Indian Forest Service Main Examination

Civil Engineering
Paper-II

Topicwise Presentation

Also useful for Engineering Services Main Examination, Civil Services Main Examination and various State Engineering Services Examinations
Civil Engineering : Indian Forest Service Main Examination (Paper-II)

© Copyright, by MADE EASY Publications.
All rights are reserved. No part of this publication may be reproduced, stored in or introduced into a retrieval system, or transmitted in any form or by any means (electronic, mechanical, photo-copying, recording or otherwise), without the prior written permission of the above mentioned publisher of this book.

First Edition: 2017
Second Edition: 2018
Preface

Our country has a vast forest cover of near about 25% of geographical area and if man doesn't learn to treat trees with respect, man will become extinct; Death of forest is end of our life. Scientific management and judicial exploitation of forest becomes first task for sustainable development.

Engineer is one such profession which has an inbuilt word “Engineer – skillful arrangement” and hence IFS is one of the most talked about jobs among engineers to contribute their knowledge and skills for the arrangement and management for sustainable development.

In order to reach to the estimable position of Divisional Forest Officer (DFO), one needs to take an arduous journey of Indian Forest Service Examination. Focused approach and strong determination are the pre-requisites for this journey. Besides this, a good book also comes in the list of essential commodity of this odyssey.

I feel extremely glad to launch the revised edition of such a book which will not only make Indian Forest Service Examination plain sailing, but also with 100% clarity in concepts.

MADE EASY team has prepared this book with utmost care and thorough study of all previous years’ papers of Indian Forest Service Examination. The book aims to provide complete solution to all previous years’ questions with accuracy.

On doing a detailed analysis of previous years’ Indian Forest Service Examination question papers, it came to light that a good percentage of questions have been asked in Engineering Services, Indian Forest Services and State Services exams. Hence, this book is a one stop shop for all Indian Forest Service Examination, CSE, ESE and other competitive exam aspirants.

I would like to acknowledge efforts of entire MADE EASY team who worked day and night to solve previous years’ papers in a limited time frame and I hope this book will prove to be an essential tool to succeed in competitive exams and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

With Best Wishes

B. Singh
CMD, MADE EASY Group
## Previous Years Solved Papers

### Indian Forest Service Main Examination

#### Civil Engineering

**Paper-II**

## CONTENTS

<table>
<thead>
<tr>
<th>SI.</th>
<th>TOPIC</th>
<th>PAGE No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construction Technology and Equipment ....</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Cement</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Mortar</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Concrete</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Stones, Bricks and Bricks Masonry ..........</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Timber</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>Oil, Varnishes Paint, Distempers &amp; Miscellaneous</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Construction Planning and Management ..36</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Project Management and Network Technique...</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>PERT and CPM</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>Crashing, Resource Allocation, Updating and Engineering Economy</td>
<td>53</td>
</tr>
<tr>
<td>4</td>
<td>Concreting Equipments</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Surveying Engineering .....................</td>
<td>83</td>
</tr>
<tr>
<td>1</td>
<td>Fundamental Concepts of Surveying and Linear Measurements</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>Compass Survey, Theodolite and Traverse Survey</td>
<td>84</td>
</tr>
<tr>
<td>3</td>
<td>Levelling, Contouring and Plane Table Survey</td>
<td>93</td>
</tr>
<tr>
<td>4</td>
<td>Calculation of Areas and Volume............</td>
<td>103</td>
</tr>
<tr>
<td>5</td>
<td>Tacheometry, Curve, Hydrographic Survey, Tides and Triangulation</td>
<td>105</td>
</tr>
<tr>
<td>6</td>
<td>Field Astronomy, Photogrammetry, Remote Sensing and Geology</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>Railway Engineering ........................</td>
<td>118</td>
</tr>
<tr>
<td>1</td>
<td>Rail Joints, Welding of Rails and Signals</td>
<td>118</td>
</tr>
<tr>
<td>2</td>
<td>Ballast, Formation and Sleepers</td>
<td>123</td>
</tr>
<tr>
<td>3</td>
<td>Geometric Design of the Track</td>
<td>125</td>
</tr>
<tr>
<td>4</td>
<td>Points and Crossing</td>
<td>129</td>
</tr>
<tr>
<td>5</td>
<td>Track Stresses, Traction and Tractive Resistance</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>Highway Engineering ..........................</td>
<td>135</td>
</tr>
<tr>
<td>1</td>
<td>Highway Planning and its Geometric Design</td>
<td>135</td>
</tr>
<tr>
<td>2</td>
<td>Traffic Engineering</td>
<td>148</td>
</tr>
<tr>
<td>3</td>
<td>Pavement Design</td>
<td>161</td>
</tr>
<tr>
<td>4</td>
<td>Highway Material and Properties</td>
<td>169</td>
</tr>
<tr>
<td>5</td>
<td>Highway Drainage</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>Hydrology</td>
<td>176</td>
</tr>
<tr>
<td>1</td>
<td>Precipitation and General Aspects of Hydrology</td>
<td>177</td>
</tr>
<tr>
<td>2</td>
<td>Evaporation, Transpiration, Evapotranspiration &amp; Stream Flow Measurement</td>
<td>183</td>
</tr>
<tr>
<td>3</td>
<td>Infiltration, Runoff and Hydrograph</td>
<td>189</td>
</tr>
<tr>
<td>4</td>
<td>Floods, Flood Routing &amp; Flood Channel</td>
<td>194</td>
</tr>
<tr>
<td></td>
<td>Water Resources and Engineering ............</td>
<td>202</td>
</tr>
<tr>
<td>1</td>
<td>Water Requirement of Crops</td>
<td>202</td>
</tr>
<tr>
<td>2</td>
<td>Design of Stable Channels and Canals</td>
<td>218</td>
</tr>
<tr>
<td>3</td>
<td>Design and Construction of Gravity Dams</td>
<td>229</td>
</tr>
<tr>
<td>4</td>
<td>Water Logging, Theories of Seepage and Spillway</td>
<td>244</td>
</tr>
<tr>
<td>5</td>
<td>River Training Work, Diversion Headwork, Cross-drainage work &amp; Miscellaneous</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>Environmental Engineering ..................</td>
<td>268</td>
</tr>
<tr>
<td>1</td>
<td>Water Quality</td>
<td>268</td>
</tr>
<tr>
<td>2</td>
<td>Treatment of Water</td>
<td>274</td>
</tr>
<tr>
<td>3</td>
<td>Development of Ground Water</td>
<td>292</td>
</tr>
<tr>
<td>4</td>
<td>Water Demand, Water Control and Distribution System</td>
<td>297</td>
</tr>
<tr>
<td>5</td>
<td>Waste Water Characteristics</td>
<td>307</td>
</tr>
<tr>
<td>6</td>
<td>Design of Sewer</td>
<td>312</td>
</tr>
<tr>
<td>7</td>
<td>Treatment of Waste Water</td>
<td>321</td>
</tr>
<tr>
<td>8</td>
<td>Solid Waste Management and Pollution</td>
<td>335</td>
</tr>
<tr>
<td>9</td>
<td>Air, Sound, Land Pollution and EIA</td>
<td>347</td>
</tr>
</tbody>
</table>
SYLLABUS

Part-A

CONSTRUCTION TECHNOLOGY, EQUIPMENT, PLANNING AND MANAGEMENT

1. Construction Technology :
   Engineering Materials:

   Physical properties of construction materials : Stones, Bricks and Tiles; Lime, Cement and Surkhi Mortars; Lime Concrete and Cement Concrete, Properties of freshly mixed and hardened concrete, Flooring Tiles, use of ferrocement, fibre-reinforced and polymer concrete, high strength concrete and light weight concrete.
   Timber : Properties and uses; defects in timber; seasoning and preservation of timber. Plastics, rubber and damp-proofing materials, termite proofing, Materials, for Low cost housing.

   Design of Brick masonry walls as per I.S. codes, factors of safety, serviceability and strength requirements; plastering, pointing. Types of Floors & Roofs. Ventilators, Repairs in buildings. Functional planning of building : Building orientation, circulation, grouping of areas, privacy concept and design of energy efficient building; provisions of National Building Code. Building estimates and specifications; Cost of works; valuation.

2. Construction Equipment :
   Standard and special types of equipment, Preventive maintenance and repair, factors affecting the selection of equipment, economical life, time and motion study, capital and maintenance cost. Concreting equipments : Weigh batcher, mixer, vibration, batching plant, Concrete pump. Earth-work equipment : Power shovel hoe, bulldozer, dumper, trailors, and tractors, rollers, sheep foot roller.

3. Construction Planning and Management : Construction activity, schedules, job layout, bar charts, organization of contracting firms, project control and supervision. Cost reduction measures.


Part-B

SURVEY AND TRANSPORTATION ENGINEERING


Drainage of roads : Surface and sub-surface drainage.

Part-C

HYDROLOGY, WATER RESOURCES AND ENGINEERING

**Hydrology** : Hydrological cycle, precipitation, evaporation, transpiration, depression storage, infiltration, overland flow, hydrograph, flood frequency analysis, flood estimation, flood routing through a reservoir, channel flow routing-Muskingam method. Ground water flow : Specific yield, storage coefficient, coefficient of permeability, confined and unconfined aquifers, aquitards, radial flow into a well under confined and unconfined conditions, tube wells, pumping and recuperation tests, ground water potential.

**WATER RESOURCES ENGINEERING** : Ground and surface water resource, single and multipurpose projects, storage capacity of reservoirs, reservoir losses, reservoir sedimentation, economics of water resources projects.

**IRRIGATION ENGINEERING** : Water requirements of crops : consumptive use, quality of water for irrigation, duty and delta, irrigation methods and their efficiencies.

**Canals** : Distribution systems for canal irrigation, canal capacity, canal losses, alignment of main and distributory canals, most efficient section, lined canals, their design, regime theory, critical shear stress, bed load, local and suspended load transport, cost analysis of lined and unlined canals, drainage behind lining.

**Water logging** : causes and control, drainage system design, salinity.

**Canal structures** : Design of cross regulators, head regulators, canal falls, aqueducts, metering flumes and canal outlets.

**Diversion head work** : Principles and design of weirs of permeable and impermeable foundation, Khosla’s theory, energy dissipation, stilling basin, sediment excluders.

**Storage works** : Types of dams, design, principles of rigid gravity and earth dams, stability analysis, foundation treatment, joints and galleries, control of seepage.

**Spillways** : Spillway types, crest gates, energy dissipation.

**River training** : Objectives of river training, methods of river training.

Part-D

ENVIRONMENTAL ENGINEERING

**Water Supply** : Estimation of surface and subsurface water resources, predicting demand for water, impurities, of water and their significance, physical, chemical and bacteriological analysis, waterborne diseases, standards for potable water.

**Intake of water** : pumping and gravity schemes. Water treatment : principles of coagulation, flocculation and sedimentation; slow-, rapid-, pressure-, filters; chlorination, softening, removal of taste, odour and salinity.

**Water storage and distribution** : storage and balancing reservoirs : types, location and capacity.

**Distribution system** : layout, hydraulics of pipe lines, pipe fittings, valves including check and pressure reducing valves, meters, analysis of distribution systems, leak detection, maintenance of distribution systems, pumping stations and their operations.

**Sewage systems** : Domestic and industrial wastes, storm sewage-separate and combined systems, flow through sewers, design of sewers, sewer appurtenances, manholes, inlets, junctions, siphon. Plumbing in public buildings.

**Sewage characterization** : BOD, COD, solids, dissolved oxygen, nitrogen and TOC. Standards of disposal in normal water course and on land.

**Sewage treatment** : Working principles, units, chambers, sedimentation tanks, trickling filters, oxidation ponds, activated sludge process, septic tank, disposal of sludge, recycling of waste water.

**Solid waste** : collection and disposal in rural and urban contexts, management of long-term ill-effects.

1. Water Quality

Q.1 Describe the impact of acid mine drainage on a aquatic system.  
[8 marks : 2000]

Solution:
Acidic mine drainage in river or other stream water can impact water quality and animals and people supported on these streams in following way:
1. **Water Contamination**: Due to the acidic water along with the metal ions such as Fe, Cu, As etc. increases the toxicity of the water and thus affect the aquatic life and get into the food chain.
2. It may disturb the reproduction system of aquatic life such as fish and thus may decrease their population.
3. It also affects the infrastructure by corrosion.
4. Acid mine drainage increases the acidity of a stream by introducing hydrogen ions. Acidity is commonly measured by pH values. However, pH is not always a good indicator of the presence of AMD because it only indicates the concentration of hydrogen ions in the solution.
5. Ferrous iron (Fe$^{2+}$) from acid-generating reactions and calcium (Ca$^{2+}$) from acid-neutralizing reactions may contribute to higher than average levels of water hardness in watersheds with active or abandoned mines.

Q.2 What is impact of suspended solids on water treatment? How it is measured?  
[10 marks : 2001]

Solution:
**Impact of suspended solids:**
1. It has a psychological effect and makes the water aesthetically displeasing.
2. If suspended solids are biologically active (organic) they may form disease causing organics.
3. Suspended solids provide absorption sites for chemical and biological reagents thereby interferes with the further treatment of water.
4. It partially shields the micro-organism present in water thereby reduces efficiency of disinfection.

**Measurement of suspended solids**: Measurement of suspended solids is done by gravimetric method. In which first total solids can be determined by evaporating the water sample at 104°C, than weighing the dry residue left, after suspended solids can be found by filtering the water sample and weighing the residue left on the filter paper.

Q.3 Write short term and long term implications on human health of concentration of following parameters is significantly increased than the permissible levels: 
1. Coliforms  
2. Chlorides  
3. Cadmium  
[10 marks : 2002]

Solution:
1. **Coliforms**: Coliforms are bacteria that are always present in digestive tracts of animal, humans and are found in their wastes. They are also found in plant and soil material. Presence of coliform bacterial in drinking water is taken as evidence of recent pollution with human and animal faces. Most coliform
bacteria do not cause disease, but some rare strain of E. Coli can cause serious illness. These can remain in water for long time. These serve as indicator organism for more harmful pathogenic bacteria.

2. Chlorides: These are present in water in form of sodium chloride or may be due to leaching of marine sedimentary deposits. The presence of high concentration of chloride in river or stream water may indicate pollution from sea water. Industrial or domestic waste. The high concentration of chloride produces bitter taste in mouth. It also causes airway irritation, wheezing, difficulty “breathing, sore throat, cough, chest tightness, eye irritation, skin irritation. It can also create dangerous carcinogenic compound due to reaction with some organic matter.

3. Cadmium: Cadmium in water supply is usually due to e-waste, metal industries. Short term effect of high level cadmium can cause nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbance, liver injury and renal failure, while long term effect of high concentration, of cadmium include kidney, liver, bone and blood damage.

Q.4 Define solids in aqueous system. Enumerate the types of solids in water. Explain their sanitary significance.

Solution:

Solids in aqueous system:
The term “solids” is generally used when referring to any material suspended or dissolved in wastewater that can be physically isolated either through filtration or through evaporation

Type of solids in water:
1. Fixed Solids
2. Settleable solids
3. Supernatant solids
4. Total Dissolved Solids
5. Total Suspended Solids
6. Total Solids
7. Volatile solids

Solids can be classified as either filterable or nonfilterable. Filterable solids may either be settleable or nonsettleable. Solids can also be classified as organic or inorganic. “Filterable” solids are so small that they will pass through a standard laboratory filter, while “nonfilterable” solids are large enough to be captured on a standard filter pad. The nonfilterable solids are termed “settleable” if the solids settle out in a standard laboratory settling container within a specified period of time. They are called “non-settleable” if they fail to settle out within that time period. If solids are “organic”, the material is carbon-based and will burn. “Inorganic” solids, on the other hand, are mineral based and generally will not burn. Any material that was at one time living (for example: body wastes, starches, sugars, wood, bacteria and cotton) are all organic while limestone, iron and calcium are inorganic.

The amount of solids in wastewater is frequently used to describe the strength of the waste. The more solids present in a particular wastewater, the stronger that wastewater will be. If the solids in wastewater are mostly organic, the impact on a treatment plant is greater than if the solids are mostly inorganic. Normal domestic wastewater contains a very small amount of solids when compared to the amount of water that carries it, generally less than 0.1%. This can be misleading, however, because it may take only a very small amount of organic residue to create large pollution problems. The number and severity of pollution problems will depend on the type of solids that are involved. As a general rule, large quantities of organic solids will create more pollution problems than will the same quantity of inorganic solids. Therefore, not only is it important to know how much solids are present in the waste, but also the type of solids that are present. The test procedures for solids provide essential information about the level and type of solids coming into the treatment plant and whether the solids are actually being removed in the plant processes.
Q.5 What are common water borne diseases and their causes?  

[10 marks : 2006]

Solution:

Water borne diseases are those diseases which spread primarily through contaminated waters; and the important causes of these water borne diseases are:

1. **Diseases caused by bacterial infections:**
   - (i) Typhoid fever and Paratyphoid fever (caused by salmonella typhi bacteria)
   - (ii) Cholera (caused by vibrio-cholerae bacteria)
   - (iii) Bacillary dysentery (caused by shiga bacillus or flexner-bacillus, or sonne bacillus)

2. **Diseases caused by viral infections:**
   - (i) Infectious hepatitis or infectious jaundice (caused by hepatitis virus)
   - (ii) Poliomyelitis (caused by poio virus)

3. **Diseases caused by protozoal infections:**
   - (i) Amoebic dysentery (caused by entamoeba hystolytic germ).

All these water borne diseases are infectious diseases in the sense that although they may also spread through direct contact, or through flies or filth, etc.; yet since water is the main and prime media responsible for the start and spread of these diseases, they are termed as **water borne diseases.**

The germs or micro-organisms (of different origins as stated above) responsible for spreading these diseases, enter the human body with food or water which has been contaminated by the excreta of patients with the disease, or of carriers of the organisms. Shallow well waters in villages are more likely to get such contaminations due to the leakage of sewage from cesspools, etc. Sometimes, in cities too, the sewer pipe line may leak into a water pipe through some faulty joint, thereby contaminating the same. Since the water pipe lines and sewer lines generally pass through different streets, chances of such contaminations are rare. However, the pollutants can sometimes seep into a leaky water pipe joint, from the dirty surroundings around the water pipe. Sometimes, the water drawn at the waterworks itself may get contaminated due to the inflow of sewage into the source, which may go unnoticed due to the negligence of the waterworks management. All such situations may contaminate the water and may spread any such water borne disease among its consumers. In hot countries, these diseases may also spread through other means, such as infected dust, or transmission by flies which have fed first on the infected excreta and then leaving the infection on human foods or drinks.

Q.6 What is waterborne disease? Name any two waterborne diseases?  

[2 marks : 2009]

Solution:

Water borne diseases are those disease which are spread primarily through contaminated water. They may also transfer through direct contact yet water is prime and main media responsible for start and spread of diseases. Examples of these disease are Typhoid fever, Paratyphoid fever, Cholera, Amoebic dysentery etc.

Q.7 Explain the significance of nitrogen and phosphorus from the point of view of water quality  

[5 marks : 2010]

Solution:

**Nitrogen content:** The presence of nitrogen in water is an indication of organic matter. It may occur in following forms:

- (a) Free ammonia which indicates very first stage of decomposition or organic matter i.e. recent pollution,
- (b) Organic ammonia which indicates nitrogen present in undecomposed organic form
- (c) Nitrites which indicate partly decomposed organic matter and
- (d) Nitrates, which indicate presence of fully oxidised organic matter in water.
Phosphorus content: It is present primarily in form of phosphate in water. Primary source of phosphate in water is fertilizer. Phosphorus acts as nutrient for plant and animals but over production of phosphorus results into high growth of plankton, leading to algal boom or thermal stratification of water bodies, termed eutrophication of lakes.

Q.8 Enumerate and discuss the common tests that would be conducted for the examination of water at laboratory attached to water treatment plant, also explain the significance of these tests.

[10 marks : 2011]

Solution:
Several laboratory tests are conducted on water (raw as well as treated) to determine its characteristics and to determine the degree of treatment required to make it potable, as stated in the text. Usually the following tests will be required to be performed in the water testing laboratory:

1. To find the turbidity of a given sample of water.
2. To find the odour of a given sample of water.
3. To find the colour of a given sample of water.
4. To determine the pH value of a given sample of water.
5. To determine the carbonate, bicarbonate and hydroxide alkalinity in a given sample of water.
6. To find out the concentration of chlorides in the given sample of water.
7. To estimate the hardness of the given sample of water by EDTA method.
8. To determine residual chlorine in a given sample of water.
9. To determine the chlorine demand of a given sample of water.
10. To determine the available chlorine percentage in a given bleaching powder.
11. To determine the amount of dissolved oxygen (D.O.) in the given sample of water by Winkler method.
12. To determine the amount of total solids, suspended solids and dissolved solids in a given sample of water.
13. To determine the quantity of alum required to coagulate a given sample of water.

Q.9 Write a brief note on ‘MPN’.

[5 marks : 2012]

Solution:
Most probable number test (MPN test):

(i) MPN test is multiple tube fermentation test in which we mix water samples with different dilution ratio and lactose broth which acts as nutrient to coliformic micro organisms. (Coliformic micro organism utilizes lactose broth and results in the formation of acids and CO₂).

(ii) The samples are incubated at 35°C for 48 hours and after incubation these are tested for the presence of acids and CO₂. Then, referring to the standard table corresponding to the result observed. MPN/100 ml is noted. This MPN represents the microbial density which is most likely to be present in water.

Q.10 Enumerate diseases transmitted by water. How is guinea worm disease controlled?

[10 marks : 2012]

Solution:
Water borne diseases are those diseases which spread primarily through contaminated waters; and the important of these water borne diseases are:

Diseases caused by bacterial infections:

(i) Typhoid fever and Paratyphoid fever (caused by salmonella typhi bacteria)
(ii) Cholera (caused by vibrio-cholera bacteria)
(iii) Bacillary dysentery (caused by shiga bacillus or flexure-bacillus, or same bacillus)
Diseases caused by viral infections:
(i) Infectious hepatitis or infectious jaundice (caused by hepatitis virus) (ii) Poliomyelitis (caused by polio virus)

Diseases caused by protozoal infections:
(i) Amoebic dysentery (caused by entamoeba hystolytic germ) Guinea worm disease can be prevented by avoiding drinking unsafe water.

Following these simple control tactics can completely prevent the spread of the disease:

Guinea-worm disease can be prevented by avoiding drinking unsafe water.
• Drink only water from protected sources (such as from boreholes or hand-dug wells) that are free from contamination.
• Prevent people with swellings and wounds from entering ponds and other water used for drinking.
• Always filter drinking water from unsafe sources, using a cloth filter or a pipe filter, to remove the tiny "water fleas" that carry the Guinea worm larvae.
• Treat unsafe drinking water sources with an approved larvicide. This will kill the tiny "water fleas."
• Provide communities with new safe sources of drinking water and repair broken safe water sources (e.g., hand-pumps) if possible.

Q.11 Explain the significance of following parameters from the point of view of water quality.
(i) Nitrogen content
(ii) BOD
(iii) Dissolved oxygen
(iv) Chlorides

[4 marks : 2013]

Solution:
(i) Nitrogen content: The presence of nitrogen in water is an indication of presence of organic matter and it may occur in one or more following form (i) free ammonia (ii) organic nitrogen (iii) nitrates (iv) nitrates. Free ammonia is an indication of recent pollution, organic ammonia in form of undecomposed organic matter. Nitrates represent partly decomposed organic matter and nitrates indicate fully oxidised organic matter.

(ii) BOD (Biochemical oxygen demand): It is the amount of oxygen required by the micro organism to carry out the decomposition of biodegradable organic matter present in waste water. It represents presence of biodegradable organic matter in waste water.

(iii) Dissolved oxygen: At particular temperature maximum quantity of oxygen present in water is termed as saturation dissolved oxygen. Any deficiency observed in the value of dissolved oxygen indicates the presence of biological activity in water. A minimum of 4 ppm dissolved oxygen is required for survival of fishes.

(iv) Chlorides: These are generally present in water in the form of sodium chloride. The presence of high quantity of chloride in river or stream water represents pollution of water due to sewage and other human and industrial waste.

Q.12 Explain the significance of following in context of water quality.
(i) Nitrate
(ii) Hardness
(iii) Alkalinity
(iv) Iron
(v) Fluoride

[10 marks : 2015]

Solution:
1. Nitrate (NO$_3$-): Presence of nitrates represent fully oxidized organic matter. Hence it signifies old pollution in water. Usually presence of water is not harmful but in some cases in large concentration, nitrate affects the health of infants. Due to presence of acids in intestine, nitrate converts to nitrite, resulting into 'blue baby' disease or 'methemoglobinemia'. Acceptable limit of nitrate in water is 45 mg/litre.
2. **Hardness**: It is characteristic of water which prevents the formation of sufficient lather or foam, when such hard water is mixed with soap. It is represented by presence of multivalent cations in water, major constitutes of which are ‘Ca’ and ‘Mg’'. It leads to incrustation and corrosion of pipe. It also makes the food tasteless. For domestic supplies it should be in the range of 75 to 150 mg/l.

3. **Alkalinity**: It is the measure of quantity of ions present in the water that are capable of neutralizing the hydronium ion (H'). In other words it is the ability of water to neutralize acids. It represents presence of either organic matter or dissolved gases in the water. It imparts bitter taste in water. It also leads to incrustations of pipes. It is measured in equivalents of calcium carbonate.

4. **Iron**: Presence of iron in the water results into reddish brown color. It is present in conjugation with organic matter. It is generally found in water which is divided of oxygen. Acceptable limit of iron in water is 0.1 mg/l.

5. **Fluoride**: It is required upto a limit of 1 mg/l for growth of permanent teeth and to prevent dental cavities. But if it is greater than 1.5 mg/l, it causes decolorization of teeth and if it is more than 5 mg/l, it causes deformation of bones.

Q.13 **Explain the impacts of disposal of wastewater with following characteristics into fresh water:**

(i) **Nutrients** (ii) **Heavy metals** (iii) **Oil and grease** (iv) **Suspended solids**

[8 marks : 2017]

**Solution:**

Impacts of disposal into fresh water:

(i) **Nutrients**: Eutrophication arises from the oversupply of nutrients, which leads to overgrowth of plants algeae. After such organism dies, the bacterial degradation of their biomass consumes the oxygen from the water thereby creating the state of hypoxia.

It is almost always induced by the discharge of nitrate or phosphate containing detergents, fertilizers or sewage into the aquatic system.

(ii) **Heavy metals**: Major industrial sources of wastewater include surface treatment processes with metals like As, Co, Cu, Zn, Ni, Cd, Pb, Hg and Cr as well as industrial products that at the end of their use are discharged into WWTP's facilities.

Toxic metals in wastewater are one of the main causes of river water and sediment pollution. Heavy metals are often released into the aquatic environment through atmospheric deposition or anthropogenet sources. The impacts of heavy metals on aquatic ecosystems are well documented.

(iii) **Oil and grease**: The excessive discharge of oil and grease to sewerage system, problems may occur with clogging of sewers and pumping plants and with the interference of biological treatment processes.

(iv) **Suspended solids**: There is considerable effect of suspended and dissolved solids in the irrigation water on the growth of plants. The salts increase the osmotic potential of the soil water and increase in osmotic pressure of the soil solution increases the amount of energy which plants must expend to take up water from the soil.

Q.14 **Specify permissible drinking water quality standard for the following parameters and explain the effects of these parameters on human health:**

(i) **Fluorides** (ii) **Nitrates** (iii) **Chlorides** (iv) **Total hardness** (v) **Total dissolved solids**

[10 marks : 2017]

**Solution:**

(i) **Fluorides**:

- The fluorides upto 1 mg/l helps to prevent dental cavities. During formation of permanent teeth it combines chemically with tooth enamel, resulting in harder, stronger teeth that are most resistant to decay.
• The excess consumption (> 1.5 mg/l to 2mg/l) results in decoloration of teeth called mottling of teeth. Infants are affected only.
• Greater than 5 mg/l causes deformation of tones called bone fluorosis.
• The acceptable limit is upto 1 mg/l and greater than 1.5 mg/l is cause for rejection.

(ii) Nitrates:
• Nitrates is not harmful as it is fully oxidised. But too much of nitrates affects infants because it causes blue baby disease or Mathemoglobinemia. Nitrate concentration should not be more than 45 mg/l.
  Its concentration is measured by colour matching technique.

(iii) Chlorides:
• Chlorides increases the electrical conductivity of water and thus increases its corrosivity. Chloride toxicity has not been observed in humans except in case of impaired sodium chloride metabolism. e.g. in congestive heart failure.
  The acceptable limit is 200 mg/l and cause for rejection is 1000 mg/l.

(iv) Total Hardness:
• It is defined as the concentration of multivalent metallic cations in solution. Multivalent metallic ions most abundant in natural water are calcium and magnesium. Hard water leads to lesser foam formation, hence consumption of soap would be more. It leads to scaling of boilers. It causes corrosion and incrustation of pipes. It make food tasteless. Acceptable limit = 200 mg/l and permissible limit = 600 mg/l.

(v) Total dissolved solids:
• The amount of TDS in water affects its taste, too little TDS make water tastes flat. The elevated levels of TDS do not prevent a health problem and are actually good for health unless chemicals like chlorine and chloramines are present. Water with zero TDS is bad for health for two reasons:
  (a) It doesn’t supply any minerals.
  (b) Hungry water (deficient in TDS) with steal minerals from the body.
• The acceptable limit of TDS (in mg/l) is 500 mg/l and cause for rejection is 2000 mg/l.

---

### 2. Treatment of Water

**Q.15** Design size and number of units of rapid sand filters for a town with following data:

- Average quantity of water required per capita = 150 lpd
- Population served = 50000
- Seasonal variation factor = 2.0
- Hourly variation factor = 2.9
- Rate of filtration = 150000 l/m²/d
- Backwash time = 30 min/d

[15 marks : 2000]

**Solution:**

For given data:

- Average daily demand = 50000 × 150 = 7.5 × 10^6 litres/day = 7.5 MLD
- Maximum daily demand = 2.0 × 7.5 = 15 MLD

Assuming 5% of daily demand kept for backwashing and time of backwashing is 30 mins

\[
\text{Effective design discharge} = \left( \frac{15}{24 - \frac{30}{60}} \right) \times 1.05 \times 24 = 16.085 \text{ MLD}
\]
Rate of filtration = 150000 l/m²/d

Area of filter media = \frac{16.085 \times 10^6}{150000} = 107.23 \text{ m}^2

Number of filters = \frac{1.22 \sqrt{Q}}{Q} = \frac{1.22 \times \sqrt{16.085}}{4.89} = 5

Area of each filter = \frac{107.23}{5} = 21.45 \text{ m}^2

Taking filter to be square of side ‘B’

So \quad B^2 = 21.45

\quad B = 4.63 \text{ m}

So total 6 = 5 + 1 (Standby) filter should be provided of square dimension with side 4.63 m

Q.16 What are merits and demerits of rapid sand filters as compared to slow sand filters?

[10 marks : 2001]

Solution:

Rapid sand filters are typically designed as part of multi-stage treatment systems used by large municipalities. Various advantages and disadvantages of rapid sand filter with respect to slow sand filter are following

Advantages

- Rapid sand filters have much higher flow rate than a slow sand filter; about 150 to 200 million gallons of water per acre per day.
- Rapid sand filter requires relatively small land area.
- These are less sensitive to changes in raw water quality, e.g. turbidity.
- Rapid sand filter requires less quantity of sand.

Disadvantages:

- Large pore size of rapid sand filter will not, without coagulant or flocculent, remove pathogens smaller than 20 \mu m.
- Rapid sand filter requires greater maintenance than a slow sand filter and are generally ineffective against taste and odour problems.
- These produce large volumes of sludge for disposal.
- Rapid sand filter requires ongoing investment in costly flocculation reagents.
- In rapid sand filter treatment of raw water with chemicals is essential.
- For rapid sand filter working skilled supervision is essential.
- Cost of maintenance is higher for rapid sand filter.

Q.17 Calculate the area of filtering media required for treating water by mean of rapid sand filters with the given data

1. Population = 200000
2. Rate of supply = 200 lit/head/day
3. Maximum demand = 1.5 times the average demand

Assume other data if necessary

[10 marks : 2001]

Solution:

Given:

- Population = 200000
- Rate of supply = 200 lit/head/day
- Average demand = 200000 \times 200 \times 10^{-3} = 40000 \text{ m}^3$/day
Maximum discharge, \[ Q_p = 1.5 \times 40000 = 60000 \text{ m}^3/\text{day} \]
Assuming time for backwashing as 30 minutes, water required for backwashing as 5% of maximum discharge
Effective discharge, \[ Q_{eff} = \frac{60000}{23.5} \times 24 \times 1.05 = 64340.42 \text{ m}^3/\text{day} \]
Assuming rate of filtration as 4000 lit/m²/hour
Area of filtering media required = \[ \frac{\text{Effective discharge}}{\text{Rate of filtration}} = \frac{64340.42 \times 10^3}{4000 \times 24} = 670 \text{ m}^2 \]
Number of filters = \[ 1.22 \sqrt{Q} = 1.22 \sqrt{64340.42 \times 10^{-6} \times 10^3} = 9.78 \approx 10 \]
So,
Area of single filter = \[ \frac{670}{10} = 67 \text{ m}^2 \]
So 10 + 1 (for standby) filters of 67m² area should be provided.

Q.18 The available chlorine of bleaching powder to be used for chlorination of water is found to be 20%. Calculate the amount of this bleaching powder for disinfecting 10⁶ litres of water per day whose chlorine demand is 2 mg per litre.

Solution:
Given:
\[ \text{Chlorine demand} = 2 \text{ mg/l} \]
Assuming residual chlorine = 0.2 mg/l
Total chlorine dosage required = \[ 2 + 0.2 = 2.2 \text{ mg/l} \]
Volume of water = \[ 10^6 \text{ litres} \]
Mass of chlorine required = \[ 2.2 \times 10^{-6} \times 10^6 = 2.2 \text{ kg} \]
Mass of bleaching powder required = \[ \frac{2.2}{0.2} = 11 \text{ kg} \]

Q.19 Design a primary circular sedimentation tank for a town of population 50000 making all the necessary but reasonable assumptions

Solution:
Given:
\[ \text{Population of town} = 50000 \]
Assuming average per capita demand as 325 lpd
Average daily demand, \[ Q_{avg} = 50000 \times 325 \]
\[ = 16.25 \times 10^6 \text{ litres/day} \]
Maximum daily demand, \[ Q = 1.8 \times Q_{avg} = 1.8 \times 16.25 \times 10^6 = 29.95 \times 10^6 \text{ litres/day} \]
\[ = \frac{29.25}{86400} \times 10^6 \times 10^{-3} = 0.3385 \text{ m}^3/\text{s} \]
Assuming retention time, \[ t_R = 6.5 \text{ hours} \]
Volume of sedimentation tank, \[ V = 0.3385 \times 6.5 \times 3600 = 7921 \text{ m}^3 \]
Assuming overflow rate, \[ SOR = 15 \text{ m/day} = 1.736 \times 10^{-4} \text{ m/s} \]
Plan area of tank required, \[ A_p = \frac{Q}{SOR} = \frac{0.3385}{1.736 \times 10^{-4}} = 1949.88 \approx 1950 \text{ m}^2 \]
Let diameter of sedimentation take be ‘D’
So,
Plan area \[ = \frac{\pi D^2}{4} = 1950 \]
Diameter, \[ D = \frac{49.82 \text{ m}}{50 \text{ m}} \]
Also, Volume, \[ V = D^2 \left(0.011D + 0.785H\right) \]
\[ 7921 = 50^2(0.011 \times 50 + 0.785H) \]
Height of tank, \[ H = 3.33 \text{ m} \]
Providing a free board of 0.3 m, size of primary sedimentation tank should be 50 m (diameter) \times 3.63 m (height)

Q.20 Clearly distinguish between different settling process also giving examples of treatment units in water or waste water treatment, where these process are utilized?

[12 marks : 2003]

Solution:
The settling/sedimentation involved in raw and waste waters has generally been divided into the following four types:

**Type 1 settling:** This type of settling refers to the settling of discrete particles, such as the removal of grit and sand from raw waters, containing low concentrations of solids. The settling of discrete particles in dilute concentrations is thus covered under this type of settling. The characteristics of particles don't change with time.

**Type 2 settling:** This type of settling refers to the settling flocculent particles in rather dilute suspensions. This settling helps in the removal of a portion of the suspended solids in the primary settling tanks, and in upper portions of the secondary settling tanks.

**Type 3 settling:** This type of settling, called hindered or zoned settling, involves the settling of the flocculent particles in concentrated suspensions, in which interparticle forces are sufficient to hinder the settling of the neighbouring particles, thereby tending the particles to remain in fixed positions with respect to each other, causing settling of the mass of particles as a unit, developing a solid liquid interface at the top of the settling mass. The settling that occurs in the secondary settling tank of a Biological Sewage Treatment Unit, is an example of this type of settling.

**Type 4 settling:** When solids are present in excessive concentration, thereby forming a structure or sludge blanket, such as at the bottom of a deep secondary settling tank or in a sludge thickener unit, the settling occurs only by compression, caused by the weight of the particles which are constantly being added to the structure by settling from the supernatant liquid. Such settling of particles in the form of sludge blanket in wastewater treatment is usually represented as Type 4 settling.

Q.21 What do you understand by the term “Optimum coagulant dose”? Explain the procedure to determine the optimum coagulant dose in laboratory. Duly taking into consideration the necessary optimum pH condition?

[10 marks : 2003]

Solution:

**Optimum coagulant dose:** Optimum coagulant does may be defined as minimum quantity of given coagulant (in mg) which produces a good floc when mixed with the given raw water (1 litre). The quantity of coagulant greater or lesser than this optimum dose will give unsatisfactory floc formulations.

Optimum coagulant dose is determined by “Jar test”.

The jar test involves the use of a stirring device. The stirrer consists of six paddles capable of rotation with variable speed between 0 to 100 rpm. In the test, 1 litre water is placed in each of the jars or beakers, which are closed with different amounts of coagulant say (alum). After rapid mixing to disperse the chemicals, the samples are stirred slowly for floc formation; and then allowed to settle under quiescent conditions. For this purpose, the jars are initially mixed at a speed of 60 to 80 rpm for 1 minute, and then stirred at a speed of
30 rpm for 15 minutes. After the stirrer is stopped, the nature and settling characteristics of the floc are observed and recorded in qualitative terms, such as poor, fair, good, very good, or excellent. A hazy sample indicates poor coagulation, while proper coagulated water contains floc that is well formed, with clear liquid between particles. The lowest alum dosage that provides good turbidity removal during the jar test is considered for the first trial dosage in plant operation, and the final optimum quantity is adjusted by actual observations at the WTP (Water Treatment Plant).

Q.22 What do you understand by residual chlorine and break-point chlorination?

Solution:

Break point chlorination is a term which gives us an idea of the extent of chlorine added to the water. In fact, it represents, that much dose of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

![Figure indicating break-point chlorination]

When chlorine is added to the water, it first of all, generally reacts with the ammonia present in the water, so as to form chloramines. These chloramines respond to the DPD test in the same manner as does free chlorine. Therefore, the DPD test will, indicate the quantum of total residual chlorine, “combined” as well as “free chlorine”. Hence, if chlorine is slowly added to the water, and the residual is tested, it will be found that the residual will go on increasing with the addition of chlorine. (However, some chlorine is consumed for killing bacteria, and thus the amount of residual chlorine shall be slightly less than that added. The addition of chlorine is continued beyond the point B, the organic matter present in water starts getting oxidised, and, therefore, the residual chlorine content suddenly falls down, as shown by the curve BC. The point C is the point beyond which any further addition of chlorine will appear equally as free chlorine, since nothing of it shall be utilized. This point “C” is called the breakpoint, as any chlorine that is added to water beyond this point, breaks through the water, and totally appears as residual chlorine. The addition of chlorine beyond break point is called break point chlorination.

Q.23 Chlorine usage in the treatment of 25000 m³ of water per day is 9 kg. The residual chlorine after 10 minutes contact is 0.2 mg/l. Calculate the dosage in milligrams per litre and chlorine demand of water?

Solution:

Given: Total mass of chlorine required = 9 kg = 9 × 10⁶ mg
Total volume of water = 25000 m³ = 25 × 10⁶ litres
Chlorine dosage = \( \frac{9 \times 10^6}{25 \times 10^6} = 0.36 \) mg/litre
Chlorine demand = Chlorine dosage – Residual chlorine
= 0.36 – 0.2 = 0.16 mg/litre
Q.24 What is softening of water? Explain the zeolite process with a neat sketch. Also write the advantages and disadvantages of this method of softening?

[10 marks : 2005]

Solution:

**Softening:** The reduction or removal of hardness from water is known as water softening.

**A zeolite softener** (or a cation exchanges unit) resembles a sand filter in which the filtering medium is a zeolite rather than sand. The hard water enters through the top, and is evenly distributed on the entire zeolite bed. The softened water is collected through one strainers at the base. When a significant portion of the sodium in the zeolite has been replaced by calcium and magnesium, it is regenerated by first washing it with water by reversing the flow, and then treating it with 10 per cent solution of brine (NaCl). The excess brine solution retained in the zeolite after the treatment is removed by again washing it with good water. The regenerated zeolite can be used afresh for softening.

\[
\begin{align*}
\text{Ca/Mg} & \quad \text{CO}_3^{--} \\
\text{HCO}_3^{--} + \text{Na}_2\text{Z} & \quad \text{Ca/Mg} \quad \text{Z} + \text{Na} \\
\text{Cl}^{--} + \text{Na}_2\text{Z} & \quad \text{(Exhausted bed)} \\
\text{SO}_4^{--} & \quad \text{(zeolites)} \\
& \quad \text{hardness}
\end{align*}
\]

Now, Regeneration,

\[
\begin{align*}
\text{Ca/Mg} \quad \text{Z} + \text{NaCl} & \quad \text{Na}_2\text{Z} + \text{Ca/Mg Cl} \\
& \quad \text{(Exhausted bed)}
\end{align*}
\]

The advantages and disadvantages of this method are given below:

**Advantages:**
1. Water of zero hardness can be obtained, and hence, useful for specific uses in textile industries, boilers, etc.
2. The plant is compact, automatic and easy to operate.
3. No sludge is formed, and hence, there is no problem of sludge disposal.
4. The RMO (Running maintenance and operation) cost is quite less.
5. It also removes ferrous iron and manganese from water.
6. There is no difficulty in treating water of varying quality.
7. There is no problem of incrustation of pipes of the distribution system, as is there in the lime soda process.

Disadvantages:
1. This process is not suitable for treating highly turbid waters, because the suspended impurities get deposited around the zeolite particles, and thus cause obstruction to the working of the zeolite.
2. The process leaves sodium bicarbonate in water, which causes priming and foaming in industrial or boiler feed waters.
3. The zeolite process is costlier and unsuitable for treating waters containing iron and manganese. This is because of the fact that the iron zeolite or manganese zeolite formed during the chemical reactions, cannot be regenerated into sodium zeolite. The zeolite is thus wasted, although the iron and manganese are removed from the water.

Q.25 A water treatment plant has a design capacity of 25 MLD and uses bleaching powder which contains 22% available chlorine. The chlorine demand was found to be 1.5 mg/l. If the residual chlorine in treated water has to be 0.2 mg/l. Calculate the daily requirement of bleaching powder.

[10 marks : 2006]

Solution:
For given data:

\[
\text{Total chlorine demand} = 1.5 + 0.2 = 1.7 \text{ mg/l} \\
\text{Mass of chlorine required} = 1.7 \times 25 \times 10^6 = 42.5 \times 10^6 \text{ mg} = 42.5 \text{ kg} \\
\text{Required bleaching powder} = \frac{42.5}{0.22} = 193.18 \text{ kg}
\]

Q.26 Discuss the construction details and working of a rapid gravity filter, with the help of a neat sketch?

[10 marks : 2006]

Solution:
In Rapid gravity filter following components are constructed:

1. **Enclosure tank:** It consists of an open water-tight rectangular tank, made of masonry or concrete. The depth of the tank may vary from 2.5 to 3.5 m. In order to achieve uniform distribution of water, the area of the filter units should not be kept larger, and is generally limited to about 10 to 80 m² for each unit. The number of units at a filter plant may be roughly estimated by the equation developed by Morrell and Wallace, which states that

\[
N = 1.22\sqrt{Q}
\]

Where

- \(N\) = Number of filter units
- \(Q\) = Plant capacity in million litres per day

2. **Base material:** In slow as well as rapid gravity filters, the base material is gravel, and it supports the sand. But in a rapid gravity filter, in addition to supporting the sand, it distributes the wash water. It consists of 60 to 90 cm thick gravels of different sizes, placed in layers. Generally, five to six layers, each of 10 to 15 cm in depth are used. The coarsest gravel (about 40 mm in size) is used in the bottom-most layer, and the finest gravel (about 3 mm in size) is used in the top-most layer. The size of the gravel in the bottom-most layer is thus generally kept between 20 to 40 mm; in the intermediate layers, between 12 to 20 mm, and 6 to 12 mm (when two intermediate layers are used); and in the top most layer, between 3 to 6 mm. In a rapid gravity filter, the distribution of the wash water is the critical function of the gravel layer and hence careful grading and equally careful placing of the materials is important.
3. **Filter media:** The filtering media consists of sand layers, about 60 to 90 cm in depth, and placed over a gravel support. The effective size ($D_{10}$) of the sand varies from 0.35 to 0.55 mm.

4. **Under-drainage system:** In slow sand filters, the under-drainage system was provided only to receive and deliver the filtered water. Whereas, in rapid gravity filters, the under drainage system serves two purposes; viz.

   (i) To receive and collect the filtered water, and

   (ii) To allow the back washing for cleaning of filter.

The under drainage system should, therefore, be designed in such a way that in addition to collecting the filtered water during its downward journey, it should be capable of passing the wash water upward at sufficiently high velocity. Back washing in fact consists of passing filtered water upward through the bed at such a velocity that it causes the sand bed to expand until its thickness is 25 to 40% greater than during filtering, depending upon the media. The grains move through the rising water, rub against each other and are cleaned of deposits. A bed is usually washed when head loss through the filter reaches 2 to 3 m. The back wash water should usually move up at a high rate of about 300-900 litres/minute/m² of filter area, or more, depending on the design, while applying it evenly and uniformly over the under portion of the gravel or sand bed. Since the rate of application of wash water is so much.

**Q.27** With a sketch describe the zeolite process of removal of hardness. What are advantages of it?  

**Solution:**

A zeolite softener (or a cation exchange unit) resembles a sand filter in which the filtering medium is a zeolite rather than sand. The hard water enters through the top, and is evenly distributed on the entire zeolite bed. The softened water is collected through the strainers at the base. When a significant portion of the sodium in the zeolite has been replaced by calcium and magnesium, it is regenerated by first washing it with water.
by reversing the flow, and then treating it with 10 per cent solution of brine (NaCl). The excess brine solution retained in the zeolite after the treatment is removed by again washing it with good water. The regenerated zeolite can be used afresh for softening.

**Advantages:**

(Refer to Question No. 24)

Q.28 Calculate the quantity of zeolite required to soften 2.27 ML of water of 572 ppm to 286 ppm hardness. The interval between successive generation is 3 hours and the capacity of exchanger is $27.46 \times 10^6$ mg/m³.

Solution:

(Assuming 2.27 ml water to be treated per day)

Total amount of hardness of raw water = $2.27 \times 10^6 \times 572 \times 10^{-6} = 1298.44$ kg

Final hardness of water = $2.27 \times 10^6 \times 286 \times 10^{-6} = 649.22$ kg

For 3 hour generation period

Hardness removed for generation period = $\frac{3}{24} \times (1298.44 - 649.22) = 81.15$ kg

The quantity of zeolite required = $\frac{81.25 \times 10^6}{27.46 \times 10^6} = 2.955$ m³

Q.29 What is coagulation? Name any two coagulants?

Solution:

Coagulation is a chemical technique which is directed towards the destabilization of charged colloidal particles. Some examples of coagulants are Alum (Al$_2$(SO$_4$)$_3$·18H$_2$O), Copperas (FeSO$_4$·7H$_2$O), Sodium aluminate (Na$_2$Al$_2$O$_4$).

Q.30 Draw a sketch of grease trap and describe its working.

Solution:

**Grease Traps**: Grease and oil traps are those trap chambers which are constructed in a sewerage system to remove oil and grease from the sewage before it enters into the sewer line. Such traps are located near the sources contributing grease and oil to these wage. They are, therefore, generally located at places, such as, automobile repair work-shops, garages, kitchens of hotels, oil and grease industries, etc.

The removal of oil and grease from the sewage before it enters into the sewer pipe is considered necessary because of the following reasons:

(i) The grease and oil, if allowed to enter the sewer, will stick to the sewer sides, and thus reducing the sewer capacity.

(ii) The suspended matter which would have, otherwise, flown along with the sewage, also sticks to the sides of the sewer, due to sticky nature of oil and grease; thus further reducing sewer capacity.

(iii) The presence of oil and grease in the sewage adds to the possibilities of explosions in the sewers.

(iv) The presence of oil and grease in sewage makes the sewage treatment difficult, as their presence adversely affects the biochemical reactions.

**The principle on which oil and grease traps work**: The grease and oil being lighter in weight, float on the top surface of the sewage. Hence, if an outlet draws the sewage from lower level, grease and oil will get excluded. Based on this principle, the grease and oil trap chambers are designed in such a way that the outlet level is located near the bottom of the chamber, and the inlet level is kept near the top of the chamber,
Q.31 Explain the relationship between HOCl and OCl⁻ occurring at various pH levels with the help of suitable sketch.

[5 marks : 2010]

Solution:

When chlorine is added to water, it forms hypochlorous acid or hypochlorite ions. The reactions that take place are:

\[ \text{Cl}_2 + H_2O \xrightarrow{\text{pH} < 7} \text{HOCI} + \text{HCl} \]

The hypochlorous acid is unstable and may break into hydrogen ions and hypochlorite ions:

\[ \text{HOCl} \xrightarrow{\text{pH} > 8} \text{H}^+ + \text{OCl}^- \]

The above reaction is reversible and depends upon the pH value of water. The dissociation of hypochlorous acid into ions is more effective at high pH values and vice versa. Thus, at pH values greater than 10, only OCl⁻ ions are found; while in pH values of less than 7 (more than 5), HOCl will generally exist without dissociating into OCl⁻ ions; and in the pH range of below 5, chlorine does not react and remains as elemental chlorine. The variation of existence of chlorine species with pH and temperature, is shown in figure.

Q.32 Write short notes on chlorination and desalination.

[5 marks : 2010]

Solution:

**Chlorination:** Chlorine in its various forms is invariably and almost universally used for disinfecting public water supplies. It is cheap, reliable, easy to handle, easily measurable and above all capable of providing residual disinfecting effects for long periods. Thus affording complete protection against future recontamination...
of water in distribution system. Its only disadvantage is that when used in great amount, it imparts bitter taste to the water.

**Desalination:** It is the method of converting salty water into fresh water. It is a costly process. The water obtained by desalination proves much costlier than naturally available treated water. Following methods can be adopted for desalination forecasting:
(i) Desalination by evaporation and distillation
(ii) Electrodialysis method
(iii) Reverse osmosis method
(iv) Freezing process
(v) Solar distillation method

**Q.33** In a continuous flow settling tank 3 m deep and 50 m long, what flow velocity of water would you recommend for effective removal of 0.025 mm particles at 25°C? The specific gravity of particles is 2.65 and kinematic viscosity for water may be taken as 0.01 cm²/sec.  

[10 marks : 2010]

**Solution:**

For given data: diameter, \( d = 0.025 \times 10^{-3} \), \( v = 0.01 \times 10^{-6} \) m²/s

Settling velocity,
\[
V_s = \frac{(G - 1) \cdot g \cdot d^2}{18v} = \frac{(2.65 - 1) \times 9.81 \times (0.025 \times 10^{-3})^2}{18 \times 10^{-6}} = 5.62 \times 10^{-4} \text{ m/s}
\]

Retention time,
\[
t = \frac{D}{V_s} = \frac{3}{5.62 \times 10^{-4}} = 5338 \text{ seconds}
\]

Horizontal flow velocity,
\[
V_f = \frac{L}{t} = \frac{50}{5338} = 9.37 \times 10^{-4} \text{ m/s}
\]

**Q.34** What is type-I settling, drive an expression for type-I settling. How analysis of type-I settling is done?  

[10 marks : 2011]

**Solution:**

Type-I Settling: Particles whose shape, size, specific gravity do not change with time are called as "DISCRETE PARTICLES" and particles whose surface properties are such that they coalesce/combine with other particles upon contact thereby changing shape, size and specific gravity of particles are called "FLOCCULATING PARTICLES" settling of discrete particles in dilute suspension is called as Type-I settling.

When a particle is suspended in water, initially it has only two forces acting upon it viz.

1. Force of gravity,
   \[
   F_g = \rho_p \cdot V_p \cdot g
   \]
   Where \( \rho_p \) and \( V_p \) are density and volume of particles respectively.

2. Buoyant force,
   \[
   F_B = \rho_w \cdot V_p \cdot g
   \]
   Where \( \rho_w \) is the density of water.

Now, for \( F_g = F_B \), \( \rho_p = \rho_w \) and no acceleration of the particles will take place.

If \( \rho_p \neq \rho_w \), which usually always happens, a net force acts on the particles and particle accelerates in the direction of net force \( (F_{\text{net}}) \).

Thus
\[
F_{\text{net}} = (\rho_p - \rho_w) \cdot g \cdot V_p = \text{Driving force for acceleration.}
\]

Once motion of particles has started, a third force come into play due to viscous friction. This force is called as "DRAG FORCE" \( (F_D) \), given by
\[
F_D = \frac{1}{2} \cos \theta A_p \cdot \rho_w \cdot V_p^2
\]
where, $A_p$ is the exposed plan area of the particle.

Where $C_D = \text{Drag coeff.}$

\[
\therefore \quad (\rho_p - \rho_w)g V_p = \frac{1}{2} C_D A_p \rho_w V_p^2
\]

For spherical particles,

\[
\frac{V_p}{A_p} = \frac{\pi}{6} \frac{d^3}{g^2} = \frac{2}{3} \frac{d}{g}
\]

\[
\therefore \quad V_p^2 = \frac{4}{3} g^2 (\rho_p - \rho_w) d \frac{C_D \rho_w}{\rho_p}
\]

Drag. coeff. \quad $C_D = \frac{24}{Re}$ (for laminar flow)

Here, $Re = \text{Reynold's no.} = \frac{\nu \rho_w d}{\mu}$

where, $\mu$ is the dynamic viscosity.

Substituting $C_D$ in (i)

\[
\nu = \frac{g d^2 \rho_w (G - 1)}{18 \mu} \quad G = \text{Sp. gravity of particles.}
\]

**Q.35 Discuss the working of a skimming tank with the help of a neat sketch. How are disposal of skimming done?**

**[10 marks : 2011]**

**Solution:**

**Skimming Tanks:** Skimming tanks are sometimes employed for removing oils and grease from the sewage, and placed before the sedimentation tanks. They are, therefore, used where sewage contains too much of grease or oils, which include fats, waxes, soaps, fatty acids, etc. These materials may enter into the sewage from the kitchens of restaurants and, houses, from motor garages, oil refineries, soap and candle factories, etc. They are, thus, normally present in large amounts in the industrial wastewaters.

If such greasy and oily matter is not removed from the sewage before it enters further treatment units, it may form unsightly and odorous scums on the surface of the settling tanks, or interfere with the activated sludge treatment process, and inhibit biological growth on the trickling filters.

These oil and greasy materials may be removed in a skimming tank, in which air is blown by an aerating device through the bottom. The rising air tends to coagulate and congeal (solidify) the grease, and cause it to rise to the surface (being pushed in separate compartments), from where it is removed.

![Diagram of skimming tank](image-url)

(a) L-section (b) X-section

The typical details of a skimming tank are shown in figure. It consists of a long trough shaped structure divided into two or three lateral compartments by means of vertical baffle walls (having slots in them) for a short distance below the sewage surface. The baffle walls help in pushing the rising coagulated greasy material into both the side compartments (called stilling compartments). The rise of oils and grease is
brought about by blowing compressed air into the sewage from diffusers placed at the bottom of the tank. The collected greasy materials are removed (i.e. skimmed off) either by hand or by some mechanical equipment. It may then be disposed of either by burning or burial.

Q.36 Why is recarbonation carried out, while softening water by lime soda process? [5 marks : 2012]

Solution:
The sodium salts which are finally formed in the lime - soda method, are soluble in water, but are generally not objectionable in the amounts resulting from the softening process. Most of the calcium carbonate and magnesium hydroxide which is formed, get precipitated and can be sedimented out in the sedimentation tank. However, a little quantity may remain as finely divided particles, and may cause troubles by getting deposited on the filter to cause enlargement of the sand grains called incrustation of filter media; or in the pipes of the distribution system. To prevent this, it is generally necessary that the water be recarbonated by passing carbon dioxide gas through it, as it leaves the sedimentation tank. In the recarbonation process, the insoluble carbonates combine with the carbon dioxide to again form the soluble bicarbonates.

\[
\begin{align*}
\text{CaCO}_3 (s) + CO_2 + H_2O &\rightarrow \text{Ca(HCO}_3\text{)}_2 \\
\text{Mg(OH)}_2 (s) + CO_2 + H_2O &\rightarrow \text{MgCO}_3
\end{align*}
\]

Q.37 Explain the terms ‘Super chlorination and Dechlorination’ When is super chlorination done? [5 marks : 2012]

Solution:
Super chlorination: Supper chlorination is a term which indicates the addition of excessive amount of chlorine (i.e. 5 to 15 mg/l) to the water. This may be required in some special cases of highly polluted waters, or during epidemics of water borne diseases. It may be used when there is a reason to believe that the water contains cysts of histolytic (i.e. the organism which causes amoebic dysentery).

The huge quantity of chlorine which is added in superchlorination is such as to give about 1 to 2 mg/l of residue beyond the break point, in the treated water.

Dechlorination: The dechlorination means removing the chlorine from water. This is generally required when superchlorination has been practised. The dechlorination process may either be carried out to such an extent that sufficient residual chloring (0.1 to 0.2 mg/l) do remains in water after dechlorination; or otherwise, if full chloring has been removed, additional chloring will generally be added to maintain such residues.

The dechlorination may be carried out by adding certain chemicals to water or by simply aerating the water. These chemicals are called dechlorinating agents.

The common dechlorinating agents are: Sulphur dioxide gas (SO₂), Activated carbon, Sodium thiosulphate (Na₂S₂O₃), Sodium metabisulphite (Na₂S₂O₅), Sodium sulphite (Na₂SO₃), Sodium bisulphite (NaHSO₃), and Ammonia as NH₄OH.

Q.38 Why is it economical to remove carbonate hardness than non-carbonate hardness when lime soda process is employed for softening of water? [5 marks : 2012]

Solution:
In lime soda process, following factors make removal of non-carbonate hardness uneconomical:
(i) For removal of non carbonate hardness of magnesium in addition of lime, soda-ash is also required.
(ii) In removal of non-carbonate hardness precipitate of Mg(OH)₂ is formed, which require pH of 11 or more. So additional lime or soda-ash is required to increase the pH value of water, which effectively do not remove any hardness.
(iii) Sludge due to precipitate of Mg(OH)₂ and CaCO₃ is very large, which causes considerable problem of disposal of sludge.
Q.39 Calculate quantity of bleaching powder required per day to disinfect 200 mlpd water.

Solution:

Assuming 0.3 ppm as total chlorine demand and 30% available chlorine in bleaching powder

Weight of chlorine required = 200 \times 0.3 \times 10^{-6} \times 10^6 = 60 \text{ kg}

Quantity of bleaching powder = \frac{60}{0.3} = 200 \text{ kg/day}

Q.40 Show that the settling velocity of spherical particle in a liquid under the condition when Reynolds number is less than 0.5 may be given by expression.

\[ V_s = \frac{g}{18} (S_s - 1) \frac{d^2}{v} \]

Solution:

For Reynolds number ≤ 0.5 (less than unity), a case of discrete settling can be assumed.

When a discrete particle settles down in water, its downward settlement is opposed by the drag force offered by the water. The effective weight of the particle (actual weight - buoyancy) causes the particle to accelerate in the beginning, till it attains a sufficient velocity \(v_s\) at which the drag force becomes equal to the effective weight of the particle. After attaining that velocity \(v_s\), the particle falls down with that constant velocity.

Effective weight of the particle = Total weight - Buoyancy

\[ = \frac{4}{3}\pi r^3 \gamma_s - \frac{4}{3}\pi r^3 \gamma_w \]

\[ \text{(Where 'r' is radius of particle, } \gamma_s \text{ is unit weight of particle and } \gamma_w \text{ is unit weight of water)} \]

also,

Drag force = \(C_D \times A \times \rho_w \times \frac{V_s^2}{2}\)

(Where \(C_D\) is coefficient of drag, \(A\) is area of particle, \(\rho_w\) is density of water and \(v = \) velocity of fall.) Now, when \(v\) becomes equal to \(v_s\), the drag force becomes equal to the effective weight of the particle.

\[ \therefore \quad C_D \times A \times \rho_w \times \frac{V_s^2}{2} = \frac{4}{3}\pi r^3 (\gamma_s - \gamma_w) \quad \text{[} \therefore A = \pi r^2 \text{]} \]

\[ \Rightarrow \quad \frac{V_s^2}{2} = \frac{4}{3}\pi r^3 (\gamma_s - \gamma_w) \]

\[ \Rightarrow \quad V_s^2 = \frac{4}{3}\pi r^3 (\gamma_s - \gamma_w) \]

\[ \Rightarrow \quad V_s^2 = \frac{4}{3}\pi r^3 \frac{g(\gamma_s - \gamma_w)}{\rho_w \cdot C_D} \]

\[ \Rightarrow \quad V_s^2 = \frac{4}{3}\pi r^3 \frac{d(\gamma_s - \gamma_w)}{\rho_w \cdot C_D} \]

\[ \Rightarrow \quad V_s^2 = \frac{4}{3}\pi r^3 \frac{d(\rho_s g - \rho_w g)}{\rho_w \times C_D} \]

\[ \Rightarrow \quad V_s^2 = \frac{4}{3}\pi r^3 \frac{d \times \rho_w g \left( \frac{\rho_s}{\rho_w} - 1 \right) \times \frac{1}{\rho_w \cdot C_D}}{C_D} \]

\[ \frac{V_s^2}{d \times g \times \left( S_s - 1 \right)} \times \frac{1}{C_D} \]

For \(Re = 0.5(< 1)\)

\[ \frac{C_D}{R_e} = \frac{24}{V_s d} \]

[Where \(v\) is kinematic velocity]
\[ V_s^2 = \frac{4}{3} \times g \times d \times (S_s - \eta) \times \frac{V_d}{24} \]

\[ \Rightarrow \]

\[ V_s = \frac{g}{18} (S_s - \eta) \times \frac{d^2}{v} \]

Q.41  Enumerate the chemicals which are used for coagulation. Discuss their comparative merits and demerits.  

[5 marks : 2013]

Solution:

Important coagulants used in coagulation process are as follows:

(i)  Alum (Al\(_2\)(SO\(_4\))\(_3\) \cdot 18\ H_2\ O)

(ii) Copperas (FeSO\(_4\) \cdot 7H_2\ O)

(iii) Chlorinated Copperas (Fe\(_2\)(SO\(_4\))\(_3\) \cdot FeCl\(_3\))

(iv) Sodium Aluminate (Na\(_2\)Al\(_2\)O\(_4\))

These can be classified as alumium and iron salts.

Comparison of Alum and Iron Salts (as Coagulants) : The alum and the iron salts are having their own advantages and disadvantages, as summarized below:

(i) Iron salts produce heavy floc and can, therefore, remove much more suspended matter than the alum.

(ii) Iron salts, being good oxidizing agents, can remove hydrogen sulphide and its corresponding tastes and odorous from water.

(iii) Iron salts can be used over a wider range of pH values.

(iv) Iron salts cause staining and promote the growth of iron bacteria in the distribution system.

(v) Iron salts impart more corrosiveness to water than that which is imparted by alum.

(vi) The handling and storing of iron salts require more skill and control, as they are corrosive and deliquescent. Whereas, no such skilled supervision is required for handling alum.

Q.42  Write causes and effects of hardness and its removal by lime-soda process.  

[5 marks : 2014]

Solution:

Hardness : It is the concentration of multivalent metallic cations (M\(^{n+}\)) in a solution. At super saturated conditions, these hardness causing cations react with anions in water resulting in the formation of solid precipitate. Depending upon the associating anions, hardness is classified as carbonate hardnes or non-carbonate hardness. Hardness which is equivalent to alkalinity of water is termed as carbonate hardness and remaining hardness being the non-carbonate hardness.

Source : Multivalent metallic cations like Calcium (Ca\(^{2+}\)) and Magnesium (Mg\(^{2+}\)) are abundantly present in natural waters. Other cations that are found in smaller proportions are iron (Fe\(^{3+}\)), Manganese (Mn\(^{2+}\)), Aluminium (Al\(^{3+}\)).

Impact of hardness : Hard water leads to excessive consumptions of soap thereby posing an economic loss to the user. Usually soaps containing sodium ions (Na\(^{+}\)) react with multivalent cations to form precipitate. This precipitate gets adhered to tanks, clothes, dishes etc. Magnesium hardness has a laxative effect on certain persons.

Lime-Soda Process for Removing Hardness : In this process, lime [Ca(OH)\(_2\)] and soda ash [Na\(_2\)CO\(_3\)] are added to the hard water ; which react with calcium and magnesium salts, so as to form insoluble precipitates of calcium carbonate and magnesium hydroxide [Mg(OH)\(_2\)]. These precipitates can be sediments out in a sedimentation tank. The chemical reactions which may be involved are :
Q.43 Explain break point chlorination with a neat diagram.

Solution:

**Break-point Chlorination**: Break point chlorination is a term which gives us an idea of the extent of chlorine added to the water. In fact, it represents, that much dose of chlorination, beyond which any further addition of chlorine will equally appear as free residual chlorine.

When chlorine is added to the water, it first of all, generally reacts with the ammonia present in the water, so as to form chloramines. These chloramines respond to the D.P.D. test in the same manner as does free chlorine. Therefore, the D.P.D. tests will indicate the quantum of total residual chlorine, "combined" as well as "free". Hence, if chlorine is slowly added to the water, and the residual is tested, it will be found that the residual will go on increasing with the addition of chlorine. (However, some chlorine is consumed for killing bacteria, and thus the amount of residual chlorine shall be slightly less than that added, as shown by the curve AB in figure below. If the addition of chlorine is continued beyond the point B, the organic matter present in water starts getting oxidised, and, therefore, the residual chlorine content suddenly falls down, as shown by the curve BC.

![Figure indicating break-point chlorination](image)

The point C is the point beyond which any further addition of chlorine will appear equally as free chlorine, since nothing of it shall be utilized. This point C is called the 'break point', as any chlorine that is added to water beyond this point, breaks through the water, and totally appears as residual chlorine. The addition of chlorine beyond break point chlorination.

Q.44 The quantity of chlorine used to treat 20000 m$^3$ of water per day is 8 kg. The residual chlorine after contact period of 10 min is found to be 0.2 mg/l. Calculate the chlorine dosage in mg/l and the chlorine demand of water.

Solution:

Chlorine used per litre of water $= \frac{8 \times 10^3}{20000 \times 10^3} = 4 \times 10^{-4}$ g/litre $= 0.4$ mg/l

Residual chlorine = 0.2 mg/l

Actual chlorine demand = 0.4 - 0.2 = 0.2 mg/l