Techno India NJR Institute of Technology

(Approved by AICTE, New Delhi and Affiliated to Rajasthan Technical University Kota (Raj.))

Lab manual

Environment Engineering Design and Lab

Semester: VI   Year: III (2023-24)

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RAJASTHAN TECHNICAL UNIVERSITY, KOTA
Syllabus
3rd Year - VI Semester: B.Tech. (Civil Engineering)

6CE4-21: Environmental Engineering Design and Lab

Credit: 1.5   **Max. Marks: 100(IA:60, ETE:40)**
0L+0T+3P   **End Term Exam: 3 Hours**

Design

1. Population forecasting and water demand
2. Water Quality parameters
3. Design of Sedimentation tanks, coagulation and flocculation tanks
4. Design of rapid and slow sand filters
5. Design of disinfection units and transmission systems
6. Design of Sewer lines and storm water systems
7. Design of aerobic and anaerobic treatment units
8. Design of suspended and attached growth systems

Lab.

1. Physical Characterization of water: Turbidity, Electrical Conductivity, pH
2. Analysis of solids content of water: Dissolved, Settleable, suspended, total, volatile, inorganic etc.
3. Alkalinity and acidity, Hardness: total hardness, calcium and magnesium hardness
4. Optimum coagulant dose
5. Chemical Oxygen Demand (COD)
6. Dissolved Oxygen (D.O) and Biochemical Oxygen Demand (BOD)
7. Break point Chlorination
8. Bacteriological quality measurement: MPN,

PREREQUISITES - 1

DEFINITIONS

1. **pH** is an indicator of acidity or alkalinity. pH is a logarithmic scale and an increase or decrease of one pH unit is a 10 fold change. Neutral water has a pH of 7, acidic solutions have values between 0-6 and alkaline solutions have values between 8-14.

2. **Temperature:** It is a measure of the average energy (kinetic) of water molecules. It is measured on a linear scale of degrees Celsius or degrees Fahrenheit. It is one of the most important water quality parameters. Temperature affects water chemistry and the functions of aquatic organisms. It influences the:

    - Amount of oxygen that can be dissolved in water,
    - Rate of photosynthesis by algae and other aquatic plants,
    - Metabolic rates of organisms,
    - Sensitivity of organisms to toxic wastes, parasites and diseases, and timing of reproduction, migration, and aestivation of aquatic organisms

Turbidity is a measure of the cloudiness or haziness in water caused by suspended solids (eg sediment, algae). Turbidity is expressed in Nephelometric Turbidity Units (NTU) and is measured using a relationship of light reflected from a given sample.

Conductivity: This is a measure of the capability of a solution such as water in a stream to pass an electric current. This is an indicator of the concentration of dissolved electrolyte ions in the water. It doesn't identify the specific ions in the water. However, significant increases in conductivity may be an indicator that polluting discharges have entered the water.

Total Hardness: Hardness is predominantly caused by divalent cations such as calcium, magnesium, alkaline earth metal such as iron, manganese, strontium, etc. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness.

Dissolved Oxygen(DO): Dissolved oxygen is oxygen gas molecules (O_2) present in the water. Plants and animals cannot directly use the oxygen that is part of the water molecule (H_2O), instead depending on dissolved oxygen for respiration. Oxygen enters streams from the surrounding air and as a product of photosynthesis from aquatic plants. Consistently high levels of dissolved oxygen are best for a healthy ecosystem. Levels of dissolved oxygen vary depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow. Water at higher temperatures and altitudes will have less dissolved oxygen. Dissolved oxygen reaches its peak during the day. At night, it decreases as photosynthesis has stopped while oxygen consuming processes such as respiration, oxidation, and respiration continue, until shortly before dawn. Human factors that affect dissolved oxygen in streams include addition of oxygen consuming organic wastes such as sewage, addition of nutrients, changing the flow of water, raising the water temperature, and the addition of chemicals. Dissolved oxygen is measured in mg/L.

0-2 mg/L: not enough oxygen to support life.
2-4 mg/L: only a few fish and aquatic insects can survive.
4-7 mg/L: good for many aquatic animals, low for cold water fish
7-11 mg/L: very good for most stream fish

7. **Phosphates:** Occur in natural or wastewaters as orthophosphates, condensed phosphates and naturally found phosphates. Their presence in water is due to detergents, used boiler waters, fertilizers and biological processes. They occur in solution in particles or as detritus. They are essential for the growth of organisms and a nutrient that limits the primary productivity of the water body. Inorganic phosphorus plays a dynamic role in aquatic ecosystems; when present in low concentration is one of the most important nutrients, but in excess along with nitrates and potassium, causes algal blooms. It is calculated by the stannous chloride method. In acidic conditions orthophosphate reacts with ammonium molybdate forming Molybdophosphoric acid, reduced further to molybdenum blue by stannous chloride. The intensity of the blue colour is directly proportional to the concentration of phosphate. The absorbance is noted at 690nm using spectrophotometer.

8. **Chlorides:** The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution by sewage, industrial wastes, intrusion of seawater or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants.

9. **Biological Oxygen Demand (BOD):** Biological Oxygen Demand (BOD) is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions. The test is used to determine the pollution load of wastewater, the degree of pollution and the efficiency of wastewater treatment methods. 5-Day BOD test being a bioassay procedure (involving measurement of oxygen consumed by bacteria for degrading the organic matter under aerobic conditions) requires the addition of nutrients and maintaining the standard conditions of pH and temperature and absence of microbial growth inhibiting substance.

10. **Chemical Oxygen Demand (COD):** Chemical oxygen demand (COD) is the measure of oxygen equivalent to the organic content of the sample that is susceptible to oxidation by a strong chemical oxidant. The intrinsic limitation of the test lies in its ability to differentiate between the biologically oxidisable and inert material. It is measured by the open reflux method.

11. **Sludge Volume Index (SVI):** SVI is used to describe the settling characteristics of sludge in the aeration tank in Activated Sludge Process. It is a process control parameter to determine the recycle rate of sludge. It is defined as 'the volume (in ml) occupied by 1 gram of activated sludge after settling the aerated liquid for 30 minutes.

PREREQUISITES - 2

DRINKING WATER QUALITY STANDARDS

Indian Standard: IS: 10500:2012

S. No.	Parameter	Acceptable limit	Permissible limit in the absence of alternate source
1.	Colour (Hazen units)	5	15
2.	Odour	Agreeable	Agreeable
3.	pH value	6.5–8.5	No relaxation
4.	Taste	Agreeable	Agreeable
5.	Turbidity (NTU units)	1	5
6.	Total dissolved solids (mg/l)	500	2000
7.	Aluminium (mg/l)	0.03	0.2
8.	Ammonia (mg/l)	0.5	No relaxation
9.	Anionic detergents (as MBAS) (mg/l)	0.2	1.0
10.	Barium (as Ba) (mg/l)	0.7	No relaxation
11.	Boron (as B) (mg/l)	0.5	1.0
12.	Cadmium (mg/l)	0.003	No relaxation
13.	Calcium (as Ca) (mg/l)	75	200
14.	Chloramines (as Cl_2) (mg/l)	4.0	No relaxation
15.	Chloride (as Cl) (mg/l)	250	1,000
16.	Copper (mg/l)	0.05	1.5
17.	Fluoride (mg/l)	1.0	1.5
18.	Iron (mg/l)	0.3	No relaxation
19.	Lead (mg/l)	0.01	No relaxation
20.	Magnesium (mg/l)	30	100
21.	Mercury (mg/l)	0.001	No relaxation
22.	Nickel (mg/l)	0.02	No relaxation
23.	Nitrate (mg/l)	45	No relaxation
24.	Phenolic compounds (as C_6H_5OH) (mg/l)	0.001	0.002
25.	Selenium (as Se) (mg/l)	0.01	No relaxation
26.	Sulphate (as SO_4) (mg/l)	200	400
27.	Sulphide (as H_2S) (mg/l)	0.05	No relaxation
28.	Total alkalinity (as $CaCO_3$) (mg/l)	200	600
29.	Total arsenic (mg/l)	0.01	No relaxation
30.	Total chromium	0.05	No relaxation
31.	Total hardness (as $CaCO_3$) (mg/l)	200	600
32.	Zinc (mg/l)	5.0	15.0
33.	Aldrin/Dieldrin (µg/l)	0.03	No relaxation
34.	Chlorpyriphos (µg/l)	30	No relaxation
35.	2,4-D (µg/l)	30	No relaxation
36.	DDT (µg/l)	1.0	No relaxation
37.	Endosulfan (µg/l)	0.4	No relaxation

SEWAGE DISPOSAL STANDARDS

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE
NOTIFICATION
New Delhi, the 13th October, 2017

Sl. No.	Industry	Parameters	Standards	
1	2	3	4	
			Effluent discharge standards (applicable to all mode of disposal)	
			Location	Concentration not to exceed
			(a)	(b)
"105	Sewage Treatment Plants (STPs)	pH	Anywhere in the country	6.5-9.0
		Bio-Chemical Oxygen Demand (BOD)	Metro Cities*, all State Capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep	20
			Areas/regions other than mentioned above	30
		Total Suspended Solids (TSS)	Metro Cities*, all State Capitals except in the State of Arunachal Pradesh, Assam, Manipur, Meghalaya Mizoram, Nagaland, Tripura Sikkim, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep	<50
			Areas/regions other than mentioned above	<100
		Fecal Coliform (FC) (Most Probable Number per 100 milliliter, MPN/100ml	Anywhere in the country	<1000

*Metro Cities are Mumbai, Delhi, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad and Pune.

Note :

(i) All values in mg/l except for pH and Fecal Coliform.

(ii) These standards shall be applicable for discharge into water bodies as well as for land disposal/applications.

(iii) The standards for Fecal Coliform shall not apply in respect of use of treated effluent for industrial purposes.

(iv) These Standards shall apply to all STPs to be commissioned on or after the 1st June, 2019 and the old/existing STPs shall achieve these standards within a period of five years from date of publication of this notification in the Official Gazette.

(v) In case of discharge of treated effluent into sea, it shall be through proper marine outfall and the existing shore discharge shall be converted to marine outfalls, and in cases where the marine outfall provides a minimum initial dilution of 150 times at the point of discharge and a minimum dilution of 1500 times at a point 100 meters away from discharge point, then, the existing norms shall apply as specified in the general discharge standards.

(vi) Reuse/Recycling of treated effluent shall be encouraged and in cases where part of the treated effluent is reused and recycled involving possibility of human contact, standards as specified above shall apply.

(vii) Central Pollution Control Board/State Pollution Control Boards/Pollution Control Committees may issue more stringent norms taking account to local condition under section 5 of the Environment (Protection) Act, 1986".

EXPERIMENT NO: 1

DETERMINATION OF pH & ALKALINITIY

AIM: TO DETERMINE pH OF A GIVEN WATER SAMPLE

INTRODUCTION:

The term pH refers to measure of hydrogen ion concentration in a solution and defined as the negative log of H+ ions concentration in water and wastewater. Values of **pH**, 0 to a little less than 7 are termed as acidic and values of **pH** a little above **7** to **14** are termed as basic. When the concentration of H+ and OH- ions are equal then it is termed as neutral **pH**.

APPARATUS: pH meter, Beaker

REAGENT: Buffer solutions of known pH value

PROCEDURE:

Three major steps are involved in the experiment.
1. Preparation of Reagents
2. Calibrating the Instrument
3. Testing of Sample

STEPS:

- Perform calibration of pH meter using standard pH solutions. The calibration procedure would depend on pH range of interest.
- In a clean dry 100 ml beaker take the water sample and place it in a magnetic stirrer, insert the Teflon coated stirring bar and stir well.
- Now place the electrode in the beaker containing water sample and check for the reading in pH meter. Wait until you get a stable reading.
- Take the electrode from the water sample, wash it with distilled water and then wipe gently with soft tissue.

RESULT:

pH of given water sample is _____.

ENVIRONMENTAL SIGNIFICANCE:

Determination of pH is one of the important objectives in biological treatment of the wastewater. In anaerobic treatment, if the pH goes below 5 due to excess accumulation of acids, the process is severely affected. Shifting of pH beyond 5 to 10 upsets the aerobic treatment of wastewater. In these circumstances, the pH is generally adjusted by addition of suitable acid or alkali to optimize the treatment of the wastewater. pH value or range is of immense importance for any chemical reaction. A chemical shall be highly effective at a particular pH. Chemical coagulation, disinfection, water softening and corrosion control are governed by pH adjustment. Lower value of pH below 4 will produce sour taste and higher value above 8.5 a bitter taste. Higher values of pH hasten the scale formation in water heating apparatus and also reduce the germicidal potential of chlorine. High pH induces the formation of tri-halomethanes, which are causing cancer in human beings.
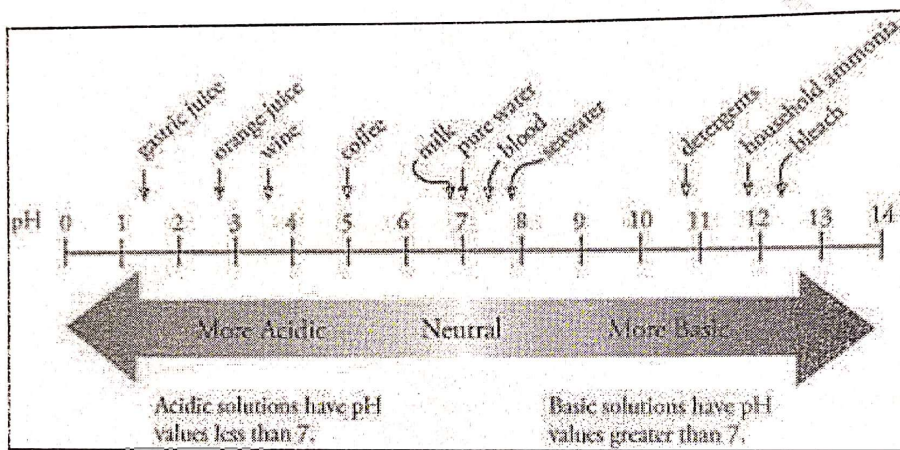
DETERMINATION OF ALKALINITIY

AIM: TO DETERMINE ALKALINITY OF A GIVEN WATER SAMPLE

INTRODUCTION:

Alkalinity is primarily a way of measuring the acid neutralizing capacity of the water. In other words, its ability to maintain a relatively constant pH. The ability of natural water to act as a buffer is controlled in part by the amount of carbonate ion in solution. Carbonate ion and calcium ion both come from calcium carbonate or limestone. So water that comes in contact with limestone will contain high levels of both Ca^{++} and CO_3^- and have elevated hardness and alkalinity.

PRINCIPLE:

The alkalinity of water is a measure of how much acid it can neutralize. When a water sample that has a pH of greater than 4.5 is titrated with acid to a pH 4.5 end point, all OH^-, CO_3^{2-} and HCO_3^- will be neutralized. For pH more than 8.3, add phenolphthalein indicator, the colour changes to pink colour. This pink colour is due to presence of hydroxil ions. If sulphuric acid is added to it, the pink colour disappears i.e. OH^- ions are neutralized. Then add mixed indicator, the blue colour appears. While adding acid, the colour changes to orange, this colour change indicates that all the CO_3 & HCO_3 has been neutralized. This is the end point.

APPARATUS: Burette, pipette, Conical flask, Beakers, Burette stand and Clamp

CHEMICALS: Sodium carbonate, Standard Sulphuric acid, Phenolphthalein and Methyl orange indicator, Methyl red & Bromocersol green

PROCEDURE:

The procedure involves two phases.
1. Preparation of reagents
2. Testing of water sample

PREPARTION OF REAGENTS:

The following reagents are required to be prepared.
- Sulphuric acid solution (0.02 N)
- Phenolpthalein Indicator
- Mixed Indicator

Sulphuric acid solution (0.02 N)

Take 500 ml of distilled water in a 1000 ml standard flask. Exactly measure 28 ml of concentrated sulphuric acid and add slowly along the sides of the standard flask. Then make up the volume up to the mark. The strength of this

solution is 1 N. For preparing 0.02 N sulphuric acid solution, exactly measure 20 ml of 1 N solution and make up to 1000 ml in a standard flask.

Phenolphthalein Indicator

For preparing 0.02 N sulphuric acid solutions, exactly measure 20 ml of 1N solution and make up to 1000 ml in a standard flask. Weight 1 gm of phenolphthalein and add 100 ml of 95% ethyl alcohol or 100 ml of distilled water.

Mixed Indicator

Dissolve 100 mg bromcresol green and 20 mg methyl red in 100 ml 95% ethyl alcohol or 100 ml of distilled water.

TESTING OF WATER SAMPLE:

Using a measuring cyclinder exactly measure 100 ml of sample and pour it in a 250 ml of conical flask. Fill the burette with 0.02N sulphuric acid. Add few drops of phenolphthalein indicator to the conical flask. If the contents in the conical flask turns pink then titrate it against 0.02N sulphuric acid till the pink colour disappears. Note down the titrate value (V1). The value of titration is 0.5 ml. This value is used in calculating the phenolphthalein alkalinity. To the same solution in the conical flask add few drops of mixed indicator and the solution turns blue. Continue the titration from the point where stopped. Titrate till the solution become red. The entire volume (V2) of sulphuric acid noted down and is accountable in calculating the total alkalinity. Repeat the titration from concordant values.

Burette solution: Sulphuric acid solution

Pipette solution: Sample

Indicator: Phenolphthalein Indicator, Mixed Indicator

CALCULATION:

Calculation of Phenolphthalein Alkalinity

Burette solution: Sulphuric acid solution

Pipette solution: Sample

Indicator: Phenolphthalein Indicator

End point: Disappearance of pink colour

Sr.No.	Volume of sample (ml)	Burette reading (ml)		Vol. of 0.02N Sulphuric acid (ml)
		Initial	Final	

Phenolphthalein Alkalinity= Vol of Sulphuric acid (V1) x Normality x 50 x 1000/ Vol. of sample taken

Calculation of Total Alkalinity

Burette solution: Sulphuric acid solution
Pipette solution: Sample
Indicator: Mixed Indicator
End point: Appearance of red colour

Sr.No.	Volume of sample (ml)	Burette reading (ml)		Vol. of 0.02N Sulphuric acid (ml)
		Initial	Final	

Total Alkalinity = Vol of Sulphuric acid (V2) x Normality x 50 x 1000/ Vol. of sample taken

ENVIRONMENTAL SIGNIFICANCE:

Large amount of Alkalinity imparts bitter taste in water. The principal objection of alkaline water is the reactions that can occur between alkalinity and certain cations in water. The resultant precipitate can foul pipes and other accessories of water distribution systems.

a. Chemical coagulation of water and waste water – to neutralize acids produced during flocculation, the sample should be alkaline as otherwise further floc formation slowly ceases.

b. Corrosion control: to control the corrosion due to acids, natural water is rendered to alkaline.

c. Effluents of wastewater: wastewater containing excess caustic (hydroxide) alkalinity is not to be discharged into natural water bodies or sewers.

Alkaline Water Science: Water pH vs. Alkalinity

pH: Measures the concentration of hydrogen ions

The PH Scale
Acidic   Alkaline
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Neutral
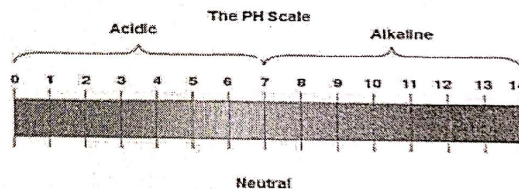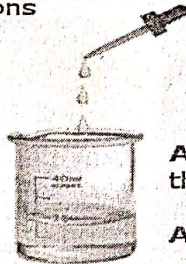
Alkalinity: Measures the ability of the water to neutralize acid

Alkaline water can neutralize stomach acid.

Alkaline ionized water has higher alkalinity than regular water

RESULT:

Total Alkalinity present in water sample is _____.

EXPERIMENT NO: 2

DETERMINATION OF HARDNESS IN WATER

AIM: TO DETERMINE HARDNESS OF GIVEN WATER SAMPLE

INTRODUCTION:

Hardness is caused by divalent metallic cations. The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. The major anions associated with these cations are sulphates, carbonates, bicarbonates, chlorides and nitrates. The hardness of water varies considerably from place to place. In general, surface water is softer than groundwater. The hardness of water reflects the nature of the geological formations with which it has been in contact.

The total hardness of water is defined as the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in mg/l. Hardness are of two types, temporary or carbonate hardness and permanent or non carbonate hardness. Temporary hardness is one in which bicarbonate and carbonate ion can be precipitated by prolonged boiling. Non-carbonate ions cannot be precipitated or removed by boiling, hence the term permanent hardness. IS value for drinking water is 300 mg/l as $CaCO_3$.

APPARATUS: 50 ml Burette, 20 ml Pipette, 250 ml Conical flask, 100 ml Beaker, 250 ml beaker, Glass funnel.

REAGENTS: EDTA solution, Standard $CaCO_3$ solution, Eriochrome Black–T indicator, Buffer solution.

THEORY:

EDTA (Ethylenediamine tetra acetic acid) forms colorless stable complexes with Ca^{2+} and Mg^{2+} ions present in water at pH = 9-10. To maintain the pH of the solution at 9-10, buffer solution ($NH_4Cl + NH_4OH$) is used. Eriochrome Black-T (E.B.T) is used as an indicator. The sample of hard water must be treated with buffer solution and EBT indicator which forms unstable, wine-red colored complex s with Ca^{2+} and Mg^{2+} present in water.

APPARATUS:

- Beaker
- Burette
- Pipette
- Conical flask
- Measuring cylinder

PROCEDURE:

1. Standardization of EDTA

(i) Pipette out 20 ml of standard hard water into a conical flask.

(ii) Add 5 ml of buffer solution and few drops of Eriochrome Black-T. The indicator, which is originally blue color would acquire a wine-red color.

(iii) Titrate with EDTA solution taken in the burette, till the wine red color changes to blue which is the end point. Let the burette reading of EDTA be V2 ml.

2. Determination of Total hardness

Repeat the above titration method for sample hard water instead of standard hard water. Let the burette reading of EDTA be V3 ml.

3. Determination of Permanent hardness

Take 100 ml of sample hard water in 250 ml beaker. Boil it to remove temporary hardness to about half of this volume and cool to room temperature. Filter through filter paper to remove insoluble $CaCO_3$ and $MgCO_3$. Make up the volume to the original 100 ml by adding distilled water. Now pipette out 20 ml of this solution into a clean conical flask. Then repeat the process of titration steps as mentioned above. Let the burette reading of EDTA be V4 ml.

OBSERVATIONS:

1. Standardization of EDTA

Sr.No.	Volume of hard water taken (ml)	Burette reading (ml)		Vol. of EDTA consumed (V2) (ml)
		Initial	Final	

2. Determination of Total Hardness

Sr.No.	Volume of hard water taken (ml)	Burette reading (ml)		Vol. of EDTA consumed (V2) (ml)
		Initial	Final	

3. Determination of Permanent Hardness

Sr.No.	Volume of hard water taken (ml)	Burette reading (ml)		Vol. of EDTA consumed (V2) (ml)
		Initial	Final	

CALCULATIONS:

1. Standardization of EDTA $M_1V_1 = M_2V_2$

   Where, M_1 = Molarity of standard hard water

   V_1 = Volume of standard hard water in conical flask

   M_2 = Molarity of EDTA

   V_2 = Volume of EDTA consumed (burette reading)

2. Determination of Total hardness $M_2V_2 = M_3V_3$

   Where, M_3 = Total hardness of sample water

   V_1 = Volume of sample hard water in conical flask

3. Determination of Permanent hardness $M_2V_2 = M_4V_4$

   Where, M_4 = Permanent hardness of sample water

   V_4 = Volume of sample hard water in conical flask Note: Multiply M_3 and M_4 with 105 to covert hardness into parts per million (ppm).

4. Determination of Temporary hardness Temporary hardness = Total hardness − Permanent hardness

RESULT:

Total Hardness present is a water sample is _____.

ENVIRONMENTAL SIGNIFICANCE:

Hard water is as satisfactory for human consumption as soft waters. Because of their action with soap, however, their use for cleansing purpose is quite unsatisfactory, unless soap costs are disregarded. Soap consumption by hard waters represents an economic loss to the water user. Sodium soaps react with multivalent metallic cations to form a precipitate, thereby losing their surfactant properties. In recent years these problems have been largely alleviated by the developments of soaps and detergents that do not react with hardness. Boiler scale, the result of the carbonate hardness precipitation, may cause considerable economic loss through fouling of water heater and hot water pipes. Change in pH in the water distribution systems may also result in deposits of precipitates. Bicarbonates begin to convert to the less soluble carbonates at pH values above 9.0. Magnesium hardness, particularly associated with the sulfate ion has a laxative effect on persons unaccustomed to it. Magnesium concentrations of less than 50 mg/l are desirable in potable waters, although many public water supplies exceed the amount. Calcium hardness presents no public health problem. In fact, hard water is apparently beneficial to the human cardiovascular system.

Water Hardness Scale		
Grains/Gallon	mg/L & ppm	Classification
Less than 1	Less than 17.1	Soft
1 to 3.5	17.1 to 60	Slightly hard
3.5 to 7.0	60 to 120	Moderately hard
7.0 to 10.5	120 to 180	Hard
10.5 and over	180 and over	

Note - one grain per gallon = 17.1 parts per million (ppm)

EXPERIMENT NO: 3

TOTAL SOLIDS (TS)

AIM: TO DETERMINE TOTAL SOLIDS OF GIVEN SAMPLE.

PRINCIPLE:

Total solids are determined by evaporating a well mixed sample and dried to constant weight in an oven at 103 to 105^0C and weighing the dry residue left. The increase in final weight than the initial weight of crucible indicates total solids.

APPARATUS: Crucible, Muffle furnace, measuring cylinder, weight balance, oven, desiccators.

PROCEDURE:-

1. Take the weight of empty crucible
2. Take 50 ml of given water sample in a crucible.
3. Evaporate the sample at 103 to 1050C for 24 hrs.
4. Again ignite the crucible for 15-20 minutes in a muffle furnace whose temperature is maintained to 550+500C until the constant weight is attained. Cool it.
5. Note down the weight of crucible with residue.

OBSERVATION:

1. Weight of empty crucible (B): _____ gm
2. Weight of empty crucible with residue (A): _____ gm.

CALCULATION:

Total solids (TS) mg/l = {(A-B) x 1000 x 1000} / ml of sample (V), where,

    A: Final weight of the crucible with residue in gm

    B: Initial weight of the empty crucible in gm.

    V: Volume of sample taken in ml.

RESULT:-

The amount of total solids determined from the given water sample is _____ mg/l.

ENVIRONMENTAL SIGNIFICANCE:

Total solids determination is used to assess the suitability of potential supply of water for various uses.

CONCLUSION:-

The amount of total solids determined from the given water sample is _____ mg/l.

TOTAL SUSPENDED SOLIDS (TSS)

AIM: TO DETERMINE TOTAL SUSPENDED SOLIDS FROM GIVEN SAMPLE.

PRINCIPLE:

The residue which remains on filter paper after filtration. The dry weight of this residue is termed as total suspended solids.

APPARATUS:

Whatman filter paper no. 44, measuring cylinder, weight balance, oven, desiccator, funnel, tripod stand.

PROCEDURE:

1. Take a tripod stand and put it on the table to which funnel is placed.
2. Take initial weight of Whatman filter paper as (W1)
3. Now place the Whatman filter paper three folded on the funnel.
4. Pour the well mixed sample on the Whatman filter paper.
5. Wait for some time so as to drain out the water sample completely.
6. Now remove the Whatman filter paper and keep it in the oven. Care should be taken to see that the filter paper should not be scratched.
7. Now take the final weight of the filter paper along with residue as (W2).

OBSERVATIONS:

1. Initial weight of Whatman filter paper (W1): _____ gm.
2. Final weight of Whatman filter paper with residue (W2): _____ gm.

CALCULATION:

Total suspended solids (TSS) mg/l = { (W2-W1) x 1000 x 1000 } / ml of sample (V)

where,

W1---- Initial weight of filter paper in gm.

W2: Final weight of filter paper with residue in gm.

V: Volume of sample taken.

RESULT:

The amount of total suspended solids determined from the given water sample is _____ mg/l.

ENVIRONMENTAL SIGNIFICANCE:

1. Suspended solid material may be objectionable in water. Organic suspended are degraded anaerobically may release obnoxious odors.
2. Measures the quality of the wastewater influent and effluent.
3. Extremely valuable in the analysis of polluted waters.

APPLICATION OF DATA:

1. To evaluate the strength of domestic wastewater.
2. To determine the efficiency of treatment units.

CONCLUSION:-

The amount of total suspended solids determined from the given water sample is _____ mg/l.

TOTAL DISSOLVED SOLIDS (TDS)

$$TDS\ (mg/l) = TS - TSS$$

ENVIRONMENTAL SIGNIFICANCE:

1. TDS stands for total dissolved solids, and represents the total concentration of dissolved substances in water.
2. An elevated total dissolved solids (TDS) concentration is not a health hazard. The TDS concentration is a secondary drinking water standard and, therefore, is regulated because it is more of an aesthetic rather than a health hazard.
3. High concentration produces hard water, which leaves deposits and films on fixtures and on the insides of hot water pipes and boilers.
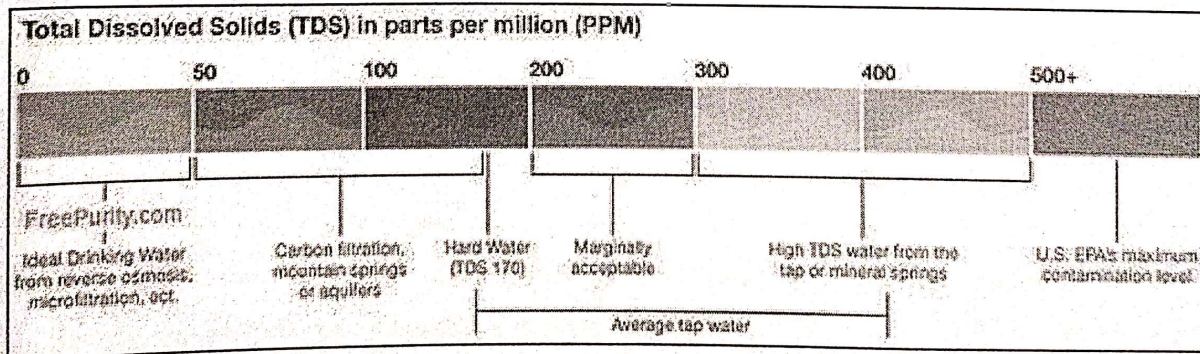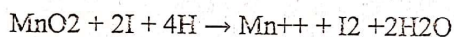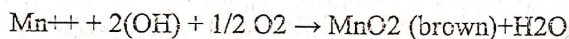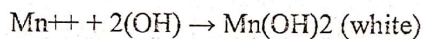
EXPERIMENT NO: 4

DISSOLVED OXYGEN

AIM: TO DETERMINE DISSOLVED OXYGEN OF GIVEN SAMPLE.

PRINCIPLE:

DO rapidly oxidizes the divalent manganous to its higher valency which forms a brown hydrated oxide precipitate after addition of NaOH and KI. In the presence of iodide ions in an acidic solution the oxidized manganese reverts to the divalent state and liberates Iodine from KI equivalent to the original DO content.

The liberated Iodine is then titrated against Sodium thiosulphate solution with starch as an indicator. MnSO4 reacts with alkali to form white precipitate Mn(OH)2 thus indicating absence of oxygen in the sample.

REACTION:

$$Mn^{++} + 2(OH) \rightarrow Mn(OH)_2 \text{ (white)}$$

$$Mn^{++} + 2(OH) + 1/2 \, O_2 \rightarrow MnO_2 \text{ (brown)} + H_2O$$

$$MnO_2 + 2I + 4H \rightarrow Mn^{++} + I_2 + 2H_2O$$

APPARATUS:

BOD bottles (capacity 300 ml), burette, pipettes, conical flask, burette stands, tile, measuring cylinder, weight balance, glass rod, beakers.

REAGENTS:

1. **Winkler's A solution:**

   Dissolve 48 gm tetra hydrate manganous sulphate in 100 ml distilled water. Filter if necessary.

2. **Winkler's B solution:**

   Dissolve 50 gm of NaOH and 15 gm of KI in 100 ml distilled water.

3. **Starch indicator:**

   Make a paste of 2gm L.R grade soluble starch powder in distilled water. Pour this solution in 100 ml distilled water. Boil for few minutes. Cool the solution and then use.

4. **Concentrated sulphuric acid**

5. **Standard sodium thiosulphate solution:**

   Dissolve 24.82 gm Na2S2O3 in distilled water and make up to 1 liter. It becomes 0.1N. Take 250 ml of this solution and make up to 1 liter with distilled water to prepare 0.025N.

PROCEDURE:

1. Collect the sample in 300ml BOD bottle.
2. Add 2ml of Winkler's A solution and 2ml of Winkler's B solution well below the surface through the walls.

3. Stopper immediately to remove air bubbles and mix carefully by inverting bottle up and down.
4. Allow the brown precipitate to settle down leaving clear supernatant.
5. Add conc. Sulphuric acid drop by drop till precipitate digested.
6. Restopper the bottle and mix by inverting several times for complete dissolution.
7. A yellow colored solution appears.
8. Take 50 ml samples in conical flask.
9. Add few drops of starch indicator and titrate against 0.025N Na2S2O3 solution.
10. Note down the reading until the color changes from blue to colorless.

SOURCE:

1. Drinking water.
2. Tap water.

OBSERVATIONS:

1. In burette: 0.025 N sodium thiosulphate solution.
2. In conical flask: 50 ml sample + indicator.
3. Indicator: starch.
4. End point: blue to colorless.

OBSERVATION TABLE:

Sr no.	Source	Burette reading	Difference	Average

CALCULATION:

DO (mg/l) = (V x 70) / u

Where,

V= ml of titrant used for DO determination (B.R.)

u = ml of water sample taken

70 = correction factor

RESULT:

The amount of dissolved oxygen determined from the given sample is ------ mg/l.

ENVIRONMENTAL SIGNIFICANCE:

1. A minimum DO of 4 to 6 mg/l is desirable for the survival of aquatic life; higher values of DO may cause corrosion of iron and steel.
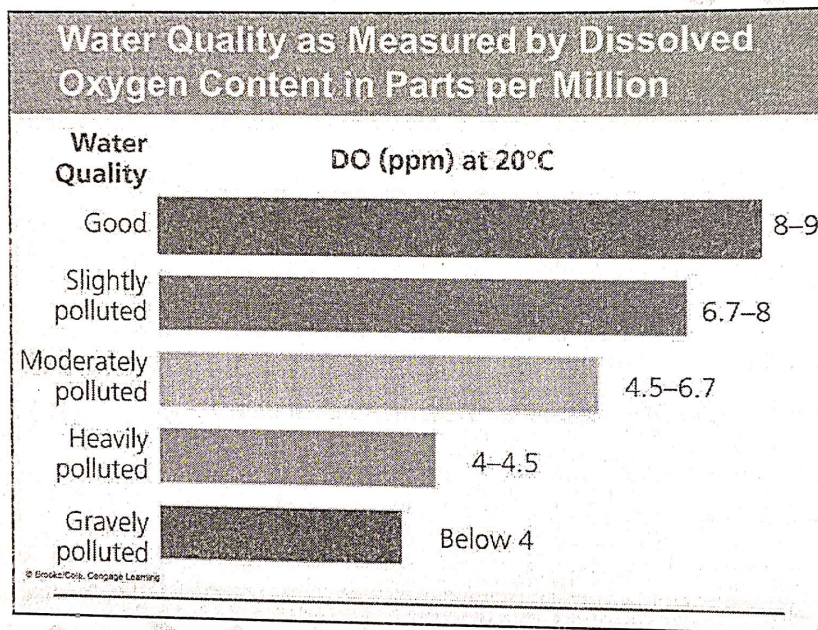
2. High temperature, biological impurities, ammonia, nitrites, ferrous iron, chemicals such as hydrogen sulphide and organic matter reduces DO values.

3. Drinking water should be rich in DO for good taste.

APPLICATION OF DATA:

1. It is necessary to know DO levels to assess the quality of raw water and to check on stream pollution.

2. DO test is basis for BOD test which is an important parameter to evaluate organic pollution potential of waste.

3. DO test is used to control oxygen in boiler feed water.

4. DO test is used to evaluate the pollution strength of domestic and industrial waste.

5. Determination of DO in waste water is useful to identify the nature of biochemical reactions whether aerobic or anaerobic.

Water Quality as Measured by Dissolved Oxygen Content in Parts per Million

Water Quality	DO (ppm) at 20°C
Good	8–9
Slightly polluted	6.7–8
Moderately polluted	4.5–6.7
Heavily polluted	4–4.5
Gravely polluted	Below 4

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CONCLUSION:-

The Dissolved Oxygen derived from the given water sample is _____ .

CHEMICAL OXYGEN DEMAND (COD)

AIM: TO DETERMINE COD OF THE GIVEN WATER SAMPLE.

PRINCIPLE:

The organic matter present in sample gets completely oxidized by K2Cr2O7 in presence of H2SO4 to form CO2 and H2O. The K2Cr2O7 gives the O2 required for the oxidation of organic matter.

REACTION:

$$2\ K_2Cr_2O_7 + 8H_2SO_4 = K_2SO_4 + 2\ Cr_2(SO_4)_3 + 8H_2O + 3\ O_2$$
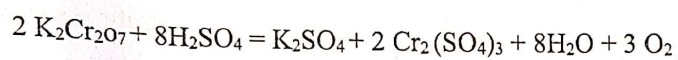
APPARATUS:

COD Digester, Spectrophotometer, Measuring cylinder, Beakers, Volumetric flask.

REAGENTS:

1. **Potassium Dischromate solution**

   Dissolve 10.216 gm of $K_2Cr_2O_7$ in 500 ml distilled water. Add 167 ml concentrated H_2SO_4 and 33.3 gm $HgSO_4$ to the solution. Mix well and dilute to 100 ml.

2. **H₂SO₄ Reagent**

   Dissolve 10.1 gm of $HgSO_4$ into 1000 ml concentrated H_2SO_4.

3. **Potassium Hydrogen Phthalate stock solution**

   Dissolve 0.425 gm of KHP in to 50 ml distilled water using a volumetric flask.

PROCEDURE:

1. Take COD vials with stopper.

2. Add 2 ml of sample in the COD vials.

3. Add 1.5 ml of potassium dischromate reagents.

4. Add 3.5 mal of sulphuric acid reagent.

5. COD the vials become hot.

6. Cap the vials tightly.

7. Switch on the COD digester and fix the temperature at 1500C and set the time at 2 hours.

8. Now place the COD vials into a COD digester and heat for 2 hours.

9. The digester automatically switches off. Then remove the vials from the digester and take readings on spectrophotometer.

RESULTS:

The amount of COD determined from the provided water sample is _____ mg/l.

ENVIRONMENTAL SIGNIFICANCE:

1. COD values are practically important in the survey designed to determine and control the losses to sewer systems.
2. The ratio of BOD to COD is useful to assess the amenability of water for biological treatment.
3. It is useful to assess strength of water, which contain toxins and biologically resistant organic substance.
4. For domestic and some industrial waste water, COD value is about 2.5 times BOD values.
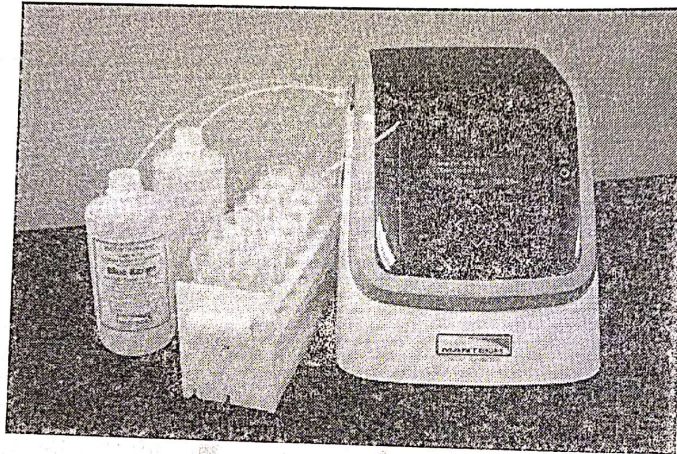
CONCLUSION:-

The Chemical Oxygen Demand derived from the given water sample is _____.

BIOCHEMICAL OXYGEN DEMAND (BOD)

AIM: TO DETERMINE BOD OF GIVEN SAMPLE.

PRINCIPLE:

The BOD is an empirical test which measures the oxygen required by the micro organisms for the biochemical degradation of organic matter to carbon dioxide and water at 200C temperature. The test consists of determination of DO prior to following period of 5 days. The difference between first day DO and fifth day DO is the amount of BOD.

APPARATUS:

BOD bottles (capacity 300 ml),BOD Incubator, burette, pipettes, conical flask, burette stands, tile, measuring cylinder, weight balance, glass rod, beakers.

REAGENTS:

1. **Phosphate buffer solution**

   Dissolve 8.5 g KH_2PO_4, 21.75 g K_2HPO_4, 33.4 g Na_2HPO_4, and 17.4 g NH_4Cl in1000 ml distilled water.

2. **Magnesium Sulphate Solution**

   Dissolve 22.5 g $MgSO_4.7H_2O$ in 1000 ml distilled water.

3. **Calcium Chloride solution**

   Dissolve 27.5 g $CaCl_2$ in 1000 ml distilled water.

4. **Ferric Chloride Solution**

   Dissolve 0.25 g $FeCl_3 .6H_2O$ in 1000 ml distilled water.

5. **Winkler's A solution**

   Dissolve 48 gm tetra hydrate manganous sulphate in 100 ml distilled water. Filter if necessary.

6. **Winkler's B solution**

   Dissolve 50 gm of NaOH and 15 gm of KI in 100 ml distilled water.

7. **Starch indicator**

   Make a paste of 2gm L.R grade soluble starch powder in distilled water. Pour this solution in 100 ml distilled water. Boil for few minutes.

   Cool the solution and then use.

8. **Concentrated sulphuric acid**

9. **Standard sodium thiosulphate solution**

   Dissolve 24.82 gm $Na_2S_2O_3$ in distilled water and make up to 1 liter. It becomes 0.1N. Take 250 ml of this solution and make up to 1 liter with distilled water to prepare 0.025N.

PROCEDURE:

1. Take the sample in 2 BOD bottles.
2. Fill another two BOD bottles with distilled water.
3. Add 1 ml each of phosphate buffer,magnesium sulphate,calcium chloride,and ferric chloride solutions in all above bottles.
4. Find immediately DO of the sample and distilled water on 1st day.
5. Incubate at 200C for 5 days the other two bottles. Tightly stopper to prevent any air entry into the bottles.

6. Determine DO content in the incubated bottles at the end of 5 days by using DO estimation method.

OBSERVATION:

1. In burette : 0.025N sodium thiosulphate solution
2. In conical flask : 50 ml sample + indicator
3. Indicator : Starch
4. End Point : Blue to Colourless

SOURCE:

1. Wastewater
2. Tap water
3. Drinking water
4. Distilled water

OBSERVATION TABLE:

Sr no.	Source	Burette reading	Difference	Average

CALCULATION:

1. Initial DO of the sample = D_0
2. Final DO after 5 days of the sample = D_5
3. Initial DO of distilled water (Blank) = C_0
4. Final DO after 5 days of distilled water (blank) = C_5
5. DO depletion of the sample = $D_0 - D_5$
6. DO depletion of distilled water = $C_0 - C_5$
7. DO depletion due to microbes = $(D_0 - D_5) - (C_0 - C_5)$
8. BOD (mg/l) = $(D_0 - D_5)$ x Volume of bottle - $(C_0 - C_5)$/ ml of sample

RESULT:

The amount of BOD determined from the given sample is ------ mg/l.

ENVIRONMENTAL SIGNIFICANCE:

1. It is principle test which gives biodegradability of a sample and the strength of waste. Hence the amount of pollution can be measured.
2. Efficiency of any treatment plant can be judged by considering influent BOD and effluent BOD and so also the organic loading on the unit.
3. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants.

CONCLUSION:-

The Biochemical Oxygen Demand derived from the given water sample is _____.

BOD Level (in ppm)	Water Quality
1 - 2	**Very Good** There will not be much organic waste present in the water supply.
3 - 5	**Fair: Moderately Clean**
6 - 9	**Poor: Somewhat Polluted** Usually indicates organic matter is present and bacteria are decomposing this waste.
100 or greater	**Very Poor: Very Polluted** Contains organic waste.

EXPERIMENT NO: 6

SLUDGE VOLUME INDEX (SVI)

AIM: TO DETERMINE SVI OF GIVEN SAMPLE.

PRINCIPLE:

SVI determination is based on estimating the volume of sludge settled in 30 minutes per gram of MLSS (mixed liquor suspended solids).

APPARATUS:

Imhoff cone or 1000ml measuring cylinder, 50 ml measuring cylinder, crucibles, beaker, Whatman filter paper no.40, funnel, stand, hot air oven.

PROCEDURE:

1. Take exactly one liter of a mixed liquor sample and allow it to settle in on Imhoff cone.
2. Record the volume of settled sludge (V ml/l) at the end of 30 minutes.
3. Weigh a clear and empty crucible as (W1)
4. Stir up the Imhoff cone contents well, collect 50ml of the mixed liquor in a crucible and evaporate to dryness in a hot air oven.
5. Cool the crucible to room temperature and weigh with solids residue as (W2)
6. Weigh another clean and empty crucible as (W3)
7. Stir up the Imhoff cone content again and collect 50ml of the mixed liquor and filter through Whatman filter paper no.40 and collect the filtrate in the crucible and evaporate to dryness.
8. Cool the crucible with dissolved solids residue and weigh as (W4).

OBSERVATIONS:

1. Weigh of empty crucible (W1)= _____ gm
2. Weigh of crucible with unfiltered residue (W2) = _____ gm
3. Weigh of another empty crucible (W3) = _____ gm
4. Weigh of crucible with filtered residue (W4)= _____ gm
5. Volume of settled sludge (V) = _____ ml

CALCULATIONS:

1. Mixed liquor total solids (MLTS), mg/l

$$= \frac{(W2-W1) \times 1000}{\text{Sample taken}}$$

2. Mixed liquor dissolved solids (MLDS), mg/l

$$= \frac{(W4-W3) \times 1000}{\text{Original sample taken}}$$

3. Mixed liquor suspended solids (MLSS), mg/l

$$= MLTS - MLDS$$

$$SVI \text{ ml/g} = \frac{V \times 1000}{MLSS}$$

RESULT: The amount of SVI determined from the provided sample is _____

ENVIRONMENTAL SIGNIFICANCE:

1. The value of SVI is of operational importance since it reflects changes in the treatment system.

ANALYSIS OF DATA:

1. SVI is used for determining the quality of sludge produced in a biological aeration unit and hence its efficiency.

2. It is used for determining the recirculation ratio necessary for maintaining a specified MLSS concentration in the aerator.

3. It is also used for estimating suspended solids concentration in recirculated sludge.
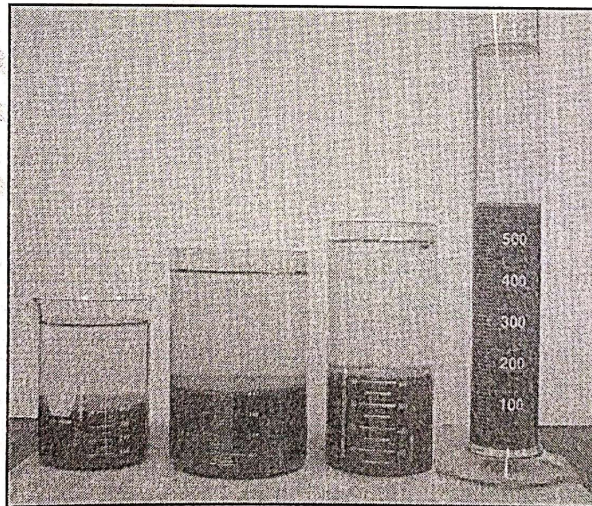
CONCLUSION:-

The sludge volume index of the given sample is _____.