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Lesson Plan 17: Chemical Parameters  
in the Drinking Water Quality Testing  
Trainer Manual.

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# Arsenic in Drinking Water



# Learning Expectations

1. Identify the health impacts of harmful levels of arsenic in drinking water
2. Discuss arsenic mitigation options

# Where Does Arsenic Come From?

- Natural in groundwater and some surface water
- Human activities



(Credit: WHO Synthesis Report on Arsenic in Drinking Water, 2002)

# Background Arsenic Levels

<b>Water Source</b>	<b>Typical Concentrations</b>
Rain and snow	< 0.03 ug/L
River water	< 2 ug/L
Lake water	< 1 ug/L
Seawater	1.5 ug/L
Groundwater	< 10 ug/L

# How Are We Exposed?

## Ingestion

- Drinking water  **Most significant**
- Eating food

## Absorption through skin

- Bathing
- Handling contaminated substances

## Inhalation

- Breathing sawdust or smoke from burning wood treated with arsenic
- Living in areas with high levels in rock

Usually minor

# What Does Arsenic Look Like in Water?

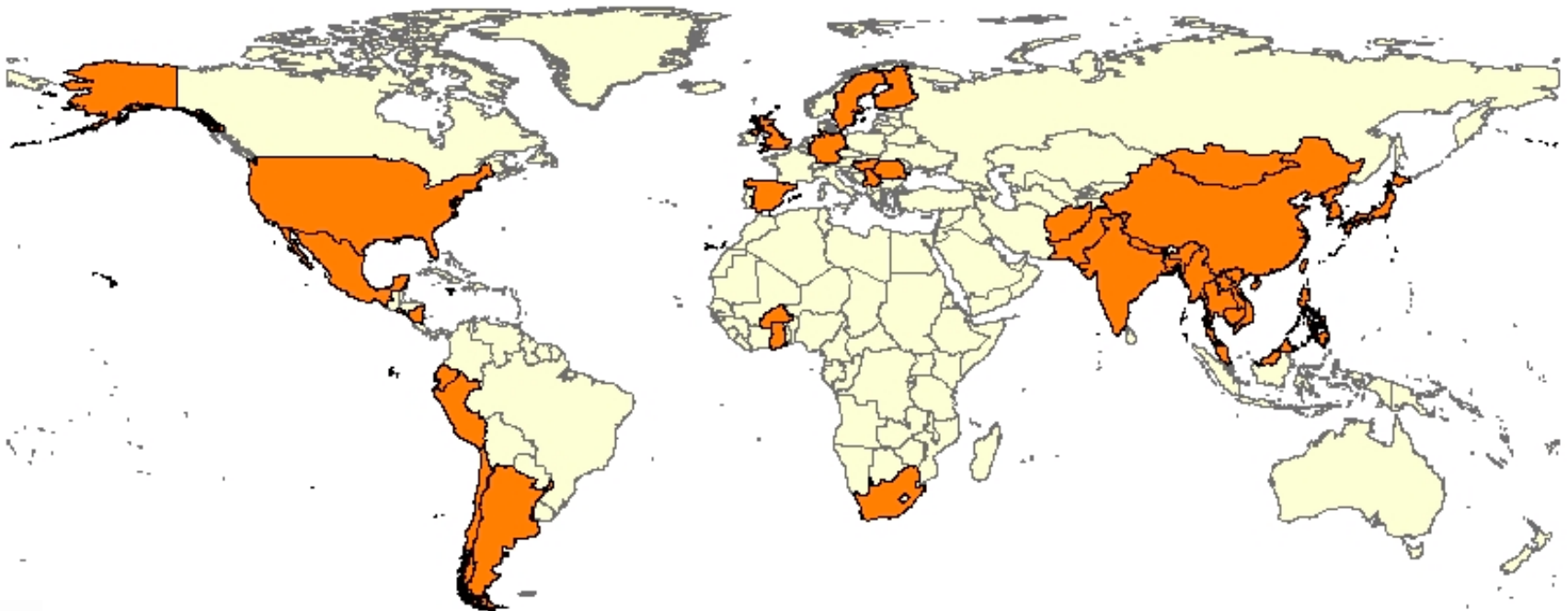
- Odorless, tasteless, colorless
  - There is only one way to tell if present – TESTING!
- Levels will vary significantly from well to well, even is close by
- Present in many conditions
  - Wet, dry





# Where in the World is Arsenic Found?

Countries Known to be Affected  
by Arsenic in their Drinking Water (2005)



(Credit: Zheng Gong, MIT Department of Civil and Environmental Engineering, 2005) 9

# Countries With Predicted Arsenic

**TABLE 4. State of Arsenic Contamination in Groundwaters in Different Countries of the World**

predicted contaminated regions with reported contamination			predicted contaminated regions with no measurements or reported contamination		
country	condition	% area <sup>b</sup>	country	condition	% area <sup>b</sup>
Bangladesh (2)	reducing	35.4	Estonia	reducing	37.2
Cambodia (25, 26)	reducing	45.8	Amazon basin <sup>a</sup>	reducing	32.6
Vietnam (8, 9, 25)	reducing	15.8	Lithuania	both	35.0
Taiwan (27)	reducing	8.2	Congo	reducing	30.1
Nepal (28)	reducing	3.2	Russia	both	14.8
Romania (29)	reducing	3.5	Myanmar	both	9.2
USA (7, 10, 23)	both	8.3	Poland	both	8.8
Argentina (30)	oxidizing	4.9	Cameroon	both	14.0
India (31)	both	6.4	Ukraine	oxidizing	7.0
China (4, 32)	both	2.5	Byelarus	oxidizing	3.3
Hungary (29)	reducing	7.4	Zambia	oxidizing	7.0
Finland (33)	unknown	34.7	Nigeria	oxidizing	9.0
Greece (34)	unknown	0.1	Angola	oxidizing	5.5
			Kenya	oxidizing	2.4
			Ethiopia	oxidizing	5.3

<sup>a</sup> Average values for Peru, Brazil, and Colombia. <sup>b</sup> % Area in each country with probability of arsenic contamination > 0.75



(Amini et al., *E, S & T*, March 2008)

# What Are the Health Effects?



# How Can We Prevent and Treat Arsenic Poisoning?

- Prevention
  - Drink arsenic-free water
  - Good nutrition
- Treatment
  - Switch to drinking arsenic-free water
  - Nutrition and vitamin supplements
  - Moisturizing and disinfecting infections in lesions
  - Some medicines; results not proven

(WHO Bulletin, 2000. Smith, Lingus & Rahman, "Contamination of drinking water by arsenic in Bangladesh: a public health emergency")

# Arsenicosis Reversal



(Credit: CAWST)

After receiving a rainwater harvesting tank through an Arsenic Mitigation Program in Bangladesh, Halima's symptoms of arsenicosis disappeared.

# Guidelines for Arsenic in Drinking Water

**WHO**                      **10 ug/L (ppb) = 0.01 mg/L (ppm)**

Australia                7 ug/L  
Canada                    25 ug/L  
EU                         10 ug/L  
Japan                      10 ug/L  
USA                        10 ug/L

Bangladesh            50 ug/L  
Cambodia                50 ug/L  
China                      50 ug/L  
India                       50 ug/L  
Lao                         50 ug/L  
Myanmar                50 ug/L  
Nepal                      50 ug/L  
Pakistan                 50 ug/L  
Vietnam                 10 ug/L urban, 50 ug/L rural



# How Do We Test for Arsenic?

- Test strips
- Colour reference charts
- Digital photometer



Test strips (Credit: Hach)



Colour comparison (Credit: ENPHO)



Digital photometer (Credit: Palintest)

# Arsenic Mitigation Options

## Arsenic Mitigation

```
graph TD; A[Arsenic Mitigation] --> B[Alternative Arsenic-Free Sources]; A --> C[Arsenic Removal Technologies];
```

### Alternative Arsenic-Free Sources

- Safe tube wells
- Improved dug wells
- Deep wells
- Rainwater harvesting
- Surface water

### Arsenic Removal Technologies

- Oxidation
- Coagulation
- Adsorption
- Surface Complexation



# Safe Tube Wells

**Tube wells with arsenic levels within the relevant standards**

Advantage:

- Immediate solution

Limitations:

- Need regular monitoring
- Convenient?
- Customs and religious restrictions?

Cost:

- Testing cost
- Drilling and installing shallow tube well costs ~US\$100-300



# Improved Dug Wells

**Cover existing dug wells to minimize microbiological contamination**

Advantages:

- Simple

Limitations:

- May dry up in dry season
- Risk of arsenic contamination
- Digging may not be easy
- Potential taste and smell problems

Cost:

- New: US\$1000+
- Rehabilitation: US\$300
- Minimal maintenance



# Deep Wells



## Deep wells to tap arsenic-free aquifers

Advantages:

- Generally no microbiological contamination

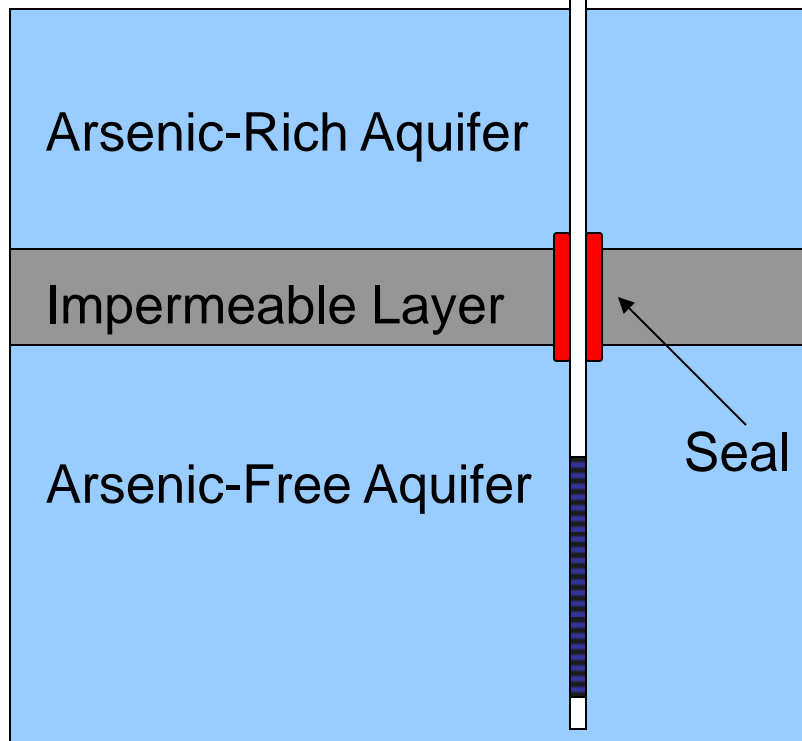
Limitations:

- Improper drilling/sealing → contamination
- Long-term arsenic levels unknown
- Appropriate geology not everywhere
- May require more sophisticated pump

Cost:

- US\$200-1000+

Minimal environmental impact



# Rainwater Harvesting



Collect rainwater from roof in storage tanks or containers for later use

Advantages:

- Low risk of microbiological contamination

Limitations:

- Rainfall pattern → may need large collection tank → higher cost
- Some roofs not suitable
  - Thatch

Cost:

- US\$200+ initial



# Surface Water

Treat surface water from ponds, rivers, springs, canals, etc.

Advantages:

- Low risk of arsenic contamination

Limitations:

- High risk of microbiological contamination
- Difficult to collect and transport (time and energy)

Cost:

- Cost of household or community water treatment



# Surface Complexation

## Example: *Kanchan*<sup>TM</sup> Arsenic Filter



### What is It?

- Adaptation of biosand filter: a layer of rusty nails is placed in the diffuser basin
- Also removes microbiological contamination

### How Does it Work?

- Arsenic adsorbed onto rusty iron nails
- Rust and arsenic flake off and caught in the biosand filter

### What is the Effectiveness?

- 85-95% arsenic removal

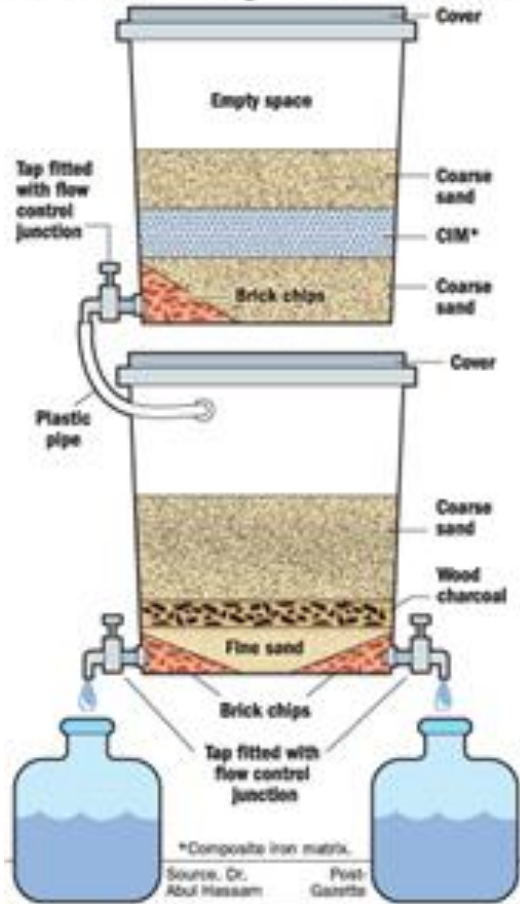
### Cost:

- US\$12-75 (depends on concrete or plastic)

# Surface Complexation

## Example: Sono (3-Kolshi) Filter

SONO filter: Cleaning arsenic from well water



(Credit: [www.robrasa.com](http://www.robrasa.com))

### What is It?

- Three bucket system with composite iron matrix (CIM)
- Also removes microbiological contamination

### How Does it Work?

- Manganese in CIM catalyzes oxidation of As(III) to As(V) which is removed by strong adsorption with CIM

### What is the Effectiveness?

- 90-95% arsenic removal

### Cost:

- US\$40-50

# Adsorption

## Example: MAGC-Alcan Filter

### What is It?

- Two buckets in series
- Both buckets filled with activated alumina

### How Does it Work?

- Adhesion of arsenic to activated alumina

### What is the Effectiveness?

- 80-85% arsenic removal

### Cost:

- US\$10 capital cost
- US\$10-15 activated alumina replacement cost/year





# Adsorption

## Example: Shapla Filter

### What is It?

- Brick chips coated with ferrous sulphate placed in a ceramic container

### How Does it Work?

- Adhesion of arsenic to the brick chips

### What is the Effectiveness?

- 80-90% arsenic removal

### Cost:

- US\$10 capital cost
- US\$10-15 brick chip with ferrous sulphate replacement cost/year



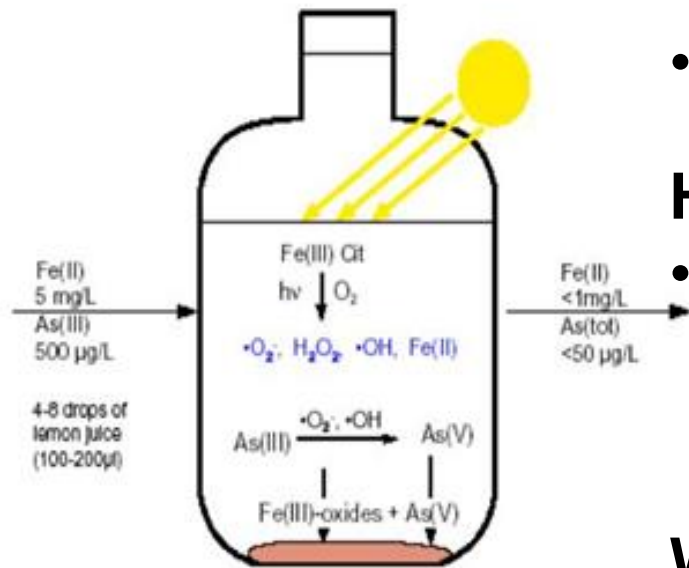
# Oxidation

## Example: Solar Oxidation and Removal of Arsenic (SORAS)

### What is It?

- Lemon juice added to water in a PET container and then placed in the sun
- Also treats microbiological contamination

Photo-oxidation and removal of As



### How Does it Work?

- As(III) oxidized to As(V), adsorbs to iron hydroxide in water, precipitates and settles to the bottom

### What is the Effectiveness?

- If iron > 8 ppm, 75-90% arsenic removal
- If iron < 5 ppm, <50 % arsenic removal

**Cost:** Minimal

# Coagulation

## Example: 2-Kolshi Filter

### What is It?

- Iron sulphate, sodium hypochlorite and ash are added to water and then filtered
- Also treats microbiological contamination

### How Does it Work?

- As(III) oxidizes to As(V), co-precipitates with iron, filtered to remove flocs

### What is the Effectiveness?

- 90% arsenic removal

### Cost:

- US\$10 capital cost
- US\$10-15 chemical replacement cost/year



# Review

1. What are the health impacts of excessive arsenic in drinking water?
2. What are some of the mitigation options for arsenic in drinking water?