Access to arsenic safe drinking water service by 2030: a scalable example for millions in Asia

Presentation by

Joyashree Roy

Bangabandhu Chair Professor

Asian Institute of Technology, Thailand

Professor of Economics, Jadavpur University , India (on lien)

@ 5th International Forum on Sustainable Future in Asia/NIES, Myanmar, 2020, January 21

Department of Energy, Environment and Climate Change
School of Environment, Resources and Development

Co-authors

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Anupam Debsarkar
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Global Change Programme, Jadavpur University, Kolkata, India

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Access to safe drinking water is recognized as a fundamental human right (UN 28-July-2010). Is a prominent SDG (2015).

6 CLEAN WATER AND SANITATION

Arsenic is ubiquitous in Earth's crust, but the problem is most severe in Bangladesh, and parts of India. Also in Chile, parts of the US and Mexico, etc. 70 countries.

Chronic exposure to arsenic leads to internal cancers, gangrenes and amputations, neuropathy, skin lesions and painful ulcers. And low IQ in children.

In 2002, the WHO called this the largest mass poisoning in recorded history

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Vulnerable population

~200 million people worldwide

as

Arsenic is naturally present in their drinking water

Nature of Vulnerability?

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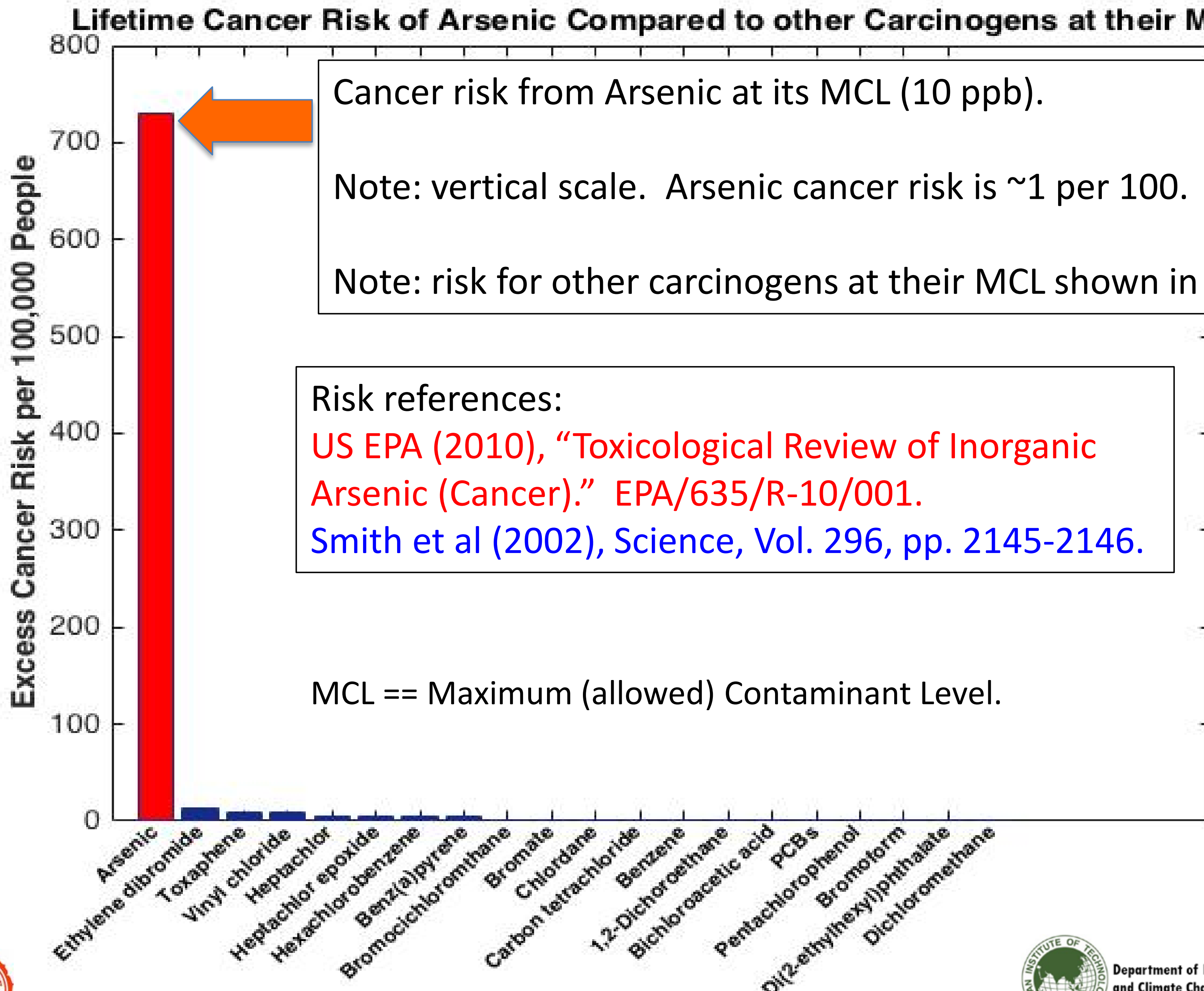

Cancer risk from Arsenic at its MCL (10 ppb).

Note: vertical scale. Arsenic cancer risk is ~1 per 100.

Note: risk for other carcinogens at their MCL shown in blue.

Risk references:

US EPA (2010), "Toxicological Review of Inorganic Arsenic (Cancer)." EPA/635/R-10/001.

Smith et al (2002), Science, Vol. 296, pp. 2145-2146.

MCL == Maximum (allowed) Contaminant Level.

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Sharing a success story
Based on a completed project on

Electrochemical Arsenic Remediation (ECAR)

Now running commercially

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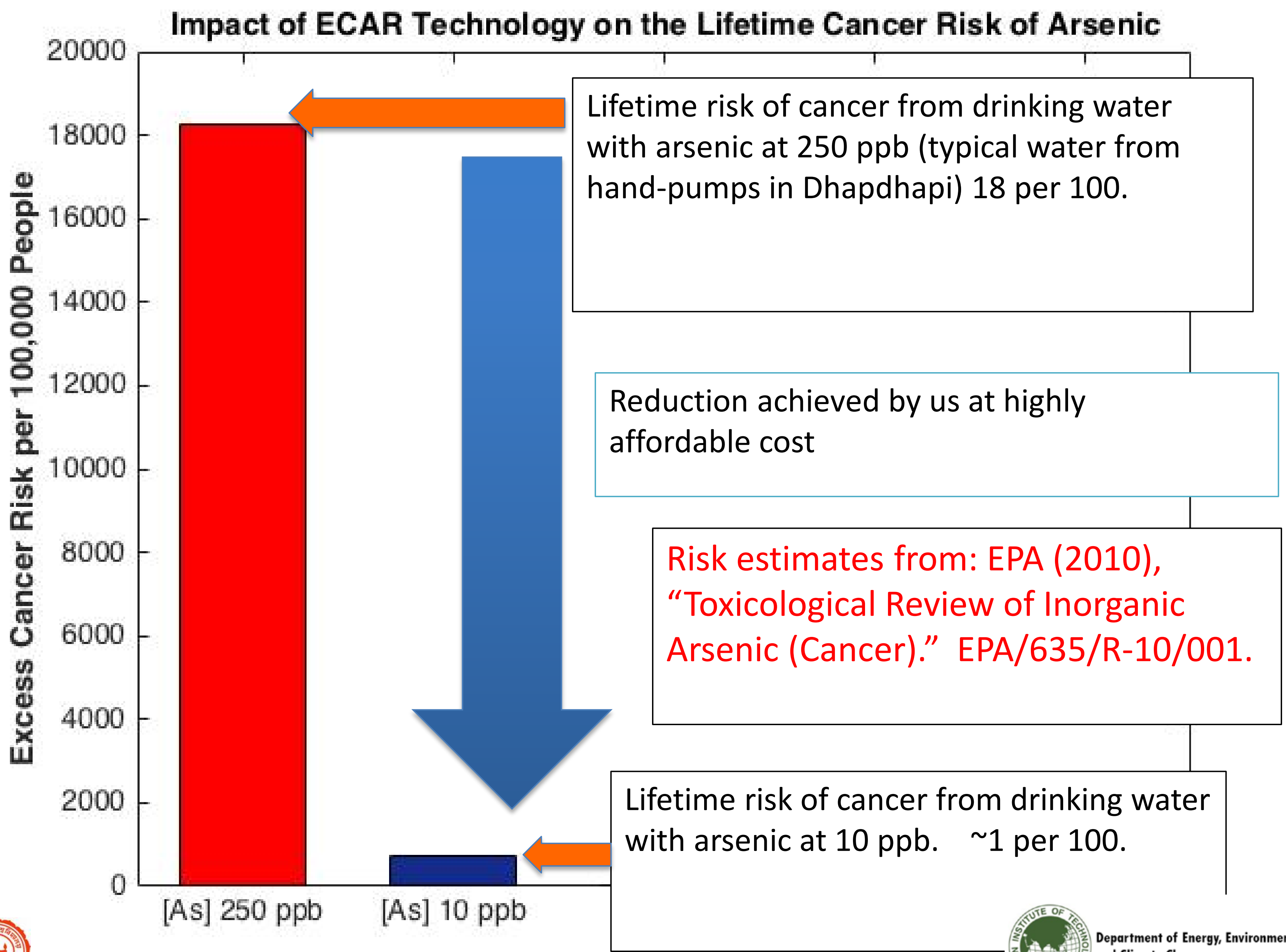

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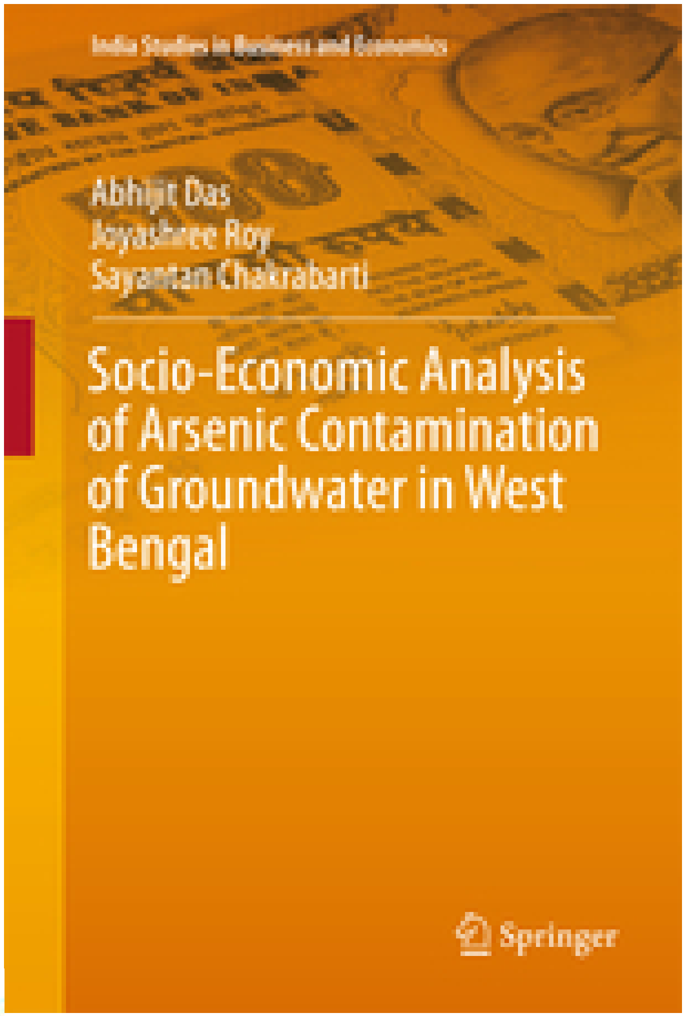
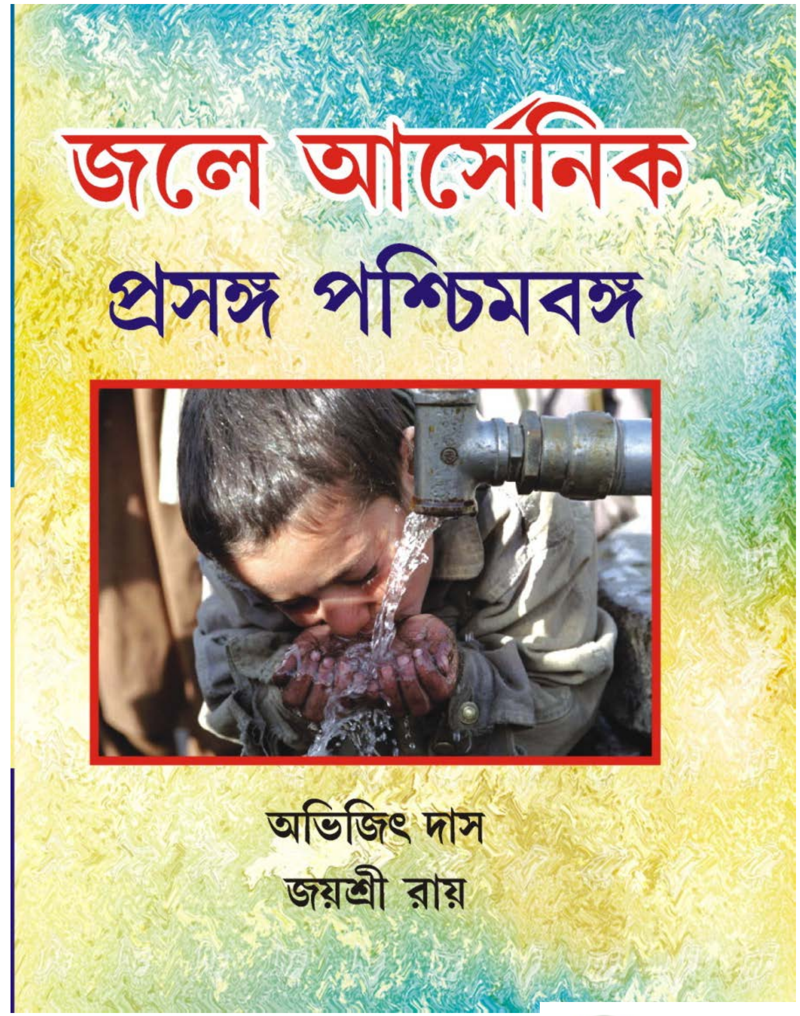
Project starts from

a very detailed scientific understanding of the past efforts, failure/success stories, patented technology innovation and strong research collaboration

Documents on Lessons learnt from past efforts in India



2016



2015

Arsenic in water: Context West Bengal
Abhijit Das and Joyashree Roy

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Partners and Project Details

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IUSSTF
Indo-US Science and Technology Forum

DEVELOPMENT IMPACT LAB
A USAID Development Lab
Headquartered at UC Berkeley

BERKELEY LAB

Prof Ashok Gadgil, Project Team Leader

Deputy for Science and Technology, Energy Technologies Area, Lawrence Berkeley National Lab
Professor, Civil and Environmental Engineering, University of California, Berkeley

Prof Joyashree Roy, India Team Leader

Professor of Economics, Jadavpur University (Kolkata),
Coordinator, Global Change Programme at Jadavpur University

LUMINOUS
WATER TECHNOLOGIES PVT. LTD.

LivPure Pvt.Ltd.

Private investor -Licensee

Mr. RS Rajan

Managing Director, Luminous Water Technologies Pvt. Ltd

Dr. Pratik Mukherjee

Vice President, R&D, LivPure

History: A massive campaign to switch to handpumps for drinking water in rural Bangladesh and India in 1980s.







Arsenicosis – ulcers, gangrenes, and cancers -- started appearing in the population from early 1990s.

These pictures show various Arsenic Removal Units (or ARUs) placed in the district of Murshidabad, West Bengal, by NGOs, charitable organizations, Corporate donations via CSR activities, etc.

Photos were taken by Mr. Das in his doctoral study of the functioning of these ARUs after their placement.

The ARUs are usually based on sound technologies, shown to work in the lab, and were expected to work in the field.

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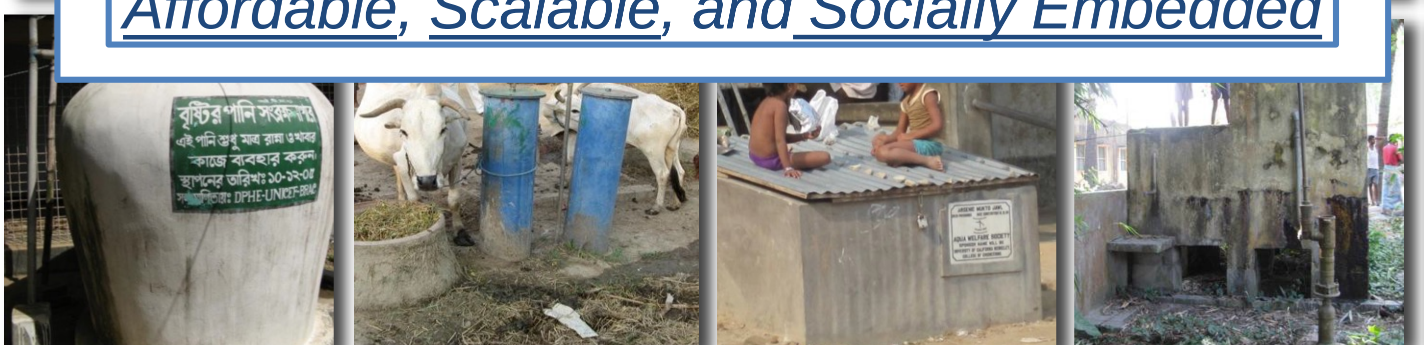
>95% of these failed within 1 year*!

*Ph.D. Thesis, Abhijit Das, Jadavpur University, 2012

Need: a <u>Sustainable</u> Technology <u>*System*</u>

= Effective, Robust, <u>Financially Viable</u>, <u>Locally Affordable</u>, <u>Scalable</u>, and <u>Socially Embedded</u>



These pictures show various Arsenic Remediation Units (or ARUs) placed in the district of Murshidabad, West Bengal, by NGOs, charitable organizations, Corporate donations via CSR activities, etc.

Photos were taken by Mr. Das in his systematic study of the functioning of these ARUs after their placement.

The ARUs were based on sound technologies, and shown to work in the lab, and were expected to work in the field.

On closer inspection, the Technologies had not failed.
The technologies all indeed removed arsenic
just fine in the lab

The Technologists had failed!!

The systems were unsustainable: financially non-viable, not embedded in the societal context, without incentives or structures for their continued maintenance and repair, without knowledge transfer to local community stakeholders

No remediation: Assessment of GDP loss

- For one district of West Bengal annual loss is Rs 229 (~ $6) million due to work day loss (at 2008 prices), medical expenditure, averting actions.
- Rs 297 is the monthly benefit per household
- Thus investing in arsenic safe drinking water is economically feasible and beneficial.

Roy Joyashree (2008), Economic Benefits of from Arsenic Removal from Ground Water -:A Case Study of from West Bengal, India. *Science of the Total Environment*, (STOTEN), Vol 397/1-3 pp 1-12.

Our project vision for Social embedding in resource poor region of

Arsenic Safe Water Access System

simultaneous and not sequential actions on critical effort strategies to address contextual challenges

to disrupt the incumbent regime

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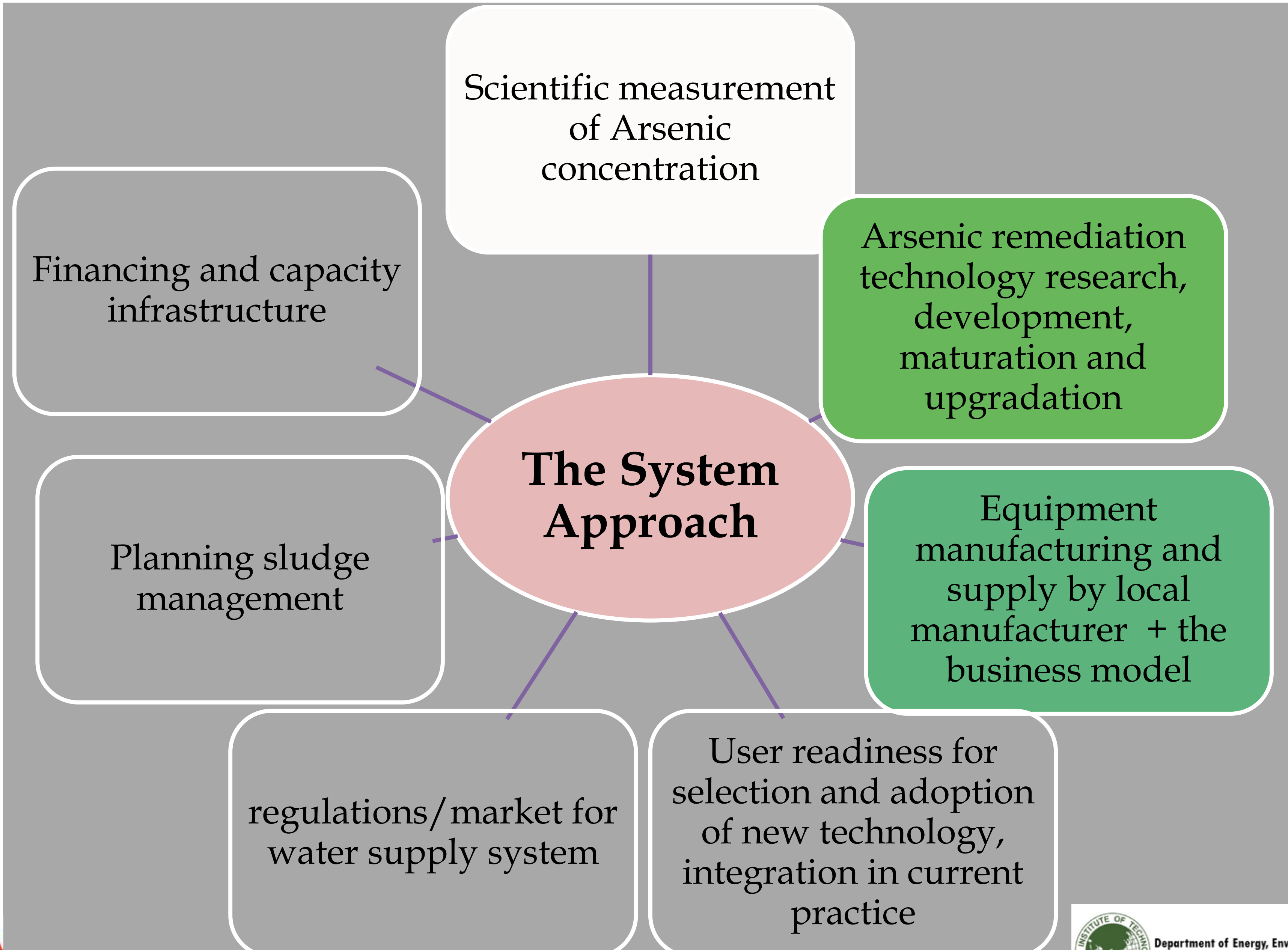
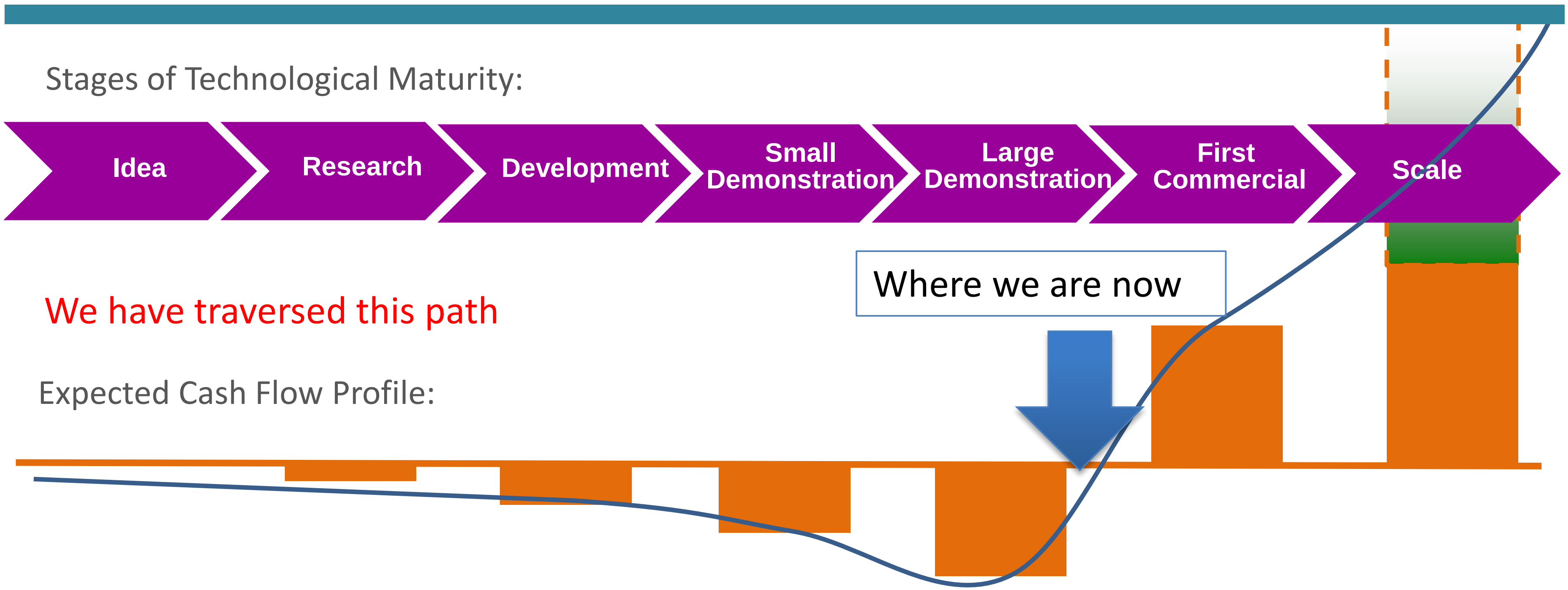
Critical effort strategies for

Arsenic Safe Water Access System

- Appropriate design of community scale technology
- To increase economic opportunity
- Bridging the scientific knowledge divide
- Broader process of social embedding [e.g local legal compliance, regulation, markets, infrastructures and cultural symbols].


The System Approach
Scientific measurement of Arsenic concentration
Arsenic remediation technology research, development, maturation and upgradation
Equipment manufacturing and supply by local manufacturer + the business model
User readiness for selection and adoption of new technology, integration in current practice
regulations/market for water supply system
Planning sludge management
Financing and capacity infrastructure

Cash Flow and Financing Challenges Facing Promising New Technologies



Sources of Capital:

At Risk Capital

Loan Finance

Angel / Seed / Government Grants

Venture Capital

Private Equity

Bank Loans / Equip. Finance

Public Market

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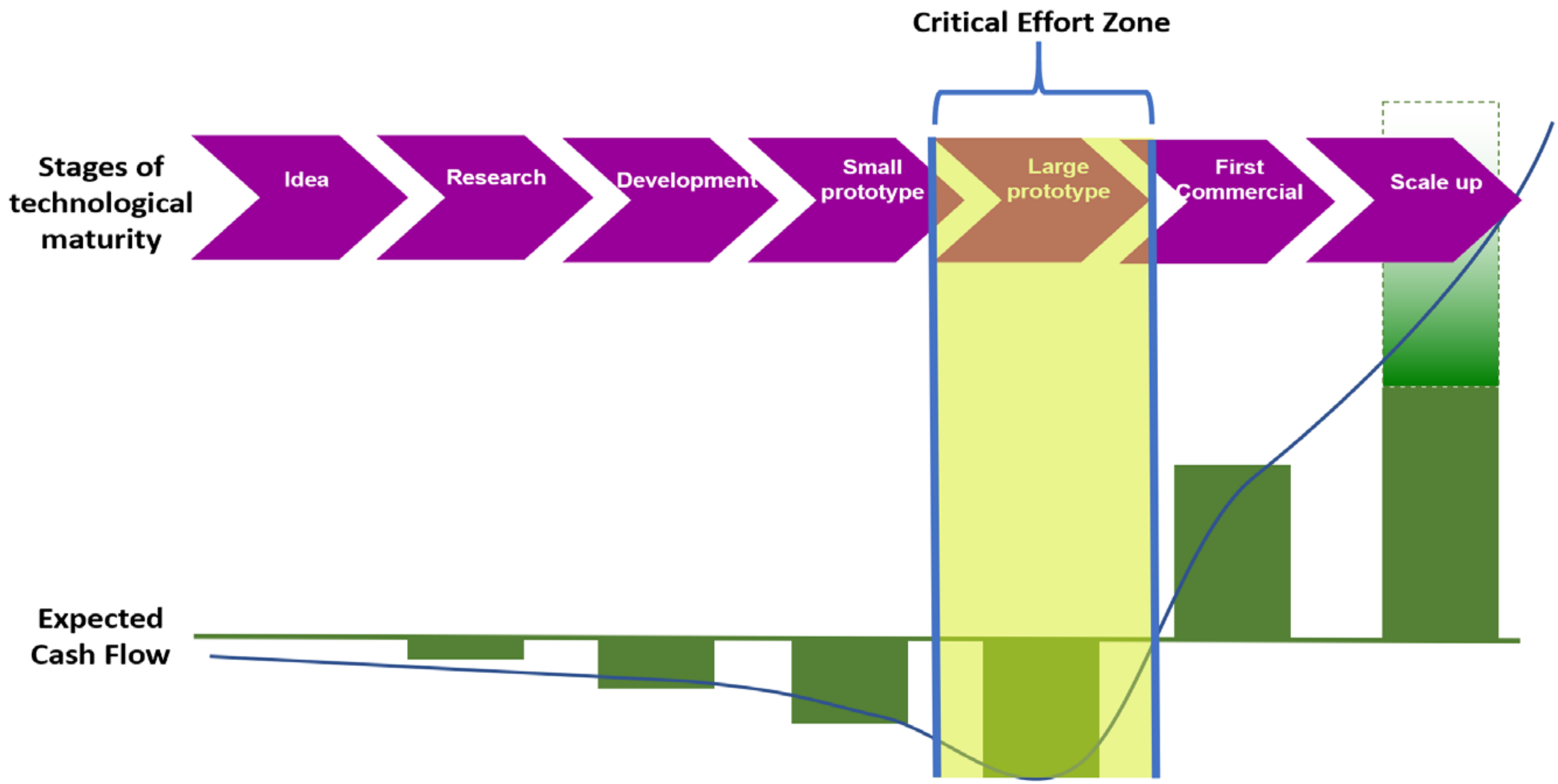
Crossing the critical effort zone requires more than technology efficacy— it requires attention to social placement within the unique social and physical contexts



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Path we traversed for our vision of Rural Transformation through Advanced technology

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For 2005-2009 we focused on getting the basic fundamental science right,
And gradually started scaling up the technology.

Berkeley Lab 2006. 0.2L

Amirabad High School 2010. 100L

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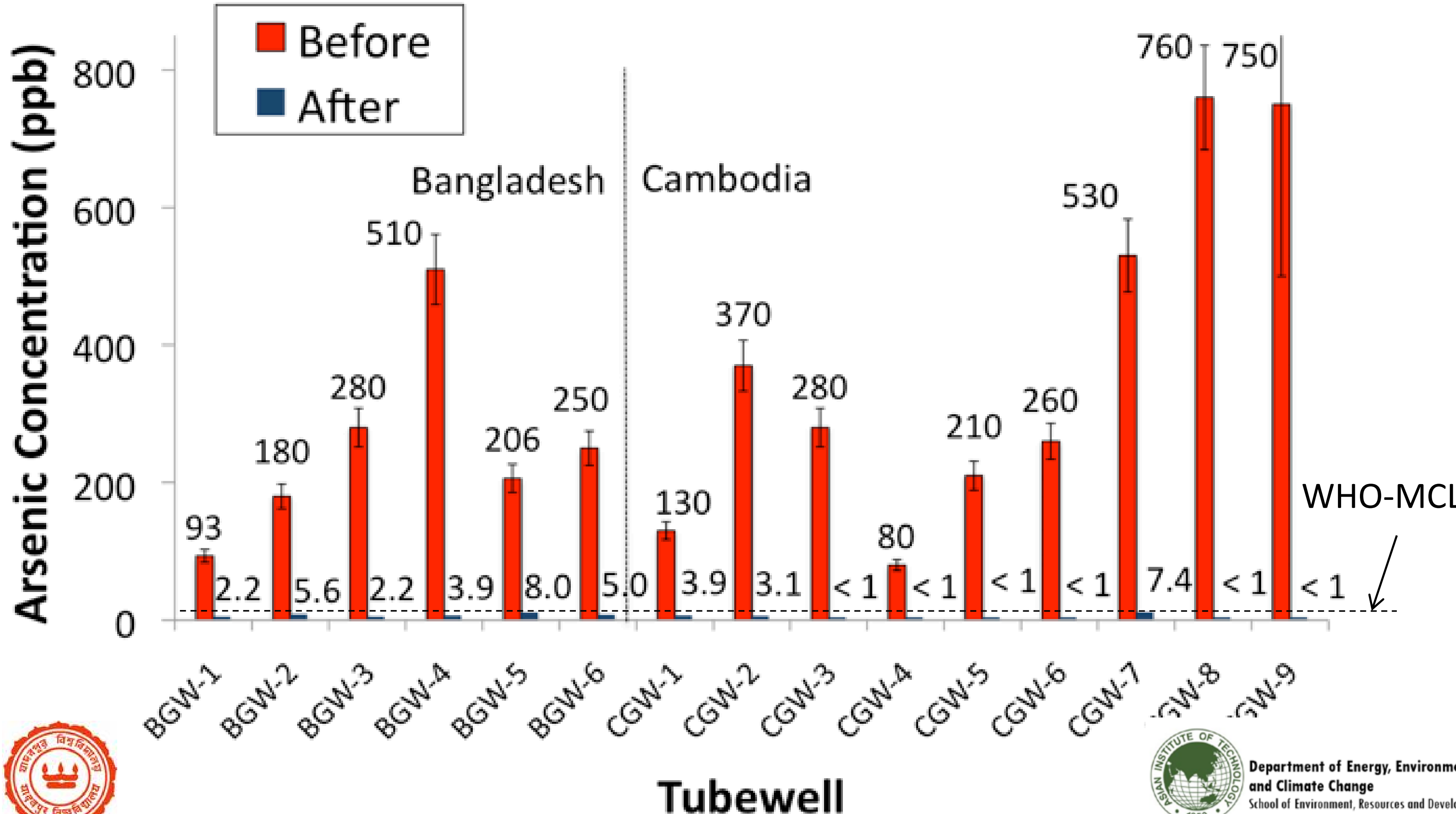
Arsenic Removal – 2008-2009

In Real Groundwater- Bangladesh and Cambodia



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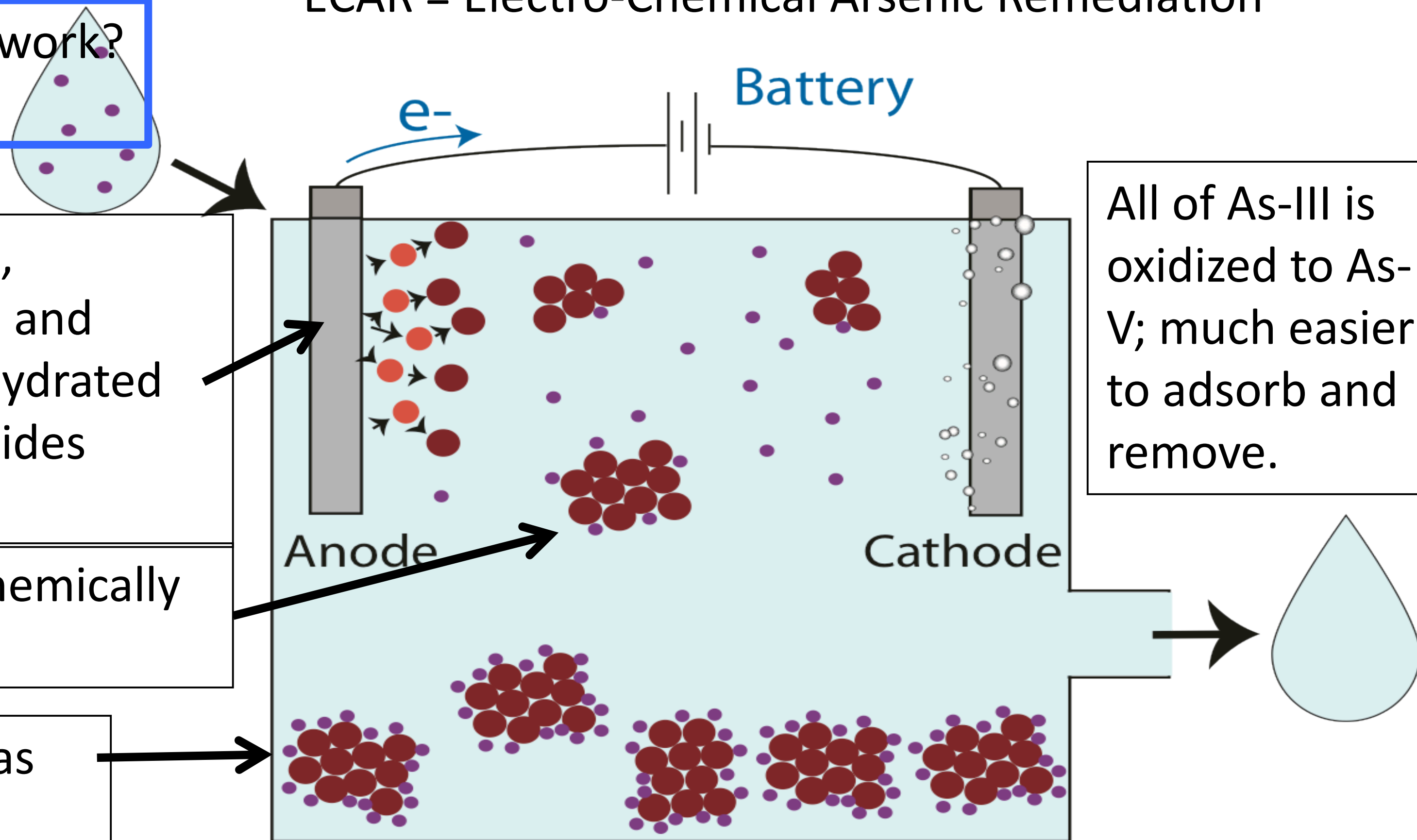
ECAR was designed to fit within a sustainable and scalable system

ECAR = Electro-Chemical Arsenic Remediation

How does ECAR work?
The Big Picture



Fe-II is produced, oxidizes to Fe-III, and precipitates as Hydrated Fe-III-OxyHydroxides ("HFO")

P, Si, and As-V chemically sorb to HFO

Then settle out as sludge

All of As-III is oxidized to As-V; much easier to adsorb and remove.

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ECAR is novel and compares favourably to some other technologies

Name	ECAR	Activated Alumina	Zero-Valent Iron/SONO	MIT Kanchan	Ferric Chloride + Bleach	Solar Oxidation
Effectiveness	●	●	◐	○	●	○
Cost per person	●	◐	○	●	◐	●
Waste Produced	●	○	○	◐	◐	●
Ease of Use	●	○	○	○	○	○
Supply Chain	●	◐	●	●	○	●
Scalability	●	◐	○	○	●	○
Main Challenge(s)	Requires electricity	Toxic & corrosive regeneration chemicals required	Hard to scale, High cost, Maintenance	Hard to scale, Ineffective at high arsenic concentrations	Supply chain, Skilled operation	Labor intensive, ineffective at high arsenic concentrations

● Favorable ◐ Somewhat Favorable ○ Unfavorable

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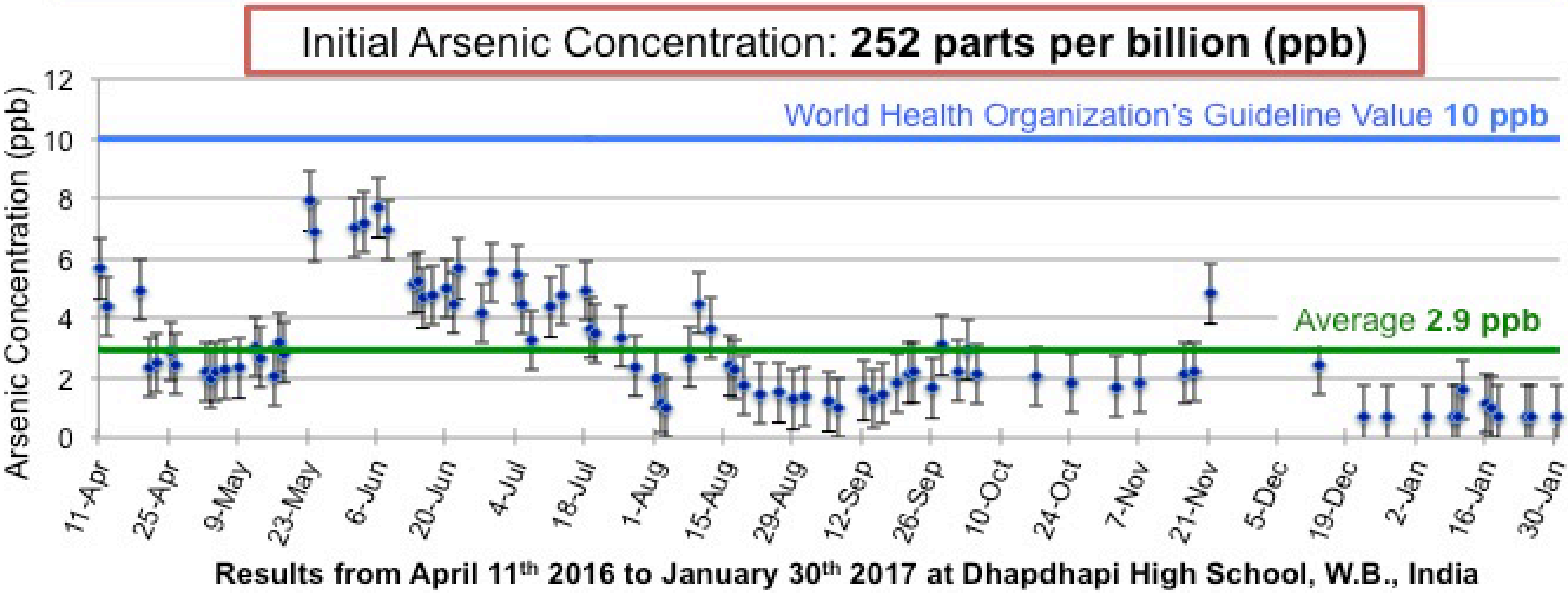
ECAR Reduces Arsenic in Groundwater to Safe Levels

ECAR: ElectroChemical Arsenic Remediation

GadgilLab.berkeley.edu



- Product water meets all chemical and biological aspects of **IS 10500:2012** as tested repeatedly by independent **NABL lab** in India.
- Data shown for samples flown to Berkeley and analyzed with ICP-OES with Hydride Generation Cell. Daily multipoint calibration before and after measurements. Agreement with NABL collected and sampled data of lower periodicity.

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If we save children then next generation will be saved

- 1400L from 3 contaminated wells treated sequentially
- Raw: 50 - 150ppb As, spiked with additional As-III
- Treated water: less than 10 ppb of total arsenic in all case

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600L Prototype at JU: 2013

(Practical-scale 600-L reactor)

Jadavpur University,
Kolkata, 2013

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Installed and tested at Dhapdhapi High School 2012-2013

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10,000 lit prototype: Site preparation at Dhapdhapi High School

July 2014

January 2015

March 2015

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Berkeley scientists and Berkeley-team engineer start working with the fabricator on the design

July, 2014

Technology transfer in action

Discussions with Shri Hari, Mumbai regarding the design of dosing tank

November, 2014

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Dec 2014-
March 2015

Berkeley-team engineer working with manufacturer

Fabrication in Mumbai

March 2015

Arrival of dosing tanks at the site

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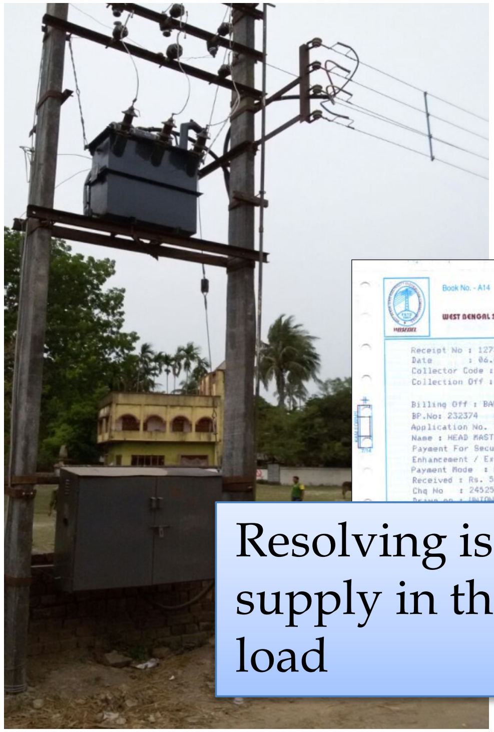
Collaboration with field site community for technology trial

The team visiting frequently the site to collaborate with school authority. Photo – July 2014



Book No. - A14 WBSEDCL - 9B Serial No. B 7810049

Money Receipt

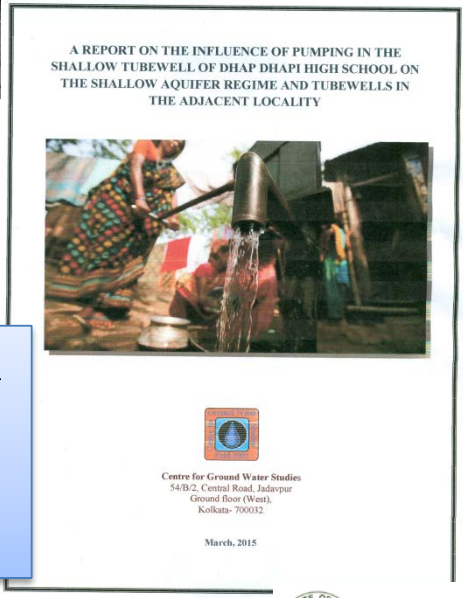
WEST BENGAL STATE ELECTRICITY DISTRIBUTION COMPANY LIMITED

(A GOVERNMENT OF WEST BENGAL ENTERPRISE)

Receipt No : 127300889940
Date : 06.01.2015 11:11:22
Collector Code : 1971011003 Counter: 01
Collection Off : BARUIPUR CUSTOMER CARE CENTER

Billing Off : BARUIPUR CUSTOMER CARE CENTER
BP.No: 232374 Consumer Id: 113000977
Application No. : 1002276965
Name : HEAD MASTER D.D.HIGH SCHOOL
Payment For Security Deposit (Request Reason: Load Enhancement / Extension)
Payment Mode : Cheque
Received : Rs. 56687.00
Chq No : 245257 Date: 05.01.2015

Resolving issues regarding electricity supply in the school with additional load



A REPORT ON THE INFLUENCE OF PUMPING IN THE SHALLOW TUBEWELL OF DHAP DHAPI HIGH SCHOOL ON THE SHALLOW AQUIFER REGIME AND TUBEWELLS IN THE ADJACENT LOCALITY

Centre for Ground Water Studies
54/B/2, Central Road, Jadavpur
Ground floor (West),
Kolkata- 700032

March, 2015

GCP-JU assigned scientific study to a third party to answer the questions raised by the community during their visits.
March 2015

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Plant is designed to treat 10,000 L per day

June 2015

Pilot Plant Commissioning started at the Dhapdhapi School site: June 2015

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Social placement and building trust with the community

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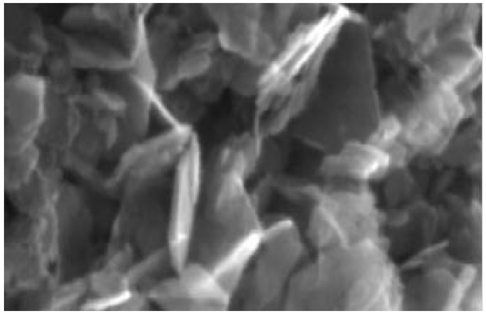
We pursued three tracks in parallel. (1) science research, (2) technology development and testing, and (3) education and outreach for technology adoption, understanding social and institutional priorities



Fundamental Science

Technology Development

Education and Outreach

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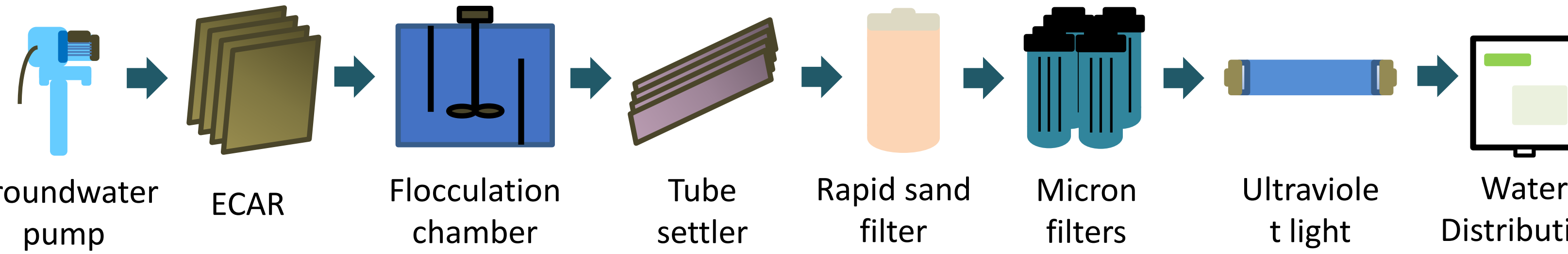
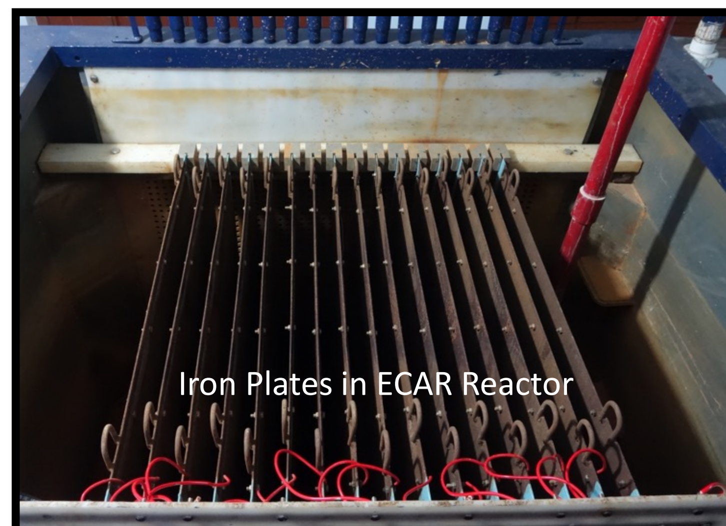
ECAR plant in Dhapdhapi

Process flow schematic (below)



ECAR Reactors


Iron Plates in ECAR Reactor

Sludge Management

- Only about **250 g sludge per person per year** is produced.
- **Currently** sludge is collected by Department of Civil Engineering, Jadavpur University, for research to immobilize it in concrete blocks. Results are very good.

- On-site we have a scientifically constructed sludge bed.
- Talked to Ramky Enviro Engineers, a Hazardous Waste Management company approved by the Govt. of WB and WBPCB. Ramky is ready to take the sludge for scientific disposal at Haldia site, after JU research need is met.

Communication with the network of actors by GCP-JU

Jul 2014- March 2015

At the office of Panchayat Samiti

FROM : SECY SCHOOLEDUCATION FAX NO. : 23376561 04 Aug. 2014 15:19 P 1

Government of West Bengal
School Education Department
Bikash Bhavan, Bidhannagar
Kolkata-700 091
Tel.No. 033-2334-2228, Fax No. 033-2337-6561

No. 409 – SSE / 14

Dated, Kolkata, the 4th August, 2014

From : Arnab Roy,
Secretary to the Government of West Bengal,

To : Smt. Joyashree Roy,
ICSSR National Fellow,
Professor of Economics (EoL0,
IUSSTF – Project Coordinator,
Coordinator – Global Change Programme – JU
UPE II EEC – Group Coordinator,
Jadavpur University,
Kolkata – 700 032

Sub: Pilot projects on arsenic safe water at Dhapdhapi High School and Madanpur Nivedita Vidyapith Primary School, PS: Baruipur, Dist - South 24-Parganas.

Sir,

Kindly refer to your letter dated 17.7.2014.

This is to inform you that the Department has no objection to your proposal for implementation of a pilot project for arsenic remedial technology in the two schools identified by your organization.

Thanking you,

Yours faithfully,
(Arnab Roy)
Secy. to the Govt. of West Bengal

Enclo: As stated.

Communication with the School Education Department, Govt. of West Bengal

DHAP DHAPI HIGH SCHOOL (H. S.)
P.O. - Dhapdhapi, P.S. - Baruipur, Dist - 24 Pgs(s)
Recognised & Aided
INDEX NO. - C1-082, H.S. CODE NO.-02150

Global Change Programme
Jadavpur University
Kolkata – 700 032, India

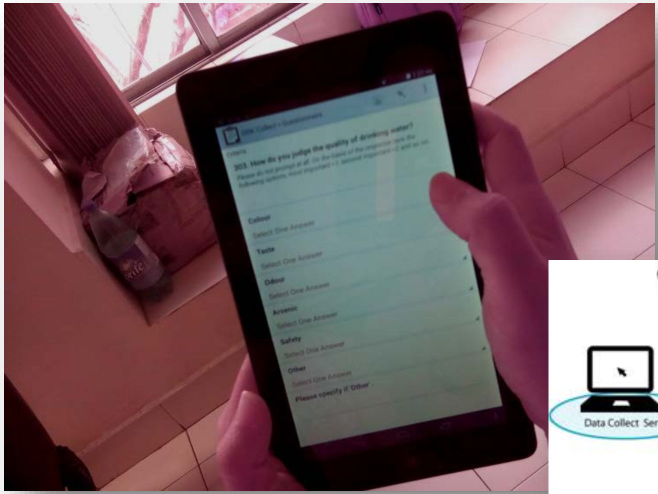
Communication with Dhapdhapi High School

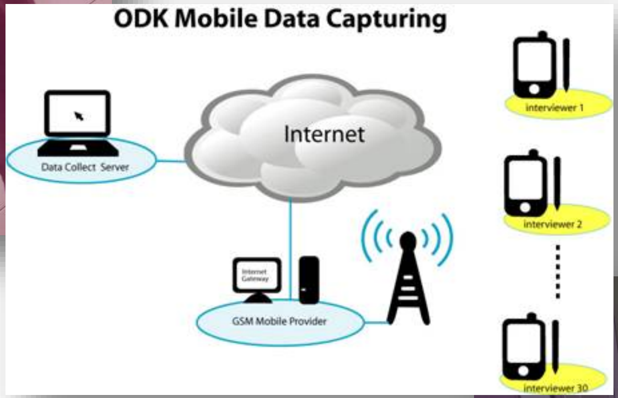
Global Change Programme
Jadavpur University
KOLKATA-700 032, INDIA

Communication with ATF

Assessing purchasing interest and ability

GCP-JU developing a field survey instruments using ODK – a tab based data collection and cloud computing method





There is additional collaboration between Berkeley and GCP-JU to undertake a similar field study on water pricing in a different location in September, 2014

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School students, teachers, and staff access free safe water from dispensing kiosk with electronic cards since September 2017. Rest of the safe water is sold to the community households at **Rs. 6.00** for **10L**. Pilot plant capacity is **10,000 Liters per day.** Water fully meets IS 10500:2012

Pre paid
Water ATM card

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Design for “User Experience” or Front End

(a) sample of the water-debit cards distributed to the students and teachers of Dhapdhapi. In Bengali, the cards say, “Let us protect our and our family’s health, by using arsenic-free water from arsenic-safe sources"

(b) a school girl that has just received her own card with spaces for name, grade level, roll number, and water card number,

(c) automatic water dispensing units installed for water delivery

(d) a water queue formed during first water distribution in September 2016.

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With grateful acknowledgement of support from:

DEVELOPMENT IMPACT LAB
A USAID Development Lab
Headquartered at UC Berkeley

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CENTER FOR RESPONSIBLE BUSINESS

SIEMENS | Stiftung

ज्ञान-विज्ञान विमुक्तये
UGC
University Grants Commission

BLUM CENTER
FOR DEVELOPING ECONOMIES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

P3 award competition
people prosperity planet
a student design competition for sustainability

Reed Elsevier

THE UNIVERSITY OF CALIFORNIA BERKELEY
LET THERE BE LIGHT
1868

BERKELEY LAB

UNIVERSITY of CALIFORNIA
OFFICE OF THE PRESIDENT

The Andrew and Virginia Rudd Family Foundation

NCIIA

Rudd Family Foundation
BIG IDEAS @BERKELEY

JEWISH COMMUNITY Teen FOUNDATIONS

ECAR is backed by science and engineering design and socio-economic analysis and large number of peer reviewed publications

- Delaire Caroline, Abhijit Das, Susan Amrose, Ashok Gadgil**, Joyashree Roy**, Isha Ray (2017), Determinants of the use of alternatives to arsenic-contaminated shallow groundwater: an exploratory study in rural West Bengal, India, *Journal of Water and Health,* 15.5, pp 799-812.

- Hernandez, D., K, Boden, P, Paul., S, Bandaru, Sreeman, Mypati., A, Roy., S, Amrose., **J, Roy**, A, Gadgil (2019), Strategies for successful field deployment in a resource-poor region: Arsenic remediation technology for drinking water, *Development Engineering*. https://doi.org/10.1016/j.deveng.2019.100045.

- Roy Joyashree (2008), Economic Benefits of from Arsenic Removal from Ground Water -:A Case Study of from West Bengal, India. *Science of the Total Environment*, (STOTEN), Vol 397/1-3 pp 1-12.

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- *Production and transformation of mixed valent nanoparticles generated from Fe(0) electrocoagulation.* K. Dubrawski, C.M. van Genuchten, C. Delaire, S.E. Amrose, A. J. Gadgil, and M. Mohseni, **Environmental Science and Technology**, ***2015***.

- *Electrochemical Arsenic Remediation: Field Trials in West Bengal,* Amrose, Bandaru, Delaire, van Genuchten, Dutta, Deb Sarakar, Orr, Roy, Das, Gadgil, **Science of the Total Environment**, 488-489:539-546, ***2014***.

- *Fe(III) Nucleation in the Presence of Bivalent Cations and Oxyanions Leads to Subnanoscale 7 Å Polymers,* van Genuchten, Pena, Gadgil, **Environmental Science and Technology**, 48: 11828-11836, ***2014.***

- *Structure of Fe(III) precipitates generated by the electrolytic dissolution of Fe(0) in the presence of groundwater ions,* van Genuchten, Pena, Amrose, Gadgil, **Geochimica et Cosmochimica Acta**, 127 :285–304, ***2014***.

- *Arsenic removal from groundwater using iron electrocoagulation: effect of charge dosage rate,* Amrose, Gadgil, Srinivasan, Kowolik, Muller, Huang, and Kostecki. **Journal of Environmental Science and Health, Part A**, 48(9):1019-1030, ***2013***.

- *Modeling As(III) oxidation and removal with iron electrocoagulation in groundwater,* Li, van Genuchten, Addy, Yao, Gao, and Gadgil. **Environmental Science and Technology**, 46(21):12038–12045, ***2012***.

- *Removing arsenic from synthetic groundwater with iron electrocoagulation: An Fe and As k-edge EXAFS study,* van Genuchten, Addy, Pena, and Gadgil. **Environmental Science and Technology**, 46(2):986–994, ***2012***.

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Thank You

ECAR team at the site , July 2016

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