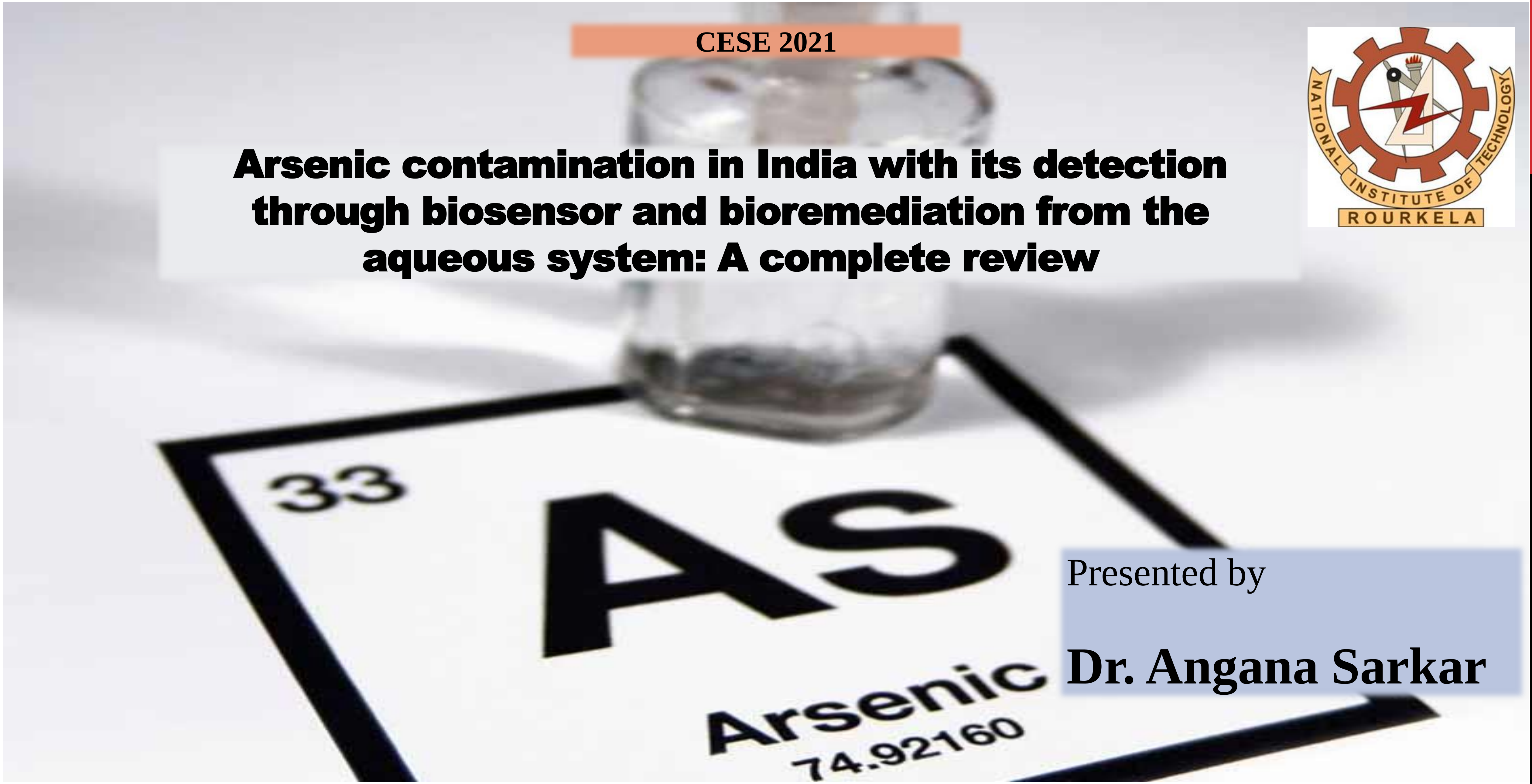
CESE 2021

# Arsenic contamination in India with its detection through biosensor and bioremediation from the aqueous system: A complete review




Presented by

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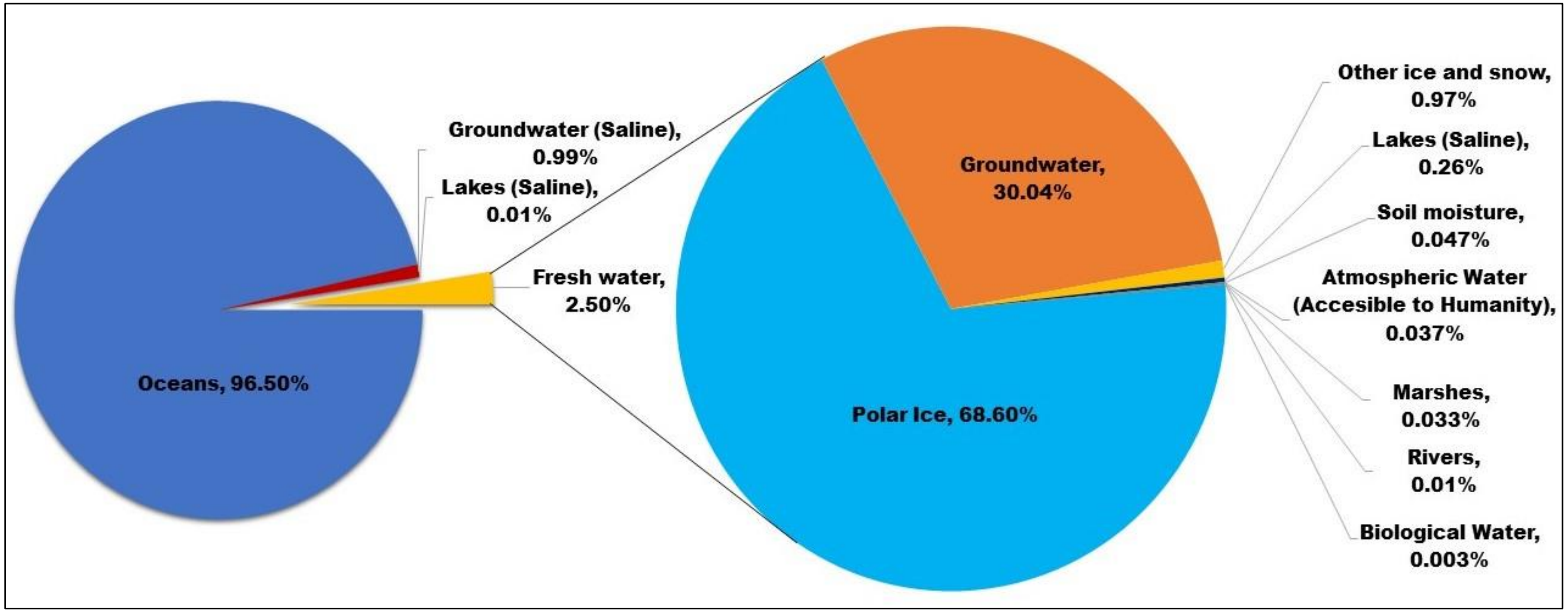
# INTRODUCTION

- Water is the main constituent of Earth's atmosphere.
- The progressive destruction, worldwide shortage, and excessive contaminations of water resources along with unfavorable activities build on a wide range of water crises across the world.
- About 71% of Earth's surface i.e. 2/3rd is surrounded by water, but a small bit of water happens to be freshwater i.e. 2.5%

## Global Water Scenario



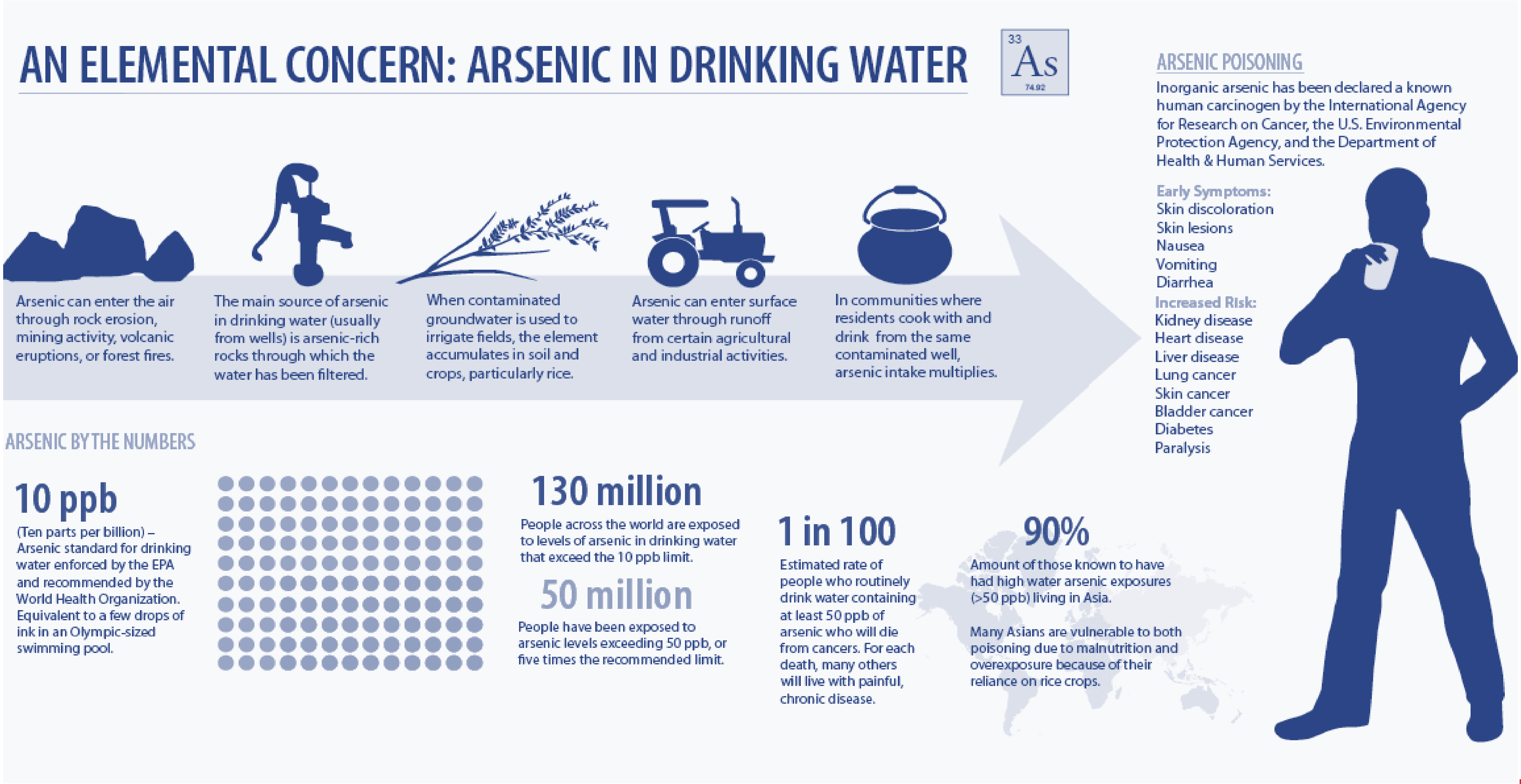
# Groundwater contamination

- Groundwater is considered an essential wellspring of drinking water, as it is more convenient and cheaper, and being less exposed to pollution than surface water.
- The recent few decades have witnessed a rise in the number of both geogenic and anthropogenic contaminants proving to be a genuine danger for groundwater use.
- Primary sources for anthropogenic contamination come from industries, sewage disposal, and agricultural activities.

## Major groundwater contaminants

- Nitrate
- Arsenic
- Chromium
- Iron
- Manganese
- Nickel
- Fluoride
- Cadmium
- Cobalt
- Lead
- Mercury
- Zinc

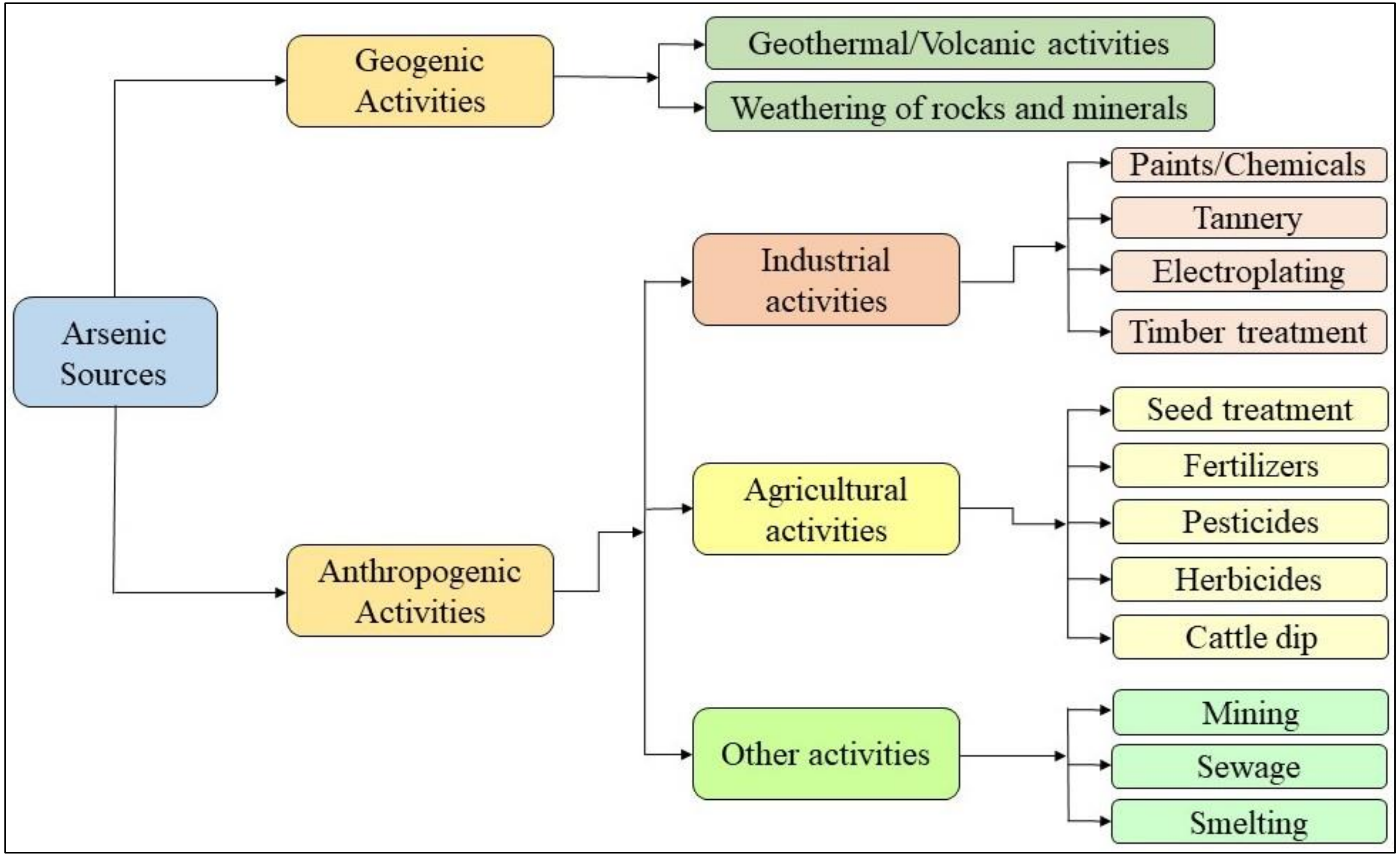
# Groundwater Arsenic contamination




Source: The Circle of Blue http://www.circleofblue.org/2011/world/infographic-an-elemental-concern-arsenic-in-drinking-water/

# Sources of arsenic in groundwater

- Arsenic appears as a constituent in more than 200 minerals.
- Arsenic is commonly found associated with sulfate/sulfide, chlorides, and oxides.



# Mechanism of arsenic mobilization in groundwater

Following three hypotheses have been proposed for the above cause:

- ❑ Oxidation of arsenic-rich pyrite followed by arsenic liberation.
- ❑ Reductive dissolution of iron hydroxides followed by adsorbed arsenic liberation into the groundwater.
- ❑ Anionic exchange between adsorbed arsenic and phosphate from fertilizers .

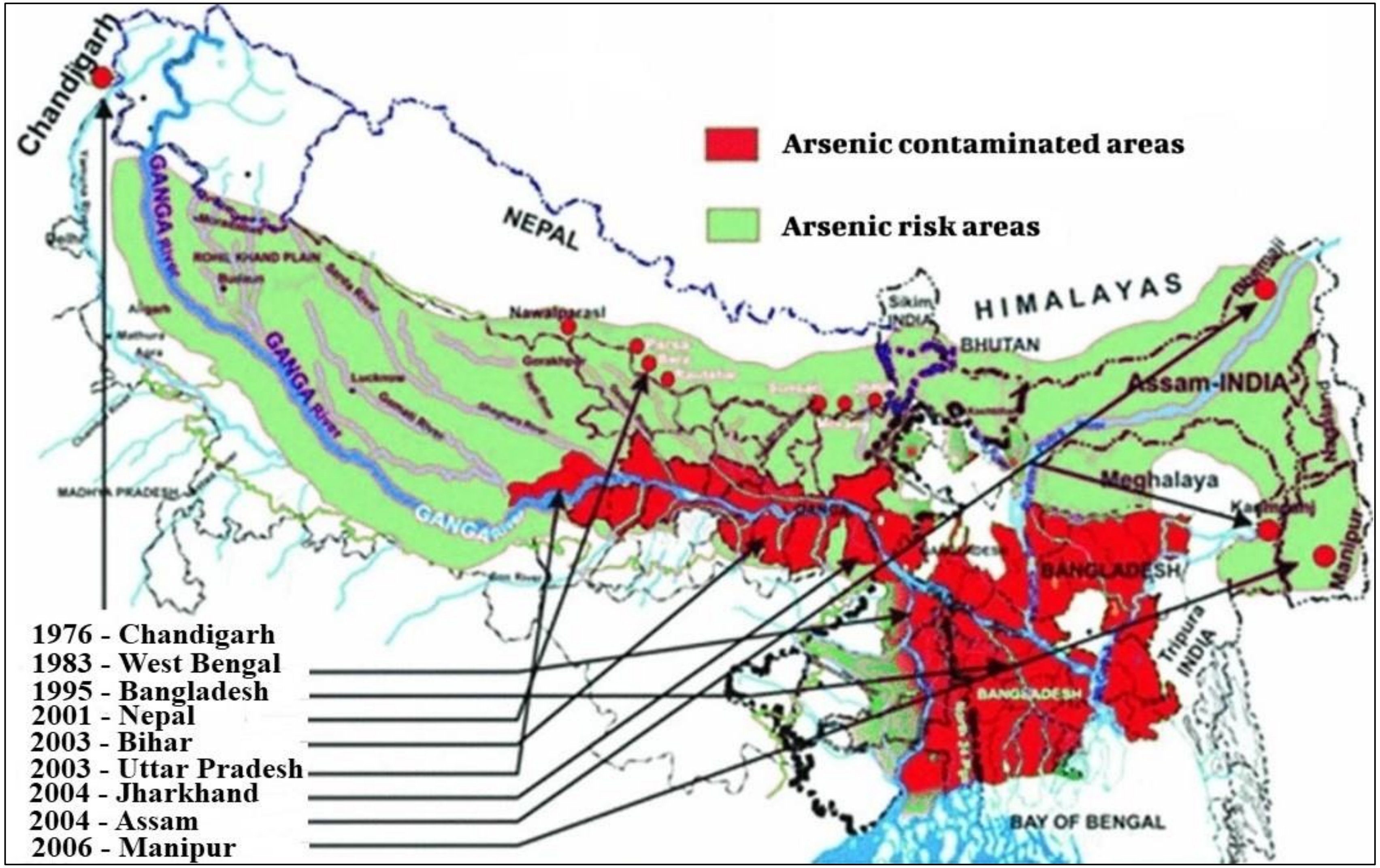
## Arsenic mobilization in shallow aquifers

- ❑ Oxidation of sulfide minerals has been upheld firmly as the primary cause of arsenic contamination in groundwater.
- ❑ This oxidation is only possible in some portions of aquifers, specifically in shallow aquifers.
- ❑ The chemical reaction is expressed as:

$$2FeS_2 + 9O_2 + 4H_2O \rightarrow 8H^+ + 4SO_4^{2-} + 2Fe(OH)_3$$

- ❑ Adsorption of arsenic to iron oxides is generally strong, resulting in low aqueous concentration under aerobic and acidic to neutral conditions
- ❑ Although at a high pH level (>8.5) the adsorption interaction gets weak, resulting in desorption of arsenic from oxide surface and an increase in dissolved concentrations. Such systems were accountably considered for the liberation of arsenic in these sedimentary aquifers.

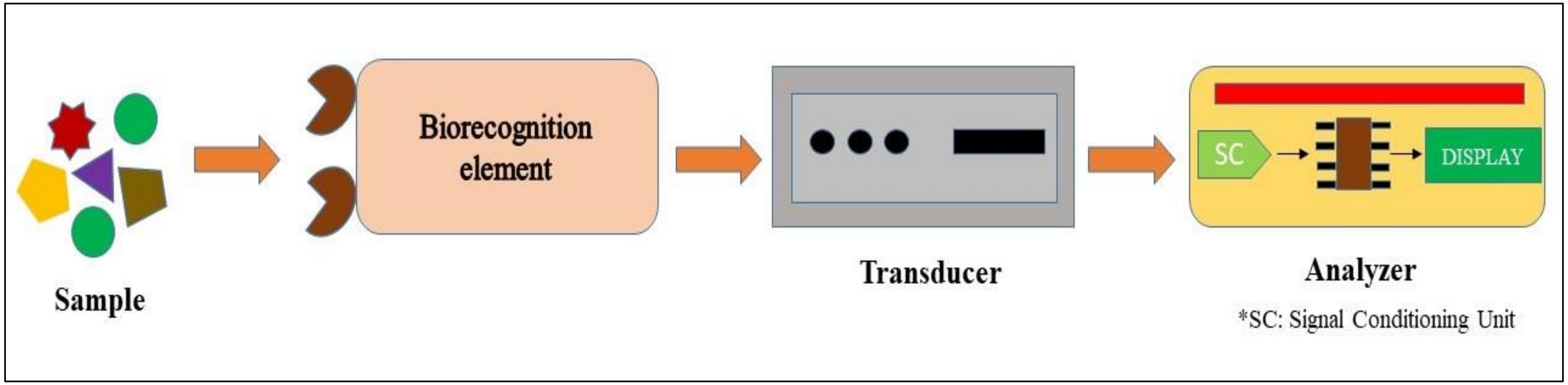
# Groundwater Arsenic Contamination in Ganga-Meghna-Brahamaputra Plain with year of Identification



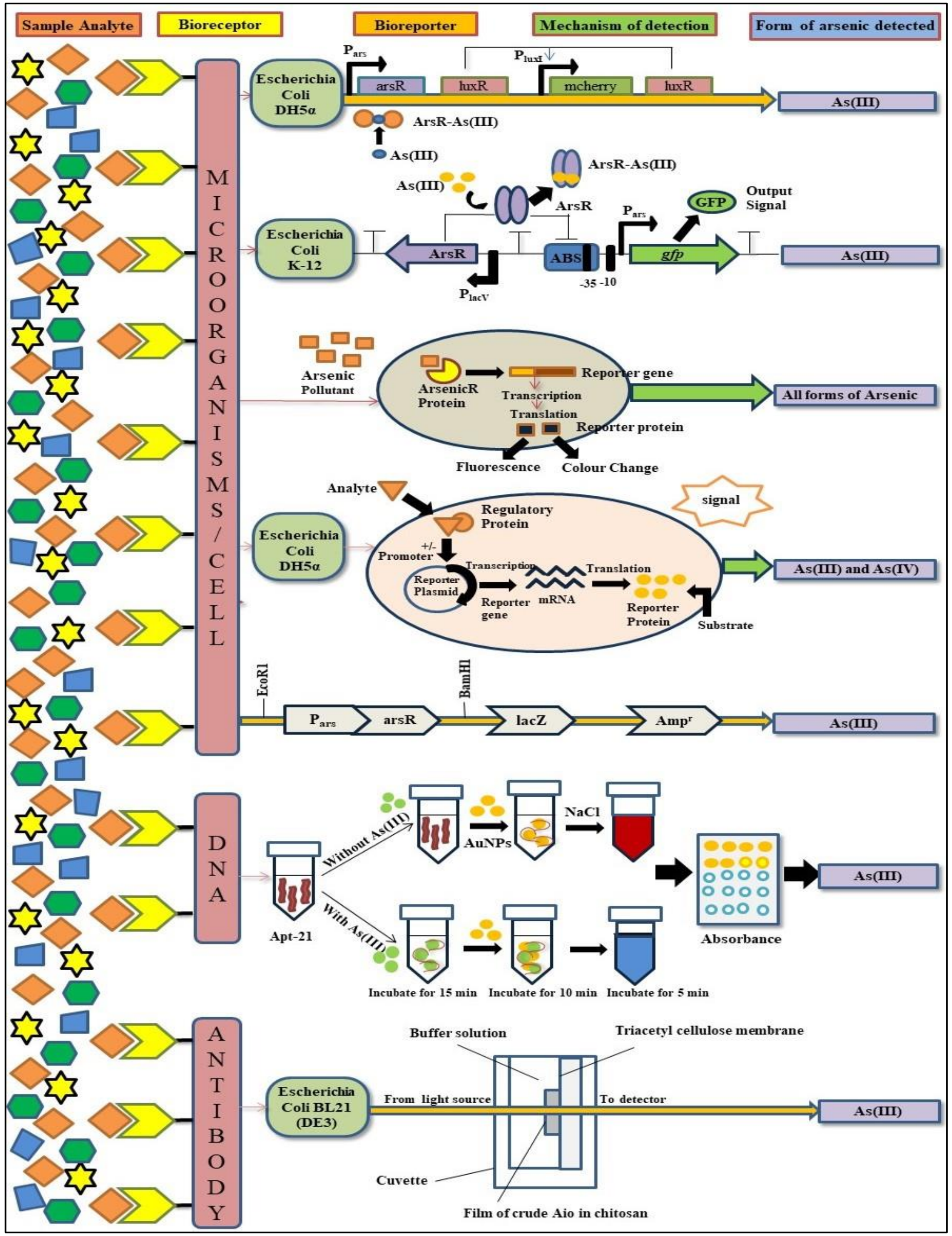
# Detection of Arsenic in an aqueous system using Biosensor

## What is a biosensor

- A biosensor is a scientific device where a response that is biological in nature is converted to an electrical signal.
- A biosensor basically integrates a biological element with the help of a transducer that is physicochemical in nature.
- The signal generated is in proportion to a single analyte which is then finally transmitted to a detector.
- Biosensors provide better sensitivity and stability than other standard methods.




**Components of Biosensor**

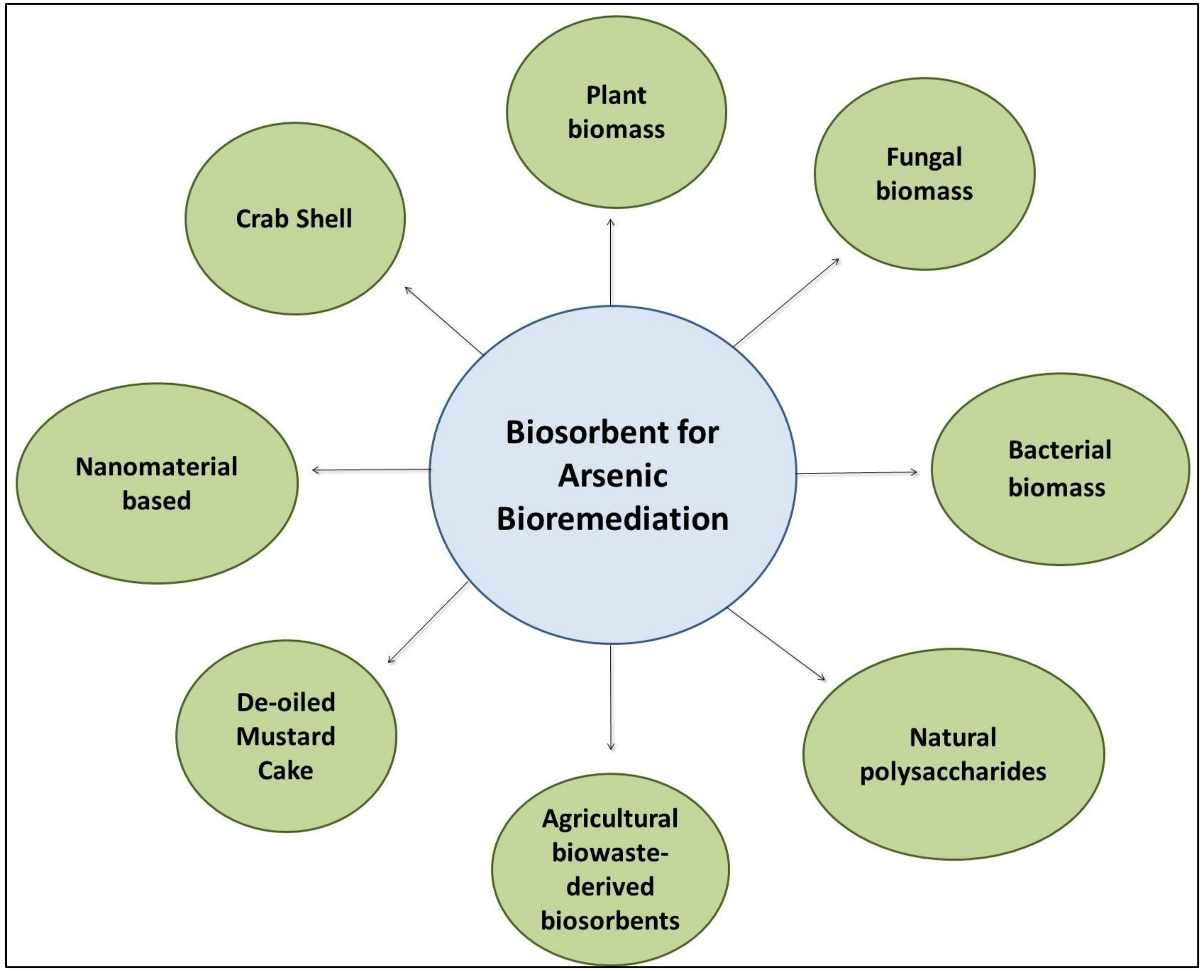



# General mechanism of arsenic biosensor

| Type of biosensor | Biological element used | Form of Arsenic detected | Limit of detection | References |
|---|---|---|---|---|
| Bacterial biosensor | *Escherichia coli* strain BL21(DE3) | As(III) & As(V) | 1 and 3 µM respectively | Daneshpour et al., 2014 |
| | FGE-sulfatase-based bacterial biosensor | As(III) | 5 µg/L | Sangkaew et al., 2019 |
| | *Escherichia coli* - DH5α cells | As(III) | Range of detection: 10–150 µg/L | Ivanina and Shuvaeva., 2009 |
| Whole-cell biosensor | Photosynthetic bacterium *Rhodovulum sulfidophilum* | As(III) | 3 µg/L | Fujimoto et al., 2006 |
| | *Escherichia coli* K-12 genome | As(III) | Range of detection: 0.1 to 4 µM | Chen et al., 2019 |
| Nanomaterial based biosensors | Glutathione-capped CdTe Quantum Dots | As(III) | $5.0 \times 10^{-6}$ to $25 \times 10^{-5}$ mol $L^{-1}$ | Wang et al., 2011 |
| | Au@Ag core–shell nanoparticles based biosensor | As(III) | Detection range: 0.5-10 µg/L | Song et al., 2016 |
| DNA biosensor | DNA functionalized single-walled carbon nanotube hybrids | As(III) | 0.05 µg/L | Liu and Wei., 2008 |
| | Self-assembled monolayer (SAM) of β-merceptoethanol (MCE) deposited on gold (Au) substrate | As(III) | $0.01 \times 10^{-6}$ g $mL^{-1}$ | Solanki et al., 2009 |

# Bioremediation of Arsenic from an aqueous system

- Bioremediation is an innovative and effective technique applied to neutralize or eliminate heavy metals that are present in water or contaminated soil.
- Biological organisms play an important role in the bioremediation of heavy metals like arsenic.




Bacterial biomass system bioremediation of arsenic could be classified into five different classes:

- Cytosolic arsenate reduction system
- Respiratory arsenate reduction *ARR* system
- Arsenite efflux system
- Respiratory arsenite oxidizing *Aio* system
- Methylation system

# CONCLUSION

- Shortage of water suitable for consumption is a matter of serious concern that is affecting humans over the past few decades.
- With the increase in urbanization and industrialization, water is getting contaminated with toxic heavy metals.
- Heavy metals like arsenic cause serious health concerns when they enter the human body beyond a certain limit.
- Several Indian states are greatly affected due to the presence of toxic heavy metals like arsenic present both in surface and groundwater.
- Biosensors being highly sensitive and selective in nature could be used for the detection of arsenic in water.
- The arsenic detected can be neutralized or eliminated with the help of biological organisms by the process of bioremediation.
- It is a cost-effective and efficient process that has replaced the traditional methods of remediation.
- The process has become successful over time and the concepts can be used to develop biofilters for such neutralization purposes.

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