

Topics to learn

A. Chemistry

- As(III) ↔ As(V) oxidation reactions
- Iron oxidation & precipitation
- Adsorption chemistry of GFH
- Competing anions (phosphate, silica)
- Chlorination chemistry
- pH effects

B. Water treatment

- Sedimentation & turbidity control
- Iron removal
- Media adsorption (EBCT, breakthrough curves)
- UV/chlorine disinfection

C. Hazardous waste management

- Arsenic sludge stability
- Safe disposal pathways
- Regulatory guidelines

D. Basic hydrodynamics

- Flow rate
- Pressure drop
- Pumping & solar power compatibility

Glossary of must-know terms

- **Arsenite (As III)**
 - Toxic form of arsenic that does not adsorb well. Must be oxidized.
- **Arsenate (As V)**
 - Easily adsorbed form of arsenic. Target product after oxidation.
- **Adsorption**
 - Process where contaminants stick to a media surface (GFH).
- **Granular Ferric Hydroxide (GFH)**
 - Iron-based media used to remove As(V). Single-use, not regenerable.
- **Breakthrough Curve**
 - Graph showing when the filter stops removing arsenic effectively.
- **EBCT (Empty Bed Contact Time)**
 - Time water must spend in the media bed for proper adsorption.
- **Turbidity**
 - Cloudiness of water caused by suspended solids.
- **Oxidation**
 - Chemical reaction that adds oxygen or removes electrons.
Used to convert As(III) to As(V).
- **ORP (Oxidation Reduction Potential)**
 - Indicates how oxidizing/reducing the water environment is.
- **Co-precipitation**
 - Contaminants attach to particles that precipitate out of solution.
- **Disinfection**
 - Killing bacteria/viruses using chlorine or UV.
- **Hazardous waste**
 - Spent GFH containing arsenic — must be safely disposed.
- **Encapsulation**
 - Mixing arsenic-laden waste with cement so it cannot leach.

All key reactions + concepts

A. Arsenic Forms

- **As(III)** = arsenite → highly toxic, difficult to remove
- **As(V)** = arsenate → less toxic, easier to remove using GFH

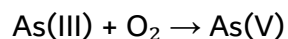
B. Oxidation Reactions

1. Chlorine oxidation



Arsenous acid + hypochlorous acid → dihydrogen arsenate + chloride ions + hydrogen ions

2. Aeration (slow)



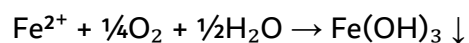
Arsenic(III) + oxygen → Arsenic(V)

3. UV-assisted oxidation

UV + oxygen → converts As(III) to As(V) more slowly than chlorine.

C. Iron Reactions (Important for pre-treatment)

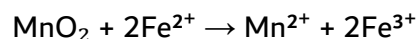
Iron oxidation



Ferrous iron + oxygen + water → ferric hydroxide precipitate ↓

This forms rust particles that must be filtered out.

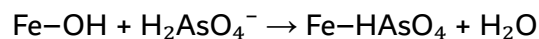
Catalytic iron removal (MnO_2 media)



Manganese dioxide + ferrous iron → manganese ions + ferric iron

D. GFH Adsorption Chemistry

GFH removes arsenic by adsorption onto iron-hydroxide surfaces.



Iron hydroxide + dihydrogen arsenate → iron arsenate + water

Important concepts:

- Best pH = **5.5–7.5**
- Competes with: **phosphate, silicate**
- Cannot be regenerated → becomes **hazardous waste**

E. Disinfection

Chlorine equilibrium



Hypochlorous acid $\rightleftharpoons$ hydrogen ion + hypochlorite ion

F. Sludge/Waste Handling

GFH after exhaustion contains **concentrated arsenic**.

Safe disposal:

- Dry
- Seal in double-layer bags
- Encapsulate (cement/sand)
- Dispose in hazardous waste facility

1. Arsenic chemistry you *must* know

1.1 Oxidation states of arsenic

Arsenic exists mainly in water as:

- **As(III)** → arsenite (more toxic, harder to remove)
- **As(V)** → arsenate (less toxic, easier to remove)

You must understand:

Why oxidation is required

GFH and iron-based media remove **As(V)** extremely well but remove **As(III)** poorly.

So first step in many systems:

Arsenic (III) → oxidation → Arsenic (V)

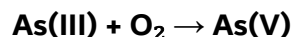
2. Oxidation reactions you should understand

2.1 Oxidation using chlorine (if used)



Arsenous acid + hypochlorous acid → arsenate + chloride ion + hydrogen ions

2.2 Oxidation using dissolved oxygen (slow)

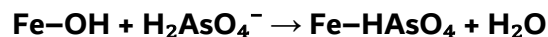


This reaction is very slow in natural groundwater, which is why oxidants or aeration are used.

3. Iron chemistry & adsorption — essential for GFH

GFH works via **adsorption**, not precipitation. You need to understand:

3.1 Surface binding mechanism



Iron hydroxide + arsenate → iron arsenate + water

This explains why:

- pH must be controlled (best between 5.5–7.5)
- Competing ions (phosphate, silica) reduce performance

- Media eventually saturates and must be replaced

3.2 Iron oxidation in water

If the water contains natural iron (Fe^{2+}):

Ferrous iron + oxygen + water $\rightarrow$ ferric hydroxide precipitate ($\downarrow$)



Why this matters:

Iron oxidation may cause clogging and must be treated before GFH or managed using coarser filters.

4. Filtration principles you should learn

You'll use several types of filters:

4.1 Sediment filtration

Removes turbidity, clay, suspended solids.

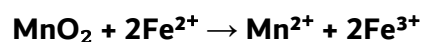
No chemistry, but essential:

- Prevents clogging of downstream media
- Allows GFH to function efficiently

4.2 Iron removal filtration

Often involves aeration + sand/manganese media.

Manganese dioxide catalytic reaction:



Manganese dioxide + ferrous iron $\rightarrow$ manganese ions + ferric iron

This produces iron particles, which are then filtered.

4.3 Adsorption media (GFH)

Concepts to know:

- Breakthrough curve
- Empty bed contact time (EBCT)
- pH dependence
- Competing anions

- Media exhaustion

5. Basic water-quality parameters

Parameter	Why it matters
pH	Controls adsorption efficiency of GFH
Iron (Fe)	Causes clogging, indicates need for iron pre-removal
Arsenic (As)	Target contaminant
Silica	Competes with arsenate on GFH
Phosphate	Competes strongly → reduces GFH life
Turbidity	High turbidity = rapid filter clogging
ORP (oxidation-reduction potential)	Tells you if As(III) or As(V) is present

6. Microbiological treatment concepts

If you will include a **chlorination or UV disinfection** step:

6.1 Chlorination



Hypochlorous acid $\rightleftharpoons$ hydrogen ion + hypochlorite ion

HOCl is the stronger disinfectant.

Concepts:

- CT value (concentration × time)
- Residual chlorine target (0.2–0.5 mg/L)

6.2 UV disinfection

Concepts:

- UV dose (mJ/cm^2)
- Pathogen inactivation kinetics
- Pre-filtration requirement (low turbidity)

7. Sludge & waste chemistry

After filtration, arsenic ends up as **adsorbed arsenic on GFH media**.

You must understand:

7.1 Why GFH cannot be regenerated easily

Because arsenate binds strongly to Fe–OH surfaces.

7.2 Why GFH is hazardous waste

Spent media contains concentrated arsenic.

7.3 Leaching tests (TCLP)

To ensure arsenic doesn't leach back out during disposal.

7.4 Safe disposal steps

- Drying
- Double-bagging
- Encapsulation in concrete or stabilized matrix
- Sending to hazardous waste landfill

(This is what India's CPCB and international guidelines recommend.)

8. Fluid dynamics & system engineering basics

Important concepts

- Head loss
- Flow rate in LPH
- Gravity vs pumped flow
- Pressure drop across media beds
- Residence/contact time

These help you size:

- Borewell pump
- Pipe diameter
- Filter dimensions
- Backwash rates (if applicable)