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Disinfection
Part- I

Environmental Engineering-I

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Contents

- Disinfection techniques- Ozonation, u/v radiation. Chemistry of chlorination, chlorine demand curve. Types of chlorination, Application of Chlorine

Some common water-borne diseases prevented by disinfection

Bacterial	Viral	Protozoan
Typhoid fever	Hepatitis	Amoebiasis
Para-typhoid	Rotavirus diarrhea	Giardiasis
Bacterial diarrhea		Crypto-sporidiasis
Cholera		

Overview of the Process

- The purpose of disinfecting drinking water is to destroy organisms that cause diseases in human beings.
- Most pathogenic bacteria are removed from water in varying degrees during the different treatment processes (coagulation, sedimentation, and filtration).
- Disinfection is used to ensure satisfactory removal of pathogens from potable water.

Suitability of the disinfectant

1. Disinfectant shall be effective in killing the microorganisms.
2. Should be cheap and readily available.
3. Should be safe to handle and easy to apply.
4. It should not make water toxic in nature.
5. It should have ability to persist in residual state.

Disinfection Methods

1. Boiling
2. High pH (Excess lime)
3. Silver treatment
4. Potassium Permanganate
5. Chlorination
6. Ozonation
7. UV irradiation
8. Other halogens (Iodine and Bromine)

1. Boiling

- Water shall be boiled at least for 3 mins.
- Most effective
- Can kill bacteria and viruses
- Can not be used on large scale
- During epidemics it is used in domestic scale.

2. High pH Treatment (Excess Lime)

- Lime can destruct bacteria at high pH values
- In this case, no residual will remain after neutralization
- Studies showed that

– higher removal of viruses was obtained with higher pH values

– Optimum pH in the range of 11.2 to 11.3

– Optimum contact time in the range of 1.56 to 2.40 hours

– Complete destruction of viruses was obtained at pH of 11.0 and contact time of 5.0 hours and 10 minutes

3. Silver Treatment

- Silver when immersed in water has inhibiting effect on bacterial life.
- As silver is costly this method can be used in small scale.

4. Ultraviolet (UV) Irradiation

- Can disinfect both water and wastewater.
- However, its use in drinking water disinfection is limited to small installations such as aboard ships because it does not produce residual.
- In wastewater treatment, and when compared to

chlorination and Ozonation, UV was found

- More effective
- More economical

- UV irradiation is gaining prominence.

Ultraviolet (UV) Irradiation

5. Ozonation

- General characteristics of ozone

-- Powerful oxidant

-- More powerful than Hypochlorous acid

-- Unstable in aqueous solutions

-- Has a half of 20 to 30 minutes in distilled water

-- Widely used in drinking water treatment

-- Is produced on -- site and can not be stored site

6. Potassium Permanganate

- Commonly used in rural areas.
- Used for purification of open well water supplies.
- $KMnO_4$ is dissolved in bucket and added in well water.
- Water should not be used during first 48 hours after $KMnO_4$ addition

CHLORINATION

Why Chlorination?

Chlorine is widely used

– Effective at low concentration

– Cheap

– Forms residual if applied in sufficient dosages

Chlorine is applied as:

– Gas (most common), Cl_2

– Hypochlorite (Bleaching Powder) $Ca(OCl)_2$

- Chlorine is a strong oxidizing agent
  - It oxidizes enzymes of microbial cells that are necessary for metabolic processes, thus, inactivating (destroying) the microbial cells.

Chlorination Reaction

- Chlorine gas reacts with water to form
  - Hypochlorous acid (HOCl)
  - Hydrochloric acid (HCl)

$$Cl_2 + H_2O \rightarrow HOCl + HCl$$

- Hypochlorous acid dissociates to hypochlorite ion

$$HOCl \leftrightarrow H^+ + OCl^-$$

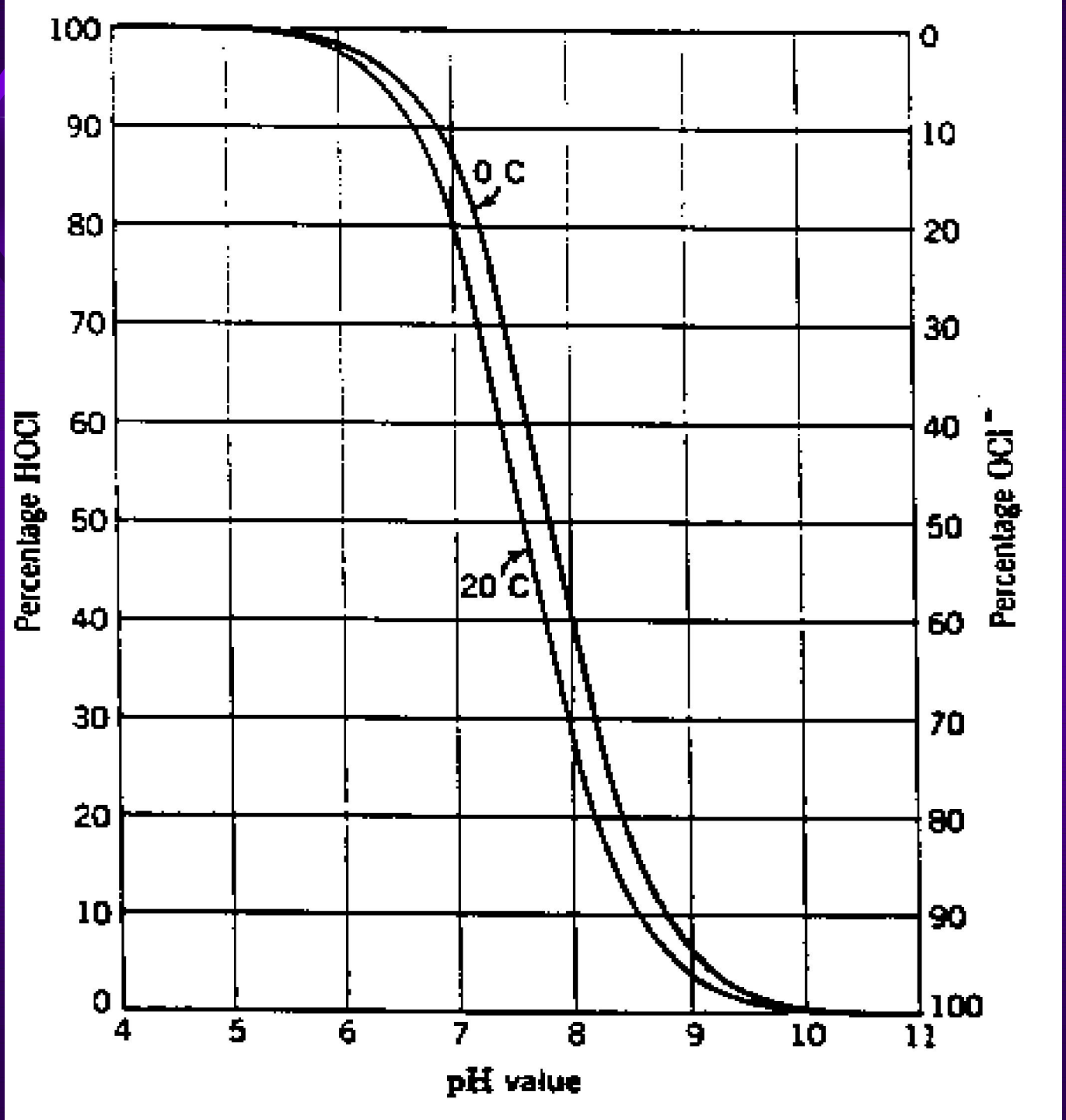
- The dissociation of the HOCl is a function of pH

- **Hypochlorous acid is 80 times more effective disinfectant than hypochlorite ions.**
- Chlorine will appear in water in three forms

i. Elemental chlorine (Cl^-)

ii. HOCl

iii. OCl^-


Percentage HOCl
Percentage OCl⁻
pH value
0 C
20 C
100
90
80
70
60
50
40
30
20
10
0
4
5
6
7
8
9
10
11

pH	Remark
< 5	Only elemental of molecular chlorine is present
5 to 10	Both HOCl and OCl^- present
>10	Only hypochlorite ions are present

- Below pH 7 conc. of HOCl is more.
- **pH of water should be less than 7 to prevent ionization of Hypochlorous acid.**

Chlorine demand

- When chlorine is added in water it reacts with organic and inorganic impurities.
- The amount of chlorine utilized for this is known as chlorine demand.
- The remaining chlorine will appear as available residual chlorine.
- Which serves as disinfectant to kill the pathogens

Dosages, Demand and Residuals – Short Summary

- **Dosage: the amount of chlorine added**
- **Demand: the amount of chlorine needed to oxidize materials (reaction)**
- **Residual: the amount of chlorine remaining after oxidation.**

Residual Chlorine = Dosage – Demand

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Part-II

FORMS OF APPLICATION OF CHLORINE

Chlorine can be applied in water by following forms

1. As Bleaching powder or Hypochlorite
2. As Chloramines
3. As free Chlorine gas
4. As Chlorine dioxide

1. Bleaching powder

- Chemical formula is Ca $(OCl)_2$.
- Available chlorine is 20 to 40 %.
- When it is added in water following reaction takes place

$$\mathbf{Ca(OCl)_2 + H_2O \rightarrow 2HOCl + Ca(OH)_2}$$

- Hypochlorous acid acts as disinfectant.

- As it contains 20 -40% chlorine it requires higher transportation cost and space for storing.
- Therefore used in small scales i.e. rural water supply schemes

2. Chloramines

- The free chlorine can react with compounds such as **ammonia, proteins, amino acids and phenols** that may be present in water to form chloramines and chloro-derrivatives which constitute as combined chlorine.
- Combined chlorine possesses disinfection properties.

Reaction with Ammonia

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$$

monochloramine

$$NH_2Cl + 2\,HOCl \rightarrow NHCl_2 + 2H_2O$$

dichloramine

$$NHCl_2 + 3\,HOCl \rightarrow NCl_3 + 3H_2O$$

nitrogen – trichloride

pH range	Chloramines formed
< 4.4	Trichloramine only
4.4 to 5	Dichloramine only
5 to 8	Both Mono and Dichloramine (Equal quantities at pH =7)
> 8.5	Monochloramine only

Advantages

1. More effective than chlorine alone
2. Prevents tastes and odour
3. Water treated with chloramines causes less irritation of eyes and odours.
4. No danger of overdose
5. Less chlorine is required

3. Free chlorine

- Generally applied in gaseous form or liquid form.
- 2.48 times heavier than air and 1.44 times heavier than water.
- Strong oxidant
- Forms residual
- By products are formed e.g. THMs
- Works under specific pH.

4. Chlorine Dioxide (ClO_2)

- Chlorine dioxide is created by mixing solutions of sodium chlorite and chlorine.
- Chlorine dioxide is generated on site

$$2NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$$

- The advantages of chlorine dioxide are:

1. it is a strong bactericide and viricide over a wide pH range.
2. It forms a slight residual in the distribution system.

3. It does not react with nitrogen to form chloramines.
4. It does not react with organic matter to form Trihalomethanes (THMs).

- **Chloroform and Bromoform are THMs**
- The disadvantages of chlorine dioxide are its high cost and its tendency to create chlorate and chlorite, which are potential toxins.
- Chlorine dioxide is used for taste and odor control as well as disinfection.

FORMS OF CHLORINATION

Forms of chlorination

1. Plain Chlorination
2. Pre-Chlorination
3. Post Chlorination
4. Double of multiple Chlorination
5. Break point Chlorination
6. Super Chlorination
7. De-Chlorination

1. Plain Chlorination

- Application of chlorine to raw water before it enters into distribution system.
- Sometimes added to reservoirs to check growth of weeds, organic matter , algae etc.
- It can be practiced for water with turbidities 20 to 30 NTU.
- Dose range – 0.5 to 1 ppm

2. Pre Chlorination

- Chlorine is applied before treatment specially before filtration.
- Sometimes added before sedimentation.
- Advantages

i. Reduces bacterial load on filtration
ii. Reduces coagulant required.
iii. Controls growth of algae
iv. Eliminates tastes and odour.

3. Post Chlorination

- Addition of chlorine after treatment i.e. after filtration.
- Added before water enters into distribution system.

4. Double Chlorination

- Application of chlorine at two or more points in purification process.
- Usually added -

i. Before sedimentation tank

ii. After filtration

- This is done if water is more contaminated.

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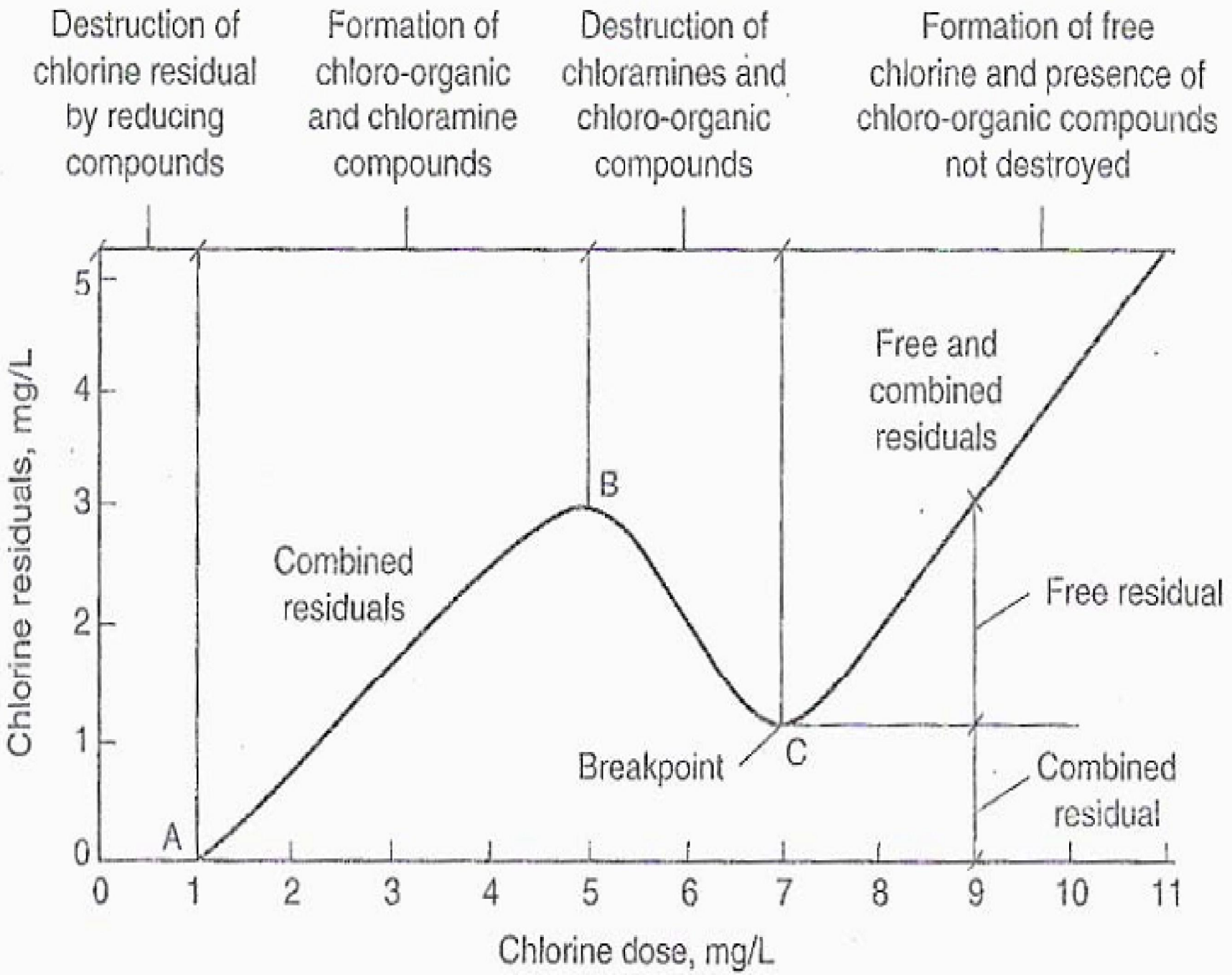
5. Break Point chlorination

-When chlorine is added it reacts first with the reducing compounds such as Fe^{+2}, Mn^{+2}, NO^{-2} , and the chlorine will be reduced to the none effective chloride ion Cl^- (from zero to point A on the figure).

- When adding more chlorine it will react with NH_3 to form chloramines as shown in the chlorine chemistry (from point A to B).

-When adding more chlorine some chloramines are oxidized to nitrogen gas and the chlorine is reduced to the none effective Cl^- ion.(from point B to C).

-Continued addition of chlorine will produced free available chlorine (at point C). point C is called the break point.


Destruction of chlorine residual by reducing compounds
Formation of chloro-organic and chloramine compounds
Destruction of chloramines and chloro-organic compounds
Formation of free chlorine and presence of chloro-organic compounds not destroyed
Chlorine residuals, mg/L
Chlorine dose, mg/L
Free and combined residuals
Combined residuals
Free residual
Combined residual
Breakpoint
A
B
C
0
1
2
3
4
5
6
7
8
9
10
11

6.Super chlorination

- Chlorine is applied beyond break point.
- It is done after filtration with contact time of 30 to 60 mins.
- It is practiced when there is **epidemics** in the society.

7. De Chlorination

- Process of removing excess chlorine from water is known as De-Chlorination.
- Can be achieved by aeration or using chemicals such as sodium thiosulphate , sodium bi sulphate, sodium sulphite, Activated carbon, potassium permanganate.

FACTORS AFFECTING CHLORINATION

1. Turbidity

- Turbidity affects chlorination process as efficiency of disinfection process decreases if water is more turbid.
- Pathogens can shelter behind solid particles.
- So, chlorine is added after removing turbidity i.e. after filtration.

2. Presence of metallic compounds

- Fe and Mn consumes more chlorine if present in water.
- So, chlorine is added when Fe and Mn are removed from water.

3. Ammonia compounds

- Ammonia forms combined chlorine compounds which are not so powerful disinfectants as compared to free available chlorine.
- Therefore more chlorine is added so that after formation of chloramines, excess free chlorine is available for speedy disinfection

4. pH of water

- Increasing pH reduces effectiveness of chlorine.

pH	Amount of HOCl
Up to 6.7	95% of total free chlorine
At 7	80% of total free chlorine
At 8	30% of total free chlorine
At 9	5% of total free chlorine

5. *Temperature of water*

- Reduction in temperature decreases killing power of both free and combined available chlorine.

6. Time of contact

- Percent kill of pathogens depends upon contact of chlorine and micro-organisms
- Time of exposure or time of contact is needed. Usually for free chlorine 10 min time is required as compared to 60 mins for combined chlorine.

7. Nature and Concentration of bacteria and viruses

- Bacteria spores are more resistant
- Polio virus is most resistant

Objective Questions

1. Molecular formula for bleaching powder is _____.
2. The disinfection by chlorination is most effective at pH ____ (2/5/10/7)
3. _____ means removing excess chlorine from water.
4. HOCl is _____ times more powerful than OCl^-.

Theory Questions

Q1. Explain 'Break Point Chlorination'.

Q2. Explain

i. Pre-chlorination
ii. Post-chlorination
iii. Super chlorination
iv. De-chlorination
v. Double or multiple chlorination

Q3. Discuss factors affecting Chlorination.

Q4. Discuss chemistry of chlorination.