# PHARMACEUTICAL ENGINEERING

## UNIT 5 NOTES

### MATERIALS OF PLANT CONSTRUCTION

- FACTORS AFFECTING MATERIALS OF PLANT CONSTRUCTION

### CORROSION

- THEORIES OF CORROSION
- TYPES OF CORROSION
- PREVENTION

IMPERFECT PHARMACY

# PHARMACEUTICAL PLANT CONSTRUCTION

- For manufacturing of pharmaceuticals, bulk drugs, antibiotics and various other biological products, a number of equipments used.
- A wide variety of materials are used for manufacturing of these equipments.
- Now selecting appropriate materials for pharmaceutical plant construction is crucial to ensure product quality, process efficiency & regulatory compliance.

## FACTORS AFFECTING CHOICE OF MATERIAL

Several factors influence the choice of materials for pharmaceutical plant construction as follows:

- Physical Factors
- Chemical Factors
- Economical Factors
- Regulatory Compliance
- Environmental & Safety Considerations

## ① Physical Factors

Various physical factors can affect choice of material for pharmaceutical plant construction.

- **Strength & Durability :** Materials must endure mechanical stresses, pressure and wear during operations. Steel and iron are commonly used for their strength in handling high pressure application.

- **Thermal Properties :** Consideration of thermal conductivity and expansion is essential, especially in processes involving significant temperature variations. Materials with suitable thermal properties prevent structural deformations and maintain process efficiency.

- **Ease of Fabrication & Maintainance :** Materials that are easy to fabricate and maintain can reduce construction & operational costs. For instance plastics can be mould into various shapes, facilitating equipment design flexibility.

- **Cleanability & Sterilization :** Surfaces of materials should be smooth for easy cleaning and sterilization, maintaining hygienic conditions essential in pharmaceutical production.

## ② CHEMICAL FACTORS

Following chemical factors affect the choice of material for pharmaceutical plant constructions as follows :

- **Corrosion Resistance :** Materials must withstand exposure to various chemicals without degrading. Steel stainless steel is often preferred for its corrosion resistant properties.

- **Contamination Prevention :** The choosen material should not react with pharmaceutical substances, ensuring product purity and safety.

## ③ ECONOMICAL FACTORS

- **Cost Effectiveness :** The cost & maintainance of pharmaceutical plant should be economic, considering both initial investment & long term maintainance cost. Selecting materials that require lower maintainance can be more cost-effective over time.

## ④ REGULATORY COMPLIANCE

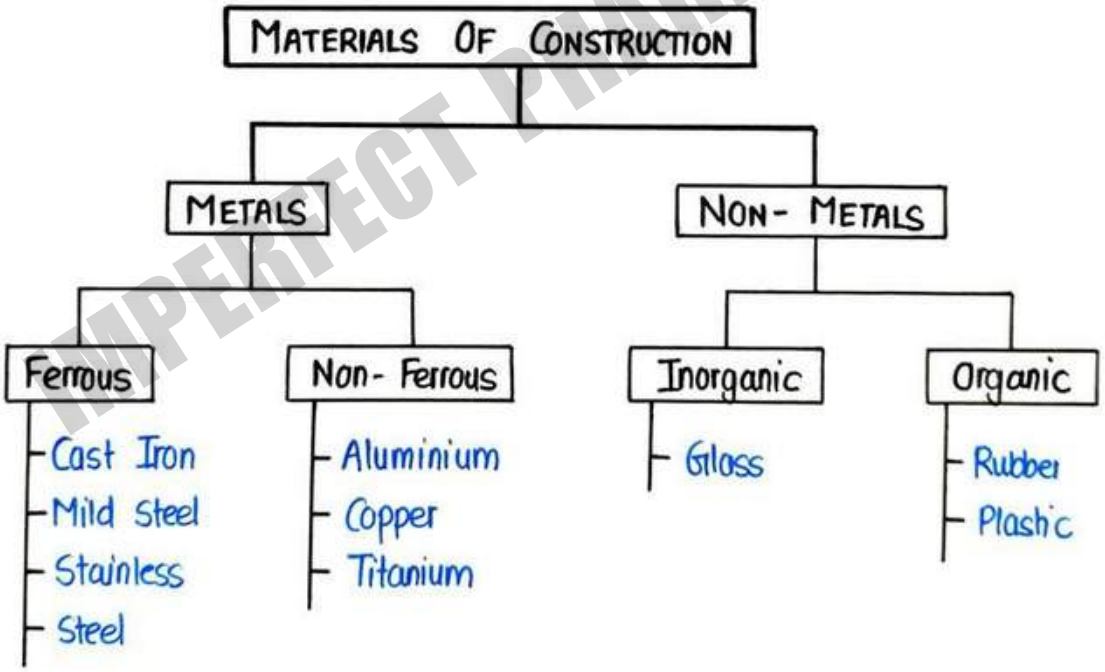
- Materials must meet industry standards and regulations to ensure product safety and quality.
- They should comply with guidelines of FDA.

## ⑤ Environmental & Safety Considerations

- Selecting environmentally friendly materials and considering both workers and end-users is equally important.

# Classification Of Materials

The materials used for pharmaceutical plant construction can be classified as follows



## ① METALS

- Metals are class of materials that are typically hard, shiny and have good electrical & thermal conductivity.
- They are usually malleable, means they can be pounded into various shapes without breaking i.e., they can be stretched into thin wires.
- They are further divided into two types :

(1) Ferrous Metals
(2) Non- Ferrous Metals

### (1) FERROUS METALS

- Ferrous Metals contain iron as their principal element and are alloyed with other materials with enhanced properties :
- They generally include

ⓐ Mild Steel
ⓑ Cast Iron
ⓒ Stainless Steel



ⓐ **Mild Steel** :
- It contains low carbon content (up to 2%)
- It is very hard & has greater mechanical strength.
- It is used in construction of bars, pipes and plates.
- However, It has limited corrosion resistance, so it's commonly used where no chemical exposure occurs.

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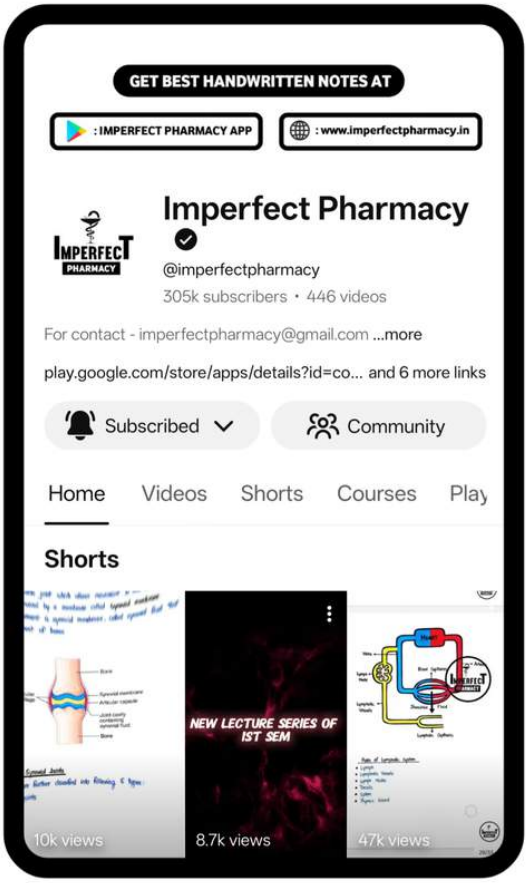


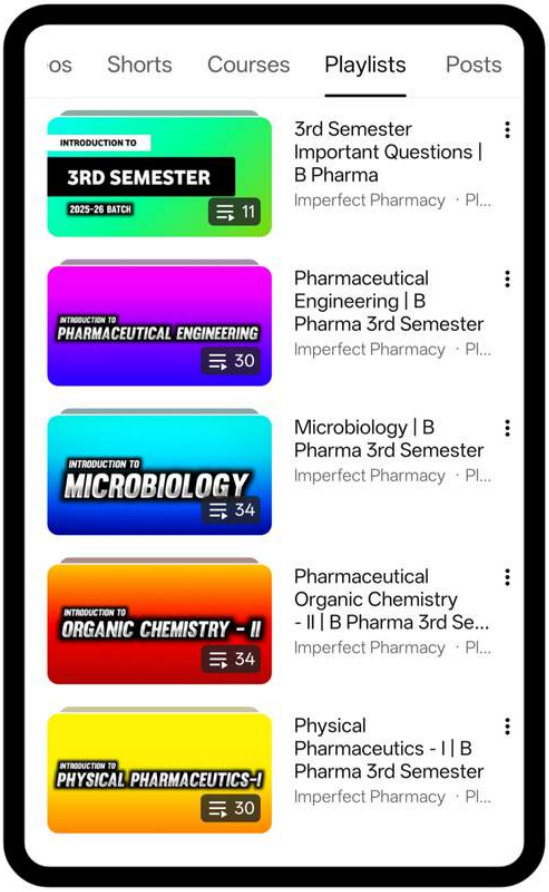


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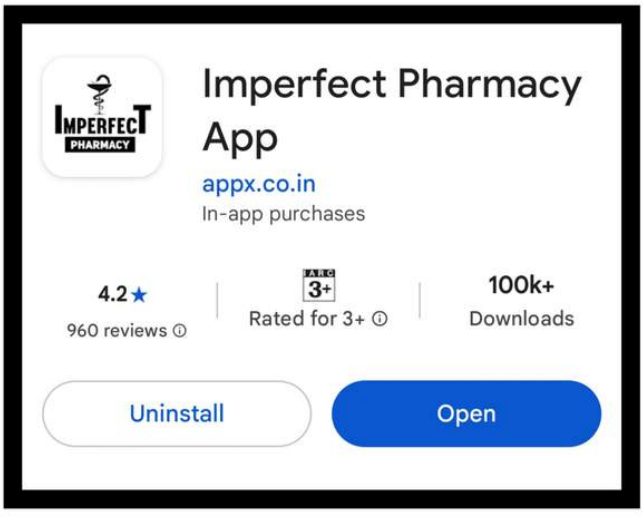


ⓑ **Cast Iron** :
- It consist of carbon with proportion of carbon.
- It is used widely due to its high availibility & inexpensiveness.
- It is used to make jacket of steam pans.
- It is susceptible to corrosion, so it's coated for protection when needed.

ⓒ **Stainless Steel** :
- It is an alloy of iron
- It usually contains chromium & nickel which makes the steel corrosion resistant.
- It is abundantly used in pharmaceutical plant constructions due to its :
  - Heat Resistance
  - Corrosion Resistance
  - Cleaning & Sterilization



## (2) NON-FERROUS METALS

- These metals are lightweight and corrosion-resistant
- There are following non-ferrous metals that are mainly used in pharmaceutical plant construction :

ⓐ Aluminium
ⓑ Copper
ⓒ Titanium

ⓐ **Aluminium** :
- Aluminium is a cheap, lightweight & corrosion resistant metal widely used in pharmaceutical plant construction.
- It is mainly used for transport containers (such as Drum, barrels)

ⓑ **Copper** :
- It has excellent thermal & electrical conductivity.
- It is commonly used in heating & cooling systems and electrical wiring.

ⓒ **Titanium** :
- It is lightweight, having high strength and offers excellent corrosion resistance.
- It is used in critical applications, such as heat exchanger and equipment exposed to aggressive chemicals.

## ② NON - METALS

- Non- Metals are elements that typically lack the characteristics of metals.
- They are generally poor conductors of heat and electricity and have lower & melting boiling points.
- They are of two types :

(1) Organic Non- Metals
(2) Inorganic Non- Metals

### (1) ORGANIC NON- METALS

- They are derived from organic compounds, these materials are valued for their flexibility, lightweight & resistant to chemical attack.
- Following organic non- metals are commonly used in pharmaceutical plant construction.

ⓐ Rubber
ⓑ Plastics

ⓐ **Rubber** :
- It is often used as lining for tanks and pipes to prevent corrosion.
- It provides insulation against friction and chemical reactions.

ⓑ **Plastics** :
- They are widely used in pharmaceutical plants due to their chemical resistance and ease of fabrication.
- Plastic containers are used for storing a number of substances such as inorganic salts & weak mineral acid.

## (2) INORGANIC NON- METALS

- These materials are derived from inorganic compounds, offering high chemical stability.
- It mainly consist of glass.

@ Glass :
- Glass has the advantages of superior protective qualities, attractiveness and low cost.
- It is transparent, inert and resistant to most chemicals.
- They are available in variety of sizes, shapes & colours.

# BASICS OF MATERIAL HANDLING SYSTEM

- Material Handling systems refer to the equipment, methods and processes used to move, store, control and protect materials throughout the manufacturing, distribution & disposal processes.
- In Pharmaceutical Industries, material handling is crucial to ensure product integrity, safety & efficiency.

## OBJECTIVES OF MATERIAL HANDLING SYSTEMS

- Efficient Movement : Minimize time & effort in material transportation.
- Safety : Ensure the safety of workers & materials during handling.
- Cost Effectiveness : Optimize resources to reduce operational cost.
- Product Integrity : Prevent contamination or damage to materials.
- Regulatory Compliance : Meet standards such as GMP.



## TYPES OF MATERIAL HANDLING SYSTEMS

① Manual Material Handling
② Mechanical Material Handling
③ Automated Material Handling
④ Bulk Material Handling Systems

## ① Manual Material Handling

- It relies on human effort to move and handle materials.
- Example : Lifting , carrying or pushing carts.

## ② Machanical Material Handling

- It uses equipment to move materials.
- Example : Cranes, Conveyors .

## ③ Automated Material Handling

- It employs automated systems to perform material handling tasks with minimal human intervention.
- Example : Robotics. Automated Guided Vehicles.

## ④ Bulk Material Handling Systems

- Designed for handling large quantities of materials.
- Example : Belt Conveyors.



### ADVANTAGES

- Improved Productivity
- Enhanced Safety
- Flexibility
- Better Quality Control

# CORROSION

- Corrosion is defined as as natural process occurring due to chemical reaction b/w a metal & the environment that changes the properties of metal.
- It leads to gradual degradation & deterioration of a material.
- It is an oxidation process.
- It often results in the formation of more chemically stable oxides, hydroxides or other compounds, which weaken the material's structural integrity & functionality.
- It can occur under various environmental conditions, such as exposure to air, moisture, chemicals or certain gases.
- Example: Formation of rust on the surface of Iron.

## THEORIES OF CORROSSION

- Theories of corrosion explain the processes and mechanisms by which corrosion occurs in metals.
- The three most widely accepted theories are:

① Acid Theory
② Dry Theory
③ Electrochemical (Galvanic) Theory

## ① Acid Theory Of Corrosion

- This theory states that corrosion occurs due to the presence of acids in the environment.
- These acids, such as Carbonic acid, formed by reaction of atmospheric carbon di oxide with water reacts with metals like Iron.

$$H_2O + CO_2 \longrightarrow H_2CO_3 \text{ (Carbonic Acid)}$$
$$Fe + H_2CO_3 \longrightarrow FeCO_3 + H_2\uparrow$$

## ② Dry Corrosion Theory

- Dry corrosion occurs due to the direct chemical interaction of a metal with its environmental gases, primarily in the absence of moisture
- It can be further divided into 3 types:

ⓐ Oxidation Corrosion (Due to Oxygen)
ⓑ Corrosion by other Gases
ⓒ Liquid metal corrosion



ⓐ **Oxidation Corrosion**: Metal directly reacts with oxygen in the absence of moisture to form Metal Oxides

$$2Cu + O_2 \longrightarrow 2CuO$$
$$4Fe + 3O_2 \longrightarrow 2Fe_2CO_3$$

ⓑ **Corrosion By Other Gases** : Halogens ( Cl, Fl, Br) or sulfer can react with metals to form Halides or sulfides.

$$Ag + 1/2\,Cl_2 \longrightarrow AgCl$$

© **Liquid Metal Corrosion** : This type of corrosion occurs when a solid metal comes into contact with liquid metal.

$$Zn + Hg \longrightarrow ZnHg$$

## ③ GALVANIC ( ELECTROCHEMICAL THEORY )

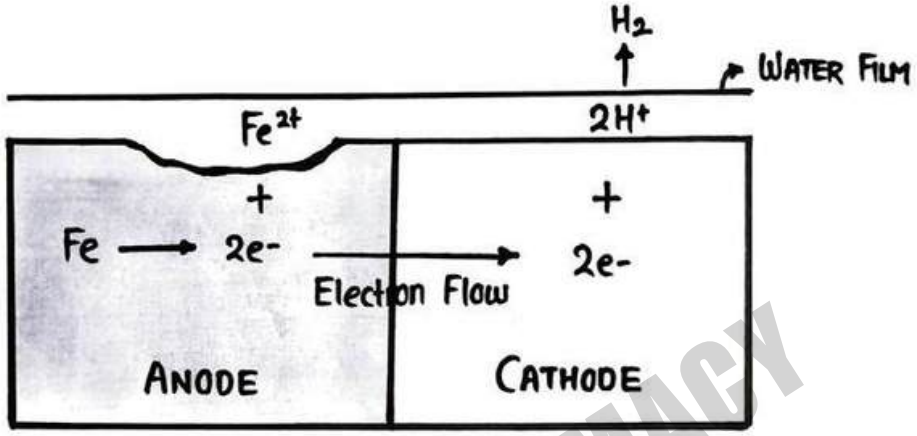
- This is the most widely accepted theory of corrosion.
- It describes corrosion as an Electrochemical process involving the transfer of electrons between two different points on the same metal or between two dissimilar metals in contact.
- It can be further subdivided into two types :

ⓐ Corrosion Reaction on Single Metal

ⓑ Corrosion Reaction between two different Metals

## @ Corrosion Reaction On Single Metal

It occurs when a metal interacts with its environment, forming an electrochemical cell with cathodic and anodic regions on the same metal in the presence of water or Electrolyte.




### Reactions at Anode (Oxidation)

$$Fe \longrightarrow Fe^{2+} + 2e^-$$

### Reactions at Cathode (Reduction)

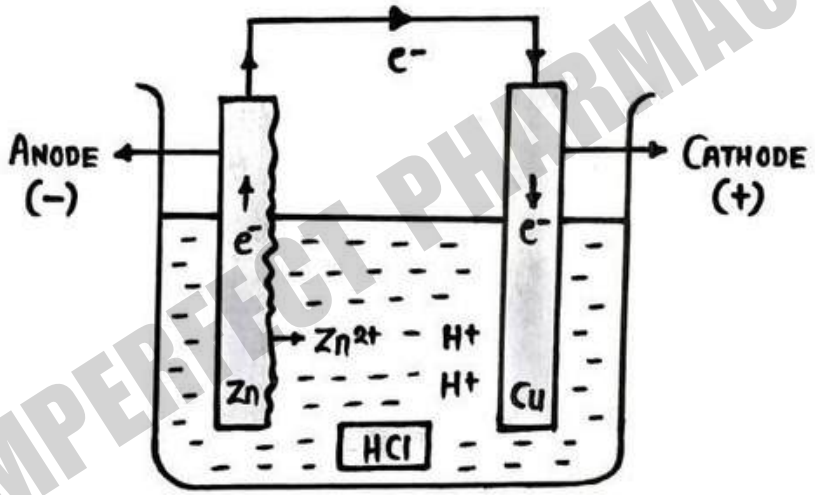
$$2H^+ + 2e^- \longrightarrow H_2 \uparrow$$

## ⓑ Corrosion Reaction Between Different Metals

- It is also known as Galvanic Cell Corrosion.
- It occurs when two dissimilar metals come into electrical contact in the presence of an Electrolyte.

### Key Features :

- Anode & Cathode : The more active metal acts as the anode & corrodes while the less active metal acts as the cathode.
- Electrolyte : It acts as the conducting medium to allow the flow of ions.






### Reactions

- At Anode (Oxidation) : $Zn \longrightarrow Zn^{2+} + 2e^-$
- At Cathode (Reduction) : $2H^+ + 2e^- \longrightarrow H_2 \uparrow$

# Types Of Corrosion

It can be divided into following types:

- Uniform Corrosion
- Pitting Corrosion
- Crevice Corrosion
- Stress Corrosion
- Galvanic Corrosion
- Erosion Corrosion
- Microbial Corrosion

## ① Uniform Corrosion

- It is a type of corrosion that occurs evenly across the surface of a material, typically metal, due to exposure to environmental factors such as moisture, oxygen or chemicals.
- Its predictable and often manageble through regular maintainance and protective coatings.

## ② Pitting Corrosion

- Pitting corrosion is a localized form of corrosion that creates small, often deep pits or holes in the surface of a material.
- This type of corrosion is usually caused by the presence of chloride ions, acidic environments or lack of protective oxide layers.

## ③ Crevice Corrosion

- Crevice stands for Cleavage.
- It is a form of localized corrosion occurs in confined places when solutions can accumulate, such as gaps, joints.
- It is common in steel and other metals exposed to chloride rich environment.

## ④ Stress Corrosion

- This type of corrosion results from the combine action of Mechanical stress and a corrosive environment.
- It often leads to formation and propagation of cracks.

## ⑤ Galvanic Corrosion

- It occurs when two dissimilar metals are in electrical contact in an electrolyte.
- The more active metal corrodes preferentially.

## ⑥ Erosion Corrosion

- It is caused by the relative movement between a fluid and a metal surface, leading to the removal of protective oxide layer & accelerated material loss.

## ⑦ Microbial Corrosion

- It is a type of corrosion caused by action of microorganisms.
- It is frequently observed in pipelines & storage tanks.

# PREVENTION OF CORROSION

Corrosion can be minimized or prevented through various methods, depending on the material, environment and type of corrosion.

① Protective Coatings
② Material Selection
③ Environmental Control
④ Corrosion Inhibitors
⑤ Design Modifications
⑥ Regular Maintainance

## ① Protective Coatings

- The application of a paint or powder coating is a cost effective way of preventing corrosion.
- They form a barrier between the metal and the environment.

## ② Material Selection

- Using corrosion resistant materials like stainless steel, aluminium, titanium or plastic is the most simple and effective way to prevent corrosion.

## ③ Environmental Control

- Corrosion is caused by a chemical reaction between the metal and gases in the surrounding environment.
- Reducing exposure to moisture and electrolytes can minimize the corrosion

## ④ Corrosion Inhibitors

- Corrosion Inhibitors are chemicals that react with the surface of the metals or surrounding gases to suppress electrochemical reactions.
- They applied on surface of a metal, where they form a protective film.

## ⑤ Design Modification

- During designing of equipments, sharp corner & crevices must be avoided as they are prone to localized corrosion.
- Use smooth designs with fewer joints.
- Design should avoid trapping dust & water.

## ⑥ Regular Maintainance

- The equipment should be regularly checked for any sign of corrosion.
- If there is any damage, it should be timely repaired & maintained.

# THANK YOU

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