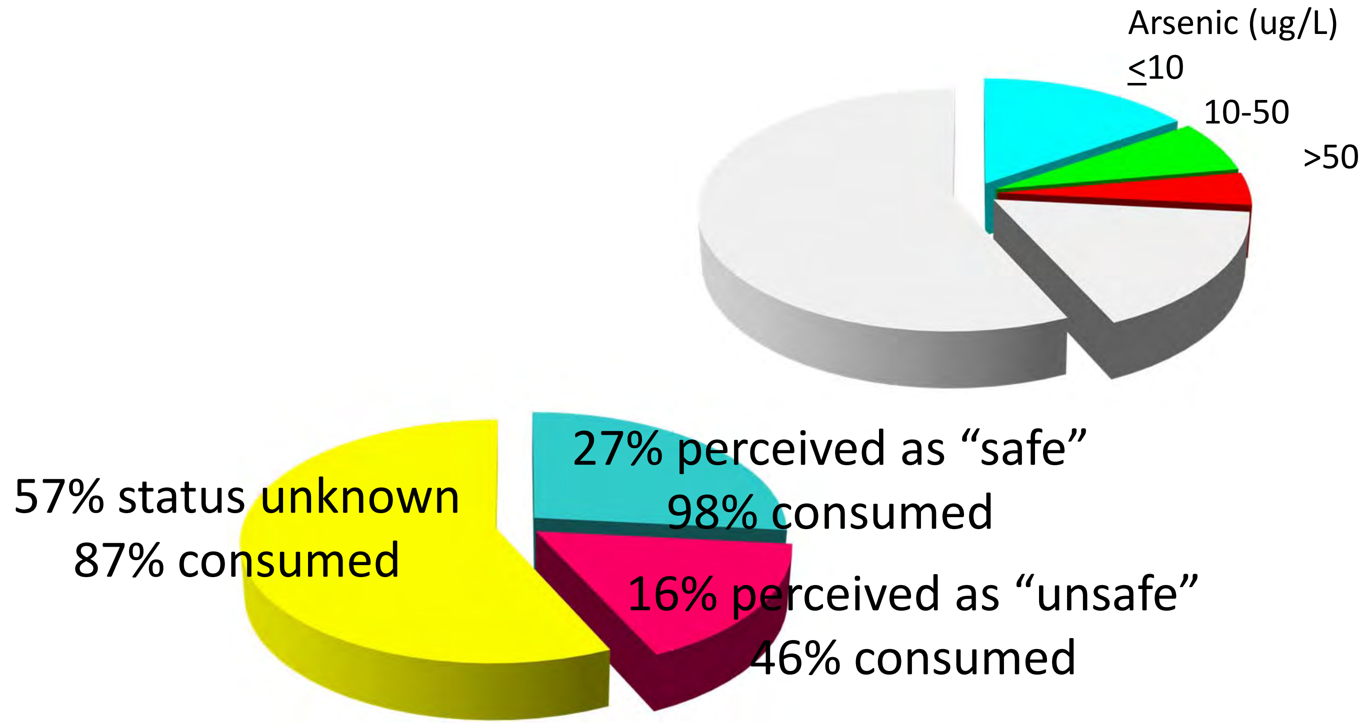
Tubewell status according to households (n=10,027)



Tubewell usage according to households (n=10,027)



Actual arsenic concentration relative to perceived status (n=10,027)



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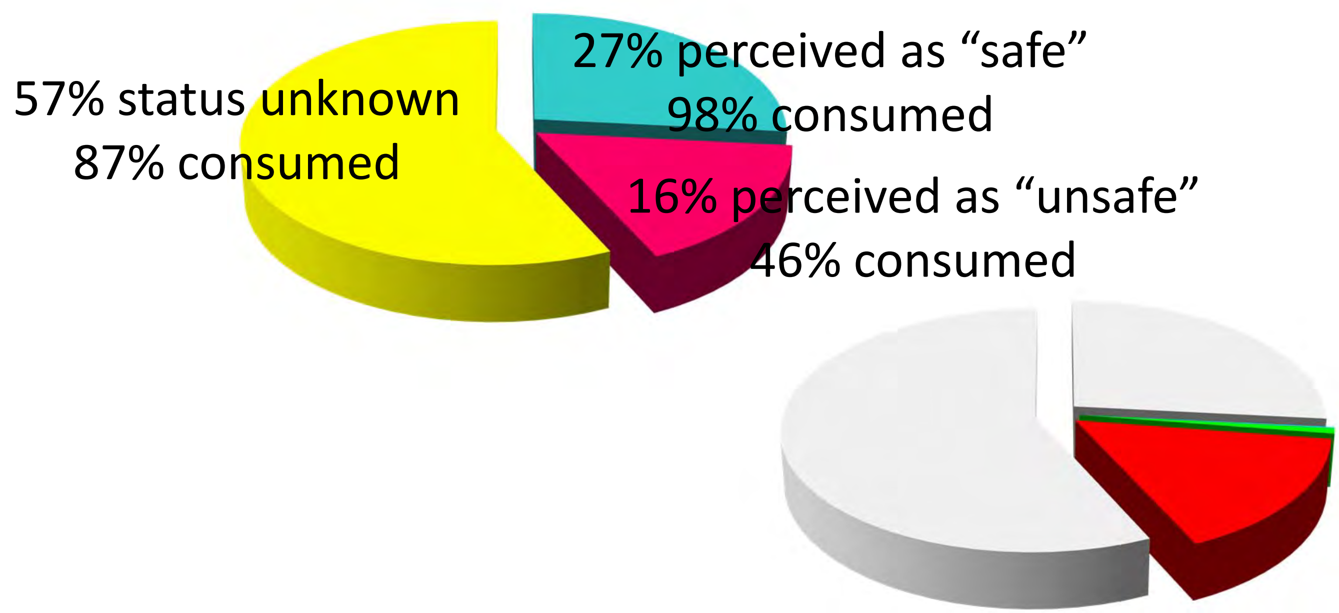

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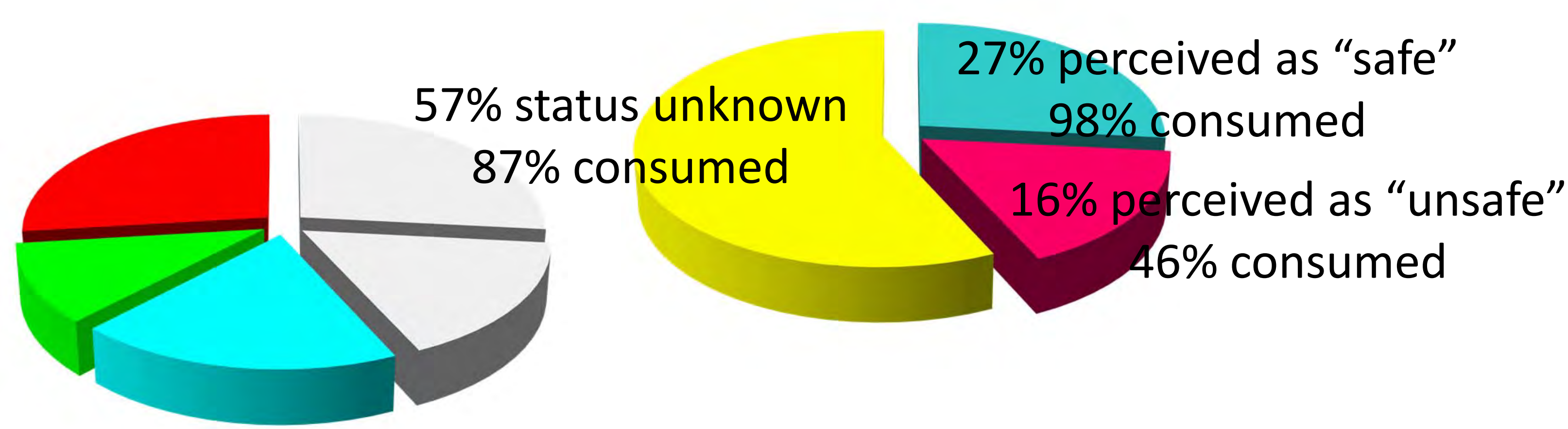
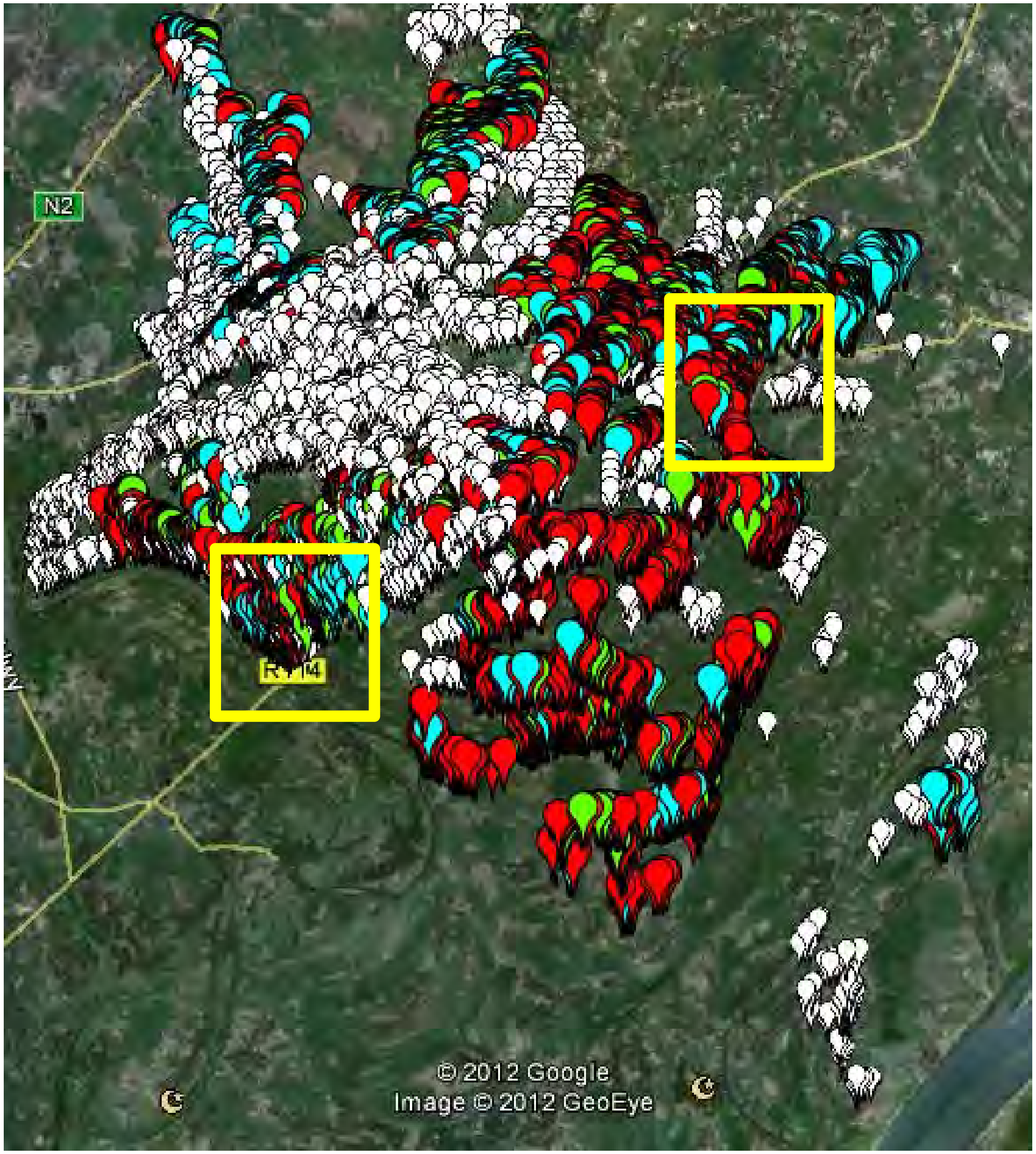
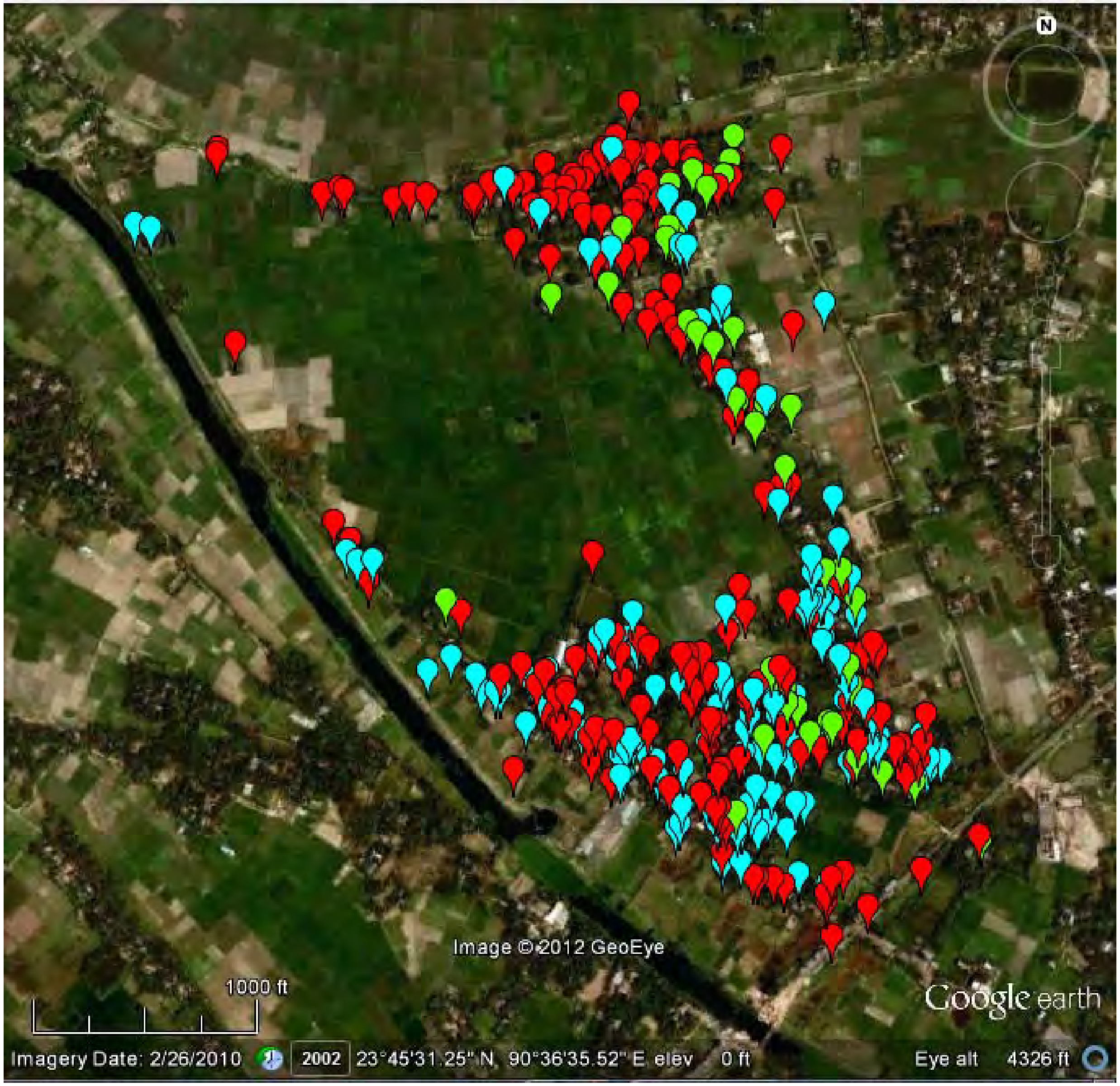


Close-up of 2 villages

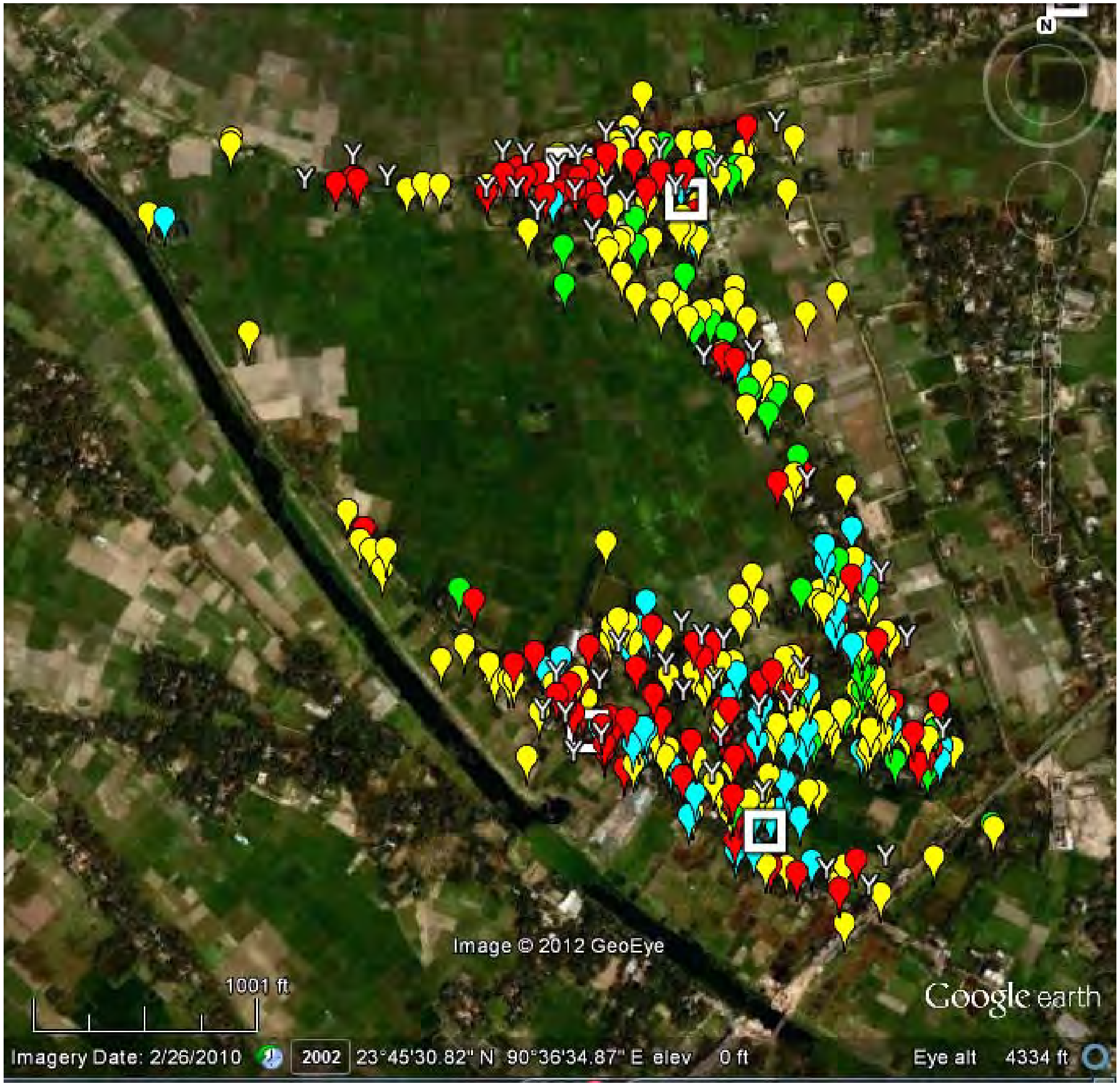


Most high-arsenic wells within walking distance of low-arsenic well



Edbardi village
193/357 wells
54% >50 ug/L

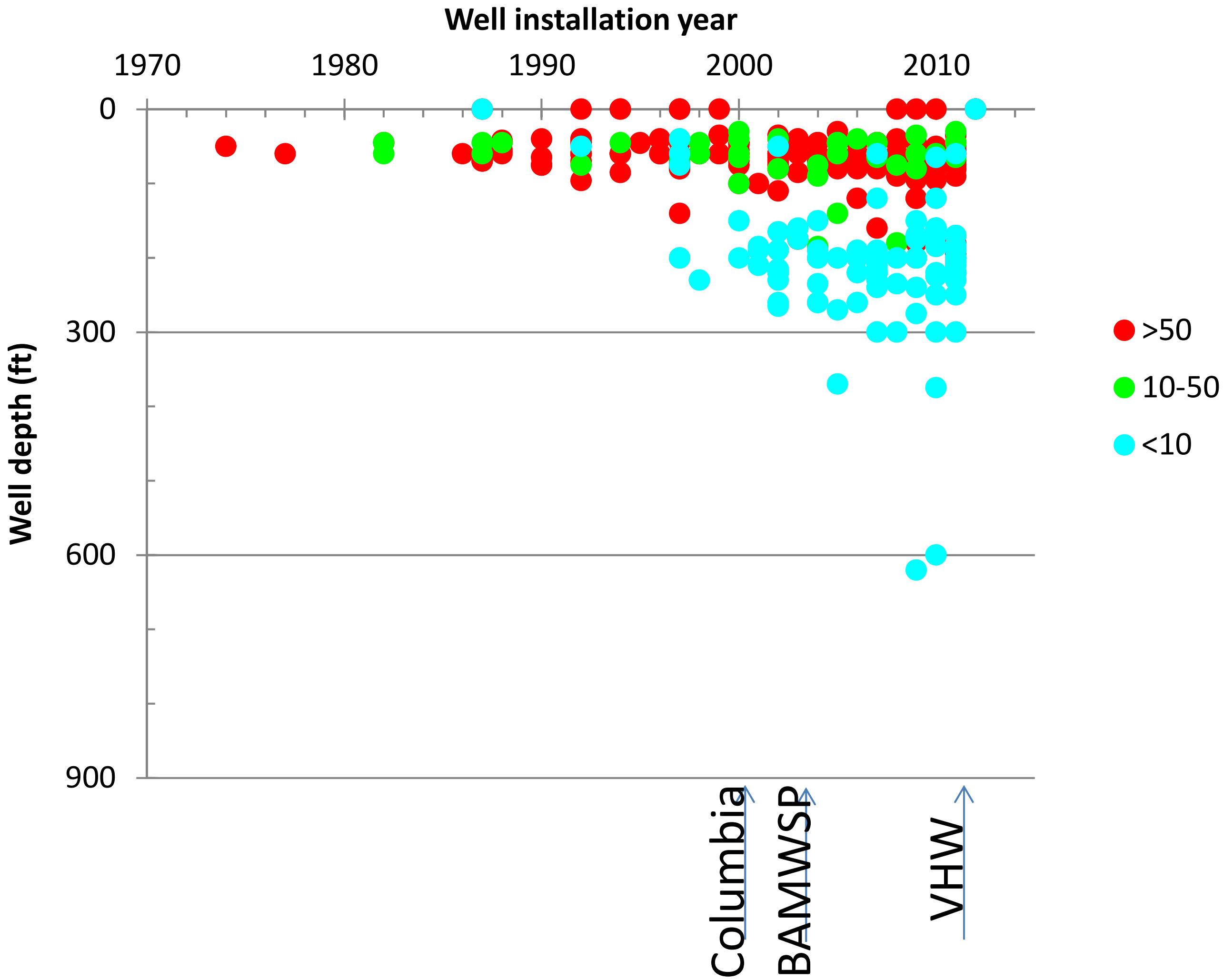
Two main obstacles to lowering of exposure



Edbardi village
176/357 wells
49% untested

53/105
50% of households
knowingly drink
from unsafe well

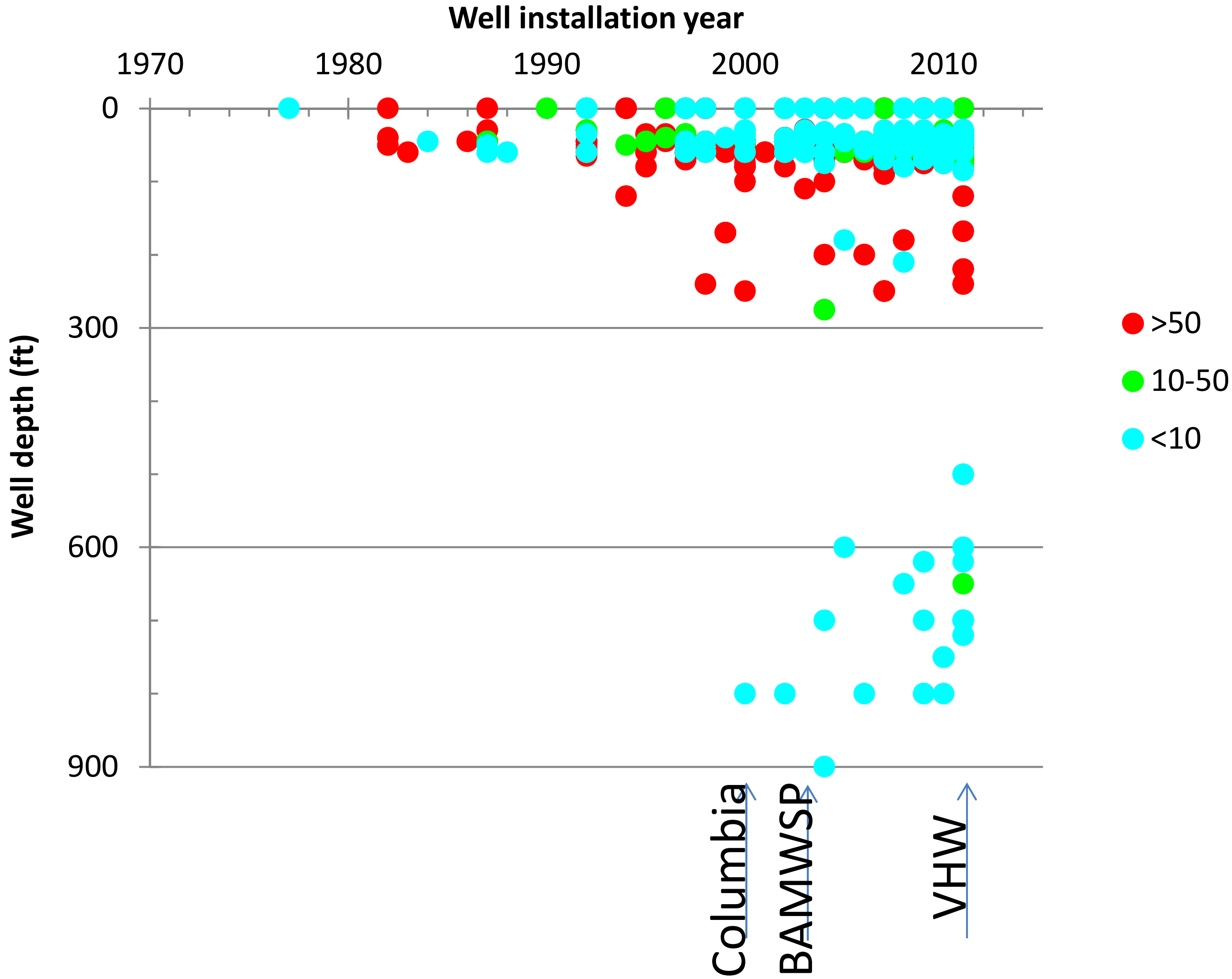
Arsenic-safe depth within reach of local drillers in Edbardi village



“Hand-flapper”
1 day

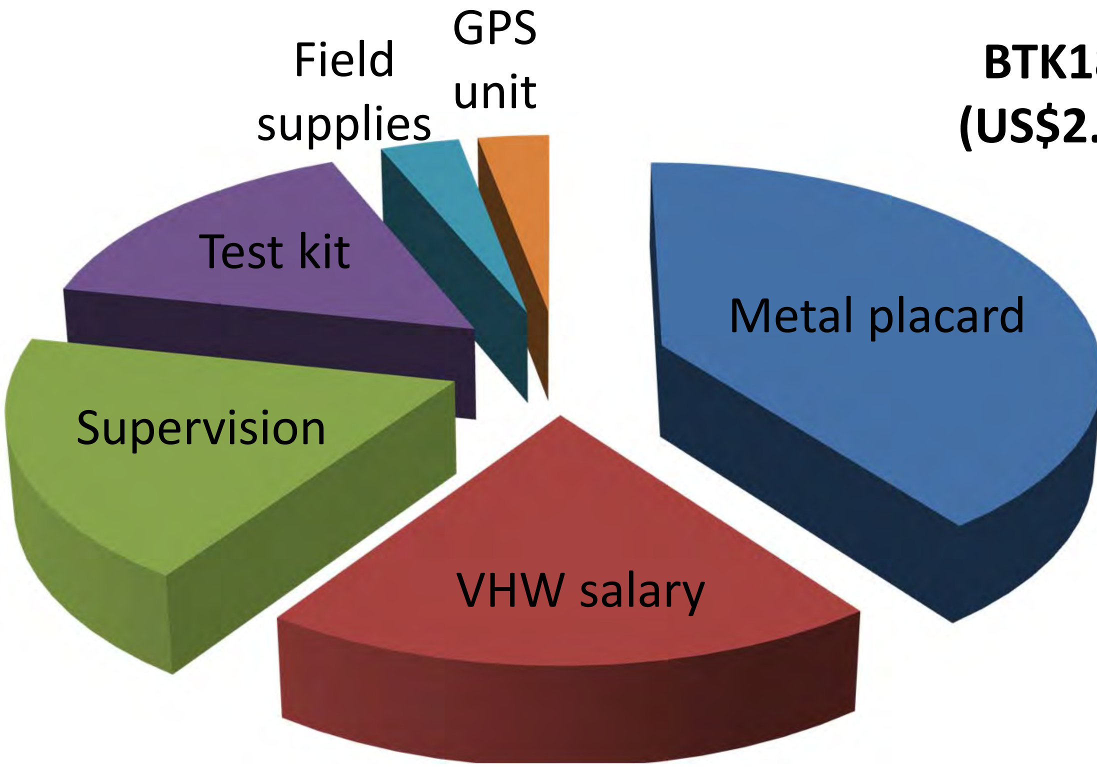
“Donkey pump”
~5 days

Arsenic-safe depth beyond reach of local drillers in Dakshinpara village



Cost of tubewell testing relative to installation

Total budget for testing 30,000 wells (5% twice for quality-control)
2 supervisors and 10 village-health workers for 12 months
BTK 5,400,000 (US$66,000)



BTK180/test (US$2.20/test)

BTK180/test (US$2.20/test) vs. BTK8,000-24,000 (US$100-300) for a 100-300 ft tubewell

US$22 million for testing 10 million tubewells vs. >US$1 billion spent by households

Findings

Status of 57% of wells unknown in Araihazar because of installations of last 10 years, probably an even higher portion in other As-affected areas

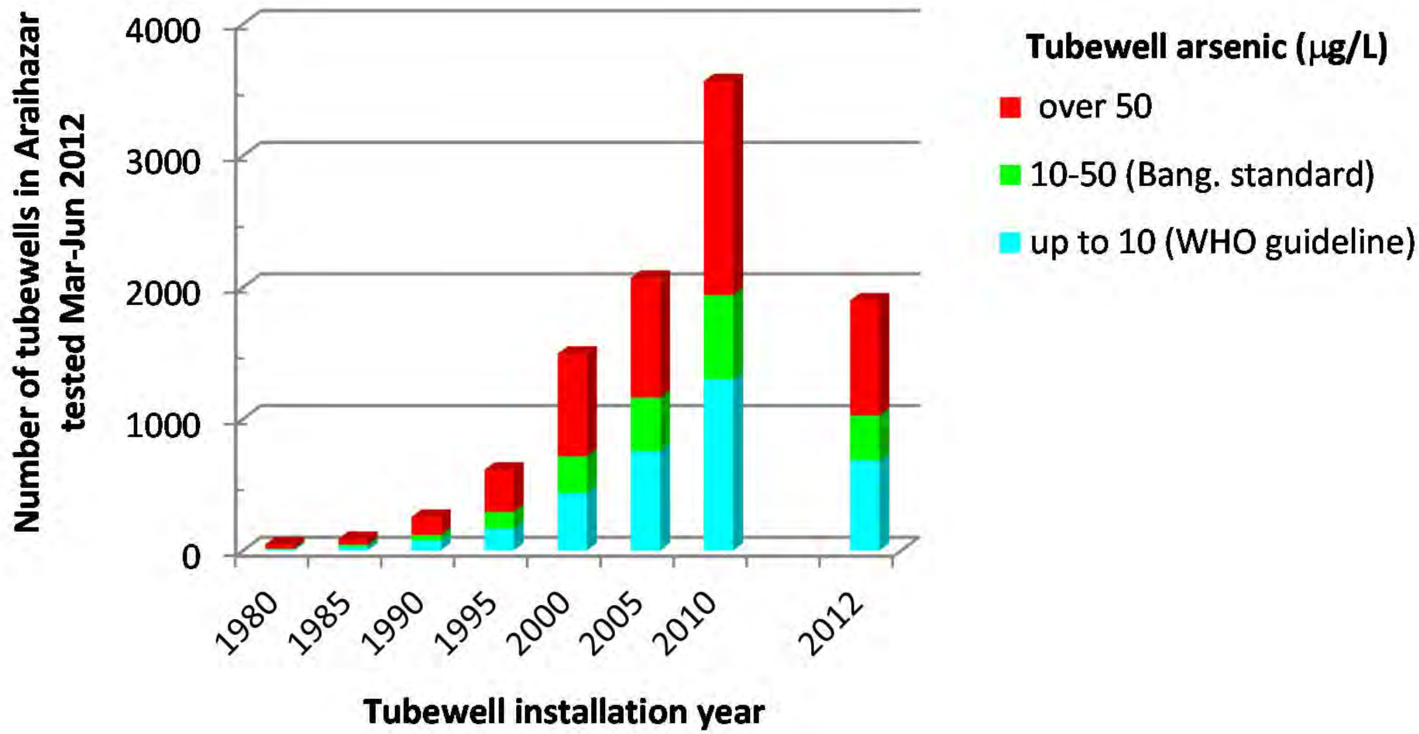
65% of households aware of high arsenic in their well still drinking and cook from it, in many case even if a low-arsenic well is within walking distance

Proportion of tubewells meeting the Bangladesh standard for arsenic installed since the 2003 blanket survey has increased only from 50 to 55%

Over 300 deep wells installed in 21 villages that need them, 9 villages that don't, but none in 17 villages that do

Recently introduced ITS Arsenic Econo-Quick kit adequately establishes well status relative to WHO guideline (10 ug/L) and Bangladesh standard (50 ug/L)

Village workers can test 12 wells/day at a total cost of BTK180/well that covers the kit, hand-held GPS for data entry, placard, and salaries (incl. supervisors)



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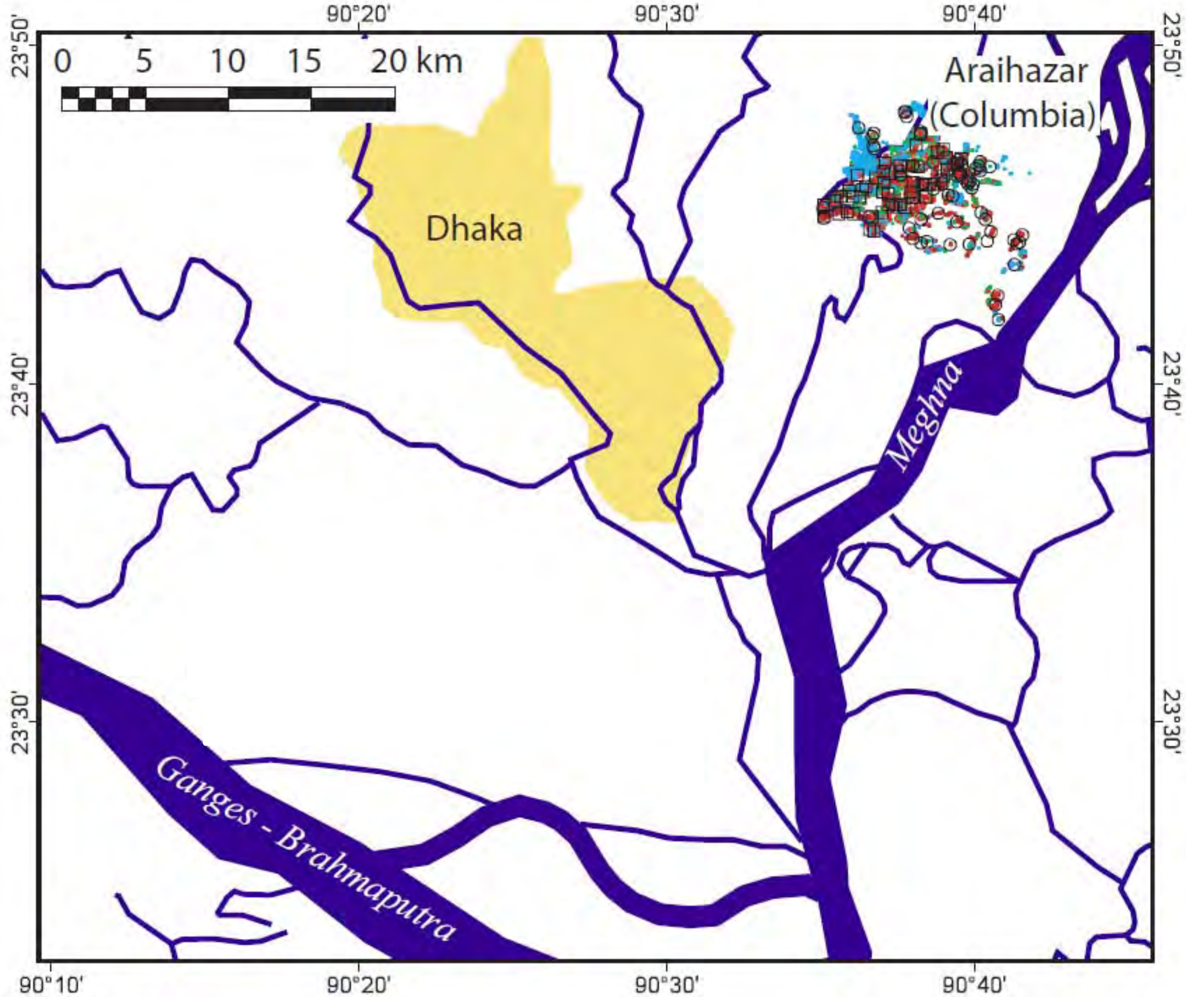
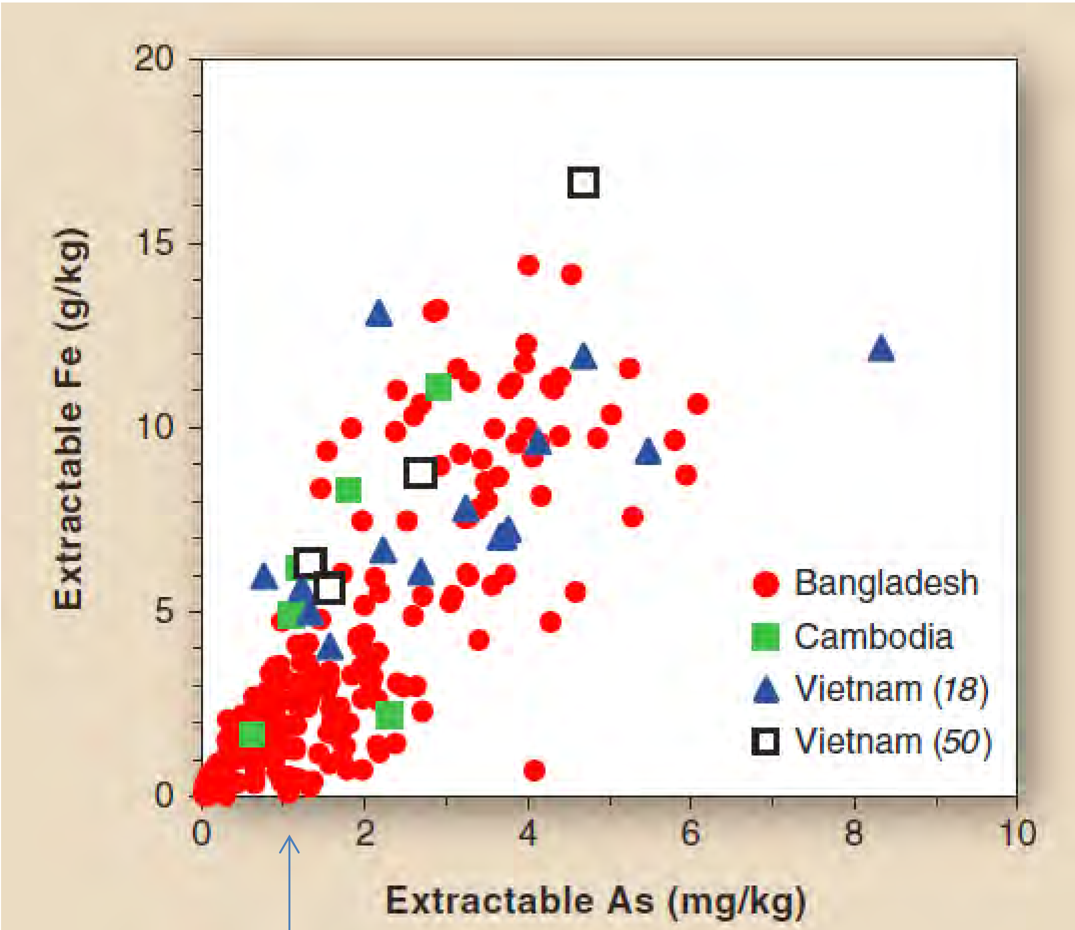
Extras


90°20'
90°30'
90°40'
23°50'
0 5 10 15 20 km
Araihazar
(Columbia)
Dhaka
23°40'
Meghna
23°30'
Ganges - Brahmaputra
90°10'
90°20'
90°30'
90°40'

Where does the arsenic come from?



Fendorf et al. *Science* 2010

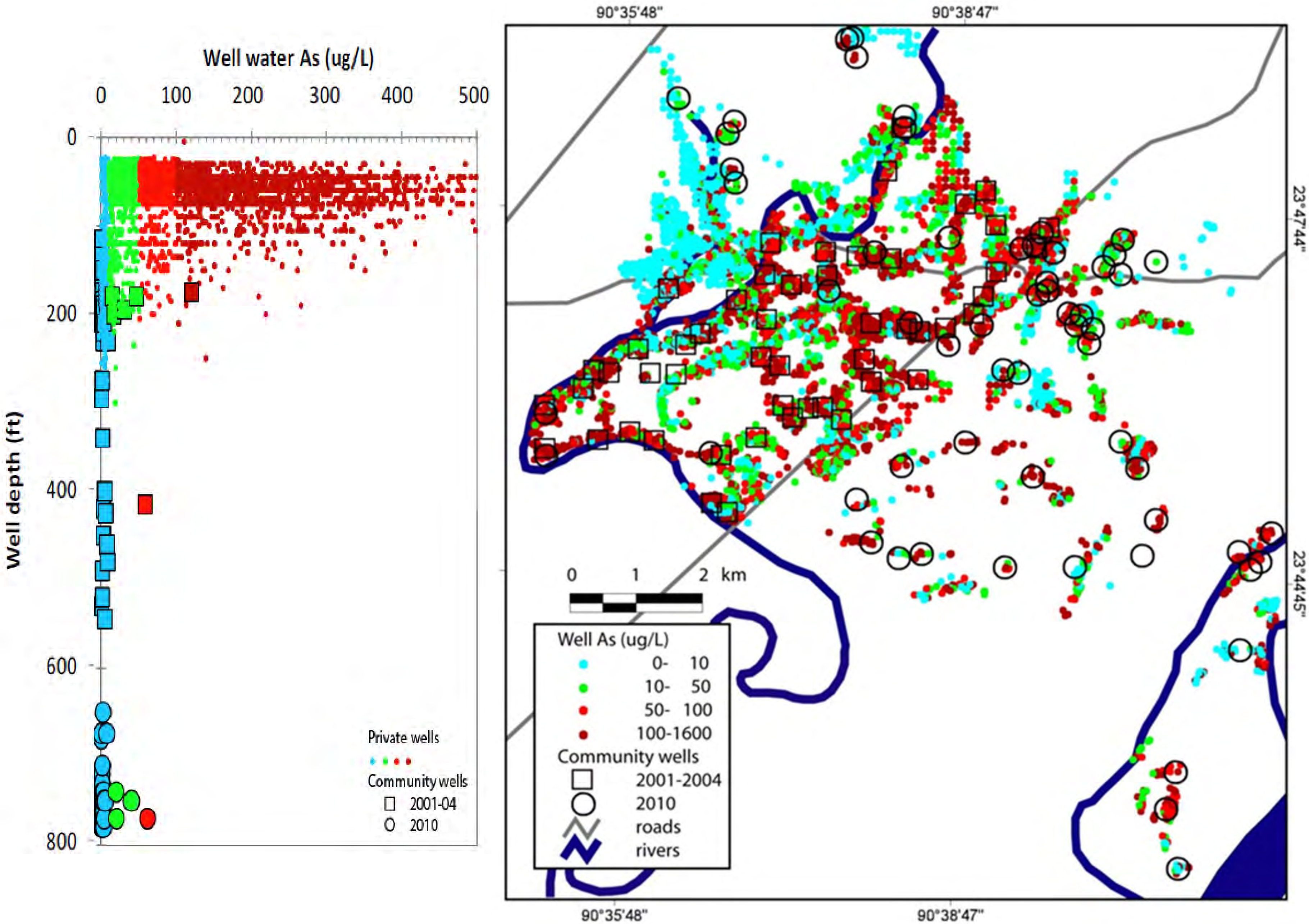
Crustal As ~ 1 mg/kg

Fe(III) oxides

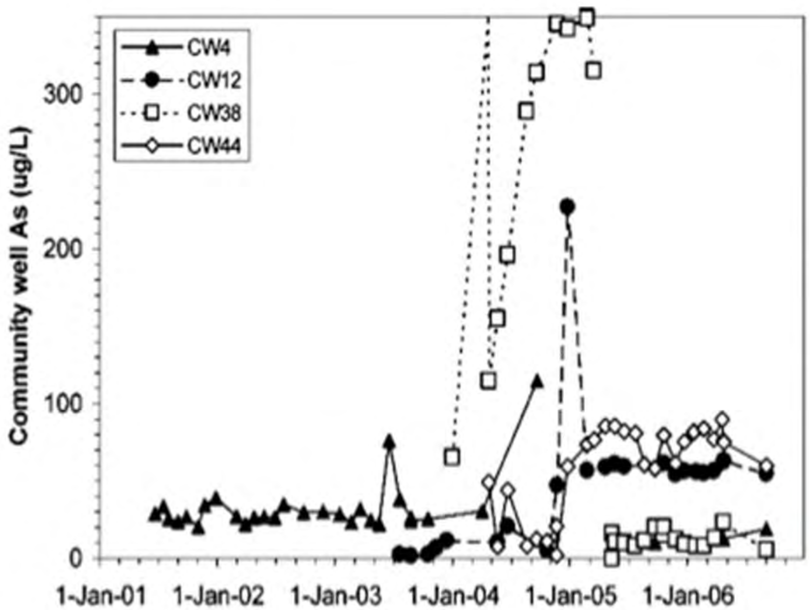
Dissolution of iron oxides driven by organic matter degradation

Fe(II) oxides

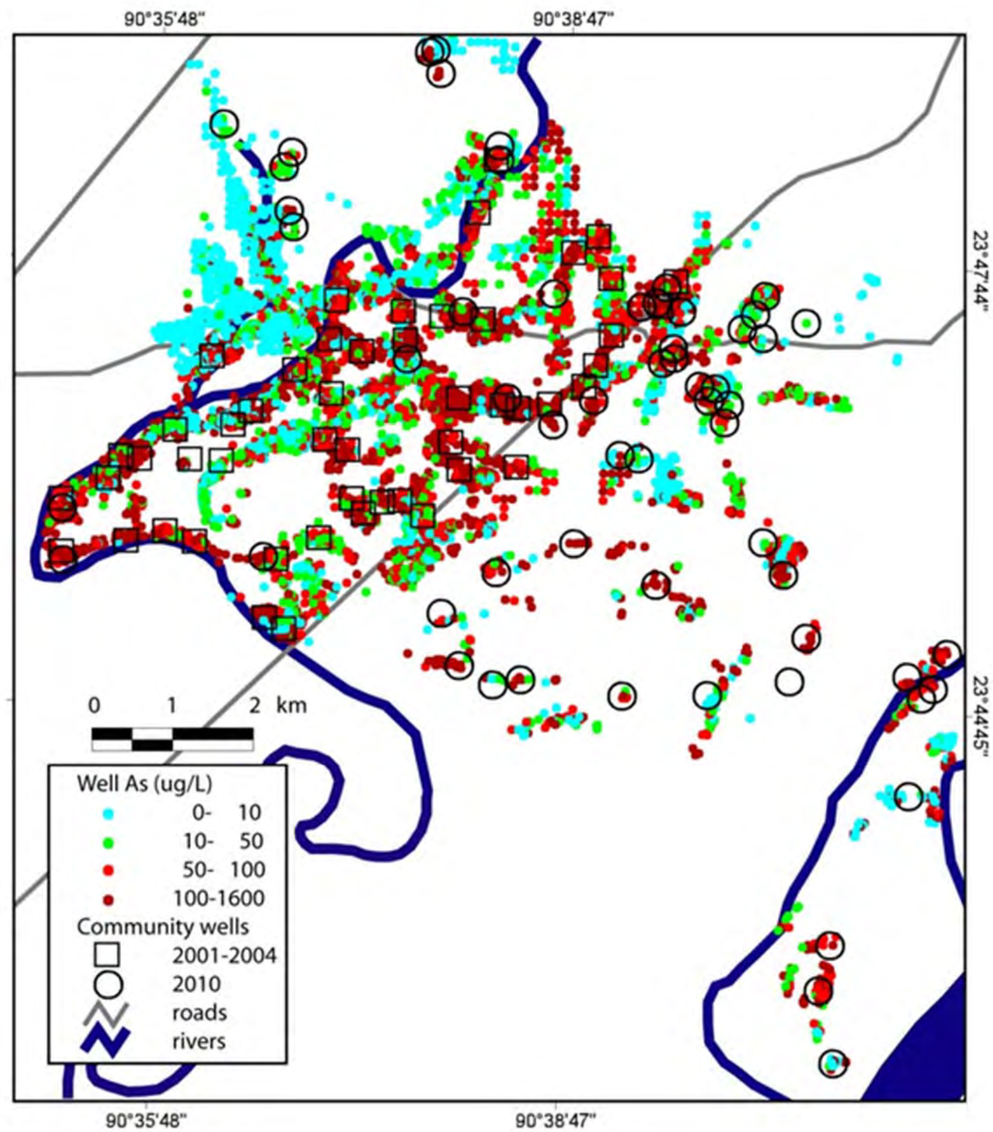
What if there is no low-arsenic well within walking distance?

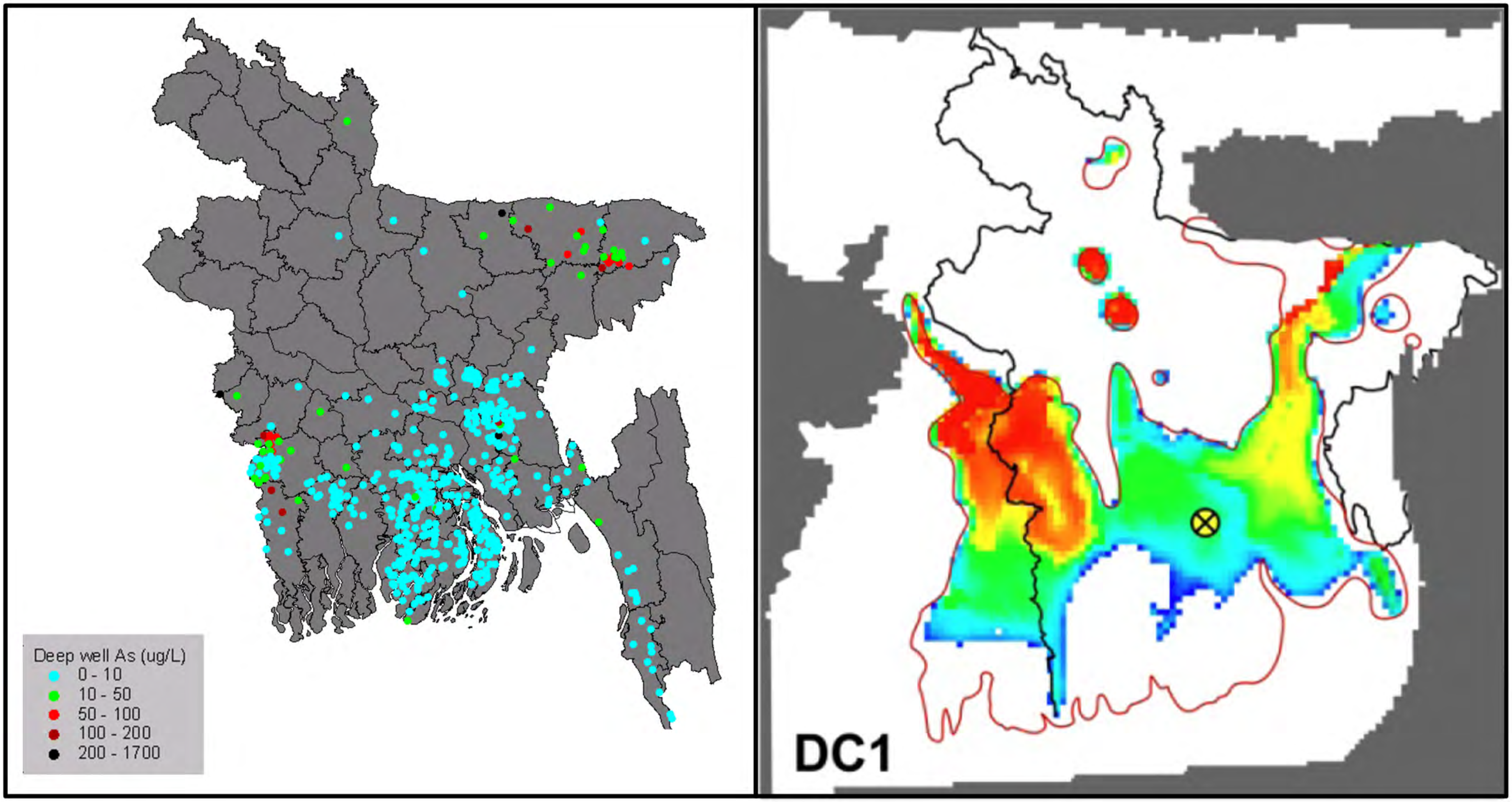


“Only”4 failures out of 50 community wells over 10 years



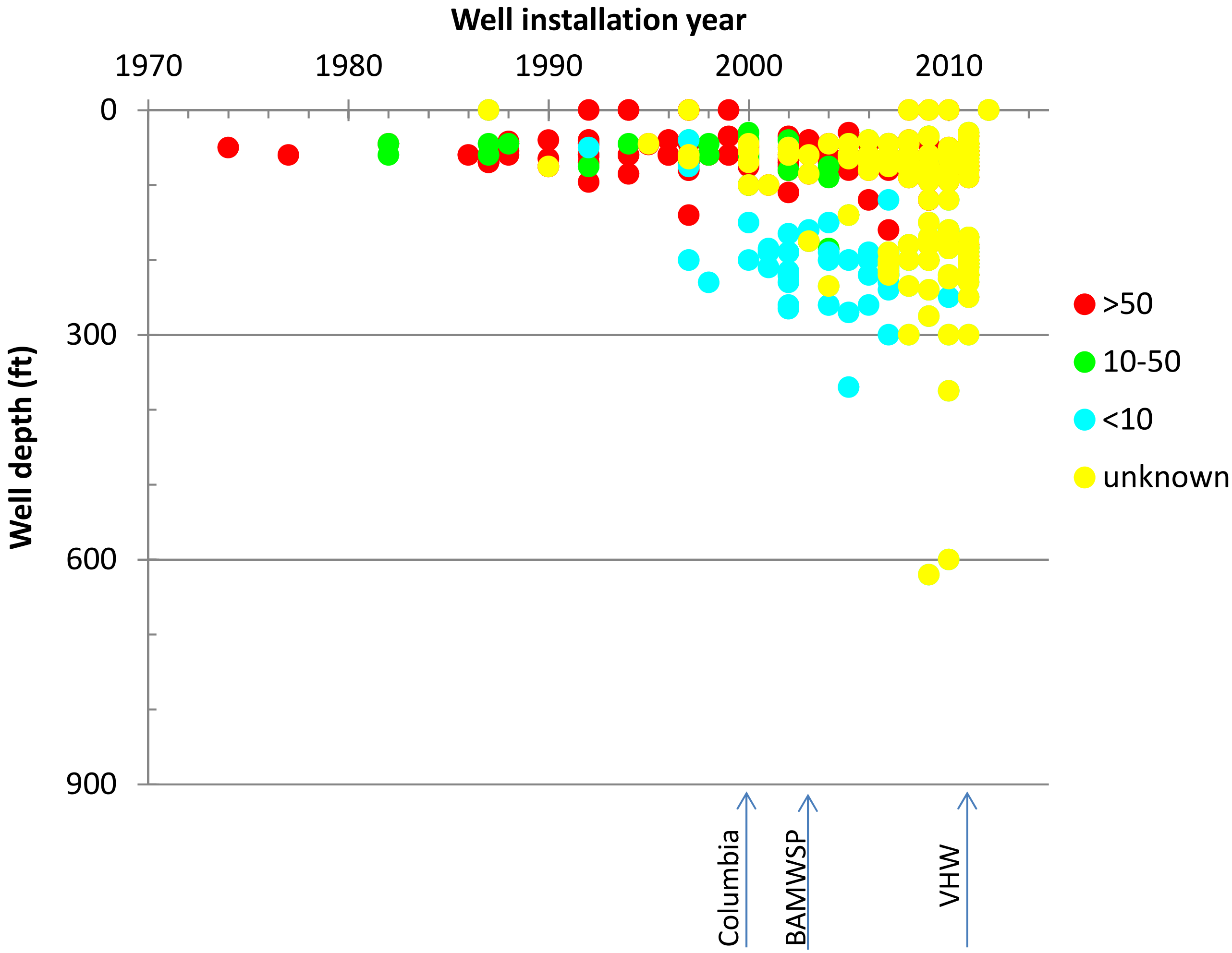
van Geen et al., 2007

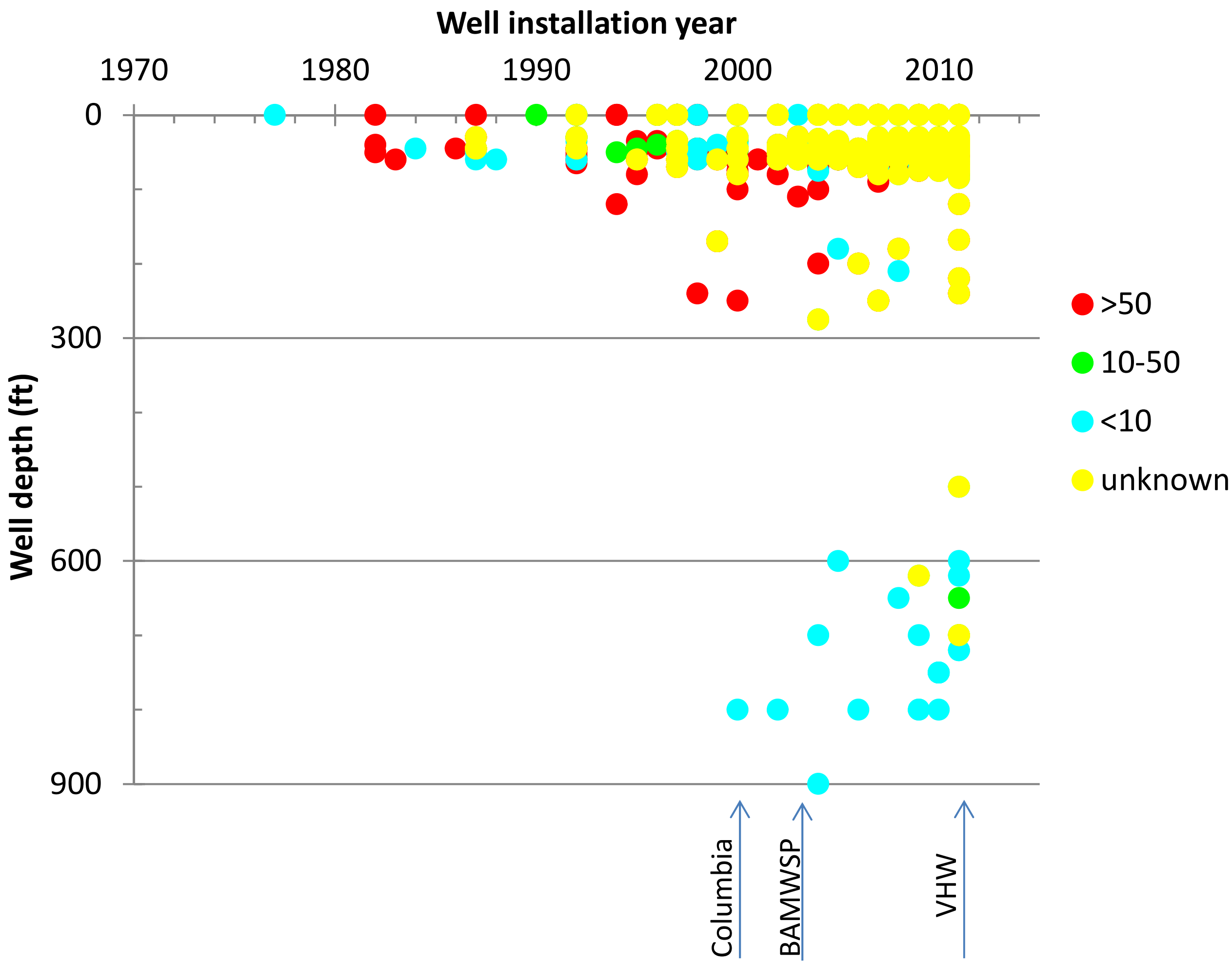




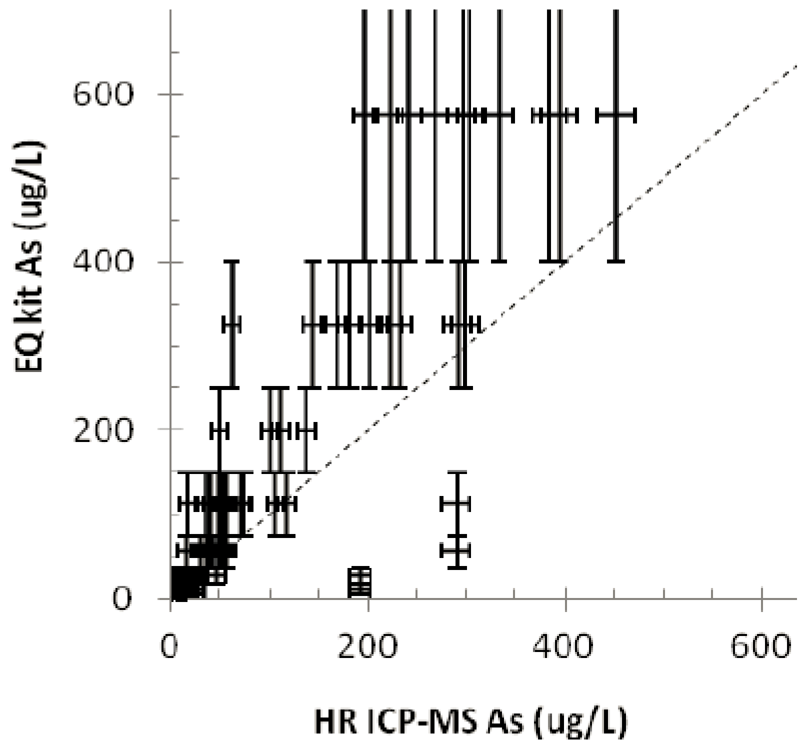
Radloff et al. *Nature Geoscience* 2011

Depth and age of tubewells




Well installation year
1970
1980
1990
2000
2010
0
300
600
900
Well depth (ft)
>50
10-50
<10
unknown
Columbia
BAMWSP
VHW

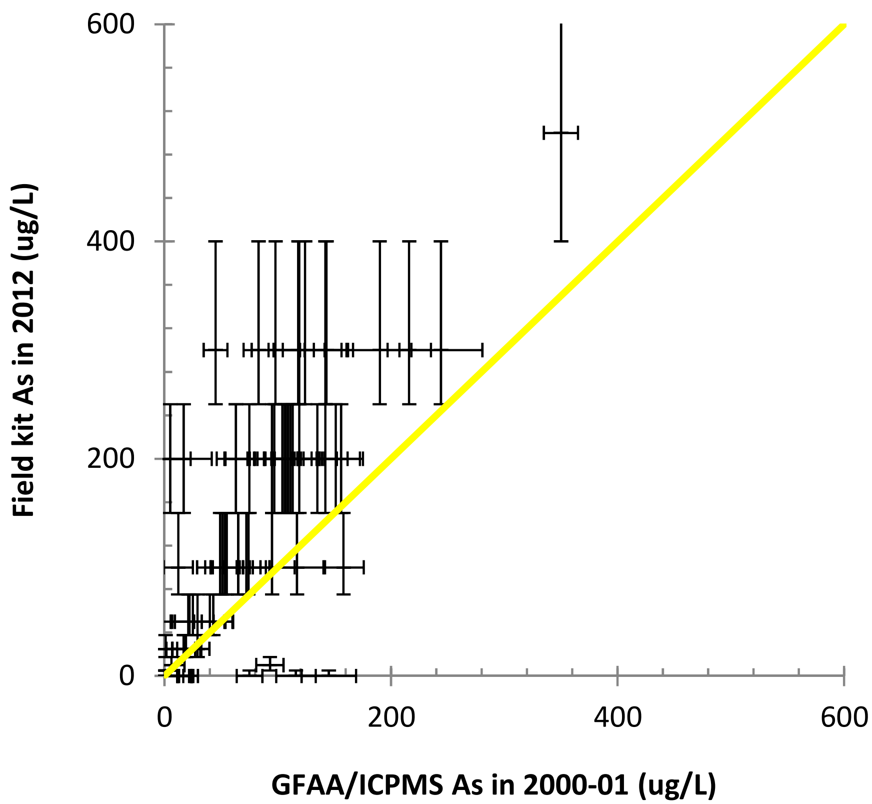
Performance of field kit when deployed by village health workers

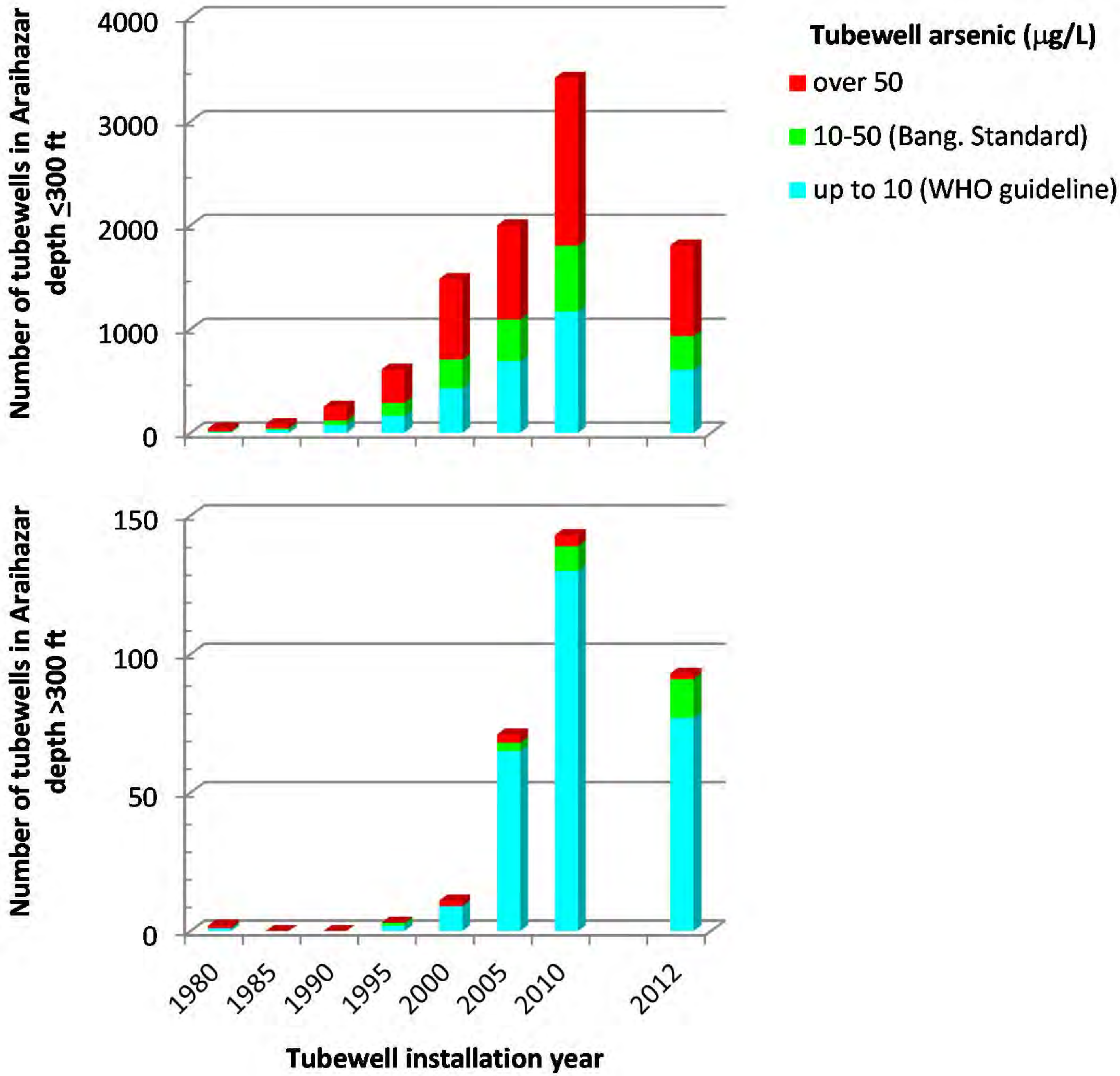


N=189	kit underestimate	kit overestimate
Relative to 10 ug/L	9%	0.5%
Relative to 50 ug/L	3%	4%

George et al. *Env. Sci. Technol.* under revision

Comparison with laboratory for wells still tagged after 10 years




Number of tubewells in Araihazar depth ≤300 ft
4000
3000
2000
1000
0
Tubewell arsenic (μg/L)
over 50
10-50 (Bang. Standard)
up to 10 (WHO guideline)
Number of tubewells in Araihazar depth >300 ft
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2012
Tubewell installation year

Accounting

Monthly budget - Arsenic Testing Project, Araihazar									
Expected duration	12 months								
Assumptions:					Compensation				
No. wells tested by each VHW (12 per day and 20 days per month)			240		BTK 20/test			@82 BTK/USD	
5% of wells re-tested by manager and supervisor			120		BTK 40/test				
Personnel		No.		Fixed	Compensation	Travel allowance	Total/month		
local PI, manager, and supervisor		2		BDT 70,000	BDT 4,800	BDT 10,000	BDT 84,800		
Village health workers		10		BDT 4,100	BDT 4,800		BDT 89,000		
Supplies									
Metal placards + SS wire @ BTK75 ea.							BDT 180,000		
Miscellaneous (notebooks, pliers, markers, tissue, etc.)							BDT 15,000		
Monthly							**BDT 368,800**		
12 months/28,800 tests							**BDT 4,425,600**	USD 53,971	
Provided separately:									
12 Handheld GPS units @USD164 ea.								USD 1,968	
Econo-Quick kits @USD85/300 tests								USD 8,160	
Total								**USD 64,099**	(or USD 2.23/test)

2,400 x 12 mo. = 28,800 in 1 yr (BAMWSP ~15,000 for Araihazar in 2003)

Cost to households of re-installing 5 million wells ~ UD$500 million
Cost of testing these wells ~$10 million

Like drilling, testing could be for-profit
Key role for gov't/NGOs/universities is training and (re-)certification program

Actual arsenic concentration relative to perceived status (n=10,027)